Corvallis Watershed Stream Temperature Monitoring
Summer 2016

Addendum to Stream Temperature Monitoring Report for 2015

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Executive Summary

The intensive stream temperature monitoring in the Corvallis Watershed that was begun in 2010 was continued in 2016 to test the consistency of trends and results found in previous years' data. In addition to air and water temperatures, stream flow data was collected to better analyze the heat input into Rock Creek from the reservoir spillway and dam valve channel.

This report is an addendum of previous reports, and summarizes the data and conclusions from the summer of 2016. Results and conclusions for the 2010-2015 are contained in the report written in 2016 following the summer of 2015's data collection. Summer temperatures were, on average, slightly cooler in 2016 than 2015, which had the warmest year on record for Oregon and Washington.

The interesting new factor in 2016 was the increased flows from the dam valve channel, which is fed by the bottom of the reservoir. In the spring and the early summer, the water temperatures at the bottom of the reservoir are significantly cooler than the surface stream temperatures. Over the summer, the bottom of the reservoir gradually heats up, and by late August is usually warmer than the streams. Flows coming out of the bottom of the reservoir due to a leaky dam valve were three to four times the amount as previous years. There was a cooling effect immediately downstream for the first half of the summer below the dam, but as the reservoir heated up, the downstream temperature just below the confluence was warmer than other streams, such as the South Fork Rock Creek above the confluence.

In 2016, as in other years, the effects of the spillway contributions to the downstream water temperatures could not be detected in the mainstem downstream of the Middle Fork of Rock. Two major tributaries to Rock Creek contribute flow between the dam and the confluence of Rock and Greasy Creeks. It is unlikely that the effects of the spillway are having an impact on temperatures at the mouth of Rock Creek.

Regarding the effects of the increased flow from the dam valve channel, flows are higher when reservoir bottom temperatures are lower in the spring and early summer in 2016. The temperature monitoring site directly below the dam in the mainstem (Site 2123) was cooler, but the effect didn't last downstream. As with previous years, the effect of the dam was not detectable downstream of the Middle Fork confluence. In the late summer and early fall, the opposite effect was recorded. The flow out of the dam valve channel is a higher proportion of the mainstem flow as stream flows diminish. However, the reservoir bottom temperatures are higher than the surrounding streams. Therefore, temperatures in the mainstem are higher than would be expected.

Introduction

The City of Corvallis and the Siuslaw National Forest have cooperatively monitored stream temperatures in the Rock Creek Watershed during the summers of 2005, 2006, and 2010 through 2014. Monitoring efforts continued in 2015 and 2016 on a volunteer basis. The ongoing objectives of the stream temperature monitoring in 2015 and 2016 are:

1. To characterize and track trends in the stream temperatures throughout the watershed.

2. To determine if it is possible to detect effects of the reservoir on downstream temperatures.

This report documents the results of the 2016 monitoring, and compares the 2016 data to previous years' monitoring data. To address the question of the reservoir's effects in more detail, streamflow data was gathered from channels around the base of the dam in 2013 through 2016 at the location of stream temperature monitoring sites.

In addition to the stream temperatures, air temperature was monitored at the same site as previous years to compare air and water temperatures and to see what the air temperature trend is between years. The air temperature station is in the riparian zone near the South Fork Rock Creek intake weir. The air temperatures in 2016 were slightly cooler than in 2015, as were stream temperatures.

Figures 1 through 7 show the location of the stream temperature monitoring sites.

Results of the stream temperature monitoring efforts are summarized in Table 1, which shows the 7-day average maximum temperatures for the monitoring sites by year. In general stream temperatures throughout the watershed were cooler in 2016 than in 2015.

Table 2 shows more detailed data summaries for the sites that exceeded the state standard of 64°F for the 7-day average maximum temperature in 2012 through 2016. In 2015, the 7-day average maximum temperatures in the Rock Creek mainstem were one to two degrees warmer than in 2014, and the number of days that stream temperatures were above 64°F increased. Temperatures in 2016 were cooler than in 2015, and the number of days stream temperatures were above 64F were approximately half of the days in 2015. The effects were more noticeable in the sites farthest downstream from the North and South Fork Rock Creek confluence.

Graphs of the daily minimum and maximum temperatures for the individual sites are included in Appendix A.

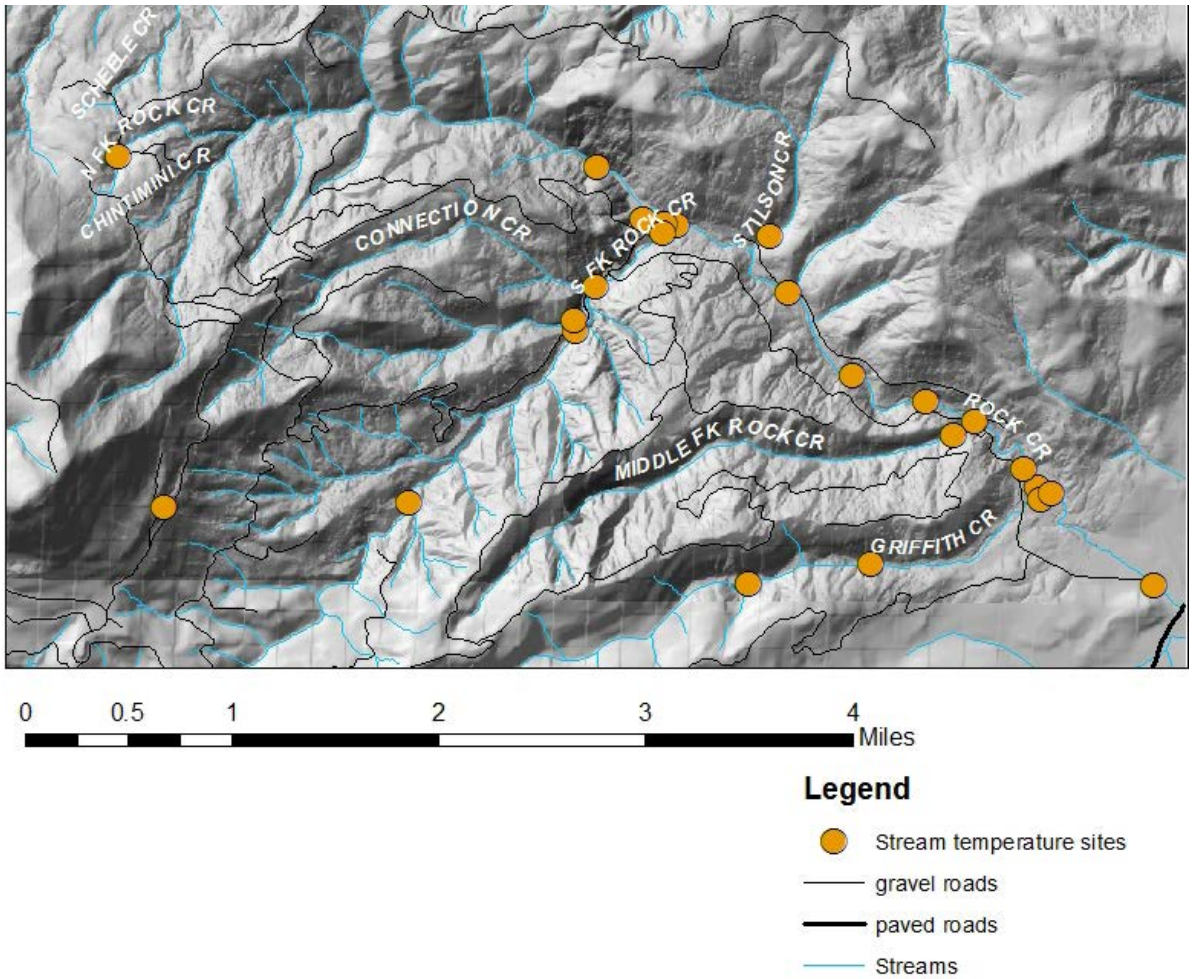


Figure 1. Overview map of stream temperature monitoring sites in the Corvallis (Rock Creek) Watershed.

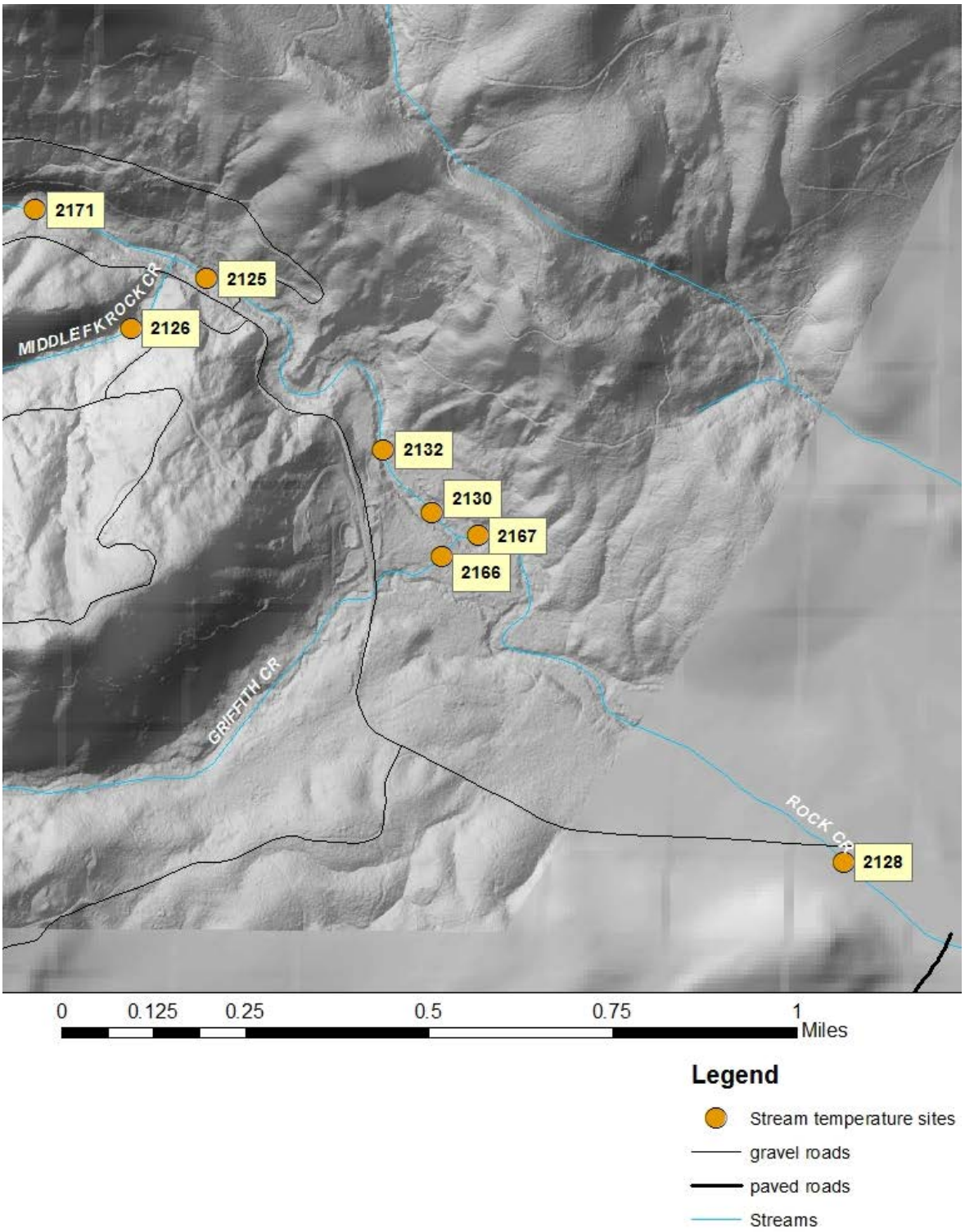


Figure 2. Stream temperature monitoring sites with site numbers, lower reaches of Rock Creek.

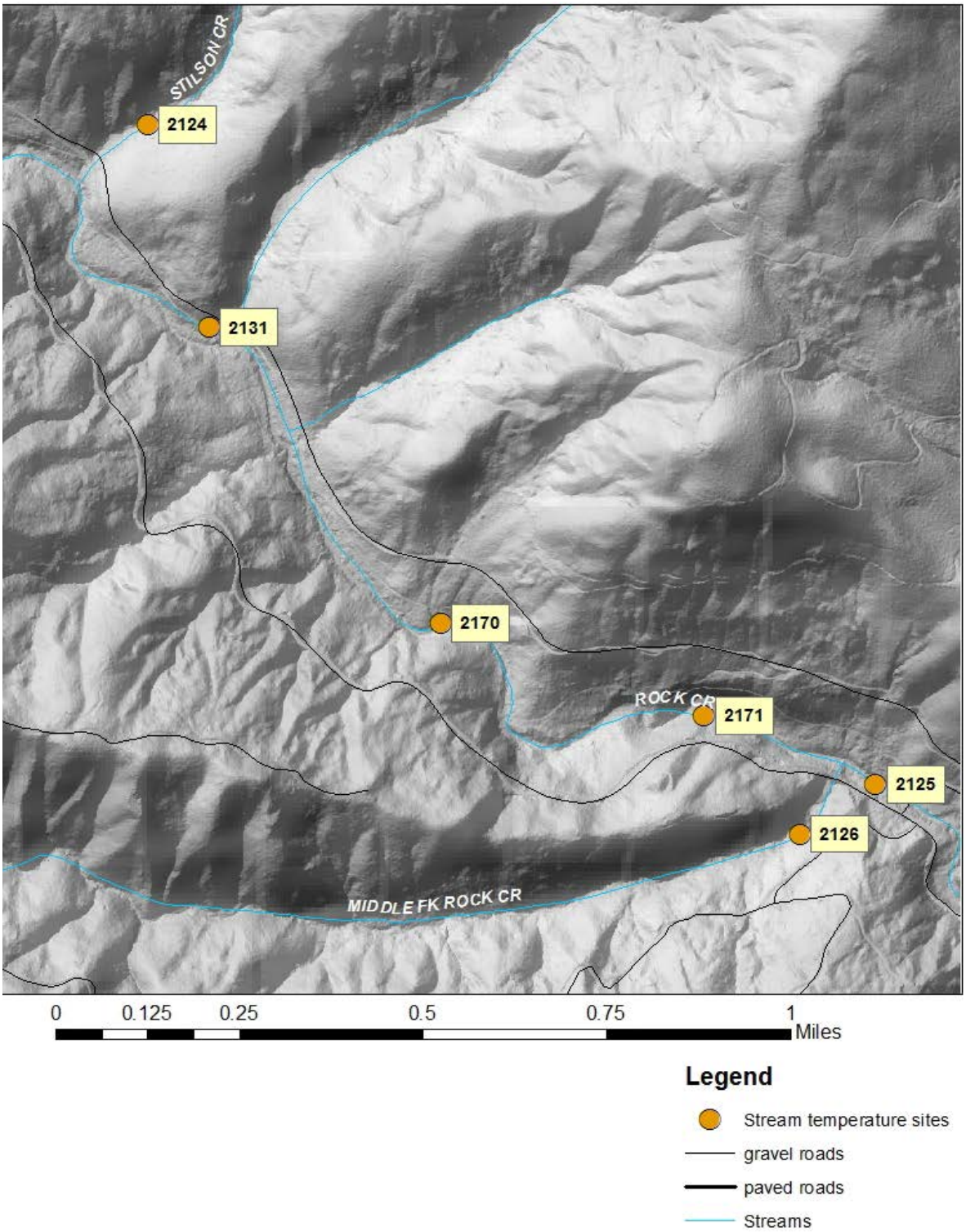


Figure 3. Stream temperature monitoring sites in Rock Creek between Middle Fork Rock Creek and Stilson Creek. (Site 2171 was not deployed in 2016).

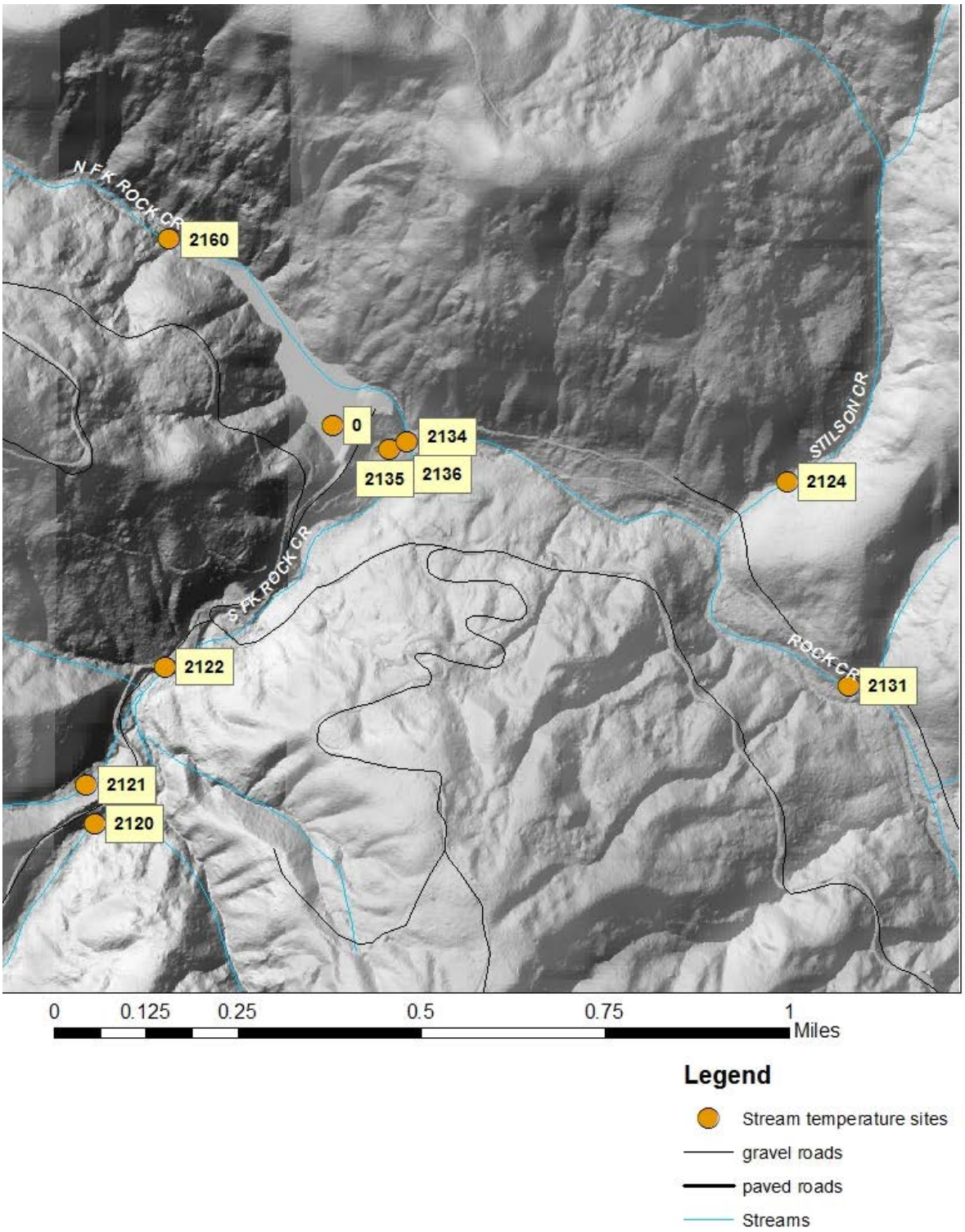


Figure 4. Stream temperature monitoring sites in lower reaches of South Fork Rock Creek and around reservoir. The site labelled "0" is the location of the probes at different depths in the reservoir.

