

VOLUME II-1
THE NATURAL ENVIRONMENT NEAR SAN ONOFRE
DRAFT FINAL REPORT 1987
PHYSICAL/CHEMICAL OCEANOGRAPHY PROGRAM
AT SONGS

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1. INTRODUCTION

A great part of MRC's program is to assess SONGS' effect on marine populations. This requires monitoring and study of the physical/chemical conditions off San Onofre in order to provide an explanation of the biological changes, natural or SONGS induced, in terms of observed physical changes and known biophysical mechanisms.

This report is oriented towards providing a review of the natural events which occurred during the period of the study. As will be shown here, there were changes in the natural environment from year to year. The changes are more pronounced during the El Nino period, August 1982 to July 1984, which brought continued high temperatures and depletion of nutrients to coastal water off San Onofre. The 1982-84 El Nino was also associated with severe winter storm waves which caused disturbance to the sea bottom. The 1982-84 El Nino is probably the largest major event during this study. Since El Nino is a very large-scale event, it has about the same overall effect on the entire area of the study.

Section 2 gives the geographic location of San Onofre, the description of the study site, and the location of the major kelp beds and creeks in the area. The data used in this report are discussed in Section 3.

Section 4 presents the oceanographic conditions off San Onofre from 1981-1986, to give an account of the natural events. It is intended to provide both overall interpretation of the events and enough detail to examine the physical/chemical conditions for comparison at specific times and places with the biological samplings.

A summary of the major oceanographic events between 1981 through 1986 is given in Section 5.

2. DESCRIPTION OF THE SITE

San Onofre Nuclear Power Station is located halfway between San Diego and Los Angeles at the edge of a roughly 6-10 kilometer wide continental shelf. Figure 2-1 shows a large regional map of the study site where San Onofre is at $117^{\circ} 33' 25''$ longitude and $33^{\circ} 22' 12''$ latitude.

Figure 2-2 is a more detailed map of the study region. It shows an area of 18 x 9 km at SONGS revealing the bathymetry and the location of the intakes and outfalls for the three units. All three intakes are located in about 8 meters of water, 3 meters off the bottom. Unit 1 uses a point discharge while Units 2 and 3 incorporate staged diffusers to disperse the once-through sea water used in the secondary cooling systems. Note the protrusion of San Mateo Point onto a locally narrowing shelf. This is the largest irregularity in the coastline and nearshore bathymetry for 10 km up or down the coast. San Onofre beach is indicated in Figure 2-2 as one of the possible areas of SONGS' impact. Figure 2-2 also shows the major cobble substrates which present areas of potential kelp habitation (see Vol IV-2 for more detail), and the major creeks in the study area.

The major kelp beds in the area are San Mateo kelp, San Onofre kelp and Barn kelp. These beds are primarily inhabited by the giant kelp Macrocystis pyrifera and provide a rich habitat for several species of fish, invertebrates and algae.

