Montana Fish, Wildlife & Parks

2015 Sun River Drainage Water Temperature

Prepared by:

Katie Vivian, Montana Fish, Wildlife & Parks

Jason Mullen, Montana Fish, Wildlife & Parks

April 2017

Introduction

Temperature regimes are critical to the success of trout populations. High temperatures increase fish physiological stress including reduced oxygen uptake and suppressed growth. While adaptive to many environmental conditions, the upper lethal temperatures for salmonids are generally greater than 77°F (Hokanson et al. 1977, Jobling 1981, Bjornn and Reiser 1991, Matthews et al. 1997, Bear et al. 2007, Ritter and Zale 2015) (Table 1). The Sun River is a major tributary to the Missouri River and has populations of brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), and several other fish species.

The Sun River drainage encompasses over 2,200 square miles and the Sun River is used to irrigate over 117,700 acres (SRWG 2012). Some of the largest irrigation entities utilizing the Sun River include the Greenfields Irrigation District (GID), Fort Shaw Irrigation District (FSID), and the Broken O Ranch (SRWG 2012). Stakeholder cooperatives such as the Sun River Watershed Group and the Cascade Country Conservation District have helped improve the water quality and in-stream availability of the Sun River over the past 25 years. However, fish populations in the Sun River below Gibson Reservoir remain suppressed and high water temperatures and low flows are a concern throughout the mainstem.

Methods

To evaluate changes in temperature in the Sun River drainage, 17 HOBO (Onset Computer Corp.) temperature loggers were deployed 9 May 2015 to 9 October 2015 by local students (Table 2). Data loggers were installed above and below major water diversions and throughout the longitudinal reach of the Sun River from Upper Willow Creek to the town of Vaughn (Figure 1). Twelve temperature loggers were placed in the mainstem of the Sun River and 5 were placed in tributaries or irrigation returns to the Sun River.

Loggers recorded a temperature reading every 30 minutes. Data were downloaded with the HOBOware software and analyzed in Microsoft Excel. Outliers due to loggers that became exposed to air were removed from the dataset. Water temperatures were compared to the 73°F threshold where Montana Fish, Wildlife & Parks may request closures if maximum water temperatures reach or exceed this threshold for at least some period of time during three consecutive days. Water temperatures were also compared to the 77°F threshold where temperatures above which may become lethal. This corresponds to the short-term upper incipient lethal temperature for brown trout, the lower of the two trout species. The short-term upper incipient lethal temperature is defined as the maximum temperature attainable by acclimation at which 50% of the test subjects survive in a laboratory setting for at least 7 days (Selong et al. 2001, Ritter and Zale 2015).

Results

Temperature patterns across locations were relatively similar. The hottest daily average temperature occurred between the end of June and the beginning of July (68-76°F) (Figure 2 and 3). Daily (24 hours) average temperature did not exceed 77°F at any of the sites from 1 June to 1 September 2015. However, in the lower section of the river (from the Simms logger and downstream), daily average temperatures regularly exceeded 73°F for several days from the end of June to 4 July 2015 (Figure 3). Daily average temperatures within the mainstem of the Sun

River at Simms, Upper Rocky Reef, and Sun River all were >73°F for at least 4 continuous days (Table 3, Figure 3). Four of the 5 temperature loggers in the tributaries recorded daily average temperatures >73°F for at least 2 continuous days (Table 3, Figure 2). The highest daily average temperatures were observed at the Upper Rocky Reef, Big Coulee, and Sun River sites. The Upper Rocky Reef site had 8 continuous days with average daily temperatures >73°F.

All five tributaries or ditches recorded maximum temperatures over 80°F and daily maximum temperatures >77°F for at least 4 days from 1 June to 1 September, except the ditch located on Cemetery Road (Table 4). In the tributaries, the hottest maximum daily temperatures were recorded from 5 June to 9 June and then again from 25 June to 3 July (Figure 4). Daily maximum temperatures in Big Coulee and Adobe Creek remained above 73°F for much of the summer season (Figure 4). The Cemetery Road site had consistently stable and low to moderate water temperatures (43-73°F). This irrigation water flowed out of a large holding pond likely contributing to the stable water temperatures. Water temperatures within all streams significantly decreased toward the middle of August with lows occurring at the beginning of October.

Daily maximum temperatures regularly exceeded 77°F from 1 June to 1 September 2015 (Table 4). Twelve of the 17 sites recorded at least 2 continuous days with daily maximum temperatures >77°F. Five of these sites had at least 5 continuous days with temperatures over 77°F (Table 4). In the mainstem of the Sun River, the hottest temperatures were observed at Simms, Upper Rocky Reef, and Sun River. These 3 sites and the lower FSID site recorded at least 9 days with daily maximum temperatures >77°F from 1 June to 1 September 2015. The maximum temperature did not exceed 77°F at the Upper Willow, Lower Willow, Parker, and Vaughn mainstem sites. In the Sun River, the hottest daily maximum temperatures were observed 25 June to 3 July (Figure 5). However, many locations remained above 73°F for much of the summer (Figure 5). Daily maximum temperatures exceeded 73°F for at least three consecutive days at all Sun River sites except Lower Willow (Table 4). Daily maximum temperatures exceeded 73°F for at least 10 consecutive days at Lower FSID, Simms, Upper Rocky, and Sun River.

Daily maximum temperatures were colder at Lower Willow compared to Upper Willow and at Lower Rocky Reef compared to Upper Rocky Reef (Table 4). For example, Upper Rocky Reef had 10 continuous days with maximum daily temperatures >77°F while Lower Rocky Reef had 2 continuous days. Similarly, Upper Willow had 8 days with maximum temperatures >73°F while Lower Willow had 3 days (Table 4). Lower FSID was slightly warmer than Upper FSID, based on more average daily temperatures >73°F, and more maximum daily temperatures >73°F and >77°F at the lower site than upper site (Table 3 and 4).

Discussion

Compared to previous years, 2015 was a slightly warmer year (Figure 6) with an average daily maximum air temperature of 84°F compared to 82°F and 81°F in 2013 and 2014, respectively. In Montana, time of day angling restrictions may be implemented when water temperatures exceed 73°F for 3 consecutive days with weather forecasts unchanging. While water temperatures exceeded 73°F at the USGS gage at Simms on several occasions in 2015, time of day angling restrictions were not implemented due to forecasted cooling trends.

