Title

Hydrologic Analysis and Restoration Considerations for the Upper Klamath Lake Sub-Basin, Klamath County Oregon

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LA222 Hydrology for Planners

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ABSTRACT

Aquatic ecosystems in the Upper Klamath Basin (Upper Basin), Oregon are degraded as a result of more than a century of land use alterations due to logging, dams, irrigated agriculture, and cattle grazing. These changes have led to degraded habitat conditions including decreased baseflow, loss of vegetation, increased stream temperature, fish impediments, and nutrient loading. All these factors negatively impact watershed function and resident fish populations, which have experienced severe declines in recent decades. The primary threats to fish populations include habitat loss, degraded water quality, barriers and entrainment, and predation and competition from non-native species. Millions of dollars have been spent since the late-1900's to restore aquatic habitat in the Upper Basin primarily to improve the distribution and abundance of endangered and threatened fish species. This project details the hydrologic characteristics of three primary tributaries in the Upper Klamath Lake Sub-Basin including Sevenmile Creek, Wood River, and the Williamson River (including spring tributaries). Available discharge data was assembled to plot seasonal fluctuations in flows and identify annual peak flow at different re-occurrence intervals. Stream systems in the UKL Sub-Basin show a range of hydrologic inflow due to groundwater and/or snow-melt run-off. Characteristics of spring-fed vs. run-off dominated stream systems are reviewed and recommendations are made for how to address restoration practices considering the hydrologic and geomorphic characteristics of stream channels.

INTRODUCTION

The Upper Basin is located in south central Oregon (Figure 1). Aquatic ecosystems in the Upper Basin are degraded as a result of more than a century of land use changes dominated by logging, dams, cattle grazing, and irrigated agriculture. Increased runoff, decreased base flow, loss of riparian vegetation, loss of fish passage, channel instability, benthic sedimentation, high stream temperatures, and nutrient loading are widespread impacts associated with these land use changes (Boyd et al. 2002). All these factors negatively impact watershed function and resident fish populations, which have experienced severe declines in recent decades. The Upper Klamath Basin historically supported a diversity and abundance of unique fish species including considerable populations of Lost River and shortnose suckers, Klamath redband rainbow trout (redband trout), Chinook salmon, bull trout, steelhead, and lamprey among others. All these species utilized Upper Klamath Lake and its tributaries throughout their lifecycles. Currently, the two sucker species are listed as endangered; bull trout are listed as threatened; redband trout are considered declining in some systems; and Chinook and steelhead no longer reach the Upper Basin due to downstream passage impediments. Millions of dollars have been spent since the late-1900's to restore aquatic habitat in the Upper Basin with the ultimate goal of increasing the abundance and distribution of these native fish species.

The objective of this study is to evaluate hydrologic characteristics of 3 primary stream systems of the Upper Klamath Lake Sub-Basin (UKL Sub-Basin) including the Sevenmile Creek, Wood River, and Williamson River as well as a their tributaries. Available discharge data for these systems was assembled to compare whether water was derived from surface water or ground water sources. Annual peak flows were used to calculate peak flow re-occurrence intervals. This project also specifically compares the characteristics of spring-fed and run-off dominated systems to recommend how hydrologic characteristics of streams should inform future restoration practices.

MAJOR TRIBUTARIES IN THE UKL SUB-BASIN

The UKL Sub-Basin is located along the border of the Cascade-Sierra Mountains and Basin and Range physiographic provinces. The UKL Sub-Basin is ~900 square miles with ~254 miles of stream systems in which all waterways drain to Upper Klamath Lake, Oregon's largest freshwater lake. Annual precipitation is dominated by snow and ranges from 65 in./yr. in Crater Lake to the north to 13.5 in./yr. in Klamath Falls to the south. Precipitation is predominately in the form of snow (Evans, 2010). The Upper Klamath Lake Sub-Basin has an extensive groundwater system with volcanic geology which is generally permeable and includes a system of interconnected aquifers (Evans, 2004).

Sevenmile System

Sevenmile Creek is 23 river miles. It originates in the forested western side of the Wood River Valley in Fremont-Winema National Forest. It then runs through private ranch lands before becoming channelized and entering Upper Klamath Lake (Figure 2). Inputs to the system include Blue Springs, Crane Creek, and Fourmile Creek. Irrigation diversions also divert a portion of the creek flow from April-October.

Wood River System

The Wood River originates on the eastern edge of the valley (Figure 3). The channel is diverted in several locations for irrigation purposes. Annie Creek, Fort Creek, and Crooked Creek tributaries also contribute flow to this system.

Williamson River System

The headwaters of the Williamson River occur 40 stream miles from Upper Klamath Lake (Figure 4). Spring Creek and the Sprague River are the major tributaries to the Williamson River with the Sprague contributing significantly to Lower Williamson flows at RM 11.

FISHERIES

The primary driver for restoration practices in the Upper Klamath Basin is to improve watershed conditions to levels that can support an increased distribution and abundance of endangered and threatened fish species.

Lost River suckers (*Deltistes luxatus*)/Shortnose suckers *(Chasmistes brevirostris)*. Lost River suckers and shortnose suckers are catostomids endemic to the Upper Klamath River Basin in Oregon and California (USGS, 2012). They were listed as federally endangered in 1988 due to range contractions, declines in abundance, and lack of evidence of recent recruitment to adult populations. They are also affected by habitat alteration and degradation as well as non-native species (USGS, 2012). Within the UKL Sub-Basin, the Lost River suckers currently spawn in the lower reaches of the Williamson River and along upwelling springs of the eastern Upper Klamath Lake shoreline. Shortnose suckers also migrate relatively short distances to spawn in springs in the lower reaches of the Williamson River. The two species are generally morphologically distinct from one another but hybrids do occur. Currently, the suckers occupy only a fraction of their former range which is now restricted to a few tributaries to Upper Klamath Lake including the Williamson River and Wood River. Historically, sucker spawning occurred in other tributaries including Crooked Creek, Fort Creek, Sevenmile Creek, Fourmile Creek, Odessa Creek, and Crystal Creek (Evans, 2004).

Bull trout *(Salvelinus confluentus)*. Bull trout are members of the salmonid family (salmon and trout) that are native to the northwest United States and western Canada. Bull trout were listed as federally threatened in 1999 primarily due to habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, past fisheries management, and the introduction of non-native species such as brown and brook trout (USGS, 2012). Bull trout populations in the Klamath Basin are evolutionarily and genetically distinct from other bull trout populations and are physically isolated from other populations near the southernmost extent of the current species distribution (USGS, 2012). Within the Upper Basin, bull trout numbers have been locally reduced by stream channelization, agricultural water diversions, and removal of riparian vegetation that has increased water temperatures, reduced water quantity and quality, and increased sedimentation (USGS, 2012). Competition and hybridization with brook and brown trout in most streams of the Upper Basin also pose significant threats (USGS, 2012). Currently, bull trout only exist in Sun Creek and Threemile Creek of UKL Sub-Basin but, historically had a population within Sevenmile Creek (Evans, 2004).

Redband Trout (*Oncorhynchus mykiss*). Oregon basin redband trout are members of the salmonid family and occupy remnant streams in seven Pleistocene lake beds in Oregon (Evans, 2004). The Klamath Basin is the only one of seven former Pleistocene lake bed systems that has an outlet to the ocean (Evans, 2004). Within the Wood River and Lower Williamson River, redband trout "pass" ODFW's fish status report. Populations "passed" due to distribution greater than six miles of habitat within their respective populations, connections to other populations, high abundance, and productivity due to redd counts showing stable or increasing trends in abundance (Evans, 2004). Despite their "passing" score by ODFW's, populations in the Wood River and likely Sevenmile Creek are still impacted by water diversions and water withdrawals (Evans, 2004).

METHODS

Seasonal, Annual Discharge Fluctuations

Available discharge data was obtained from the Klamath Basin Rangeland Trust and the Klamath Tribes who both have been recording discharge measurements in the UKL Sub-Basin since 2004. Discharge data was available for Sevenmile Creek, Blue Springs, Wood River, Fort Creek, and Crooked Creek. Hydrologic data for the two Williamson River sites was referenced from the United States Geological Service (USGS) (USGS, 2012, 2). (Gage station locations/ information, Figure 2-4/Table 1). Seasonal and/or annual hydrographs were plotted depending on the time period available to characterize both the stability and seasonality of flows.