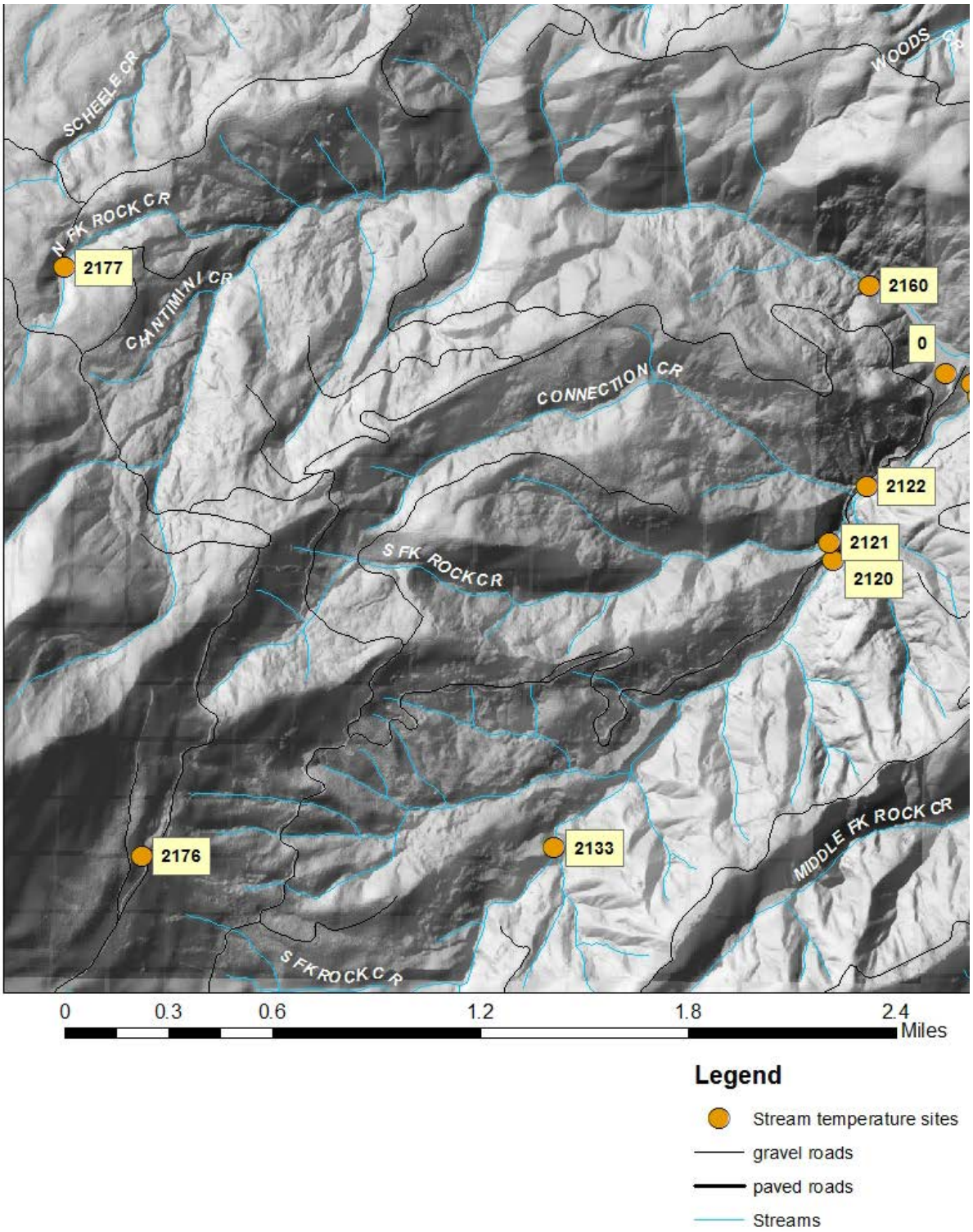


Figure 5. Stream temperature monitoring sites in the headwater springs of North Fork and South Fork Rock Creek. The sites around the reservoir are on the right side of map. (Site 2177 and 2133 were not deployed in 2016).

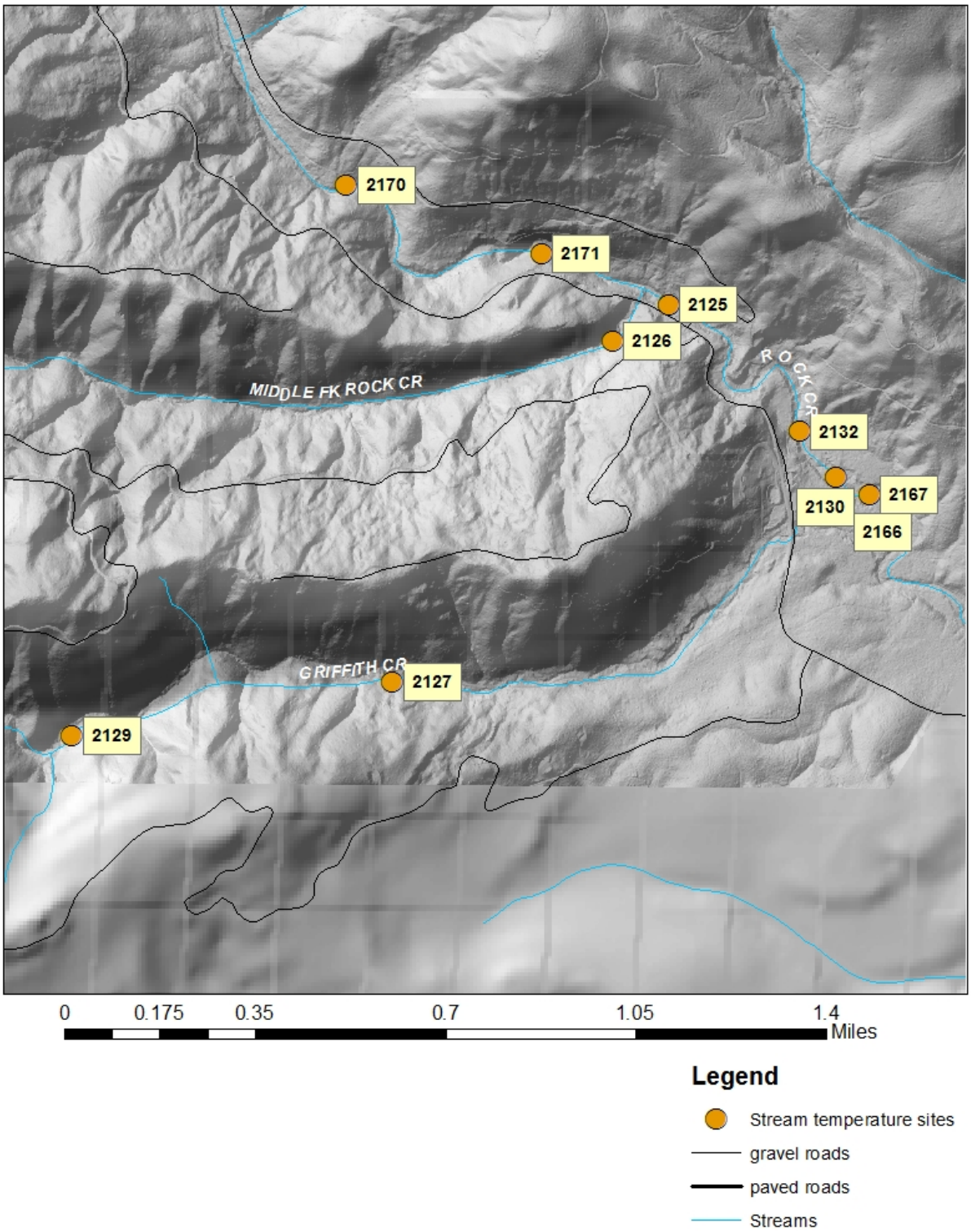


Figure 6. Stream temperature monitoring sites in Griffith Creek and lower Rock Creek. (Site 2129 was not deployed in 2016).

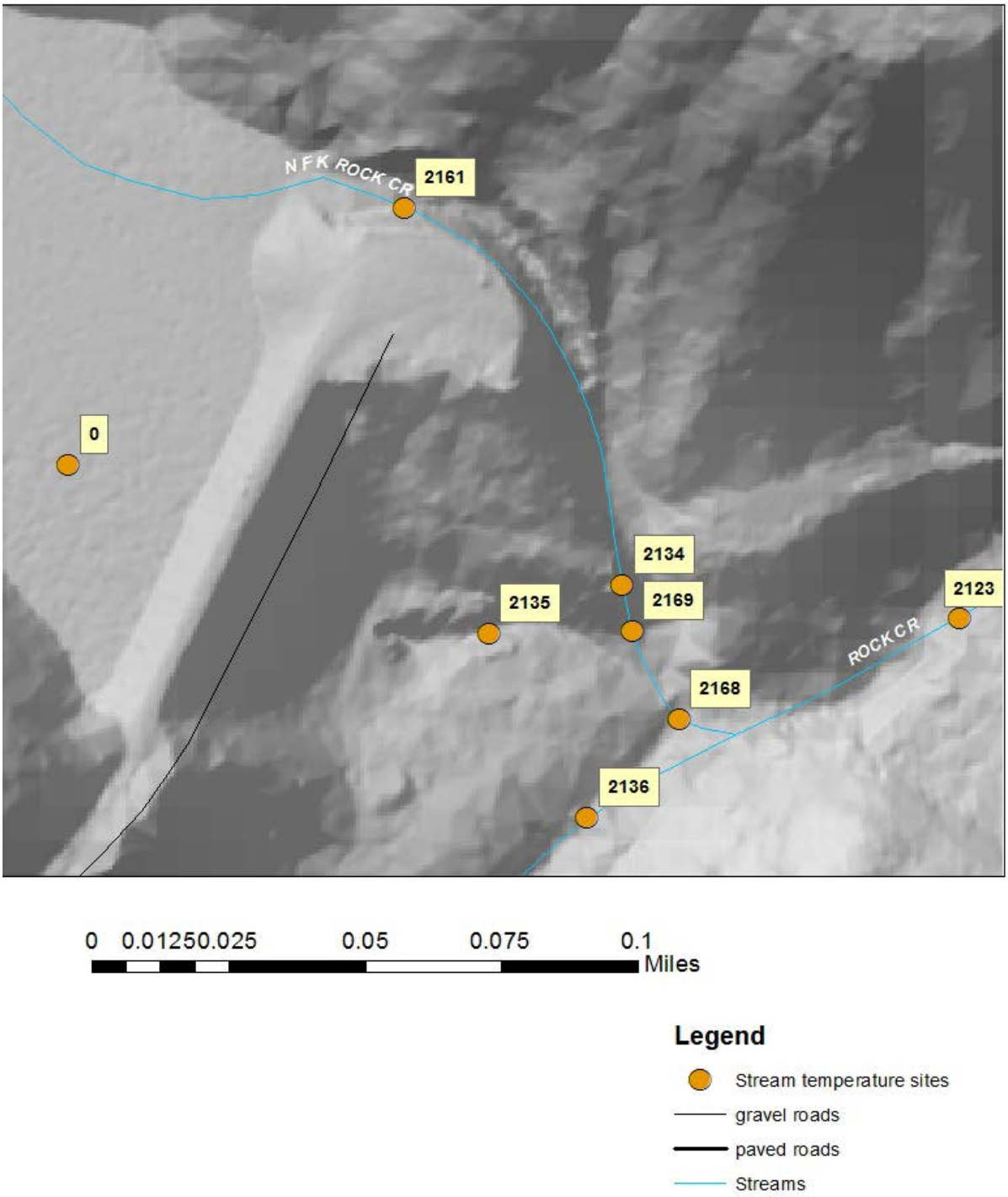


Figure 7. Stream temperature monitoring sites around the reservoir. The site marked with "0" is the valve tower in the reservoir. Six probes were suspended vertically on a rope in the reservoir.

Table 1: Data from multiple years for 7-day average maximum of daily high temperatures, Corvallis Watershed. Sites in the reservoir are shaded.

STREAM	LOCATION	STATION number	2005 7-day ave max	2006 7-day ave max	2010 7-day ave max	2011 7-day ave max	2012 7-day ave max	2013 7-day ave max	2014 7-day ave max	2015 7-day ave max	2016 7-day ave max
S FK Rock Creek	upstream from Connection Creek	2120	60.8		59.2	60.12	61.74	no data	61.08	63.52	62.14
Tributary to S FK Connection Creek	Tributary is upstream from and next to Connection Creek	2121	61.2		58.8	59.61	60.76	no data	62.59	62.97	61.00
S FK Rock Creek	Above weir tied to trash rack	2122	60.9		58.8	60.14	61.51	60.99	62.22	63.51	62.04
S FK Rock Creek AIR TEMP		2122			79.06	79.11	83.22	82.52	81.12	86.25	84.34
Rock Cr mainstem Water Temp	downstream from confluence of N Fk and S FK Rock Creek	2123	66.4	67.5	61.9	61.04	63.4	64.34	63.47	64.31	62.24
Rock Cr mainstem AIR TEMP	downstream from confluence of N Fk and S FK Rock Creek	2123	81	92							
Stilson Creek	upstream from rd 111	2124	62.5		60.2	61.39	62.12	61.86	62.96	64.07	63.29
Rock Creek mainstem	upstream from rd 111 bridge	2125	67.8		63.2	64.4	65.25	64.98	65.82	67.06	65.10
Rock Creek mainstem AIR TEMP	upstream from rd 111 bridge	2125			81.3						
Middle Fork Rock Creek	upstream from rd 3405	2126	62.3		59.6	61.44	62.35	62.16	62.20	64.31	63.15
Griffith Creek	upstream from weir	2127	60.9		59.3	60.19	61.6	61.35	62.14	63.49	61.98
Rock Creek	below bridge near entrance gate	2128			64.2	65.66	66.33	65.76	67.27	68.83	66.61

Griffith Creek	below thinning unit approx 1 mi from intake	2129			61.5	60.27	61.57	61.25	62.48	63.8	No data
Rock Cr mainstem	at waterline crossing upstream of Griffith Cr	2130			63.9	65.2	65.98	65.71	66.83	68.3	66.32
Rock Cr mainstem	0.08 miles upstream from Trib "b"	2131			61.9	63.13	LOST	64.29	64.59	65.31	64.86
Rock Cr mainstem	at City/pvt boundary above outflow in log complex	2132			63.3	64.49	65.84	65.37	66.03	68.05	65.76
S Fk Rock Creek	below thinning stand	2133			58.3	59.26	LOST	59.86	61.25	62.89	No data
N Fk Rock Creek spillway below dam	pool below spillway	2134				77.04					
Dam outlet small channel	Just below dam in small channel fed by valve leakage	2135					60.12	62.87	63.92	64.14	63.24
S Fk Rock Creek	above thinning stand (HCC in 1979?)										
S Fork Rock Creek	above dam outlet and confluence with N Fork Rock Cr	2136				62.12	62.99	no data	63.5	65.37	64.74
Top of Spillway at reservoir	Near metal ladder below sill	2161					78.91	79.57	Not used	Not used	Not used
North Fork Rock Creek	Above reservoir where creek enters reservoir	2160					60.66	60.84	61.89	61.56	Data not available
Reservoir, tied to tower rope, top probe initially	Installed June 5 2012 at 1.1 ft below water surface, 55' above bottom. Moved on 8/29/2012 to 105" below water surface. In 2014 and 2015, probe deployed 2 feet below water surface at 56 feet above bottom.	2162					74.6	72.76	76.33	73.86	72.79
Reservoir, tied to tower rope	Installed June 5 2012 at 3.75 ft below water surface, 50' from bottom anchor. In 2014 and 2015, probe was 5 feet below water surface.	2163					70.87	69.65		64.31	69.49

Reservoir, tied to tower rope	12 feet below water surface, 45.3 feet above bottom anchor	2173						67.26	70.1	69.65	69.49
Reservoir, tied to tower rope	22 feet below water surface	2180							66.82	66.74	66.43
Reservoir, tied to tower rope	17 feet below water surface, 40.3 feet above bottom anchor	2174						65.35		Not used	Not used
Reservoir, tied to tower rope	37 feet below water surface	2181							65.46	65.32	64.03
Reservoir, tied to tower rope	Installed on June 5 2012 25.5 below water surface, 28.3 ft from bottom anchor	2164					62.61	64.63			Not used
Reservoir, tied to tower rope, near bottom	Installed 3.7' from bottom anchor in 2012, at 5 feet from bottom in 2014 and 2015.	2165					60.65	62.66	64.52	64.31	63.18
Griffith Creek	mouth of creek	2166					62.86	no data	63.65	64.93	63.44
Rock Creek	just downstream of Griffith Cr mouth	2167					65.81	no data	No data	No data	No data
Spillway/dam outlet channel, 7-day ave. max when spillway is flowing	Just below spillway and dam outlet channel convergence, and upstream of South Fork Rock Creek confluence.	2168					71.4	73.96	72.22	71.29	63.125
Spillway/dam outlet channel, temperature after spillway stops flowing	Just below spillway and dam outlet channel c, and upstream of South Fork-Rock Creek confluence.	2168					61.1	63.08	69.95	64.10	63.5
Bottom of Spillway	In gravel channel just below spillway, moved from stagnant pool location used in 2011.	2169					76.99	78.46	78.87	76.03	74.52
Rock Creek mainstem	Approximately 2200 feet downstream from Trib "b"	2170						65.7	64.85	66.61	64.85

Rock Creek mainstem	Approximately 4500 feet downstream from Trib "b"	2171						66.77	65.93	66.98	Not used
Headwaters of South Fork	Bluff Springs above Road 2005	2176						45.65	45.66	46.16	46.03
Headwaters of North Fork	Just downstream of Road 2005	2177						50.11	50.26	51.19	Not used

Table 2: Comparison of sites that were above 64°F in 2012 through 2016

Site 2123: Rock Creek mainstem, below confluence of North and South Fork Rock Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	65.48	63.4	5	8/4/2012 to 8/13/2012
2013	65.92	64.34	4	6/30/2013 to 7/3/2013
2014	65.02	63.47	8	7/7/2014 to 8/27/2014
2015	66.73	64.31	14	6/7/2015 to 8/21/2015
2016	64.42	62.23	2	6/5/2016 to 6/7/2016

Site 2131: Mainstem Rock Creek 0.08 miles above Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012		LOST IN 2012		
2013	65.7	64.29	6	6/30/2013 to 7/26/2013 intermittently
2014	66.34	64.59	21	7/7/2014 to 8/28/2014
2015	66.9	66.32	22	6/7/2015 to 8/20/2015
2016	66.73	64.84	13	intermittently

Site 2170: Mainstem Rock Creek,Approximately 2200 feet downstream from Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2013	65.7	64.19	9	6/30/2013 to 8/6/2013 intermittently
2014	66.0	64.85	24	7/7/2014 to 8/27/2014
2015	68.23	66.61	24	6/7/2015 to 8/21/2015
2016	66.64	64.85	15	Intermittently

Site 2171: Mainstem Rock Creek,Approximately 4500 feet downstream from Trib "B"

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2013	66.77	65.17	17	6/28/2013 to 9/12/2013 intermittently
2014	67.5	65.93	32	7/7/2014 to 8/29/2014
2015	68.53	66.98	35	6/7/2015 to 8/21/2015
2016	Probe site not deployed			

Site 2125: Rock Creek mainstem, below Middle Fork and above the Road 111 bridge

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	66	65.25	9	8/4/2012 to 8/17/2012
2013	66.56	64.98	15	6/25/2013 to 9/11/2013 intermittently
2014	67.41	65.82	22	7/7/ to ? Probe was taken out of water on 8/13/2014
2015	68.66	67.06	36	6/7/2015 to 8/21/2015
2016	66.73	65.1	15	Intermittently

Site 2132: Rock Creek mainstem at City property boundary upstream from plant outflow in a log complex.

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.01	65.84	9	8/3/2012 to 8/18/2012
2013	66.98	65.37	21	6/27/2013 to 9/10/2103 intermittently
2014	67.46	66.03	33	7/7/2014 to 8/29/2014
2015	69.47	68.05	44	6/7/2015 to 8/21/2015
2016	67.46	65.76	22	Intermittently

Site 2130: Rock Creek mainstem upstream from Griffith Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.63	65.98	10	8/3/2012 to 8/18/2012
2013	67.07	65.71	30	6/30/2013 to 9/13/2013 intermittently
2014	67.93	66.83	43	7/6/2014 to 9/2/2014
2015	69.73	68.30	60	6/7/2015 to 9/13/2015
2016	69.77	66.32	28	Intermittently

Site 2128: Rock Creek below main bridge near mouth of creek, upstream from Greasy Creek confluence

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	67.28	66.33	14	8/2/2012 to 8/19/2012
2013	67.41	65.76	32	6/27/2013 to 9/13/2013
2014	68.57	67.27	43	7/6/2014 to 8/28/2014
2015	70.16	68.83	59	6/6/2015 to 8/28/2015
2016	68.31	66.61	32	Intermittently

Site 2122: **AIR** Temperature at South Fork Rock Creek

Year	Maximum daily high temperature	7-day average maximum temperature	Number of days that the maximum daily high is greater than 64°F	Time period when temperatures above 64°F occur
2012	84.812	83.21	96	5/31/2012 to 10/2/2012
2013	85.85	82.52	106	5/18/2013 to 10/21/2013
2014	86.07	81.12	81	5/16/2014 to 10/9/2014
2015	94.8	86.35	118	5/7/2015 to 9/24/2015
2016	89.68	84.34	102	Throughout summer

Variability in Air Temperatures, Precipitation and Stream Flows from Year to Year

Stream temperatures are influenced by a number of factors, including yearly variations in weather conditions. Air temperatures collected in the Corvallis Watershed in the riparian zone at the South Fork Rock Creek intake, and precipitation data from the Wilkinson Ridge Remote Automated Weather Stations (RAWS), are compared for the previous 6 years to show the variability from year to year.