Along with instream temperature, instream flows of the Sun River are monitored below Willow Creek at Highway 287 and at Simms by USGS gages 06082200 and 060685800, respectively. The recommended minimum instream flow is 100 cfs at Highway 287 and 130 cfs at Simms. These minimum instream flows are based on Montana Fish, Wildlife and Parks instream water reservations to benefit the fishery of 100 cfs from Diversion Dam to Elk Creek and 130 cfs from Elk Creek to Vaughn with a priority date of 7/1/1985 (Missouri River Basin, Final Order Water Reservations 1992). The water reservations were based on wetted perimeter studies that evaluated the amount of water necessary to maintain fishery values and thus serve as minimum flow targets. In 2015, the minimum instream flow of 100 cfs at Highway 287 was met until September 18th when it dropped below this level through April 14, 2016 (except for 3 days) (Figure 7). Flows were less than 60 cfs for an extended period during the 2015-2016 winter at the USGS gage near Augusta and were estimated as low as 29 cfs during this time. At the Simms gage in 2015, the flows were less than 130 cfs most days from May 2nd through May 16th, June 17th through September 3rd, and December 10th through December 31st (Figures 7 and 8).

The period of low flow observed after peak spring flows correspond with the highest daily maximum temperatures observed (Figure 8). In 2015, the peak annual flow of the Sun River at the USGS Simms gage was in the 40th percentile (14 out of 35 years of record) (Figure 9) and the mean annual flow was in the 43rd percentile (12 out of 28 years of record) (Figure 10). These data indicate that despite a near normal flow year in 2015, minimum flow targets were frequently not met, which contribute to stressful conditions for trout along with the high water temperatures.

Water temperatures capable of negatively impacting brown and rainbow trout health (>73°F and >77°F) were recorded often in the lower section of the Sun River from the Fort Shaw Irrigation District diversion and downstream. With several mainstem sites exceeding 73°F or even 77°F regularly, brown trout and rainbow trout residence or movement through the lower portion of the Sun River may be inhibited by this temperature barrier. This section of the Sun River is the most heavily dewatered portion, due to irrigation requirements in this reach and upstream. Although 2015 was slightly warmer than some recent years, the peak and mean annual flows were in the 40th and 43rd percentile compared to the period of record, indicating a near normal flow year. While some gains have been made in recent years in reducing water loss by upgrades to irrigation infrastructure to improve water conveyance efficiency, and thereby improving flows in the Sun River, continued efforts to maintain and improve flows in the mainstem Sun River are necessary to provide suitable habitat to maintain a healthy fishery.

Acknowledgements
We thank Simms High School and the geology students from Great Falls College Montana State University for deploying, maintaining, and downloading temperature loggers throughout the Sun River drainage.

Table 1. Temperature limits for rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) compiled from Jobling (1981) and Ritter and Zale (2015).

Species	Short-term UILT (°F)	Long-term UILT (°F)	Upper growth limit (°F)	References
Salmo trutta	76.5 (7 days)			Elliott et al. 1981
			67.1	Elliott et al. 1995
		73.4		Bishai 1960
		79.5		Alabaster & Downing 1966
O. mykiss	78.8 (7 days)	75.7 (60 days)	75.2	Bear et al. 2007
		79.7		Alabaster & Welcomme 1962
		78.8		Bidgood & Berst 1969
		79.3		Charlon et al. 1970
		77		Hokanson et al. 1977

Table 2. Daily (24 hour) maximum and minimum water temperature recorded by 17 HOBO data loggers throughout the Sun River drainage, Montana from 1 June to 1 September 2015. The data are organized from highest in the drainage (Upper Willow) to the most downstream logger (Vaughn) with mainstem sites listed first and then tributary and irrigation ditches.

Site name	Latitude	Longitude	Location description
Upper Willow	47.5613	-112.4054	Mainstem of Sun River upstream of Willow Creek return canal and Floweree diversion
Lower Willow	47.5583	-112.4072	Mainstem of Sun River downstream of Willow Creek return canal and Floweree diversion
Upper FSID	47.5119	-112.0730	Mainstem of Sun River upstream of Fort Shaw Irrigation diversion
Lower FSID	47.5122	-112.0720	Mainstem of Sun River downstream of Fort Shaw Irrigation diversion
Lowry Bridge	47.5127	-112.0091	Mainstem of Sun River near Lowry Bridge upstream of Simms
Simms	47.5021	-111.9326	Mainstem of Sun River located near the town of Simms
Upper Rocky	47.5183	-111.8586	Mainstem of Sun River upstream of the Rocky Reef Canal
Lower Rocky	47.5172	-111.8572	Mainstem of Sun River downstream of Rocky Reef Canal
Fort Shaw	47.5124	-111.8205	Mainstem of Sun River located near the town of Fort Shaw
Parker	47.5287	-111.7772	Mainstem of Sun River downstream of Fort Shaw
Sun River	47.5341	-111.7251	Mainstem of Sun River located near the town of Sun River
Vaughn	47.5467	-111.5305	Mainstem of Sun River located near the town of Vaughn
Simms Creek	47.4949	-111.9612	Tributary upstream of the town of Simms
Big Coulee	47.5168	-111.8876	Tributary upstream of Fort Shaw
Cemetery	47.5054	-111.8444	Irrigation ditch located near Fort Shaw Cemetery
Adobe Creek	47.5100	-111.8013	Tributary downstream of Fort Shaw
Kditch	47.5203	-111.7459	Irrigation ditch near Highway 200

Table 3. Daily average (24 hours) water temperature recorded by 17 HOBO data loggers throughout the Sun River drainage, Montana from 1 June to 1 September 2015. The data are organized from highest in the drainage (Upper Willow) to the most downstream logger (Vaughn) with mainstem sites listed first and then tributary and irrigation ditches.

	Type of Stream	Max Avg Temp	Min Avg Temp	# days avg temp >73 °F	Longest span of continuous days avg temp >73 °F	Longest span of continuous days avg temp >77 °F	Longest span of continuous days avg temp >77 °F
Upper Willow	Mainstem	71.9	56.0	0	0	0	0
Lower Willow	Mainstem	68.6	56.9	0	0	0	0
Upper FSID	Mainstem	72.6	58.2	0	0	0	0
Lower FSID	Mainstem	73.5	51.9	2	1	0	0
Lowry Bridge	Mainstem	73.9	58.7	1	1	0	0
Simms	Mainstem	74.7	52.8	7	4	0	0
Upper Rocky	Mainstem	75.6	53.4	8	8	0	0
Lower Rocky	Mainstem	75.3	59.1	1	1	0	0
Fort Shaw	Mainstem	73.6	53.8	3	2	0	0
Parker	Mainstem	71.6	57.7	0	0	0	0
Sun River	Mainstem	74.4	59.7	7	4	0	0
Vaughn	Mainstem	74.9	60.3	1	1	0	0
Simms Creek	Tributary	74.1	56.7	3	2	0	0
Big Coulee	Tributary	75.9	57.9	6	6	0	0
Cemetery	Ditch	69.3	57.5	0	0	0	0
Adobe	Tributary	73.7	53.7	4	3	0	0
Kditch	Ditch	75.5	51.9	3	3	0	0

Table 4. Daily (24 hour) maximum and minimum water temperature recorded by 17 HOBO data loggers throughout the Sun River drainage, Montana from 1 June to 1 September 2015. The data are organized from highest in the drainage (Upper Willow) to the most downstream logger (Vaughn) with mainstem sites listed first and then tributary and irrigation ditches.