Annual Peak Flow Frequency Analysis

Discharge data for Sevenmile Creek, Wood River, and the Williamson River were used to calculate re-occurrence intervals for Q_2, Q_5, Q_{25}, Q_{50}, and Q_{100} storm events. The peak flow values for each year on record were determined and these values were ordered using the Weibill plotting position. The discharge and return intervals were plotted on probability paper, and a straight line was fitted through the points to estimate larger peak flows than captured on record (i.e. Q_{25}, Q_{50}, and Q_{100}).

RESULTS

Sevenmile Creek System

Discharge values at Sevenmile Creek at Sevenmile Road from the last eight years peaked at 743cfs (2011) with high flows generally occurring in late-spring/early summer and lowest values occurring in early-fall (Figure 5, Table 1). Blue Springs, a tributary to Sevenmile Creek, had discharge values ranging from 0.17 to 26.5cfs for the six month period of record (Figure 6). Estimated peak flow re-occurrence values for Q2, Q5, Q25, Q50, and Q100 storm events on Sevenmile Creek were calculated to be 387, 553, 840, 960, and 1,080cfs, respectively (Figure 7).

Wood River System

Wood River at Weed Road had stream discharge values ranging from 71.08 to 534cfs (Figure 8). Flows were highest between the months of November and March for the 8 year period of record. Fort Creek, tributary to the Wood River, had very constant flows ranging from 46.8-55.cfs over an entire 4 year period (Figure 9). A second tributary to the Wood River System, Crooked Creek, also had stable and similar discharge measurements ranging from 44.5-54.2cfs for the 3.5 year monitoring period (Figure 10). Estimated peak flow re-occurrence values for the Wood River (at Weed Road) for Q2, Q5, Q25, Q50, and Q100 storm events were calculated to be 416, 486, 640, 694, and 749cfs, respectively (Figure 11).

Williamson River System

Discharge measurements on the Williamson River at USGS's Klamath Agency gage station near RM26.5 ranged from 10 (1991) to 983cfs (1956) since the start of record in 1954 (Figure 12). Downstream at RM 10.5 of the Williamson River (below the confluence of a large tributary, Sprague River) discharge values were higher with peak flows occurring up to 5,530cfs (1952) for the long-record of 1917 to 2012 (Figure 13). Calculated peak flow values for the Williamson River at RM 26.5 for the 2yr., 5yr., 25yr., 50yr., and 100yr. flood intervals were found to be 608, 868, 1,218, 1,300, and 1,620cfs (Figure 14).

DISCUSSION

Spring-fed and Run-off Dominated Systems

Spring-fed channels are those that receive the majority of flow from groundwater discharge (springs) (Whiting, 1994). On the other hand, run-off dominated systems receive the bulk of their water from rain or snowmelt distributed throughout the watershed (Whiting, 1995). The nature of the flow path is reflected in the hydrograph of spring-fed systems. In comparison to run-off dominated systems, spring-fed channel hydrographs are "damped" (Whiting, 2001). In this study, Blue Springs, Wood River, Fort Creek, and Crooked Creek all have characteristics of spring-fed systems showing comparatively little change throughout the year compared to a typical run-off dominated system with little base flow and more variable character depending on local precipitation (Manga, 1996). The Williamson River also originates from a spring but has a larger area to collect additional snowmelt run-off from the headwaters to the gage station at Klamath Agency and then collects water from the Sprague River which shows more seasonal variability. Blue Springs contributes water to Sevenmile Creek at RM15; however, the headwaters of Sevenmile Creek collect snow-melt run-off from its origins in the forested Fremont-Winema Forest and shows greater fluctuations in flows compared to the Wood River.

It is thought that channel sediment supply and morphology in spring-dominated systems also differs as a consequence of this distinctive hydrology (Whiting, 1994 & 2001). Spring systems generally have minimal sediment supply as the springs drainage area is small compared to run-off from a larger watershed area (Whiting, 1995). Even though the surface drainage area to the channel is very small in spring-fed channels, streambeds often lack a cover of fines indicating that sediment transport occurs frequently enough to flush fine sediment (Whiting, 2001). In Whiting and Stamm (1995) they observed 3cm diameter grains rolling in 20 cm deep flow within the Wood River, Oregon. Studies of Whiting and Moog (1994 and 2001) also found that spring-dominated channels have larger width to depth ratios, steep banks, rectangular cross-sections, increased roughness from in-channel downed timber, and limited bar development. Wider channels were attributable to spring-dominated systems not having large flows to move debris or reorient the debris to exert less resistance to the flow. With more debris in the channel, the roughness of the channel increases, and the channel needs a greater (wider) area to convey flows. Stable flow conditions also result in weak channel bar development and prevalent bankfull conditions (Griffiths, 2008). A summary and schematic of spring-fed channel and geomorphic conditions derived from Reiser, et al. (2004) can be found in Table 2 and Figure 15.

These spring-fed systems can provide important habitat for fish species as they provide cool water for refuge in the summer and warmer water temperatures in the winter (Reiser, 2004). Often, they also have high primary productivity, especially aquatic macrophytes, which provide a food source for macroinvertebrates (Reiser, 2004). Due to the stable nature of flows, Reiser et. al. (2004) hypothesizes that habitat complexity in spring-fed streams may be lower than in run-off dominated systems due to a relatively stable channel geometry with perpendicular banks and a lack of channel movement. However, habitat complexity is found from large wood that remains in place after falling into the stream and abundant aquatic macrophytes.

Restoration/Management Recommendations

There have been substantial efforts in the UKL Sub-Basin to improve habitat conditions for native fish species. Although a number of issues have contributed to their decline, the primary restoration actions to increase their abundance have included: riparian grazing management, habitat structure created through the addition of large wood and spawning gravel, and flow augmentation. These restoration actions need to consider the hydrologic characteristics of each stream and how that affects its channel form and sediment load.

Riparian Grazing Management. Constructing a riparian fence to exclude or reduce cattle grazing along riparian areas has been widely implemented in the UKL Sub-Basin. This is done to reduce channel erosion and improve water quality from surface run-off, and allow the creek to passively restore itself (through channel narrowing) rather than undertake active channel manipulation. Studies conducted by Gram Matthews and Associates in Oregon have shown that the rate of recovery for channels affected by grazing appears to be strongly influenced by the flow and sediment regime available to initiate channel change (Evans, 2004). For example, Sevenmile Creek which has a larger watershed and a more snowmelt dominated hydrograph compared to Crooked Creek, a spring-dominated system, could recover more quickly than the stable Crooked Creek system. Lower gradient reaches could also take longer to recover (Evans, 2004). Additionally, due to the characteristics of spring-fed systems described above, Crooked Creek and Fort Creek channels may have always had channels with a larger width to depth ratio compared to run-off dominated systems.

Habitat Structure. Historically, there was extensive logging in the Basin which likely altered the quantity of large wood (LW) in many of these systems. The literature suggests that LW is generally common in spring-fed channels as flow velocities aren't large enough to move the wood (Whiting, 2001, Whiting, 1994). Near the forested headwaters of these streams adding LW could be beneficial for improved complexity. In systems with larger flows, wood near in the upper reaches is carried to downstream reaches; however, in the spring-dominated systems, the large wood would likely stay close to its original placement. LW that has been manually added to the lower reaches of Crooked Creek, for example, may not have naturally occurred at this location due to the systems stable flow regime. Additionally, spring-dominated systems generally have good spawning substrate with reduced sediment supply (Table 2). Human induced sediment inputs, however, could cover clean gravel with fine sediment. If above-natural sources of sediment are introduced to these spring-fed systems, the addition of spawning gravel in these spring-systems may be warranted. However, this wouldn't fix the source of the problem and additional spawning gravel would need to be continually added.

Flow augmentation. There are extensive water diversions throughout the UKL Sub-Basin primarily used for flood irrigated cattle pasture. Agencies in the UKL Sub-Basin are working with landowners to reduce diversions through conservation measures and in-stream leasing. Regardless of a streams flow regime, reduced flows in stream systems can affect channel conditions and suitable fish habitat. Although additional studies need to be conducted, Reiser et al. 2004 hypothesized that spring-fed channels are more sensitive to changes in flow than runoff dominated systems. Reduced flows could result in a higher proportion of fine sediment settling out and spring-fed systems have a low capability to flush out sediment which could cover spawning substrate (Reiser, 2004). Reduced flows are also likely to affect stream temperatures especially in downstream reaches where the benefits of cold-water would no longer benefit lower reaches. Additionally, aquatic biomass, which has adapted to stable flow regimes, could be reduced and lessen the availability of macroinvertebrates as a food source for fish populations.

