APPENDIX A – HYDROLOGY

RECLAMATION
Managing Water in the West

HYDROLOGY REPORT
CATHERINE CREEK TRIBUTARY ASSESSMENT – GRANDE RONDE RIVER BASIN

Tributary Habitat Program, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Geology and Fluvial Analysis Group
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U.S. DEPARTMENT OF THE INTERIOR

Protecting America's Great Outdoors and Powering Our Future

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photograph: View looking east (downstream) along Catherine Creek, Reach 2 at river mile 26.0, in the Cove area, Mt. Fanny (upper left) and Phys Point (upper right) can be seen in the background. **Catherine Creek Tributary Assessment-Grande Ronde River Basin-Tributary Habitat Program, Oregon – July 29, 2010.**

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1. Summary

Catherine Creek is a large, snowmelt-dominated creek that drains part of the Wallowa Mountains of Oregon. The headwaters are steep and mountainous while the lower reaches have an exceptionally low gradient (1.9 ft/mile). Historically, the low gradient reaches were meandering and tortuous and routed through abundant wetlands, rivulets, and shallow lakes through the Grande Ronde Valley. Here the creek has been channelized and deepened to improve the local land drainage and reduce flooding for agricultural and urban use. Similarly, the lower end of the Grande Ronde River within the Grande Ronde Valley, below La Grande, Oregon has been redirected and channelized, moving the Catherine Creek-Grande Ronde River confluence downstream 22.5 miles and shortening the Grande Ronde River by 33 miles. The lowest reach of Catherine Creek is now in an oversized channel (the historic Grande Ronde River) which once had a 1.5-year return interval discharge of approximately 6,400 cfs and is now only 1,760 cfs. The modifications that have occurred have led to lower baseflows during the summer months as well. Studies have been conducted to determine how altering Rhinehart Gap, a natural constriction marking the end of the Grande Ronde Valley downstream of Catherine Creek, might further improve runoff efficiency during high flow events. Numerous diversion dams and pumps along the length of the creek remove water during the summer at a time when the creek naturally has the lowest flows, which can lead to dry or nearly dry sections of creek. Changes in climate have also occurred leading to decreased water yield in the basin and an earlier release of snowpack. This adds further stress to the system as the irrigation season is extended while the water supply is reduced.

2. Introduction

2.1 Purpose

Reclamation and Bonneville Power Administration (BPA) contribute to the implementation of salmonid habitat improvement projects in the Grande Ronde subbasin to help meet commitments contained in the 2010 Supplemental Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NOAA Fisheries 2010). This BiOp includes a Reasonable and Prudent Alternative (RPA), or a suite of actions, to protect listed salmon and steelhead across their life cycle. Habitat improvement projects in various Columbia River tributaries are one aspect of this RPA. Reclamation provides technical assistance to States, Tribes, Federal agencies, and other local partners for identification, design, and construction of stream habitat improvement projects that primarily address streamflow, access, entrainment, and channel complexity limiting factors. Reclamation's contributions to habitat improvement are intended to be within the framework of the FCRPS RPA or related commitments.

The hydrologic assessment as a part of the Catherine Creek Tributary Assessment (TA) described here will provide scientific information that can be used to help identify, prioritize, and implement sustainable fish habitat improvement projects and to help focus those projects on addressing key limiting factors to protect and improve survival of salmon and steelhead listed under the Endangered Species Act (ESA). The TA represents the initial phase of a work process adopted by Reclamation to provide specific technical details, which serve as guidance for project identification, viability of existing habitat, and project needs for rehabilitation of ESA-listed steelhead trout and spring Chinook. The TA will be provided to regional and local implementers of habitat rehabilitation projects to guide efforts towards a common goal of increased abundance and productivity of ESA-listed steelhead trout and spring Chinook.

The specific objectives of this hydrologic assessment as part of the TA include the following:

1. Identify the present condition surface water hydrologic patterns and influences of Catherine Creek utilizing available data.
2. Identify the historic conditions surface water hydrologic patterns and influences utilizing available data and historic accounts.
3. Identify any changes to historic hydrologic conditions that are well understood to include anthropogenic alterations and natural changes.
4. Estimate recent climate change effects on the hydrology of the region.

2.2 Physical Setting and Location

The Catherine Creek TA focuses on the ―valley segment” of Catherine Creek from its confluence with the Grande Ronde River at State Ditch to near its headwaters at the U.S. Forest Service (USFS) boundary at the confluence of the North and South Forks of Catherine Creek (Figure 1). This reach is approximately 55-miles long and is located within three distinct geomorphic valley types including headwater, alluvial fan, and valley bottom. Several tributaries are also of interest within this area, most notably larger tributaries within the valley segment to include Mill Creek, Ladd Creek, Little Creek, and Pyles Creek. The study area is roughly bounded by the 100-year floodplain.

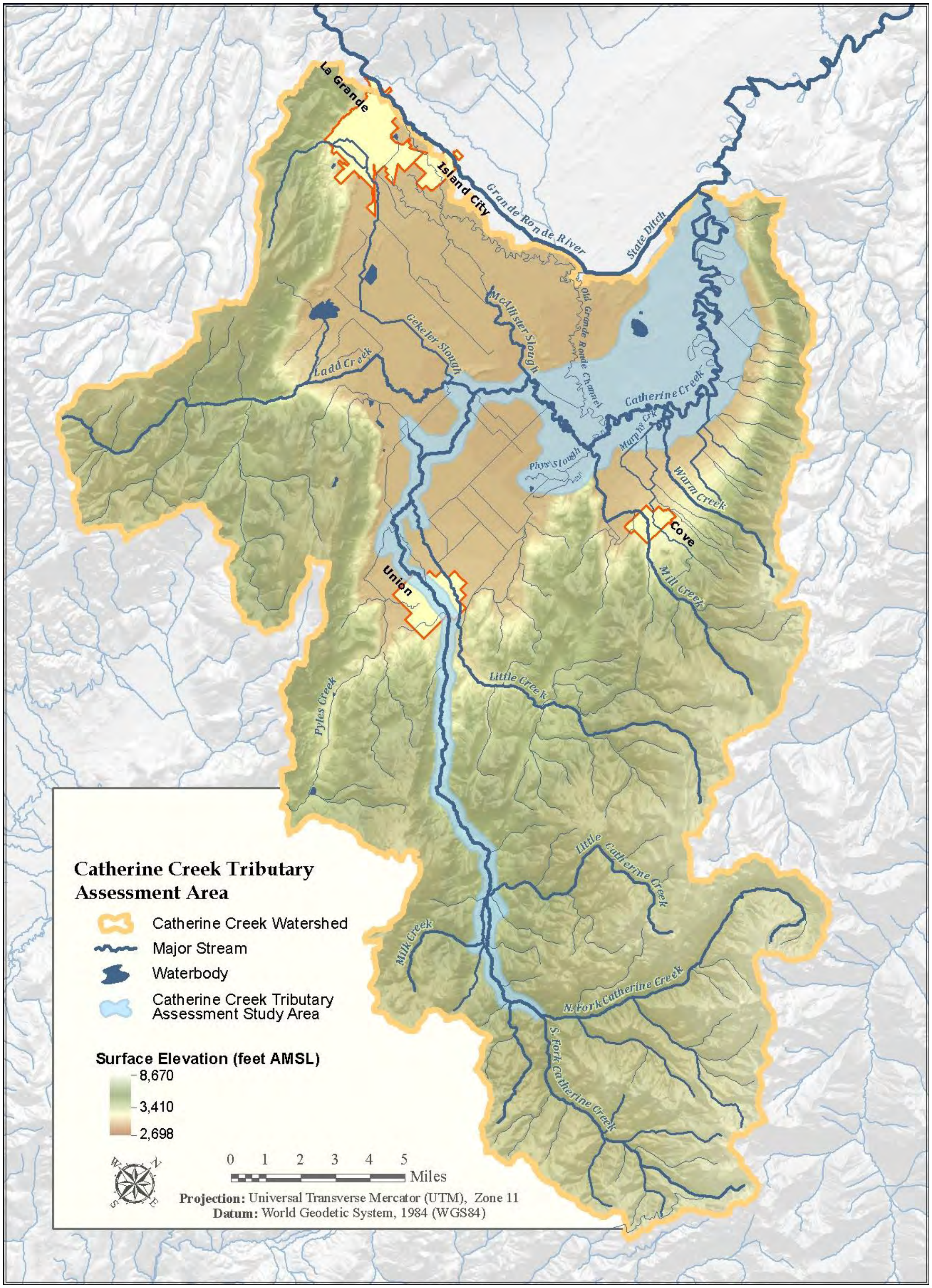


Figure 1. Catherine Creek watershed with the Tributary Assessment study area identified to encompass the lower 55-miles of Catherine Creek.

Catherine Creek is a large tributary of the Grande Ronde River, draining 402 square miles (mi^2) (Figure 2). At its confluence with Catherine Creek, the Grande Ronde River drains 735 mi^2 not including Catherine Creek. The majority of Catherine Creek and the Grande Ronde River to this point are contained within Union County in northeast Oregon and are in the Blue Mountains Ecoregion (Omernik 1995). Catherine Creek drains steep mountainsides with elevations over 8,671 feet before crossing the wide and flat Grande Ronde Valley where it meets the Grande Ronde River at an elevation of 2,677 feet above sea level. The Grande Ronde River continues downstream for 105 miles through narrow and steep mountain valleys, eventually flowing through the southeast corner of Washington State before joining the Snake River upstream of Lewiston, Idaho, and Clarkston, Washington.

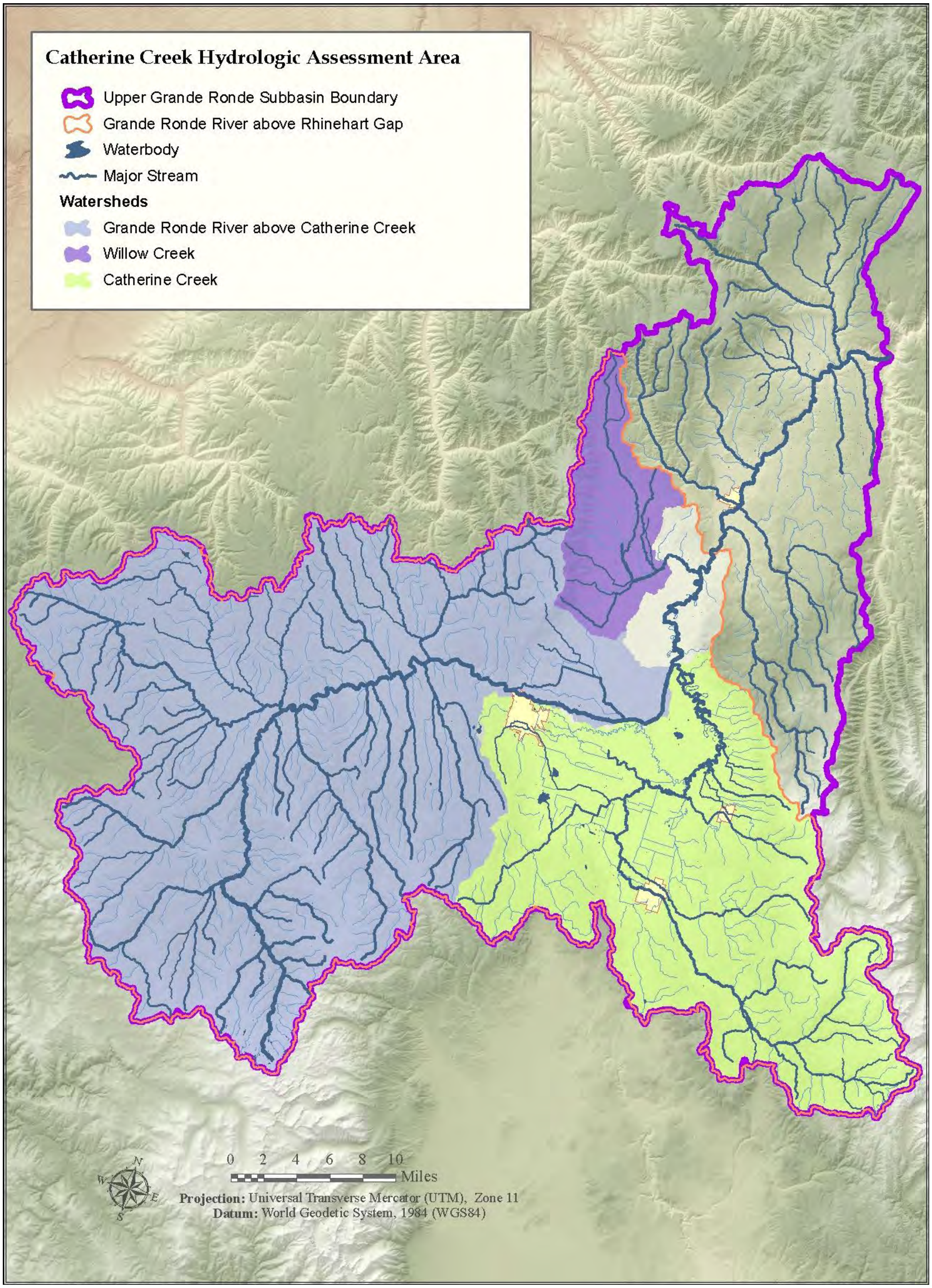


Figure 2. Grande Ronde River and Catherine Creek watersheds.

