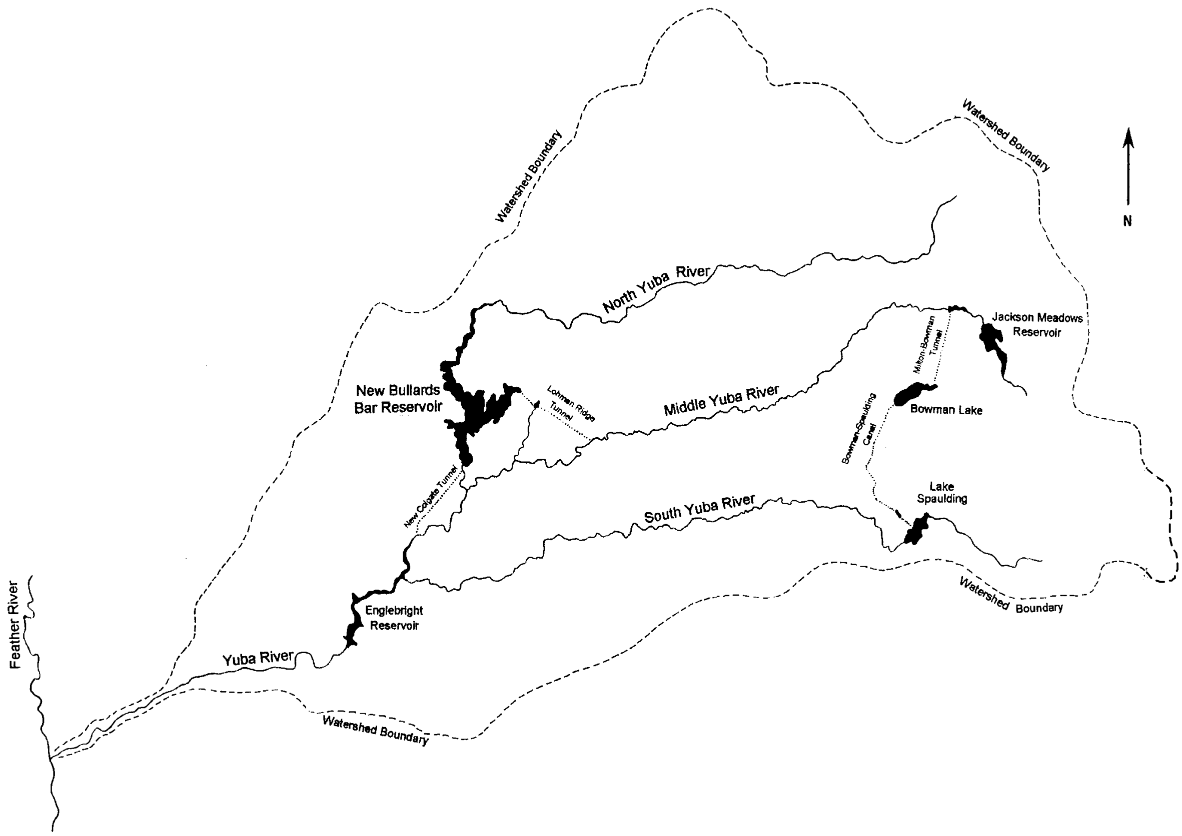
YUBA RIVER TEMPERATURE MONITORING PROJECT



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1. INTRODUCTION

1.1 Project Objective

The objective of this project was to formulate and implement a water temperature monitoring program that was sufficiently comprehensive to provide an initial basin-wide estimate of thermal diversity in the Yuba River watershed under current conditions. Specifically, water temperatures were monitored in the Yuba River from headwater reservoirs to the confluence with the Feather River during critical summer months. Information derived from the study can provide insight as to the impact of upstream operations and conditions on downstream temperatures that would prove valuable for anadromous fish restoration efforts.

1.2 Project Organization and Acknowledgements

The Yuba River Temperature Monitoring Project was funded by the United States Fish and Wildlife Service (USFWS), Order Number 1448-11332-8-M245, for the development and implementation of the monitoring program, field data reduction, and final reporting. Project administration was carried out by Craig Fleming (USFWS). The project was completed in conjunction with the California Department of Fish and Game (DFG).

The author would like to acknowledgement the assistance and guidance received from several agencies and individuals that generously contributed their time and expertise to the project; in particular, Mr. John Nelson (DFG) for providing field support and obtaining data; Ms. Julie Brown (DFG) for completing the arduous task of logger deployment and retrieval; Mr. Peter Dileanis of the United States Geological Survey (USGS) for providing flow and temperature data for the Yuba River near Marysville; Ms. Nancy Jones of the Yuba County Water Agency (YCWA) for supplying water temperature profiles for Englebright and New Bullards Bar Reservoirs, as well as flow and temperature data at several Yuba River locations; and Mr. Craig Fleming (USFWS) for project supervision.

The project area included the main stem Yuba, Middle Yuba, and South Yuba Rivers from headwater reservoirs to the confluence with the Feather River near Marysville. Additional temperature data was obtained from other agencies for New Bullards Bar Reservoir (North Yuba River), Englebright Reservoir, and main stem Yuba River locations. Figure 2.1 illustrates a general basin map of the Yuba River system. Water temperatures were monitored from late July and early August through September of 1998. Outlined herein are monitoring locations, field work, quality control, additional data sources, and summary of data sets included on diskette.

