

Progress Report
Icicle Creek Water Temperatures:
July 16, 2005 – November 9, 2005

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Introduction

Water temperature monitoring in Icicle Creek was initiated in 2005 to evaluate effects of Leavenworth National Fish Hatchery (LNFH) operations on Icicle Creek water temperatures. LNFH water operations include supplementation of Icicle Creek with releases of water stored in the Snow Creek basin, diversion of water for hatchery operations, splitting of flows by a headgate dam into an artificially constructed bypass and an altered original channel, and return to Icicle Creek of used hatchery water which consists of the diverted stream water and well water. Icicle Creek is used by bull trout *Salvelinus confluentus* and steelhead *Oncorhynchus tshawytscha* which are both listed as threatened under the Endangered Species Act. Several other fish species also use Icicle Creek. The objectives of the water monitoring were to:

1. Monitor hourly water temperatures at several locations in Icicle Creek.
2. Compare water temperatures at different locations to evaluate how specific hatchery operations affect the water temperature.

This progress report provides a summary of water temperatures collected from July 16, 2005 – November 9, 2005. Additional reports will be prepared as more data is collected.

Study Area

The Icicle Creek watershed is on the east side of the Cascade Mountains in North Central Washington and drains 214 square miles. Icicle Creek is a Class I, fifth order tributary to the Wenatchee River providing 20% of the low season flows (WRWSC 1998). Icicle Creek is 31.8 miles long from its headwaters at Lake Josephine, elevation 4,681 ft, near Stevens Pass to its confluence with the Wenatchee River in the town of Leavenworth, elevation 1200 ft. Approximately 87% of the watershed is publicly owned and managed by the U.S. Forest Service (USFS) with 74% of the watershed in the Alpine Lakes Wilderness area.

The Icicle Creek watershed is characterized by a high basin relief with a change of 6,900 ft over a horizontal distance of less than 3 mi from LNFH. The upper basin has areas that were glaciated, with steep slopes of cirque headwalls and failure escarpments that have very little water storage capacity. In the lower basin Icicle Creek flows out onto a low sloping valley composed of thick deposits of sand and gravel alluvium, and glacial deposits.

Annual mean, minimum, and maximum flows in Icicle Creek at the USGS gaging station at rm 5.8 are 630, 44, and 14,100 cfs. Precipitation in the watershed ranges from 120 inches at the crest of the Cascades to 20 inches at the east end of the watershed. Flow is primarily from snowmelt. In a hot dry summer about 21% of the flow is estimated to originate from glacier melt (Mullan et al. 1992). The 14 glaciers in the Stuart Range have the highest mean altitude (8,227 ft) of any glaciers in the North Cascades. The Icicle watershed also has 102 lakes.

There are two main water diversions on Icicle Creek. At the diversion structure at rm 5.7 the Icicle Peshastin Irrigation District diverts from 60 to 103 cfs from April through September, and the City of Leavenworth diverts about 2 cfs year round (Montgomery Water Group, Inc. 2004).

At the diversion structure at rm 4.5, LNFH diverts about 20 to 40 cfs year round while Cascade Orchard Irrigation Company diverts about 7 cfs from May through September (Montgomery Water Group, Inc. 2004). The greatest quantity of water is diverted from Icicle Creek in June, July, and August when diversions typically total from 134 to 144 cfs. Water diversions in April, May, and September are close to 120 cfs, and from October through March are about 40 cfs (Montgomery Water Group, Inc. 2004).

LNFH has water rights for 16,000 acre-ft from the Snow Lakes. The lakes drain into Snow Creek which enters Icicle Creek at rm 5.4. Flow in Snow Creek from July through September is typically from 44 to 52 cfs (Montgomery Water Group, Inc. 2004). During times of extremely low flow the amount of water diverted from Icicle Creek can exceed the natural stream flow, and supplementation from Snow Lakes probably keeps the stream from going dry in some reaches. The LNFH also uses several on-site wells to supply water. Monthly water use from the wells has typically been from 1.4 to 10.3 cfs (Montgomery Water Group, Inc. 2004 - data from mean of 1999, 2002, 2003). LNFH returns water used for rearing and holding fish both down the fish ladder into the spillway pool near rm 2.8 and at another return site downstream of the spillway pool

Methods

In July 2005 nine temperature loggers were deployed in Icicle Creek from downstream of LNFH at rm 2.6 to downstream of Eightmile Creek at rm 8.2, and an additional logger was placed in Snow Creek (Table 1 and Figure A1). Temperatures were recorded hourly using ONSET Optic Stowaway temperature loggers. Prior to deployment the accuracy of several loggers were tested at different temperatures to evaluate accuracy and comparability with each other. Loggers were selected that were within 0.1°C of each other. Each temperature logger was placed in a metal tube that was attached to a metal chain which was then secured to the stream bank. The temperature loggers were downloaded using a data shuttle. Daily minimum and maximum air temperatures were recorded at LNFH to the nearest degree Fahrenheit.

Data Analysis: Data was imported into the Boxcar Pro 4 program which was used to calculate daily minimums, maximums, and means. Raw data and the summaries were exported into Excel spreadsheets for further manipulation and analysis. Outliers in the recorded data that could be associated with having the logger out of the water or other discrepancies were excluded from the data set. To evaluate differences in water temperatures at sites we used the difference between the daily mean temperatures. We summarized differences in mean daily water temperature by month. Mean daily air temperatures were calculated by averaging the minimum and maximum air temperatures, converting to degrees Celsius, and rounding to the nearest degree Celsius. Data was evaluated to determine the 1 day maximum water temperature and to calculate the maximum mean maximum water temperature for 7 and 21 days. We also counted the number of days that the minimum water temperature was 15°C or warmer. Many studies suggest that bull trout are uncommon where water temperatures exceed 15°C for extended periods of time; however, adult bull trout are more tolerant of warmer water though are rare where temperatures are warmer than 19°C (McPhail and Baxter 1996).

Results

Daily mean water temperatures for all sites are shown in Figure A2 and listed in Table A3. The 1-day and running 7 and 21 day average maximum water temperatures are in Table 1. I have also included a count of the number of days the minimum water temperature was 15°C or warmer. Mean, maximum, and minimum daily air temperatures at LNFH are displayed in Figure A9. Daily maximum and minimum water temperatures are available upon request. Icicle Creek water temperatures at the nine stations monitored between rm 2.6 and rm 8.2 showed considerable variation from July through September. Beginning in October the water temperatures were less variable between the sites.

Comparisons of daily mean water temperatures at some of the sites were made to describe how various hatchery operations might be affecting water temperature and daily differences are shown in Figure A3 and summarized by month in Table 2.

1. ***Snow Creek Supplementation:*** Icicle Creek water temperatures upstream and downstream of Snow Creek were compared to evaluate the effect of supplementation of Icicle Creek with Snow Creek water using the LNFH water right. Upstream of Snow Creek Icicle Creek daily mean water temperatures were mostly above 15°C through August whereas in Snow Creek they were rarely above 15°C. The mean daily decreases in water temperature from upstream of Snow Creek to downstream of Snow Creek by month for August and September were -2.4°C and -2.2°C (Table 2, Figure A3 and A4). In October the difference in mean daily water temperatures was only -0.2°C. See Figure A4.
2. ***Water Diversion:*** Icicle Creek water temperatures upstream and downstream of the LNFH water diversion were compared to evaluate any immediate effects by the diversion. From July 19 to November 9 (114 days) the mean daily difference between the water temperature from upstream of the LNFH water diversion to downstream of the diversion was only +0.05°C, SD = 0.06°C (Table 2, Figure A3 and A5). The difference was less than the level of accuracy of the loggers and was considered to be insignificant.

The rate of warming by distance for the reaches upstream and downstream of the diversion was also compared. In both August and September the stream temperature increase downstream of the intake was more than double the increase upstream of the intake despite the slightly shorter distance (0.7 mi reach downstream of the diversion and 0.9 mi reach upstream of the diversion). In August and September, respectively, the temperature increase by mile was +0.8°C and +0.6°C upstream of the diversion and +2.3°C and +1.9°C downstream of the diversion.

3. ***Original Channel:*** Icicle Creek water temperatures at the upper and lower end of the original channel were compared to evaluate changes in water temperature. The rate of warming in this split channel reach was also compared to upstream reaches to see if the rate of warming was different. The mean daily water temperature increases for the almost 1-mile reach from the upper to the lower end of the original channel by month for August and September were +1.3°C and +1.0°C (Table 2, Figure A3 and Figure A6).

