

**1998 Summer Water Temperature Monitoring on Redwood Creek, California
Progress Report**

March 1999

By Vicki Ozaki, Mary Ann Madej (BRD, USGS), David Anderson

INTRODUCTION

Stream water temperature is an important factor in regulating aquatic life. Salmonids are cold water fish with distinct temperature requirements during different parts of their life cycle. Water temperatures influences egg development, rearing success (growth rate, swimming ability, ability to capture and use food), species competition, and other factors (Beshcta *et. al.*, 1987). Stream temperatures can be altered by land management activities by removing the riparian vegetation along channels. Natural watershed disturbances such as floods combined with management activities may also result in channel aggradation (infilling), bank erosion, and channel widening which directly affects stream temperature.

Summer water temperatures are a problem for juvenile steelhead and cutthroat trout, and coho salmon, because these species remain in the stream system for at least one year after hatching and may reside up to several years in Redwood Creek until migrating out to the ocean. Adult summer steelhead are also particularly vulnerable to stressful summer water temperatures because they reside in mainstem pools throughout the summer. Juvenile chinook reside in the estuary during the summer and as a result estuary conditions can greatly affect the juvenile stage of this species.

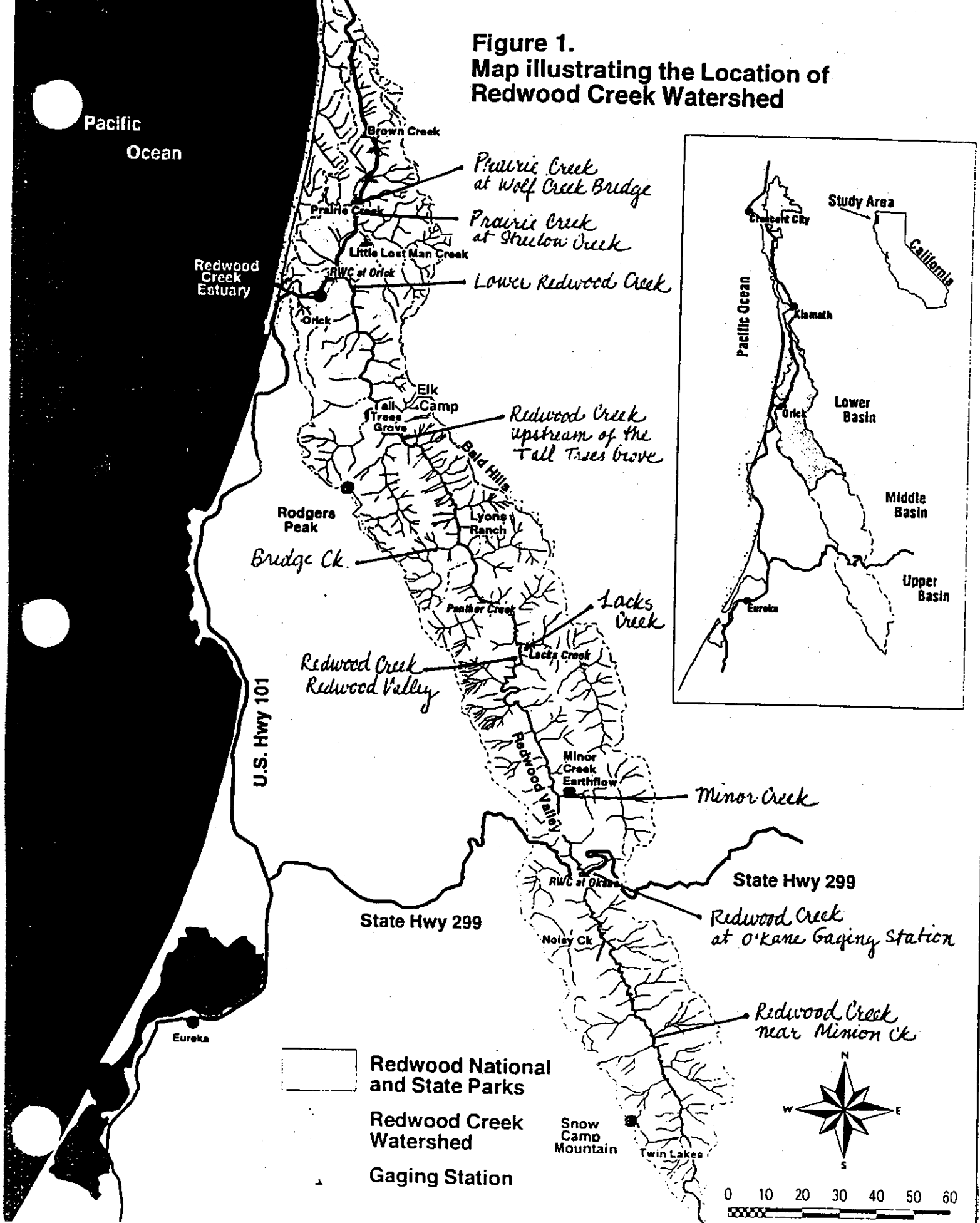
While temperature requirements for juvenile and resident salmonids are variable, most salmonid species are at risk when temperatures exceed 23-25 °C (Spence, *et. al.* 1996). The preferred temperature for steelhead trout was 10-13 °C and 12-14 °C for coho and chinook salmon. The upper lethal temperatures for steelhead trout, coho and chinook salmon were 23.9, 28.8 and 26.2°C, respectively (Bjornn and Reiser, 1991).

During the summer of 1998, Redwood National and State Parks, in cooperation with the U.S. Geological Survey, Biological Resources Division monitored the summer water temperature regime in Redwood Creek. The objective of the monitoring was to: 1) determine spatial trends in summer water temperature along Redwood Creek and in selected tributaries and, 2) to provide baseline data for long-term stream temperature trend monitoring.

STUDY AREA

The Redwood Creek basin drains an area about 738 km² in north coastal California (Figure 1). The main channel is 108 km long and roughly bisects the basin. Channel gradient decreases from 12 percent in the headwaters to 0.10 percent near the mouth. Total basin relief is 1615 m and the average hillslope gradient is 26 percent. The basin receives about 200 cm (80 in) of rainfall annually, most of which falls as rain between October and March.

Figure 1.
Map illustrating the Location of
Redwood Creek Watershed



Fish fauna in Redwood Creek is typical of the coastal streams of northern California (Brown, 1988). Both anadromous and resident fish species utilize the basin. Salmonid species include winter and summer runs of steelhead/rainbow trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*), a fall chinook run (*Oncorhynchus tshawytscha*) and coastal cutthroat trout (*Oncorhynchus clarki*). The steelhead and cutthroat trout both exhibit resident as well as anadromous life histories (Brown, 1988).

PAST STUDIES

Water temperature data from past studies on Redwood Creek were primarily point measurements with hand held thermometers. Continuous monitoring of summer stream temperatures on lower Redwood Creek on parklands began in 1992 as part of the summer steelhead monitoring program. In 1992 and 1993, water temperatures were recorded on strip-tape recorders (Ryan Peabody Thermographs). From 1994 to 1996 water temperatures were recorded with Hobo data loggers. The following is a summary of stream temperature data from previous studies.

Long-time residents of the Redwood Creek watershed recall cooler summertime water temperatures before 1964 (Van Kirk, Susie, written communication, 1994). Following the early 1970 floods on Redwood Creek, the U.S. Geological Survey measured extremely high peak water temperatures at the O'Kane gaging station from 1974-1976. Summer temperatures peaked between 30.5 and 33.5 °C, well above the upper lethal temperature for both coho salmon and steelhead trout (Dept. of Interior, 1974-1977)

Anderson (1988) determined that in the mainstem of Redwood Creek during the summers of 1980 and 1981, water temperatures were generally between the upper preferred and upper lethal temperatures for juvenile steelhead (Figure 2). In some reaches water temperatures even exceeded the upper lethal temperatures for juvenile steelhead.

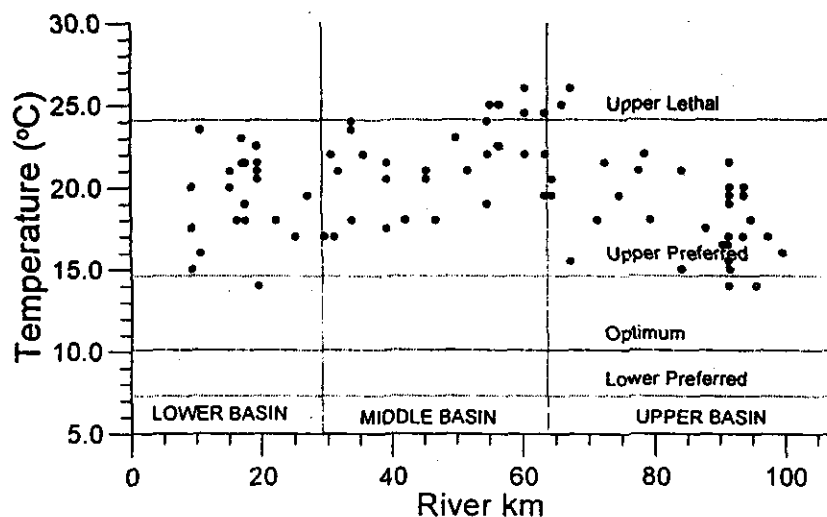


Figure 2: Ranges of mainstem surface water temperature at locations along Redwood Creek for summer-fall 1980 and 1981. Temperatures were measured from 0700 h to 2000 h. Temperature preferences referred to on the graph are for juvenile steelhead trout (from Anderson, 1988).

Stream temperature data from 1994-1998 is summarized in annual summer steelhead reports. Mainstem and tributary water temperatures from the 1996 summer steelhead survey were similar to conditions measured in previous surveys (US Dept. Interior, in house memo). The highest water temperature measured was 25-26 °C along the mainstem of Redwood Creek in Redwood Valley. All tributary summer water temperatures were cooler than the corresponding temperature of the mainstem Redwood Creek measured at the same time. In general, westside tributaries were cooler than eastside tributaries, a pattern consistent with observations from past studies from the early 1980's.

In 1997, water temperature monitoring was expanded to include the upper Redwood Creek above the park boundaries. Ozaki and others (1998) presented 1997 summer water temperature data for Redwood Creek.

Cold water refugia in the form of thermally stratified pools was also studied by several researchers on Redwood Creek in the early to mid-1980's (Keller and Hofstra, 1982; Moses, 1984; Ozaki, 1988). Cold pools, although few in number, offer high quality rearing habitat and holding areas for juvenile salmonids and holding adult summer steelhead. Juvenile salmonids have been observed utilizing cold pools during hot summers on other northcoast rivers (Nielsen and others, 1994).

METHODS

Continuous water temperature data was collected with data loggers at five sites along the main channel, four tributaries and the estuary of Redwood Creek (Figure 1). Fifteen Hobos and Optic StowAways were deployed during summer low flows in Redwood Creek. Sampling sites were selected based upon representative channel reaches and available stream access.

Prior to deployment in the stream, all data loggers were tested using a zero degree ice bath to identify non-functioning temperature probes. The sampling interval for StowAways and Hobos was 60 and 48 minutes, respectively.

Data loggers positioned in streams were suspended in the water column, placed in areas of well-mixed water and completely submerged to a sufficient depth to not be exposed to air as stream flows dropped during the monitoring period. Temperature probes recording air temperatures were hung from trees in the riparian zone. All data loggers were placed in a shaded location where possible.

RESULTS

Water temperatures were monitored at five main channel sites and the Redwood Creek estuary (Figure 1). Tributary water temperatures were also measured in Prairie, Bridge, Minor and Lacks Creek. Air temperature was also recorded at five of the monitoring sites and include: Redwood Creek near Lacks Creek (Redwood Valley), Redwood Creek near the O'Kane (Blue Lake) gaging station, Redwood Creek near Minon Creek and in Bridge and Prairie Creeks.

The mainstem and tributary monitoring locations, medium measured (air or water), recording

interval and monitoring period are listed in Table 1.