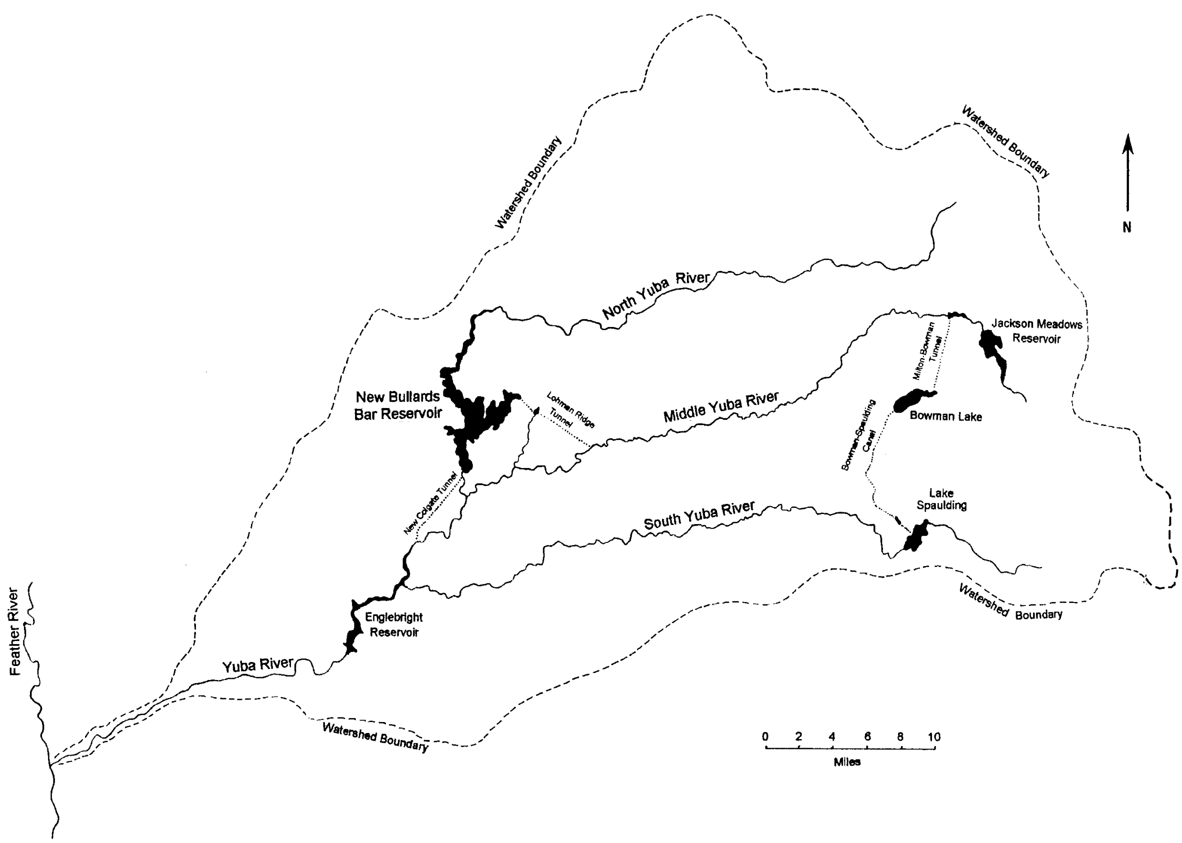

Figure 2.1. Project Area

2.1 Monitoring Locations

Water temperature was monitoring at multiple locations throughout the Yuba River basin to provide a complete and consistent data set during critical summer periods. Out of fourteen loggers, 13 were deployed and nine were retrieved. Table 2.1 summarizes logger deployment locations, approximate river mile and elevation, and status. River miles (RM) represent upstream distances measured from the confluence with the Feather River. Due to limited access it was infeasible to deploy at the Camptonville-Lohman Ridge Tunnel Outfall on the east shore of New Bullards Bar Reservoir. Loggers deployed on the Yuba River above New Colgate Tunnel Return, in the New Colgate Tunnel Return and on the Middle Yuba River at Plumbago Road were not retrieved due to high water conditions and/or limited access due to weather. The logger at Edwards Crossing on the South Yuba was missing and appears to have been vandalized. Location of deployments is shown in Figure 2.2. Loggers not retrieved this field season may be accessible next season.

2.2 Deployment/Field Work

Temperature was recorded at hourly intervals using Onset Corp. Stowaway® temperature loggers. Loggers were deployed in three-inch steel canisters attached to shore (e.g., posts) with braided wire cable. The canisters protected the devices as well as provided a means to maintain the logger at or near the bottom of the stream. The objective of logger placement was to record main stem temperatures (versus side channels or backwater areas such as sloughs).

2.3 Quality Control

Onset Corp. Stowaway® devices have a factory-specified accuracy of approximately ±0.2°C (0.38°F) for the range of temperatures normally experienced in the Yuba River. Resolution of the temperature devices is 0.01°C (and 0.01°F). All data are reported to 0.01°C (and 0.01°F). The devices used in this study were tested in a constant temperature bath and subject to variable temperature regimes to assure proper operation.

Data sets were reviewed and compared with available field notes to assess quality of data. Records were edited to remove measurements of air temperature obtained during deployment and retrieval. Further, the data sets were reviewed to determine if anomalous field conditions occurred during the deployment. For example, the logger below Englebright Dam was exposed to the atmosphere between September 13 and September 28, resulting in recorded air temperatures versus water temperatures. Such erroneous data was removed from the data set.

2.4 Additional Data Sources

In addition to the field monitoring effort, data sets were obtained from USGS and YCWA to provide a more detailed description of the system. Hourly water temperature near Marysville was obtained from the USGS. Weekly reservoir temperature profiles were obtained from YCWA for Englebright and New Bullards Bar Reservoirs. YCWA also provided flow and temperature measurements at weekly intervals throughout the study period for the Englebright Dam powerhouse, New Colgate Tunnel Return, and Yuba River near Marysville. Data sets obtained from these sources should be viewed as preliminary and subject to revision.

A brief data review was completed to determine historically available data sets for flow and temperature in the Yuba River basin. USGS data sets readily available on CD ROM disks from Earthinfo, Inc. were used for the review. Over 200 time-series records were determined to exist for flow and temperature – approximately 200 flow and 30 temperature records. Flow and temperature records for certain stations extend back to 1911 and 1963, respectively. Flow records are daily, while temperature records typically consist of mean and/or maximum and minimum values. Because flow records are kept

Table 2.1 Yuba River temperature monitoring deployment locations

Location	River Mile	Elevation (feet)	Status
Yuba River			
1. Daguerra Point	11.3	150	DR
2. Below Englebright Dam	23.4	360	DR
3. New Colgate Tunnel Return	33.5	850	DN
4. Above New Colgate Tunnel Return	33.6	850	DN
North Yuba River			
5. Camptonville-Lohman Ridge Tunnel Outfall	n/a	n/a	ND
Middle Yuba River			
6. Hwy 49 below Oregon Creek	43.8	1800	DR
7. Our House Dam	50.8	2400	DR
8. Plumbago Rd.	63.6	3100	DN
9. Below Milton Reservoir	79.9	5650	DR
South Yuba River			
10. Bridgeport	31.1	650	DR
11. Edwards Crossing	47.1	2200	DN
12. Poorman Creek	n/a	2850	DR
13. Near Washington, Below Poorman Ck.	60.4	3050	DR
14. Below Lake Spaulding	72.0	4950	DR

Notes:
River miles and elevations are estimates.
Camptonville-Lohman Ridge Tunnel located on Willow Creek arm of New Bullards Bar reservoir
Status Code: DR – deployed and retrieved; ND – not deployed; DN – deployed not retrieved

