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STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA THROUGH SEPTEMBER 1993

by Jill D. Torikai

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U.S. DEPARTMENT OF THE NAVY
NAVY SUPPORT FACILITY, DIEGO GARCIA

Honolulu, Hawaii
1995

CONVERSION FACTORS AND ABBREVIATION

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gallon per day (gal/d)	3.785	liter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year

Abbreviation used in water-quality descriptions
mg/L = milligram per liter

STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA THROUGH SEPTEMBER 1993

EXECUTIVE SUMMARY

This data summary contains hydrologic and climatic data that describe the status of ground-water resources at U.S. Navy Support Facility, Diego Garcia. Data are presented through September 1993, one month into the annual wet season.

1. OVERALL RESOURCE STATUS--At the end of September 1993, the chloride concentration of the composite water supply was 66 milligrams per liter, well below the 250 milligrams per liter secondary drinking water standard established by the U.S. Environmental Protection Agency. Most of the production wells appeared to be operating at levels consistent with past operations. Several wells at Air Operations remain out of service while they are being used to hydraulically divert the nearby fuel spill.

2. RAINFALL--Rainfall thus far in 1993 is 8 percent below the mean annual rainfall of 106 inches. This follows a year when rainfall was 12 percent below the mean annual rainfall.

3. GROUND-WATER WITHDRAWAL--Withdrawal has averaged 856,000 gallons per day during 1993, a decrease from the 1992 average of 936,000 gallons per day.

4. CHLORIDE CONCENTRATION OF PUMPED WATER--The chloride concentration of pumped water rose during the current quarter (July through September 1993) in most areas, coincident with the annual dry season (March through August). This continues a general trend of increasing chloride concentration that has persisted for more than a year, beginning in the 1992 dry season.

5. CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS--Chloride concentration rose progressively during the current quarter in monitoring wells at Cantonment and Air Operations. Chloride concentrations in the deeper monitoring wells have generally been increasing since 1992.

6. FUEL-DIVERSION PROGRAM--A fuel spill at Air Operations caused the shutdown of ten wells in May 1991. Four of the wells have resumed pumping to the water supply, but water from the remaining six wells is being used to hydraulically contain and divert fuel migration.

STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA THROUGH SEPTEMBER 1993

By Jill D. Torikai

INTRODUCTION

Background

Diego Garcia Atoll is a British Indian Ocean Territory and the site of a U.S. Navy Support Facility. The island's drinking-water supply is derived from ground water by a system of more than 100 shallow wells from five production areas (fig. 1). Pumped water from the Cantonment and Air Operations areas are combined to produce a composite water supply that accounts for about 99 percent of the total island pumpage. The remainder that is pumped is for local use at the other three areas. The system has been in effect since 1978 and has provided about 1 Mgal/d since 1984.

Long-term ground-water management is facilitated by a cooperative agreement between the Navy Support Facility and the U.S. Geological Survey (USGS). The Diego Garcia Long-Term Ground-Water Management Program involves data collection and analysis of daily rainfall, daily pumpage for individual wells, and chloride concentrations from all production and monitoring wells. The data are stored in a computerized database and analyzed for hydrologic responses to pumping and climatic variability. This report summarizes recent hydrologic events and can help to identify trends in the data.

Organization of Report

This data summary contains hydrologic and climatic data that describe the status of ground-water resources at Navy Support Facility, Diego Garcia. Data are presented through September 1993, one month into the annual wet season. Data of primary relevance to the water supply are:

1. Rainfall
2. Volume of ground water withdrawn from production wells
3. Chloride concentration of the pumped water
4. Chloride concentration of ground water sampled from monitoring wells
5. Fuel-diversion program at Air Operations

The narrative that follows refers to selected graphs to highlight recent trends in the data for the third quarter 1993. Graphs of these data are presented in the "Hydrologic-Data Section" at the end of this summary. The data section contains the following:

A. Maps of production and monitoring wells at Cantonment and Air Operations
B. Graphs of monthly mean ground-water withdrawal, 1985-93
C. Graphs of daily ground-water withdrawal, 1992-93
D. Graphs of weekly chloride concentration of pumped water, 1985-93

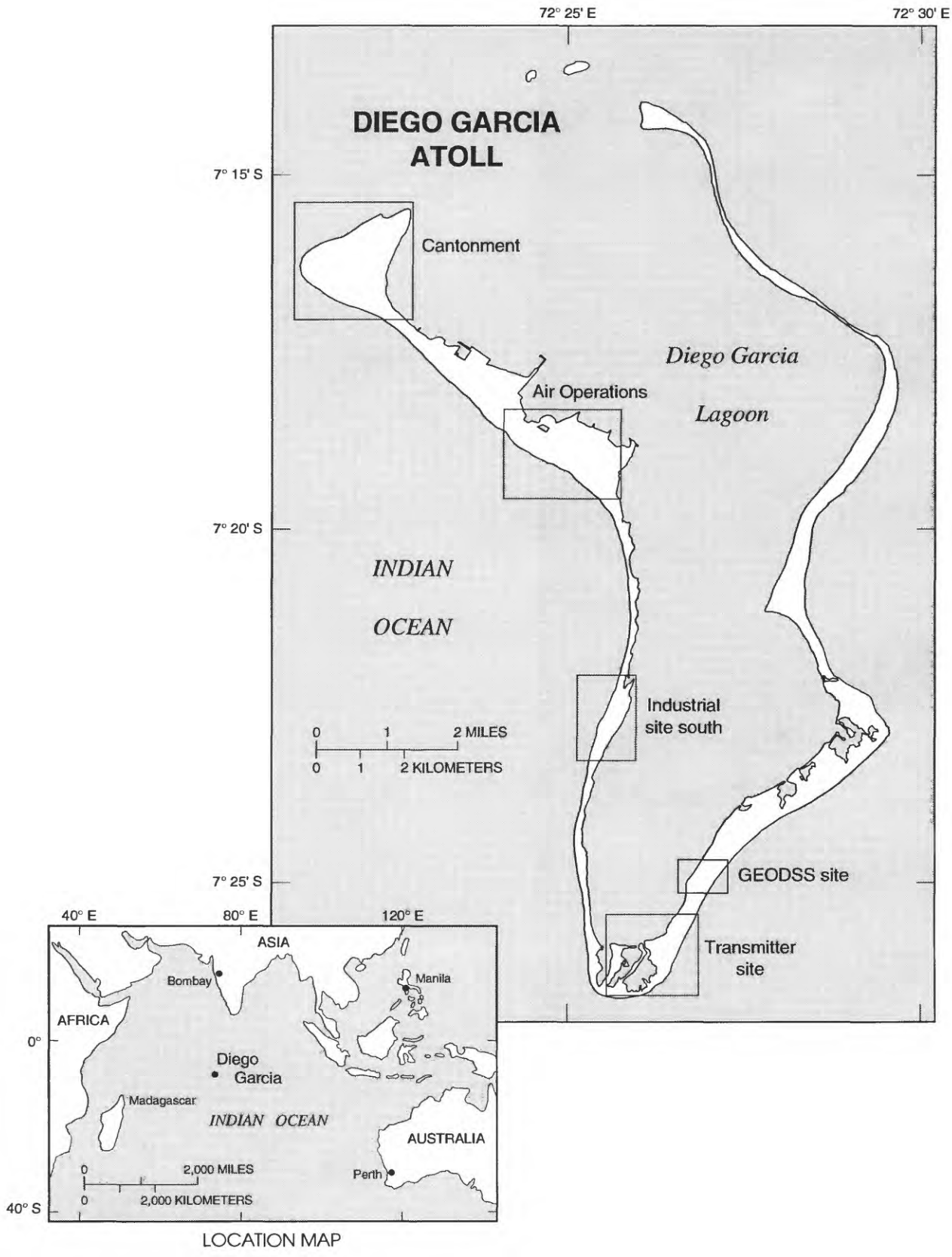


Figure 1. Areas of ground-water production, Diego Garcia.

RAINFALL

Background.--Mean annual rainfall at Diego Garcia is about 106 in/yr, with considerable month-to-month and year-to-year variability. Rainfall usually occurs in two semiannual seasons: a wet season from about September through February, and a dry season from about March through August.

Recent trends.--Rainfall in 1993 through September was 8 percent below the mean annual rainfall, while rainfall in 1992 was 12 percent below the mean (fig. 2A). September is typically the start of the wet season. The generally low rainfall pattern of the past year continued during the 1993 third quarter. Total rainfall for the quarter was 12.65 in. August was especially low with 0.80 in. rainfall.

In the smoothed rainfall departure index (fig. 2C), the pattern during 1992-93 resembles that during 1984-85. The wet seasons of both time periods were deficient, producing weaker-than-normal positive anomalies in the index. Also, the deficient wet seasons of both periods immediately followed pronounced dry seasons of their respective prior years (1991-92, 1983-84). The result, in both cases, was a persistent negative or near-zero run in the smoothed departure index, lasting about 1.5 years. Prominent negative runs such as those in 1984, 1985, and 1989 have corresponded with documented periods of freshwater lens shrinkage, saltwater intrusion, and increased salinity in pumped water (C.D. Hunt, U.S. Geological Survey, written commun., 1993).

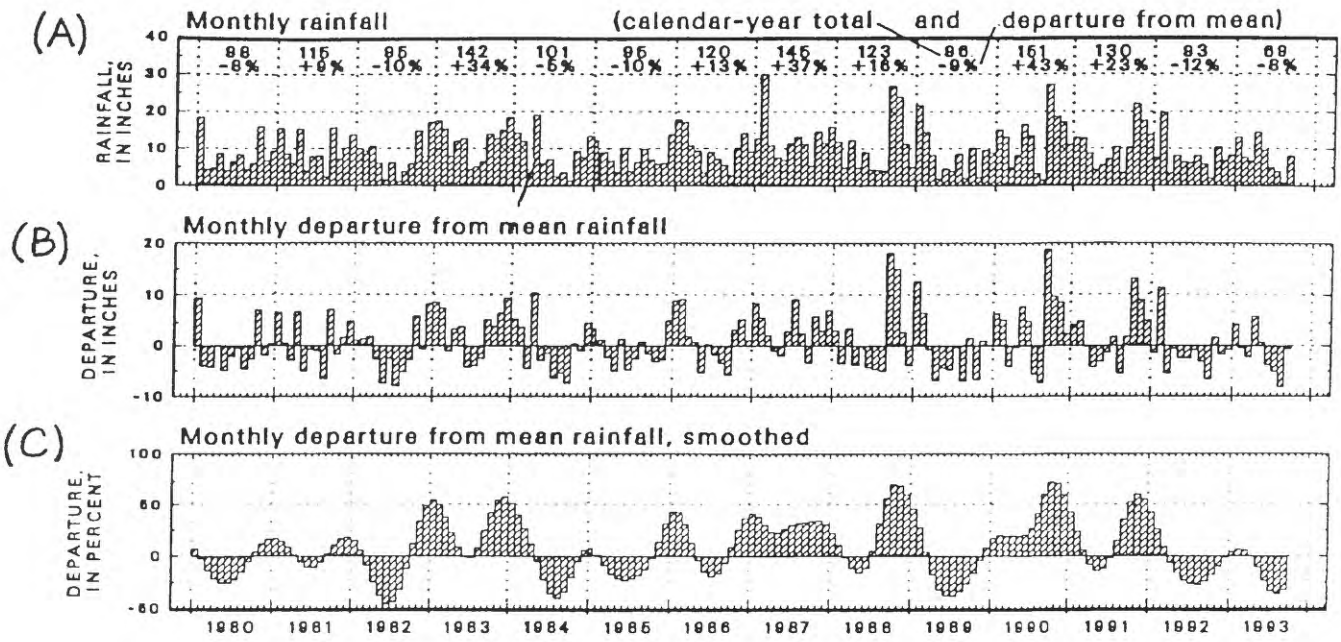


Figure 2. Monthly rainfall and rainfall-departure indexes at Air Operations, Diego Garcia, 1980-93: (A) Monthly rainfall. Graph is annotated with calendar-year totals and calendar-year departures from mean annual rainfall (mean computed for the fixed base period 1951-90); (B) Monthly departure from mean rainfall. Mean rainfall, in inches per month, is the mean annual rainfall divided by 12; (C) smoothed monthly departure from mean using an 11-point, center-weighted, moving average filter with weighing factors that approximate the normal probability distribution.

GROUND-WATER WITHDRAWAL

Background.--Withdrawal is measured by flow meters at all production wells and storage tanks in the water system, and is recorded daily.

Recent trends.--Figure 3 shows time series of monthly mean withdrawal islandwide and in each ground-water production area since 1985. Patterns of withdrawal thus far in 1993 have not changed appreciably from prior months in most areas.

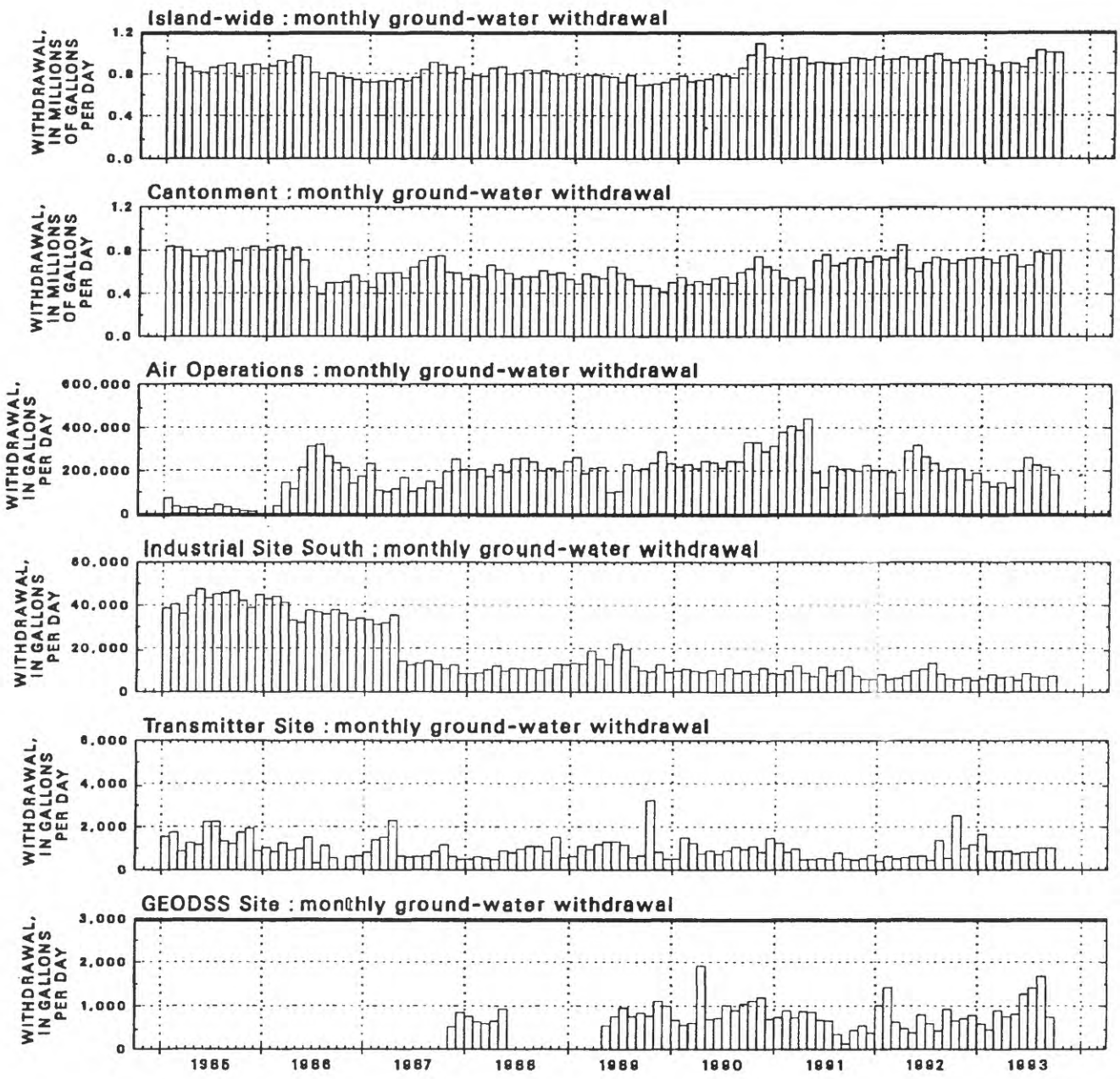


Figure 3. Monthly mean ground-water withdrawal islandwide and in the ground-water production areas, Diego Garcia, 1985-93.

CHLORIDE CONCENTRATION OF PUMPED GROUND WATER

Background.--The concentration of dissolved chloride ions is used as a quantitative measure of salinity in this summary. Chloride concentration in seawater at Diego Garcia is about 19,500 mg/L whereas a concentration of 250 mg/L is the maximum contaminant level (MCL) under secondary drinking-water standards established by the U.S. Environmental Protection Agency. Secondary standards are not mandatory requirements, but instead establish limits for constituents that may affect the aesthetic qualities of drinking water, such as taste or color.

Water is sampled weekly at all wells and storage tanks in the production system. Water in the Air Operations tank is a blend of withdrawals in the Air Operations area only, whereas the Cantonment tank is a mixture of ground water from both Air Operations and Cantonment and accounts for a predominant fraction of total, islandwide pumpage. Thus, water sampled from the Cantonment tank is used as a representative index of chloride concentration for the overall water supply.

Recent trends.--Chloride concentrations in all ground-water production areas rose distinctly during mid-1992 and leveled off or declined slightly in early 1993 (fig. 4). The increases coincided with the 1992 dry season and the declines coincided with the subsequent 1992-93 wet season, as indicated by the smoothed rainfall departure index. Chloride concentrations rose again in mid-1993 as the 1993 dry season progressed. In the Cantonment record, the dry-season chloride concentration increases of 1992 and 1993 were similar to the seasonal increases of 1985 and 1989, though not as severe.

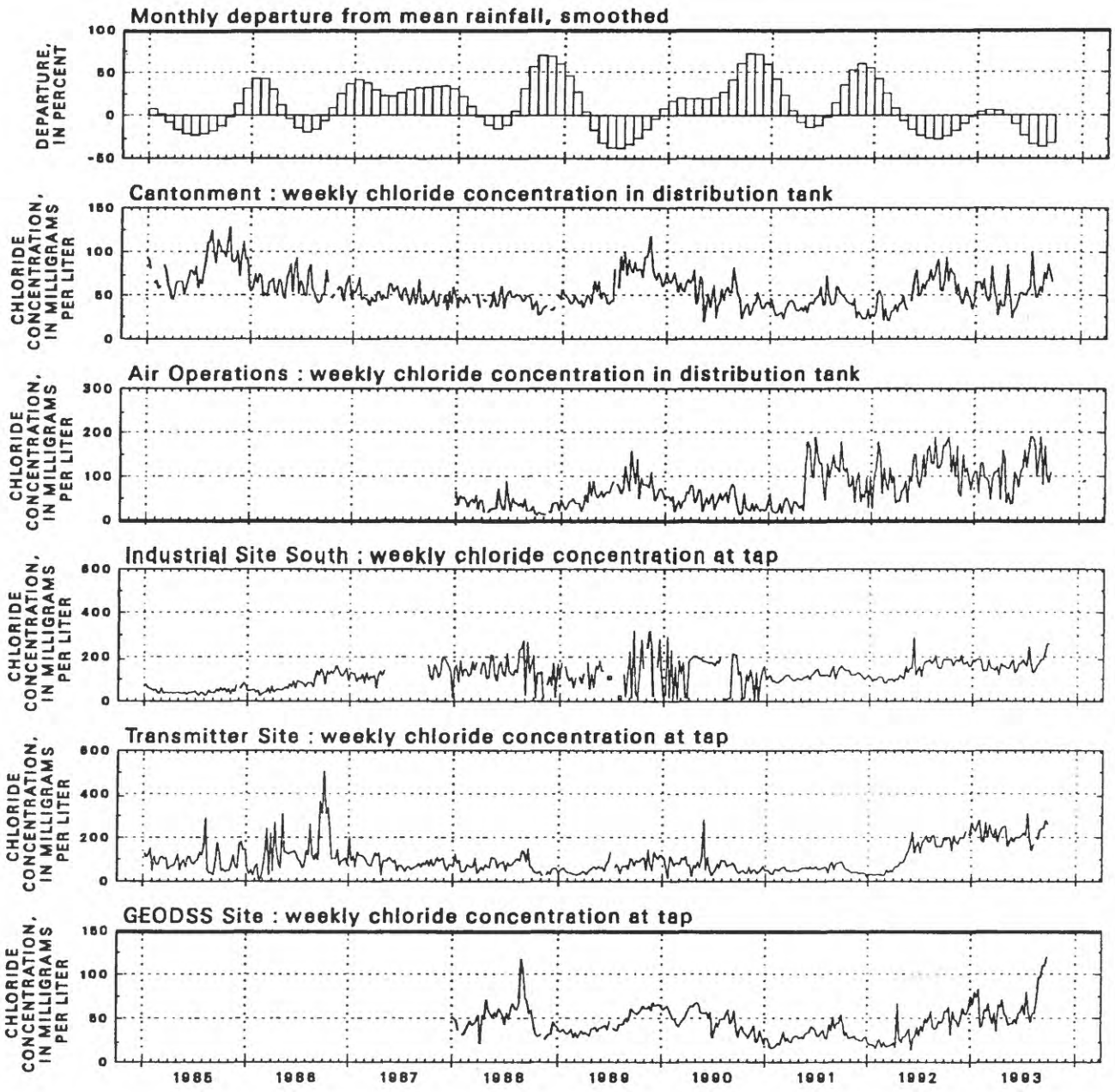


Figure 4. Weekly chloride concentration of pumped water in the ground-water production areas, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison. Different scales are used on Y-axes.

CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS

Background.--Ground water is sampled for chloride concentration in monitoring wells at 35 sites. Each site comprises several wells, with each well having a short screened (open) interval that bottoms at a different depth. The deeper wells typically tap the freshwater-saltwater mixing zone that underlies the freshwater lenses.

Recent trends.--Monitoring sites AW16 and BW09 have been selected to show trends in ground-water chloride concentration at Cantonment and Air Operations Areas, respectively. Figures 5 and 6 show time series of chloride concentration at different depths at these sites, with a smoothed rainfall index included in the figures for climatic reference. Chloride concentration rose at both sites during 1992 and then declined or leveled off in late 1992 and in the first half of 1993. During the 1993 third quarter, chloride concentrations again increased. The records show an apparent inverse correspondence to the smoothed rainfall index, with higher chloride concentration in the dry season and lower chloride concentration in the wet season.

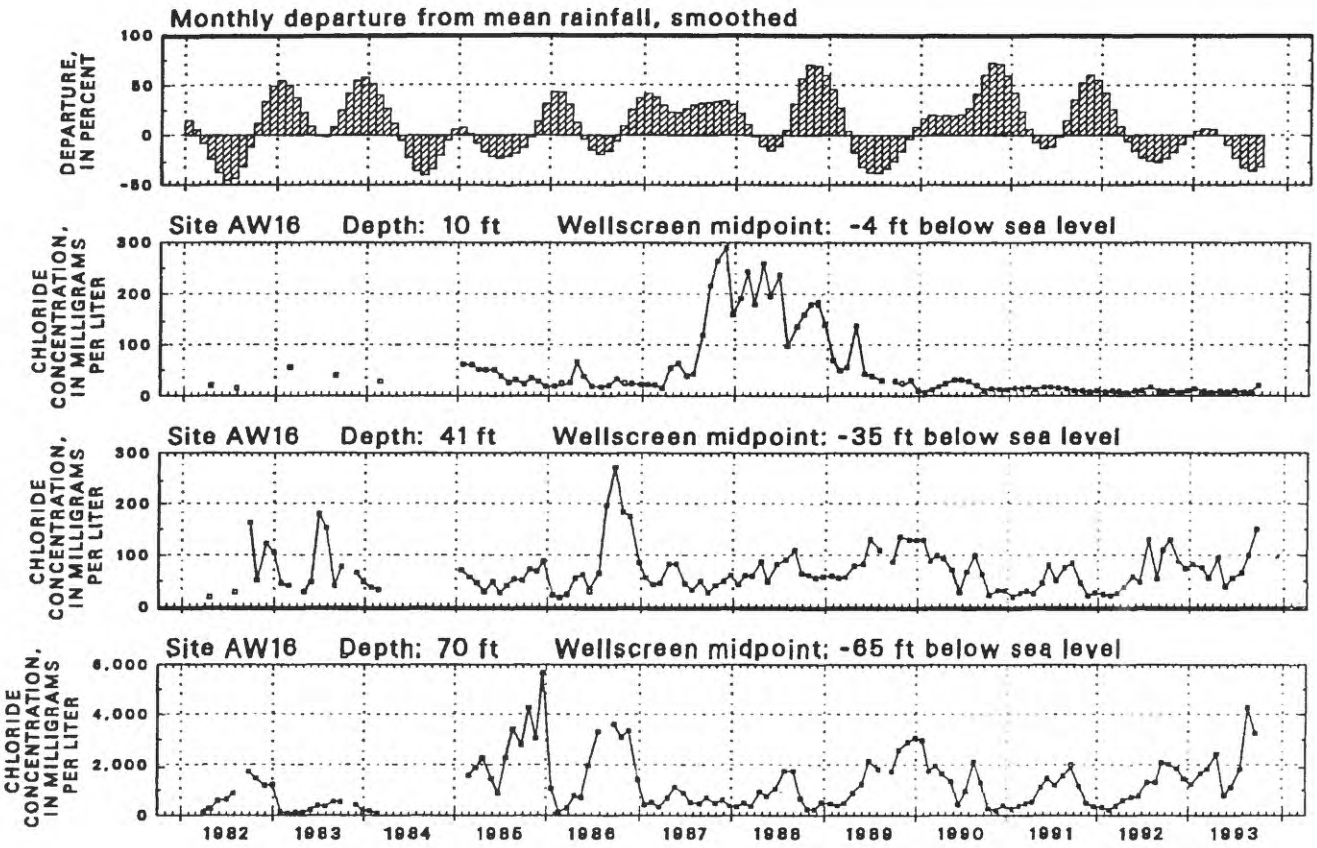


Figure 5. Monthly chloride concentration of ground water in monitoring wells at site AW16 at Cantonment, Diego Garcia, 1982-93. Rainfall departure data are shown for comparison. Different scales are used on Y-axes.

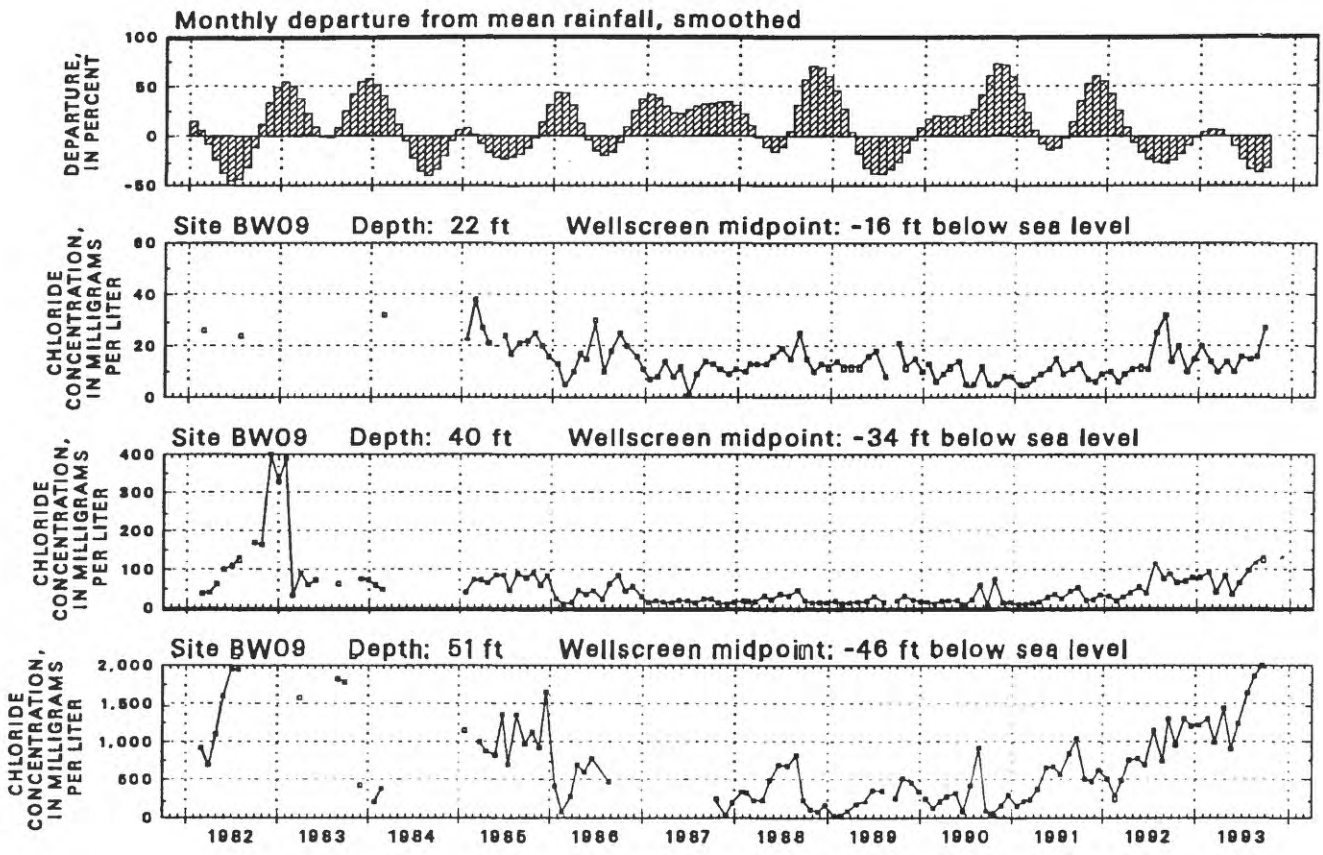


Figure 6. Monthly chloride concentration of ground water in monitoring wells at site BW09 at Air Operations, Diego Garcia, 1982-93. Rainfall departure data are shown for comparison. Different scales are used on Y-axes.

FUEL-DIVERSION PROGRAM AT AIR OPERATIONS

The normal pattern of ground-water withdrawal at Air Operations has been disrupted since May 1991 by a jet-fuel spill at the South Ramp Aircraft Parking Apron. In April 1992, a program was initiated to hydraulically divert fuel away from the drinking-water wells. The program consists of pumping water from wells AO-14 and AO-15 and directing this water through the common collection main to the wells nearest the spill (AO-10, 11, 12), where it is injected back into the aquifer. Wells AO-10 through AO-15 were shut down from May 1991 to April 1992, but have since been used in the closed recirculation loop of withdrawal and injection.

The hydraulic diversion program is based on the following target withdrawal and injection rates:

AO-14 - withdrawal at 70,000 gal/d
AO-15 - withdrawal at 80,000 gal/d
AO-10 - injection at 30,000 gal/d
AO-11 - injection at 50,000 gal/d
AO-12 - injection at 70,000 gal/d
AO-13 - off

Total recirculation: 150,000 gal/d

Daily withdrawal and injection at wells AO-10 through AO-15 are shown in figure 7.

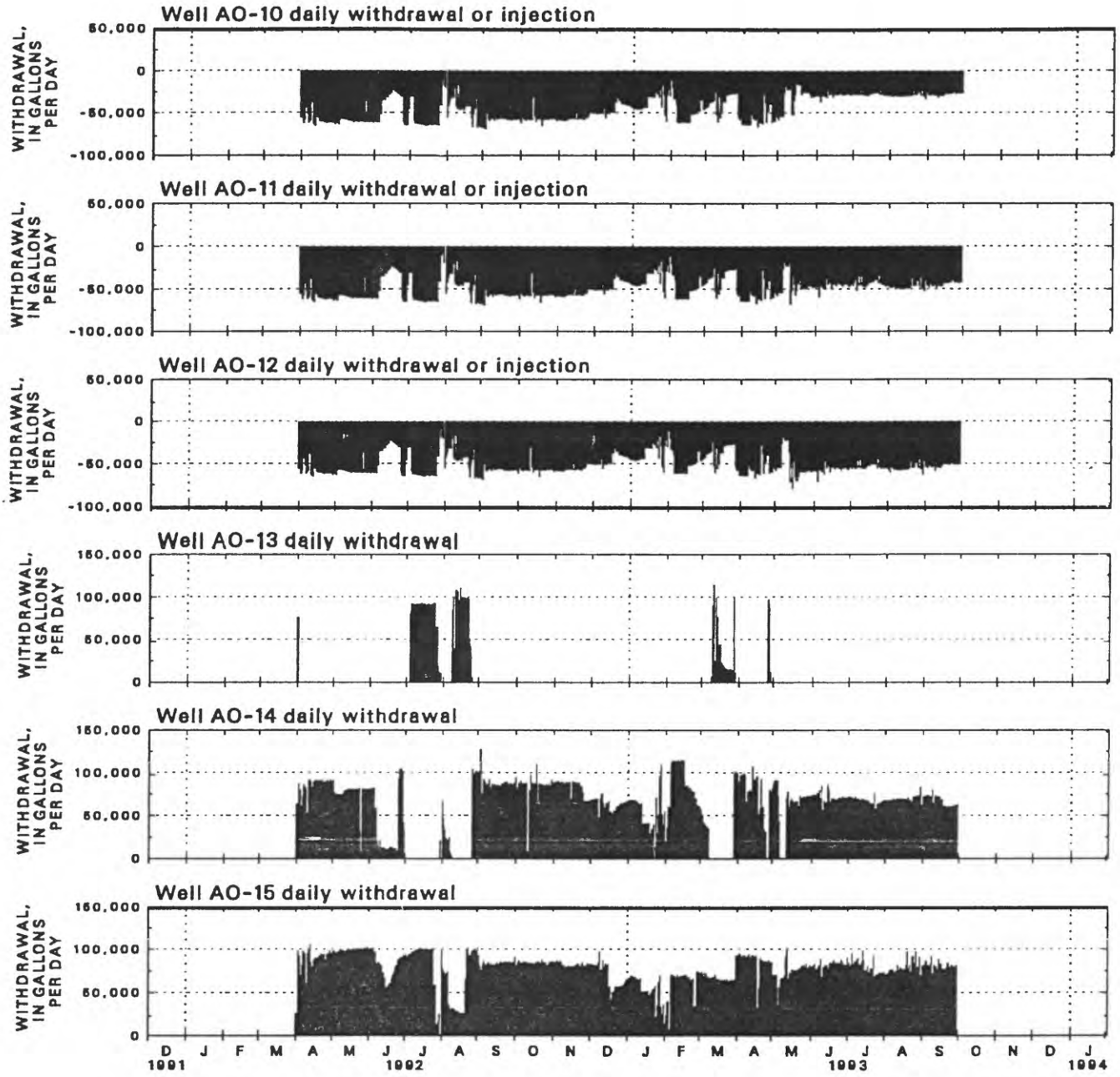


Figure 7. Daily ground-water withdrawal and injection at wells AO-10 through AO-15 at Air Operations, Diego Garcia, 1992-93. Injection is plotted as negative withdrawal, with bars extending down rather than up. Injection data for wells AO-10, 11, 12 are actual water-meter readings since May 1993. From April 1992 through May 1993, meter readings of injection were not available, and daily injection at each of the three wells was estimated to be one-third of the total daily withdrawal from wells AO-13, 14, and 15 which provided the injection-supply water. Different scales are used on Y-axes.

HYDROLOGIC-DATA SECTION

TYPES OF DATA INCLUDED

A. Maps of production and monitoring wells at Cantonment and Air Operations
B. Graphs of monthly mean ground-water withdrawal, 1985-93
C. Graphs of daily ground-water withdrawal, 1992-93
D. Graphs of weekly chloride concentration of pumped water, 1985-93

DESCRIPTIONS OF PRINCIPAL PRODUCTION SOURCES AT CANTONMENT AND AIR OPERATIONS AREAS

Cantonment Area

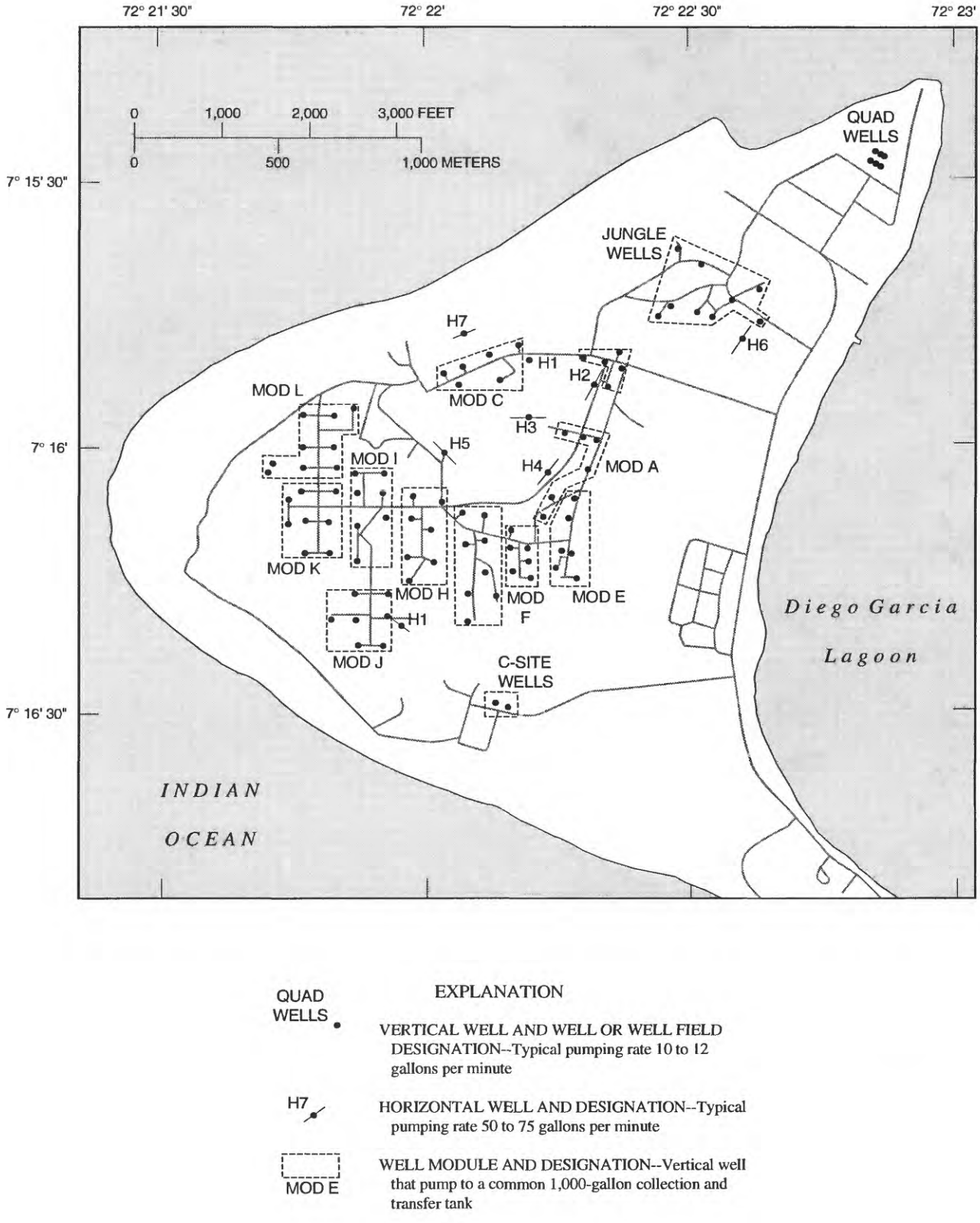
1. Modules A, C through L - each "production module" is a well field of 5 to 8 vertical wells that pump to a common collection/ transfer tank.
2. Module B is a horizontal well with a collection/transfer tank; has not pumped since August 1986.
3. Wells H1 through H7 are horizontal wells.
4. Quad wells are a well field of four vertical wells.
5. Jungle Wells are a well field of 11 vertical wells; have not pumped since February 1987.