Table 1. 1998 MAINSTEM AND TRIBUTARY MONITORING LOCATIONS					
LOCATION	UNIT #		SAMPLING INTERVAL	START DATE	END DATE
Main Channel Redwood Creek:					
Redwood Creek Estuary *	Hobo #14479	Water	48 min	7/20/98	9/18/98
Lower Redwood Creek * (south of the Redwood Creek Trailhead)	Hobo #14482	Water	48 min	9/21/98	10/20/98
	StowAway #3095	Air	24 min	7/20/98	10/20/98
Redwood Creek upstream of Tall Trees Grove (near Otter Camp) *	Hobo #14476	Water	60 ⁴⁸ min	7/22/98	9/20/98
Redwood Creek, Redwood Valley (upstream of Lack's Creek)	StowAway #374	Water	60 min	6/1/98	10-1-98
	StowAway #373	Air	60 min	6/1/98	10-1-98
Redwood Creek at O'Kane Gaging Station (near Highway 299)	StowAway #122282	Water	60 min	6/1/98	10-1-98
	StowAway #128859	Air	60 min	6/1/98	10-1-98
Redwood Creek near Minon Creek **	StowAway #122283	Water	60 min	6/5/98	9-28-98
	StowAway #128861	Air	60 min	6/5/98	9-28-98
Redwood Creek Tributary:					
Prairie Creek at Wolf Creek Bridge	StowAway #369	Air	48 ⁶⁰ min	6/1/98	10-1-98
	StowAway #371	Water	48 ⁶⁰ min	6/1/98	10-1-98
Bridge Creek ***	StowAway #162	Water	60 min	6/1/98	10-15-98
	StowAway #163	Air	60 min	6/1/98	10-15-98
Lacks Creek	StowAway #122281	Water	60 min	6/1/98	10-1-98
Minor Creek	StowAway #128860	Water	60 min	6/1/98	10-1-98
* Due to equipment problems, data for the whole time period is not available.					
** Probe buried in sediment, relocated on 8/24					
*** Incomplete record - probe in air 6/26 to 7/29					

One of the objectives was to measure the highest summer water temperature which were expected to occur in late July and early August. Most of the data loggers were deployed from June 1 to September 30. Unfortunately, data from the estuary and the two lower Redwood Creek monitoring stations were lost when a laptop with temperature data stored on it failed. At this time, the data has not been recovered. Due to the truncated data sets at lower Redwood Creek stations, data analysis was limited to August 1998.

Temperature duration graphs for August 1998 were plotted for mainstem (Figure 3) and tributary (Figure 4) stations. The plots determine the thermal signature at each site and document the percent time a given temperature was equaled or exceeded.

**1998 Redwood Creek Mainstem Monitoring Stations
Water Temperature August**

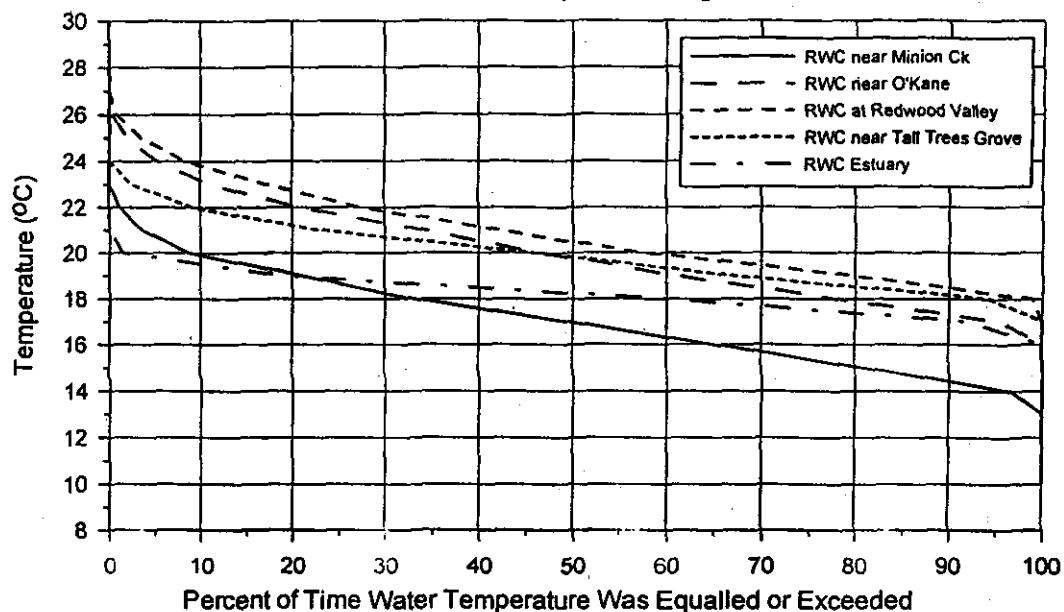


Figure 3. Temperature duration graphs for mainstem Redwood Creek stations for August 1998.

**1998 Redwood Creek Tributary Monitoring Stations
Water Temperature August**

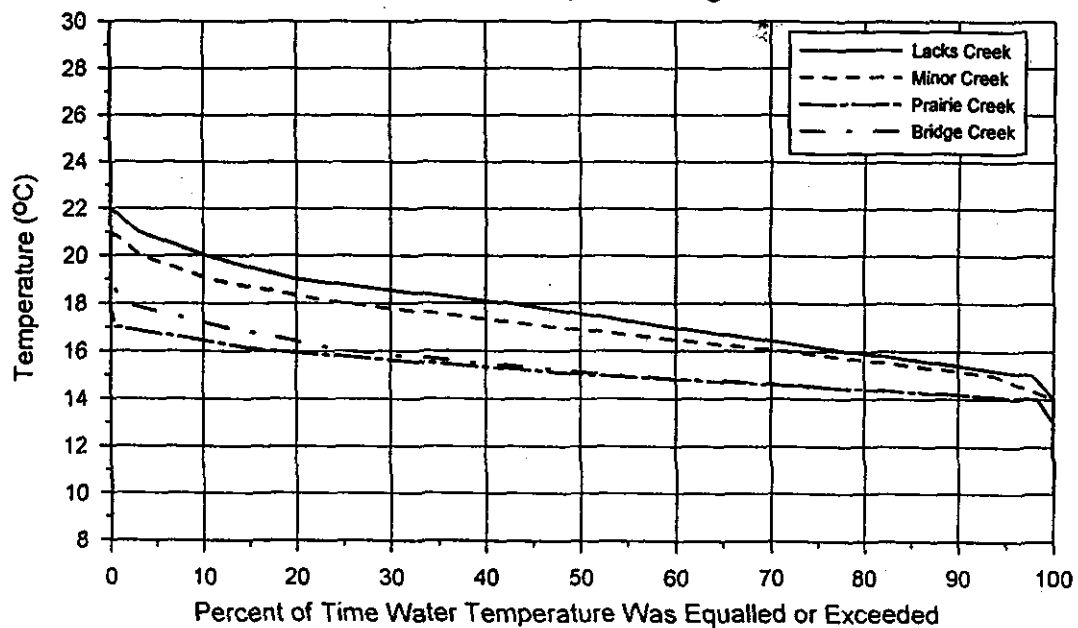


Figure 4. Temperature duration graphs for tributary Redwood Creek stations for August 1998

The maximum, minimum and average temperature, and percent time 20 °C was equaled or exceeded for mainstem Redwood Creek and selected tributaries is summarized in Table 2 for the month of August.

Table 2. MAINSTEM AND TRIBUTARY SUMMARY DATA FOR AUGUST 1998

LOCATION	Maximum Temp. (°C)	Minimum Temp. (°C)	Average Temp. (°C)	% Time Water Temperature Exceeded 20C
Main Channel Redwood Creek:				
Redwood Creek Estuary	20.2	15.9	18.1	1.5
Lower Redwood Creek	----	----	----	----
Redwood Creek upstream of Tall Trees Grove (near Otter Camp)	23.6	17.5	19.8	45.6
Redwood Creek, Redwood Valley	26.8	17.8	20.8	57.4
Redwood Creek at O'Kane Gaging Station (near Highway 299)	25.9	16.0	19.9	46.4
Redwood Creek near Minon Creek	23.0	13.5	17.0	8.7
Redwood Creek Tributary:				
Prairie Creek at Wolf Creek Bridge	16.9	13.6	15.1	0
Bridge Creek (incomplete record – probe in air 6/26 to 7/29)	18.3	13.7	15.3	0
Lacks Creek	21.8	14.4	17.5	10.2
Minor Creek	20.6	14.2	16.9	3.2

Thermographs of water and air temperature for monitoring sites on Redwood Creek are plotted in Appendix A. Redwood Creek temperature data is also stored on the Arcata network drive at the following location:

FA1:q:\data\users\geo\geomorph\stream temp\

Electronic data management and naming conventions for files are explained in Appendix B.

DISCUSSION

In general, water temperatures in Redwood Creek were slightly cooler than during the summer of 1997, but peak summer temperatures were similar in both years. Average stream temperatures along the mainstem of Redwood Creek during August shows a general pattern of stream warming from the headwaters to the middle basin and then cooling from the middle basin downstream to the Redwood Creek estuary (Figure 5).

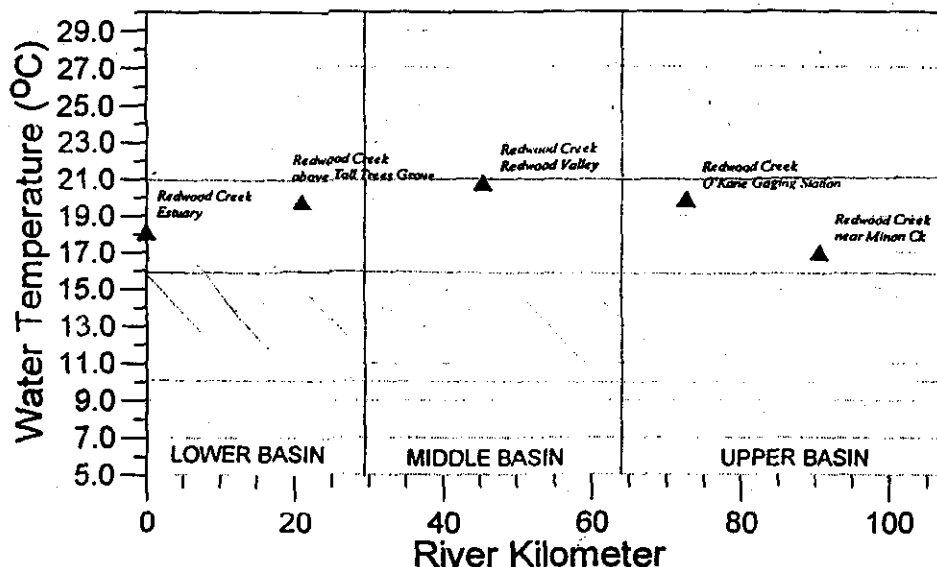


Figure 5. Average stream temperature at mainstem stations for August 1998.

In August (usually the month with the warmest stream temperatures of the year), Redwood Creek upstream of Minon Creek reached a maximum of 23 °C, and a minimum of 13.5 °C. Redwood Creek warmed considerably in the reach downstream from this station, probably due to exposure to the sun and lack of conifer canopy, as well as, in response to warm daytime air temperatures (Figure 3). August 1998 water temperature records for Redwood Creek at the O'Kane gaging station and at Redwood Valley document this warming trend. The maximum water temperature at these station was 25.9 °C and 26.8 °C respectively, several degrees warmer than the upstream station. The highest stream temperatures were recorded in this reach of stream. Redwood Creek did not recover in terms of cool temperatures at night--the minimum temperature was 16 °C at the O'Kane station and 17.8 °C in Redwood Valley. During this time period, Redwood Creek exceeded 20 °C more than 46% at the O'Kane gaging station and 57% of the time in Redwood Valley. In contrast, water temperatures exceeded 20 °C only 8.7 % of the time at Redwood Creek upstream of Minon Creek. Redwood Creek cooled a few degrees where it flows through the fog zone near the coast. Peak summer water temperature near the Tall Trees Grove was 23.6 °C; a couple of degrees cooler than upstream. However, at night the stream only cooled to 17.5 °C similar to the upstream reaches. Downstream in the Redwood Creek estuary, the peak temperature recorded in the Redwood Creek estuary was up to 6.6 °C lower than the sites in the middle basin.

Peak temperatures gage the acute stream temperature conditions fish are exposed to. In 1998, peak summer water temperatures monitored at four mainstem sites and the estuary were all above the upper preferred temperature for juvenile steelhead trout and coho salmon (Figure 6). Three sites, located between the Tall Trees Grove and Highway 299, exceeded upper lethal temperatures for steelhead and peak temperatures ranged from 24.4 – 26.8°C. Peak summer water temperatures have apparently cooled several degrees since the mid-1970's, however they still remain well above the preferred temperature of juvenile salmonids and at times exceed the upper lethal temperatures of steelhead and coho.