	Type of Stream	Max Temp	Min Temp	# days max >73 °F	Longest span of continuous days max temp >73 °F	# days max >77 °F	Longest span of continuous days max temp >77 °F
Upper Willow	Mainstem	75.9	60.6	8	5	0	0
Lower Willow	Mainstem	73.5	61.8	3	1	0	0
Upper FSID	Mainstem	80.2	63.5	22	5	7	3
Lower FSID	Mainstem	79.5	54.1	30	10	10	3
Lowry Bridge	Mainstem	79.7	63.7	28	6	7	4
Simms	Mainstem	80.2	54.8	29	11	9	5
Upper Rocky	Mainstem	82.5	55	35	12	13	10
Lower Rocky	Mainstem	77.6	63.8	25	6	3	2
Fort Shaw	Mainstem	79.5	55.3	28	9	8	5
Parker	Mainstem	74.8	62.9	7	5	0	0
Sun River	Mainstem	86.6	55.5	27	10	9	4
Vaughn	Mainstem	76.8	61.6	5	5	0	0
Simms Creek	Tributary	78.3	59.0	17	11	4	2
Big Coulee	Tributary	83.5	60.8	42	11	15	7
Cemetery	Ditch	73.1	59.8	1	1	0	0
Adobe Creek	Tributary	80.6	55.9	30	10	10	4
Kditch	Ditch	82.1	62.4	30	11	15	10

Table 5. Maximum, mean, and minimum air temperature for 2013-2016 at the Great Falls, Montana weather station. Data provided by Weather Underground Inc.

Year	Temp	Maximum	Average	Minimum
2013	Max Temp	101	59	-10
	Mean Temp	82	46	-21
	Min Temp	65	33	-33
2014	Max Temp	95	56	-9
	Mean Temp	81	44	-18
	Min Temp	68	32	-34
2015	Max Temp	100	60	1
	Mean Temp	84	47	-4
	Min Temp	68	34	-18
2016	Max Temp	97	59	0
	Mean Temp	77	47	-13
	Min Temp	61	34	-26

Figures

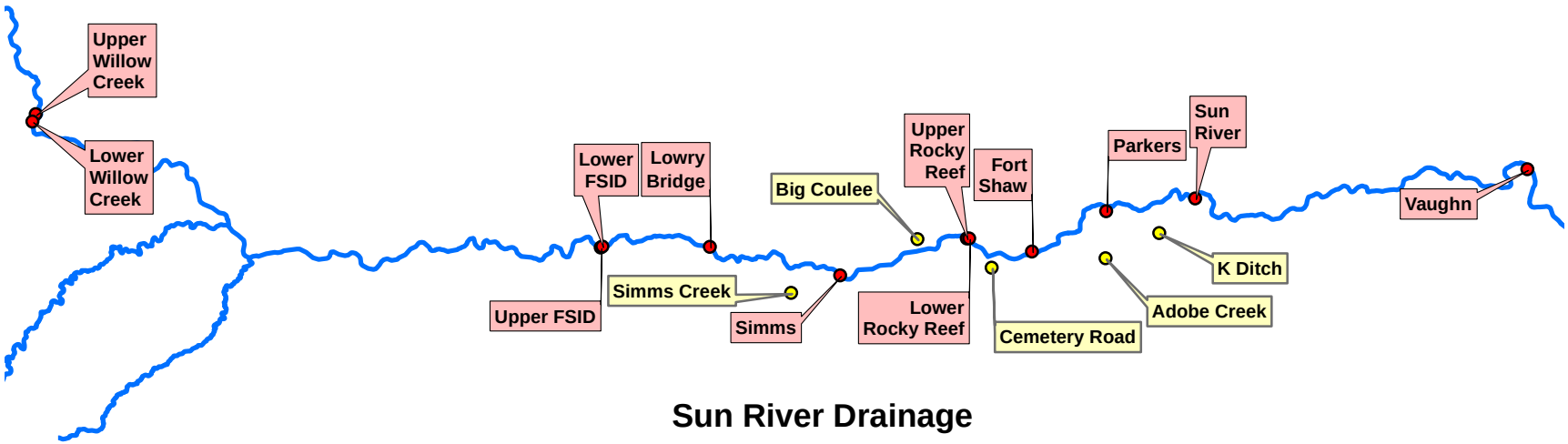

Figure 1. Locations of the HOBO data loggers (Onset Computer Corp.) in the Sun River drainage in 2015. Data loggers within the mainstem of the Sun River are labeled red and data loggers in tributaries or ditches are labeled yellow.