4. **Hatchery Return Water:** Icicle Creek water temperatures at the lower end of the original channel and in the spillway pool were compared to evaluate the effect of inflow of hatchery water. The greatest temperature change for any of the effects by month was between these sites in August when the mean daily temperature decreased an average of -3.4°C. In September the decrease was -2.3°C. In October the decrease was only -0.5°C (Table 2, Figure A3 and A7).

5. **Cumulative Affect:** Icicle Creek water temperatures from upstream of Snow Creek to downstream of the LNFH were compared to evaluate cumulative effect of the different hatchery actions on water temperature. Water temperatures were not recorded at the site downstream of LNFH from August 31 to October 3 because the logger was out of the water. In August the monthly decrease in mean daily water temperatures was -1.0°C. In July and October the mean change was an increase of about +0.5°C (Table 2, Figure A3 and A8.). After August 5 water temperatures downstream of the LNFH were consistently less than temperatures upstream of Snow Creek (Figure A3).

Table 1. Summary of running 1, 7, and 21 day daily maximum water temperatures and days minimum was $\geq 15^{\circ}\text{C}$ by site, mid July to the end of the year, 2005.

Location	RM	Dates	# Days	1-day max	7-day mean max	21-day mean max	# Days min$\geq 15^{\circ}\text{C}$
Eightmile Cmpg	8.2	Aug 27-Nov 2	68	17.3	na	na	na
Up Snow Creek	5.5	Jul 19-Nov 9	117	19.5	19.0	18.5	15
In Snow Creek	0.2	Jul 16-Nov 9	117	17.0	16.6	15.9	0
Down Snow Creek	5.4	Jul 19-Nov 9	117	18.6	18.1	17.5	1
Up LNFH Intake	4.55	Jul 19-Nov 9	114	19.2	18.6	18.0	6
Down LNFH Intake	4.45	Jul 19-Nov 9	114	19.4	18.6	18.1	5
Up Original Channel	3.8	Jul 19-Nov 9	114	21.3	20.3	19.6	8
Low Original Channel	2.85	Jul 19-Nov 9	114	25.6	24.0	22.9	11
Spillway Pool	2.8	Jul 30-Sep 11, Sep18- Nov 9	97	17.7	17.0	16.5	0
Down LNFH outfall	2.6	Jul 19-Nov 9	80	20.0	19.6	19.0	7

Table 2. Summary of effects of five different LNFH operations on Icicle Creek water temperature.

LNFH action affecting water temperature	Two sites compared	Site locations in rm	Dates compared	Mean difference °C	SD of difference °C		
Snow Creek Supplementation	Up Snow Cr and Dn Snow Cr	5.5 -5.4	Jul 16- 31	-0.2	0.2		
			Aug 1-31	-2.4	0.7		
			Sep 1-30	-2.2	0.7		
			Oct 1-31	-0.2	0.2		
Water Diversion	Dn Snow Cr and Up Intake	5.4 - 4.5	Jul 19-31	+0.4	0.06		
			Aug 1-31	+0.7	0.1		
			Sep 1-30	+0.5	0.2		
			Oct 1-31	+0.2	0.08		
	Up Intake and Dn Intake	4.5 – 4.45	Jul 19-31	0.01	0.02		
			Aug 1-31	+0.1	0.06		
			Sep 1-30	+0.07	0.04		
			Oct 1-31	0.02	0.06		
			Up Intake and Up Original Channel	4.5-3.8	Jul 19-31	+0.6	0.1
					Aug 1-31	+1.6	0.6
					Sep 1-30	+1.3	0.5
					Oct 1-31	+0.1	0.04
Original Channel	Up Original Channel and lower O. Channel	3.8 – 2.85	Jul 19-31	+0.5	0.09		
			Aug 1-31	+1.3	0.4		
			Sep 1-30	+1.0	0.3		
			Oct 1-31	+0.6	0.6		
Hatchery Return Water	Lower O. Channel and Spillway Pool	2.85 – 2.8	July	na	na		
			Aug 1-31	-3.4	1.1		
			Sep 1-30	-2.3	0.8		
			Oct 1-31	-0.5	0.6		
Cumulative Affect	Up Snow Cr and dn LNFH	5.5 – 2.6	Jul 19-31	+0.6	0.2		
			Aug 1-31	-1.0	0.7		
			Sep 1-30	na	na		
			Oct 1-31	+0.3	0.2		

Discussion

Water temperature monitoring in Icicle Creek began mid-July and only a few months of data were analyzed for this report. Water temperature comparisons from different sites reveal effects from different LNFH operations, including supplementation with water from the Snow Lakes, diversion of water, and return of used hatchery water. The biggest differences in water temperatures at the various locations were apparent in August and September. Water temperature differences were not apparent in July, but we only had temperatures for the later part of the month. There was little water temperature variability between the sites beginning in October. Additional data will be helpful in describing the temperature regime in Icicle Creek and evaluating effects of LNFH actions on water temperature.

Snow Creek Supplementation: Of the LNFH actions evaluated, inflow of water from Snow Creek had one of the greatest effects on water temperature, lowering the mean daily water temperature during August and September by over 2°C. The monitoring site upstream of Snow Creek at rm 5.5 was one of the warmest sites monitored. Inflow of water from Snow Creek cooled the stream water substantially, and the site downstream of Snow Creek had the lowest water temperatures recorded in Icicle Creek in 2005. Quantity of water inflow from Snow Creek would affect the magnitude of the temperature decrease in Icicle Creek. Further analysis could be conducted to determine the relationship between inflow from Snow Creek and relative changes in water temperature in Icicle Creek.

Water Diversion: Diversion of water had no immediate effect on water temperature in Icicle Creek. However, the rate of warming was more than doubled downstream of the diversion compared to upstream of it. The rate of warming per mile for August and September was an average of +0.7°C upstream of the diversion and an average of +2.1°C downstream of the diversion. While other factors may contribute to the increased warming, the decreased water volume would contribute to the increased rate of warming.

Original Channel: The water temperature increased typically about 1°C while flowing through the mile long original channel. The rate of temperature warming by distance was less than the reach upstream of it from the water diversion to the upper end of the original channel.

Hatchery Return Water: The spillway pool was the second coolest site measured in the stream (downstream of Snow Creek was the coolest). Water in the spillway pool would in part come from the hatchery ladder which has a combination of surface water from the diversion at rm 4.5 and well water. Water flowing down the bypass canal also enters the spillway pool, although at low flows the bypass canal is typically dry. The spillway pool is probably over 10 ft deep in areas and is used by adult salmon, steelhead, bull trout, and other fish species. The spillway pool provides cooler water compared to areas immediately downstream and in the original channel.

Cumulative Affect: We compared water temperatures from upstream of Snow Creek to downstream of LNFH to evaluate the cumulative effects of the LNFH actions. Water downstream of the LNFH is a mix of water coming down the original channel, and water returned after use by the LNFH into the spillway pool and in the return water that goes through the settling pond. The water temperatures at this site were mostly less than water temperatures

upstream of Snow Creek. The water temperature warming in the 2.9 miles reach from upstream of Snow Creek to downstream of LNFH was mostly due to warming as the stream moved downstream. The rate of warming was increased by the decrease in water flow due to the diversions. Water cooling in Icicle Creek was from inflow of supplemental water via Snow Creek and return of LNFH water. Changes in water temperatures were greatest in August and September.

Future Monitoring

This report summarizes some of the water temperatures recorded in Icicle Creek beginning mid-July through early November, 2005. Monitoring of the sites will continue. The site downstream of the LNFH water intake could be removed since there was no significant difference from the temperatures recorded upstream of the intake. The LNFH has initiated monitoring of water temperature in their return water. Additional monitoring sites in lower Icicle Creek and in the Wenatchee River should be considered.

References

- McPhail, J.D. and J.S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. British Columbia. Fisheries Management Report No. 104.
- Montgomery Water Group, Inc. 2004. Water management plan for Leavenworth National Fish Hatchery. Kirkland, Washington. 17 p.
- Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, and J.D. McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. U.S. Fish and Wildlife Service, Monograph 1, Leavenworth, Washington.
- WRWSC (Wenatchee River Watershed Steering Committee). 1998. Wenatchee River watershed action plan: a plan containing nonpoint pollution source control and implementation strategies. Chelan County Conservation District, Wenatchee, Washington.

