2.0 WRIA 53 OVERVIEW

2.1 PHYSICAL DESCRIPTION

WRIA 53 is primarily located in northern Lincoln County as shown in Figure 1. The watershed encompasses approximately 326,164 acres, or approximately 509.63 square miles. The Columbia River bisects the watershed with 118,730 acres (185.52 square-miles) located north of the Columbia River, primarily within the boundaries of the Colville Indian Reservation, and 207,432 acres (324.11 square miles) located south of the Columbia River, that area which was the primary focus of this assessment. Table 1 presents a summary of the area located within each County with lands located within the Lower Lake Roosevelt Watershed. In general, the watershed encompasses that portion of the Columbia River and it is tributaries between the confluence of the Spokane River to the east and the location of Grand Coulee Dam to the west.

TABLE 1: WRIA 53 AREA PER COUNTY			
County	***Acreage***	***Square-Miles***	***Percentage***
Lincoln	206,093	322.02	63.2
Ferry	74,542	116.47	22.8
Okanogan	44,274	69.18	13.6
Grant	1,255	1.96	0.4
TOTAL	***326,164***	***509.63***	***100***

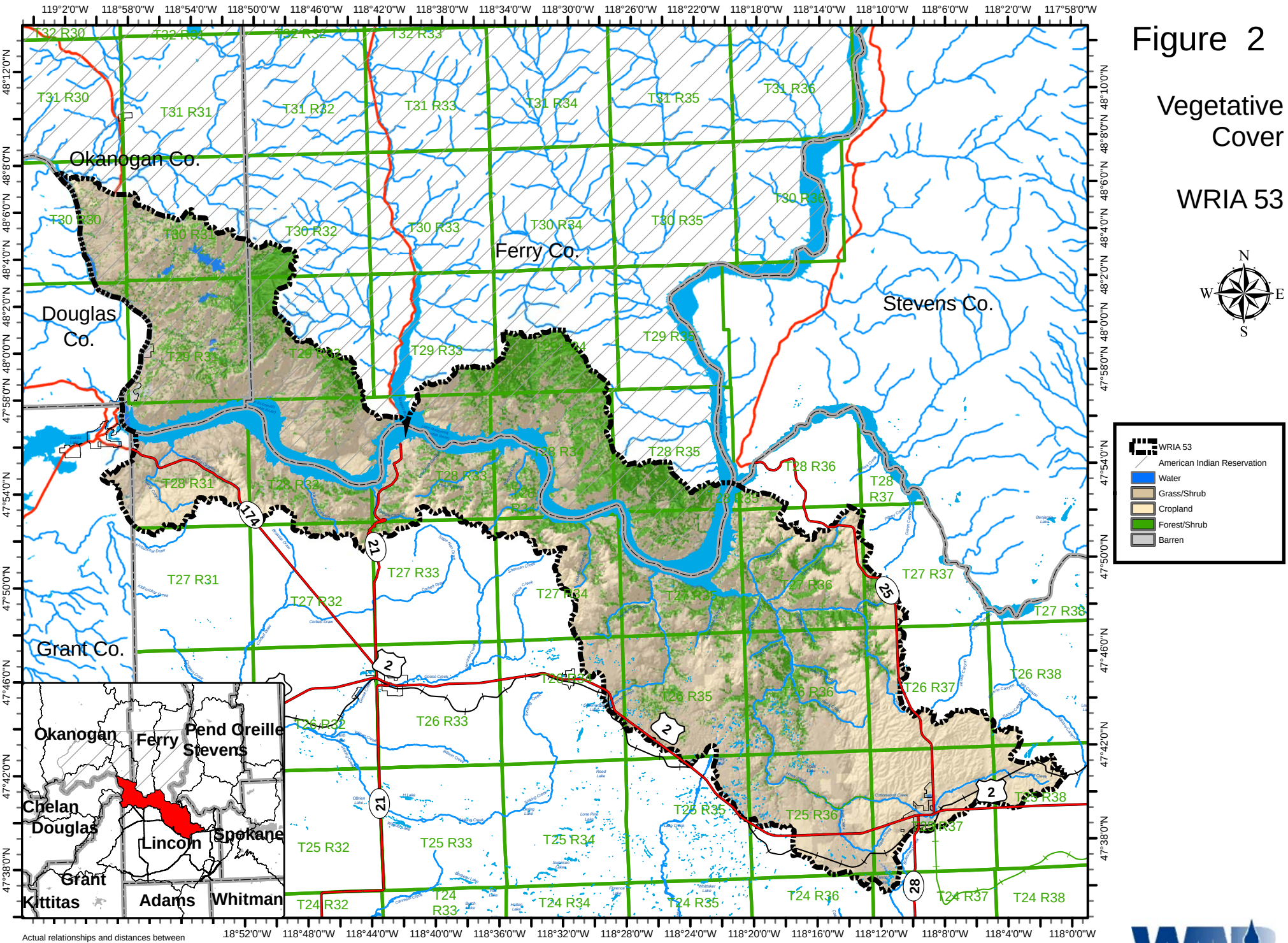
The communities of Davenport, Lincoln, Seven Bays, and numerous smaller private housing developments are within the watershed. The study area's landscape consists of forested upland regions in the eastern extent of the watershed to the sage covered scabland landscape in the southern extent. Figure 2 presents the GIS vegetative cover within WRIA 53. As shown on Figure 2 and Table 2, the landscape is primarily covered with shrub and grassland (44%) followed by timber land (28%). Only three percent of the watershed is urban area. Nine percent of the landscape is covered by water/wetlands that area mostly associated with the Columbia River. Figure 3 presents a graphical presentation of the vegetative distribution throughout the watershed.

TABLE 2: VEGETATIVE COVER IN WRIA 53		
	Acres	***%***
Total WRIA 53	326,164.00	100%
Water/Wetland	29,354.58	9%
Shrub/Grass	143,511.28	44%
Cropland	48,924.30	15%
Timber	91,325.36	28%
Barren	3,261.62	1%
Urban	9,784.86	3%

Figure 2

Vegetative Cover

WRIA 53



Actual relationships and distances between features may be different from those depicted on this map. Data was compiled from multiple sources. The data sources do not guarantee these data are accurate or complete. This map is for informational purposes only.

0 2 4 8 12 16

1:380,160 Miles 1 inch = 6 miles

Vegetation Cover – WRIA 53

	Acres	%
Total	326,162.00	100%
Water/Wetland	29,354.58	9%
Shrub/Grass	143,511.28	44%
Cropland	48,924.30	15%
Timber	91,325.36	28%
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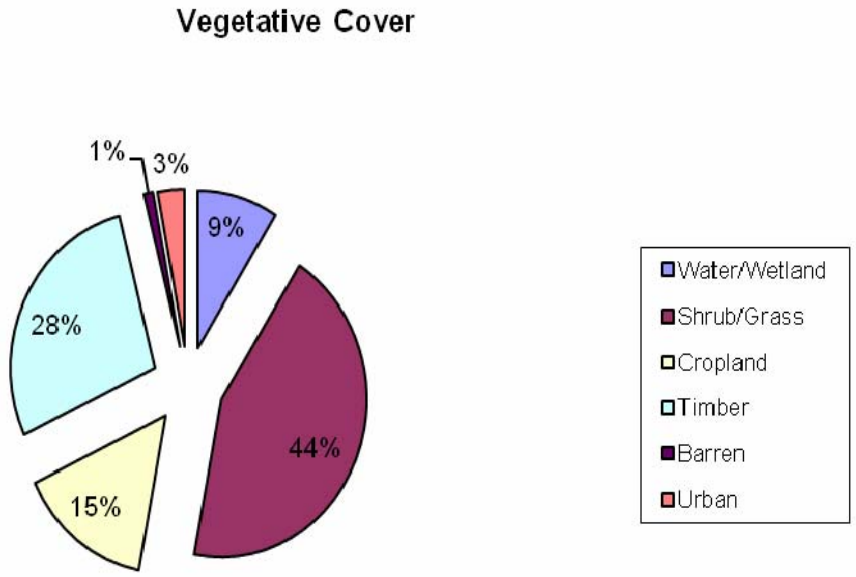


FIGURE 3

GRAPHICAL PRESENTATION OF THE VEGETATIVE COVER WITHN THE WRIA 53 – LOWER LAKE ROSEVELT WATERSHED

Prepared by: ENJS May 5, 2009

Elevation in the watershed varies from a high point located in the northern portion of the watershed in Ferry County with and approximate elevation of 4,200 feet above mean sea level (MSL) MSL (T29R34S35) to the lowest elevation of 960 feet above MSL located near Grand Coulee Dam (T29N, R31E, S30). The highest elevation in the southern portion of the watershed is located near the community of Egypt at an elevation of approximately 2,800 feet above MSL (T27N, R36E, S1). Figure 4 presents a topographical map of the WRIA 53 watershed.

The landscape is incised by drainage ways in those areas draining surface water towards the Columbia River. As shown in Figure 2 and 4, outside of the Columbia River Valley, the Hawk Creek drainage is the prominent incised channel in the watershed and drains the eastern portion of the watershed. The Columbia River Valley is typically less than two-miles in width. The tributary drainages such as Hawk Creek and Welch Creek are narrow relatively steep incised alluvial valleys with valley floors typically ½ to ¾ miles in width.

2.2 SUBBASIN DELINEATION

The technical assessment subdivided the WRIA 53 watershed into five subbasins. The subbasins were named Hawk Creek, Brody Creek South, Brody Creek North, Coulee Dan South, and Coulee Dam North (Figure 1). The subbasin delineation was facilitated due to different land use and management activities which occur in the areas. Brody Creek North and Coulee Dam North are located within the Colville Indian Reservation. Table 3 presents a summary of the area and the vegetative cover found within each subbasin.

2.2.1 Hawk Creek Subbasin

The Hawk Creek Subbasin generally refers to that portion of WRIA 53 that drains the Hawk Creek watershed. Major tributaries to Hawk Creek include Indian Creek and Cottonwood Creek. It is the largest subbasin in the watershed and occupies an area of approximately 119,065 acre (186.04 square miles), approximately 36.5 percent of the WRIA 53 watershed. This subbasin has the only incorporated area of Davenport, located in the extreme southern extent of the subbasin. It also has the community of Seven Bays, located along the Columbia River, and the private communities of Lakeview Heights, Ridgeview, Rocky Top Estates, and Deer Meadows.

2.2.2 Brody Creek South Subbasin

The Brody Creek South Subbasin refers to that portion of the watershed that lies south of the Columbia River between the confluence with Hawk Creek and the confluence with Penix Canyon. It occupies an area of approximately 50,669 acres (79.17 square miles), that area encompassing approximately 15.54 percent of the WRIA 53 watershed. Private communities within the Brody Creek South Subbasin include Hanson Harbor, Rantz Marine Park, and Roosevelt Lake Ranch Water System.

2.2.3 Coulee Dam South

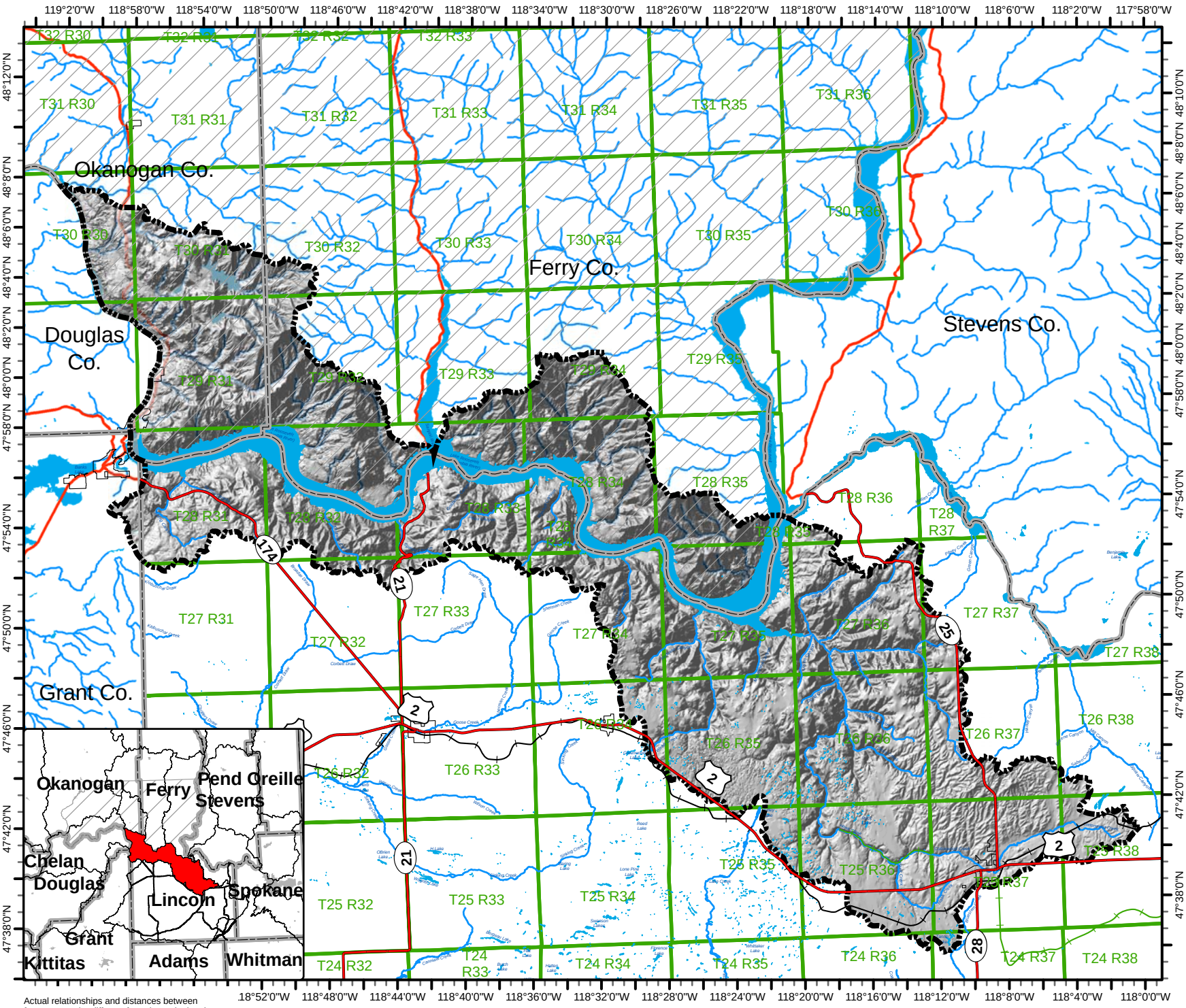
The Coulee Dam South Subbasin is located south of the Columbia River in the western extent of the watershed. It occupies an area of approximately 37,691 acres (58.89 square miles) or approximately 11.55 percent of the WRIA 53 watershed. Private communities in the Coulee Dam South Subbasin include Columbia Springs Estate, FDR Estates, Lakeview Subdivision, Roosevelt Views, and the Andrew Soresun water right.

