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Klamath River Flow and Water Temperature, Water Year 2012

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Abstract.—Water temperature was monitored at several locations in the Klamath Basin from April to October 2012. The uppermost Klamath River site was located upstream of Copco 1 Reservoir on the mainstem Klamath River, and the lowermost site was established just upstream of the Klamath Estuary near Klamath, CA. The highest daily mean water temperature recorded on the mainstem Klamath during the period of study was 24.6°C at Happy Camp, CA on August 5 and 17. Of three tributaries sampled, the Shasta River recorded the highest daily mean water temperature at 26.0°C, but only had a slight influence on mainstem water temperatures due to its low relative volume. Mainstem water temperatures peaked about two weeks later than the past 10-yr mean (2002-2011). Augmented flow releases from Lewiston Dam on the Trinity River were used to reduce risk of a potential fish kill in the lower Klamath River and significantly reduced Klamath River water temperatures during implementation.

Introduction

Water temperature is one of the most important variables affecting salmonids (Carter 2005). Water temperature influences feeding rates and growth (Hicks 1999; USEPA 2003), metabolism (Fry 1971; Beitinger and Fitzpatrick 1979), development (ODEQ 1995), timing of migration (Hicks 1999; USEPA 1999; Beeman et al. 2012), spawning (Hicks 1999), freshwater rearing (USEPA 2001a, 2003), and the availability of food (Ligon et al. 1999). Changes in temperature can also cause stress and lethality (Elliot 1981; USEPA 1999, 2001b). Temperatures at sub-lethal levels can effectively block migration (CDFG 2004), lead to reduced growth (Carter 2005), stress fish (Barthalow 2005), affect reproduction (Carter 2005), inhibit smoltification (USEPA 2001c), create disease problems (USEPA 2003), and alter competitive dominance (USEPA 1999). Further, the stressful impacts of water temperatures on

salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al. 1999). High water temperatures in the mainstem Klamath below Iron Gate Dam (IGD; river kilometer [rkm] 305.5; Figure 1) are believed to be a contributing factor in disease outbreaks of both juvenile (Foott 1995; Stocking and Bartholomew 2004; Bolick et al. 2012) and adult (Lynch and Risley 2003; USFWS 2003; CDFG 2004) salmonids. Water temperatures downstream of IGD are particularly important because IGD is the upper boundary to anadromy and because changes in flow can affect water temperatures downstream.

At the time this study was conducted, flow releases from IGD were determined by the National Marine Fisheries Service (NMFS) 2010 Biological Opinion regarding operation of the Bureau of Reclamation (BOR) Klamath Project, and BOR's agreement with PacifiCorp, given the threatened status of Coho Salmon (*Oncorhynchus kisutch*) below IGD (NMFS 2010).

The U.S. Fish and Wildlife Service's (USFWS) Arcata Fish and Wildlife Office (AFWO) has previously conducted comprehensive water quality investigations in the Klamath River Basin for the purpose of characterizing temporal and spatial variations in water quality below IGD (Ward and Armstrong 2006a, 2006b, 2006c, 2006d, 2006e). The purpose of this monitoring is to document water temperature and flow in the mainstem Klamath River downstream of IGD and select major tributaries. This empirical data provides support for modeling efforts and natural resource decisions. Water temperature data collected by AFWO will be made available upon request.

Study Site

The Klamath River originates in southern Oregon, east of the Cascade Mountain Range and flows 423 kilometers through southern Oregon and northern California bisecting the Cascade and Coast mountain ranges before entering the Pacific Ocean (National Resource Council 2008). The upper half of the watershed, upstream of IGD, is relatively flat with a series of wide valleys, several lakes, and six reservoirs. The lower half of the watershed is mostly mountainous with a narrow river canyon (Figure 1).

Climatic conditions vary throughout the watershed with coastal areas having mild wet winters, moderate annual temperatures and coastal fog (Ayres Associates 1999). Further inland, temperature fluctuations increase and become more variable between hot summers and cold winters, and precipitation generally decreases. Air temperatures are greatly influenced by elevation and local topography.

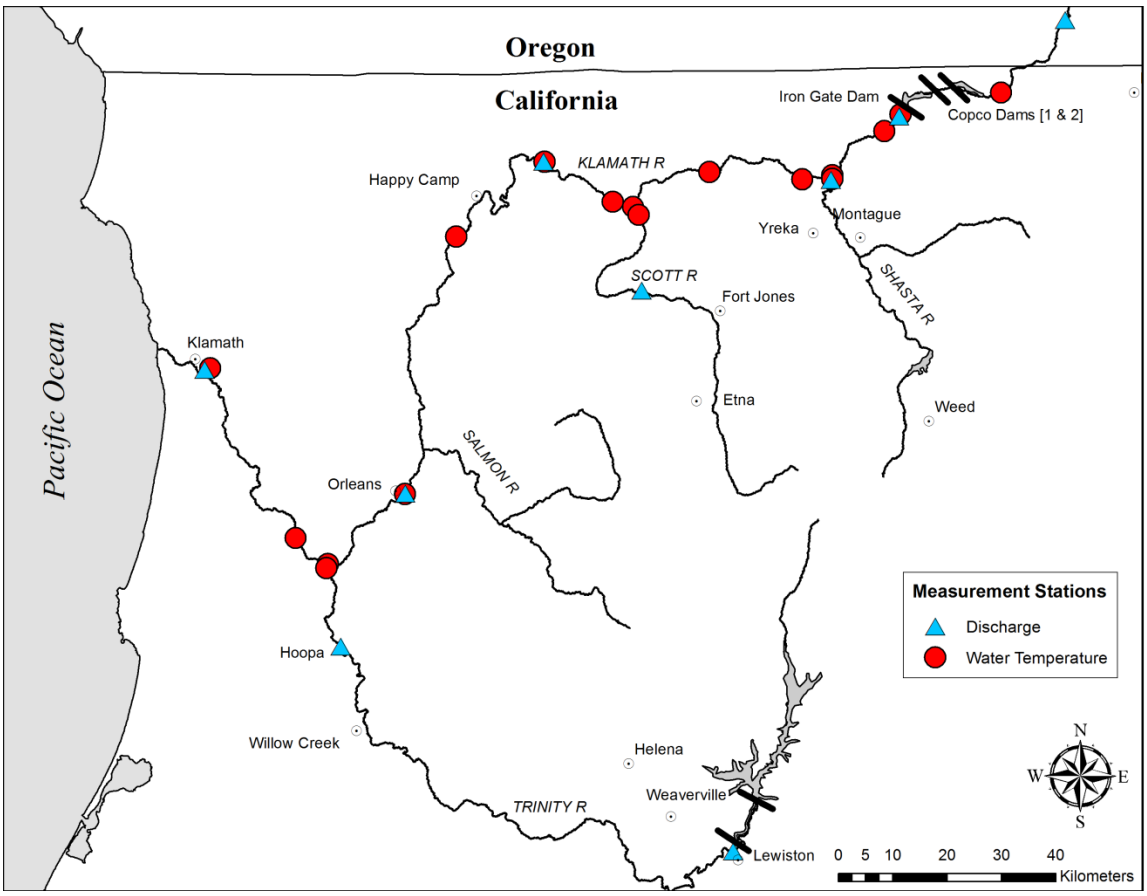

Figure 1. Klamath Basin water temperature monitoring sites (circles) and USGS stream flow gauging sites (triangles) along the mainstem Klamath River, Shasta, Scott and Trinity River during 2012. Note: only key sites are identified. Note: Bars = dams on Klamath River (Iron Gate (furthest downstream), Copco 2, and Copco 1), on Trinity River (Lewiston, and Trinity).

The Klamath River Basin drains approximately 16,000 square miles in Oregon and California (Ayres Associates 1999). Four major tributaries to the Klamath River downstream of IGD are, from upstream to downstream, the Shasta, Scott, Salmon, and Trinity rivers. The Scott River is the first tributary that typically increases flow in the Klamath River below IGD (Ayres Associates 1999) and the Trinity River is the Klamath River's largest tributary.

Major anthropogenic activities in the Klamath Basin, excluding the Trinity River, have included: hill slope and in-channel gold mining, extensive logging, middle basin hydropower development, wetland draining and diversions for agriculture in the upper Klamath Basin (West Coast Chinook Salmon Biological Review Team 1997; Hardy and Addley 2001).

Discharge and air temperature are two primary factors known to influence water temperatures in larger river systems (Caissie 2006; Isaak et al. 2012). The uppermost water temperature monitoring site along the mainstem Klamath River was located at rkm 330.7; downstream of Link, Keno, and JC Boyle dams and upstream of Copco 1, Copco 2, and Iron Gate dams (Figure 1). The lowermost temperature monitoring site in earlier years (1998 to 2007) was at Terwer (Table 1). From 2008 to 2012, the U.S. Geological Survey's gauging site known as, "Klamath River near Klamath" (KNK) was used. Both sites are only a few kilometers upstream of the estuary.

Methods

Water temperature was monitored by probes deployed by the AFWO, BOR, the Yurok Tribe's Environmental Program (YTEP), and California Department of Fish and Wildlife (CDFW). Additional water temperature data and all flow data were collected by telemetered gauging stations operated by the U.S. Geological Survey (USGS) and the California Department of Water Resources. Data from telemetered gauging stations were downloaded from the California Data Exchange Center (CDEC) website available at http://cdec.water.ca.gov or USGS gauging stations available at http://waterwatch.usgs.gov. Air temperature data were obtained from the CDEC. We conducted graphic evaluations to identify obviously erroneous data points and deleted those from our evaluation.