Air Temperature Variability

Air temperatures for the past 7 years is shown as the 7-day average of the daily maximum temperature in Figure 8. Peak air temperatures in 2016 occurred at the end of May and the end of August, but overall, summer temperatures were cooler in 2016 than in 2015 (Figure 9).

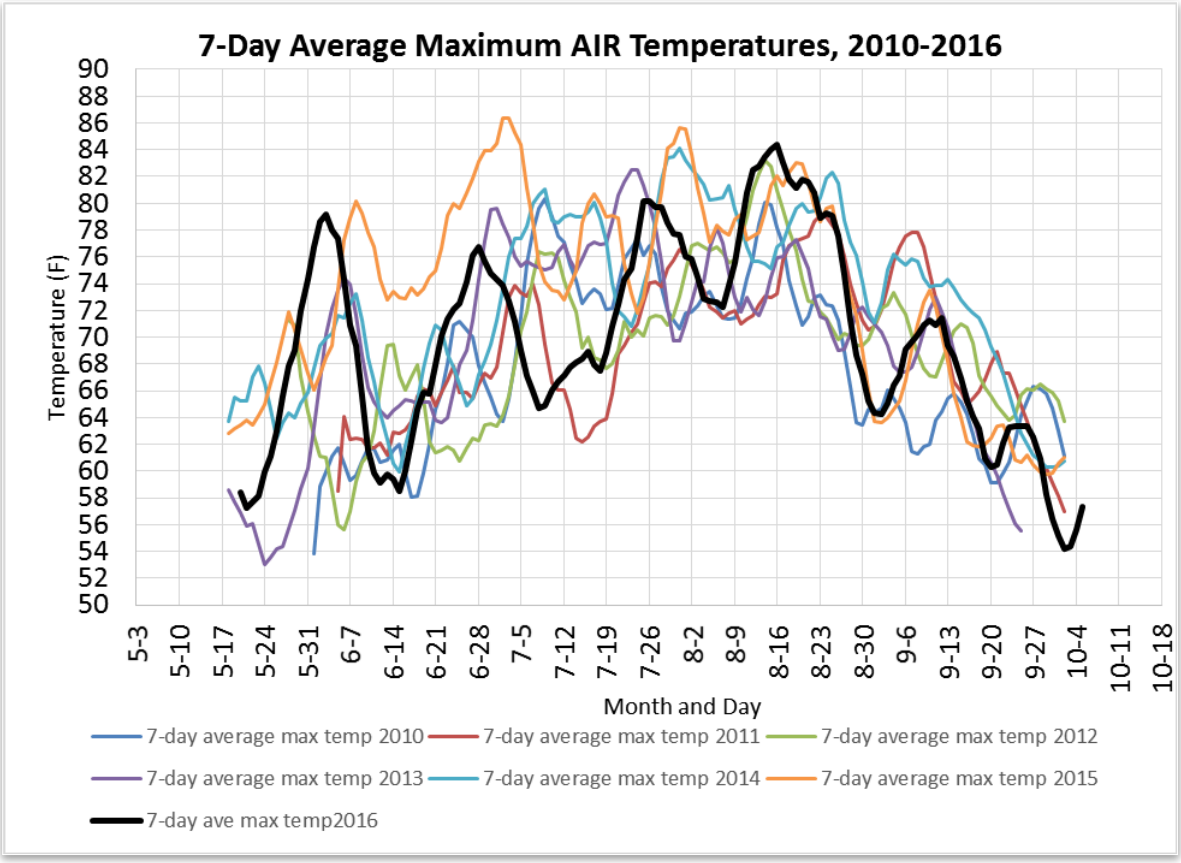


Figure 8. The 7-day running average of the daily maximum temperatures for the years 2010 through 2016. Air temperatures at the end of June, 2015 were the warmest air temperatures in the last 6 years.

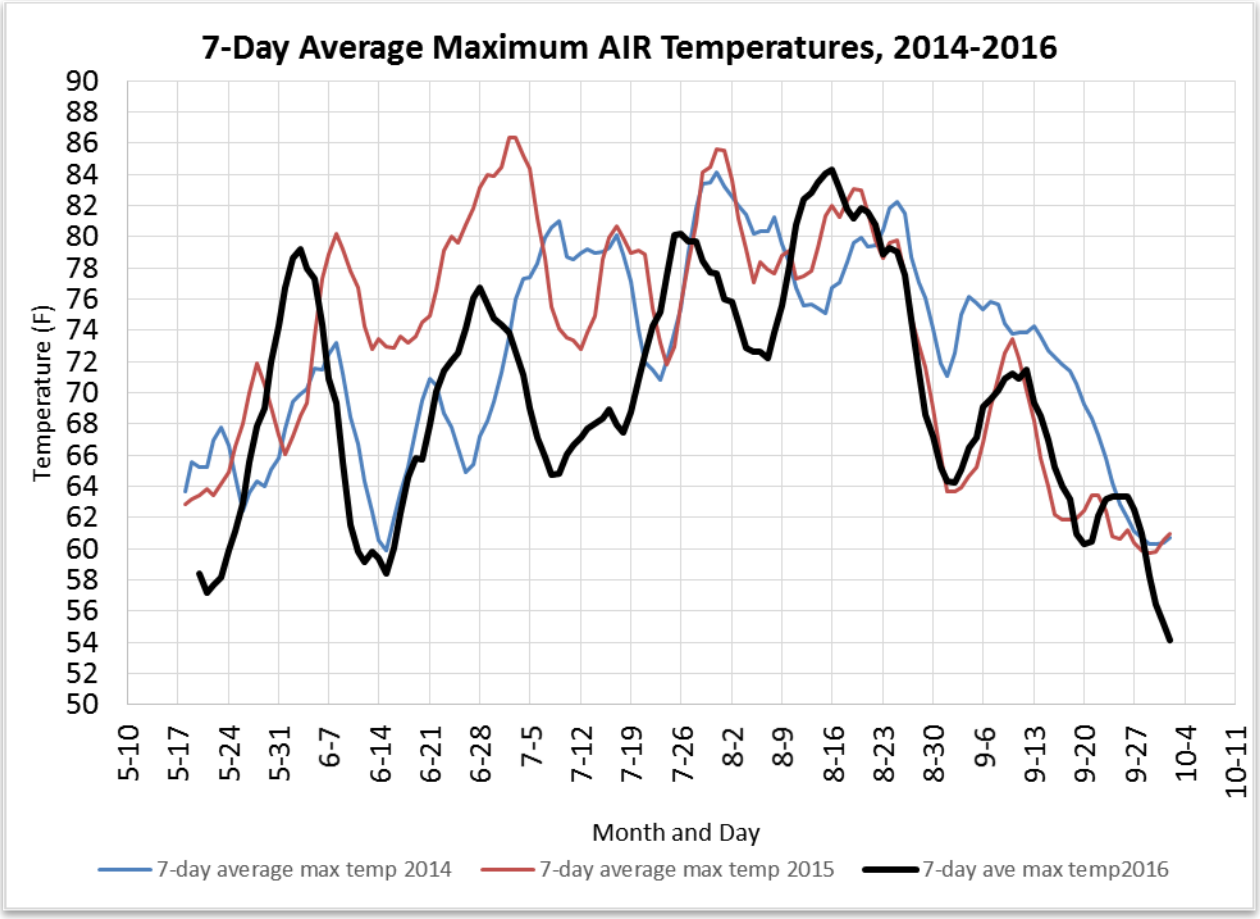


Figure 9. Comparison of the 7-day average of the daily maximum temperature for 2014, 2015 and 2016. Temperatures in 2016 were slightly cooler, although the early peak temperatures around the end of May were earlier.

Variability in Annual Precipitation

Precipitation data for monthly total precipitation from the Wilkinson Ridge RAWS site is shown for water years 2010-2016 in Figure 10. The data for 2011 was suspect, as the station did not record any precipitation for several months in the spring for that year.

The winter months of November through January 2016 were much wetter than the previous years, while the late spring-early summer months were relatively dry. Compared to 2015, water year 2016 had more rainfall during the winter and spring months (Figure 11). Summer precipitation was similar for the two years. Cumulative precipitation for 2016 was above average for the last 7 years (Figure 12).

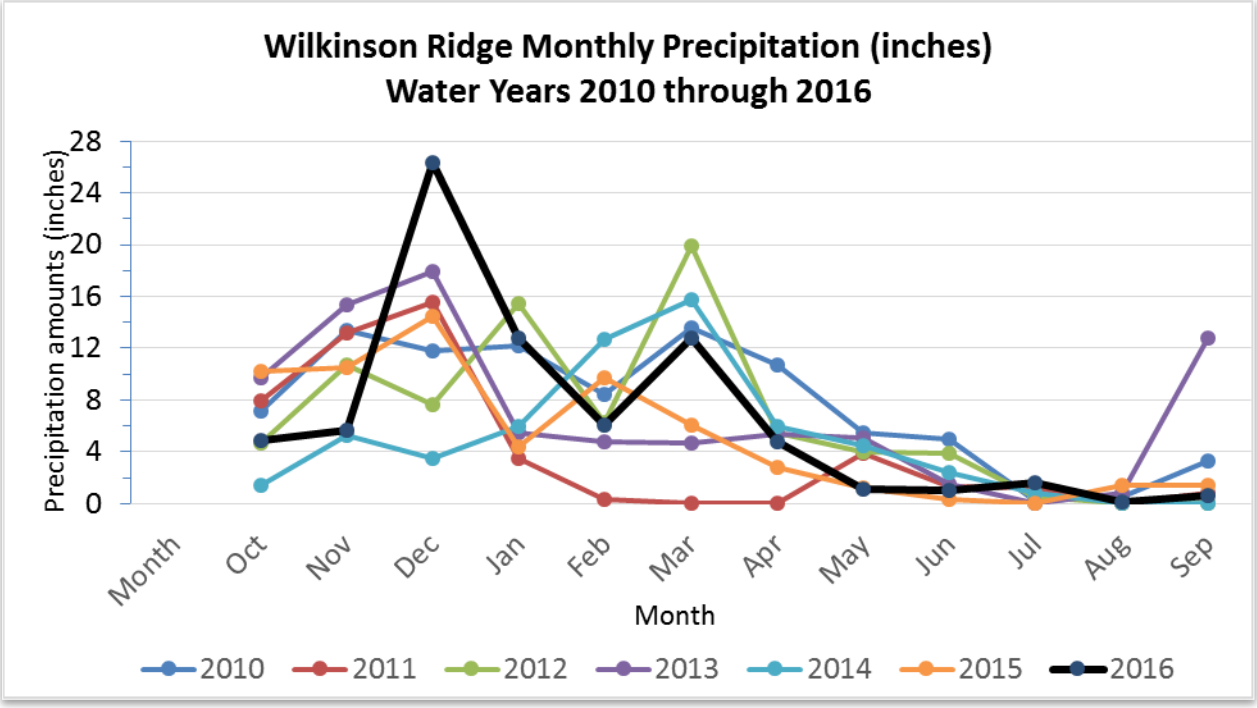


Figure 10. Monthly cumulative precipitation amounts for the Wilkinson Ridge Remote Automated Weather Station for the years 2010 through 2014. The data from 2011 (red line) was suspect, as several months recorded no precipitation.

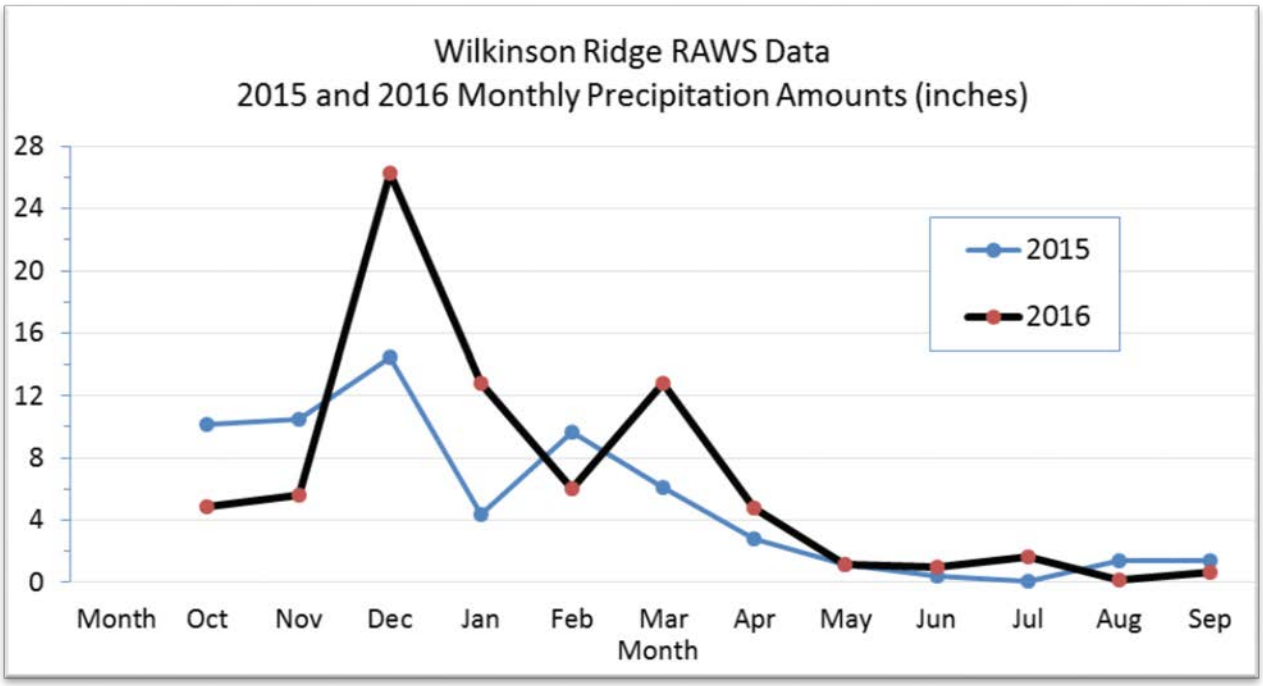


Figure 11. Comparison of month-to-month precipitation amounts at Wilkinson Ridge in 2015 and 2016. Both the winter and spring months were wetter in 2016 than the dry year of 2015.

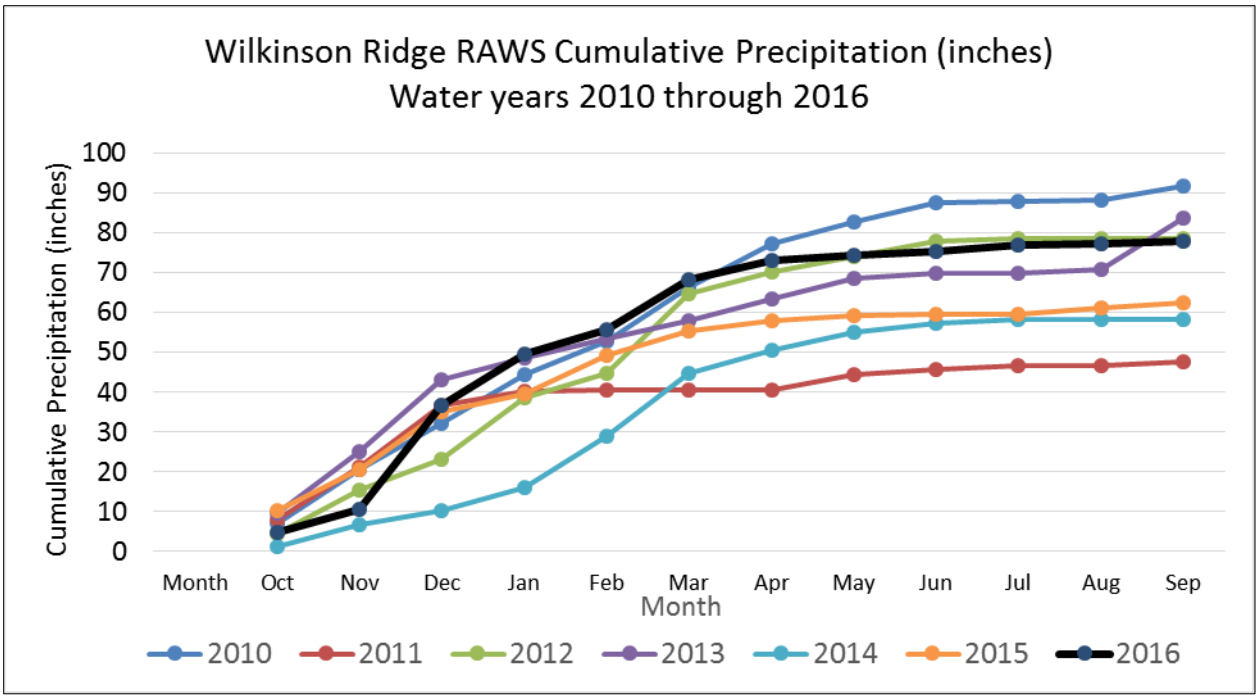


Figure 12. Annual cumulative amounts of precipitation for the Wilkinson RAWS station. The annual total amount in 2016 is above average for the time period.

Effects of Yearly Weather Variability on Stream Temperatures

One effect of the yearly weather variability on stream temperatures can be seen in Figure 14, which compares water temperature to the drainage area above that monitoring site. The lines representing different years' temperature data are all parallel, with a similar slope; however, they reflect the warmer vs. cooler years. For instance, 2015 had the highest peak air temperature, and the 7-day average of the maximum water temperature throughout the watershed reflects 2015's air temperatures, with the highest stream temperatures since 2010 throughout the watershed.

In 2016, the overall temperature trend was cooler, as shown by the solid line on Figure 13..

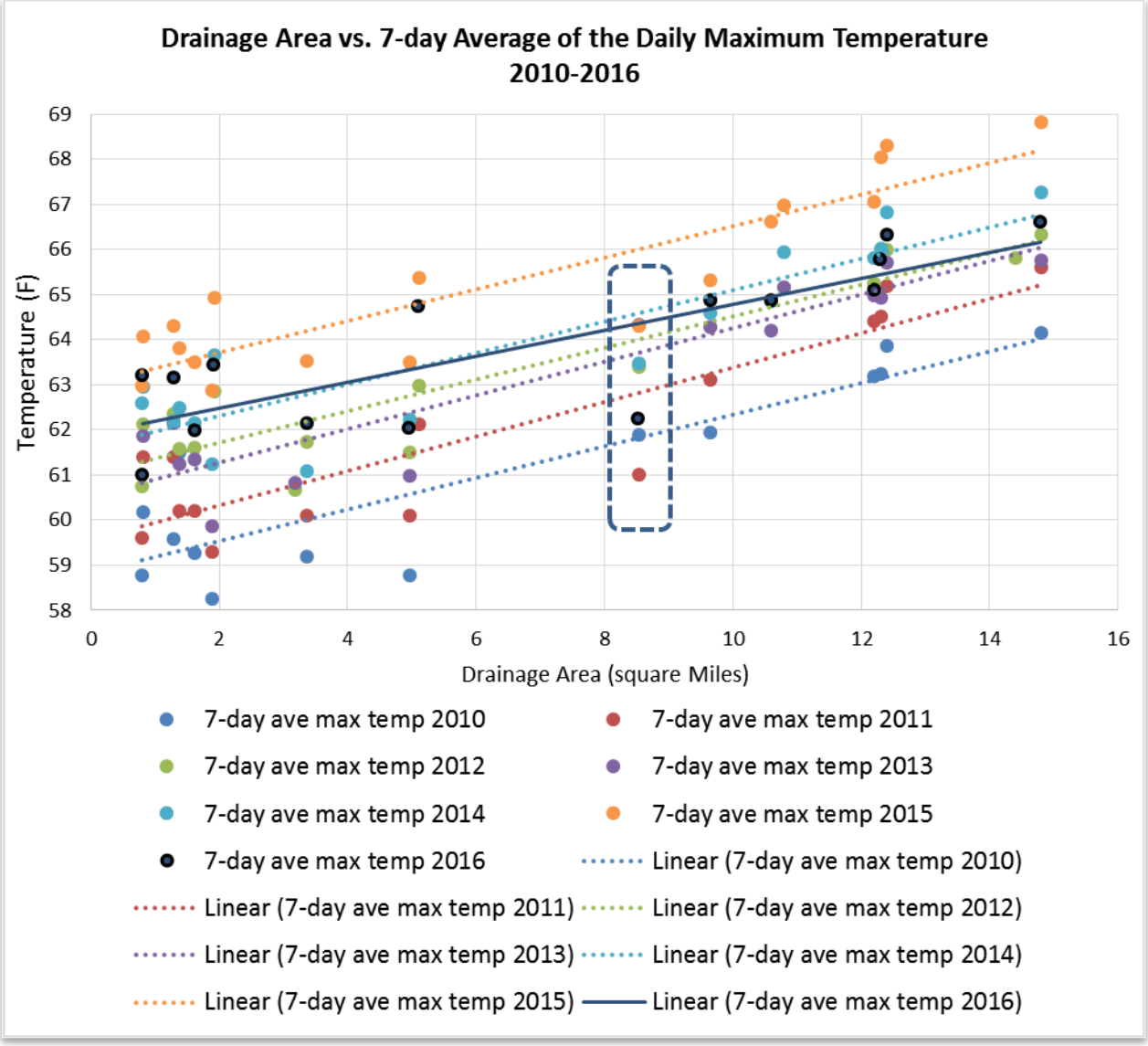


Figure 13. Comparing 7-day average maximum stream temperatures to drainage area for 7 years. The blue dotted box contains the data points for the Rock Creek mainstem site below the North and South Fork Rock Creek confluence. It is usually slightly cooler because the highest summer temperatures occur after the spillway has stopped flowing, but the influence of the dam valve channel is present.

