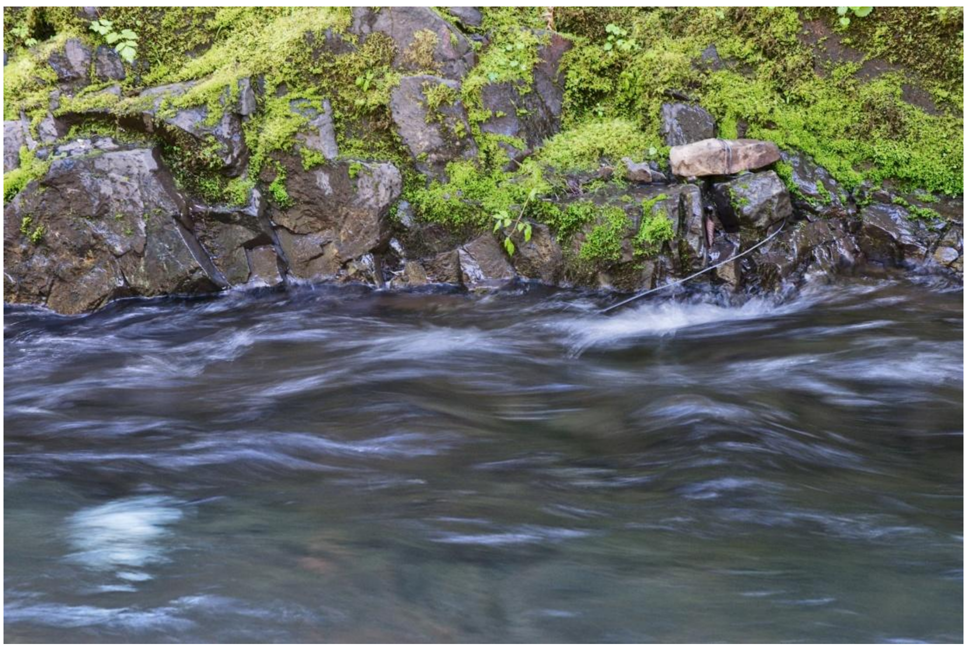
Salmonberry River Temperature Monitoring 1994-2009

A STEP Project



Wolf Creek site, May 2009, showing cable attachment and anchor rock. Monitor (in white housing) is at lower left.

Summary: This is an update of previous reports, with summer 2009 data. Water temperature loggers were placed at 10 sites in the summers of 1994-1997, 2004, 2007, and 2008, and at 15 sites in 2009. Temperature increases were recorded in 1996 and 1997, following the February 1996 flood. 2004-2007 levels were closer to 1994-95. 2008 and 2009 temperatures were elevated again, following the flood and debris torrents of December 2007. The lowest main stem site exceeded the EPA/DEQ core cold water habitat temperature standard for 77 days in 2009. All main stem sites recorded at least one day in excess of that standard in 2009. All main stem sites exceeded the EPA/DEQ spawning temperature standard from six to 23 days in 2009. The spawning standard applies to the main stem before June 15 and after September 15.

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1. Introduction

Previous reports, "Salmonberry River Temperature Monitoring 1994 -2007", and "Salmonberry River Temperature Monitoring 1994 -2008", provide the project background. PDF versions can be requested from the author at ian.fergusson@comcast.net or from Joyce Sherman at rivergraphics@spiritone.com .

The Salmonberry River is known for its run of wild winter steelhead, regarded as one of the healthiest runs on the West Coast. The South Fork of the Salmonberry has been designated as "Salmon Anchor Habitat". Relatively healthy watersheds like the Salmonberry are critical to long-term survival of salmonids, and ongoing monitoring is essential.

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 suffered debris torrents that removed miles of riparian vegetation. By contrast, Pennoyer Creek, the North Fork, and the South Fork suffered relatively little damage. Other tributaries, notably Tunnel Creek and Bathtub Creek, also suffered 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. Methodology

General methodology was described in a previous paper.

