STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

SHASTA/KLAMATH RIVERS WATER QUALITY STUDY

FEBRUARY 1986

FOREWORD

The Klamath River, originating in the south central portion of Oregon, flows southwesterly through five Northern California counties and terminates in the Pacific Ocean some 20 miles south of Crescent City. The river produces over 16 percent of the combined flow of all water-producing areas in California. This vast source of water is now protected from further development under the California Wild and Scenic Rivers Act of 1970.

The river and its tributaries are a vital source of water to Northern California. One of the most important uses of these waters downstream of Iron Gate Dam, although nonconsumptive, is the excellent habitat they provide for anadromous salmon and steelhead fisheries. The Shasta River system, tributary to the Klamath River, is used extensively and constitutes about 90 percent of the irrigation water supply in Shasta Valley. It is also used as a migration route for salmon and steelhead and provides spawning habitat for these fish.

The quality of these two rivers has been monitored at several stations for more than 20 years and resulting data show a great variation. Complaints have been received about excessive foaming, water discoloration, overabundance of algae, and unsightliness. This study was undertaken to investigate the water quality and its variation, from Iron Gate Dam to the gauging station, "Klamath River near Seiad Valley".

The information developed in this study is essential not only in managing this water resource to maximize its beneficial uses, but also to plan for future conjunctive ground and surface water uses. It should also be useful to help develop more definitive objectives for water quality control plans.

This report includes a brief overview of the study area, its geology, climate, development, and water supply. It describes the hydrologic conditions that prevail in the study area, summarizes water quality data, and sets forth findings and conclusions.

Wayne S. Gentry

Wayne S. Gentry, Chief
Northern District

CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 X °C)+32	(°F−32)/1.8

State of California
GEORGE DEUKMEJIAN, Governor

The Resources Agency
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SUMMARY

Findings

Significant findings of this investigation are:

1. The average annual flow in the Klamath River below Iron Gate Dam is about 1,600,000 acre-feet, while downstream at Seiad Valley it is 3,000,000 acre-feet.

2. Approximately 50 percent of the average annual flow in the river at Seiad Valley originates from sources upstream of the study area.

3. Although the runoff in the Klamath River was only 50 percent of normal during 1981, the average runoff during the 3-year study period (1981-1983) was about 125 percent of normal.

4. The Shasta River with 11 percent of the Klamath River drainage area above Seiad Valley contributes only about 5 percent of the flow in the Klamath River at that point.

5. Surface water resources in the Klamath River downstream of Iron Gate Dam have limited use; however, surface waters of the Shasta River are extensively developed and used.

6. Distribution and use of several tributary waters to the Klamath River are currently under the jurisdiction of court decrees.

7. Electrical conductivity values rarely exceed 300 µmohs/cm in the Klamath River and 700 µmohs/cm in the Shasta River.

8. The waters of the Klamath and its tributaries are strongly bicarbonate in character and generally contain low concentrations of chlorides and sulfates.

9. Average boron concentrations ranges from 0.1 mg/L in the Klamath, to 0.5 mg/L in the Shasta River.

10. The pH of Klamath River waters usually ranges from 7.0 to 9.0, with the highest values occurring in the summer during periods of high biological productivity.

11. Nutrient concentrations found in the Klamath and Shasta Rivers are generally higher than those found in most other Northern California waters.

12. Dissolved oxygen levels in the Klamath River seldom drop below 8 mg/L; however, the summer levels have often dropped to near 6 mg/L and in the Shasta River below 5 mg/L.

13. Diel DO fluctuations of 3 mg/L in the Klamath and 5 mg/L in the Shasta River, common during the summer months, are indicative of a productive river system.

14. Seasonal and diel temperature changes are prominent in the Klamath River. Temperatures range from winter lows near 1° C to summer highs near 27° C, while diel variations frequently exceed 5° C during the summer.

15. During the summer months, the Klamath River usually looks turbid; however, this condition is the result of organic coloring rather than suspended matter.

16. The nutrient balance, although of limited accuracy, does indicate that large amounts of nitrogen and phosphorus, primarily from upstream sources, pass through the river system each year.

17. Benthic macroinvertebrate populations are characteristic of rivers with moderate to high levels of biologic productivity.

18. The frequent occurrence and abundance of scraper and collector organisms indicate high levels of primary productivity.

19. Periphyton growths have created nuisance conditions in reaches of both the Klamath and Shasta Rivers.

Conclusions

This investigation has resulted in the following conclusions.

1. As the waters of the Klamath River are extensively developed upstream of Iron Gate Dam, and with limited additional development expected in the study reach, future flow patterns will probably change little and will continue to vary with the annual precipitation and water supply. Increased ground water development, however, can be expected to reduce the flows in the Shasta River.

2. The magnitude of the water quality parameters found in the Klamath River are greatly influenced by sources upstream of the study area.

3. Although there is large seasonal variation in the quality of Klamath River waters, their mineral quality is usually good to excellent.

4. Nutrient levels in the Klamath River are sufficient to support high to excessive productivity. When impounded in reservoirs, such as Iron Gate Reservoir, algal blooms will develop and nuisance conditions can be expected.

5. As the inflow of nutrients to the Shasta and Klamath Rivers is expected to remain high, periphyton will continue to be present at nuisance levels during some seasons at various locations in these systems.

6. While dissolved oxygen concentrations in the Klamath River are usually near saturation, they have at times been depressed well below saturation at some stations in the Shasta River during the summer months, producing stress that has probably contributed to fish kills and damaged ecosystems.

7. Seasonal and diel temperature changes are large and are an additional stress on aquatic organisms.

8. Any water resource management plan involving the Klamath River system should recognize the natural variability of quality and set realistic objectives that will protect this valuable water resource. Consideration should be given to the large seasonal and diel changes that occur in flow, temperature, and dissolved oxygen.

INTRODUCTION

This study was undertaken to expand our knowledge of the quality of the Shasta River and the Klamath River in the reach between Iron Gate Dam and Hamburg so that these valuable water resources can be properly managed and protected. The water quality of the Shasta River has been monitored near its mouth for 26 years, as has the Klamath River at Hamburg Reservoir site and near Seiad Valley. The Klamath River below Iron Gate Reservoir has been monitored for 23 years. The resultant data have provided a valuable basis for planning this study and relating study period results to long-term conditions.

Although the monitoring records indicate that the Shasta and Klamath River waters are good to excellent in mineral quality, problems related to water temperature, high levels of biological productivity, and aesthetics are apparent.

Scope

This investigation began with a review of historic water quality data and previous reports on the Klamath and Shasta Rivers. The review indicated that water quality problems related to high nutrient content and associated excessive biologic activity were prominent in the Klamath River downstream from Iron Gate Reservoir and in portions of the Shasta River.

The field investigation started in the summer of 1981 and continued through the spring of 1983. Five water quality sampling surveys were conducted during the study. Samples were collected and water quality parameters measured during day and night periods to record diel quality variations during these surveys. The monitoring of water quality was also continued during this investigation at the stations with long-term records.

To provide data that would show nutrient distribution throughout the system and indicate major source areas, concentrations of nitrogen and phosphorus were measured seasonally at a network of sampling stations. In addition to these macronutrients, measurements of the more common chemical and physical parameters were made frequently and selected samples were analyzed for trace metals. Benthic invertebrate samples were also collected at selected stations.

This report includes summaries of both historic and new data developed during this investigation. Evaluations of the hydrologic conditions and water quality characteristics of the study area rivers are presented. Estimates of nitrogen and phosphorus movement through these rivers are presented. The report contains findings and conclusions as well as descriptions of the investigation and methods used.

Area of Investigation

The reach of the Klamath River in this study extends from below Iron Gate Dam near Hornbrook downstream to Hamburg (Plate I). The river flows westerly some 50 miles through Siskiyou County and is paralleled by State Highway 96. Two major stream systems tributary to the Klamath River in this reach are the Shasta and Scott Rivers. The headwaters of the Shasta River are on the northwestern slopes of Mt. Shasta and adjacent mountain ranges near Weed, and from there the river flows northerly to its confluence with the Klamath River, about ten miles north of Yreka. The Scott River originates along the eastern slopes of the Salmon Mountains and flows northerly to its confluence with the Klamath River near Hamburg.

Geology

The area of investigation lies within two geomorphic provinces. The Cascade Range borders Shasta Valley on the east, while the Klamath Mountains border it on the west. The Klamath Mountains province includes the entire study area west of the Cascade Range. The Cascade Range is characterized by rugged topography and chains of volcanic cones with bedrocks ranging in age from pre-upper Cretaceous to Recent, and consist of thick layers of sandstone, graywacke, shales, and basalt. These formations in the eastern side of Shasta Valley are overlain by alluvium composed of sand, gravel, and clays that were deposited by streams. Most of these formations and the alluvium deposits are waterbearing. The Klamath Mountains were developed by stream erosion of an uplifted plateau and are transected by the Klamath River. The bedrocks range in age from pre-Silurian to Recent and include schist, greenstone, consolidated sedimentary rocks, and intrusive rocks ranging from granodiorite to serpentine. These formations in Scott Valley are overlain by unconsolidated alluvium consisting of sand, gravel, and clay deposits that generally produce adequate groundwater supplies.

Climate

The geographical extent of the Klamath River Basin results in a wide variety of climatic conditions. As moisture-laden air from the Pacific Ocean moves inland, it crosses the coastal mountain ranges of Northern California and Southern Oregon; as it ascends the western faces of the mountains, much of its moisture condenses and falls as rain or snow, leaving less moisture for the Cascade Range to the east. The mean annual precipitation in the basin is about 32 inches, but varies from over 60 inches annually in the northwest to 10 inches annually in Shasta Valley to the east.

The climate in this region is characterized by dry summers with high daytime temperatures and wet winters with moderate to low temperatures. About 75 percent of the annual precipitation falls between October and March and generally produces an adequate snowpack in the higher mountain ranges. In the Yreka-Montague area, the annual mean temperature is about 52° F. January is the coldest month with a mean temperature of 35° F. July is the warmest month with a mean of about 73° F. Extreme temperatures in the area vary from 112° F to -11° F.

Development

Settlement in the Klamath River Basin began in the early 1850s with the discovery of gold in California. As populations grew, and the readily available gold supply dwindled, settlers realized the vast timber stands, the rich agricultural lands, and the recreation potential were of far greater value. The current economy has grown dependent upon these resources.

Early mining activities required the first extensive use of water, and this resource became increasingly important with the discovery of the fertile valley areas along the Scott and Shasta Rivers, which were adaptable for growing irrigated crops. The first crops of vegetables and fruit were used for local consumption, but as transportation facilities improved, outside markets for hay, beef, and dairy products created an economic change in the agricultural industry. A cattle industry began to flourish and has maintained its importance in the region, with the major crops consisting of alfalfa, grain, and meadow pasture.

Production of forest products is of major importance to the economy of the area and played an important role in its development. Most of the population centers throughout the basin developed in conjunction with sawmills. Timber harvested is predominantly pine, fir, and cedar, which are processed locally, and includes the manufacture of plywood and hardboard. Also, mining of non-metal minerals, such as sand and gravel, has contributed to the economy.

Recreational activities have increased throughout the region and influenced development and need for services. Abundant wildlife attracts visitors for hunting and fishing, while opportunities for hiking, horseback riding, or enjoying the scenic beauty bring others.

About 23,000 people live within the study area, most of them in small towns and communities scattered throughout the watershed. The largest community is the City of Yreka, which is the Siskiyou County seat. With a population of about 6,000, Yreka is located in the northwestern section of Shasta Valley and is the area's trade center supported by agricultural and wood product-associated activities. Transportation and governmental activities also contribute to the local economy.

Three major highways and a Southern Pacific Railroad line provide access to the Klamath River watershed. Interstate 5 serves as the main north-south traffic corridor; U. S. 97 provides access from the northeast and State Route 96 from the west. The railroad bisects Shasta Valley and operates a spur serving Yreka. The roads not only provide avenues for movement of products to outside markets, but also bring tourists and recreationists to the region.

Water Supply

The mean annual flow of the Klamath River near Iron Gate is about 1,585,000 acre-feet, while downstream near Seiad Valley it is about 2,951,000 acre-feet. The large increase is attributed to the two major tributary drainages of the Shasta and Scott Rivers and several minor drainage basins.

Most of the streamflow occurs from December through April, while water demands are greatest from May through September. In the populated valleys, with their semi-arid climate, shortages of water in mid-summer caused problems for early settlers, and numerous reservoirs were built to provide water in the summer and fall.

Even with reservoir storage, competition for the limited surface waters resulted in battles over water rights, which eventually led to water rights defined by court decrees for several tributaries to the Klamath River. In three areas within this drainage, the Department of Water Resources is now responsible for the distribution of water according to court decrees.

Ground water is increasingly used in these basins to supplement limited and extensively used surface water supplies. Since further development of the existing surface water supplies is restricted, future requirements will likely be met by additional ground water use.

Waste Discharge

Throughout the Klamath River drainage, major point-source waste discharges have been limited primarily to lumber mill operations and domestic wastes from several cities and smaller communities in the Shasta and Scott Valleys. Such wastes are typically high in organics, exert oxygen demands in the receiving waters, and are sources of phosphorus, nitrogen, and other nutrients. They also contain chlorides, sulfates, and dissolved solids, which can add to the levels found in the receiving waters.

Additional domestic wastes are discharged through cesspools or septic tanks and leach fields in several unsewered communities scattered throughout the watershed. As populations have remained low, domestic wastes probably have had little impact on the quality of the Klamath River.

The California Water Quality Control Board, North Coast Region, has adopted waste discharge requirements for the waste disposal from the larger domestic and lumber mill sources, and impacts from these sources have been minimal.

Non-point sources associated with agricultural and timber harvest activities have probably had a greater impact on the Klamath River than point sources. These activities often increase the suspended sediment loads in nearby surface waters, and materials washed into the streams can increase nutrient levels and discolor the receiving waters.

HYDROLOGY

The hydrology of the Upper Klamath and Shasta River Basin is affected mainly by the areal and seasonal distribution of precipitation and the influence of snowmelt runoff. Variations in topography, vegetative cover, and geologic structure further affect the pattern of runoff, as well as the use of surface and ground waters.

Precipitation

The Upper Klamath and Shasta River watershed within the study area has a mean annual precipitation of about 32 inches. Approximately 85 percent of the average annual precipitation occurs between October and April, with the remainder occurring as occasional summer storms.

Precipitation patterns were abnormal during the study period (see Figure 1). During the 1981 water year, precipitation was only about 70 percent of normal. The 1982 water year had a total precipitation of 180 percent of normal with extremely heavy rainfall during November and December. The 1983 water year was 135 percent of normal with exceptionally heavy precipitation during December.

Runoff

Runoff in that reach of the Klamath River within the study area between Iron Gate Reservoir and Hamburg is influenced by two major stream systems, the Shasta and Scott Rivers, and several minor tributaries. A summary of the hydrologic conditions found to exist within this system is shown in Table 1. The average annual runoff values are based on the period of record for each station which vary from 22 years at Klamath River below Iron Gate Dam (1960) to 44 years at Klamath River near Seiad Valley (1912).

Table 1. Hydrologic Characteristics in the Study Area

Station	Ave. Annual Runoff 1,000 AF	Drainage Area Sq. Mi.	Runoff %	Drainage Area %	Ratio Ave. Runoff / Drainage Area
Klamath R. bl. Iron Gate	1,585	4,630	53	67	342
Shasta R. nr. Yreka	136	793	5	11	170
Scott R. at Mouth	615	808	21	12	761
Other tributaries	615	709	21	10	867
Klamath R. nr. Seiad Valley	2,951	6,940	100	100	425

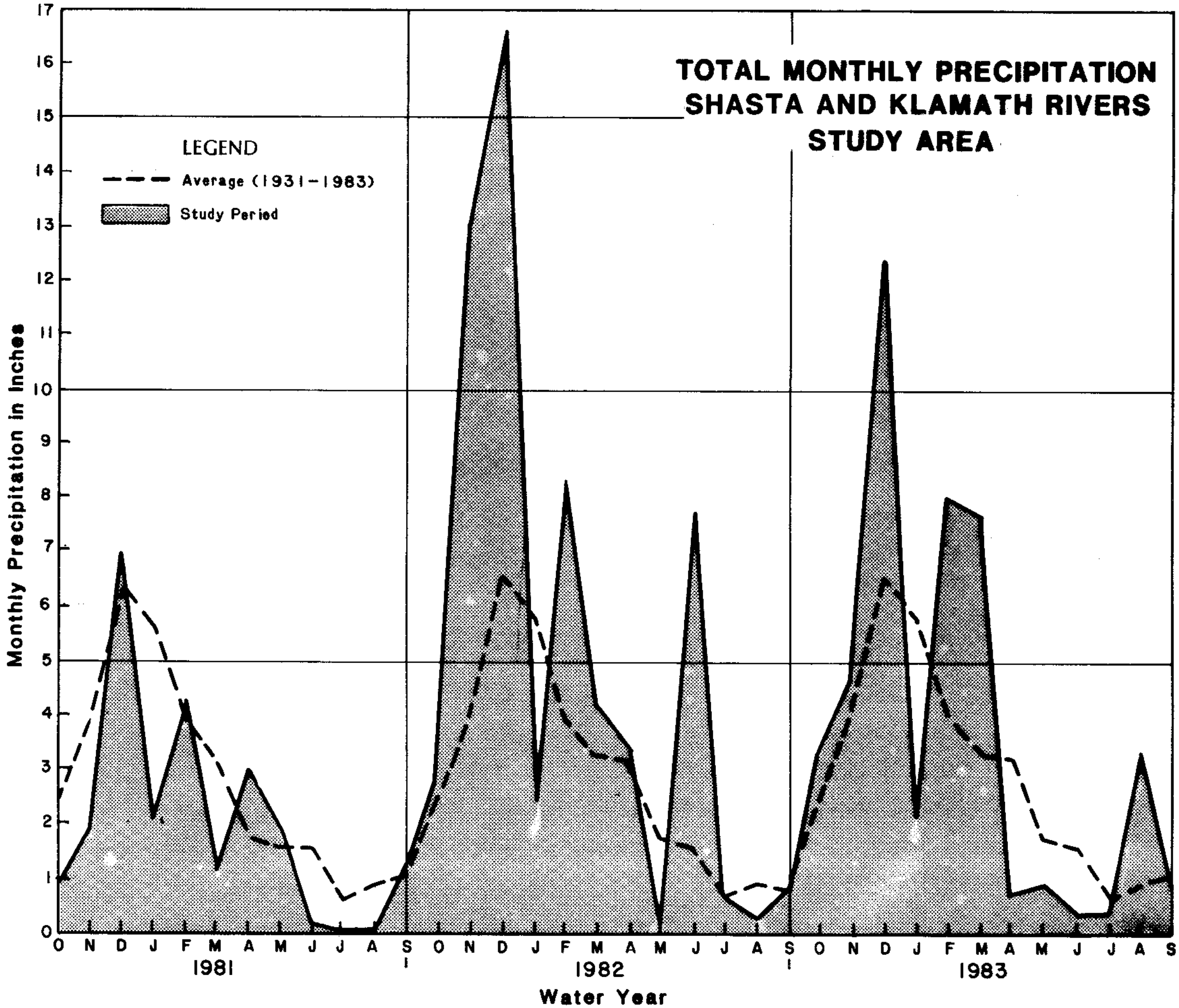

TOTAL MONTHLY PRECIPITATION
SHASTA AND KLAMATH RIVERS
STUDY AREA
LEGEND
Average (1931-1983)
Study Period
Monthly Precipitation in Inches
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1981
1982
1983
Water Year

Figure 1

Significant variances in the runoff characteristics of the stream systems are caused by several contributing factors. Flow in the Klamath River is regulated by several upstream reservoirs, powerplants, and large irrigation systems. The Shasta River, with 11 percent of the total Klamath River drainage area above Seiad Valley, contributes only 5 percent to the Klamath River flow. Shasta River flows, partly regulated by Dwinnell Reservoir[1/], supply numerous irrigation diversions, and are greatly affected by the limited rainfall in the Shasta Valley drainage basin. The high runoff in the Scott River is attributed to the absence of major storage projects in Scott Valley, steeper terrain, and the relatively high winter precipitation in most of the drainage basin.

The flow characteristics of the Klamath River near Seiad Valley are shown on Figure 2 and reflect the influence of snowmelt and surface water storage. Although less than 25 percent of the average annual precipitation falls from March through June, over 40 percent of the average annual runoff occurs during this period. Flows during 1981 were extremely low (48 percent of normal) when the precipitation during the same period was 71 percent of normal. Runoff was about 150 percent in 1982 and 165 percent in 1983, during which time the precipitation was also significantly higher than normal. The same runoff pattern occurred during these years on the upper reaches of the Klamath River as well as the Shasta and Scott Rivers.

River Profile

The Klamath River streambed has a steep gradient above Copco but, as shown in Figure 3, from Copco (F3-1630.00) to Seiad Valley (F3-1430.00) its gradient is greatly reduced. Although the average gradient in this reach of the river is considered moderate at about three feet per thousand feet, the streambed does vary, having steeper to flatter sections. In the steeper reaches of the river, water velocities are typically high, while flows in the flatter reaches are characterized by lower velocities. This is reflected in the stream bottom materials, which are typically sand, gravel, cobbles, and boulders in the steeper reaches and gravels, sand, and silts in the flatter reaches.

Water Use

In the Klamath River drainage upstream of Iron Gate Dam, Klamath River waters are stored and used extensively for power generation and to meet municipal, industrial, and agricultural demands, while downstream uses are limited to small irrigation diversions by individuals and small communities located in the rugged mountainous region along the Klamath River. The two major tributaries, Shasta and Scott Rivers, accommodate the majority of the water use in the Klamath River Basin within California.

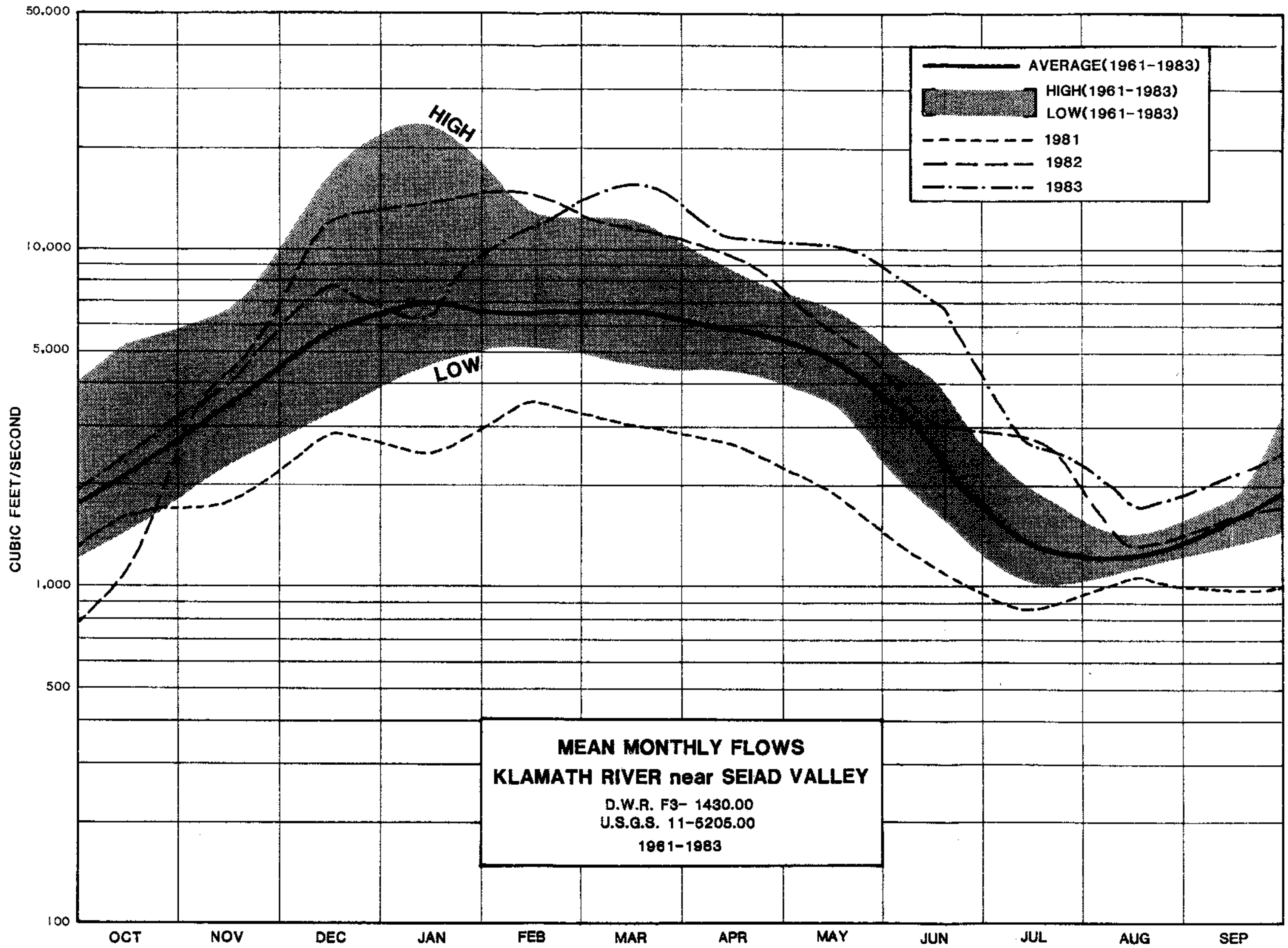
Most of the available water supply in the Shasta River Basin is used for irrigation and stock watering. Approximately 50,000 irrigated acres are devoted to the major crops of meadow pasture, alfalfa, and grain. When irrigation demands are high in the summer, flows in the river are minimal so

1/ Also known as Lake Shastina.

ground waters are used as a supplemental supply. Dwinnell Reservoir, the largest diversion facility, stores water for downstream irrigation releases as well as the municipal water supply for the community of Montague.

The Scott River and its tributaries are also used extensively for stock watering and irrigation. Some 30,000 acres of permanent pasture and alfalfa are currently under irrigation in Scott Valley. Ground water is utilized during the irrigation season to supplement the surface water supplies.