TABLE 3: SUMMARY OF SUBBASIN AREA AND VEGETATIVE COVER									
SUBBASIN	**Total Acres**	**Square Miles**	**% of WRIA 53**	**Water/ Wetland**	**Shrub/ Grass**	**Cropland**	**Timber**	**Barren**	**Urban**
Coulee Dam North	71,358.51	111.50	21.88	11%	45%	5%	36%	0%	3%
Coulee Dam South	37,691.81	58.89	11.55	7%	66%	15%	9%	1%	2%
Brody Creek South	50,669.58	79.17	15.54	9%	55%	12%	21%	0%	3%
Brody Creek North	47,376.95	74.03	14.53	9%	29%	1%	61%	0%	0%
Hawk Creek	119,065.14	186.04	36.50	9%	36%	40%	12%	0%	3%
Total WRIA 53	326,162.00	509.63	100.0	9%	44%	15%	28%	1%	3%

Figure 4

Topography

WRIA 53



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1:380,160 Miles 1 inch = 6 miles

2.2.4 Coulee Dam North

The Coulee Dam North Subbasin is that area north of the Columbia River and west of the San Poil River, that area primarily within the Okanogan County portion of the watershed. This subbasin is within the boundaries of the Colville Indian Reservation, although there are over 480 fee land owners within this portion of the watershed, according to the Okanogan County assessor records. No major communities are located within this subbasin. This subbasin is the second largest subbasin and encompasses approximately 71,358 acres (111.5 square miles), approximately 21.88 percent of the WRIA 53 watershed.

2.2.5 Brody Creek North

The Brody Creek North Subbasin is that area north of the Columbia River and east of the San Poil River, that area primarily within the Ferry County portion of the watershed. This subbasin is within the boundaries of the Colville Indian Reservation. According to the Ferry County assessor's office, there are 35 fee land owners within this portion of the watershed. No major communities are located within this subbasin. This subbasin encompasses approximately 47,376 acres (74.03 square miles), approximately 14.53 percent of the WRIA 53 watershed.

2.3 CLIMATE

The purpose of the climate analysis is to compile information on seasonal changes in precipitation and temperature and to evaluate the distribution of precipitation and temperature across the watershed. Variations in precipitation and climate are a dominating influence on groundwater recharge and streamflows and largely determine the availability of groundwater and surface water resources (Smith, 1993). Temperature and precipitation are significantly impacted by elevation in the WRIA 53 watershed with temperature generally decreasing with increasing elevations and precipitation increasing with increasing elevation.

The climate in WRIA 53 is typical of northeast Washington, combining characteristics typical of mountain climates with those more typical of a semi-arid climate. Precipitation amounts and patterns as well as temperature regimes are strongly influenced by air masses and storms from the Pacific Ocean that migrate from the west coast. The north-south trending mountain ranges and deep valleys are the dominant influence on local climate. Prevailing weather is from the west, bringing air masses from the Pacific with high moisture content and moderate temperatures. Since the mountain ranges are more or less perpendicular to the prevailing weather, the air masses are forced to rise and cool, dumping their moisture as rain or snow on the mountains and rendering the adjacent valleys relatively drier (Daley et al. 1994). Summers are generally warm or hot in most valleys and much cooler in the mountains. Summers are also relatively dry, as the majority of the moister air from the Pacific Ocean does not cross the Cascades. Arctic air from the north and continental influences from the east cause winters to be cold and relatively long.

Climatic data were reviewed from the Western Regional Climate Center (WRCC) database (WRCC, 2009). The WRCC compiles and maintains climatic data from the National Oceanographic and Atmospheric Administration (NOAA), the Natural Resource Conservation Service Snowpack Telemetry System (SNOTEL), and regional cooperators that operate individual recording stations (WRCC, 2009). Climatic data was collected for four recording

stations within or nearby the watershed. These climate stations are designated by the WRCC as Coulee Dam 1 SW, Wilbur, Davenport, and Wellpinit. Location of the climate stations are presented on Figure 1. Table 4 presents a generalized summary of the climate station data for the area of the watershed. Tables 5 through 8 summarize data for each of the four weather stations used in the WRIA 53 analysis. A description of each climate station is presented below.

Coulee Dam 1 SW

The climate station designated as Coulee Dam 1 SW (Station No. 451767) is located near the town of Coulee Dam, Washington. The station is located at 47.95056 N latitude and -119.005 W longitude. The station is located at an elevation of 1700 feet above msl. This station has a period of record from August 1, 1934 through present. Over the period of record, average monthly maximum temperature occurs in July and averages approximately 87.6 degree Fahrenheit. Average monthly minimum temperature occurs in January and averages approximately 21.5 degree Fahrenheit. Average monthly precipitation over the period of record varied from 0.43-inches in August to 1.41-inches in December, yielding an average annual precipitation of 10.52 inches (WRCC, 2009). Average annual snowfall is 15.7 inches and occurs from November through March. WRCC (2009) prepared a graph of the average daily maximum temperature, minimum temperature, and precipitation for available data from the period from 1971 through 2000 for the 30-year average. Figure 5 presents this graphical presentation of the climatic data. Historical data from the Coulee Dam station is presented in Table 5.

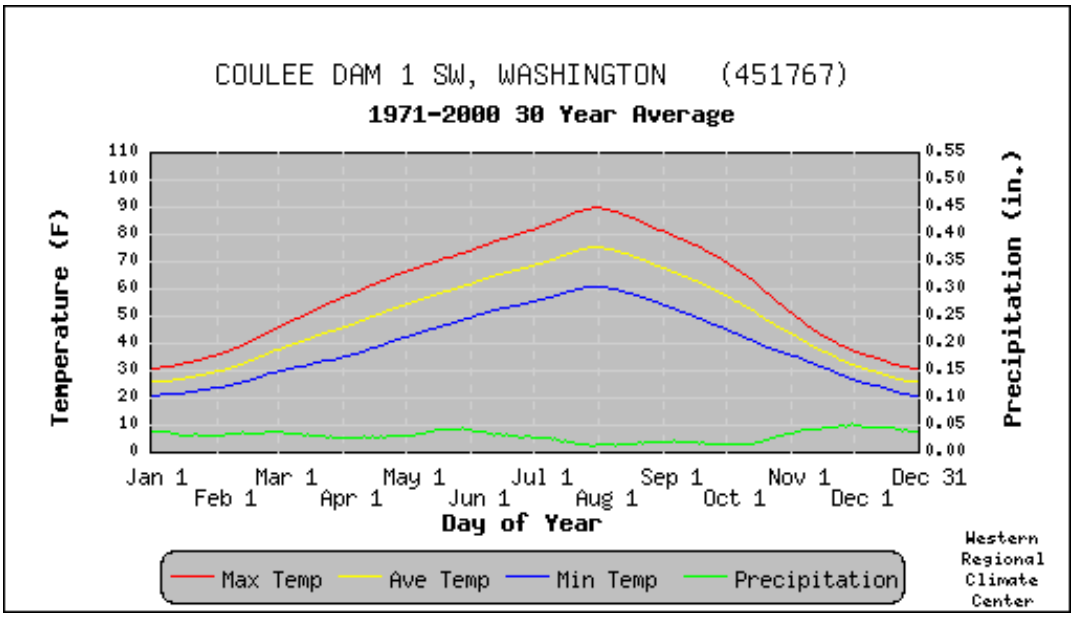


FIGURE 5: Graphical Presentation of Climate Data for the Coulee Dam Weather Station (#451767), from WRCC, 2009.

TABLE 4: PRECIPITATION AND TEMPERATURE DATA FROM WEATHER STATIONS NEAR WRIA 53												
Month	*Coulee Dam Station No. 451767*			*Wilbur Station No. 459238*			*Davenport Station No. 452007*			*Wellpinit Station No. 459058*		
	Precipitation (inches)	*Temperature (F)*		*Precipitation (inches)*	*Temperature (F)*		*Precipitation (inches)*	*Temperature (F)*		*Precipitation (inches)*	*Temperature (F)*	
		Max	*Min*		*Max*	*Min*		*Max*	*Min*		*Max*	*Min*
January	1.08	32.1	21.5	1.41	31.5	17.5	1.72	30.7	17.9	2.20	31.9	19.7
February	0.93	39.7	25.7	1.12	38.2	21.8	1.30	37.2	21.9	1.69	38.4	23.9
March	0.82	50.8	31.5	0.97	49.1	28.1	1.29	47.7	28.0	1.65	48.1	28.9
April	0.82	61.8	38.3	0.89	59.8	32.8	1.04	58.2	33.1	1.44	57.9	34.7
May	1.08	71.1	45.9	1.19	68.8	39.3	1.33	67.2	39.6	1.65	66.5	41.1
June	1.00	78.7	52.6	0.98	76.2	44.8	1.12	74.3	45.2	1.40	75.0	47.8
July	0.48	87.6	58.4	0.53	85.2	49.4	0.52	83.7	49.9	0.65	84.4	52.7
August	0.43	86.3	57.4	0.49	83.9	48.5	0.50	82.9	49.3	0.70	84.0	51.8
September	0.50	77.1	50.3	0.59	74.6	41.8	0.72	73.3	42.4	0.98	73.2	44.2
October	0.71	61.7	40.6	0.98	60.8	33.6	1.09	59.4	33.9	1.45	58.6	35.4
November	1.25	43.6	31.5	1.64	43.0	26.9	1.91	41.9	26.9	2.49	41.0	28.2
December	1.41	34.4	24.7	1.64	33.5	20.9	1.97	32.5	20.6	2.66	31.8	21.8
Annual	***10.52***	***60.4***	***39.9***	***12.44***	***58.7***	***33.8***	***14.51***	***57.4***	***34.1***	***18.95***	***57.6***	***35.8***

TABLE 5: COULEE DAM 1 SW, WASHINGTON

NCDC 1971-2000 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Monthly
Mean Max. Temperature (F)	32.5	40.0	51.2	61.7	70.6	78.4	86.2	86.4	76.3	61.2	43.0	33.3	60.1
Highest Mean Max. Temperature (F)	40.5	48.2	59.4	68.6	76.8	85.8	97.5	93.2	84.0	68.8	48.6	40.2	97.5
Year Highest Occurred	1990	1991	1992	1977	1992	1986	1985	1971	1990	1988	1990	1973	1985
Lowest Mean Max. Temperature (F)	19.9	32.4	43.7	56.6	64.8	72.9	75.3	79.6	66.0	58.1	30.6	24.2	19.9
Year Lowest Occurred	1979	1989	1975	1993	1996	1991	1993	1976	1986	1996	1985	1985	1979
Mean Temperature (F)	27.0	32.8	41.4	49.8	58.0	65.3	72.1	72.1	62.9	50.4	37.0	28.2	49.8
Highest Mean Temperature (F)	35.0	39.7	47.4	54.0	63.4	71.9	80.3	76.9	68.7	56.0	42.3	34.7	80.3
Year Highest Occurred	1990	1991	1992	1994	1993	1992	1985	1971	1998	1988	1998	1973	1985
Lowest Mean Temperature (F)	13.2	24.8	35.3	45.0	53.0	60.6	64.6	66.5	55.2	46.7	23.1	19.3	13.2
Year Lowest Occurred	1979	1989	1971	1982	1984	1981	1993	1976	1986	1984	1985	1983	1979
Mean Min. Temperature (F)	21.4	25.6	31.5	37.8	45.4	52.2	57.9	57.7	49.4	39.6	30.9	23.1	39.4
Highest Mean Min. Temperature (F)	30.0	33.1	35.4	42.7	50.9	58.4	63.6	60.9	54.3	43.4	37.3	29.8	63.6
Year Highest Occurred	1994	1992	1983	1994	1993	1992	1998	1998	1998	1979	1998	1999	1998
Lowest Mean Min. Temperature (F)	6.4	16.4	25.3	32.4	41.0	48.1	53.1	53.3	44.5	35.0	15.7	13.2	6.4
Year Lowest Occurred	1979	1985	1985	1982	1984	1981	1983	1976	1986	1984	1985	1984	1979
Mean Precipitation (in.)	1.00	1.01	0.98	0.83	1.28	0.95	0.67	0.48	0.54	0.60	1.32	1.48	11.14
Highest Precipitation (in.)	2.19	3.12	2.64	2.19	3.32	2.62	2.94	1.43	2.08	1.63	3.95	3.44	3.95
Year Highest Occurred	1986	1980	1983	1993	1980	1984	1993	1990	1986	1996	1973	1996	1973
Lowest Precipitation (in.)	0.30	0.03	0.06	0.00	0.12	0.05	0.00	0.00	0.00	0.00	0.13	0.26	0.00
Year Lowest Occurred	1985	1988	1979	1985	1992	1986	1988	2000	1990	1978	1976	1976	1985
Heating Degree Days (F)	1180.	901.	733.	458.	236.	91.	29.	19.	153.	453.	841.	1141.	6235.
Cooling Degree Days (F)	0.	0.	0.	0.	18.	100.	247.	238.	88.	1.	0.	0.	692.