Appendix Tables and Figures

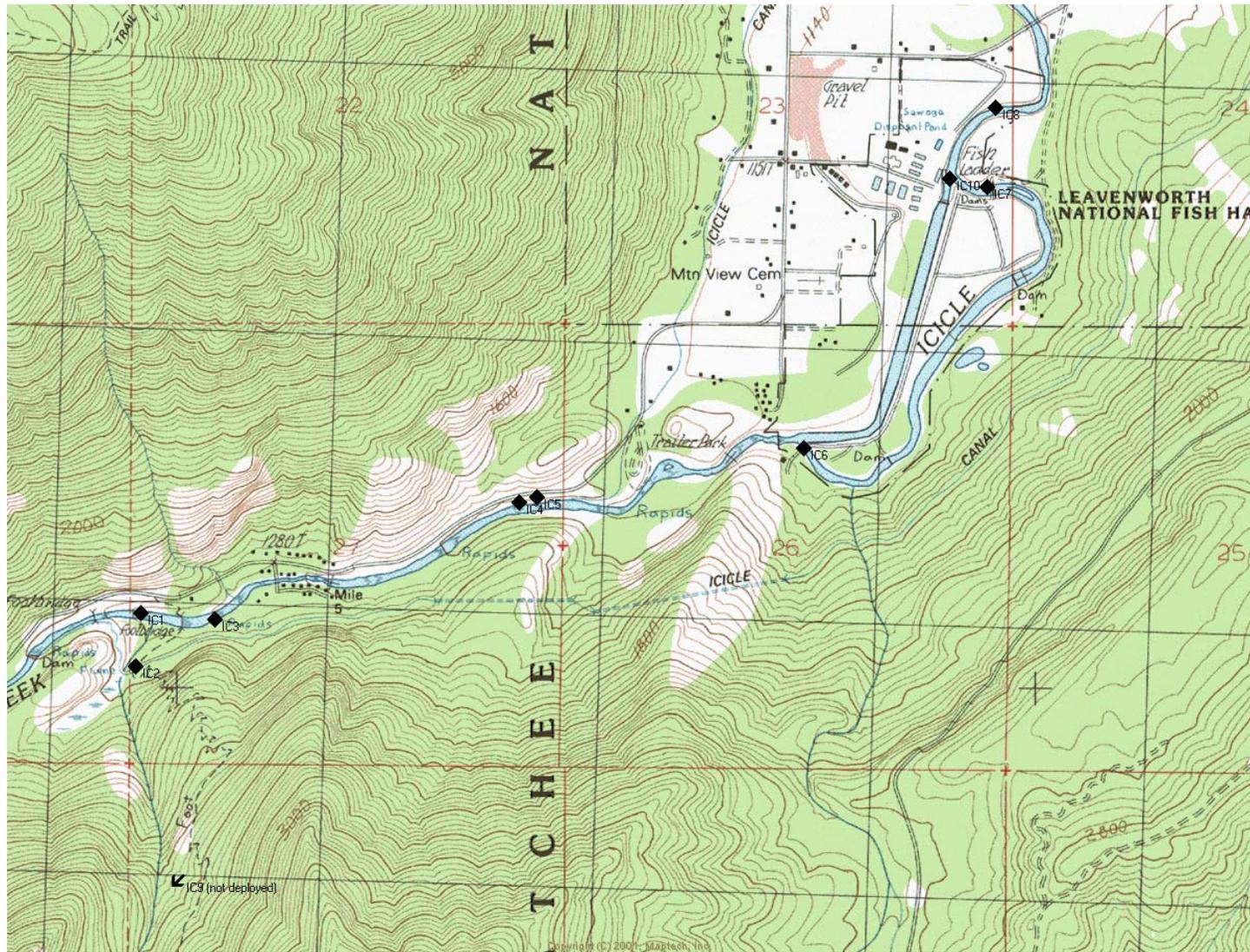


Figure A1. Locations of nine Optic StowAway Temperature Loggers in Icicle and Snow Creeks, 2005. Note logger site at rm 8.2 not on map.

Table A3. Daily mean water and air temperatures in Icicle Creek at sites from rm 2.6-8.2, July 16 – November 9, 2005.

Date	rm 8.2 mean °C up Boulder Falls	rm 5.5 mean °C up Snow Cr	rm 0.2 mean °C in Snow Cr	rm 5.4 mean °C down Snow Cr	rm 4.55 mean °C up Intake	rm 4.45 mean °C down Intake	rm 3.8 mean °C upper O. Channel	rm 2.85 mean °C lower O.Channel	rm 2.8 mean °C Spillway Pool	rm 2.6 mean °C down LNFH	rm 2.8 LNFH mean °C Air Temp
07/16/05		15.0	14.3	15.0							23
07/17/05		15.1	14.4	15.1							19
07/18/05		16.4	15.6	16.4							23
07/19/05		16.4	15.1	16.2	16.8	16.7	17.4	18.0		17.3	25
07/20/05		16.1	14.9	16.0	16.5	16.5	17.2	17.7		16.9	23
07/21/05		15.9	14.6	15.8	16.2	16.2	17.0	17.7		16.7	22
07/22/05		16.2	16.3	16.2	16.7	16.7	17.1	17.5		16.8	26
07/23/05		15.3	15.2	15.3	15.7	15.7	16.2	16.6		16.1	19
07/24/05		15.2	14.5	15.1	15.5	15.5	16.1	16.6		15.9	20
07/25/05		15.9	15.1	15.7	16.1	16.2	16.8	17.4		16.6	20
07/26/05		16.3	15.2	16.0	16.4	16.5	17.1	17.7		16.9	22
07/27/05		16.3	15.0	16.0	16.4	16.4	17.1	17.5		16.9	23
07/28/05		17.1	15.6	16.7	17.2	17.2	17.8	18.4		17.6	25
07/29/05		17.0	15.1	16.4	17.0	17.0	17.7	18.3		17.4	25
07/30/05		16.9	14.7	16.2	16.7	16.8	17.5	18.2	15.9	17.2	23
07/31/05		17.2	14.9	16.5	17.0	17.0	17.8	18.5	16.1	17.4	24
08/01/05		16.6	14.6	15.9	16.5	16.5	17.1	17.6	15.7	16.7	25
08/02/05		15.1	12.8	14.3	14.8	14.9	15.7	16.5	14.3	15.4	18
08/03/05		15.4	13.1	14.4	14.9	14.9	15.7	16.5	14.4	15.6	20
08/04/05		15.5	13.1	14.4	14.8	14.9	15.7	16.4	14.4	15.4	21
08/05/05		16.6	13.7	15.1	15.7	15.7	16.6	17.3	15.1	16.4	23
08/06/05		17.3	13.9	15.6	16.2	16.3	17.2	18.1	15.6	16.9	26
08/07/05		17.3	13.6	15.4	16.0	16.1	17.2	18.1	15.5	16.8	25
08/08/05		17.3	13.6	15.3	15.9	16.0	17.2	18.1	15.4	16.7	24
08/09/05		17.3	13.7	15.3	16.0	16.0	17.2	18.0	15.4	16.6	25
08/10/05		17.2	13.3	14.9	15.7	15.8	17.0	18.0	15.2	16.5	24
08/11/05		16.1	12.7	14.1	14.7	14.7	15.9	16.9	14.4	15.5	22
08/12/05		16.4	13.1	14.4	15.0	15.1	16.3	17.4	14.6	15.7	21