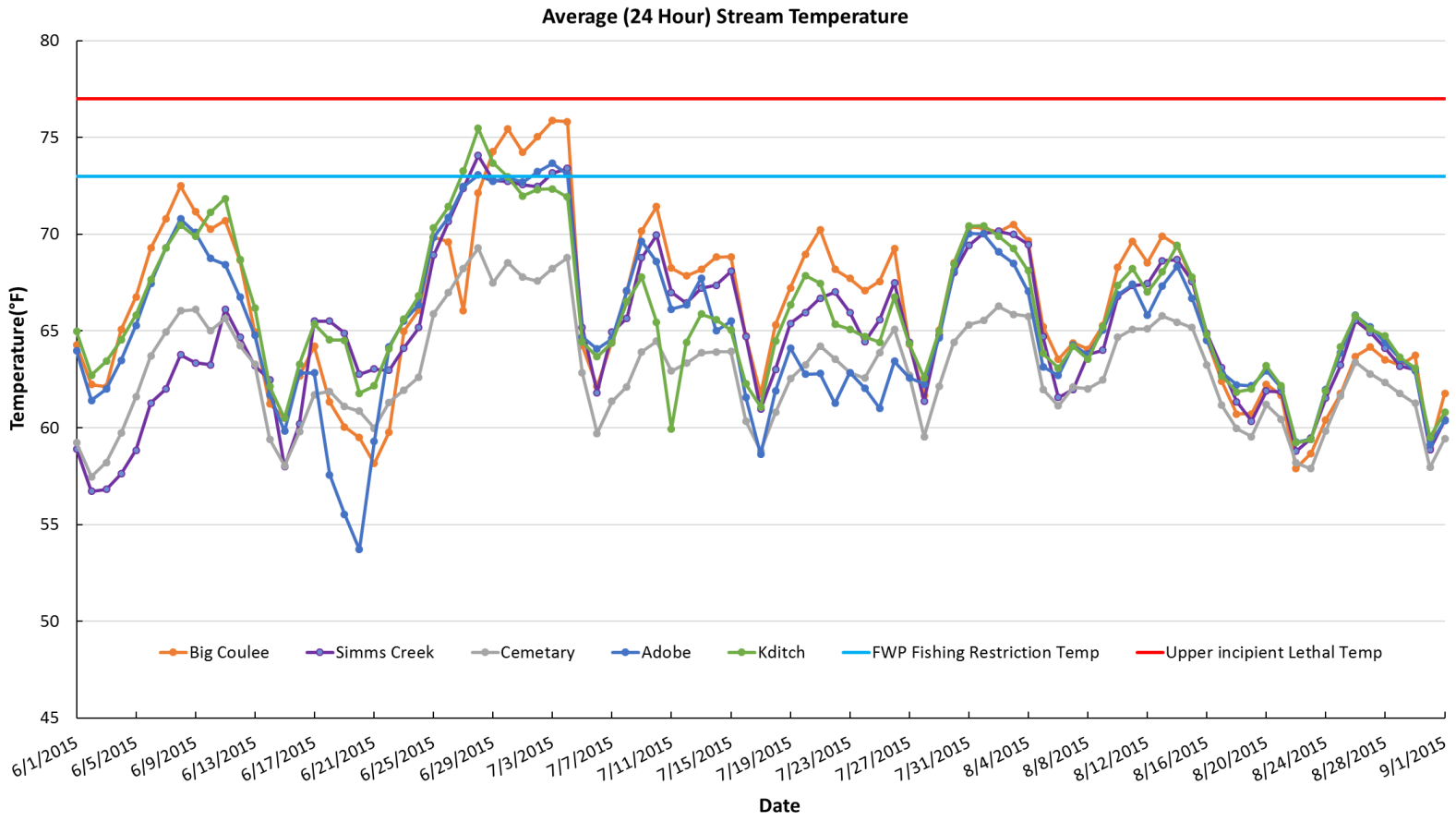

Figure 2. Average daily (24 hour) stream temperature (°F) for five tributaries or ditches to the Sun River, Montana from 1 June to 1 September 2015. Data are organized from highest (Upper Willow) to lowest (Vaughn) in the drainage (left to right within the legend).

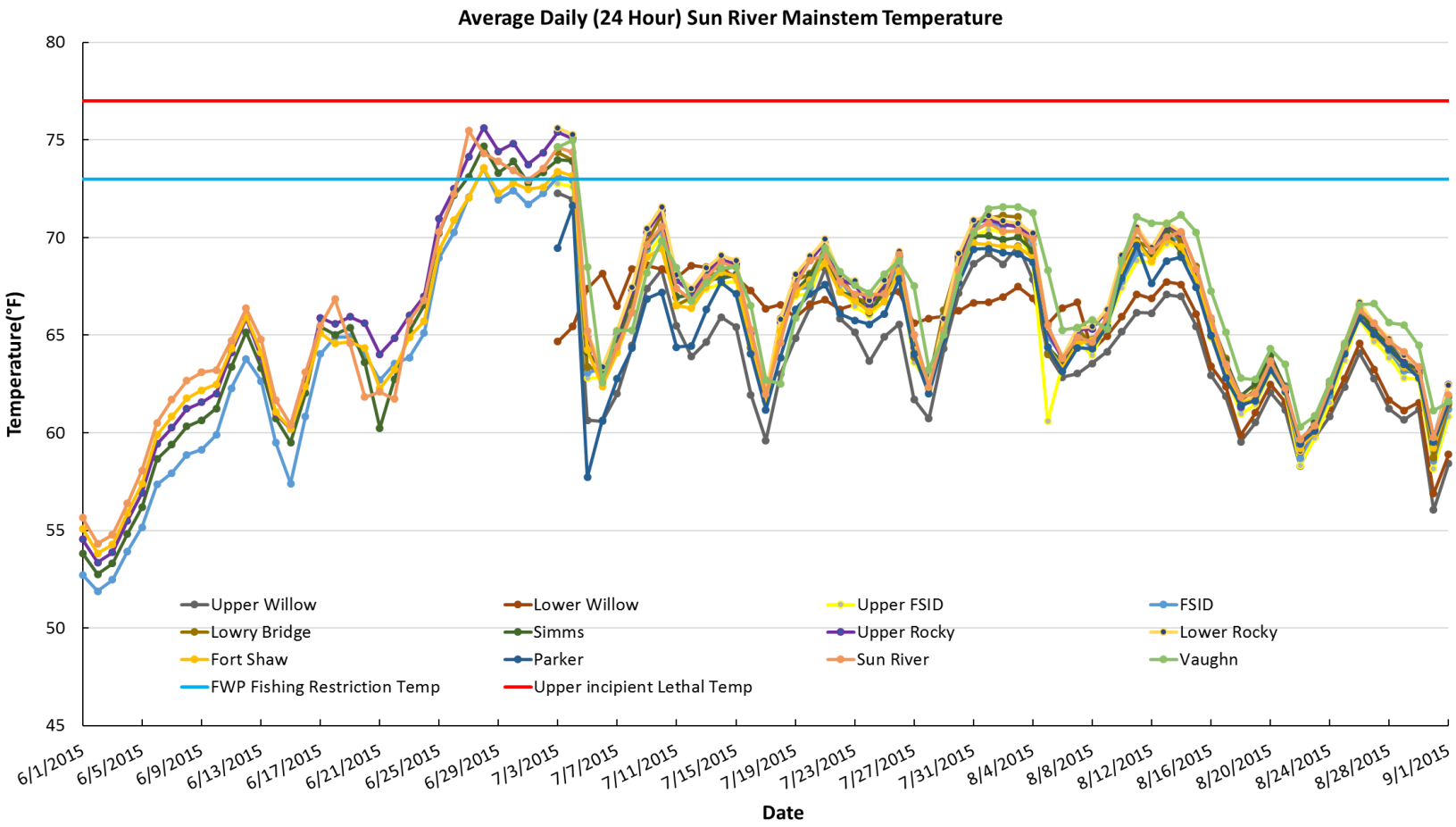

Figure 3. Average daily (24 hour) stream temperature (°F) at 12 locations within the Sun River, Montana from 1 June to 1 September 2015. Data are organized from highest (Upper Willow) to lowest (Vaughn) in the drainage (left to right within the legend).