TABLE 6: WILBUR, WASHINGTON

NCDC 1971-2000 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Monthly
Mean Max. Temperature (F)	31.6	38.3	48.7	58.7	67.7	75.3	83.9	84.3	74.4	60.1	41.6	32.3	58.1
Highest Mean Max. Temperature (F)	39.3	47.5	56.1	65.4	75.0	84.2	92.6	90.6	83.1	67.7	48.2	38.6	92.6
Year Highest Occurred	1990	1991	1992	1977	1992	1992	1985	1971	1990	1988	1989	1999	1985
Lowest Mean Max. Temperature (F)	20.2	30.0	41.5	52.8	60.7	69.1	72.7	78.8	65.3	54.9	27.3	23.9	20.2
Year Lowest Occurred	1979	1993	1971	1975	1996	1971	1993	1995	1985	1990	1985	1983	1979
Mean Temperature (F)	25.1	30.8	38.6	45.6	53.4	60.0	67.0	67.1	58.2	46.4	33.9	26.0	46.0
Highest Mean Temperature (F)	33.3	38.9	44.1	50.0	59.3	67.3	73.3	72.8	65.4	53.0	38.8	33.4	73.3
Year Highest Occurred	1994	1991	1992	1987	1993	1992	1985	1986	1990	1988	1999	1973	1985
Lowest Mean Temperature (F)	11.7	21.4	33.0	41.3	48.4	54.7	60.8	61.5	53.3	40.9	19.6	16.8	11.7
Year Lowest Occurred	1979	1985	1971	1982	1996	1976	1993	1980	1985	1984	1985	1978	1979
Mean Min. Temperature (F)	18.6	23.2	28.4	32.5	39.0	44.7	50.0	49.8	42.0	32.7	26.2	19.6	33.9
Highest Mean Min. Temperature (F)	28.5	31.2	32.6	36.1	44.6	50.3	57.3	56.0	47.6	38.2	31.2	28.6	57.3
Year Highest Occurred	1981	1992	1983	1974	1993	1992	1998	1986	1990	1988	1999	1973	1998
Lowest Mean Min. Temperature (F)	3.1	10.8	23.4	27.4	34.3	38.9	46.2	44.1	36.3	26.5	11.8	7.1	3.1
Year Lowest Occurred	1979	1985	1985	1982	1977	1976	1980	1980	1983	1984	1985	1978	1979
Mean Precipitation (in.)	1.22	1.18	1.21	0.91	1.34	0.98	0.90	0.55	0.63	0.83	1.62	1.72	13.09
Highest Precipitation (in.)	2.50	3.53	3.26	2.47	3.08	3.72	4.05	2.07	2.32	3.38	4.56	4.90	4.90
Year Highest Occurred	1986	1999	1995	1993	1989	1997	1993	1976	1979	1996	1973	1996	1996
Lowest Precipitation (in.)	0.29	0.00	0.25	0.04	0.03	0.01	0.00	0.00	0.00	0.01	0.02	0.19	0.00
Year Lowest Occurred	1972	1988	1973	1977	1992	1986	1994	2000	1999	1987	1976	1976	1988
Heating Degree Days (F)	1237.	959.	820.	582.	365.	186.	72.	66.	244.	578.	934.	1211.	7254.
Cooling Degree Days (F)	0.	0.	0.	0.	4.	36.	133.	129.	39.	0.	0.	0.	341.

TABLE 7: DAVENPORT, WASHINGTON

NCDC 1971-2000 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Monthly
Mean Max. Temperature (F)	31.1	37.3	47.5	57.2	65.8	73.3	81.9	82.8	72.8	59.1	40.7	31.5	56.8
Highest Mean Max. Temperature (F)	39.3	46.9	55.5	64.3	71.6	81.3	90.8	89.5	81.1	66.0	46.9	37.4	90.8
Year Highest Occurred	1994	1991	1992	1977	1993	1992	1985	1971	1990	1988	1997	1973	1985
Lowest Mean Max. Temperature (F)	18.5	28.3	40.4	51.7	59.8	66.9	71.1	76.4	63.3	55.0	27.3	21.1	18.5
Year Lowest Occurred	1979	1989	1975	1975	1996	1981	1993	1995	1985	1990	1985	1983	1979
Mean Temperature (F)	24.9	30.2	38.0	45.0	52.6	59.2	65.8	66.3	57.3	45.8	33.7	25.3	45.3
Highest Mean Temperature (F)	34.1	38.5	43.0	49.9	58.4	65.6	71.9	71.2	62.8	51.8	38.9	32.5	71.9
Year Highest Occurred	1994	1991	1992	1987	1993	1992	1998	1977	1998	1988	1999	1973	1998
Lowest Mean Temperature (F)	11.1	19.2	30.8	41.0	48.0	54.7	59.2	60.6	50.6	40.9	20.8	14.4	11.1
Year Lowest Occurred	1979	1985	1985	1972	1996	1981	1993	1995	1985	1984	1985	1983	1979
Mean Min. Temperature (F)	18.6	23.0	28.4	32.8	39.4	45.0	49.6	49.7	41.8	32.4	26.7	19.0	33.9
Highest Mean Min. Temperature (F)	28.9	30.3	32.5	37.6	45.1	49.9	55.2	54.5	46.4	38.1	31.7	27.8	55.2
Year Highest Occurred	1994	1992	1983	1980	1993	1992	1998	1977	1979	1979	1999	1979	1998
Lowest Mean Min. Temperature (F)	3.6	9.9	19.7	29.2	34.3	41.7	45.3	44.8	36.5	26.5	14.3	6.8	3.6
Year Lowest Occurred	1979	1985	1985	1982	1999	1994	1999	2000	1984	1984	1985	1984	1979
Mean Precipitation (in.)	1.45	1.22	1.30	1.02	1.41	1.03	0.78	0.54	0.65	0.88	1.90	1.93	14.11
Highest Precipitation (in.)	3.16	2.57	3.22	2.50	2.72	2.25	3.58	1.41	1.69	2.93	5.59	4.48	5.59
Year Highest Occurred	1995	1983	1995	1978	1980	1995	1993	1972	1977	1996	1973	1973	1973
Lowest Precipitation (in.)	0.32	0.09	0.19	0.07	0.10	0.06	0.00	0.00	0.00	0.00	0.17	0.32	0.00
Year Lowest Occurred	1985	1988	1999	1977	1982	1986	1994	2000	1990	1978	1976	1989	1994
Heating Degree Days (F)	1246.	976.	838.	601.	387.	202.	85.	81.	266.	596.	940.	1232.	7450.
Cooling Degree Days (F)	0.	0.	0.	0.	3.	27.	108.	120.	35.	0.	0.	0.	293.

TABLE 8: WELLPINIT, WASHINGTON

NCDC 1971-2000 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Monthly
Mean Max. Temperature (F)	33.0	39.3	48.9	58.9	67.6	74.9	84.3	84.7	73.9	59.3	41.0	32.4	58.2
Highest Mean Max. Temperature (F)	39.5	46.3	55.0	67.1	74.5	83.6	95.7	93.6	83.4	67.8	48.7	37.9	95.7
Year Highest Occurred	1994	1987	1986	1987	1987	1986	1985	1971	1987	1987	1999	1999	1985
Lowest Mean Max. Temperature (F)	21.5	29.1	42.5	53.2	61.4	65.5	72.8	76.8	64.6	50.7	32.2	24.9	21.5
Year Lowest Occurred	1979	1989	1971	1972	1991	1991	1993	1978	1977	1995	1985	1990	1979
Mean Temperature (F)	27.0	32.0	39.3	47.2	55.0	61.6	68.9	69.0	59.7	47.5	34.9	27.0	47.4
Highest Mean Temperature (F)	33.4	39.4	46.1	54.9	60.5	69.0	77.7	74.3	66.0	54.0	41.7	32.7	77.7
Year Highest Occurred	1994	1987	1986	1987	1987	1986	1985	1971	1987	1988	1987	1979	1985
Lowest Mean Temperature (F)	13.9	20.6	33.5	41.2	48.3	56.3	61.6	61.5	52.9	41.9	27.5	19.9	13.9
Year Lowest Occurred	1979	1989	1990	1990	1991	1991	1993	1995	1972	1995	1985	1990	1979
Mean Min. Temperature (F)	20.9	24.6	29.7	35.4	42.3	48.2	53.4	53.2	45.4	35.7	28.7	21.6	36.6
Highest Mean Min. Temperature (F)	27.7	32.4	37.4	42.6	46.9	55.1	59.6	59.9	51.5	43.1	35.1	28.2	59.9
Year Highest Occurred	1992	1987	1984	1987	1993	1992	1985	1981	1988	1988	1987	1979	1981
Lowest Mean Min. Temperature (F)	6.3	12.0	22.3	28.7	35.2	41.8	48.0	45.9	38.0	30.9	22.7	14.9	6.3
Year Lowest Occurred	1979	1989	1990	1990	1991	1990	1999	1995	1972	1972	1985	1990	1979
Mean Precipitation (in.)	1.90	1.84	1.81	1.50	1.86	1.49	0.95	0.72	0.84	1.23	2.67	2.91	19.72
Highest Precipitation (in.)	3.23	4.81	4.43	3.53	4.36	3.53	3.13	3.55	2.77	4.25	6.19	9.25	9.25
Year Highest Occurred	1980	1999	1983	1978	1998	1984	1993	1976	1986	1996	1983	1996	1996
Lowest Precipitation (in.)	0.16	0.13	0.24	0.00	0.47	0.10	0.00	0.00	0.00	0.00	0.43	0.57	0.00
Year Lowest Occurred	1985	1993	1985	1985	1992	1986	1988	2000	1999	1988	1976	1976	1985
Heating Degree Days (F)	1180.	926.	796.	536.	325.	159.	64.	52.	219.	545.	903.	1178.	6883.
Cooling Degree Days (F)	0.	0.	0.	0.	13.	56.	183.	174.	58.	1.	0.	0.	485.

Wilbur

The climate station designated as Wilbur (Station No. 459238) is located east of the town of Wilbur, Washington. The station is located at 47.75694 N latitude and -118.6775 W longitude. The station is located at an elevation of 2230feet above msl. This station has a period of record from March 1, 1892 through present. Over the period of record, average monthly maximum temperature occurs in July and averages approximately 85.2 degree Fahrenheit. Average monthly minimum temperature occurs in January and averages approximately 17.5 degree Fahrenheit. Average monthly precipitation over the period of record varied from 0.49-inches in August to 1.64-inches in November and December, yielding an average annual precipitation of 12.44 inches (WRCC, 2009). Average annual snowfall is 26.2 inches and occurs from October through April. WRCC (2009) prepared a graph of the average daily maximum temperature, minimum temperature, and precipitation for available data from the period from 1971 through 2000 for the 30-year average. Figure 6 presents this graphical presentation of the climatic data. Historical data from the Wilbur station is presented in Table 6.