As an example of the variability in stream temperatures and the timing of peak temperatures between years, Figure 14 shows the last three years of daily maximum stream temperatures for the Middle Fork Rock Creek. This site is on a tributary and is not downstream of the dam and reservoir. Warm June air temperatures occurred in late May-early June in both 2015 and 2016:, the peak stream temperature coinciding with the peak in air temperatures. However, 2016 was cooler than the previous two years for most of the summer.

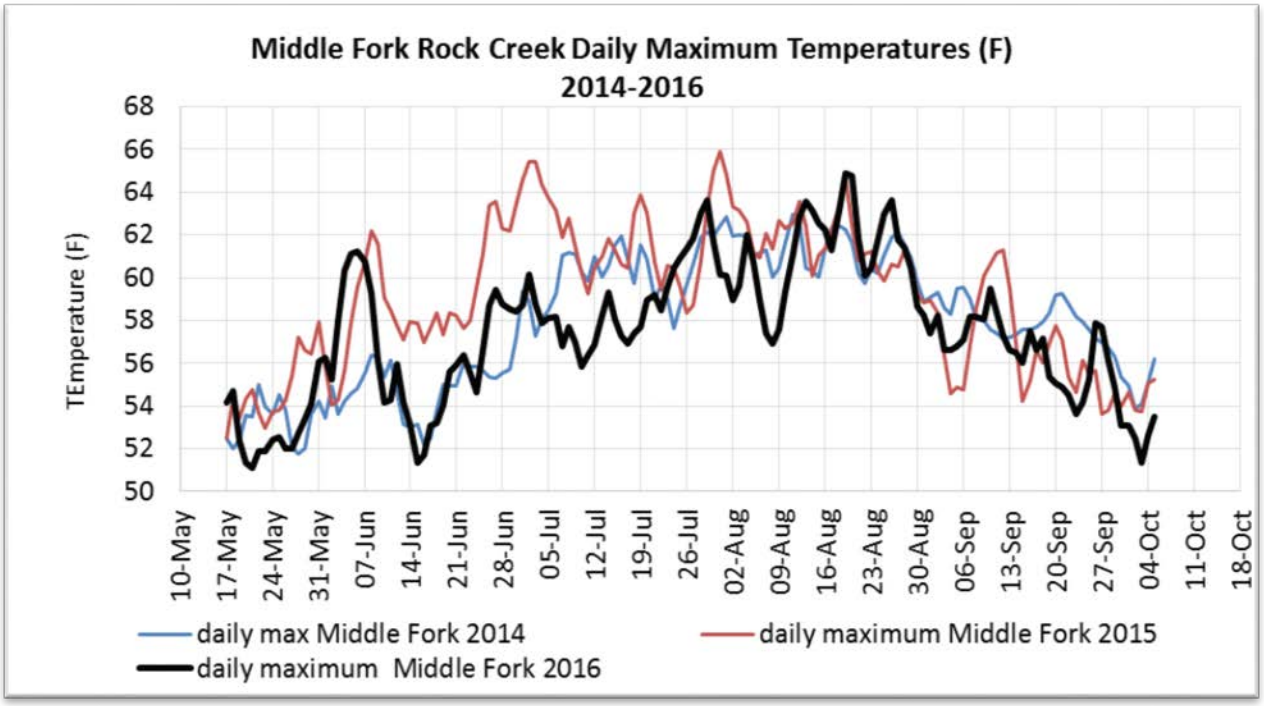


Figure 14. Daily maximum stream temperatures for the Middle Fork Rock Creek, 2014 to 2016.

Flow data

Flow data has been collected at the stream temperature monitoring sites around the confluence of the North and South Forks of Rock Creek in 2013-2016. Locations of the flow measurements were at the temperature site 2169 in the lower spillway, temperature site 2135 in the dam valve channel just downstream from the dam, the South Fork Rock Creek temperature site 2136 above the confluence, and the Rock Creek mainstem site 2123 below the confluence. For detailed results from 2013-2015, see the report for the summer of 2015.

Stream flows were measured along the same cross-sections as previous years using a Marsh-McBirney flowmeter.

In general, flows during the spring and early summer of 2016 were higher than 2015 (Figure 15). The amount of water coming out of the dam valve channel, which releases water from the bottom of the reservoir because of a leaky valve, was three to four times greater than previous years (compare Figures 16 and 18). See also Table 7, which shows the average of dam valve channel flow measurements by year. Figure 20 shows a graph of four years of dam valve channel flow measurements through the summer. The flow coming from the bottom of the reservoir in 2016 is significantly higher than the previous three years. As a result, the proportion of the mainstem flow below the confluence that was attributable to the dam valve channel was also greater in 2016. See the last row in Tables 3-6.

As a check on flow measurements, the flows measured above the confluence were added together and compared to the flow in the mainstem below the confluence. The amounts were similar, suggesting the flow measurement methodology is reasonable. See Figures 17 and 19.

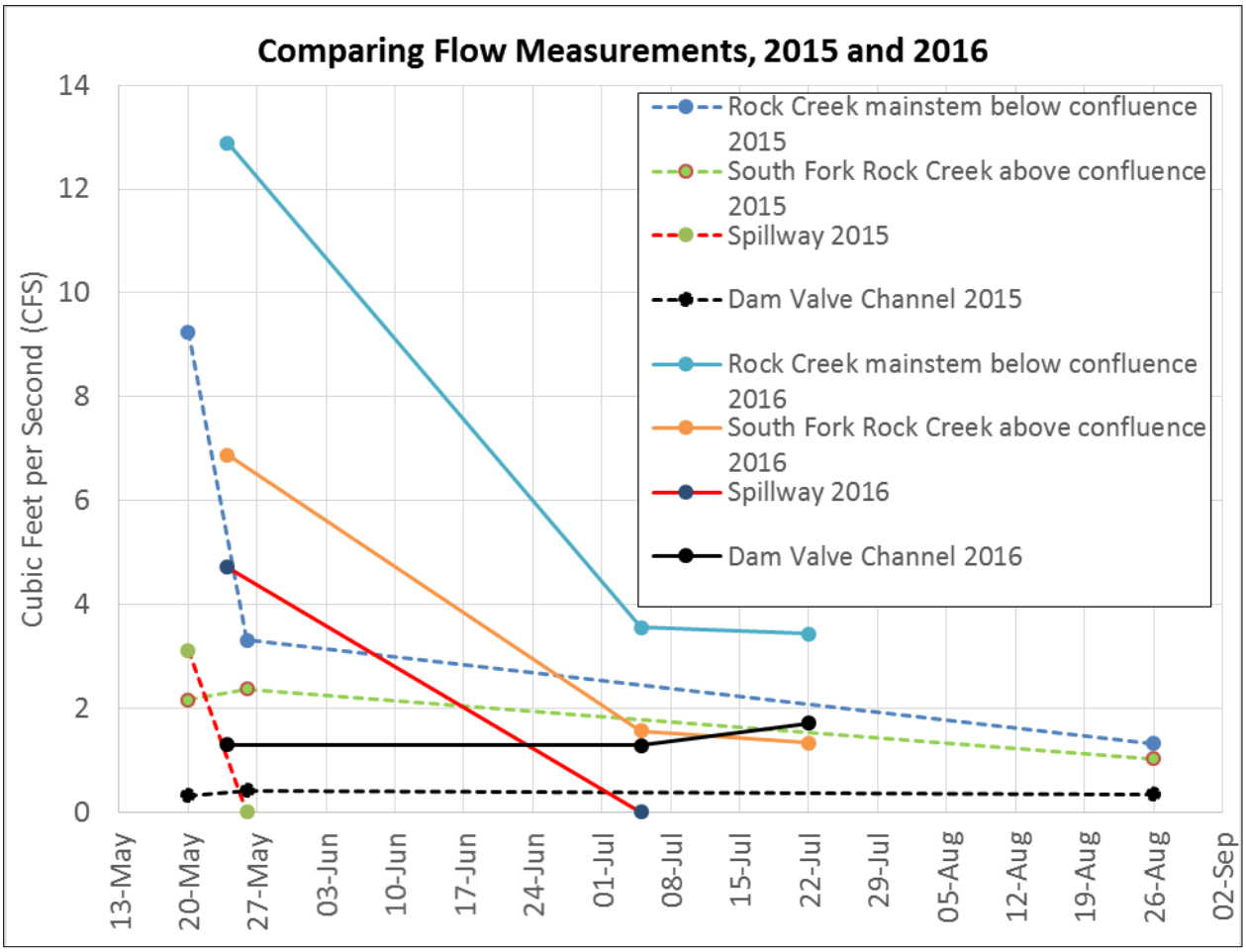


Figure 15: 2015 and 2016 late summer flows compared.

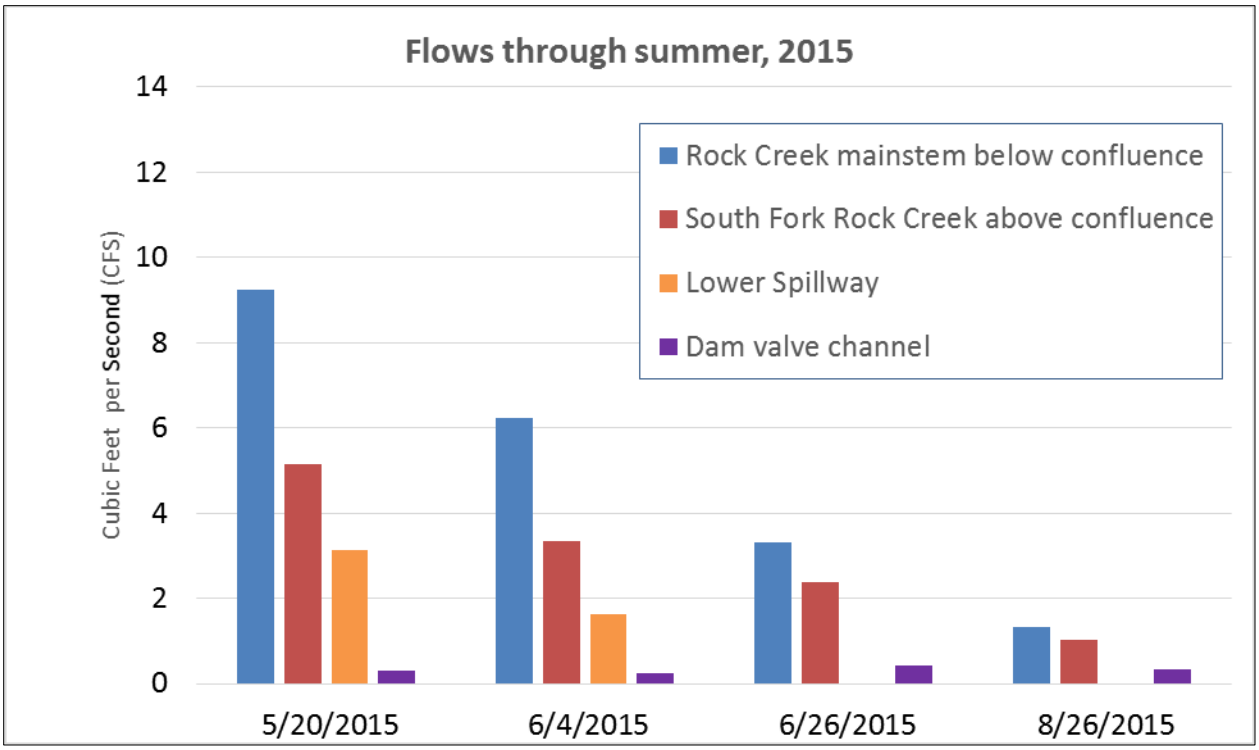


Figure 16: Comparison of flows aabove and below the North and South Fork Rock Creek confluence in 2015. The spillway stopped flowing on June 16, 2015. Flows were lower than the previous two years.

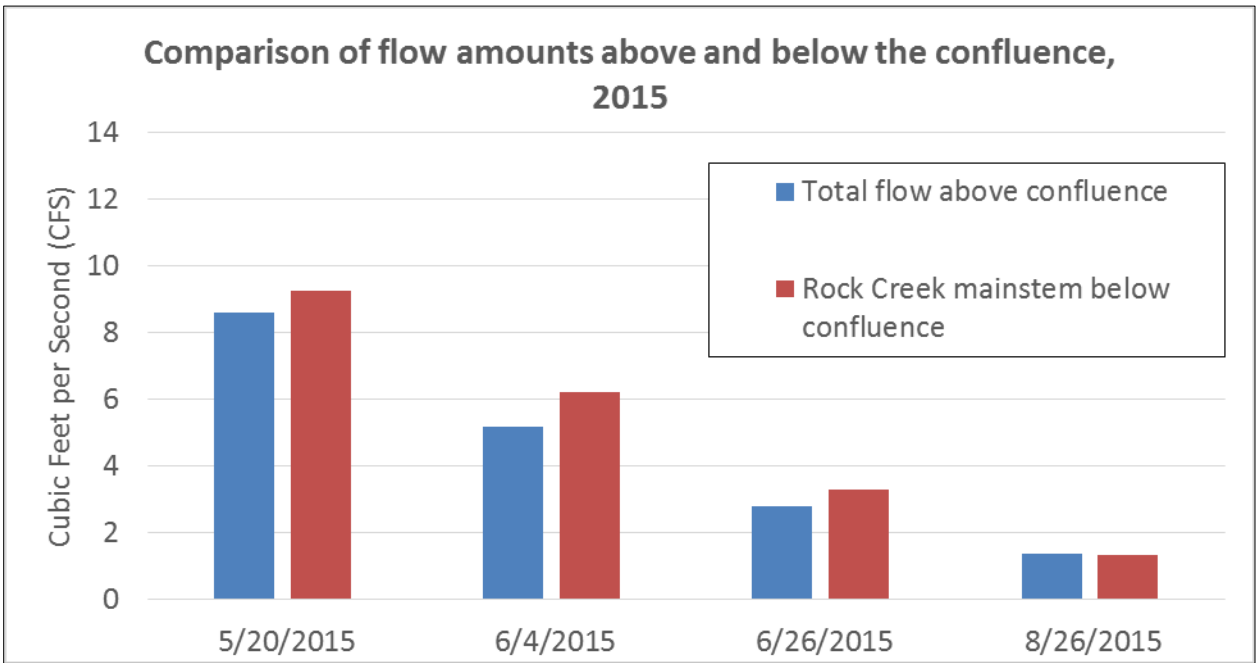


Figure 17. Bar graph comparing total amount of flow above the confluence with the Rock Creek mainstem below the confluence, 2015

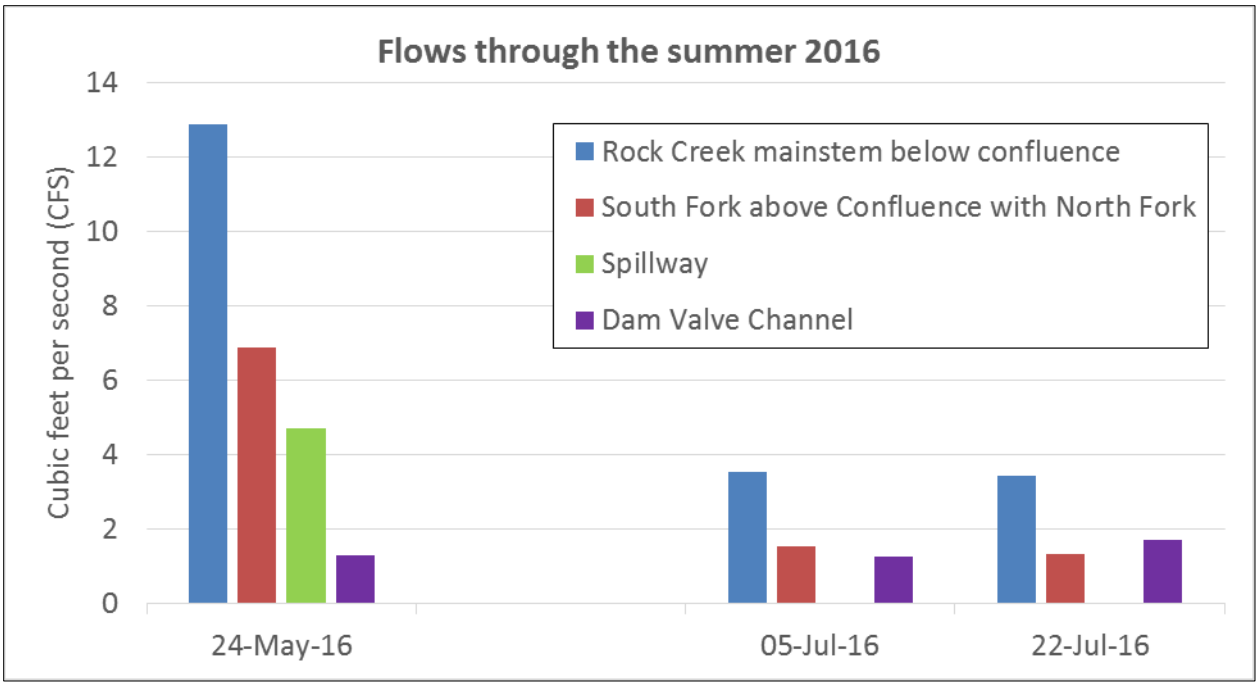


Figure 18. Comparison of flows through the summer of 2016.

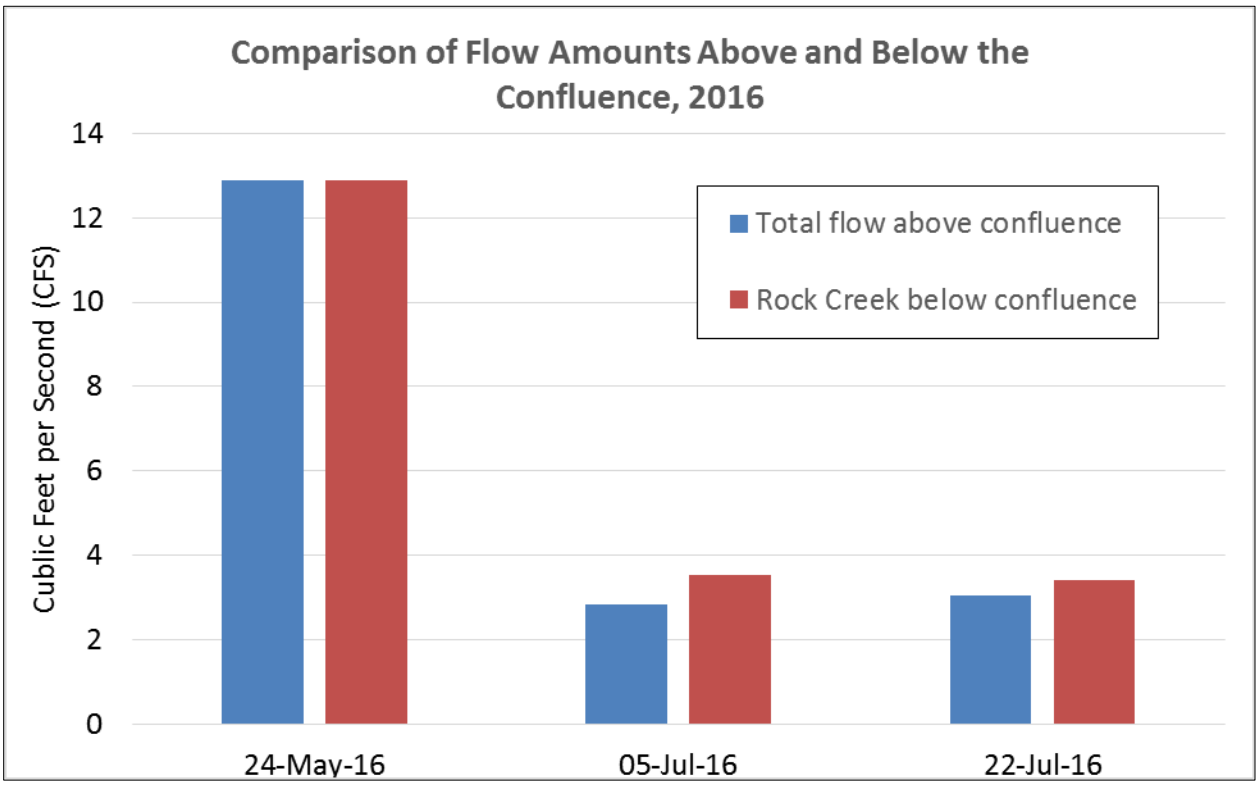


Figure 19. Comparison of total of flows above the confluence and Rock Creek below the confluence, 2016.