Figure 2



50,000
10,000
5,000
1,000
500
100
CUBIC FEET/SECOND
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
HIGH
LOW
AVERAGE(1961-1983)
HIGH(1961-1983)
LOW(1961-1983)
1981
1982
1983
MEAN MONTHLY FLOWS
KLAMATH RIVER near SEIAD VALLEY
D.W.R. F3- 1430.00
U.S.G.S. 11-5205.00
1961-1983

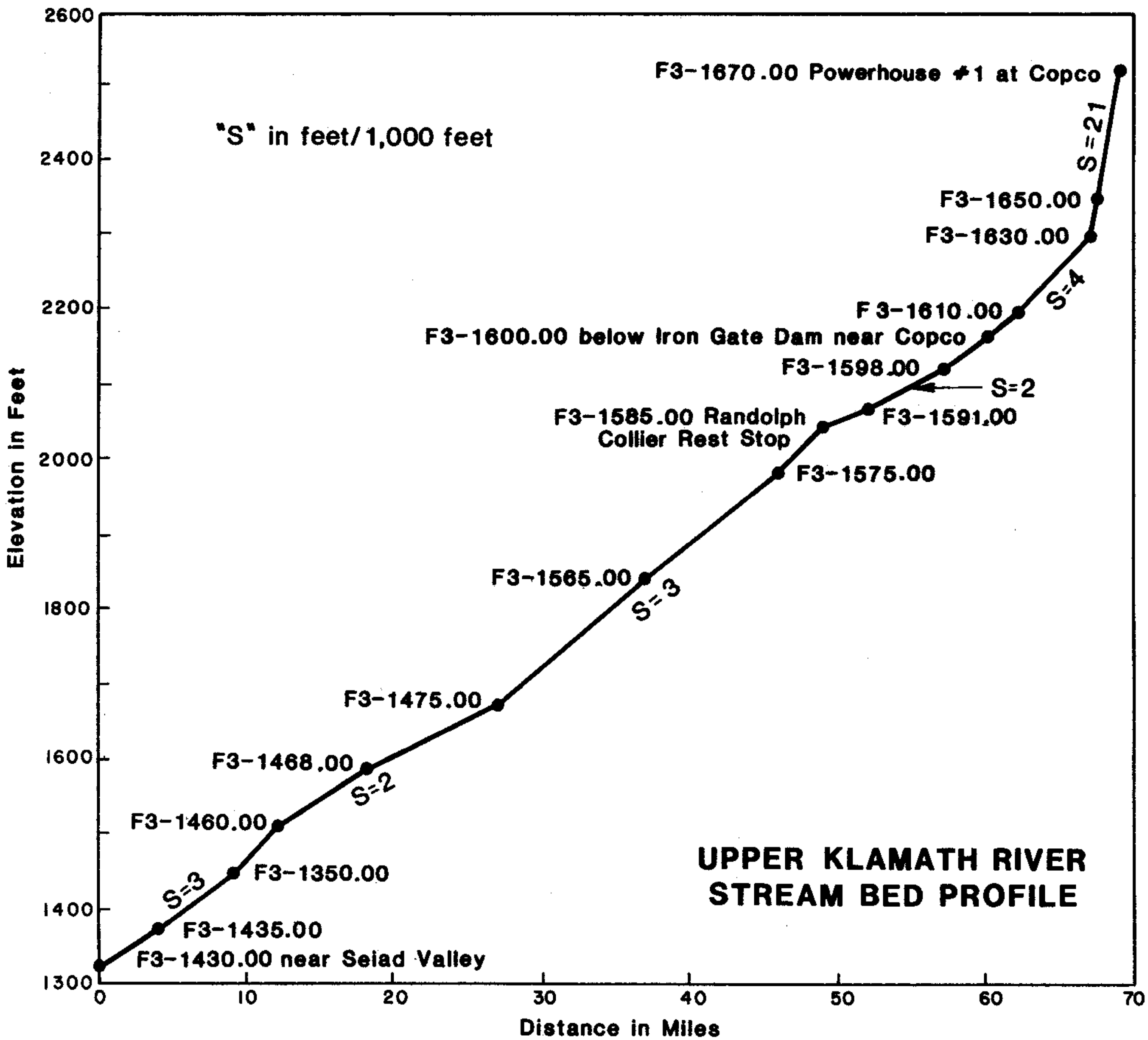

UPPER KLAMATH RIVER
STREAM BED PROFILE
"S" in feet/1,000 feet
Elevation in Feet
Distance in Miles
2600
2400
2200
2000
1800
1600
1400
1300
0
10
20
30
40
50
60
70
F3-1670.00 Powerhouse #1 at Copco
S=21
F3-1650.00
F3-1630.00
S=4
F 3-1610.00
F3-1600.00 below Iron Gate Dam near Copco
F3-1598.00
S=2
F3-1591.00
F3-1585.00 Randolph
Collier Rest Stop
F3-1575.00
F3-1565.00
S=3
F3-1475.00
F3-1468.00
S=2
F3-1460.00
F3-1350.00
S=3
F3-1435.00
F3-1430.00 near Seiad Valley

Figure 3

WATER QUALITY

To supplement historic data and help determine the quality of the Shasta River and Klamath River water in the reach between Iron Gate Dam and Hamburg, sampling surveys were conducted from the summer of 1981 through the spring of 1983. The 13 stations shown as study stations in Plate 1 were sampled periodically to determine seasonal and diel variations. Several supplemental stations where historic data are available or which were sampled during the study are also shown in Plate 1. Measurements were made to determine the chemical, physical, and biological characteristics of this important water resource. The following sections present information on the water quality measurements, sampling procedures, and analytical methods.

Water Quality Parameters

The suitability of water for beneficial use is determined by its quality, which can be divided into three categories: chemical, physical, and biological. Historically, chemical and physical characteristics have been of primary concern, but increased emphasis on environmental concerns has promoted greater interest in biological quality, which is more costly and difficult to determine.

Chemical

Precipitation, as it reaches the earth, is an excellent solvent. It contains dissolved gases, such as carbon dioxide and oxygen, but normally contains few dissolved solids. As water passes through the hydrologic cycle, either on the surface or through the ground, it dissolves minerals from the materials it contacts. The amount and type of minerals dissolved reflect the composition of these materials and the hydrologic conditions governing the rate of water movement. Often, more salts and pollutants are added by sewage, industrial wastes, and irrigation return flows. These dissolved substances can determine water's suitability for various beneficial uses.

An indication of the overall chemical quality can be obtained by determining and summing the concentrations of individual ions in a water. A measure of the total dissolved solids (TDS) can also be obtained by filtering a water sample, drying it, and weighing the residue. A third technique measures the electrical conductivity (EC) of the water sample, as that value can be related to the ionic content of the water. Ions commonly found in natural waters and most often looked for in laboratory analysis include calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, and boron. Each of these is important to one or more beneficial uses.

Another important chemical factor is pH, which is a measure of the water's acidity (hydrogen ion content). The pH scale ranges from 0 to 14, with a value of 7 being neutral. Most natural waters have a pH in the 6.5 to 8.5 range, while an acid, such as lemon juice, has a pH of about 2, and household ammonia has a pH of about 12.

Alkalinity is a measure of a water's ability to withstand changes in pH and is due to the carbon dioxide, bicarbonate, and carbonate equilibrium in the water. This buffering is important because it dampens pH fluctuations that might occur due to waste discharges or intense algal growth. It also serves as a source of inorganic carbon for plant growth.

Water contains varying amounts of certain elements which are essential to biologic productivity and are referred to as nutrients. Such metals as iron, copper, molybdenum, etc., are needed in trace amounts and are called micronutrients. Carbon, nitrogen, and phosphorus are needed in larger quantities and are referred to as macronutrients. The two elements most often considered limiting to primary productivity in aquatic systems (if there were more of that element present there would be more growth) are nitrogen and phosphorus.

Nitrogen is found in water in the form of nitrate, nitrite, and ammonium ions, ammonia gas, or as part of nitrogen-bearing organic compounds. Most aquatic plants can use nitrate, ammonia, and perhaps simple organic nitrogen compounds.

Phosphorus is found in water as orthophosphates, polyphosphates, and organic phosphorus. Most forms are converted in nature to orthophosphates by bacterial action or hydrolysis, and this is the form used by organisms. Both orthophosphate and total phosphorus levels are often included in nutrient determinations.

Dissolved oxygen (DO) is one of the most important components measured in water, as it is essential to aquatic plant and animal life. The amount of oxygen that dissolves in water is primarily a function of water temperature, air pressure (altitude), and dissolved mineral concentration. Natural aeration and oxygen from plant photosynthesis are the two most important sources of oxygen in surface waters. Dissolved oxygen is used in respiration by aquatic organisms and by biochemical demands created by decomposing organic materials. To maintain a healthy aquatic environment, DO levels should be near saturation for coldwater systems and above 5 milligrams per litre (mg/L) for warmwater systems.

Physical

Temperature and turbidity are important physical characteristics of water. Temperature greatly influences the suitability of a water for its beneficial use. The metabolisms of aquatic organisms respond to the temperature of their environment. (As a general rule, metabolic activity will approximately double with each 10° C increase in temperature, to the limit of the organism's range of tolerance.) Temperature also affects the solubility of gases and other substances in water, water density, and its viscosity. These factors are of great importance in aquatic environments.

Turbidity is the second important physical water quality characteristic often measured. Turbidity, or cloudiness, of water is caused by suspended matter, organic and inorganic, which obstructs the passage of light through the water. Highly turbid waters are unsightly and may pose a hazard for swimmers or other recreationists. As light penetration is restricted in turbid waters, turbidity can reduce biologic productivity and limit types of plants that can exist.

Another measure of suspended matter in water is the suspended solid determination. It usually correlates with turbidity but is a better measure of the sediment being transported by a stream.

Biological

Although observations were made of many organisms during this investigation, only benthic macroinvertebrates were sampled and evaluated. The numbers and assemblage of benthic organisms are excellent indicators of the general health of a stream--its productivity and its water quality. Unlike fish, which can escape adverse conditions through their mobility, benthic organisms cannot, making bottom life forms especially suited for studies aimed at determining long-term aquatic conditions.

Sampling and Analytical Methods

Water samples were collected during this study from near the center of flow at each station. At low flows, samples were usually collected by wading, while at higher flows, samples were collected from bridges or by sampling from the river bank. Most samples were collected in plastic buckets. Temperature, pH, DO, and EC measurements were usually made at the time of each visit, while water samples were collected for analysis at the Department's laboratory at Bryte.

Temperatures were measured with standard field thermometers whose calibrations had been checked in the laboratory. During some diel surveys, maximum-minimum thermometers were also placed in the river to verify the temperature variations measured during sampling visits.

Field pH was determined by using Hellige comparators with appropriate indicator solution and disk. Laboratory pH's were also run on selected samples with a calibrated glass electrode-type pH meter.

Dissolved oxygen levels were measured at the time of sampling using the modified Winkler technique. Field kits use fixing reagents in powdered form.

Electrical conductivity was measured on portable Beckman solubridges that had been checked on known solutions. Selected samples that were sent to the laboratory also had EC determinations made for quality control and to better define the TDS-EC relationship.

Turbidity samples were measured with a Hach Model 2100A turbidimeter which is a nephelometer-type instrument.

Samples for standard mineral (chemical) analysis were collected in sample-rinsed plastic bottles and transported to the Bryte laboratory for analysis. Table 2 lists the standard methods used at that laboratory.

Trace metal samples were collected in plastic buckets or dipped directly from the river. Special acid-rinsed bottles were used for sampling. Double-distilled nitric acid was added to reduce the pH to 3 and the samples were transported to the laboratory.

Table 2. Analytical Methods for Water Quality Parameters

Parameter	Method
Electrical Conductivity	Beckman Wheatstone Bridge
Total Hardness	EDA - Titrimetric - AWWA
Sodium	Flame Photometric - AWWA
Potassium	Flame Photometric - AWWA
Sulfate	Gravimetric - AWWA
Chloride	Argentometric - AWWA
Boron	Carmine - AWWA
Arsenic	Silver Diethyl - AWWA
Barium	Atomic Absorption Spectrophotometric
Cadmium	Atomic Absorption Spectrophotometric
Chromate	Atomic Absorption Spectrophotometric
Copper	Atomic Absorption Spectrophotometric
Iron	Atomic Absorption Spectrophotometric
Lead	Atomic Absorption Spectrophotometric
Manganese	Atomic Absorption Spectrophotometric
Zinc	Atomic Absorption Spectrophotometric
Mercury	Cold Vapor Atomic Absorption - EPA
Dissolved Nitrate	Brucine - AWWA
Total Ammonia	Distillation and Nesslerization - AWWA
Total Organic Nitrogen	Digestion and Nesslerization - AWWA
Dissolved Phosphate	Stannous Chloride - AWWA
Total Phosphorus	Stannous Chloride, Sulfuric Nitric Acid Digestion - AWWA

Nutrient (nitrogen and phosphorus series) samples were collected in plastic bottles and held in portable ice chests for delivery to the laboratory. When storage was to exceed 48 hours, samples were frozen and stored in a freezer.

Benthic invertebrate samples were collected with hand-held kick screens (9.5 mm mesh) or Surber samplers (0.363 mm mesh). They were preserved in formalin until delivered to the laboratory. Appendix E contains more detailed information on the methods of sampling and preservation.

STUDY RESULTS

Historic information and data were useful in designing the field investigation and providing a means of relating data developed during the abnormally dry years of 1976-77 to normal conditions. Appendixes A through E contain the surface water quality data developed during this study, as well as historic data. These appendices present data from the entire Klamath River drainage from Iron Gate Reservoir downstream to Hamburg. Sampling stations are shown in Plate 1, and data are arranged according to sample station number. Data for each station are arranged chronologically.

Chemical Characteristics

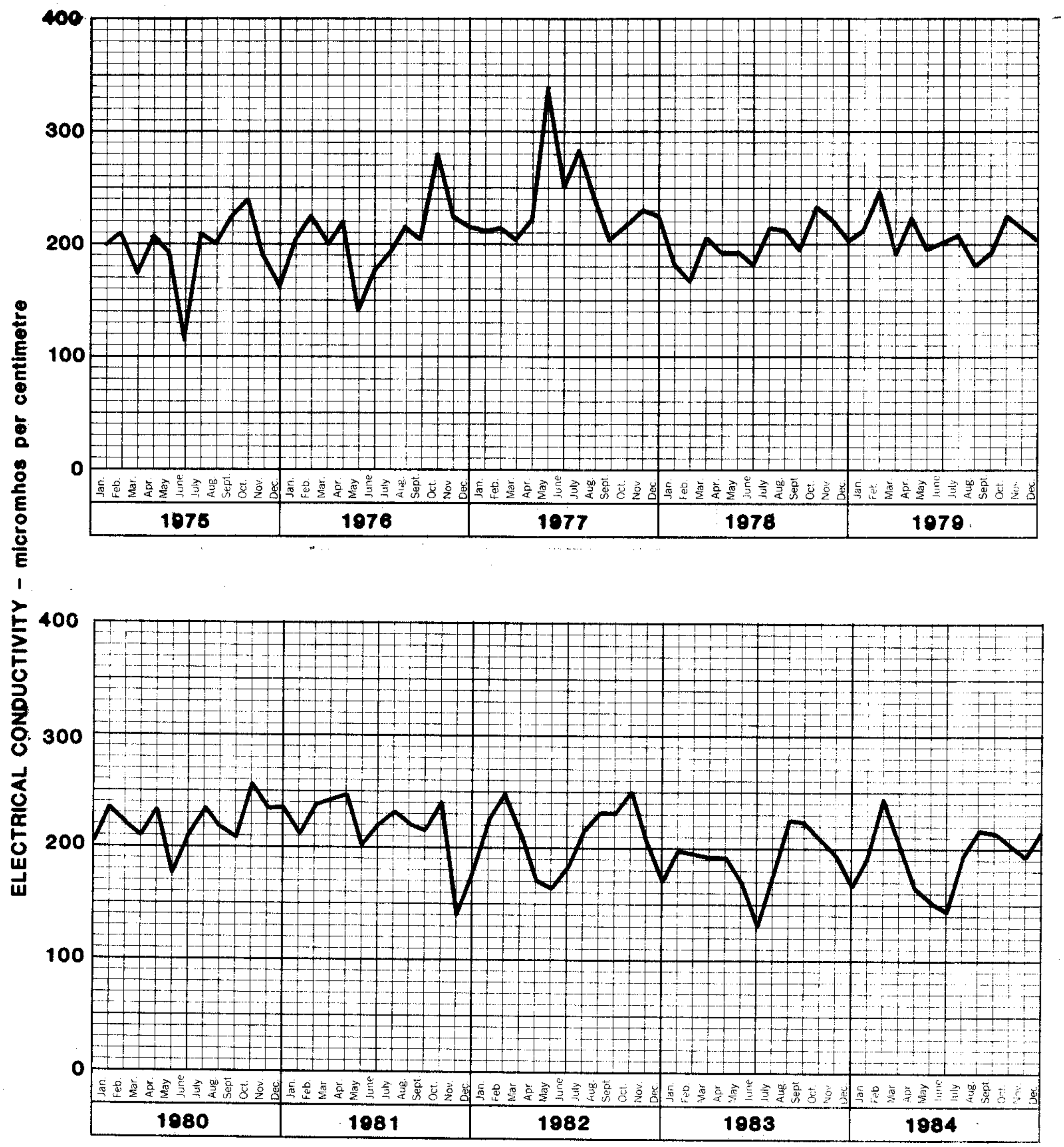
The Klamath River waters above Iron Gate Dam have as their major sources streams that drain some 4,600 square miles from Northern California and Southern Oregon and flow through several lake systems, including the Upper Klamath Lake, Copco Reservoir, and Iron Gate Reservoir. These source streams deliver waters of excellent mineral quality. The EC values range from 100 to 300 micromhos per centimeter (µmhos/cm) with an average of less than 200 µmhos/cm measured below Iron Gate Dam. The complex operations in the upper reaches of the Klamath River involve winter runoff storage, pumpback schemes, periodic waste loadings from developed areas near Klamath Falls, and reservoir releases during periods of high algal productivity. When these delayed or modified waters are released, the downstream impact is offset or changed to the extent that a normal cyclic EC pattern does not develop.

Downstream from Iron Gate Dam, more runoff and agricultural return flows from the Shasta River system join the Klamath River. During summer low-flow conditions, the Shasta River waters, used extensively for irrigation, at times have EC values exceeding 700 µmhos/cm. Although these waters have significantly higher concentrations of dissolved solids, the impact upon the Klamath River is relatively small as the Shasta River contributes only 5 percent of the total annual inflow to the Klamath River.

Below Shasta Valley, tributary inflow adds significantly to the Klamath River flow, particularly through the Scott River. These waters have a mean EC value of 215 µmhos/cm, which is about the same as that of the Klamath River waters and therefore causes little change in the EC of the river.

A small seasonal variation in EC is notable at most Klamath River sampling stations. Figure 4 gives monthly measurements of EC for the Klamath River near Seiad Valley (F3-1430.00) covering the period 1975-84. As shown, EC values normally range from about 150 to 250 µmhos/cm and fluctuate monthly with an irregular pattern of high and low values. The EC pattern is quite variable from year to year, reflecting both the variation in precipitation and the operation of the numerous upstream storage reservoirs. The effect of the drought and reduced runoff conditions on EC in 1976-77 is apparent in Figure 4, as most of the monthly measurements are above 200 with a maximum near 350 µmhos/cm. However, in January 1978, winter runoff dropped the EC of the

Figure 4



ELECTRICAL CONDUCTIVITY in KLAMATH RIVER near SEIAD VALLEY. F3-1430.00

river water at the Seiad Valley station below 200 μmhos/cm. The maximum EC measured at this station seldom exceeded 250 μmhos/cm, which indicates a total dissolved solids content of about 175 mg/L.

In contrast to the Klamath River, the Shasta River has a greater seasonal variation and a more distinct annual pattern of EC values. Figure 5 gives the monthly measurements of EC values for the Shasta River near Yreka (F2-1050.00). As shown, these values normally range from about 400 to 700 μmhos/cm, with annual highs from July to September and lows from November to March. The EC pattern also varies from year to year due to the variation in precipitation and operation of upstream storage reservoirs. The maximum EC measured at this station seldom exceeds 750 μmhos/cm, which indicates a total dissolved solid content of about 525 mg/L.

The Klamath River waters are bicarbonate in character, but generally have no dominant cation. Analyses show that these waters have adjusted sodium adsorption ratios less than 3, which is considered excellent for irrigation use.

Chlorides

Throughout the Klamath River, chloride levels are generally low. Even when flows are low and salt concentrations highest, chlorides have not been measured in excess of 15 mg/L. In the river between Iron Gate Dam and Seiad Valley, chloride concentrations usually range from less than 1 mg/L to about 10 mg/L. The Shasta River has higher chloride levels and range between 10 mg/L and 45 mg/L; the higher levels occuring during the summer months when return flows from irrigation and developed areas make up a high percentage of the river flow. The Scott River and most of the smaller tributaries of the Klamath River have chloride concentrations of less than 10 mg/L.

Sulfates

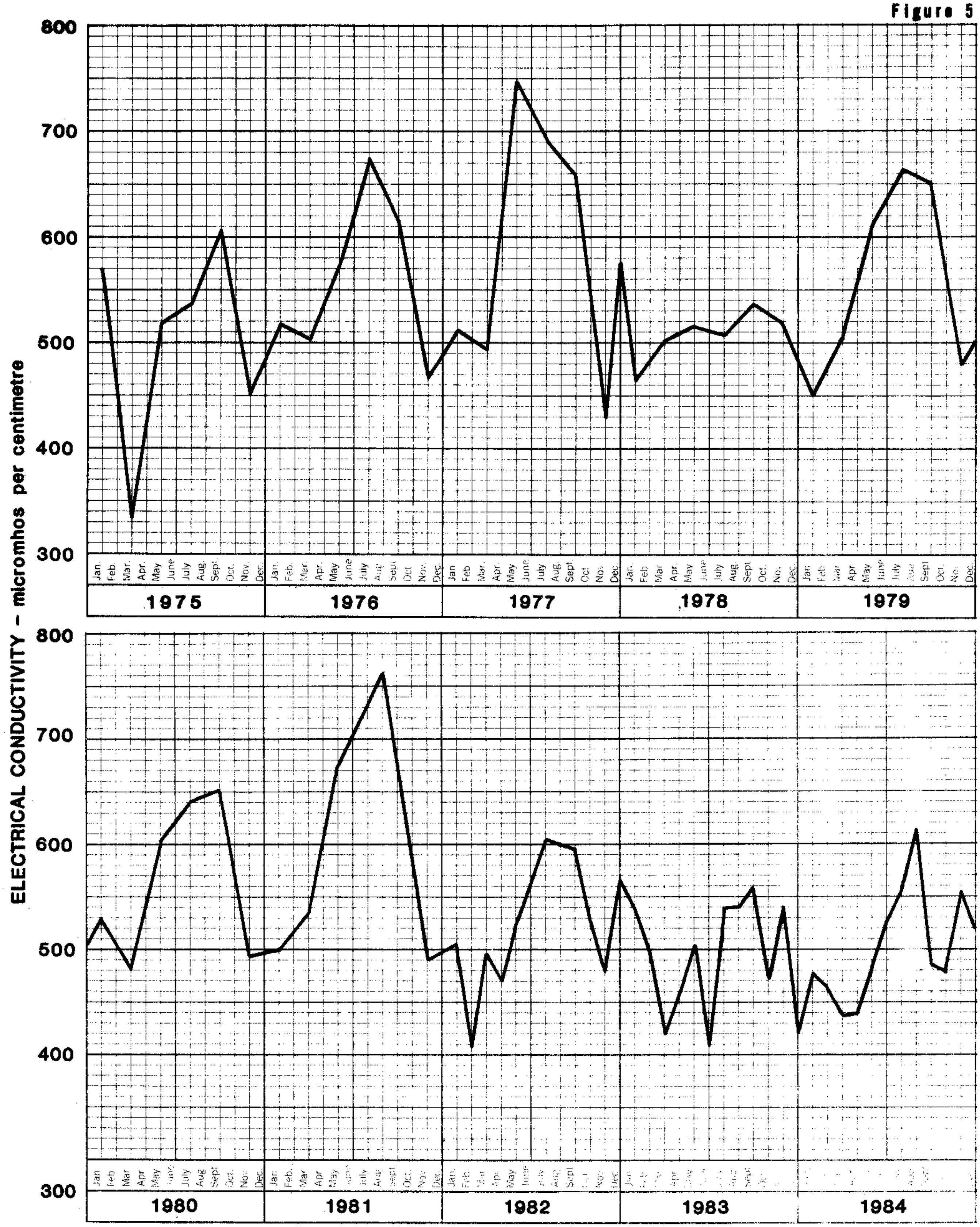
The sulfate ion concentrations in the Klamath River are very similar in pattern to the total dissolved solid and chloride concentrations in that the greatest concentrations are associated with low flows in the river upstream of Iron Gate Dam. In this reach, concentrations frequently exceed 10 mg/L and have been measured as high as 70 mg/L. The downstream tributaries to the Klamath River have sulfate concentrations that are usually less than 25 mg/L.

Boron

The average boron concentration in the Klamath River is 0.1 mg/L with a maximum value found at 0.4 mg/L. Most tributaries have low boron levels; however, the Shasta River has an average concentration of 0.5 mg/L with a maximum of 1.1 mg/L.

pH and Alkalinity

The pH of the Klamath River is quite variable, usually ranging from about 7.0 to 9.0. The highest pH values generally occur during the summer low flow periods, when biological productivity is at maximum levels.



ELECTRICAL CONDUCTIVITY in SHASTA RIVER near YREKA. F2-1050.00

Alkalinity also varies greatly but rarely exceeds 120 mg/L. Alkalinity levels are similar to the EC in seasonal and areal variation. The minimum levels are about 50 mg/L and occur during the winter and spring runoff periods. Although most tributaries to the Klamath River contain waters with low alkalinity, the Shasta River has moderately higher values ranging from about 150 mg/L to slightly less than 400 mg/L.

Nutrients

Determinations of the nutrients, nitrogen, and phosphorus were made from selected samples during the study. Nitrogen was generally present as nitrate, ammonia, and organic compounds (Appendix B). The nitrate levels in the Klamath River ranged from 0.0 to 1.6 mg/L with a median concentration of 0.42 mg/L. These levels are higher than those normally found in the rivers of Northern California; however, most of these nitrates originate in the waters upstream of the study area. The total ammonia plus organic nitrogen concentrations ranged from 0.14 to 1.7 mg/L, having a median of 0.7 mg/L in the Klamath River from below Iron Gate Dam downstream to Seiad Valley. These levels are within the range found in agricultural surface drainage and are higher than the concentrations usually found in Northern California rivers.

The dissolved orthophosphate phosphorus (PO_4) concentrations in the Klamath River below Iron Gate Dam varied from 0.00 to 0.24 mg/L with a median of 0.11 mg/L. The waters downstream near Seiad Valley had concentrations that varied from 0.00 to 0.19 mg/L with a median of 0.08 mg/L. These levels are higher than normally found in most Northern California rivers but similar to that found in agricultural surface drainage. The Shasta River, with the highest concentrations of PO_4, had median values of 0.15 mg/L; however, the downstream effect in the Klamath River is limited due to the relatively small flows of the Shasta River. Total phosphorus concentrations ranged from 0.00 to 0.38 mg/L, with median values of 0.20 mg/L for the river below Iron Gate and 0.11 mg/L downstream near Seiad Valley. These concentrations are also higher than those found in most Northern California rivers.

Dissolved Oxygen

Dissolved oxygen data in Appendix A show that levels in the Klamath River are quite variable, particularly in the spring and summer when photosynthesis adds oxygen to the system and respiration consumes it. Figure 6 shows the seasonal pattern of DO levels in the Klamath River near Seiad Valley (station F3-1430.00) based on monthly daytime measurements covering the period 1958-1983. This annual pattern is typical of other Northern California rivers, having higher oxygen levels in the winter months due to the higher solubility of oxygen in cold water and lower concentrations during the months of June, July, and August, when the water is warmer and biological processes affect the system.

Data collected during diel surveys verified that the richness of the Klamath River results in fairly large fluctuations in DO during the summer months. Diel DO variations have been measured in excess of 3 mg/L at Klamath River at Randolph Collier Rest Stop (station F3-1585.00), as shown on

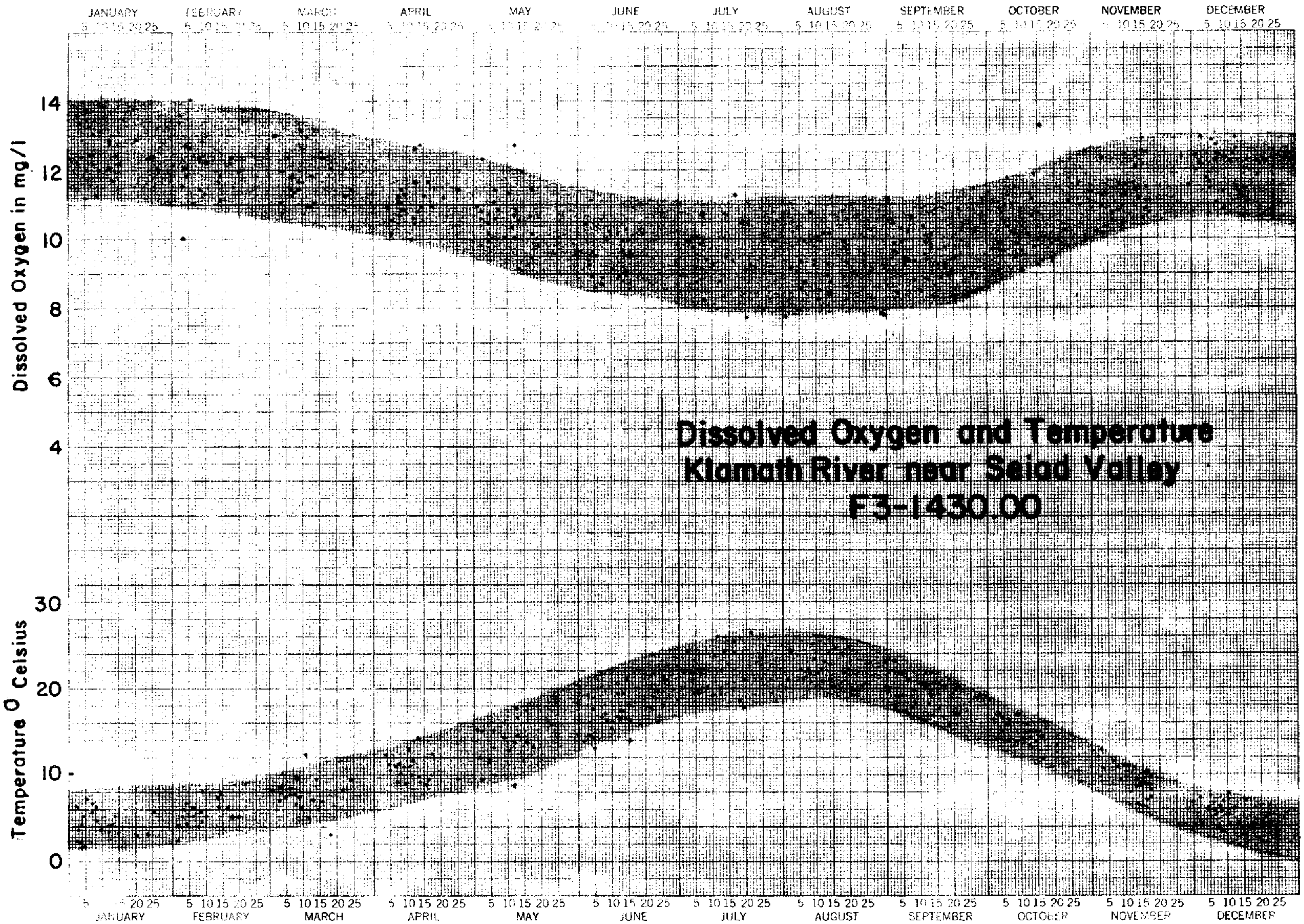

Dissolved Oxygen and Temperature
Klamath River near Seiad Valley
F3-1430.00
Dissolved Oxygen in mg/l
Temperature °Celsius
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

Figure 8

Figure 7. These data show the fluctuations in DO, which are typical of moderately productive water becoming supersaturated during the daylight hours, with oxygen produced during photosynthesis and dropping below saturation due to respiration demands during periods of reduced light. Minimum DO levels generally range between 6 and 7 mg/L along the Klamath River between Iron Gate Dam and Hamburg and are considered tolerable for most fisheries needs.