There are four major tributaries to Catherine Creek within the study area including Little Creek, Mill Creek, Pyles Creek, and Ladd Creek in addition to the upper Catherine Creek watershed (Figure 3). The stream gage ―Catherine Creek near Union" is used here to represent the upper Catherine Creek watershed. These watersheds drain most of the higher terrain in the Catherine Creek watershed, are steep, and receive a majority of the precipitation. The Grande Ronde River above the confluence with Catherine Creek and Willow Creek are two other major watersheds used in this analysis to provide a hydrologic assessment of Catherine Creek within the Grande Ronde Valley, above Rhinehart Gap. Figure 3 depicts the delineated area of each of the major watersheds used for this assessment.

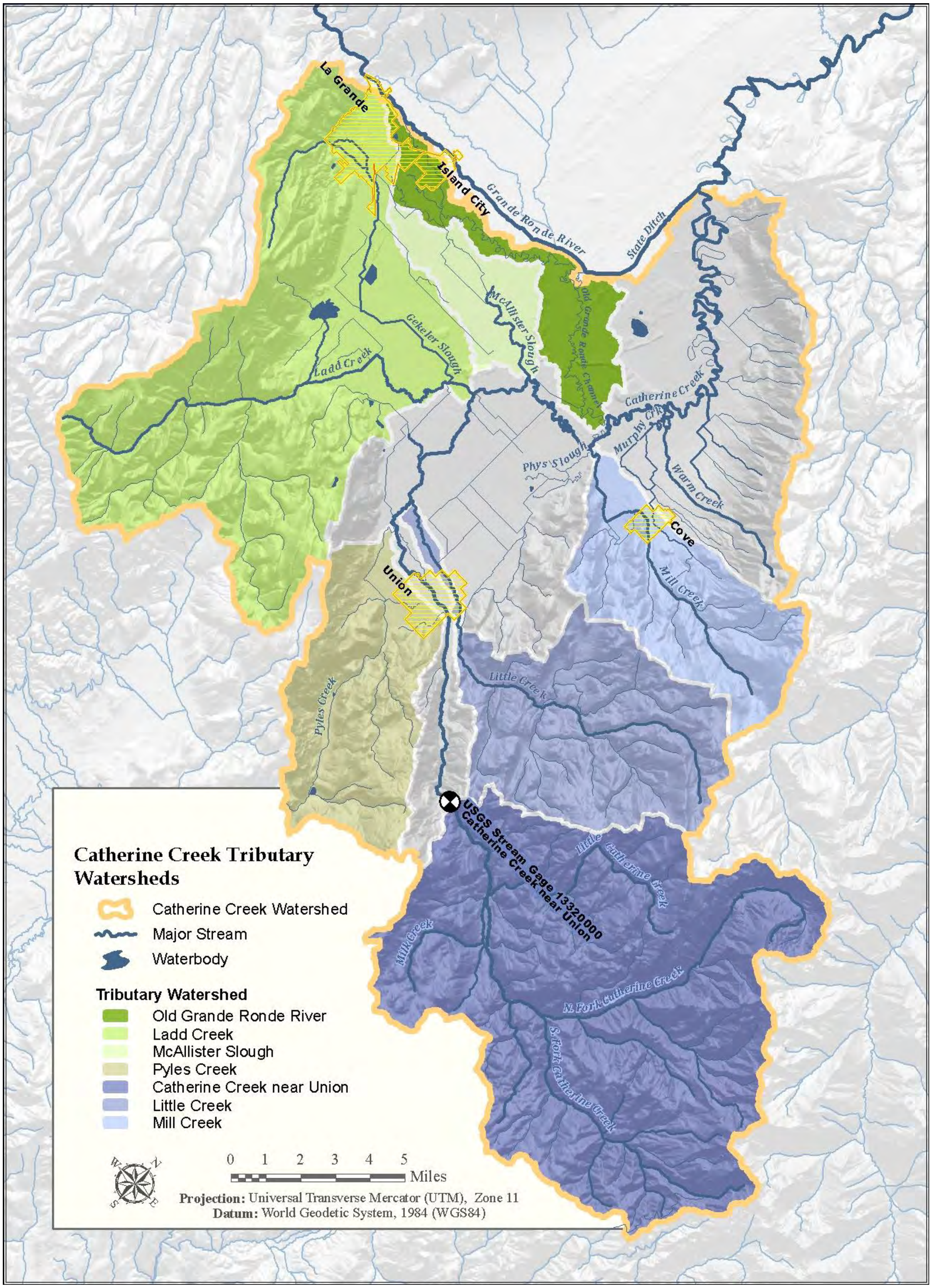


Figure 3. Catherine Creek watershed and smaller tributaries, Catherine Creek near Union gage, including Rhinehart Gap.

Three miles downstream of the Catherine Creek-Grande Ronde River confluence the Grande Ronde River flows through a narrow, confined valley known as Rhinehart Gap. Because of the profound effect Rhinehart Gap has on controlling floodflow stages well into the lower reaches of Catherine Creek, this area of the Grande Ronde River has been included as part of this hydrologic analysis in support of the hydraulic assessment of Catherine Creek.

The remaining areas above Rhinehart Gap that are not included in the preceding watersheds are broad, low relief areas with low relative precipitation. Two of the low relief areas have substantial channels apparent, McAllister Slough and the Historic Grande Ronde River. There are also a number of short, steep creeks, with low contributing areas that drain USFS lands in the northeast corner of the watershed, which are not directly included in the following analyses (Figure 3). Many of these creeks are associated with springs near the valley bottom that provide irrigation water. Figure 4 depicts the numerous springs and creeks within this area, several of which are located within the Mill Creek watershed. Mill Creek was the only tributary in this area that was included in this analysis.

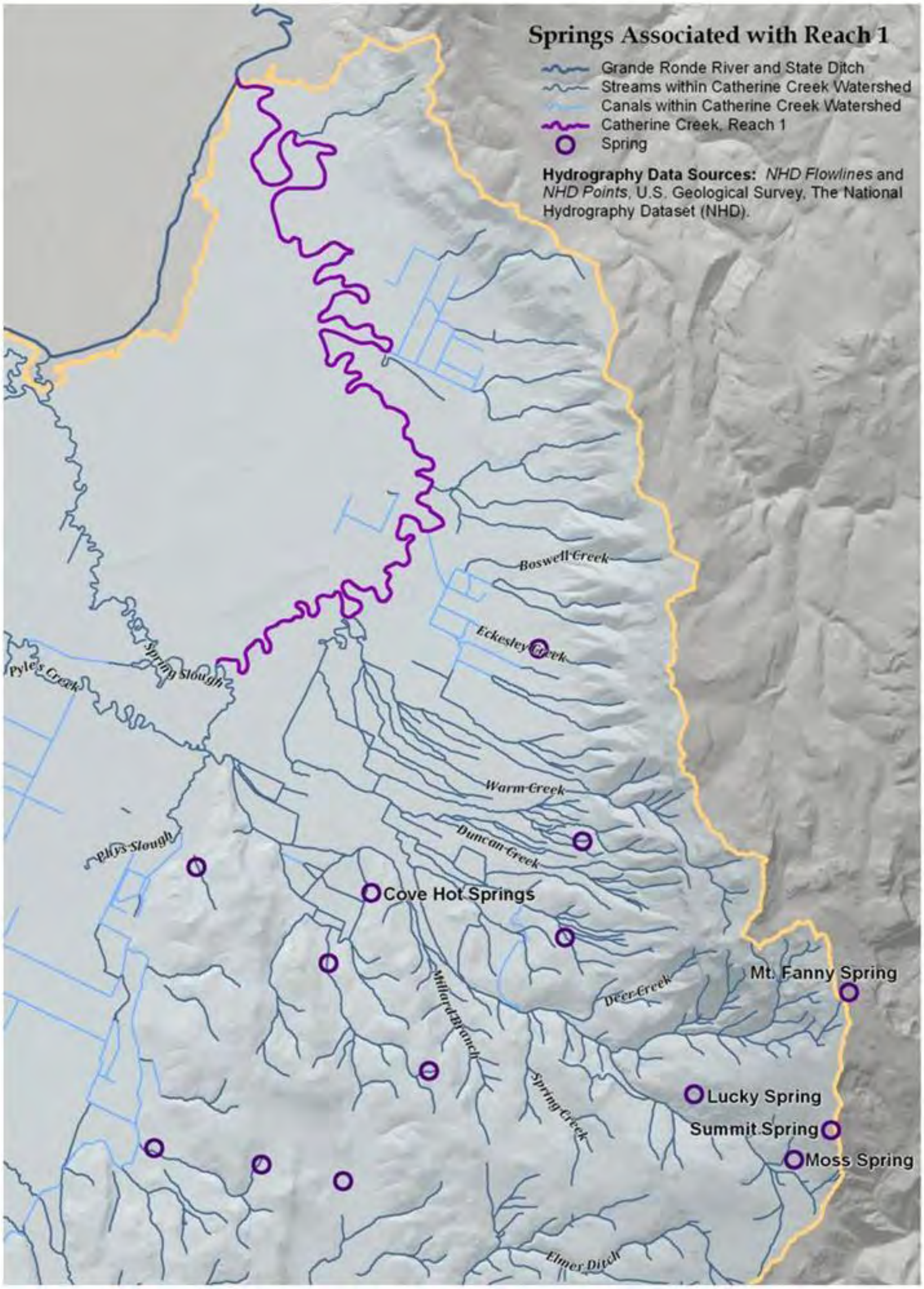


Figure 4. Springs and creeks draining to reach 1 of Catherine Creek.

2.2.1 Climate

The hydrology of Catherine Creek and surrounding watersheds is dominated by a spring snowmelt regime. Peak flows generally occur in May (Catherine Creek near Union gage has an average peak date of May 13), but can occur from April through June. Flood peaks for the Grande Ronde River tend to occur earlier, having snowmelt peaks as early as February in some years. Late fall, winter, and early spring rain-on-snow events can also develop into substantial peak flow events that can approach the magnitude of the annual snowmelt peak, but the highest annual peak discharge is typically a result of the spring melt. Winter freeze-thaw events are common in the region and can contain large quantities of ice potentially causing locally damaging floods and promote scour and bank erosion. Due to the high variation in elevation among tributaries, including the Grande Ronde River, runoff timing, and magnitudes can vary substantially.

Summers are relatively dry with low flow conditions occurring in August and September. Precipitation in the summer accounts for a very small percentage of the annual yield. Summer precipitation events are typically the result of small, localized thunderstorms that may or may not lead to noticeable changes in flow in small creeks. However, flash floods have occurred which have caused documented flooding and fish kills (Gildemeister 1998).

3. Methods

3.1 Hydrologic Analysis

3.1.1 Stream Gages

Multiple locations within and near the study area have had stream gages in the past (Figure 5). However, only three stream-discharge gages are active in the Catherine Creek assessment area including Catherine Creek near Union, Oregon (13320000), Catherine Creek at Union, Oregon (13320300), and Grande Ronde River near Perry, Oregon (13318960). General stream gage information, including years of operation, is presented in Table 1. Data from these gages was used to compute summary statistics including exceedance flows, average annual hydrographs, peak return interval discharges, water yield, and baseflows.

