Yellowhawk Stream Temperature Analysis: 2010-2013 versus 2001

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Introduction:

High summertime water temperatures in Yellowhawk Creek, tributary to Mill Creek in the Walla Walla River Basin, are a limiting factor for salmonid restoration and water quality. To improve summer water temperatures, as well as other water quality variables, riparian restoration projects were performed in the cities of Walla Walla and College Place between 2008 and 2014 (WA State Department of Ecology, grant number G0800137: "Creating Urban Riparian Buffers"). Several riparian restoration projects were conducted along Yellowhawk Creek. Available water temperature data spanning from 2001 to 2013 were examined from the source near the diversion dam to the mouth of the creek to determine if water temperature has changed after the implementation of riparian restoration.

The purpose of this analysis was to determine if high summertime temperatures show a reduction after the implementation of these riparian restoration projects. Since 2007, there have been nine projects undertaken for Yellowhawk Creek under the CURB project, covering a total of 6,985 linear feet, or 4.63 acres. Additional projects were conducted under other programs (J. Johnson, personal communication). The data used in this analysis were collected using temperature loggers deployed by the Walla Walla Basin Watershed Council (WWBWC) and the Washington Department of Fish and Wildlife (WDFW). We compare temperature data from 2001 (WDFW 2002) to the years 2010-2013 (WWBWC unpublished data) in order to assess the benefits of riparian planting in reducing stream temperatures.

Assumptions:

Two assumptions were made conducting this data analysis: 1) data sets spanning the different years of record were assumed to be comparable across years (i.e. there were no substantial differences in measurements at different logger recording locations across studies and agencies); and 2) these water temperature data represented independent observations across years.

Methods:

The data were acquired from continuously recording HOBO temperature loggers deployed by the WDFW (WDFW 2002) and the WWBWC (unpublished data). Water temperature was recorded continuously at 30-minute intervals. The WDFW provided data from 2001, to which we compared the WWBWC's data from 2010 through 2013. Although the loggers recorded temperatures year-round, we only queried data from July 1st through September 30th to examine the warmest temperatures of the year. However, for the source of Yellowhawk Creek, the only available data were collected during the summers of 2001 and 2013. Data were only available starting July 25, 2013 for this location, so for this test, we limited the dates examined to July 25 to September 30.

The data from 2001 comes from the WDFW's temperature loggers placed at the mouth of Yellowhawk Creek (46.01763°, -118.40032°), and at the source (46.07479°, -118.27394°). The data from 2010 through 2013 comes from the WWBWC's logger located near the mouth at the stream flow measurement gage (46.019130°, -118.399477°). The data from the source in 2013 was measured as part of the monitoring plan under the CURB study and was located near the Assumption Catholic Church near Tausick Way (46.067345°, -118.288260°).

The daily maximum temperatures (°C) between July 1 and September 30 were compared for this analysis as these are the most extreme values during the year. We expected maximum summertime temperature to have the greatest response to riparian restoration due to solar inputs. The data were tested for normality using a Shapiro test in R version 3.1.1 (R Core Team 2014). None of the temperature data met the assumption of normality; therefore, a Wilcoxon test in R was used to compare these data across years. One-tailed tests were performed to identify if a statistically significant reduction in stream temperature could be detected spanning this time period. Each recent year (2010, 2011, 2012, and 2013) was compared to 2001 in separate tests.

Data were also gathered for the following variables: stream discharge (cfs) located at the temperature logger managed by the WWBWC, air temperature (°F) and precipitation. Climate data (air temperature and total precipitation) were acquired from the NOAA site at the Whitman Mission (NOAA 2014). The within year correlation between these data sets were examined to understand the relationship between these variables and stream temperature. Correlations were performed in Excel. The stream flow and stream temperature data were compared as daily average values measured between June 1 and September 30. The climate data was compared as monthly average air temperature and total monthly precipitation to monthly average water temperature.

Results and Discussion:

Stream temperatures were about 2°C lower at the mouth of Yellowhawk Creek than at the source. This reduction in stream temperature is likely due to spring creek and groundwater inflows through the study area. Water temperatures are high in Mill Creek where the diversion into Yellowhawk Creek is located. Therefore, the spring inflows are important in reducing stream temperatures and improving salmonid habitat.