AFWO used temperature probes manufactured by Onset Computer Corporation® to collect water temperature data every half-hour during Water Year (WY) 2012, October 1, 2011 to September 30, 2012. Prior to and after deployment, each probe was subjected to a performance test to verify it was recording within the manufacturer's accuracy specification of ± 0.2 degrees Celsius (˚C). The instruments proved accurate and reliable for all but one probe. Data from the effected probe were not used but data were available from a co-located temperature logger operated by CDFW. A copy of the AFWO quality assurance protocol is available upon request. Water temperatures at Terwer, CA (rkm 10.8) and mainstem Klamath River at Weitchpec (rkm 70.2) were measured and recorded during earlier years of this study with Hydrolab DataSonde 4a ® multiprobes (OTT Hydromet, Loveland, Colorado) at 30-minute intervals or a Hobo® tidbit thermistor at 1-hr intervals. Prior to deployment, each instrument was calibrated. Sondes were calibrated using the manufacturer's suggested methods (Hydrolab Corporation 1999).

Temperature loggers were deployed at 20 mainstem and four tributary sites (Table 1). Stream discharge data were downloaded from CDEC or USGS for five mainstem and three tributary stream flow gauging stations (Table 2). Air temperature was downloaded from CDEC for two locations in the Klamath Basin to show general trends (Table 3).

Table 1. Water temperature monitoring sites on the Klamath, Shasta, Scott, and Trinity rivers from USFWS, Yurok Tribe, and CDFW. Note: Not all data identified in this table are presented in the report but are available upon request.

Location	Site Description	rkm	Lat	Long	USFWS	Yurok Tribe	CDFW
Klamath River	above Copco Reservoir	330.7	41°57'57"	122°12'58"	x		
Klamath River	at Iron Gate Hatchery Bridge	305.1	41°55'53"	122°26'24"	x		x
Klamath River	below Bogus Creek (at trap)	300.3	41°55'5"	122°27'6"	x		
Klamath River	below R-Ranch	299.9	41°54'13"	122°28'34"	x		
Klamath River	above Interstate 5 (at trap)	287.9	41°51'47"	122°33'53"	x		
Klamath River	above Shasta River	284.5	41°49'52"	122°35'31"	x		
Shasta River[a]	Shasta River	1.6	41°49'30"	122°35'33"	x		
Klamath River	at Trees of Heaven	277.5	41°49'30"	122°39'30"	x		
Beaver Creek[b]	Beaver Ck near mouth	0.5	41°52'15"	122°48'58"	x		
Klamath River	above Beaver Ck	259.3	41°52'11"	122°48'60"	x		
Klamath River	at Walker Ck Bridge	251.4	41°50'15"	122°51'53"	x		
Klamath River	at Kinsman Ck (at trap)	234.6	41°48'36"	123°0'51"	x		
Klamath River	above Scott River	230.5	41°46'46"	123°01'59"	x		
Scott River[c]	at Johnsons Bar	2.4	41°45'57"	123°01'16"	x		
Klamath River	below Scott River	225.1	41°47'16"	123°04'44"	x		
Klamath River	at Seiad Valley	206.8	41°51'15"	123°13'49"	x		
Klamath River	below Happy Camp	162.2	41°43'47"	123°25'28"	x		
Klamath River	at Orleans	95.1	41°18'11"	123°32'04"	x		
Klamath River	at Weitchpec	70.2	41°11'10"	123°42'09"		x	
Trinity River[d]	near mouth	0.8	41°10'45"	123°42'21"		x	
Klamath River	below Weitchpec	62.0	41°13'42"	123°46'24"		x	
Klamath River	above Blue Creek	26.6	41°25'24"	123°55'46"		x	
Klamath River	above Blakes Riffle	13.0	41°30'40"	123°46'20"		x	
Klamath River	Terwer	10.8	41°30'54"	123°59'56"	x		

[a] Shasta River confluence is 284.2 rkm from mouth of Klamath River.

[b] Beaver Creek confluence is 259.3 rkm from mouth of Klamath River.

[c] Scott River confluence is 230.1 rkm from mouth of Klamath River.

[d] Trinity River confluence is 70.0 rkm from mouth of Klamath River.

Table 2. U.S. Geological Survey stream flow gauging station locations along the Klamath, Shasta, Scott, and Trinity rivers.

Site Description	Station Number	rkm	Latitude	Longitude
Below J.C. Boyle Power plant	11510700	354.4	42°05'05"	122°04'20"
Iron Gate Dam	11516530	305.5	41°55'41"	122°26'35"
Shasta River at Yreka[a]	11517500	0.8	41°49'23"	122°35'40"
Scott River near Ft Jones[b]	11519500	28.2	41°38'27"	123°00'50"
Klamath River near Seiad Valley	11520500	206.8	41°51'14"	123°13'52"
Klamath River at Orleans	11523000	95.1	41°18'13"	123°32'00"
Trinity River at Hoopa[c]	11530000	20.0	41°03'00"	123°40'21"
Klamath River near Klamath	11530500	13.0	41°30'40"	123°58'42"

[a] Shasta River confluence is 284.2 rkm from mouth of Klamath River.

[b] Scott River confluence is 230.5 rkm from mouth of Klamath River.

[c] Trinity River confluence is 70.0 rkm from mouth of Klamath River.

Table 3. California Data Exchange Center (CDEC) air temperature monitoring locations in the Klamath Basin.

Site Description	Station ID	rkm	Elevation (ft)	Latitude (N)	Longitude (W)
Collins Baldy	CLB	239.8	5,493	41°77'50"	122°95'03"
Somes Bar	SSB	107.0	920	41°33'30"	123°50'00"

For this report, daily flow and temperature (daily mean, maximum, and minimum) were reported from part of WY 2012 (April 15 September 30) and for part of WY 13 (October 1 to October 15), because this is the time period when water temperature can exceed critical thresholds for fish migration, development, rearing and survival. Graphical presentations were made of water temperatures using the previous 8-, 9-, or 10-year daily mean water temperatures (2004 to 2011 or 2003 to 2011 or 2002 to 2011 respectively) depending on availability of data.

Results and Discussion

Hydrology

A total of 1,073,000 acre-feet of water was released from IGD to the Klamath River in WY 2012, the 12th highest volume compared to the previous 21 years (Figure 2). Flow from IGD increased from around 1,000 cubic feet per second (cfs) to about 4,000 cfs in April and decreased after April to about 1,000 cfs in early July through September (Figure 3). Timing and duration of tributary accretions were due

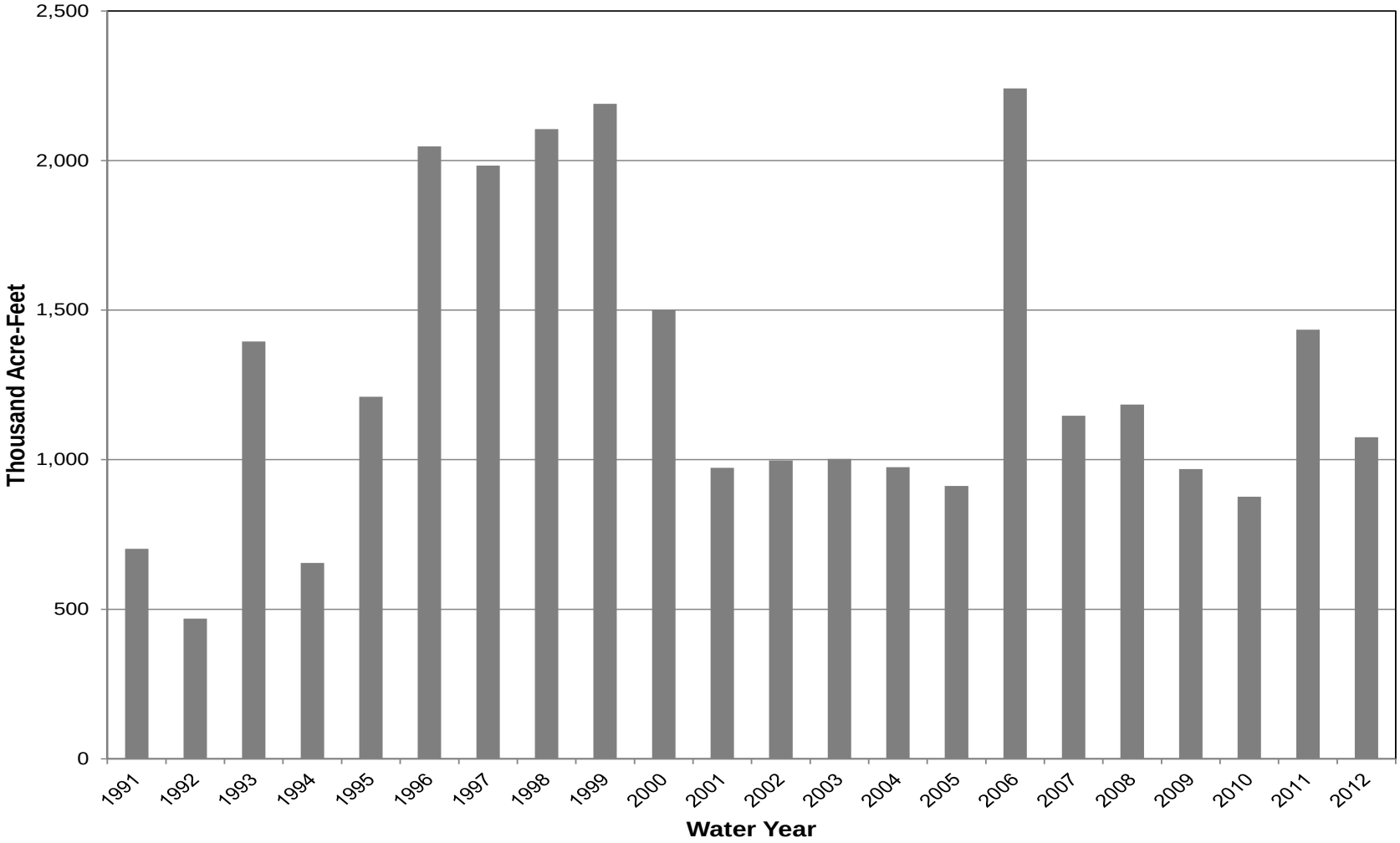

Figure 2. Total annual flow volume released from Iron Gate Dam for Water Years 1991 to 2012

to IGD releases, with the greatest accretions occurring in winter and spring from precipitation and snow melt. In WY 2012, the highest peak flow from IGD was 3,970 cfs on April 8, but at Seiad Valley, Orleans, and Klamath, the highest peak flows occurred on March 31. The second highest daily peak flows occurred in late April at all four sites, then flows decreased into mid-August. A supplemental flow release from Lewiston Reservoir on the Trinity River from mid-August to late-September resulted in increased flows in the Klamath River downstream of Weitchpec to reduce the risk of a fish kill (TRRP - Fall Flow Subgroup 2012). A one-day pulse of 1,565 cfs was released from Iron Gate Dam on August 31 for the Yurok Boat Dance, and was ramped down to 1,000 cfs in early September.

