Salmonberry River Temperature Monitoring

STEP Project Progress Report 2011

Mainstem station below Belfort Creek, showing flagging at cable attachment point (Joyce Sherman photo).

Summary: Water temperature loggers were placed at 10 sites in the summers of 1994-1997, 2004, 2007, and 2008, and at 14 sites in 2009-2011. The lowest seven miles of the mainstem exceed DEQ's core cold water habitat standard, even in cool summers such as 2010 and 2011. The site near the Salmonberry mouth exceeded the DEQ core cold water habitat temperature standard for 76 days in 2009, 41 days in 2010, and 61 days in 2011. Four of the seven monitored tributaries have recorded seven-day average daily maximum temperatures above the DEQ standard. A test of 1-hour and 2-hour recording intervals was performed in 2011. A recommendation of changes needed to meet DEQ "A" level data quality is included.

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10/4/2011

1. Introduction

The Salmonberry River is known for its run of wild winter steelhead, regarded as one of the healthiest runs on the West Coast. The Salmonberry also supports Chinook salmon, coho salmon, cutthroat trout, and rainbow trout (an isolated population in the North Fork headwaters). The South Fork of the Salmonberry was designated as "Salmon Anchor Habitat" by the Oregon Department of Forestry (this designation has since been changed to "Aquatic Anchor Habitat". Relatively healthy watersheds such as the Salmonberry are critical to long-term survival of salmonids, and ongoing monitoring is essential.

A STEP project was started in 1993, with the goal being long-term monitoring of winter steelhead spawning and summer water temperatures. Spawning surveys have been conducted every year; temperature monitoring has occurred in the summers of 1993 through 1997, 2004, and 2007-2011.

During the period we have been monitoring the Salmonberry, two major weather events have reshaped the landscape. In February 1996 a severe rain-on-snow event occurred. Of the monitored sites, Wolf Creek and Kinney Creek experienced debris torrents that removed miles of riparian vegetation. By contrast, Pennoyer Creek, the North Fork, and the South Fork saw relatively little damage. Other tributaries, notably Tunnel Creek and Bathtub Creek, also experienced debris torrents. The main stem was channelized. The Port of Tillamook Bay Railroad was severely damaged; repairs required about $12 million.

In December of 2007 a severe 3-day rain event occurred. Most of the tributaries that were slowly recovering from the 1996 flood were scoured again. In addition, the South Fork was damaged, as was the lowest mile of the North Fork. The main stem was much channelized, and deep pools were filled in. Observers who have seen the results of both events agree that the 2007 flood was worse. The POTB Railroad was damaged to such an extent that repairs will not be attempted; the estimate exceeded $50 million.

2. Acknowledgements

Numerous organizations have provided support for this project over the years. The Oregon Department of Fish and Wildlife North Coast District Office is the STEP sponsor. The STEP Advisory Committee approved a grant in 2008 that allowed the purchase of additional data loggers. Oregon Department of Environmental Quality has provided valuable technical assistance. Marty and Joyce Sherman started the project, and have remained involved throughout. Volunteers, without whom there would be no data, have come from Americorps, Clark-Skamania Flyfishers, Native Fish Society, Northwest Steelheaders, Oregon Trout, Rainland Flycasters, Sierra Club, and Trout Unlimited.

3. Equipment and Methodology

Until 2008, ODFW provided Onset Hobo® temperature loggers, with resolution of 0.1^{o} C. Accuracy is unknown, but is probably ±0.5^{o} C. Beginning in 2008, we have been using NexSens® model 1921G loggers purchased by ODFW for dedicated use by the project team, with resolution of 0.5^{o} C and accuracy of ±1^{o} C. In 2008 the project was awarded a STAC mini-grant, and we purchased 10 additional NexSens® model 1921G loggers. These were deployed at additional sites beginning in 2009. See "5. Locations".

The resolution of the NexSens® loggers is not sufficient to meet DEQ "A" level data quality. The limited memory of the loggers allows readings every two hours over the course of a summer, but not every hour, which also causes the data to miss "A" level quality. For those reasons, we are planning to seek grant money to replace the 1921G loggers with another model that can use the same waterproof housing and software but allows more frequent readings and has resolution/accuracy sufficient to meet DEQ "A" level data quality.

See “9. Recording Frequency Test” for an estimate of the number of days where the maximum daily temperature can be missed with 2-hour readings compared to hourly readings.

Data loggers are placed following standard protocols (OWEB, 1999; Dunham et al, 2005). Turbulent, well-mixed sites are selected. Placement is as close to the thalweg as possible. Data loggers are shielded from direct sunlight by white PVC housings. They are anchored with a rock and duct tape, and secured with cable to a log, root wad, or to a second rock. A plastic plant nursery tag, inscribed “Temperature monitor attached-please do not disturb” with permanent marker, is attached to the anchor end of the cable (away from the data logger). See Figures 1 and 2.