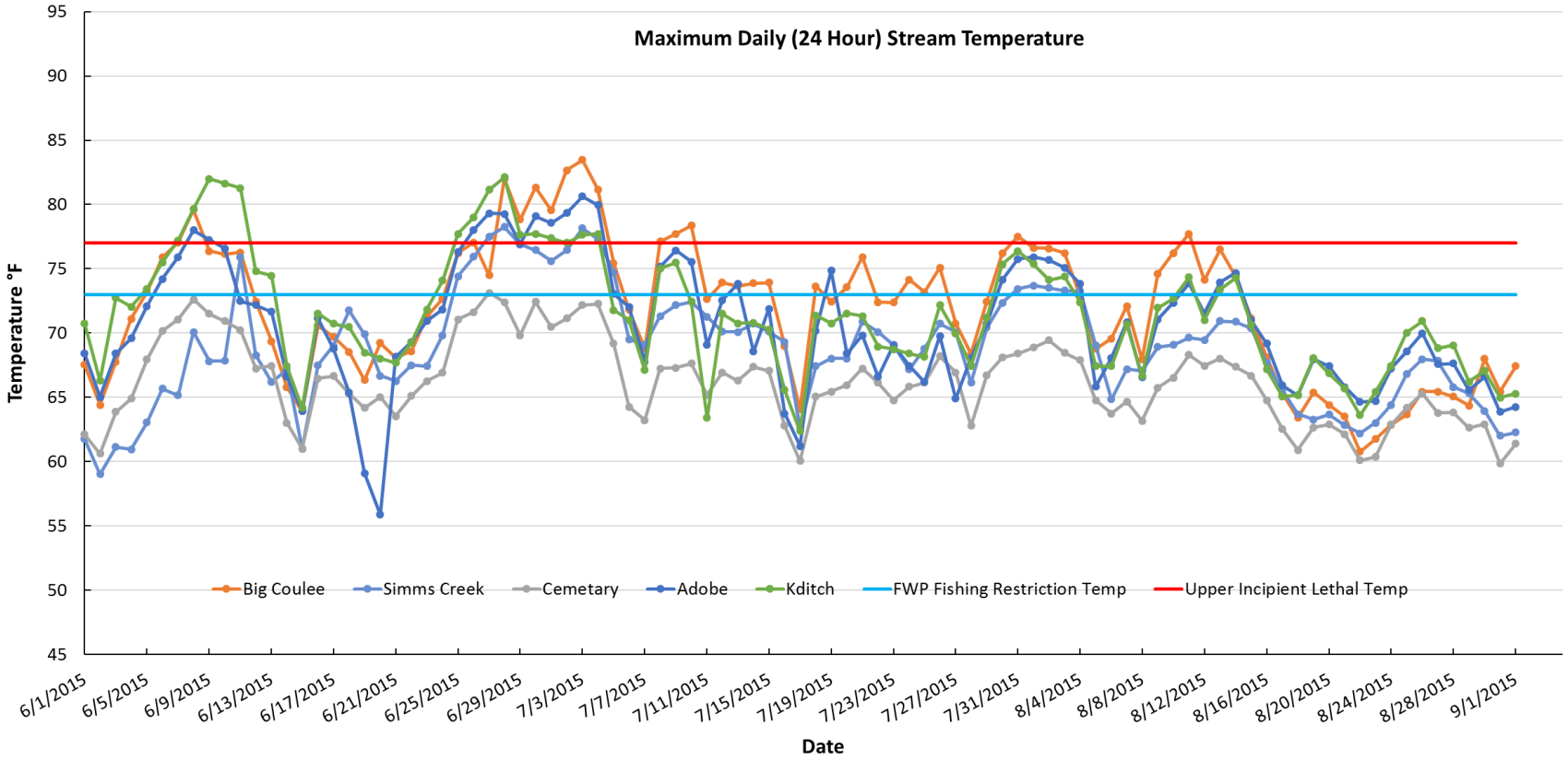

Figure 4. Maximum daily (24 hour) stream temperature (°F) for five tributaries or ditches to the Sun River, Montana from 1 June to 1 September 2015. Data are organized from highest (Upper Willow) to lowest (Vaughn) in the drainage (left to right within the legend).