Recent years showed a slight reduction in stream temperature (-0.8°C) when comparing 2010, 2011 and 2012 to 2001; however, 2013 showed a slight increase across years (+0.5°C). Comparisons across the years at the mouth of Yellowhawk Creek were significantly lower comparing 2010, 2011 and 2012 to 2001 (Table 1). The comparisons between 2013 and 2001 were not statistically significant at the mouth or the source of Yellowhawk Creek (Table 1). Similarly, when we examined the number days exceeding 20°C and 17.5°C across the years and sites, 2013 had more days with higher temperatures than were measured in 2001 (Table 2). In summary, the stream temperature in Yellowhawk Creek was lower in 3 out of the 4 comparisons tested.

To accurately test the efficacy of riparian treatment, we need to account for other variables acting on stream temperatures, such as air temperature, precipitation, and stream flow. Although climate cannot be controlled, years can be scanned for air and precipitation measures that are comparable to the 2001 data set. Summertime air temperatures (number of days ≥ 90°F), and total precipitation (inches) are shown in Figure 1 for the years examined in our comparisons. These data indicate that 2013 was the hottest year examined, followed by 2001. For precipitation, 2010 and 2013 were the wettest summers, and 2011 and 2012 were the driest summers of the years considered. Stream flow varied significantly among years (Table 3).

Correlations among the co-dependent variables indicate that climate could be driving the observed results. Air temperature and stream temperature were highly correlated with r^2 ranging from 0.92 to 0.99. Stream flow (cfs) and total monthly precipitation were inversely and moderately correlated with stream temperature ranging from -0.47 in 2012 to 0.68 in 2011 for stream flow and -0.53 in 2012 to -0.98 in 2013 for total precipitation. Therefore, the data indicates that air temperature is a strong driver in measured stream temperatures, and it is likely that the reduced temperatures measured are due to inter-annual variation in climatic variables. Certainly, cloud cover, precipitation, stream flow and air temperature are inter-related factors.

Recently implemented riparian restoration projects (2012 – 2014) likely have not had enough time to mature; therefore additional effects to temperature could be measured in the future. Furthermore, additional riparian restoration along the Yellowhawk Creek could result in more temperature reductions. Certainly, when considering these individual small projects on city lots, numerous projects are likely needed to see measureable shifts in stream temperature.

Effectiveness monitoring of the riparian restoration projects would provide better study design than the examination of archival data sets as performed in this analysis. Effectiveness monitoring would be implemented to collect pre-treatment data prior to the implementation of restoration projects, and subsequently post-treatment data after the project reaches a completed, or functional, state. Stream flow is controlled at into Yellowhawk Creek and related to measured stream temperatures. Therefore, stream flow could be held constant for test periods to remove the effect of inter-annual variation in this variable. Additionally, other landscape elements can also be influencing stream temperature such as water/ withdrawals, properties that remove riparian shading during this time period and any other loss of riparian vegetation. Monitoring of the state and status of the landscape between the measurement points is necessary to understand the relative effect of restoration treatments.

Overall, it appears that in most years examined maximum daily stream temperatures show a significant reduction during the 3 of the 4 years examined. Other factors such as air temperature are likely exerting a strong influence on stream temperature and preclude a true test of the hypothesis that the riparian restoration projects have a direct influence on the stream temperatures measured during this time period. Certainly, more restoration projects and better monitoring data will assist in identifying if restoration efforts are translating into stream temperature benefits.

Table 1. Mean daily maximum summertime stream temperatures (°C) and p-values for the Wilcoxon tests for years 2001, 2010-2013. Temperatures measure at the mouth include dates from July 1 to September 30, temperatures at the source include dates from July 25 to September 30.

Year	2001	2010	2011	2012	2013
			Source		
Mean Daily Max	21.88960	ND	ND	ND	22.23106
P-value					0.95
			Mouth		
Mean Daily Max	19.92174	19.22391	19.08696	19.14130	20.39022
P-value*	-	0.032	0.0028	0.022	0.98

*tested against the 2001 mean value

Table 2. Number of days above 20°C and above 17.5°C (State of Washington criteria for salmonid rearing) for years 2001, 2010-2013. Temperatures measured at the mouth include dates from June 1 to September 30, temperatures measured at the source include dates from July 25 to September 30.