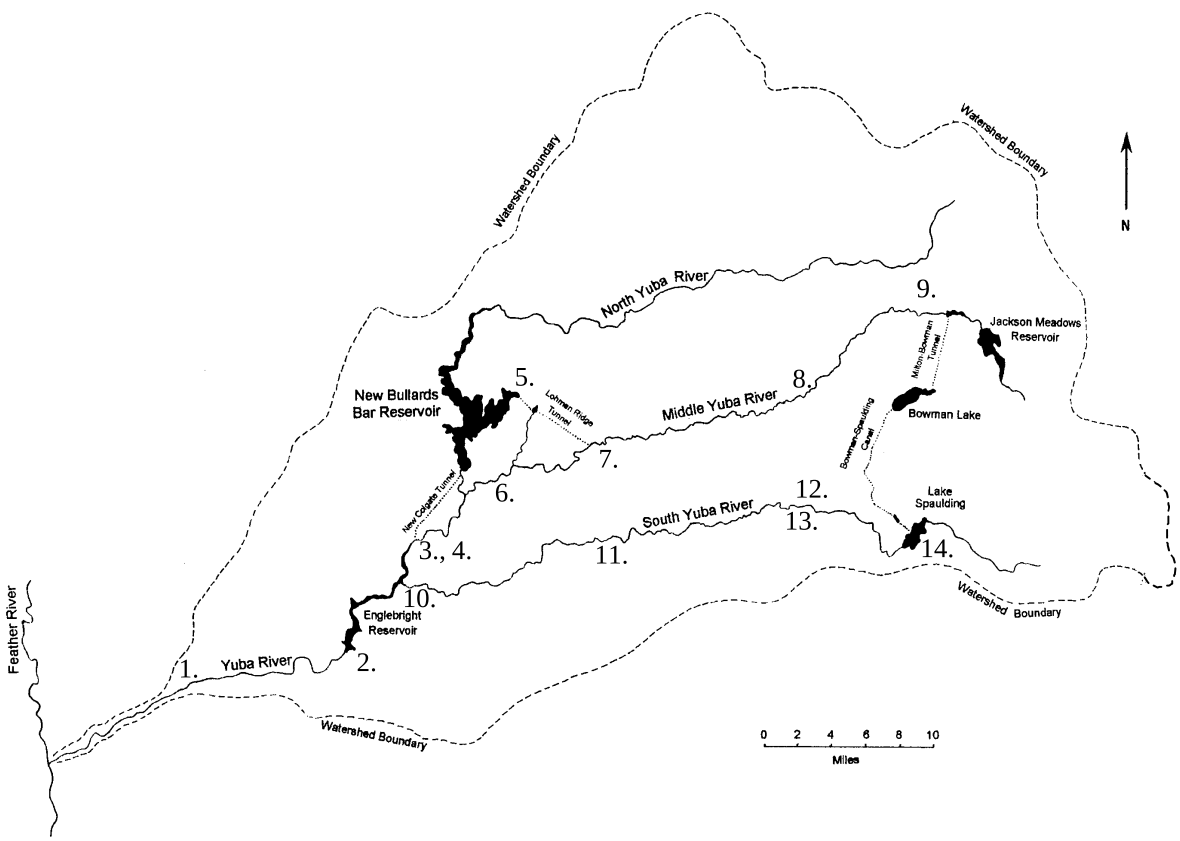

Figure 2.2 Water temperature deployment locations

individually for stage and flow (similarly for mean, maximum and minimum water temperature) a single station may include several records. An additional search of general water quality analyses showed nine stations where grab samples of water temperature data were available from 1966 through 1980. The search results are summarized in Appendix A.

2.5 Data Sets

All field data sets are included on diskette as Microsoft Excel® files. Daily mean, maximum, and minimum water temperatures were determined from the hourly field data. Appendix B includes figures for hourly field data and daily statistics at each project monitoring location. Data obtained from other sources is also included on diskette. The USGS data is included with the hourly data and daily statistics. The YCWA data is included in two separate files, one containing reservoir data and one containing river data. Table 2.2 outlines the files included on diskette.

Table 2.2 Project data

File Name	File Contents
hourtemp.xls	Hourly field data for all locations, including Marysville (USGS)
dailytemp.xls	Daily mean, maximum, and minimum temperatures including Marysville (USGS)
ycwa1.xls	Englebright and New Bullards Bar Reservoir data (YCWA)
ycwa2.xls	Yuba River temperature data (YRWA)

Records are different lengths depending on deployment dates and certain records are missing data due to equipment malfunction or field conditions. For example, the USGS water temperature data from Marysville was incorrect prior to September 9, 1998 due to a buried temperature probe. Table 2.3 defines period of record for all hourly temperature data. Additional data notes are included in the computer files available on diskette.

Table 2.3 Period of record for hourly data sets.

Locations	Period of record
Camptonville-Lohman Ridge Tunnel Outfall (CLRT)	Not Deployed
New Colgate Tunnel Return (NCTR)	Not Retrieved
Middle Yuba Below Milton Reservoir (MYMR)	(8/5/98 17:00 - 9/30/98 23:00)
Middle Yuba at Plumbago Road (MYPR)	Not Retrieved
Middle Yuba at Our House Reservoir (MYOHR)	(7/21/98 18:00 - 9/30/98 23:00)
Middle Yuba below Oregon Creek (MYOC)	(7/23/98 11:00 - 9/30/98 23:00)
South Yuba below Lake Spaulding (SYLS)	(7/20/98 15:00 - 9/30/98 23:00)
South Yuba near Washington (SYW)	(7/20/98 18:00 - 9/30/98 23:00)
Poorman Creek (PC)	(7/20/98 18:00 - 9/30/98 23:00)
South Yuba at Bridgeport (SYB)	(7/20/98 13:00 - 9/30/98 23:00)
South Yuba at Edwards Crossing (SYEC)	Lost
Yuba River above Colgate Tunnel (YRCT)	Not Retrieved
Yuba River below Englebright (YRE)	(8/6/98 14:00 - 9/13/98 8:00 and 9/28/98 10:00 - 9/30/98 23:00)
Yuba River below Daguerre Dam (YRDD)	(7/23/98 13:00 - 9/30/98 23:00)
Yuba River at Marysville* (YRM)	(9/9/98 16:00 - 9/30/98 23:00)

Notes:
*USGS station

The temperature monitoring program provided significant insight to current water temperature conditions on a basin-wide scale for critical summer months (not including the North Yuba above New Bullards Bar). Generally, headwater reaches of the Yuba River are small, cool streams that heat appreciably in their descent to low elevation reservoirs. These low elevation reservoirs release nearly constant temperature, cool hypolimnetic water (low level or bottom releases) through hydropower production facilities to downstream river reaches.

Available field data were used to characterize the temperature regime for the South, Middle and main stem Yuba Rivers. Due to significant variability in water temperatures throughout the monitoring period, August data were used for interpretation. Though data was unavailable at several monitoring locations, data supplied by other agencies or from neighboring monitoring sites were examined to provide insight into potential thermal characteristics. Because extrapolation of thermal characteristics in space and time is uncertain an introduction to important processes that can affect water temperature are included. Low elevation reservoir data and the role these reservoirs play are briefly discussed at the conclusion of the section.