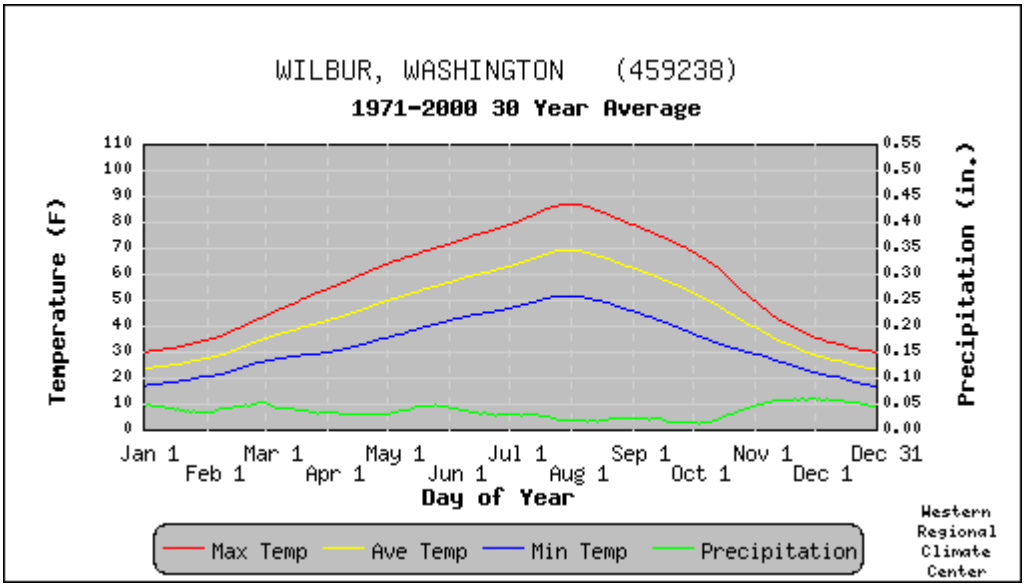


FIGURE 6: Graphical Presentation of Climate Data for the Wilbur Weather Station (#459238), from WRCC, 2009

Davenport

The climate station designated as Davenport (Station No. 452007) is located in the eastern area of the town of Davenport. The station is located at 47.65028 N latitude and -118.14556 W longitude. The station is located at an elevation of 2440 feet above msl. This station has a period of record from March 1, 1893 through present. Over the period of record, average monthly maximum temperature occurs in July and averages approximately 83.7 degree Fahrenheit. Average monthly minimum temperature occurs in January and averages approximately 17.9 degree Fahrenheit. Average monthly precipitation over the period of record varied from 0.50-inches in August to 1.97-inches in December, yielding an average annual precipitation of 14.51 inches (WRCC, 2009). Average annual snowfall is 38.8 inches and occurs from October through May. WRCC (2009) prepared a graph of the average daily maximum

temperature, minimum temperature, and precipitation for available data from the period from 1971 through 2000 for the 30-year average. Figure 7 presents this graphical presentation of the climatic data. Historical data from the Davenport station is presented in Table 7.

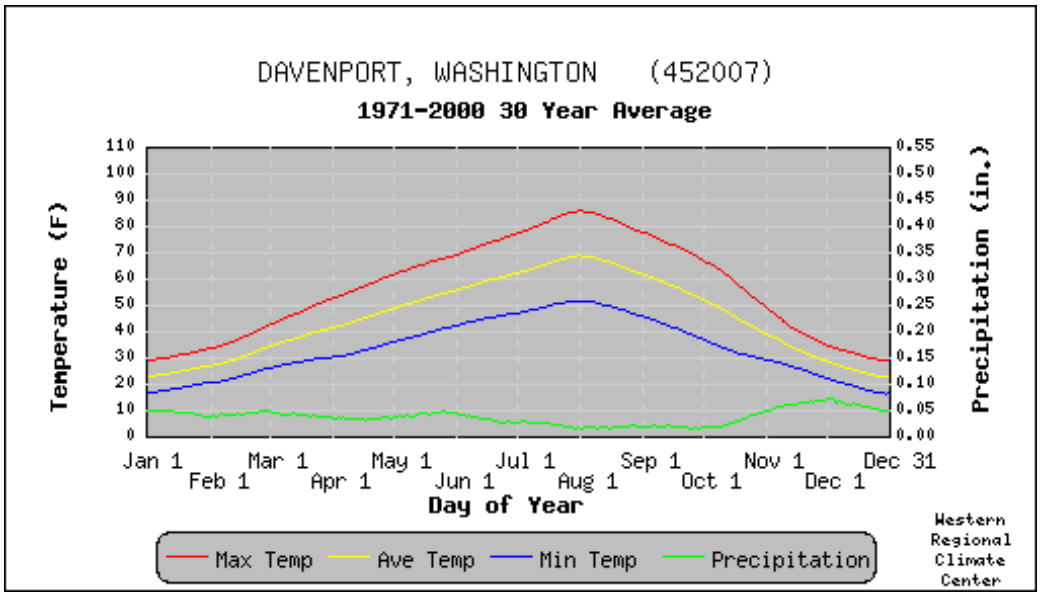


FIGURE 7: Graphical Presentation of Climate Data for the Davenport Weather Station (#452007), from WRCC, 2009.

Wellpinit

The climate station designated as Wellpinit (Station No. 459058) is located immediately north of the town of Wellpinit. The station is located at 47.89639 N latitude and -117.99333 W longitude. The station is located at an elevation of 2490 feet above msl. This station has a period of record from August 1, 1923 through December 31, 2007. Over the period of record, average monthly maximum temperature occurs in July and averages approximately 84.4 degree Fahrenheit. Average monthly minimum temperature occurs in January and averages approximately 19.7 degree Fahrenheit. Average monthly precipitation over the period of record varied from 0.65-inches in August to 2.66-inches in December, yielding an average annual precipitation of 18.95 inches (WRCC, 2009). Average annual snowfall is 44.7 inches and occurs from November through April. WRCC (2009) prepared a graph of the average daily maximum temperature, minimum temperature, and precipitation for available data from the period from 1971 through 2000 for the 30-year average. Figure 8 presents this graphical presentation of the climatic data. Historical data from the Wellpinit station is presented in Table 8.

2.3.1 Basin Scale Temperature

The average monthly and annual air temperatures were obtained from PRISM (Daly and Taylor, 1998). The temperature was imported into a GIS layer to generate an area-weighted average annual air temperature for the WRIA 53 watershed, and is presented in Figure 9. Data to derive the average annual maps are presented in Table 9. Average annual air temperature for the WRIA 53 ranges from approximately 41 degrees Fahrenheit located in the northeastern highlands of the

Coulee Dam North Subbasin to 51 degrees Fahrenheit along the main stem of the Columbia River.

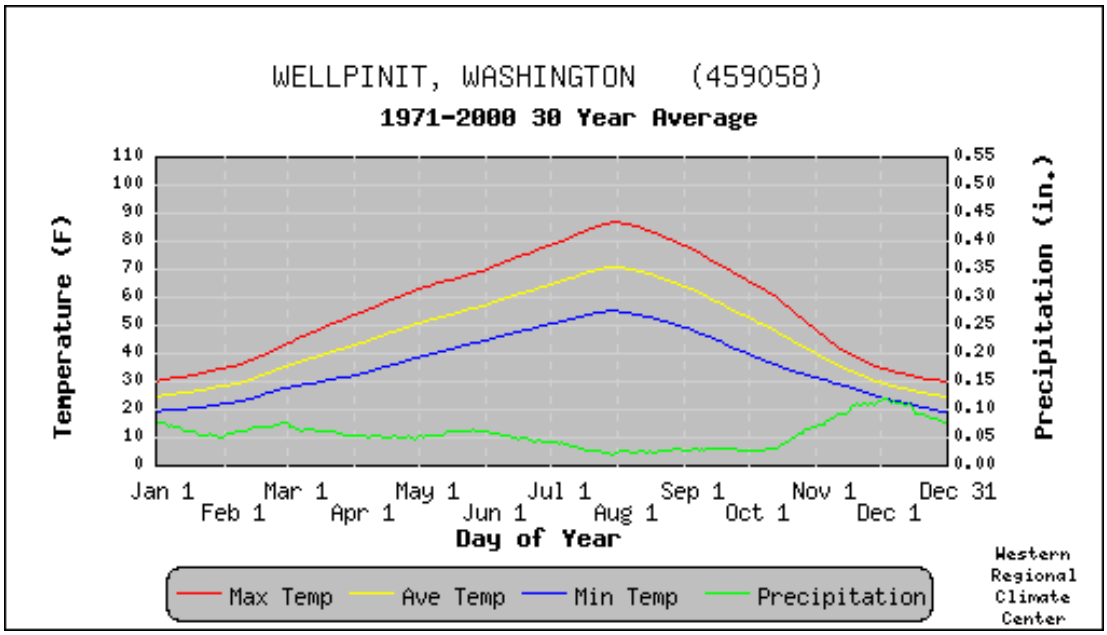


FIGURE 8: Graphical Presentation of Climate Data for the Wellpinit Weather Station (#459058), from WRCC, 2009

2.3.1 Basin Scale Precipitation

Table 9 presents the raw monthly and annual precipitation data for the WRIA 53 watershed. Utilizing this data, an isohyetal precipitation distribution map was developed for the entire WRIA 53 watershed based on PRISM (Daly and Taylor), a statistical topographic model developed by Daly and others (1994) for mapping precipitation in mountainous terrain. The isohyetal precipitation distribution was imported into a GIS layer, and is presented in Figure 10. As shown on Figure 10, the average annual precipitation ranges from approximately 9-inches along the Columbia River to approximately 21 –inches in the highlands in the northern part of the watershed on the Colville Indian Reservation. In the southern half of the watershed, precipitation is typically lowest along the Columbia River and increases as you move south in the watershed to an average annual precipitation of approximately 15-inches per year near Davenport, Washington.

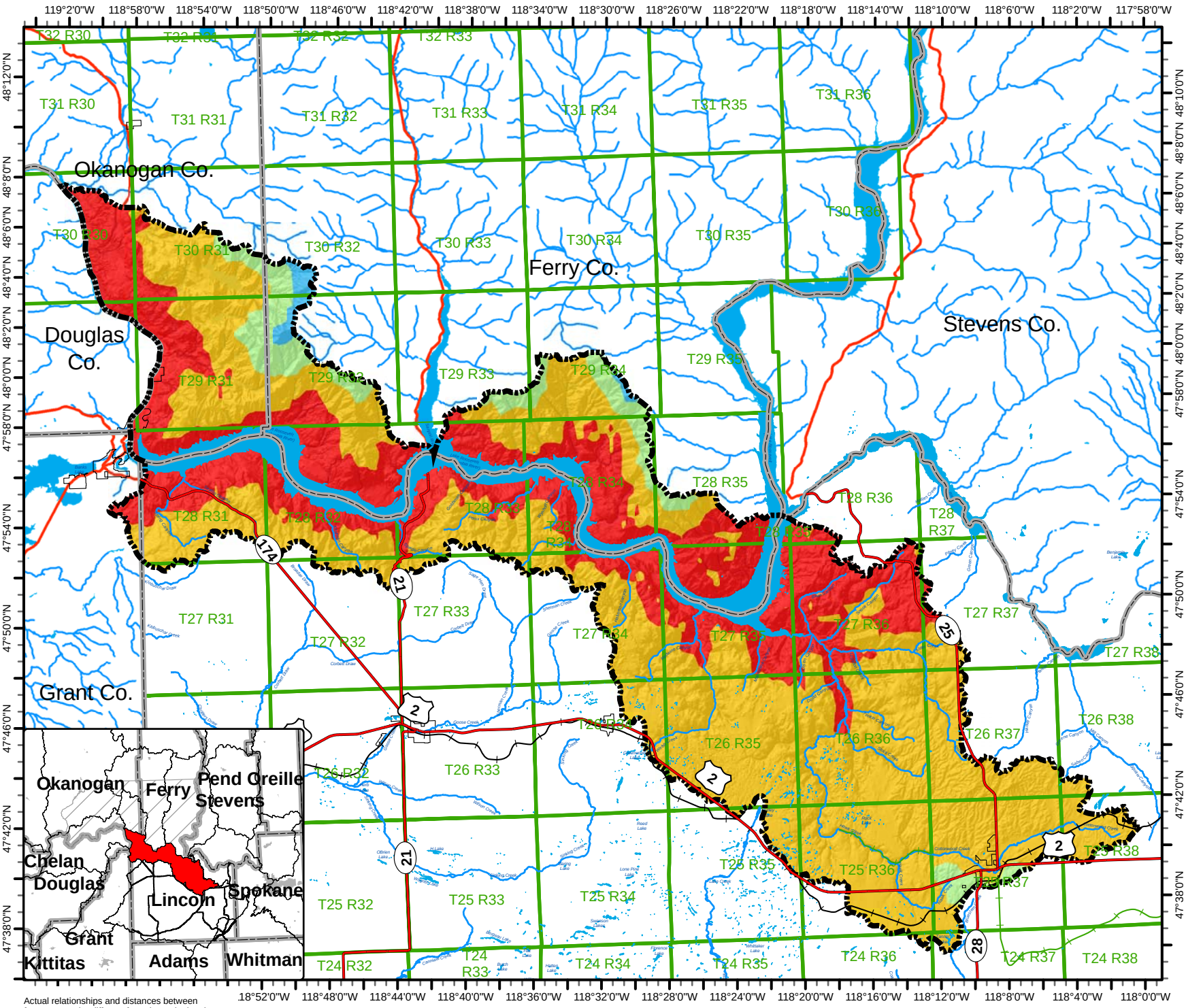
Assuming an area of 207,426.5 acres in the watershed south of the Columbia River, and an average annual precipitation of 12.555 inches per year (Table 9), approximately 217,020 acre-feet of precipitation will fall within the southern portion of the WRIA 53 watershed. Approximately 341,247 acre-feet of water will fall within the entire boundaries of WRIA 53.

TABLE 9: CLIMATE DATA USED TO DEVELOP AVERAGE ANNUAL MAPS													
WRIA 53	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Average Temperature (F)	25.55	31.125	39.525	47.925	55.95	62.725	69.9	68.975	60.775	48.9	35.925	28.15	47.95
Average Max. Temperature (F)	31.4	38.45	49.3	60.05	69.15	76.5	85.65	84.6	75.2	60.55	42.7	33.55	58.9
Average Min. Temperature (F)	19.7	23.8	29.75	35.8	42.75	48.95	54.15	53.35	46.35	37.25	29.15	22.75	37
Average Total Precipitation (in.)	1.4	1.115	1.055	0.94	1.215	1.065	0.505	0.465	0.62	0.905	1.58	1.69	12.555
Average Total Snowfall (in.)	8.9	4.4	2.05	0.25	0.05	0	0	0	0	0.25	3.2	7.75	2.2375
Average Snow Depth (in.)	4.5	4	0.5	0	0	0	0	0	0	0	0.5	2	1

Figure 9

Average Annual Temperature (F)

WRIA 53



Actual relationships and distances between features may be different from those depicted on this map. Data was compiled from multiple sources. The data sources do not guarantee these data are accurate or complete. This map is for informational purposes only.