Flows from IGD were lower than the previous 10-yr mean (2002 to 2011) in the early spring, but exceeded the mean by about 1,000 cfs in April and early May (Figure 4). The highest flow in the Shasta River during the reporting period was 258 cfs (7.4%) of the Klamath River flow at IGD, which was 3,510 cfs the same day. Flows in the Scott River peaked at 3,130 cfs (31.4% of Klamath River flows at Seiad) and in the Klamath River at Seiad at 9,949 cfs, both on April 24. Flow in both streams decreased to base levels by early July. Flows peaked in the mainstem Klamath at Orleans on April 24 at 29,539 cfs, and in the Trinity River (rkm 20.0) at 13,364 cfs (45.2% of Klamath River flow at Orleans) on April 23.

Water Temperatures of the Mainstem Klamath River

Copco (rkm 330.7) to Iron Gate Dam (rkm 305.5)

Daily mean water temperatures were generally lower just upstream of Copco 1 Reservoir during spring and summer months than those observed below IGD at Iron Gate Hatchery Bridge (IGHB; rkm 305.1; Figure 5). Highest daily mean water temperature at the Copco 1 monitoring site was 21.7°C on August 18 and 22.6°C at IGHB on August 14 and August 21. Water temperatures cooled down after the third week in August at both sites.

At IGHB, from mid-April to mid- October, 2012, daily mean water temperatures exceeded the 10-yr maximum daily mean water temperature for 20 calendar days and was cooler than the 10-yr minimum daily mean water temperatures for 10 days (Figure 6). The daily mean water temperatures in WY 2012 peaked about two weeks later than the peak of the prior 10-yr mean. After the peak, water temperatures generally decreased until early October, similar to that observed in other years.

Mainstem Near Shasta River Confluence (rkm 284.2)

From mid-April to mid-October, 2012, the daily mean water temperature measured in the Klamath River upstream of the Shasta River (rkm 284.5) peaked at 23.2°C on August 17 and 18 (Figure 7). The daily mean water temperature in the Shasta River (rkm 0.5) peaked at 26.0°C on July 12. The highest daily mean mainstem water

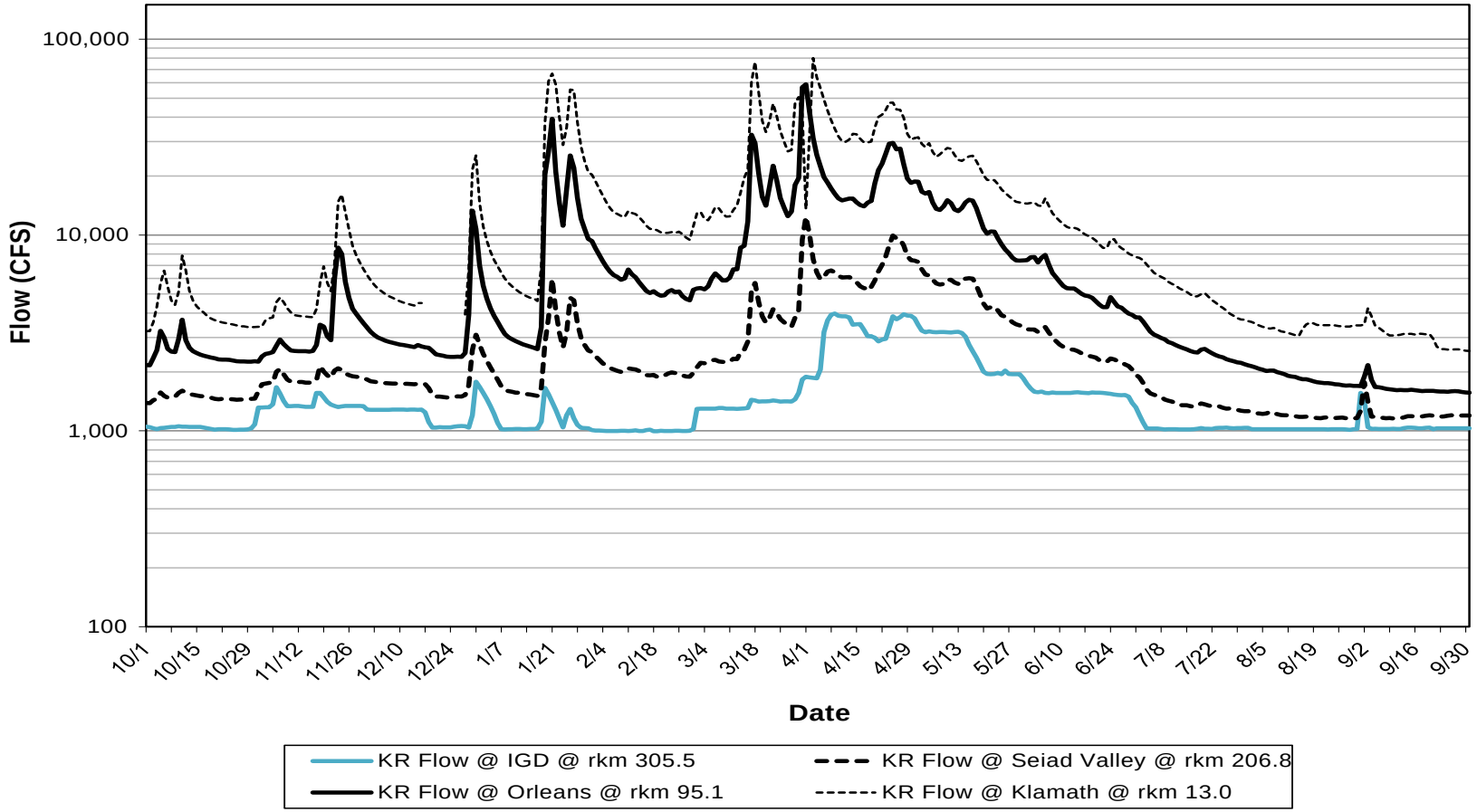

Figure 3. Daily mean flow (cubic feet per second) of the Klamath River (KR) from U.S. Geological Survey stream flow gauge locations at Iron Gate Dam (IGD), Seiad Valley, Orleans, and Klamath, water year 2012 (October 1, 2011-September 30, 2012).

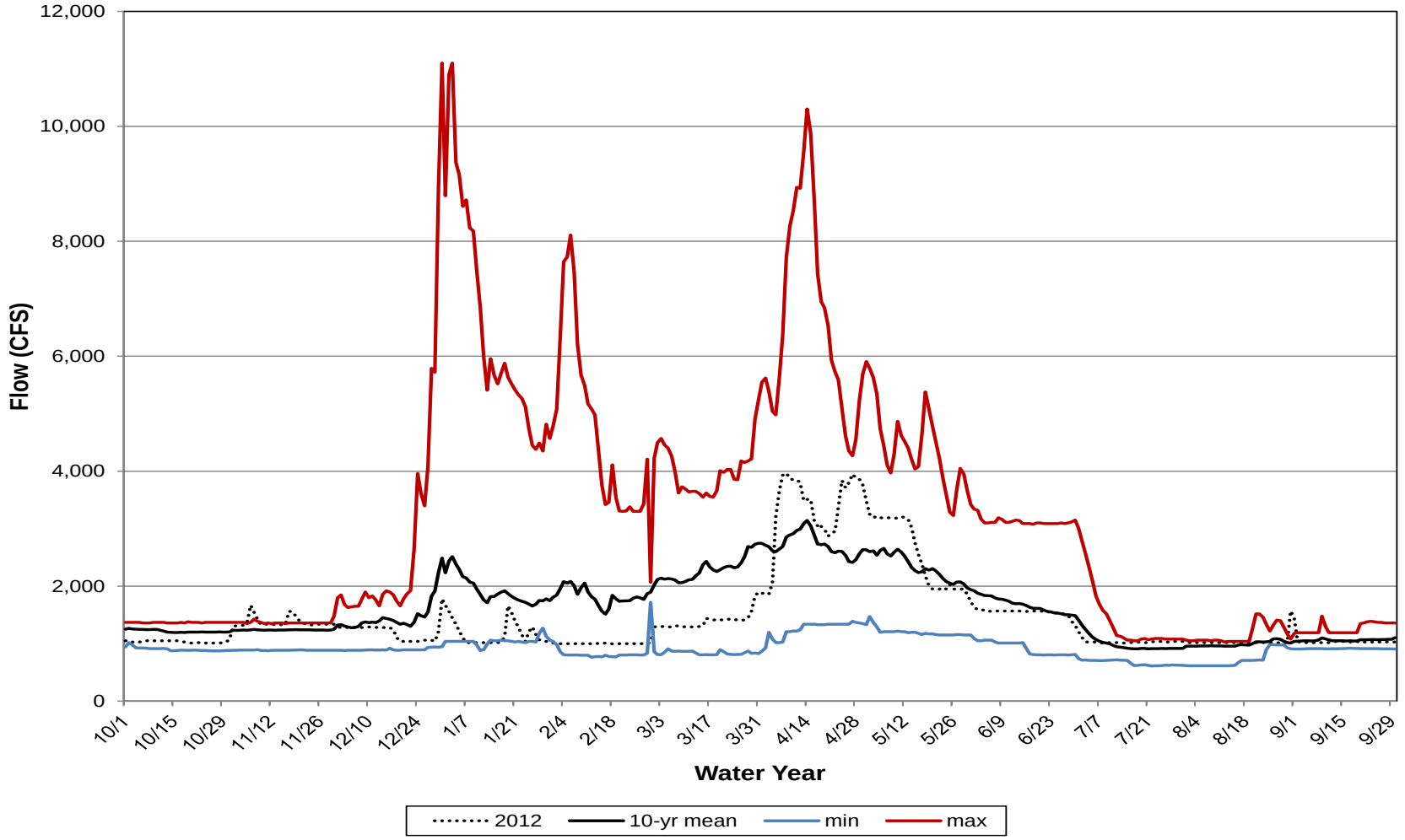

Figure 4. Daily mean flow in cubic feet per second (CFS) on the mainstem Klamath River at Iron Gate Dam (rkm 305.5) for water year 2012 (October 1, 2011-September 30, 2012) and the previous 10-year (WY 2002 to 2011) daily mean, minimum (min) and daily maximum (max).