Fig. 1 (left). Data logger inside protective housing, with anchor, ready to be placed in the water. Fig. 2 (right). Cable anchoring method used when there is no convenient root wad or other structure for securing the cable. In this case, the cable anchor is placed in the water behind a boulder upstream of the anchored data logger, or at a secure spot on the bank.

Since 2004, when the data suggested that several sites had become dewatered, sites in small tributaries are visited at least once during August to check water levels.

4. Quality Control and Data Storage

Handheld thermometers (alcohol in glass tubes) with 1ºC graduations are used to check temperatures at placement and retrieval. They are also used in midsummer checks. With handheld, non-certified thermometers and two-hour reading intervals, this process is of limited value. Beginning in 2010, the handheld thermometers were checked against a NIST-traceable digital thermometer provided by DEQ.

Currently we use cool (~10ºC) and warm (~20ºC) water baths pre-deployment and post-deployment to check accuracy of the data loggers, using a NIST-traceable thermometer provided by DEQ, following the procedures in OWEB (1999).

All procedures have been changed to comply with the quality assurance requirements for OWEB/DEQ “A” quality data. A quality assurance plan will be produced. As discussed above, with the current set of data loggers, the “A” level quality standard cannot be met, as “A” level requires instrument accuracy of ±0.5ºC. Nevertheless, we have instituted procedures to meet all other requirements so that all procedures are in place when the current loggers are replaced. The data will meet “B” level standards and will be eligible for uploading to DEQ’s LASAR database following DEQ approval.

After downloading, data are checked for anomalies. The most likely is a period of extreme highs and lows, corresponding to a period when the site was dewatered and the logger was recording air temperatures. This occurred at three sites in 2004. In this case, the data were retained and marked, but not used in reporting. A related situation occurs when a stream comes close to dewatering, when a high proportion of the surface flow is made up of groundwater percolating out. This situation shows up in the data as relatively cool temperatures with little daily variation. In those cases, data are used in reporting.

Data are stored in Microsoft Excel spreadsheets on the hard drive of a personal computer, and backed up to an external hard drive. Both drives are stored at the author's home (contact ian.fergusson@comcast.net). Data are uploaded to the ODFW Data Clearinghouse (https://nrimp.dfw.state.or.us/dataclearinghouse/default.aspx?p=1) annually. Reports can also be found at that site.

5. Locations

14 sites are monitored: seven main stem sites (three were added in 2009) and seven tributary sites (two were added in 2009). One site, on the North Fork, is monitored with two separate data loggers, for redundancy. In Table 1, "River Mile" refers to main stem sites only, and measurement begins at the river mouth. "Miles from Divide" refers to the hydrologic length of the primary stream channel down to the monitoring site, tracing the primary channel from the closest point on the topographic divide. National Geographic TOPO® software was used.

Table 1. Salmonberry River temperature monitoring sites.

Number	Site Name	River Mile (Main stem)	Miles From Divide	Stream Order	Site Established
1	Main stem above Pennoyer Cr.	13.9	5.4	2nd	1994
2	Pennoyer Cr.		3.2	2nd	1994
3	Wolf Cr.		4.6	3rd	1994
4	Main stem below Wolf Cr.	11.7	7.6	4th	1994
5	Kinney Cr.		2.6	3rd	1994
6	Main stem above North Fork	8.5	10.8	4th	2009
7	North Fork (main)		8.6	4th	1994
8	North Fork (backup)		8.6	4th	2009
9	Main stem below North Fork	8.2	11.1	5th	1994
10	Bathtub Cr.		2.1	2nd	2009
11	South Fork		3.4	3rd	1994
12	Main stem below South Fork	6.5	12.7	5th	2009
13	Belfort Cr.		2.1	2nd	1994
14	Main stem below Belfort Cr.	3	16.3	5th	1994
15	Main stem above mouth	0.3	19.2	5th	2009

The map in Appendix A shows monitor locations, keyed to the numbers in Table 1.

We do not have complete data for each site for each year. Over the course of the project, 5 monitors have been lost. Occasional battery failures have occurred. Some data are missing for unknown reasons. All data from the 4 sites monitored in 1993 are unusable, as the launching process tagged the beginning dates as 1/1/1980. Since the begin date represents the date the device was turned on in the ODFW office (date unknown), and field notes relating to placement and retrieval dates were lost, there is no way to associate the 1993 temperatures with exact dates.

In 2004, 3 monitors (upper main stem, Kinney Cr., and South Fork) recorded temperatures so high relative to other sites and other years that the data are suspect and have not been included in analyses. The likely explanation is that they were placed in areas where the water went underground, and the monitors were recording air temperatures.

Table 2. Data availability by year.