Air Operations Area

1. Wells AO-2 through AO-5 are vertical wells.
2. Wells AO-6 through AO-9 are horizontal wells.
3. Wells AO-10 through AO-12 are horizontal wells; currently receiving injection water to divert fuel contaminants from a nearby spill.
4. Wells AO-13 through AO-15 are horizontal wells; AO-14 and AO-15 are currently pumping water to injection wells AO-10 through AO-12, while AO-13 is not pumping.
5. AO-16 through AO-19 are horizontal wells.

SECTION A

Maps of production and monitoring wells at Cantonment and Air Operations



EXPLANATION

QUAD WELLS — VERTICAL WELL AND WELL OR WELL FIELD DESIGNATION--Typical pumping rate 10 to 12 gallons per minute

H7 — HORIZONTAL WELL AND DESIGNATION--Typical pumping rate 50 to 75 gallons per minute

MOD E — WELL MODULE AND DESIGNATION--Vertical well that pump to a common 1,000-gallon collection and transfer tank

Figure A1. Ground-water production wells and well fields at Cantonment, Diego Garcia.

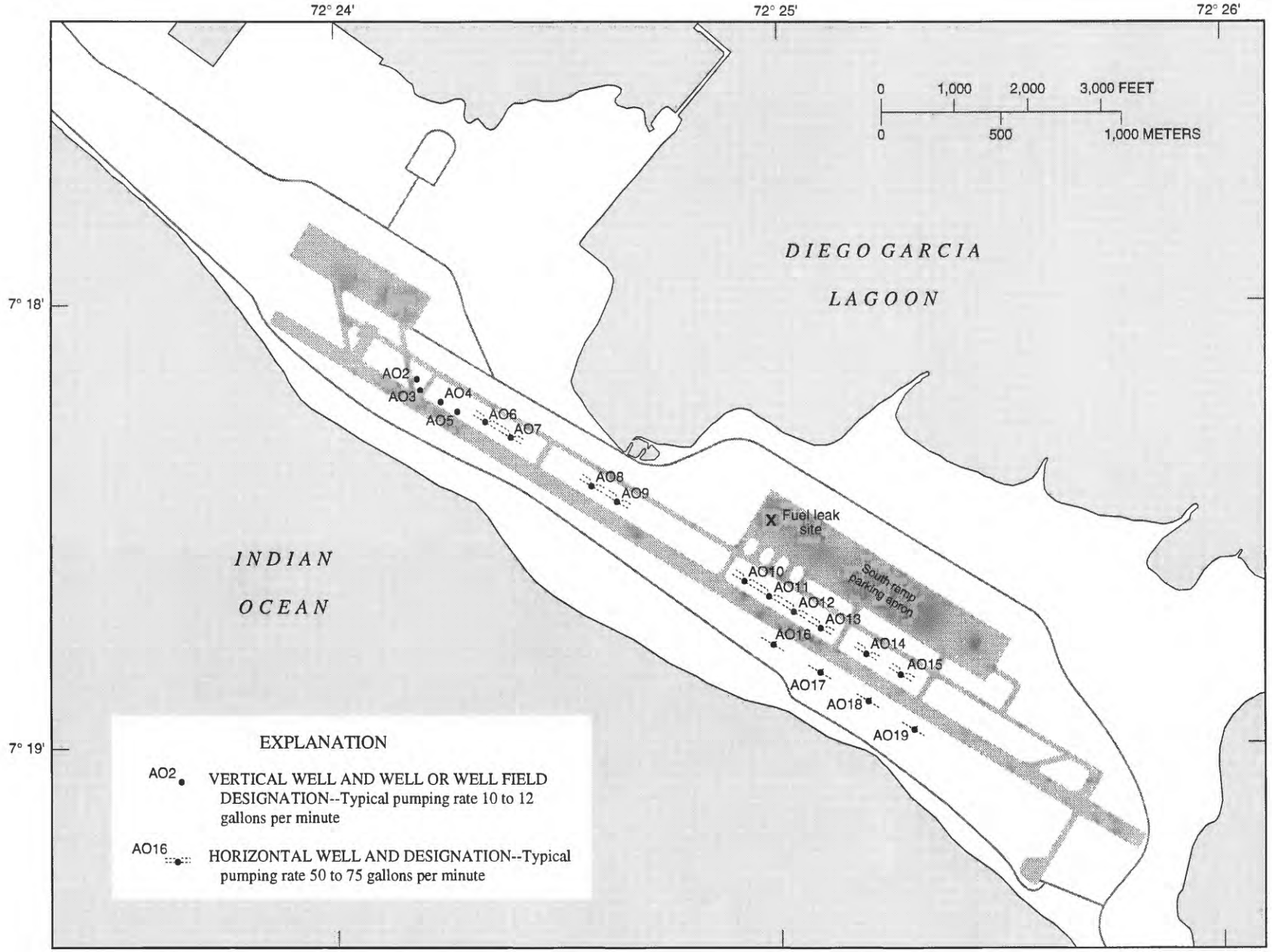
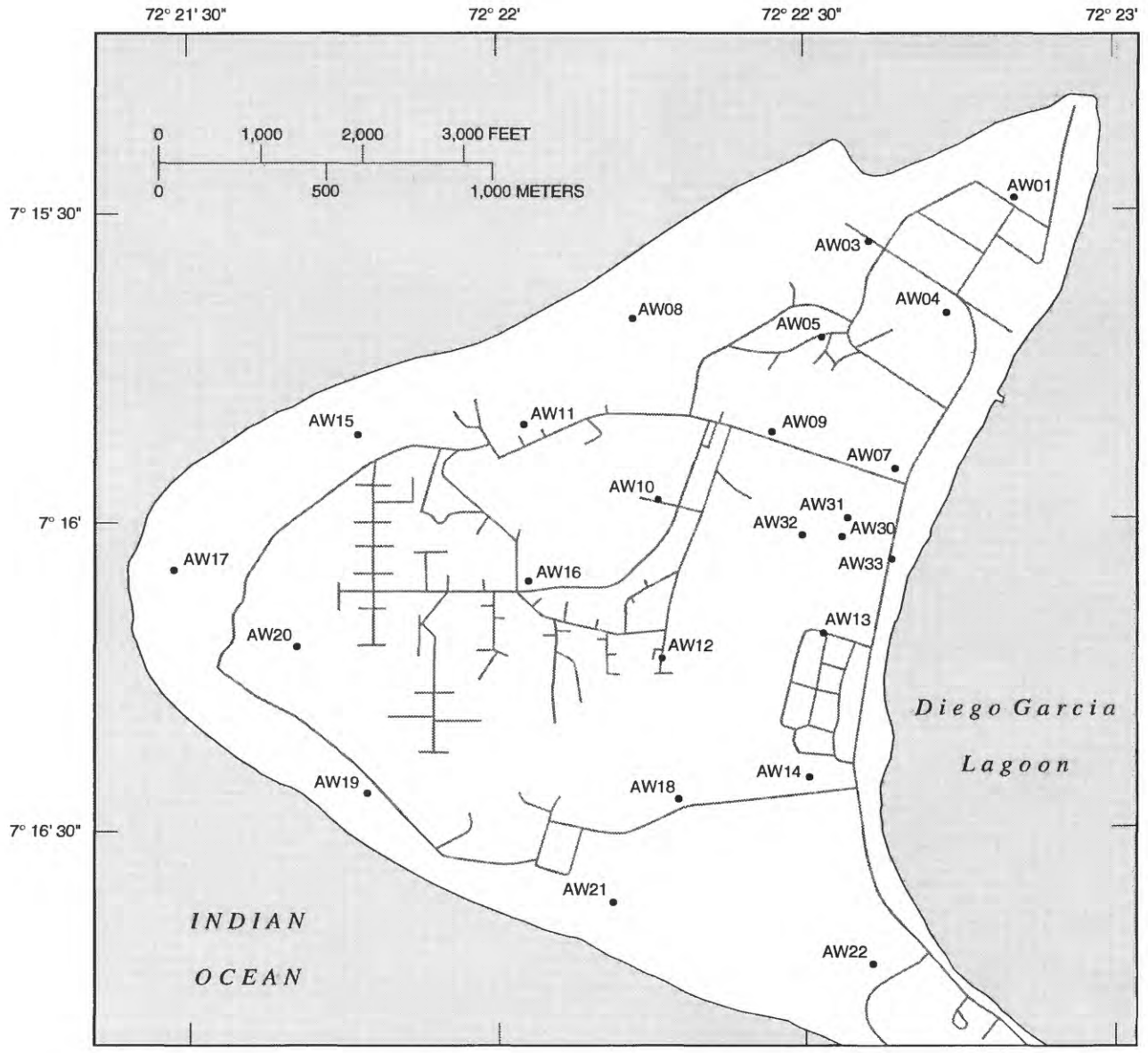


Figure A2. Ground-water production wells at Air Operations, Diego Garcia.



EXPLANATION

AW21 MONITORING SITE AND DESIGNATION--Consisting of two or more monitoring wells with short (2 to 5 foot) open intervals of different depths

Figure A3. Monitoring wells at Cantonment, Diego Garcia.

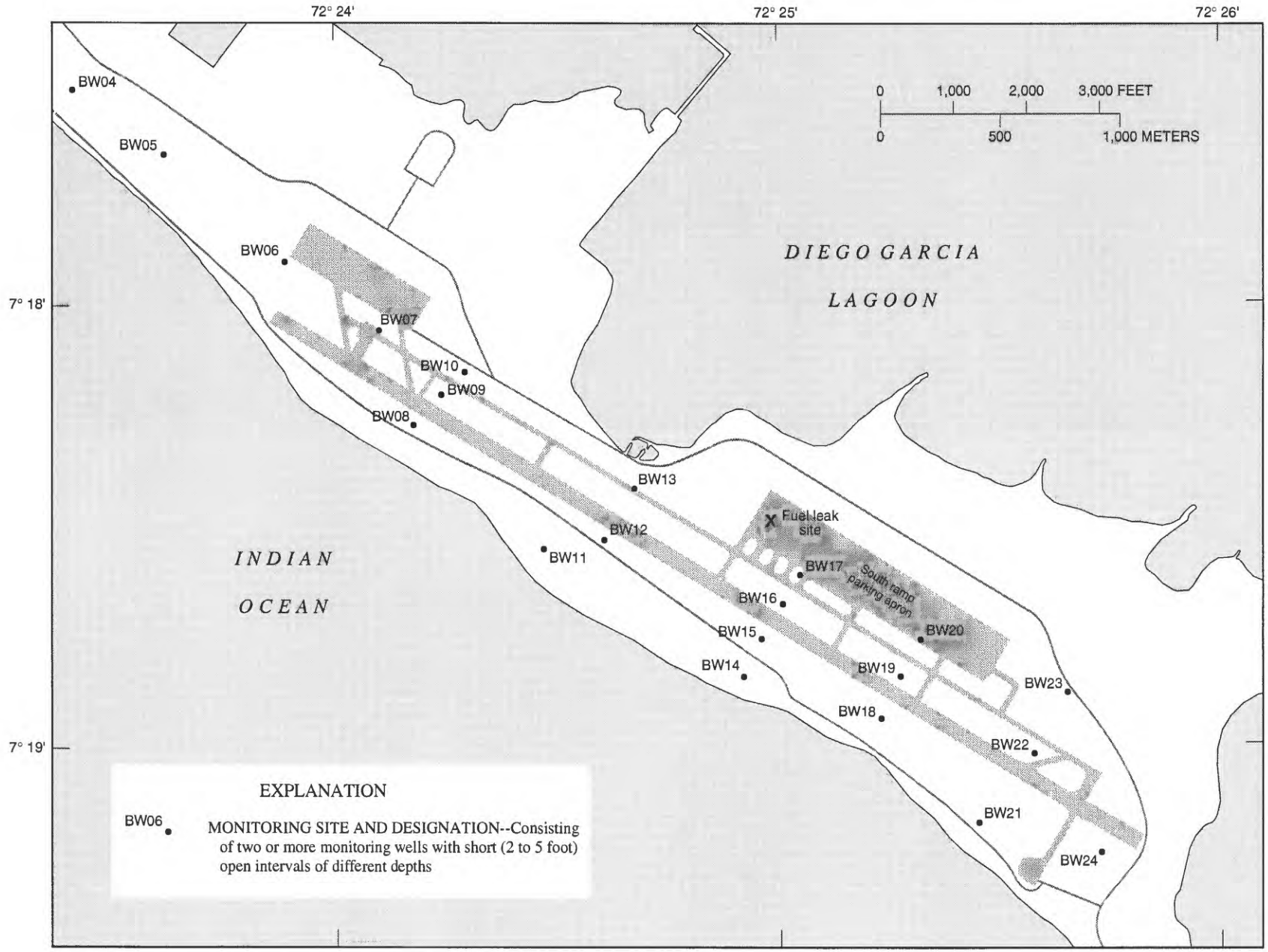


Figure A4. Monitoring wells at Air Operations, Diego Garcia.

SECTION B

Graphs of monthly mean ground-water withdrawal, 1985-93

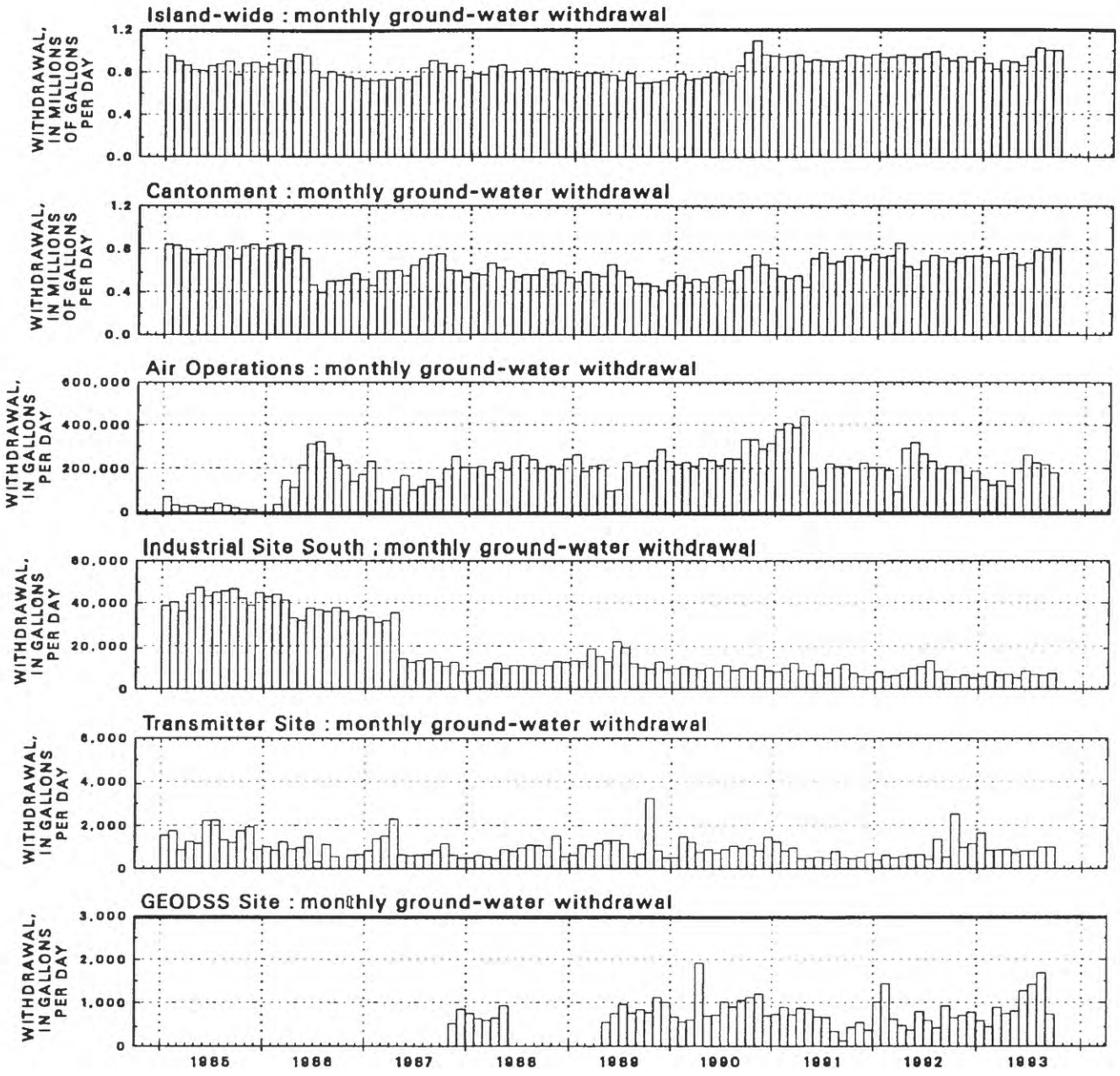


Figure B1. Monthly mean ground-water withdrawal islandwide and in the ground-water production areas, Diego Garcia, 1985-93.

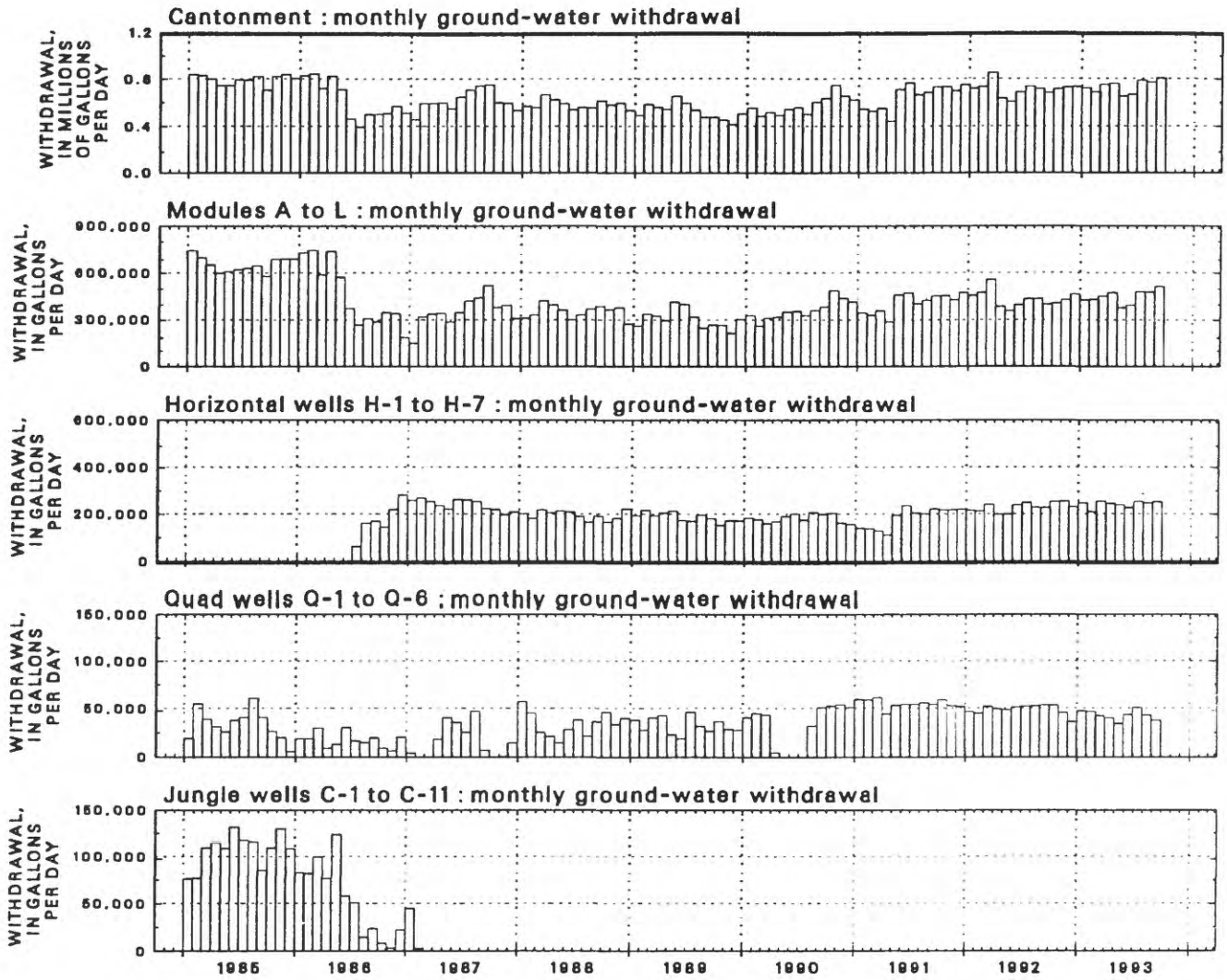


Figure B2. Monthly mean ground-water withdrawal at Cantonment, Diego Garcia, 1985-93.