Diel DO levels in the Shasta River system are shown in Figure 8 and follow patterns typical of highly productive streams. This river system had larger fluctuations of DO levels along with lower minimum values than the Klamath River. Fluctuations as high as 5 mg/L occurred at Shasta River near Grenada (F2-1350.00) and a minimum value of 4.7 mg/L at Shasta River below Dwinnell Reservoir (Lake Shastina) (F2-1399.00). Lake Shastina provides downstream releases to the Shasta River. These reservoir waters are highly productive with frequent algal blooms occurring during the warm summer months. These enriched releases could and probably have significantly reduced the downstream DO levels by creating a high Biochemical Oxygen Demand (BOD) loading caused by the decomposition of the algal mass.

Summer DO values for the Scott River at Mouth (F2-5000.00) are shown in Figure 9 and ranged from 7.6 to 9.5 mg/L. Saturation values usually remained near 100 percent, indicating a lower level of biological productivity.

Physical Characteristics

Temperature and turbidity are important characteristics that influence the Klamath River's suitability for beneficial use. Each of these parameters shows significant annual variations.

Temperature

Within the Klamath River system, seasonal temperature changes are large. Monthly daytime measurements made near Seiad Valley (station F3-1430.00) during the period 1958-1983 show a typical seasonal pattern, with a wide range of temperatures ranging from winter lows of about 1° C in January to a summer high of 27° C in July (Figure 6).

The water temperatures measured during this investigation appear normal with summer highs near 26° C and late winter lows of 5° C. Measurements made during the diel surveys showed a consistent change at each of the stations on the Klamath River of 2° C in February, while in July the 24-hour change varied from 3.5° C to 6° C (Figure 7).

The highest peak temperatures were fairly consistent at 26° C from Iron Gate Dam to Hamburg; however, the low temperatures varied with the lowest being measured at Randolph Collier Rest Stop (station F3-1585.00). The greatest diel change of 6° C measured in the Klamath River during this study was also measured at this station. At this station, streamflow characteristics and ambient temperature differences could combine to allow a greater heat loss during nighttime hours. The diel fluctuations gradually decrease to 3.5° C some 30 miles downstream at Sarah Totten Campground (station F3-1460.00).

Klamath River below Iron Gate Dam (F3-1599.01)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

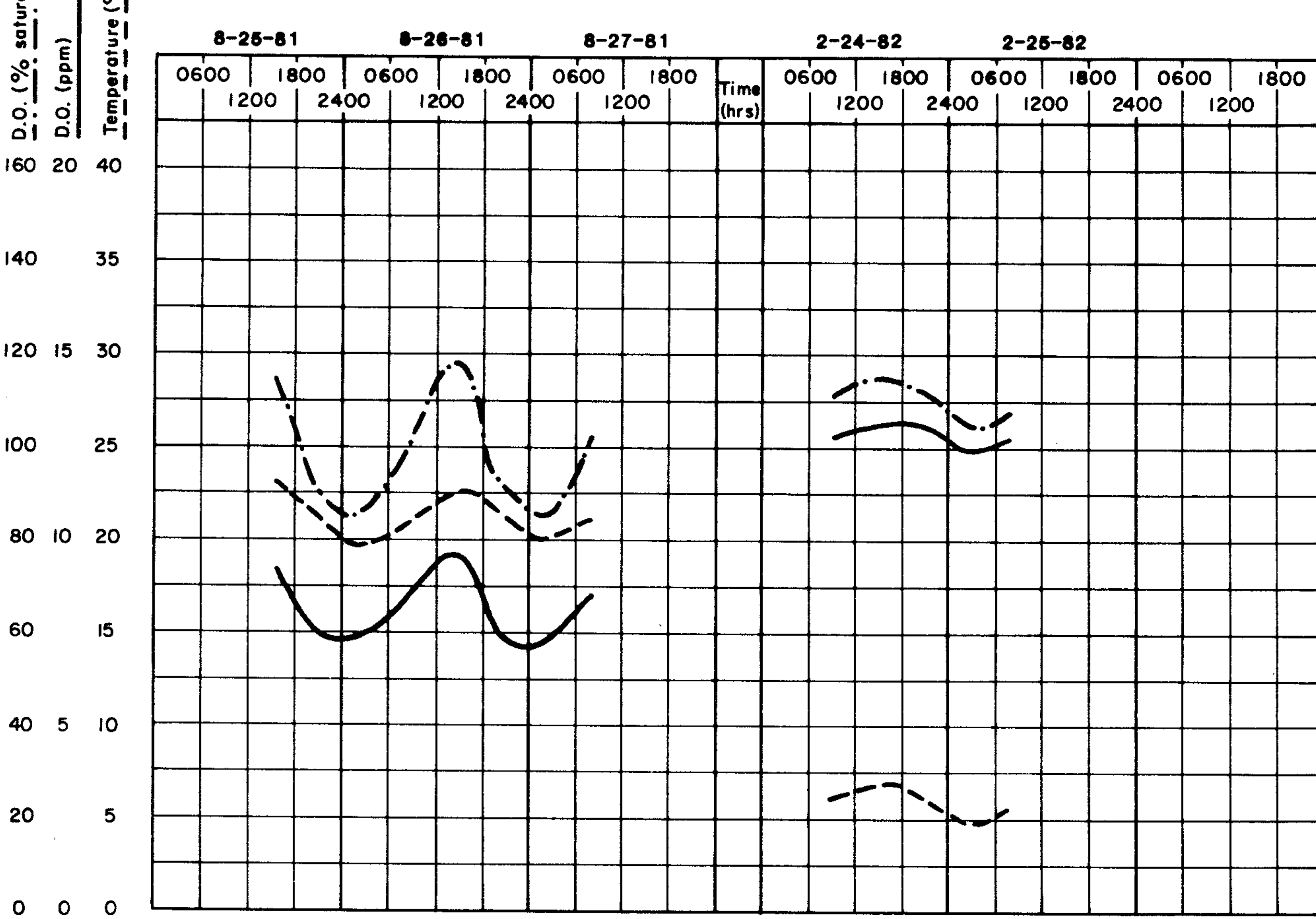


Figure 7a

Klamath River below Iron Gate Dam (F3-1599.01)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

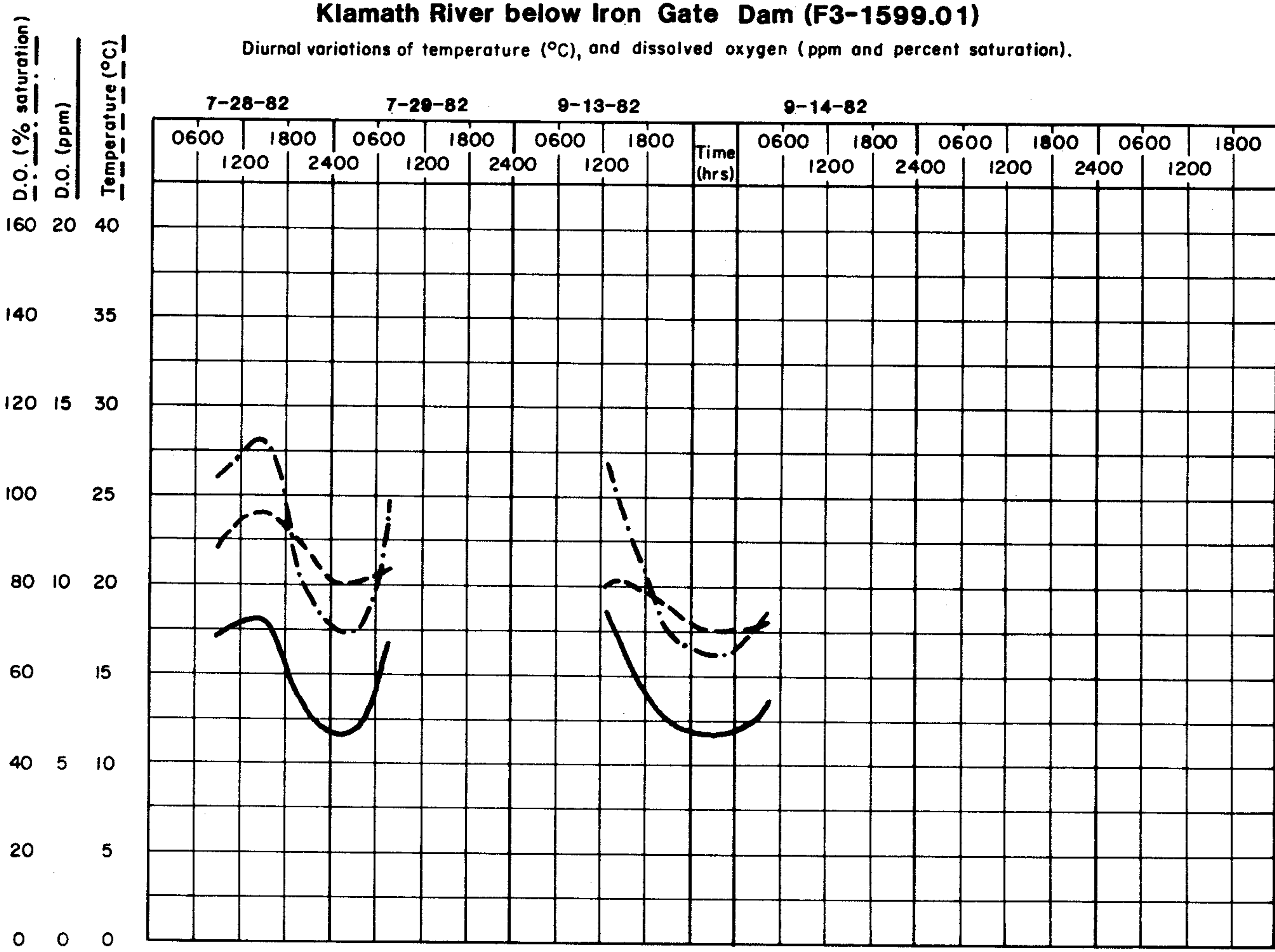


Figure 7a

Klamath River below Iron Gate Dam (F3-1599.01)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

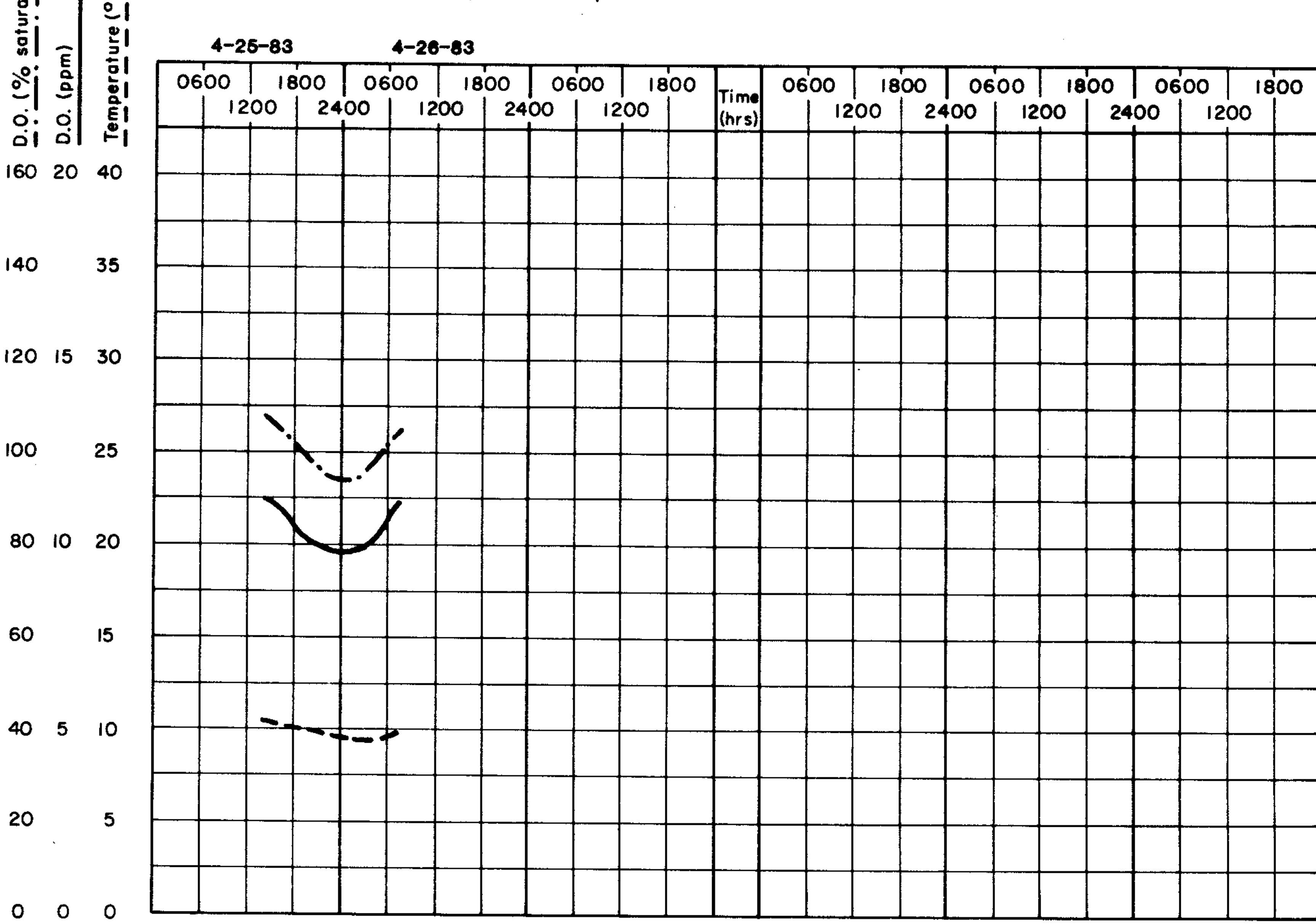


Figure 7a

Klamath River at Randolph Collier Rest Stop (F3-1585.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

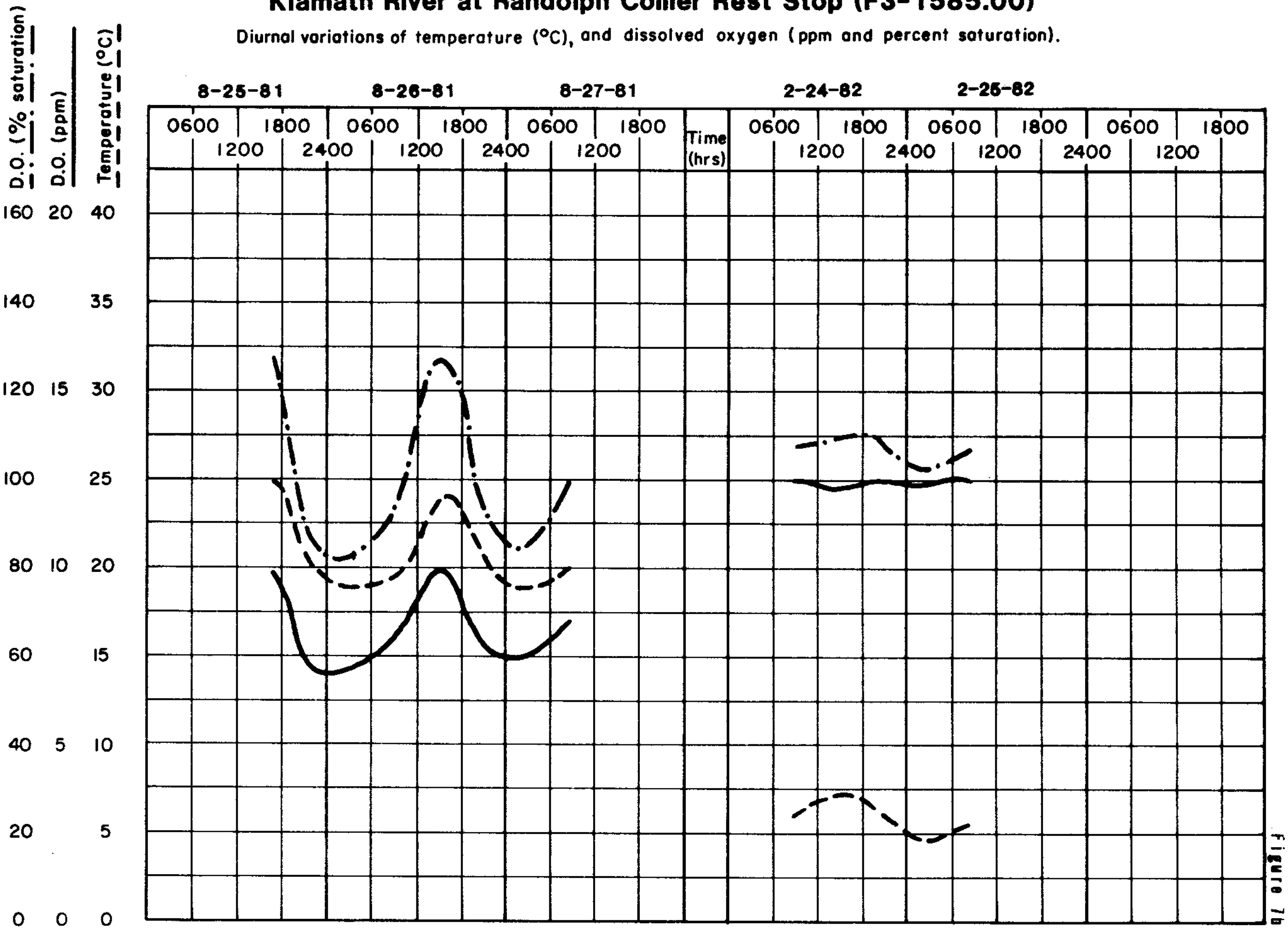


Figure 7b

Klamath River at Randolph Collier Rest Stop (F3-1585.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

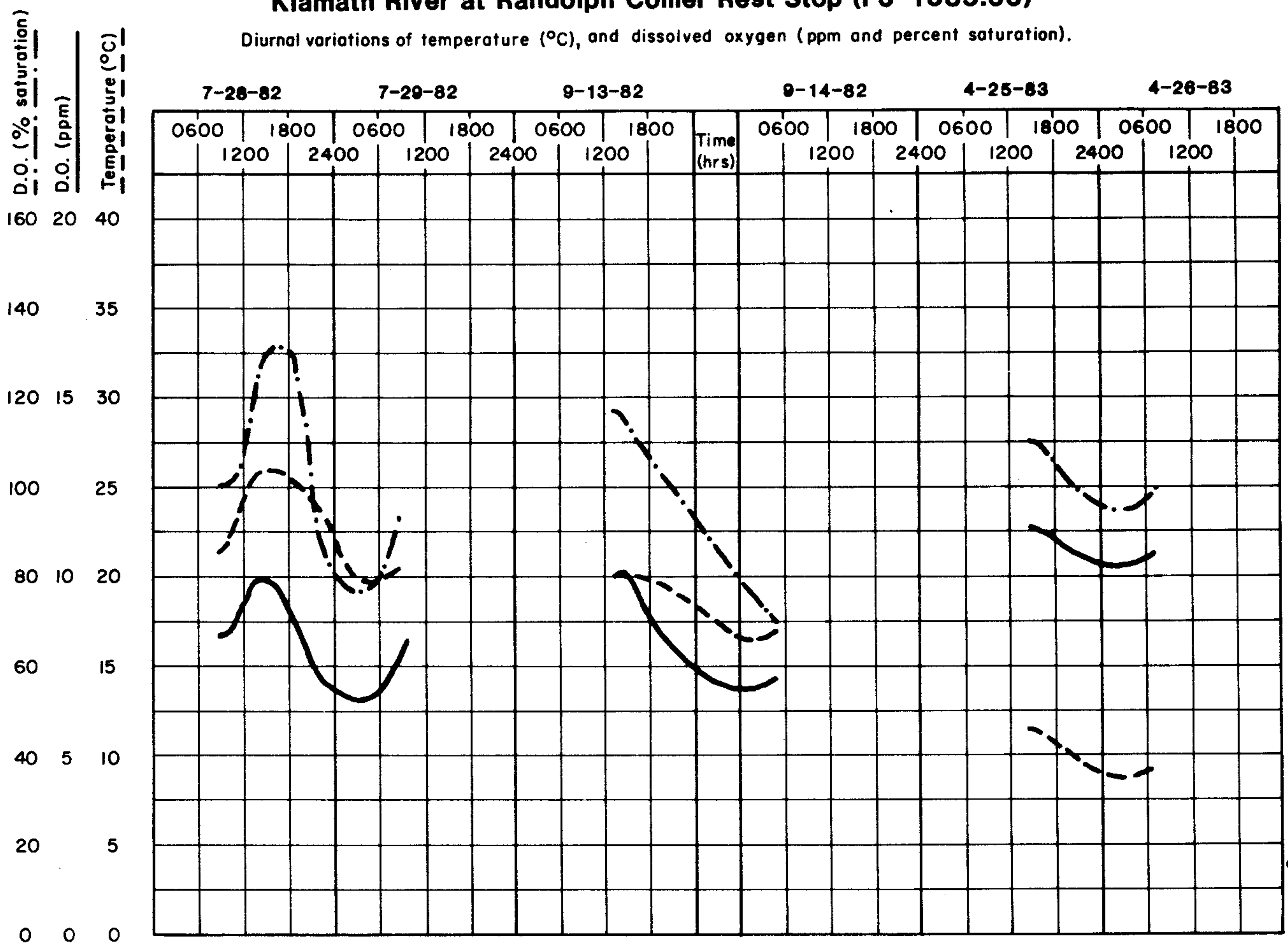


Figure 7b

Klamath River below Shasta River (F3-1575.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

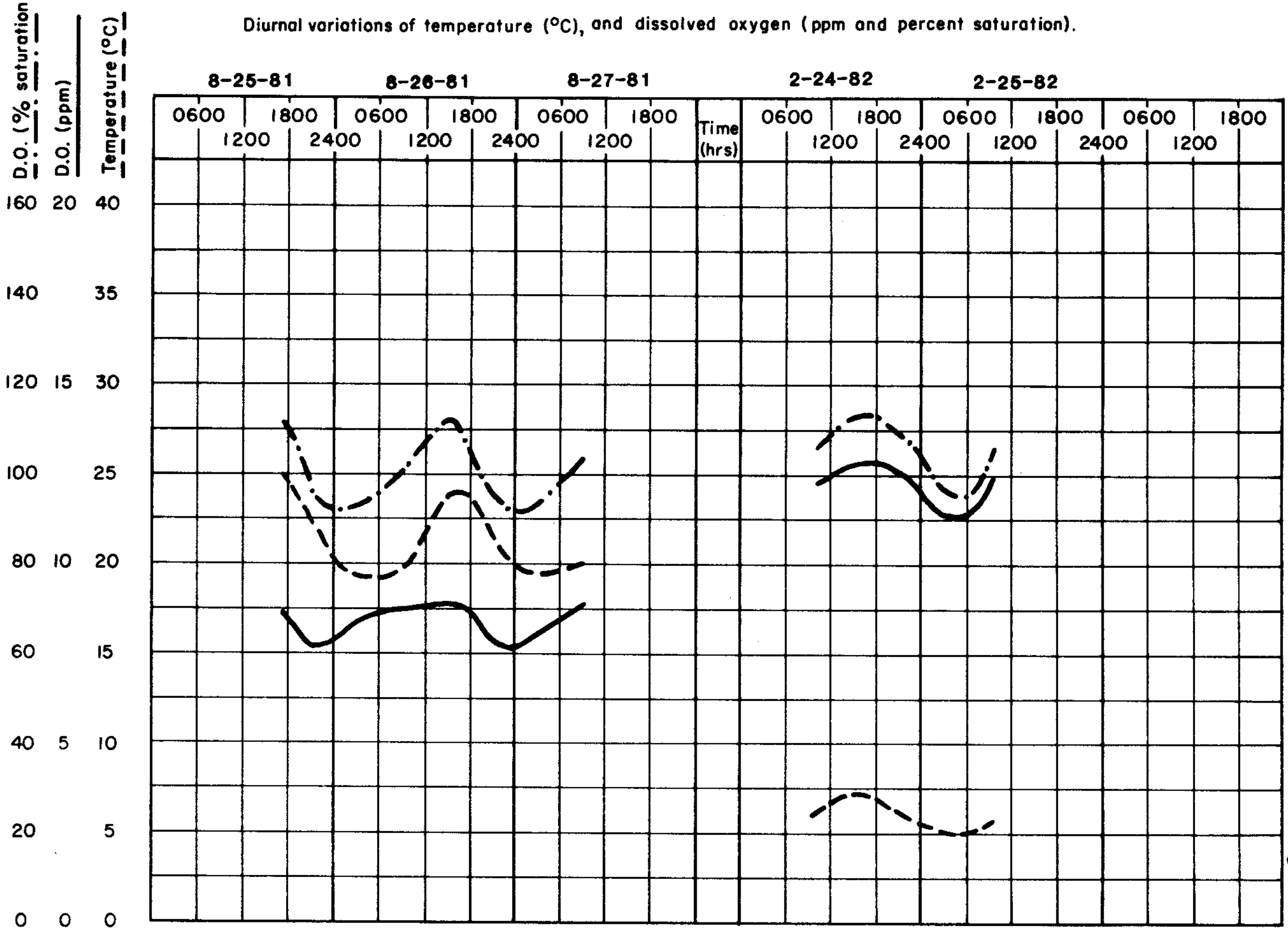


Figure 7c

Klamath River below Shasta River (F3-1575.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