Year	2001	2010	2011	2012	2013
			Source		
# days > 20°C	51	ND	ND	ND	55
# days > 17.5°C	61	ND	ND	ND	62
			Mouth		
# days > 20°C	52	44	28	44	72
# days > 17.5°C	88	74	82	78	94

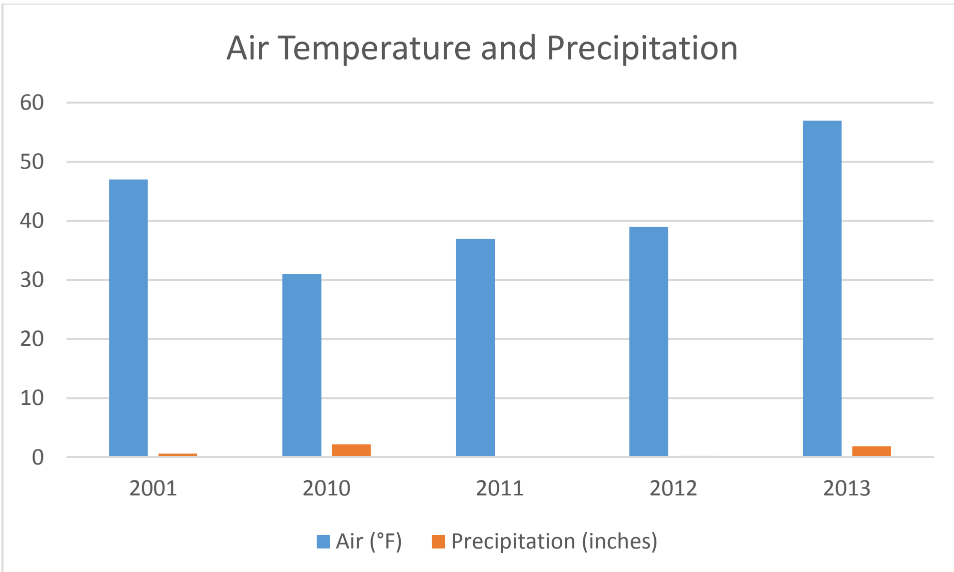
Table 3. Mean daily discharge and p-value for the t-tests measured at the mouth of Yellowhawk Creek between July 1 and September 30.

Year	2010	2011	2012	2013
Mean Value	12.66260	23.11053	15.95308	16.39096

P-Value*	-	< 0.001	< 0.001	< 0.001

*tested against the 2010 mean value

Figure 1. Number of days that air temperature exceeded or equaled 90°F for years 2001, 2010, 2011, 2012, and 2013; total precipitation from July through September of years 2001, 2010, 2011, 2012, and 2013.



Citations:

National Oceanic and Atmospheric Administration (NOAA). 2014.
http://www.ncdc.noaa.gov/cdo-web/datasets/ANNUAL/stations/COOP:459200/detail

Washington State Department of Fish and Wildlife (WDFW). 2002. Assessment of Salmonids and Their Habitat Conditions in the Walla Walla River Basin within Washington, Project No. 1998-02000, submitted to Bonneville Power Administration. 142 pages.

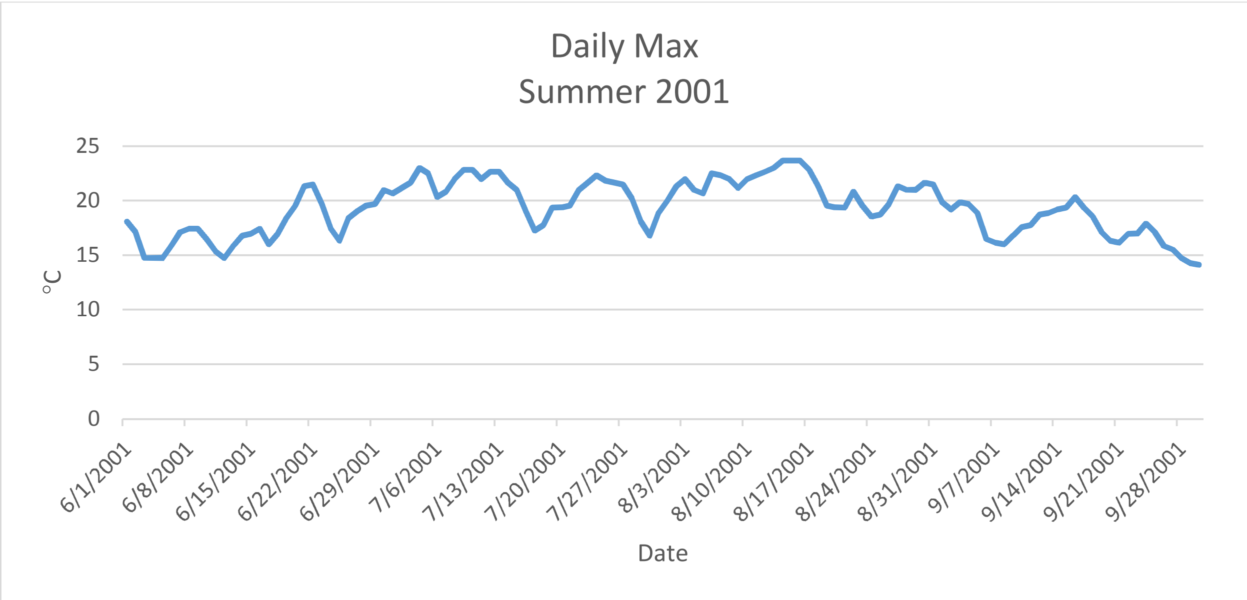
Washington State Department of Ecology (DOE). 2007. Walla Walla River Tributaries Temperature Total Maximum Daily Load Study, Publication No. 07-03-014. https://fortress.wa.gov/ecy/publications/publications/0703014.pdf

