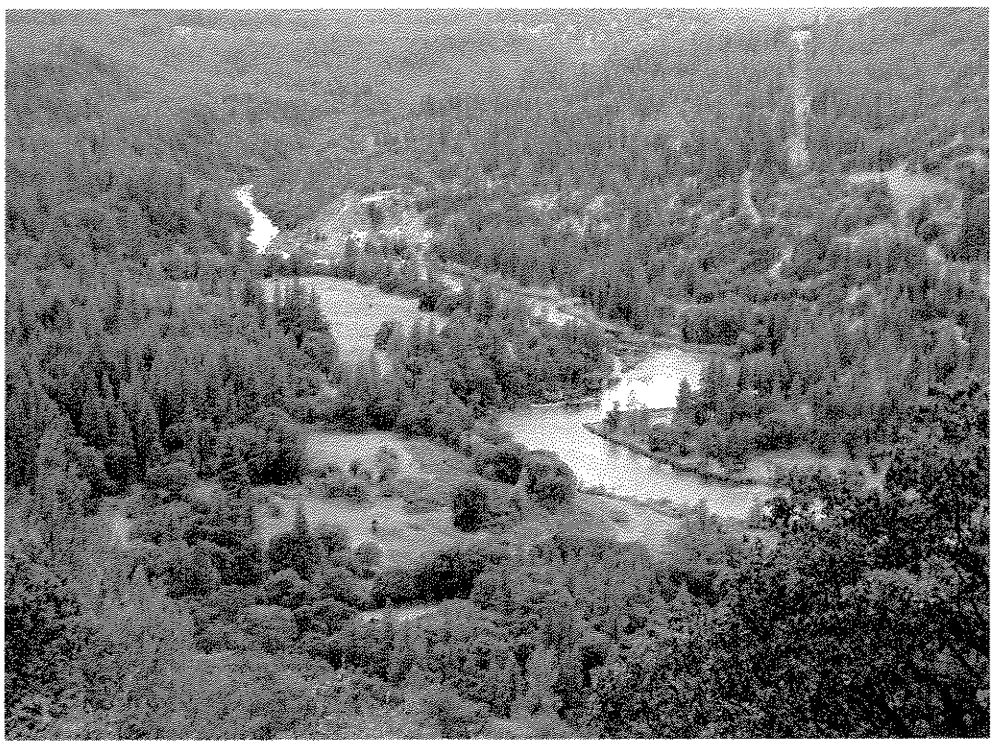
File: WATER QUALITY
Author: US BUREAU OF LAND MANAGEMENT

2002 and 2003 Upper Klamath River Water Temperature Monitoring

Bureau of Land Management
Lakeview District
Klamath Falls Resource Area



Prepared by Mike Turaski, Hydrologist
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Overview

The Bureau of Land Management (BLM) conducted water temperature monitoring at various sites in the Klamath River in 2003 and 2003 (Table 1, Figure 1). The objectives of this effort were to (1) characterize spatial and seasonal trends water temperature trends in the Upper Klamath Wild and Scenic River and adjacent river reaches and (2) provide high quality water temperature data for use by stakeholders in the ongoing FERC relicensing and TMDL processes.

In addition to summaries of the water temperature data, two other data sets are presented in this report. Instantaneous (collected every 30 minutes) and average daily streamflow is monitored by the USGS, and is provided herein to provide context for interpreting water temperature trends. Air temperature was monitored by the BLM at the USGS stream gage. This data also helps explain observed water temperatures.

Table 1. Locations of temperature probes installed by the BLM in the Klamath River in 2002 and 2003.

Site Number	Description	River Mile	Period of Record	
			2002	2003
KR3810	Klamath River downstream from J.C. Boyle Dam	224.5	6/12 – 12/31	1/1 – 9/21
KR3680	Klamath River upstream from springs in the J.C. Boyle Bypass Reach	223.9	6/14 – 12/31	1/1 – 9/21
KR3640	Klamath River near one of the springs in the J.C. Boyle Bypass Reach	223.4	6/14 – 11/7	No Data
KR3360	Klamath River upstream from J.C. Boyle Powerhouse	220.4	6/12 – 12/31	1/1 – 9/21
KR3275	Klamath River at USGS gaging station, downstream from J.C. Boyle Powerhouse	219.7	5/17 – 12/31	1/2 – 9/21
KR3275 Air	Air temperature at USGS gaging station, downstream from J.C. Boyle Powerhouse	219.7	7/2 – 12/31	1/1 – 9/22
KR3050	Klamath River upstream from Frain Ranch	215.5	5/17 – 10/31	No Data
KR2760	Klamath River immediately upstream from Oregon-California boundary	209.2	5/17 – 10/31	No Data
KR2600	Klamath River at Access #2, upstream from Copco I Reservoir	204.3	6/10 – 10/31	No Data

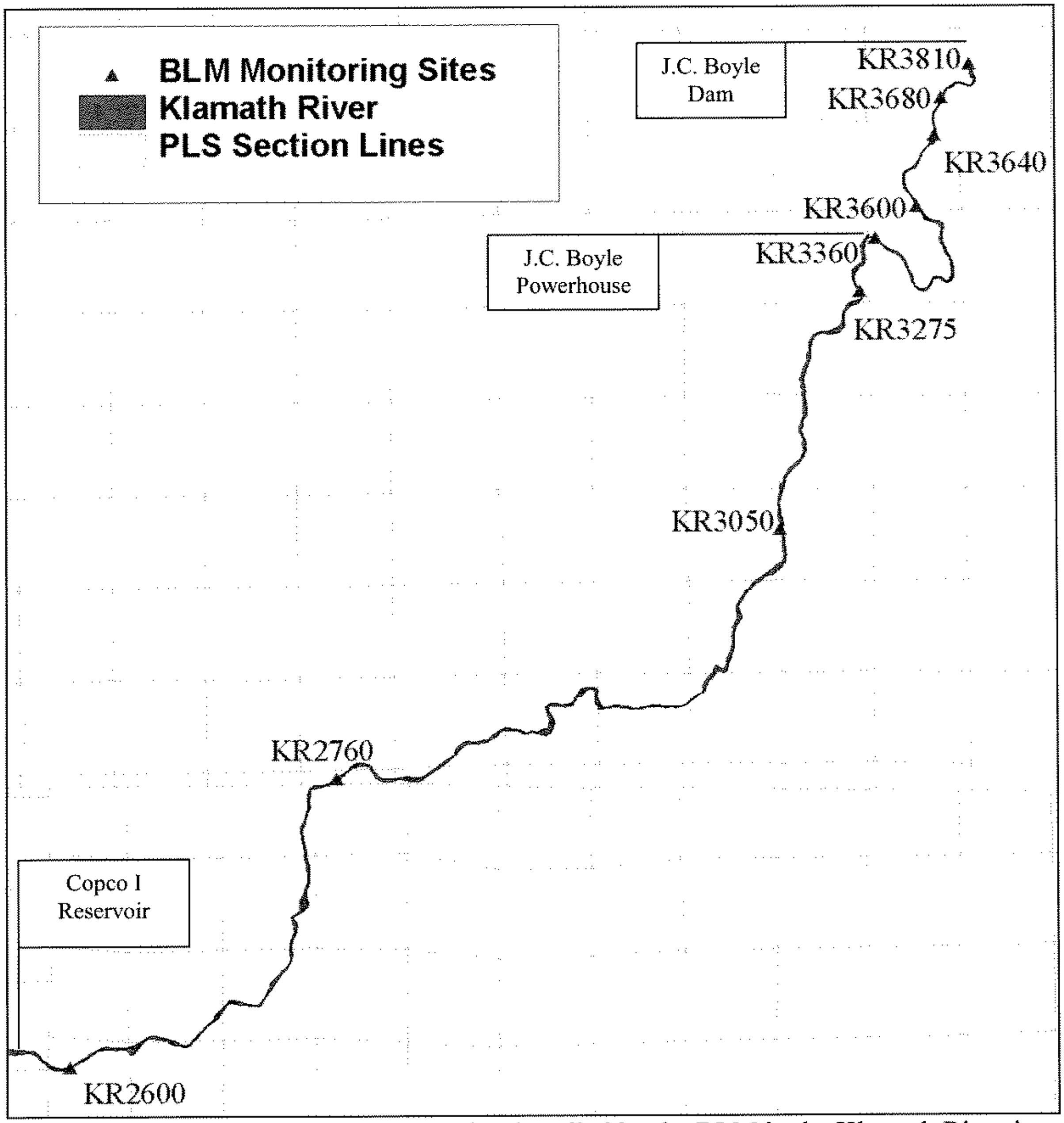


Figure 1. Locations of temperature probes installed by the BLM in the Klamath River in 2002 and 2003.

Quality Assurance/Quality Control

Water and air temperature data was collected using Optic Stowaway and Tidbit data loggers produced by Onset Computer Corporation. Optic Stowaway data loggers have an accuracy of ±0.6°F and a precision of 0.4°F. Tidbit data loggers have an accuracy of ±1.0°F and a precision of 2.0°F.