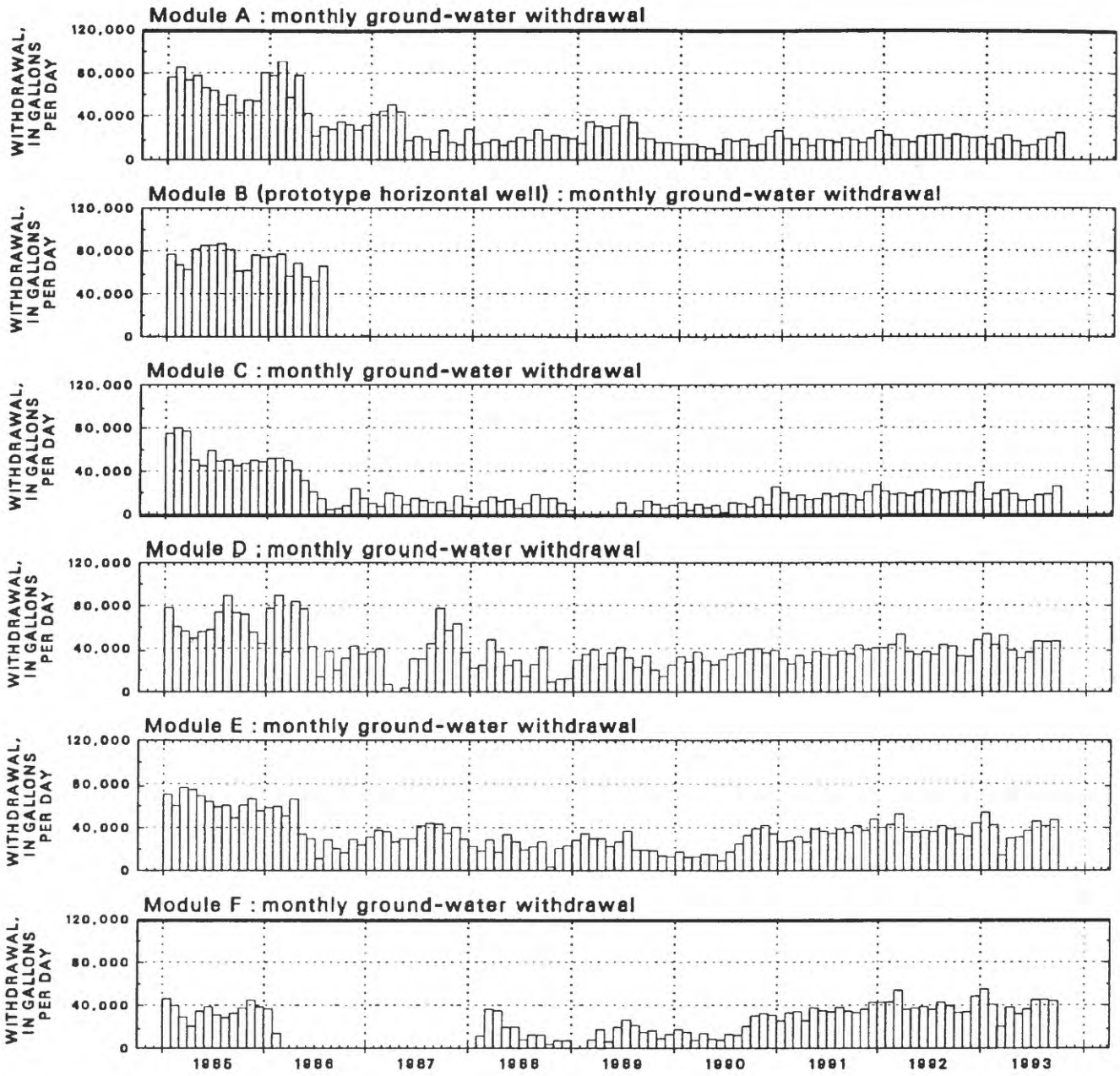


Figure B3. Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego, Garcia, 1985-93.

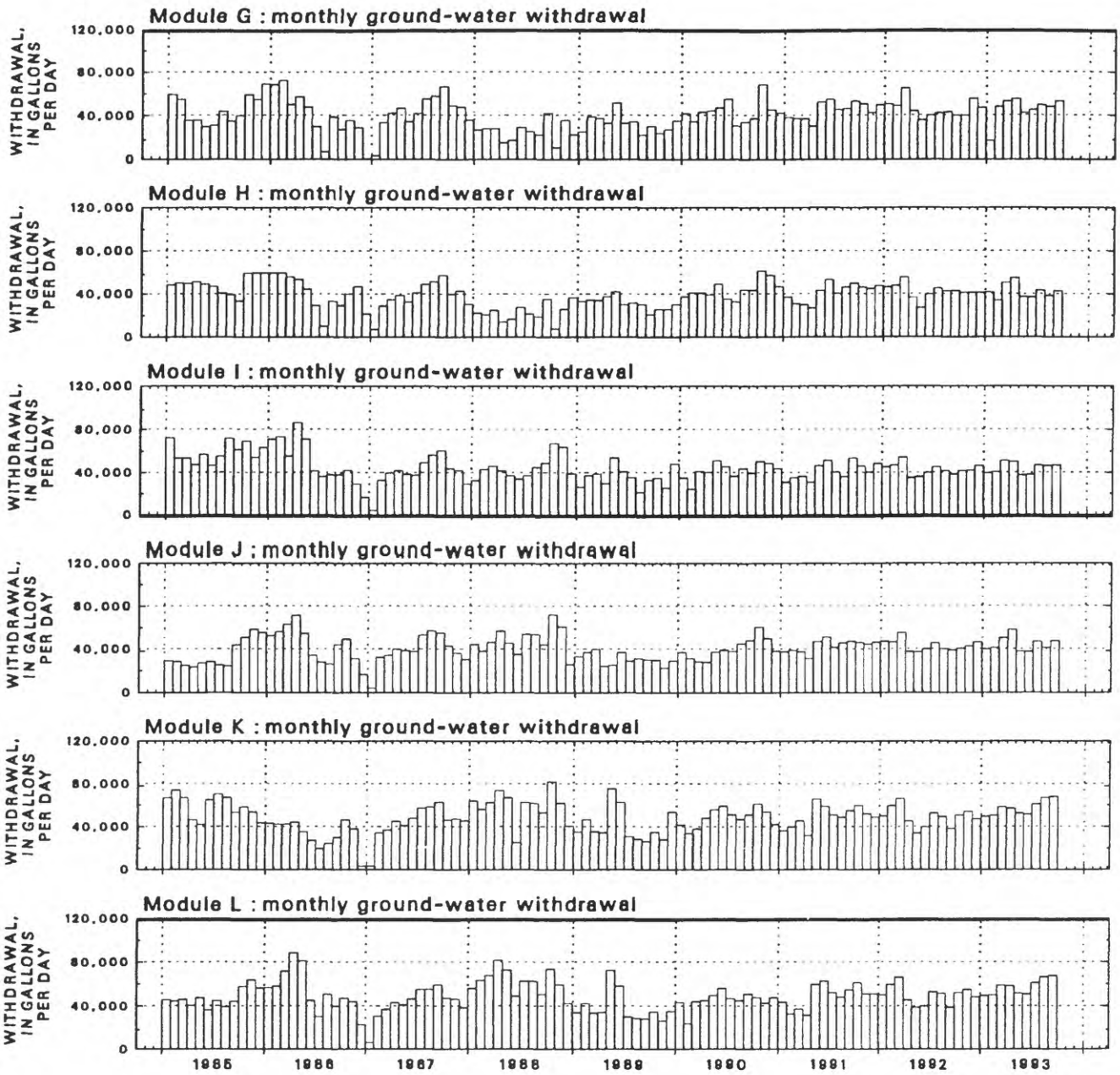


Figure B3 continued.--Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, 1985-93.

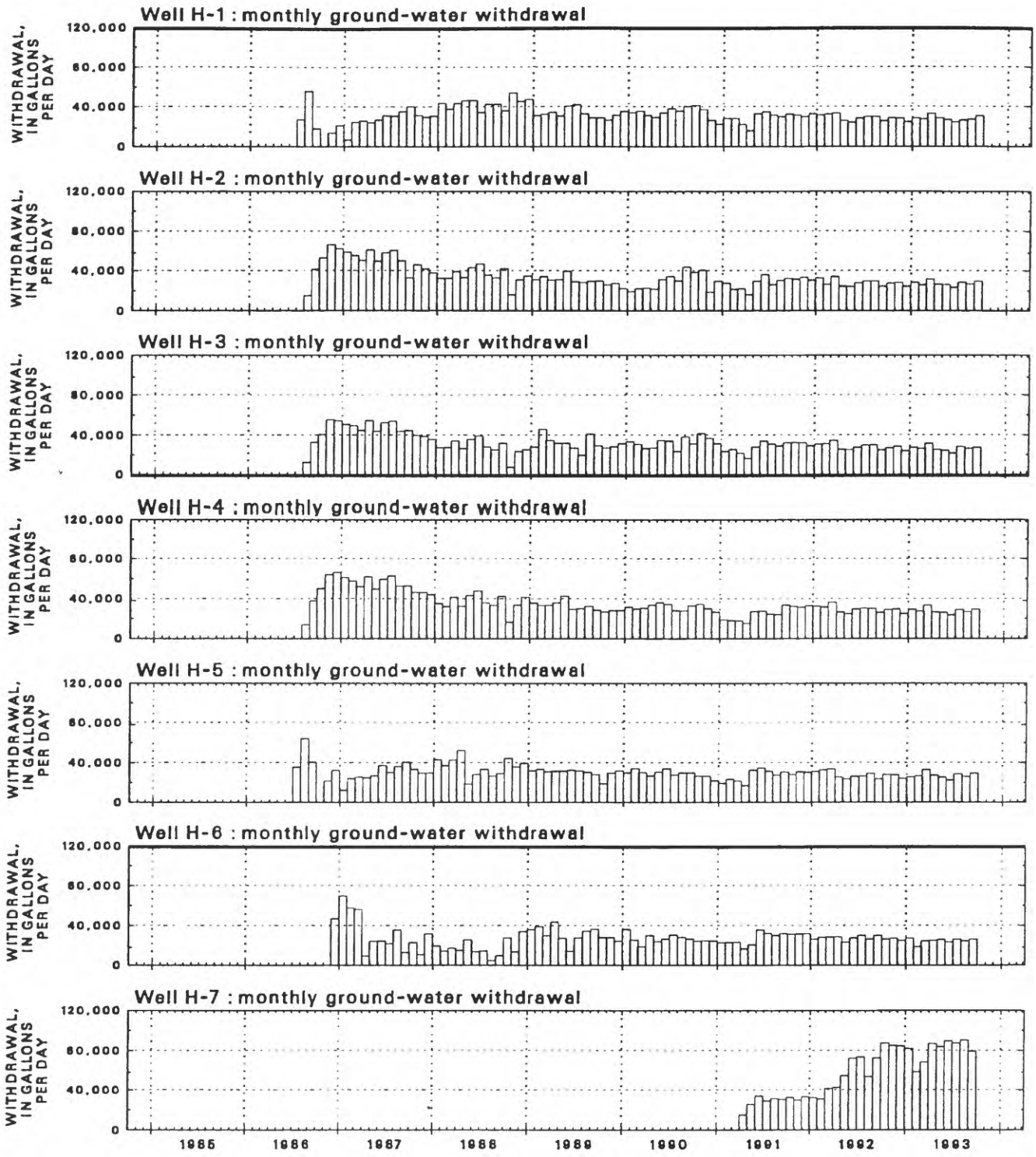


Figure B4. Monthly mean ground-water withdrawal at wells H-1 through H-7 at Cantonment, Diego Garcia, 1985-93.

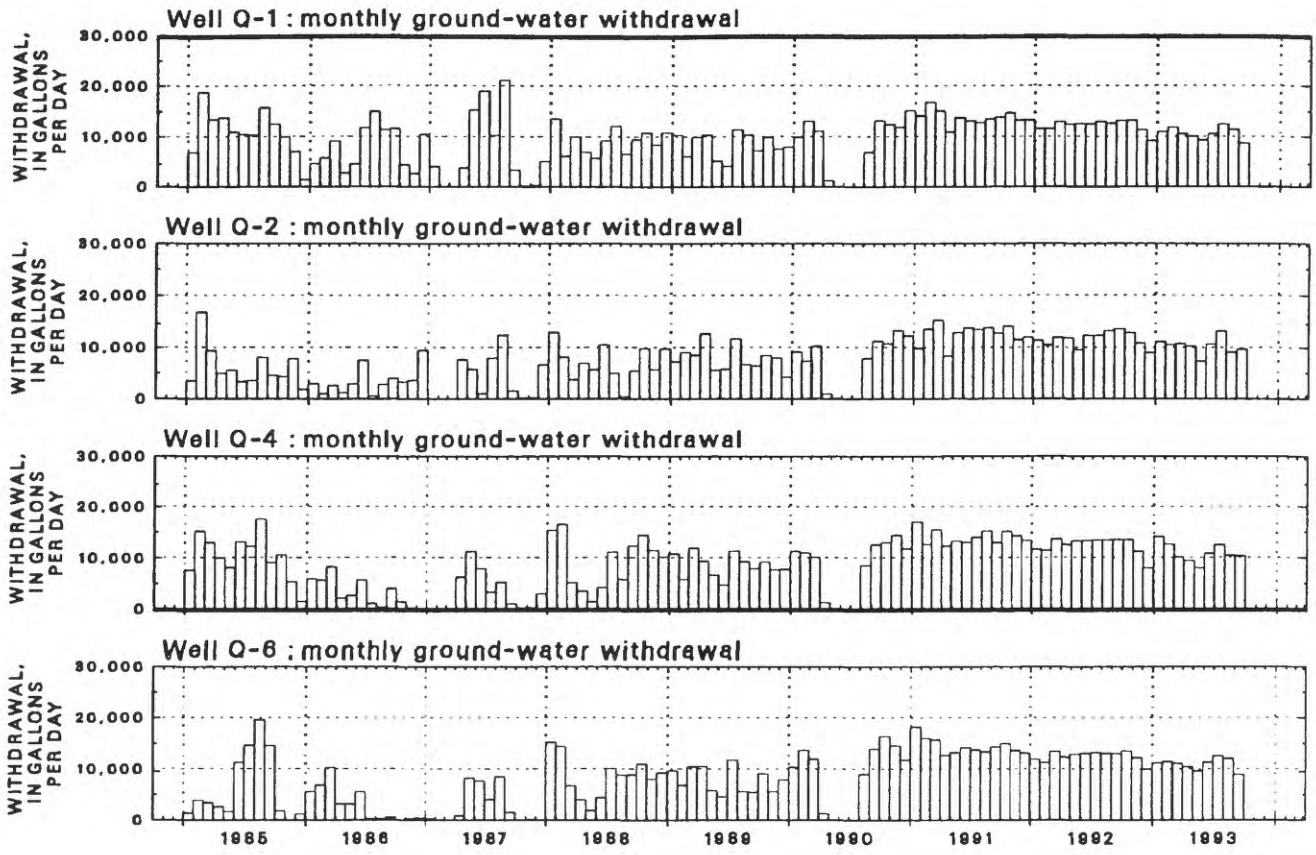


Figure B5. Monthly mean ground-water withdrawal at wells Q-1, 2, 4, and 6 at Cantonment, Diego Garcia, 1985-93.

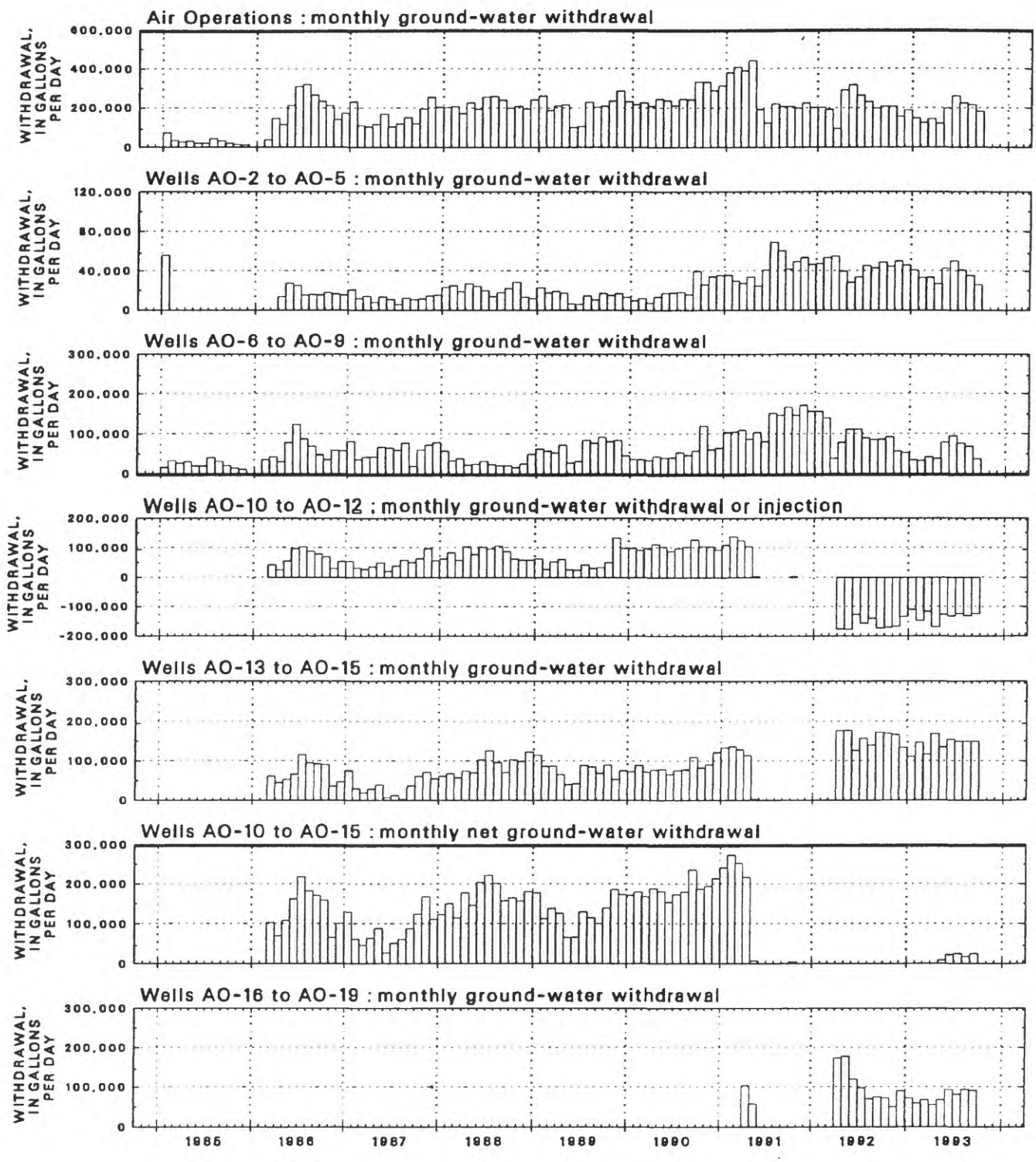


Figure B6. Monthly mean ground-water withdrawal at Air Operations, Diego Garcia, 1985-93.