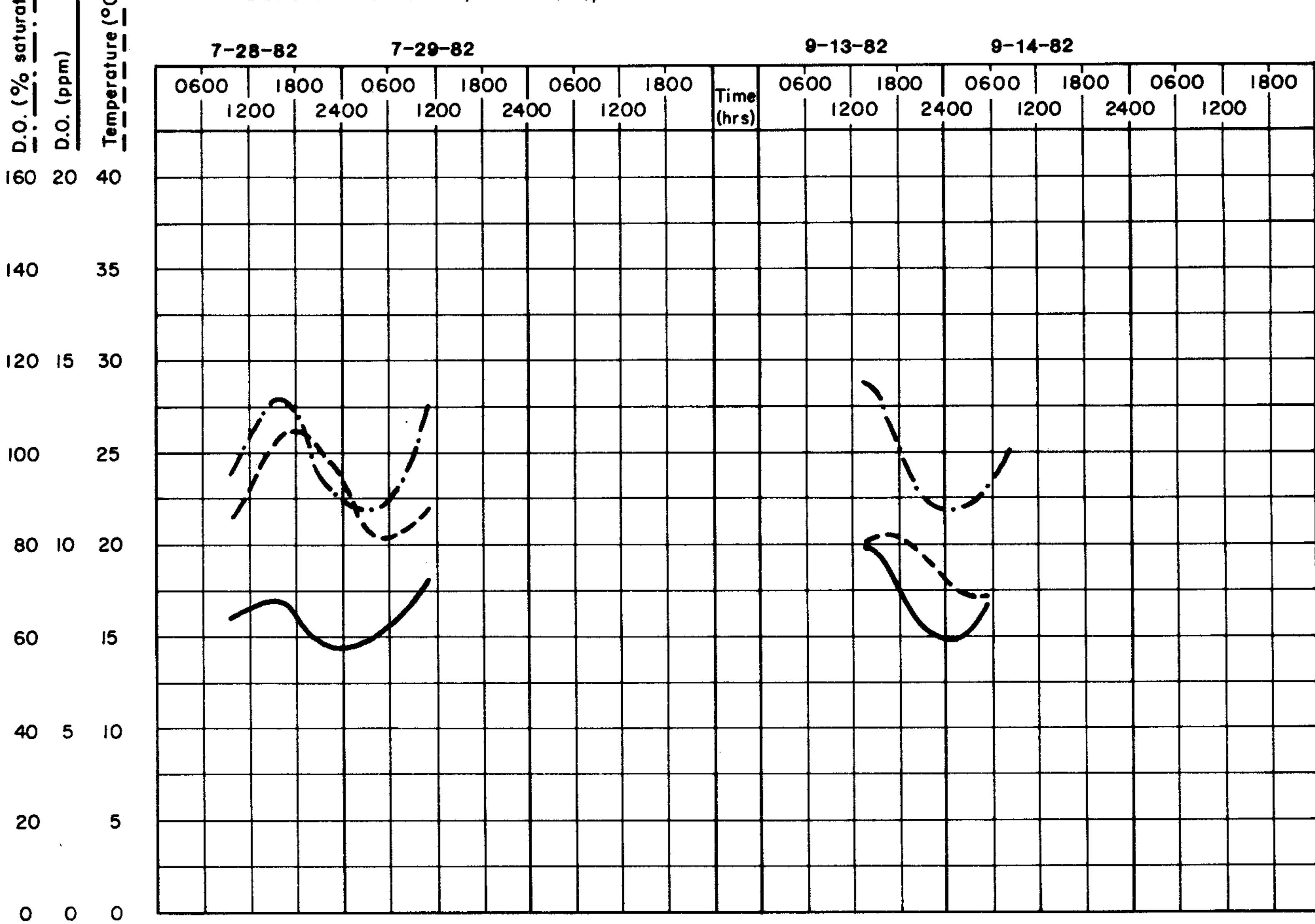


Figure 7c

Klamath River below Shasta River (F3-1575.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

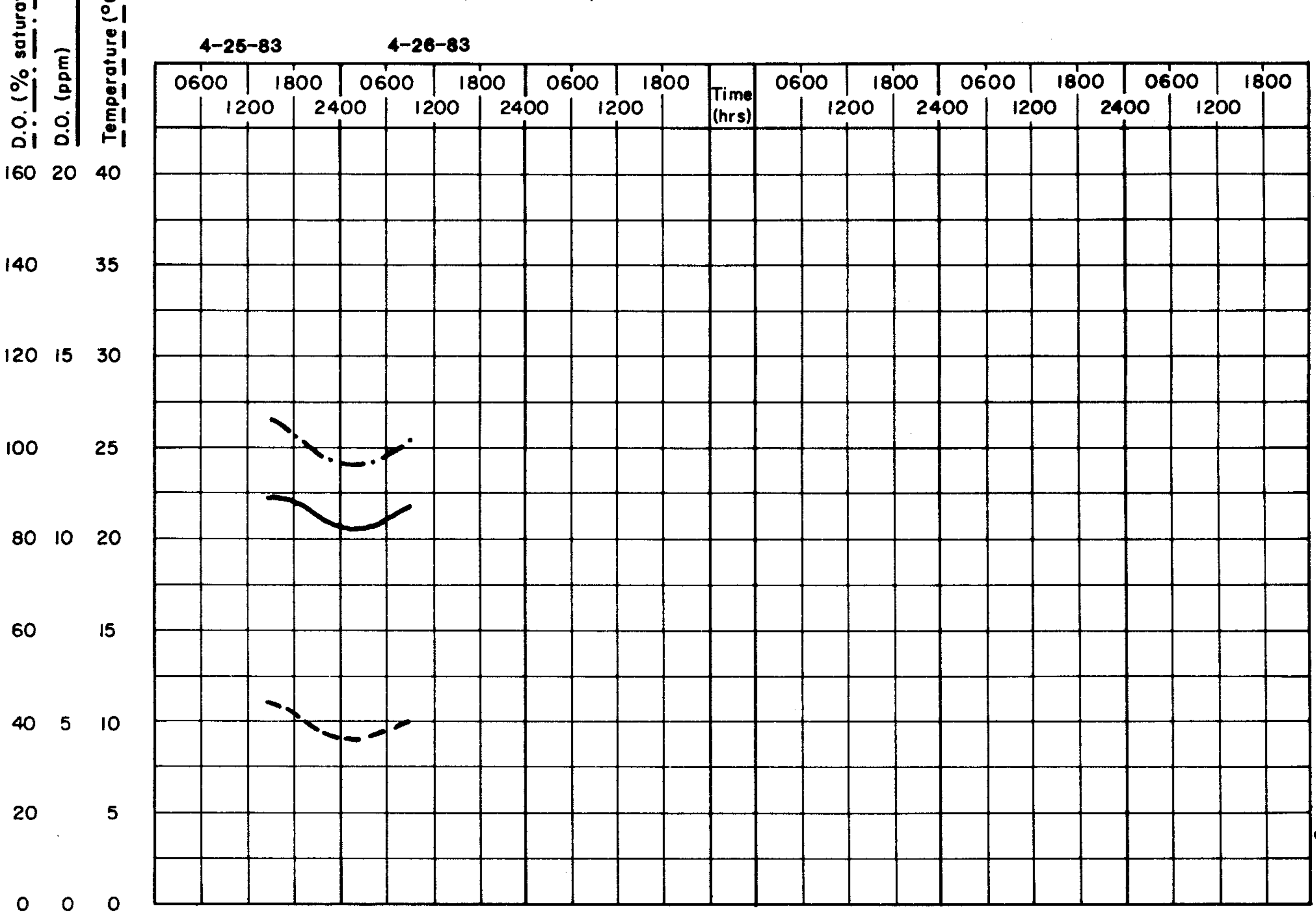


Figure 7c

Klamath River above Hamburg Reservoir Site (F3-1470.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

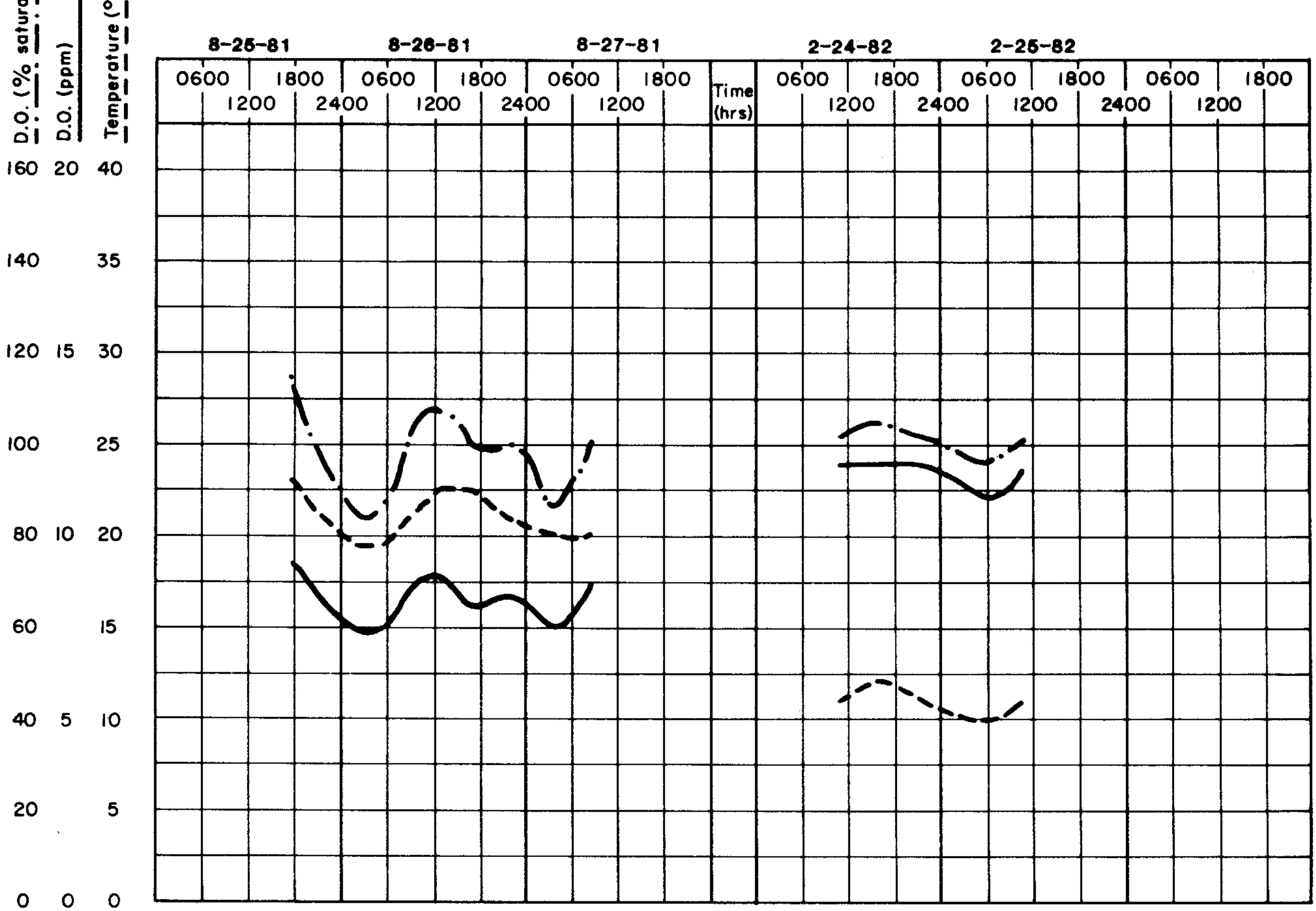


Figure 7d

Klamath River above Hamburg Reservoir Site (F3-1470.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

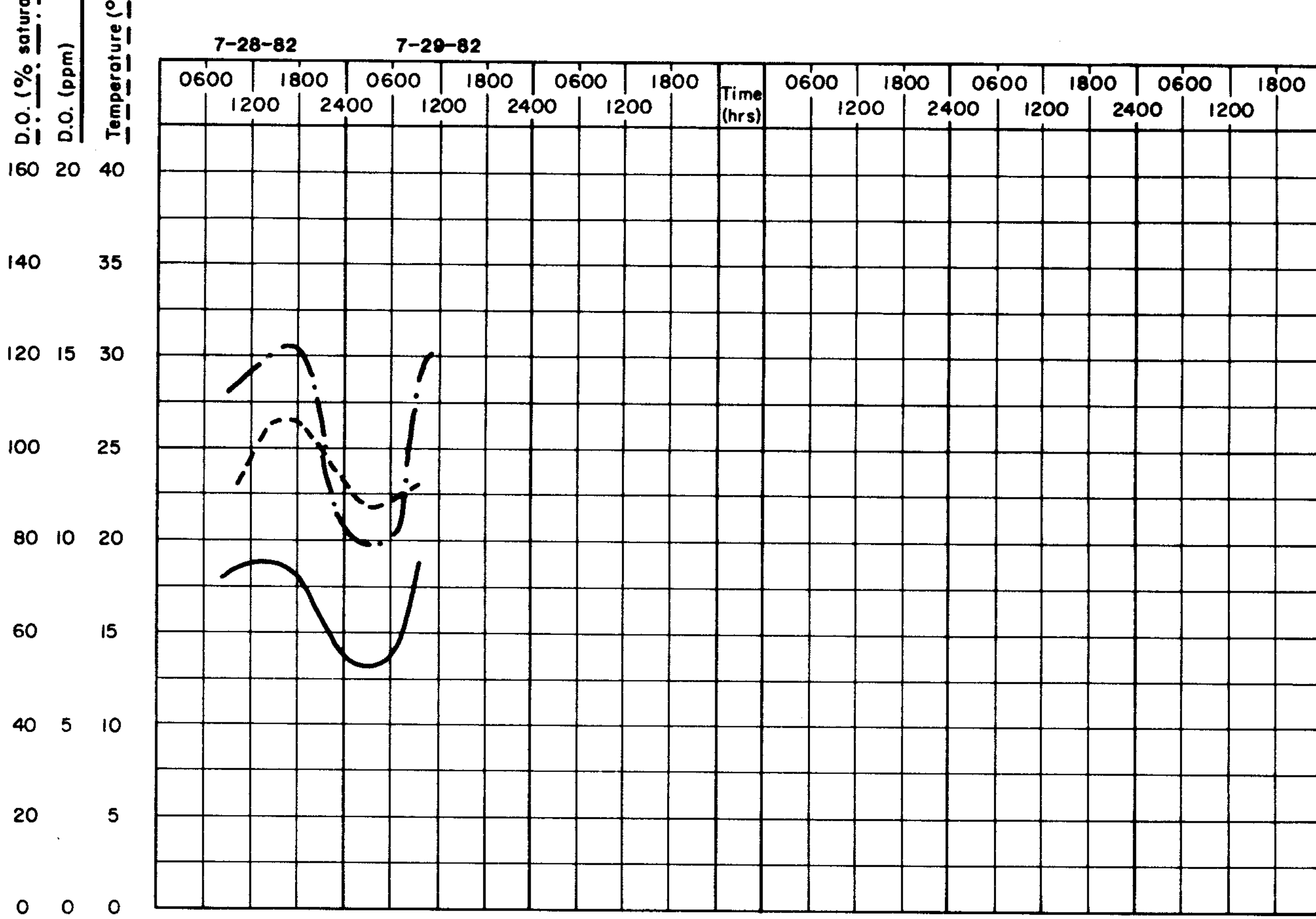


Figure 7d

Klamath River at Sarah Totten Campground (F3-1460.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

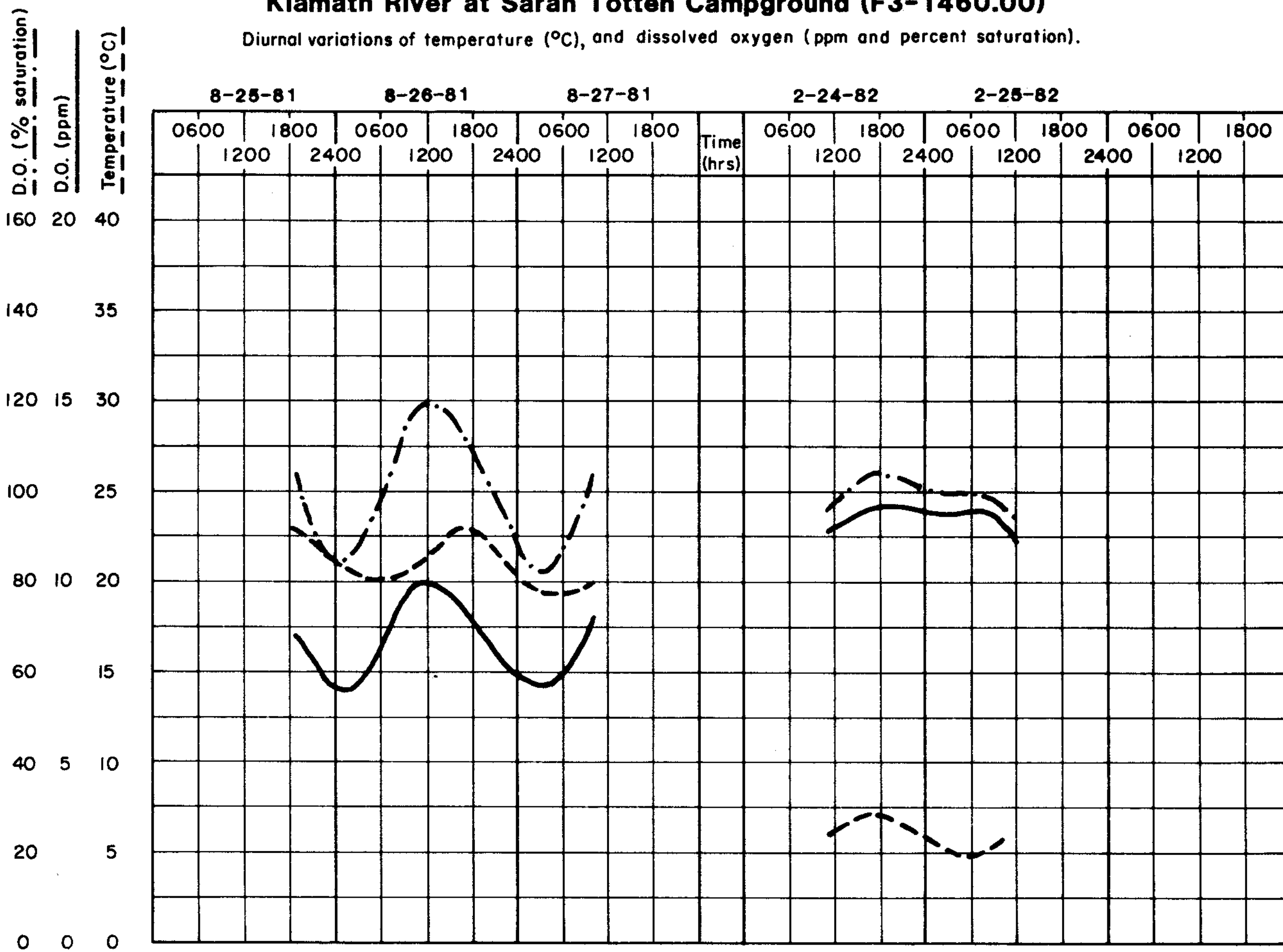


Figure 7e

Klamath River at Sarah Totten Campground (F3-1460.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

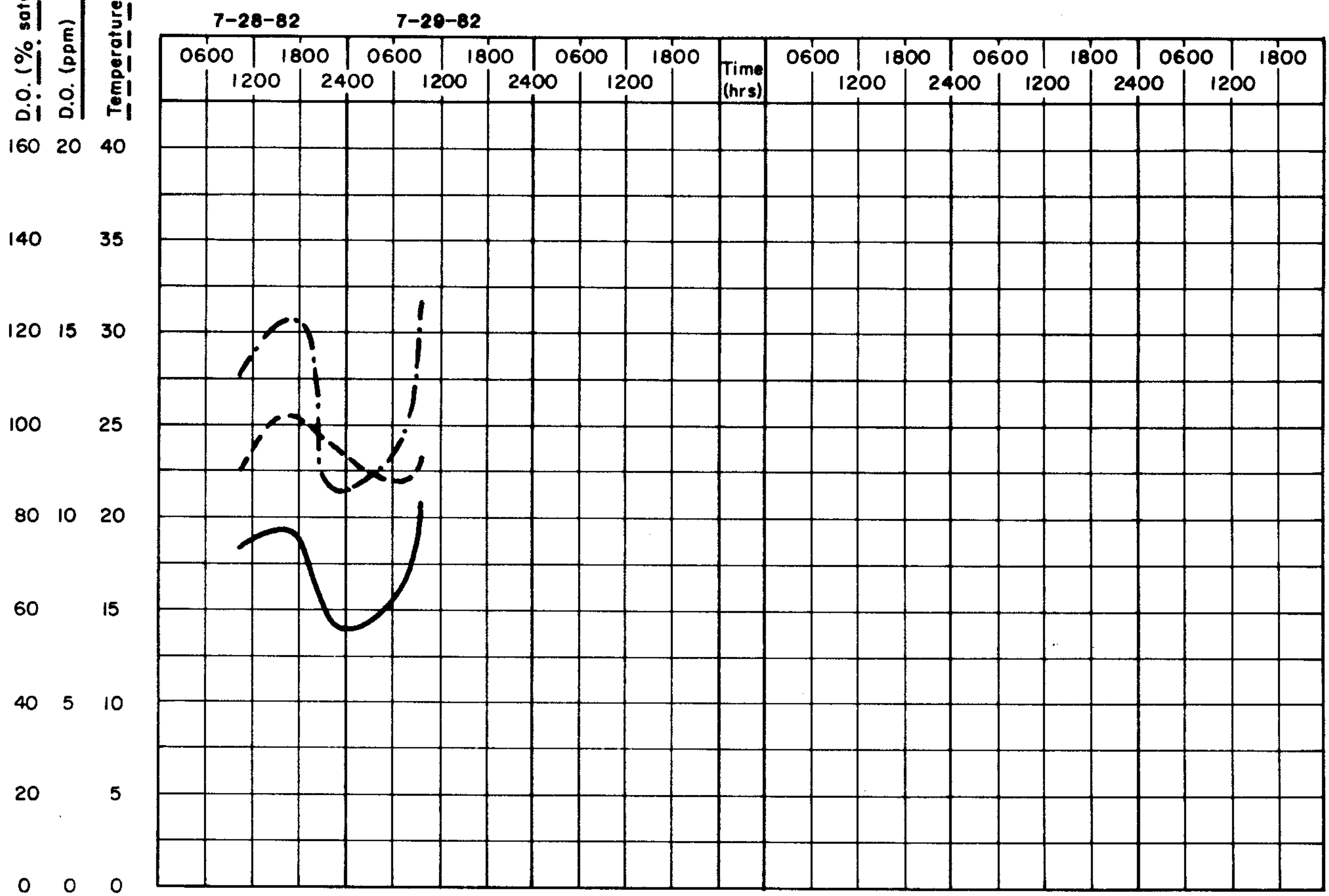


Figure 7e

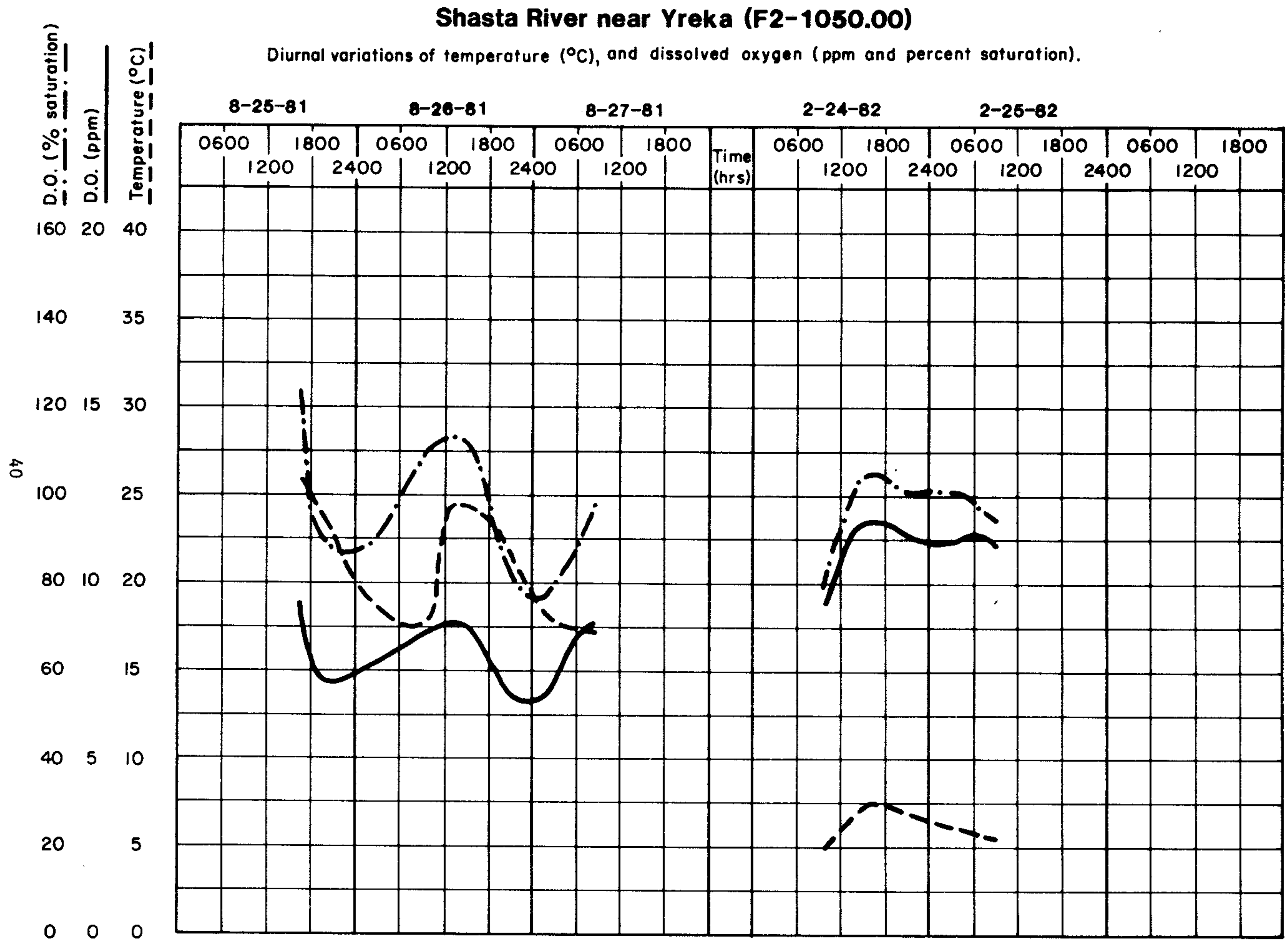

Shasta River near Yreka (F2-1050.00)
Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).
D.O. (% saturation)
D.O. (ppm)
Temperature (°C)
8-25-81
8-26-81
8-27-81
2-24-82
2-25-82
0600
1200
1800
2400
Time (hrs)
160 20 40
140 35
120 15 30
100 25
80 10 20
60 15
40 5 10
20 5
0 0 0

Figure 8a

Shasta River near Yreka (F2-1050.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

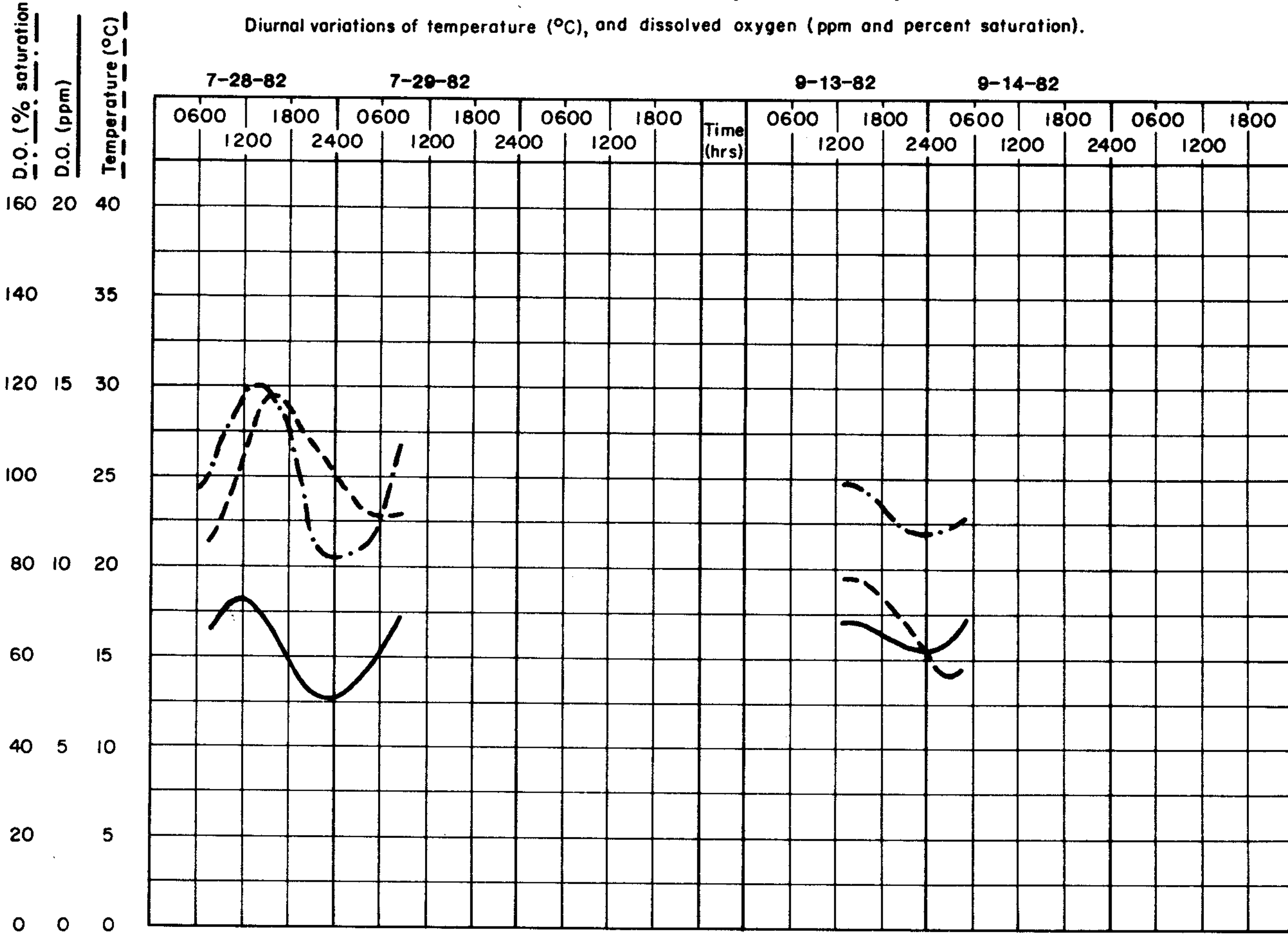


Figure 8a

Shasta River near Yreka (F2-1050.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