Until 2008, ODFW provided Onset Hobo® temperature loggers. The Hobo® loggers have a resolution of 0.1° C. Accuracy is unknown, but is probably in the neighborhood of ±0.5° C. Beginning in 2008, we used NexSens® model 1921G loggers, with resolution of 0.5® C and accuracy of ±1° C.

In 2008 the project was awarded a STAC mini-grant, and we purchased 10 additional NexSens® model 1921G loggers. They arrived too late to be used in the summer of 2008, but were deployed at additional sites beginning in 2009. See "3. Locations".

The Hobo® loggers were encased in a waterproof white plastic housing provided by the manufacturer.

NexSens® loggers have a small black and clear waterproof plastic housing; we encased these further in white PVC pipe, with both ends of the pipe open and the sides drilled with holes to ensure adequate water flow (Fig. 1). These are anchored with a rock and duct tape, and secured with cable to a root wad or to a second rock (see cover photo).

A test over two hot days in August 2008 revealed a maximum of 1°C difference between shielded and unshielded loggers, when deployed in shallow water fully exposed to the sun. With careful site selection, this condition should not occur, but is possible in late summer in small tributaries. As standard procedure, we deploy all the NexSens® loggers in the white PVC housing, regardless of site.

Fig. 1. A NexSens® data logger in the waterproof housing, lower right, and another in the same housing but further encased in a section of PVC pipe. This photo is from a test comparing temperatures recorded by shielded and unshielded loggers.

From 1994 through 1997, the data loggers recorded the temperature every 2.4 hours. In 2004 and 2007, the sampling frequency was every 3.2 hours. In 2008 and 2009 the frequency was every 2.0 hours.

3. Locations

15 sites are monitored: seven main stem sites (three were added in 2009) and eight tributary sites (two were added in 2009). See Table 1.

Table 1. Salmonberry River temperature monitoring sites.

Number	Site Name	River Mile	Stream Order	Established
1	Main stem above Pennoyer Cr.	13.9	2nd	1994
2	Pennoyer Cr.	13.9	2nd	1994
3	Wolf Cr.	12.4	3rd	1994
4	Main stem below Wolf Cr.	11.7	4th	1994
5	Kinney Cr.	10.9	3rd	1994
6	Main stem above North Fork	8.4	4th	2009
7	North Fork (main)	8.3	4th	1994
8	North Fork (backup)	8.3	4th	2009
9	Main stem below North Fork	8.2	5th	1994
10	Bathtub Cr.	7	2nd	2009
11	South Fork	6.7	3rd	1994
12	Main stem below South Fork	6.5	5th	2009
13	Belfort Cr.	3.1	2nd	1994
14	Main stem below Belfort Cr.	3	5th	1994
15	Main stem above mouth	0.3	5th	2009

Figure 2 shows monitor locations, keyed to the numbers in Table 1.