Name	1994	1995	1996	1997	2004	2007	2008	2009	2010	2011
Mainstem Above Pennoyer Cr.	X	X	X	X		X	X	X	X	X
Mainstem Below Wolf Cr.	X	X	X	X		X	X	X	X	X
Mainstem above North Fork								X	X	X
Mainstem Below North Fork	X	X	X	X		X	X	X	X	X
Mainstem Below South Fork								X	X	X
Mainstem Below Belfort Cr.	X	X	X	X			X	X	X	X
Mainstem At Mouth								X	X	X
Pennoyer Creek	X	X	X	X	X	X	X	X	X	X
Wolf Creek	X	X	X	X	X		X	X	X	X
Kinney Creek	X	X		X		X	X	X	X	X
North Fork	X	X	X	X	X		X	X	X	X
North Fork backup								X	X	X
Bathtub Creek								X	X	X
South Fork	X	X	X			X	X	X	X	X
Belfort Creek	X	X		X		X	X	X	X	X

X=good data; solid box = missing or suspect data

6. Objectives and Criteria

The primary reasons for gathering temperature data are to determine if summer water temperatures meet the requirements for salmonid spawning and rearing, and whether any discernible temperature trends exist.

Oregon DEQ has designated the Salmonberry main stem and tributaries as "core cold-water habitat" (http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230a.pdf). The DEQ "Core Cold Water Habitat" standard (16^{o} C), is defined as the upper limit for core juvenile salmonid rearing habitat (except for bull trout). The pertinent wording in the Oregon Administrative Rules (340-041-0028 (4) (b)) is "*The seven-day-average maximum temperature of a stream identified as having core cold water habitat use…may not exceed 16.0 degrees Celsius (60.8 degrees Fahrenheit)*."

The DEQ salmonid spawning criterion is 13^{o} C (55.4^{o} F; governed by OAR 340-041-0028 (4) (a)). This standard applies to the Salmonberry main stem and the tributaries shown on DEQ's salmon and steelhead spawning use map (http://www.deq.state.or.us/wq/rules/div041/fufigures/figure230b.pdf). Relevant spawning use periods for the Salmonberry are Sep 1 – Jun 15 for the main stem, Oct 15 – Jun 15 for Bathtub Creek and Wolf Creek, and Nov 1- Jun 15 for Kinney Creek, South Fork, and North Fork. Since we generally deploy the monitors from late May or early June through mid-September, there is little overlap with designated spawning periods. However, violations of the standard within those limited periods might indicate a need to extend the monitoring periods.

The seven-day moving average of the daily maximum temperatures (abbreviated 7DADM) helps avoid the results being unduly affected by the maximum temperature of a single day. The 7DADM reflects an average of maximum temperatures that fish are exposed to over a week-long period. It is calculated as the average of the current day and the previous six days.

7. Results Relative to EPA/DEQ Standards

A. Cold Water Habitat Standard

Table 2. Salmonberry River Main Stem: number of days in excess of DEQ Core Cold Water Habitat Standard (16°C; 60.8°F), and maximum recorded 7DADM

		RM 13.9 Above Pennoyer	RM 11.7 Below Wolf	RM 8.5 Above N Fork	RM 8.2 Below N Fork	RM 6.5 Below S Fork	RM 3 Below Belfort	RM 0.3 Above Mouth
1994	Days > 16°C	0	0	M	0	M	**26**	M
	Max 7DADM	14.1	15.9	M	15.5	M	**17.9**	M
1995	Days > 16°C	0	0	M	0	M	**23**	M
	Max 7DADM	13.5	15.7	M	15.9	M	**17.8**	M
1996	Days > 16°C	0	**6**	M	**7**	M	**51**	M
	Max 7DADM	14.1	**16.4**	M	**16.9**	M	**19.4**	M
1997	Days > 16°C	0	**6**	M	0	M	**47**	M
	Max 7DADM	13.8	**16.3**	M	15.9	M	**18.5**	M
2004	Days > 16°C	M	M	M	M	M	M	M
	Max 7DADM	M	M	M	M	M	M	M
2007	Days > 16°C	0	0	M	0	M	M	M
	Max 7DADM	13.3	15.2	M	15.4	M	M	M
2008	Days > 16°C	0	0	M	**2**	M	**33**	M
	Max 7DADM	14.2	15.5	M	**16.2**	M	**18.1**	M
2009	Days > 16°C	0	**15**	**27**	**20**	**29**	**61**	**76**
	Max 7DADM	16.0	**17.6**	**19**	**18.4**	**19.6**	**21.6**	**23.3**
2010	Days > 16°C	0	0	0	0	**20**	**33**	**52**
	Max 7DADM	14.3	15.6	15.7	15.4	**16.7**	**17.9**	**19.6**
2011	Days > 16°C	0	0	0	0	**4**	**41**	**61**
	Max 7DADM	14.1	15.1	15.6	15	**16.1**	**17.9**	**19.1**

Even in relatively cool summers such as 2010 and 2011, the lowest 7 miles of the main stem routinely exceed the core cold-water habitat standard.