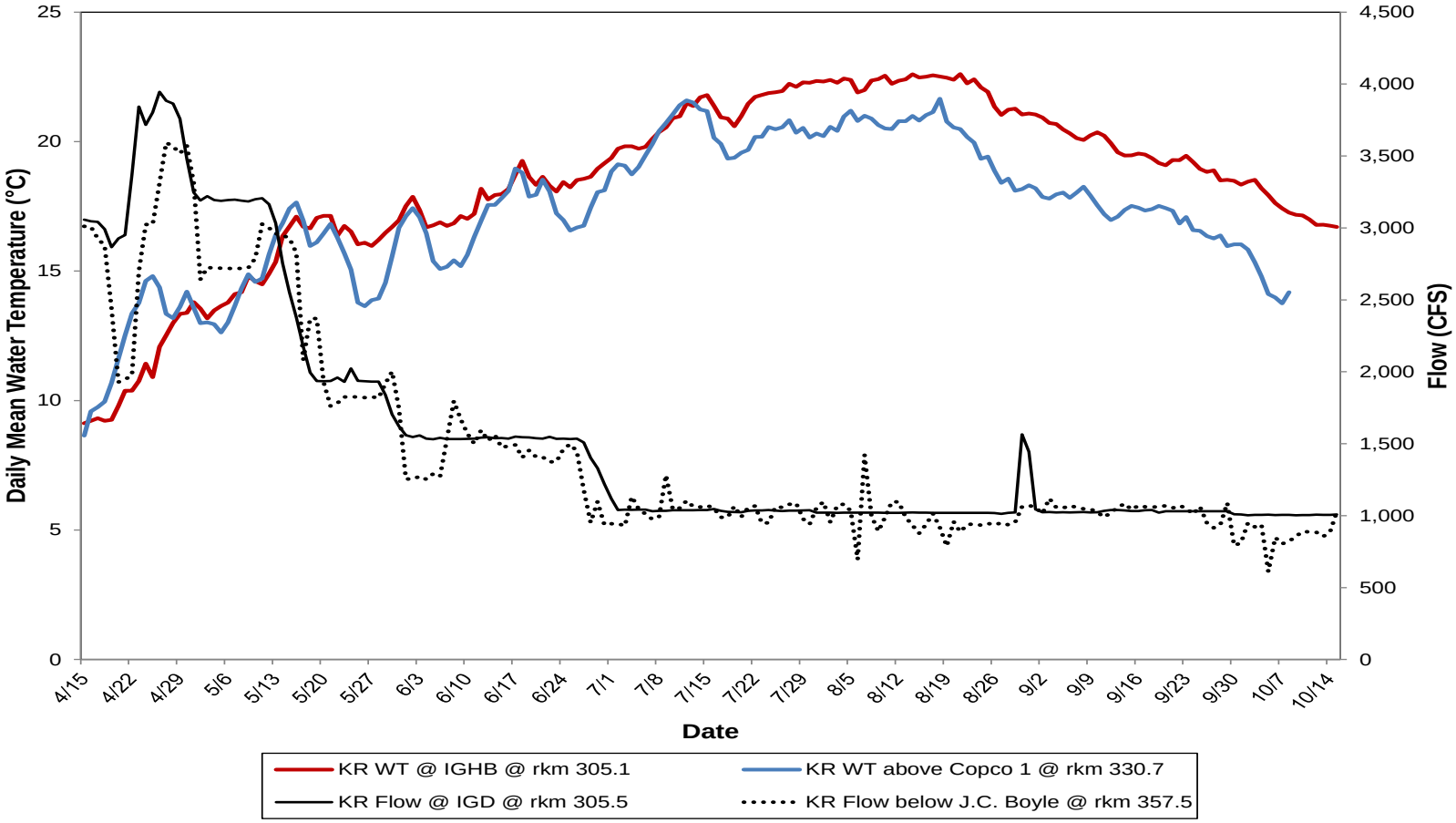

Figure 5. Daily mean flow on the mainstem Klamath River (KR) from U.S. Geological Survey gauges below J.C. Boyle Power House and Iron Gate Dam (IGD) and daily mean water temperatures at Iron Gate Hatchery Bridge (IGHB) and upstream of Copco 1 Reservoir from April 15 to October 15, 2012. Note: water temperature was not measured above Copco 1 after October 8.

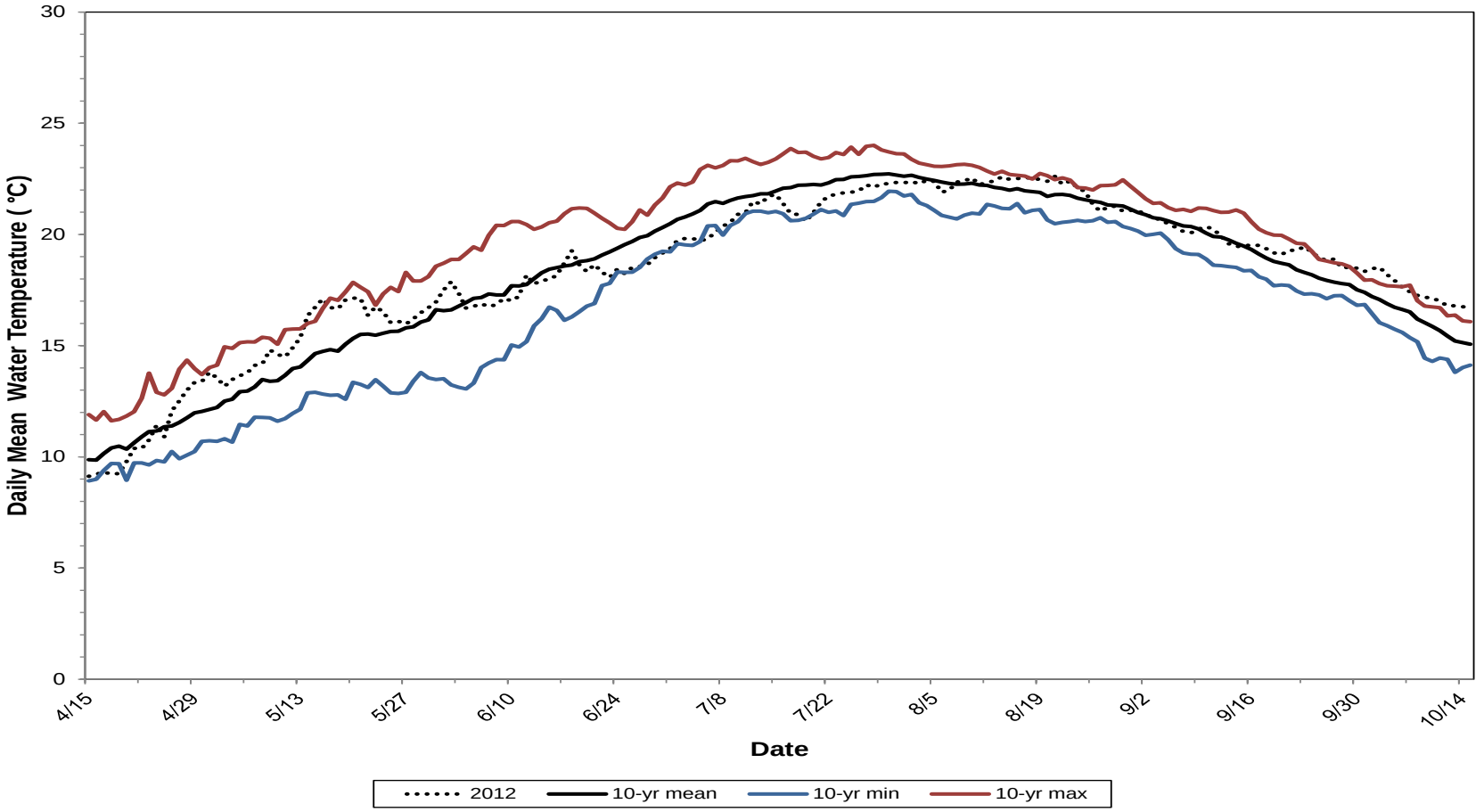

Figure 6. Average, minimum, and maximum daily mean water temperatures for the 10-yr period (April 15 to October 15, 2002 to 2011) at Iron Gate Hatchery Bridge (rkm 305.1) compared to daily mean water temperatures recorded from April 15 to October 15, 2012.