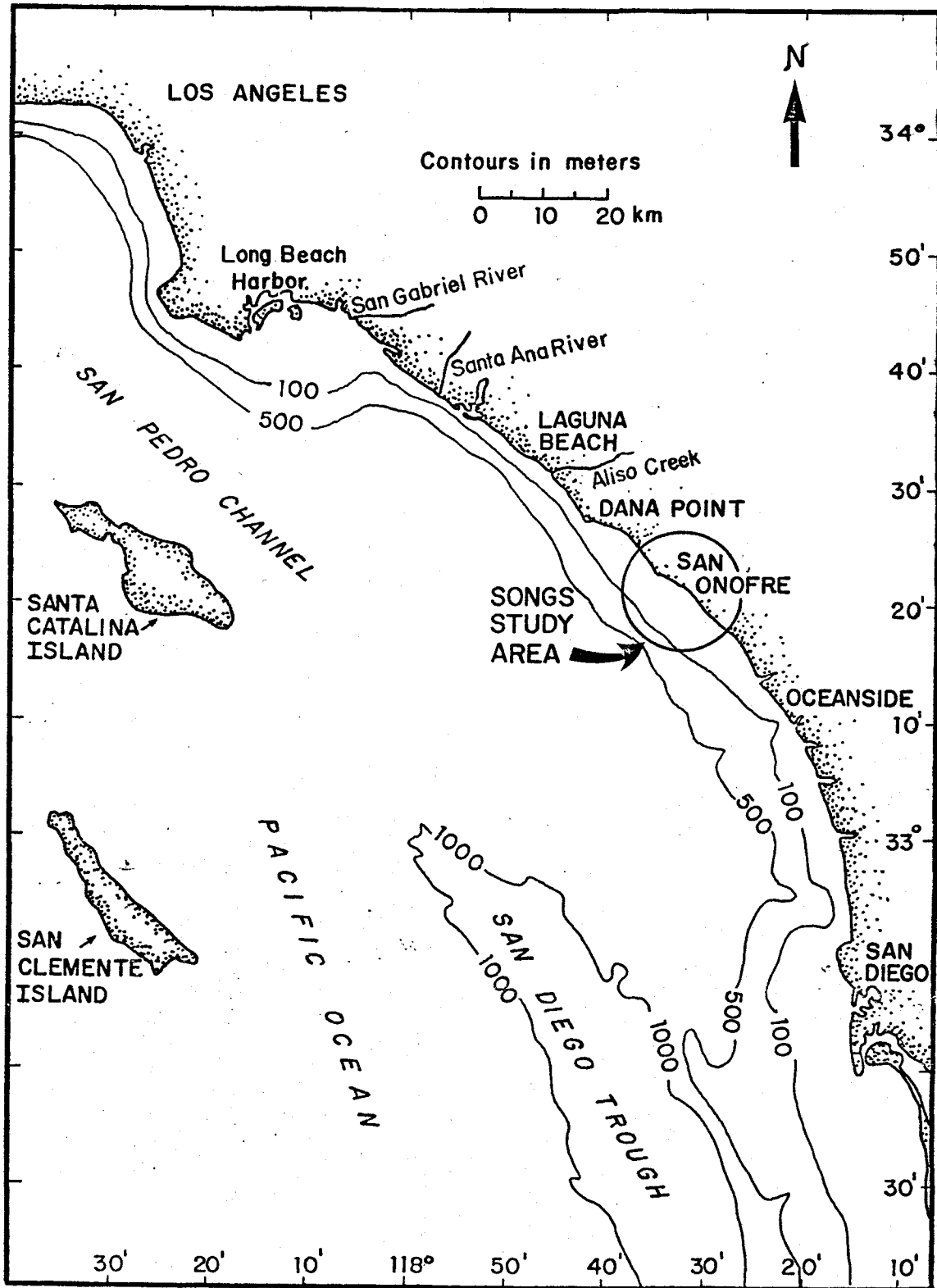
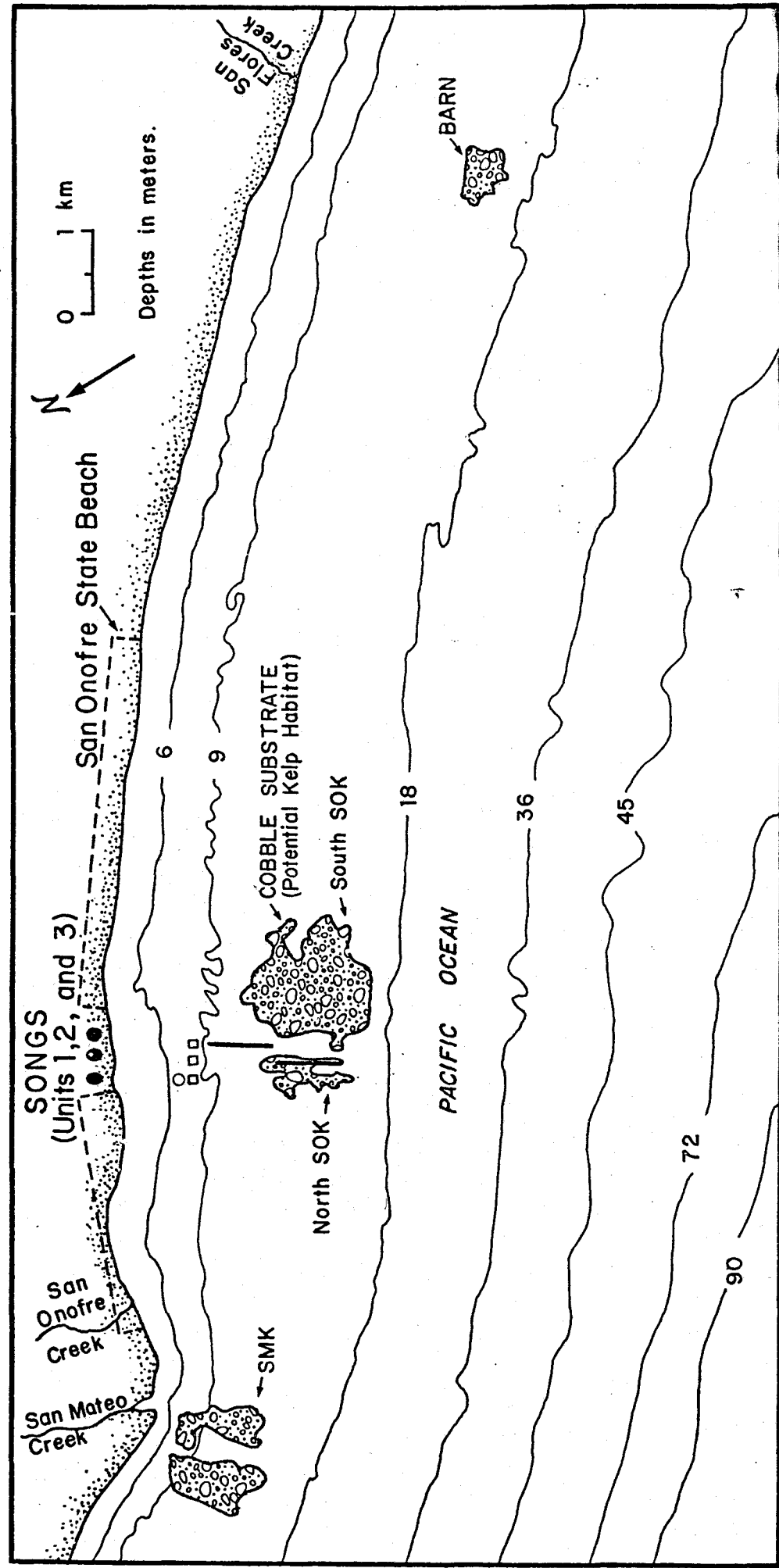


Figure 2-1. Regional map of the study site

Upcoast
Downcoast



□ = UNITS 1, 2, & 3 INTAKES
○ = UNIT 1 DISCHARGE
— = DIFFUSER LINES

Figure 2-2. Detailed map of the study site

For the analyses of the continuous data of temperature and irradiance measurements, we have chosen to show our results from stations SMK45 and SOK45. The latter station is constructed by averaging the hourly measurements from SOKU45 and SOKD45. This is designed to represent time series with as few data graphs as possible. SOKU45 and SOKD45 are located in the vicinity of the San Onofre kelp bed and SMK45 is located in the San Mateo kelp bed. Both stations are in a total water depth of 14 meters.