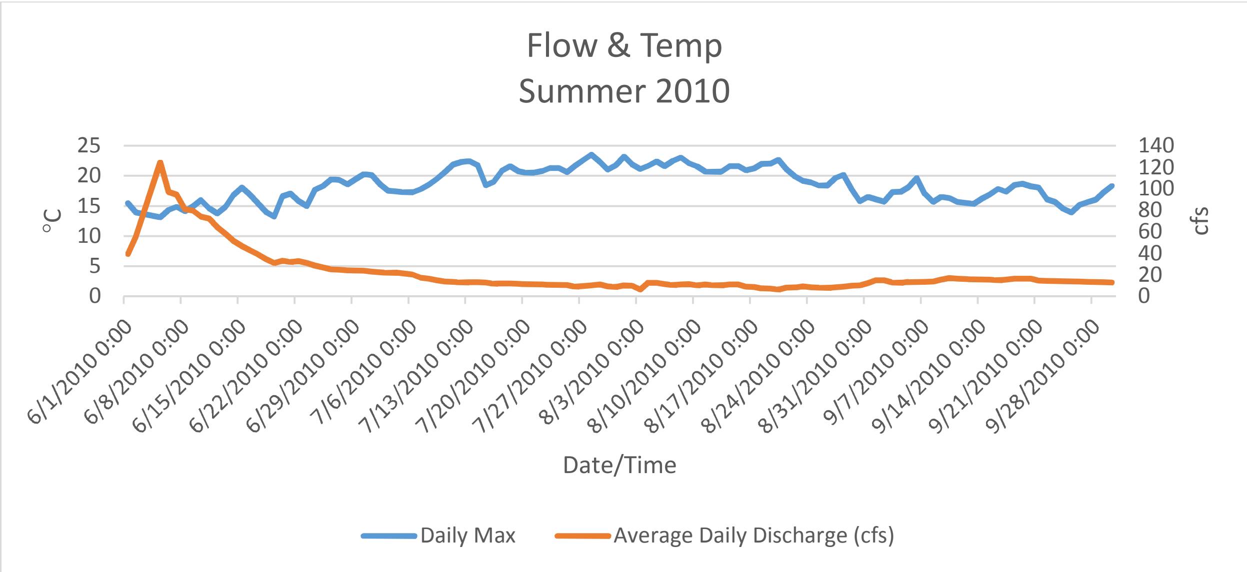
R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