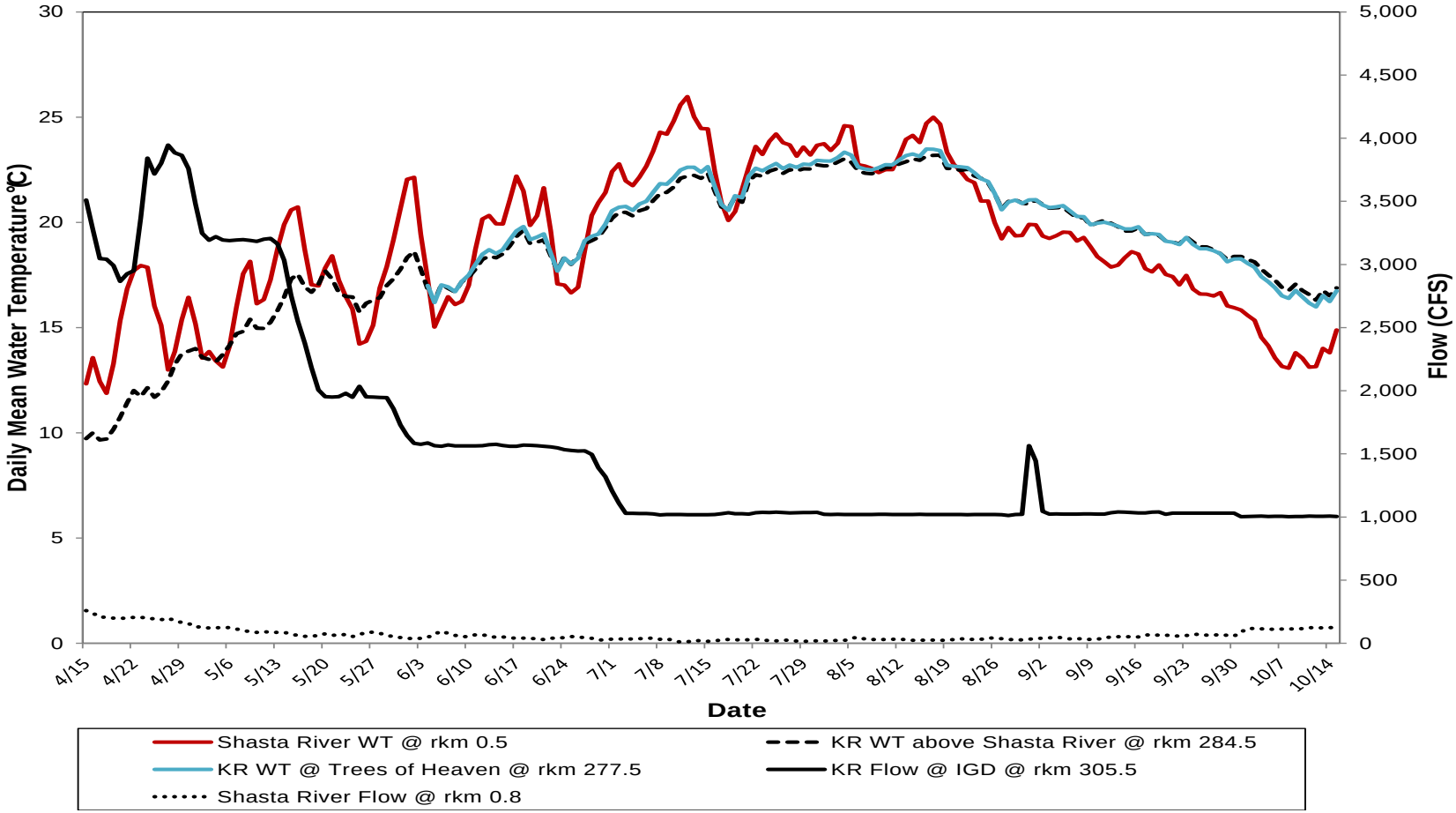

Figure 7. Daily mean flow at U.S. Geological Survey stream gauge on the Shasta River and in the mainstem Klamath River (KR) at Iron Gate Dam (IGD) and daily mean water temperatures (WT) in the mainstem Klamath River just upstream of the Shasta River, in the Shasta River, and in the Klamath River downstream at Trees of Heaven Campground from April 15 to October 15, 2012. Note water temperature at Tree of Heaven Campground was not measured before June 4, 2012.

temperature at Trees of Heaven Campground (rkm 277.5) below the confluence with the Shasta River was 23.5°C on August 16 and 17. Water temperatures decreased at all three locations after mid-August through September with the Shasta River water temperatures becoming cooler than mainstem Klamath temperatures from late August through mid-October.

Mainstem Klamath near Scott River Confluence (rkm 230.1)

From mid-April to mid-October the daily mean temperature of the Scott River (range 7.5 to 23.8°C) was consistently cooler than the of the Klamath River upstream (range 10.1 to 24.2 °C) or downstream (range 10.0 to 23.2°C) from its confluence (Figure 8). Daily mean temperature of the Klamath River was generally cooler downstream of the Scott River confluence by about 1.0-2.0°C until late June, when water temperatures below the Scott River were roughly the same or higher than above the Scott River confluence. Peak daily mean water temperature upstream of the Scott River was 24.2°C measured on August 17 compared to Seiad Valley, which peaked at 24.5°C the same day. The Scott River's daily mean water temperature peaked at 23.8°C on August 16. Generally water temperatures increased at all three monitoring sites until mid-August through September. Air temperature appeared to influence water temperatures from mid-April to mid-October.

Seiad Valley (rkm 206.8)

Daily mean water temperatures at Seiad Valley fell within the range of the 10-yr mean from mid-April to mid-October, 2012 (Figure 9). The daily mean water temperature at Seiad Valley peaked at 24.5°C on August 17. The April 15 to October 15, 2012 daily mean water temperatures fell mostly within the 10-yr daily mean, minimum, and maximum temperatures except the peak daily mean water temperature was about two weeks later. After the peak in 2012, water temperature declined through September.

Happy Camp (rkm 162.2)

In past years the warmest water temperatures in our study reach have been from Hamburg (rkm 226.0) to below Happy Camp (CDWR 1987). Daily mean water temperatures at Happy Camp fell within the range of the minimum, maximum and average 9-yr daily mean water temperature except for two time periods (August 16 and 17; and October 13 to 15; Figure 10). Daily mean water temperature at Happy Camp peaked at 24.6°C on August 5 and 17. The trend in water temperature was similar to 9-yr average except the peak daily mean water temperature was about two weeks later. After the peak in 2012, water temperature declined through September.

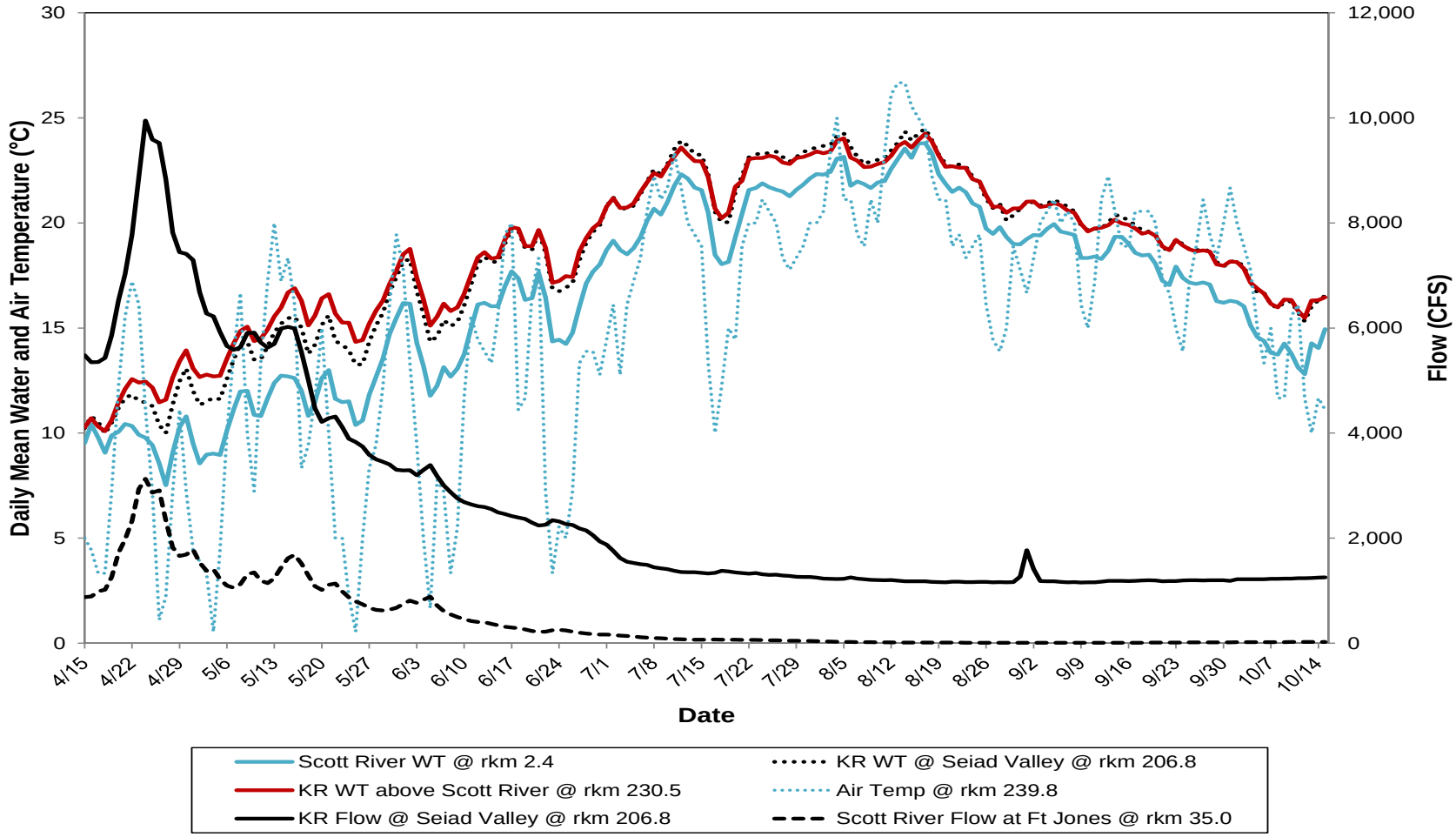

Figure 8. Daily mean flow from U.S. Geological Survey stream gauges on the Scott River and Klamath River (KR) at Seiad Valley, and daily mean water temperatures (WT) recorded on the mainstem Klamath River upstream of the Scott River, in the Scott River, and at Seiad Valley from April 15 to October 15, 2012. Daily mean air temperature was recorded at Collins Baldy at rkm 239.8 from a CDEC gauging station.