3.1 Important Processes

Several processes affect the thermal regime of rivers and reservoirs. In the Yuba River system these include, but are not limited to meteorological conditions, hydrology, subsurface flow, tributary influences, water resources development and associated operations, stream morphology, and physical factors. Each of these topics is briefly outlined below.

- meteorological conditions: heat exchange through the air-water interface is the primary mechanism for thermal loading of water bodies. Short-term response to meteorological conditions is illustrated in the diurnal pattern of water temperatures in rivers and lakes. Surface waters also respond to warm and cool periods (days or weeks). Similarly, seasonal changes are reflected in stream and reservoir temperatures. Lakes and reservoirs typically respond slower to changes in meteorological conditions than rivers due to their much larger thermal mass and different mixing mechanisms. In the Yuba River system elevation also plays an important role: meteorological conditions may vary dramatically between headwater locations and the valley floor. Longer time scale meteorological events also play an important role, e.g., extended drought periods, sequential years of above average precipitation, climate change issues, etc.
- hydrology: flow affects transit time, depth, and surface area of streams and lakes. Decreased flow can lead to longer transit times, which translates to greater exposure time and increased thermal loading. Reduced flow rate can also lead to decreased depth, smaller surface area, and overall decreases in unit volume. For streams, these changes coupled with base flow considerations can impact water temperature. Storage and residence times are critical hydrology issues for lakes and reservoirs.

- subsurface flow: influence of groundwater can have profound impact on streams, both locally and for large distances. Spring fed streams can sustain base flows and cool temperatures throughout warm summer months and conversely can maintain relatively warm waters through cold winter months. Accretions can moderate diurnal variations and in alluvial reaches can be appreciable sources of water for large river systems. Subsurface flows (quantity and temperature) into rivers and reservoirs are difficult to quantify.
- tributary influences: tributary contributions can directly affect water temperature depending on quantity and quality of influent water. Similarly to springs, tributaries can have local or far reaching effects on stream water temperature. Several sizeable tributaries contribute flow and potentially cool water to higher elevation reaches of the Yuba River system. Tributary influences to reservoirs can be appreciable quantity and quality of tributary contributions and thermal structure of reservoir.
- developed water resources and associated operations: lakes, reservoirs, and associated operations/diversions have a profound impact on the Yuba River system. DWR (1964) reports mean annual runoff near Smartville at approximately 2.335 million acre-feet for the 1906-56 period with the North, Middle, and South Yuba Rivers contributing roughly 46, 16 and 31 percent of the flow (the remaining 7 percent includes contributions from Deer Creek and other intermediate drainages). Further, approximately 380,000 acre-feet per year of water, approximately 16 percent, is exported from the Middle and South Yuba Rivers into the Bear River watershed, with approximately 50,000 acre-feet returning to the Yuba River mostly via the Deer Creek drainage. At the time of the DWR investigation, completed in 1964, facilities were being added to the upper basin systems and capacities expanded. Current export capacity was not investigated. These operations, plus appreciable storage potential, have a dramatic impact on the Yuba River system. Selected system features and some of the current beneficial uses are outlined below.
  - Sierra lakes and reservoirs (230,000 acre-feet of storage): power production, irrigation, recreation, domestic and urban demand
  - Inter- and intra-basin diversions: (see above)
  - New Bullards Bar Reservoir (960,000 acre- feet of storage): power production, water supply, flood control, recreation, fisheries benefits
  - Englebright Reservoir (70,000 acre-feet of storage): power production, sediment control, recreation, fisheries benefits
- stream morphology: stream profile, cross-section form, geology, sediment load, hydrology, as well as other factors affect stream morphology, which in turn impact flow velocity, depth, surface and width – important factors in thermal loading and/or heat exchange at the air water interface. In addition, river aspect can play a role in topographic and riparian shading, which for small streams can reduce incoming short-wave (solar) radiation.
- physical factors: stream elevation, aspect, bed conduction, riparian and topographic shading, are examples of physical factors that can affect the thermal regime of rivers. Bathymetry, overall aspect, elevation, and volume can play important roles in lakes and reservoirs.

Complete analyses of field data would require significant additional information. For the purposes of this report only field water temperature data were used.

3.2 South Yuba River

The South Yuba River was monitored at five locations. Temperature loggers were deployed at Lake Spaulding (RM 72.0), Edwards Crossing (RM 47.1), Washington (RM 60.4), Bridgeport (RM 31.1), and one logger was placed in Poorman Creek (near Washington). The logger at Edwards Crossing was lost. Diurnal range, mean daily water temperatures (monthly average) and monthly maximum and minimum temperatures are compared at each location.

Below Lake Spaulding

Examination of the August hourly field data and daily statistics included in Appendix B illustrate that the South Yuba River below Lake Spaulding has a diurnal range of approximately 3°C (5.4°F) with a daily mean of roughly 15°C (59.0°F). Minimum and maximum water temperature ranged from 13.2°C to 18.6°C (55.8°F to 65.5°F), respectively. It is unknown if the relatively small diurnal range is a result of low-level releases from Lake Spaulding, local meteorological conditions, system operations, or a combination of processes.

Near Washington

Approximately 12 miles downstream near Washington the river diurnal range increased to roughly 4°C (7.2°F) and mean daily water temperatures were just over 20°C (68°F). Note, the mean daily water temperature varied between about 19°C (66.2°F) and 23°C (73.4°F) throughout the month as the river responded to short-term changes (days or weeks) in meteorological conditions. For example, the hot period that peaks on about August 13 was reflected in all South Yuba temperature records. Minimum and maximum water temperature ranged from 17.7°C to 25.3°C (63.9°F to 77.5°F), respectively.

Near Bridgeport

Over 40 miles downstream of Lake Spaulding the South Yuba River near Bridgeport experienced a diurnal range of about 4°C (7.2°F) and mean daily temperature of 23°C (73.4°F). The daily mean varied from 21°C to 25°C (69.8°F to 77°F) over the month of August. Minimum and maximum water temperature ranged from 19.1°C to 27.6°C (66.4°F to 81.7°F), respectively.

Poorman Creek

Poorman Creek, a tributary to the South Yuba River at approximately RM 59, was monitored just upstream from the confluence. This stream had a diurnal range of about 5°C (9°F) with a daily mean of about 16°C (60.8°F). Minimum and maximum water temperature ranged from 12.6°C to 22.0°C (54.7°F to 71.6°F), respectively. The large diurnal range exhibited by this stream is probably due to its small nature – small bodies of water with less thermal mass and depth have the ability to lose and gain heat quicker than larger systems.