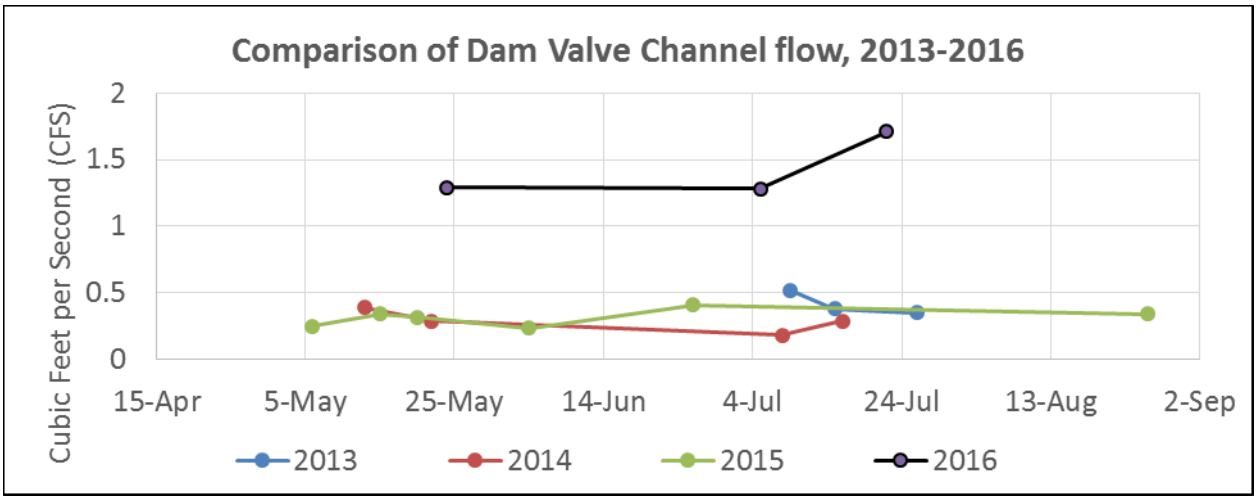


Figure 20. Comparing four years of flow measurements at the dam valve channel.

Table 3: Stream flows measured through the summer in cubic feet per second (CFS) 2013. *(Numbers in red were corrected after the 2013 report was written).*

Site	Flow May 14 (CFS)	Flow June 4 (CFS)	flow July 9 (CFS)	Flow July 15 (CFS)	Flow July 26 (CFS)
Rock Creek mainstem below confluence	10.12	15.15	5.9	4.52	3.94
South Fork Rock Creek above confluence	7.39	9.71	5.7	4.64	4.09
Lower Spillway cross-section	2.9	5.94	0.92	0.55	0
Dam valve channel			0.52	0.38	0.35
Ratio of lower spillway to mainstem flow	***0.30***	***0.22***	***0.16***	***0.12***	***0.00***
Ratio of dam valve channel to mainstem flow			***0.088***	***0.084***	***0.088***

Table 4: Stream flows measured through the summer in cubic feet per second (CFS) 2014.

Site	Cubic ft/sec on 5/13/2014	CFS on 5/22/2014	CFS on 6/6/2014	CFS on 7/8/14	CFS on 7/16/2014
Rock Creek mainstem below confluence	48.16	23.3	13.69	4.89	4.27
South Fork Rock Creek above confluence	23.8	13.45	9.99	4.69	4.36
Lower Spillway cross-section	25.55	9.27	3.22	1.3	0
Dam valve channel	0.39	0.29	not measured	0.18	0.29
Ratio of lower spillway to mainstem flow	**0.53**	**0.40**	**0.24**	**0.26**	**0**
Ratio of dam valve channel to mainstem flow	**0.0081**	**.0124**		**.037**	**.068**

Table 5: Stream flows measured through the summer in cubic feet per second (CFS) 2015.

Site	Cubic ft/sec on 5/6/2015	Cubic ft/sec on 5/15/2015	Cubic ft/sec on 5/20/2015	Cubic ft/sec 6/4/2015	Cubic Ft/sec on 6/26/2015	Cubic ft/sec on 8/26/2015
Rock Creek mainstem below confluence	12.5	10.77	9.25	6.235	3.31	1.32
South Fork Rock Creek above confluence	5.8	5.55	5.156	3.328	2.37	1.02
Lower Spillway	3.62	3.8	3.12	1.612	0	0
Dam valve channel	0.25	0.34	0.317	0.233	0.41	0.34
Ratio of lower spillway to mainstem flow	**.29**	**.35**	**.34**	**.26**	**0**	**0**
Ratio of dam valve channel to mainstem flow	**0.02**	**0.032**	**0.034**	**0.037**	**0.124**	**0.25**

Table 6 : Stream flows measured through the summer in cubic feet per second (CFS) 2016.

Site	Cubic ft/sec on 24-May-2016	Cubic ft/sec on 05-July-2016	Cubic ft/sec on 22-July-2016
Rock Creek mainstem below confluence	12.89	3.55	3.43
South Fork Rock Creek above confluence	6.88	1.56	1.33
Lower Spillway	4.72	0	0
Dam valve channel	1.29	1.28	1.71
Ratio of lower spillway to mainstem flow	**0.37**	**0**	**0**
Ratio of dam valve channel to mainstem flow	**0.1**	**0.35**	**0.49**

Table 7: Average of flow measurements from dam valve channel, summers 2013-2106

	2013	**2014**	**2015**	**2016**
Average of flow measurements from dam valve channel (CFS)	0.41	0.29	0.315	1.43

Temperature Monitoring Results from the Reservoir

Water levels in the reservoir reflect the differences between yearly stream flows (Figure 21). Stream flow was lower in the spring and early summer of 2013 as compared to 2012, and the cumulative precipitation amounts were even lower in 2014. As a result, the reservoir stopped spilling 2 weeks earlier in 2013 than 2012, and even earlier in 2014.This trend continued in 2015, when the spillway stopped flowing on June 16, 2015, a month earlier than the previous year. In 2016, reservoir levels and the date the spillway stopped flowing were similar to 2014 (Figure 21)

In addition to the probes that were placed in the North Fork Rock Creek above the reservoir, and the probes placed in channel locations downstream of the reservoir, six probes were suspended on a rope from the tower in the deepest part of the reservoir. Figures 4 and 7 show the map view of the probes that bracketed the reservoir. Figure 22 shows the depth of the probes and the level of the reservoir through the summers in 2016.

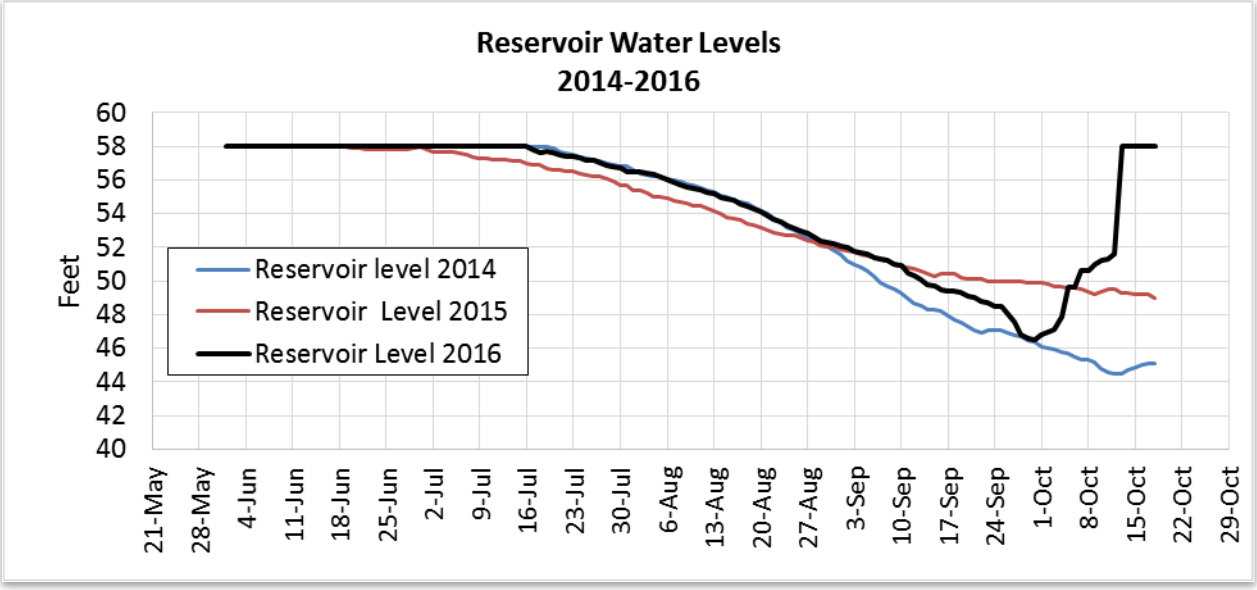


Figure 21. Comparison of reservoir levels through the summer for 2014-2016. Reservoir levels in 2016 were similar to 2014. The spillway stopped flowing later in 2016 than in 2015.

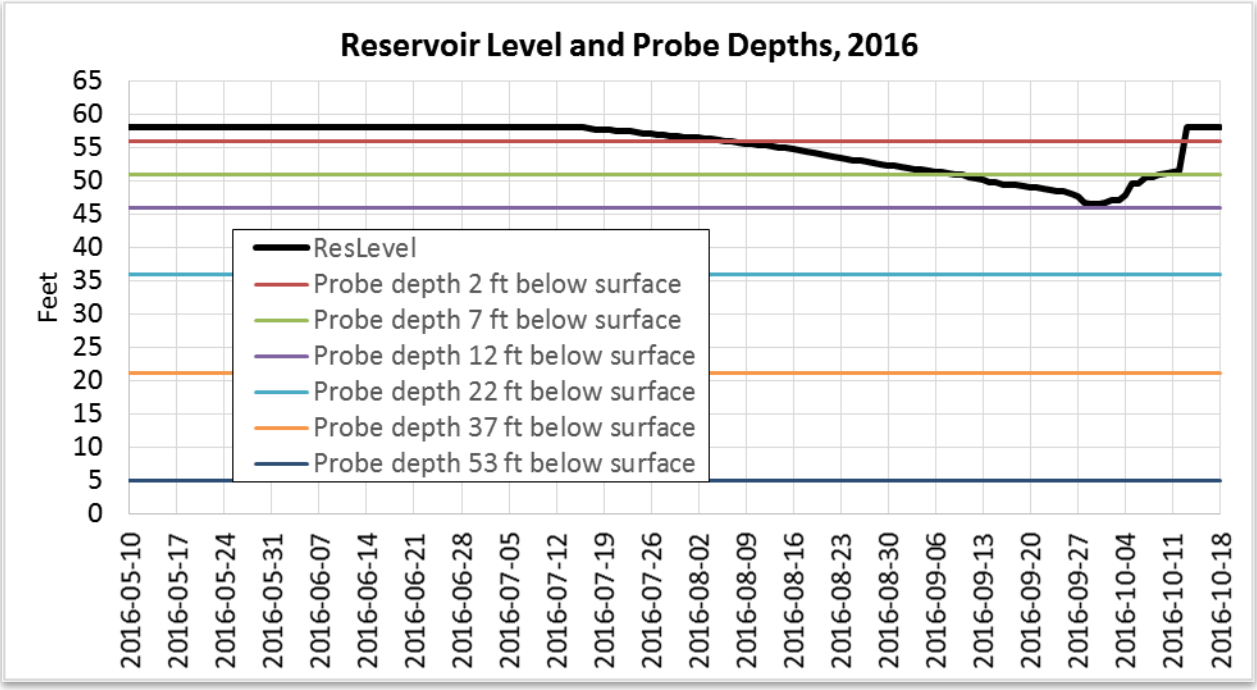


Figure 22. Depth of temperature probes on rope suspended from wooden tower in the reservoir compared with surface water level through the summer. The intersection of the black line (water surface) and the probe depth corresponds to the end of the data line in Figure 25.

Reservoir temperatures at the bottom also reflect the climatic variables. In 2014, reservoir bottom temperatures were consistently a couple of degrees warmer than 2013 from early July

through the first of November, even though the 7-day average of the maximum daily air temperature was slightly cooler. In 2015, in keeping with an unusually warm June, the reservoir bottom temperatures were the warmest recorded in June in seven years of data collection (Figure 24). Air and stream temperatures were cooler in 2016, and the bottom of the reservoir was cooler than the previous two years (Figure 23).

The largest variability between the top and the bottom of the reservoir occurs in the early summer (Figure 26). By September, the difference in temperature between the surface of the water and the bottom of the reservoir is greatly reduced. See the graphs for 2015 and 2016 (Figures 24 and 25)

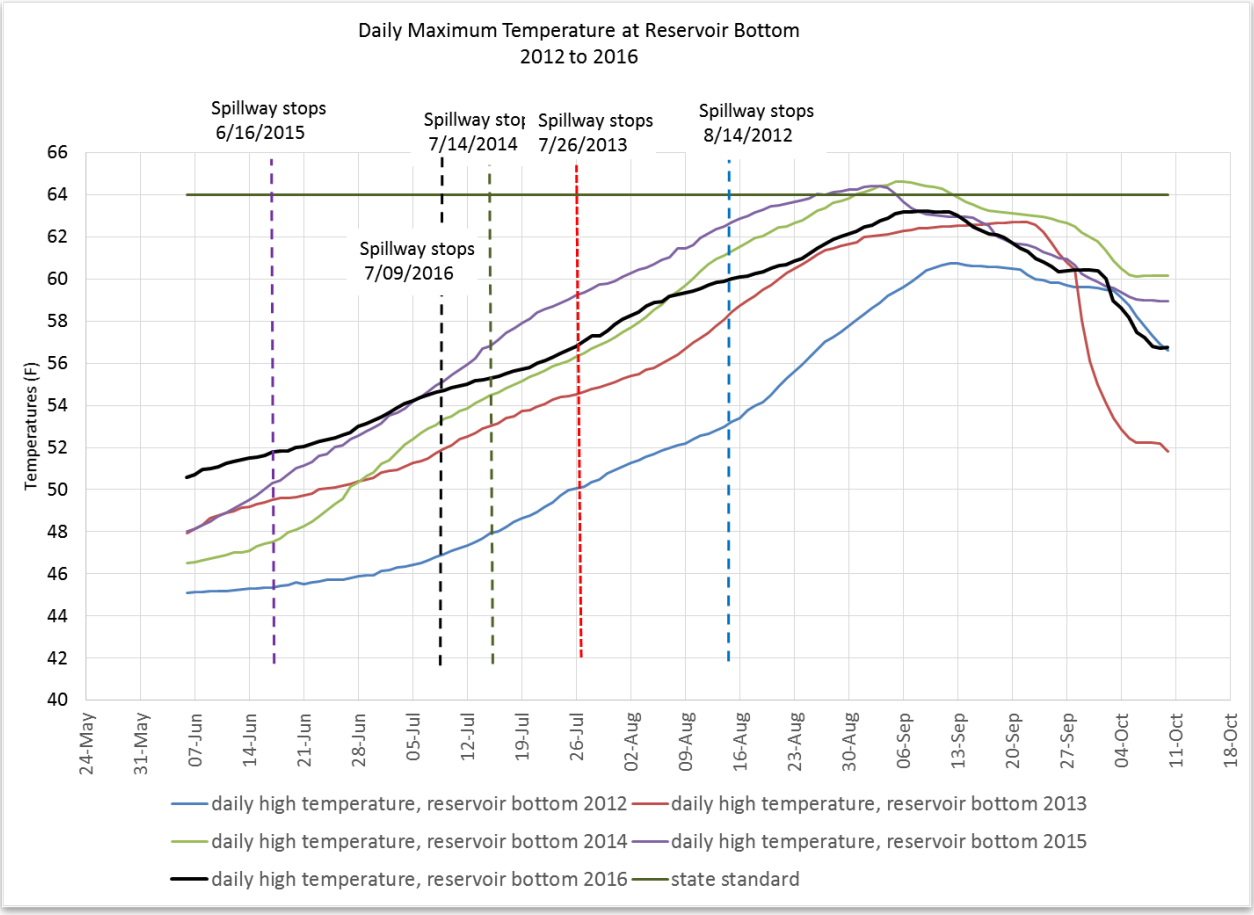


Figure 23: Temperature trends at the bottom of the reservoir are compared to the reservoir water levels through the summer of 2016. The bottom temperature gradually rises, even in the early summer when the reservoir is full and the water level isn't changing.