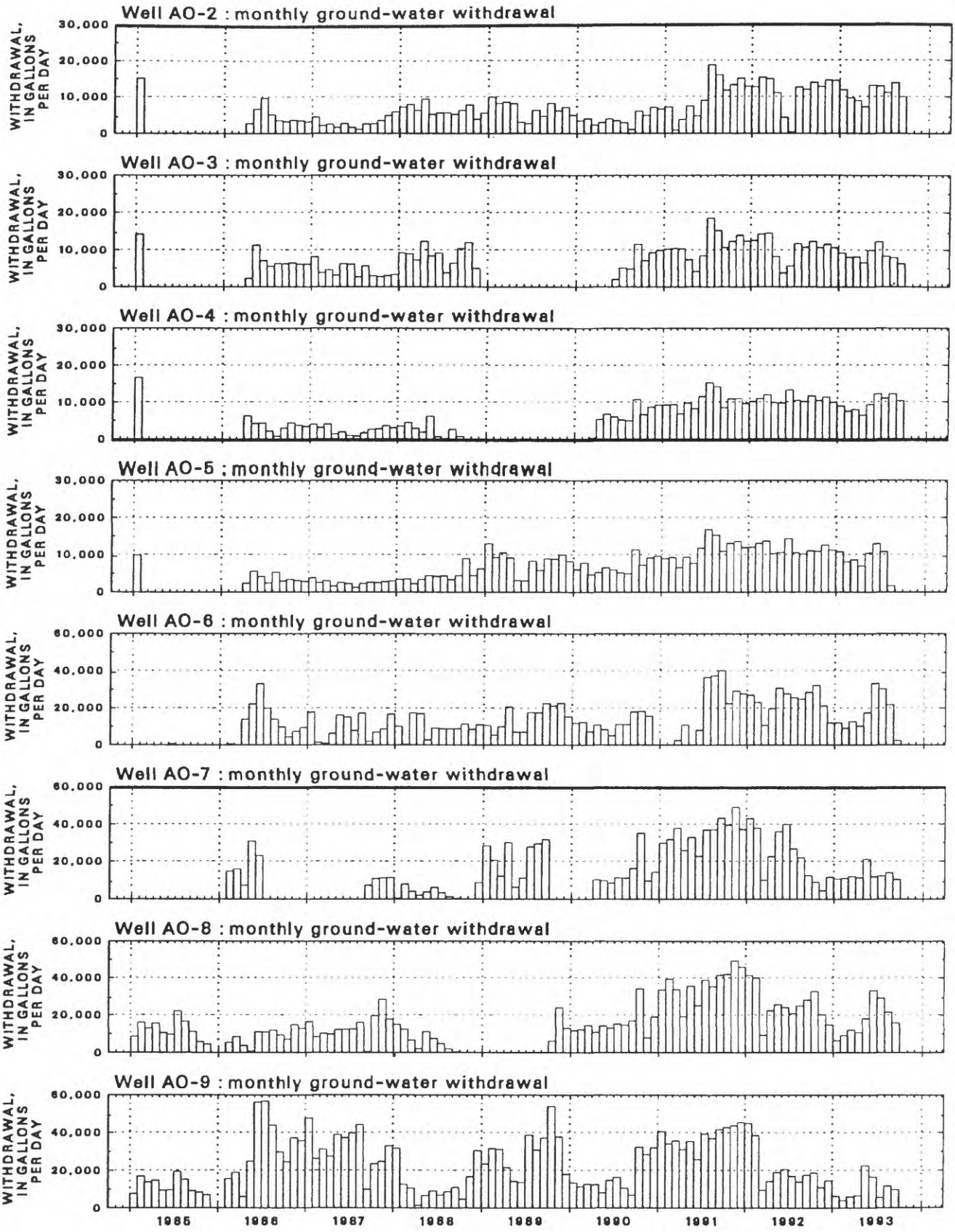


Figure B7. Monthly mean ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93.

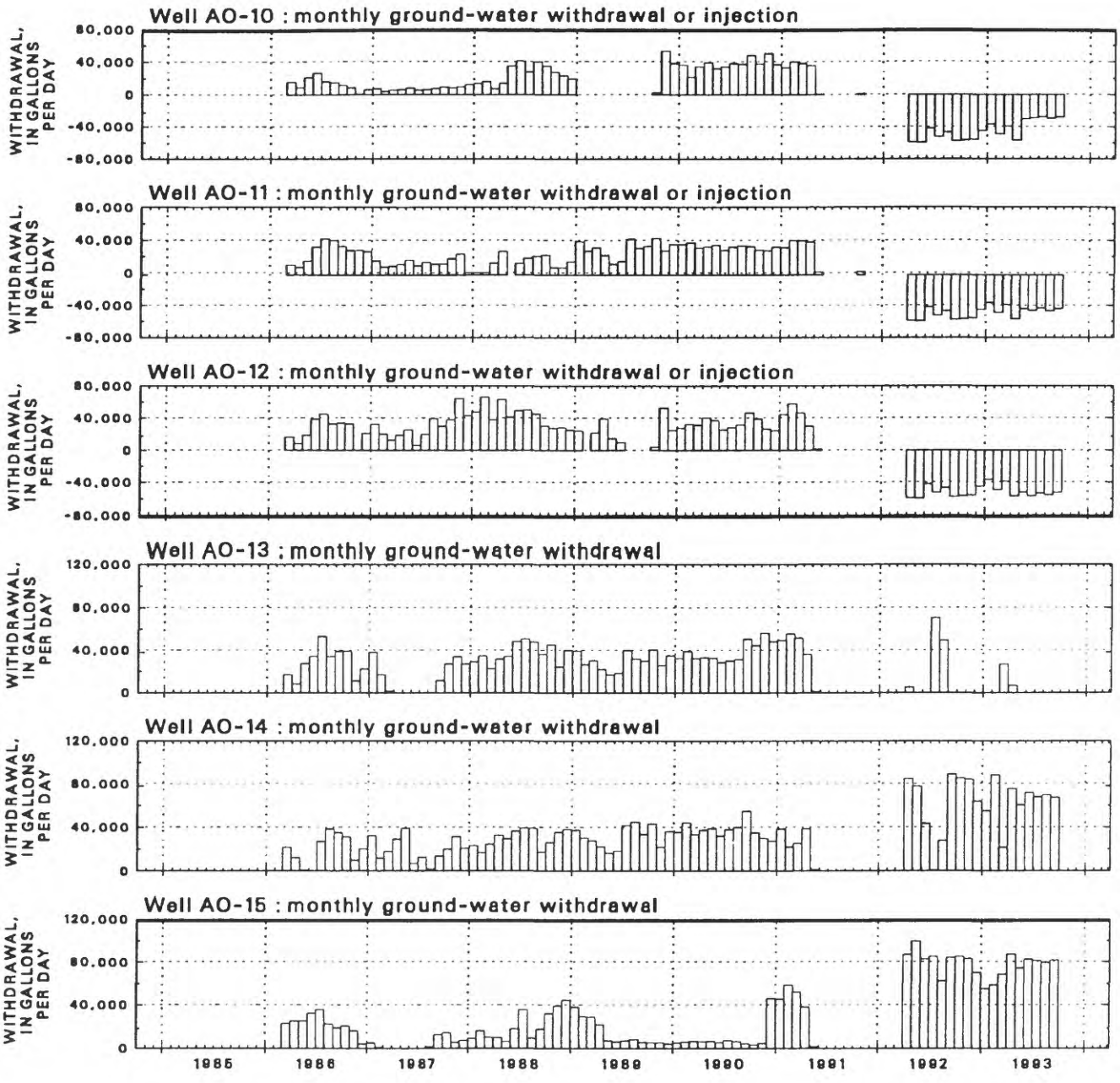


Figure B7 continued.--Monthly mean ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93.

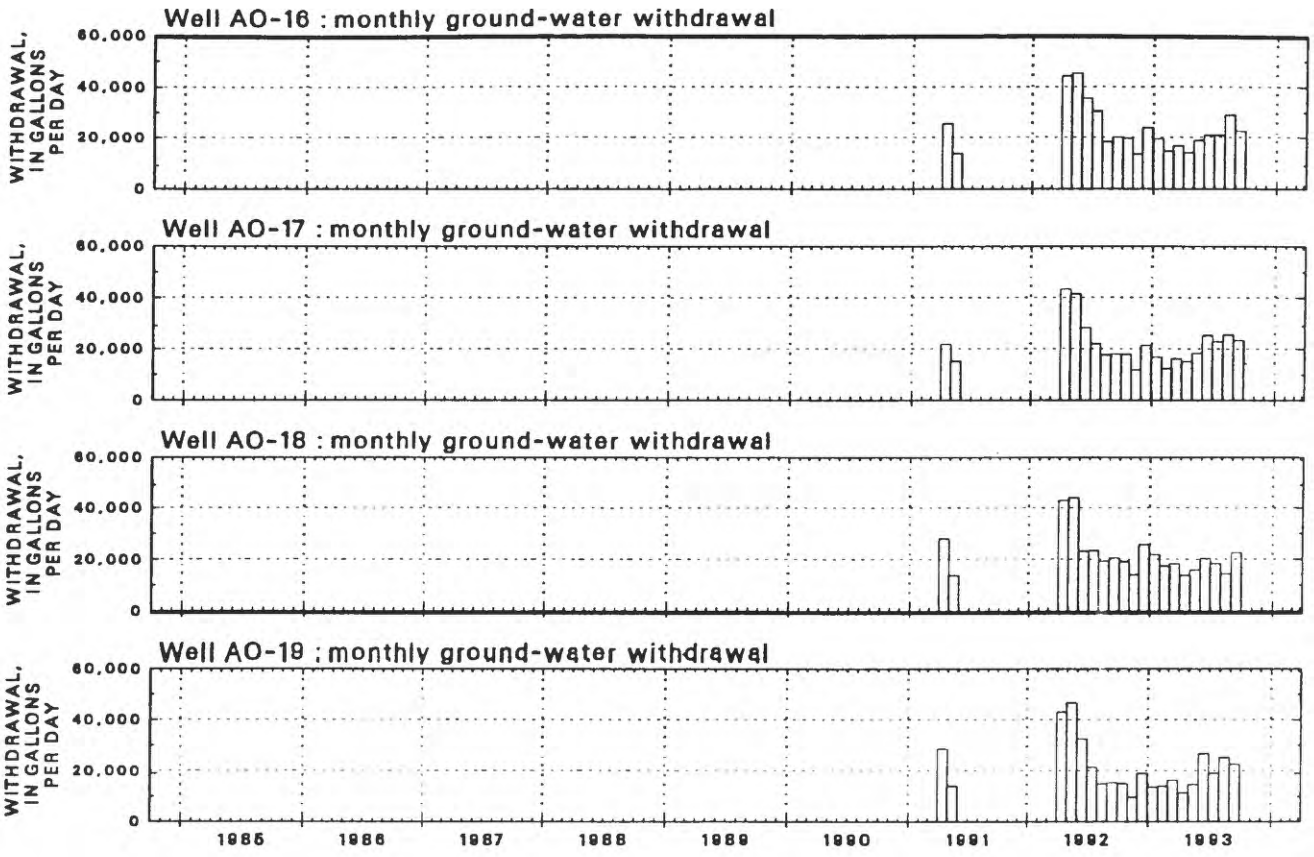


Figure B7 continued.--Monthly mean ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93.

SECTION C

Graphs of daily ground-water withdrawal, 1992-93

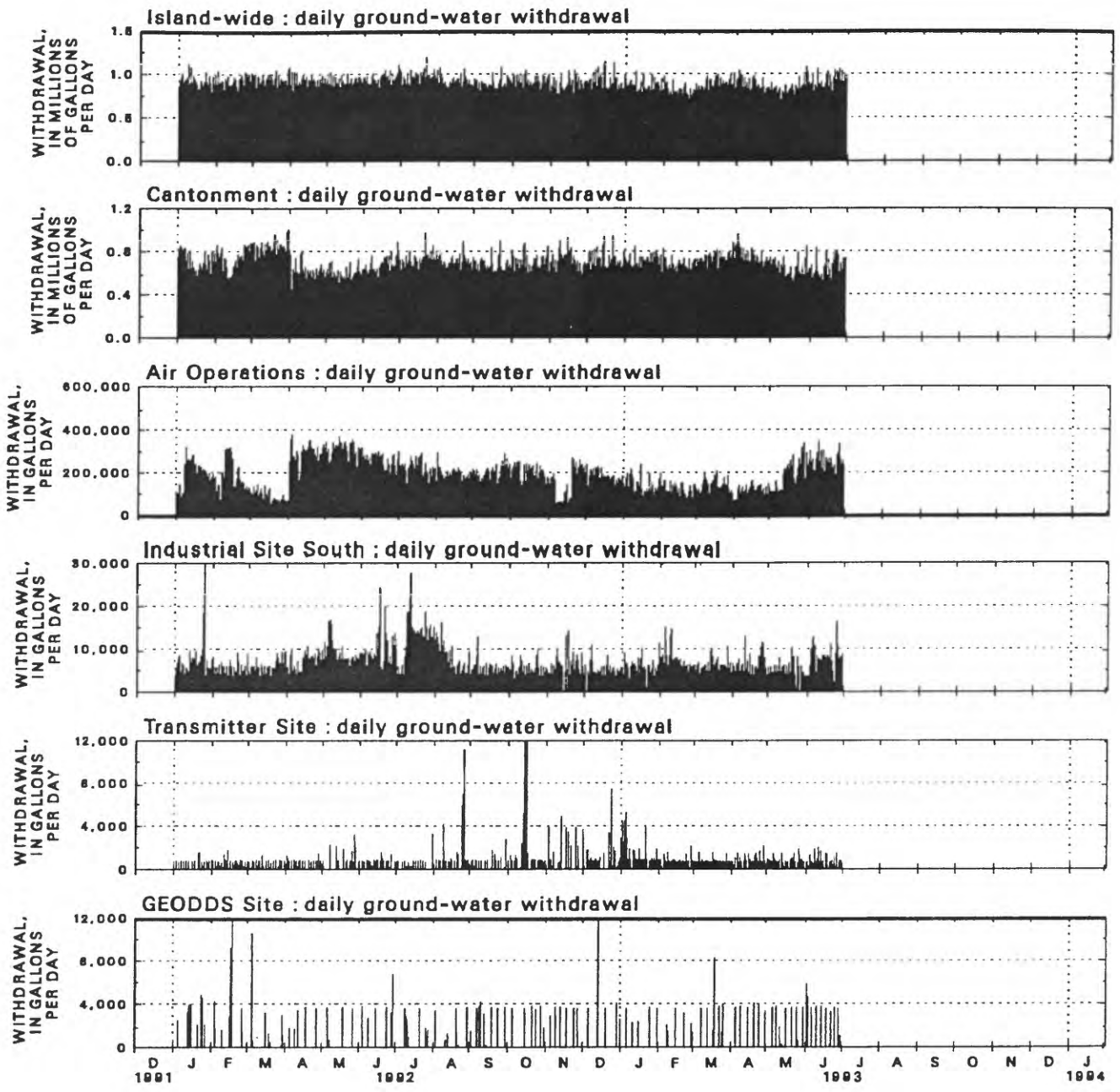


Figure C1. Daily ground-water withdrawal islandwide and in ground-water production areas, Diego Garcia, 1992-93.

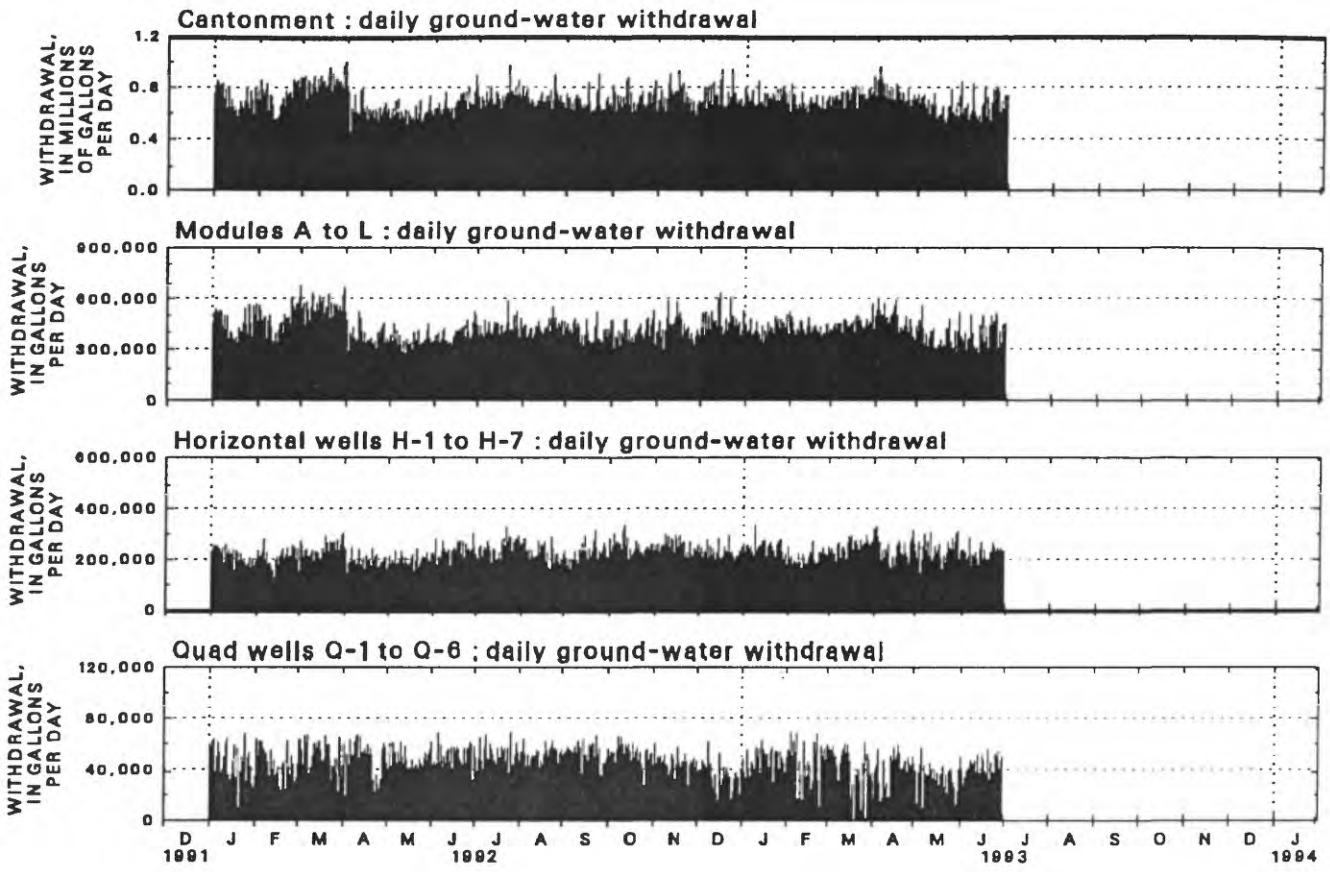


Figure C2. Daily ground-water withdrawal at Cantonment, Diego Garcia, 1992-93.