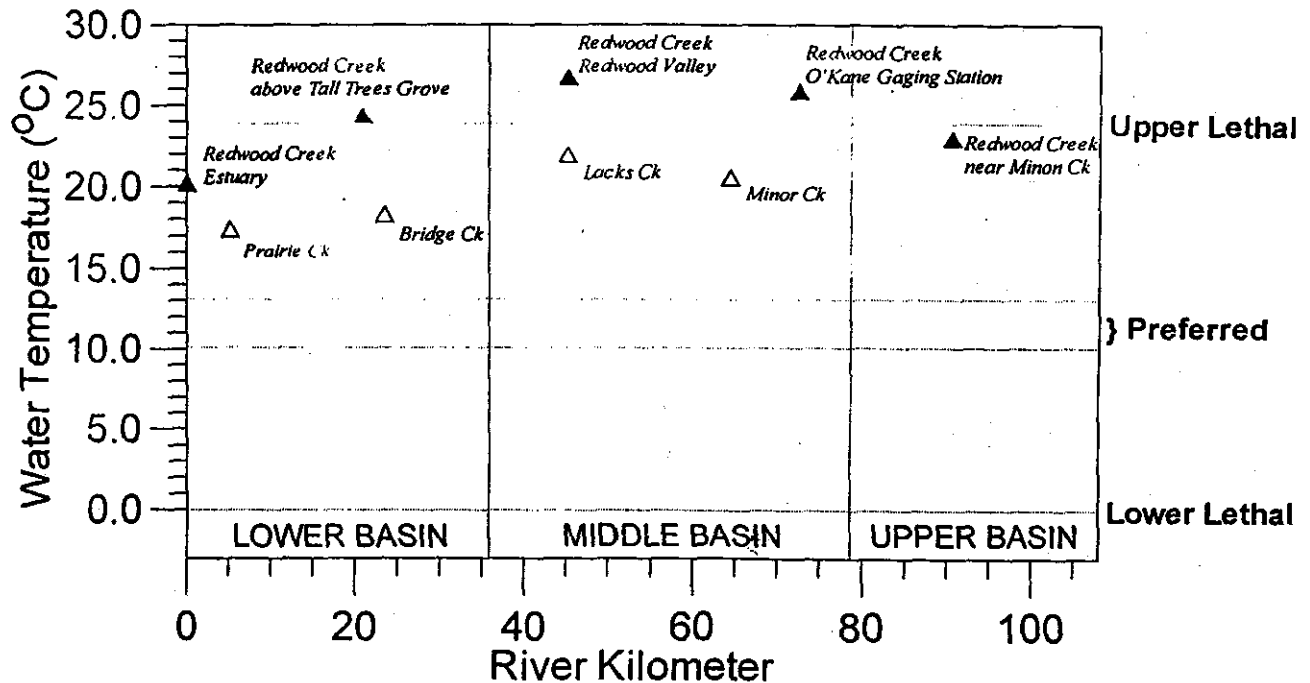


Figure 6. Peak water temperatures recorded at mainstem stations along Redwood Creek and in tributaries during the summer 1998. Temperature preferences on the graph are for juvenile steelhead trout (Bjornn and Reiser, 1991).

Chronic water temperature problems for Redwood Creek can be evaluated using the temperature exceedence graphs (Figure 3 and 4). For most August 1998, water temperature exceeds the preferred temperature for juvenile steelhead at mainstem stations and on average the stream exceeds the preferred water temperature more than 99 percent of the time. Redwood Creek at Redwood Valley and at the O'Kane gaging station exceed the upper lethal temperature of juvenile steelhead more than 5 and 8 percent of the time, respectively.

The average temperature in the Redwood Creek estuary (18°C) for August was about 4°C above the preferred temperature for juvenile chinook. However, peak summer temperature (20.2°C) were well below the upper lethal temperature.

Stream temperatures in four tributaries were also monitored. All tributaries had cooler water temperatures in August than the mainstem stations; however, all exceeded the preferred temperature of both juvenile steelhead trout and coho salmon (13 and 14 °C, respectively) more than 98 percent of the time (Figure 4). East-side tributaries in the middle basin of Redwood Creek were several degrees warmer than west-side tributaries.

Based on temperatures recorded 1998, warm summer water temperatures appear to be a concern to rearing juvenile chinook salmon in the estuary, and rearing juvenile coho salmon and steelhead trout and adult summer steelhead holding in the mainstem of Redwood Creek.

MANAGEMENT RECOMMENDATIONS:

- 1.) An evaluation of the relationship between channel widening, changes in the riparian canopy and stream temperature should be pursued. Currently a Master's thesis on the changes in riparian canopy is being completed.
- 2.) Finalize a stream temperature monitoring protocol for Redwood National Park and develop excel macros to streamline data analysis.
- 3.) Continue basin-wide monitoring of Redwood Creek to provide baseline stream temperature data.
- 4.) Monitor water temperature year-round at selected gaging stations.

REFERENCES

- Anderson, D.G. 1988. Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California. M.S. Thesis, Humboldt State University, Arcata, California. 99 pp.
- Anderson, D.G. 1993. Status of summer steelhead trout in Redwood Creek, Redwood National Park, California. *In*: Proceedings of the Fourth Conference on Research in California's National Parks. eds. S.D. Veirs, T.J. Stohlgren, and C. Schonewald-Cox. Transactions and Proceedings NPS/NRUC/NRTP-93/9. U.S. Department of Interior, National Park Service, Denver, Colorado. p. 1-8.
- Beschta, R.L., Bilby, R.E., Brown, G.W., Holtby, L.B., and Hofstra, T.D. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. *In*: Streamside Management forestry and Fishery Interactions. eds. E.O. Salo and T.W. Cundy. University of Washington, Institute of Forest Resource. Contribution No. 57. p. 191-232.
- Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. *In*: Influences of forest and rangeland management on salmonids fishes and their habitats. ed. W.R. Meehan. Special Publication 19. American Fisheries Society, Bethesda, Maryland. p. 83-138.
- Brown, R.A. 1988. Physical resaring habitat for anadromous salmonids in the Redwood Creek basin, Humboldt County, California. M.S. Thesis, Humboldt State University, Arcata, California. 132 pp.
- Keller, E.A. and Hofstra, T.D. 1983. Summer cold pools in Redwood Creek near Orick, California, and their importance as habitat for anadromous salmonids. *In*: Proceeding of the First Biennial Conference of Research in California National Parks, Davis, California. Septmeber 9-10, 1982. p.221-224.
- Moses, C.G. 1984. Pool morphology of Redwood Creek, California. M.S. Thesis. University of California Santa Barbara. Santa Barbara, California. 117 p.
- Nielsen, J., Lisle, T. and Ozaki, V. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Transactions of the American Fisheries Society. V. 123. p. 613-626.
- Ozaki, V., Madej, M.A., and Anderson, D.G. 1998. 1997 Summer water temperature monitoring on Redwood Creek, California. Progress Report. U.S. Dept. of Interior, National Park Service, Redwood National Park. 28 p.
- Ozaki, V. 1988. Geomorphic and hydrologic conditions for cold pool formation on Redwood Creek, California. Redwood National Park Technical Report 24. U.S. Dept. of Interior, National Park Service, Redwood National Park. Arcata, California. 57 p.

Spence, B.C, Lomnický, G.A., Hughes, R.M., and Novitzki, R.P. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Corp., Corvallis, OR. 356 p.

U.S. Dept. Interior, National Park Service, Redwood National Park. 1996. 1996 Redwood Creek Summer Steelhead Trout Survey. In House Memo. 13 p.

U.S. Dept. Interior, U.S. Geological Survey. 1974. Water Resources Data California. Volume 2. Pacific Slope Basins from Arroyo Grande to Oregon State Line except Central Valley. U.S. Geol. Survey Water-Data Report CA-94-2.

VanKirk, S. 1994. Historical information on Redwood Creek. In-house report. 33 p.

Appendix A

*Plots of water and air temperatures for monitoring sites on
Redwood Creek and selected tributaries.*

Temperature is plotted in degrees Celsius. The maximum and minimum water temperature is also included.

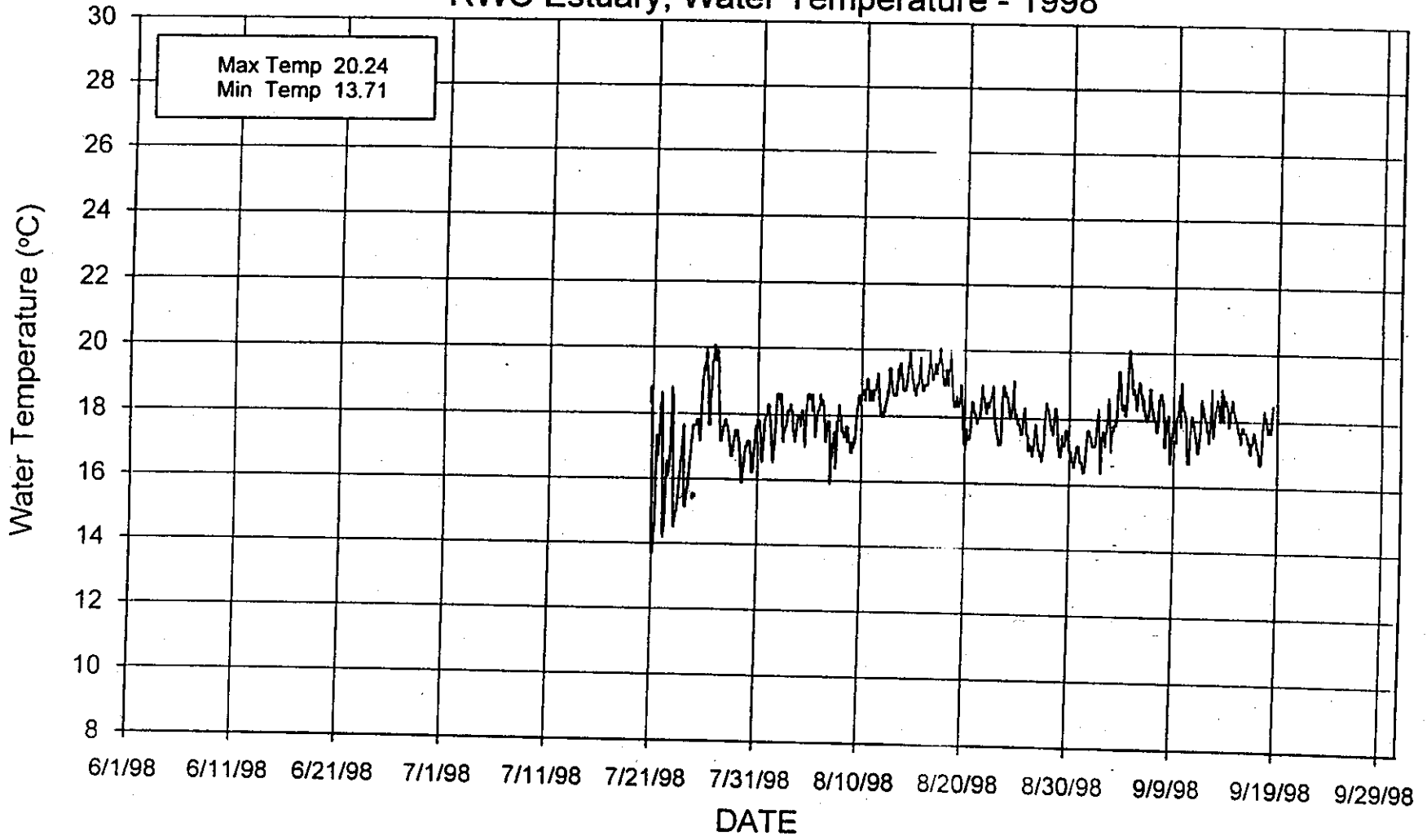
MAIN CHANNEL STATIONS:

Redwood Creek Estuary
Redwood Creek Lower near Redwood Creek Trailhead
Redwood Creek upstream of the Tall Trees Grove
Redwood Creek upstream of Lacks Creek, Redwood Valley
Redwood Creek at O'Kane gaging station
Redwood Creek upstream of Minon Creek

TRIBUTARY STATIONS:

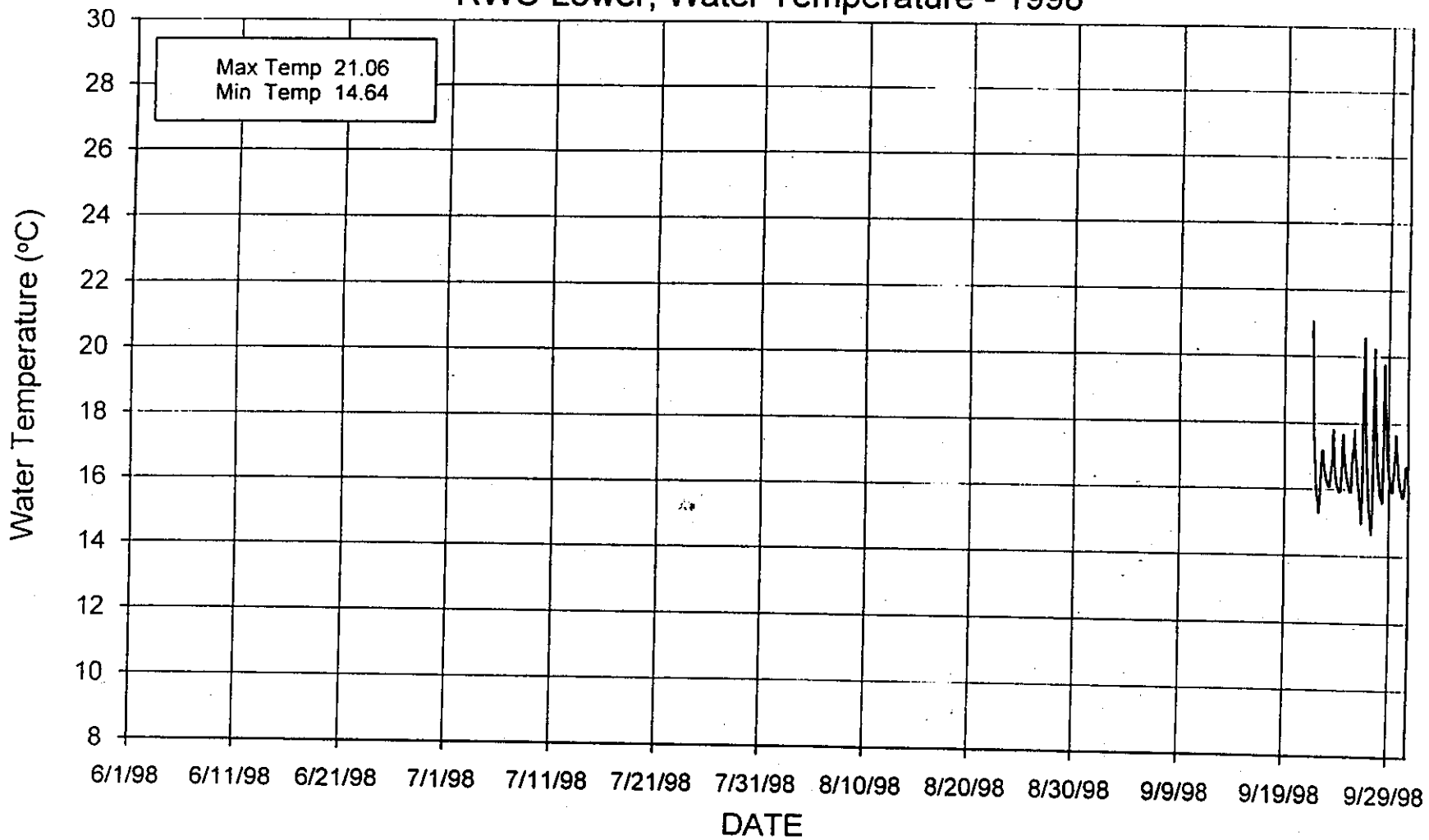
Prairie Creek
Bridge Creek
Lacks Creek
Minor Creek