Data collection and QA/QC procedures were consistent with direction in the Oregon Plan Water Quality Monitoring Guidebook. Pre-deployment accuracy checks of temperature loggers were conducted in both 2002 and 2003; post-deployment accuracy checks were conducted in 2002 and will be conducted in 2003 (Tables 2 and 3). Field audits were measured using a traceable, calibrated digital thermometer with an accuracy of ±0.1°F manufactured by Control Company. Following retrieval of the temperature probes, the calibrated thermometer measurement for a given date and time was compared with the instream probe measurement closest to that time.

Subsequent to data collection, data was summarized using the Hydrostat Microsoft Excel program created by ODEQ.

Table 2. Quality control data for summer 2002 Klamath River temperature probes.

Site	**Serial Number**	**Accuracy Checks**		**Field Audits (Date, Time, and Temperature)**				
		Pre-	Post-	Date	Measurement with Calibrated Thermometer		Data Recorded by Instream Probe	
KR3810	515430	Passed	Passed	6/11/02	19:05	64.0 °F	20:00	63.9 °F
				9/8/02	15:00	63.4	15:00	63.3
				11/8/02	14:30	42.6	14:00	42.6
KR3680	295592	Passed	Passed	6/13/02	15:00	68.2	16:00	68.7
				9/8/02	14:35	64.1	15:00	64.0
				11/8/02	14:05	42.8	14:00	43.0
KR3640	283792	Passed	Passed	6/13/02	16:00	55.5	16:00	55.9
				9/8/02	14:25	54.0	14:30	54.2
				11/8/02	13:45	47.5	13:30	47.5
KR3360	515427	Passed	Passed	6/11/02	17:45	56.5	20:00	56.6
				9/8/02	13:35	56.2	14:00	56.3
				11/1/02	13:05	48.4	13:00	48.5
KR3275	515425	Passed	Passed	5/16/02	18:15	58.2	18:30	58.1
				6/28/02	17:30	68.0	17:30	68.1
				7/11/02	10:00	65.4	10:00	64.6
				9/8/02	13:05	61.6	13:05	61.5
KR3275 Air	515434	Passed	Passed	7/11/02	11:30	91.8	11:30	89.3
				9/8/02	13:05	62.8	13:00	65.2
KR3050	515424	Passed	Passed	5/16/02	16:46	60.6	17:00	60.5
				9/8/02	12:35	61.0	13:00	61.3
				11/1/02	11:55	45.9	11:00	45.1
KR2760	515423	Passed	Passed	5/16/02	15:20	61.3	16:00	61.6
				9/8/02	11:35	54.7	12:00	54.7
				11/1/02	11:00	44.8	11:00	44.8
KR2600	283793	Passed	Passed	6/9/02	20:00	60.2	20:30	61.4
				11/1/02	8:30	41.4	8:30	42.1

Table 3. Quality control data for summer 2003 Klamath River temperature probes.

Site	Serial Number	Accuracy Checks		Field Audits (Date, Time, and Temperature)				
		Pre-	Post-	Date	Measurement with Calibrated Thermometer		Data Recorded by Instream Probe	
KR3810	181248	Passed	Passed	5/13/03 9/22/03	13:50 8:55	53.6 ˚F 61.3	14:00 8:00	54.2˚F 61.5
KR3680	283792	Passed	Passed	5/13/03 9/22/03	14:20 10:10	55.2 61.2	15:00 10:00	55.3 60.9
KR3360	283793	Passed	Passed	5/13/03 9/22/03	14:40 9:45	55.6 53.6	15:00 9:00	55.8 53.3
KR3275	407305	Passed	Passed	6/19/03 9/22/03	12:10 9:20	63.1 55.0	12:30 9:00	63.2 53.9
KR3275 Air	182456	Passed	Passed	5/16/03 9/22/03	12:00 9:30	58.5 53.2	12:30 9:30	57.9 46.2

Results- River Discharge

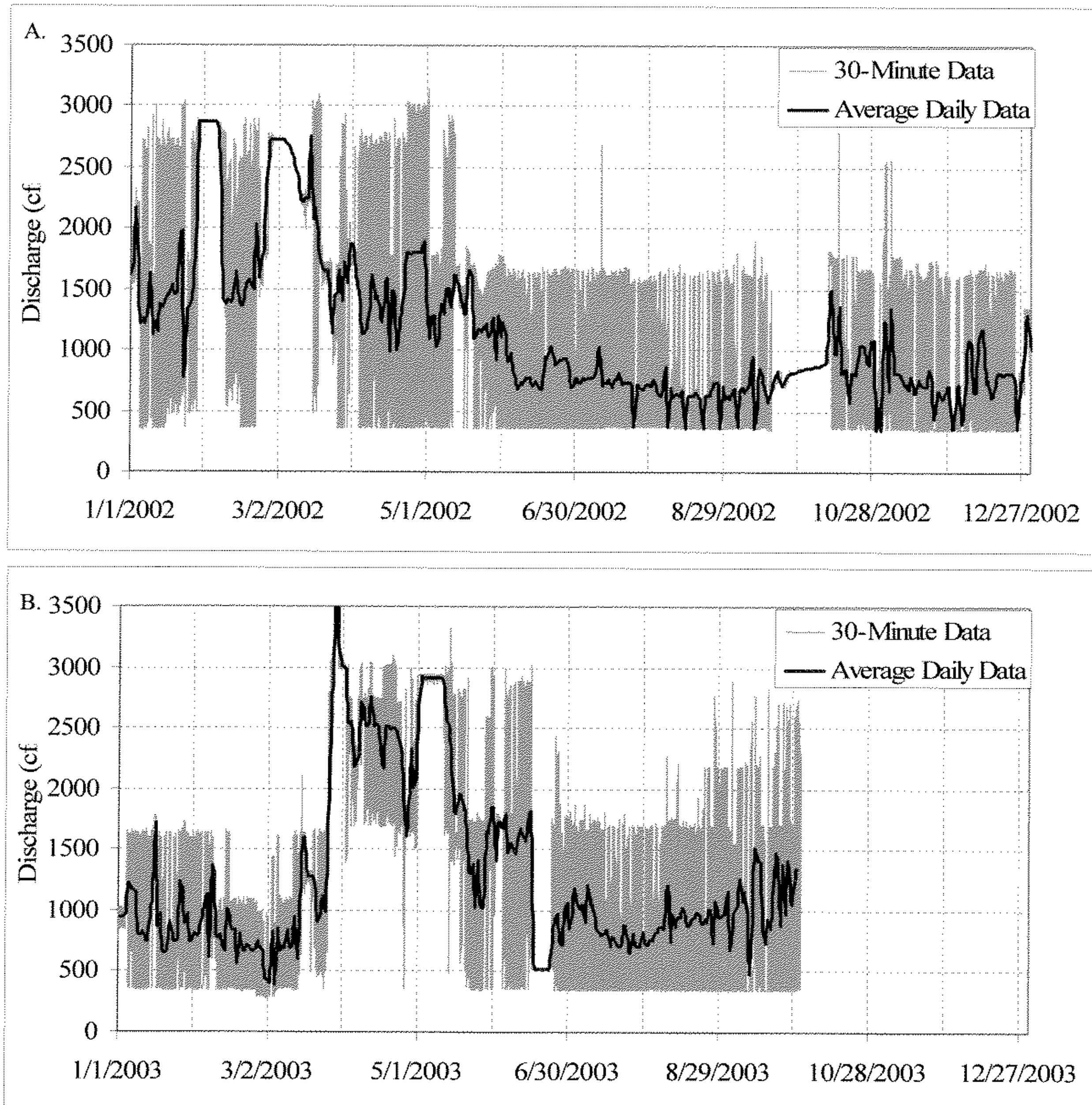


Figure 2. Instantaneous (30-minute) and average daily streamflow from the USGS downstream from the J.C. Boyle Powerhouse (USGS gage 11510700) for (A) 2002 and (B) 2003. Note the daily flow fluctuations caused by operation of the J.C. Boyle Powerhouse.

The monitoring area is characterized by three distinct flow regimes. In the upper portion of the J.C. Boyle Bypass Reach, flows for most of the year remain steady at 100 cfs. Springs in the middle of the bypass reach provide 220 cfs of inflow, resulting in year-round flows of 320 cfs in the lower portion of that reach. Downstream from the J.C. Boyle Powerhouse (the "peaking reach"), average daily flows range from 500 to 3000 cfs (Figure 2). During the 2002 and 2003 calendar years, as in most years, hydroelectric peaking operations caused large fluctuations around the daily average flows.

Two controlled releases of steady flows greater than the normal 100 cfs bypass reach minimum flow occurred during 2002 and 2003. The first, from 9/17/02 to 10/8/02, consisted of ~580 cfs releases into the bypass reach (resulting in flows on the order of 800 cfs at the downstream end of the bypass reach) followed by a period of slightly higher steady flows in the peaking reach. The second, from 6/15/03 to 6/22/03, consisted of steady ~300 cfs releases into the bypass reach (resulting in flows on the order of 520 cfs at the downstream end of the bypass reach).