Comparing water temperatures from the three South Yuba River monitoring locations show that river temperature rises quickly with increasing distance downstream of Lake Spaulding Dam. Figure 3.1 illustrates weekly mean temperature for the three South Yuba River locations plotted versus river mile. A smoothed line has been plotted through the data. Included in the graph is an approximate bed elevation profile of the river. Note the rapid increase in mean daily water temperature between Lake Spaulding Dam (elevation 4950) and Washington (elevation 3050) – roughly about 5°C (9°F) over 12 miles, or about 0.4°C (0.7°F) per mile. Though no data were available at Edwards Crossing, data available at Bridgeport show that over the next 22 miles the river temperature increase is on the order of 3°C (5.4°F), or about 0.14°C (0.25°F) per mile; significantly less than between Lake Spaulding and Washington.

The transition between the high elevation Sierra Nevada reservoirs and the mid- to low-elevation reservoirs is a critical zone of thermal loading during summer months. Small releases from upstream reservoirs result in shallow stream depths, low mean velocities, increased transit time, and appreciable thermal loading. Flow, river morphology, tributary accretions, river aspect, and meteorological conditions can directly influence rate of thermal loading. As such, the thermal loading rates presented above are gross estimates for comparison purposes only and applicable for a specific set of flow, meteorological, and upstream and tributary water temperature conditions.

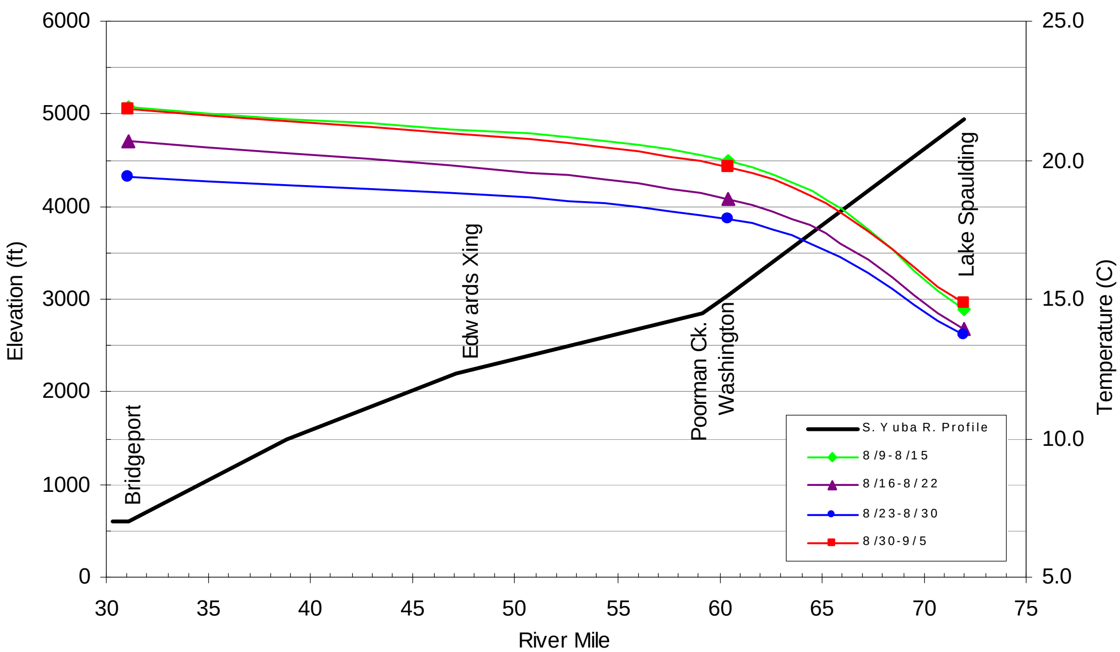

Figure 3.1. South Yuba River bed elevation profile and weekly mean water temperature at field monitoring locations (8/9/98 – 9/5/98)

Additional data at Edwards Crossing would prove useful. However, the difference between Washington and Bridgeport was relatively small considering the distance. It may be more valuable to monitor additional upstream locations where rapid heating occurs.

3.3 Middle Yuba River

The Middle Yuba River was monitored at four locations; Milton Reservoir (RM 79.9), Plumbago Road (RM 63.6), Our House Reservoir (RM 50.4), and at Highway 49 below Oregon Creek (RM 43.8). The logger at Plumbago Road was unable to be retrieved. Diurnal range, mean daily water temperatures (monthly average) and monthly maximum and minimum temperatures are compared at each location.

Below Milton Reservoir

Examination of the August hourly field data and daily statistics included in Appendix B illustrate that the Middle Yuba River below Milton Reservoir has a diurnal range of approximately 2°C (3.6°F). Mean daily temperature for most of the month was approximately 8°C (46.4°F) and minimum and maximum water temperature ranged from 7.3°C to 14.8°C (45.1°F to 58.6°F), respectively (see discussion addressing flow change, below). It is unknown if the relatively small diurnal range is a result of low-level releases from Milton Reservoir and/or Jackson Meadows Reservoir, local meteorological conditions, system operations, or a combination of processes. The temperature record also appears to capture the thermal response to a flow change, where flows were ramped down in early August (gradual increase in water temperatures), then abruptly increased on 8/26/98 (rapid decrease in water temperature). Appropriate flow and meteorological data are required to substantiate this conclusion.

Our House Dam

Our House Dam is located nearly 30 miles downstream of Milton Reservoir. Diversions from the Middle Yuba River to the North Yuba River are made from this location via the Lohman Ridge-Camptonville Tunnel. Diurnal water temperatures ranged from about 4°C (7.2°F) with a mean daily temperature of 21°C (69.8°F). The mean daily temperature varied from 13°C to 19°C (55.4°F to 66.2°F) over the month. Minimum and maximum water temperature ranged from 17.5°C to 25.3°C (63.3°F to 77.5°F), respectively.

Highway 49 below Oregon Creek

Water temperature was monitored at Highway 49 below Oregon Creek, 36 miles downstream of Milton Reservoir. Diurnal range was about 4°C (7.2°F) with a daily mean of about 22°C (71.6°F). Minimum and maximum water temperature ranged from 17.3°C to 25.5°C (63.1°F to 77.9°F), respectively.

Field data suggest that the Middle Yuba River responds in a similar fashion to the South Yuba River, namely, river temperatures rise quickly with increasing distance downstream of Milton Reservoir. Figure 3.2 illustrates mean weekly temperatures at three locations on the Middle Yuba River plotted versus river mile. A smoothed line has been plotted through the data. Included in the graph is an approximate bed elevation profile of the river. Upon initial inspection of Figure 3.2 it may appear that water temperatures on the Middle Yuba River do not rise as abruptly as South Yuba River water temperatures; however, there is limited available data between Milton Reservoir and Our House

Reservoir. Given similarities between the Middle and South Yuba Rivers (bed slopes, elevation changes, meteorological conditions, river aspect and morphology, reduced headwater flows), water temperatures may rise at a faster rate than shown by the smoothed lines in Figure 3.2. A significant difference of the Middle Yuba River is the headwater source is much cooler, averaging around 10°C (50°F) versus about 14°C (57°F) for the South Yuba. However, water temperatures at Oregon Creek (RM 43.8) range from 18.0°C (64.4°F) to 20.4°C (68.7°F), only slightly below those near Bridgeport (RM 31.1) on the South Yuba River, which ranged from 19.4°C (66.9°F) to 21.9°C (71.4°F). Due to lack of data at critical intermediate locations (e.g., Plumbago Road), thermal loading rates were not approximated for the Middle Yuba River.