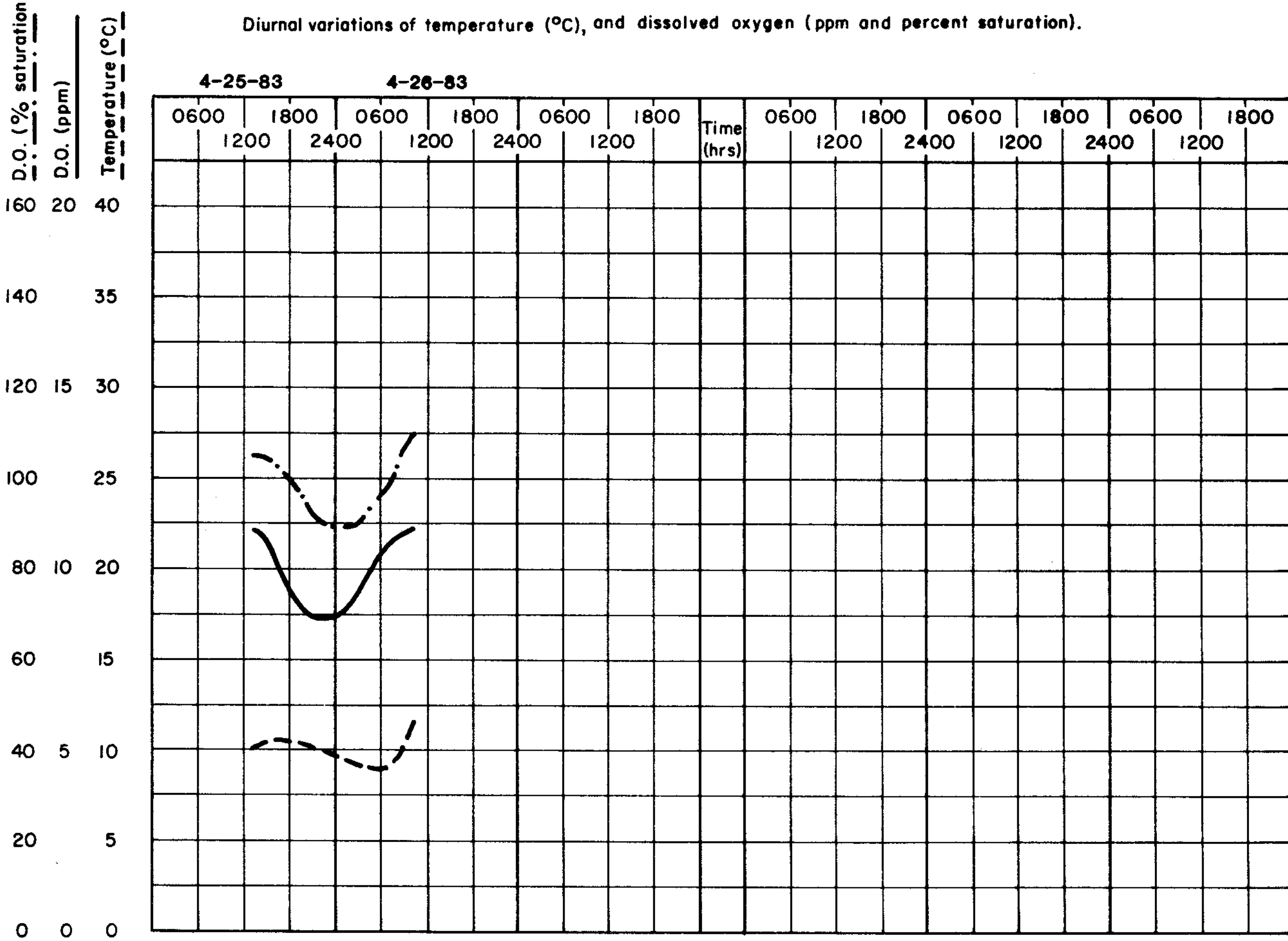


Figure 8a

Yreka Creek above Shasta River (F2-1056.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

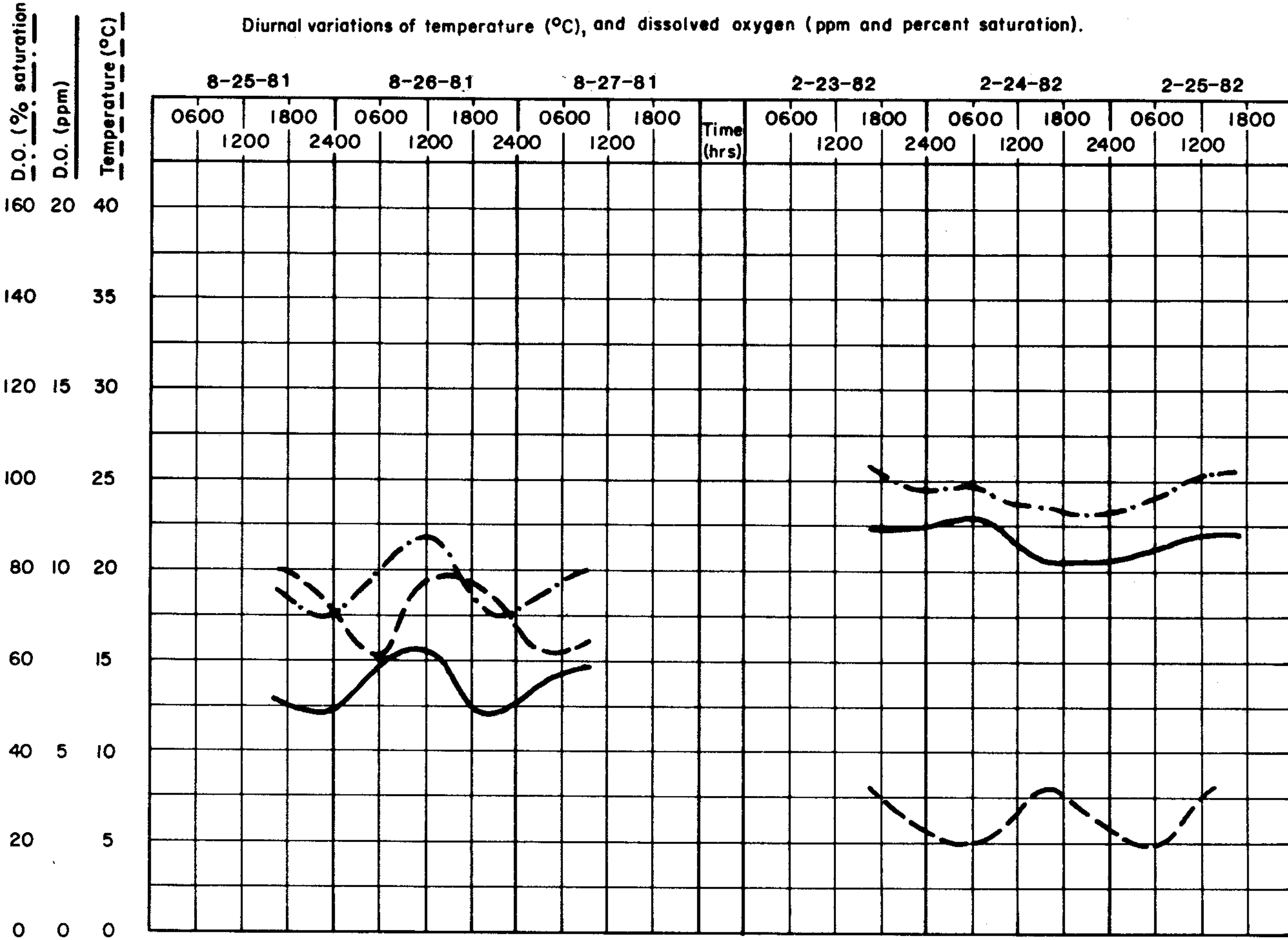


Figure 8b

Yreka Creek above Shasta River (F2-1056.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

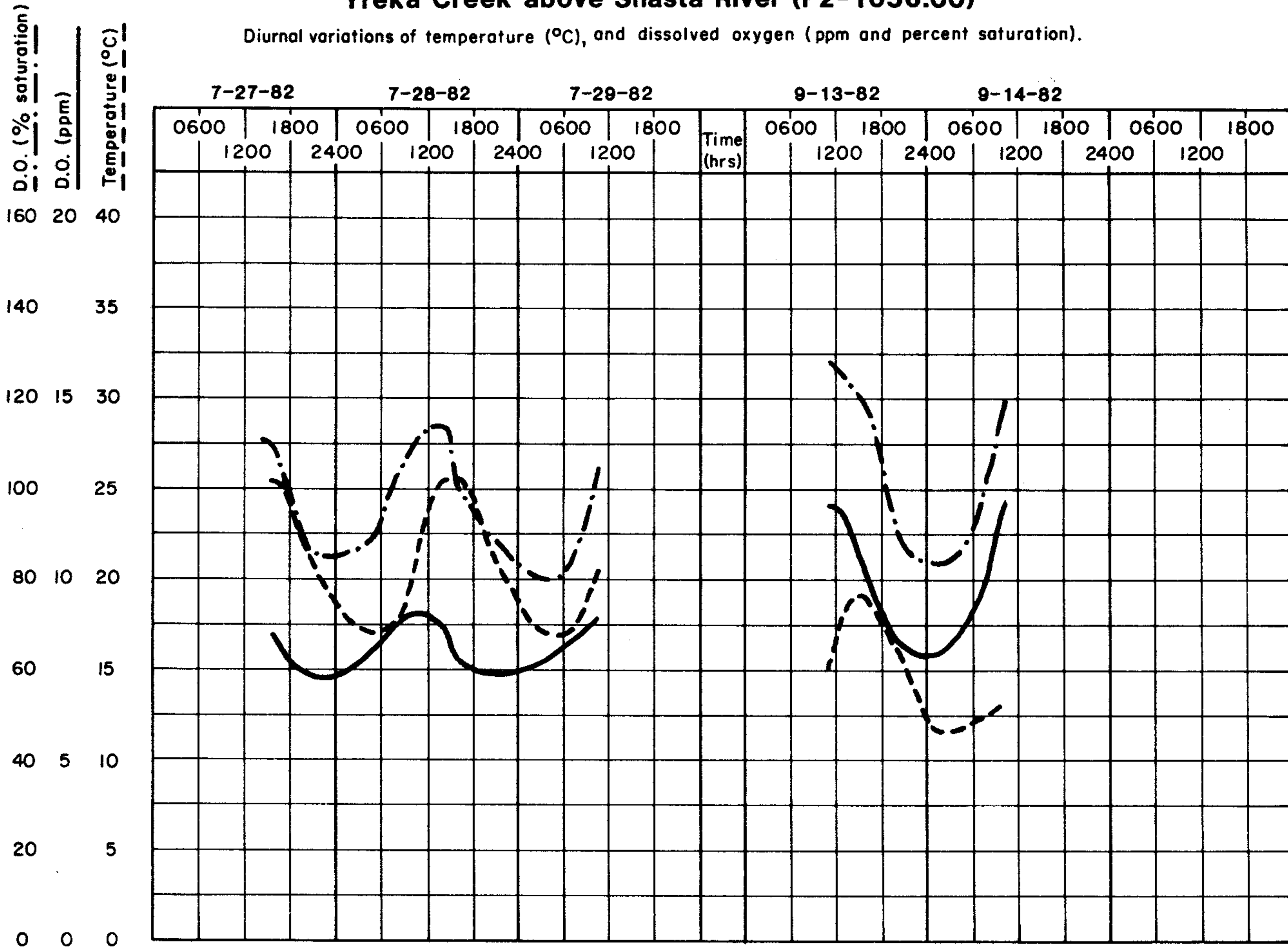


Figure 8b

Yreka Creek above Shasta River (F2-1056.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

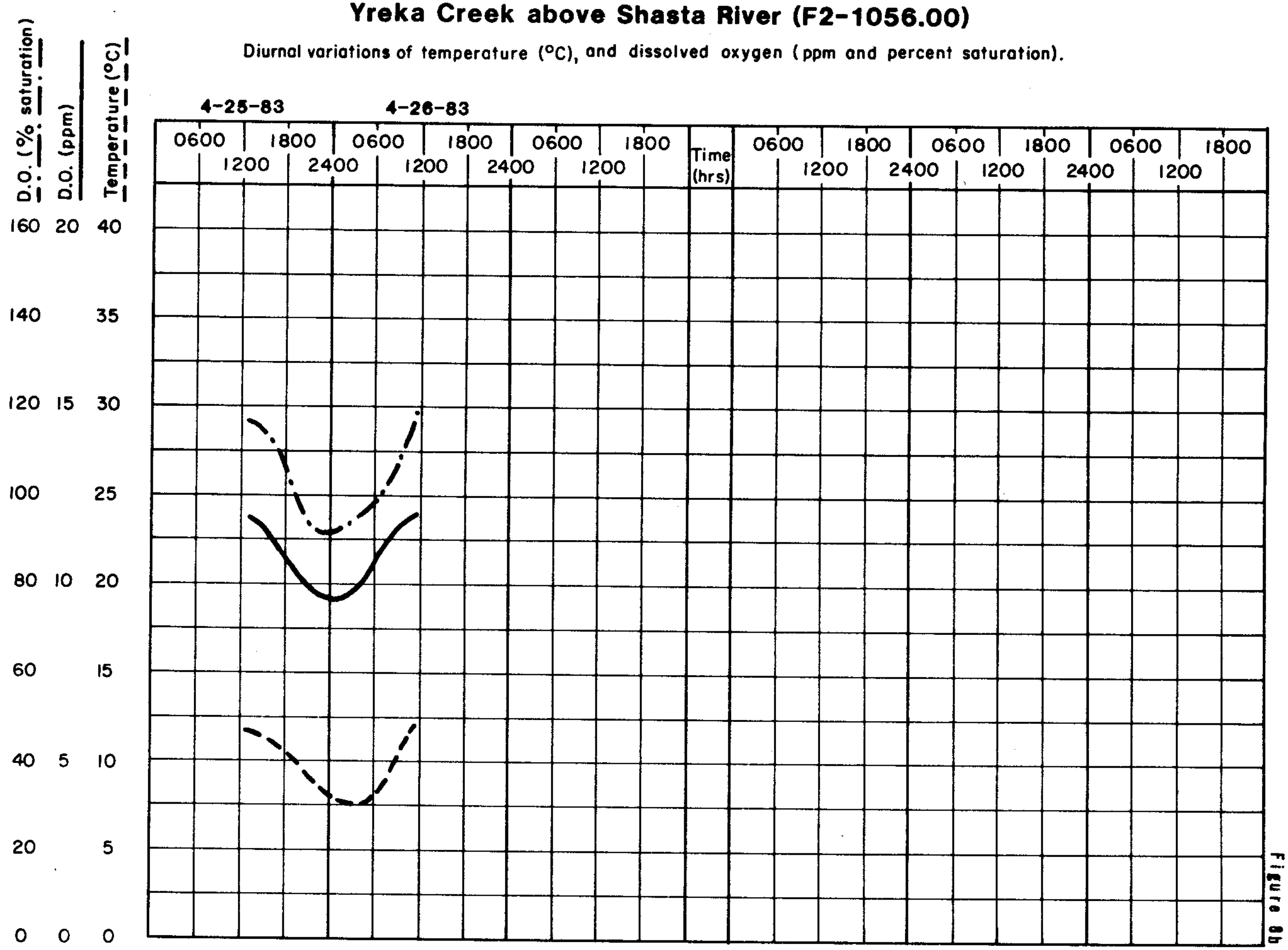
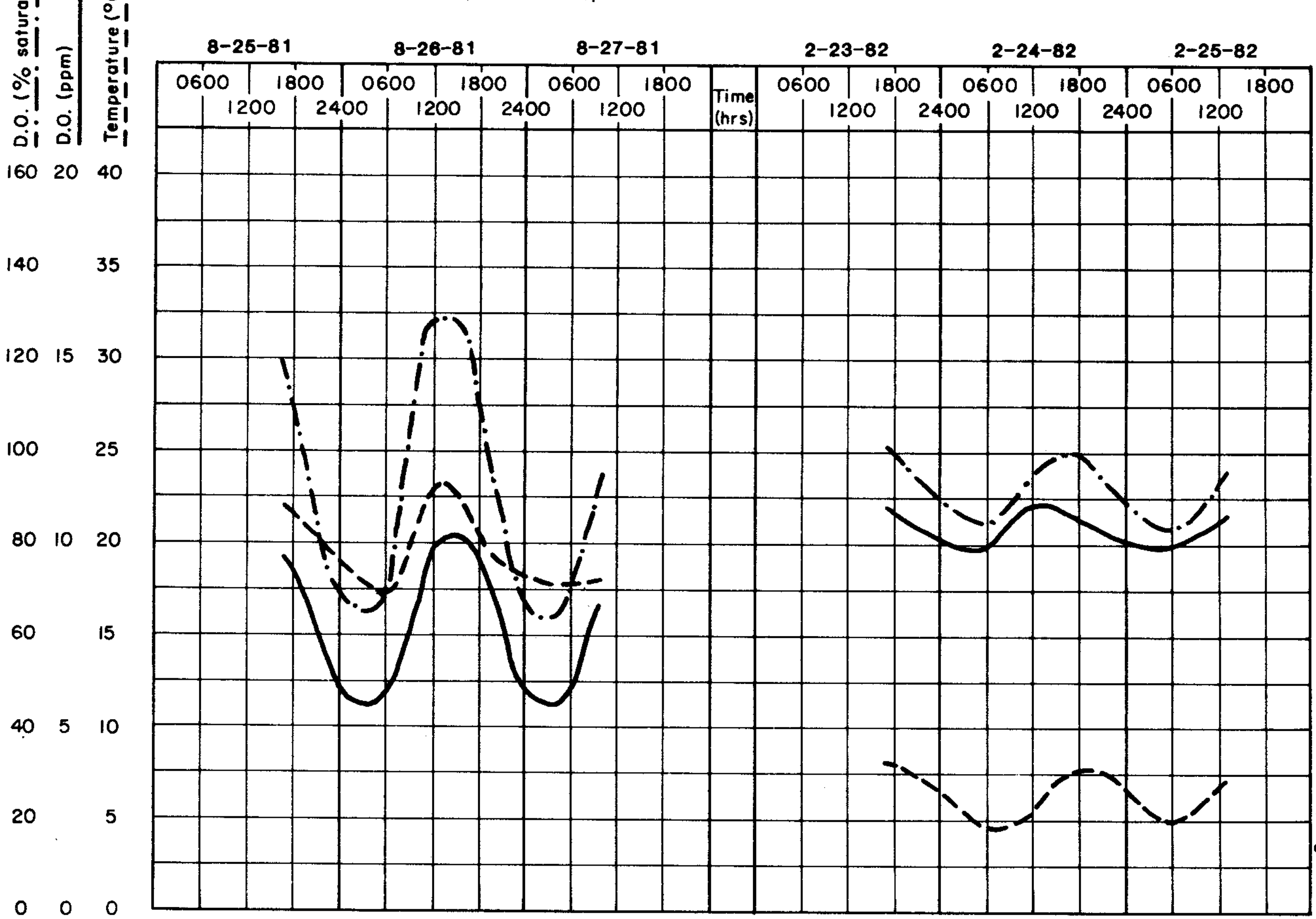


Figure 8b

Shasta River above Yreka Creek (F2-1055.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).



46

Figure 8c

Shasta River above Yreka Creek (F2-1055.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

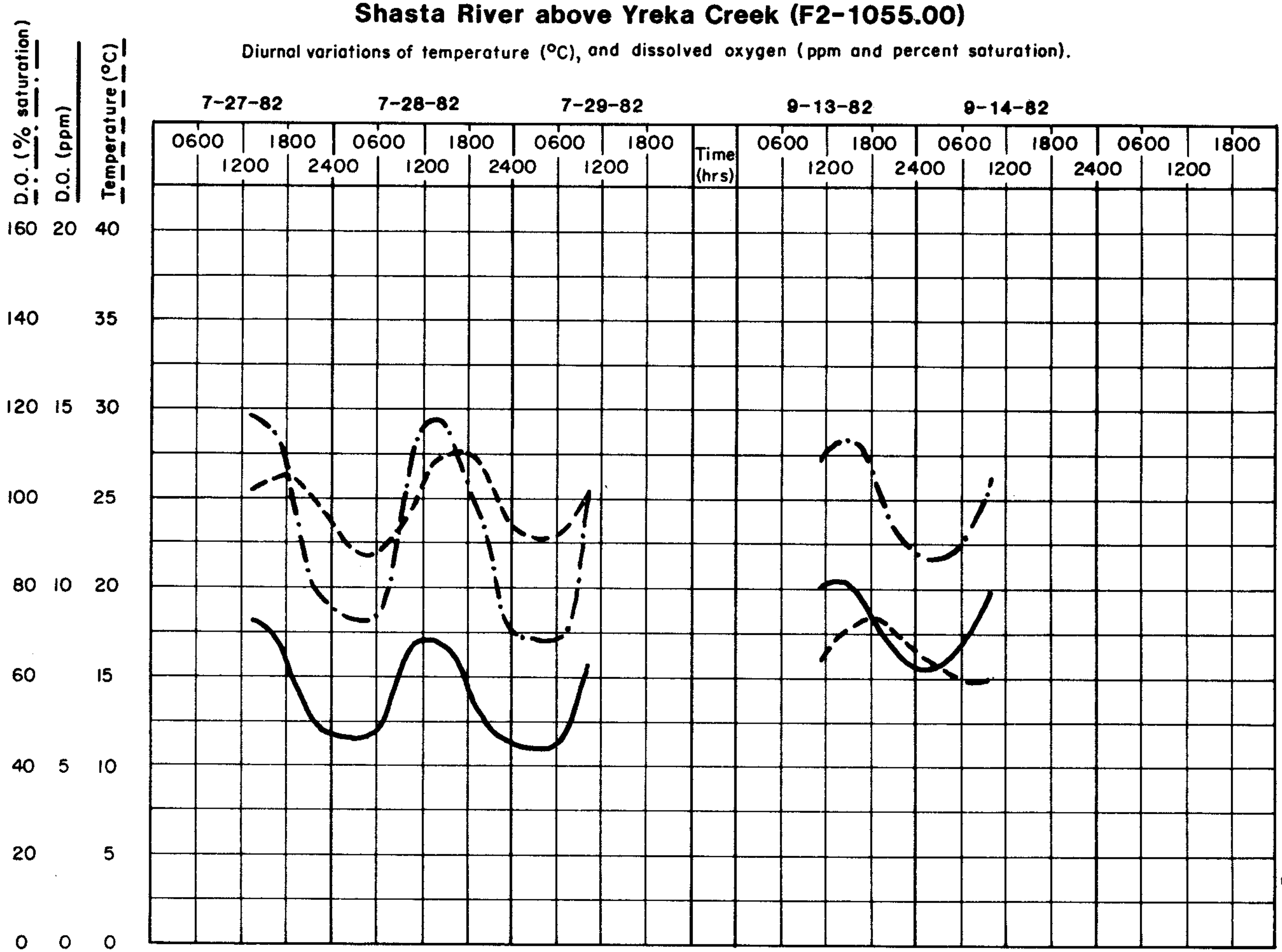


Figure 8c

Shasta River above Yreka Creek (F2-1055.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

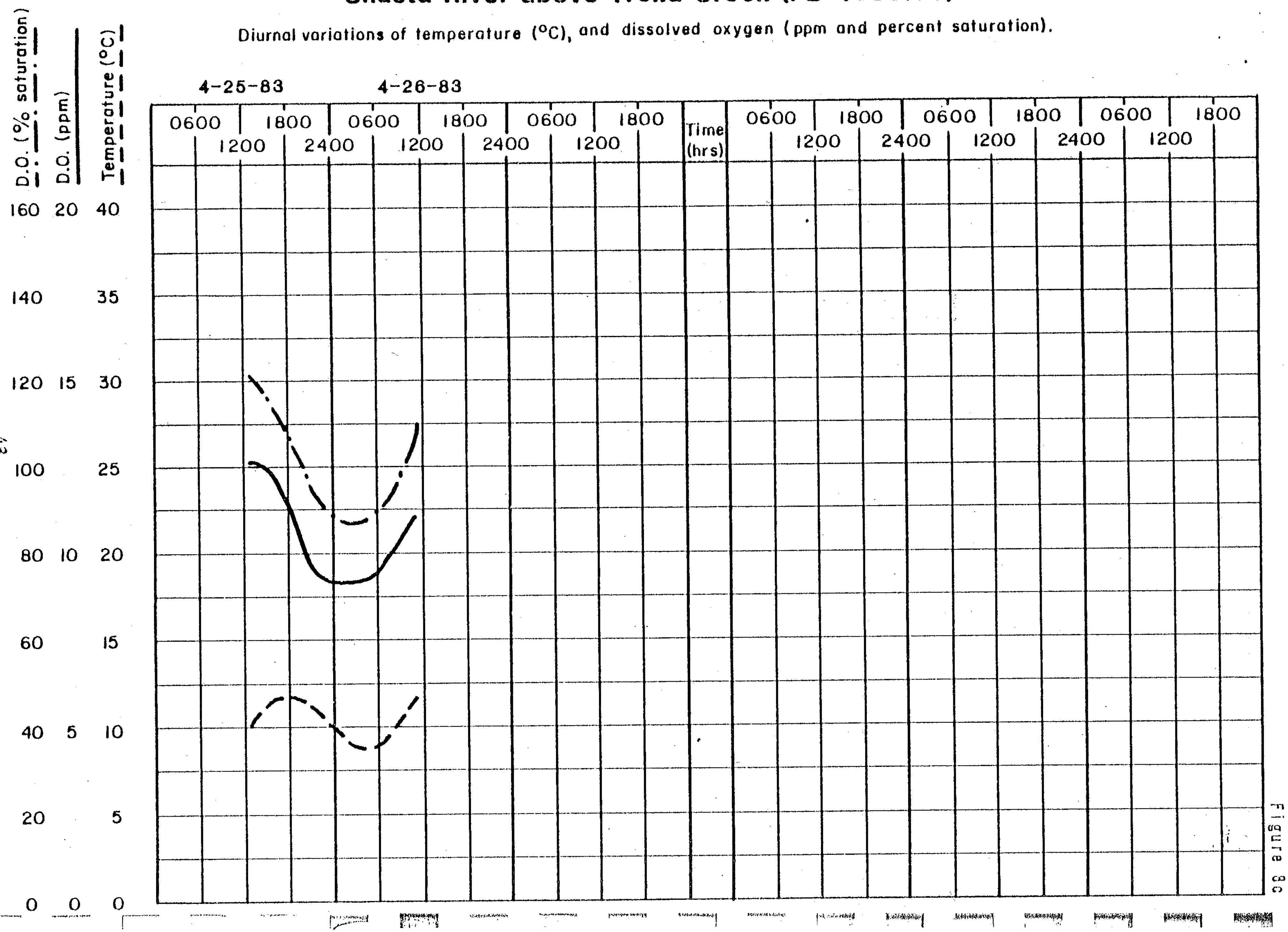


Figure 8c

Shasta River below Little Shasta River (F2-1149.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