Results – Air Temperature

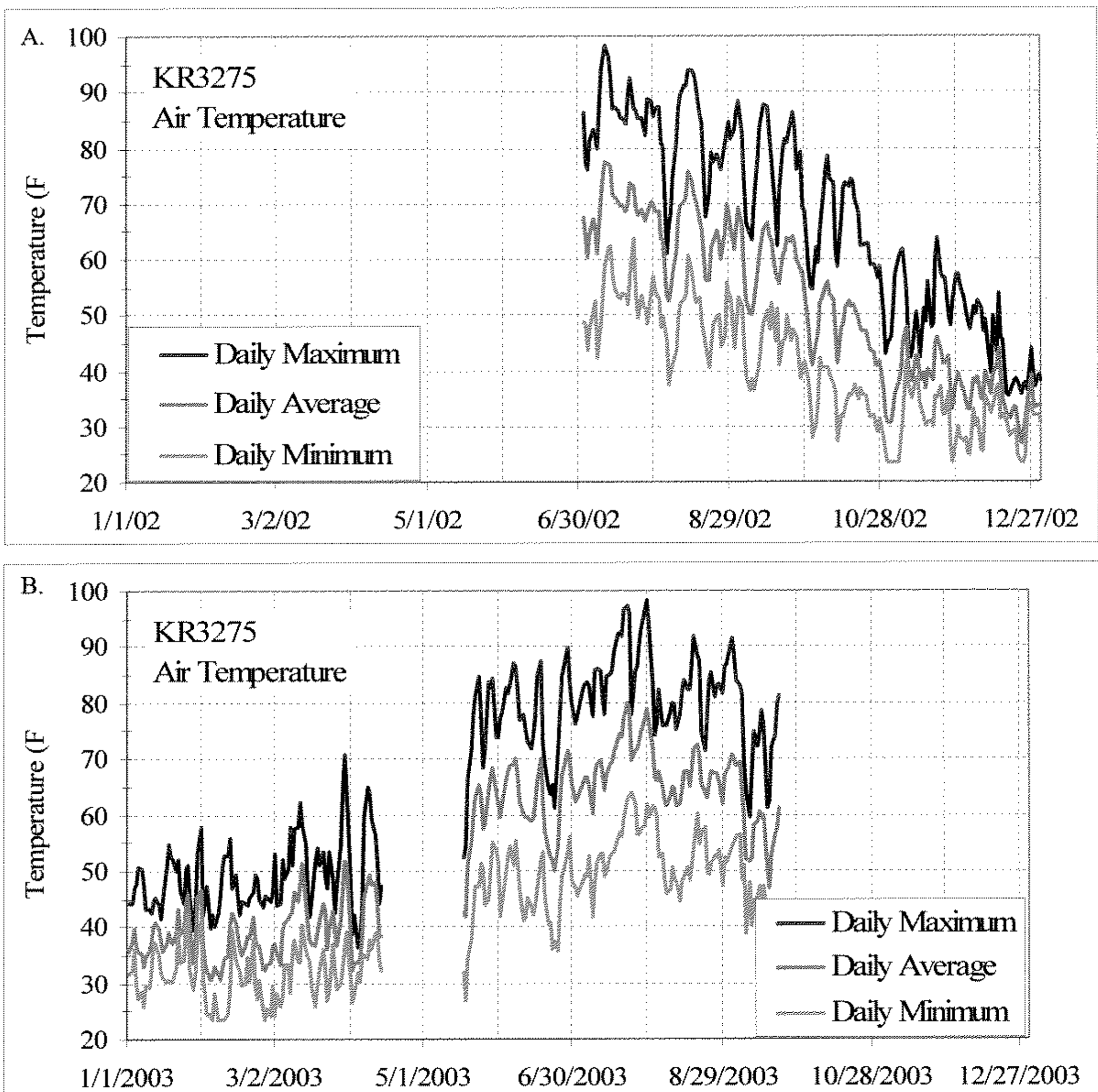


Figure 3. Daily maximum, average, and minimum air temperatures measured at the USGS stream gage during (A) 2002 and (B) 2003.

Air temperatures at the USGS gage range from 20°F to 100°F (Figure 3). Average daily air temperatures range from 30°F to 80°F. Daily temperatures fluctuations are on the order to 30 to 35°F during the summer and 10 to 15°F during the winter.

Results – Water Temperature – J.C. Boyle Bypass Reach

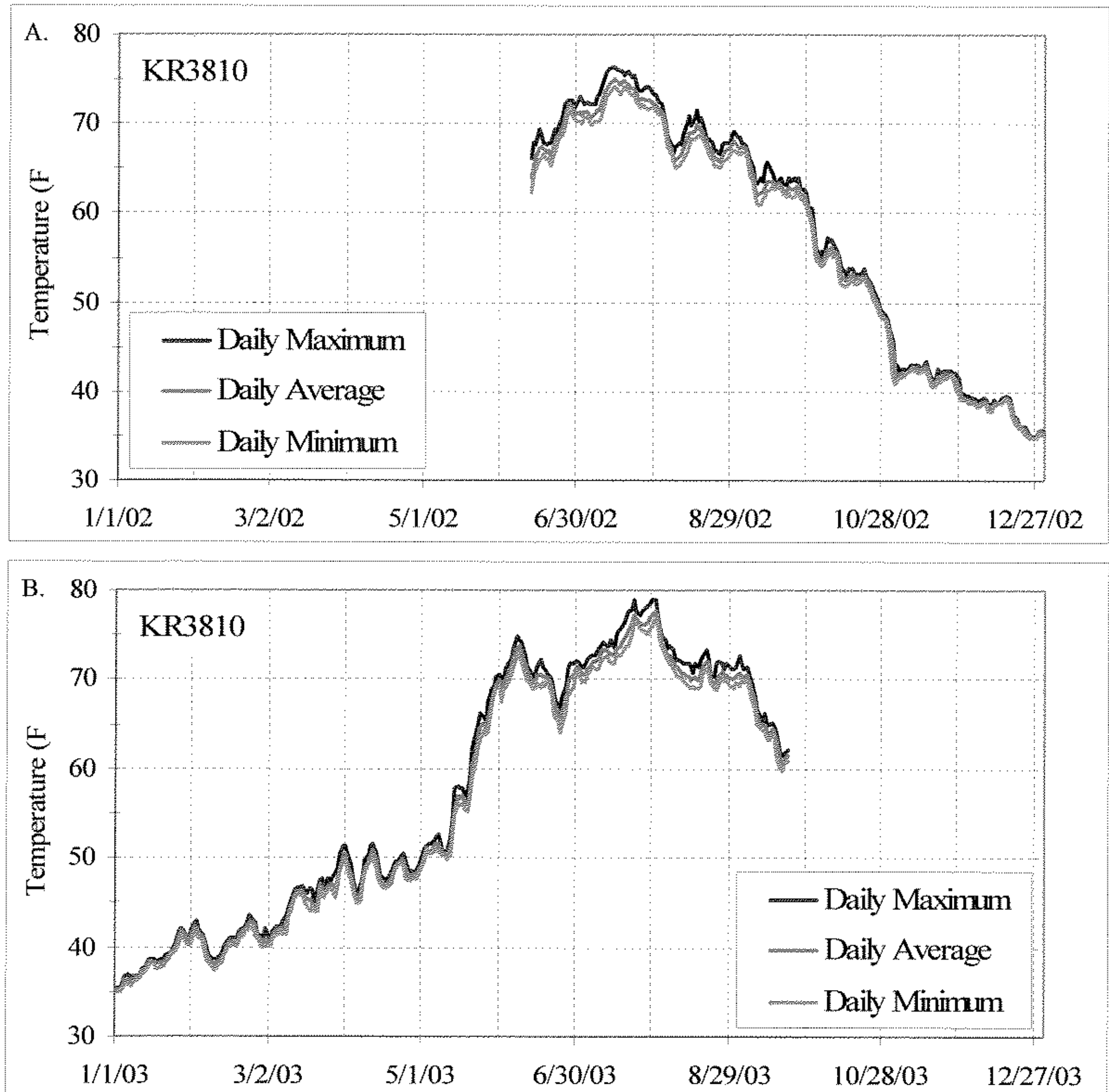
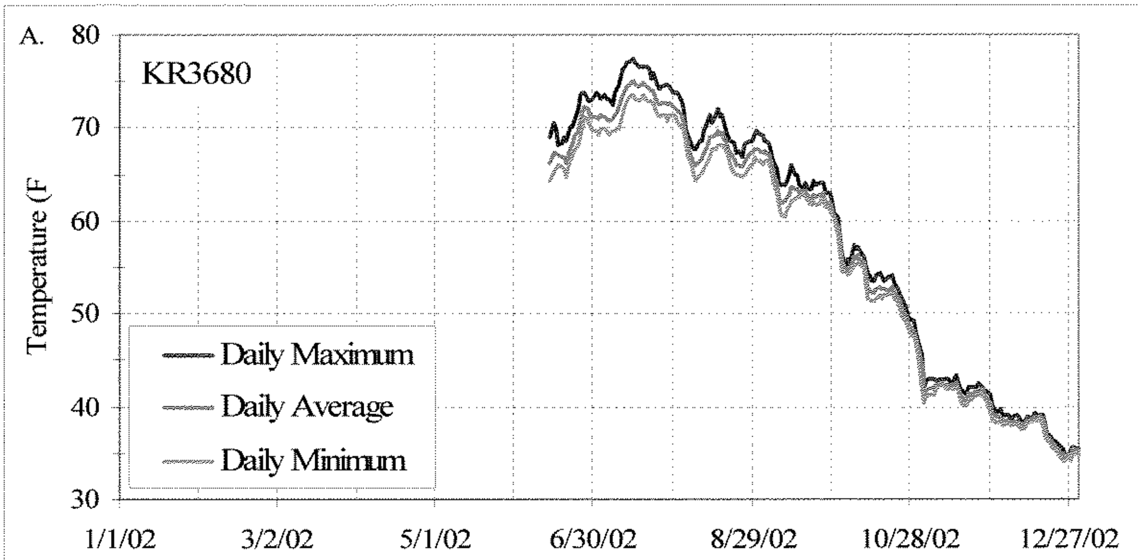


Figure 4. Daily maximum, average, and minimum water temperatures measured downstream from J.C. Boyle Dam during (A) 2002 and (B) 2003.