4. OCEANOGRAPHIC CONDITIONS

4.1. Temperature and Nutrients

The coastal waters off San Onofre over the last ten years have been temperate: surface temperature in late summer is typically near 20°C (68°F), with a maximum near 25°C (77°F); winter surface temperature is typically near 15°C (57°F). At a depth of 14 m, temperatures around 15°C are typically found in any season. Table 4-1 shows the basic statistics of bottom temperature at stations SMK45 and SOK45 for various seasons and years. This table gives the mean, standard deviation (STD), maximum (max), minimum (min) temperatures, and number of days used in the calculations (N).

Apart from its direct effect on biochemical processes, temperature has strong indirect influence on the conditions of life in the sea. One of the most important is the effect of temperature stratification on the availability of nutrients in shallow coastal waters. The density of the ocean waters near SONGS varies mainly because of varying temperature. Vertical stratification of density, with warmer waters overlying colder, strongly inhibits vertical mixing because of the energy required to overcome the force of buoyancy. A large part of the dissolved nutrients used by plant life in the nearshore waters comes from a reservoir of nitrate and phosphate in deep waters, which only becomes available in shallow waters through vertical mixing or mass movements. Since plant life in the sea depends largely on bringing together light from above and dissolved nutrients from below, the limitation of vertical mixing by stratification of temperature may be critical.

Off San Onofre, the concentration of nitrate is low in waters greater than 14°C, and increases rapidly with decreasing temperature below 14°C. The stratum in which nutrients increase rapidly with depth is called the nutricline. Taking nitrate as representative of other nutrients as well, the top of the nutricline near San Onofre is

TABLE 4-1

STATISTICS OF BOTTOM TEMPERATURE (C)

YEAR	SEASON	SMKH5				SOKH5					
		MEAN	STD	MAX	MIN	N	MEAN	STD	MAX	MIN	N
81-82	WINTER	14.7	1.2	17.9	12.5	142	14.5	1.1	18.4	12.9	140
82	SUMMER	14.5	1.9	19.9	11.6	128	15.1	2.0	20.5	11.8	183
82-83	WINTER	16.1	0.6	18.5	14.3	143	16.2	0.7	19.1	14.7	143
83	SUMMER	16.2	1.8	20.6	12.5	121	16.6	1.7	21.6	12.9	164
83-84	WINTER	16.1	2.0	20.9	12.8	182	16.1	2.0	20.9	13.4	181
84	SUMMER	16.8	1.7	23.4	12.8	162	17.3	2.0	23.1	12.0	175
84-85	WINTER	14.4	1.9	19.7	11.8	126	13.8	2.8	19.0	0.0	182
85	SUMMER	15.2	2.1	20.8	11.1	138	15.0	2.1	21.5	10.6	174
85-86	WINTER	14.9	1.0	18.1	12.7	176	15.3	1.3	19.3	13.5	181
86	SUMMER	14.0	1.7	18.3	10.7	180	14.6	2.2	20.5	11.1	183
86-87	WINTER	16.8	0.6	18.1	15.2	81	17.6	1.8	23.7	15.2	92

generally located close to the isothermal surface at 14°C, at whatever depth that may be. Figure 4-1 shows the relationship between nitrate and temperature. The theoretical relation of N-T is given by:

$$N = 4.065 \int^1 \operatorname{erfc} \left\{ (T-13.91)/1.16 \right\}$$

where $\int^1 \operatorname{erfc}$ is the first integral of the complementary error function. For further discussion on this relation, see Reitzel et al (1987, Vol. V-2).

The main agent of vertical mixing in the nearshore waters off San Onofre is the turbulence generated by wind stress on the surface and by bottom stress due to local currents. The main agent opposing vertical mixing is solar heating of the sea surface, setting up a density stratification that inhibits the vertical turbulence. Sometimes in mid winter the turbulence dominates and the nearshore water column is almost completely mixed, with the top only a small fraction of a degree Celsius warmer than the bottom. Commonly the top to-bottom difference in 14 m depth is about one degree in winter, rising in irregular steps during calm periods in spring to about five degrees in summer, and falling back in steps with autumn storms to its winter value.

Time histories of daily averages of surface and bottom temperatures are shown in Figures 4-2 and 4-3. They are plotted year by year, from 1981 through 1986, for the entire data set. These plots present daily means, from which the internal waves are effectively filtered out, and they show the detailed course of the onset and breakdown of stratification, upwelling and downwelling episodes, and the major changes in the El Nino years. As a useful rough index of nutrient availability in different seasons and years, the fraction of time below 14°C is a useful quantity to keep in mind while examining these histories.