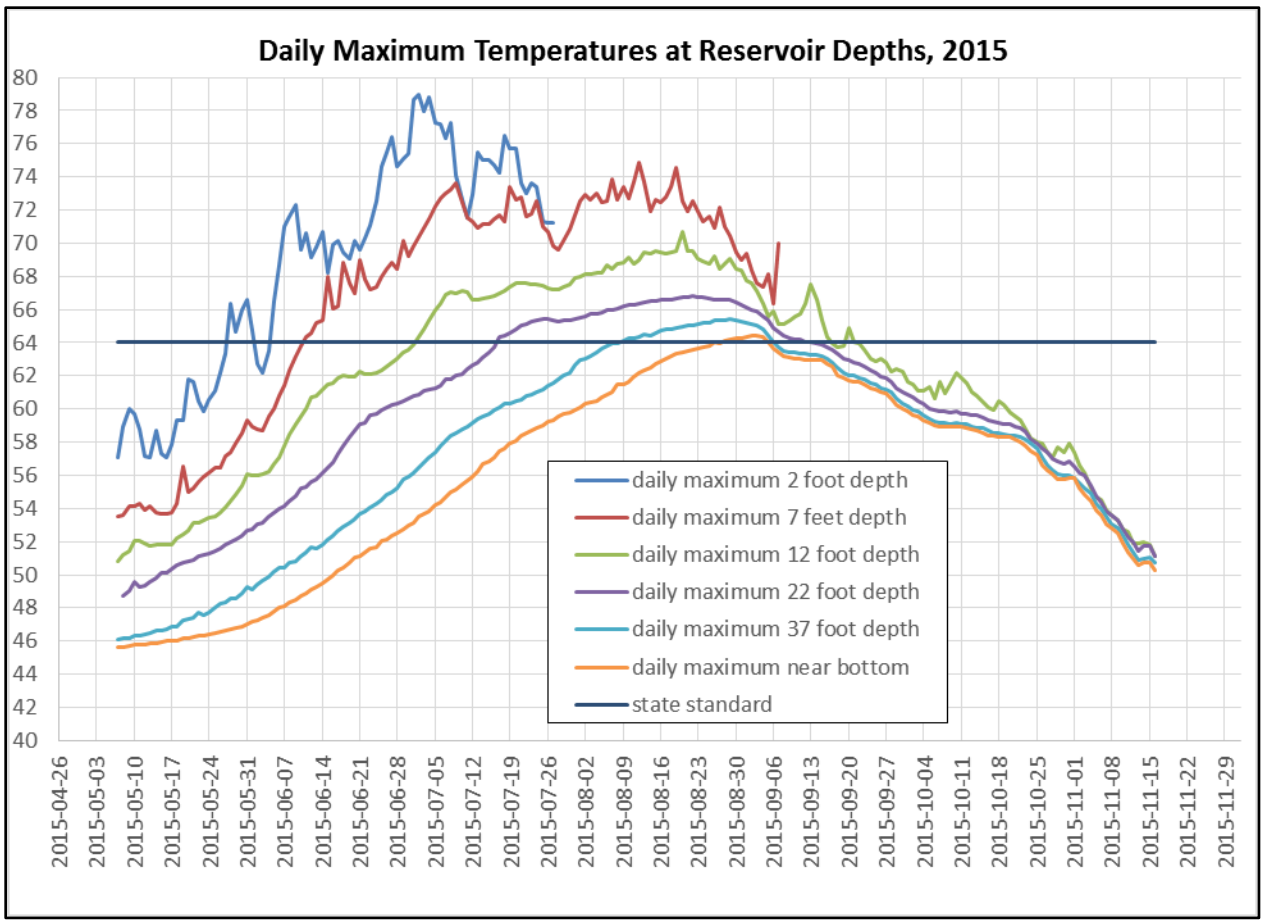
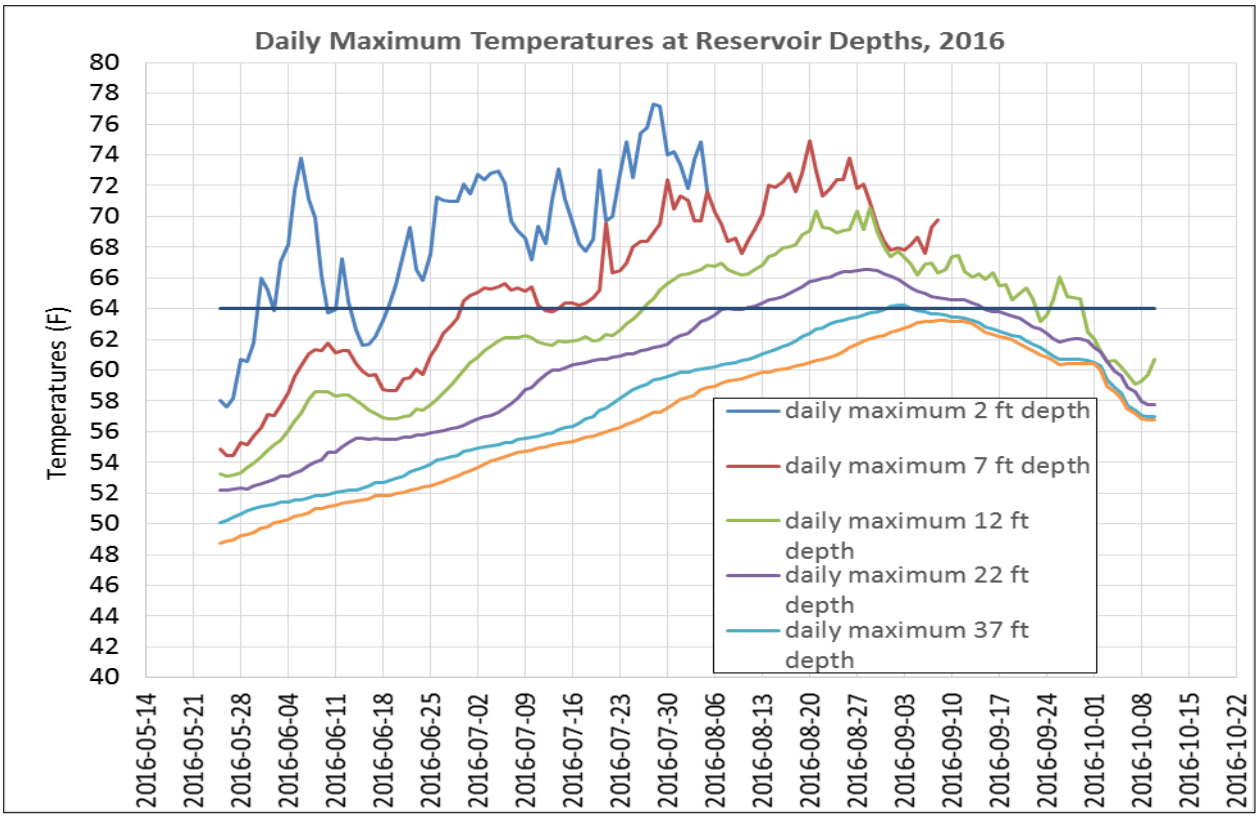


Figure 24: Comparison of temperatures in the reservoir at the monitored depths in 2015. The bottom of the reservoir was slightly above 64F in early September,



Fiure 25. Comparison of temperatures in reservoir at the monitored depths for 2016.

Figure 27 shows the comparison of daily maximum water temperatures around the North and South Fork confluence below the dam for 2015 and 2016.

The increased flows from the dam valve channel are evident downstream in 2016, as compared to 2015. In 2015, the spillway temperature mimics the air temperature trends and the temperatures in the spillway gravel bar (Ste 2169) which is coming out of the surface of the reservoir is simpair to the temperatures in the channel above the confluence (Site 2168). Site 2168 combines the flow from the spillway and the dam valve channel before it joins the South Fork. The temperatures in the Rock Creek mainstem below the confluence (Site 2123) drops over time as the spillway flow decreases.

In contrast, in 2016 the mainstem temperatures are very similar to the channel (Site 2168) just above the confluence. The increased dam valve channel flow is diluting the effect of the spillway in the early summer. Between July 9 and August 27,m the mainstem below the confluence and the dam valve channel are similar in temperature. After August 27, 2016, the dam valve channel is 2 to 4 degrees warmer than the mainstem. Therefore, increased flows from the dam valve channel in late summer and fall are not having a cooling effect downstream.

In all years of monitoring, beginning in early August, the temperatures of the dam valve channel, the bottom of the reservoir, and the mainstem of Rock Creek below the confluence begin to converge, and there isn't much difference between the bottom of the reservoir and the Rock Creek mainstem. After early September, the bottom of the reservoir is actually warmer than the mainstem of Rock Creek (Figures 26 and 27).

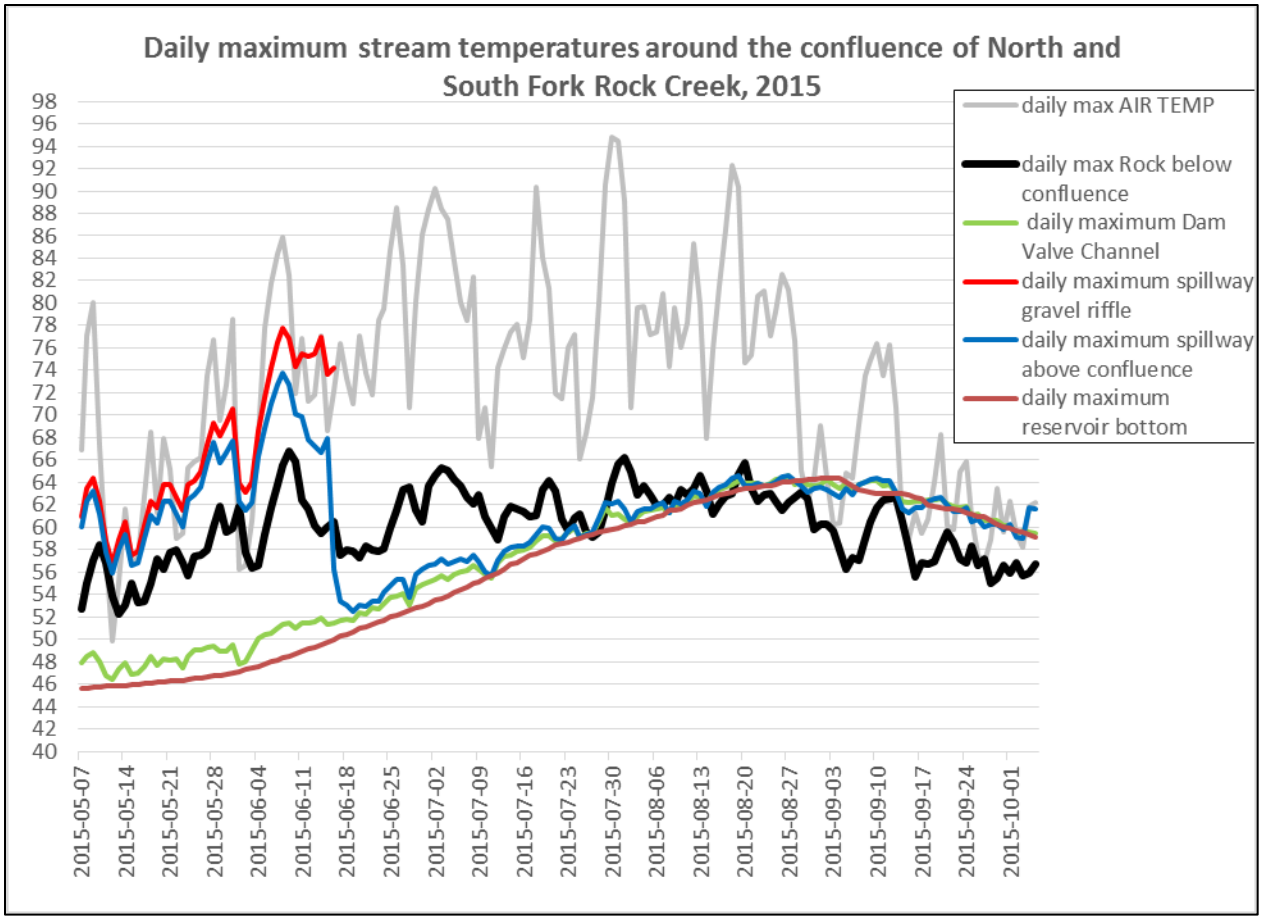


Figure 26: Comparison of daily maximum temperatures in the channels below the dam and around the confluence of the North and South Forks of Rock Creek 2015.

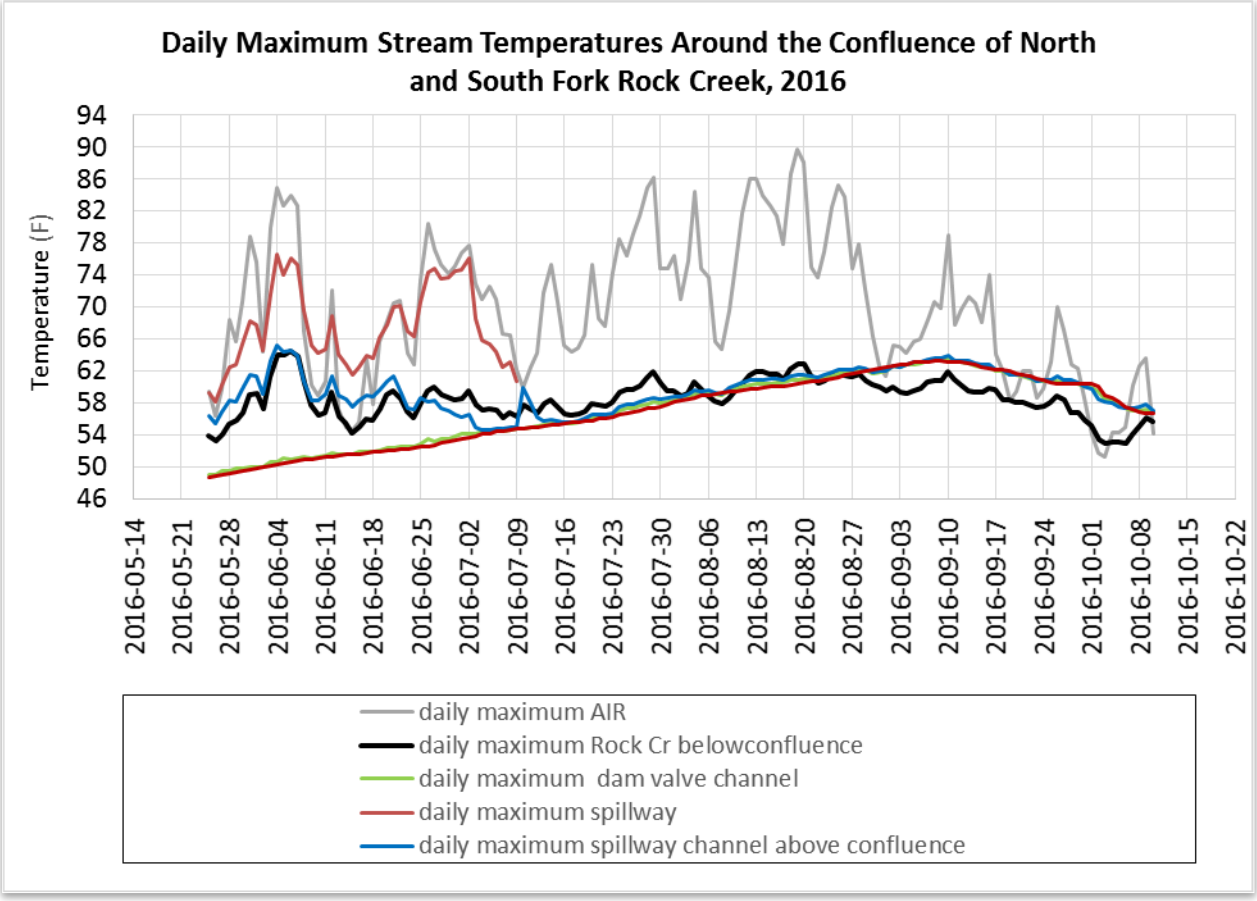


Figure 27.

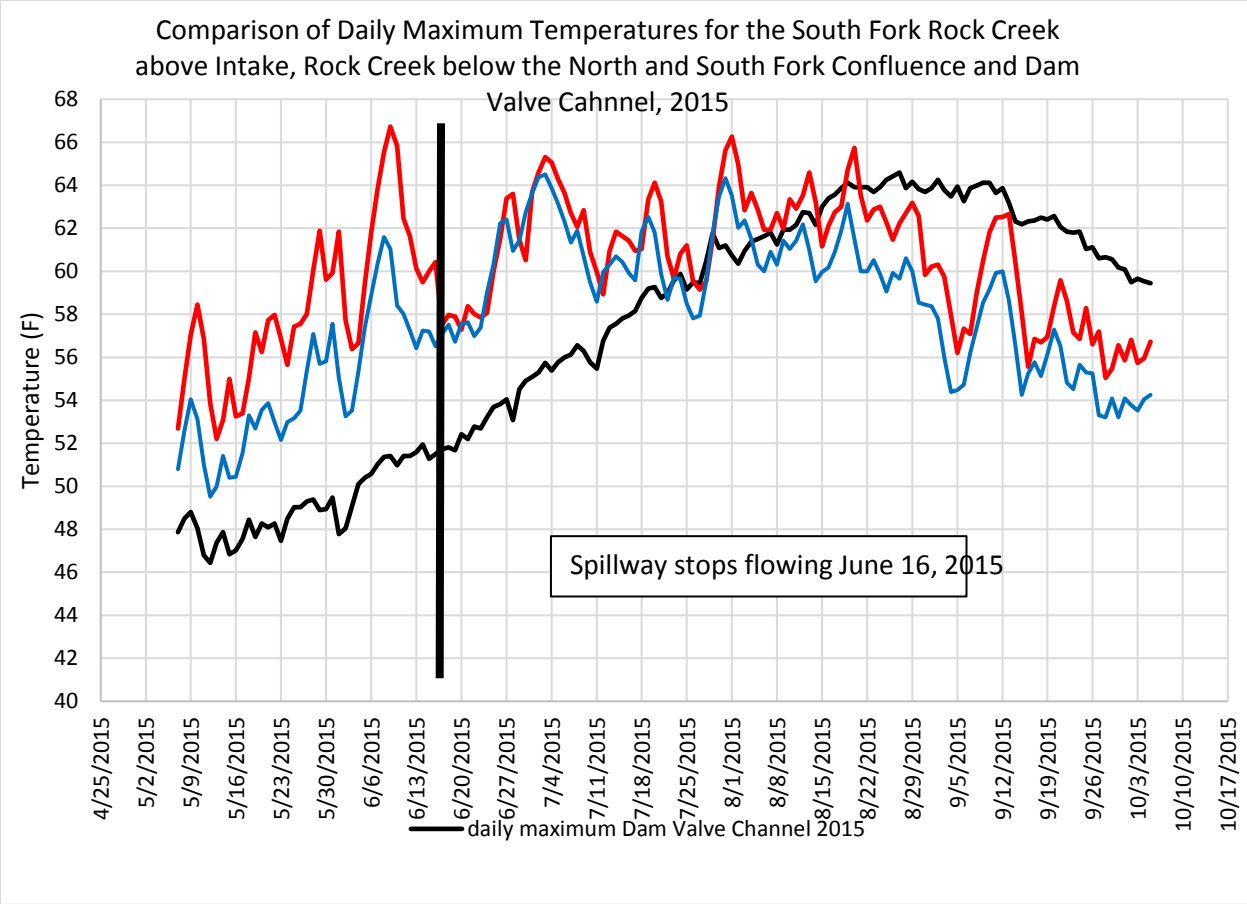
How much heat does the spillway contribute to the Rock Creek mainstem?

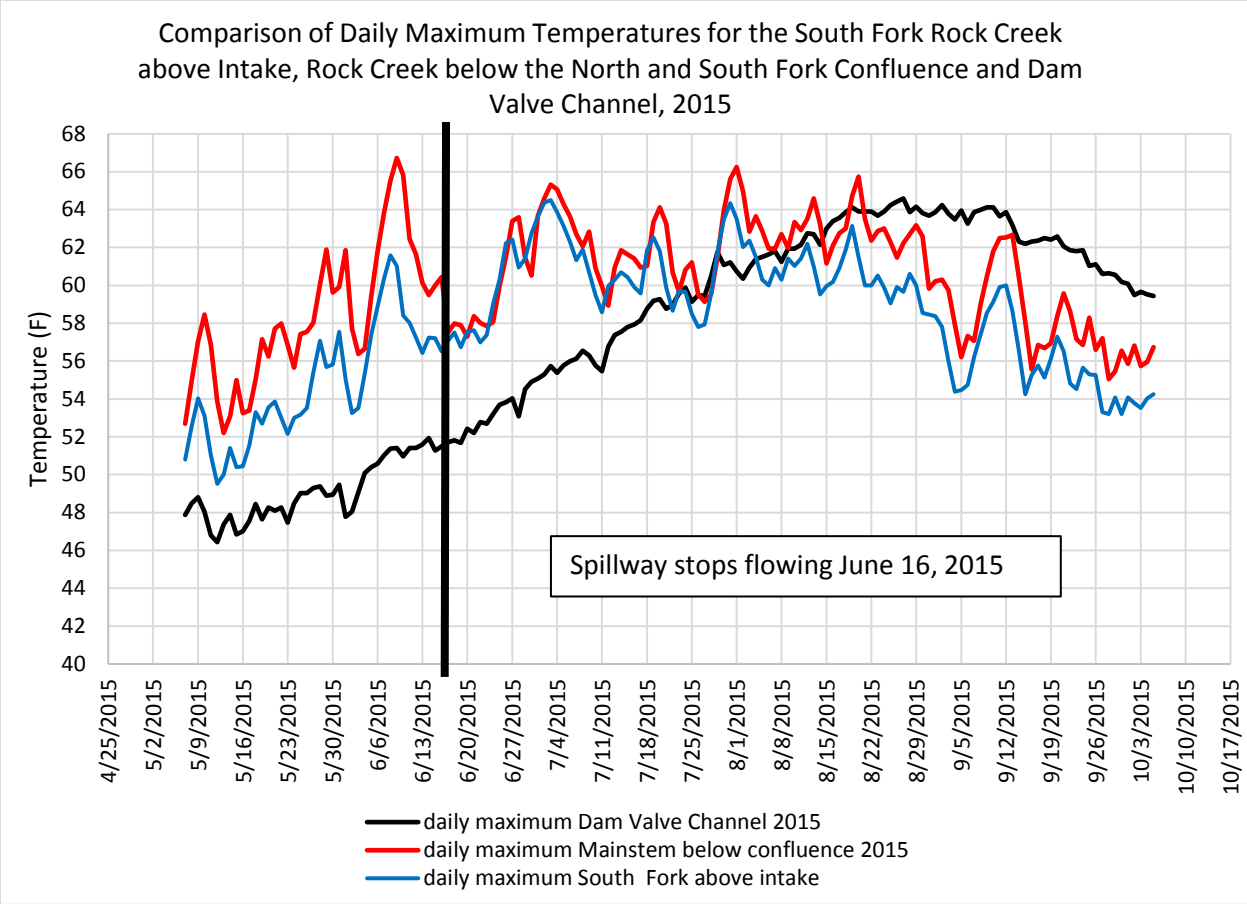
How far downstream can the effect of the spillway be detected in the mainstem stream temperatures below the dam? To analyze this question, the temperature between the South Fork Rock Creek site above the intake was compared to the temperature of sites in the downstream Rock Creek mainstem. If the temperature of the South fork above the intake is compared to the mainstem below the North and South Fork confluence, the temperature difference is greater while the spillway is flowing (Figures 28 and 29). In Figures 30 and 31, the South Fork Rock Creek temperature (daily maximum temperature) above the intake was subtracted from the temperature at the mainstem sites and this difference valve is displayed. These graphs of the difference in temperature (F) shows that there is a decrease in the temperature difference as the spillway flow diminishes. After the spillway flow stopped, daily maximum temperatures below the confluence were closer to the temperatures of the South Fork. There is a distinctive "signature" to the graphs. Can this abrupt decrease in the difference in temperature between sites be seen farther downstream? At what point does the difference in a site's temperature compared to the South Fork before and after the spillway flow stops become similar?