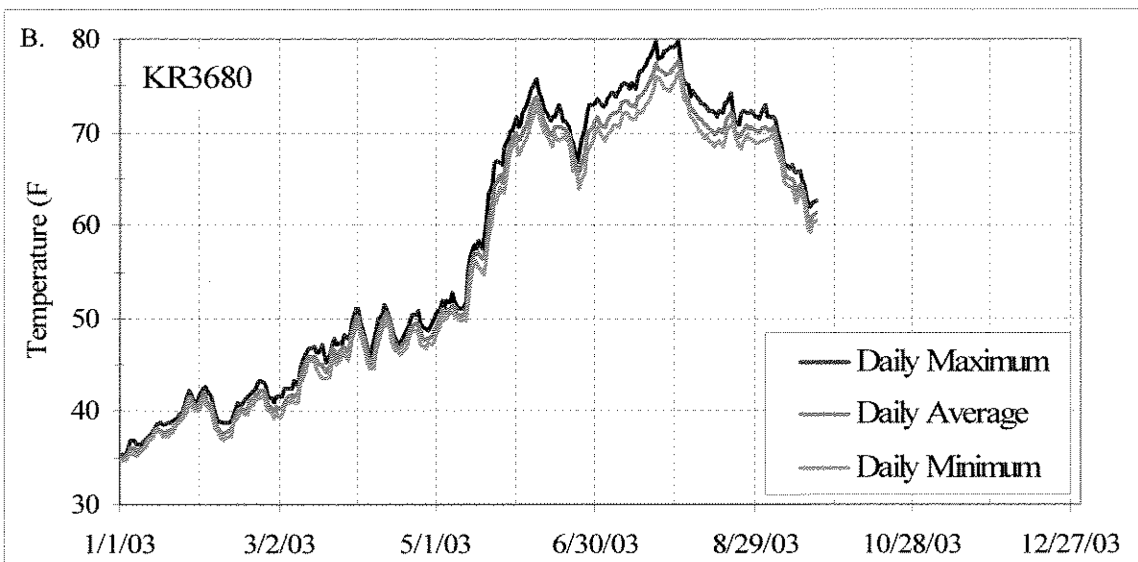


Figure 5. Daily maximum, average, and minimum water temperatures measured upstream from the springs in the J.C. Boyle Bypass Reach during (A) 2002 and (B) 2003.

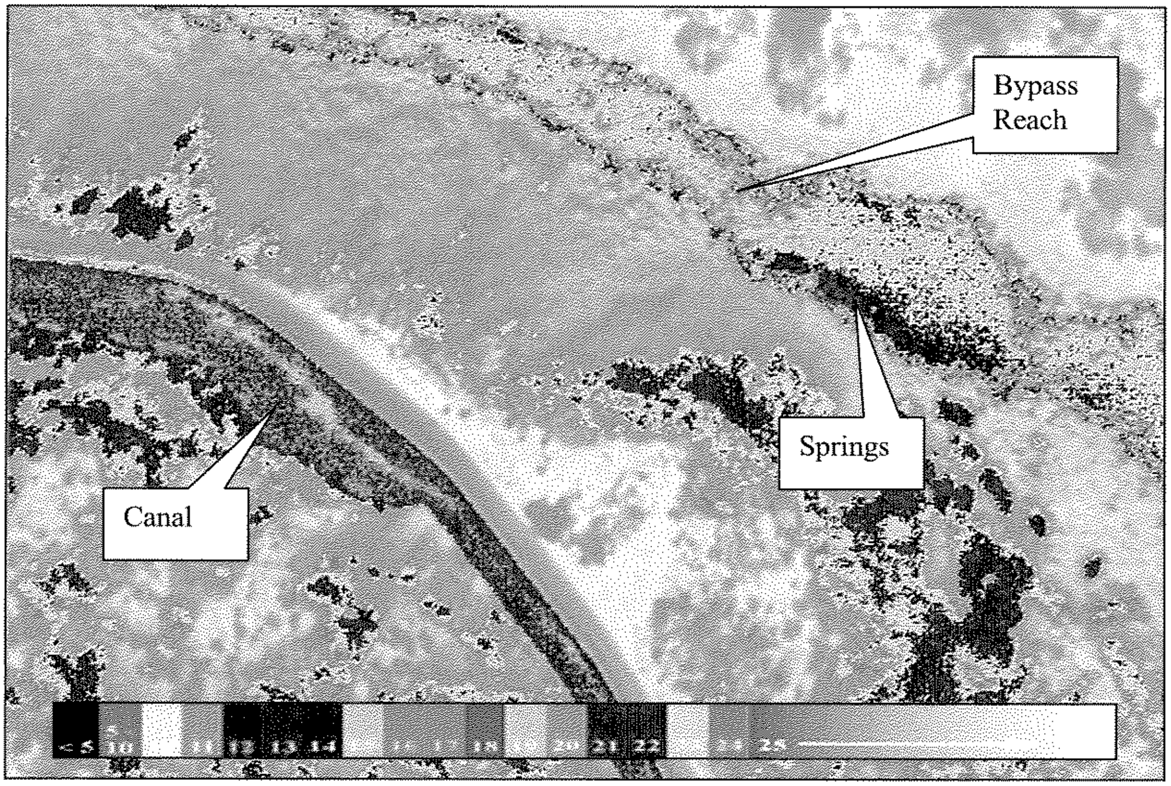


Figure 6. Summer 2001 FLIR imagery of a spring discharge area in the J.C. Boyle Bypass Reach. This image depicts water temperatures of 59 ˚F upstream from the springs, 53 ˚F issuing from the springs, and 70 ˚F in the diversion canal.

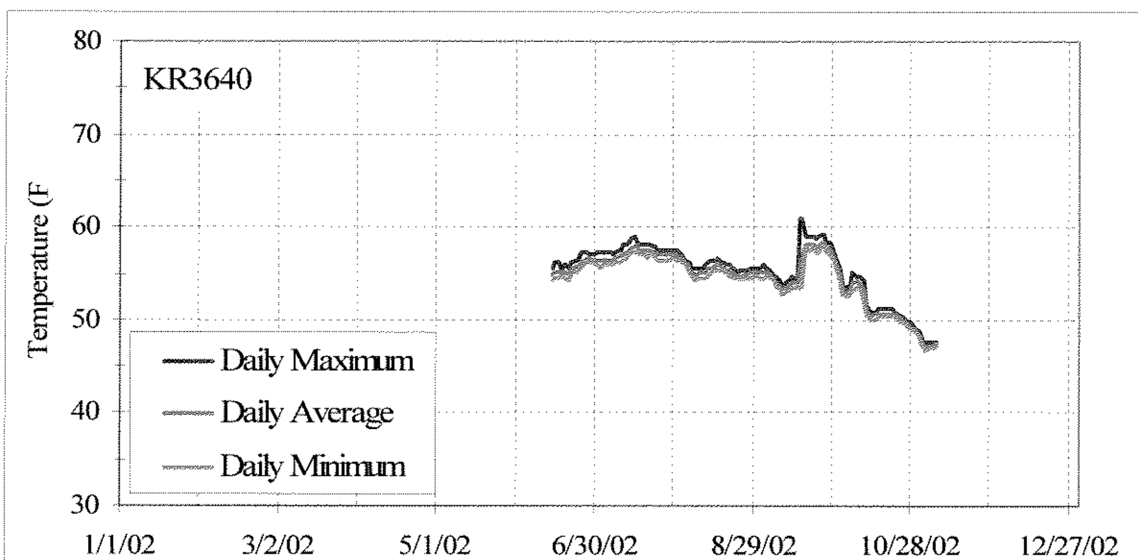


Figure 7. Daily maximum, average, and minimum water temperatures measured in the immediate vicinity of the springs in the J.C. Boyle Bypass Reach during 2002. The increase in water temperatures at this site during the controlled release of mid-September indicates that this probe is influenced by river flows as well as spring discharge.