CONCLUSION

The watershed of the UKL Sub-Basin has had a range of land-use changes that have contributed to the decline of resident fish populations. Discharge measurements from these systems have shown variably due to groundwater and run-off dominated inputs. Although all of the systems studied are fairly stable when compared to flashy systems found in Mediterranean climates, their flow regime characteristics are still important to consider. The distinct “flattened” flow regime of spring-fed systems leads to differences in channel characteristics. Spring-fed channels typically have larger width to depth ratios, less sediment inputs, more large wood, and poorly developed bars than run-off dominated systems. These different characteristics should to be considered when planning for future management and restoration actions.

REFERENCES

Boyd, M. S., Kirk, M. Wiltsey, and B. Kasper. 2002. Upper Klamath Lake drainage total maximum daily load and water quality management plan (WQMP). Oregon Department of Environmental Quality, Portland, Oregon.

Griffiths, R.E., Anderson, D.E., Springer, A.E., 2008. The morphology and hydrology of small spring-dominated channels. Geomorphology 102, 511-521.

Manga, M. 1996. Hydrology of spring-dominated streams in the Oregon Cascades. Water Resources Research 32, 2435-2439.

Reiser, D.W., Chapin, D., DeVries, P., Ramey, M.P. 2004. Flow Regime and Ecosystem Interactions in Spring-Dominated Streams: Implications for Selecting Instream Flow Methods. Hydroecol. Appl. 1, 93-104.

Whiting, P.J., Moog, D.B., 2001. The geometric, sedimentologic and hydrologic attributes of spring-dominated channels in volcanic areas. Geomorphology 39, 131-149.

Whiting, P.J., Stamm, J.F., 1995. The hydrology and form of spring-dominated channels. Geomorphology 12, 233-240.

USGS Western Fisheries Research Center: Klamath Falls Research Station (http://wfrc.usgs.gov/fieldstations/klamath/species.html) April 23, 2012.

USGS Flow Data. (http://waterdata.usgs.gov/usa/) April 30, 2012.

Upper Klamath Lake Watershed Assessment. June 2010. Prepared by David Evans and Associates for the Klamath Watershed Partnership. (and references within)

Discharge Data Summary	Location of Measurement	Time Period	~Frequency	Data Source	Range of Recorded Flows (cfs)
Sevenmile Creek	RM 7.1	10/6/2004 to 2/28/2012	Bi-weekly	Klamath Tribes	0-743.34
Blue Springs	unknown	4/22/2002 to10/21/2002	Daily	KBRT	0.17-26.5
Wood River	RM 6	10/6/2004 to 3/26/2012	Bi-weekly	Klamath Tribes	71.08-534
Fort Creek	unknown	6/2/1999 to 6/23/2004	Daily	KBRT	46.84-55.59
Crooked Creek	unknown	6/4/1999 to 2/13/2003	Daily	KBRT	44.5-54.18
Williamson River (Klamath Agency)	~RM 26.5	10/1/1954 to 5/12/2011	Daily	USGS #11493500	10-1,590
Williamson River (below Sprague River confluence)	~RM 10.5	10/1/1917 to 4/30/2012	Daily	USGS #11502500	470-17,100

Table 1. Summary of discharge data obtained and used in hydrologic analysis.

Habitat Attribute	Spring-Dominated Streams
Water temperature	• more uniform; typically cooler in warmer months
Turbidity	• lower
Dissolved oxygen	• typically high, but dependent on source of spring flow
Nutrient levels	• higher P in volcanic areas • lower N
Stream flow	• more uniform, but can fluctuate considerably in conduit flow springs common in limestone terranes • timing of peak flows delayed by several months in diffuse flow springs of western North America
Channel morphology	• rectangular shape • high width to depth ratios • few bars • often higher proportion of fine sediments
Aquatic macrophytes	• typically more abundant and persistent
Riparian vegetation	• herbaceous component dominant; woody component less important
Invertebrate diversity	• often lower
Invertebrate abundance	• typically higher
Species dispersal (between habitats)	• lower
Fish assemblages	• restricted to cool water fish
Spawning habitat	• very good in many streams (Oregon Cascades) reduced flushing of fine sediments possible in some springs
Substrates	• compacted substrates due to calcareous sedimentation

Table 2. Habitat attributes of spring-dominated streams compared to run-off dominated channels (extracted from Reiser, 2004).

FIGURES

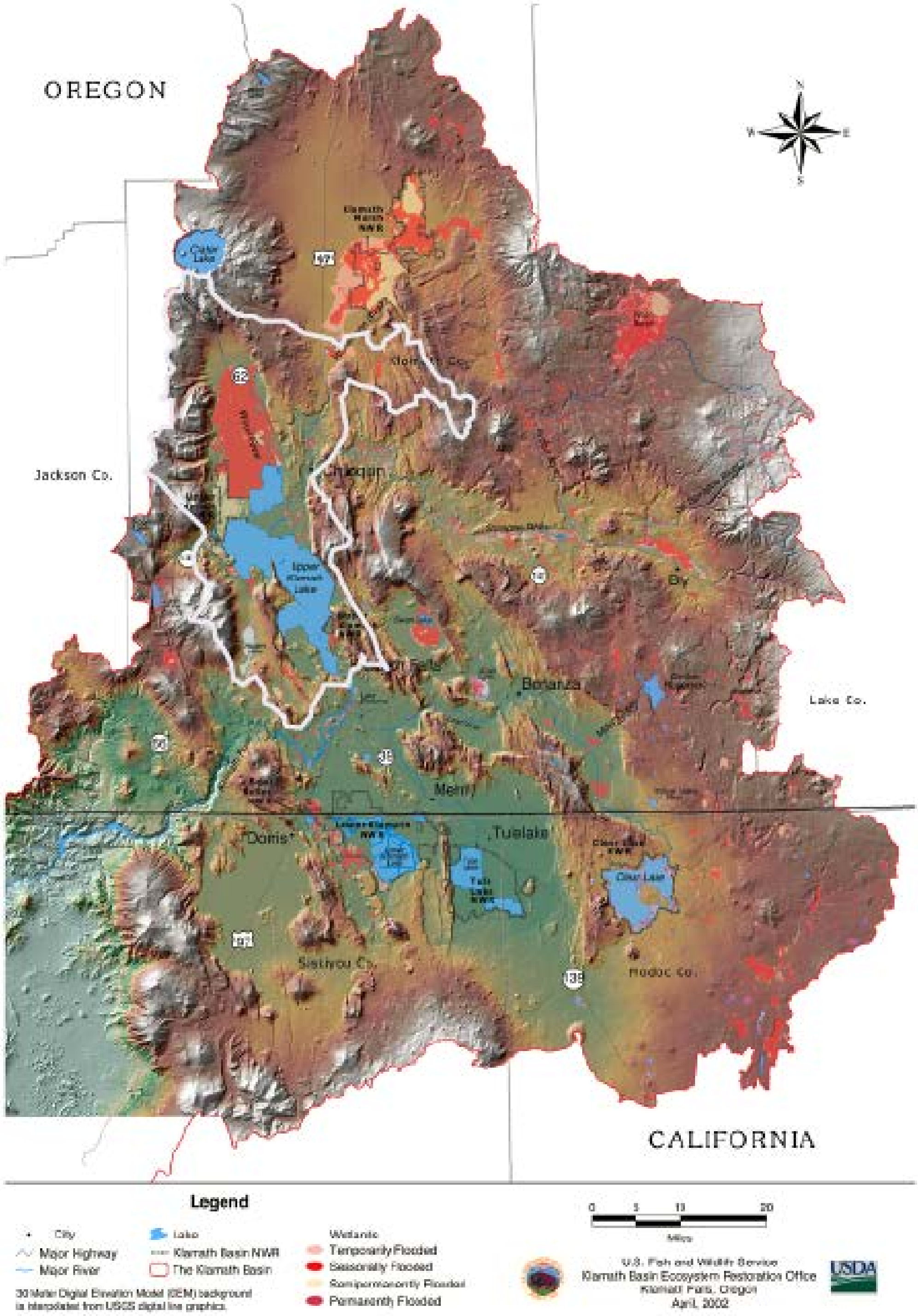


Figure 1. Location of UKL-Sub-Basin in the Upper Klamath Basin, Oregon (modified from BOR, 2002).