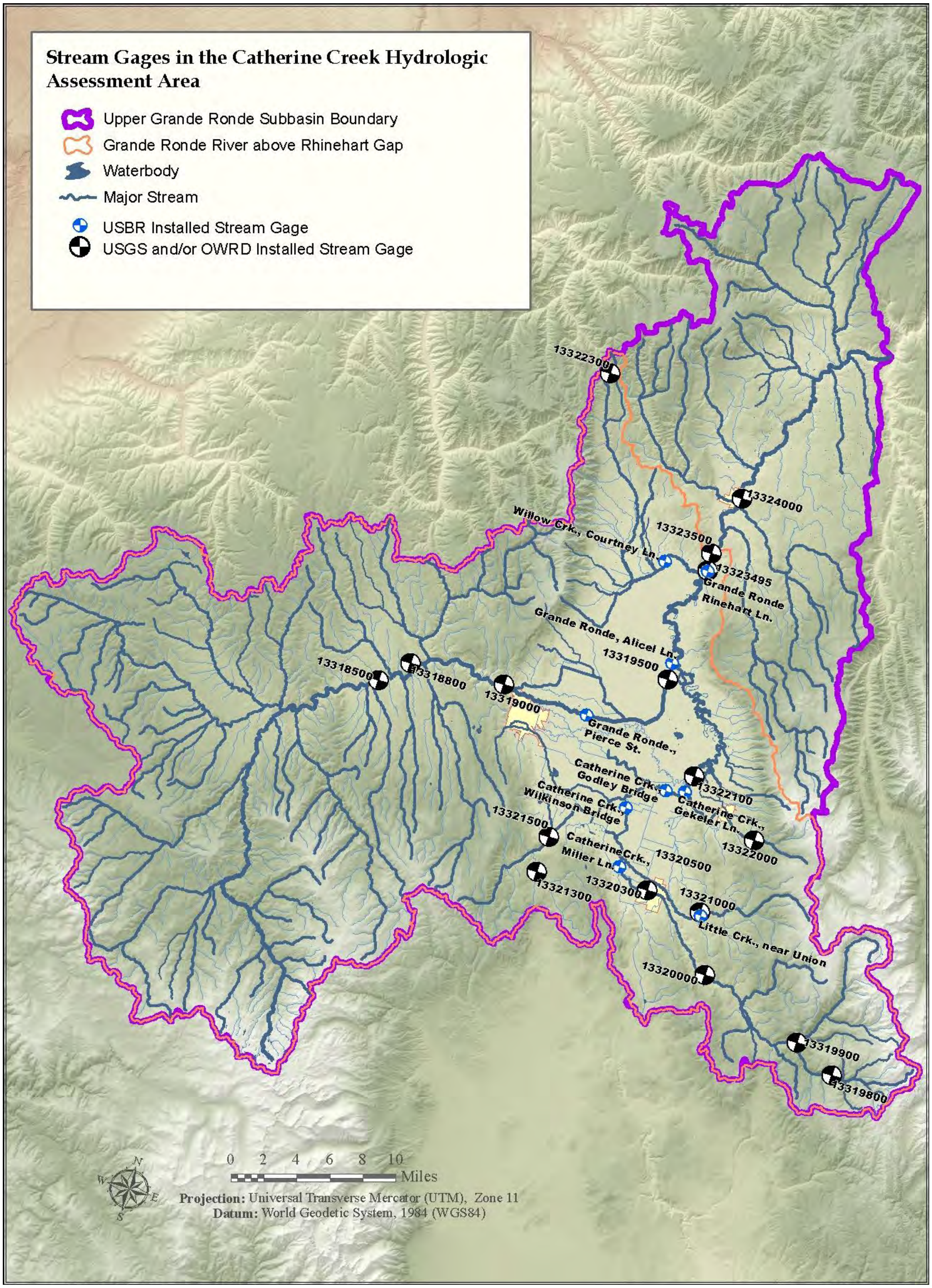


Figure 5. Stream gages in the Catherine Creek area. Reclamation gages were installed in 2010.

Table 1. Active and discontinued stream gages in the assessment area indicating the type of data available and the range of years the gage was active. (Note – Data may not be continuous; peak data refers to the annual maximum instantaneous discharge; and years are calendar years).

Station Number	Station Name	15-minute Data	Daily Mean Data	Peak Data	Start Year	End year	Active ?
13318500	GRANDE RONDE RIVER NEAR HILGARD, OR	no	yes	no	1937	1956	No
13318800	GRANDE RONDE R AT HILGARD, OR	no	yes	no	1966	1981	No
13319000	GRANDE RONDE R AT LA GRANDE, OR	no	yes	yes	1903	1989	No
13318960	GRANDE RONDE R NR PERRY, OR	yes	yes	yes	1997	2009	Yes
13319500	STATE D NR ALICEL, OR	no	no	no	1918	1918	No
13319700	*S CATHERINE CR D NR MEDICAL SPRINGS, OR	no	yes	no	1966	1984	No
13319800	S FK CATHERINE CR NR MEDICAL SPRINGS, OR	no	yes	no	1926	1927	No
13319900	N FK CATHERINE CR NR MEDICAL SPRINGS, OR	no	yes	no	1992	1999	No
13320000	CATHERINE CR NR UNION, OR	yes	yes	yes	1911	2009	Yes
13320300	CATHERINE CR AT UNION, OR	yes	yes	yes	1996	2009	Yes
13320400	LITTLE CR AT HIGH VALLEY NR UNION, OR	no	no	yes	1948	1979	No
13320500	LITTLE CR AT SERLAND RANCH NR UNION, OR	no	no	no	--	--	No
13321000	LITTLE CR NR UNION, OR	no	no	no	1918	1918	No
13321300	LADD CANYON NR HOT LAKE, OR	no	no	yes	1953	1972	No
13321500	LADD CREEK NEAR HOT LAKE, OR	no	no	no	1918	1918	No
13322000	MILL CR NR COVE, OR	no	no	no	1918	1921	No
13322100	GRANDE RONDE R NR COVE, OR	no	no	no	1955	1981	No
13322300	DRY CREEK NEAR BINGHAM SPRINGS, OR	no	no	yes	1965	1979	No
13323495	GRANDE RONDE R NR IMBLER, OR	no	yes	no	1997	2003	No
13323500	GRANDE RONDE R NR ELGIN, OR	no	yes	yes	1955	1981	No
13324000	GRANDE RONDE R AT ELGIN, OR	no	no	yes	1904	1919	No

* Gage is on a ditch that carries water out of S Catherine Ck to the Powder River watershed.

Table 2. Watershed characteristics for stream gages.

Station Number	Station Name	Area [sq mi]	Maximum Elevation [ft]	Mean Elevation [ft]	Minimum Elevation [ft]
13320300	CATHERINE CR AT UNION OR	111	8671	5149	2763
13320000	CATHERINE CR NR UNION OR	103	8671	5271	3097
13322300	DRY CREEK NEAR BINGHAM SPRINGS OR	1.4	4776	4443	3919
13324000	GRANDE RONDE R AT ELGIN OR	1411	8671	4221	2641
13318800	GRANDE RONDE R AT HILGARD OR	543	7933	4672	3002
13319000	GRANDE RONDE R AT LA GRANDE OR	686	7933	4582	2833
13322100	GRANDE RONDE R NR COVE OR	357	8671	4095	2683
13323500	GRANDE RONDE R NR ELGIN OR	1251	8671	4219	2667
13323495	GRANDE RONDE R NR IMBLER OR	1248	8671	4221	2669
13318500	GRANDE RONDE RIVER NEAR HILGARD OR	496	7933	4742	3059
13321300	LADD CANYON NR HOT LAKEOREG	16	4989	4120	3532
13321500	LADD CREEK NEAR HOT LAKEOR	40	5790	4310	2901
13320400	LITTLE CR AT HIGH VALLEY NR UNION OR	16	6771	5093	3217
13320500	LITTLE CR AT SERLAND RANCH NR UNION OR	0.7	3893	3472	3049
13321000	LITTLE CR NR UNION OR	31	6771	4520	2987
13322000	MILL CR NR COVE OR	12	7137	5456	3482
13319900	N FK CATHERINE CR NR MEDICAL SPRINGS OR	34	8652	5957	3712
13319800	S FK CATHERINE CR NR MEDICAL SPRINGS OR	16	8671	6050	4482
13319500	STATE D NR ALICEL OR	734	7933	4481	2678

Stream gage data were extrapolated from existing stream gages to other locations along Catherine Creek in order to develop input boundary conditions for the TA hydraulic model (Appendix D—Hydraulics). The hydraulic model was run with peak recurrence flow discharges and the model was set up to include changes (increases) in discharge with distance downstream.

The upstream gage data was extrapolated to downstream locations by delineating watersheds along Catherine Creek at points with substantial discharge changes including Catherine Creek below Pyles Creek, Catherine Creek below Little Creek, Catherine Creek below Ladd Creek, Catherine Creek below McAllister Slough, Catherine Creek below the "Old" (Historic) Grande Ronde River Channel, Catherine Creek below Mill Creek, and Catherine Creek at the State Ditch confluence. The extrapolation was done by multiplying the average annual precipitation ratio for the watersheds (ratio of the average annual precipitation volume for the watershed at the point of interest to the average annual precipitation volume for the watershed at the stream gage) and the known discharge from the stream gage. The average annual precipitation volume was calculated using average annual precipitation data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM 2006) developed by Oregon State University as shown in Figure 6 and polygons of delineated watershed areas using a geographical information system (ESRI's ArcMap v.9.3). The watershed areas were delineated from 10-meter (m) digital elevation models (DEMs) using ESRI's ArcMap v.9.3.

The upstream gages data were adjusted to downstream locations using only the precipitation volume technique and do not account for downstream attenuations in flows or water withdrawals. All spatial adjustments of data to downstream locations for statistical analyses were performed in the same way.

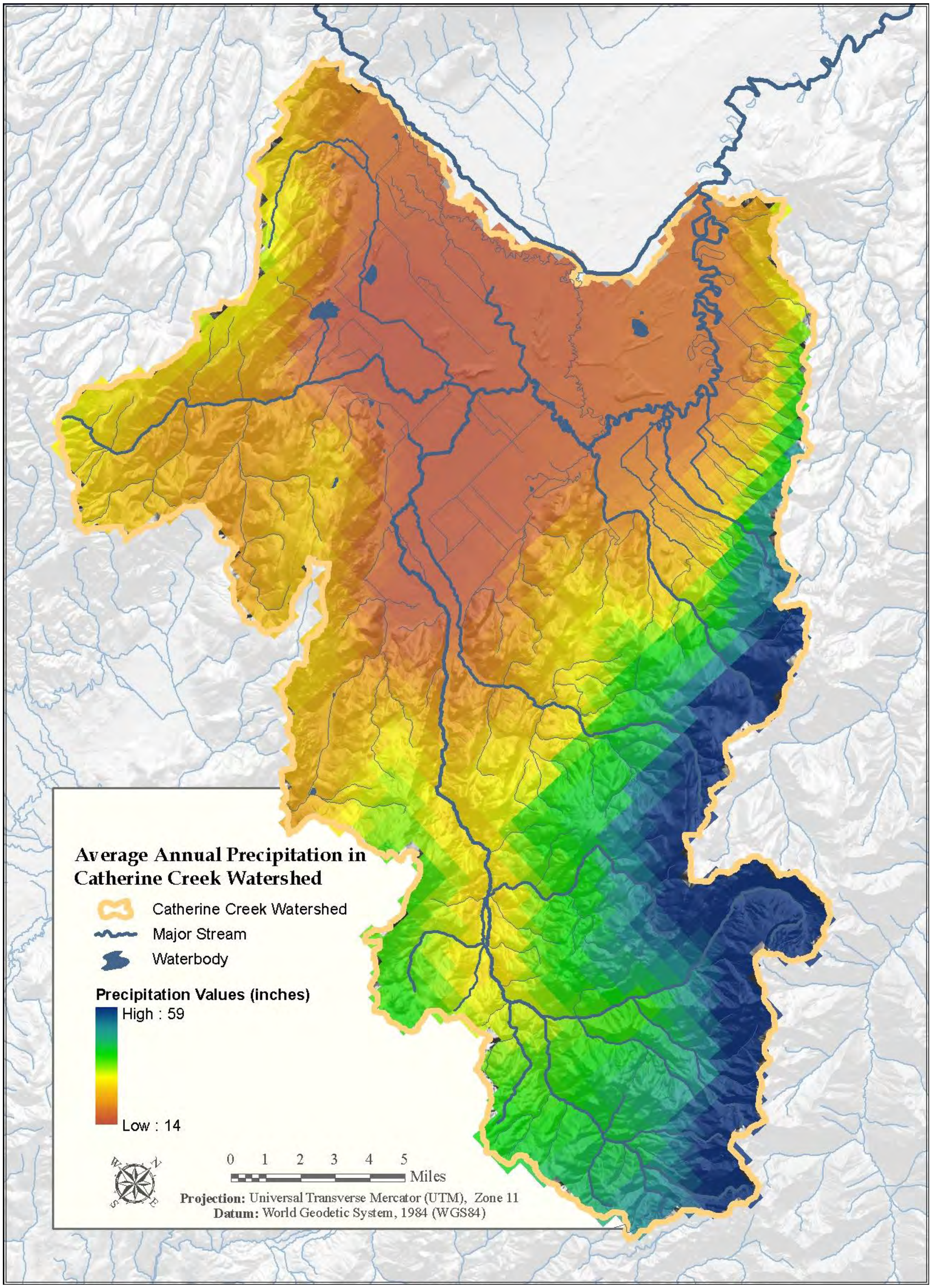


Figure 6. Catherine Creek watershed/PRISM data – average annual precipitation in the Catherine Creek watershed.

As part of this assessment, Reclamation installed nine surface water gages in the assessment area in the fall and winter of 2010 (Table 3). Each gage consists of a logging device, which contains either a pressure transducer or radar and temperature probe that measures water surface stage and temperature hourly. The main goal of the gage network is to provide stage data for hydraulic and water temperature models. At the time of this writing, none of the gages have rating curves established but several of those that do not experience backwater conditions may be developed in the future for discharge estimation. Discharge measurements are planned during 2011 and 2012 to eventually have additional discharge information throughout Catherine Creek within the Grande Ronde Valley. Uses will include the further refinement of the hydraulic model and to provide increased knowledge of conditions for future project implementation and monitoring.

Table 3. Reclamation stream gages installed in 2010. All stream gages measure water stage. The Grande Ronde River at Pierce and Rhinehart Lane measure air temperature while all others measure water temperature.