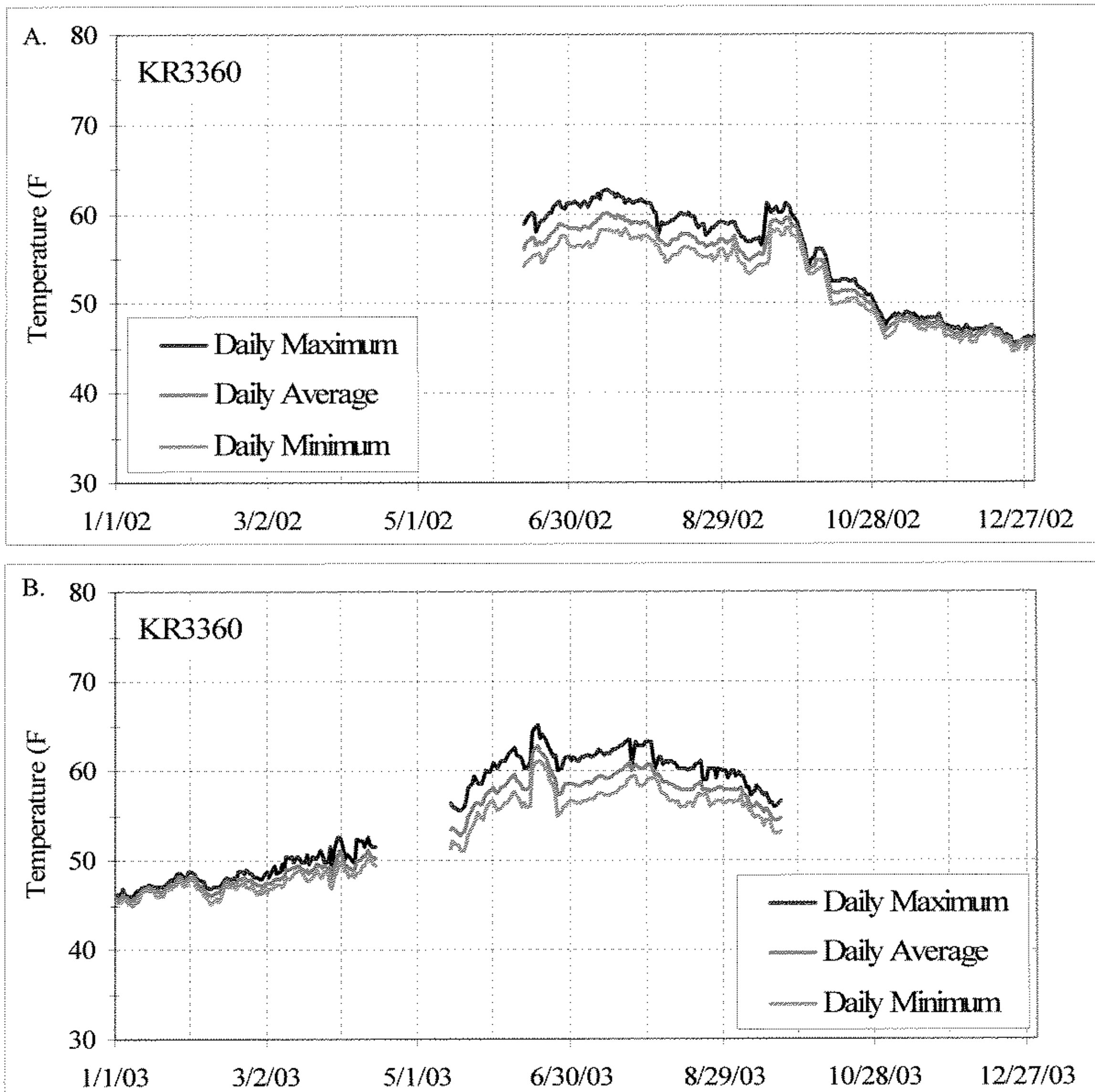


Figure 8. Daily maximum, average, and minimum water temperatures measured at the downstream end of the J.C. Boyle Bypass Reach during (A) 2002 and (B) 2003.

Results – Water Temperature – J.C. Boyle Peaking Reach

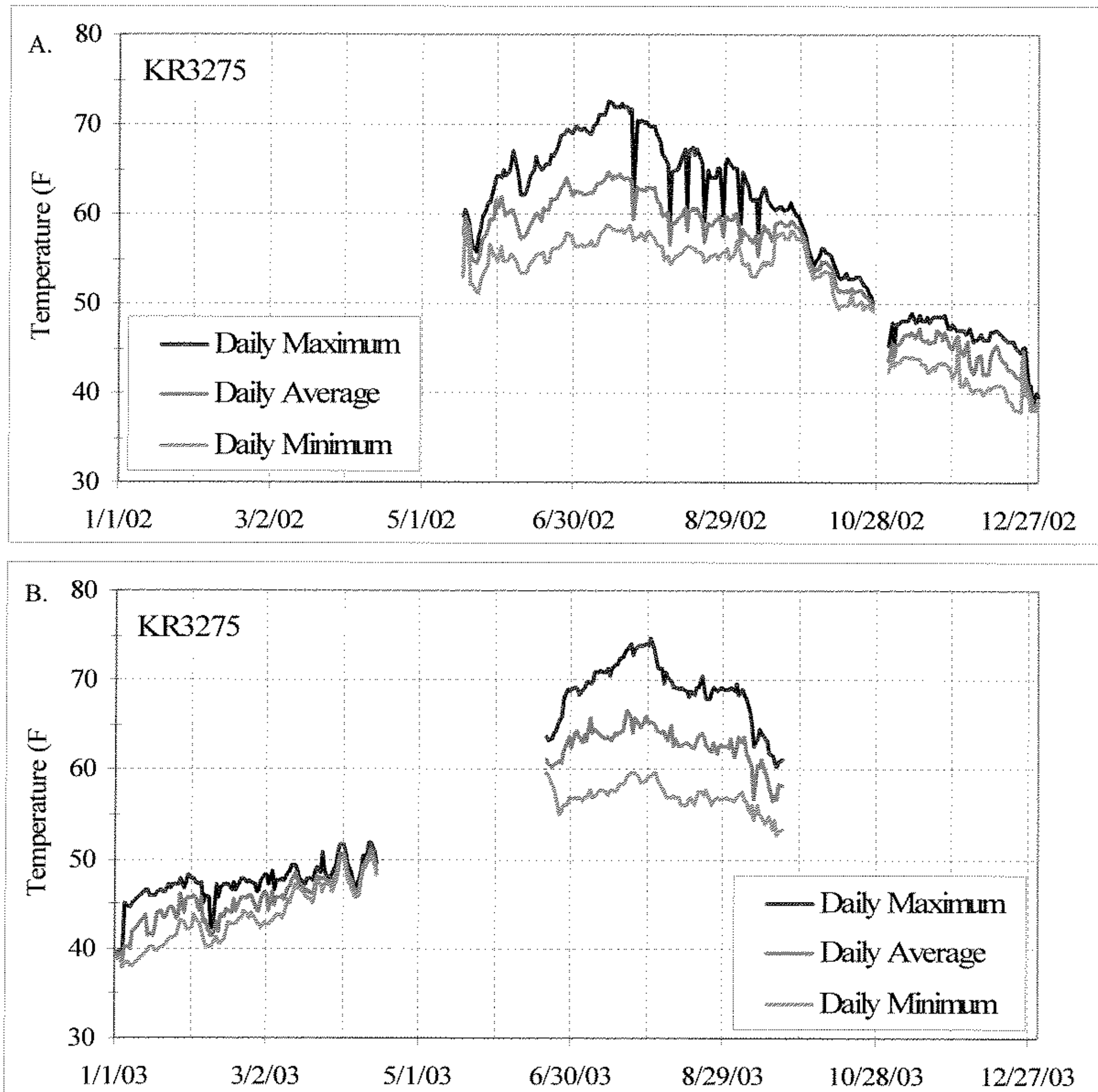


Figure 9. Daily maximum, average, and minimum water temperatures measured at the USGS stream gage downstream from the J.C. Boyle Powerhouse during (A) 2002 and (B) 2003.

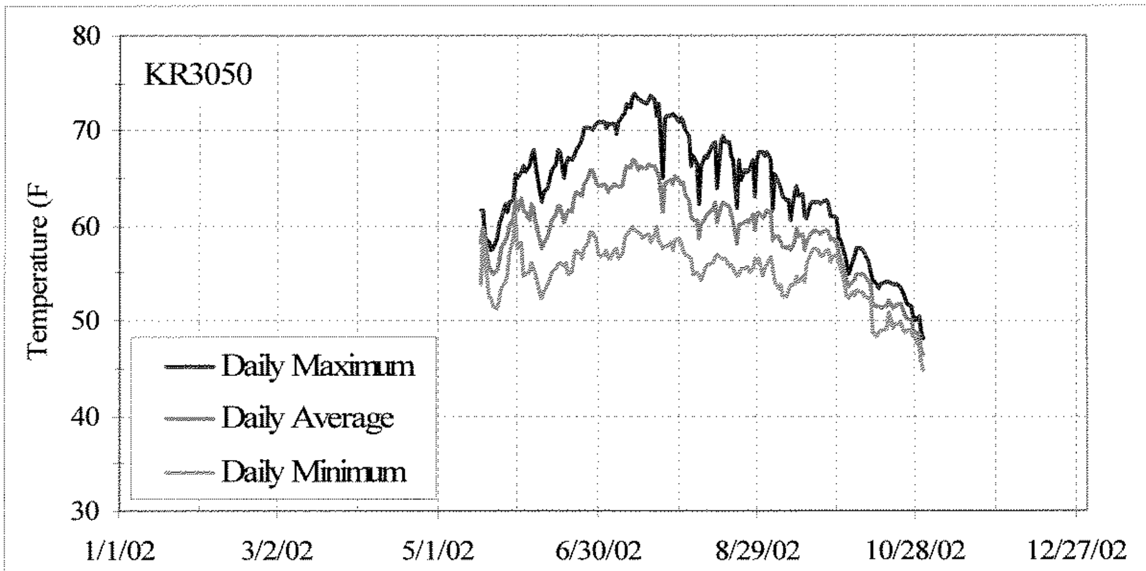


Figure 10. Daily maximum, average, and minimum water temperatures measured at Frain Ranch in the J.C. Boyle Peaking Reach during 2002.