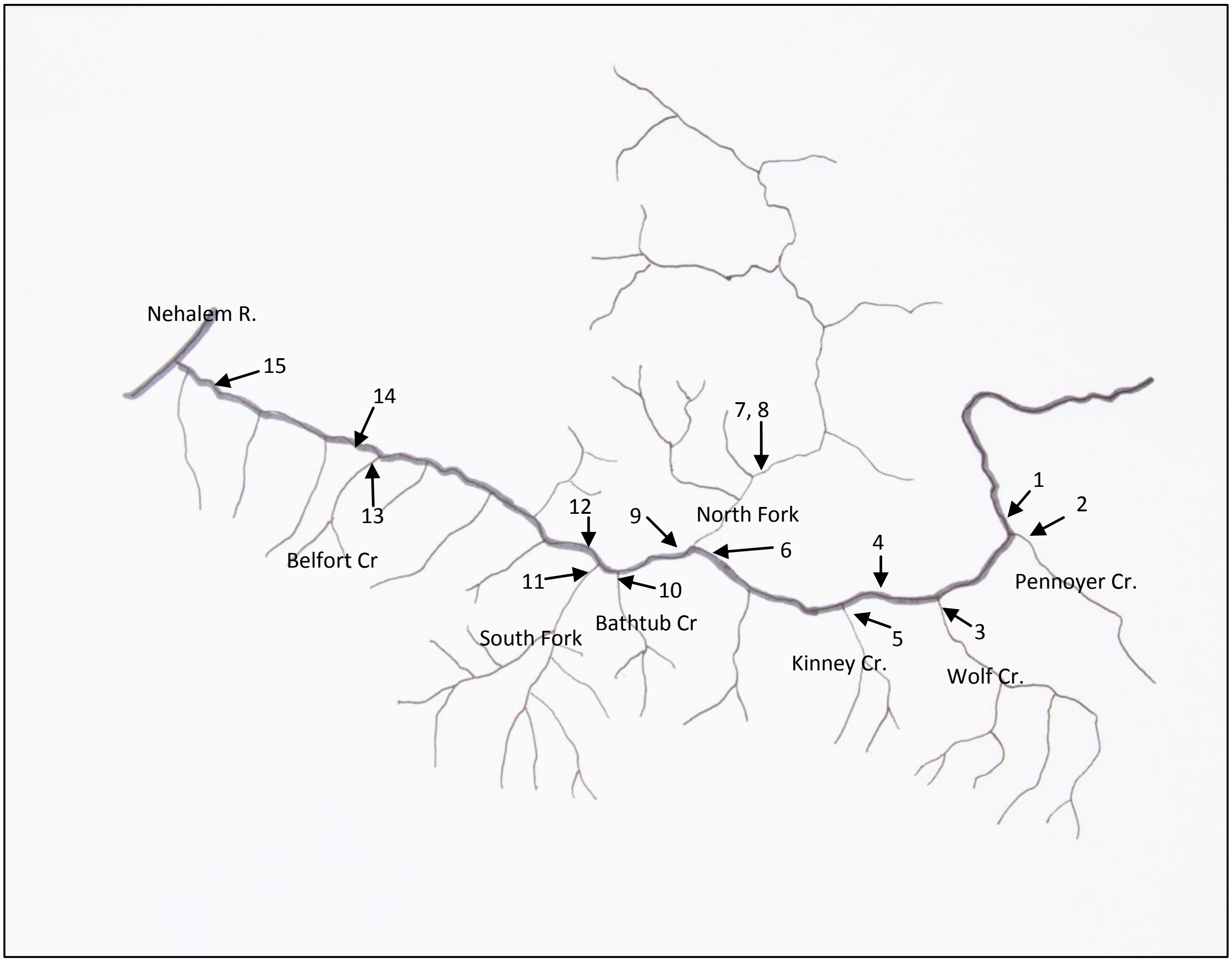

Fig. 2. Salmonberry River and tributaries, with data logger locations.

We do not have complete data for each site for each year. Over the course of the project, 4 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 were not included in the analysis. The likely explanation is that they were placed in areas where the water went underground, and the monitors were exposed to air temperatures.

This inconsistency of data from year to year is one reason we wanted to increase the number of sites monitored. For example, in 2004 and 2007 we have no data on the lower 8 miles of the main stem.

The following table summarizes data availability for each location by year.

Table 2. Data availability by site. X=good data; solid box=missing or suspect data.

Stream Order	Name	1994	1995	1996	1997	2004	2007	2008	2009
2nd	Mainstem Above Pennoyer Cr.	X	X	X	X		X	X	X
4th	Mainstem Below Wolf Cr.	X	X	X	X		X	X	X
4th	Mainstem above North Fork								X
5th	Mainstem Below North Fork	X	X	X	X		X	X	X
5th	Mainstem Below South Fork								X
5th	Mainstem Below Belfort Cr.	X	X	X	X			X	X
5th	Mainstem At Mouth								X
2nd	Pennoyer Creek	X	X	X	X	X	X	X	X
3rd	Wolf Creek	X	X	X	X	X		X	X
3rd	Kinney Creek	X	X		X		X	X	X
4th	North Fork	X	X	X	X	X		X	X
4th	North Fork backup								X
2nd	Bathtub Creek								X
3rd	South Fork	X	X	X			X	X	X
2nd	Belfort Creek	X	X		X		X	X	X

4. Objectives and Criteria

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

We use the DEQ/EPA "Core Cold Water Habitat" standard (16^{o} C), which 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) 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 Salmonberry is designated by Oregon DEQ as core cold-water habitat. The designation applies to the entire length of the Salmonberry and all its tributaries.