Date	rm 8.2 mean °C up Boulder Falls	rm 5.5 mean °C up Snow Cr	rm 0.2 mean °C in Snow Cr	rm 5.4 mean °C down Snow Cr	rm 4.55 mean °C up Intake	rm 4.45 mean °C down Intake	rm 3.8 mean °C upper O. Channel	rm 2.85 mean °C lower O.Channel	rm 2.8 mean °C Spillway Pool	rm 2.6 mean °C down LNFH	rm 2.8 LNFH mean °C Air Temp
08/13/05		16.6	12.5	14.0	14.8	14.9	16.4	17.7	14.5	15.7	22
08/14/05		16.6	12.8	14.1	14.7	14.8	16.4	17.7	14.4	15.4	21
08/15/05		17.1	13.2	14.5	15.2	15.3	17.0	18.4	14.7	15.7	23
08/16/05		17.2	13.1	14.2	15.1	15.4	17.5	19.2	14.5	15.7	25
08/17/05		16.4	12.7	13.7	14.4	14.6	16.7	18.4	13.9	14.9	25
08/18/05		16.2	12.2	13.3	14.1	14.3	16.4	18.0	13.6	14.8	19
08/19/05		15.9	12.1	13.1	13.8	14.0	16.3	18.0	13.3	14.3	20
08/20/05		16.5	12.5	13.5	14.2	14.4	16.7	18.5	13.6	14.6	20
08/21/05		17.1	13.3	14.1	14.9	15.1	17.5	19.4	14.2	15.2	23
08/22/05		16.7	12.6	13.4	14.4	14.6	17.0	18.9	13.9	15.0	24
08/23/05		15.3	11.3	12.1	12.9	13.1	15.6	17.4	12.6	13.6	23
08/24/05		14.4	10.8	11.5	12.3	12.5	14.9	16.6	12.0	12.9	16
08/25/05		14.6	11.2	11.8	12.5	12.6	14.3	16.0	12.1	13.1	18
08/26/05		15.2	11.6	12.4	12.9	13.0	14.5	15.9	12.5	13.5	19
08/27/05	14.7	15.6	11.7	12.8	13.5	13.6	14.9	16.1	13.0	14.2	22
08/28/05	14.8	15.6	11.9	12.9	13.4	13.4	14.6	15.7	12.9	13.9	22
08/29/05	14.0	15.1	11.0	12.0	12.9	13.0	14.8	17.1	12.6	13.9	21
08/30/05	13.0	13.7	10.5	11.3	11.8	11.9	12.9	14.0	11.7	12.6	15
08/31/05	13.4	14.2	10.5	11.4	12.1	12.1	13.3	14.4	11.9		17
09/01/05	13.8	14.5	10.9	11.6	12.2	12.3	13.6	14.8	12.1		18
09/02/05	14.5	15.3	11.4	12.2	12.8	12.9	14.4	15.6	12.7		19
09/03/05	13.4	14.6	10.5	11.2	12.1	12.2	14.0	15.5	12.0		16
09/04/05	12.1	13.3	9.7	10.3	11.0	11.2	12.7	14.1	11.0		14
09/05/05	11.7	12.6	9.3	10.0	10.6	10.6	12.0	13.1	10.5		14
09/06/05	11.8	12.7	9.5	10.1	10.7	10.7	12.1	13.1	10.6		16
09/07/05	12.3	13.2	10.0	10.6	11.2	11.2	12.7	13.9	11.0		
09/08/05	13.3	14.0	10.7	11.3	11.9	12.0	13.5	14.8	11.7		
09/09/05	12.4	13.4	9.7	10.3	11.1	11.2	12.6	13.8	11.2		23
09/10/05	11.3	12.0	9.1	10.0	10.3	10.4	11.1	11.9	10.3		14
09/11/05	10.9	11.6	9.3	10.0	10.4	10.4	11.0	11.5	10.3		13
09/12/05	11.3	12.0	9.4	10.2	10.7	10.7	11.6	12.3			15
09/13/05	11.1	11.9	9.1	9.8	10.3	10.4	11.6	12.6			14
09/14/05	11.9	12.6	9.6	10.2	10.8	10.9	12.4	13.5			16

Date	rm 8.2 mean °C up Boulder Falls	rm 5.5 mean °C up Snow Cr	rm 0.2 mean °C in Snow Cr	rm 5.4 mean °C down Snow Cr	rm 4.55 mean °C up Intake	rm 4.45 mean °C down Intake	rm 3.8 mean °C upper O. Channel	rm 2.85 mean °C lower O.Channel	rm 2.8 mean °C Spillway Pool	rm 2.6 mean °C down LNFH	rm 2.8 LNFH mean °C Air Temp
09/15/05	11.9	12.8	9.3	9.8	10.5	10.6	12.4	13.6			17
09/16/05	10.6	11.8	9.0	9.3	9.8	9.9	11.1	12.1			15
09/17/05	10.8	11.4	9.0	9.4	9.9	10.0	11.4	12.7			12
09/18/05	10.9	11.6	8.8	9.2	9.7	9.7	11.3	12.5	9.7		13
09/19/05	11.4	12.3	9.0	9.5	10.1	10.2	12.0	13.4	10.1		14
09/20/05	10.7	11.7	8.3	8.8	9.4	9.5	11.1	12.3	9.4		14
09/21/05	9.4	10.4	7.4	7.8	8.3	8.4	10.2	11.3	8.4		12
09/22/05	9.0	10.0	7.5	7.8	8.2	8.3	9.5	10.3	8.3		12
09/23/05	8.8	9.8	7.2	7.6	8.1	8.1	9.7	10.8	8.2		11
09/24/05	8.5	9.4	7.2	7.7	8.0	8.0	8.9	9.8	8.1		11
09/25/05	9.1	9.8	7.8	8.3	8.6	8.6	9.4	10.1	8.7		13
09/26/05	9.4	10.1	8.2	8.7	9.0	9.0	9.8	10.4	9.0		15
09/27/05	10.0	10.8	8.5	9.1	9.5	9.5	10.4	11.1	9.5		14
09/28/05	9.0	9.8	7.8	8.3	8.6	8.6	9.5	10.3	8.7		14
09/29/05	10.7	11.1	10.1	10.4	10.4	10.5	10.9	11.5	10.3		14
09/30/05	11.0	11.7	10.4	11.3	11.6	11.6	11.7	12.1	11.5		17
10/01/05	9.2	9.9	8.2	9.5	9.8	9.8	9.8	11.0	9.9		13
10/02/05	7.6	8.4	7.0	7.9	8.0	8.1	8.1	10.8	8.2		8
10/03/05	7.4	8.2	7.0	7.8	7.9	7.9	8.0	10.6	8.1		7
10/04/05	6.5	7.5	6.6	7.0	7.5	7.2	7.7	9.1	7.6	7.0	8
10/05/05	7.0	7.4	7.4	7.4	7.5	7.6	7.7	8.0	7.7	7.9	9
10/06/05	8.0	8.4	8.1	8.4	8.5	8.6	8.7	8.9	8.5	8.7	11
10/07/05	8.3	8.8	8.2	8.8	9.0	9.0	9.1	9.5	9.1	9.3	11
10/08/05	7.3	7.8	7.4	7.7	7.9	7.9	8.0	8.4	8.1	8.2	9
10/09/05	7.2	7.6	7.3	7.6	7.7	7.7	7.8	8.1	7.9	8.0	8
10/10/05	6.9	7.4	7.5	7.4	7.5	7.6	7.7	8.0	7.7	7.8	10
10/11/05	7.7	8.1	7.9	8.1	8.2	8.2	8.4	8.7	8.3	8.5	10
10/12/05	7.4	8.0	7.8	7.9	8.1	8.2	8.3	8.6	8.2	8.4	14
10/13/05	7.9	8.4	8.1	8.4	8.5	8.5	8.7	9.0	8.5	8.8	11
10/14/05	8.0	8.5	8.3	8.5	8.6	8.6	8.8	9.1	8.6	8.9	13
10/15/05	8.6	9.1	8.9	9.1	9.3	9.3	9.4	9.6	9.2	9.5	
10/16/05	8.7	9.1	8.6	9.0	9.1	9.2	9.3	9.5	9.1	9.4	13
10/17/05	9.7	10.1	9.7	10.2	10.3	10.3	10.5	10.5	10.1	10.4	13