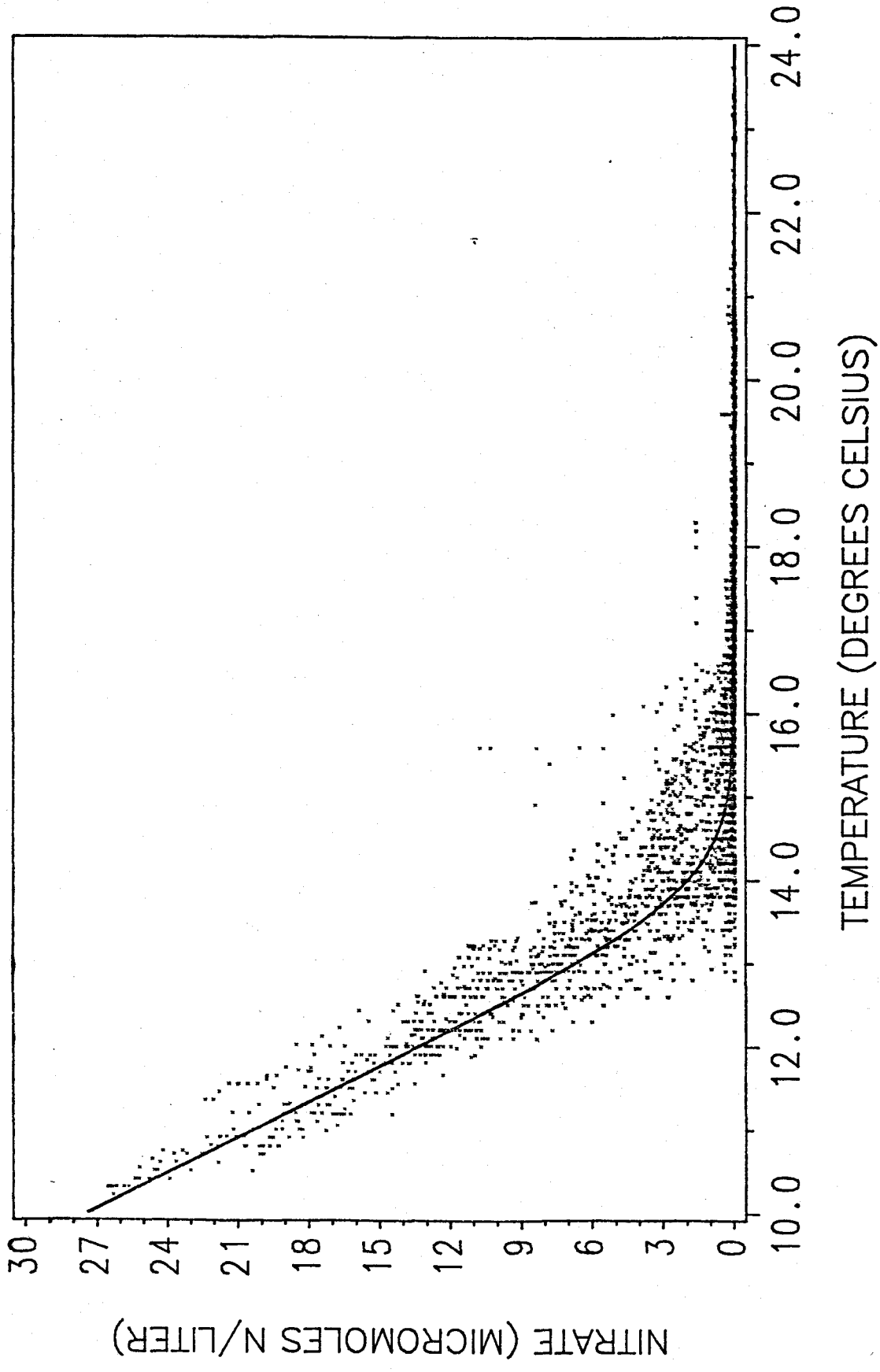


Figure 4-1. Measured nitrate versus temperature with the solid line representing the N - T relationship