The same method was applied to other sites in the mainstem below the dam to see if this signature drop in the temperature difference persisted downstream. The graphs in the following section (Figure 32) analyzing the differences in temperature 2015 and 2016 show the difference in daily maximum temperature between the Rock Creek mainstem sites and the South Fork above the intake until the spillway stops flowing. A linear trend line was added to the graphs to clarify the trend in the temperature differences.

While the cooler dam valve water lowered temperatures downstream in the spring and early summer, they had the opposite effect in the fall. As reservoir temperatures gradually warmed up through the summer, so did the downstream temperatures as comparied to the South Fork above the intake. (Figures 34 and 35). Note that on Figure 33, the data for 2016, as compared to Figure 34, the 2015 data, the difference between the South Fork and the mainstem (heavy black line) jumps at the beginning of September. The input of warmer temperatures with the higher dam valve channel flow are having an effect downstream.

Results for previous years are discussed in the report for the summer of 2015. Similar results can be seen for the years 2012 through 2015.


Comparison of Daily Maximum Temperatures for the South Fork Rock Creek above Intake, Rock Creek below the North and South Fork Confluence and Dam Valve Cahnnel, 2015
Temperature (F)
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
4/25/2015
5/2/2015
5/9/2015
5/16/2015
5/23/2015
5/30/2015
6/6/2015
6/13/2015
6/20/2015
6/27/2015
7/4/2015
7/11/2015
7/18/2015
7/25/2015
8/1/2015
8/8/2015
8/15/2015
8/22/2015
8/29/2015
9/5/2015
9/12/2015
9/19/2015
9/26/2015
10/3/2015
10/10/2015
10/17/2015
Spillway stops flowing June 16, 2015
daily maximum Dam Valve Channel 2015


Comparison of Daily Maximum Temperatures for the South Fork Rock Creek above Intake, Rock Creek below the North and South Fork Confluence and Dam Valve Channel, 2015
Temperature (F)
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
4/25/2015
5/2/2015
5/9/2015
5/16/2015
5/23/2015
5/30/2015
6/6/2015
6/13/2015
6/20/2015
6/27/2015
7/4/2015
7/11/2015
7/18/2015
7/25/2015
8/1/2015
8/8/2015
8/15/2015
8/22/2015
8/29/2015
9/5/2015
9/12/2015
9/19/2015
9/26/2015
10/3/2015
10/10/2015
10/17/2015
Spillway stops flowing June 16, 2015
daily maximum Dam Valve Channel 2015
daily maximum Mainstem below confluence 2015
daily maximum South Fork above intake

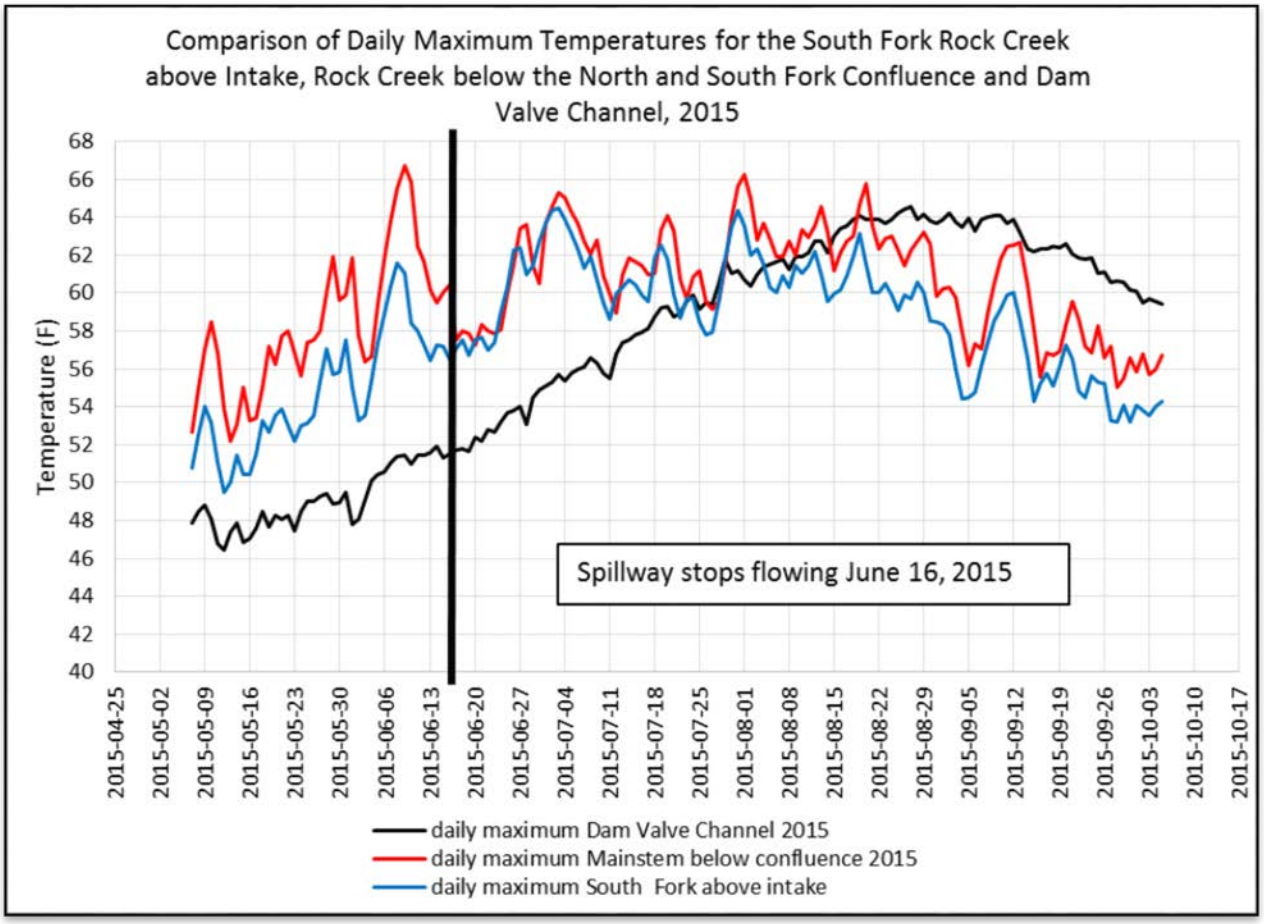


Figure 28. 2015 daily maximum temperatures above and below the influence of the dam and spillway. Note that after the spillway stops flowing on June 16, the difference is less. The dam valve channel has less flow, and therefore, less effect on the temperatures downstream than in 2015. In the late summer and early fall, when the dam valve channel temperatures are higher than the stream temperatures, it doesn't cause as much of a difference between the South Fork and the mainstem below the confluence as in 2016.

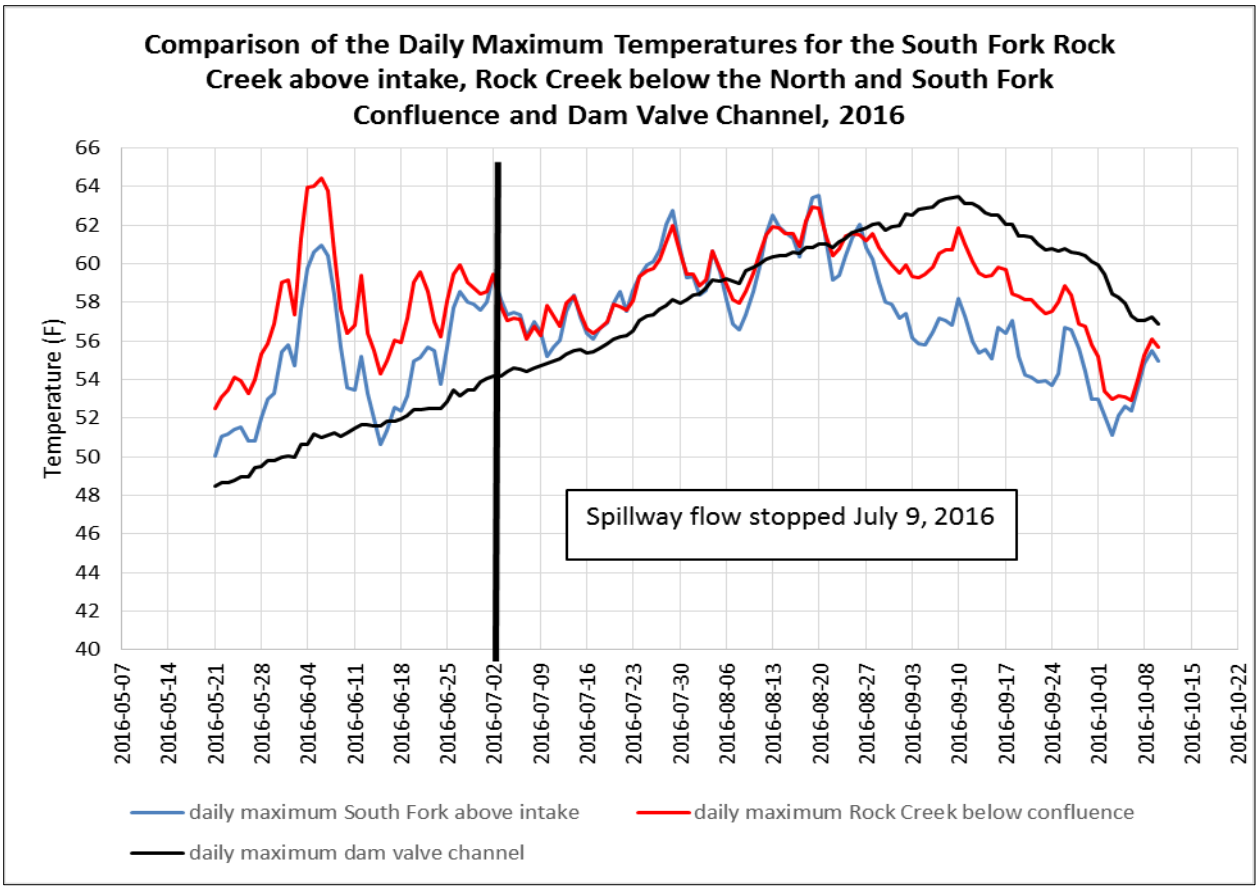


Figure 29. Comparison of daily maximum temperatures at the South Fork above the intake, Rock Creek mainstem below the confluence, and the dam valve channel. Three to four times more water was consistently coming out of the dam valve in the summer of 2016. As a result, when flows drop in the late summer, the flow from the dam valve becomes a bigger portion of the downstream flow. At the same time, the water temperatures at the bottom of the reservoir are gradually heating up. The combination of more water and warmer water from the bottom of the reservoir results in higher temperatures in the mainstem as compared to the South Fork. This effect wasn't seen in previous years when the dam valve flow was much less.

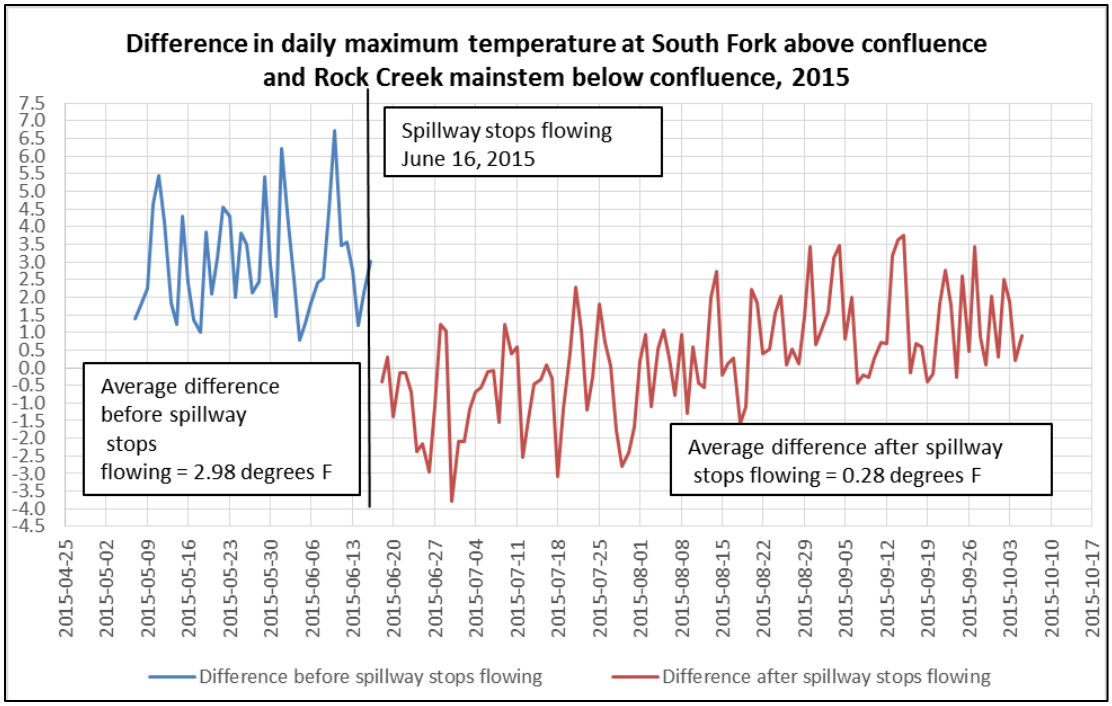


Figure 30. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2015.

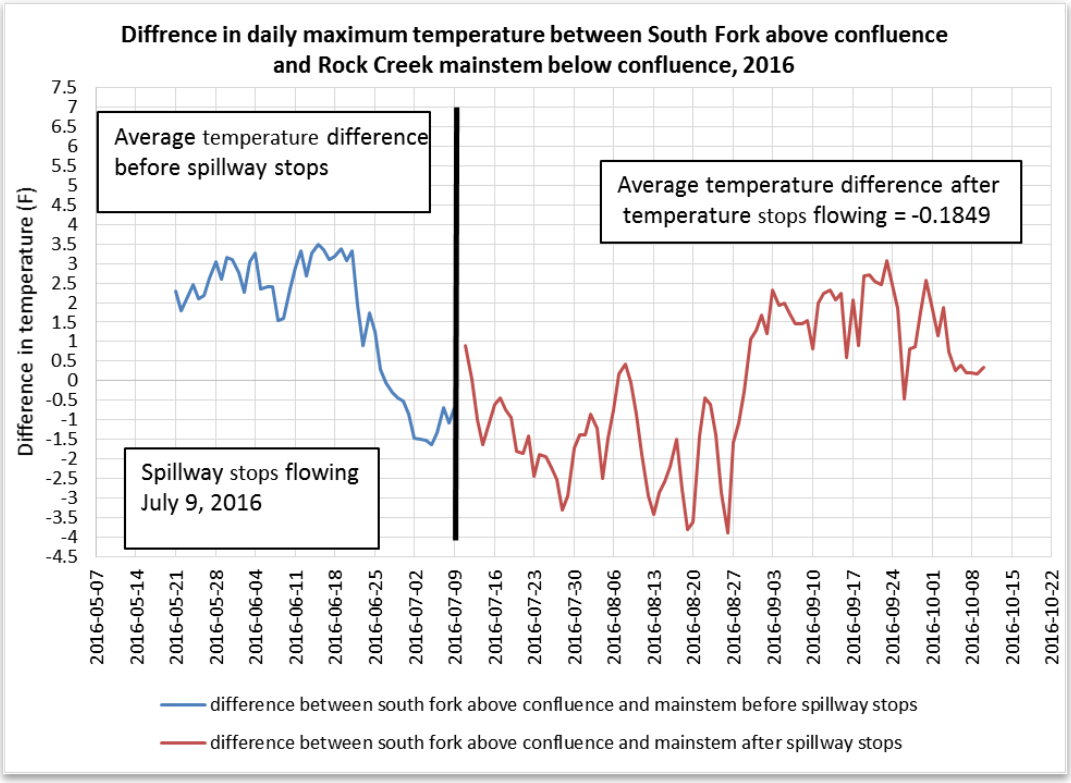
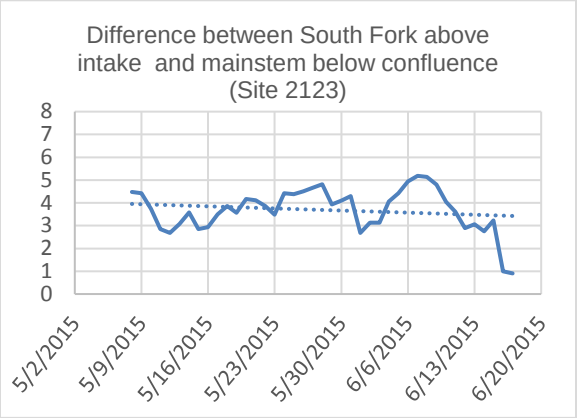
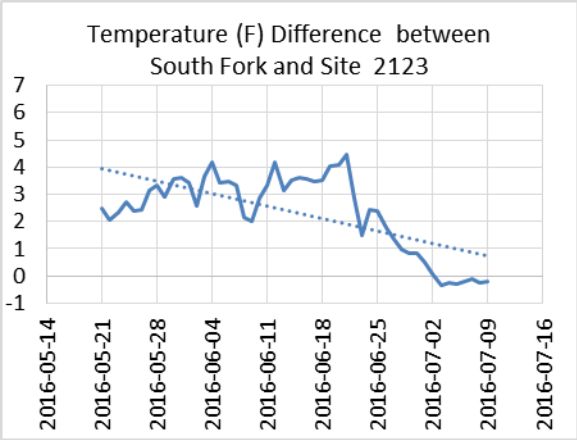


Figure 31. Difference in daily maximum temperatures between the South Fork Rock Creek and the mainstem Rock Creek below the confluence in 2016.

2015 and 2016 Differences between South Fork site above the intake and Rock Creek mainstem sites below the dam

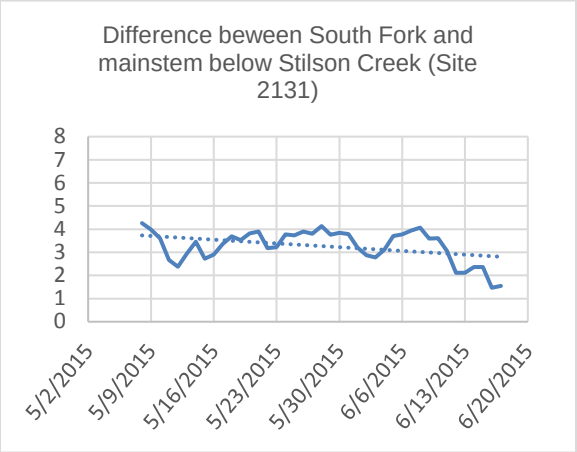


Summer 2015

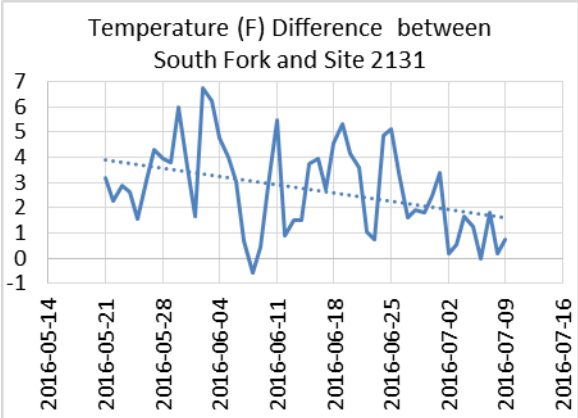


Summer 2016

Figure 32a. Site 2123 is .02 miles downstream from the dam. Drainage area to site 2123 is 8.53 square miles.

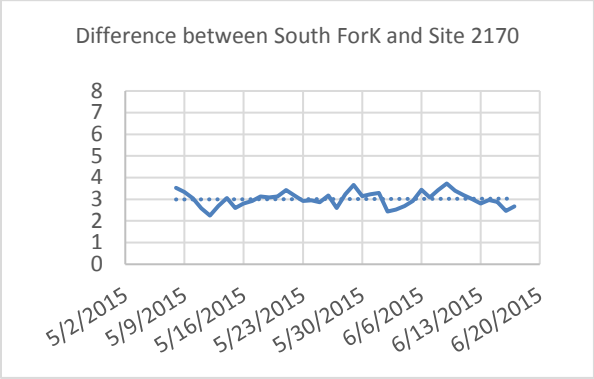


Summer 2015

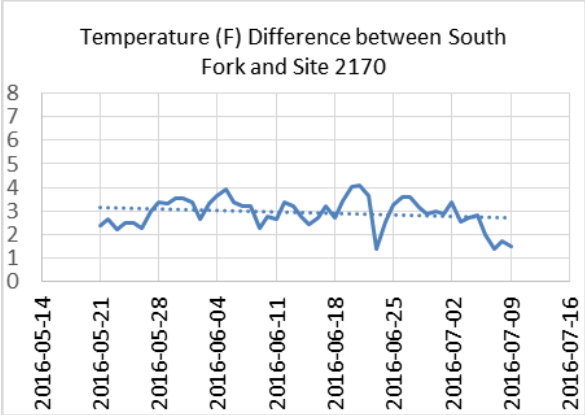


Summer 2016

Figure 32b. Site 2131 is 0.77 miles downstream from the dam. Drainage area to site 2131 is 9.65 square miles.