Stream Gage	Gage Type	RM
Catherine Creek at Geckler Lane	Pressure Transducer/Water Temperature	23.7
Catherine Creek at Godley Road	Pressure Transducer/Water Temperature	26.6
Catherine Creek at Miller Lane	Pressure Transducer/Water Temperature	36.5
Catherine Creek at Wilkinson Lane	Pressure Transducer/Water Temperature	31.9
Grande Ronde River at Alicel Lane	Pressure Transducer/Water Temperature	--
Grande Ronde River at Pierce Road	Radar/Air Temperature	--
Grande Ronde River at Rhinehart Lane	Radar/Air Temperature	--
Little Creek near Union	Pressure Transducer/Water Temperature	--
Willow Creek at Courtney Lane	Pressure Transducer/Water Temperature	--

Published discharge data was collected from the U.S. Geological Survey (USGS) and Oregon Water Resources Department (OWRD) websites (2011). Stream gaging in the study area is limited and only the Catherine Creek near Union, Oregon (13320000) gage has a long-term record. Gage 13320000 contains published flow records spanning the period between 1911 and 2009. Available data from gage 13320000 was summarized, analyzed, and subsequently used to develop synthetic discharges for the hydraulic model of Catherine Creek, which extends beyond the confluence with the Grande Ronde River and terminates at Rhinehart Gap.

3.1.2 Flood Frequency Analyses

Flood frequency analyses were carried out following the guidelines set forth in Bulletin 17B (IACWD 1982), including the use of log-Pearson type III distributions for gages with sufficient record. Published regression equations were used for streams with insufficient (sample size less than 10) or nonexistent gage records (OWRD 2006). OWRD (2006) developed peak flow return interval discharge regression equations (Table 4) for ungaged streams in Eastern Oregon following the U.S. standard protocol described in Bulletin 17B (IACWD 1982). Where the record is sufficient, a log-Pearson type III analysis was completed using the USGS software program PeakFQWin (Flynn, Kirby, and Hummel et al. 2006) on the historic (systematic) record. The period of record for all analyses included data through water year 2009 when available.

Table 4. Peak flow regression equations for northeastern Oregon (OWRD 2006). Area is in square miles and discharge is in cfs.

Return Interval Discharge	Equation	Standard Error [percent]	Average Standard Error of Sampling [percent]	Average Prediction Error [percent]	Equivalent Years of Record
Q(2)	=21.83*Area^0.7546	56.8	10.9	58.2	1.3
Q(5)	=36.8*Area^0.7459	47.3	10.1	48.6	2.5
Q(10)	=47.68*Area^0.7431	44.8	10.2	46.1	3.6
Q(25)	=61.9*Area^0.7415	44.3	10.7	45.8	5.2
Q(50)	=72.81*Area^0.7408	45.1	11.2	46.8	6.1
Q(100)	=84.03*Area^0.7402	46.7	11.8	48.5	6.8
Q(500)	=111.9*Area^0.7388	52.2	13.3	54.3	7.7

Bulletin 17B (IACWD 1982) includes a technique for determining peak discharges using a weighted average from log-Pearson III type analyses and regional regression equations (Wiley, Atkins Jr., and Tasker 2000), which is useful when gages contain a minimal period of record and extension of the record is desired to estimate floods of low frequency. The following equation was applied to all stream gages where the systematic record was at least 10 years to provide a reasonable estimate of Q_s (Wiley, Atkins Jr., and Tasker 2000):

$$Q_W = \frac{(Q_S N + Q_R E)}{(N + E)}$$

Q_W	weighted average discharge
Q_S	discharge from the log-Pearson III analysis
Q_R	discharge from the regression equation
N	number of years of peaks
E	equivalent years of record

3.1.3 Significant Tributary Hydrology

There are four major tributaries to Catherine Creek within the study area and below gage 13320000 (upper Catherine Creek) including Pyles Creek at river mile (RM) 36.9, Little Creek at RM 35.9, Ladd Creek at RM 31.4, and Mill Creek at RM 24.1. The average annual precipitation volume for each of the five watersheds (upper Catherine Creek, Pyles Creek, Little Creek, Ladd Creek and Mill Creek) was calculated using average annual precipitation data from PRISM 2006 clipped by polygons of delineated watershed areas using a geographical information system (ESRI’s ArcMap v.9.3). Watershed areas were delineated from 10-m DEMs using ESRI’s ArcMap v.9.3. Average annual precipitation depth data was multiplied by watershed area to determine average watershed annual precipitation volume. Finally, the ratio of the annual precipitation volume for each watershed to the annual precipitation volume of the upper Catherine Creek watershed at the stream gage 13320000, Catherine Creek near Union, was used to scale the long-term (87 years) Catherine Creek discharge gaging record to each tributary.

3.1.4 Climate Analysis

Four climate stations in or near the study area were used to evaluate historic trends for average monthly temperatures, precipitation, and snowfall.

Climate data was compiled from the National Ocean and Atmospheric Administration Cooperative Observer Program (NOAA COOP) website (2011) for two climate stations located within the study watershed, Cove and Cove 1E, to develop a record of weather from 1948 to 2009. These stations are both near the town of Cove, Oregon in the Mill Creek watershed. These stations are located in the lower valley of Catherine Creek and were used to represent the lower elevations of the watershed. Average monthly temperatures, precipitation, and snowfall were calculated to determine overall average values and to evaluate trends over time.

Climate station data from two Natural Resource Conservation Service (NRCS) SNOTEL sites were analyzed to evaluate historic trends of monthly average temperature, precipitation, and snowfall for areas representing the high elevation zone of Catherine Creek. The —Moss Spring” station was established in 1981 and is located near the eastern edge of the Mill Creek watershed divide in the Wallowa Mountains. The Taylor Green site was established in 1979 and is located in the South Fork of Catherine Creek watershed near the southern watershed divide. Climate stations in or near the Catherine Creek watershed including those utilized and discussed are shown in Figure 7.

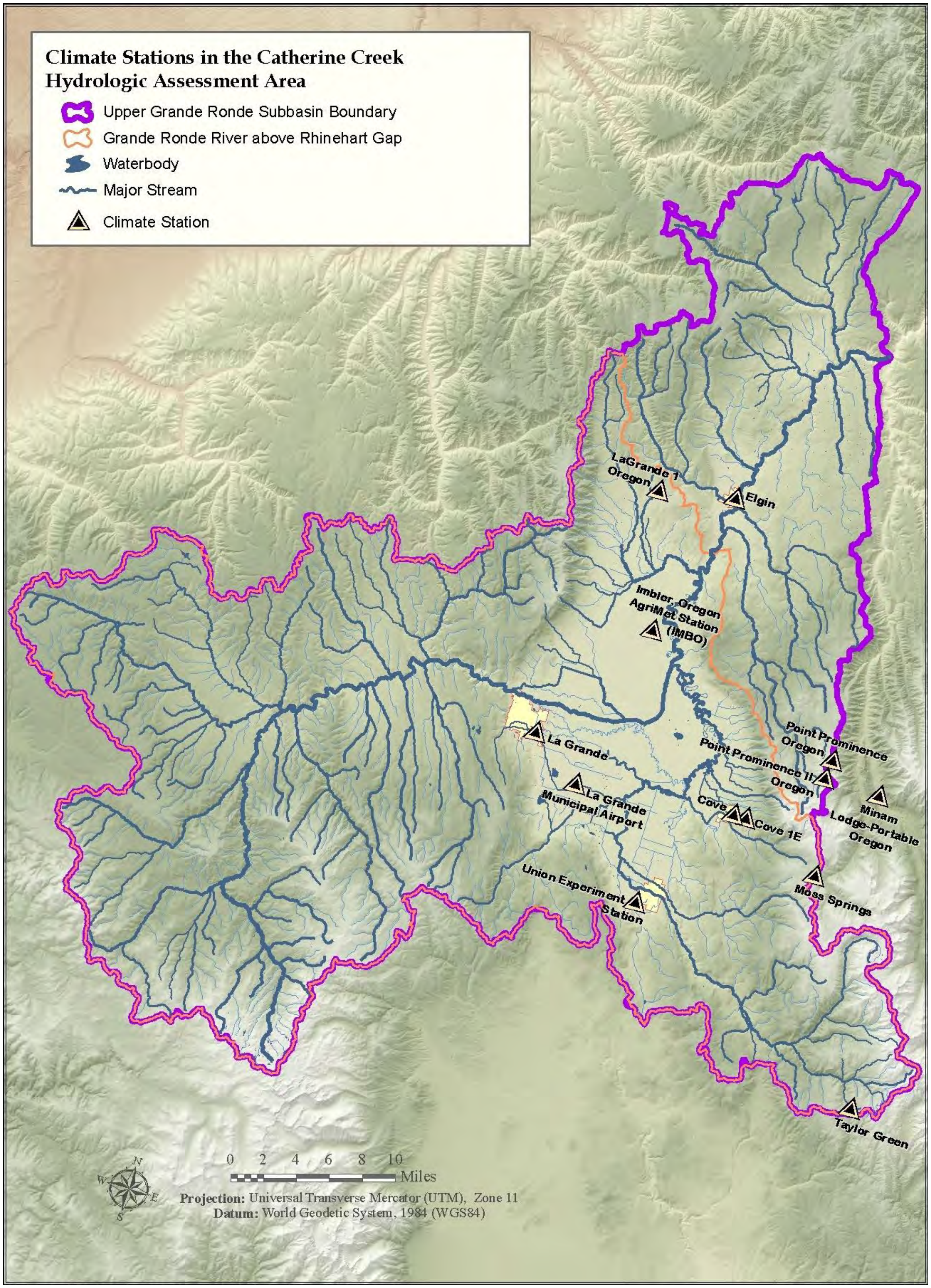


Figure 7. Climate stations in or near the Catherine Creek watershed.

4. Historical Conditions

Native Americans lived in the Grande Ronde area for thousands of years before explorers came through the area in approximately 1811 (Gildemeister 1998). The Grande Ronde Valley was covered in grasslands, wetlands, and a lake known as Tule Lake which was reported to be anywhere from 1,600 acres (Gildemeister 1998) to 20,000 acres (Duncan 1998) depending on source. Beckham (1995) recounts many early pioneers' and explorers' notes on the Grande Ronde Valley. In general, they documented the valley bottom as having the following characteristics: woody trees were only present along the banks of the creeks and rivers; springs were common along the margins of the valley; camas covered much of the valley bottom; while willows, alders, and cottonwoods lined the creeks and rivers (Duncan 1998; Beckham 1995). Areas adjacent to the creek had an abundance of willows and patches of cottonwoods and the soil was “excellent” but swampy in most places along the flat valley (Beckham 1995). The streambanks were noted to be “high and muddy” (Beckham 1995).

Homesteading began in the Grande Ronde Valley in 1860 and the city of La Grande was founded in 1862 (Gildemeister 1998). Duncan (1998) notes that soon after settlement began water became the “center…of nearly…every economic activity of significance.” Agriculture and mills became commonplace in the valley which required both water and flood control. One of the earliest projects in the Grande Ronde Valley to drain the land for agriculture was the construction of State Ditch which began in 1870 (Gildemeister 1998). Initially 6 feet wide and 3 feet deep, it was designed to reduce flooding by diverting some of the Grande Ronde River water in a more direct route (north) through the valley (Gildemeister 1998). The ditch-diverted water from the Grande Ronde River and, taking a shorter course by approximately 33 miles, delivered it back to the Grande Ronde River further down the valley below the confluence of the Grande Ronde River and Catherine Creek. Over time, the ditch took a larger portion of the total Grande Ronde River; presently it conveys the total flow of the Grande Ronde (Flow Technologies 1997). No information has been found that indicates when the full flow of the Grande Ronde River began coursing down State Ditch.

In 1870, a “mammoth” canal was dug to divert Catherine Creek before it entered Tule Lake near the current area of Ladd marsh (Beckam 1995; Gildemeister 1998). The lake was owned by the State of Oregon after being acquired through the Swamp Lands Act, which opened it to “reclamation.” The canal brought the creek east of the lake and connected it directly downstream (north) of the lake, expediting water through the valley.

One of the earliest documented pumps for water diversion was placed in the Grande Ronde River for the city of La Grande in 1892 (Beckham 1995). Since this time, pumps and further diversion dams have been placed throughout Catherine Creek for surface water diversion. Since most water withdrawals are for irrigation and occur during the warm summer irrigation period when creeks are flowing at or near baseflow, it is assumed that discharge during these periods were higher than they are now. Therefore, it is also understood that the rate of decrease in discharge, as peak flows recede and the irrigation season begins, is likely higher now than was historically before irrigation became common.

Historical accounts describing the Catherine Creek watershed above the town of Union were not found. Several of the lower valley descriptions, however, make some general comments regarding the vegetation that was observed further up on the mountainsides: pine, cedar, larch, and birch (Beckham 1995). Timber harvest has varied considerably in Union County but show a generally increasing trend between 1896 and 1990 (McIntosh 1992). On average 36-million board feet were harvested per year prior to 1941, rising to an average of 98 million between 1941 and 1990 (McIntosh 1992).

In 1955, Reclamation completed a report focused on storing spring high flow waters in reservoirs and irrigating more of the high quality soils in the valley bottom (McKay, Dexheimer, and Nelson 1955). A dam was to be located just below the Little Catherine Creek and Catherine Creek confluence near RM 50.1 and was to have an outlet capacity of 2,000 cfs. The 100-year flood was estimated to be 2,230 cfs at the time. A second dam was to be on the Grande Ronde River above the confluence with Spring Creek. The study underscores two relatively constant concerns in the Grande Ronde Valley that hold true today: flooding and limited irrigation water. The project plan was to develop enough storage to irrigate 58,754 acres using 189,000 acre-feet of water as part of the two dam projects and provide additional storage for flood control. The Catherine Creek project was to provide water for 13,471 acres of irrigated land while the Grande Ronde River project was to supply water for 45,283 acres.