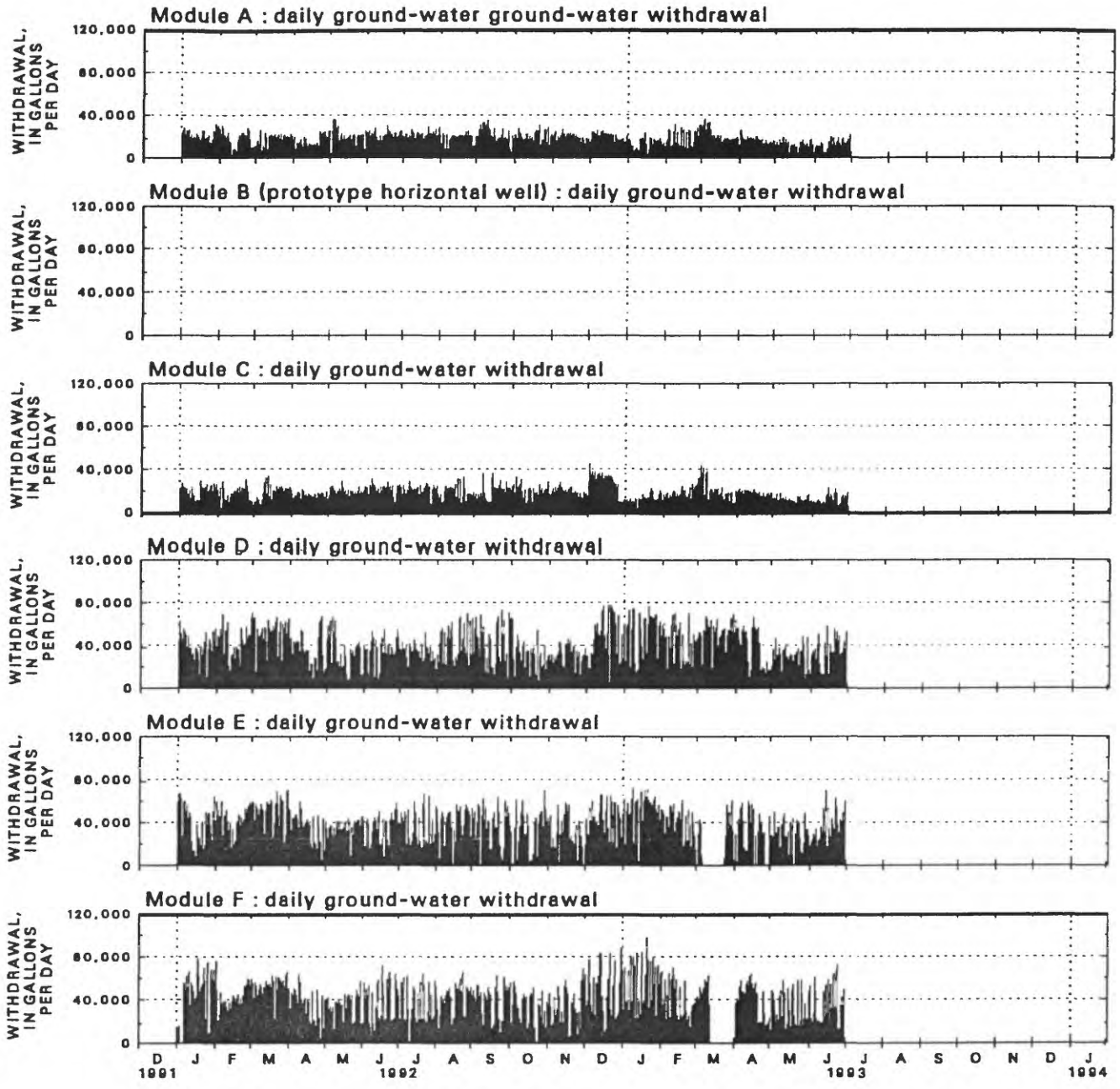


Figure C3. Daily ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, 1992-93.

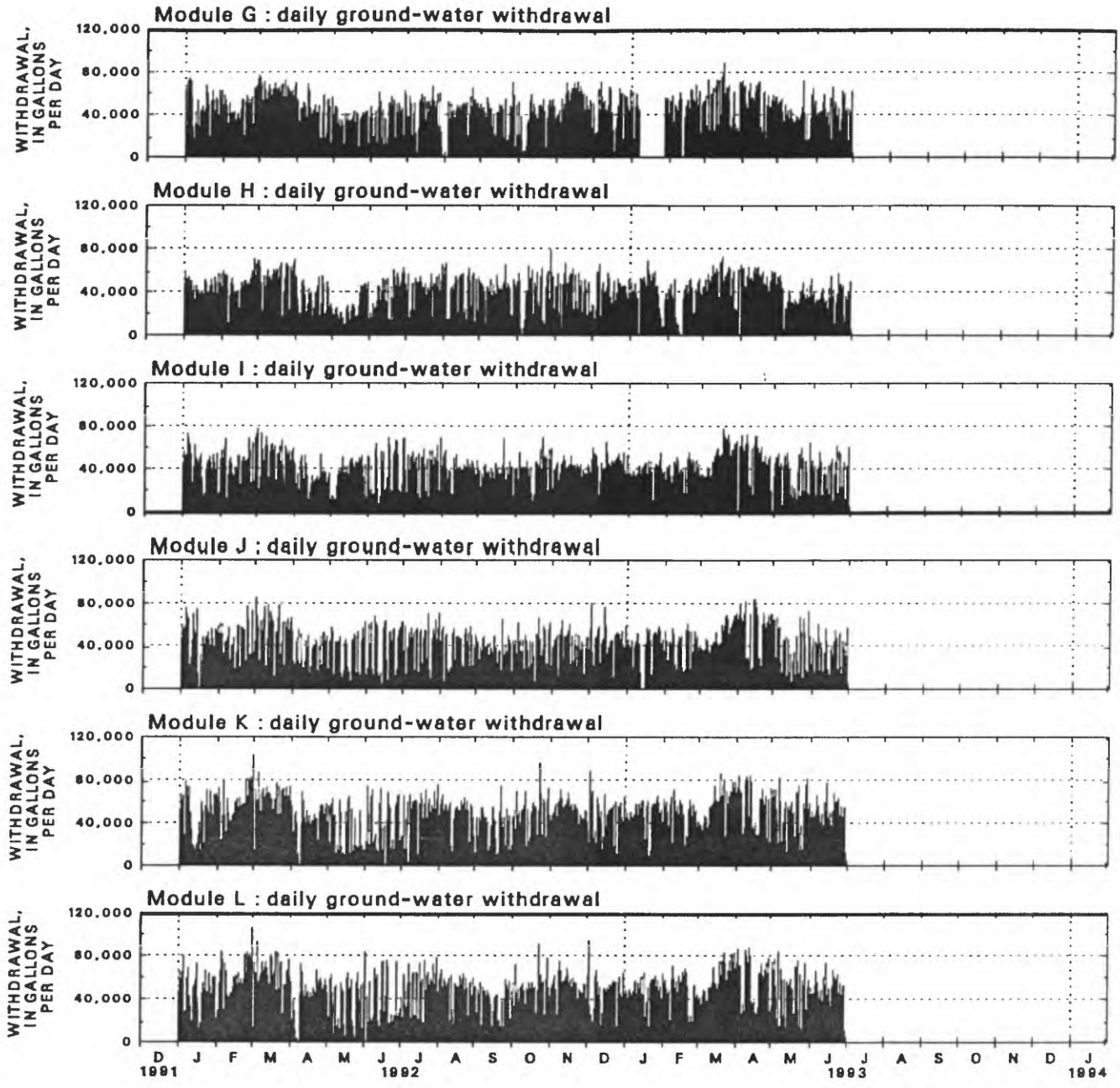


Figure C3 continued.--Daily ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, 1992-93.

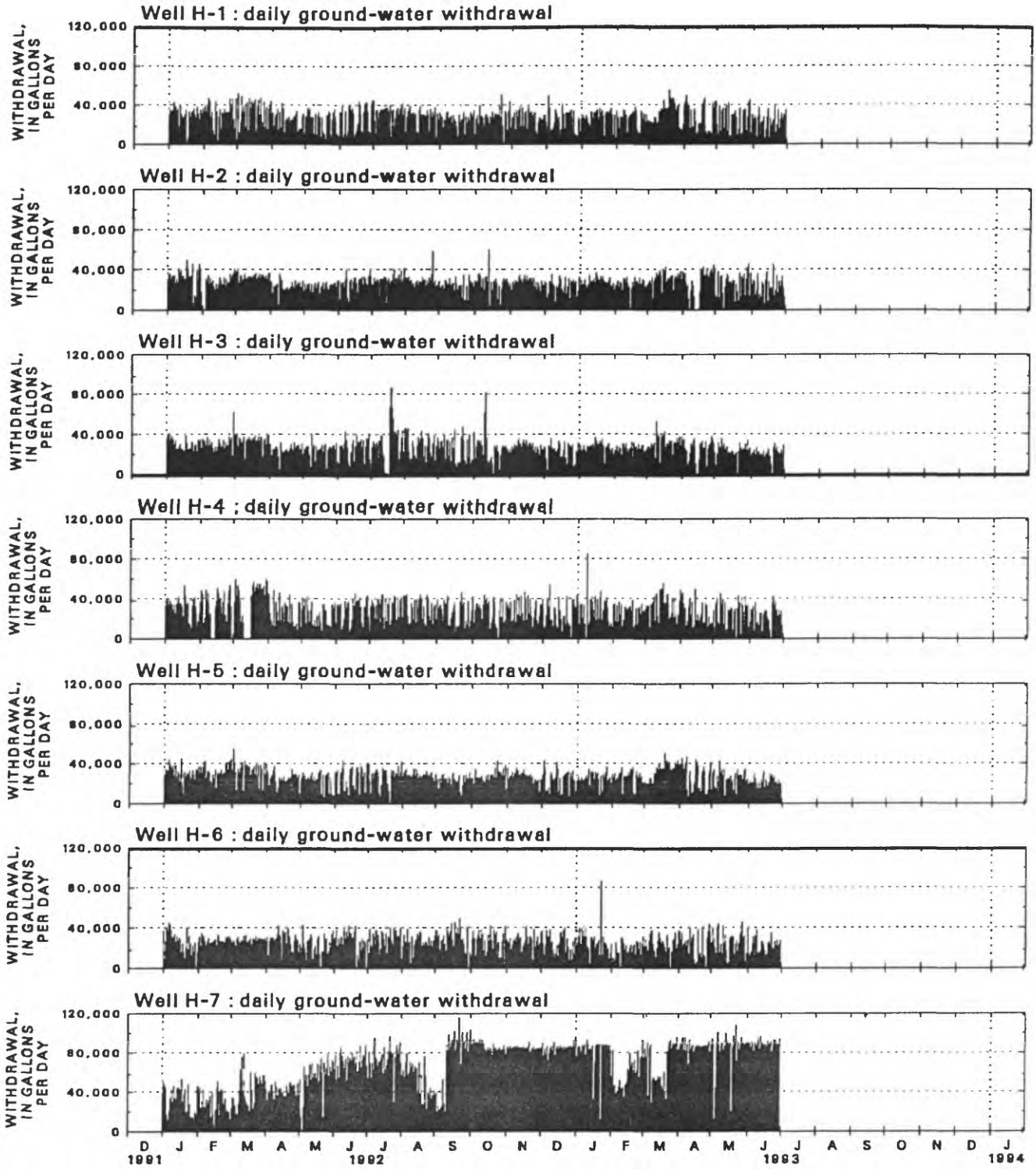


Figure C4. Daily ground-water withdrawal at wells H-1 through H-7 at Cantonment, Diego Garcia, 1992-93.

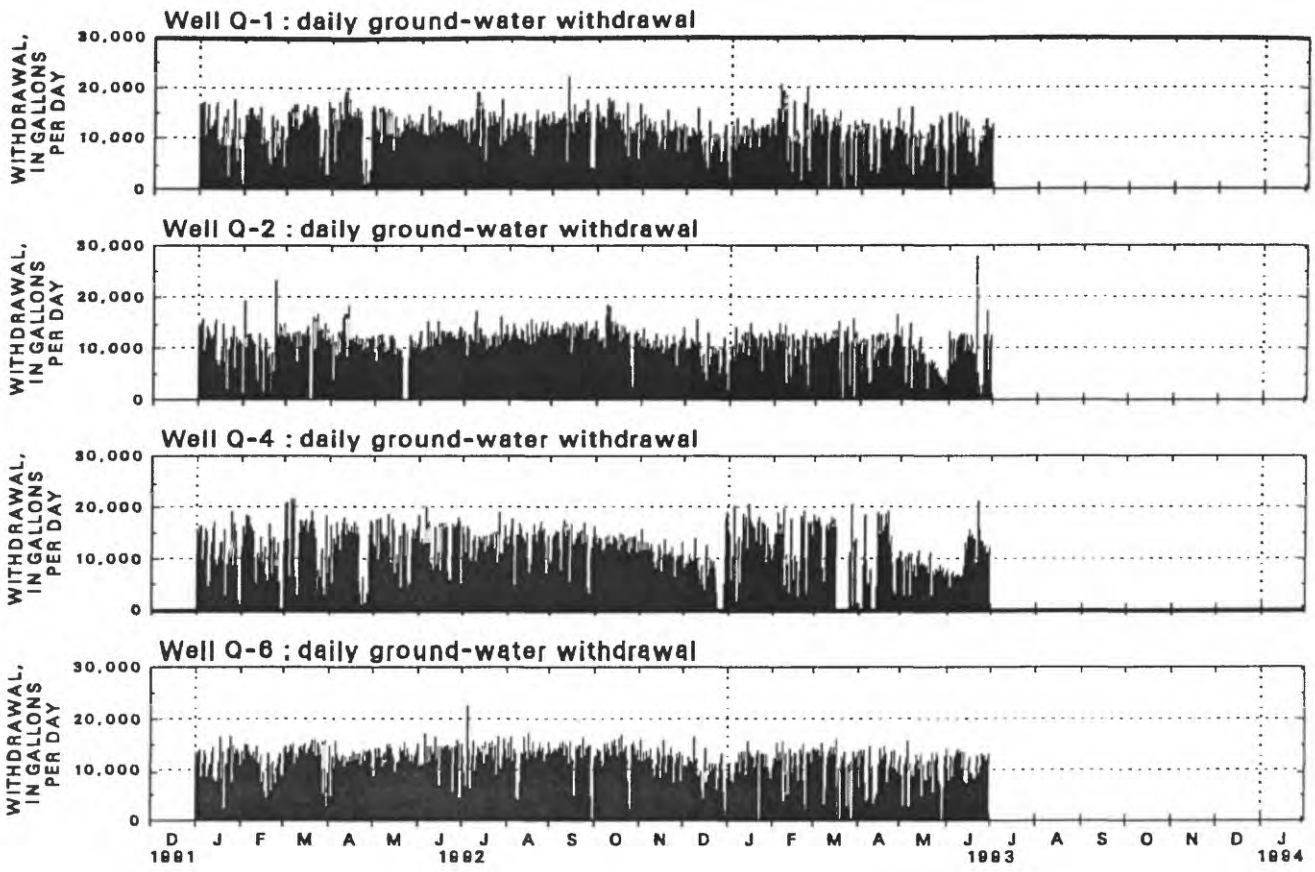


Figure C5. Daily ground-water withdrawal at wells Q-1, 2, 4, and 6 at Cantonment, Diego Garcia, 1992-93.

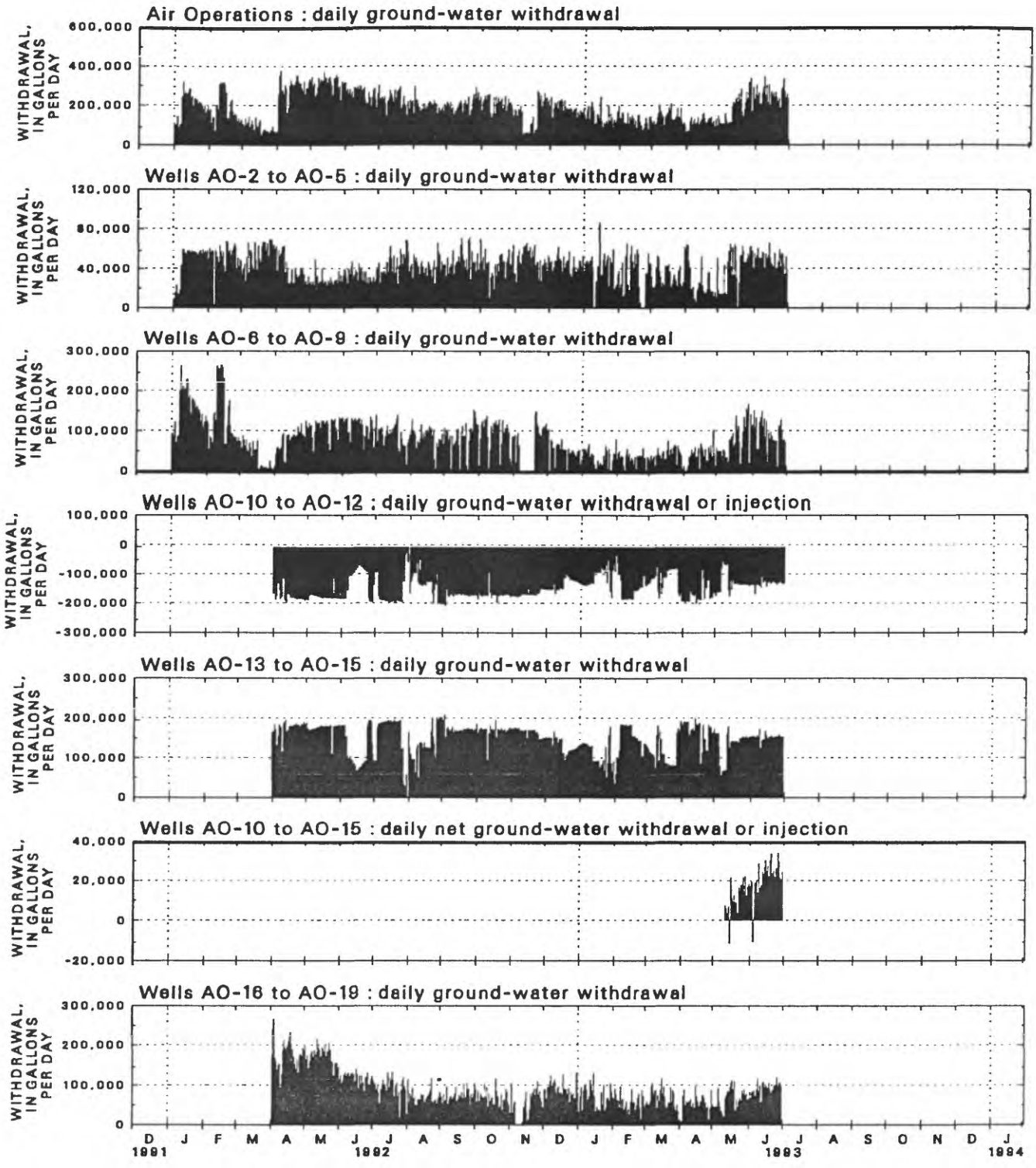


Figure C6. Daily ground-water withdrawal at Air Operations, Diego Garcia, 1992-93.

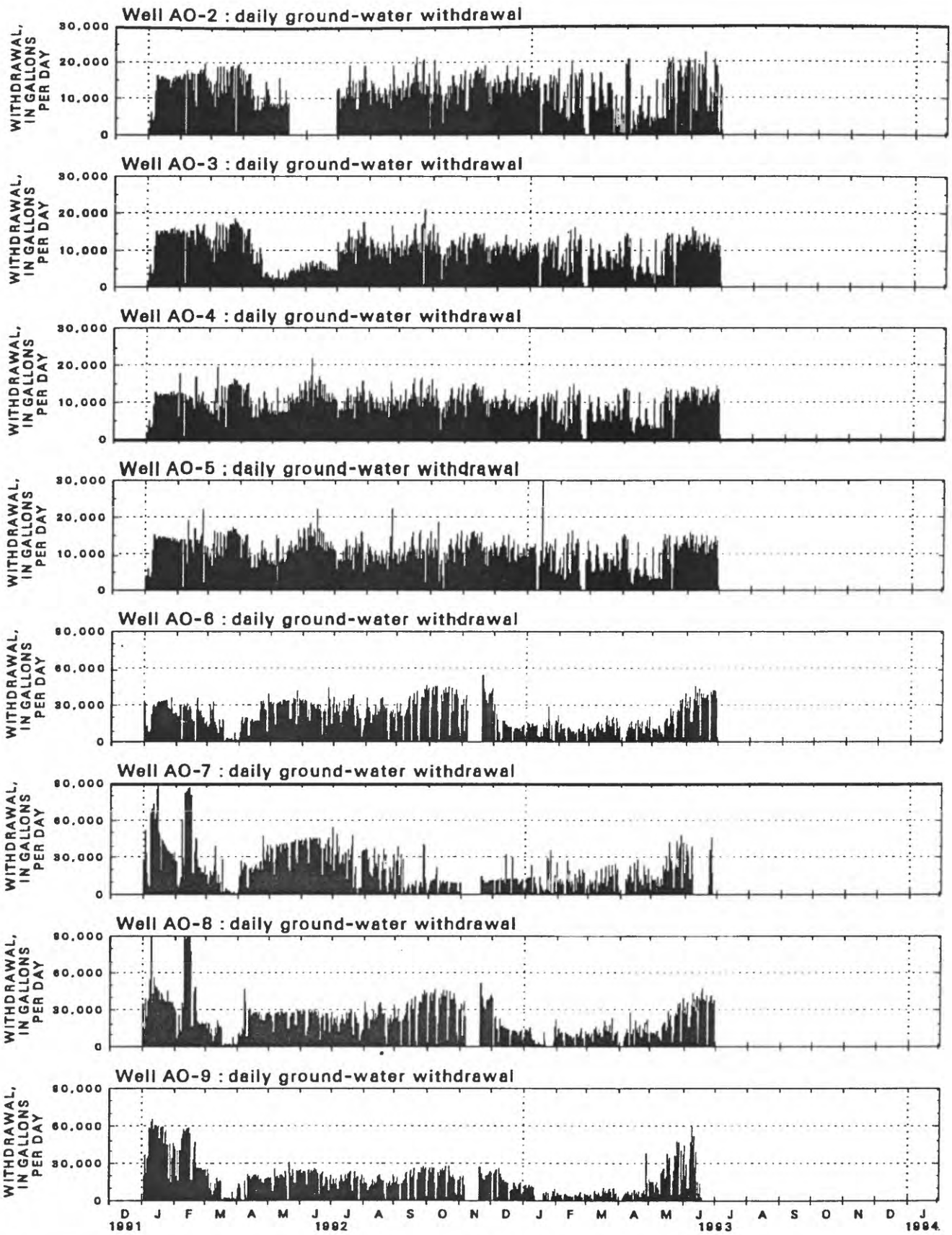


Figure C7. Daily ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1992-93.