Table 3. Salmonberry River Tributaries: number of days in excess of DEQ Core Cold Water Habitat Standard (16°C; 60.8°F), and maximum recorded 7DADM

		Penn. Cr	Wolf Cr	Kinney Cr	North Fork	Bathtub Cr	South Fork	Belfort Cr
1994	Days > 16°C	0	0	0	0	M	0	0
	Max 7DADM	14.3	14.4	12.6	15.1	M	13	12.9
1995	Days > 16°C	0	0	0	0	M	0	0
	Max 7DADM	14.2	14.3	13	15.3	M	13.2	13.2
1996	Days > 16°C	0	**12**	M	**3**	M	0	M
	Max 7DADM	14.8	**16.9**	M	**16.2**	M	13.7	M
1997	Days > 16°C	0	**15**	**11**	0	M	M	0
	Max 7DADM	14.2	**16.8**	**16.2**	15.5	M	M	13.1
2004	Days > 16°C	0	0	M	0	M	M	M
	Max 7DADM	14.5	14.7	M	13.7	M	M	M
2007	Days > 16°C	0	M	0	M	M	0	0
	Max 7DADM	13.7	M	15.4	M	M	13.2	13.5
2008	Days > 16°C	0	0	0	0	M	0	0
	Max 7DADM	14.1	15.4	15	15.3	M	14.1	14.9
2009	Days > 16°C	0	**13**	**5**	**18**	**9**	0	0
	Max 7DADM	15.9	**17.4**	**16.3**	**18.4**	**17.0**	15.3	15.9
2010	Days > 16°C	0	**3**	0	0	0	0	0
	Max 7DADM	14	**16.1**	14.8	15.8	15.4	13.9	14.2
2011	Days > 16°C	0	0	0	0	0	0	0
	Max 7DADM	13.1	15.7	14.5	15.1	14.6	13.5	14.2

M=no data

B. Salmonid Spawning Standard

Relevant spawning use periods are Sep 1 – Jun 15 for the main stem; Oct 15 – Jun 15 for Bathtub Creek and Wolf Creek, and Nov 1- Jun 15 for Kinney Creek, South Fork, and North Fork. Our monitoring periods overlap these only slightly; nevertheless, the 13°C standard is exceeded routinely in the main stem, and rarely in the tributaries. The periods exceeding the standard are after Sep 1. We have observed Chinook in the mainstem in September, but it is not known whether they are spawning at that time, or are merely using the Salmonberry as a temporary refuge from even higher Nehalem River temperatures.

Table 4. Salmonberry River Main Stem - Days DEQ Spawning Standard exceeded (before 6/15 and after 9/1)

	Total Number of Days DEQ Spawning Standard (13 °C; 55.4°F) Exceeded													
	Above Pennoyer		Below Wolf		Above N Fork		Below N Fork		Below S Fork		Below Belfort		Above Mouth	
Year	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1	≤ 6/15	≥ 9/1
1994 (6/6-9/24)	0	0	0	4	M	M	0	4	M	M	0	24	M	M
1995 (4/24-9/23)	0	0	0	21	M	M	0	23	M	M	0	23	M	M
1996 (6/3-9/21)	0	0	0	14	M	M	0	17	M	M	4	19	M	M
1997 (5/25-9/24)	0	0	0	16	M	M	0	16	M	M	5	18	M	M
2004 (5/29-9/18)	M	M	M	M	M	M	M	M	M	M	M	M	M	M
2007 (6/4-9/8)	0	0	0	8	M	M	0	8	M	M	M	M	M	M
2008 (6/1-9/5)	0	0	0	5	M	M	0	4	M	M	0	5	M	M
2009 (5/30-9/12)	0	5	0	6	4	10	2	10	4	10	10	12	11	12
2010 (4/26-9/18)	0	0	0	0	0	0	M	M	0	14	0	14	0	14
2011 (5/23-9/19)	0	12	0	19	0	9	0	9	0	9	0	17	0	17

M=missing data

Table 5. Salmonberry River Tributaries - Days DEQ Spawning Standard exceeded (before 6/15 only)

Total Number of Days DEQ Spawning Standard (13 °C; 55.4°F) Exceeded							
Year	Penn. Cr	Wolf Cr	Kinney Cr	North Fork	Bathtub Cr	South Fork	Belfort Cr
1994 (6/6-6/15)	n/a	0	0	0	M	0	n/a
1995 (4/24-6/15)	n/a	0	0	0	M	0	n/a
1996 (6/3-6/15)	n/a	0	M	0	M	0	n/a
1997 (5/25-6/15)	n/a	0	0	0	M	M	n/a
2004 (5/29-6/15)	n/a	0	M	0	M	M	n/a
2007 (6/4-6/15)	n/a	M	0	M	M	0	n/a
2008 (6/1-6/15)	n/a	0	0	0	M	0	n/a
2009 (5/30-6/15)	n/a	6	0	0	4	0	n/a
2010 (4/26-6/15)	n/a	0	0	0	0	0	n/a
2011 (5/23-6/15)	n/a	0	0	0	0	0	n/a