RWC Estuary, Water Temperature - 1998



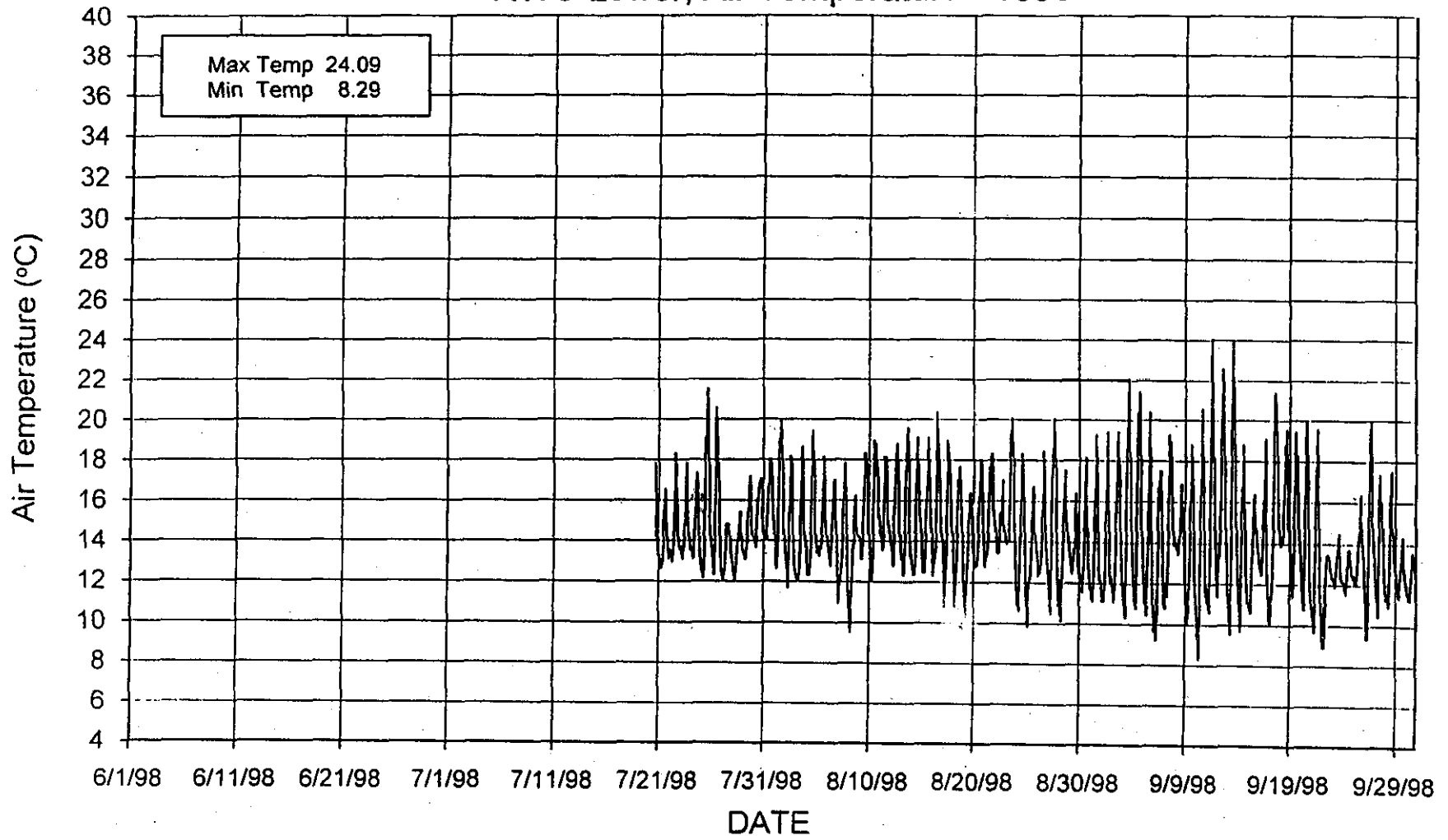
12158

RWC Lower, Water Temperature - 1998



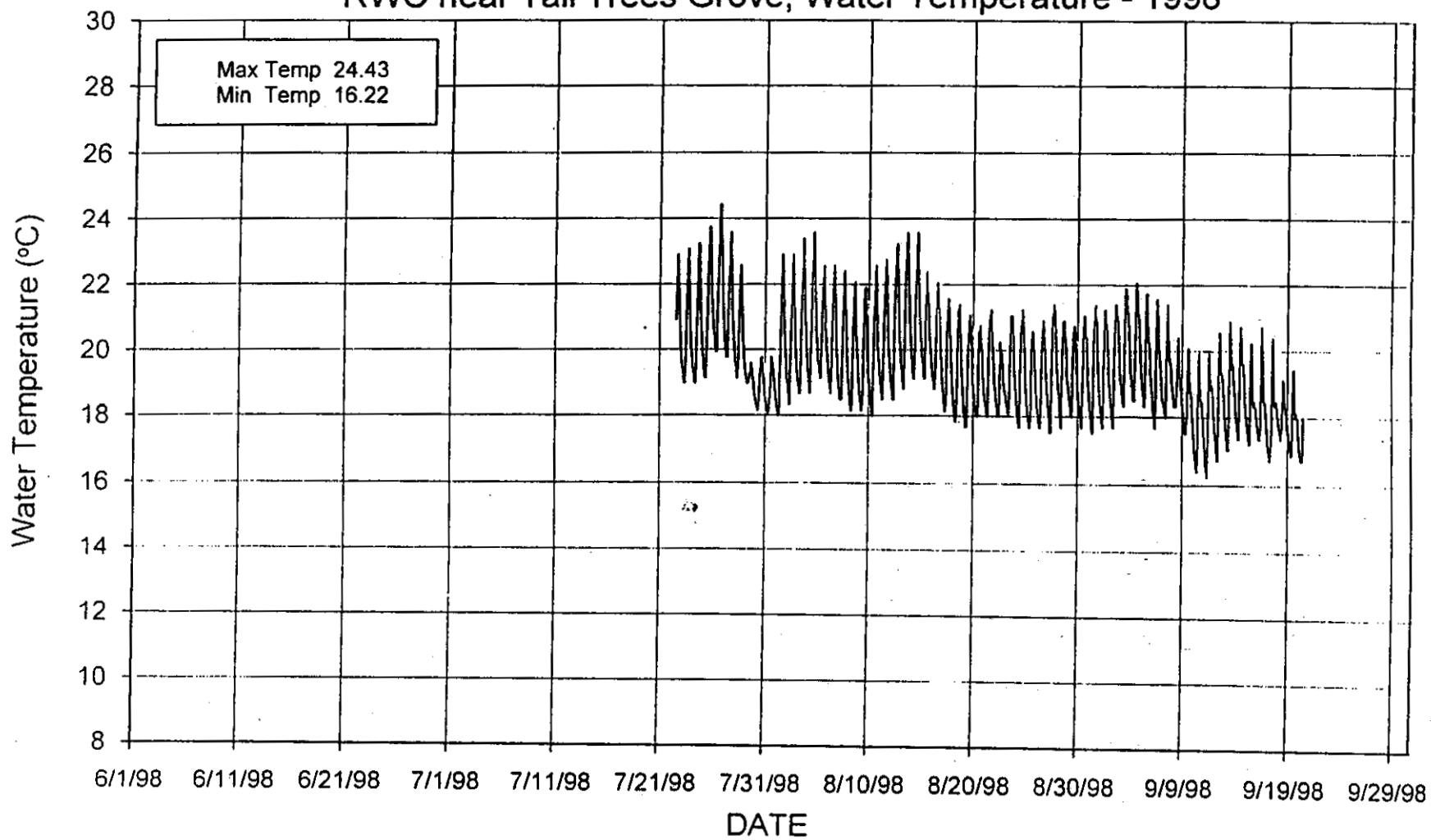
12159

RWC Lower, Air Temperature - 1998



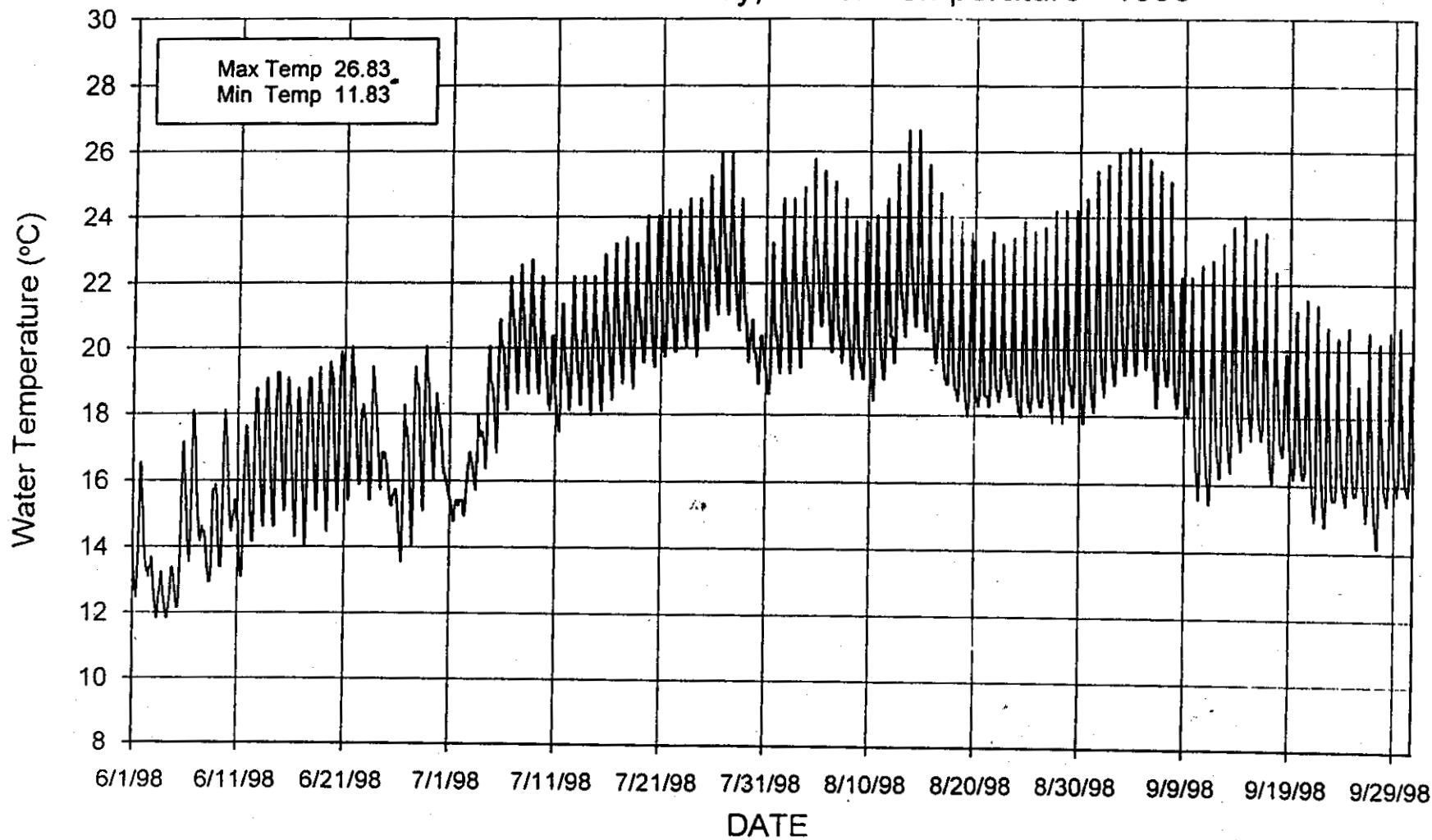
12160

RWC near Tall Trees Grove, Water Temperature - 1998



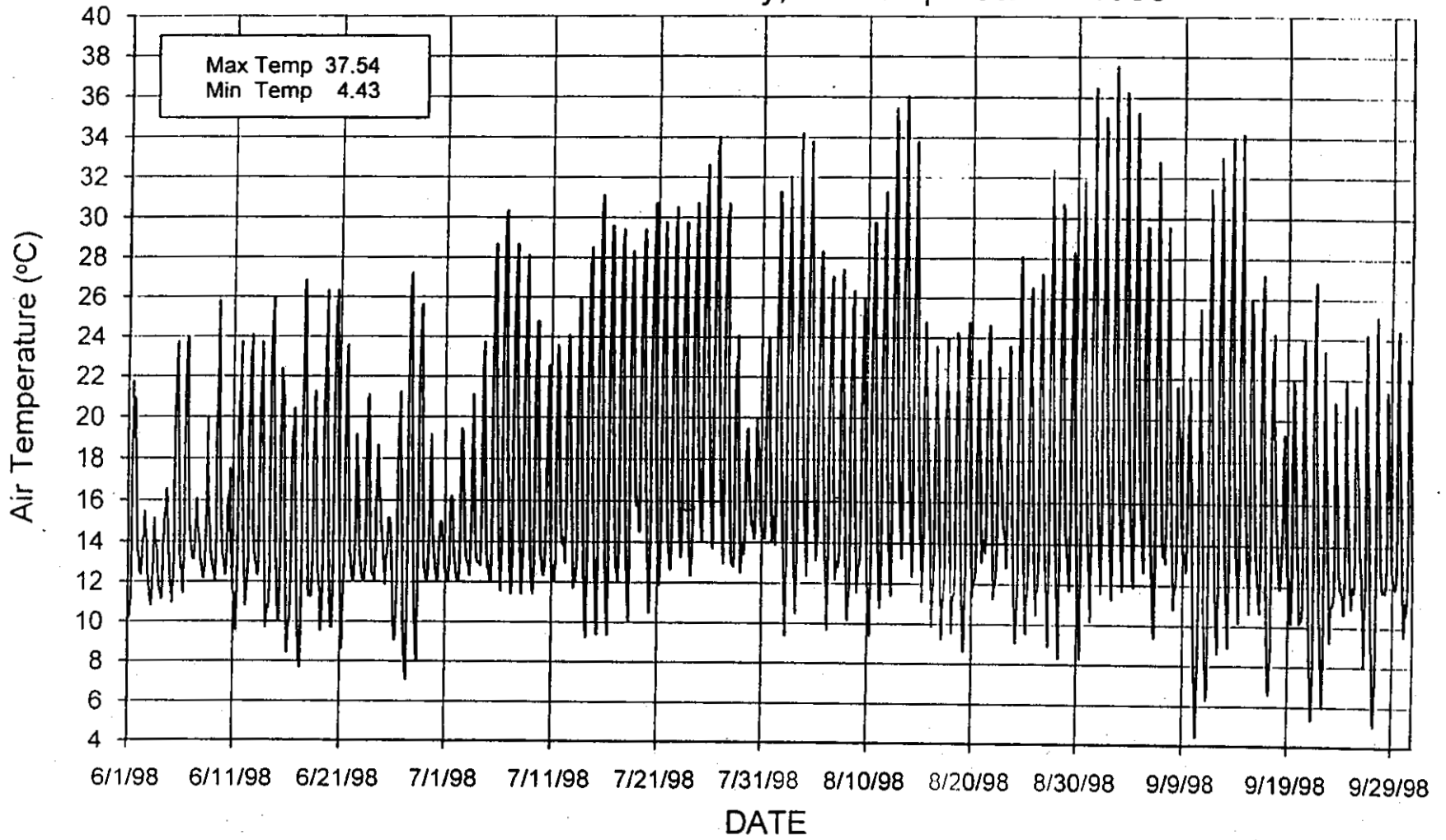
12161

RWC at Redwood Valley, Water Temperature - 1998