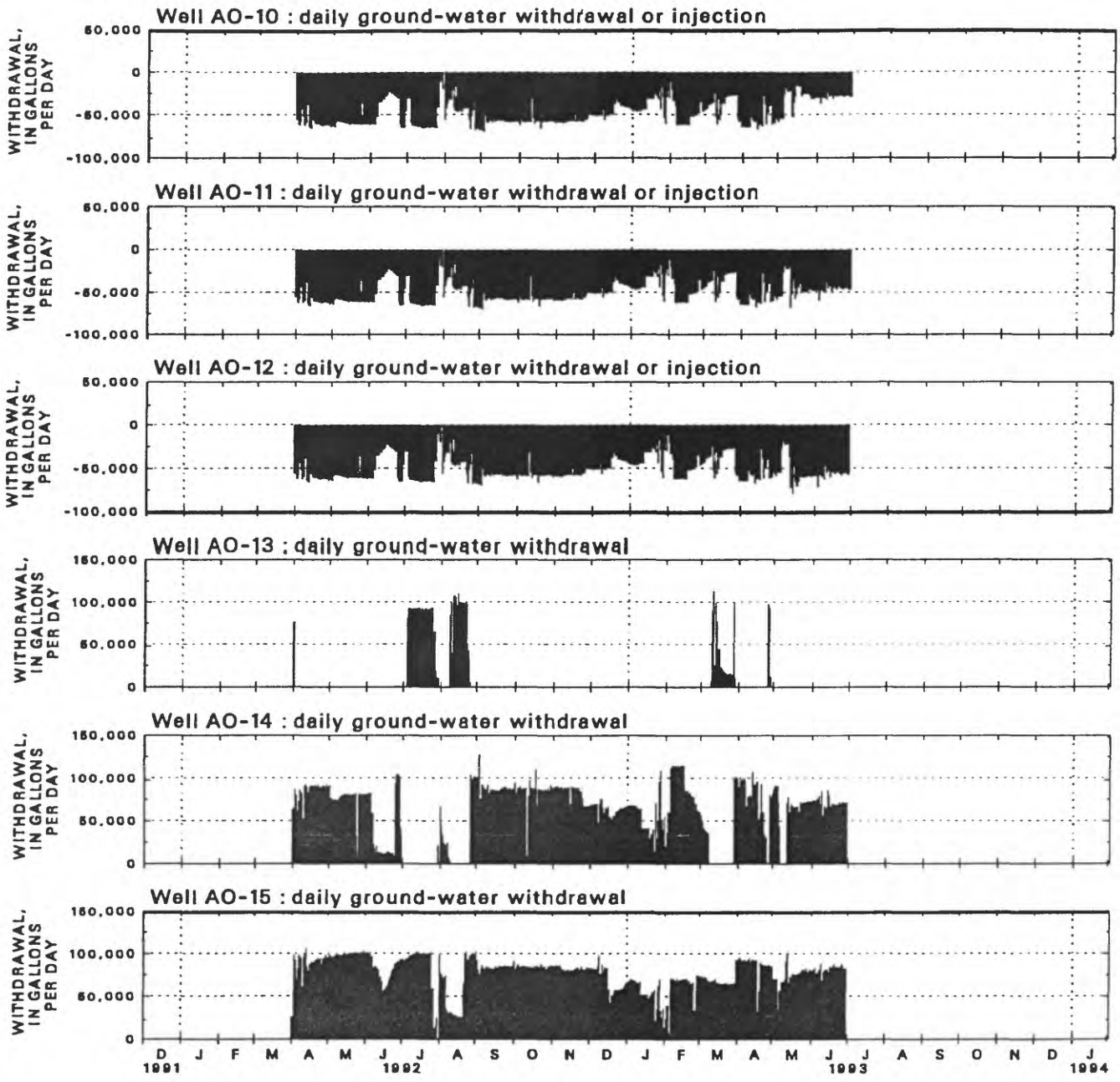


Figure C7 continued.--Daily ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1992-93.

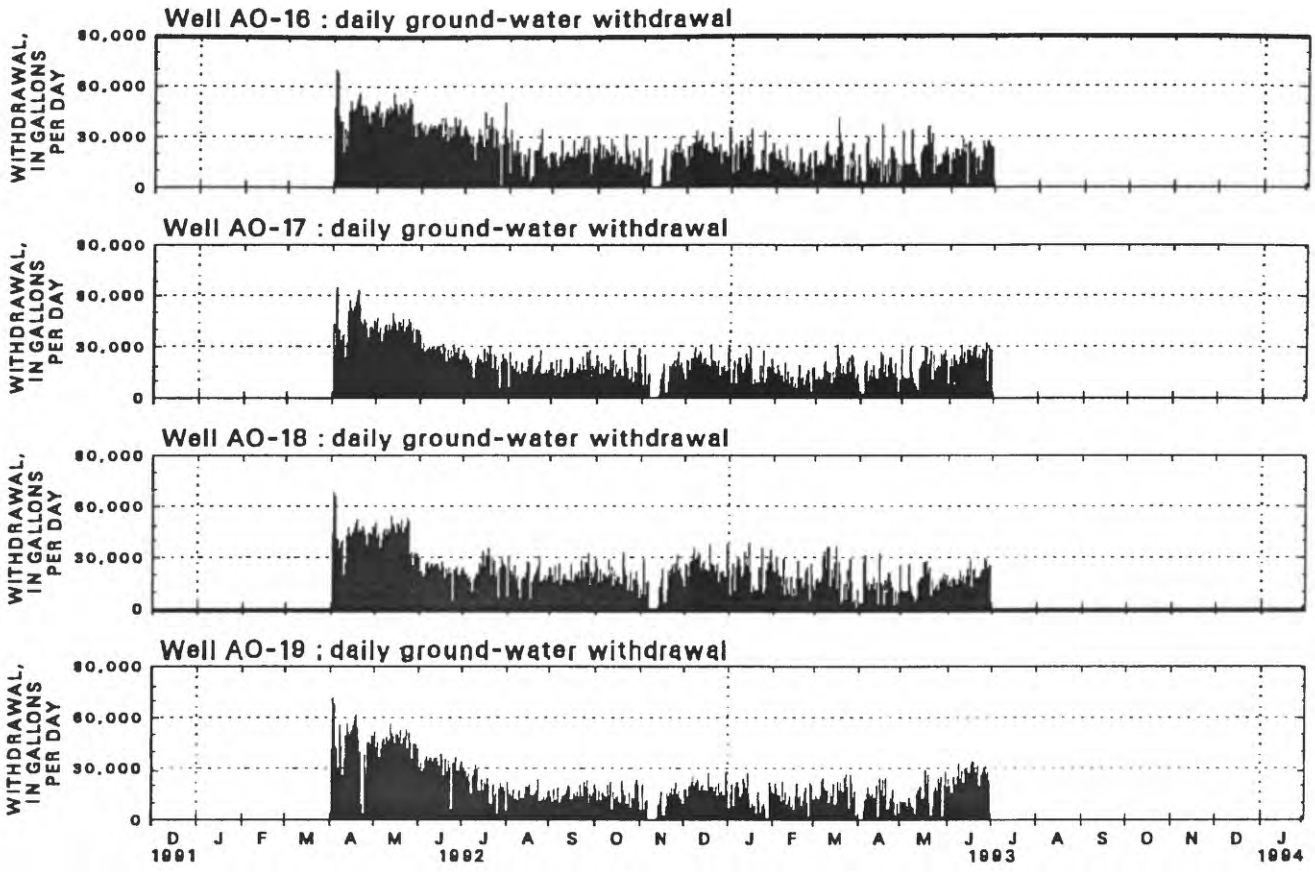


Figure C7 continued.--Daily ground-water withdrawal at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1992-93.

SECTION D

Graphs of weekly chloride concentration of pumped ground water, 1985-93

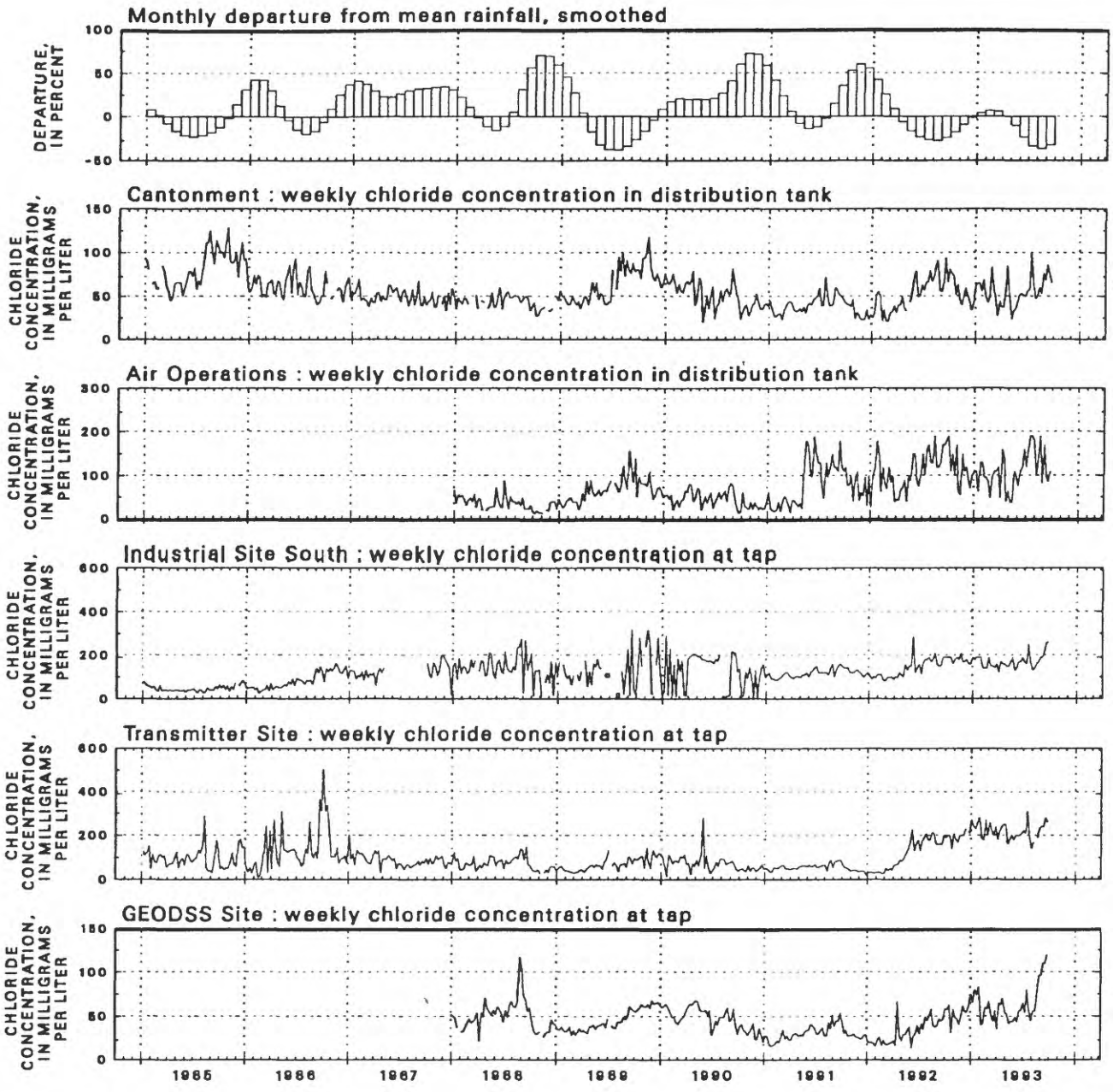


Figure D1. Weekly chloride concentration of pumped water in the ground-water production areas, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.

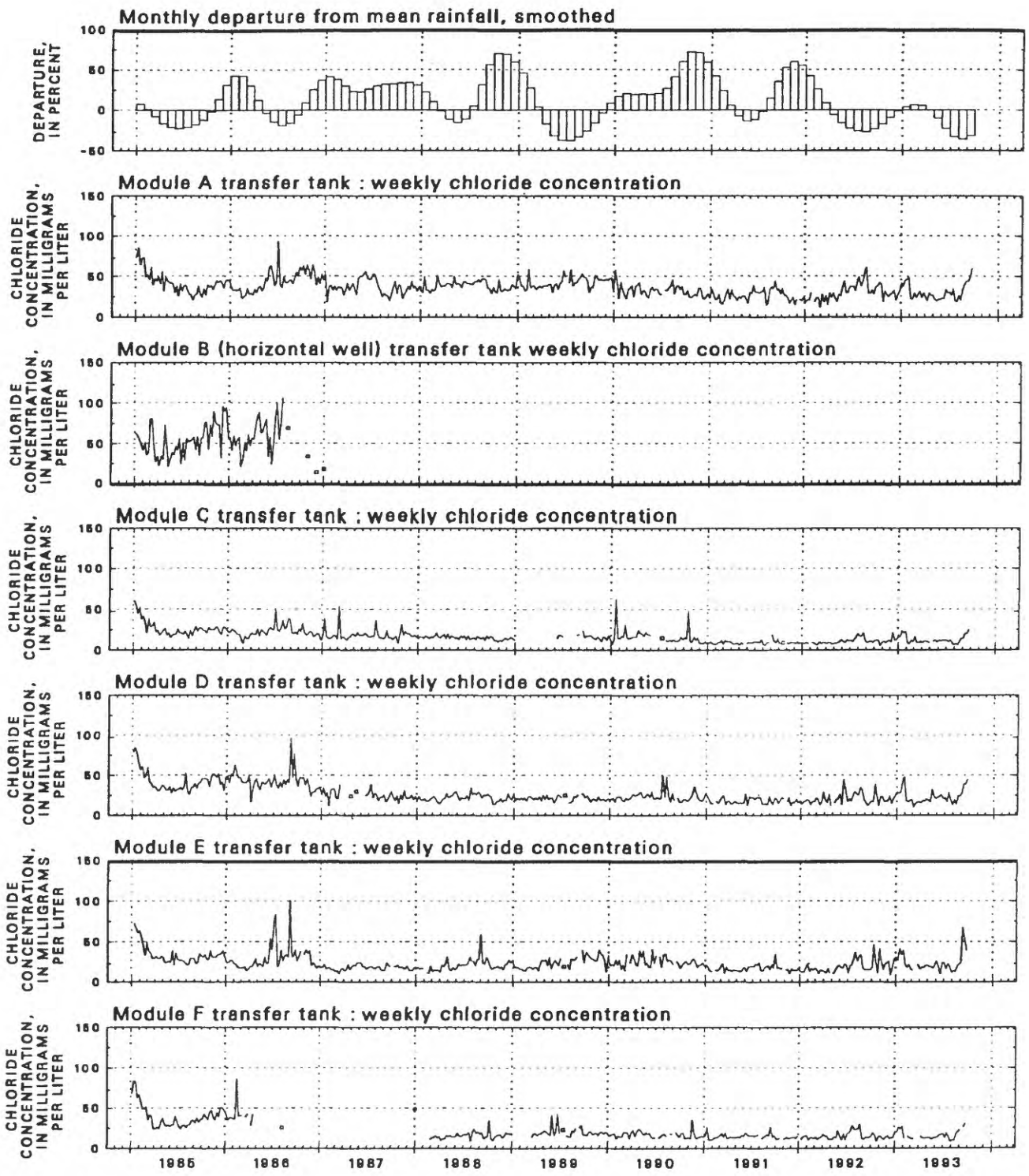


Figure D2. Weekly chloride concentration at Modules A through L at Cantonment, Diego Garcia, 1985-92. Rainfall departure data are shown for comparison.

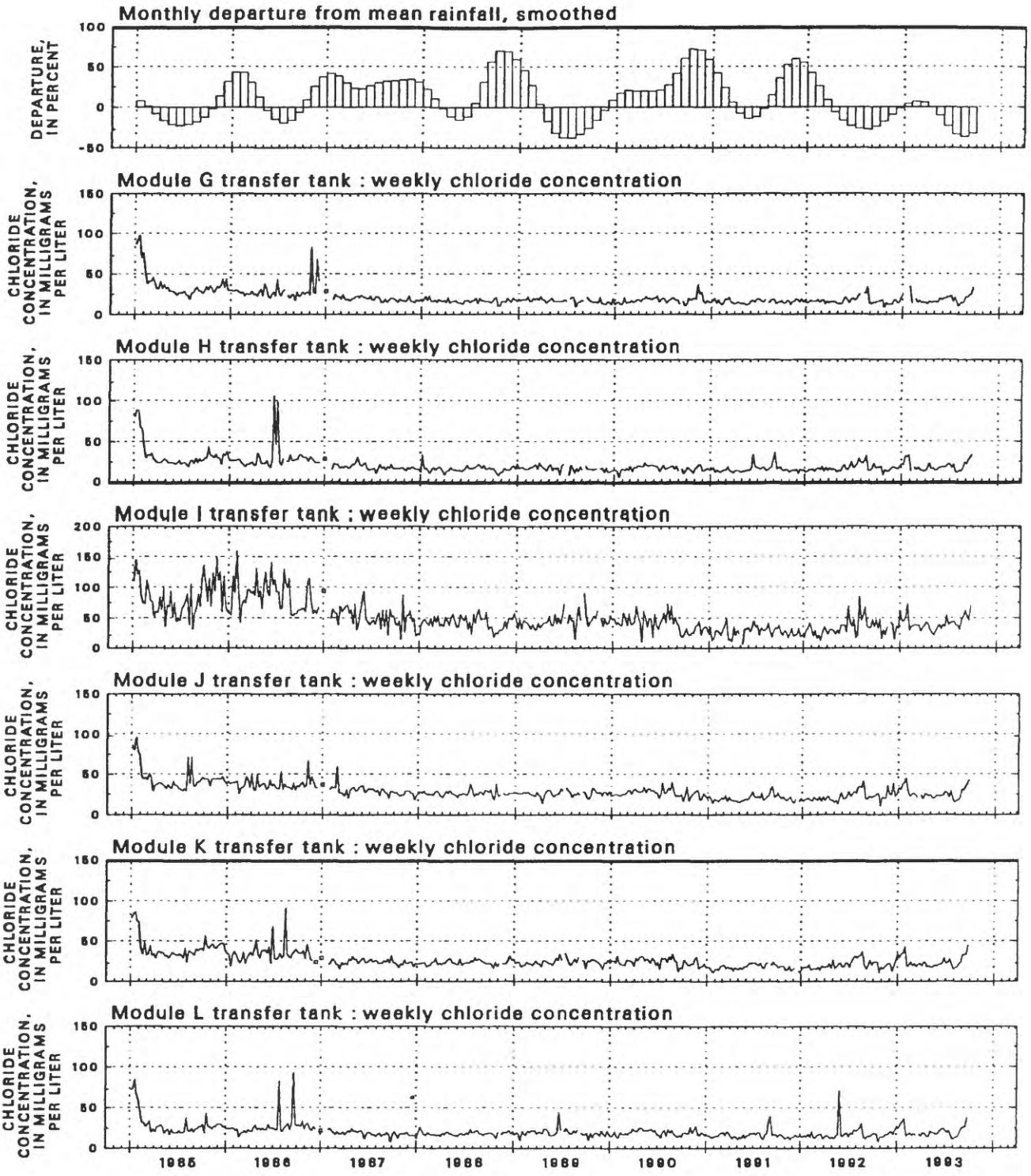


Figure D2 continued.--Weekly chloride concentration at Modules A through L at Cantonment, Diego Garcia, 1985-92. Rainfall departure data are shown for comparison.