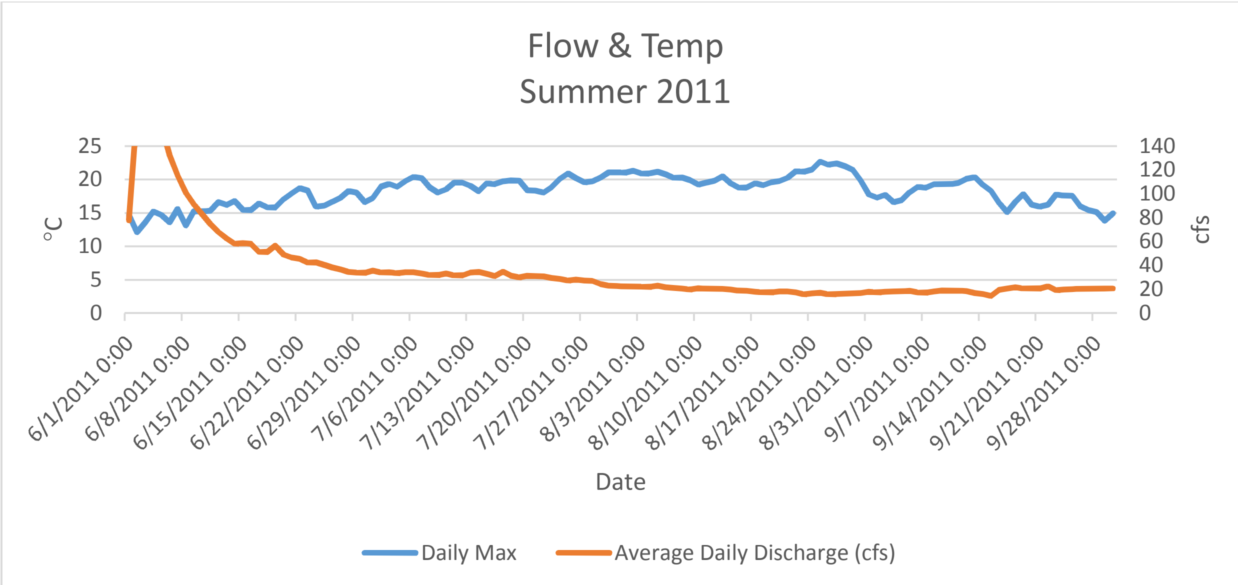
Appendix A.

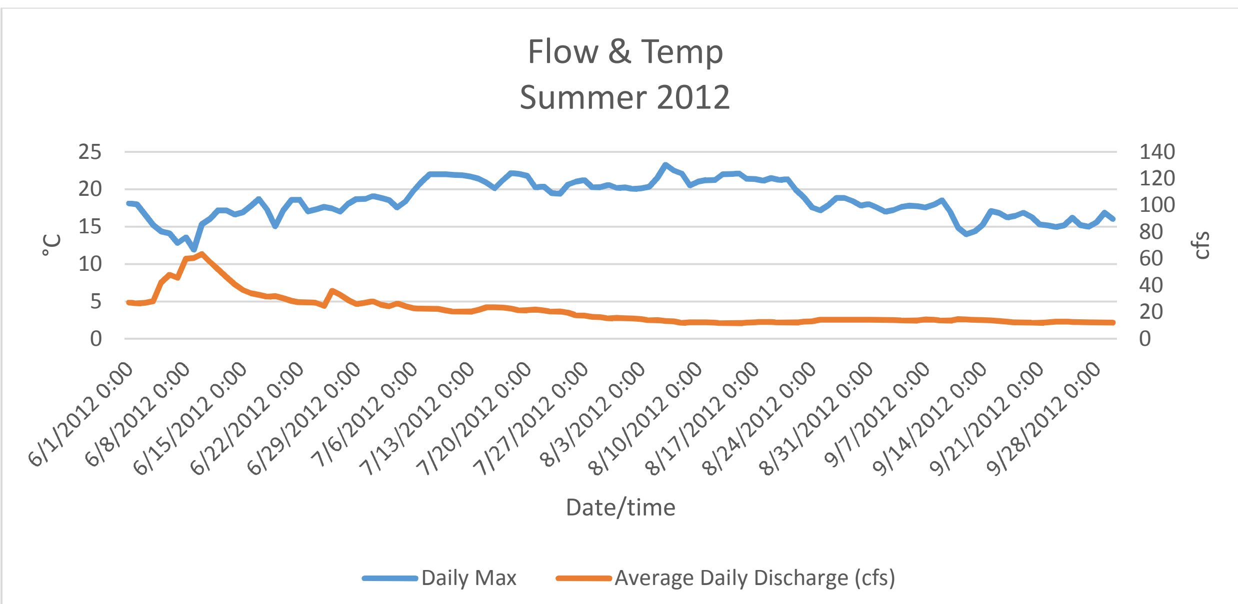
Summertime logger data, 2001, 2010, 2011, 2012, 2013