In addition, in this report (2009) we began tracking temperatures relative to the DEQ salmonid spawning criterion (13^{o} C, 55.4^{o} F) for the main stem and for 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 daily, as the average of the current day and the previous six days.

5. Results Relative to EPA Standards

Tables 3, 4, and 5 summarize the number of days the DEQ temperature standards were exceeded at each site. In comparing one year to another, it is important to consider the date ranges as well, since data loggers were in the water for longer periods in some years.

Table 3. Violations of DEQ core cold water habitat standard.

	Table 2. Days With Violations of DEQ Core Cold Water Habitat Standard (16°C; 60.8°F)													
	Main Stem							Tributaries						
Year	Above Pennoyer	Below Wolf	Above N Fork	Below N Fork	Below S Fork	Below Belfort	Above Mouth	Penn. Cr	Wolf Cr	Kinney Cr	North Fork	Bathtub Cr	South Fork	Belfort Cr
1994 (6/6-9/24)	0	0	M	0	M	29	M	0	0	0	0	M	0	0
1995 (4/24-9/23)	0	0	M	0	M	24	M	0	0	0	0	M	0	0
1996 (6/3-9/21)	0	6	M	8	M	53	M	0	13	M	7	M	0	M
1997 (5/25-9/24)	0	7	M	0	M	50	M	0	16	14	0	M	M	0
2004 (5/29-9/18)	M	M	M	M	M	M	M	0	0	M	0	M	M	M
2007 (6/4-9/8)	0	0	M	0	M	M	M	0	M	0	M	M	0	0
2008 (6/1-9/5)	0	0	M	2	M	34	M	0	0	0	0	M	0	0
2009 (5/30-9/12)	1	16	27	20	29	61	77	0	13	5	19	9	0	0

M = missing data

The difference between 2008 and 2009 is probably due to the difference in weather patterns during those two summers, as suggested by the following chart (Fig. 3), where 2009 had two extended periods with temperatures considerably higher than 2008. Air temperature data are from the Vernonia weather station; data beyond July 2009 were not available at the time of this report.

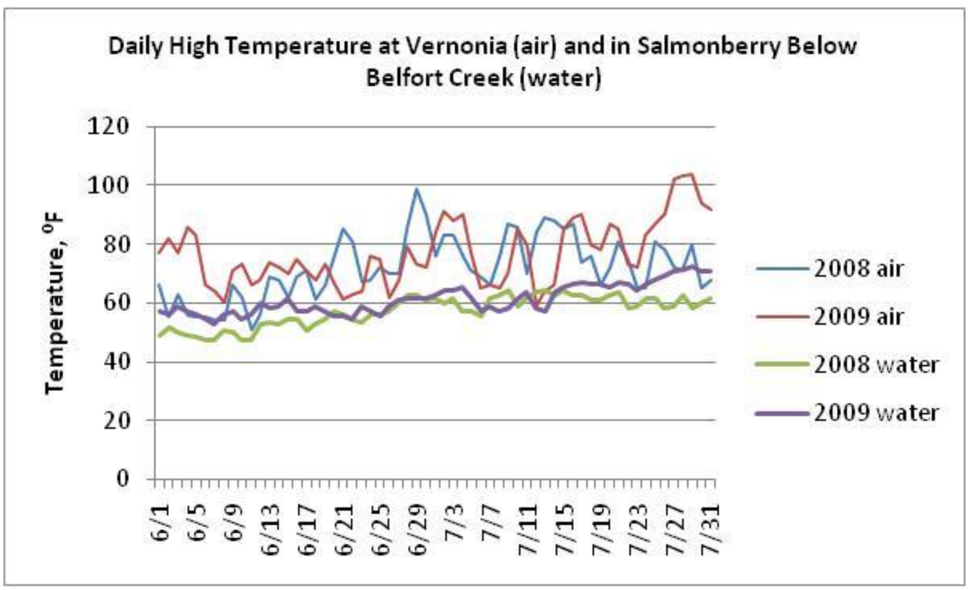

Fig. 3. High temperatures in air and water, June 1 through July 31, 2008 and 2009.