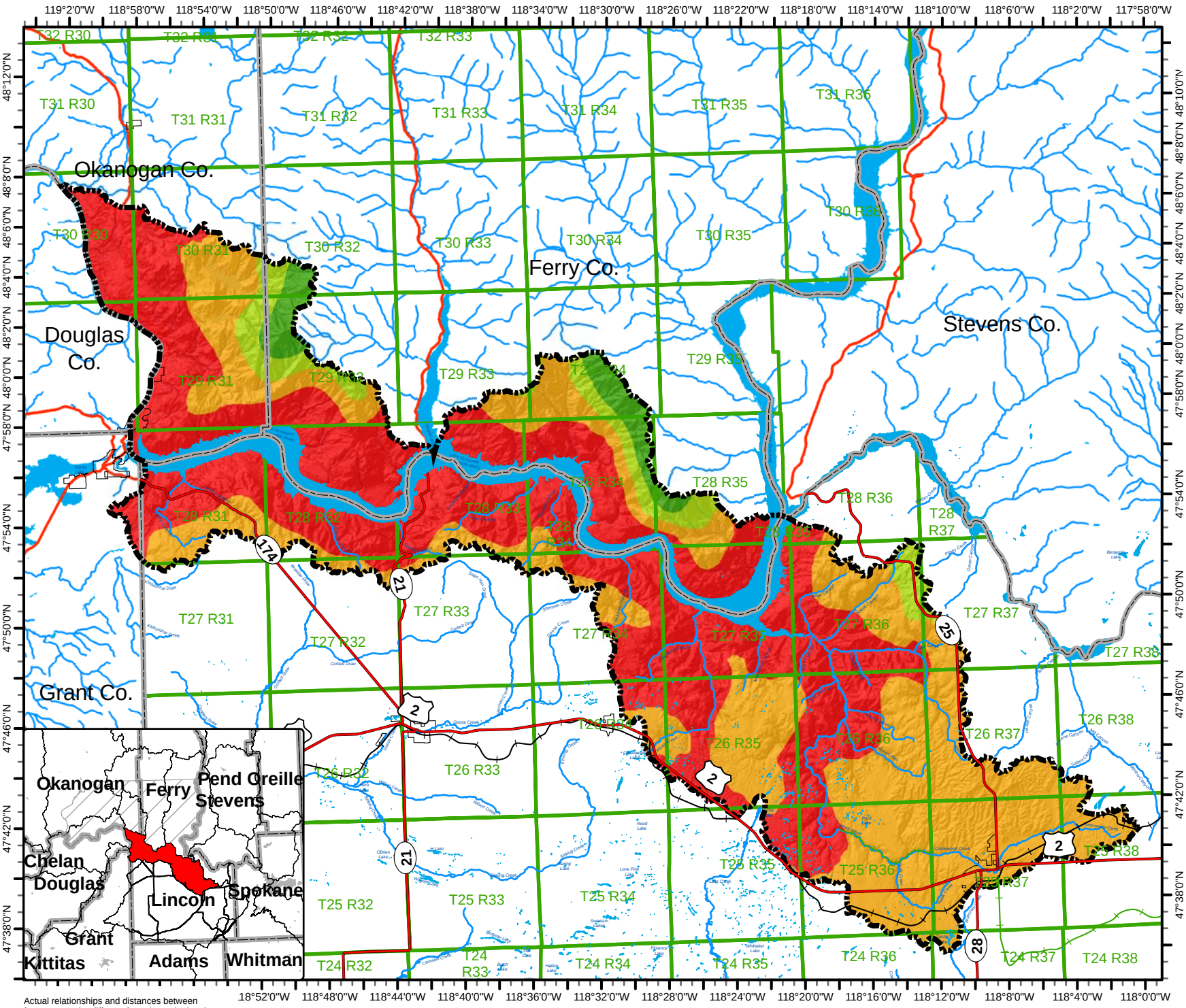
0 2 4 8 12 16

1:380,160 Miles 1 inch = 6 miles

Figure 10

Average Annual Precipitation (in)

WRIA 53



Actual relationships and distances between features may be different from those depicted on this map. Data was compiled from multiple sources. The data sources do not guarantee these data are accurate or complete. This map is for informational purposes only.

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1:380,160 Miles 1 inch = 6 miles

2.4 GEOLOGIC SETTING

The surficial geology of WRIA 53 is summarized in Stoffel et al. (1991), Waggoner (1990), Hansen et al. (1994) and Whiteman (1994). No single report was found that presents a comprehensive review of WRIA 53 geology. The WRIA 53 watershed lies within the northern extent of the Columbia Basin. Figure 11 presents a generalized geologic map of the extent of the Columbia Basin. Figure 12 presents a detailed geologic map of the WRIA 53 watershed.

This section presents a brief review of the geologic framework of the aquifers found within the WRIA 53 area. Potable groundwater in WRIA 53 is found predominantly in Pleistocene Cataclysmic Flood deposits and younger alluvial sediments, Miocene continental flood basalt and intercalated sedimentary units of the Columbia River Basalt Group (CRBG), and pre-basalt basement rocks (predominantly crystalline intrusive rocks and metamorphic rocks. In addition, loess, which is not typically an aquifer hosting unit, is found across much of the land surface of upland areas within the WRIA. Generally from youngest to oldest, the main geologic units found within WRIA 53 include the following:

- Holocene alluvial and colluvial deposits less than 10,000 years old.
- Pleistocene Cataclysmic Flood deposits ranging in age from approximately 12,000 years to more than 800,000 years.
- Pleistocene loess (the Palouse Formation) ranging in age from approximately 12,000 years to possibly over 1,000,000 years.
- Columbia River Basalt Group, which in WRIA 53 includes units ranging in age from approximately 14.5 million years to 16.5 million years.
- Pre-basalt basement rocks that probably include intrusive rocks over 40 million years old, and may include metasedimentary rocks greater than 600 million years old.

The CRBG is the most widespread and common of the rock types hosting potable groundwater currently being used in WRIA 53. Basalt flows of the CRBG underlie most of the WRIA except the northern and eastern edges where pre-basalt basement rocks crop out at the Earth's surface. The following sections summarize the basic geologic setting of these rocks, and the folding and faulting that influences their distribution. Much of this discussion is based on regional characterization efforts on-going within the Columbia Basin Ground Water Management Area (GWMA) (GWMA, 2004, 2007a, 2007b, 2009a, 2009b, 2009c, 2009d).

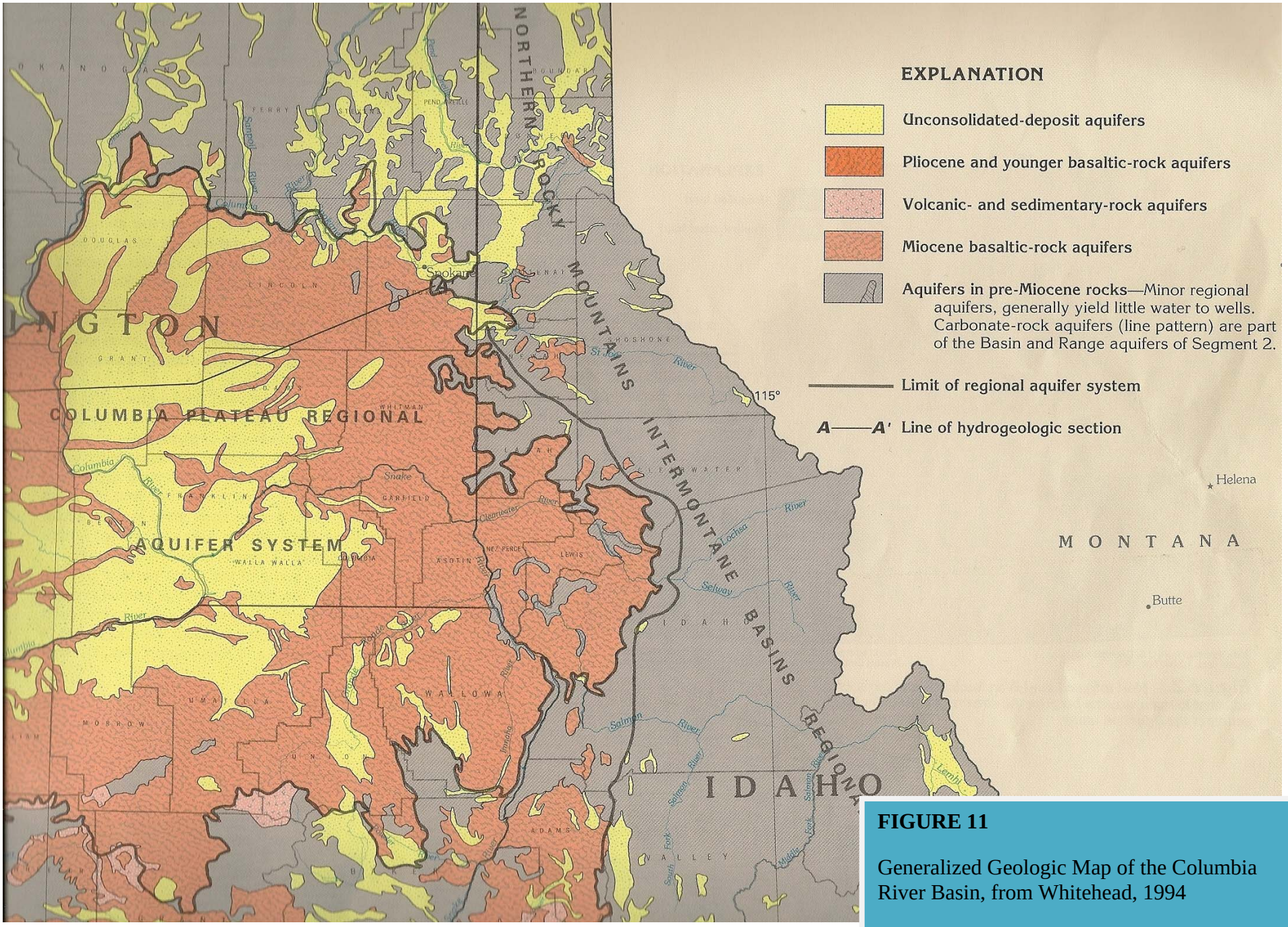


FIGURE 11

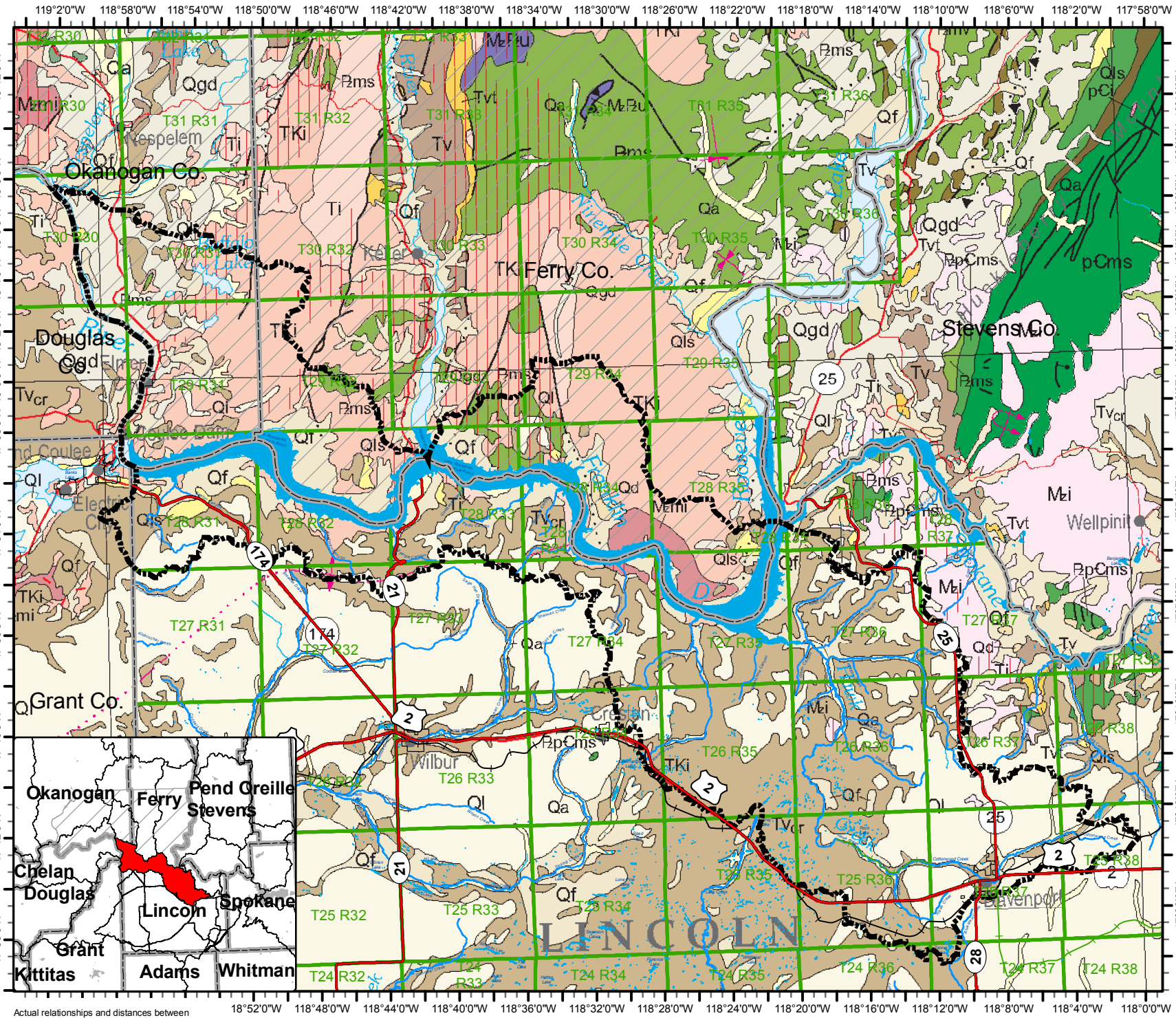
Generalized Geologic Map of the Columbia River Basin, from Whitehead, 1994