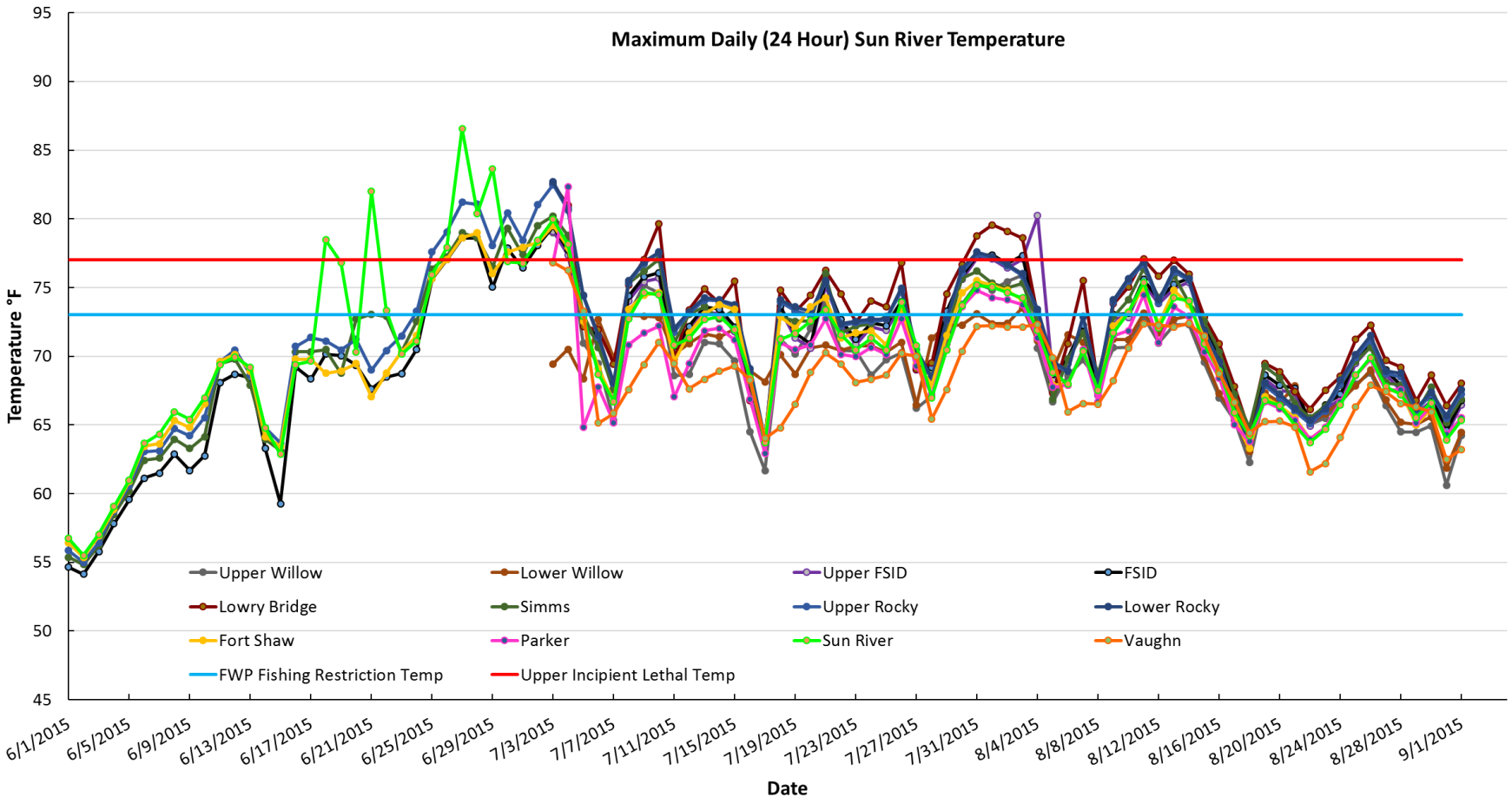

Figure 5. Maximum daily (24 hour) stream temperature (°F) at 12 locations within the Sun River, Montana from 1 June to 1 September 2015. Data are organized from highest (Upper Willow) to lowest (Vaughn) in the drainage (left to right within the legend).

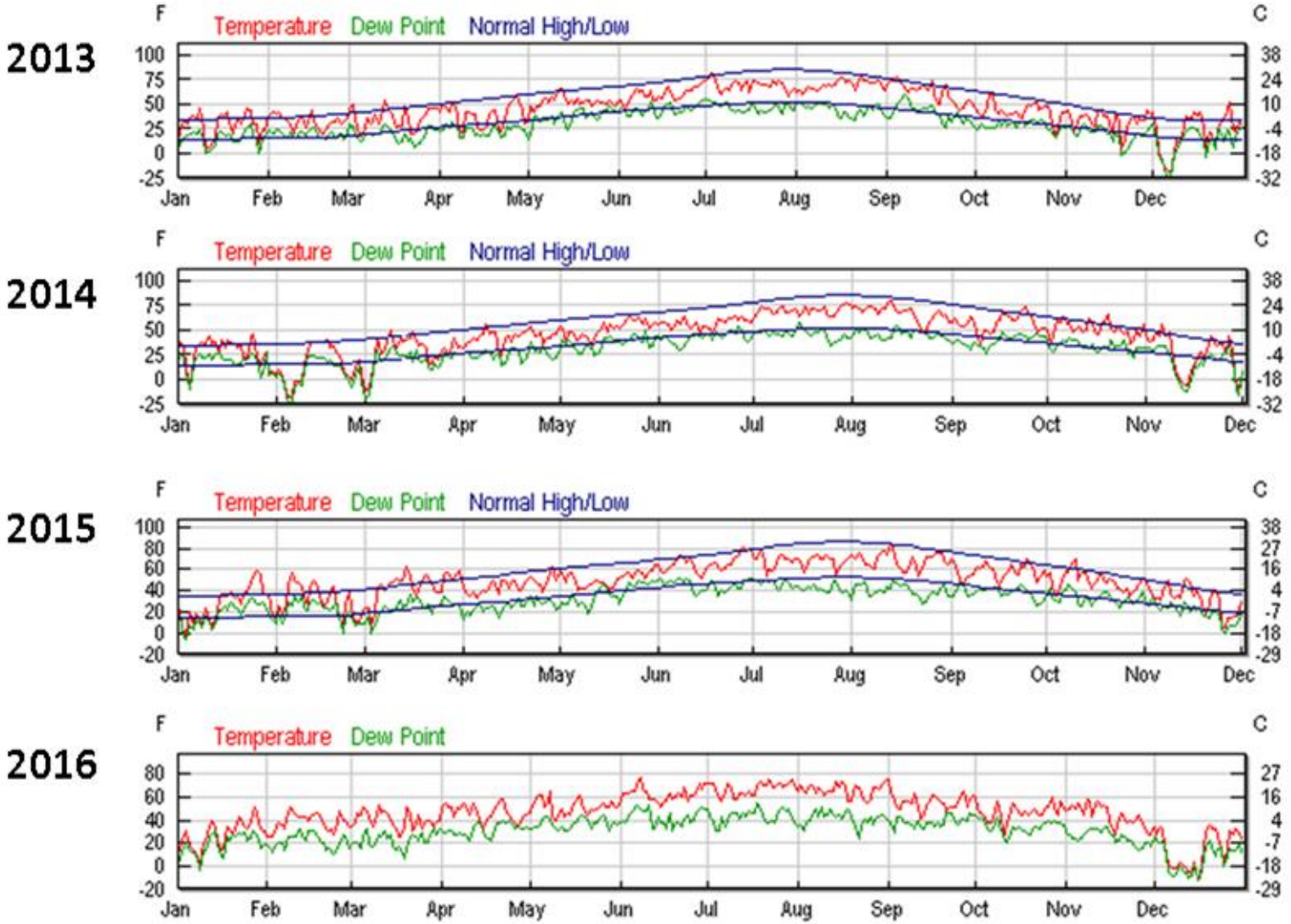

Figure 6. Average air temperature (°F) for 2013-2016 at the Great Falls, Montana weather station. Data provided by Weather Underground Inc. (2009).