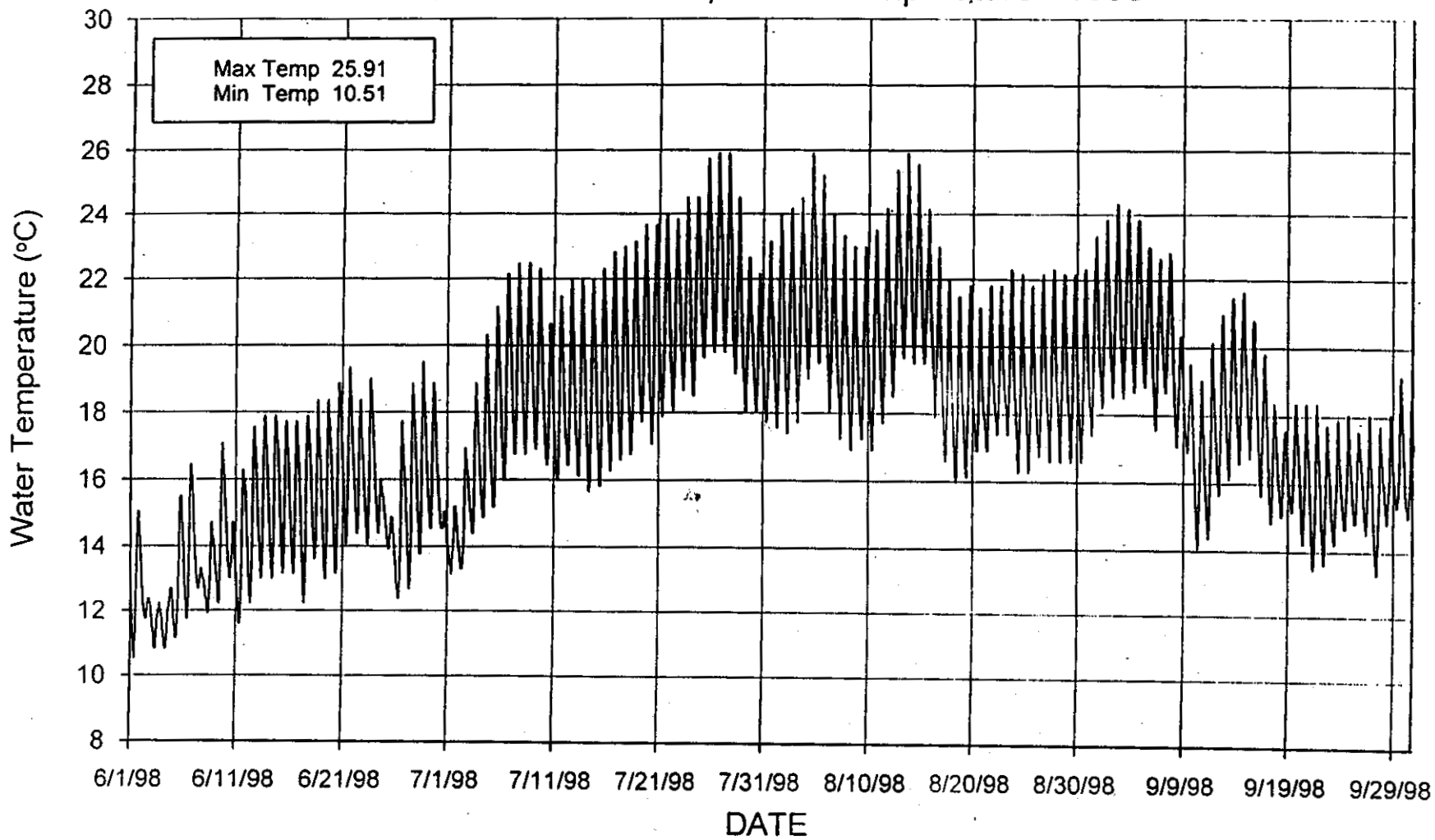
12162

RWC at Redwood Valley, Air Temperature - 1998



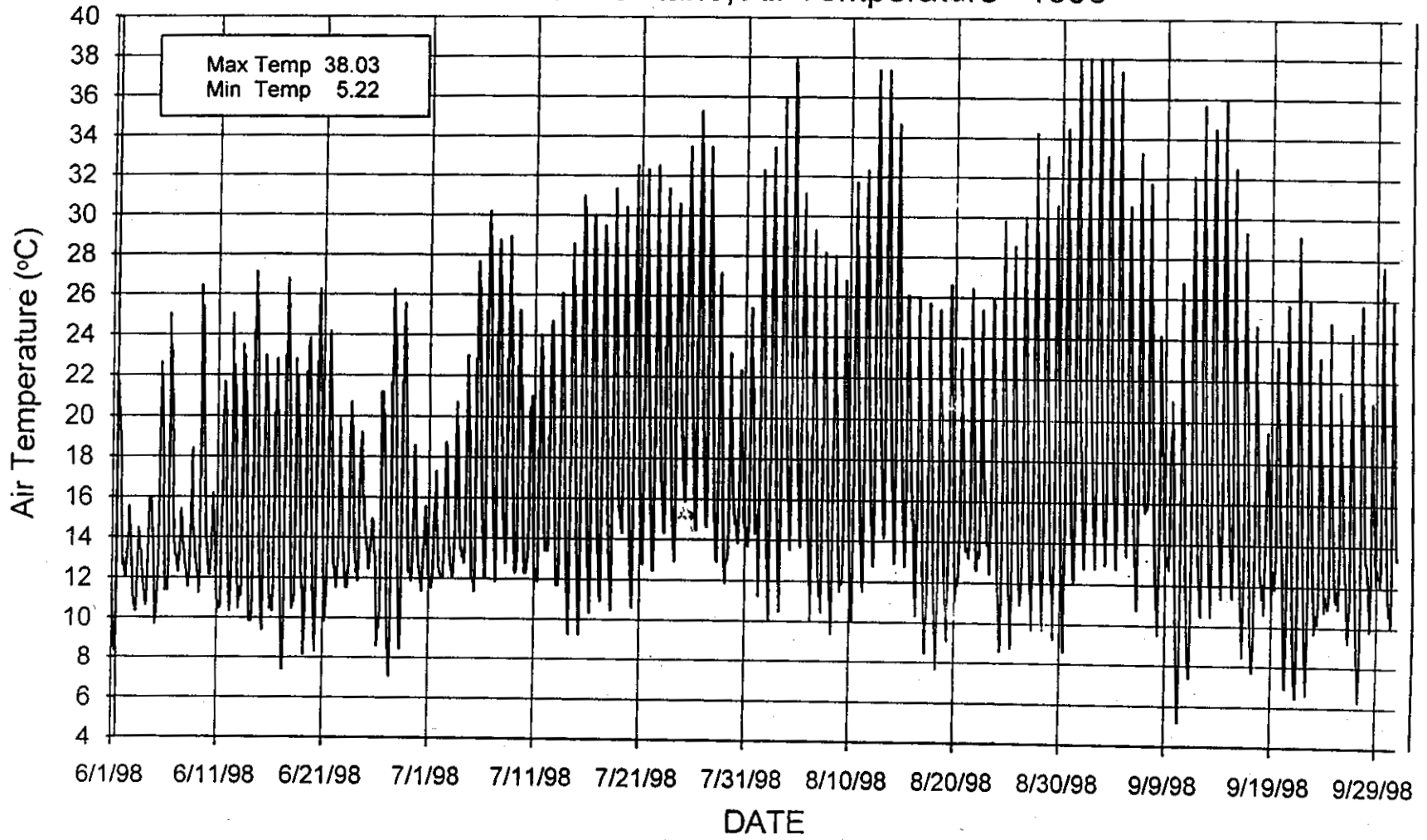
12163

RWC near O'Kane, Water Temperature - 1998



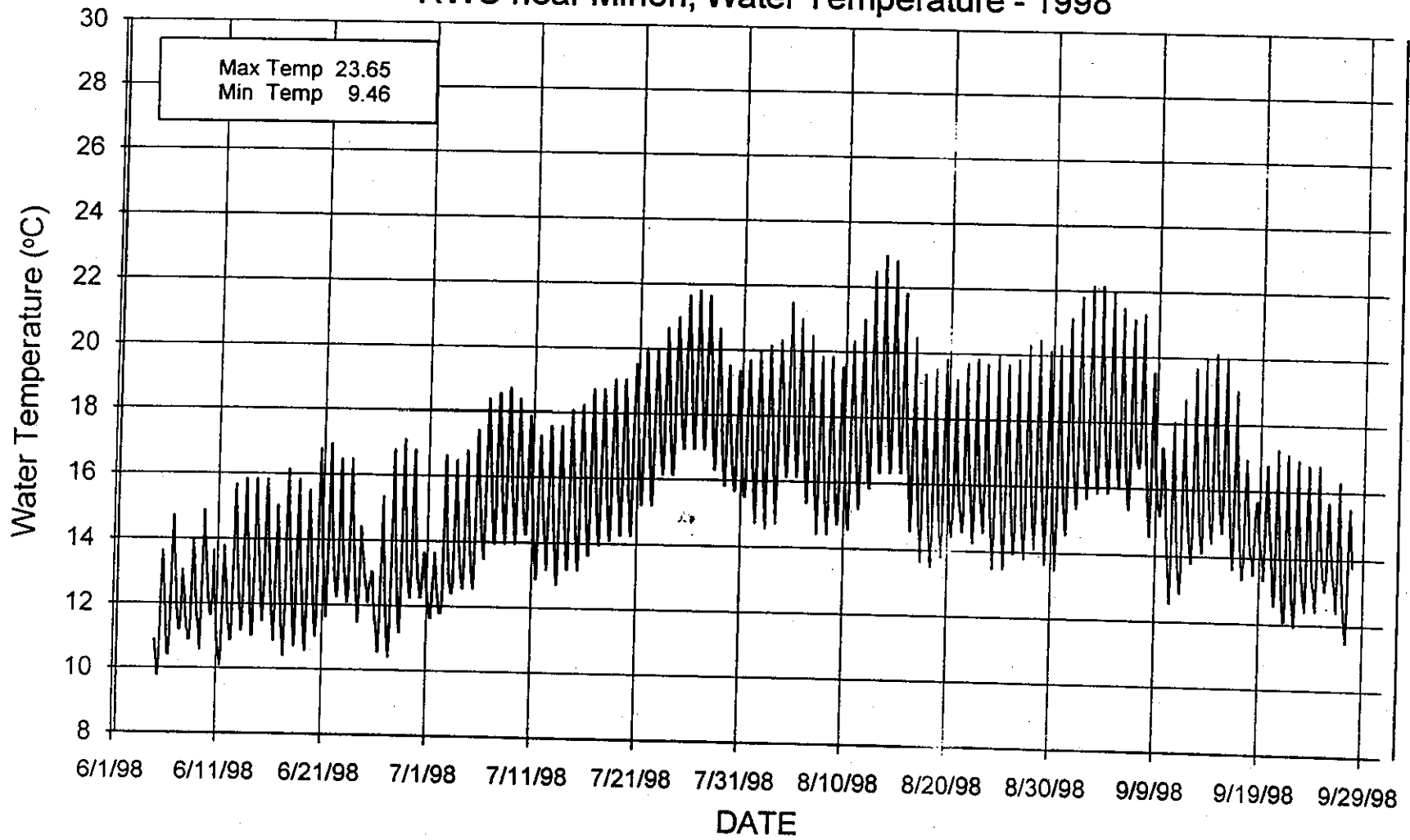
12164

RWC near O'Kane, Air Temperature - 1998



12165

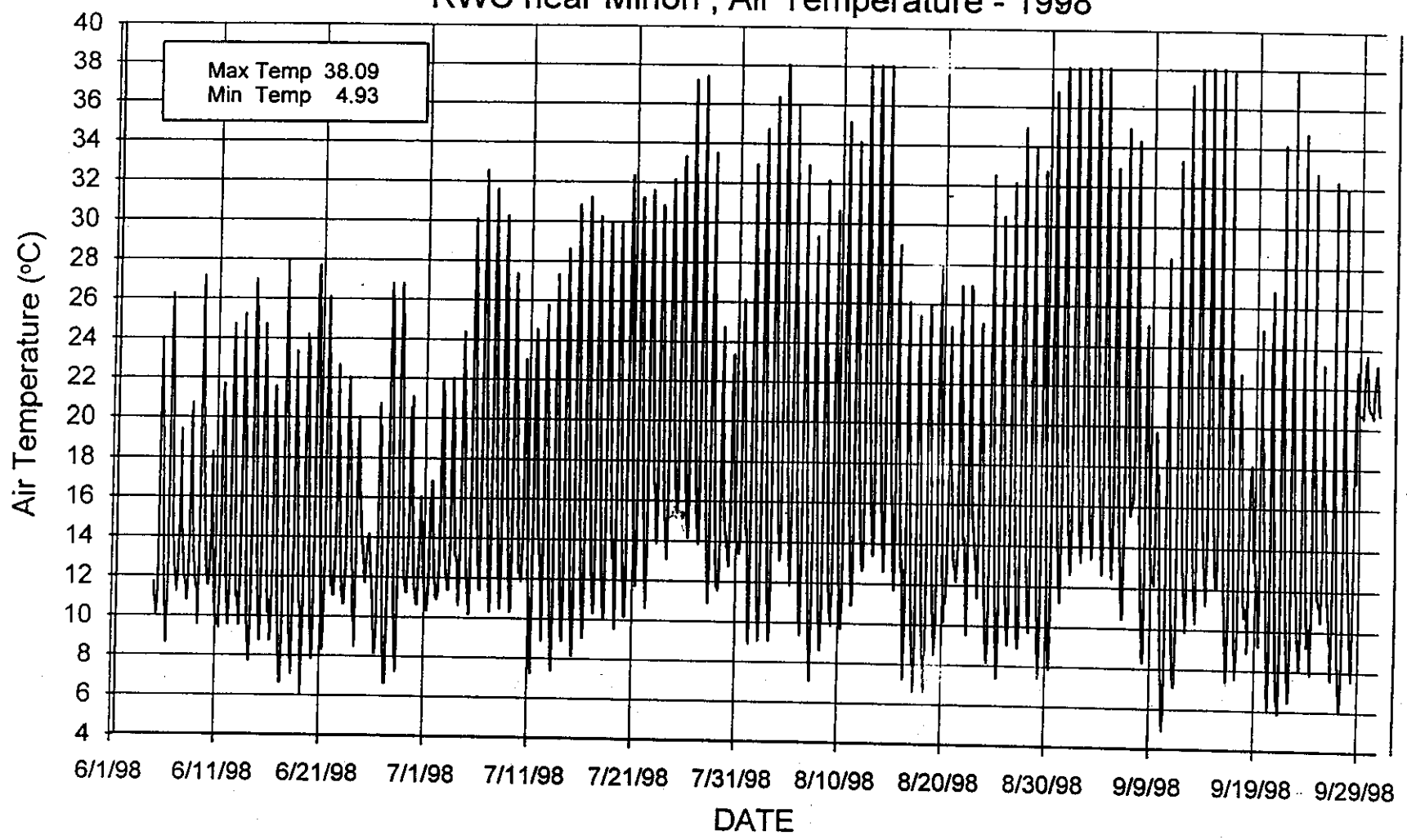
RWC near Minon, Water Temperature - 1998