A project to assess the potential to develop groundwater resources was undertaken by Reclamation in 1966 (Ham 1966). The report suggests that groundwater resources within the Grande Ronde Valley could be developed with safe yields of 25,000 to 40,000 acre-feet and that the withdrawals would benefit soil drainage. An exception is the Sand Ridge area, which does not have an adequate shallow aquifer for development (Reclamation 2002).

The U.S. Army Corps of Engineers (USACE) (1996) conducted a flood control study to determine the benefits of excavating within Rhinehart Gap (RM 102 on the Grande Ronde River) to increase the flow capacity and reduce upstream backwater effects. They developed annual peak return flow discharges based on the USGS gages Grande Ronde River at Elgin (13324000), Grande Ronde River near Elgin (13323500), and Grande Ronde River at La Grande (13319000). Final return interval discharges for the computed 2, 10, 50, and 100-year discharges were 4,490; 7,360; 9,910; and 11,000 cfs, respectively. The study determined that flood reductions in the Grande Ronde Valley were possible through excavation within the Rhinehart Gap reach. Excavating 700,000 cubic yards of material could potentially reduce the 100-year discharge ponding elevation in the Grand Ronde Valley by approximately 4 feet and a 3-foot reduction could potentially be obtained with

330,000 cubic yards of excavation. No work on this has been completed to date and excavation would likely require relocating the highway and rail line within this area.

Discharge measurements have been limited historically; however, several major floods were documented to have occurred prior to any established stream gages in the basin. Pre-settlement flooding of the Grande Ronde Valley was annual and could inundate as much as 72,000 acres (Duncan 1998) or more. Flooding could last as long as 5 months and proceed into summer. The flood of 1894 reportedly inundated 50,000 acres in the Grande Ronde Valley with a flow of 9,500 cfs from the Grande Ronde River. Major flood events that occurred and were documented before 1911, when stream gages began operation, are provided in Table 4. As early as 1865, floods began inundating the city of La Grande (Figure 8). Multiple debris flows and flash floods were also reported by Gildemeister (1998), which further documents large numbers of Chinook salmon killed in the upper headwater areas.

Table 5. Documented historic floods prior to stream gaging (1911) in the Grande Ronde Valley.

Year	Discharge [cfs]*	Notes
1865	10,000	Grande Ronde River (Gildemeister 1998)
1865	3,000	Catherine Creek (USACE 1950)
1876	9,000	Grande Ronde River (Gildemeister 1998)
1876	2,500	Catherine Creek (USACE 1950)
1881	10,000	Spring flood on Catherine Creek, December flooding on Grande Ronde River (Gildemeister 1998)
1882	2,600	Catherine Creek (USACE 1950)
1891	unknown	July thunderstorm on Catherine Creek (Gildemeister 1998)
1893	1,500	Catherine Creek (USACE 1950)
1894	9,500	April 1st Grande Ronde River
1895	2,000	Catherine Creek (USACE 1950)
1907	unknown	5-7 foot wall of debris at Oro Dell, Grande Ronde River (Gildemeister 1998)
1908	unknown	Dam at Perry partially destroyed, Grande Ronde River
1908	1,600	Catherine Creek (USACE 1950)
* cfs – cubic feet per second		

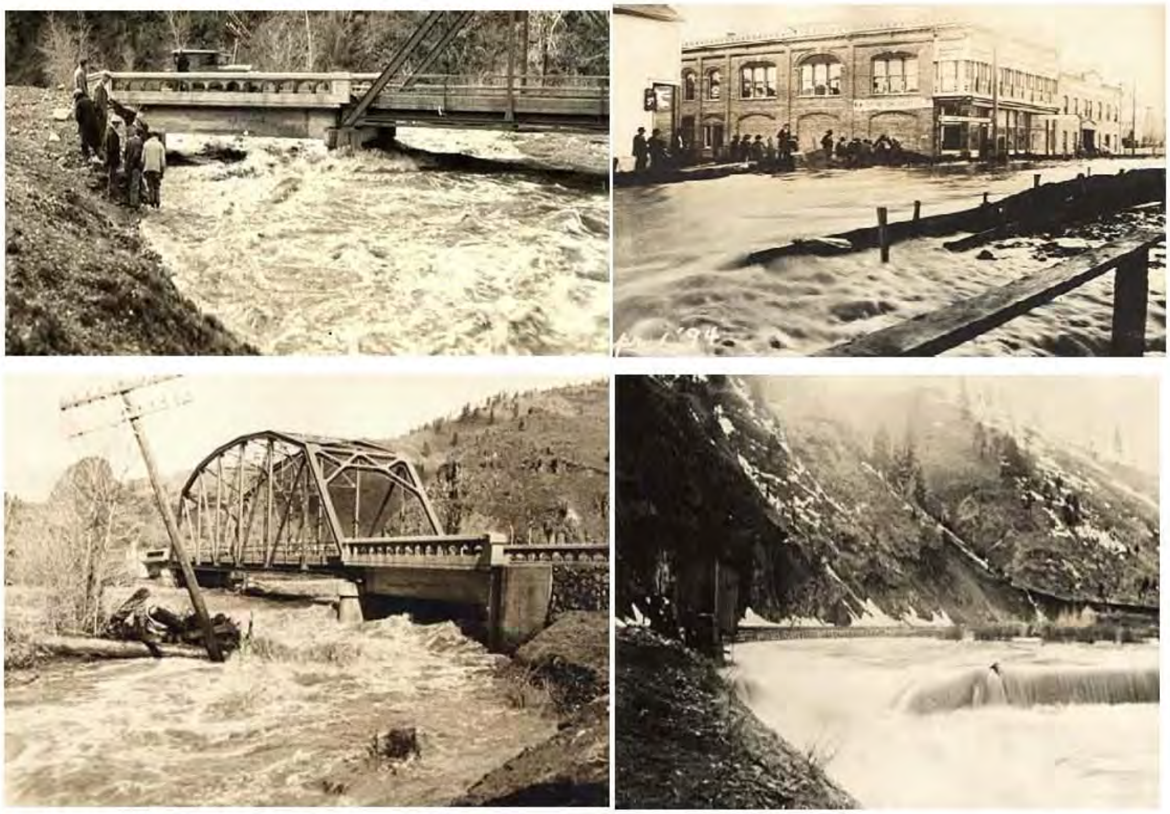


Figure 8. The Grande Ronde Valley endured a large flood in the spring of 1894. The top right picture shows downtown La Grande, Oregon, on April 1. Oregon State Planning Board Records, Oregon State Planning Board Photograph Box, Grande Ronde Flood Photographs, OPB0002.

4.1 Historic Changes

Since being settled in the 1800s, the Grande Ronde Valley has gone through many changes, which has affected the local hydrology. Land cover has changed from a landscape of meandering channels with shallow lakes and wetlands to a valley floor where water is channelized, piped, and ditched. The find sediments in the valley bottom, with low infiltration and conductivity, have been drained for agriculture. Wetlands have been drained and Catherine Creek has been channelized to encourage drainage. Small urban areas, such as towns of La Grande, Union, and Cove have increased the impervious areas in the basin along with the several highways and other surface roads that are weaved throughout the watershed. The combination of land use changes since settlement and redirection of water have likely decreased the amount of water storage in the watershed and developed somewhat higher peak discharges.

Interpreting and understanding the historic hydrologic conditions of Catherine Creek is a difficult task given that little information exists regarding historic climate and hydrologic data prior to the beginning of the 20th Century. However, inferences can be made based upon know historic changes to physical processes for which we have known hydrologic relationships. For example, we know that several sections of lower Catherine Creek were channelized to drain the valley bottom more rapidly after peak runoff and to reduce flooding for agricultural purposes. In areas where levees are not overtopped, channelization would decrease the amount and area of standing water available on flood plains to infiltrate valley soils. In areas where levees are overtopped, channelization may increase the amount of time flood plains are inundated. Deep channelized sections within Catherine Creek likely drain adjacent lands quicker and lower the adjacent water table, which would reduce soil moisture deeper than would otherwise occur. With the number of alterations that have occurred in the Grande Ronde Valley, it is difficult to say how baseflows have been affected. However, further study would be needed to determine if baseflows have been substantially reduced.

Physical changes to the Grande Ronde Valley have likely had dramatic effects upon the annual hydrograph exiting the valley in terms of flood peaks, baseflow, and temperature. Historic descriptions of the valley as swampy with lakes, replete with beaver, ―snaking" channels, full of springs and rivulets, describes a valley that is generally wet with soils that are moist a substantial part of the year. These conditions capture spring snowmelt peaks and dissipate floods over the valley bottom. This would tend to attenuate flood peaks downstream of the valley while increasing the duration of flooding within the valley. A portion of the floodwaters would be stored in the wetlands and released slowly over the summer and possibly into fall. Stored water in a wetland system and through hyporheic exchange with valley soils would likely have provided cooler temperatures with increased survivability of salmonids in the warm months possibly into the late summer.

Other changes that have occurred which are likely to have a hydrologic influence on Catherine Creek include logging, road construction, surface water diversion and storage, groundwater diversion, and land use (i.e., wetlands and grasslands to agricultural land and urban areas). The magnitude of change caused by these drivers is difficult to quantify. However, they can be lumped as to their typical cumulative effects to the shape of the hydrograph in both magnitude and timing. Logging and road construction likely resulted in increased and shorter duration peak flows. Diversions and storage likely decreased instream flows and lowered baseflows during the dry season relative to the historic regime. Other techniques can be used to attempt to quantify the cumulative effects of these alterations through spatially explicit hydrologic modeling; however, this is outside the scope of this TA.

5. Present Conditions

The present condition of Catherine Creek and the Grande Ronde Valley is quite different from the historical condition. Duncan (1998) compares what humans have done to the water in the Grande Ronde Valley to ―moving the living room furniture.” While some of the difference has been due to direct changes made for altering how water is stored and moves throughout the watershed, there has also been a substantial amount of indirect change to the local hydrology. For instance, there is currently an additional 5.5 percent of the watershed (estimated from National Land Cover Database [NLCD] 2006) which is impervious surface due to human activity (e.g., buildings and roads), whereas historically, there was little impervious surface. The conversion of grasslands, wetlands, riparian areas, and other types of natural features to agriculture has likely had measureable changes to evapotranspiration rates, infiltration, interception, groundwater storage, and surface runoff. Forestry practices, including road building, culvert placement, harvesting, planting, and forest fuels management also has likely affected watershed hydrology.

Current land cover (land use) mapping in the Catherine Creek watershed illustrates the extent of urban and agricultural land uses that have altered the local hydrology (Figure 9). The percentages of various land cover classifications for the Catherine Creek watershed are shown in Table 6. Agricultural lands are situated in the lower portions of the watershed along with the majority of ―developed” area. Forested lands include most of the headwater areas of the upper Catherine Creek watershed.

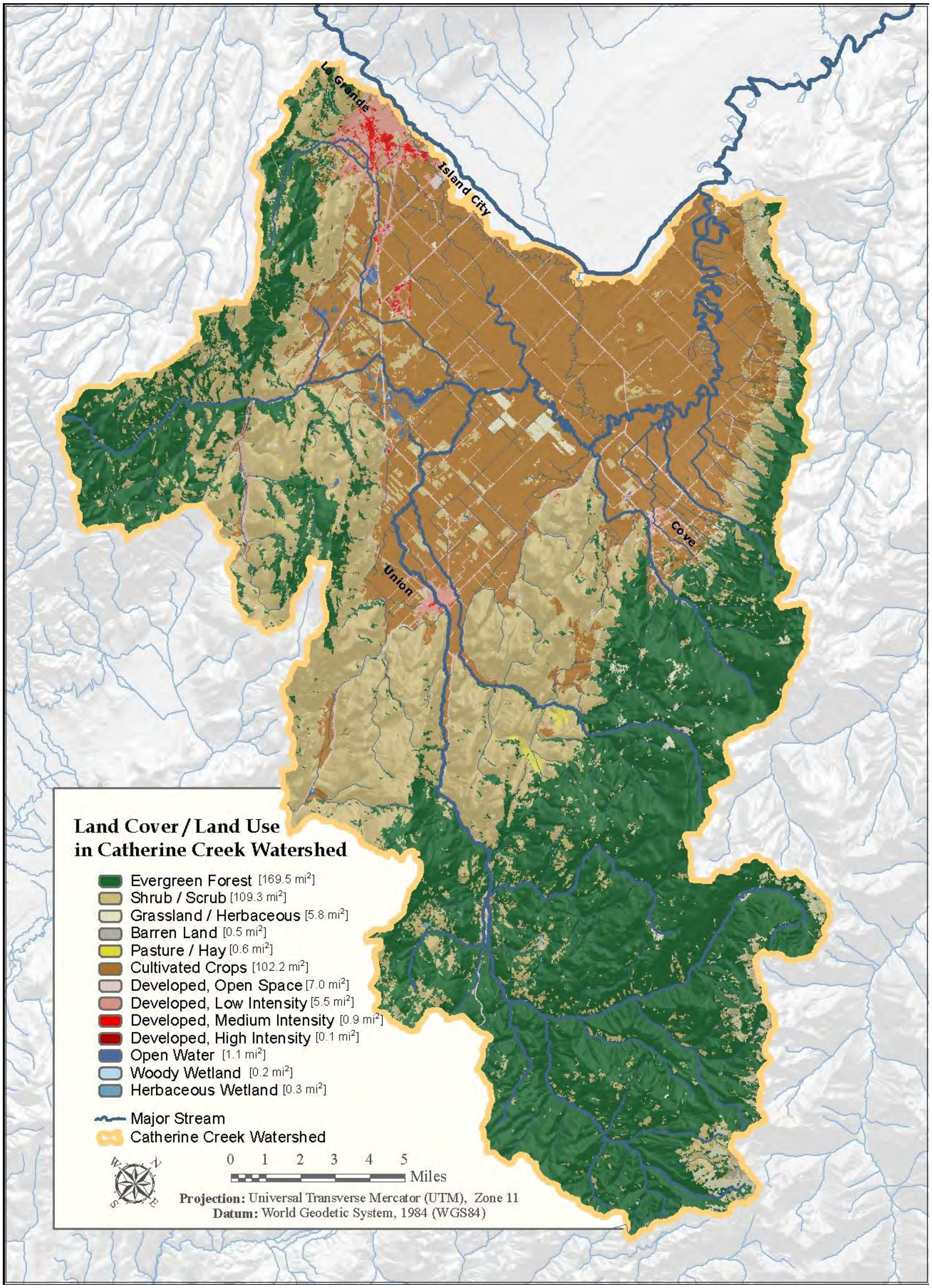


Figure 9. Land cover classes in the Catherine Creek watershed using the National Land Cover Database (NLCD) (2006).