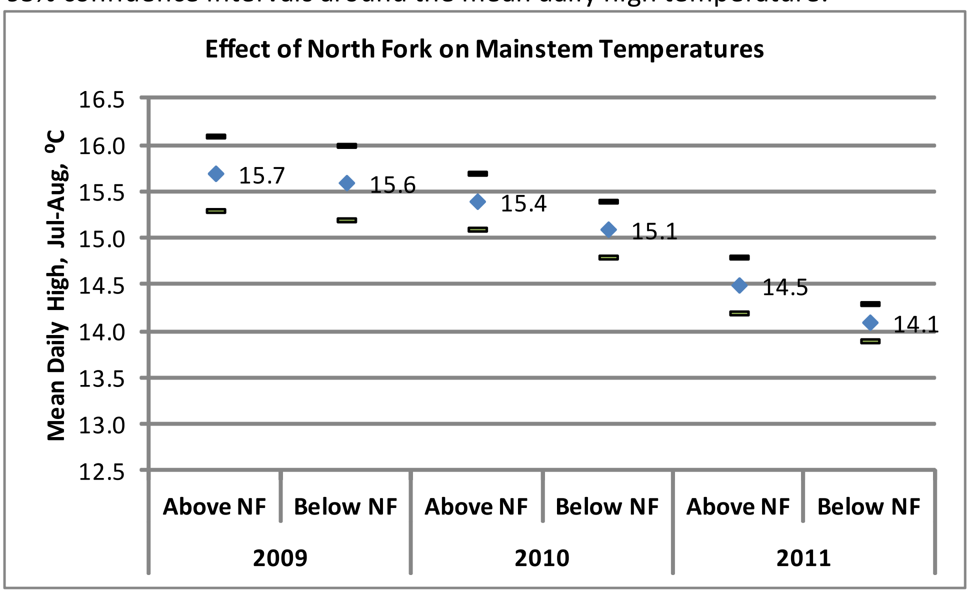
M=missing data; n/a=spawning standard does not apply

8. Effect of North Fork on Main Stem Temperatures

The North Fork enters at about river mile 8.3, and contributes about the same amount of water as the main stem does at that point. If those forks (North Fork and upper main stem) are significantly different in temperature, the effect should be visible at the station just downstream of the North Fork. The site in the main stem just upstream of the North Fork was established in 2009; the sites in the North Fork and just downstream of the North Fork were established in 1994. The site in the North Fork is more than one mile above the mouth. Temperatures might be cooler there than at the mouth, as the usual pattern is for temperatures to increase in a downstream direction. However, there could be significant groundwater inputs in the lower mile, and three permanent tributaries enter the North Fork between the monitoring station and the mouth.

Figure 3 shows the mean July/August daily high temperature in the mainstem above and below the North Fork confluence. Horizontal bars show 95% confidence intervals. The mean temperatures have been adjusted by the deviation of the data loggers from a NIST certified thermometer, as measured in post-deployment accuracy checks. This process removes measurement differences between loggers as a source of variation. In each of the three years, the station below the North Fork confluence has recorded temperatures lower than the station above the North Fork, suggesting that the North Fork has a cooling influence. There is considerable overlap in confidence intervals, which makes a definitive statement difficult.

Figure 3. Effect of North Fork on mainstem temperatures; horizontal bars show 95% confidence intervals around the mean daily high temperature.



9. Recording Frequency Test

Dunham et al (2005) presented a chart that can be used to determine the probability of underestimating the maximum daily temperature, for a given sampling frequency and daily range in temperature. From that chart, it appears that the probability of underestimating the daily maximum temperature (and overestimating the daily minimum) in a stream with the Salmonberry's typical daily range is about 1% for a 2-hour sampling interval.

In 2011 I conducted a test of 1-hour vs. 2-hour readings. At three locations, I deployed two data loggers in the same PVC housing, one programmed as usual to read every two hours throughout the summer, and the other programmed to read every hour beginning July 1 (to accommodate the memory limitations). Upon downloading and examining the data, it became apparent that the inherent variation between loggers made a direct comparison difficult. Instead, I examined only the loggers programmed to read every hour, to find instances where a reading was higher or lower than both of the adjacent ones, and also represented the maximum or minimum temperature recorded that day. For example, if a 5PM reading was higher than the 4PM or 6PM reading and was also the maximum for the day, then that is one occurrence of a “missed” high temperature on a two-hour reading schedule.

The total sample size was 79 days X 3 sites X 2 two-hour series per day (even-hour readings or odd-hour readings), or 474 opportunities. Out of those opportunities, the daily high was missed 57 times, or 12%, considerably higher than the estimate I had previously made from the Dunham chart. The daily low was missed 25 times, or 5%.