Table 4. Violations of the DEQ spawning temperature standard, main stem Salmonberry.

	Days With Violations of DEQ Spawning Standard (13°C; 55.4°F)													
	Main Stem (Sep 1- Jun 15)													
	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	**9**	M	M	0	**6**	M	M	0	**24**	M	M
1995 (4/24-9/23)	0	0	0	**22**	M	M	0	**23**	M	M	0	**23**	M	M
1996 (6/3-9/21)	0	**2**	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	**6**	**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	**6**	0	**6**	**4**	**10**	**2**	**10**	**4**	**10**	**11**	**12**	**11**	**12**

M=missing data

On the main stem, it appears that the spawning standard has regularly been exceeded in September, even before the two major floods. Violations prior to June 15 were more frequent in 2009 than 2008, which appears to be related to weather. Figure 4 shows precipitation and air temperatures at the Vernonia weather station during the 3-week period ending June 15 (loggers were deployed at the end of May or beginning of June; it is assumed that weather in the week immediately preceding those dates has some effect on water temperatures). In 2009, precipitation was much less and air temperatures were much lower than 2008. Both conditions would likely result in higher water temperatures in 2009.

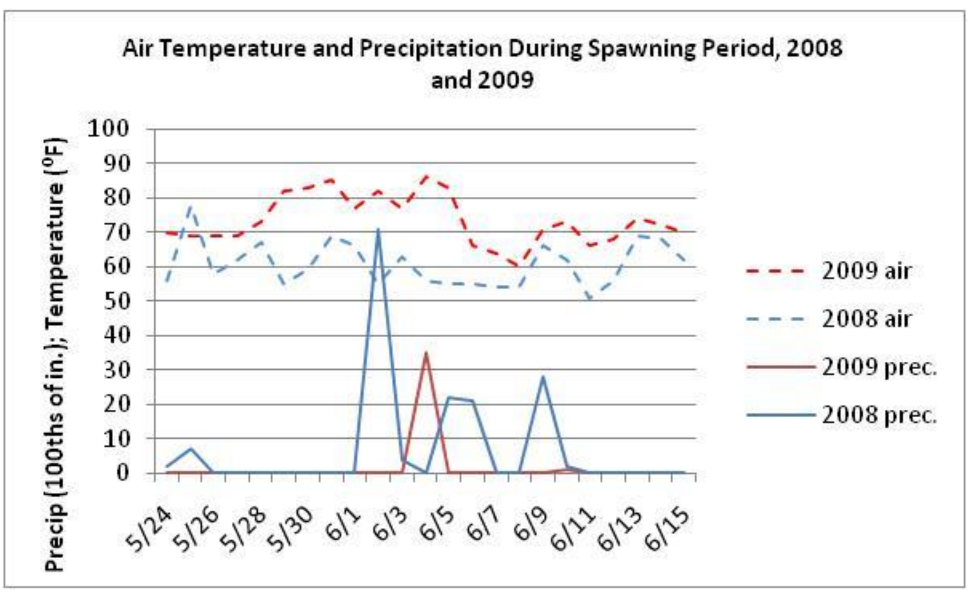

Fig. 4. Air temperature (high) and precipitation at Vernonia weather station during the time data loggers were measuring water temperatures relative to the spawning standard.

Table 5. Violations of the DEQ spawning temperature standard, tributaries. Loggers are pulled before October 15, so the only violations recorded would be prior to June 15.