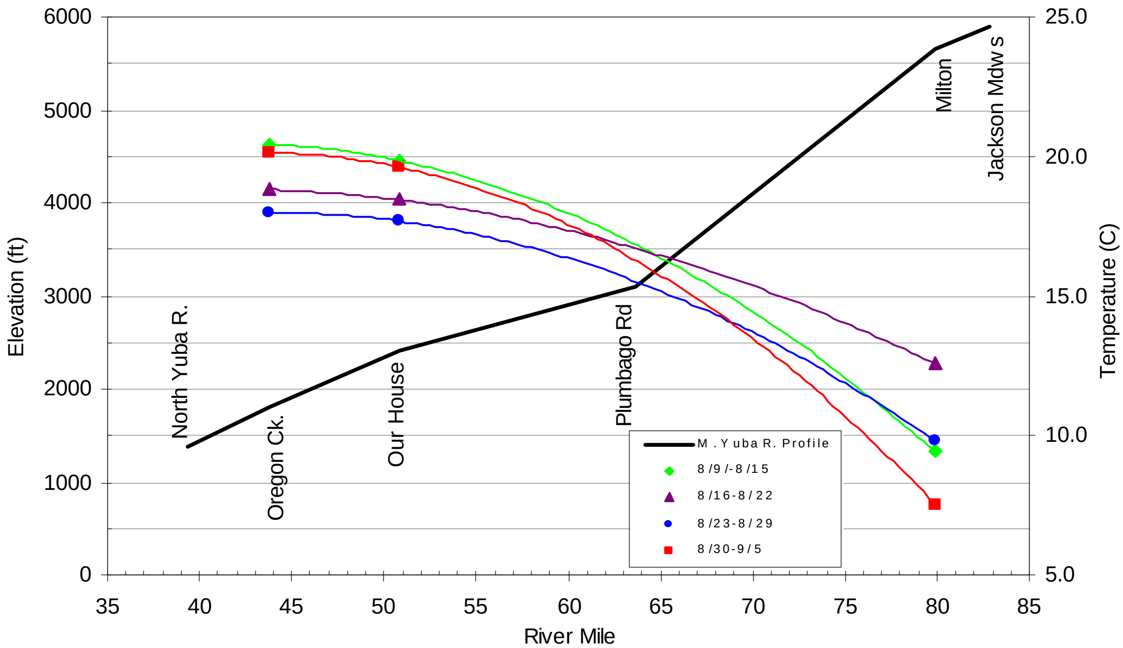

Figure 3.2 Middle Yuba River bed elevation profile and weekly mean water temperature at field monitoring locations (8/9/98 – 9/5/98)

For both the South and Middle Yuba Rivers cool sources at headwater reservoirs may originate as low-level releases (Lake Spaulding and Jackson Meadows Reservoirs). However, even if low-level releases are not significantly cooler than surface waters at headwater reservoirs, meteorological conditions change quickly as the rivers rapidly descend from higher elevations (in excess of 5000 feet) to lower elevations. Though tributaries may supply limited cool water, meteorological conditions prevail and rapid and significant increases in river thermal loading occur.

3.4 Yuba River

The main stem Yuba River was defined as the reach from the mouth upstream to the confluence of the North and middle Yuba Rivers. This reach was further subdivided into two reaches based on thermal regime: upstream of Englebright Dam (upper) and downstream of Englebright Dam (lower). Each reach is addressed below.

Yuba River – Upper Reach: Englebright Dam to Middle/South Yuba River Confluence
Two locations were monitored in the upper Yuba River reach: New Colgate Tunnel Return (RM 33.5) and above New Colgate Tunnel Return (RM 33.6). Neither of these temperature loggers was recovered. However, additional data available from YCWA and information obtained from other monitoring locations yields insight into thermal conditions at these locations.

<u>New Colgate Tunnel Return</u>: Though hourly data from New Colgate Tunnel Return was unavailable, YCWA weekly grab samples were available throughout the study period. Figure 3.3 illustrates that water temperatures were nearly constant at or below 10°C (50°F) for all but one measurement (8/20/98). Measurements were taken between 7:00 a.m. and 3:30 p.m. Because diurnal variation were significantly moderated due to low-level diversions to the New Colgate Tunnel from New Bullards Bar Reservoir (under 1998 reservoir storage conditions), the weekly measurements could be used to reliably estimate mean daily water temperatures.

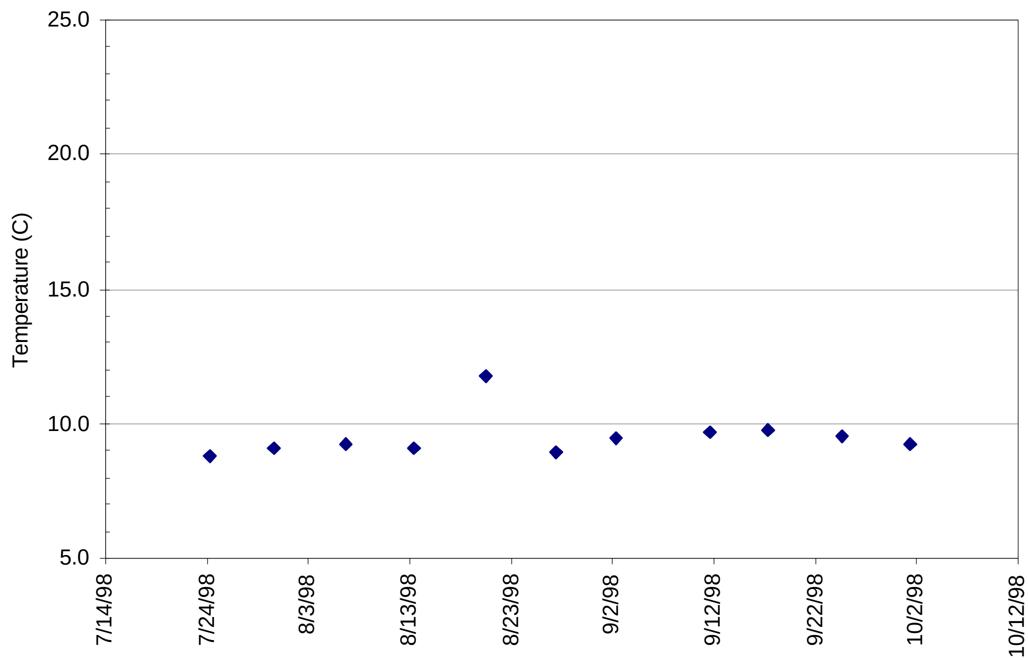

Figure 3.3 Weekly water temperature at New Colgate Tunnel Return, 7/24/98 – 10/2/98 (YCWA)