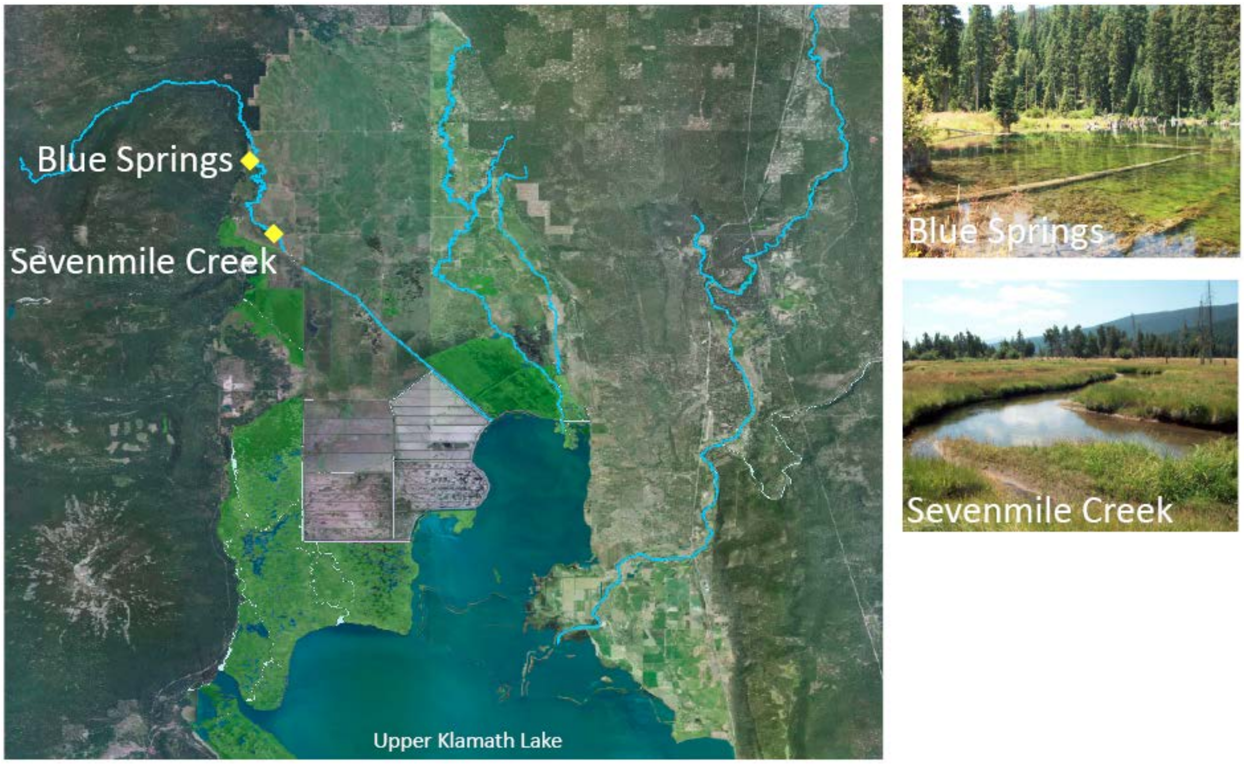


Figure 2. Gage station locations for Sevenmile Creek and Blue Springs in the UKL Sub-Basin, Oregon.

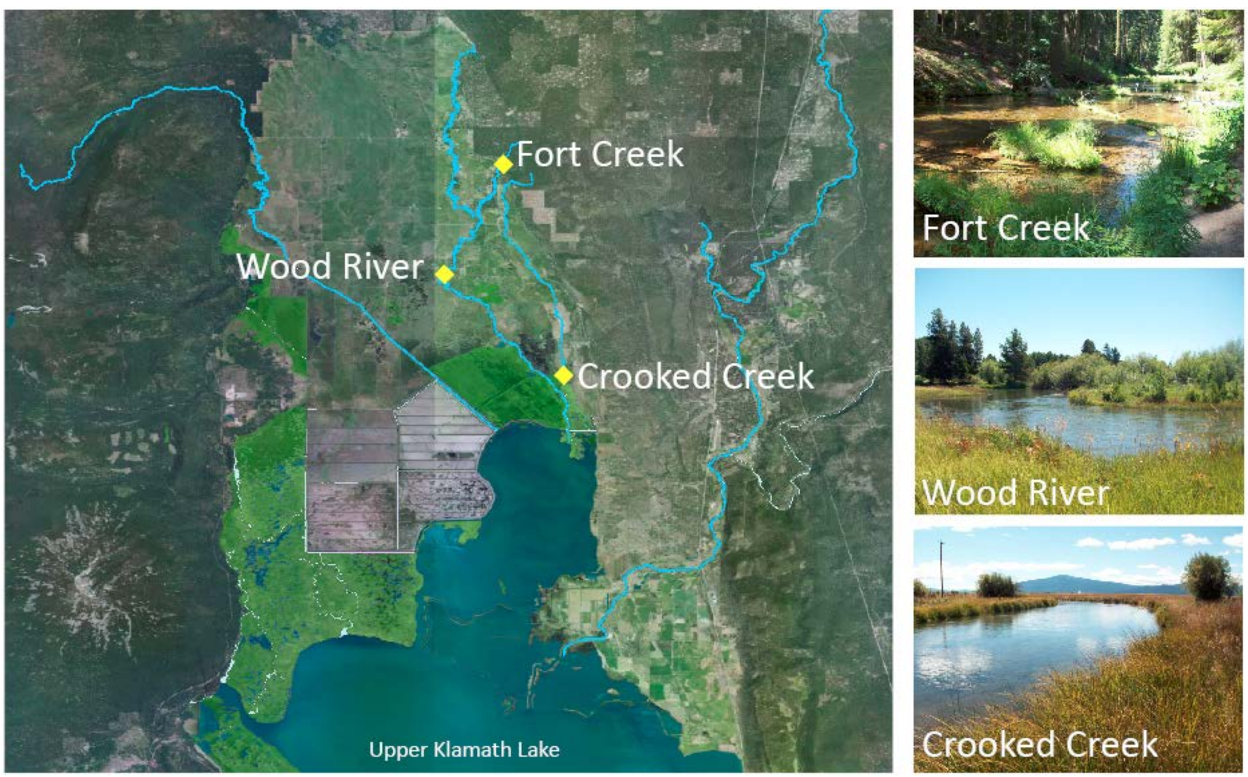


Figure 3. Approximate gage station locations for the Wood River, Fort Creek, and Crooked Creek in the UKL Sub-Basin, Oregon.