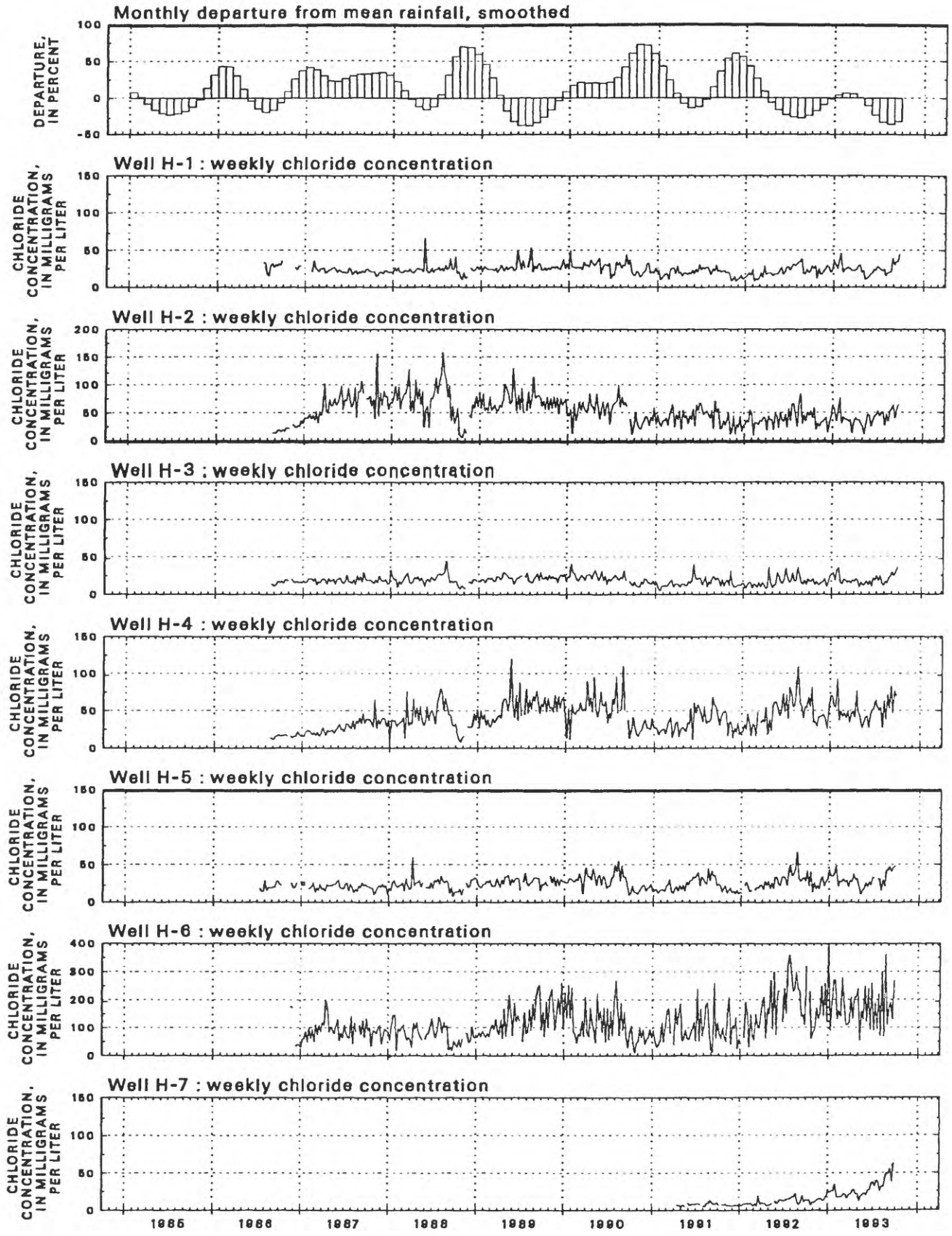


Figure D3. Weekly chloride concentration at wells H-1 through H-7 at Cantonment, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.

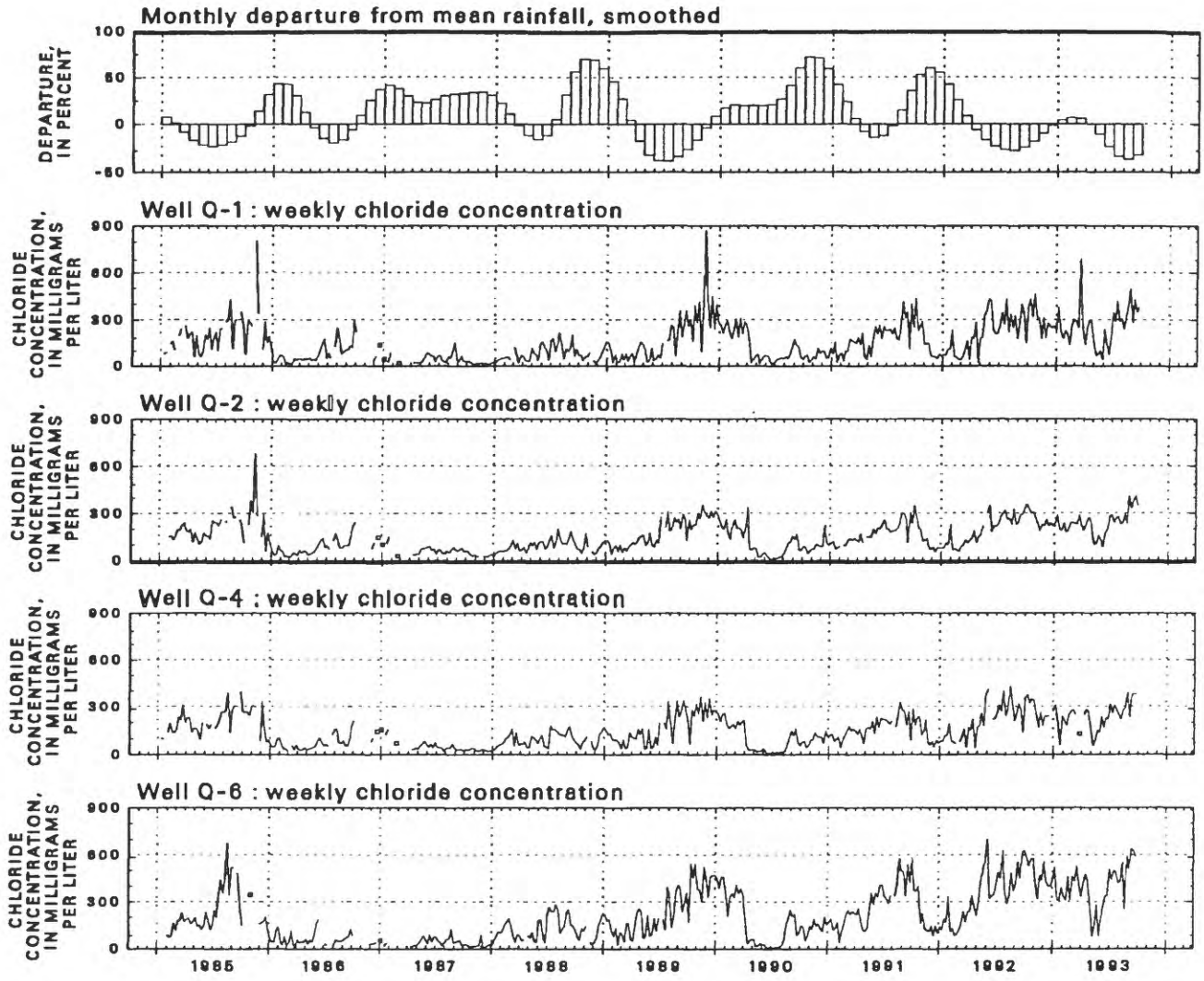


Figure D4.Weekly chloride concentration at wells Q-1, 2, 4, and 6 at Cantonment, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.

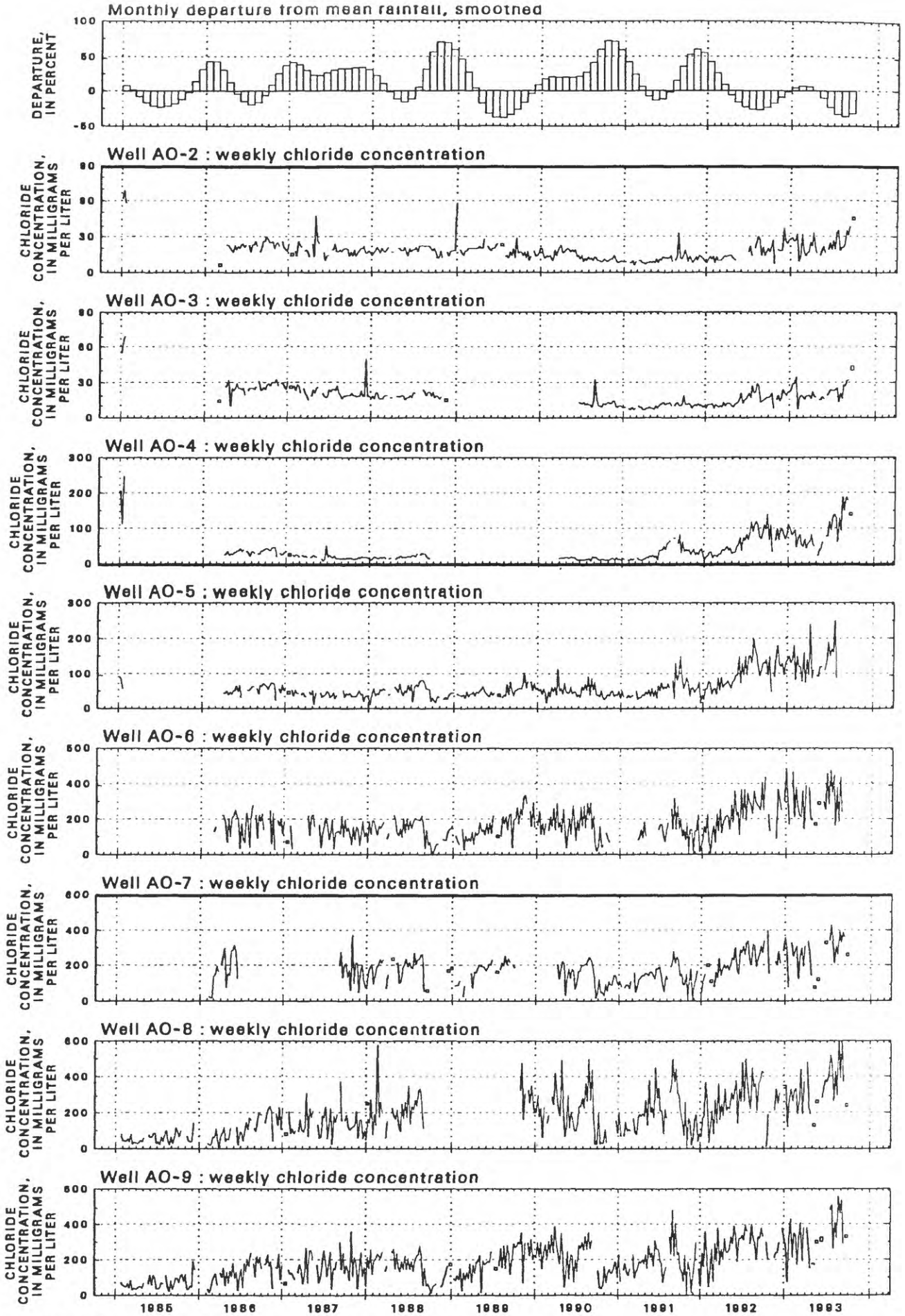


Figure D5. Weekly chloride concentration at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.

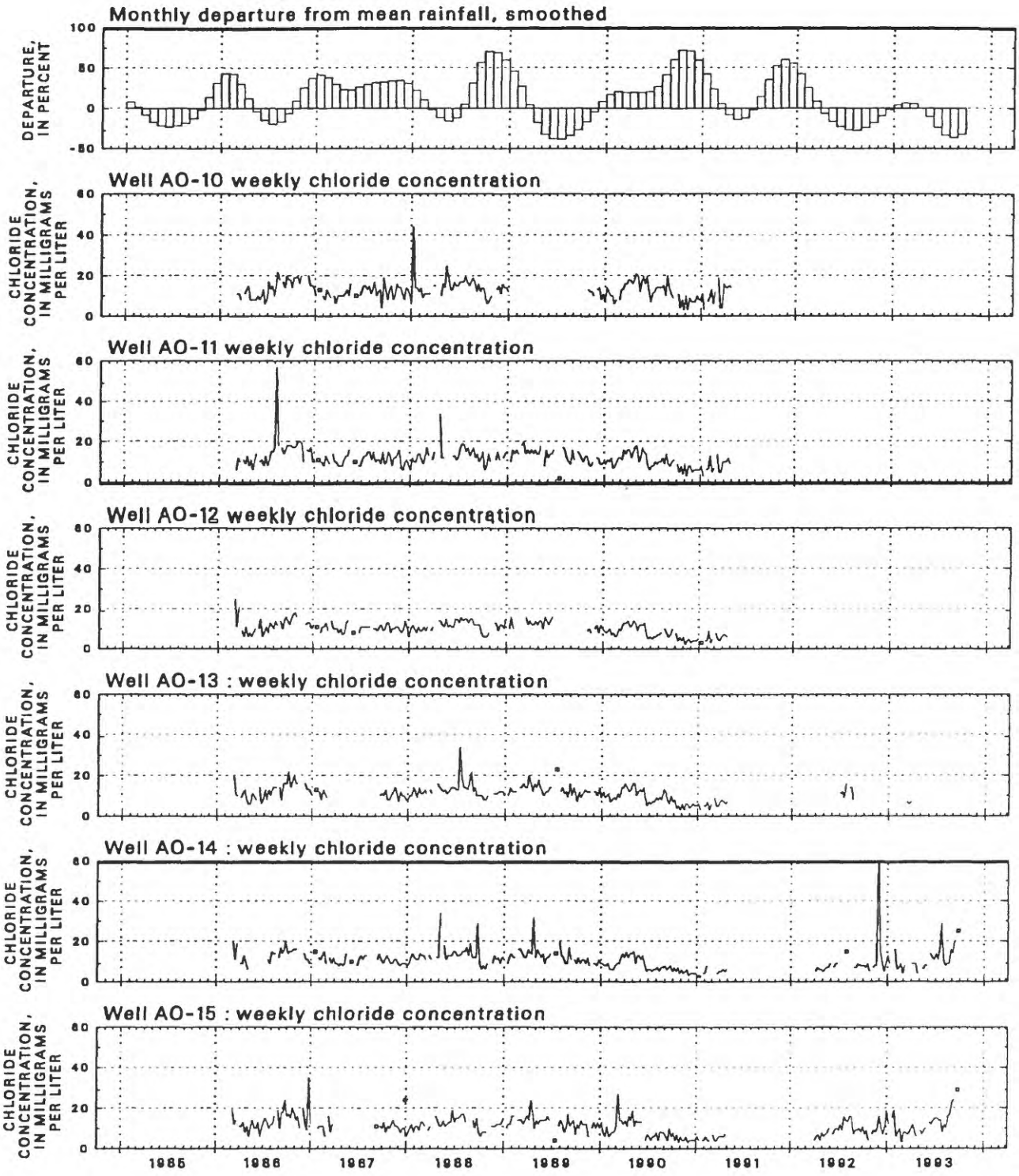


Figure D5 continued.--Weekly chloride concentration at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.

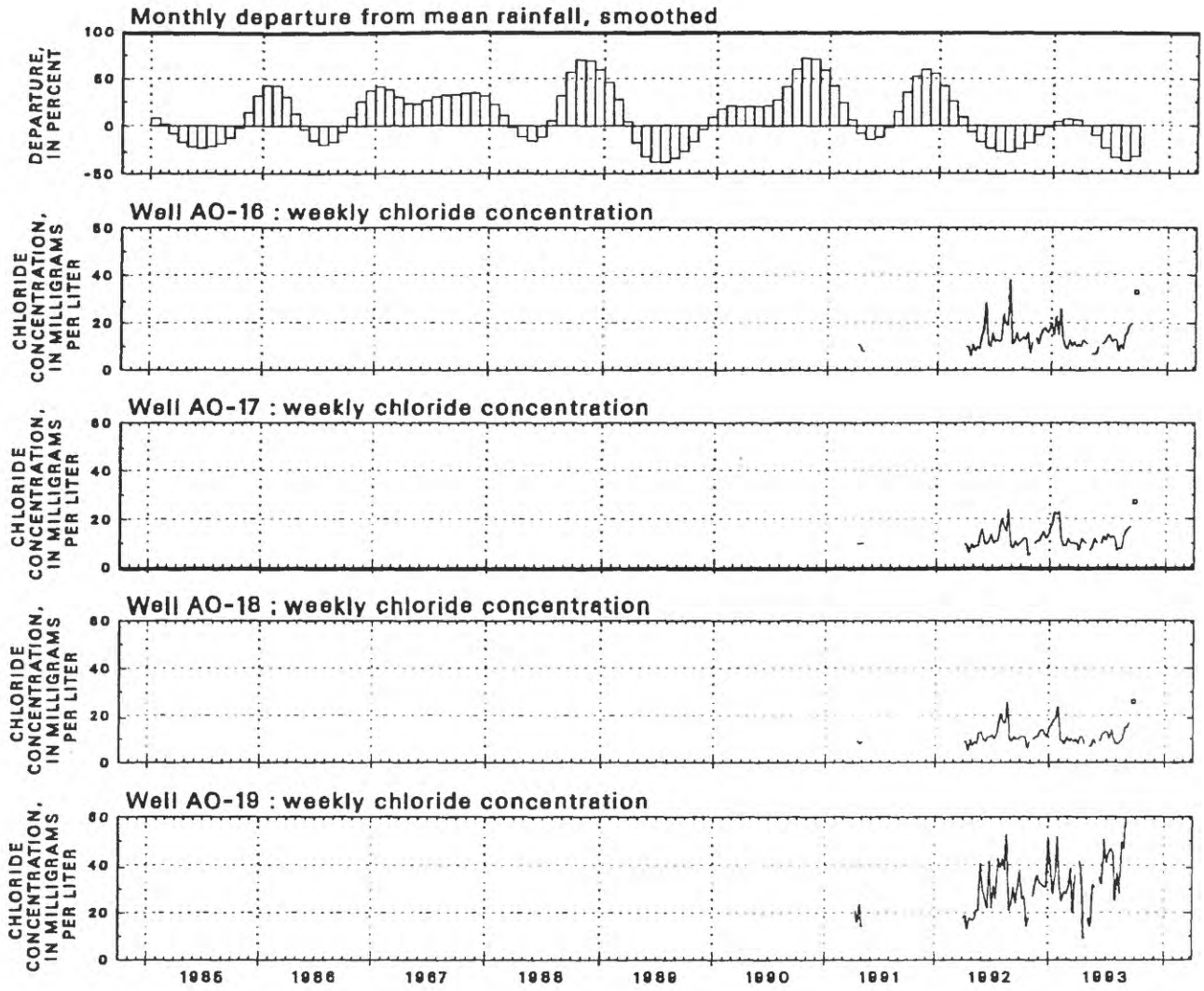


Figure D5 continued.--Weekly chloride concentration at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1985-93. Rainfall departure data are shown for comparison.