<u>Yuba River above New Colgate Tunnel Return</u>: New Colgate Tunnel Return is located at approximately river mile 33.5, roughly 6 miles downstream from the confluence of the Middle and North Yuba Rivers. Contribution of the North Yuba during the study period was insignificant, as releases from New Bullards Bar Reservoir directly to the North Yuba River were negligible. Thus, the bulk of the flow in the Yuba River above New Colgate Tunnel Return was derived from the Middle Yuba River, which was monitored below Oregon Creek near Highway 49 approximately ten miles upstream (RM 43.8). As noted previously, upstream heating

between Our House reservoir (RM 50.8) and RM 43.8 was modest, less than 1°C (1.8°F). Thus, it could be assumed that heating in the subsequent ten miles to New Colgate Tunnel return would be moderate as well. Additional data should be gathered to validate this assumption.

Yuba River – Lower Reach: Feather River to Englebright Dam
Two locations were monitored in the lower Yuba River reach; below Englebright Dam (RM 23.4) and at Daguerre Dam (RM 11.3). Hourly water temperature data were also available at the USGS gage near Marysville for part of September. Weekly grab samples near Simpson Lane were available throughout the study period from YCWA. A consistent set of hourly August data was not available for this reach. General findings will be discussed, but comparisons were difficult to draw given limited data.

<u>Yuba River below Englebright Dam</u>: water temperatures below Englebright Dam were nearly constant at about 11°C (51.8°F) and had essentially no diurnal signal. YCWA grab sample data from the powerhouse at Englebright Dam were typically more than 0.5°C (0.9°F) higher than measured field data from this study.
<u>Yuba River at Daguerre Dam</u>: water temperatures at Daguerre Dam, located 12 miles downstream of Englebright Dam, illustrated a diurnal range of about 3°C (5.4°F) with a mean of about 13°C (55.4°F).
<u>Yuba River at Marysville</u>: Data near Marysville was unavailable for the month of August with the exception of weekly grab samples supplied by YCWA. Because these data were taken at various times of day, under various flow and meteorological conditions a comparison of data sets could not be made. Using available data daily mean river temperatures were probably 1°C to 3°C (1.8°F to 5.4°F) warmer at Marysville than at Daguerre Dam.

The overall rate of heating in the Yuba River below Englebright Dam appears to be fairly uniform downstream of Englebright Dam. Diversions, tributary and return flow contributions, and subsurface flow processes may play a significant role in this reach. The most important feature in this reach is the cool water release from Englebright Dam that reproduces a headwater condition at a relatively low elevation: releases are fairly constant, cool, and begin to heat in downstream reaches. The major differences are that flows are highly regulated and releases are often appreciable compared to headwater reaches. The large flow volume below Englebright Dam provides appreciable stream velocities as well as increased depths and thermal mass. These factors result in lower rates of thermal loading than in small headwater reaches.

3.5 Low Elevation Reservoirs

Englebright and New Bullards Bar Reservoirs play key roles in the thermal structure of the Yuba River in downstream reaches. Both reservoirs are prone to stratification during summer periods. However, Englebright Reservoir is strongly influenced by operations at New Bullards Bar Reservoir. Both reservoirs utilize low-level releases for power production. These releases typically have very little or no diurnal signal and are well below reservoir surface water temperatures. These constantly cool releases significantly affect the thermal regime of the river, especially downstream of Englebright Dam.

Water temperature profiles were measured two to three times per month at Englebright and New Bullards Bar Reservoirs during the study period. These data were obtained from YCWA for the study period included with the river monitoring results.

3.5.1 New Bullards Bar

New Bullards Bar, located at RM 41.4, is a large reservoir with nearly one million acre-feet of storage. Beyond being a significant quantity of stored water, this deep reservoir provides cool water releases to the Yuba River via New Colgate Tunnel Return during summer months. Figure 3.4 illustrates New Bullards Bar Reservoir water temperature profile from July 9 through October 1, 1998. Color-coded contours ranging from cooler (blue) to warmer (red) represents water temperature. Early in the summer period waters warmer than 18°C (64.4°F) occupied the top twenty feet of the reservoir, while in mid-September depth of this warm water layer deepened to approximately 50 feet. The onset of fall cooling, as depicted by decreasing surface water temperatures, is apparent by October 1. Note, reservoir elevations at New Bullards Bar are declining through this period from 1953.1 feet on July 9 to 1896.0 feet on October 1, though this is not depicted in Figure 3.4. For the 1998 field season, reservoir storage was high. Under depressed reservoir storage the thermal structure of New Bullards Bar Reservoir could differ significantly.

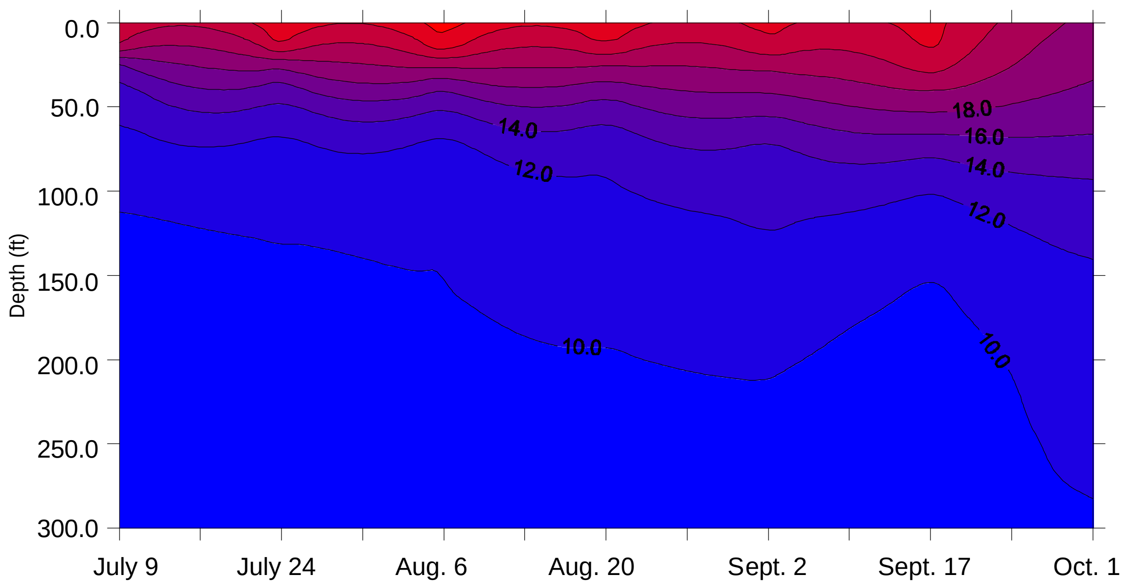

Figure 3.4 New Bullards Bar Reservoir profile water temperature (Celsius), July 9 1998 through October 1, 1998.