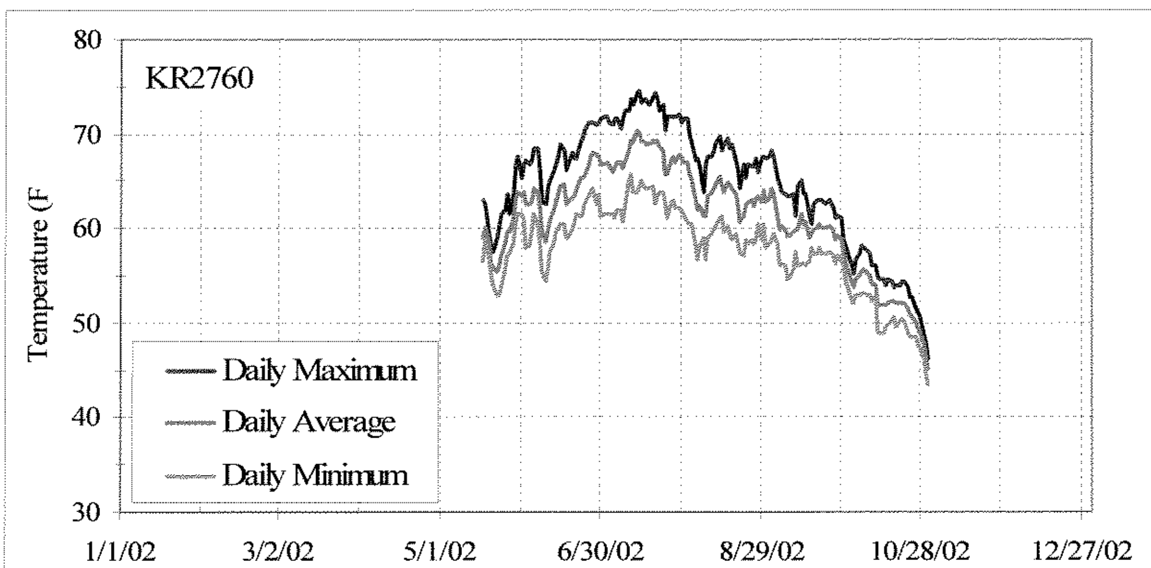


Figure 11. Daily maximum, average, and minimum water temperatures measured immediately upstream from the OR-CA state line in the J.C. Boyle Peaking Reach during 2002.

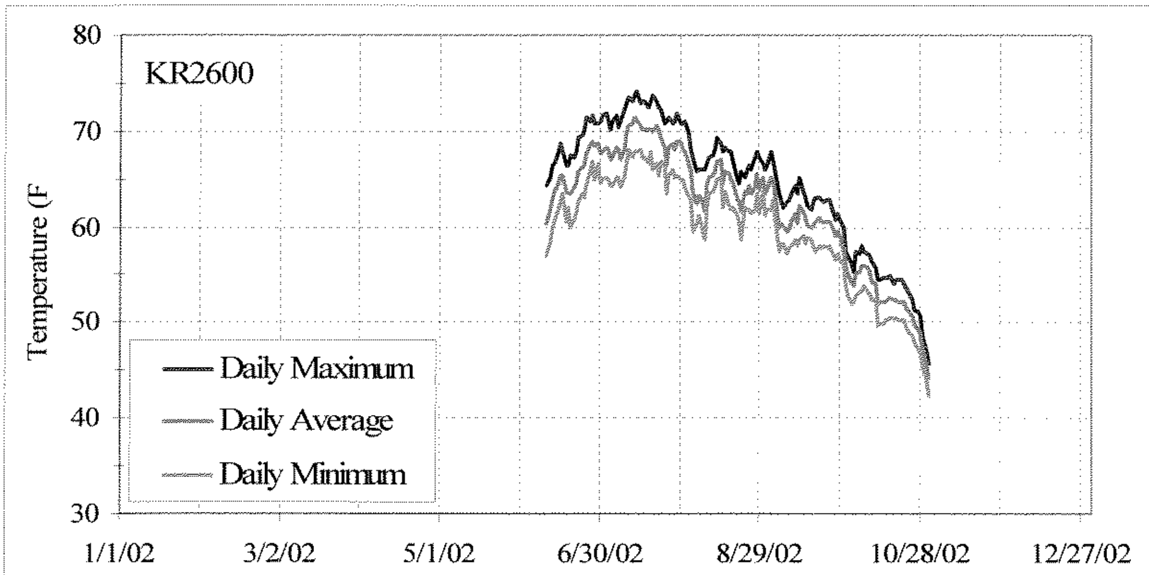


Figure 12. Daily maximum, average, and minimum water temperatures measured at the downstream end of the J.C. Boyle Peaking Reach during 2002.

Interpretation –Water Temperature Patterns and Effects of Flow Regulation

J.C. Boyle Bypass Reach

Reduced river flows immediately downstream from J.C. Boyle Dam cause increased warming rates (expressed in terms of change in water temperature over a given distance) in the upper portion of the bypass reach. Maximum and average daily water temperatures in this sub-reach were above 70 ˚F for one month in 2002 and almost three months in 2003 (Figures 4 and 5). In the winter, cool water temperatures in J.C. Boyle Reservoir result in reservoir releases with temperatures in the range of 35 to 45 ˚F.

Springs in the middle portion of the bypass reach contribute a steady flow of approximately 220 cfs to the 100 cfs released from the dam. The temperature of these springs is on the order of 50 to 55˚F and does not vary substantially through the year (Figures 6 and 7). A comparison of thermal regimes above the springs and at the downstream end of the bypass reach suggests that these inflows attenuate seasonal water temperature fluctuations (Figures 5 and 8). Downstream from the springs, summer water temperatures are markedly lower and winter water temperatures are markedly higher (relative to water temperatures upstream from the springs).

From 9/17/2002 to 9/25/2002, a controlled flow release resulted in bypass reach flows much higher than the normal flow of 320 cfs. Over the roughly 8-day period, flows at the downstream end of the reach gradually ranged from 760 to 800 cfs (Figure 2A). These flows appeared to result in a reduced warming rate in the upper portion of the bypass reach (Figure 13). The controlled flow release resulted in slightly increased water temperatures at the downstream end of the bypass reach (daily maximum water temperatures increased from 57 to 61˚F, still well below the Oregon water temperature standard of 68˚F) (Figure 14).

The June 2003 controlled release of 520 cfs had effects similar to the September 2002 release. Warming rates in the upper portion of the J.C. Boyle Bypass reach appear to have declined slightly due to increased flow through the dam (Figure 15). At the downstream end of the bypass reach, maximum daily temperatures increased from 61 to 65°F.

Empirical data regarding water temperature patterns in the bypass reach during steady flows greater than 100 cfs (at the upstream end of the reach) is limited. As stated above, only two such events occurred in the period of record discussed in this report.

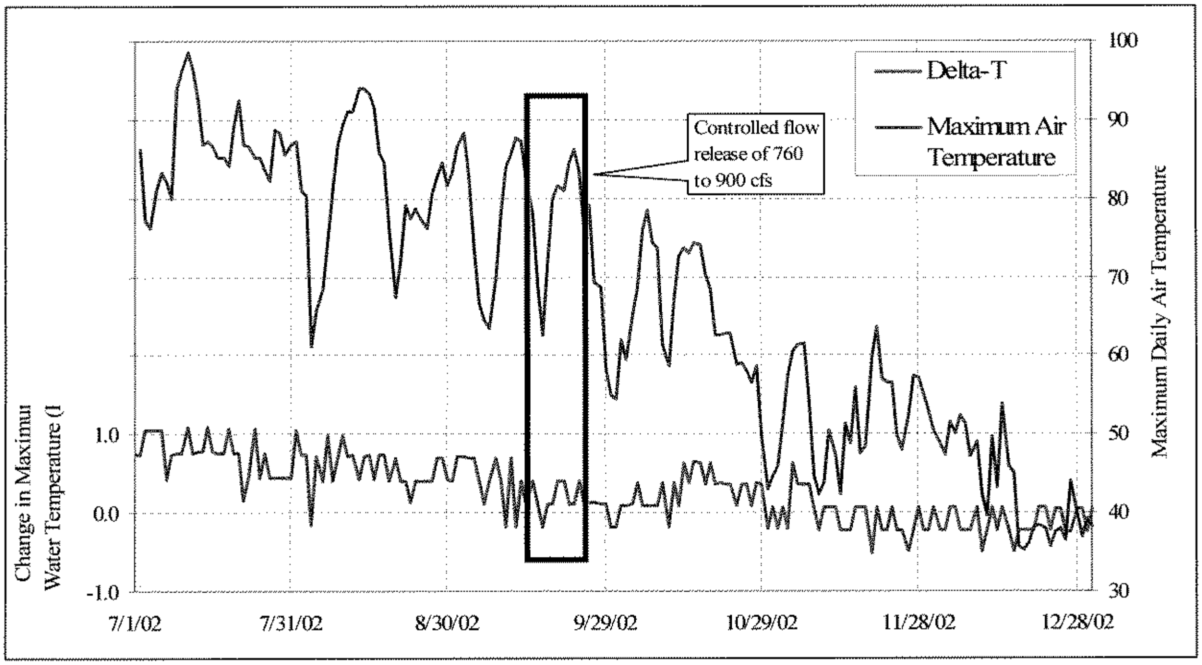


Figure 13. Comparison of warming rate (Delta-T, calculated as the difference between maximum daily water temperatures at the KR3810 and KR3680 sites, left axis) and maximum daily air temperature (right axis) before, during, and after the 2002 controlled flow release.