Table 6. **Land cover proportions using NLCD (2006) in the Catherine Creek watershed.**

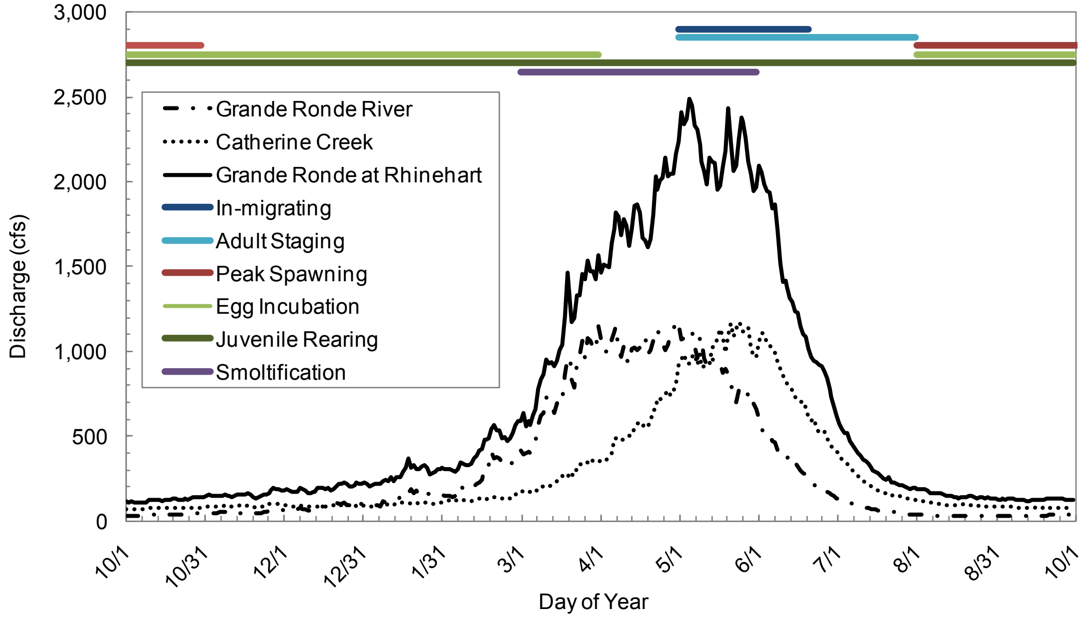
Description	Area [mile^2]	Area [percent]
Open Water	1.1	0.3%
Wetlands	0.5	0.1%
Developed	13.5	3.4%
Barren Land	0.5	0.1%
Forest	169.5	42%
Shrub / Scrub	109.3	27%
Agriculture	108.6	27%

The cumulative effects of watershed management practices in the upper watershed are likely of importance to hydrologic impacts to Catherine Creek; however, this is beyond the scope of this document. Within the study area, changes to hydrology have mostly occurred in accordance with land use changes in the Grande Ronde Valley. Channelization, levee construction, ditching, piping, well drilling, and draining of wetlands and lakes has likely altered the Catherine Creek hydrograph as it progresses through the valley. For most flow conditions, Catherine Creek now flows downstream through the valley much more expediently than in historic times. However, some large-scale physical conditions have not changed. Rhinehart Gap and the low gradient valley persist and still control large floods in the valley. Historically, annual floodwaters would have likely been temporarily stored in the valley bottom and released slowly through the drier months. Presently, Rhinehart Gap along with the flat slope of the valley cause large floods to be stored in the valley as well; however, it is assumed here that storage and release of floods occurs in different locations and with different timing due to alterations of the valley. In some locations, large flood events may store floodwaters longer than historically due to over-topping of streamside levees and trapping of floodwaters behind them. Along Highway 203 upstream of Union and throughout the lower valley, multiple sub-reaches of Catherine Creek have been straightened through channelization efforts. In addition, an extensive network of levees in the lower reaches further advance water through the valley by eliminating floodplain and shallow subsurface storage. Finally, surface water diversions out of Catherine Creek and its major tributaries (both pumps and gravity) occur throughout the valley for mostly agricultural purposes. These diversions deplete and at times, can eliminate summer low flows within Catherine Creek that was likely a perennial stream historically throughout its length. Surface water diversions feed a network of pipes and ditches throughout the valley where water is diverted, used, pumped, and re-used until minimal water is left to return to Catherine Creek due to clearing of land and likely increased evapotranspiration within the valley.

5.1 Hydrologic Results

5.1.1 Mean Annual Hydrograph

Estimated mean annual hydrographs for Catherine Creek and the Grande Ronde River at their confluence, and for the Grande Ronde River below their confluence (at Rhinehart Gap) are superimposed on Chinook salmon life stage usage (Appendix F) in Catherine Creek (Figure 10). The data used to develop the Catherine Creek hydrograph (Catherine Creek near Union, Oregon) is above most major diversions and over-estimates low summer flows when used to extrapolate flows downstream. Because the water of Catherine Creek is withdrawn for irrigation purposes, flows below Lower Davis Dam at RM 34.4 are frequently very low and even near zero during the irrigation season (approximately June through September). The Catherine Creek at Union, Oregon stream gage has a shorter period of record (1996 to present) and so was not used to develop long-term estimates of downstream and tributary hydrology; however, this stream gage better represents the low flow conditions typically experienced at and below the town of Union. There are however, three storage and diversion dams (Upper Davis, Lower Davis, and Elmer) and numerous pumped diversions below the stream gage which have further capacity to reduce irrigation season discharges. Comparing the –near Union” to the –at Union” stream gage (Figure 11) over the same period (water years 1999 to 2009) illustrates the impact of diversions on irrigation season discharges between these two stream gages.



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exceedance) for Catherine Creek and Grande Ronde River at their confluence with Chinook salmon life stage usage. Grande Ronde River is estimated using data combined from two USGS gages, Grande Ronde at La Grande (13319000), and Grande Ronde at Perry (13318960). Catherine Creek is estimated from the Catherine Creek near Union gage (13320000). Note – data used to develop Catherine Creek is above most major diversions and does not properly reflect low summer flows which may be zero during the irrigation season.

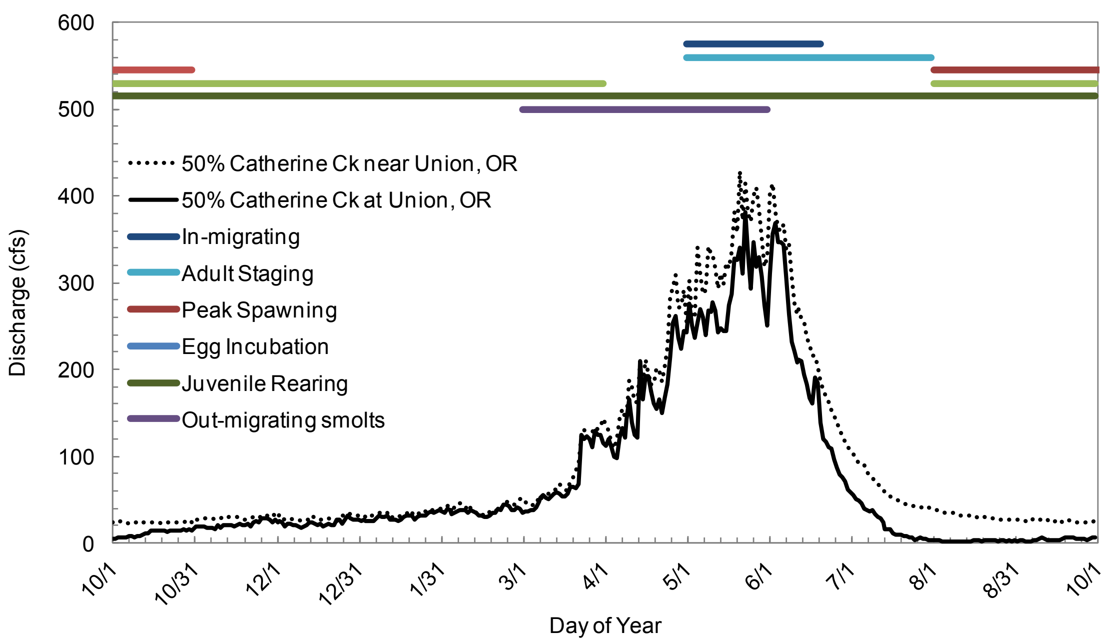

Figure 11. Estimated mean annual hydrograph (based on daily data and the 50 percent probability exceedance) for Catherine Creek with Chinook salmon life stage usage. Two stream gaging stations are shown, Catherine Creek near Union gage and Catherine Creek at Union gage. Catherine Creek near Union is above most major diversions while the "near Union" stream gage includes substantial diversions.

5.1.2 Exceedance Flows

Estimated mean daily exceedance flow hydrographs for Catherine Creek at the confluence with the Grande Ronde River and for the Grande Ronde River at Rhinehart Gap are presented in Figures 12 and 13, respectively. The data used to develop the exceedance flows are from upstream gages (Catherine Creek near Union [13320000] and Grande Ronde near Perry [13318960]) and the data do not account for most water withdrawals, and therefore, overestimate July through October flows. The 50-percent exceedance value represents the average annual hydrograph while the 5-percent exceedance and 95-percent exceedance values represent less frequent low and high mean daily flows that can be expected. Relative to the Grande Ronde, Catherine Creek has a sharper spring peak with a shorter window of time for peak flows. Being of higher elevation, it appears that Catherine Creek is also less affected by winter and early spring peaks, which indicates that the Grande Ronde may have earlier snowmelt and a stronger rainfall influence than Catherine Creek.

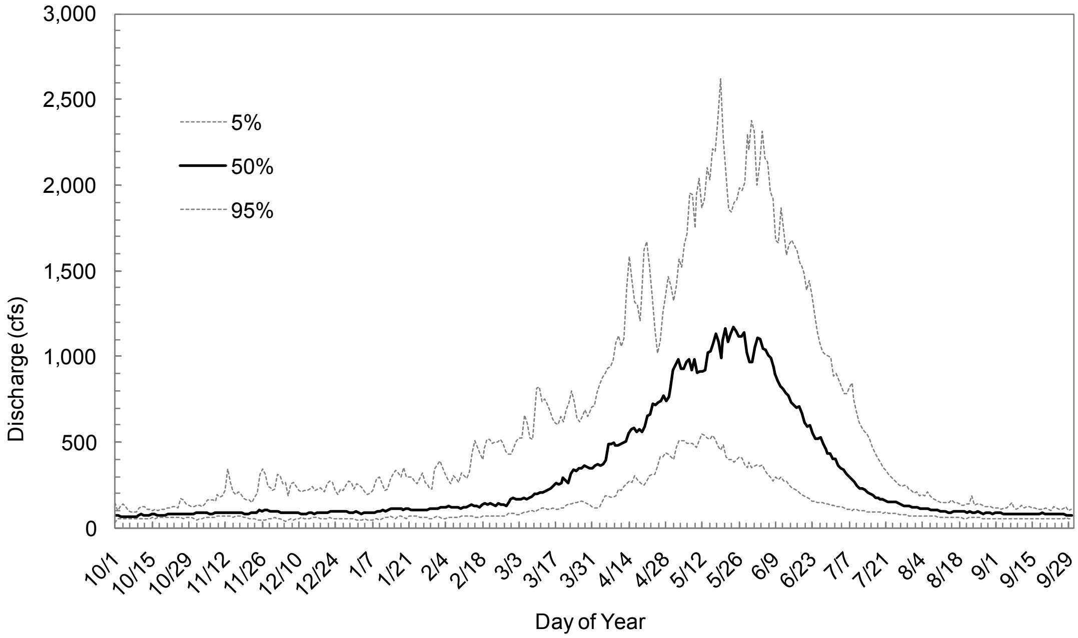

Figure 12. Estimated mean daily flow percent exceedance values for Catherine Creek at the confluence with the Grande Ronde River. Note – the data used to extrapolate this graph are from the Catherine Creek near Union (13320000) stream gage and the data do not account for all water withdrawals, and therefore, overestimate July through October flow. The 50 percent value represents an average annual hydrograph.