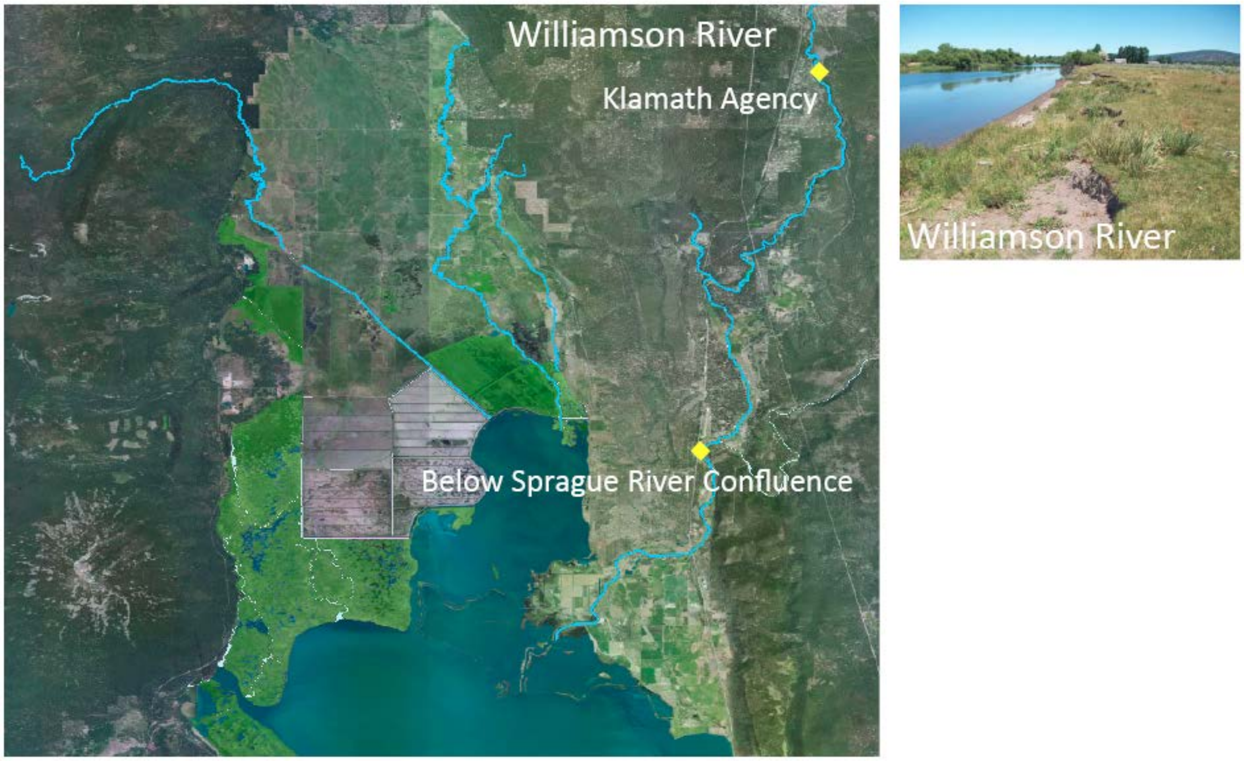


Figure 4. Approximate gage station locations for the Williamson River in the UKL Sub-Basin, Oregon.

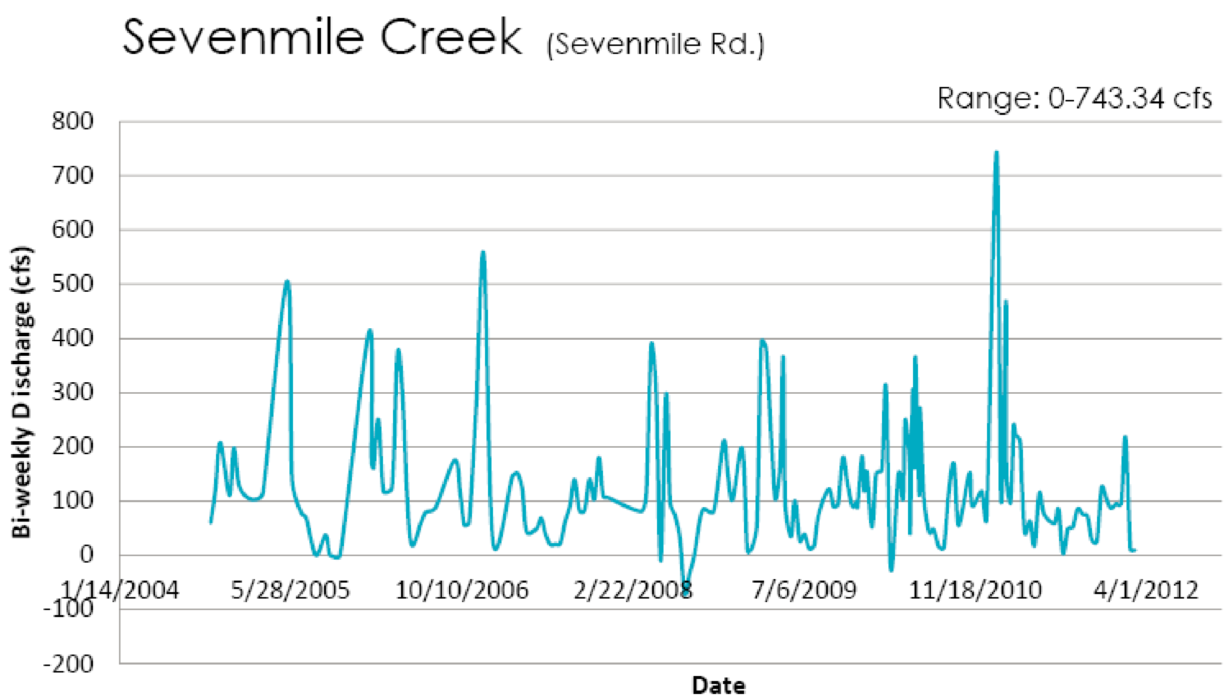


Figure 5. Discharge measurements of Sevemile Creek at Sevenmile Road measured approximately every two weeks during 10/6/2004-2/28/2012.

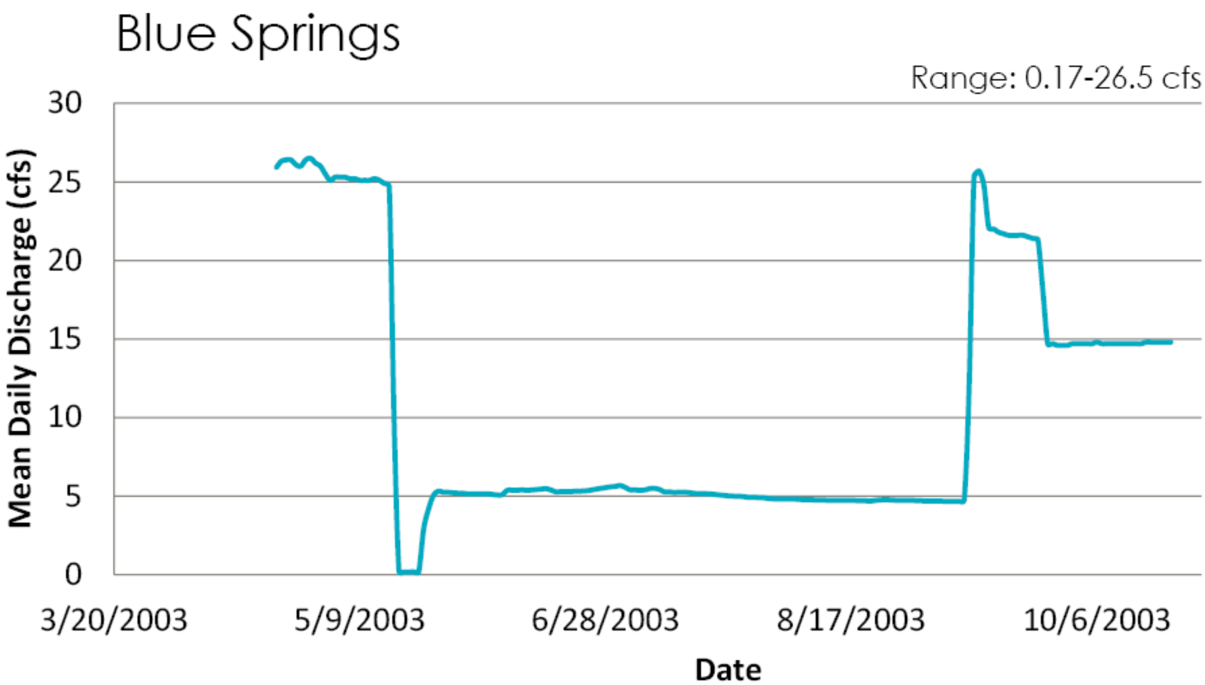
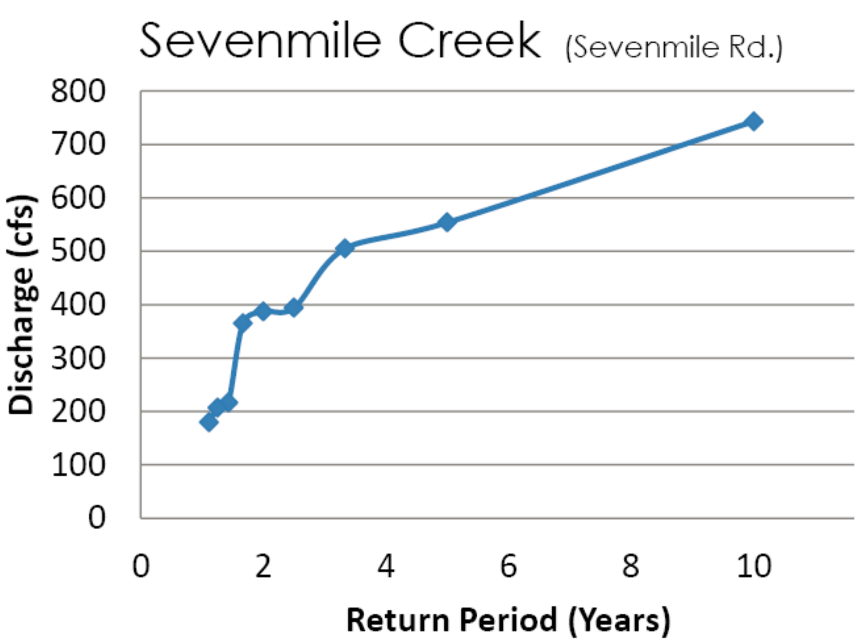


Figure 6. Discharge measurements of Blue Springs, tributary to Sevenmile Creek, measured daily from 4/22/2002-10/21/2002.