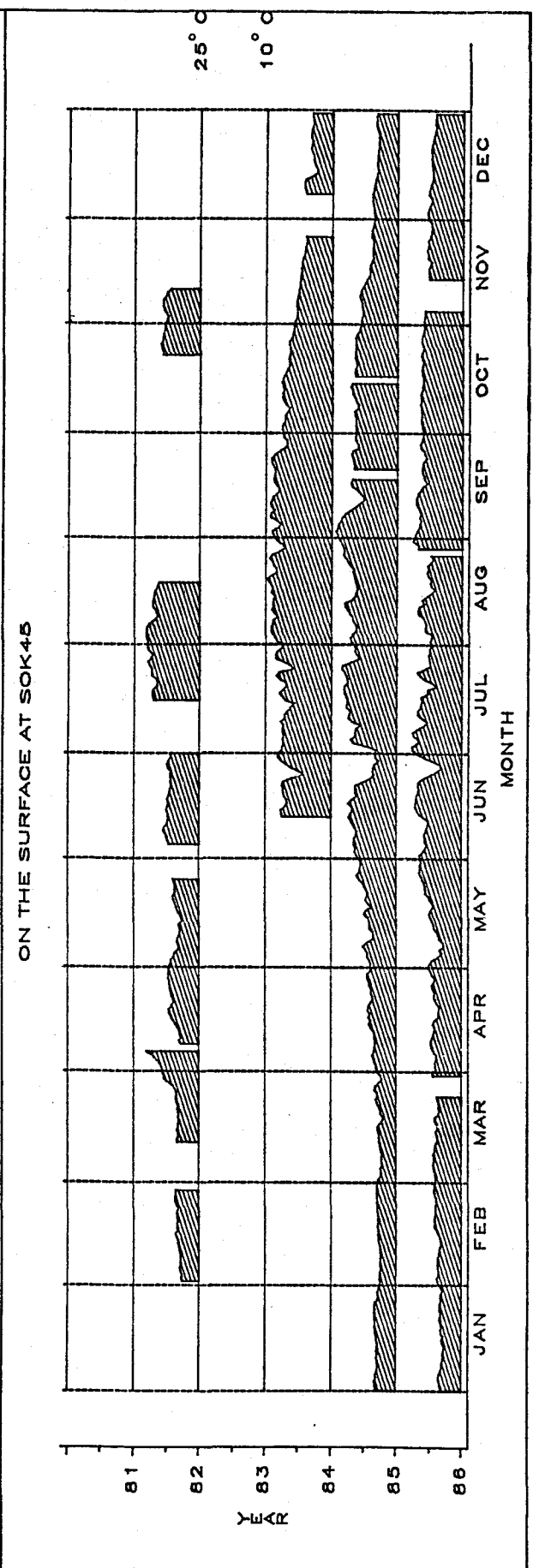
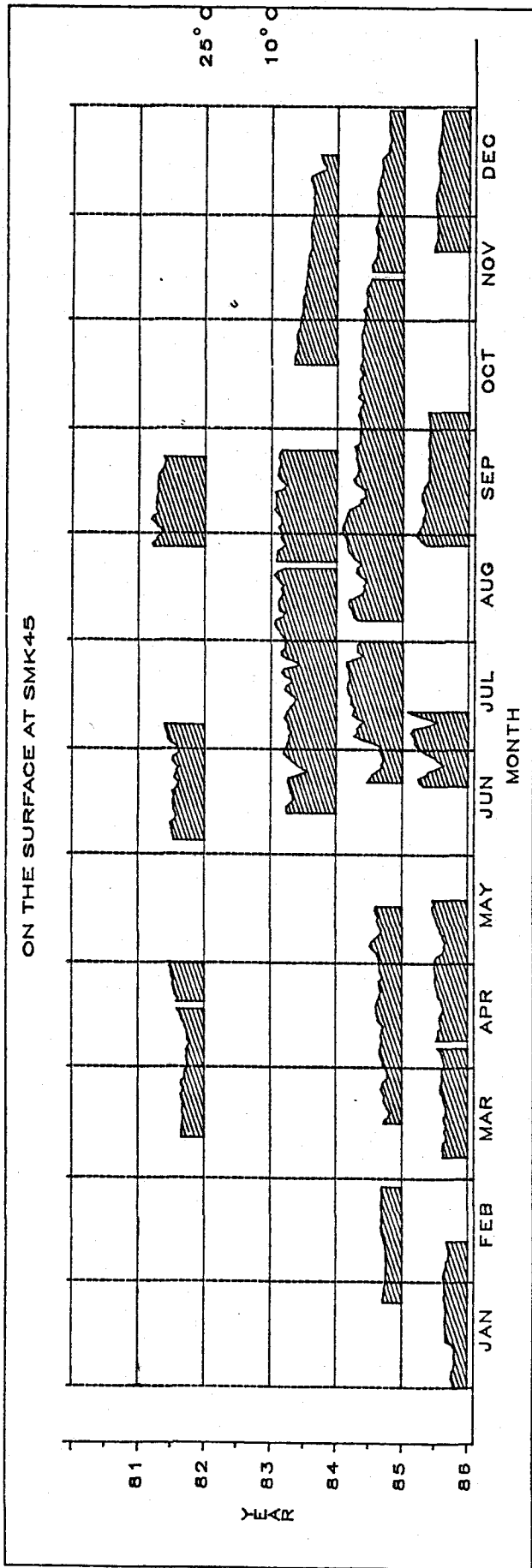