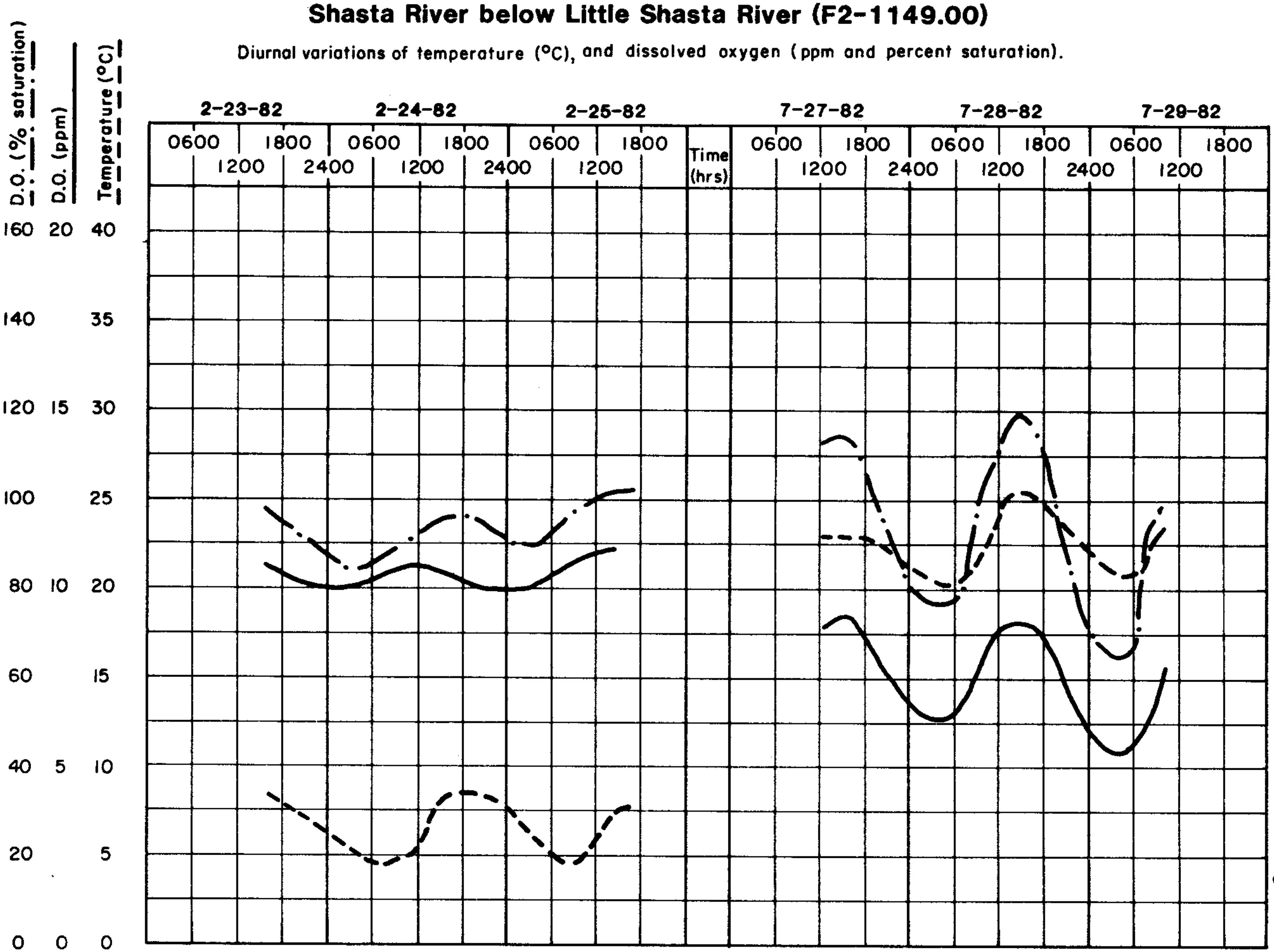


Figure 8d

Shasta River below Little Shasta River (F2-1149.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

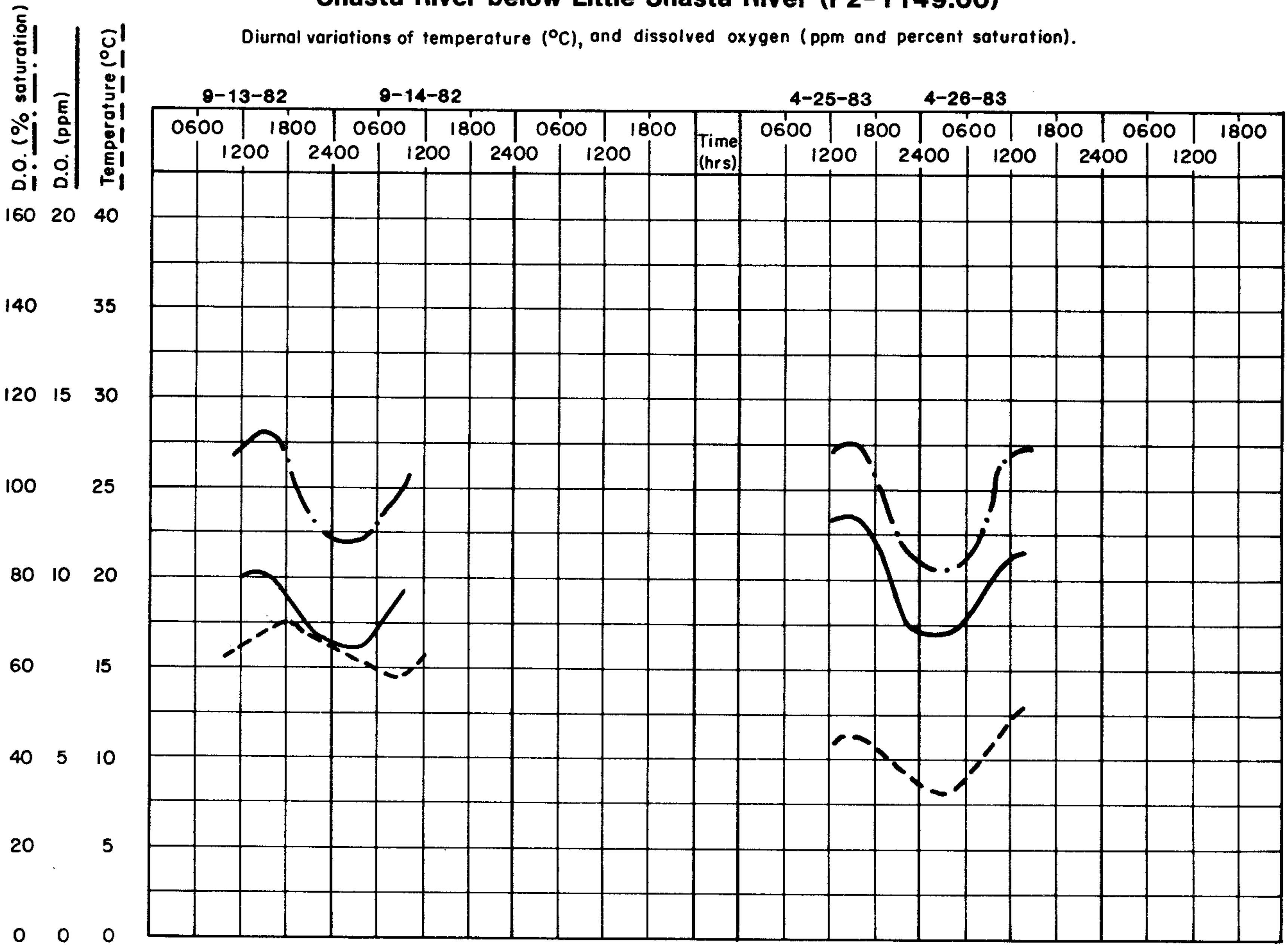


Figure 8d

Shasta River above Little Shasta River (F2-1151.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

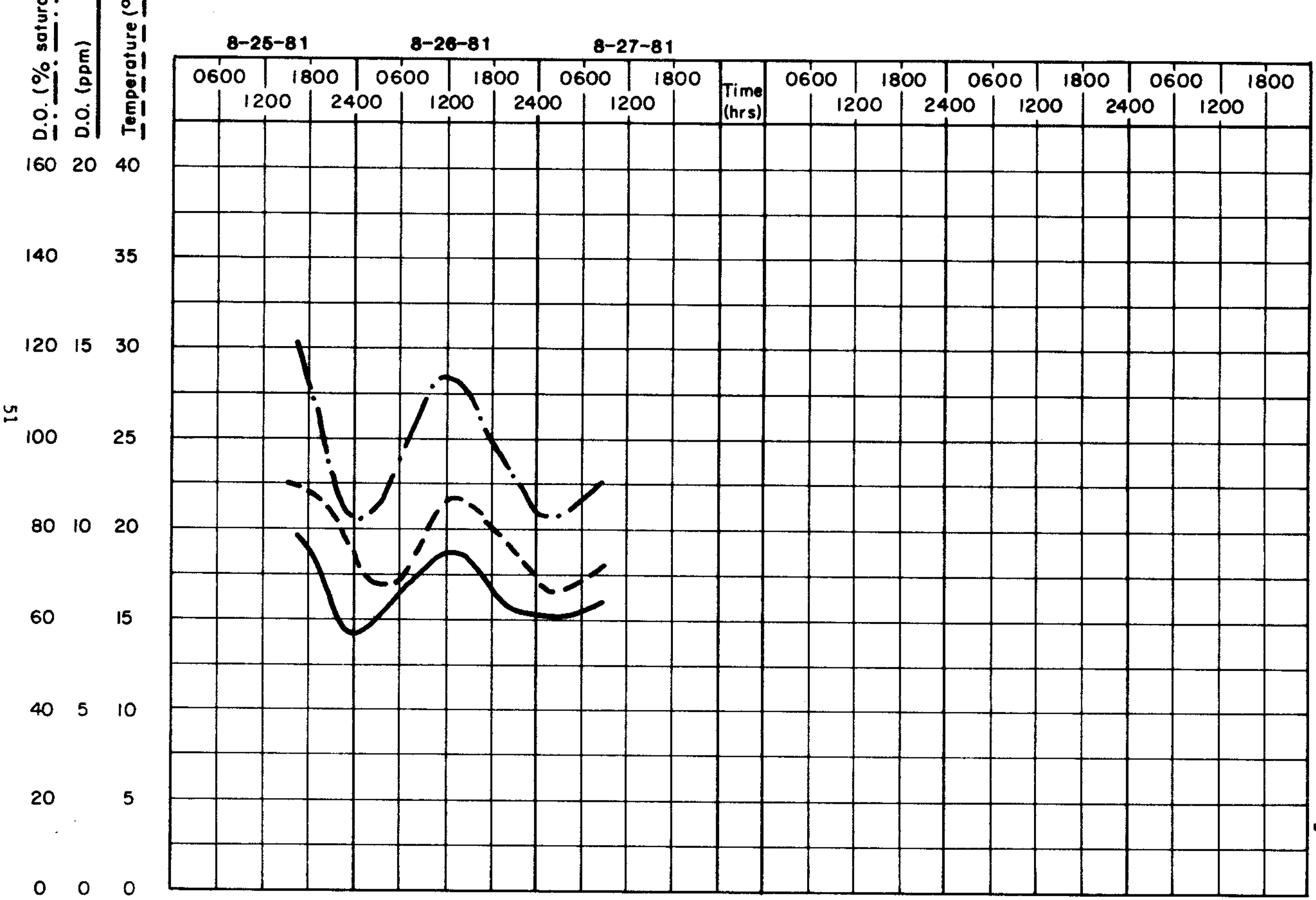


Figure 8e

Shasta River near Grenada (F2-1350.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

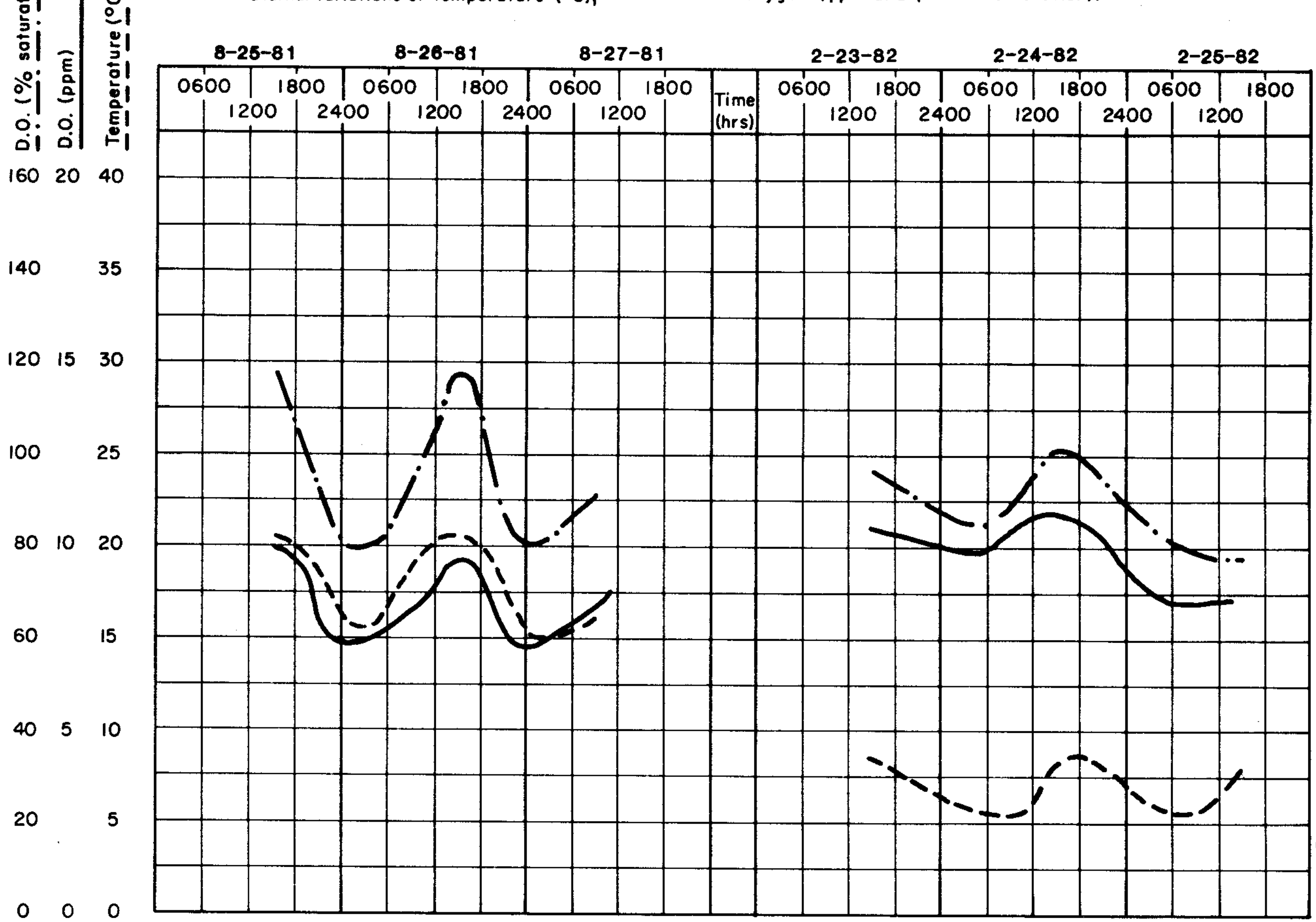


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Figure 8f

Shasta River near Grenada (F2-1350.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

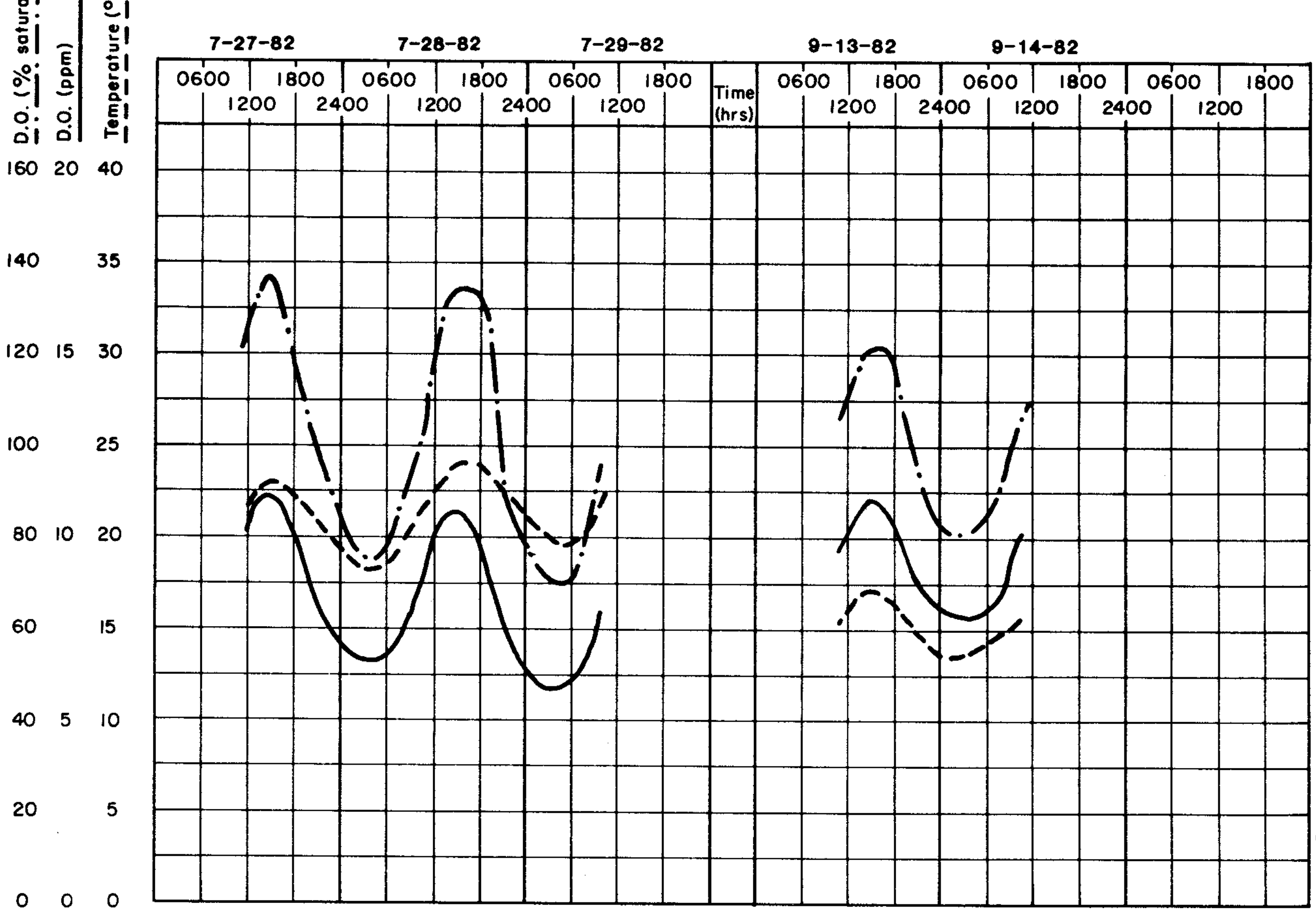

Figure 8f

Shasta River near Grenada (F2-1350.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

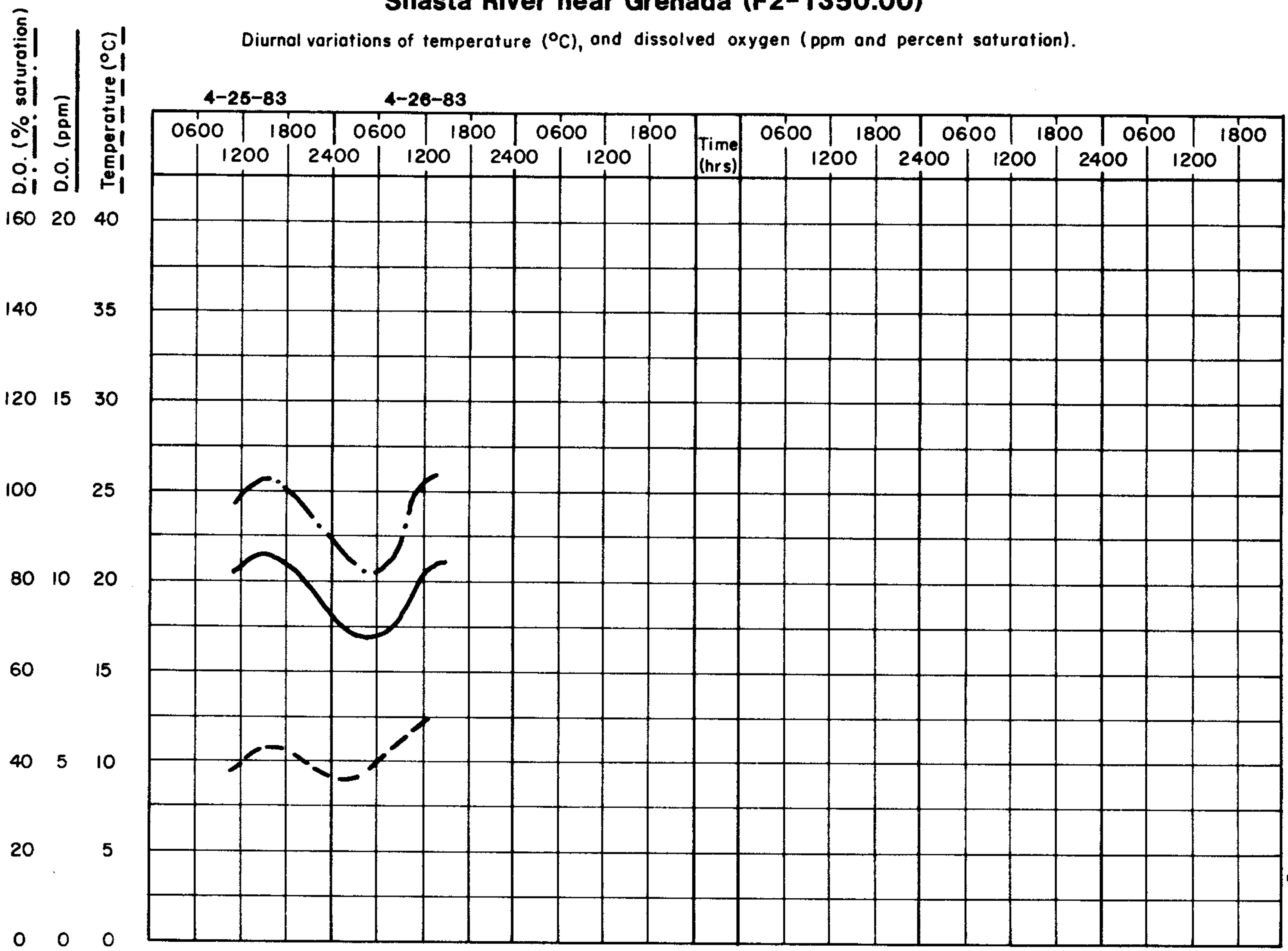

Figure 8f

Shasta River near Big Springs (F2-1380.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

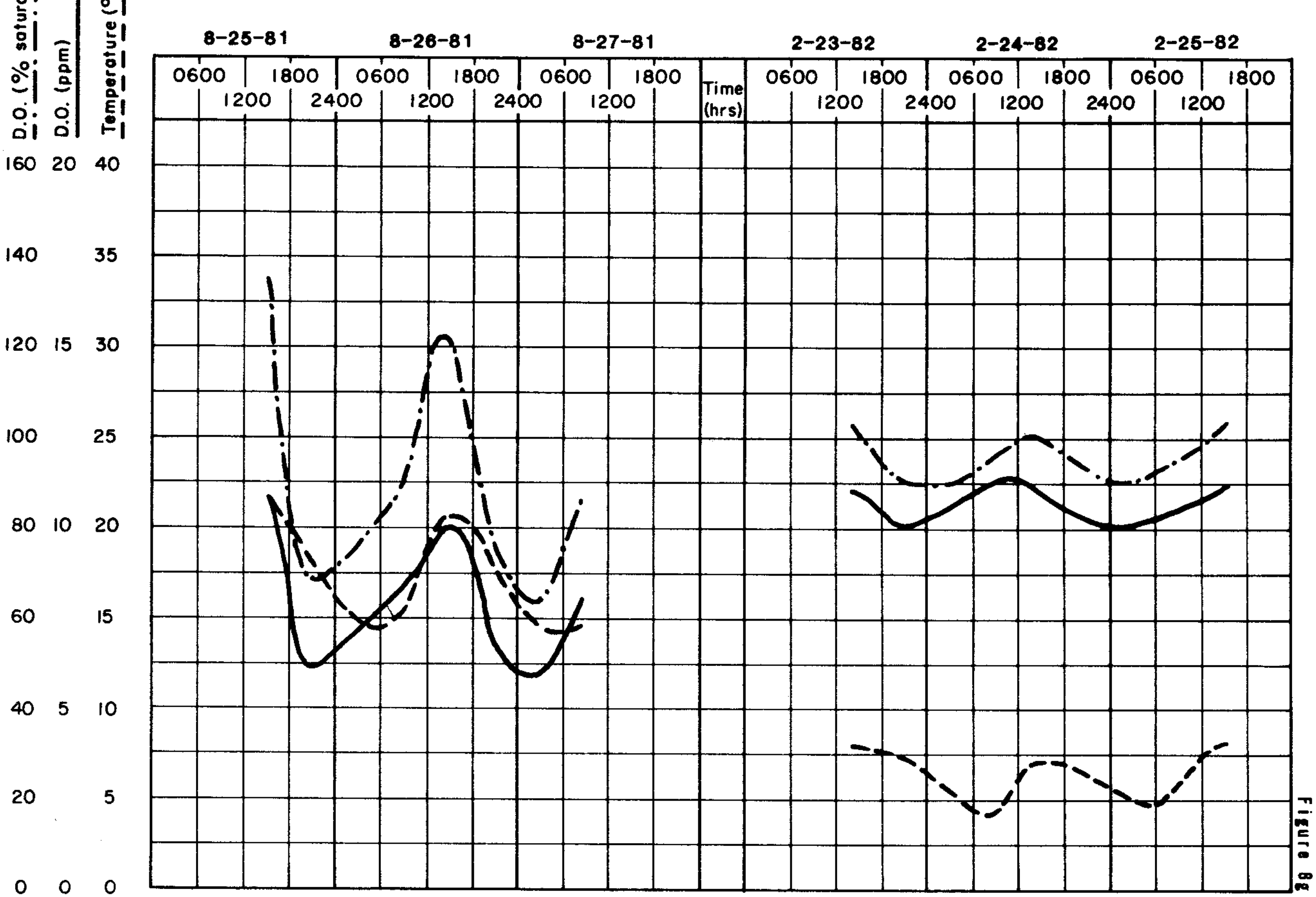

Figure 8g

Shasta River near Big Springs (F2-1380.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