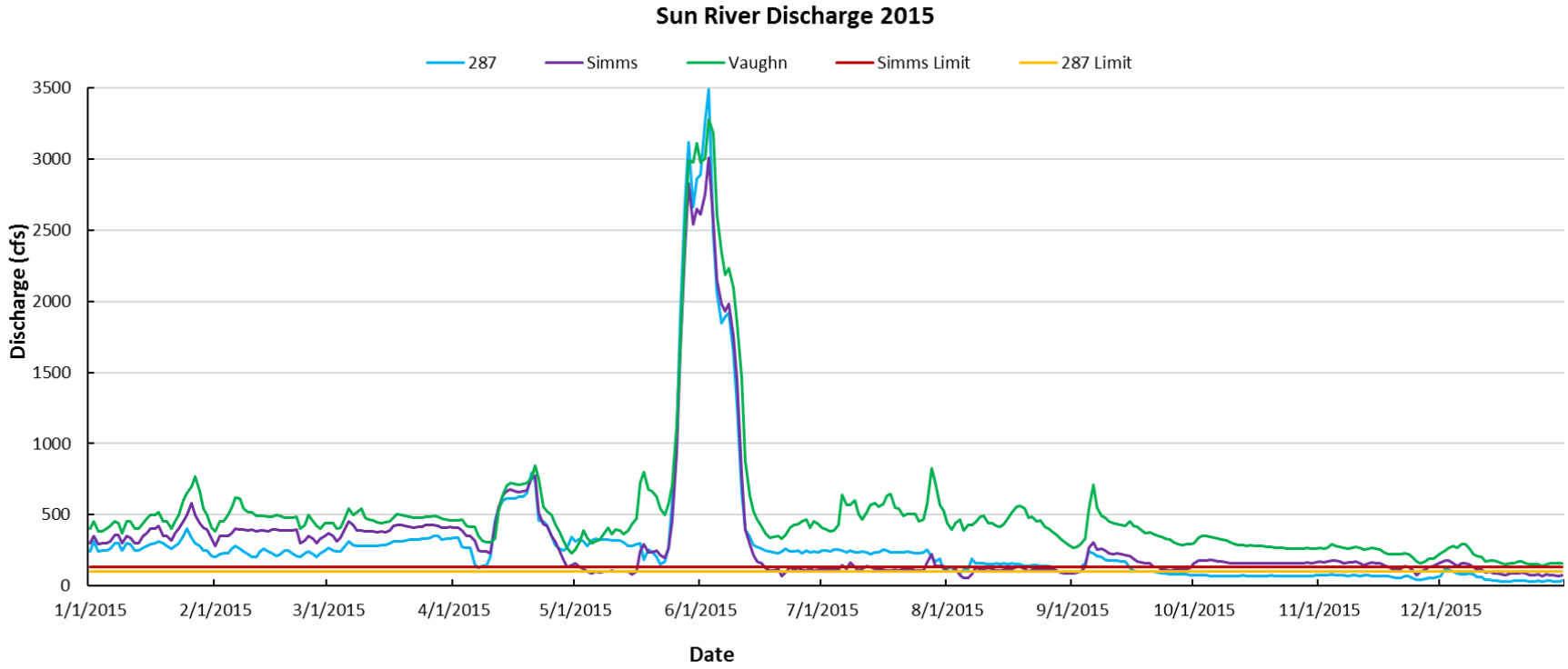

Figure 7. Average discharge (cfs) of the Sun River at the below Willow Creek, Simms, and Vaughn USGS gage sites in 2015. The recommended minimum instream flows for the below Willow Creek site (100 cfs) and the Simms site (130 cfs) are labeled in yellow and red, respectively.

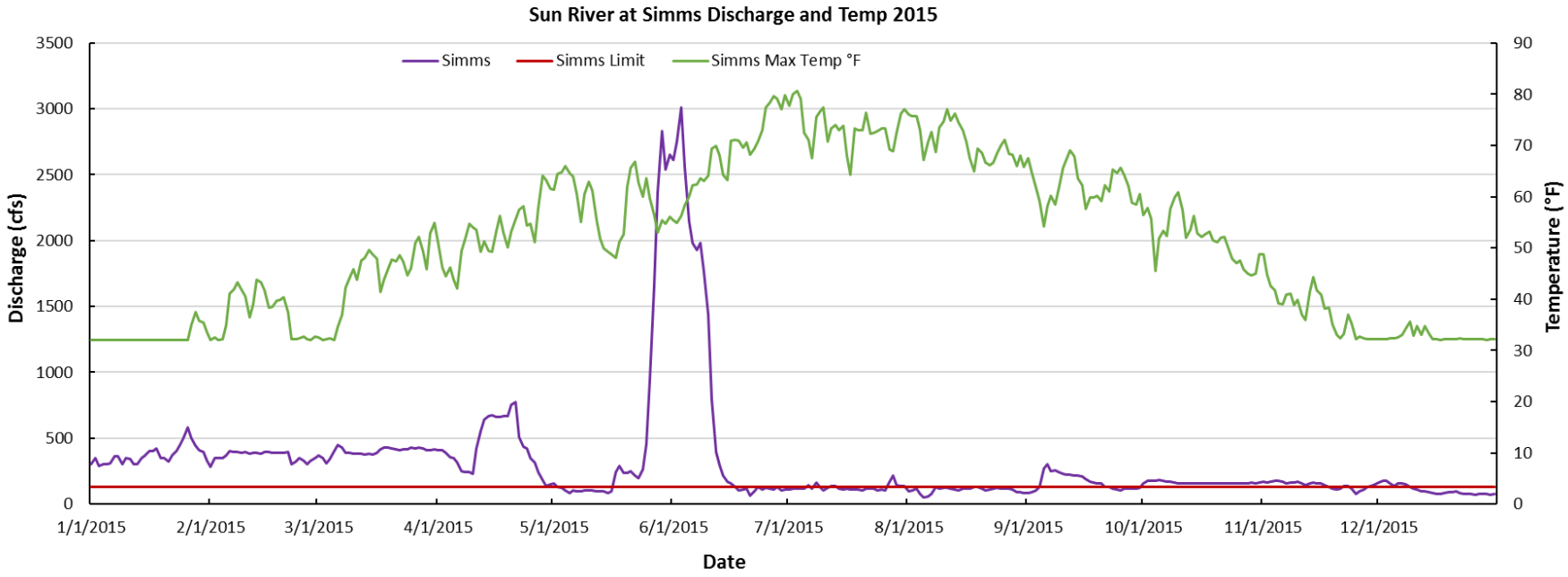

Figure 8. Daily maximum temperature (°F) and average discharge (cfs) of the Sun River at Simms USGS gage site (060685800) in 2015. The recommended minimum instream flows for the Simms USGS gage site is in red.