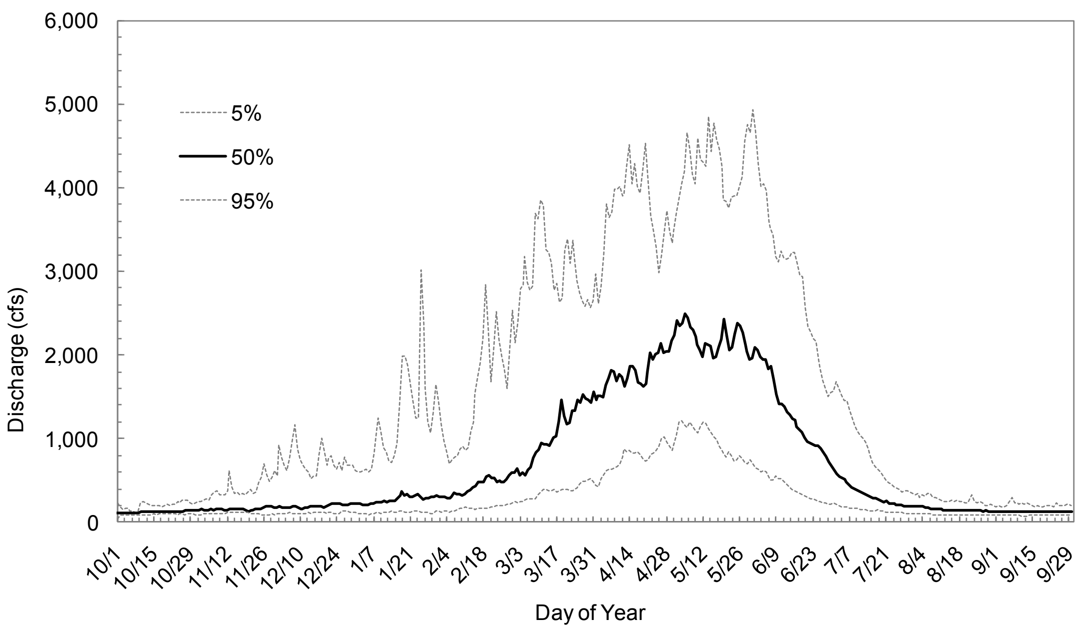

Figure 13. Estimated mean daily flow percent exceedance values for the Grande Ronde River at Rhinehart Gap. Note – the data used to extrapolate this graphy are from upstream gages (Catherine Creek near Union [13320000] and Grande Ronde near Perry [13318960]), and the data do not account for all water withdrawals, and therefore, overestimate July through October flows. The 50 percent value represents an average annual hydrograph.

5.1.3 Peak Flow Events

There are three general types of peak flow events in Catherine Creek that produce large floods. The most common cause is the annual spring snowmelt events that typically occur from April through June. In 87 years of record, only one annual peak discharge was not a result of the spring melt. Winter melt and fall through early spring rain and rain-on-snow events can cause notable peak flow events in Catherine Creek. However, it appears that the maximum annual flood has nearly always been from snowmelt in the spring. Rain driven events are usually of shorter duration, often less than a day but sometimes lasting several days and can lead to local flooding. Winter melt and rain-on-snow events can cause significant local damage due to ice break-up commonly found in the study area during extreme cold conditions.

In the spring, Catherine Creek typically has a later peak runoff than the Grande Ronde River. A comparison of peak flows showed that peaks in the Grande Ronde can be hours to months earlier than Catherine Creek. This may be partially attributable to the slightly lower average watershed elevation of the Grande Ronde River, above the Grande Ronde Valley, relative to the Catherine Creek watershed. Due to the timing differences between the two hydrographs, landowners in the lower Grande Ronde Valley have occasionally noticed that the lower reaches of Catherine Creek can have reverse flow upstream of the Grande Ronde confluence.

Annual flood peak discharges were calculated for each historic stream gage as described in ―Methods.” Annual flood peak discharges as return interval discharges are presented in Table 7 for all historic stream gages within the study area. The return interval discharges presented include those calculated statistically from the systematic record, those calculated from regression equations, and a weighted average peak discharge (of the two methods) following OWRD (2006). For gages where an insufficient or non-existent gage record prevents a statistical inference, only the regression equation results are presented. At stream gages where at least 20 years of record exist under recent climitalogical conditions, the systematic record provides the preferred estimate of peak flows. Where fewer peaks are available, or when the data is not recent, then the preferred estimate may come from the weighted estimate. Where no, or very few, systematic data are available, the regression equation estimates may be the only option.

Table 7. Annual peak discharges for all historic gages in the study area specified as return intervals.

Station Number	Station Name	Peak Data	Q1.5	Q2	Q5	Q10	Q25	Q50	Q100	Q500	Basis
13318500	GRANDE RONDE RIVER NEAR HILGARD, OR	no		2,190	3,080	3,740	4,640	5,360	6,110	7,940	W '06
""	""			2,190	3,010	3,590	4,360	4,950	5,570	7,130	S '06
""	""			2,360	3,770	4,790	6,160	7,220	8,300	10,900	R '06
13318690	GRANDE RONDE RIVER NR PERRY, OR	yes		3,038	4,552	5,706	7,317	8,600	9,945	13,354	W
""	""		2,519	3,046	4,504	5,587	7,089	8,307	9,609	13,030	S
""	""			2,979	4,745	6,037	7,756	9,081	10,440	13,776	R
13318800	GRANDE RONDE R AT HILGARD, OR	no		2,360	3,290	3,990	4,950	5,700	6,480	8,360	W '06
""	""			2,340	3,200	3,790	4,560	5,150	5,750	7,230	S '06
""	""			2,530	4,040	5,140	6,610	7,740	8,890	11,700	R '06
13319000	GRANDE RONDE R AT LA GRANDE, OR	no		3,233	4,872	6,078	7,736	9,063	10,468	14,068	W
""	""		2,643	3,237	4,874	6,077	7,729	9,053	10,460	14,080	S
""	""			3,015	4,802	6,109	7,849	9,190	10,565	13,941	R
13319500	STATE D NR ALICEL, OR	no		3,173	5,051	6,424	8,252	9,662	11,107	14,655	R
13319800	S FK CATHERINE CR NR MEDICAL SPRINGS, OR	no		176	290	373	482	566	652	865	R
13319900	N FK CATHERINE CR NR MEDICAL SPRINGS, OR	no		238	390	500	646	759	874	1,159	R
13320000	CATHERINE CR NR UNION, OR	yes		750	1,013	1,182	1,394	1,550	1,702	2,049	W
""	""		645	751	1,008	1,167	1,357	1,492	1,621	1,907	S
""	""			722	1,168	1,494	1,925	2,257	2,598	3,437	R
13320300	CATHERINE CR AT UNION, OR	yes		893	1,363	1,700	2,150	2,502	2,866	3,775	W
""	""		728	907	1,390	1,736	2,199	2,560	2,934	3,865	S
""	""			764	1,236	1,580	2,036	2,387	2,747	3,634	R
13320400	LITTLE CR AT HIGH VALLEY NR UNION, OR	yes		119	192	245	317	371	424	548	W
""	""		90	116	182	227	282	322	361	449	S
""	""			180	296	381	492	578	666	883	R
13320500	LITTLE CR AT SERLAND RANCH NR UNION, OR	no		17	29	38	49	58	67	89	R
13321000	LITTLE CR NR UNION, OR	no		290	474	608	785	921	1,061	1,406	R
13321300	LADD CANYON NR HOT LAKE, OR	yes		92	130	153	180	201	222	272	W
""	""		78	96	141	170	205	231	256	314	S
""	""			37	62	80	103	122	140	187	R
13321500	LADD CREEK NEAR HOT LAKE, OR	no		353	577	740	955	1,120	1,290	1,709	R
13322000	MILL CR NR COVE, OR	no		141	232	299	387	454	523	695	R
13322100	GRANDE RONDE R NR COVE, OR	no		1,843	2,952	3,762	4,839	5,668	6,519	8,610	R
13322300	DRY CREEK NEAR BINGHAM SPRINGS, OR	yes		36	47	55	67	75	85	107	W
""	""		32	37	47	54	62	68	74	88	S
""	""			28	46	60	78	92	106	141	R
13323495	GRANDE RONDE R NR IMBLER, OR	no		4,738	7,506	9,533	12,236	14,321	16,457	21,698	R
13323500	GRANDE RONDE R NR ELGIN, OR	yes		3,440	4,804	5,787	7,151	8,186	9,226	11,621	W
""	""		2,876	3,375	4,543	5,267	6,131	6,742	7,329	8,628	S
""	""			4,744	7,516	9,545	12,251	14,339	16,478	21,725	R
13324000	GRANDE RONDE R AT ELGIN, OR	yes		4,947	7,579	9,435	11,907	13,786	15,693	20,198	W
""	""		3,928	4,915	7,417	9,072	11,130	12,630	14,110	17,460	S
""	""			5,197	8,225	10,442	13,400	15,682	18,020	23,754	R

Annual peak return interval discharges were calculated for points along Catherine Creek and its major tributaries within the study area utilizing the historic period of record at the Catherine Creek near Union gage (13320000) and adjusting for additional area and precipitation volume as described in ―Methods.” For this analysis, all available data were used through water year 2009. Flow locations along Catherine Creek were used to supply model flow boundary conditions for HEC-RAS hydraulic analysis (see Appendix D – Hydraulics).

Tributary peak flows were developed based upon gage 13320000 and adjusted for drainage area and precipitation volume as described in ―Methods.” Peak flows for the four major tributaries to Catherine Creek within the study area including Little Creek, Mill Creek, Pyles Creek, and Ladd Creek are also included in Table 8. Peak flows along Catherine

Creek were not adjusted for timing of hydrographs or flood routing and were assumed to peak at the same time, which may greatly overestimate peak flows within the valley.

Table 8. Peak flow data for major tributaries and at flow change locations along Catherine Creek. Data extrapolated from Catherine Creek near Union stream gage. Peak flows along Catherine Creek were not adjusted for timing of hydrographs or flood routing and were assumed to peak at the same time, which may greatly overestimate peak flows within the valley.

	RM	Peak Flow	Peak Flow	Peak Flow	Peak Flow	Peak Flow	Peak Flow	Peak Flow	Peak Flow
Location		**Q1.5**	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**	**Q500**
	[miles]	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]	[cfs]
Catherine Ck below Pyles Ck	36.9	941	1,109	1,523	1,791	2,126	2,374	2,619	3,188
Catherine Ck below Little Ck	35.9	973	1,146	1,574	1,851	2,198	2,454	2,708	3,295
Catherine Ck below Ladd Ck	31.4	1,325	1,562	2,144	2,522	2,995	3,344	3,689	4,490
Catherine Ck below Mill Ck	24.1	1,546	1,822	2,501	2,942	3,493	3,900	4,303	5,237
Catherine Ck below Old Grande Ronde River Channel	22.5	1,632	1,924	2,641	3,107	3,689	4,119	4,544	5,530
Catherine Ck below Eckesley Ck	15.8	1,763	2,078	2,854	3,356	3,985	4,450	4,909	5,975
Grande Ronde River below Catherine Ck	NA	4,456	5,376	7,818	9,547	11,858	13,672	15,564	20,317
Grande Ronde River below Willow Ck	NA	4,779	5,757	8,342	10,162	12,589	14,488	16,464	21,413
Little Ck	NA	189	223	306	359	427	477	526	640
Ladd Ck	NA	292	344	473	556	660	737	813	990
Mill Ck	NA	191	226	310	364	433	483	533	649
Pyles Ck	NA	146	172	237	279	331	369	407	496
NA – not applicable.									

5.1.4 Low Flows

The September 95 percent exceedance probability discharge and the lowest September discharge in the daily discharge record for both stream gages on Catherine Creek were calculated (Table 9). September generally has the lowest flows of the year but they can also occur in August. The 95 percent exceedance probability describes the discharge that is equaled or exceeded at least 95 percent of the time. Low flow metrics were not extrapolated to downstream locations because of the error that would be introduced as a result of the complex water withdrawal system that has a significant effect on low flows.

Table 9. Low flow metrics for Catherine Creek stream gages.

	Catherine Creek Near Union, OR		Catherine Creek At Union, OR		
	Low Flow	Low Flow	Low Flow	Low Flow	
Location	95% Sept. Exceedance	Minimum flow	95% Sept. Exceedance	Minimum flow	
	[cfs]	[cfs]	[cfs]	[cfs]	
Catherine Ck near Union*	19	8	--	--	
Catherine Ck at Union*	--	--	2	0	

The Catherine Creek near Union, Oregon stream gage and the Catherine Creek at Union, Oregon stream gage were both used to develop estimates of the low flows. Because the "near" union stream gages is above most water withdrawals, it better indicates the "natural flow" condition, which describes the amount of, water that would be discharging under natural, or non-diversion conditions. The "at" Union stream gage is below many of the diversions and better indicates existing conditions during the irrigation season. A comparison of September flows between the "near" and "at" Union stream gages indicates that flows are regularly less than 25 percent of the natural flow during the irrigation season and can even be zero in locations below senior water rights such as Lower Davis Dam. In reach 1, which historically contained the Grande Ronde River, the change has been even more significant due to the loss of Grande Ronde River baseflows through efforts that created the State Ditch.