Days With Violations of DEQ Spawning Standard (13°C; 55.4°F)							
Tributaries (Oct 15 or Nov 1 - Jun 15; loggers pulled in Sept.)							
Year	Penn. Cr	Wolf Cr	Kinney Cr	North Fork	Bathtub Cr	South Fork	Belfort Cr
1994 (6/6-9/24)	n/a	0	0	0	M	0	n/a
1995 (4/24-9/23)	n/a	0	0	0	M	0	n/a
1996 (6/3-9/21)	n/a	0	M	0	M	0	n/a
1997 (5/25-9/24)	n/a	0	0	0	M	M	n/a
2004 (5/29-9/18)	n/a	0	M	0	M	M	n/a
2007 (6/4-9/8)	n/a	M	0	M	M	0	n/a
2008 (6/1-9/5)	n/a	0	0	0	M	0	n/a
2009 (5/30-9/12)	n/a	0	0	0	5	0	n/a

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

These five tributaries are shown as having salmon/steelhead spawning use on DEQ's spawning use map. One other listed tributary, Belding Creek, is not monitored for temperature.

6. Effect of North Fork on Main Stem Temperatures

With one data logger just above the North Fork confluence and one just below, we are able to assess the effect of the North Fork on main stem temperatures. The logger above the North Fork was first placed in summer 2009.

Figure 5 shows the complete temperature record for a day in June and another day in August. The Excel RAND() function was used to select a random June day and a random August day. On both days, the cooling effect of the North Fork is obvious (enters at point C, at River Mile 8.3). Each segment in figure 5 represents the complete temperature record at a given main stem site for one day, starting with midnight and ending at 10 PM.

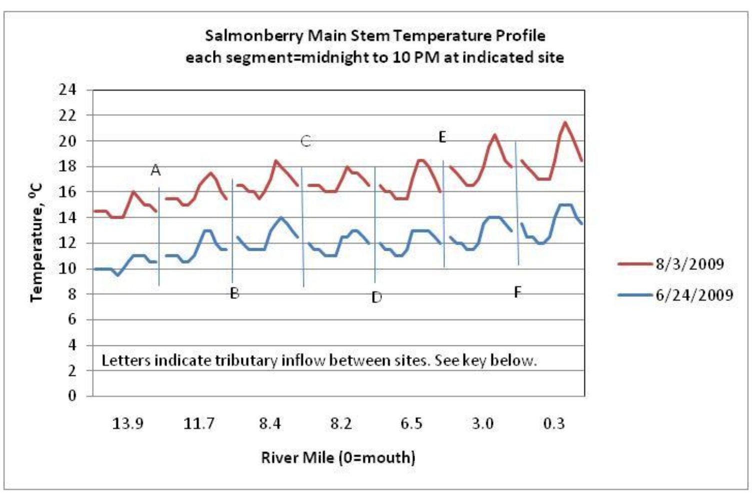

Fig. 5. Daily temperature profiles by river mile.

Tributary inflows: A= Pennoyer Cr., Kinney Cr., Baldwin Cr., Little Baldwin Cr., Wolf Cr; B= Kinney Cr., Belding Cr.; C=North Fork; D= Bathtub Cr., South Fork; E= Clay Cr., Tunnel Cr., Tank Cr., Preston Cr., Belfort Cr.; F= Brix Cr., Buick Canyon Cr.

7. Subsurface Flow in Kinney Creek

On August 1 I checked three of the sites in the upper reaches: Kinney Creek, Wolf Creek, and the main stem below Wolf Creek. The December 2007 debris flows had left large alluvial deposits, and I wanted to see if the flow had gone underground at any of the sites. The Kinney Creek data logger was still submerged, but was located right where the stream re-emerged from an underground stretch (Fig. 6).

Fig. 6 (left). Kinney Creek site, 8/1/2009. The orange cord (in circle) is attached to a handheld thermometer placed inside the logger housing. The thermometer registered 15^{o}C at 1:55 PM; the data logger record showed 15.5^{o}C at 2:00 PM.

Fig. 7 (above) The stream subsides into the gravel about 150 m. above the monitor site. The water temperature was18^{o}C at 2:10 PM; the bulb of the thermometer was in the shade of the rock (circle).

The temperature loss over a span of 150 m. was 3^{o}C (5.4^{o}F), probably the result of mixing with hyporheic flow and heat exchange with the gravel. The alluvial deposits resulting from debris torrents provide a mixed blessing: maximum tributary temperatures are held down, possibly resulting in a similar effect on the main stem, but less surface water is available for fish and other organisms.