It is important to note that the daily high is never overstated by using a 2-hour interval, meaning that all the reporting centered around the daily high (7DADM, for example) is conservative. Nevertheless, this test underscores the need to replace the current data loggers with units having greater memory.

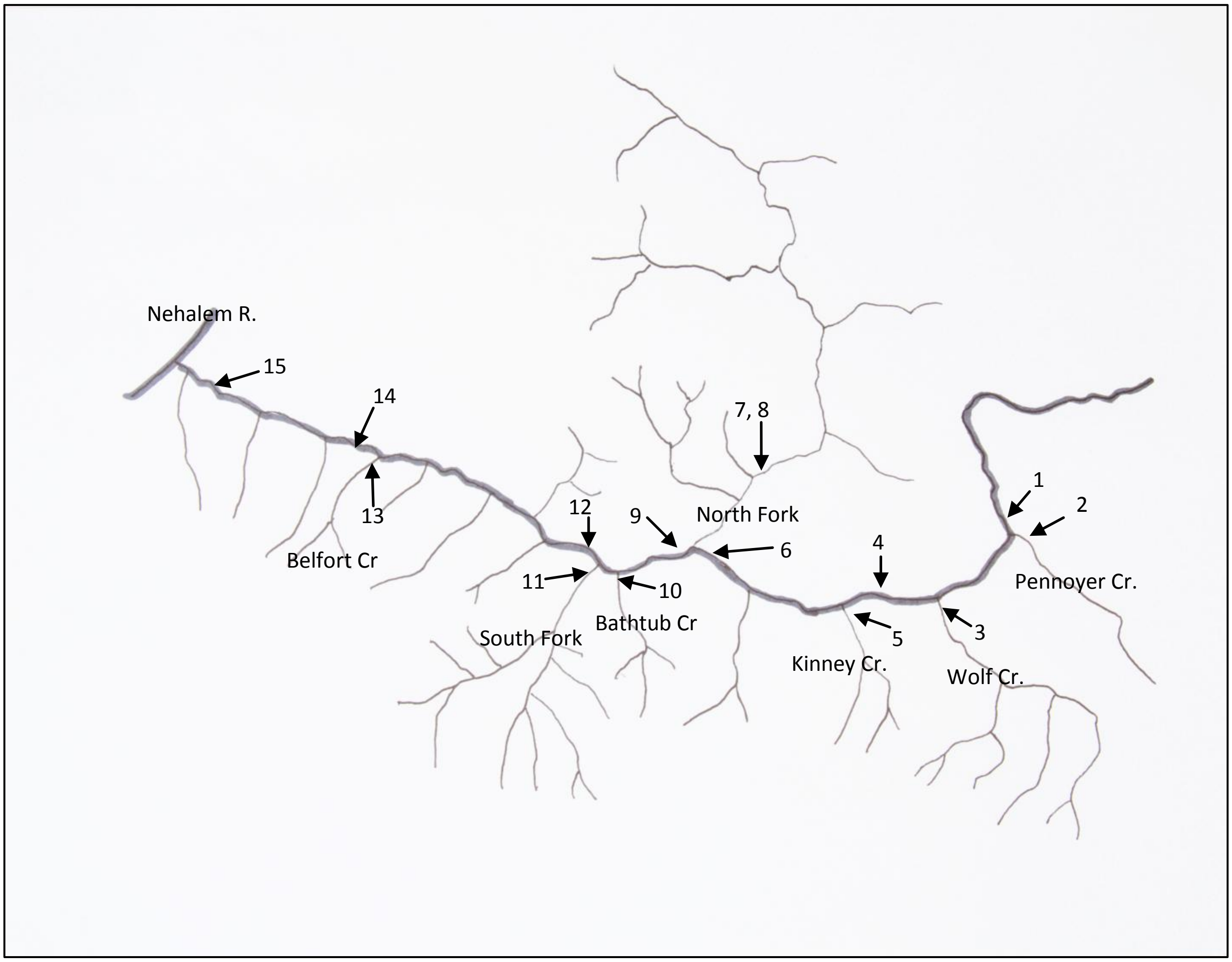
Citations

Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data loggers: a user’s guide. Gen. Tech. Rep. RMRS-GTR-150WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Oregon DEQ website water quality rules section (http://www.deq.state.or.us/wq/rules/div041tblsfigs.htm).

Oregon Watershed Enhancement Board, 1999. Water Quality Monitoring Technical Guidebook (http://www.oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf).