Q2	387.24 cfs
Q5	553.8
Q25	840
Q50	960
Q100	1,080

Figure 7. Measured annual peak flows and estimated re-occurrence intervals for Sevemile Creek at Sevenmile Road from 10/6/2004-2/28/2012.

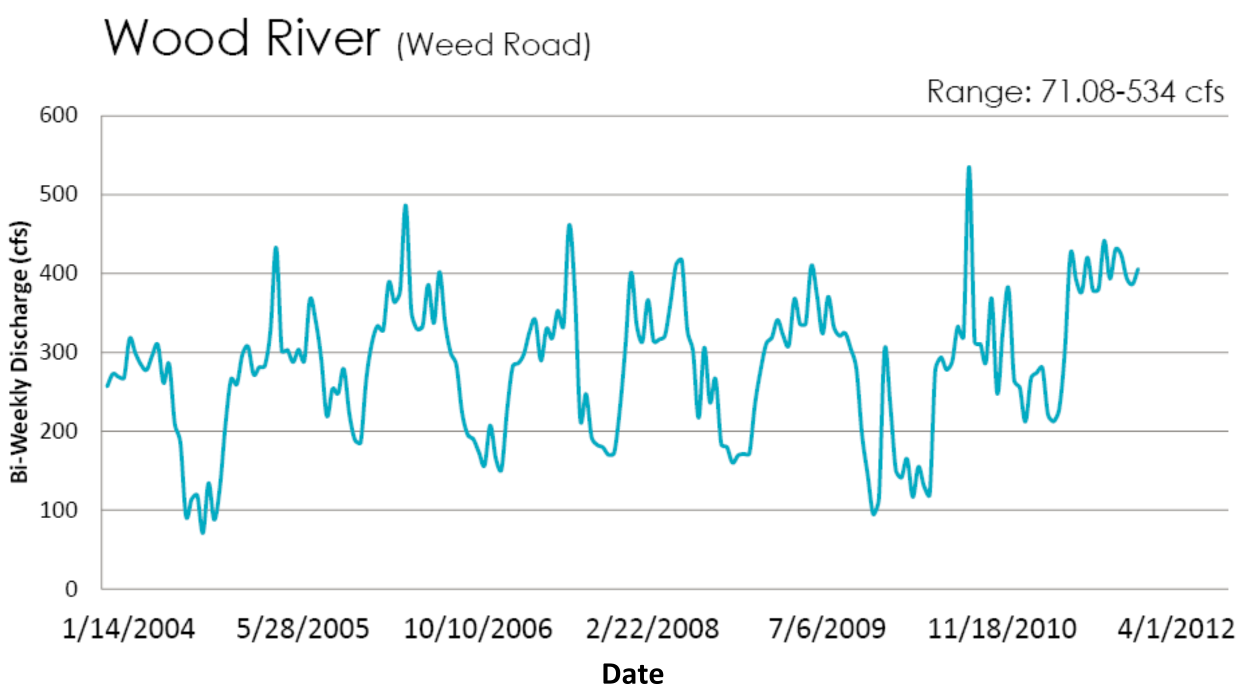


Figure 8. Discharge measurements of the Wood River, measured approximately every other week from 10/6/2004-3/26/2012.

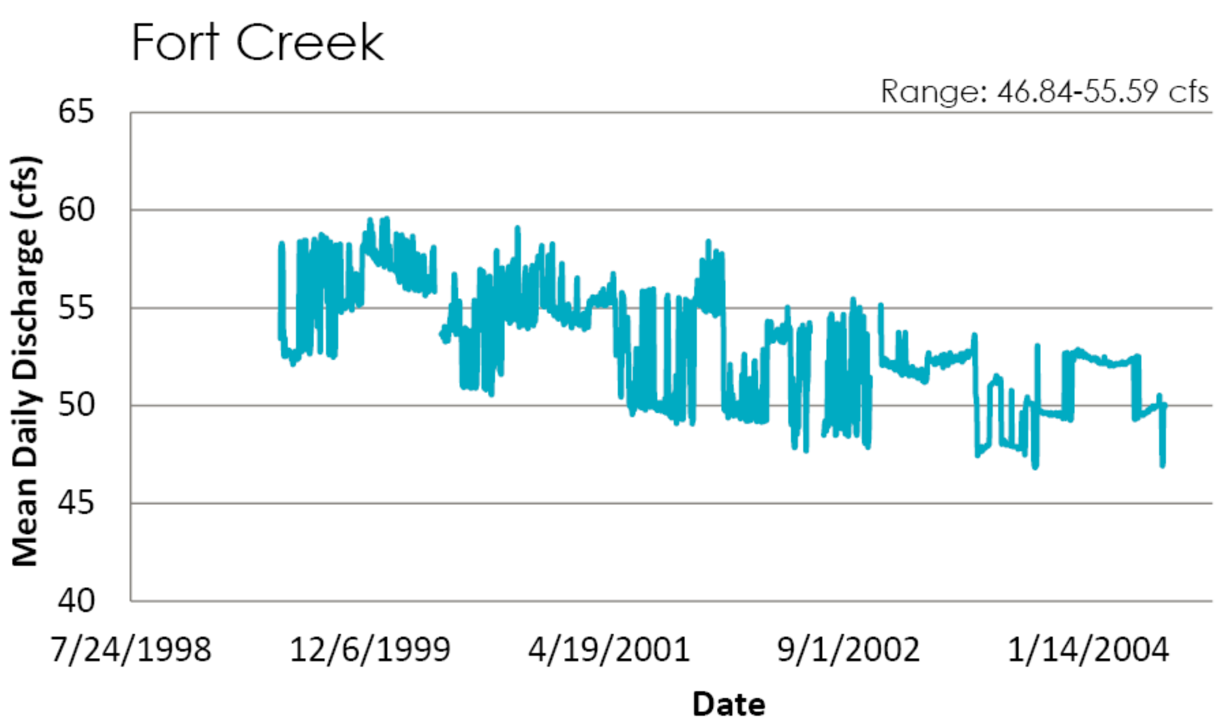


Figure 9. Discharge measurements of Fort Creek, tributary to the Wood River, measured daily from 6/2/1999-6/23/2004.