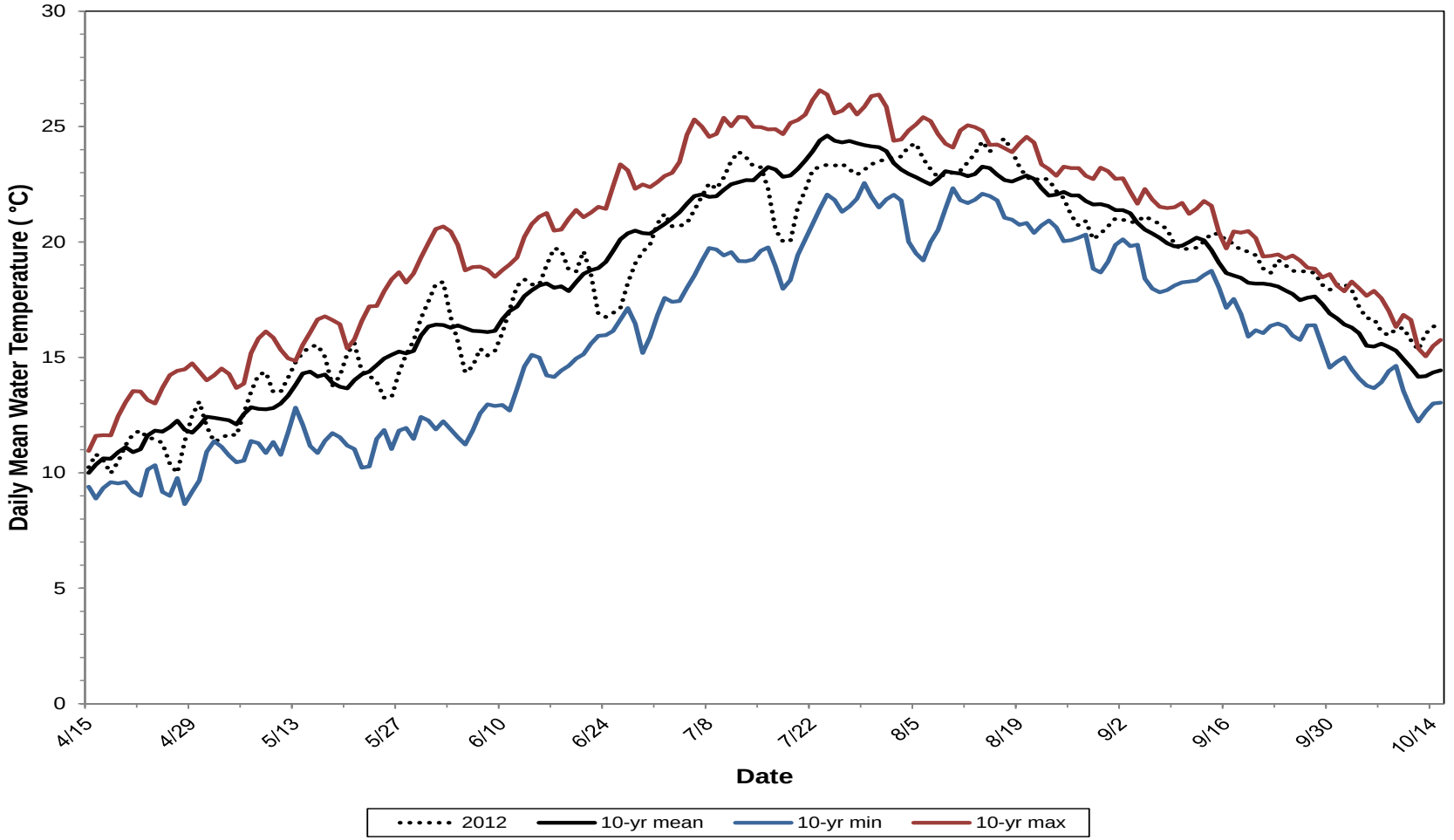

Figure 9. Average, minimum, and maximum daily mean water temperatures for the 10-yr period (April 15 to October 15, 2002 to 2011) at Seiad Valley (rkm 206.8) compared to daily mean water temperatures recorded from April 15 to October 15, 2012.

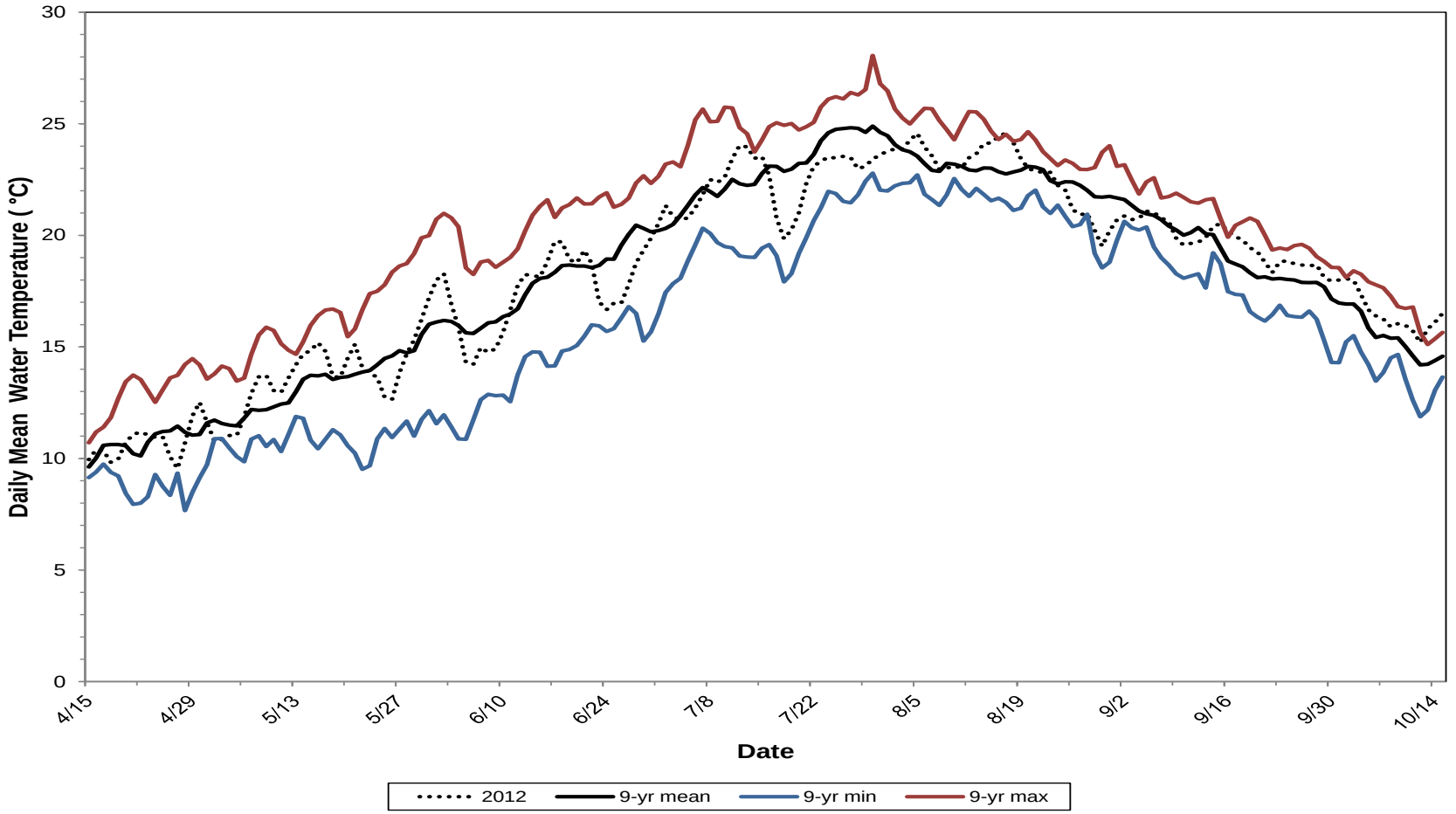

Figure 10. Average, minimum, and maximum daily mean water temperatures for the 9-yr period (April 15 to October 15, 2003 to 2011) at Happy Camp (rkm 162.2) compared to daily mean water temperatures recorded from April 15 to October 15, 2012.

Orleans (rkm 95.1)

Daily mean water temperatures from mid-April to mid October 2012 exceeded the highest daily mean values measured over the prior 9-yrs for 21 days, and were cooler than the minimum daily mean water temperature for 4 days (Figure 11). In 2012, water temperature peaked at 24.2°C on August 16 and 17. This peak was about two weeks later than the 9-yr daily mean water temperature peak. After mid-August, water temperatures declined through September. Generally, daily mean water temperatures at Orleans were cooler (range 9.0 to 24.2 °C) than at Happy Camp (range 9.6 to 24.6°C) for the period from April 15 to October 15, probably due to numerous cool water tributary accretions and a topographic shading effect provided by the river's north to south orientation in this portion of the basin (Figure 1).

Mainstem Klamath River above the Trinity River confluence (rkm 70) to Klamath (rkm 13.0)

The mainstem Klamath River daily mean water temperature just upstream of the Trinity River confluence at Weitchpec (rkm 70.2) peaked at 24.0°C on August 17 and the peak temperature in the Trinity River, measured 0.8 rkm upstream of the Klamath River, was 24.1°C on August 14 and 15 (Figure 12). Daily mean water temperatures at KNK (rkm 13.0) peaked at 23.5°C on August 14. Air temperature appeared to influence water temperatures.

Temperatures in the lower Klamath River at KNK were lower than the maximum daily mean water temperature for the previous 8-yr period except for 8 days that exceeded the maximum daily mean water temperature between April 15 and October 15 and 9 days which were cooler than the minimum daily mean water temperature during the same period (Figure 13). In 2012, the peak was about two weeks later than the peak of the 10-yr daily mean water temperature.