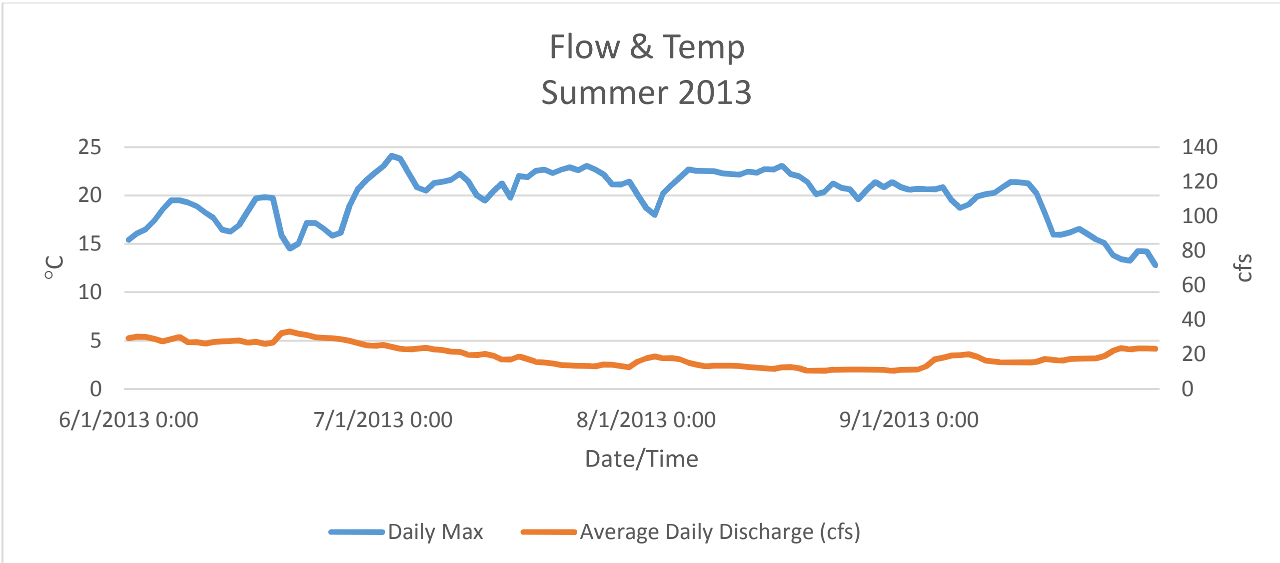
June 1 – September 30






Flow & Temp
Summer 2011
25
20
15
10
5
0
°C
140
120
100
80
60
40
20
0
cfs
6/1/2011 0:00
6/8/2011 0:00
6/15/2011 0:00
6/22/2011 0:00
6/29/2011 0:00
7/6/2011 0:00
7/13/2011 0:00
7/20/2011 0:00
7/27/2011 0:00
8/3/2011 0:00
8/10/2011 0:00
8/17/2011 0:00
8/24/2011 0:00
8/31/2011 0:00
9/7/2011 0:00
9/14/2011 0:00
9/21/2011 0:00
9/28/2011 0:00
Date
Daily Max
Average Daily Discharge (cfs)


Flow & Temp
Summer 2012
25
20
15
10
5
0
°C
140
120
100
80
60
40
20
0
cfs
6/1/2012 0:00
6/8/2012 0:00
6/15/2012 0:00
6/22/2012 0:00
6/29/2012 0:00
7/6/2012 0:00
7/13/2012 0:00
7/20/2012 0:00
7/27/2012 0:00
8/3/2012 0:00
8/10/2012 0:00
8/17/2012 0:00
8/24/2012 0:00
8/31/2012 0:00
9/7/2012 0:00
9/14/2012 0:00
9/21/2012 0:00
9/28/2012 0:00
Date/time
Daily Max
Average Daily Discharge (cfs)



Flow & Temp
Summer 2013
25
20
15
10
5
0
°C
140
120
100
80
60
40
20
0
cfs
6/1/2013 0:00
7/1/2013 0:00
8/1/2013 0:00
9/1/2013 0:00
Date/Time
Daily Max
Average Daily Discharge (cfs)

Appendix B.

Air temperature and precipitation data, 2001, 2010-2013

Year	2001	2010	2011	2012	2013
# days ≥ 90°F	47	31	37	39	57
Total Precipitation, 7/1-9/30	0.60 in.	2.19 in.	0.10 in.	0.26 in.	1.88 in.