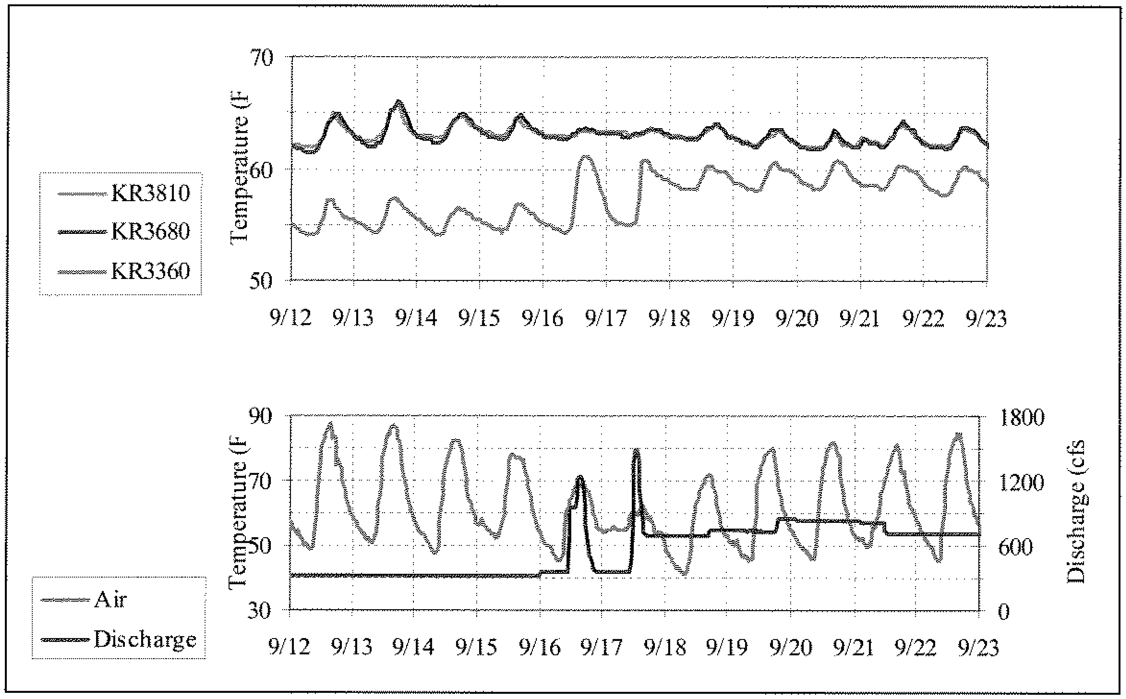


Figure 14. Comparison of water temperature at three stations (KR3810, upstream end of bypass reach; KR3680, upstream from bypass springs; KR3360, downstream end of bypass reach), air temperature, and approximate flow at the downstream end of the bypass reach before and during the September 2002 controlled flow release.

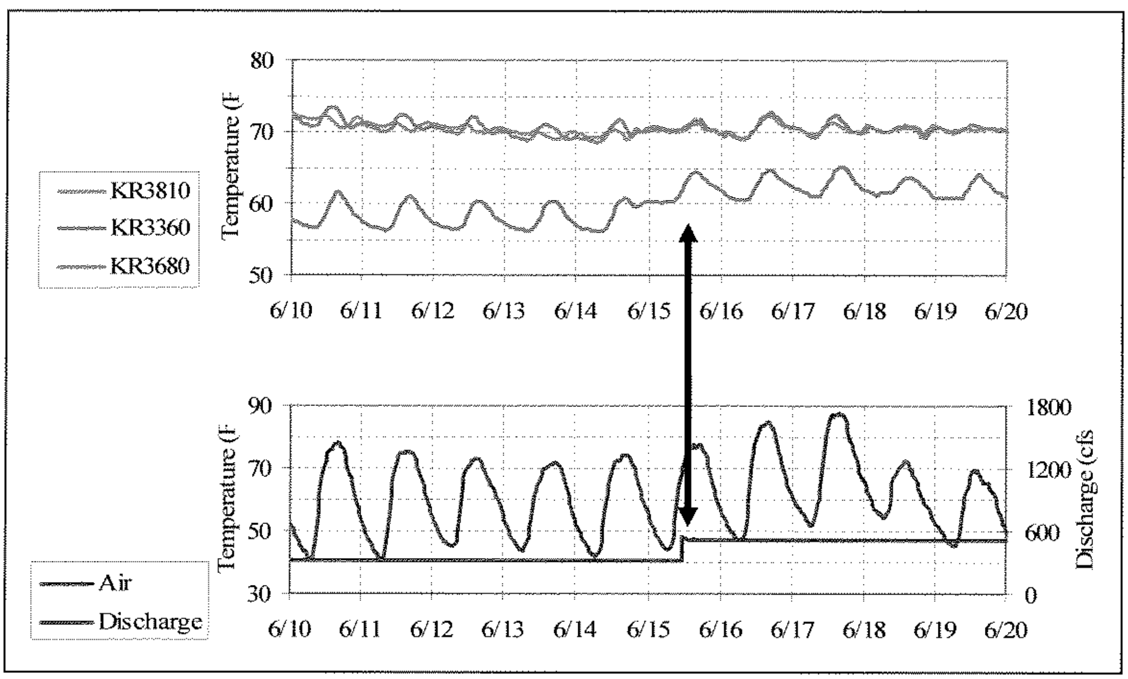


Figure 15. Comparison of water temperature at three stations(KR3810, upstream end of bypass reach; KR3680, upstream from bypass springs; KR3360, downstream end of bypass reach),, air temperature, and approximate flow before and during the June 2003 controlled flow release (the onset of the release is marked with an arrow).

J.C. Boyle Peaking Reach

Flows in the J.C. Boyle Peaking Reach are a mixture of cool inflows from the bypass reach and warmer releases from the powerhouse (Figure 16). During normal operations of the J.C. Boyle facilities, flows into the peaking reach from the bypass reach are 320 cfs, of which 220 cfs is derived from springs. Discharge from the powerhouse changes on an hourly basis during much of the year, and can range from 0 to more than 2500 cfs. At any given time, water temperature in the peaking reach is controlled, in part, by the relative proportions of cool bypass reach flows and warmer powerhouse releases. When powerhouse releases are low, flows are dominated by contributions from the bypass reach and the temperature in the peaking reach is relatively cool. As powerhouse releases begin to increase (typically during the mid-morning), the bypass reach flows become a smaller proportion of total flow in the peaking reach and water temperatures increase at a rapid rate. The warming caused by powerhouse operations is more rapid and of higher magnitude than warming caused solely by daily cycles of increased ambient air temperatures and increased solar radiation (Figure 17).

The river warms as it flows from the powerhouse to Copco I Reservoir (Figure 19). The highest warming rates (expressed in terms of change in temperature over a given distance) are coincident with high air temperatures. Daily releases of large volumes of impounded water during hydroelectric peaking operations may also cause increased warming rates.

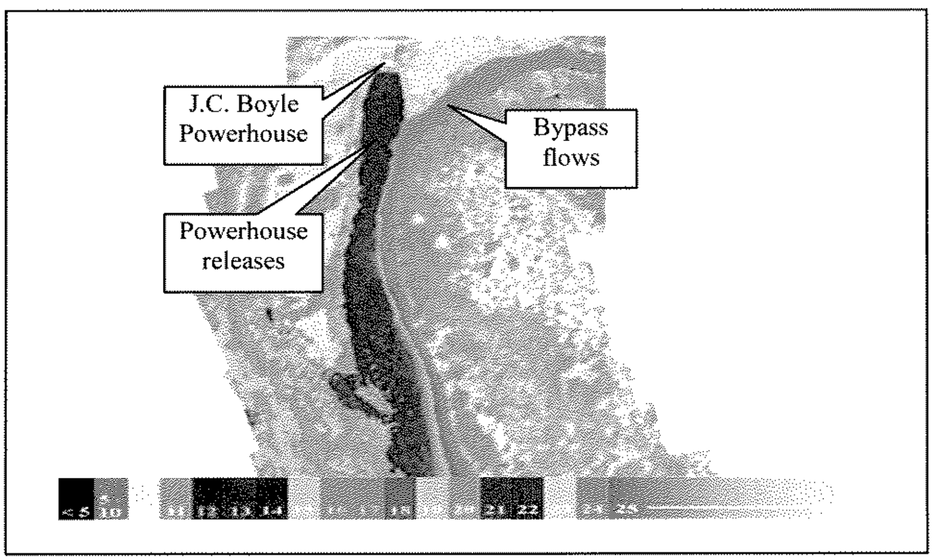


Figure 16. Summer 2001 FLIR imagery of the confluence of the bypass reach with the J.C. Boyle Powerhouse tailrace. The temperature of the Bypass flows is approximately 62˚F, while the tailrace flows are about 70˚F.