Generally water temperature in the Klamath River above Weitchpec was warmer than the Trinity River from early May through September. Water temperatures in the lower Klamath River were cooler than those at Weitchpec from June to mid-September. This is likely due to the influence of cool marine air in this section of the river and accretions of coastal tributaries such as Blue Creek, Ah Pah Creek, Omagaar Creek, etc.

Augmented Fall Flows

Two flow augmentation actions were implemented in WY2012. A pulse flow was provided from IGD on August 31 for the Yurok Boat Dance (Figure 14). Iron Gate Dam flows increased from 1,022 to 1,565 cfs then decreased to 1,044 cfs on September 2. Augmented flows were also released from Lewiston Dam on the Trinity River and increased flows at Hoopa from mid-August to late-September. The augmentation from the Trinity River was intended to reduce the risk of a fish kill in the Klamath River downstream of Weitchpec (TRRP-Fall Flow Subgroup 2012).

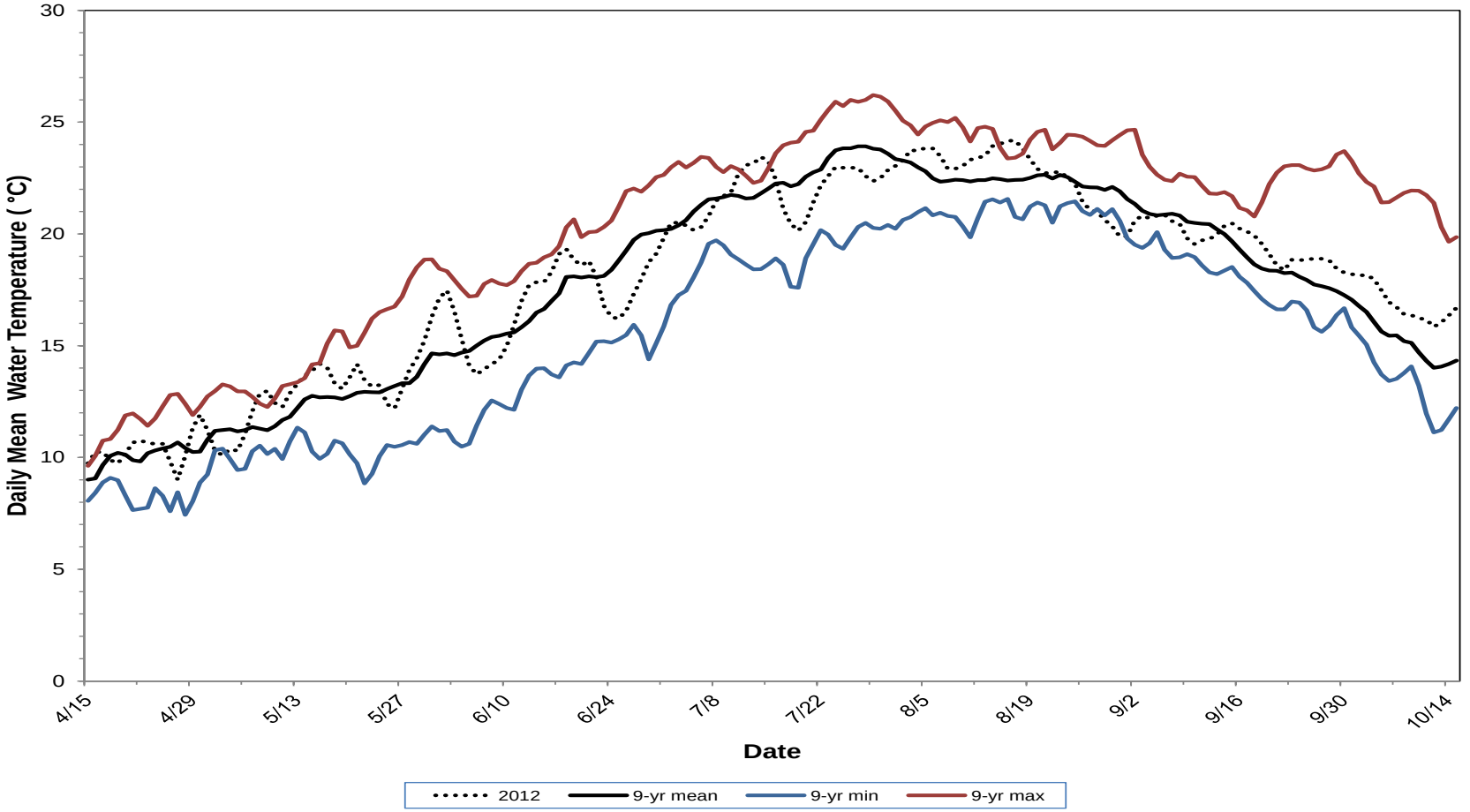

Figure 11. Average, minimum, and maximum daily mean water temperatures for the 9-yr period (April 15 to October 15, 2003 to 2011) at Orleans (rkm 95.1) compared to daily mean water temperatures recorded from April 15 to October 15, 2012.

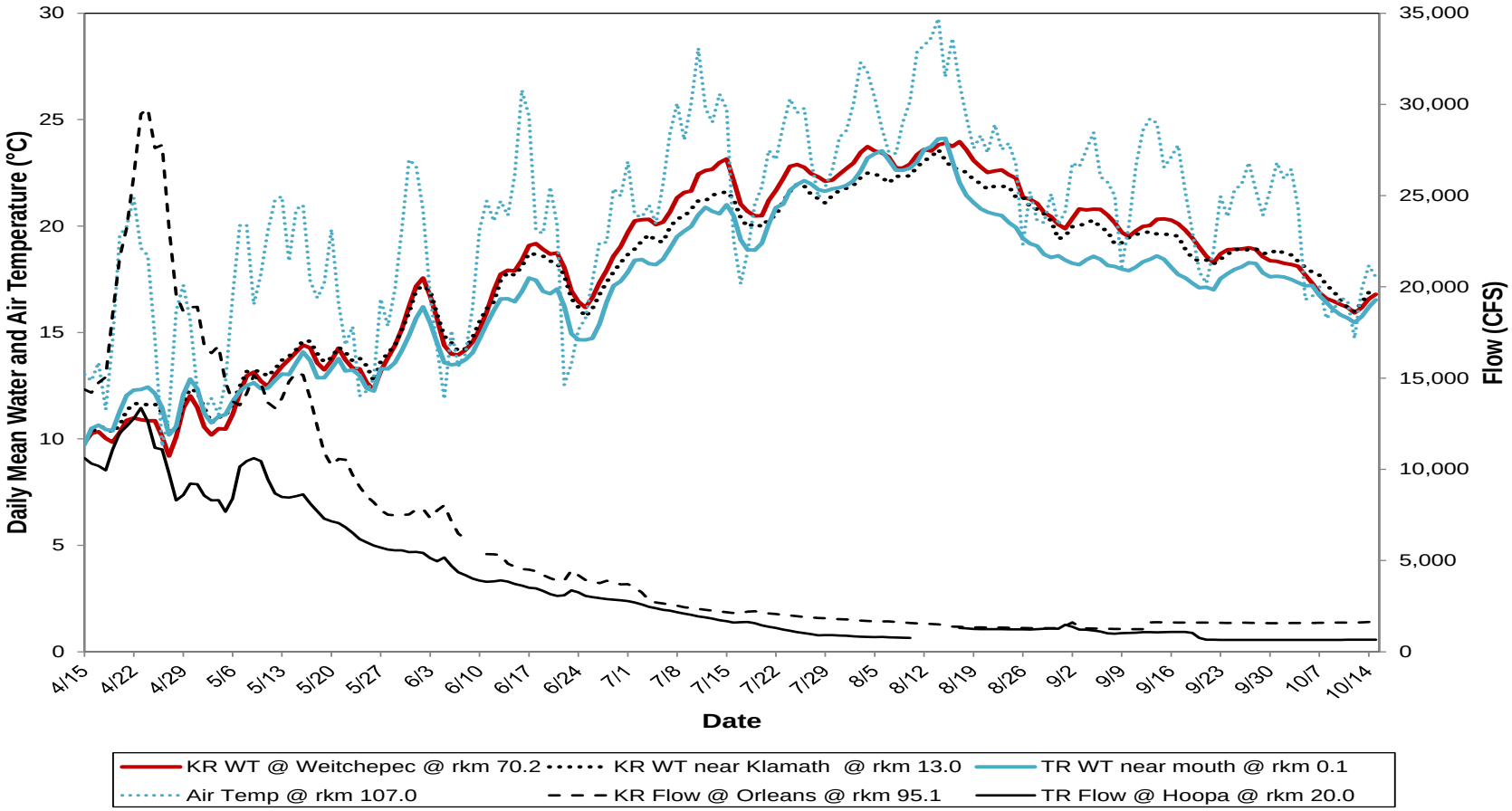

Figure 12. Daily mean flow from US Geological Survey stream gauges on the mainstem Klamath River (KR) at Orleans and in the Trinity River (TR) at Hoopa, and daily mean water temperatures (WT) recorded at Weitchpec, in the Trinity River, and in the Klamath River near Klamath from April 15 to October 15, 2012. Daily mean air temperature was recorded at Somes Bar at rkm 239.8 from a CDEC gauging station.