Max Temp 23.65
Min Temp 9.46

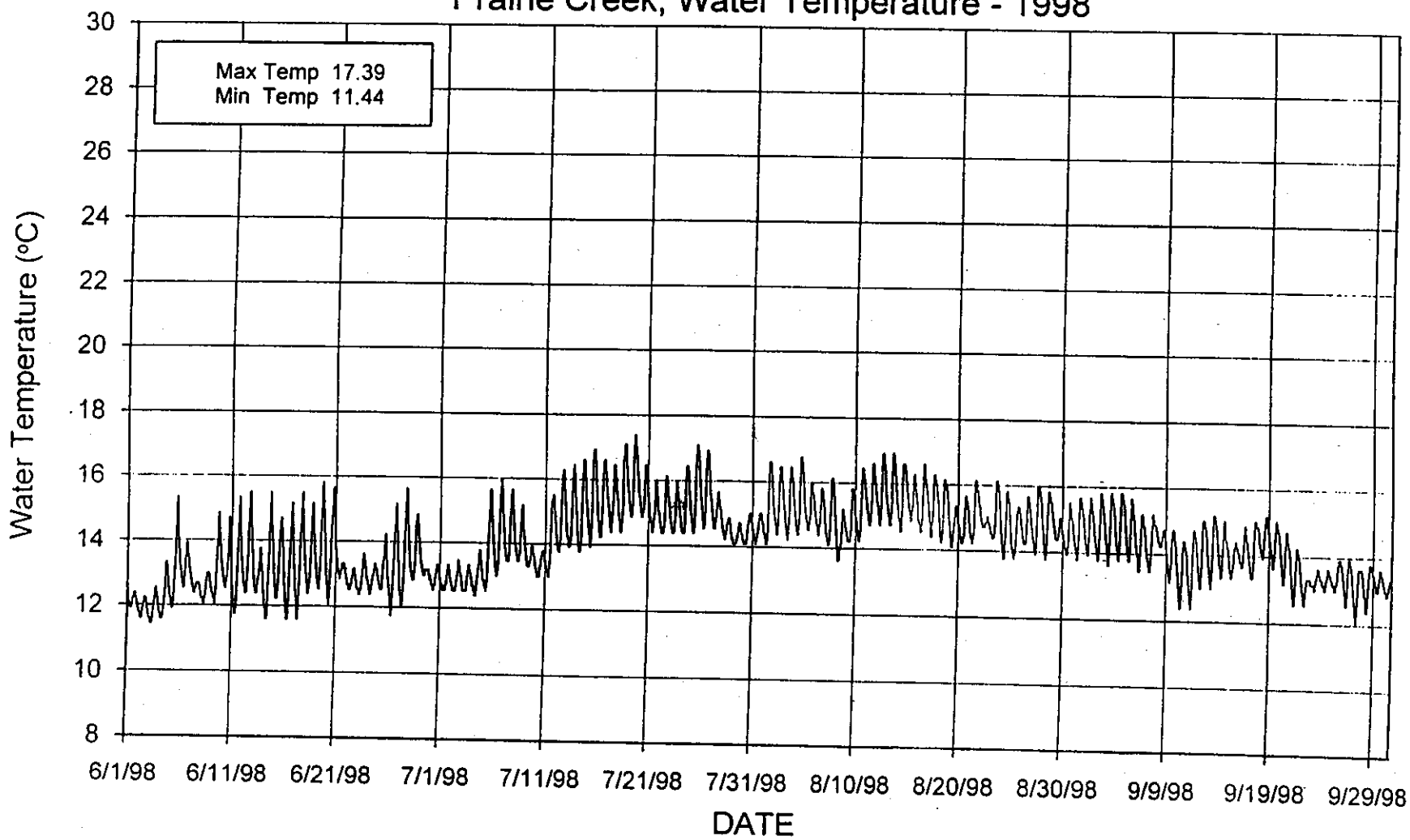
12166

RWC near Minon , Air Temperature - 1998



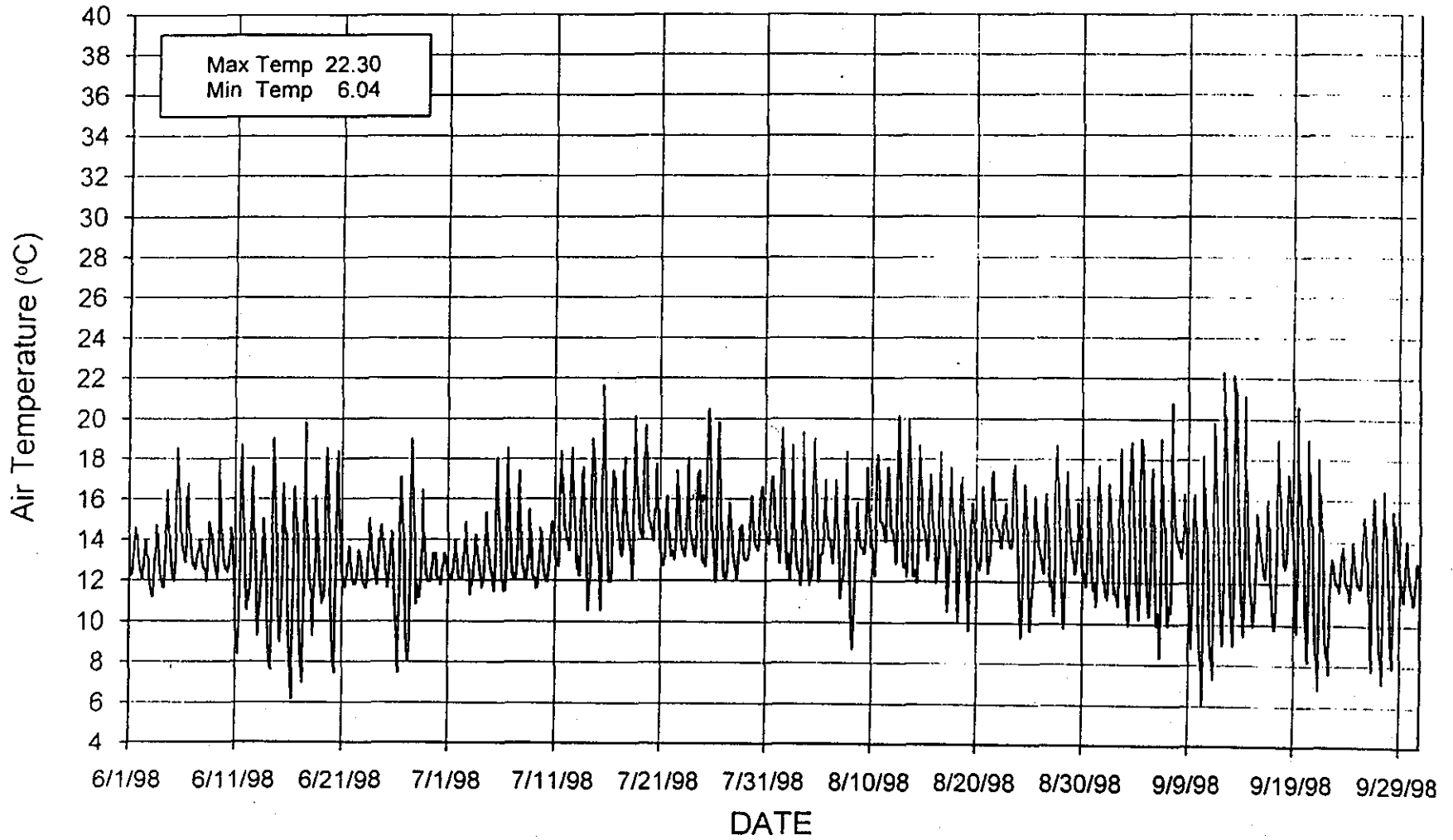
12167

Prairie Creek, Water Temperature - 1998



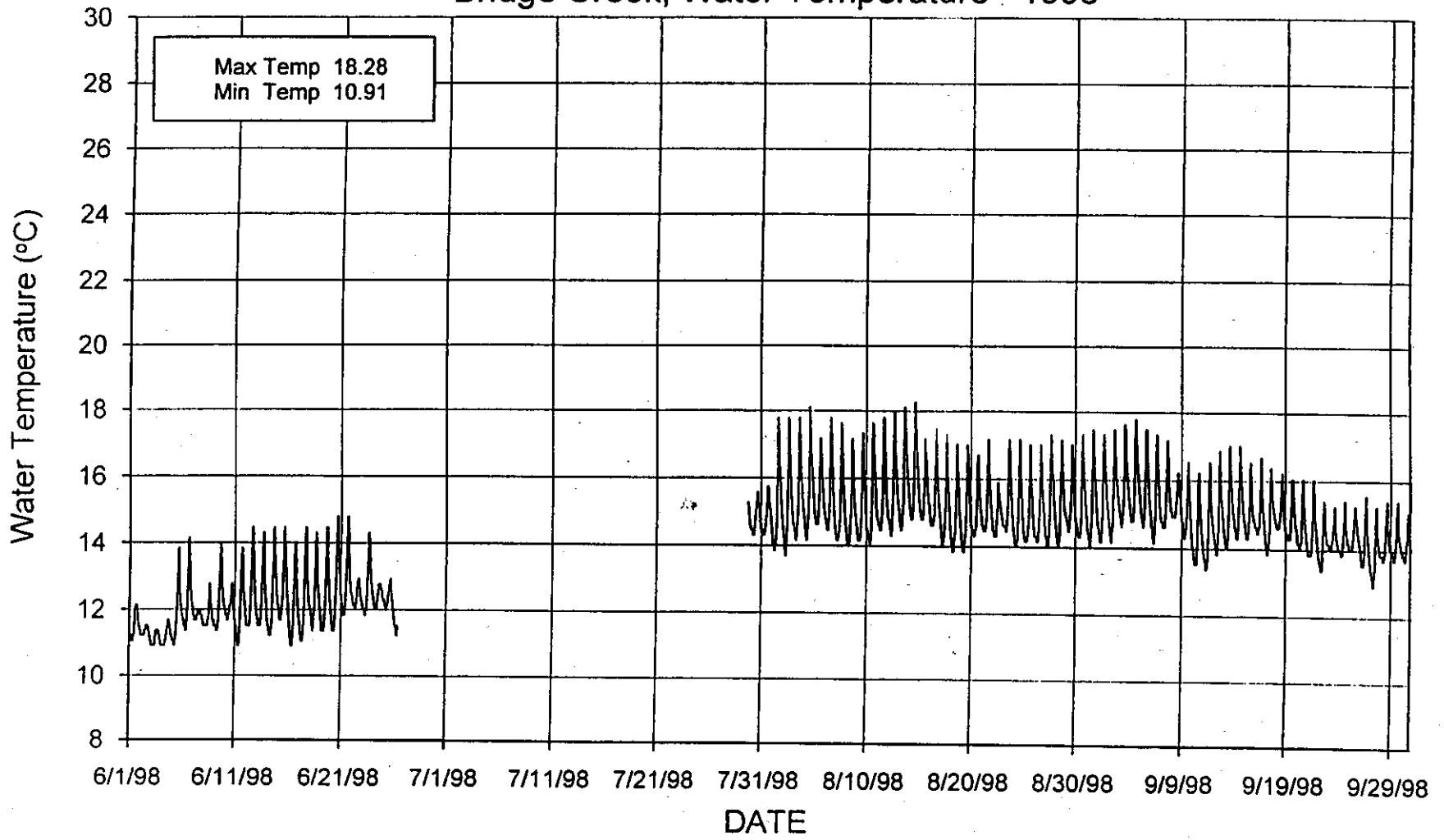
12168

Prairie Creek, Air Temperature - 1998



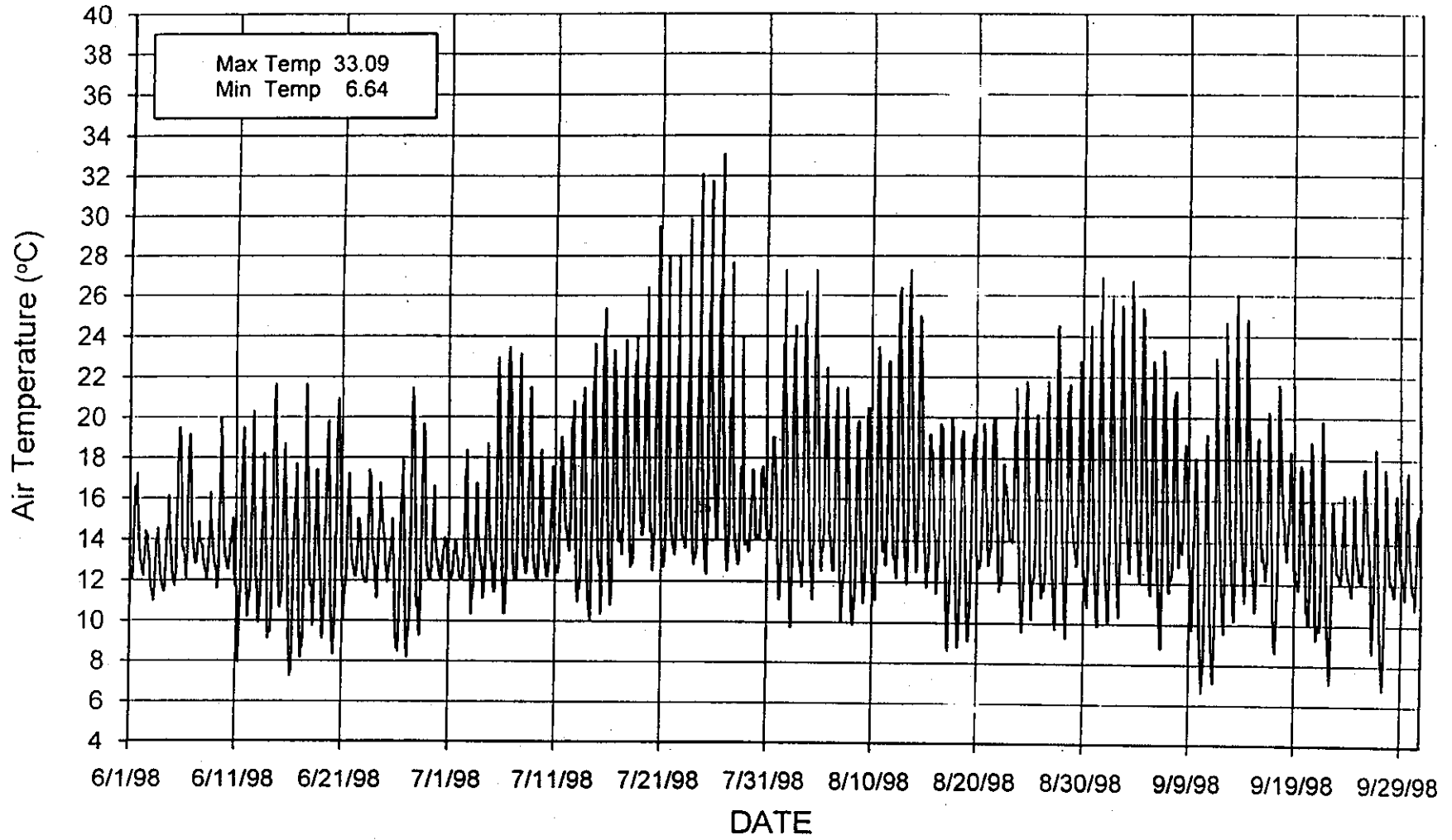
12169

Bridge Creek, Water Temperature - 1998



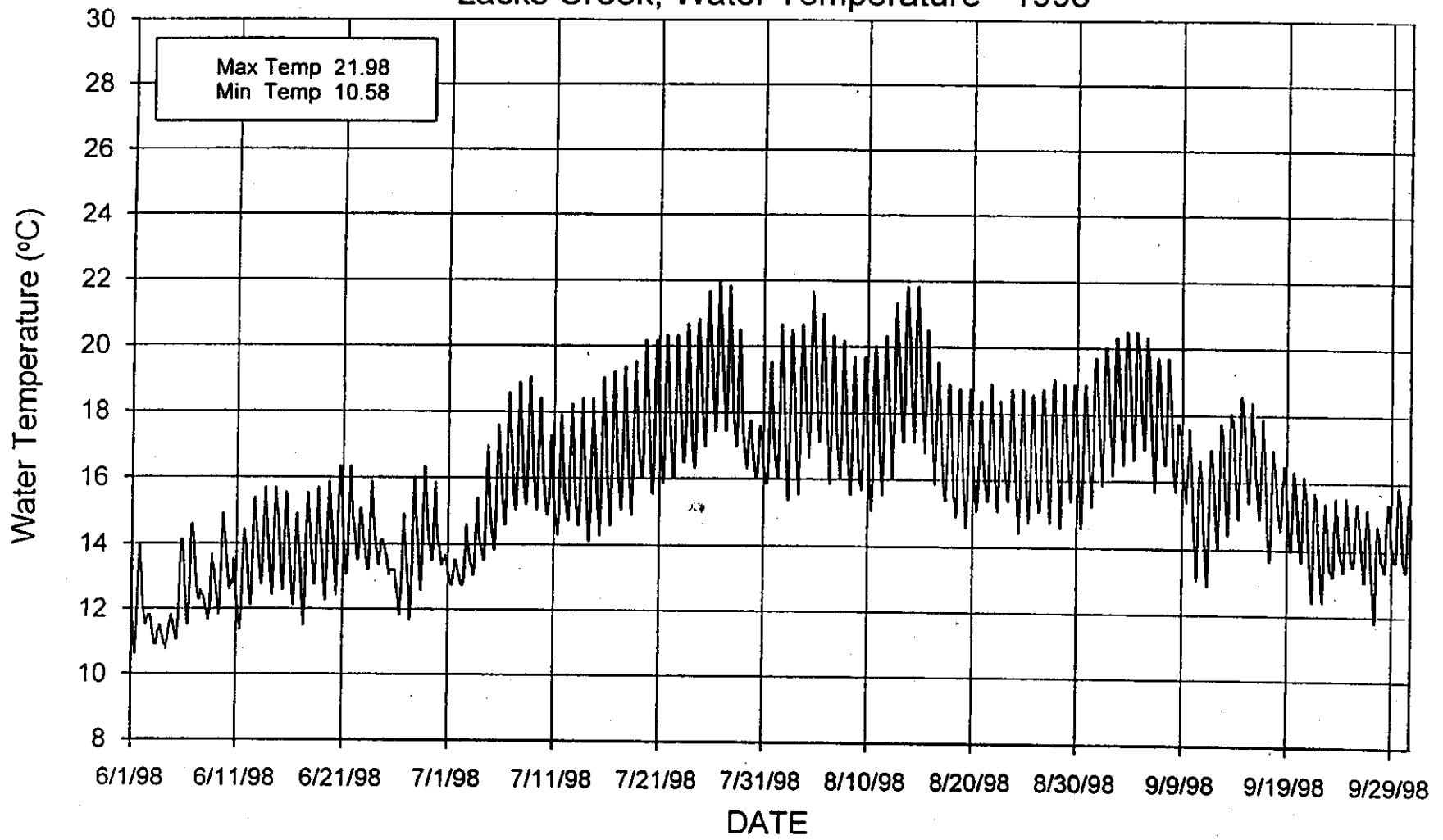
12170

Bridge Creek, Air Temperature - 1998



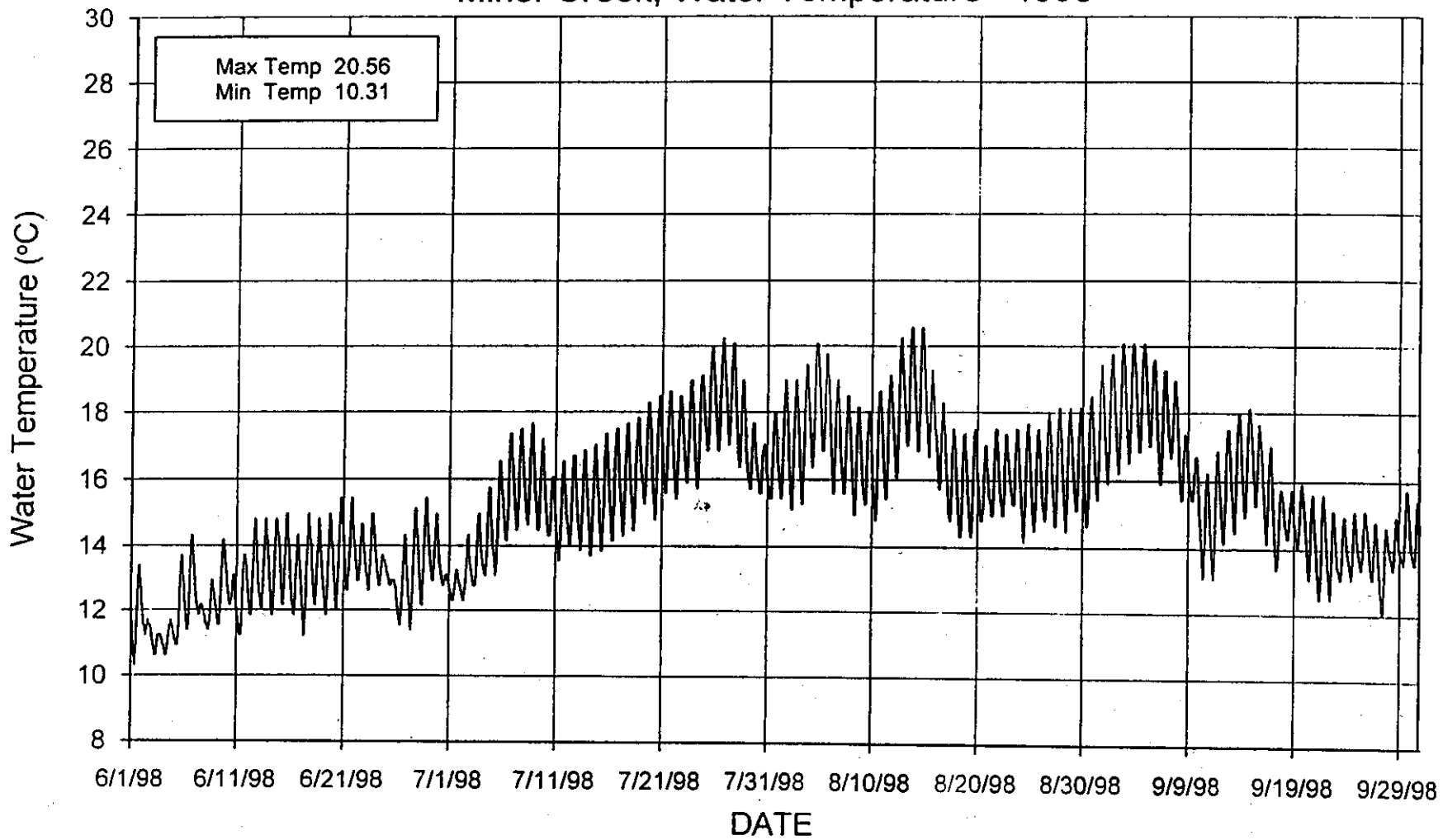
12171

Lacks Creek, Water Temperature - 1998



12172

Minor Creek, Water Temperature - 1998



12173

Appendix B

Redwood Creek Stream Temperature Data Management and Filename Conventions

DATA MANAGEMENT:

Digital copies of stream temperature data for mainstem and tributary stations are stored on the Arcata network drive (FA1) in the following subdirectory:

Q:\data\users\geo\geomorph\stream temp

Temperature data is also organized/stored by "YEAR" (ex. \1998Data). These subdirectories contain all the different file formats: Onset database files (*.dft), Onset export data files (*.txt) and final Excel data.

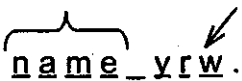
Final mainstem and tributary temperature data (excel files) are stored in the following subdirectories:

Subdirectory	Station Location	Years of Data
Mainstem Stations:		
Q:\data...\RWC-Estuary	Redwood Creek Estuary	1997
Q:\data...\RWC-Lower	Lower Redwood Creek near Redwood Creek Trailhead	1997*
Q:\data...\RWC-TTC	Redwood Creek upstream of Tall Trees Grove (near Otter Crossing)	1997
Q:\data...\RWCUS-Lacks	Redwood Creek at Redwood Valley upstream of Lacks Creek	1997 & 1998
Q:\data...\RWC-O'Kane	Redwood Creek at O'Kane Gaging Station	1997 & 1998
Q:\data...\RWCUS-Minor	Redwood Creek upstream of Minor Creek	1997 & 1998
Tributary Stations:		
Q:\data...\Bridge Ck.	Bridge Creek	1997
Q:\data...\Prairie Ck @ Wolf	Prairie Creek at Wolf Creek Bridge	1995 -1998