Date	rm 8.2 mean °C up Boulder Falls	rm 5.5 mean °C up Snow Cr	rm 0.2 mean °C in Snow Cr	rm 5.4 mean °C down Snow Cr	rm 4.55 mean °C up Intake	rm 4.45 mean °C down Intake	rm 3.8 mean °C upper O. Channel	rm 2.85 mean °C lower O.Channel	rm 2.8 mean °C Spillway Pool	rm 2.6 mean °C down LNFH	rm 2.8 LNFH mean °C Air Temp
10/18/05	9.5	10.1	9.5	10.0	10.2	10.2	10.3	10.5	10.4	10.6	16
10/19/05	9.5	10.1	10.0	10.1	10.3	10.3	10.4	10.5	10.3	10.5	14
10/20/05	9.0	9.5	9.3	9.5	9.7	9.7	9.8	10.1	9.8	10.0	
10/21/05	8.2	8.8	8.8	8.7	8.8	8.9	9.0	9.4	9.1	9.3	12
10/22/05	7.2	8.0	8.1	7.7	7.8	7.8	7.8	8.4	8.1	8.2	11
10/23/05	7.0	7.7	8.2	7.5	7.6	7.7	7.7	8.2	7.8	7.9	11
10/24/05	7.3	7.8	8.2	7.7	7.7	7.8	7.8	8.3	7.9	8.0	11
10/25/05	7.0	7.6	8.0	7.5	7.5	7.6	7.7	8.2	7.8	7.9	11
10/26/05	6.9	7.6	7.7	7.4	7.6	7.6	7.7	8.4	7.9	8.0	11
10/27/05	5.0	6.0	6.1	5.5	5.7	5.7	5.8	6.8	6.1	6.2	6
10/28/05	5.6	6.2	6.6	6.0	6.1	6.1	6.2	6.8	6.3	6.4	4
10/29/05	5.5	6.1	6.0	5.7	5.8	5.9	5.8	6.1	6.1	6.1	7
10/30/05	5.0	5.7	5.5	5.3	5.4	5.4	5.5	5.7	5.6	5.7	6
10/31/05		4.7	5.1	4.1	4.4	4.4	4.5	4.8	4.8	4.7	7
11/01/05		3.8	4.4	3.4	3.4	3.5	3.6	3.7	3.7	3.7	6
11/02/05		4.1	4.2	3.7	3.9	3.9	4.0	4.2	4.2	4.2	3
11/03/05		3.8	4.0	3.5	3.6	3.6	3.7	3.8	3.8	3.8	5
11/04/05		4.0	3.8	3.6	3.8	3.8	3.8	4.0	4.1	4.0	2
11/05/05		3.3	3.3	2.7	2.9	2.9	3.0	3.2	3.2	3.2	4
11/06/05		2.9	3.1	2.4	2.5	2.6	2.6	2.8	2.9	2.8	4
11/07/05		2.7	2.6	2.3	2.3	2.3	2.3	2.4	2.6	2.5	4
11/08/05		2.8	2.9	2.5	2.6	2.6	2.7	2.8	2.8	2.8	2
11/09/05		3.3	3.1	3.0	3.1	3.1	3.0	3.1	3.2	3.2	

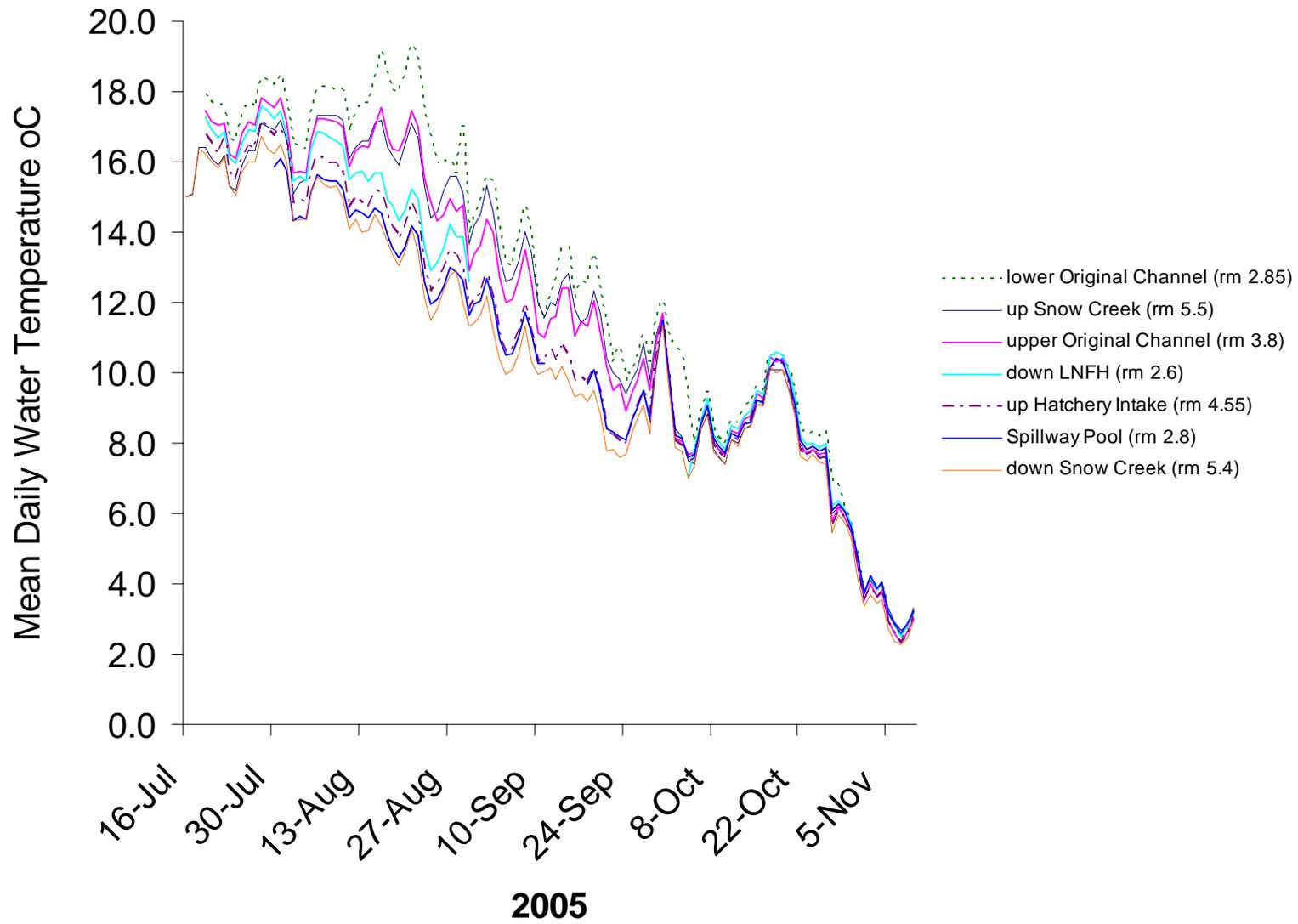


Figure A2. Mean daily water temperatures at seven sites in Icicle Creek between rm 2.6 and rm 5.5, July 16-November 9, 2005.