Because many more diversions are located below the Catherine Creek at Union, Oregon stream gage, any extrapolation to downstream locations would provide optimistically high values; therefore, no such extrapolation was completed as part of this assessment.

5.2 Diversion Dams and Inter-basin Transfers

There are nine inline diversion dams along Catherine Creek within the assessment reaches that include many pumps, which draw off surface water from Catherine Creek. This assessment only discusses the main diversion dams.

Reach 1 includes Elmer Dam (RM 13.1) which can create a backwater approximately 14.6 miles long (to near Godley Lane at RM 26.7) given the extremely low gradient of this reach. The Elmer Dam Reservoir services several pumps to irrigation agricultural lands in the area with water rights totaling approximately 29 cfs. Additionally, there are water rights for another 298 acre-feet of water. The water is pumped from the resulting reservoir at multiple locations with a total capacity of approximately 20 cfs.

In reach 2, Upper Davis Dam (RM 34.4) and Lower Davis Dam (RM 34.8) backwater Catherine Creek over 2 miles, to near the mouth of Pyles Creek. Lower Davis has a total water right of approximately 47 cfs and Upper Davis has approximately 60 cfs. Surface diversion ditches and pumps are used to withdraw water at these locations. Both dams were completely reconstructed in 2011 and are equipped with radial gates and vertical slot fish ladders.

There are four diversion dams in reach 3. Swackhammer diversion located at RM 40.6 was reconstructed in 1995 for improved fish passage and further modified in 2005. The water rights associated with it are approximately 30.5 cfs, but the ditches have a limited capacity and diversions are limited to less than 24 cfs (Hattan 2011). The Godley diversion located at RM 40 was originally constructed in 1950 with modifications made in 1990 for improved fish passage. The Grande Ronde Model Watershed (GRMW) added a step-pool fishway in 2011. It has a total water right of just over 17 cfs. The Townley-Dobbin Diversion located at RM 39.9 was completely reconstructed in 2010 to include a step-pool fishway and has a water right of approximately 4.5 cfs. The Hempe-Hutchinson Diversion located at RM 39.6 was partially reconstructed in 1994 and retained a previously built fishway. It has a water right of approximately 31 cfs but may only have the capacity to divert around 15 cfs (Hattan 2011).

Two diversions dams are located in reach 4. The Catherine Creek Adult Collection Facility (CCACF) operated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is located at RM 42.2 and the "State" Diversion is located at RM 42.5. CCACF was totally reconstructed in 1995 and fish passage facilities were added around 2000. A vertical slot fish passage facility was added to the State Diversion in 2007. CCACF has a total potential diversion capacity of 4.75 cfs although less is generally withdrawn (Hattan 2011). State Diversion has water rights for over 13 cfs; however, ditch capacity typically limits the discharge to not more than approximately 10 cfs (Hattan 2011).

There are several inter-basin transfers out of the Catherine Creek watershed including the South Fork Catherine Creek Ditch and the Trout Creek Ditch. These are both in the headwaters of Catherine Creek and both divert water into the Powder River watershed. OWRD operated a flow gage on the South Fork Ditch (South Catherine Creek Ditch near Medical Springs, Oregon, 13319700) from 1966 to 1984. The gage data indicate a maximum withdrawal of 32 cfs early in the season, which tapers off until late July or early August when the diversion is stopped. The water rights for this ditch have a priority date of 1918, which is a relatively junior water right in comparison to water rights downstream.

5.3 Reclamation Stream Gages

Only a brief period of data has been collected and downloaded from the stream gages Reclamation began installing in September 2010. Some of these gages will be useful in evaluating streamflows throughout the assessment area in the future, while others will be used for calibration of hydraulic models. At the time of this assessment, rating curves to estimate discharge have not been developed and still require several discharge measurements to be collected at to develop such curves. Once discharges and water surface stage relationships are developed, the stream gages will provide important information on the amount, temperature, and timing of water as it travels downstream. The stream gages will further provide valuable data to calibrate and validate hydraulic models for assessing current and proposed project conditions.

5.4 Climate Results and Climate Change

Until recently, climate was considered to be relatively consistent over time (known as stationarity). Current research into climate change has led to long-term historical studies of climate that illustrate the dynamic nature of climate over time (non-stationarity) (Milly et al. 2008). For instance, Nelsen et al. (2010) discovered that the early 20th century was a particularly wet period in the Pacific Northwest. This coincides with the beginning of much of the stream discharge and weather data collection in the region. This also coincides with the earliest memories of many locals when recounting past conditions.

It is useful to analyze time series of hydrologic data to understand past and current conditions. According to Mote et al. (2005), the upper Grande Ronde region has seen a 20 to 80 percent decrease in the April 1 snow water equivalent (SWE) from 1950 to 1997 or more than a 15 cm decrease between 1950 and 1999 (Regonda et al. 2005). Regonda, et al. (2005) further demonstrates the relationship of SWE to precipitation and SWE to November through March temperature. They found that while an increase in winter temperature does have some effect on reducing SWE, it mainly correlates to a reduction in winter precipitation. This suggests that the decrease in SWE is not a problem due to a lack of water storage as snowpack, but simply that there is less precipitation overall as a result of climate change.

Using stream discharge data from gages in and around Catherine Creek with data from water years 1948 to 2010, the annual water yield and 50-percentile flow dates were calculated (Table 10) for each water year similar to the work of Stewart, Cayan, and Dettinger 2005. The 50-percentile flow date can be considered an estimate of the annual peak flow date in snowmelt regimes such as those in the Grande Ronde. This analysis indicates that there has been a reduction in annual water yield of approximately 13 percent in Catherine Creek above Union and 8 percent in the Grande Ronde River above La Grande since 1948. Additionally, there has been a reduction of approximately 15 percent in the annual water yield of the Grande Ronde River watershed as measured above Troy, Oregon since 1948. Further, the 50-percentile date for flow has shifted earlier. It occurs approximately 11 days earlier in Catherine Creek (near Union) and 6 days earlier in the Grande Ronde (at La Grande) than it did in 1948.

Table 10. Change in the annual water yield and fifty percentile discharge date between water years 1948 and 2010.

Station Name	Station Number	Decrease in Annual Water Yield [percent]	Decrease in Arrival of 50 Percentile Date [Days]
Catherine Creek near Union, OR	13320000	13	11
Grande Ronde River at La Grande, OR	13319000	8	6
Grande Ronde River at Troy, OR	13333000	15	4
Imnaha River near Imnaha, OR	13292000	16	7
Bear Creek near Wallowa, OR	13330500	14	4

6. Discussion

Peak flows in the Grande Ronde Valley are exacerbated by the extreme low gradient (approximately 0.006 percent) in the lower valley, the constriction at Rhinehart Gap, and the confluence of two rivers (Catherine Creek and Grande Ronde River) that have distinct differences in the timing of peak flows. As a result, spring flooding can be more substantial and last longer than typically experienced on other creeks and rivers in the area.

Unlike typical rivers which only flood as a result of their own discharge, flooding in reach 1 of Catherine Creek can be a result of high discharges coming down Catherine Creek, the Grande Ronde River, or both simultaneously. Peak flows can occur from January through early June on Catherine Creek with peak flows typically occurring in April or May. The average peak flow date is May 12. The Grande Ronde River peak flows tend to occur earlier and over a much broader range of dates, typically December through May with an average peak flow date of March 6. Further, because Catherine Creek high flows tend to have a long duration such that high flows (not necessarily the peaks) in both Catherine Creek and the Grande Ronde often happen simultaneously, flooding in the lower Grande Ronde Valley is often substantial and can occur over an extended period of time.

Climate induced patterns in peak flow event timing suggest that peak flows are happening early in the year by as much as 11 days on Catherine Creek and 6 days on the Grande Ronde. This tends to result in less water being available in the summer and an extended irrigation season with higher subsequent demand. In addition, climate change may lead to higher probabilities for having winter rain-on-snow events, which result in early season flood events, and less water stored as snow throughout the spring. Winter rain-on-snow events can also develop large peak flows which can lead to flooding that is exacerbated by ice jams.

Winter disturbance (i.e., flood) events in Catherine Creek may have important consequences for flooding and salmonid survival. During frigid winter periods, ice build up on the creek is typical and can be followed by high winter flow events that break up and carry ice downstream. Thick surface layers of ice alone could be a limiting factor for fish survival and when combined with high flow events could result in fatalities to overwintering juvenile fish. Ice flows can also cause substantial scouring of the creek bottom leading to the direct mortality of incubating eggs. The relative commonality of such events in Catherine Creek points to a data gap in our knowledge as to this potential stress on ESA-listed salmonids within Catherine Creek.

A changing climate is important to consider in view of hydrologic conditions especially when dealing with already over-allocated resources and temperature sensitive salmonids. With an expected increase in average temperatures and an associated reduction in regional snowpack, the challenges facing natural resources, including salmon and other stream dependant species, will continue to grow (Mote et al. 2003). Battlin et al. (2007) modeled the relationship between Chinook salmon and climate change in the Snohomish River basin in Western Washington River and found that a mean increase of 1.5°C by 2050 could reduce the population by 40 percent. However, they also concluded that river restoration that included large increases in juvenile rearing habitat could limit the decline to 5 percent. Although it is not appropriate to directly transfer these numbers to Catherine Creek, it does underscore the importance of improving salmonid conditions through habitat restoration to improve the biological resilience of the creek.

Low flow issues are most apparent during the summer irrigation season. Improving summer discharges for fishery benefits will require both increasing our understanding of the quantity and timing of water as it moves through the assessment area and working with watershed stakeholders to find conservation improvements. Improving our knowledge of the system will require increased knowledge and mapping of local sources and sinks within Catherine Creek. Gages placed by Reclamation throughout the study area will provide much improved knowledge over time. However, many data gaps still exist for improving our knowledge of hydrologic conditions throughout the assessment area. There are several sources and sinks that affect summer hydrology that are unknown at a level of detail necessary to determine the type of actions necessary to improve flows including:

- Where can the creek go dry in the summer?
- Where are all the pumps along the river, how much do they divert and when?
- Do irrigation return flows contribute to baseflows, and if so, where and how much?
- How do the oxbows used for storage function in a typical year?

7. References

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8. Geospatial Data Source and Description

Average Annual Precipitation – PRISM Precip_Annual, PRISM Climate Group at Oregon State University. This data contains spatially gridded average annual precipitation for the climatological period 1971-2000.

Catherine Creek Tributary Assessment Study Area – GRCC_StudyAreaBoundaries, Reclamation PNGIS. This data set was digitized based on FEMA 100-year flood plain.

Catherine Creek Watershed – CatherineCreekWatershed, Reclamation PNGIS. This data set was created from the USGS 10-meter National Elevation Dataset.

City Limits – City Civil Divisions, NAVTEQ. NAVTEQ incorporated and enhanced data from a number of sources to produce a geospatial dataset of boundaries for medium and larger sized U.S. cities.

Climate Station – climate_stations, NOAA National Weather Service COOP, NRCS Snotel, Reclamation Agrimet, USFS/BLM RAWS. This data set was created from geographic coordinates obtained online from NOAA, NRCS, Reclamation, USFS and BLM websites.

Catherine Creek Hydrologic Assessment Area – gr_nre, Reclamation River Systems Analysis Group. This data set was created from the USGS 10-meter National Elevation Dataset.

Land Cover/Land Use – NLCD 2006 Land Cover, U.S. Geological Survey. The National Land Cover Database (NLCD) is public domain information on land use and land cover.

Major Stream – NHD Flowlines, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

Spring – NHD Points, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

Surface Elevation – 10-meter digital elevation model (DEM) and hillshade, Reclamation PNGIS. This data set was created from USGS National Elevation Dataset 1/3 arc-second FLT (binary) files.

Tributary Watershed – SignificantWatersheds_CCW, Reclamation PNGIS. This data set was created from the USGS 10-meter National Elevation Dataset.

Upper Grande Ronde Subbasin Boundary – HydroUnit_8th_WBD, Natural Resource Conservation Service. This data set is a complete digital hydrologic unit boundary layer to the Subbasin (8-digit) 4th level for the entire United States.

USBR Installed Stream Gage – StreamGages_UGRSB, Reclamation River Systems Analysis Group. This data set was created from recorded location coordinates.

USGS and/or OWRD Installed Stream Gage – StreamGages_UGRSB, Reclamation River Systems Analysis Group. This data set was created from geographic coordinates obtained online from USGS and OWRD websites.

Watersheds – gr_cc, wc_cl, and CatherineCrkWshed, Reclamation River Systems Analysis Group and PNGIS. These data sets were created from the USGS 10-meter National Elevation Dataset.

Waterbody – NHDWaterbodies, U.S. Geological Survey. The National Hydrography Dataset (NHD) is a feature based database of the nation's surface water drainage system.

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