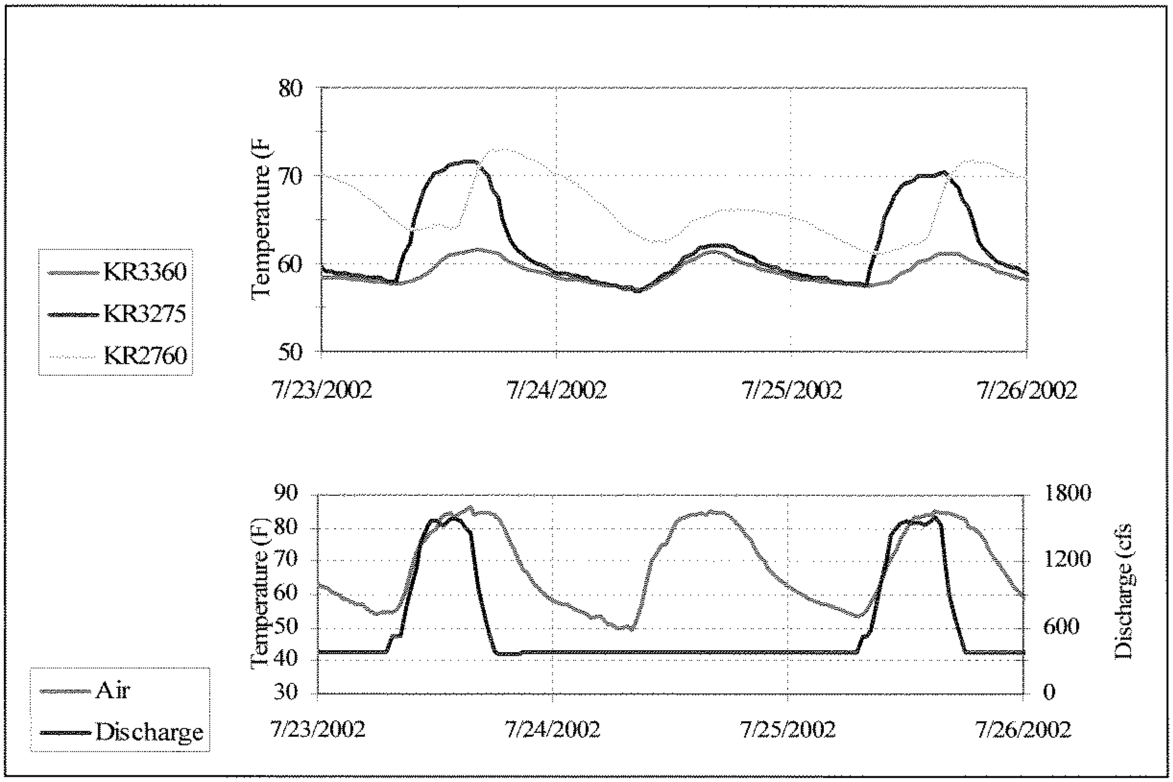


Figure 17. Water temperature patterns at two sites in the peaking reach and one site at the downstream end of the bypass reach, compared with flow and air temperature. Note the relatively more rapid warming rate associated with hydroelectric peaking to 1500 cfs on 7/23 and 7/25.

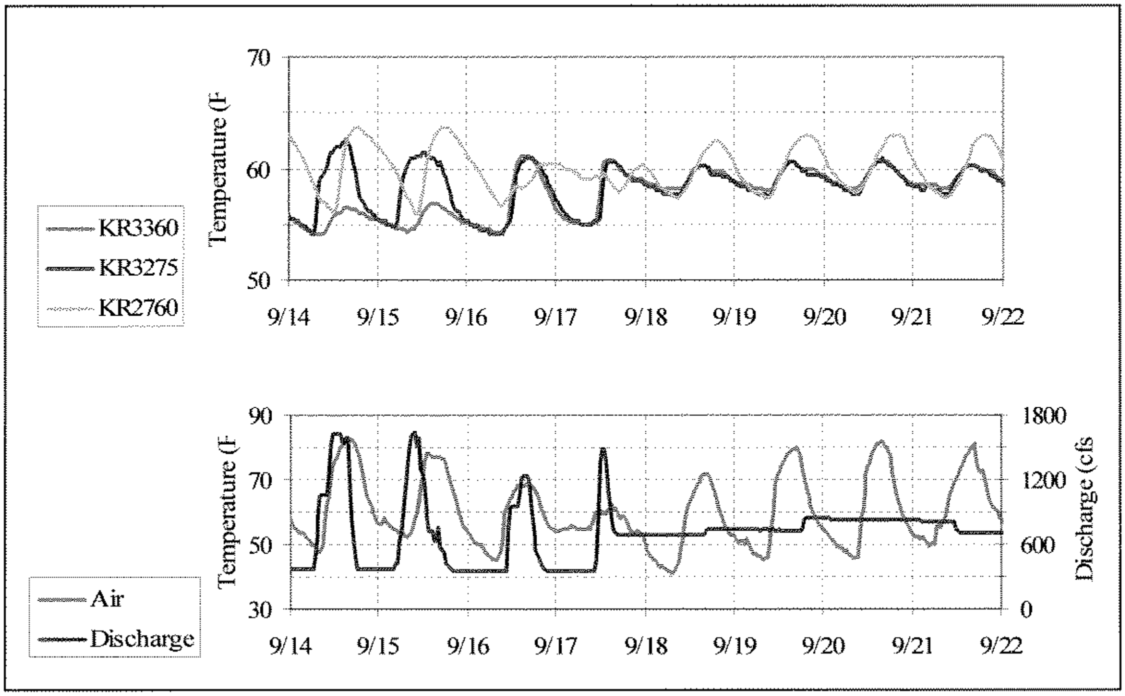


Figure 18. September 2002 water temperature patterns at two sites in the peaking reach and one site at the downstream end of the bypass reach, compared with flow and air temperature. Note the different patterns associated with hydroelectric peaking to 1500 cfs on 9/14 and 9/15 and steady flows from 9/18 to 9/22.

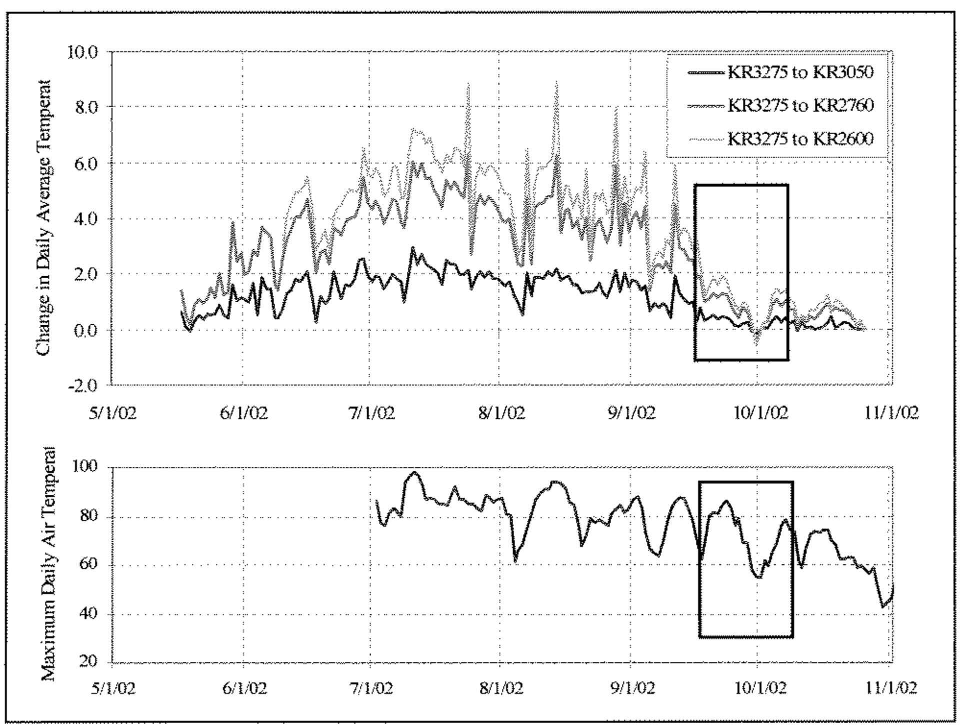


Figure 19. Changes in average daily water temperature between the USGS gage (KR3275) and three downstream measurement sites, compared with maximum daily air temperatures. The controlled flow release (~800 cfs) is indicated by the box.