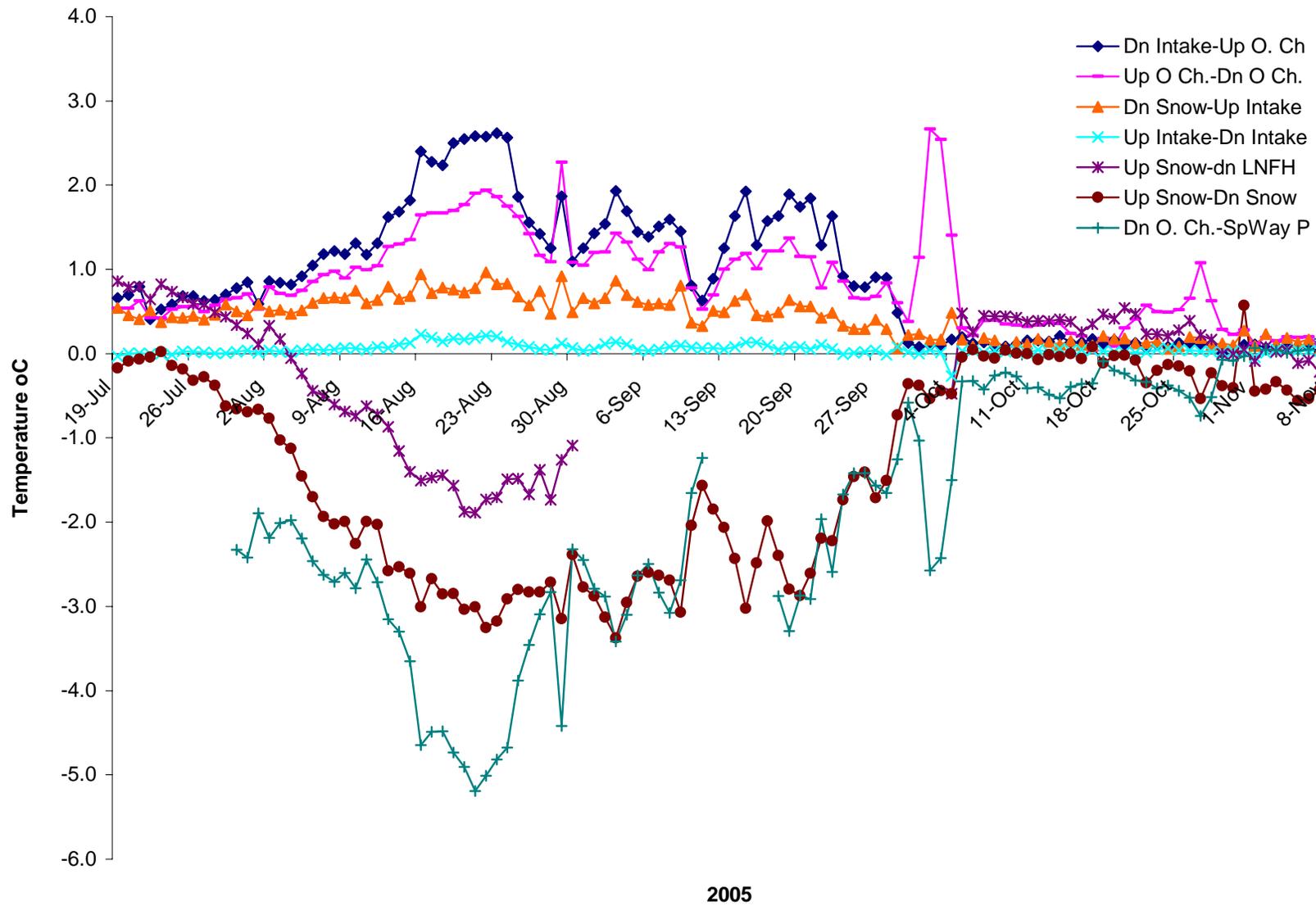


Figure A3. Temperature differences between seven sites in Icicle Creek between rm 2.6 and rm 5.5, July 16-November 9, 2005.

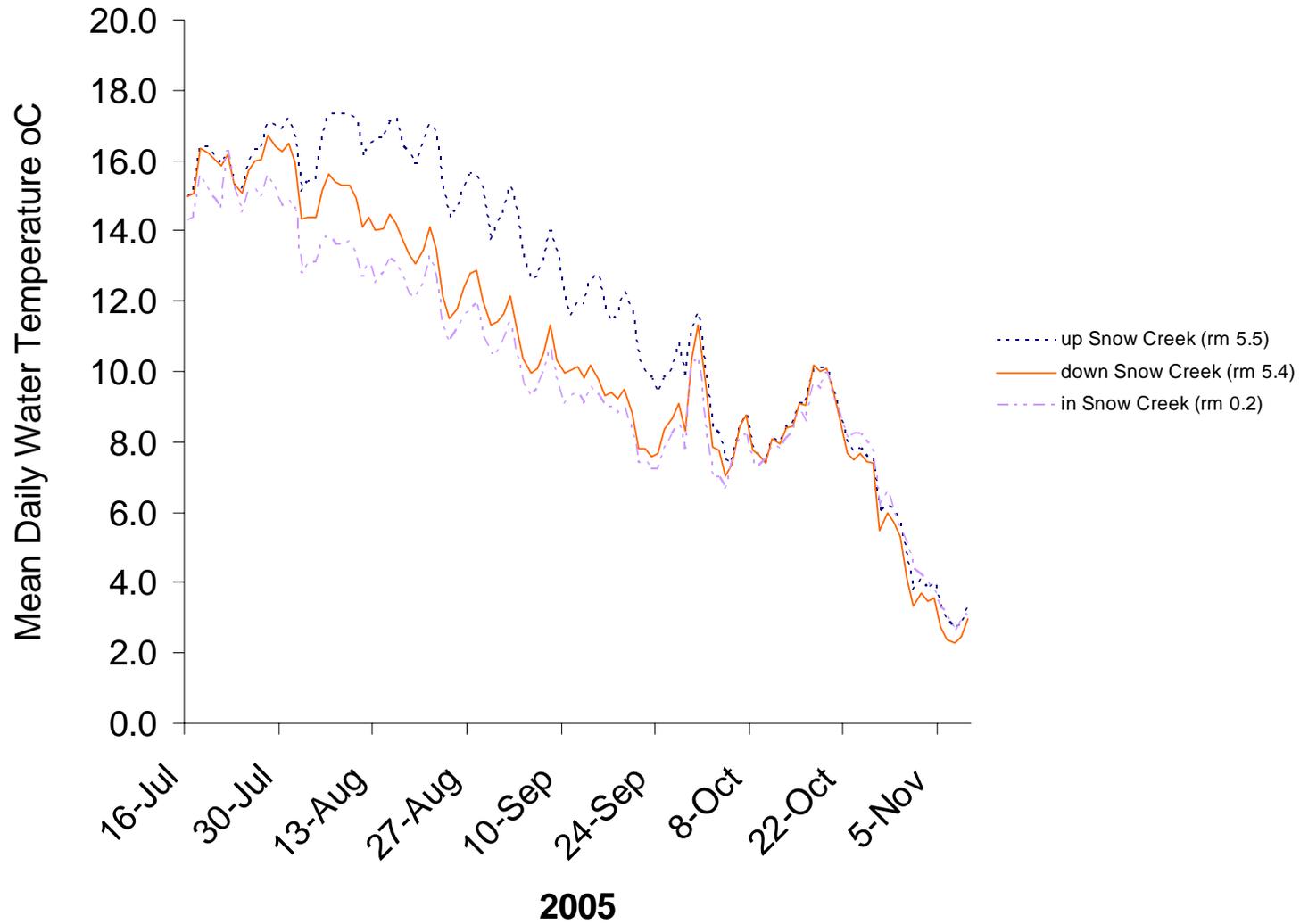


Figure A4. Comparison of mean daily water temperatures in Icicle Creek upstream and downstream of Snow Creek and in Snow Creek, July 16-November 9, 2005.

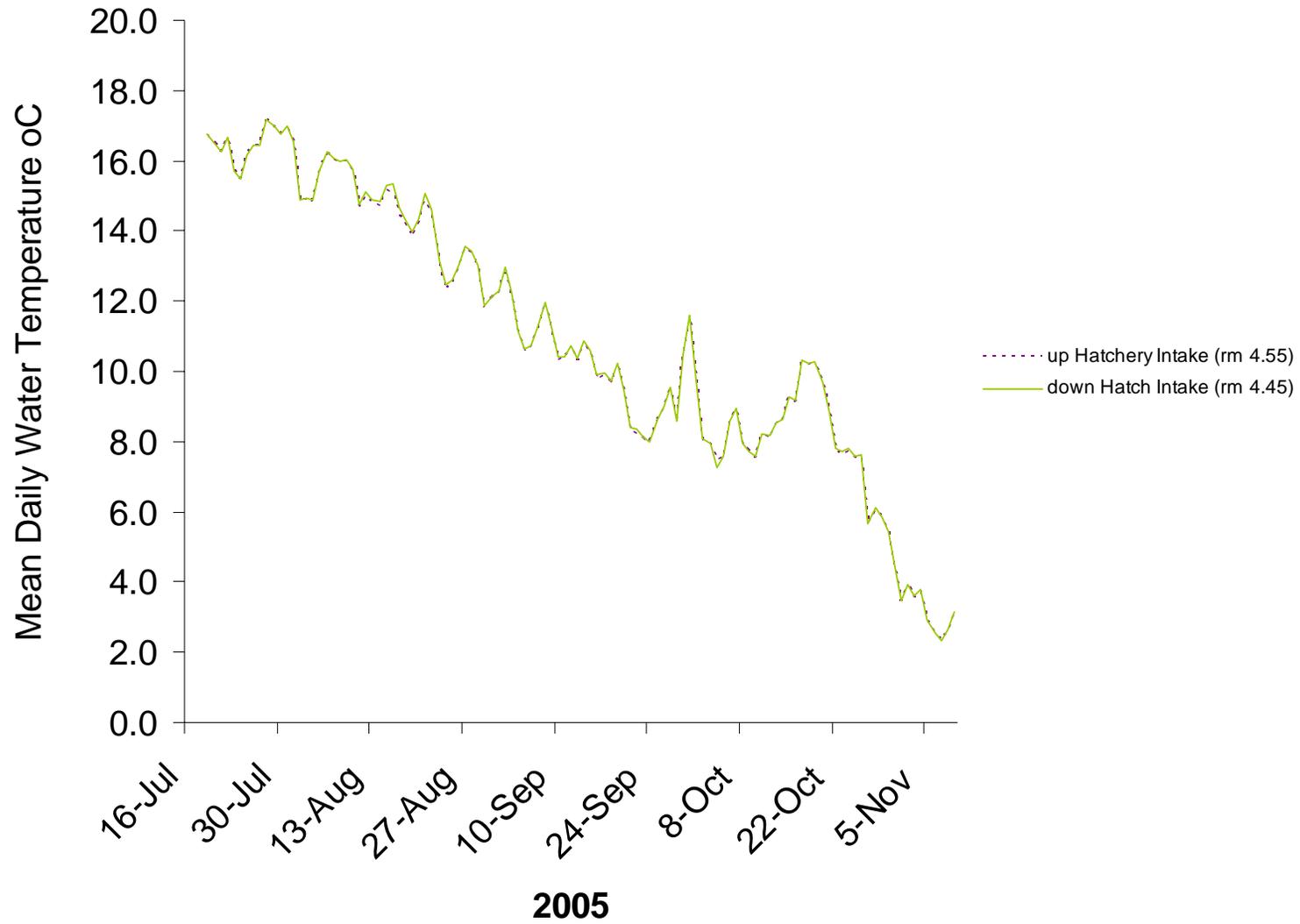


Figure A5. Comparison of mean daily water temperatures in Icicle Creek upstream and downstream of the LNFH water diversion intake and in Snow Creek, July 19-November 9, 2005.