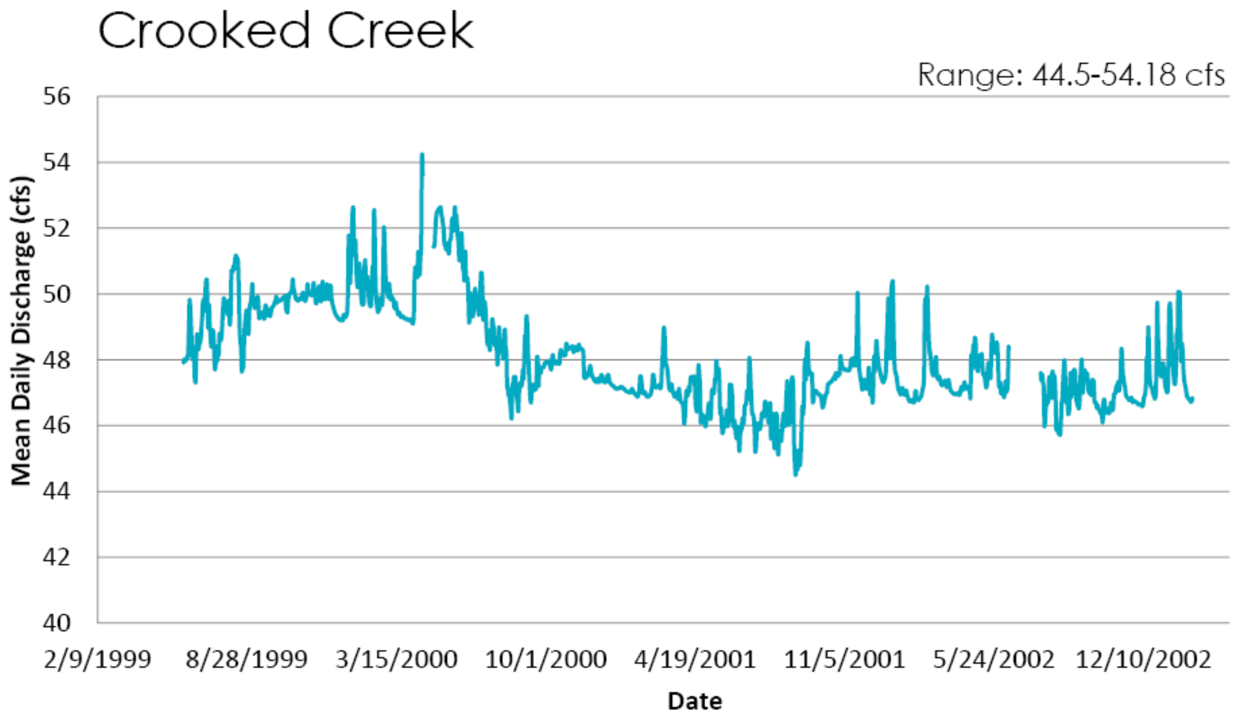
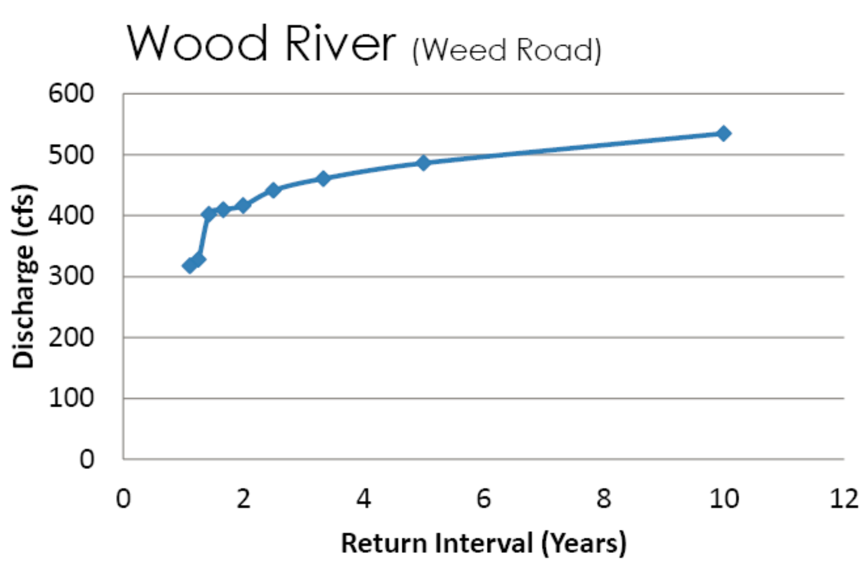


Figure 10. Discharge measurements of Crooked Creek, tributary to the Wood River, measured daily from 6/4/1999-2/13/2003.



Q2	416.59 cfs
Q5	486.27
Q25	640
Q50	694
Q100	749

Figure 11. Measured annual peak flows and estimated re-occurrence intervals for the Wood River at Weed Road from 10/6/2004-3/26/2012.

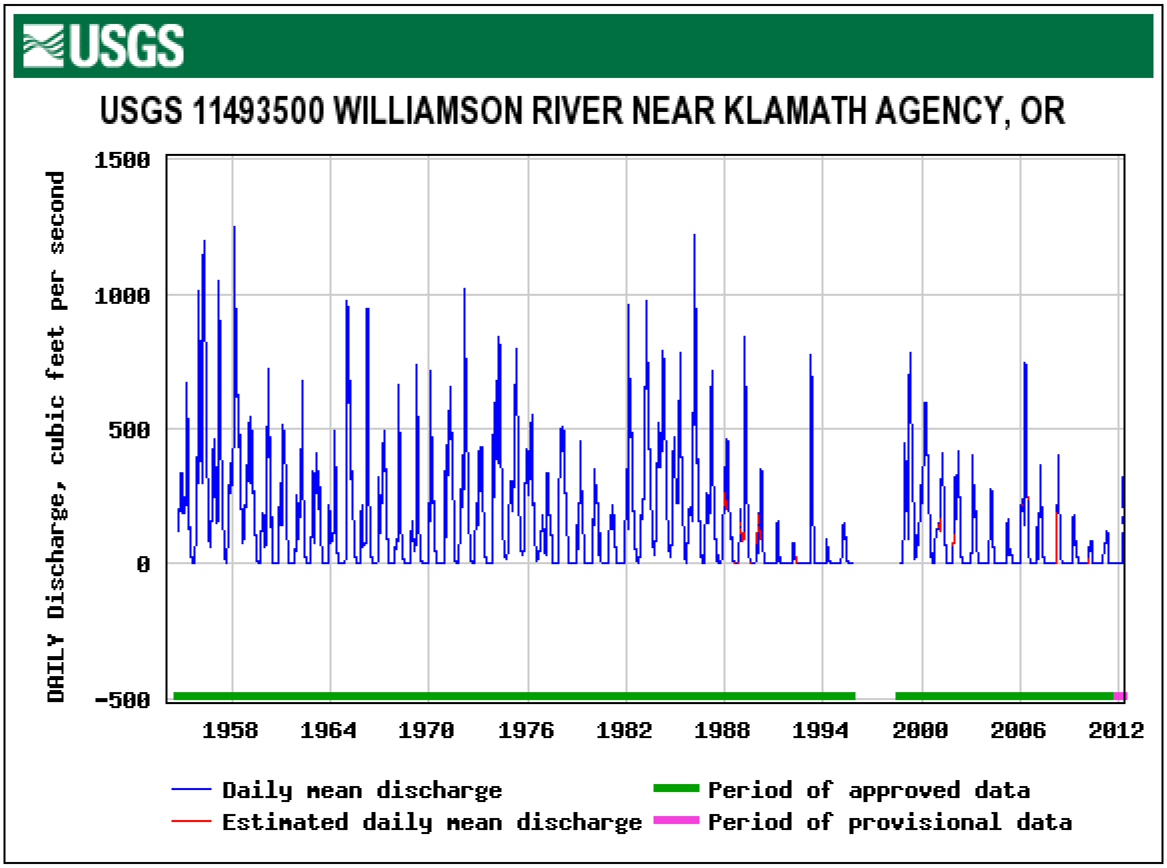


Figure 12. Daily discharge measurements of the Williamson River measured near Klamath Agency from 10/1/1954 to 5/12/2011.