Q:\data...\Lacks Ck	Lacks Creek	1997 & 1998
Q:\data...\Minor Ck	Minor Creek	1997 & 1998

* Fish and Wildlife Branch, RM&S has earlier temperature data.

Redwood Creek Stream Temperature Data (3/17/99)

Naming Convention and locations for Redwood Creek and tributary stream temperature monitoring stations.

station w (water) or a

 name_yrw.

station prefix code:

mainstem stations – first five letters in filename
 tributary stations – first three letters in filename

<i>STREAM TEMPERATURE MONITORING STATIONS</i>			
Station Prefix	Description	Location	
Redwood Creek Mainstem Stations	rwest	Redwood Creek estuary.	At end of RWC levees, located mid-channel.
	rflow	Lower Redwood Creek	Located downstream of Hayes Creek in wide section of channel near the Redwood Creek Trail trailhead
	rwtg	Redwood Creek upstream of Tall Trees Grove (near Otter Crossing)	Redwood Creek upstream of Tom McDonald Creek near Otter Camp. Probe moved around in reach from year to year based on location of LWD.
	rwokn	Redwood Creek at O'Kane gaging station	Located ~ 20 yards upstream of cableway. Tied off on water intake tubes in channel. Air temp recorded at gaging hut.
	rwal	Redwood Creek at Redwood Valley upstream of Lacks Creek	Located ~150 yards upstream of Lacks Creek. Air temp recorded on R-bank ~ 6 ft off ground in riparian zone.
	rwmn	Redwood Creek upstream of Minon Creek	Located 100 yds upstream of summer road crossing near Minon Ck. Air temp on left bank.
Tributary Stations	prw	Prairie Creek at Wolf Creek Bridge	Located about 150 ft upstream of the Wolf Creek Bridge.
	prs	Prairie Creek at Streeflow Creek	Located on Prairie Ck above Streeflow Ck behind house.
	bri	Bridge Creek	Located upstream of log jam on left bank.
	lac	Lacks Creek	Located at gaging station downstream of bridge on Lacks Ck.
	min	Minor Creek	Located about 40 yds upstream of bridge on Minor Creek on the right bank.