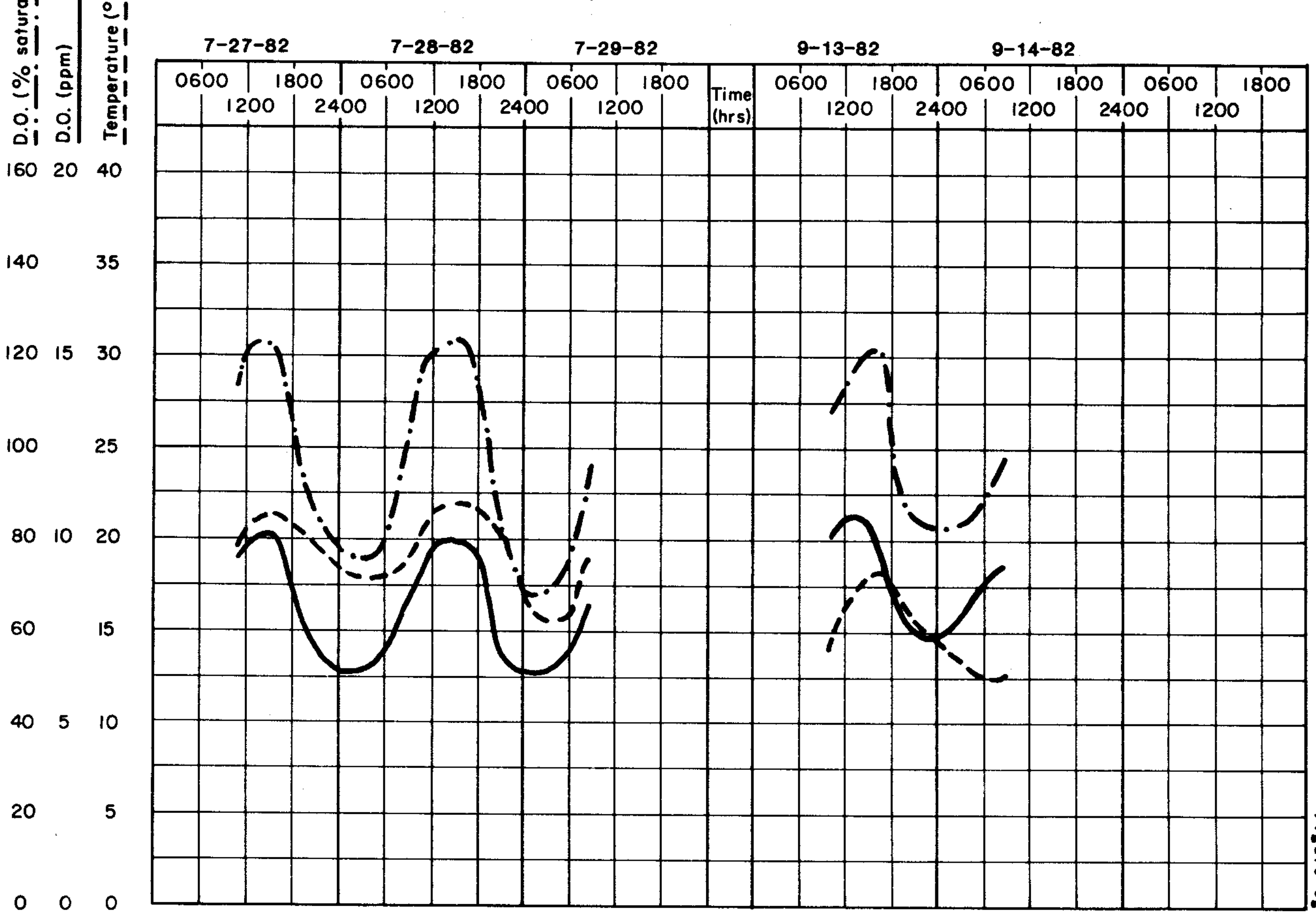

Figure 8g

Shasta River near Big Springs (F2-1380.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

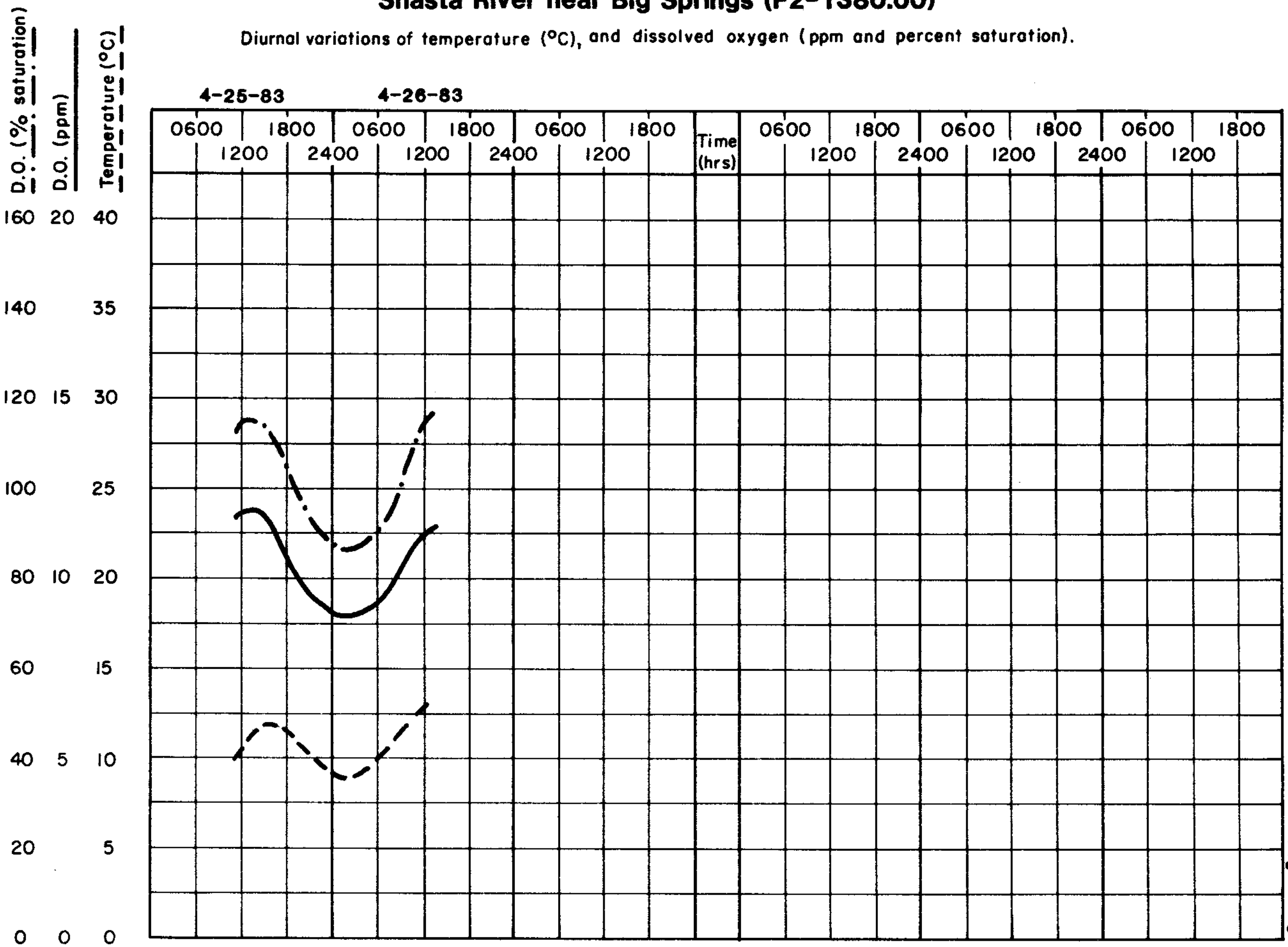

Figure 8g

Shasta River below Dwinnell Reservoir (F2-1399.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

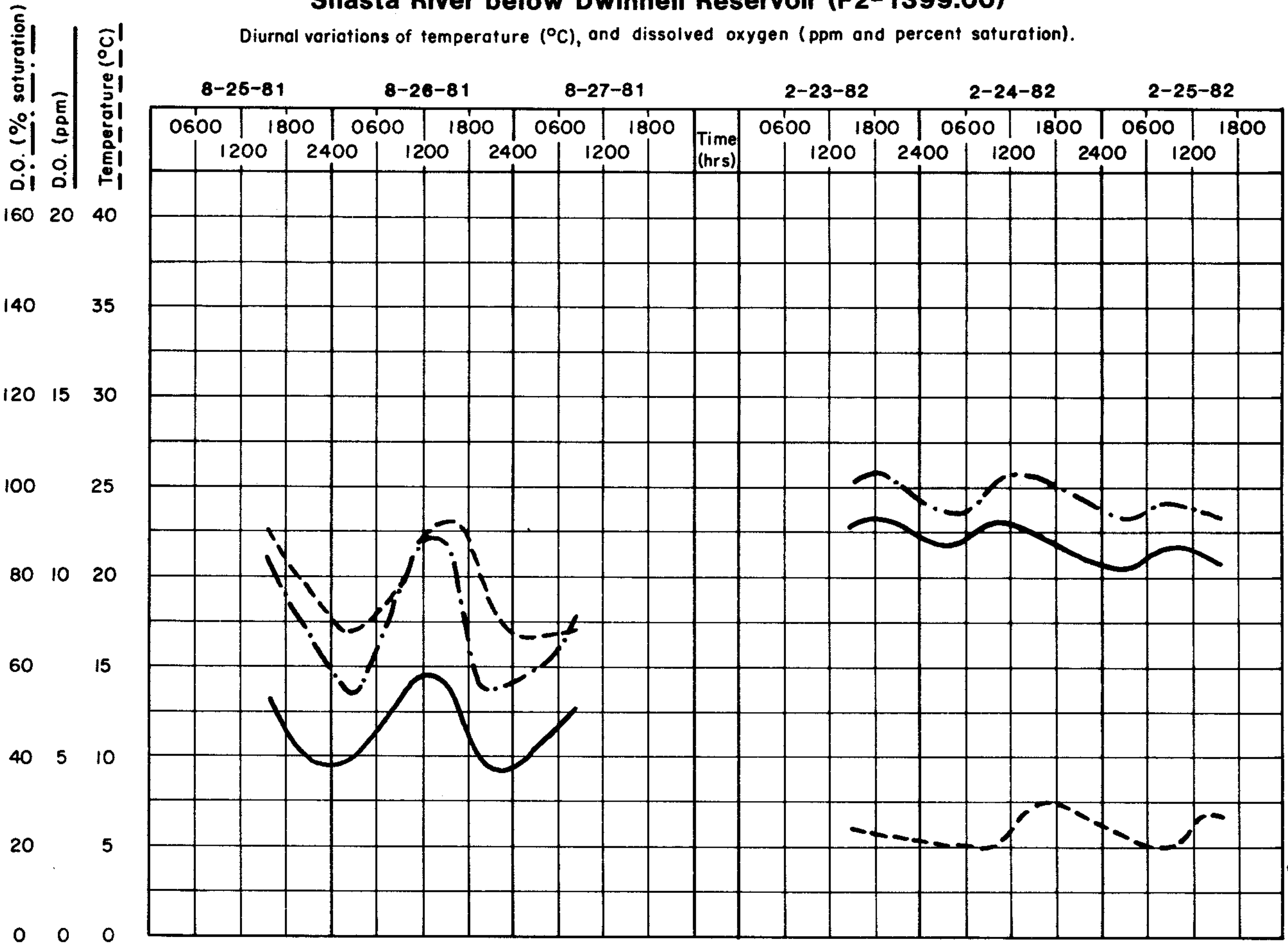

Figure 8h

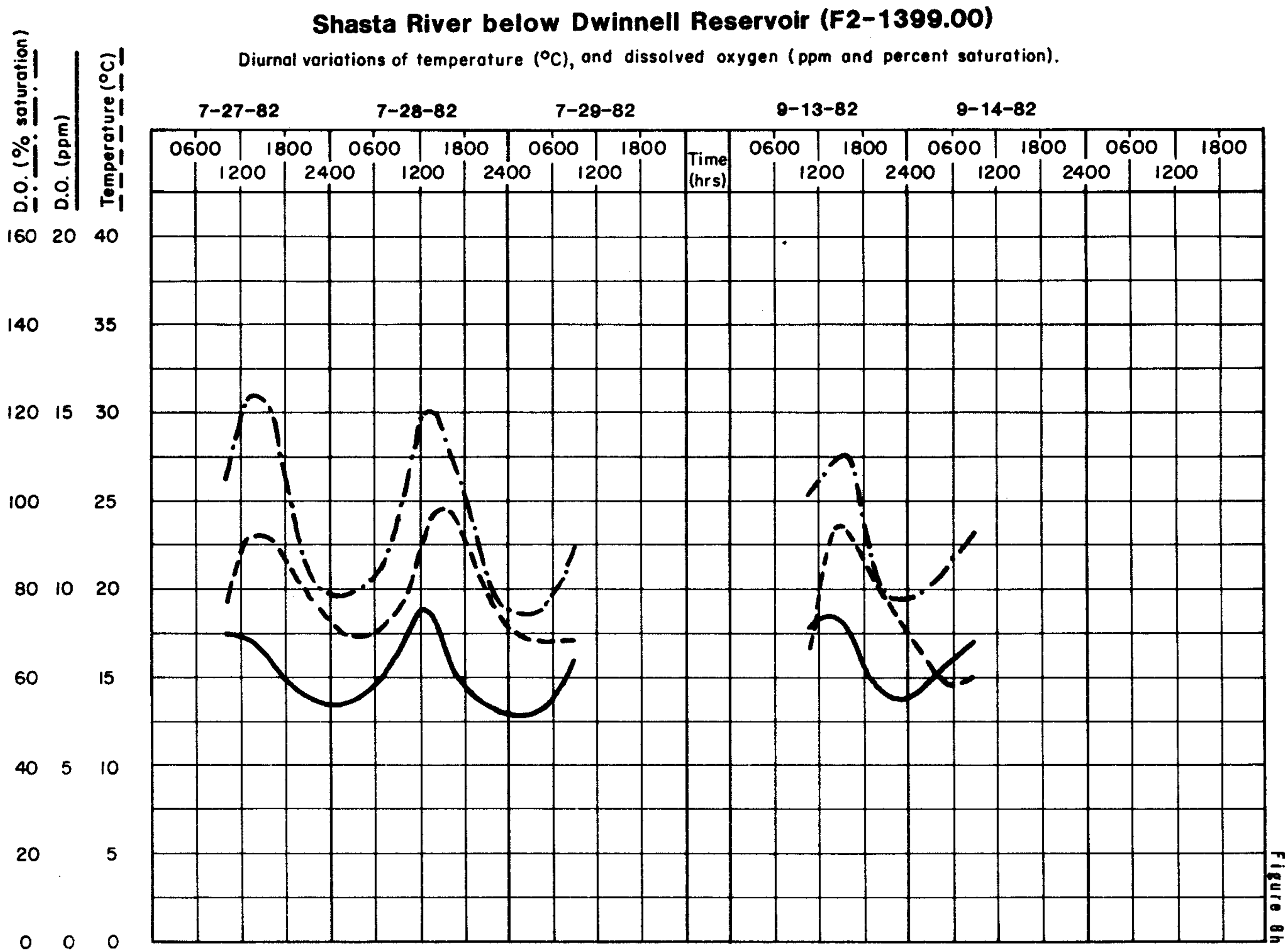
Shasta River below Dwinnell Reservoir (F2-1399.00)
Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).
D.O. (% saturation)
D.O. (ppm)
Temperature (°C)
7-27-82
7-28-82
7-29-82
9-13-82
9-14-82
Time (hrs)
0600
1200
1800
2400
160 20 40
140 35
120 15 30
100 25
80 10 20
60 15
40 5 10
20 5
0 0 0

Figure 8h

Shasta River below Dwinnell Reservoir (F2-1399.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

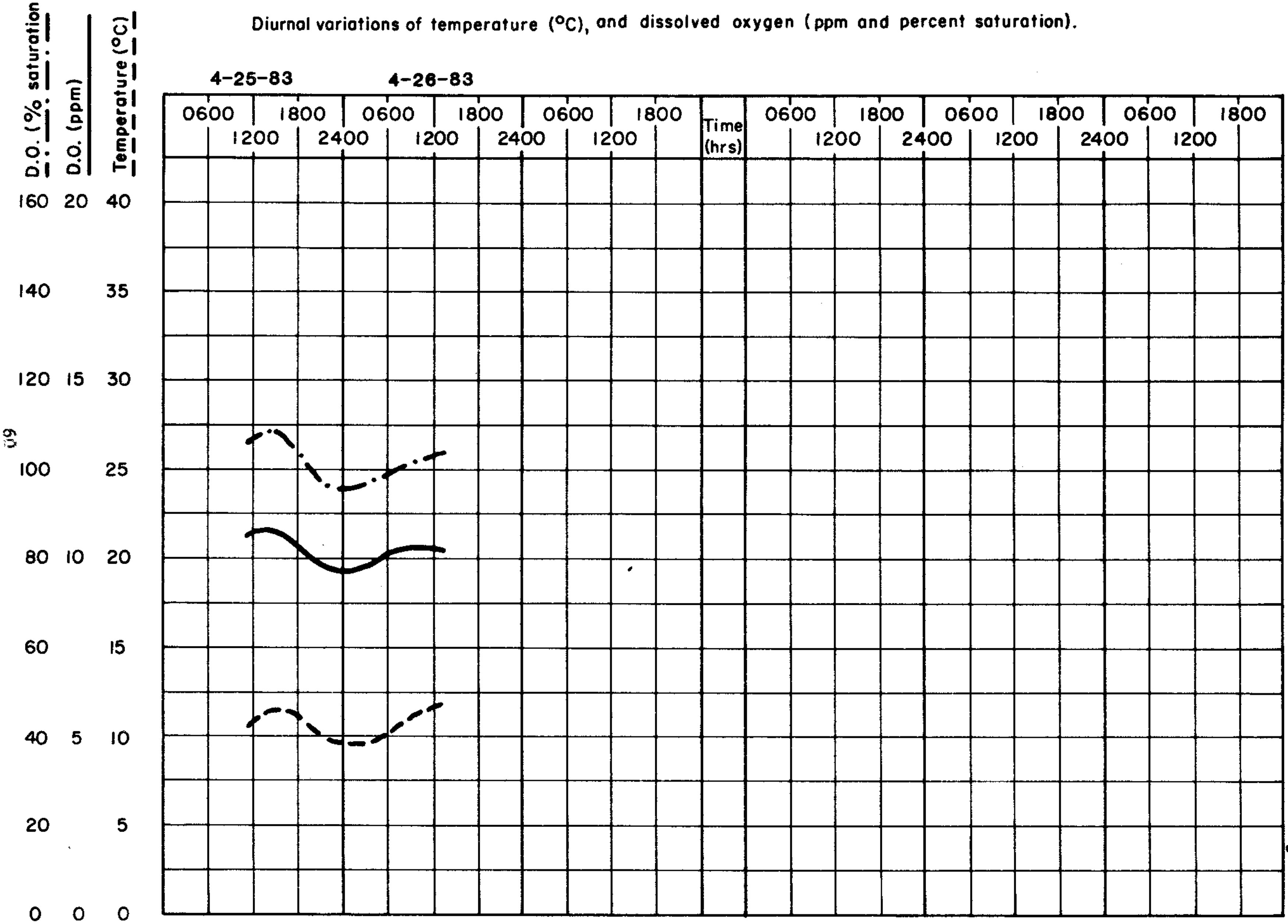

Figure 8h

Scott River at Mouth (F2-5000.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

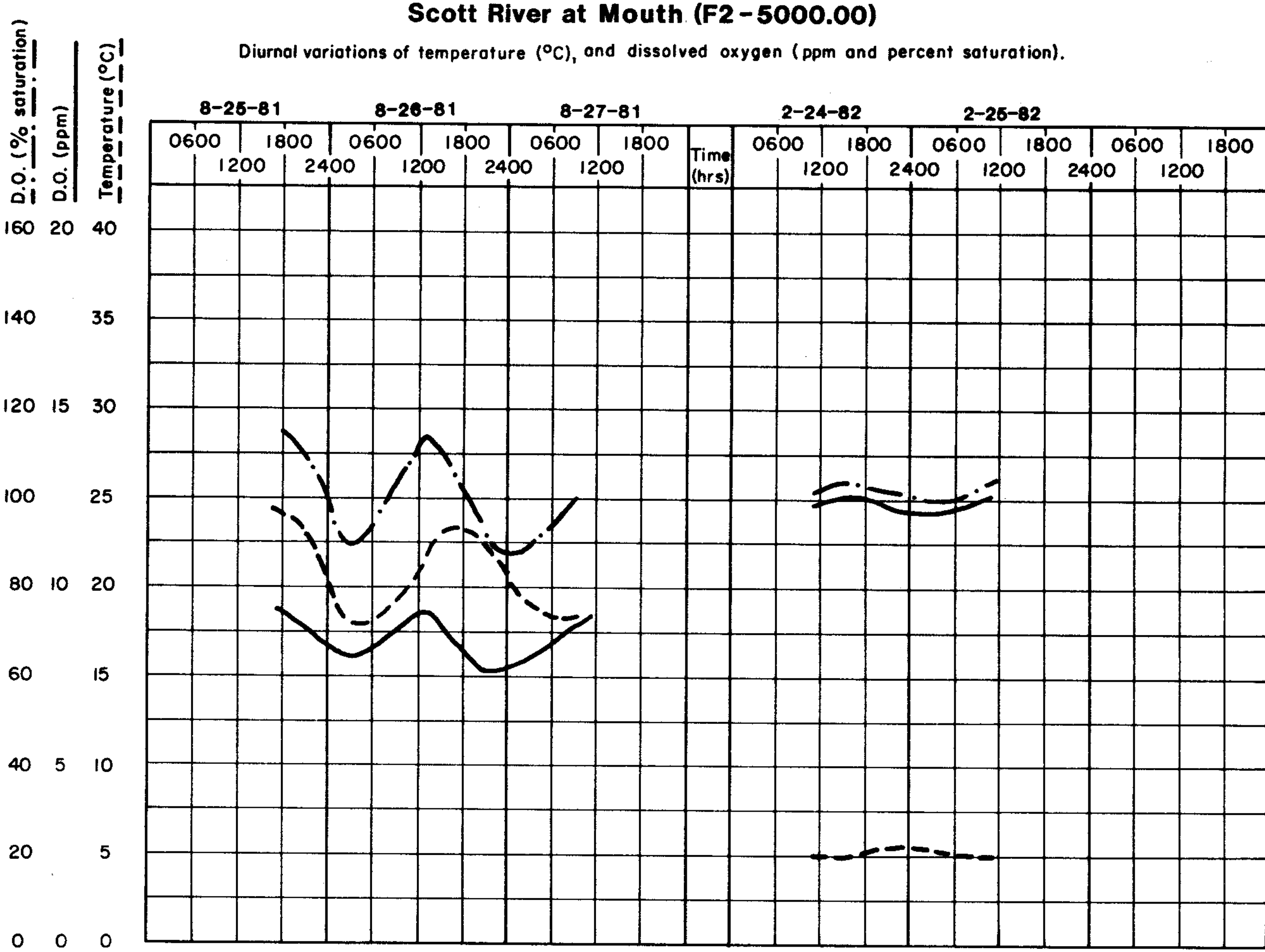

Figure 9a

Scott River at Mouth (F2-5000.00)

Diurnal variations of temperature (°C), and dissolved oxygen (ppm and percent saturation).

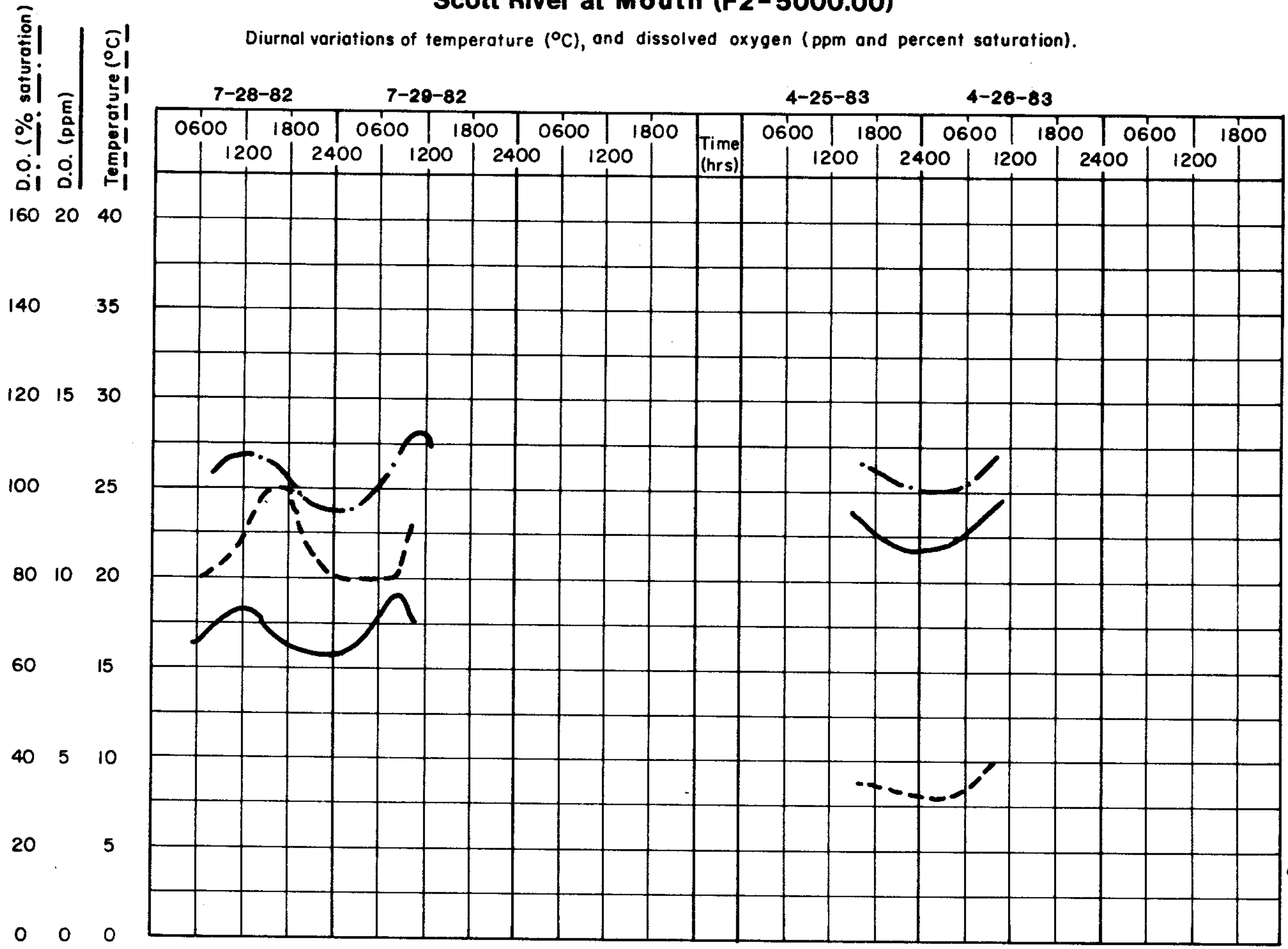

Figure 9a

In the upper reaches of the Shasta River, high summer temperatures between 22° to 28° C were observed, with temperature variations that ranged from 4° to 8° C (Figure 8). February diurnal temperature variations ranged from 2° to 4° C. At station F2-1050.00 near the mouth of Shasta River, the maximum temperature observed in July reached 29.5° C, with a temperature variation of 8° C. During the February diel, the maximum water temperature dropped to 7° C and diel variations were less than 3° C.

The high July water temperatures and associated large diurnal fluctuations in the Shasta River system could be stressful to temperature-sensitive aquatic organisms and probably make this river system unsuitable for some. These higher temperature waters are, however, more desirable for most irrigation uses.

In the Scott River at station F2-5000.00, high summer temperatures ranged to about 25° C while winter lows were about 5° C (Figure 9). Summer diel variation was as great as 6° C.

Turbidity

Turbidity patterns in the study reach of the Klamath River are similar to those found in other rivers of Northern California in that the turbidity levels tend to increase with flow and increase in a downstream direction. In the Klamath, this pattern is also apparent but only through station F3-1470.00 near Hamburg. The station downstream near Seiad Valley (F3-1430.00) has less turbidity. This is mainly the result of inflowing tributaries such as the Scott River that are clear under normal flow conditions.

Highest turbidities usually occur during the high flows of January through April. Table 3 shows a summary of turbidity measurements at key stations where long-term monthly data were available. These data represent turbidity values from 1973 through 1983.

At these levels of turbidity, the Klamath River waters often appear turbid and usually have a brownish gray organic color, probably due to the presence of humic materials.

Suspended Solids

Suspended solids is that portion of the total solids content that can be separated from a sample by filtration, and can consist of both settleable and nonsettleable matter. These solids, as well as any nonfilterable colloidal solids directly affect turbidity by scattering or absorbing light which can greatly reduce the light transmitting properties in water. The suspended solids in surface waters normally contain both mineral and organic matter. The organic fraction, referred to as volatile suspended solids, is determined by oxidation under high temperature conditions. All classifications of the total solids found to exist in source waters are reported as concentrations in milligrams per liter.