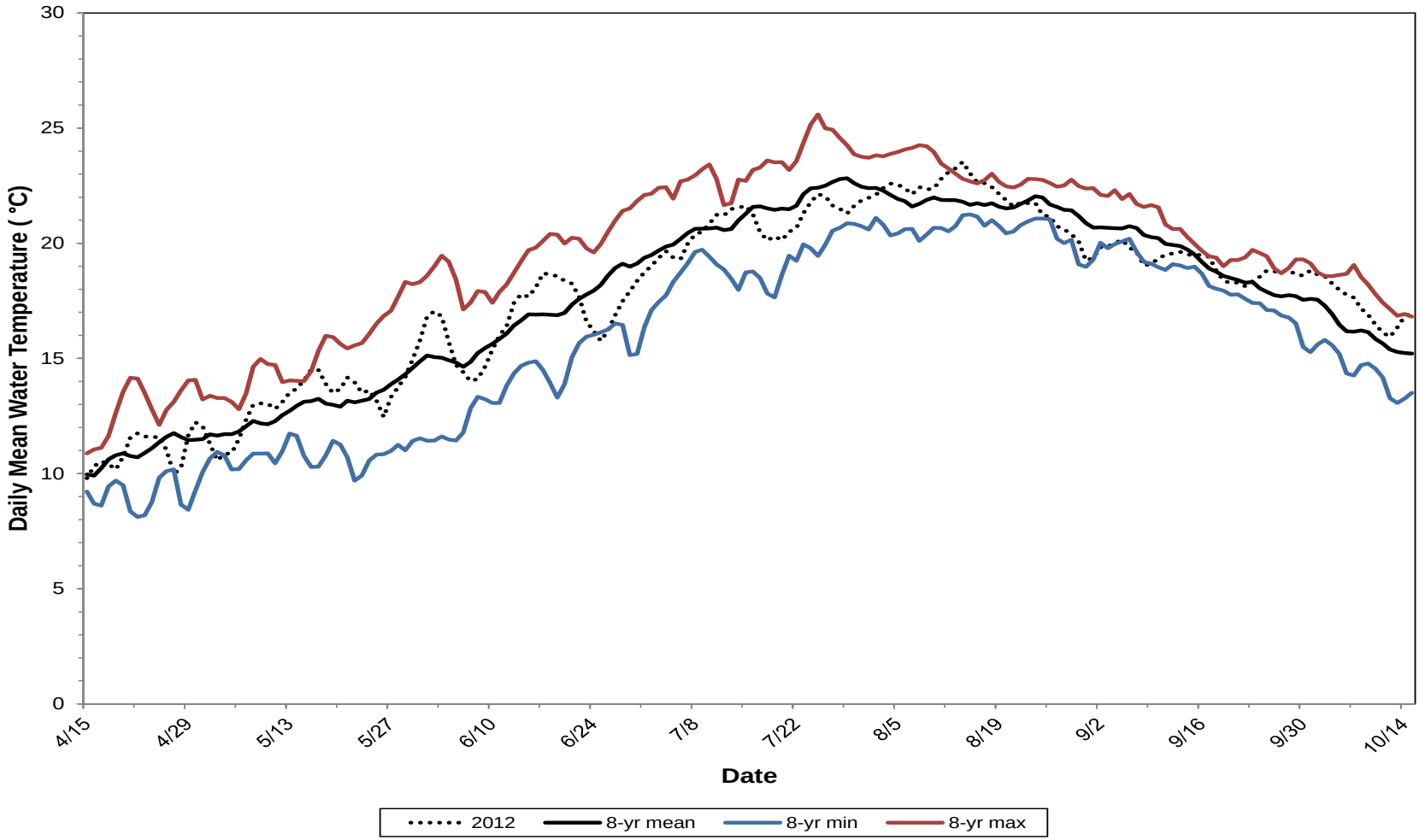

Figure 13. Average, minimum, and maximum daily mean water temperatures for the 8-yr period (April 15 to October 15, 2004 to 2011) at Klamath near Klamath (rkm 13.0) compared to daily mean water temperatures recorded from April 15 to October 15, 2012.

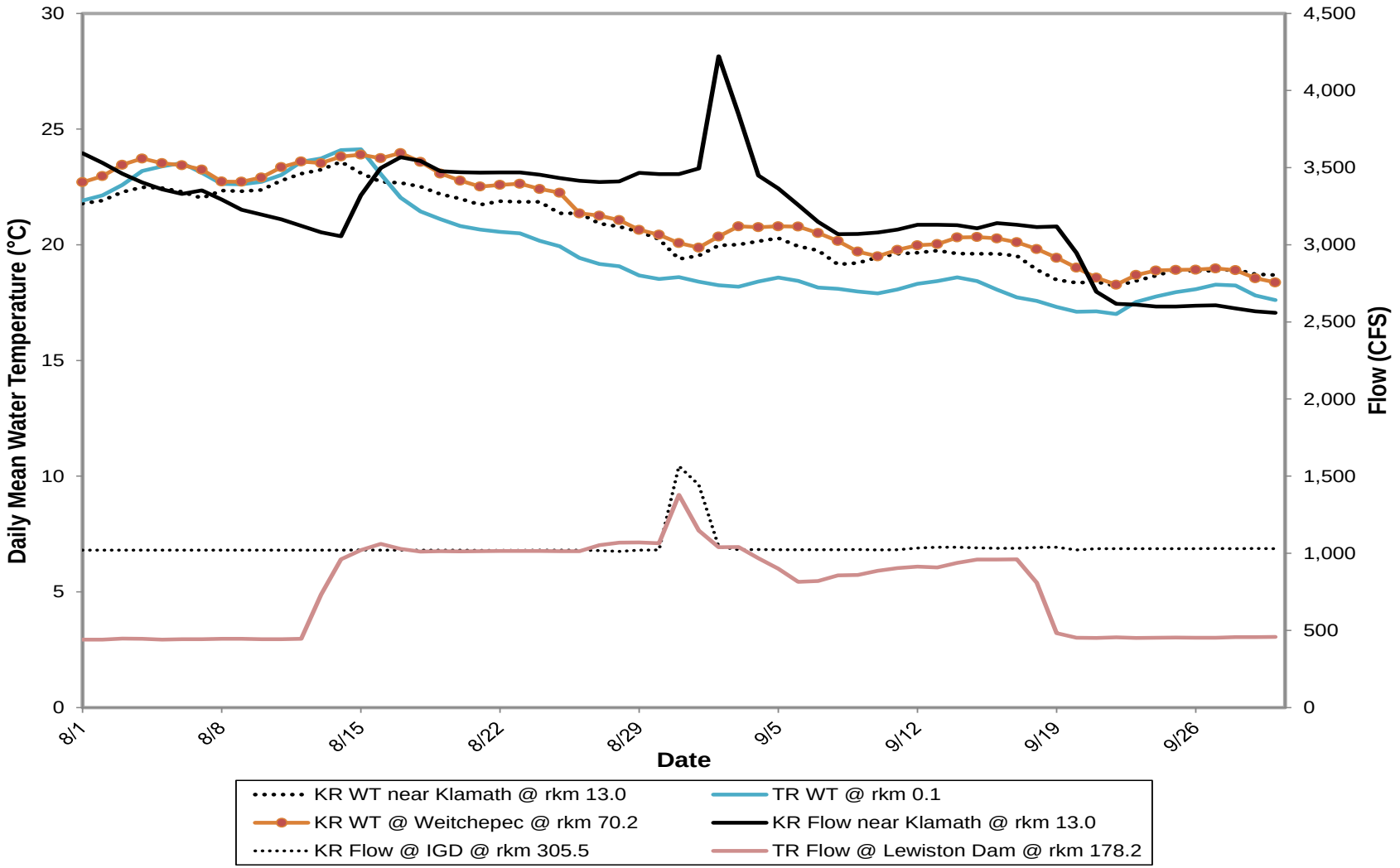

Figure 14. Effect of augmented fall flows measured at U.S. Geological Survey gauges on the Trinity River (TR), at Hoopa, and Klamath River (KR), at Orleans and Klamath, on daily mean water temperatures (WT) at Weitchpec and Klamath near Klamath and Trinity River during WY2012.

Flow releases were increased from Lewiston Dam on August 12 from 446 cfs to 1,060 cfs and remained at approximately 1,000 cfs until August 30. Flows were again increased on August 31 to 1,378 cfs for a day, then decreased to between 800 to 900 cfs until September 20 when flows decreased to 453 cfs.

The intent of the augmented flow was to increase water velocities and achieve higher turnover rates of water in holding areas of the lower Klamath River during the peak of the fall Chinook salmon migration period (TRRP - Fall Flow Subgroup 2012). Higher turnover rates have been shown to reduce the ability of the parasite *Ichthyophthirius multifilis* (commonly known as "ich") to find and attach to a host fish during its free-swimming infectious stage (Bodensteiner et al. 2000). Other benefits higher base flows include decreasing water temperatures in the lower Klamath River, increasing water velocities to flush parasites from the system, diluting parasite concentrations, eliminating thermal barriers to upstream migration, and decreasing densities and residence time of adult salmon by dispersing adults upstream to the spawning grounds. .

Water temperatures of the Trinity River during the augmented flow release had a noticeable influence on the thermal regime of the Klamath River below the Trinity River confluence (Figure 14). Flows from Lewiston Dam during augmentation accounted for about 25 to 40% of the total flow of the lower Klamath River at the USGS Gage site at KNK. This thermal dilution and coastal climate contributed to an average water temperature reduction of about 0.6 and 0.7˚C just below Weitchpec (rkm 62.0) and at KNK, respectively. The maximum water temperature reduction at each of these sites was 1.0 and 1.4˚C respectively. Following the augmented flow, water temperature differences, as measured in the Klamath and Trinity Rivers at Weitchpec, decreased back to less than 0.6˚C through the end of September.

Summary

Flow releases from IGD total 1,073,000 acre-feet of water to the Klamath River in WY 2012 which ranked it in 12th place compared to the previous 21 WYs. In the spring, water temperature increased as flows decreased and exposure to daylight increased. Water temperatures generally decreased after mid-August with decreasing daylight.

During spring and summer months, water temperature generally increased downstream of Copco 1 and were warmest by Happy Camp before cooling in a downstream direction. This cooling was possibly from cooler tributary accretions, topographical shading, and coastal cloud cover.

Mainstem Klamath River daily mean water temperatures in 2012 were mostly in the range of the previous 10-yr means between mid-April through September. During 2012, mainstem water temperatures peaked about two weeks later than the daily mean over the previous 8 to 10 years. Augmented dam releases from Lewiston Dam on the Trinity River were used to abate a potential fish kill in the lower Klamath

River and significantly influenced Klamath River water temperatures downstream of the Trinity.

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