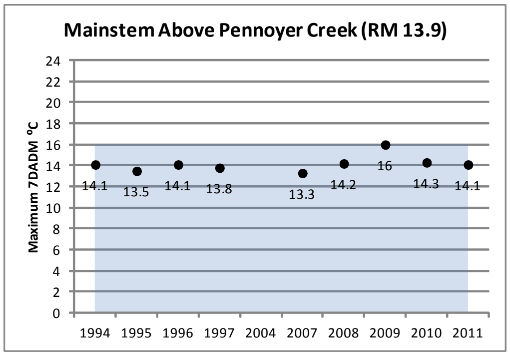
Appendix A. Site Locations

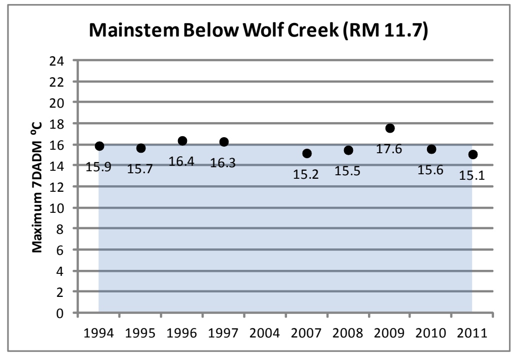


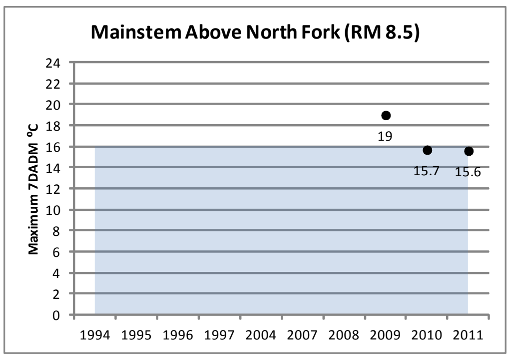
Salmonberry River main stem is shown as a bold line. One inch=1.4 miles.

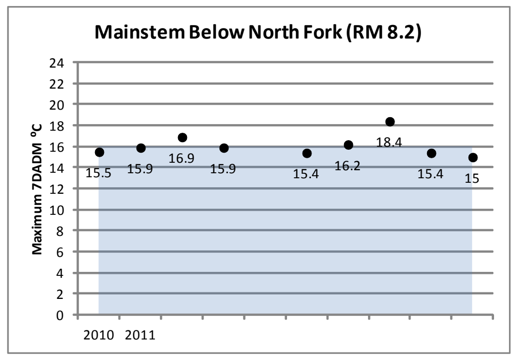
Appendix B. Maximum 7DADM by Site and Year

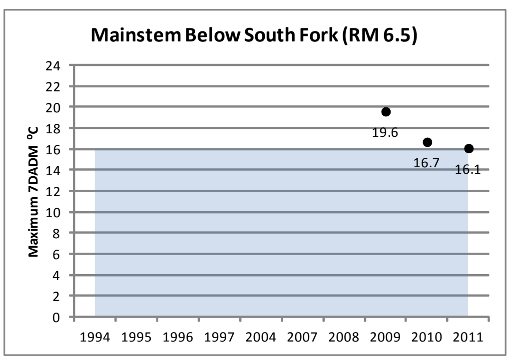
The shaded area in the following charts represents temperatures at or below the 16ºC standard. The data points show the maximum 7DADM attained at the site.