Historic data of suspended solids concentrations in the Klamath River system is unavailable, however samples collected and analysed during the study period indicate the great variation that exists in these waters. The median

Table 3. Turbidities in the Klamath River System
(1973-1983)

	Nephelometric Turbidity Units		
	Minimum	Median	Maximum
Klamath River below Iron Gate Dam (F3-1599.01)	0	3	42 1/
Shasta River near Yreka (F2-1050.00)	0	2	300 2/
Klamath River above Hamburg Reservoir Site (F3-1470.00)	0	5	200
Scott River near Fort Jones (F2-5250.00)	0	2	220
Klamath River near Seiad Valley (F3-1430.00)	0	4	170 3/

1/ Exceeded twice since 1962 (50 & 1000)
2/ Exceeded once since 1950 (400)
3/ Exceeded once since 1958 (210)

concentration found in the Klamath River between Iron Gate Dam and Hamburg was about 8 mg/L and values varied from 0 mg/L in late summer to a high of 36 mg/L during the early spring high runoff conditions. During the same period, the median concentration of volatile suspended solids was 2 mg/L with a fluctuation of 0 mg/L to a high of 5 mg/L. In the Shasta River system, the median concentration of suspended solids was about 6 mg/L with values ranging from a low of 0 mg/L to a high of 49 mg/L. The volatile suspended solids, with a median value of 2 mg/L, ranged from 0 mg/L to a high of 8 mg/L. The magnitude of these suspended solids appears consistent with other Northern California rivers with relatively high concentrations during winter runoff conditions and lower values during the lowflow summer months. The concentrations of volatile suspended solids do indicate a relatively high percentage of organic material.

Biological Characteristics

Numerous aquatic plants and animals inhabit the waters and riparian zones of the Shasta and Klamath Rivers, and many influence the water quality. Deer or deer tracks were seen in the vicinity of all stations. Cattle and horses use the Shasta River extensively and commonly have access to the Klamath River. These animals often contribute to the turbidity and add nutrients to the rivers.

Salmon, trout and some warmwater fish are found in the Shasta and Klamath Rivers. Both rivers play an important role in providing habitat for spawning salmon and steelhead trout. Vascular aquatic plants are present along much of the river edges. Many of these plants are bottom-attached species that bring nutrients back into the water system from the sediments. In many reaches of the rivers, periphyton, which often includes streamers of filamentous algae, covers the river bottom. This has resulted in slippery footing conditions which are hazardous to fisherman and other recreationist.

The detailed results of benthic organism sampling and related information on sampling methods and evaluations are included in Appendix E. Benthic samples indicate that portions of both the Shasta and Klamath Rivers contain stressed ecosystems. This is indicated by low diversities and equitability factors. The seasonal variation and assemblage of organisms indicate that a major stress is caused by the large flow variations that occur during the winter storms and spring snowmelt period. There are also indications that temperature and/or dissolved oxygen levels have also caused stress at some stations.

In the benthic macroinvertebrate samples collected from the study area, the organism densities found were characteristic of river systems with moderate to high levels of productivity. The abundance and frequent occurrence of scrapers and collectors also indicated high level of primary productivity within the systems.

Nutrient Balance

Although most of the nutrients present in the Klamath River originate from upstream sources, additional nutrient sources within the drainage basin add significant amounts to the river each year. These nutrients are contributed by atmospheric sources, natural surface runoff, ground water accretion, wildlife, domestic wastes, recycling from lake sediments and other sources.

Since nitrogen and phosphorus are considered to be the two major limiting nutrients for phytoplankton production, it would appear desirable to define the magnitude of these nutrients moving through the river system. To make such a balance requires knowledge of the nutrient sources, the quantities from each source, what happens to the nutrients within the river and their final disposition.

Although data limitations make it impossible to develop a detailed nutrient balance, even an approximation of the mass flow of nutrients through the system should be useful in identifying the major sources. In this study the balance included nutrient inputs to the river from the Klamath River below Iron Gate Dam, Shasta and Scott Rivers, and the minor tributaries. The downstream Klamath River station near Seiad Valley is the control station whereby outflowing nutrients were accounted for, thus allowing the calculation of any nutrient gain or loss in the river system. An estimate of the monthly variation in nitrogen and phosphorus concentrations was made, and applied to the corresponding monthly flows. The resultant monthly tonnage values were converted to annual values for the six-year period from 1978 through 1983. These estimated nitrogen and phosphorus values entering and leaving, and net changes found to exist in the river system, are shown in Table 4.

Table 4. Klamath River Nutrient Balances

	Nitrogen (Tons)					
	1978	1979	1980	1981	1982	1983
Inflow*	3900	2500	3500	2700	6000	6300
Outflow	3500	2300	3400	3000	5600	6900
Net Change	-400	-200	-100	+300	-400	+600
	Phosphorus (Tons)					
Inflow*	410	280	380	340	620	770
Outflow	390	270	370	350	610	770
Net Change	-20	-10	-10	+10	-10	-

* The magnitude of the inflowing nutrient sources to the Klamath River, expressed in average percentages, are shown in Table 5.

Table 5. Klamath River Nutrient Sources

	Nitrogen (%)	Phosphorus (%)
Klamath River below Iron Gate Dam	79	68
Shasta River near Yreka	5	10
Scott River at Mouth	9	17
Minor Tributaries	7	5

The majority of the nutrients, nitrogen 79 percent and phosphorus 68 percent, present in the Klamath River originate from sources upstream of the study area. The nutrient balance for the Klamath River suggests that between 2,000 and 7,000 tons of total nitrogen move through the river system annually with a net change from -100 to +600 tons. These net changes appear to be reasonable considering the numerous physical and biochemical processes that can store in, remove from, or add nutrients to this river system.

Annual phosphorus loadings varied between 200 and 800 tons, with net changes from -10 to +10 tons. A phosphorus loss in a river system is generally associated with deposition in bottom sediments or uptake by biological organisms. A gain of phosphorus will often be the result of higher flows that resuspend sediments or increase biological release.

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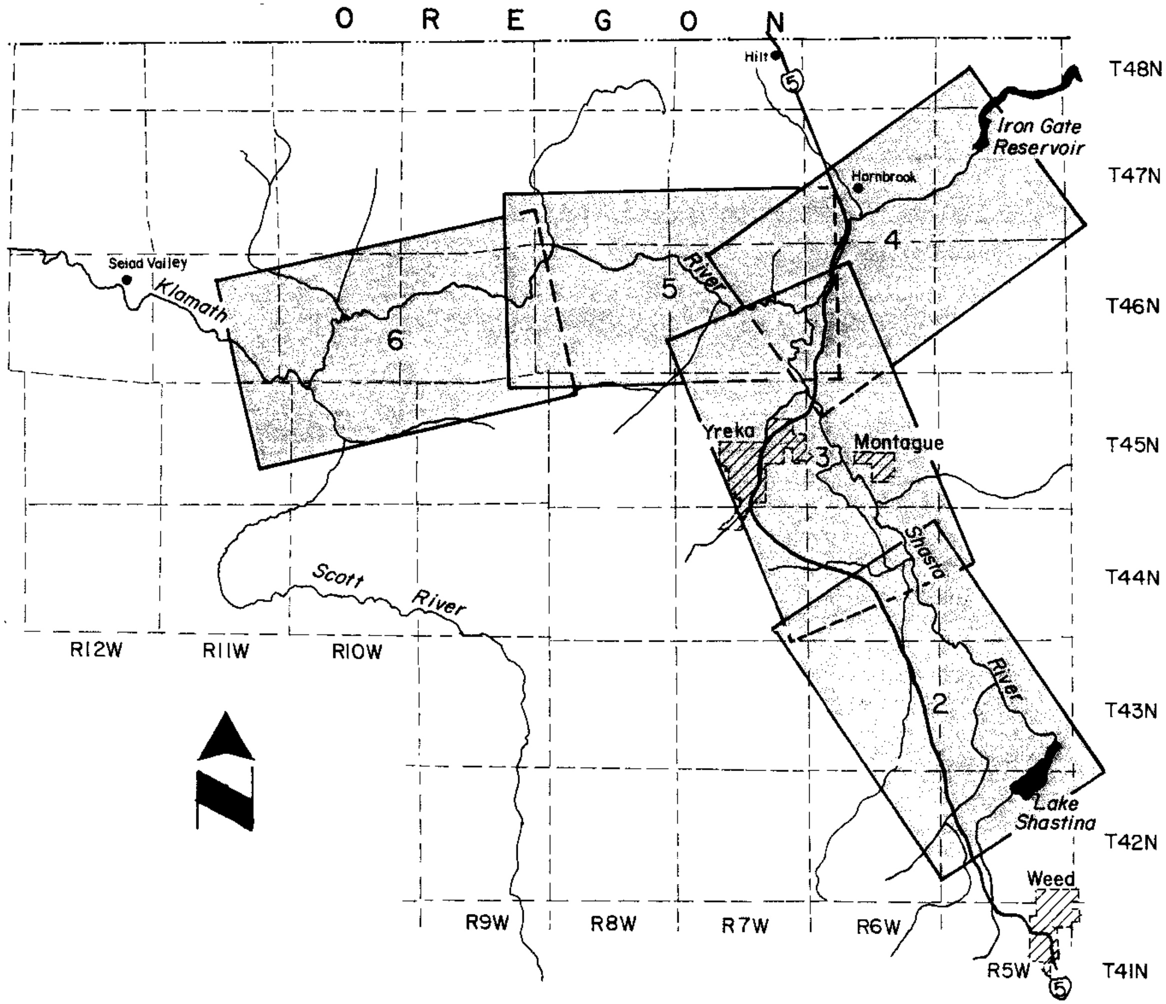
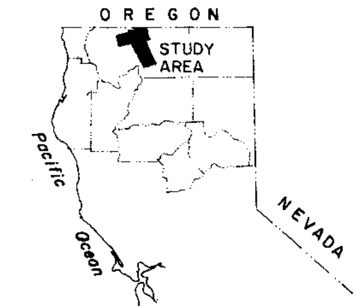




Location Map

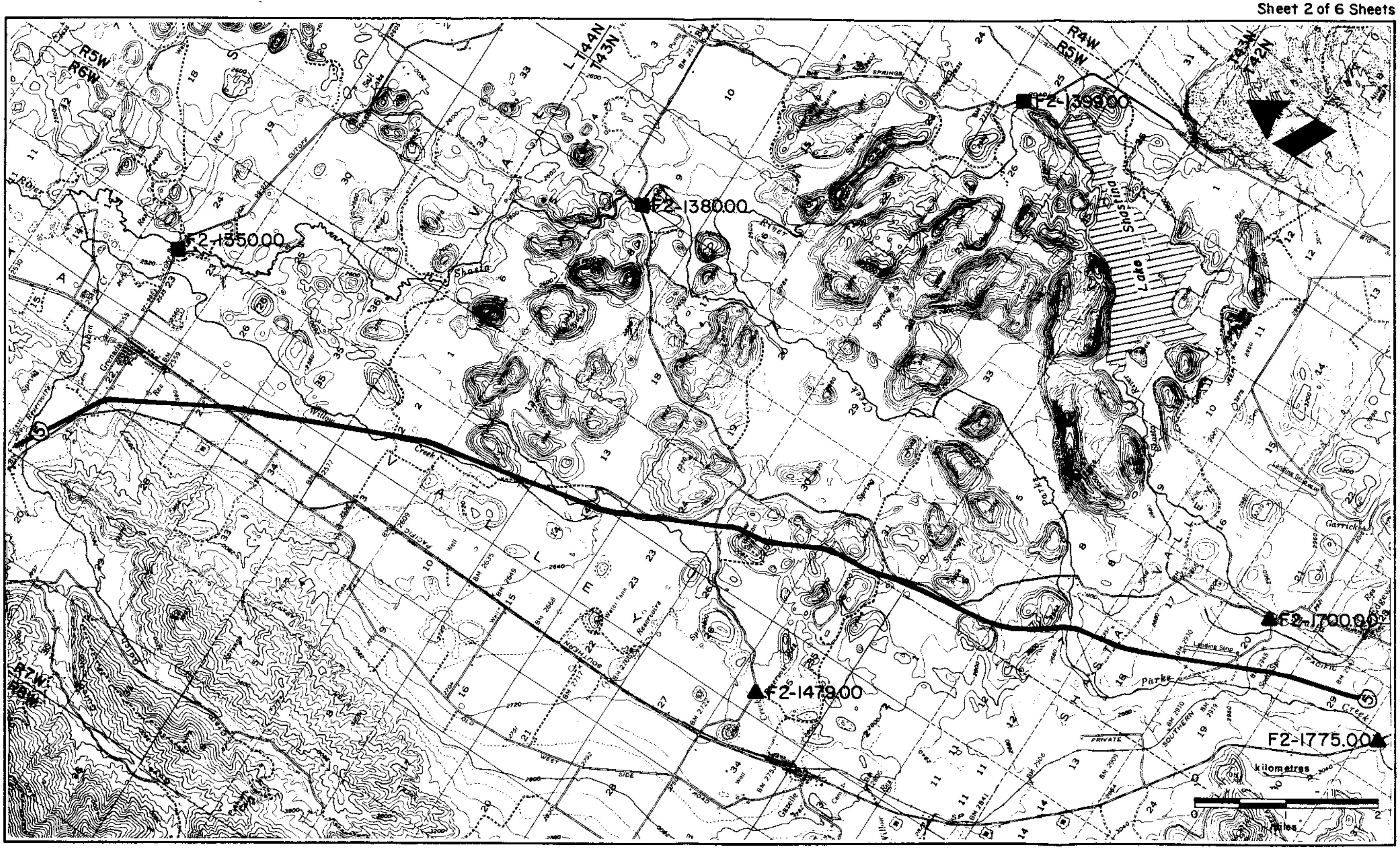
Legend

■ Study Sampling Stations

▲ Supplemental Stations

0 1 2 3 4 5 6
miles

Shasta/Klamath Rivers Water Quality Study 1986



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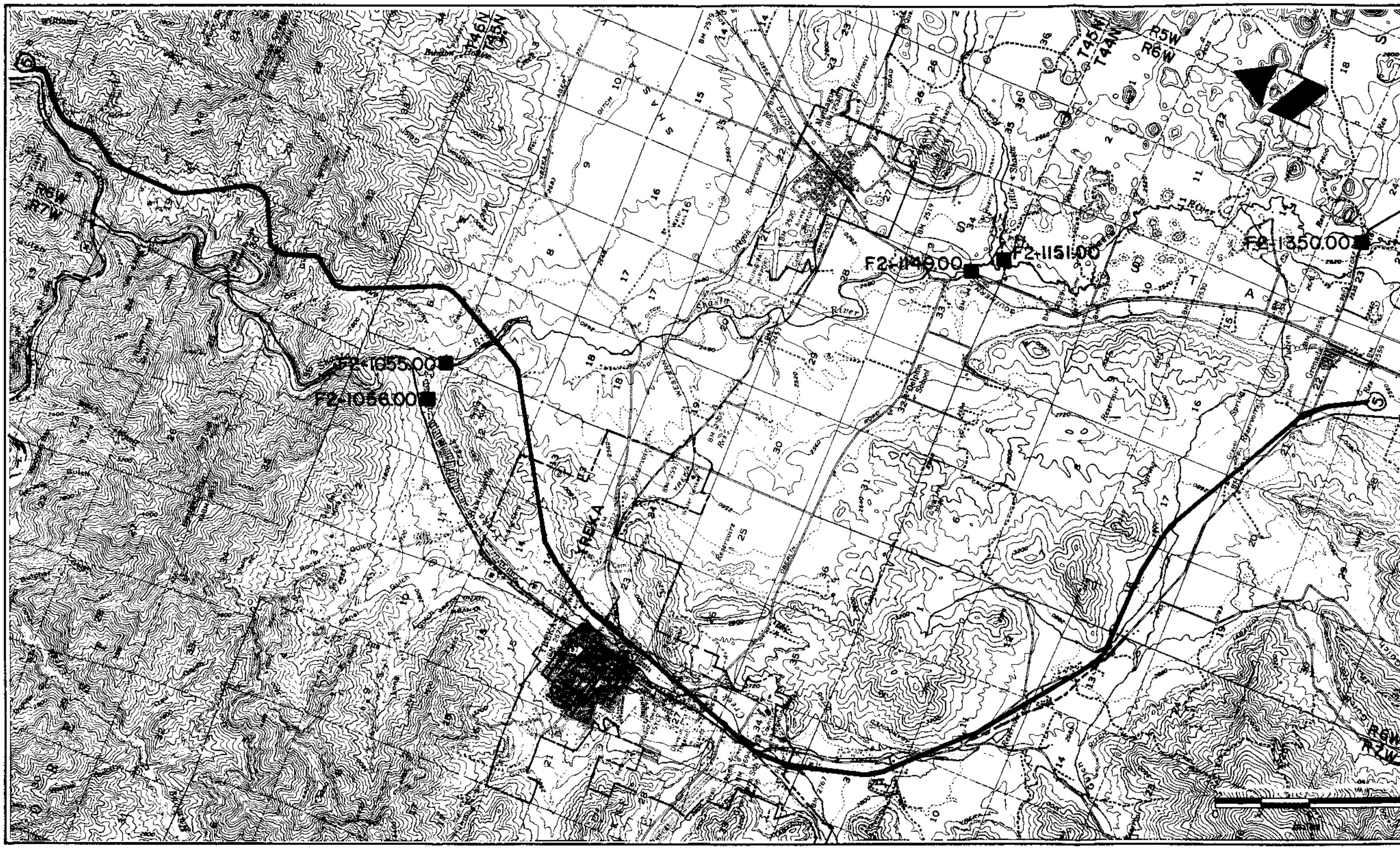

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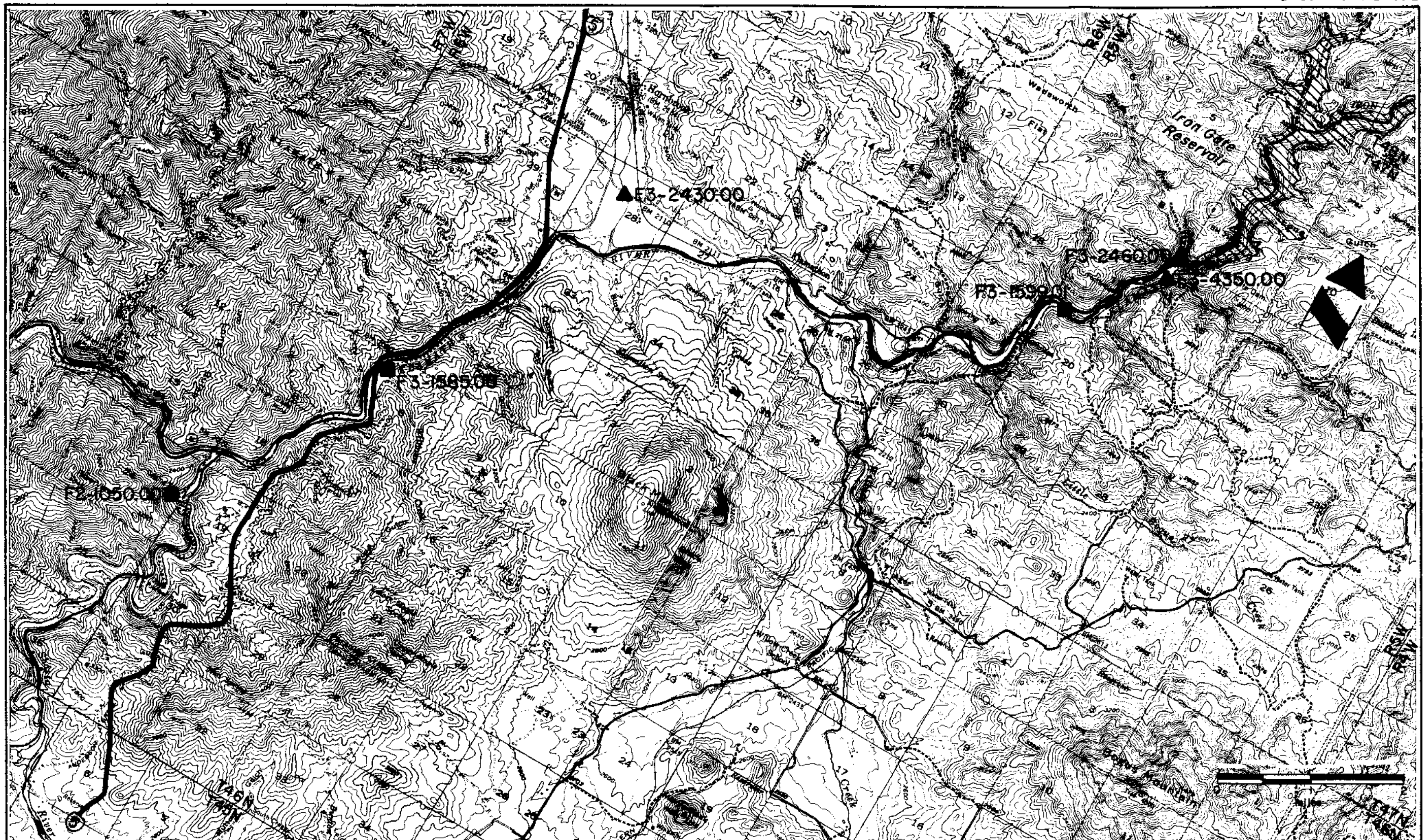

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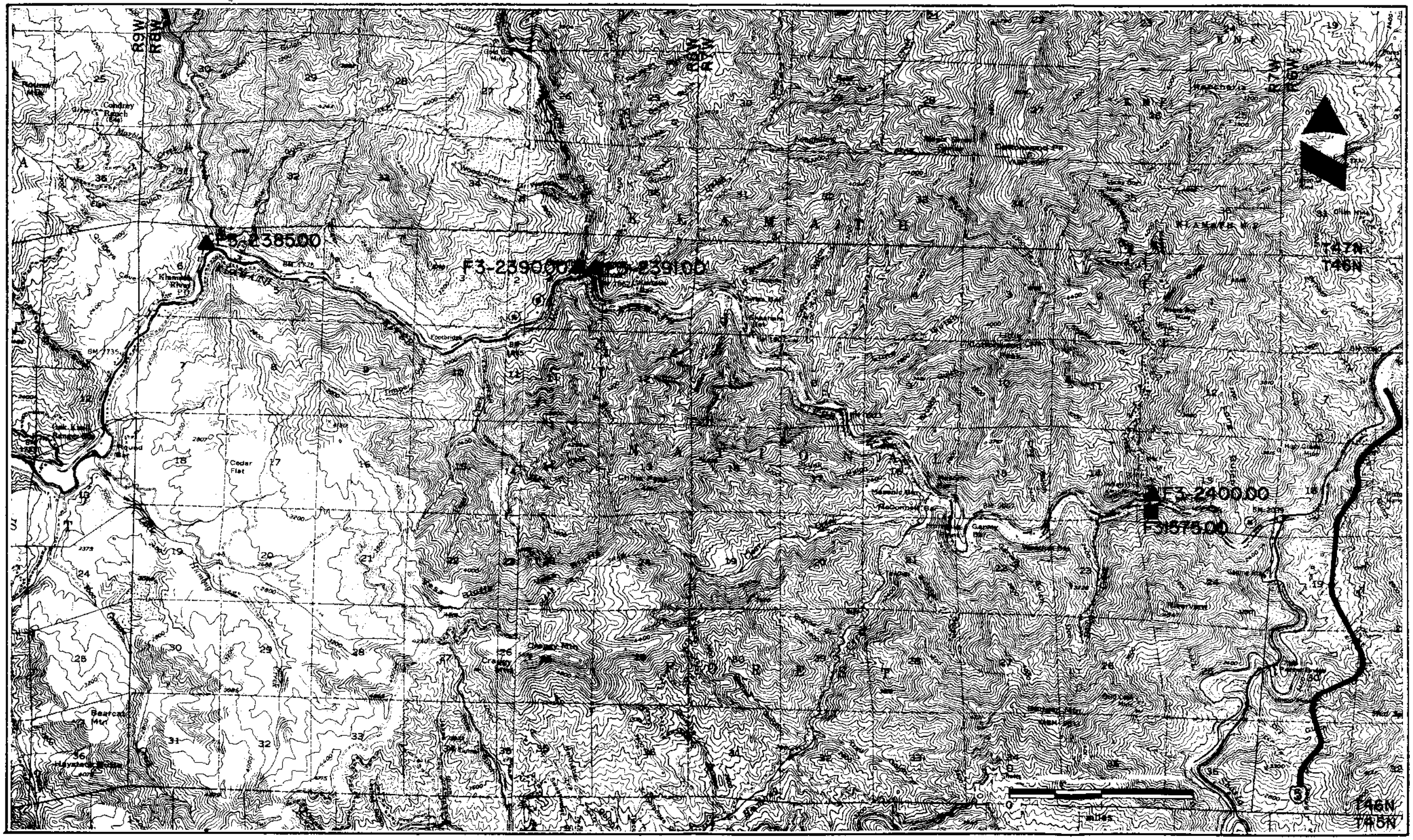

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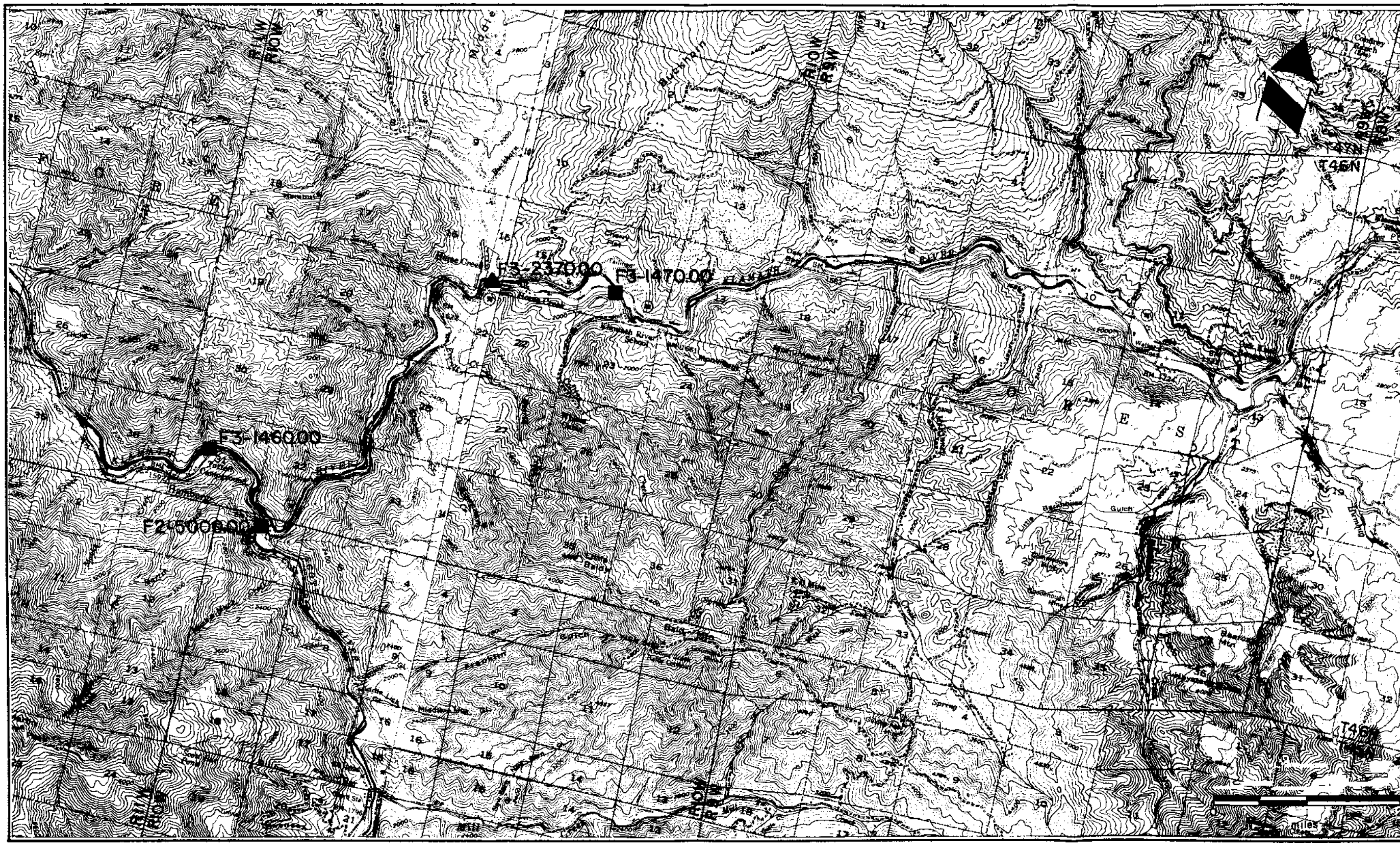

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