Concerned that the original location would not stay wet, I moved the data logger to a point about 50 m. upstream of Fig. 7, to a pool at the end of a steep stretch where the water was running more freely (Fig. 8.). The water had also gone underground above this point, but had emerged a short distance above. The temperature at the new location was 16.5^{o}C at 2:30 PM.

Fig 8. New location of Kinney Creek logger, visible in shade of the boulder at right. The water temperature was 16.5^{o}C at this point.

Figure 9 is a chart of high and low temperatures for Kinney Creek and Pennoyer Creek. Pennoyer Creek was relatively unaffected by the February 1996 and December 2007 floods. Kinney Creek was greatly affected, with debris torrents removing riparian vegetation for miles and generating large alluvial deposits. Notice the separation of highs and lows throughout the summer. In contrast, Kinney Creek highs and lows show little separation starting early in July. Even after the logger was moved August 1, the effect of substantial underground flow on the daily temperature range is obvious.

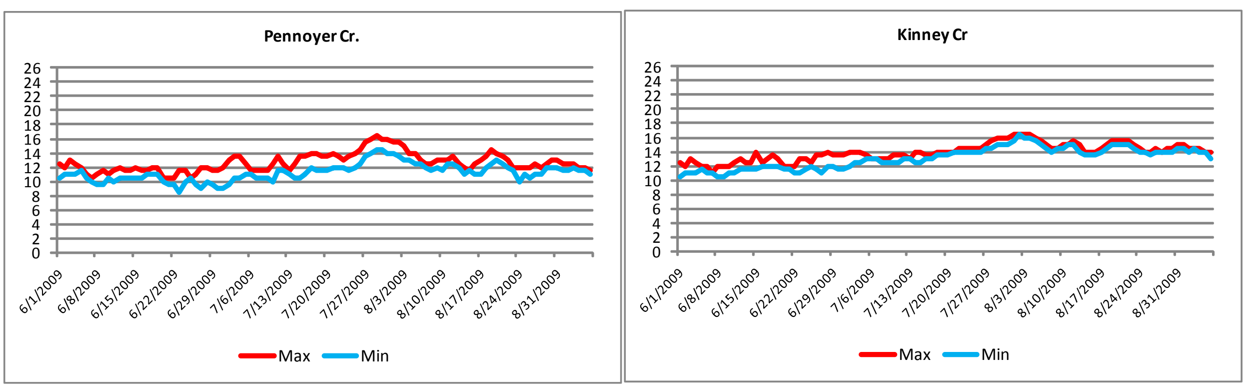

Fig. 9. Daily high and low temperatures, Pennoyer and Kinney Creeks, summer 2009.

It appears that high temperatures in a highly disturbed stream are moderated by underground flow. However, the underground heat loss does not appear to return the temperature profile to a condition approximating an undisturbed stream. Table 6 compares monthly average temperatures in Kinney Creek and Pennoyer Creek. The two streams are similar in drainage area and elevation. The high, low, and mean temperatures in Kinney Creek are all higher than in Pennoyer Creek. The daily temperature range is compressed in Kinney Creek in July and August. Daytime highs are held down by the underground flow, and nighttime lows are elevated.

Table 6. Monthly average temperatures, Kinney Creek and Pennoyer Creek.

	Monthly Average High, Low, and Mean Temperatures							
	High		Low		Mean		Range	
	Pennoyer	Kinney	Pennoyer	Kinney	Pennoyer	Kinney	Pennoyer	Kinney
June	11.5	12.7	10.2	11.4	10.8	11.9	1.3	1.3
July	13.5	14.1	11.5	13.3	12.5	13.6	1.9	0.8
August	13.1	15.0	11.9	14.6	12.5	14.7	1.1	0.5

8. Future Plans

In 2010 we will probably deploy some of the loggers earlier, coinciding with spawning ground surveys in April and May. With 20 loggers available in total, and 15 sites, we will probably add redundancy at some sites rather than adding more sites. Kinney Creek (because of dewatering) and the South Fork (Salmon Anchor Habitat) would be good candidates for redundancy.