Inflow quantity and water temperatures were not examined for this analysis. Access to the monitoring location at the Lohman Ridge-Camptonville Tunnel Outfall was not readily available and a logger was not deployed. The objective of monitoring at this location was to determine inflow water temperature to New Bullards Bar Reservoir from Middle Yuba River and Oregon Creek diversions. No information was available to estimate the potential range of values for this water.

3.5.2 Englebright Reservoir

Englebright Reservoir, located at river mile 23.4, has a capacity of roughly 70,000 acre-feet. Releases are maintained at essentially constant levels for extended periods during summer season. That is, the reservoir acts as an afterbay for New Bullards Bar Reservoir by moderating peaking power operations via the New Colgate Return Tunnel. Reservoir elevation is maintained within a small range throughout this period. Figure 3.5 illustrates Englebright Reservoir water temperature profile from July 9 through October 1, 1998. Color-coded contours ranging from cooler (blue) to warmer (red) represents water temperature. As with New Bullards Bar Reservoir, heating and deepening of the surface waters occurred as summer progressed. However, between August 6 and August 20 the reservoir de-stratified. It is postulated (based on increased flows at Marysville) that releases from New Bullards Bar Reservoir were increased during this period, reducing the retention time (flow through time) of Englebright Reservoir. These operations appear to have eliminated stratification, as well as prevented formation of stratification. When flows were reduced in early September stratification again developed. The small intrusion of cold water on July 9 (left edge of Figure 3.5) is a relic of the program used to interpolate the data and is not reflected in the measured data.

Though the reservoir is relatively small and typically stratified, cool water reserves are replenished with releases from New Bullards Bar Reservoir. Thus, the Yuba River below Englebright Dam receives cool water throughout the summer period. Reservoir thermal conditions can differ dramatically depending on system hydrology (wet years versus dry years), operations, carry-over storage, rate of draw down, and meteorological conditions.

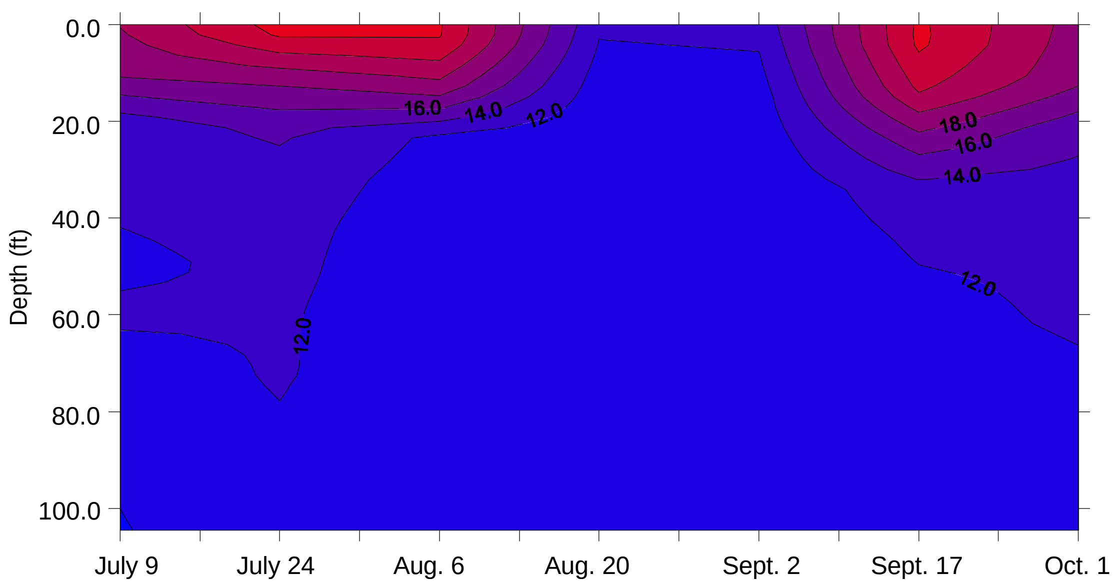

Figure 3.5 Englebright Reservoir profile water temperature (Celsius), July 9 1998 through October 1, 1998.

4.1 Summary

Hourly field data were collected or obtained at 9 locations on the South, Middle, and main stem Yuba Rivers throughout the critically warm summer months. Weekly instantaneous water temperature data were supplied at four river locations by YCWA. YCWA also supplied approximately twice monthly reservoir profiles for New Bullards Bar and Englebright Reservoirs. Data at several monitoring locations were unavailable due to loss, high flows, or access limitations. All hourly data were reviewed and non-valid data (e.g., air temperatures) removed. Daily mean, maximum, and minimum water temperatures were computed from hourly data. All data sets, including those supplied by other agencies are included on computer diskette.

Reporting included a summary of monitoring locations, methods, quality control, and data obtained from other sources. South, Middle and main stem Yuba Rivers thermal characteristics were presented noting data and analyses limitations. Though meteorological, flow, operations, and other potentially influential factors were not directly included in interpretation, field data showed that the Middle and South Yuba River heated appreciably in the first ten to twenty miles below the headwater reservoirs. Data from the larger, low elevation reservoirs, New Bullards Bar and Englebright, illustrate that these reservoirs have a significant influence on thermal characteristics below Englebright Dam. Specifically, these reservoirs operate in tandem to allow cool water releases from Englebright Dam to the lower Yuba River throughout the summer period.

4.2 Recommendations

The Yuba River Water Temperature Monitoring Project provided an initial examination of temperature conditions in the Yuba River Basin (excluding the North Yuba above New Bullards Bar) during the summer period. The current level of water resources development in the basin integrates the North, Middle, South and main stem Yuba Rivers through a unique system of storage, diversion, power production, and water supply operations. Given that the water resources of the Yuba River are heavily developed and California experiences a wide range of hydrological and meteorological conditions several recommendations have been identified. Specifically,

- continue temperature monitoring (including locations where data were unavailable in this study due to loss, high flows, or access limitations)
- extend temperature monitoring to include year-round-deployments
- monitor North Yuba River above New Bullards Bar Reservoir
- collect flow data coincident with temperature data
- collect associated and applicable meteorological data
- provide agency collaboration of data collection and dissemination

Efficient and effective planning and operation of water resources is data intensive. Consistent and comprehensive monitoring programs, addressing critical system data, will allow informed decisions as multiple uses share common water supplies while demand continues to grow.

5. REFERENCES

Department of Water Resources (DWR). 1964. *Yuba and Bear Rivers Basin Investigation, Bulletin, No. 115*. The Resources Agency of California. April.