Figure 4-2: Time histories of daily mean surface temperatures

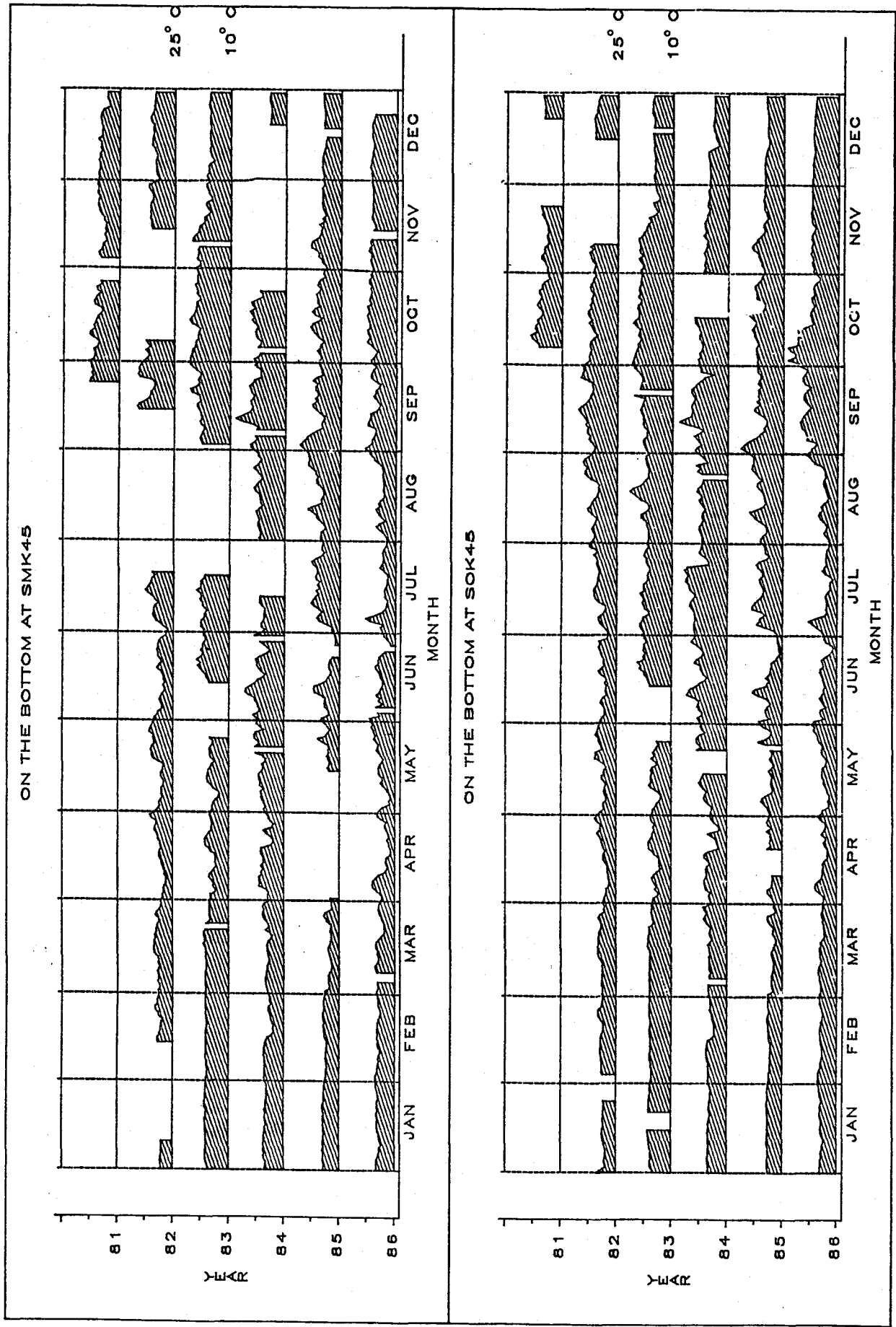


Figure 4-3. Time histories of daily mean bottom temperatures

The isopleths of temperature and nutrient versus depth at the inshore stations are displayed in Figures 4-4 and 4-5. They clearly show the distribution of these physical variables with depth. The change in the difference between surface and bottom temperature (ΔT) over various months can easily be seen in Figure 4-4.

4.1.1. Internal waves

Just as the interface between air and water at the sea surface is disturbed by waves, so are internal interfaces between density strata in the water column. More complicated but essentially similar waves occur in an overall density gradient without sharp interfaces. Internal waves off San Onofre may be as much as a few meters high, comparable to surface waves, but they have much smaller wave velocities (on the order of 10 cm/sec) and much longer periods, ranging from tens of minutes up to tidal periods of 1/2 day and one day. The most important are the tidal internal waves, which originate at the shelf break and advance toward the shore; these are active in summer when stratification is greatest.

As a result of internal waves, vertical profiles of water properties can change significantly from hour to hour; this should be kept in mind in interpreting measurements. Internal waves in nearshore waters can periodically raise the nutricline a few meters above its mean level, bringing nutrients closer to shore than they would otherwise reach. High internal waves can also break as they approach the shore, contributing to nearshore vertical mixing.

4.1.2. Upwellings and Downwellings

The velocities of currents near the shore off San Onofre, in total water depths of 20 m or less, are mainly controlled by a balance of bottom stress against surface slope or wind stress; as a result, velocities generally fall off with depth and approach zero near the bottom. The rotation of the earth accelerates moving water to the

ISOPLETHS OF TEMPERATURE (°C) - Inshore Stations

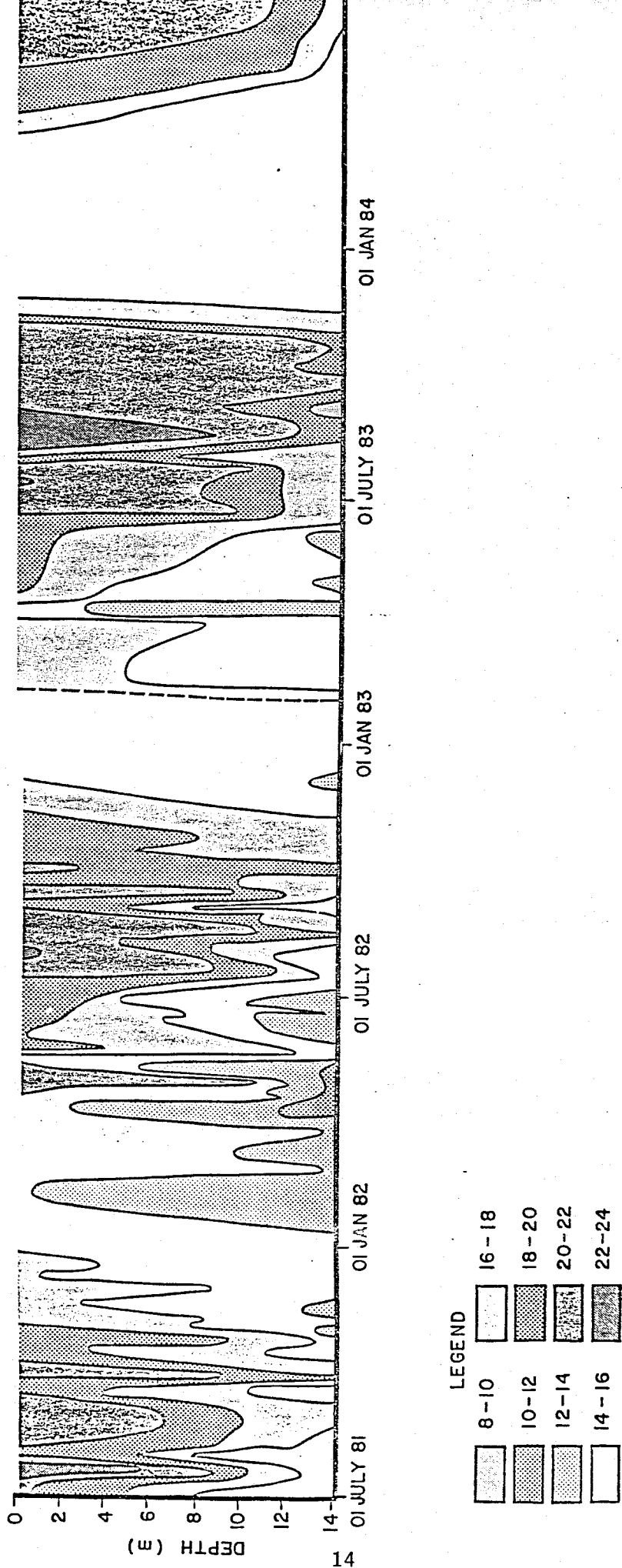


Figure 4-4. Isopleths of (NO₃+NO₂) versus depth over time. Data collected from stations at water depth less than 30 m. Units of (NO₃+NO₂) in micro moles/liter