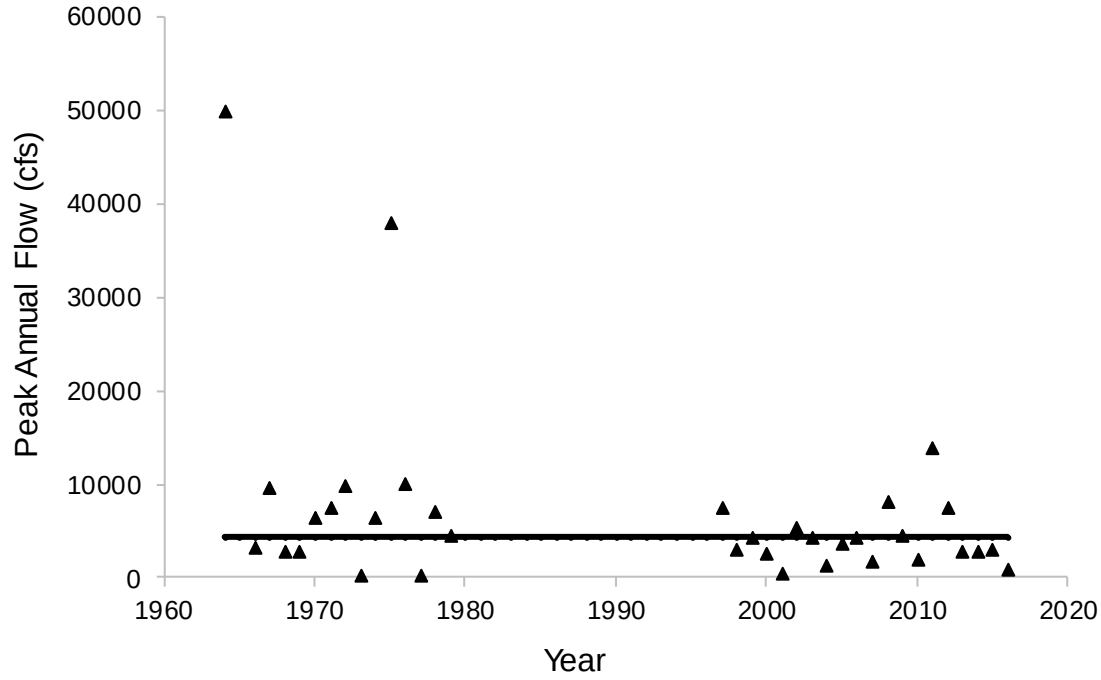

Figure 9. Peak annual flow for the Sun River at Simms (triangles) at USGS gaging station 06085800 and the median peak annual flow for the period of record (solid line), 1964-2016.

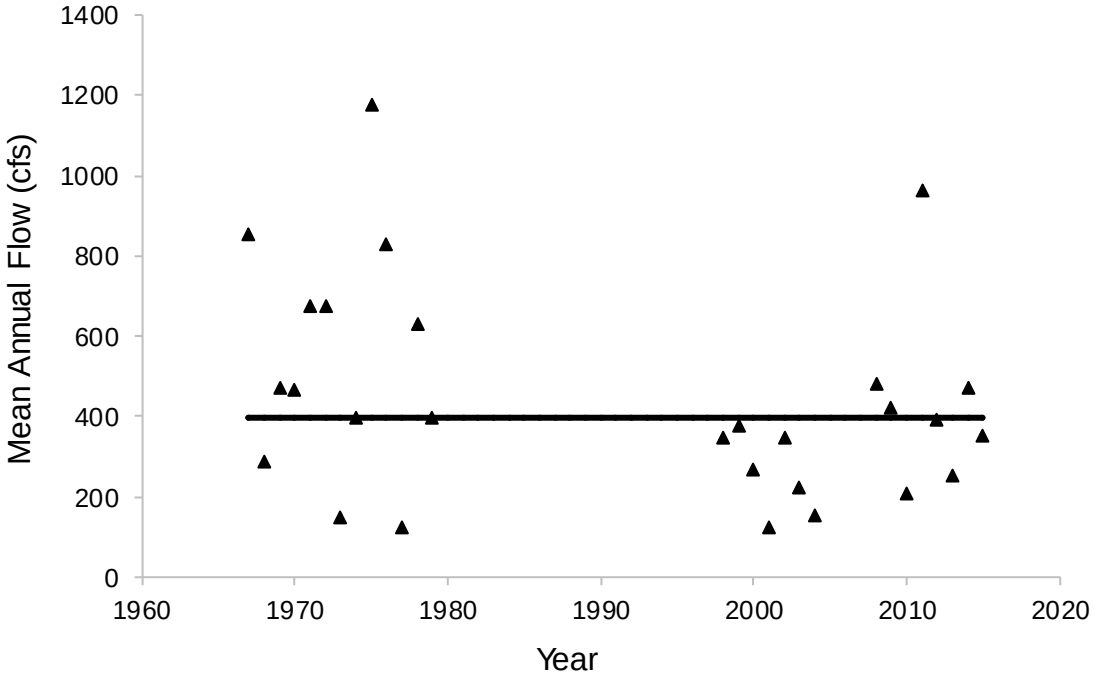

Figure 10. Mean annual flow for the Sun River at Simms (triangles) at USGS gaging station 06085800 and the median mean annual flow for the period of record (solid line), 1967-2015.

Literature Cited

Alabaster, J.S. and A.L. Downing. 1966. A field and laboratory investigation of the effect of heated effluents on fish.

Alabaster, J.S. and R.L. Welcomme. 1962. Effect of concentration of dissolved oxygen on survival of trout and roach in lethal temperatures. Nature 194:107–107.

Armour, C. L. 1990. Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish and Wildlife Service, Biological Report 90(22), Fort Collins, Colorado.

Bear, E.A., T.E. McMahon, and A.V. Zale. 2007. Comparative thermal requirements of westslope cutthroat trout and rainbow trout: implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society. 136:1113–1121.

Bidgood, B.F. and A.H. Berst. 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of the Fisheries Board of Canada 26:456–459.

Bishai, H.M. 1960. Upper lethal temperatures for larval salmonids. Journal du Conseil 25:129–133.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan, editor. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. 19:- Bethesda, M.D.

Charlon, N., B. Barbier, and C. Bonnet. 1970. Résistance de la truite arc-en-ciel (Salmo gairdneri Richardson) a des variations brusques de température. Annuals of Hydrobiology 1:7–89.

Elliott, J.M. 1981. Some aspects of thermal stress on freshwater teleosts. Stress and fish. Academic Press, New York.

Elliott, J.M. and J.A. Elliott. 1995. The effect of the rate of temperature increase on the critical thermal maximum for parr of Atlantic salmon and brown trout. Journal of Fish Biology 47:917–919.

Hokanson, K.E.F., C.F. Kleiner, and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 34:639–648.

Jobling, M. 1981. Temperature tolerance and the final preferendum-rapid methods for the assessment of optimum growth temperatures. Journal of Fish Biology 19:439–455.

Mathews, K.R. and N.H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. Journal of Fish Biology 50:50–67.

Missouri River Basin, Final Order of the Board of Natural Resources and Conservation establishing water reservations above Fort Peck Dam. July 1, 1992.

NOAA National Centers for Environmental Information. 2017. State of the Climate: National Overview for Annual 2016. Accessed 7 March 2017. Available at <http://www.ncdc .noaa.gov/sotc/ national/201613>.

Ritter, T.D. and A.V. Zale. 2015. Salmonid movements and thermal hydrodynamics at a montane river system confluence: thermal refugia in the Smith River basin. Final report to Montana Fish, Wildlife, and Parks. December 2015.

Selong, J.H., T.E. McMahon, A.V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026–1037.

SWRG (Sun River Watershed Group). 2012. Special study report. Great Falls, Montana.

Weather Underground, Inc. 2009. Weather History & Data Archive: Weather Underground. Online. Accessed 7 Mar. 2017. Available at <http://www.wunderground.com/history/>.