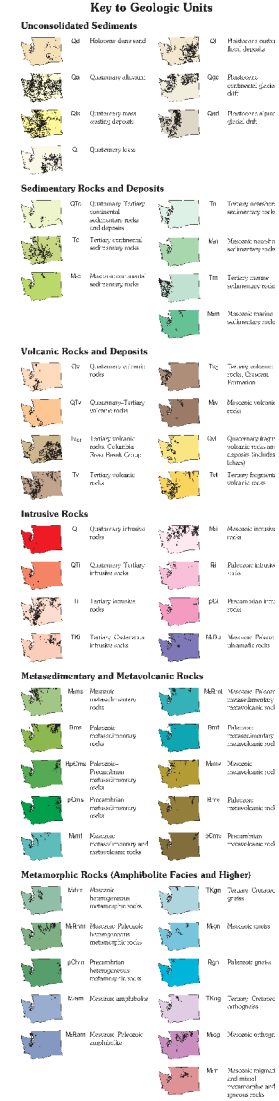
Prepared by: ENJS May 5, 2009

Figure 12

Geology

WRIA 53





Actual relationships and distances between features may be different from those depicted on this map. Data was compiled from multiple sources. The data sources do not guarantee these data are accurate or complete. This map is for informational purposes only.

0 2 4 8 12 16

1:380,160 Miles 1 inch = 6 miles

WNR GROUP

2.4.1 Suprabasalt Sediments

The sediments overlying the CRBG within the region, referred to here as the suprabasalt sediments, consist of a wide variety of recent alluvial sands and gravels, to older loess, to much older (pre-cataclysmic flood) river and lake deposits. Within WRIA 53 the two main types of suprabasalt sediment units are Pleistocene Cataclysmic Flood deposits and loess. In addition, localized accumulations of alluvial sand and gravel (Quaternary alluvium) may be found in and near modern stream channels. Basic observations about these units are as follows:

- Quaternary alluvium – These strata consist of a variable mix of silt, sand, and/or gravel deposited following the Pleistocene Cataclysmic Floods as colluvium, on alluvial fans, as debris flows, and as reworked valley fill deposits along stream courses.
- Pleistocene Cataclysmic Flood deposits – This unit consists of a variety of sedimentary strata deposited under different sedimentologic conditions across the region during Pleistocene Cataclysmic flooding (Missoula Floods) between at least 1,000,000 years to 13,000 years before present (Bretz and others, 1956; Baker and Nummedal, 1978; Waitt, 1980, 1985; Baker and others, 1987, 1991; Kiver and others, 1989; Waitt and others, 1994). Cataclysmic Flood deposits can be divided into three basic sediment facies which can form the basis for subdividing the flood deposits into mappable subunits. These facies include:
    - Interbedded silt and fine-grained sand (Figure 13) deposited in areas were Cataclysmic Flood waters backed up behind hydrologic barriers and are typically found around the edges of basin areas and on highlands adjacent to large flood eroded coulees. In the GWMA, these strata are commonly referred to as Touchet Beds.
    - Laminated to massive, uncemented, felsic to basaltic, fine to very coarse-grained sand (Figure 14) containing variable numbers of thin, lenticular, silt to fine gravel interbeds. Where the basalt content in these deposits is high they will often be referred to as “black sands.”
    - Well stratified to massive, uncemented, unweathered, mixed lithology (although basalt content is usually high), pebble to boulder gravel (Figure 15) with matrix sand ranging from absent to basaltic and granular. Flood deposited gravel is commonly referred to and mapped as the Pasco gravel.

  Quaternary loess (Figure 16) – This unit consists predominantly of silt and silty sand typically shown on area geologic maps as loess. These strata are also referred to in some reports as the Palouse Formation (Grolier and Bingham, 1971; Rigby and others, 1979; Baker and others, 1987, 1991; Kiver and others, 1989; McDonald and Busacca, 1989, 1992; Busacca and McDonald, 1994; Schuster and others, 1997).

Figure 13. Intercalated sand and silt typical of the Touchet Beds. This outcrop in the Walla Walla Basin shows the distinctive layered nature of these Pleistocene Catalysmic Flood deposits.

Figure 14. Outcrop of typical Pleistocene Cataclysmic Flood deposited sand showing the distinctive bedding characteristics of these strata.

Figure 15. Photograph of large scale cross-bedded pebble cobble gravel of the Pleistocene Cataclysmic Flood gravel facies.

Figure 16. Photograph of Pleistocene loess. This outcrop shows the blocky massive nature of typical loess found throughout the region.

2.4.2 Columbia River Basalt Group

Collectively the CRBG consists of a thick sequence of more than 300 continental tholeiitic flood basalt flows that cover an area of more than 59,000 mi^2 (164,000 km^2) in Washington, Oregon, and western Idaho (Tolan et al., 1989; Camp et al., 2003; Camp and Ross, 2004) with a maximum thickness of over10,000 feet (3.2 km) occurring in the Pasco Basin area (Reidel et al., 1982, 1989a,b). CRBG flows erupted during a period from about 17 to 6 Ma from long (6 to 30 mi, 10 to >50 km), north-northwest-trending linear fissure systems located in eastern Washington, northeastern Oregon, and western Idaho. Although CRBG eruptive activity spanned an 11 million year period, most (>96 volume %) of the CRBG flows were emplaced over a 2.5 million year period from 17 to 14.5 Ma (Swanson et al., 1979a; Tolan et al., 1989) (Figure 17).

During CRBG volcanism, most of the flows emplaced were of extraordinary size, commonly exceeding 215 to 340 mi^3 (1,000 to > 1,600 km^3) in volume, having traveled many hundreds of miles from their linear vent systems, and covering many thousands of square miles (Tolan et al., 1989; Reidel et al., 1989b). These enormous CRBG lava flows are hundreds to thousands of times larger than any lava flow erupted during recorded human history. Figure 18 presents a same-scale comparison between a single, fairly typical CRBG flow, the Laki (Skaftar Fires) flow field, the largest basalt eruption in recorded human history (Thordarson and Self, 1993), and the ongoing Pu'u O'o eruption on the Island of Hawaii. CRBG flows represent the largest individual lava flows known on the earth (Tolan et al., 1989).

The CRBG has been divided into a host of regionally mappable units (Figure 19). Unit definition is based on variations in physical, chemical, and paleomagnetic properties - in regard to stratigraphic position - that exist between flows and packets of flows (Swanson et al., 1979a; Beeson et al., 1985; Reidel et al., 1989b; Bailey, 1989). The CRBG underlying the Columbia Basin region is subdivided into four formations. These formations are, from youngest to oldest, the Saddle Mountains Basalt, Wanapum Basalt, Grande Ronde Basalt, and Imnaha Basalt (Swanson et al., 1979a, b). These formations have been further subdivided into members defined, as are the formations, on the basis of a combination of unique physical, geochemical, and paleomagnetic characteristics. These members can be, and often are, further subdivided into flow units (e.g., Beeson et al., 1985). Of the major CRBG units, only portions of the Wanapum Basalt (Priest Rapids Member and Roza Member) and parts of the much thicker Grande Ronde Basalt underlying WRIA 53.

<u>Intraflow Structures</u>

Vertical exposures through CRBG flows reveal that each flow unit generally exhibits the same basic three-part internal arrangement of intraflow structures (Figure 20). These features originated either during the emplacement of the flow or during the cooling and solidification of the lava after it ceased flowing. These features are referred to as the flow top, flow interior, and flow bottom (Figure 20). The combination of a flow top of one flow and the flow bottom of the overlying flow is commonly referred to as an interflow zone (Figure 20). If a sediment interbed is present between the two flows, it is also be part of the interflow zone.

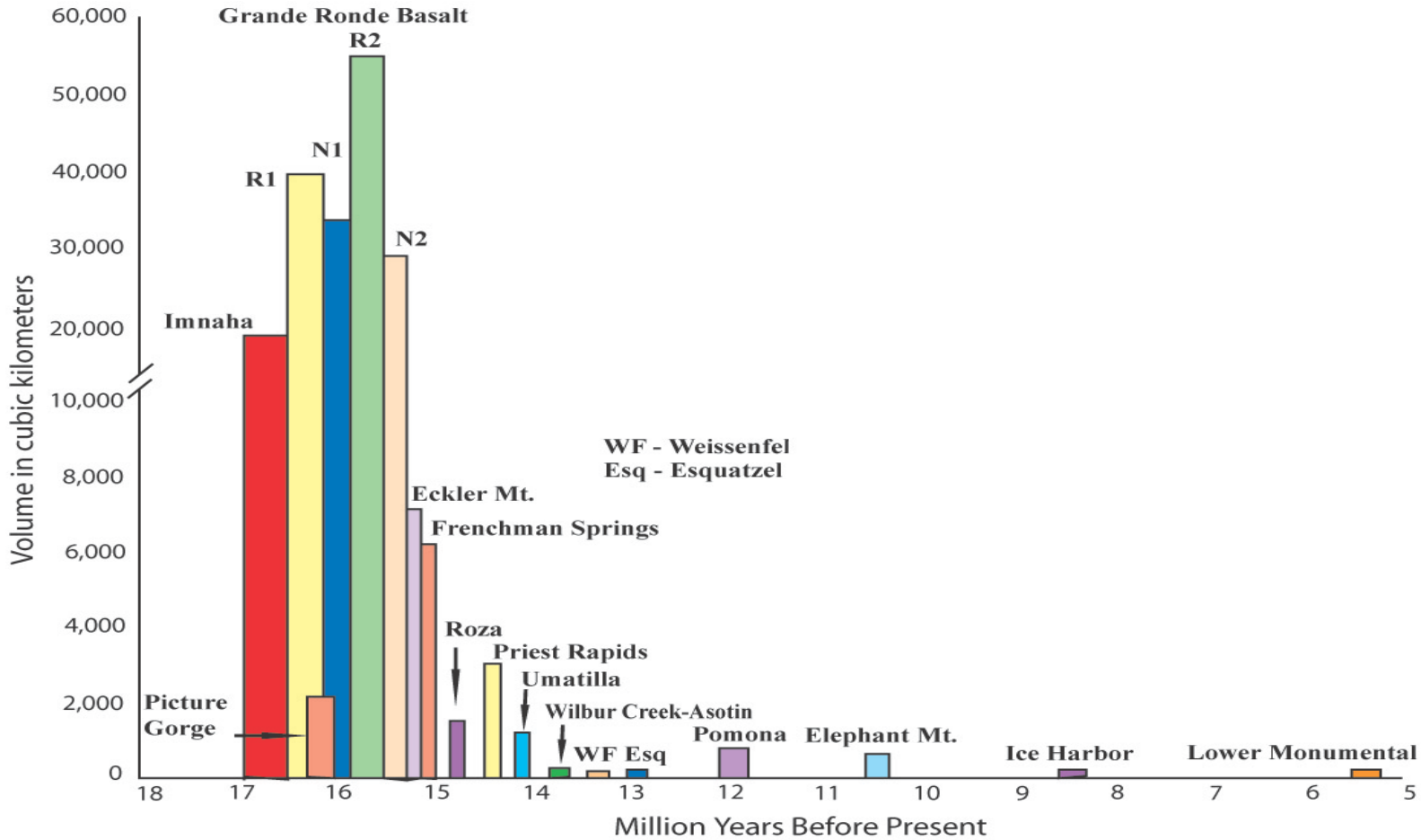


Figure 17. Plot showing the emplacement history for the CRBG units based on volume estimates from Tolan and others (1989). Note the change in scale for volume. Members consisting of a single flow (e.g., Pomona Member) are presented by a single line. Letters designate the following units: E = Eckler Mtn. Member; FS = Frenchman Springs Member; R = Roza Member; PR = Priest Rapids Member; U = Umatilla Member; W = Wilbur Creek Member; A = Asotin Member; WF = Weissenfels Ridge Member; EQ = Esquatzel Member; P = Pomona Member; EM = Elephant Mtn. Member; B = Buford Member; IH = Ice Harbor Member; L = Lower Monumental Member.