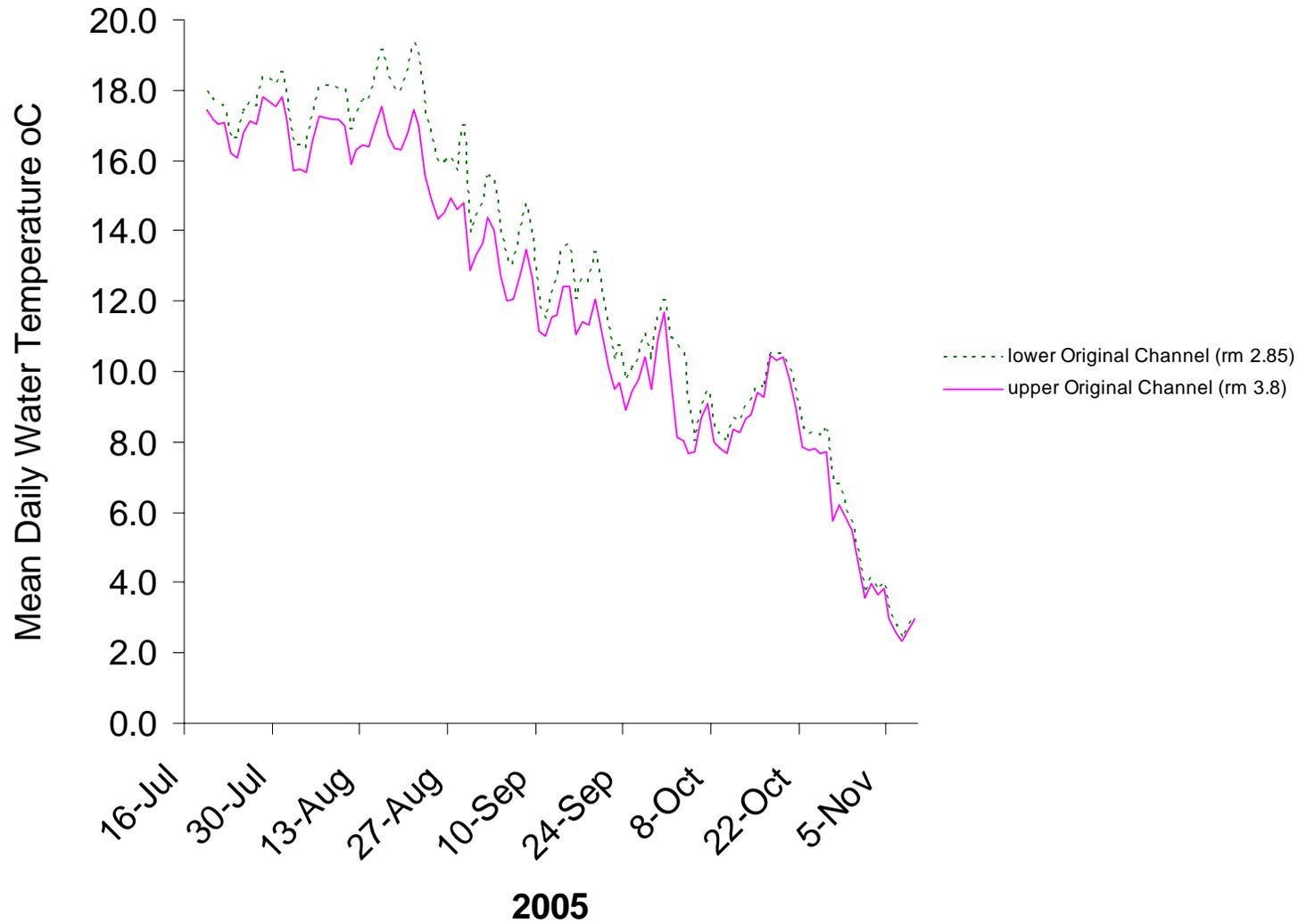


Figure A6. Comparison of mean daily water temperatures in Icicle Creek at the upper and lower end of the original channel, July 19-November 9, 2005.

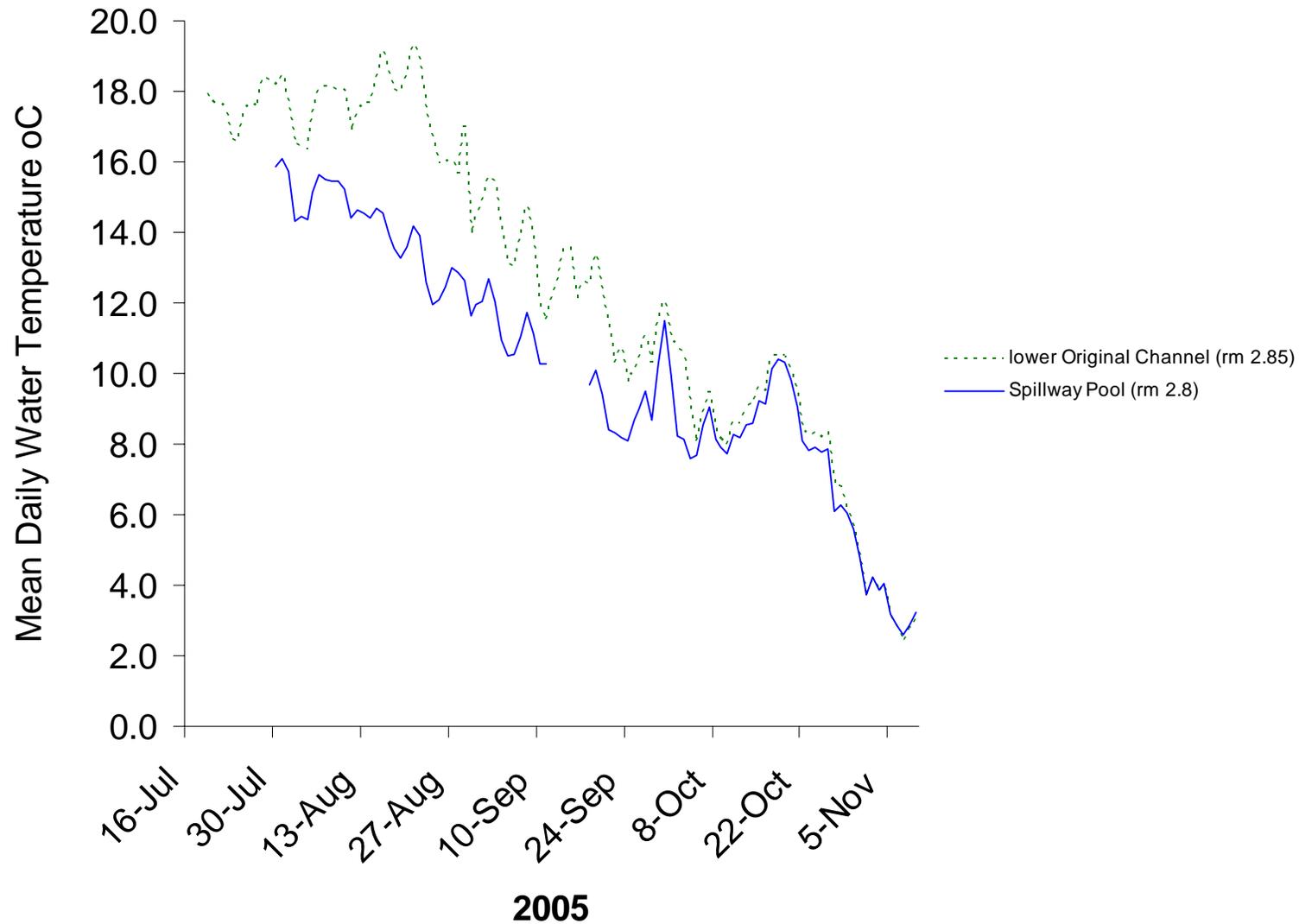


Figure A7. Comparison of mean daily water temperatures in Icicle Creek at the lower end of the original channel and in the spillway pool, July 19-November 9, 2005.