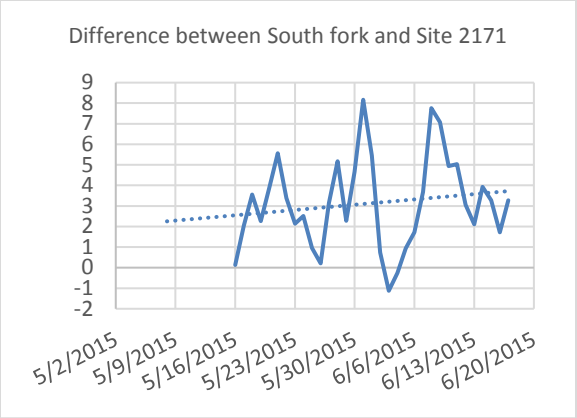


Summer 2015



Summer 2016

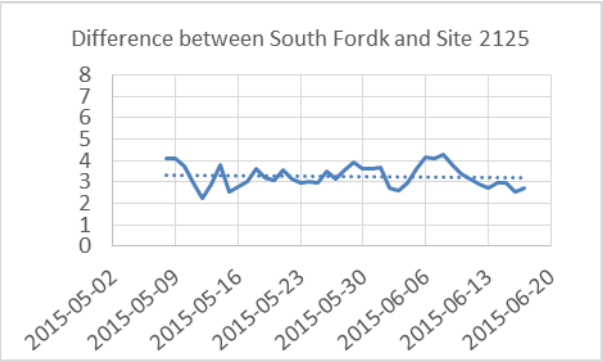
Figure 32c.: Site 2170 is 1.35 miles downstream from the dam. Drainage area to site 2170 is 10.6 square miles.



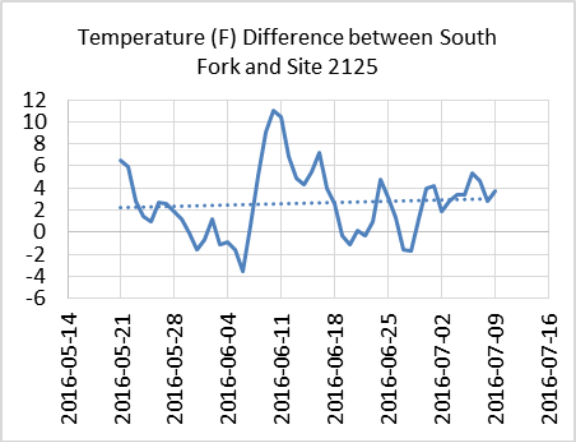
Summer 2015

No data from Summer 2016

Figure 32d. Site 2171 is 1.9 miles downstream from the dam. Drainage area to site 2171 is 10.8 square miles.

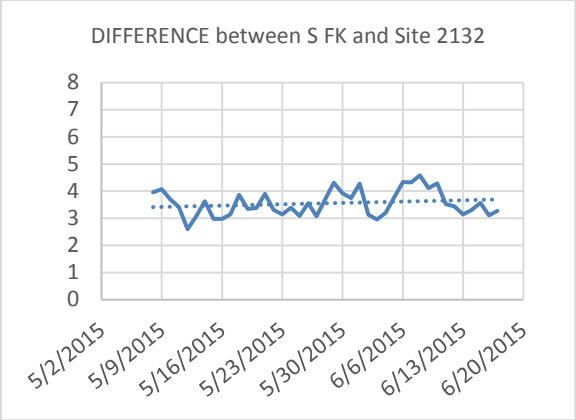


Summer 2015

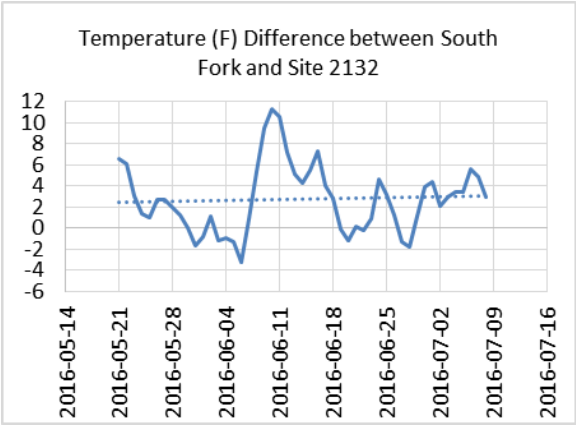


Summer 2016

Figure 32e. Site 2125 is 2.17 miles downstream from the dam. Drainage area to site 2125 is 12.2 square miles.

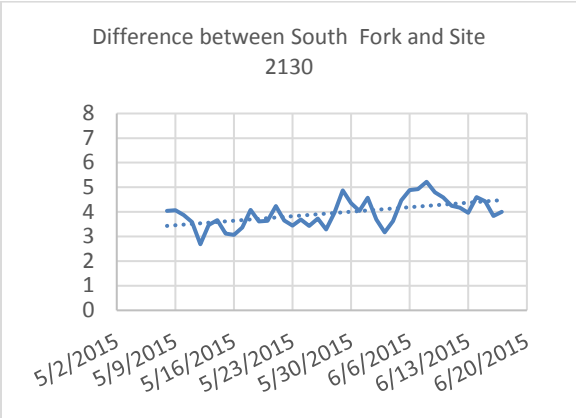


Summer 2015



Summer 2016

Figure 32f. Site 2132 is 2.67 miles downstream from the dam. Drainage area to site 2132 is 12.3 square miles.



Summer 2015

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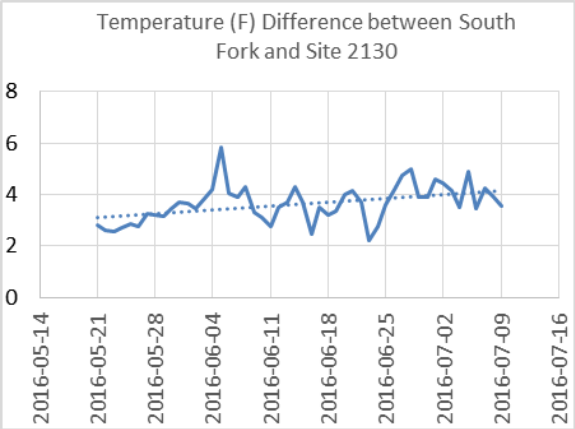
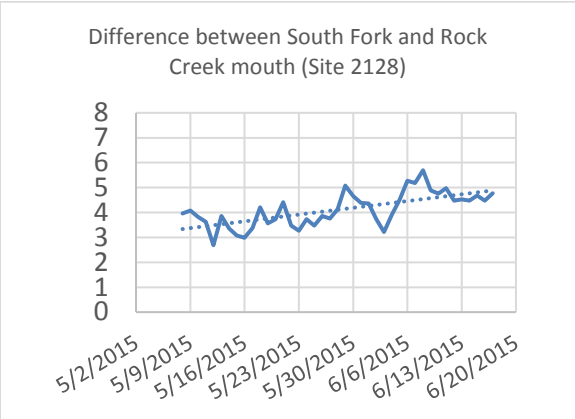
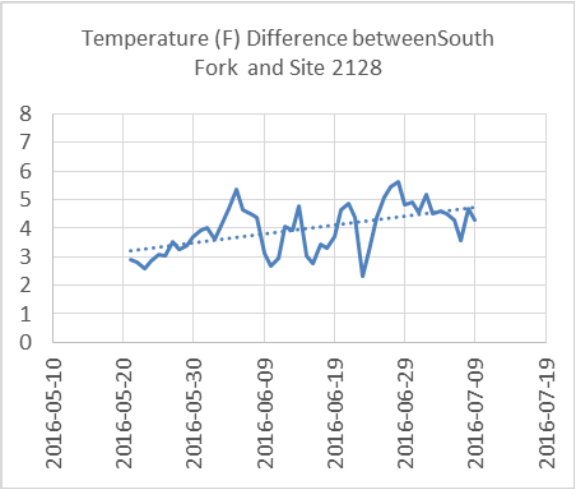


Summer 2016

Figure 32g. Site 2130 is 2.79 miles downstream from the dam. Drainage area to site 2130 is 12.4 square miles



Summer 2015



Summer 2016

Figure 32h. Site 2128 is 3.72 miles downstream from the dam near the mouth of Rock Creek.. Drainage area to site 2128 is 14.8 square miles

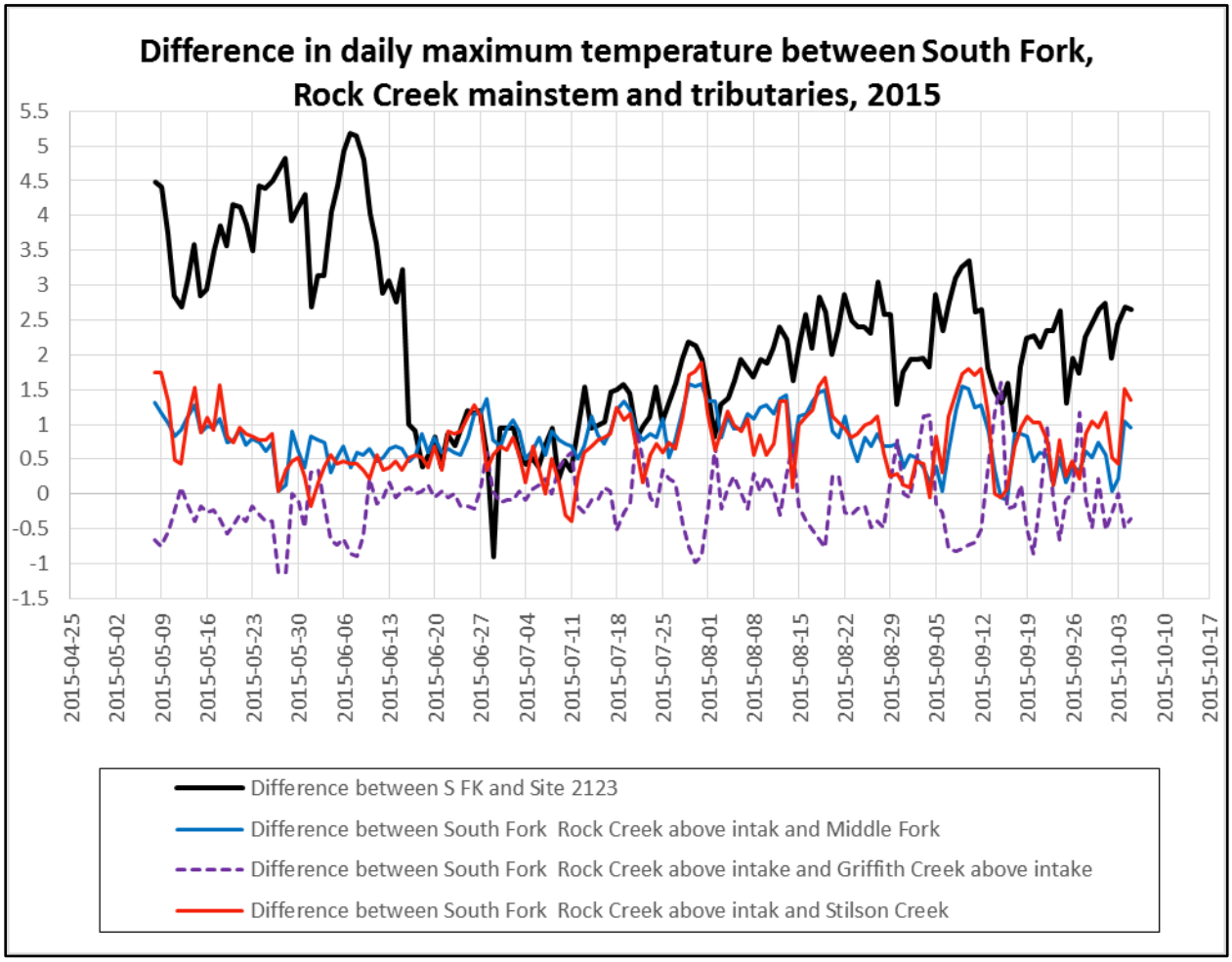


Figure 33. The vertical black dashed line marks the date spillway flow stops. Note the abrupt drop in the difference in temperature between the South Fork Rock Creek and the mainstem after the spillway stops flowing. This decrease in the temperature difference is due to the decrease in the spillway flow contribution downstream. It can be seen as an indicator of the effect of the spillway downstream.

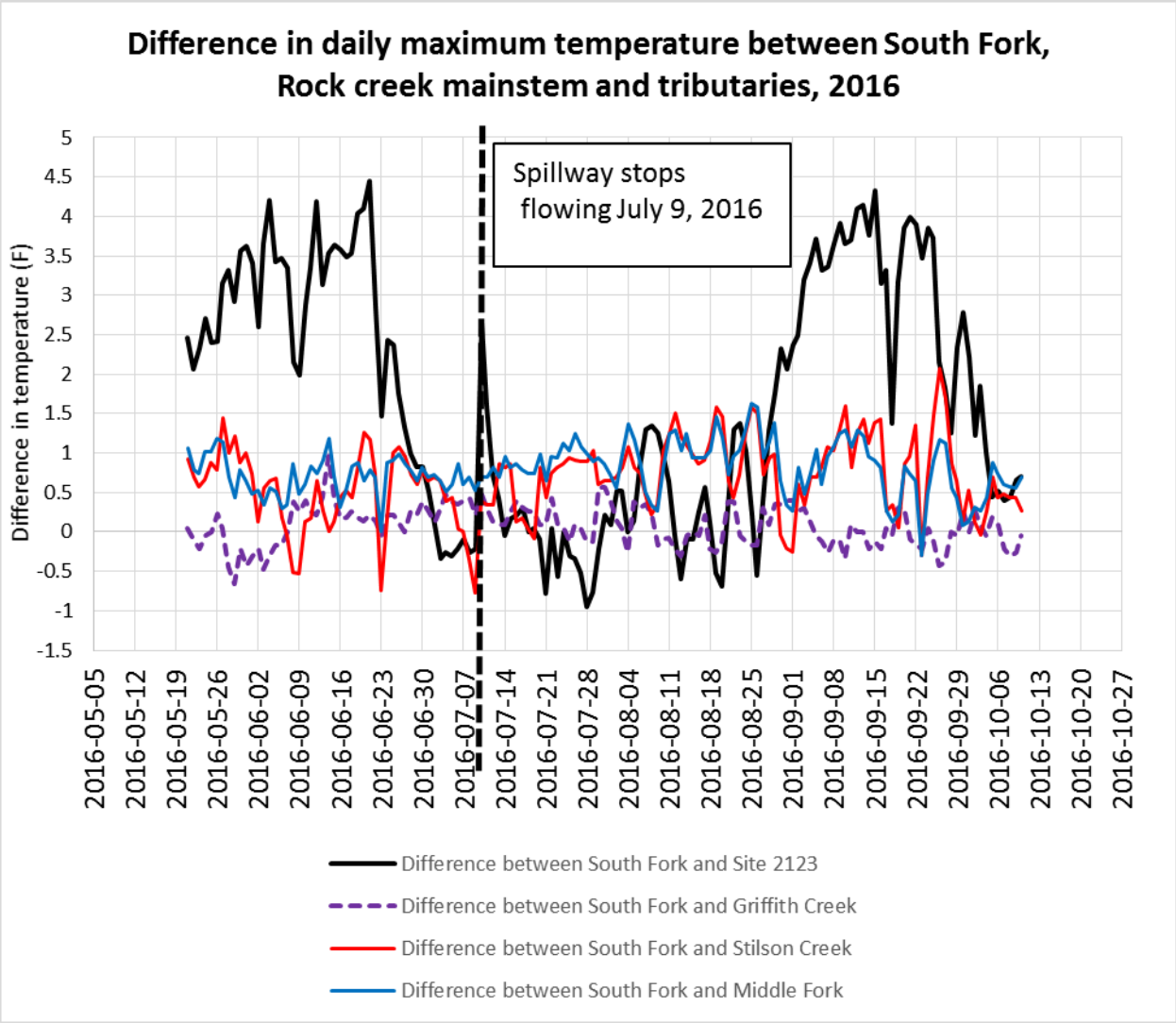


Figure 34: The vertical black dashed line marks the date spillway flow stops. Note the abrupt drop in the difference in temperature between the South Fork Rock Creek and the mainstem after the spillway stops flowing. This decrease in the temperature difference is due to the decrease in the spillway flow contribution downstream. It can be seen as an indicator of the effect of the spillway downstream.

For the past 5 years of data, the effects of the spillway on stream temperature in the mainstem of Rock Creek cannot be detected farther than just past Site 2125, just downstream from the Middle Fork Rock Creek (2.17 miles from the dam). The length of the mainstem where the temperature difference signature can be detected varies by year. For instance, in 2014, which had higher springtime flows, the effects of the spillway were lost between 0.77 and 1.35 miles downstream; in 2015, which had low flows in the spring, the effects of the spillway were detected to approximately 2.17 miles from the dam. ***Even in 2016, when the colder dam valve channel flow during the early summer was three to four times that of previous of years, the effect of the cold water did not persist father than the confluence of the mainstem with the Middle Fork.*** None of the years of data showed an effect of the spillway persisting

to the mouth of Rock Creek. Therefore, alterations to flow management at the dam would not have an effect on on Greasy Creek (Table 8)

Table 8: Summary of the trends in temperature differences between the South Fork Rock Creek above the intake and sites in the Rock Creek mainstem. A downward trend suggests the spillway flow is having an influence, an upward trend suggests that the spillway is not a factor in stream temperatures at that site.

	distance downstream from dam (miles)	Summer 2012	Summer 2013	Summer 2014	Summer 2015	Summer 2016
2123	0.02	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference
2131	0.77	no data	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference	downward trend in temperature difference
2170	1.35	no data	downward trend in temperature difference	upward trend in temperature difference	neutral	downward trend in temperature difference
2171	1.9	no data	upward trend in temperature difference	upward trend in temperature difference	downward trend in temperature difference	No data, probe at 2171 not deployed.
2125	2.17	upward trend in temperature difference	neutral	neutral	slightly downward trend in temperature difference	upward trend in temperature difference
2132	2.67	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference
2130	2.79	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference
2128	3.72	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference	upward trend in temperature difference

Summary and Conclusions

As in past years, the regional climatic trends are reflected in the stream temperatures and flow amounts recorded in the Corvallis Watershed. According the National Oceanic and Atmospheric Administration (NOAA), 2015 was the warmest summer on record for Oregon, and was 4.6°F above normal. In the Corvallis Watershed, the summer of 2015 had the warmest stream temperatures since monitoring began in 2010. For most of the summer of 2016, air temperatures in the watershed were cooler than the previous year, although late May and summer temperatures were similar. Precipitation in the early Spring was higher in 2016 than 2015, but the late spring and summer precipitation was similar for both years. Overall, the 7-day average of the daily maximum temperature was slightly cooler in 2016 than in 2015 throughout the watershed.

The main factor that was different between the two years was the increased flow from the bottom of the reservoir (the dam valve channel) in 2016. The increased flow due to a leaky valve created a natural experiment to see what effect increased flows of water from the reservoir bottom would have on downstream temperatures. The temperature difference between the South Fork Rock Creek above the intake, and the sites in the mainstem of Rock Creek below the dam were analyzed, as they were in past years. Similar to past years, the difference in temperatures between the South Fork and immediately below the dam decreased as spillway flow decreased , with the effect diminishing with distance. No effect from the dam, either from the spillway or the dam valve channel was detected past the confluence of the mainstem with the Middle Fork of Rock Creek in 2016, similar to past years. Therefore, the increased release of cold water in the early part of the summer from the bottom of the dam hs no discernable effect on the mainstem past the Middle Fork, and any benefit from cold water releases did not reach the mouth of Rock Creek.. Also, the bottom of the reservoir gradually heats up during the summer, and at the end of the summer, the bottom of the reservoir is warmer than the mainstem immediately below the dam. The combination of increased flows from the dam valve channel and the higher late summer temperatures in the bottom of the reservoir resulted in higher-than-expected temperatures in the mainstem directly below the dam.