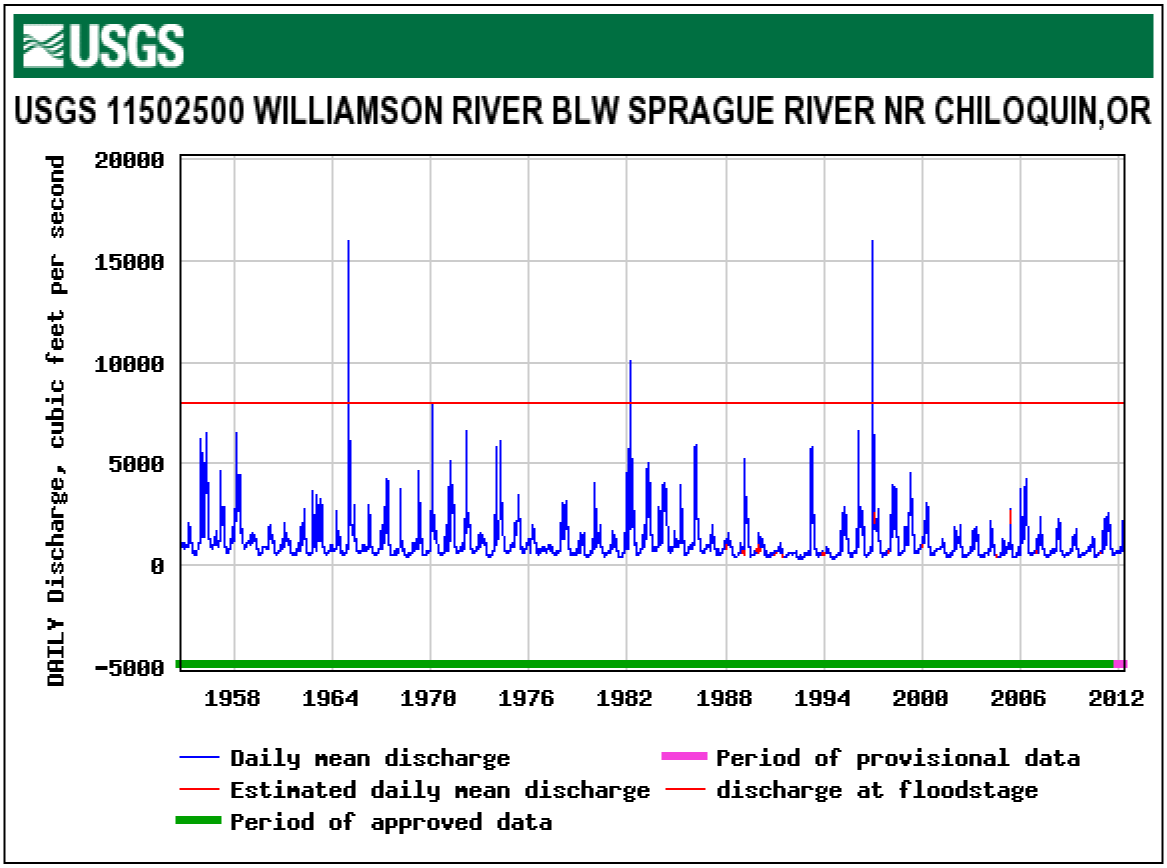
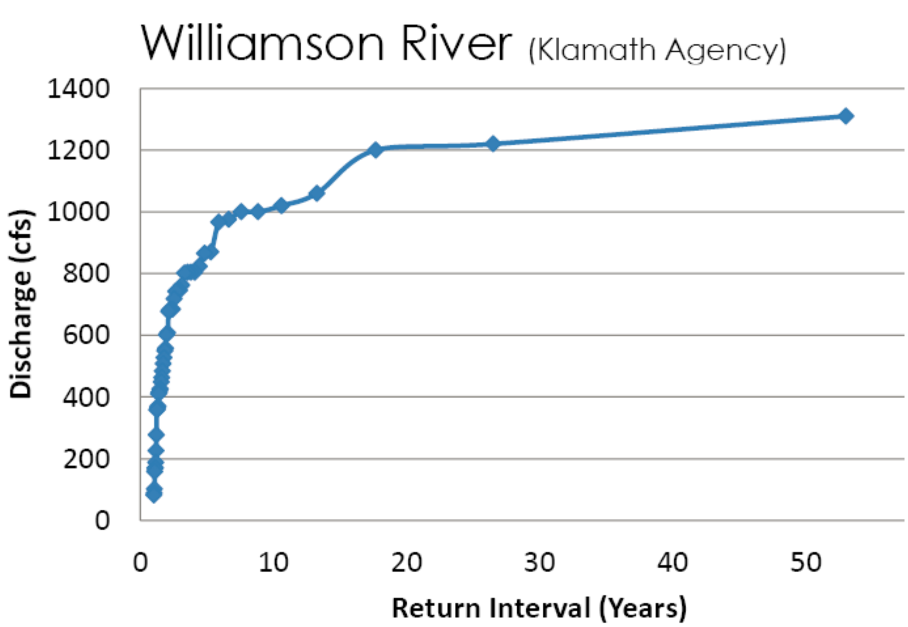


Figure 13. Daily discharge measurements of the Williamson River measured below the confluence with the Sprague River from 10/1/1917 to 4/30/2012.



Q2	608 cfs
Q5	868
Q25	1,218
Q50	1,300
Q100	1,620

Figure 14. Measured annual peak flows and estimated re-occurrence intervals for the Williamson River near Klamath Agency from 10/1/1954 to 5/12/2011.

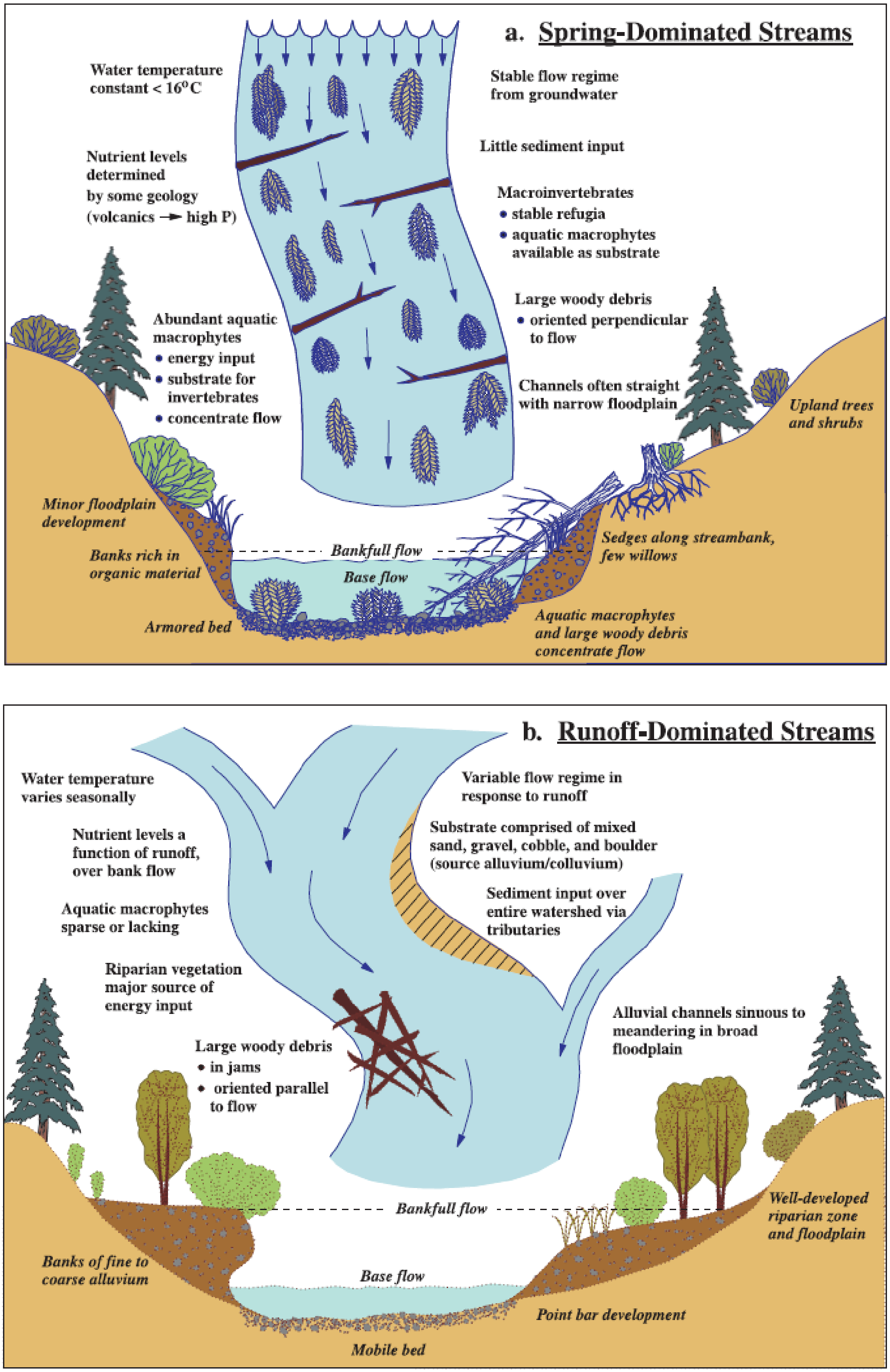


Figure 15. Comparison of channel and geomorphic characteristics of a) spring-dominated vs. b) run-off dominated streams (extracted from Reiser, 2004).