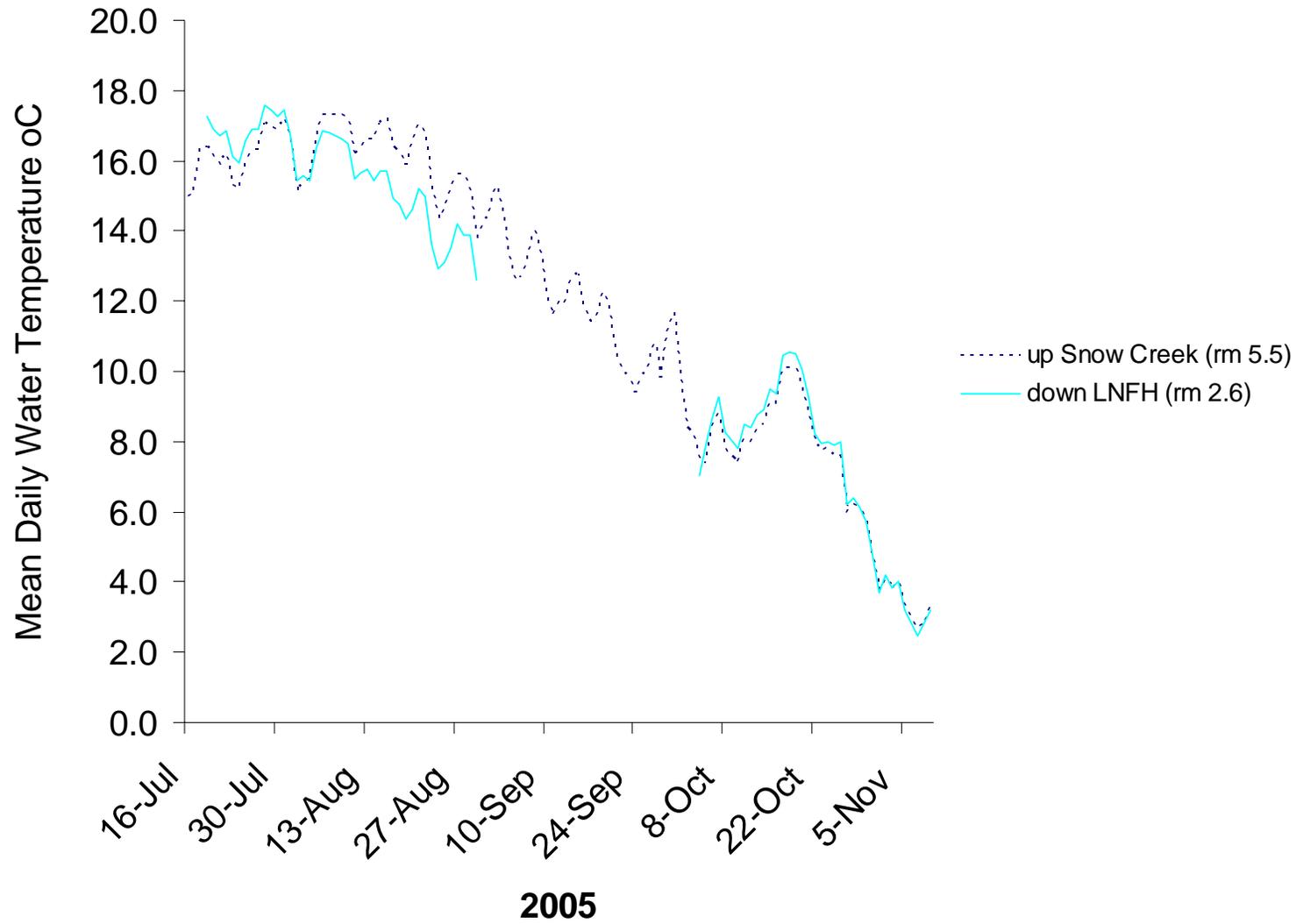


Figure A8. Comparison of mean daily water temperatures in Icicle Creek upstream of Snow Creek and downstream of the LNFH, July 16-November 9, 2005.

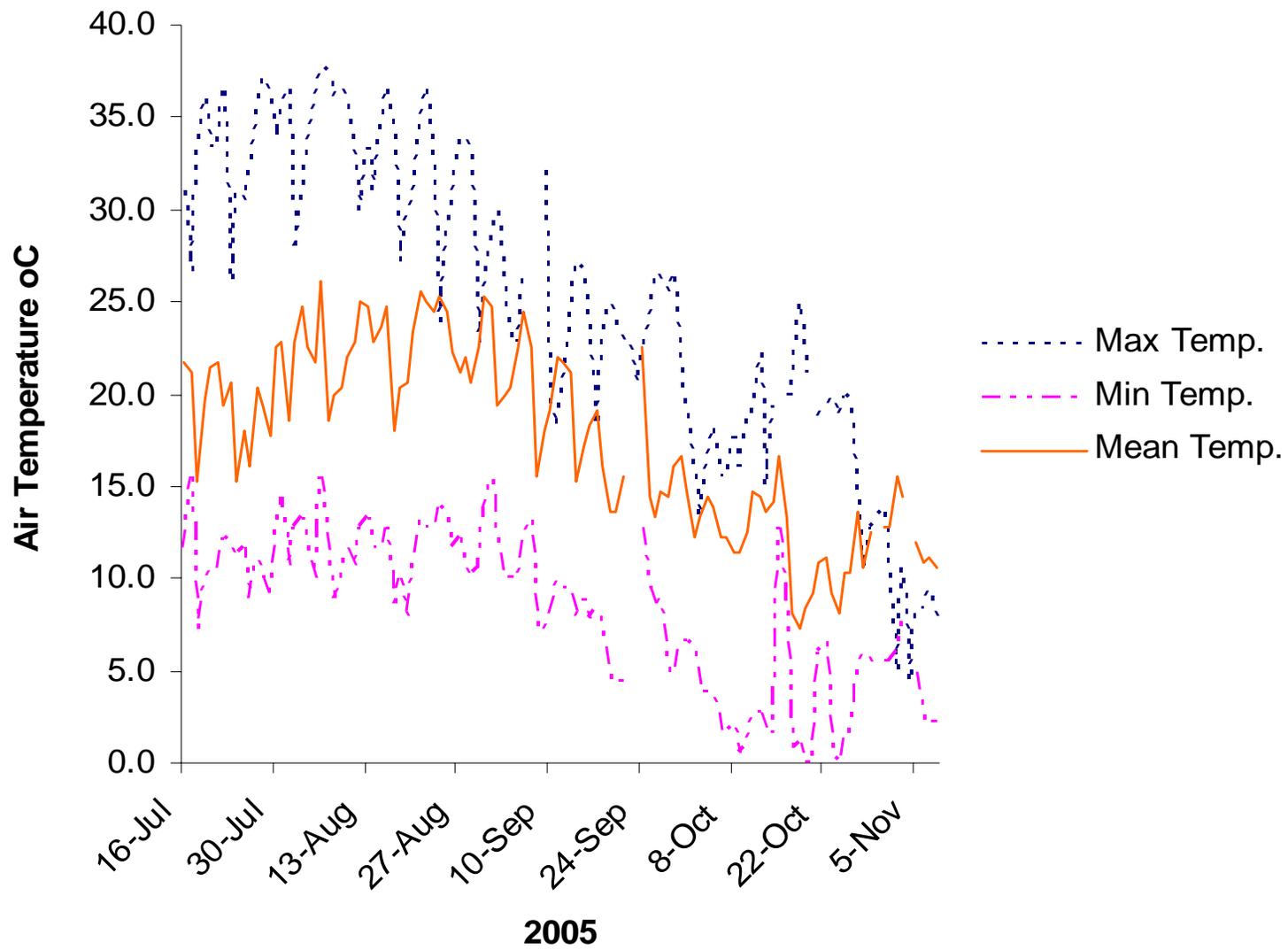


Figure A9. Maximum, minimum, and mean daily air temperatures recorded at LNFH, July 16-November 9, 2005.