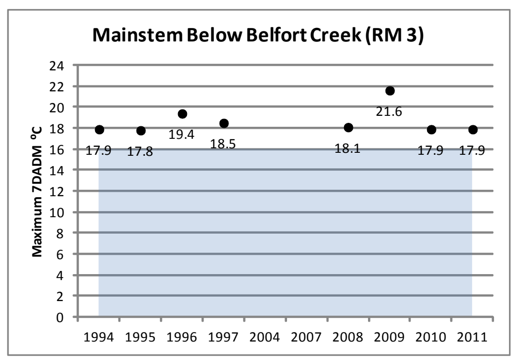


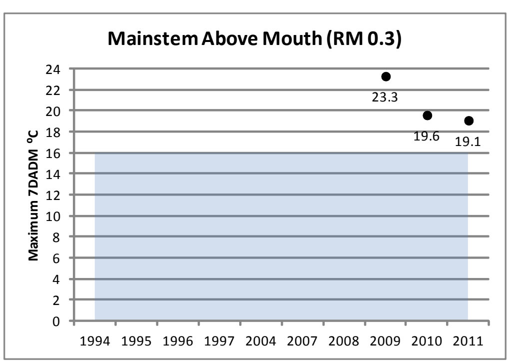


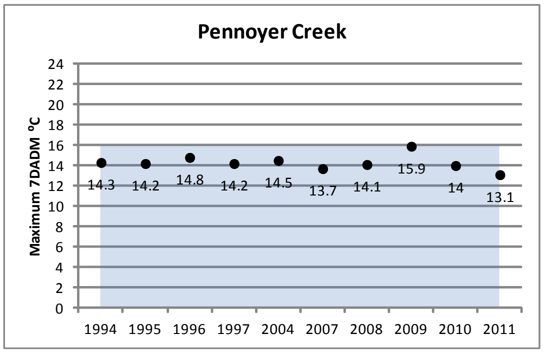


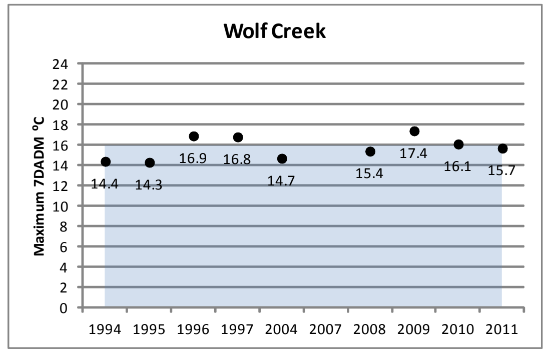


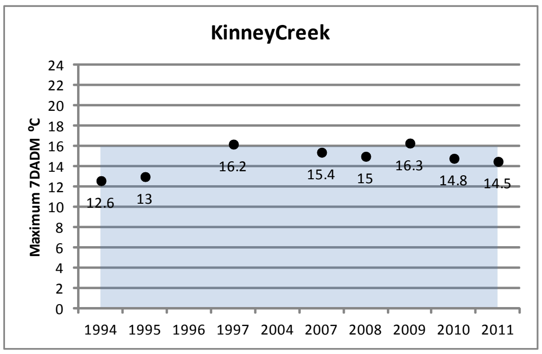


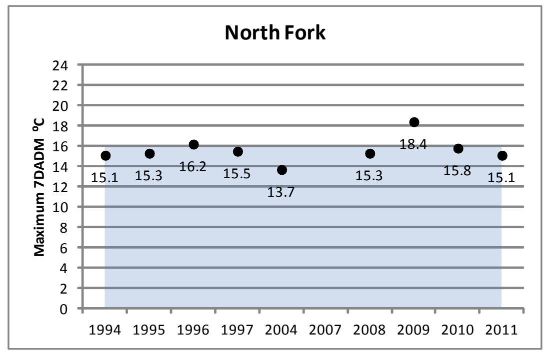


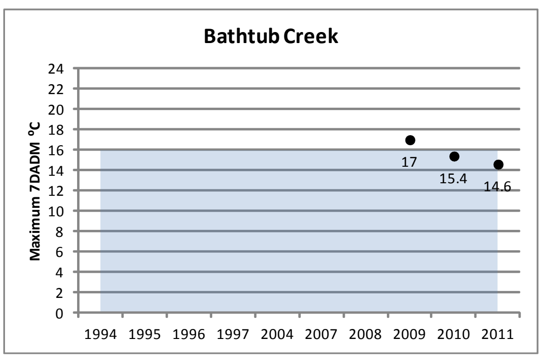


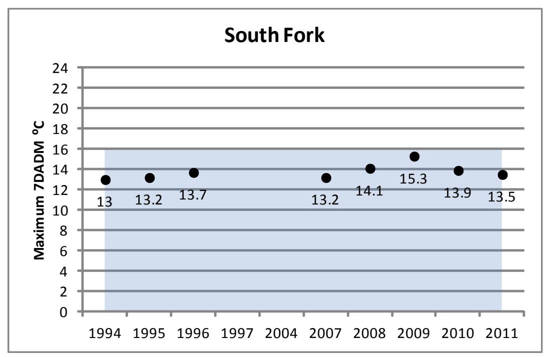

Pennoyer Creek
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
14.3 14.2 14.8 14.2 14.5 13.7 14.1 15.9 14 13.1
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011

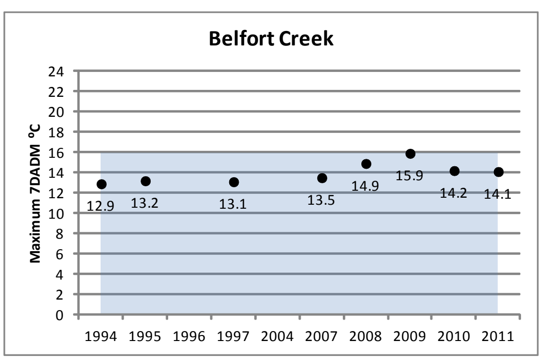

Wolf Creek
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
14.4 14.3 16.9 16.8 14.7 15.4 17.4 16.1 15.7
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011


KinneyCreek
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
12.6 13 16.2 15.4 15 16.3 14.8 14.5
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011


North Fork
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
15.1 15.3 16.2 15.5 13.7 15.3 18.4 15.8 15.1
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011


Bathtub Creek
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
17 15.4 14.6
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011


South Fork
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
13 13.2 13.7 13.2 14.1 15.3 13.9 13.5
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011


Belfort Creek
Maximum 7DADM °C
24
22
20
18
16
14
12
10
8
6
4
2
0
12.9 13.2 13.1 13.5 14.9 15.9 14.2 14.1
1994 1995 1996 1997 2004 2007 2008 2009 2010 2011