ISOPLETHS OF NO₃ & NO₂ — Inshore Stations

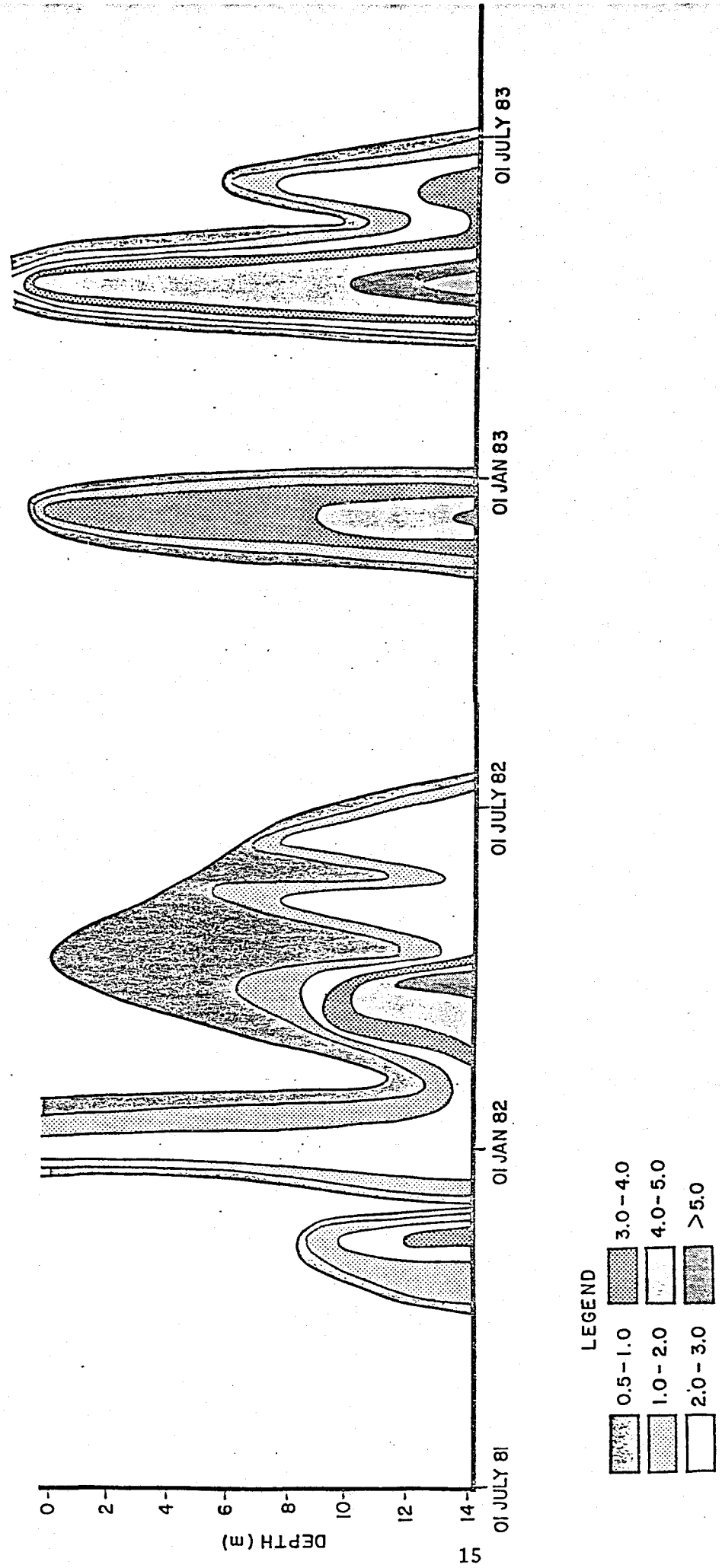


Figure 4-5. Isopleths of temperature versus depth over time. Data collected from stations at water depth less than 30 m.

right of its path in proportion to its velocity. The faster moving upper layers of a downcoast current will be more strongly accelerated offshore than the lower layers, producing an offshore flow of surface water which is replaced by an onshore flow of deeper water. This circulation would continue in uniform water, but when temperature and density are stratified a new balance can be struck with nearshore water colder than the water offshore at the same depth. Events of this sort are called upwellings, and are a principal means by which nutrients are brought into shallow nearshore waters. Events of the opposite kind, with upcoast currents leading to an accumulation of warm surface water near the shore, are called downwellings, and deprive the nearshore waters of nutrients. Major events take time to develop, and do not track current fluctuations faster than a day or two; the larger events generally do not last more than a week or ten days.

Upwellings off San Onofre become noticeable with the onset of stratification in March or April, as solar heating of the sea (including photosynthetic radiation) increases from its winter minimum. Upwellings that come close to the surface in shallow water may continue to occur through mid July, the season of maximum insolation, but are rare in late summer because strong downcoast winds are less frequent and the thicker layer of warm surface water is harder to break through. August and September, in fact, may be marked by nearshore downwellings in which the temperature at 14 m depth approaches 20°C.

4.1.3. El Nino

The occurrences of upwellings and downwellings are described above in very general terms because they may vary greatly from year to year, or over longer cycles of several years. The greatest interannual variability comes from El Nino events, which may affect a single season or extend over two successive years. The immediate cause of El Nino events is a slackening of the trade winds over the Pacific Ocean.