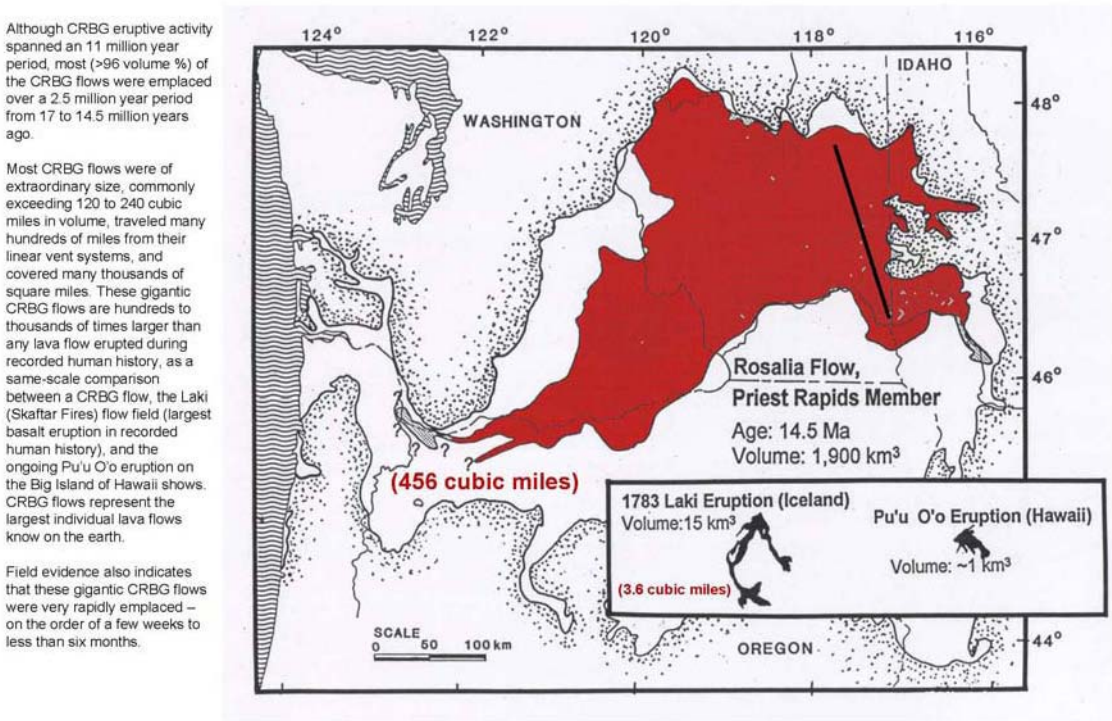


Figure 18. Same scale diagram comparing the extent of an average CRBG flow unit, Rosalia Flow, Priest Rapids Member, Wanapum Basalt to two modern basalt flow units.

The ***flow top*** is the crust that formed on the top of a molten lava flow. Flow tops commonly consist of glassy to very fine-grained basalt that is riddled with countless spherical and elongate vesicles. Vesicles represent gas bubbles that were trapped (frozen) as the flow solidified. These gasses were originally dissolved in the magma, but reduction in pressure as the magma reached the surface allowed these gasses to come out of solution. CRBG flow tops can display a wide range of variation in both their physical character and thickness (USDOE, 1988). The physical character of flow tops falls between two basic end-members, a simple vesicular flow top and a flow top breccia. A simple ***vesicular flow top*** (Figure 21) commonly consists of glassy to fine-grained basalt that displays a rapid increase in the density of vesicles as you near the top of the flow (USDOE, 1988; McMillian et al., 1989). Vesicles may be isolated or interconnected, resulting respectively in lower and higher permeability and effective porosity (USDOE, 1988). Tensional cooling joints, related to flow top formation/flow emplacement, can augment the overall permeability of this feature. A ***flow top breccia*** (Figure 22) consists of angular, scoriaceous to vesicular fragments of basaltic rubble that lies above a zone of non-fragmented, vesicular to vuggy basalt. Flow top breccias can be very thick, accounting for over half the flow thickness (>90 ft (30 m)) and laterally extensive (USDOE, 1988). Laterally extensive flow top breccias are relatively common features within the CRBG.

Series	Group	Formation	Member	Isotopic Age (m.y)	Magnetic Polarity
Miocene, Upper	Columbia River Basalt Group, Yakima Basalt Subgroup	Saddle Mountains Basalt	**Lower Monumental Member**	6	N
			Ice-Harbor Member	8.5	
			Basalt of Goose Island		N
			Basalt of Martindale		R
			Basalt of Basin City		N
			Buford Member		R
			Elephant Mountain Member	10.5	N, T
			Pomona Member	12	R
			Esquatzel Member	N	
Miocene, Middle			**Weissenfels Ridge Member**		
			Basalt of Slippery Creek		N
			Basalt of Tenmile Creek		N
			Basalt of Lewiston Orchards		N
			Basalt of Cloverland		N
			Asotin Member	13	
			Basalt of Huntzinger		N
			Wilbur Creek Member		
			Basalt of Lapwai		N
			Basalt of Wahluke		N
			Umatilla Member		
			Basalt of Sillusi		N
			Basalt of Umatilla		N
		Wanapum Basalt	**Priest Rapids Member**	14.5	
			Basalt of Lolo		R
			Basalt of Rosalia		R
			Roza Member		T, R
			Shumaker Creek Member		N
			Frenchman Springs Member		
			Basalt of Lyons Ferry		N
			Basalt of Sentinel Gap		N
			Basalt of Sand Hollow	15.3	N
			Basalt of Silver Falls		N, E
			Basalt of Ginkgo	15.6	E
			Basalt of Palouse Falls		E
			Eckler Mountain Member		
			Basalt of Dodge		N
			Basalt of Robinette Mountain		N
			Vantage Horizon		
Miocene, Middle		Grande Ronde Basalt (Prineville Basalt)	**Member of Sentinel Bluffs**	15.6	
			Member of Slack Canyon		
			Member of Fields Spring		
			Member of Winter Water		N_2
			Member of Umtanum		
			Member of Ortley		
			Member of Armstrong Canyon		
Miocene, Lower			**Member of Meyer Ridge**		
			Member of Grouse Creek		
			Member of Wapshilla Ridge		R_2
			Member of Mt. Horrible		
			Member of China Creek		N_1
			Member of Downy Gulch		
		Picture Gorge Basalt	**Member of Center Creek**		
			Member of Rogersburg		R_1
			Teepee Butte Member		
			Member of Buckhorn Springs	16.5	
		Imnaha Basalt			R_1
					T
					N_0
				17.5	R_0

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Figure19. Stratigraphic nomenclature of the CRBG. From Tolan and others (1989) and Reidel and others (1989b).

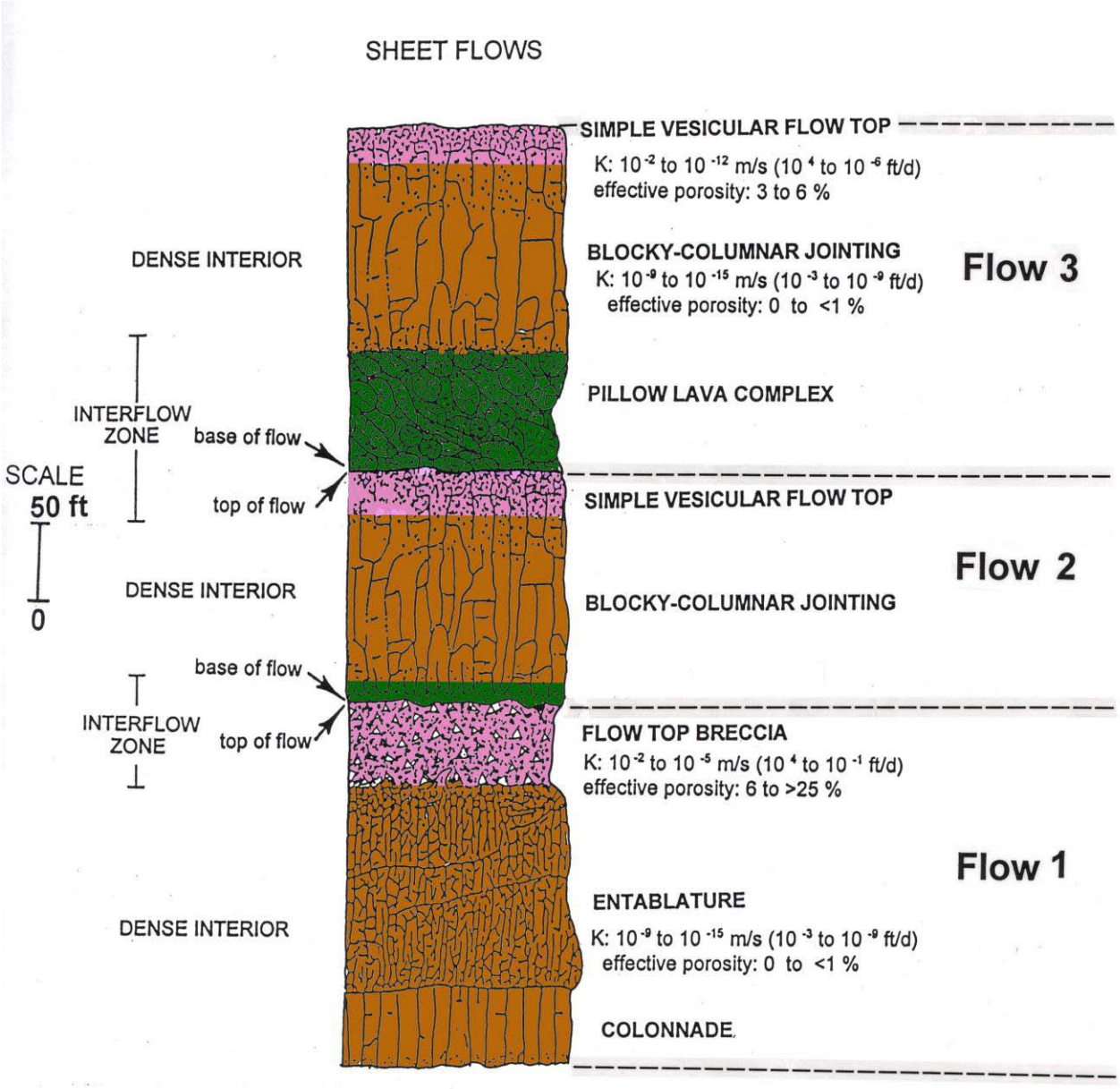

Figure 20. Diagram showing the basic intraflow structures found in typical CRBG flows.

Figure 21. Photograph of a relatively simple flow top. At the base of the outcrop the flow top is beginning to transition into the entablature/colonnade jointing style of the dense flow interior. ns.

CRBG ***flow interiors*** typically consist of dense, non-vesicular, glassy to crystalline basalt that contains numerous contraction joints (termed cooling joints) that formed when the lava solidified. CRBG cooling joints most often form regular patterns or styles, with the two most common being ***columnar-blocky*** and ***entablature-colonnade*** jointing. ***Columnar-blocky*** jointing typically consists of mostly vertical-oriented, poorly to well-formed, polygonal columns that can range from 2 feet to greater than 10 feet (>1 to 3 m) in diameter (Figure 23). The vertical columns are often cut by horizontal to subhorizontal cooling joints. ***Entablature-colonnade*** jointing (Figure 24) displays a more complex pattern that forms within a single flow. The entablature portion displays a pattern of numerous, irregular jointed small columns to randomly oriented cooling joints that abruptly overlie a thinner zone displaying well-developed columnar jointing. Another characteristic of the entablature is that the basalt comprising it contains a very high percentage of glass (50 to 95%) in contrast to the colonnade (Long and Wood, 1986; USDOE, 1988).

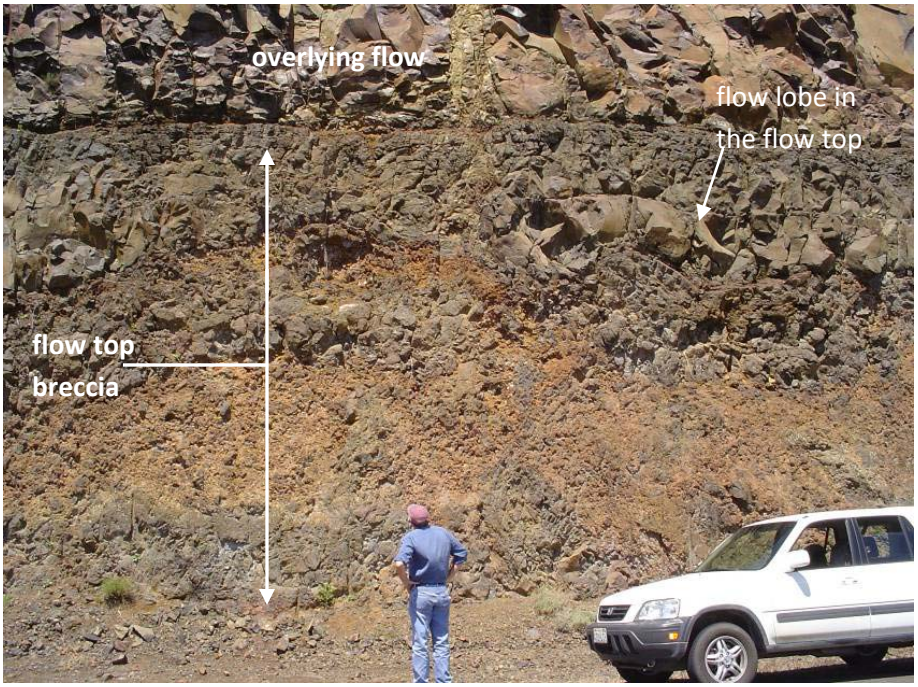

Figure 22a. Outcrop of a relatively thick flow top breccia. Several flow lobes are visible in the flow top.

Figure 22b. Close up photograph of the blocky textures typical of flow top breccias.