Normally the trade winds drive tropical surface water to the west, maintaining a thickened wedge of warm, clear, and nutrient poor water on the Asian side of the Pacific. If the winds slacken for several months or more, the water in this wedge flows eastward in a massive internal surge and piles up on the American side of the Pacific, raising mean sea level by as much as 10 or 20 cm, raising temperature by as much as 2 or 3°C, and submerging the nearshore nutricline to depths of several tens of meters. It is this depression of the nutricline which removes nutrients from the base of most marine food chains, with serious results for populations of marine fish and birds. The slackening of the trade winds also allows the westerly winds of the temperate zones to encroach on the tropics, causing unusually severe storms and rain on the west coasts of the Americas in lower latitudes.

The years of detailed oceanographic recording near SONGS extend from 1976 through 1986. In the middle of this period, and as SONGS Units 2 and 3 went from testing to full operation, an extreme El Nino event occurred, starting in the late summer of 1982 and lasting through the summer of 1984. This event was comparable to previous events in 1957-8, 1941-2, and 1914-15, indicating a mean recurrence interval of something over 20 years for such major events.

During the El Nino period (1982-84), several cruises were conducted. Data from these cruises are used here to identify the major changes in natural environment associated with the El Nino event. The data used here are from stations 30 to 100 m water depth, at 5 to 7 km offshore from the shoreline.

Figures 4-6 through 4-8 present isopleths of the following variables: $\text{NO}_3 + \text{NO}_2$ versus depth over time, $\text{NO}_3 + \text{NO}_2$ versus temperature over time, temperature versus depth over time, and salinity versus depth over time. These plots are a composite of data taken at several stations in the study area. The contours are drawn to minimize gradients and without reference to other data in order to

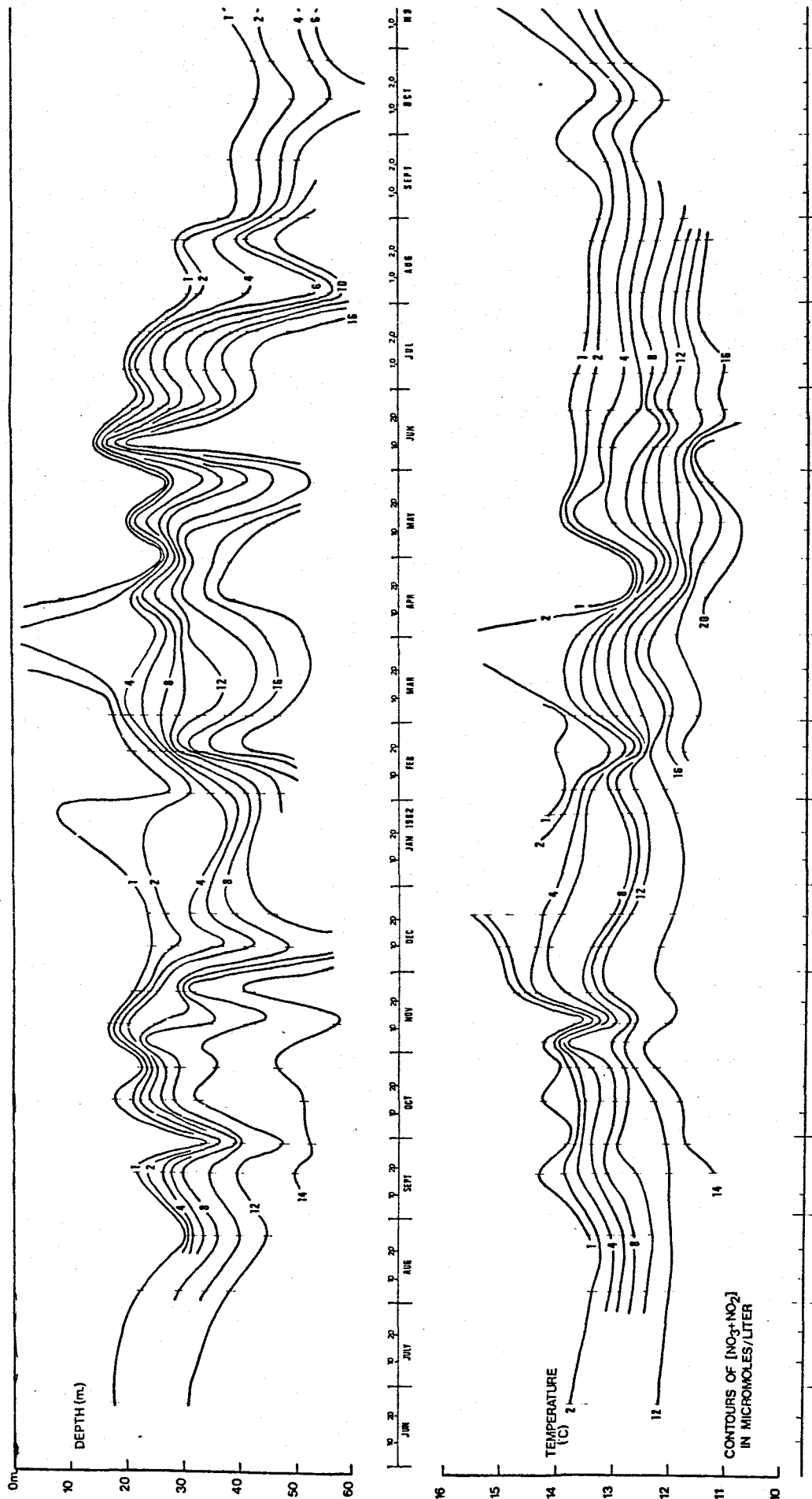


Figure 4-6a. Isopleths of (NO_3+NO_2) versus depth and temperature over time for offshore stations, 5 km offshore.