Figure 23. The classic columnar jointing seen in so many CRBG flow units.

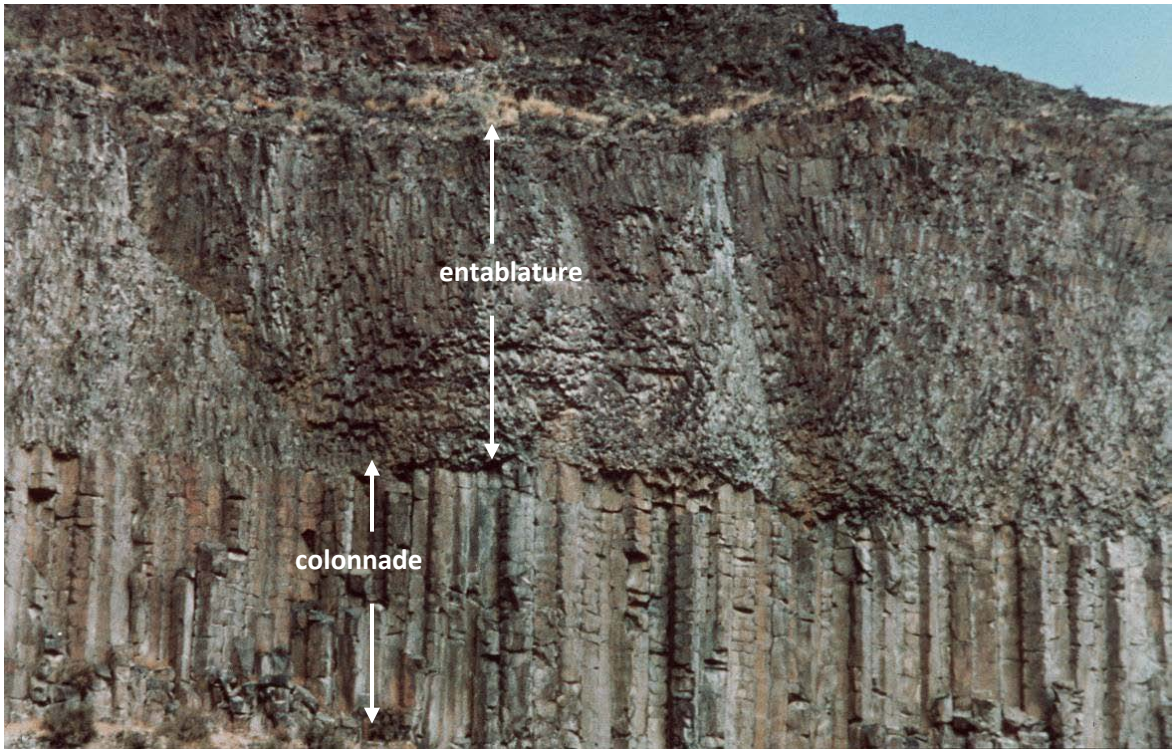

Figure 24. The entablature-colonnade style of jointing also commonly seen in the CRBG.

The physical characteristics of CRBG ***flow bottoms*** largely are dependent on the environmental conditions the molten lava encountered as it was emplaced (Mackin, 1961; Swanson and Wright, 1978, 1981; USDOE, 1988; Beeson et al., 1989; Reidel et al., 1994; Beeson and Tolan, 1996). If the advancing CRBG lava encountered relatively dry ground conditions, the flow bottom that results typically consists of a narrow (<3 ft/<1 m) zone of sparsely vesicular, glassy to very fine-grained basalt (Figure 24). This type of flow bottom structure is very common within the CRBG. Where advancing lava encountered lakes, rivers, and/or areas of water-saturated, unconsolidated sediments, far more complex flow bottom structures formed (Mackin, 1961; Schmincke, 1967; Bentley, 1977; Grolier and Bingham, 1978; Byerly and Swanson, 1978; Swanson et al., 1979a; Swanson and Wright, 1978, 1981; Bentley et al., 1980; Camp, 1981; Beeson et al., 1979, 1989; Stoffel, 1984; Tolan and Beeson, 1984; Ross, 1989; Pfaff and Beeson, 1989; Reidel et al., 1994; Beeson and Tolan, 1996). Where advancing lava encountered a lake, a ***pillow lava complex*** (Figure 25) would be created as the lava flowed into the lake. ***Spiracles*** are much rarer flow bottom features, inferred to have been created when flowing lava rapidly crossed wet sediments and the trapped water within the sediments was superheated, explosively converting to steam. The last type of flow bottom structure involves lava/sediment interaction which created a wide range and scale of invasive features. Tongues and lobes of lava emanating from the base of advancing CRBG flows occasionally burrowed into poorly consolidated sediments due to inherent density differences. Where this invading lava encountered water-saturated sediments, phreatic brecciation sometimes occurred creating a basalt/sediment mixture called a ***peperite***. CRBG flows are known to not only invade sediments, but were capable of lifting and rafting sediment blocks many miles (Byerly and Swanson, 1978; Swanson and Wright, 1978; Beeson et al., 1979, 1989; Stoffel, 1984; USDOE, 1988; Ross, 1989).

Figure 25. A classic pillow lave complex. This pillow lava complex, at the base of the Ginkgo flow, in the lower Frenchman Springs Member, is exposed on Washington Route 24 near Vantage, Washington.

2.4.3 Pre-basalt Basement Rocks

The entire WRIA 53 area is underlain by pre-basalt basement rocks. These rocks, which consist predominantly of granite and related felsic crystalline rocks and low to medium grade metamorphic rocks, especially quartzites and phyllites, crop out along most of the southern shore of Lake Roosevelt, in steptoe buttes (such as Creston Butte) found in and near the WRIA, in the canyon bottom along the middle reaches of Hawk Creek, and in the highlands separating the WRIA from the Spokane River to the north and east. Fracture and shear zones, including faults, are known to cross-cut these rocks.

2.4.4 Structural Geology

The Columbia Basin has experienced 4,500 to more than 10,000 feet (1,500 – 3,000 m) of subsidence since the onset of CRBG volcanism approximately 17 million years ago (Myers and Price, 1979; Reidel et al., 1982, 1989b; USDOE, 1988; Watters, 1989). Although this region is commonly called the Columbia Plateau or Columbia Plain (Baker et al., 1987; USDOE, 1988), from a structural geology standpoint this entire region is more properly a "basin" due to the regional-scale subsidence experienced in the area/in the area (Campbell, 1989). In addition to regional subsidence, this region has been under gone a general north-south compression/east-west extension stress regime from the beginning of CRBG time (Davis, 1981; Myers and Price, 1979, 1981; Reidel et al., 1982, 1989a; USDOE, 1988; Watters, 1989) to the present-day (USDOE, 1988; Geomatrix, 1988, 1990). This stress regime has led to the formation of folds and faults in the Yakima Fold Belt and Columbia Trans-Arc Lowland. Within the Cascade Range, deformation associated with the Cascade volcanic arc (e.g., intra-arc grabens) also occurs and "overprints" these regional structures. Differences in the styles of folding and faulting allow this region to be subdivided into four distinct structural subprovinces: the Yakima Fold Belt, Blue Mountains, Palouse Slope, and Clearwater Embayment (Myers and Price, 1979; WPPSS, 1981; USDOE, 1988; Reidel et al., 1989a). WRIA 53 lies on the northern edge of the Palouse Slope, where that structural subprovince is transitioning into the Okanagan Highlands structural subprovince which essentially comprises the area north of Lake Roosevelt.

The Palouse Slope structural subprovince comprises much of the eastern half of the Columbia Plateau. The Palouse slope usually displays a regional dip slope (<1 to 2 degrees) extending from highs of 3,000 feet (900 m) in western most Idaho and north-central Washington to lows in south-central Washington (Myers and Price, 1979; USDOE, 1988). Deformation on the Palouse Slope is primarily characterized by north to northwest trending and several east-west trending folds with little or no apparent topographic expression (Swanson et al., 1980; Tolan and Reidel, 1989). Dips on these folds typically are less than 5 degrees. A few faults and shear zones, generally with the same orientation as the low amplitude folds noted above, have been mapped within this region (Tolan and Reidel, 1989).

Within WRIA 53, one of the most notable structures influencing the area is an east-west oriented, low amplitude anticline that essentially follows the drainage divide which defines much of the southern boundary of the WRIA west of Jump Canyon (Waggoner, 1990). CRBG strata on the north side of this anticline dip towards Lake Roosevelt. Strata on the south side of structure dip southward into the Columbia Basin. This structure, at least in part, could account for the widespread occurrence of pre-basalt basement on the south side of Lake Roosevelt.

East of Jump Canyon predominant CRBG dips appear to be to the south. The absence of pre-basalt basement at the mouth of Hawk Creek also may be because of structure. In this area, the top of the pre-basalt basement is below Lake Roosevelt Lake. Faults mapped in the canyon of the middle reach of Hawk Creek may have dropped the pre-basalt basement deeper in this area, putting it below the level of Lake Roosevelt.

Several generally north-south oriented fault zones in pre-basalt basement rocks are mapped north of Lake Roosevelt (Waggoner, 1990). These structures appear to continue south of the Lake in pre-basalt basement. However, their extent and characteristics within the WIRA beneath the CRBG is not known.

2.5 Hydrologic Setting

The hydrology of WRIA 53 is dominated by several ground water and surface water systems. The surface water systems are fairly limited, and consist predominantly of intermittent streams in the many canyons which drain northwards into Lake Roosevelt, spring-feed streams located on the slopes overlooking Lake Roosevelt, and Hawk Creek. Many of the springs in the WRIA are feed by groundwater discharge from CRBG aquifers. Lake Roosevelt, the largest body of surface water in the WRIA, is not discussed in this report.

The groundwater systems underlying the WRIA are hosted predominantly by alluvial and Pleistocene Cataclysmic Flood deposits, the CRBG, and pre-basalt basement. The basic hydrology of WRIA 53 is summarized in this section. More detailed information about surface water and ground water in the WRIA is provided in Section 4.0, Water Resources.

2.5.1 Surface Water Hydrology

As noted above, surface water within WRIA 53 generally is found in intermittent streams found in the canyons that drain northwards into Lake Roosevelt, spring feed streams generally on slopes above Lake Roosevelt, and in the Hawk Creek system. Figures 1 and 2 show the locations of many of the streams found within WRIA 53. The precipitation that contributes water to all of these streams in the form of direct run-off generally comes in a few main forms, namely snow-melt, and intermittent fall, winter, and spring rain.

Hawk Creek is the largest perennial stream in the WRIA, although reaches of it can run dry during the summer and autumn (Lundgren, David, Lincoln County Conservation District, 2009 personal communication; Hawk Creek Report of Referee, January 30, 1932). Flow in this stream is estimated to be on the order of a few cfs, although long-term, detailed gauge data was not found for the stream. One would expect, and anecdotal statements made by WRIA participants indicate, flows in Hawk Creek are highest in the late winter and spring. In addition, given the sporadic nature of spring, summer, and autumn rain-fall, one should expect periodic flash flow events in this stream as a result of rare, but intense local rain-fall events.

Gauge data was not found for any of the springs or other streams in the WRIA. Anecdotal comments made by WRIA participants suggest that flow in these streams and springs changes seasonally. Some of the water that infiltrates into the ground in the WRIA resurfaces in the springs that feed the upper reaches of Hawk Creek and many of the northwards draining

perennial and intermittent streams west of Hawk Creek. Generally, those streams that flow during a portion of or all of the dry summer and early autumn months are feed by springs.

2.5.2 Groundwater Hydrology

The spring feed streams noted in the previous section are feed by ground water discharging from one or more of the aquifer systems underlying the WRIA. Three basic aquifer systems are interpreted to underlie the WRIA, each within by a specific rock or host material.

One of these is found within the alluvial sediments which are widespread along the shores of Lake Roosevelt and localized in tributary stream valleys and channeled scabland areas along the southern fringe of the WRIA. This aquifer system generally is unconfined and strongly influenced by precipitation and stream flow. Typically the alluvial system will display a high degree of continuity with nearby surface waters. Based on surface geologic maps of this area (Waggoner, 1990), and GWMA's soon to be completed subsurface mapping, one would expect the alluvial aquifer system to be broken up into a number of smaller isolated subsystems, the lateral extent of which are controlled by CRBG and pre-basalt basement rock outcrops.

The second groundwater system in the WRIA is found within the CRBG. This system consists of a series of semi-confined to confined, planar-tabular water-bearing zones found at the tops and bottoms of individual CRBG units. Depending on local conditions, the CRBG aquifer system may display limited to no continuity with surface water, or a high degree of continuity with surface water. CRBG aquifers generally will display far more lateral continuity, because of the widespread nature of CRBG basalt layers, than the alluvial system. Recent GWMA work suggests the main sources of recharge to this system is a small component of modern precipitation driven recharge and a much larger, but also much older and currently inactive process related to Pleistocene Cataclysmic Floods.

The third main aquifer system in the WRIA is found within pre-basalt basement rocks. Very little is known about this system except that it generally is low yield, and found primarily within joints and fractures within these rocks. These joints and fractures likely will be narrow, planar, and elongate features that may propagate to the ground surface where some recharge can occur. Like the CRBG system, the degree of hydrologic continuity between the pre-basalt basement system and surface water likely is controlled by local conditions, and can be quite variable. However, based on anecdotal evidence gleaned from water well reports and personal interviews, the connection generally will be limited to none.