Summary of Ground-Water Data for Tutuila and Aunuu, American Samoa, for July 1985 through September 1996

By Scot K. Izuka

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BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Mark Schaefer, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
677 Ala Moana Blvd., Suite 415
Honolulu, HI 96813

Copies of this report can be purchased from:

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	by	to obtain
inch (in.)	2.54	centimeters
inch/month (in/mo)	2.54	centimeters per month
foot (ft)	0.3048	meter
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile, statute (mi)	1.609	kilometers
square mile (mi^2)	2.590	square kilometers
gallon	3.785	liters
million gallons (Mgal)	3,785	cubic meters
million gallons per day (Mgal/d)	0.04381	cubic meter per second
gallons per minute (gal/min)	3.785	liters meter per minute

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

Vertical datum

All elevations in this report are referenced relative to mean sea level.

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Abstract

Ground-water and rainfall data for the period July 1985 through September 1996 from Tutuila and Aunuu, American Samoa, are plotted in time-series graphs and summarized. The data include pumpage and chloride concentrations from 49 production wells on Tutuila and 3 production wells on Aunuu, water level measurements from 9 wells on Tutuila, and rainfall from 2 gages on Tutuila.

Rainfall averaged 13.2 inches per month at the rain gage at Afono and 17.1 inches per month at the rain gage in Aasufou over the period from 1985 to 1996. The Tafunafou, Malaeimi-Mesepa, Malaeloa-Leone, and Iliili areas in western Tutuila had pumpages ranging from 0.9 to 2 million gallons per day each and chloride concentrations usually less than 500 milligrams per liter. The Aoloaufou area, also in Western Tutuila, produced about 0.06 to 0.10 million gallons per day with chloride concentrations less than 20 milligrams per liter.

Most wells in central and eastern Tutuila pumped less than 0.2 million gallons per day with chloride concentrations that frequently exceeded 500 milligrams per liter. The Fagatogo and Pago Pago areas which each produced about 0.75 to 1.2 million gallons per day with chloride concentrations below 100 milligrams per liter were exceptions. Chloride concentrations in Fagaalu, Aoa, and Fagasa were below 500 milligrams per liter, but these areas have been pumped for less than 6 years and at rates less than 0.1 million gallons per day each. The Aua area produced 0.6 to 1.1 million gallons per day but chloride concentrations have risen to more than 500 milligrams per liter. Wells on Aunuu each produced about 0.01 to 0.03 million gallons per day of water with chloride concentrations that frequently exceeded 1,000 milligrams per liter.

In the 12-month period ending September 1996, rainfall at both the Aasufou and Afono gages was lower than average. Total pumpage for most areas remained about the same as in previous months. Most wells showed an increase in chloride concentrations except wells in Aoloaufou, Aoa, Sailele and well 163 in Pago Pago where chloride concentrations remained about the same as in previous months. Water levels in Tafunafou, Iliili, and Pago Pago remained at about the same elevation above sea level as in previous years, water levels in two of the three monitor wells in Aua remained below sea level as in previous years, and water levels in Laulii and Fagaalu declined relative to previous years.

INTRODUCTION

The American Samoa Government, through the American Samoa Environmental Protection Agency (ASEPA), American Samoa Power Authority (ASPA), and the Department of Public Works (DPW), has maintained a cooperative effort with the U.S. Geological Survey (USGS) to collect the principal data needed to monitor ground-water resources on Tutuila, the largest and most populated island in the South Pacific archipelago of American Samoa, and the small, nearby island of Aunuu (fig. 1). This report is the second in a series of annual summaries of ground-water data. The purpose of these annual summaries is to present the data as time-series graphs that can be used to analyze trends.

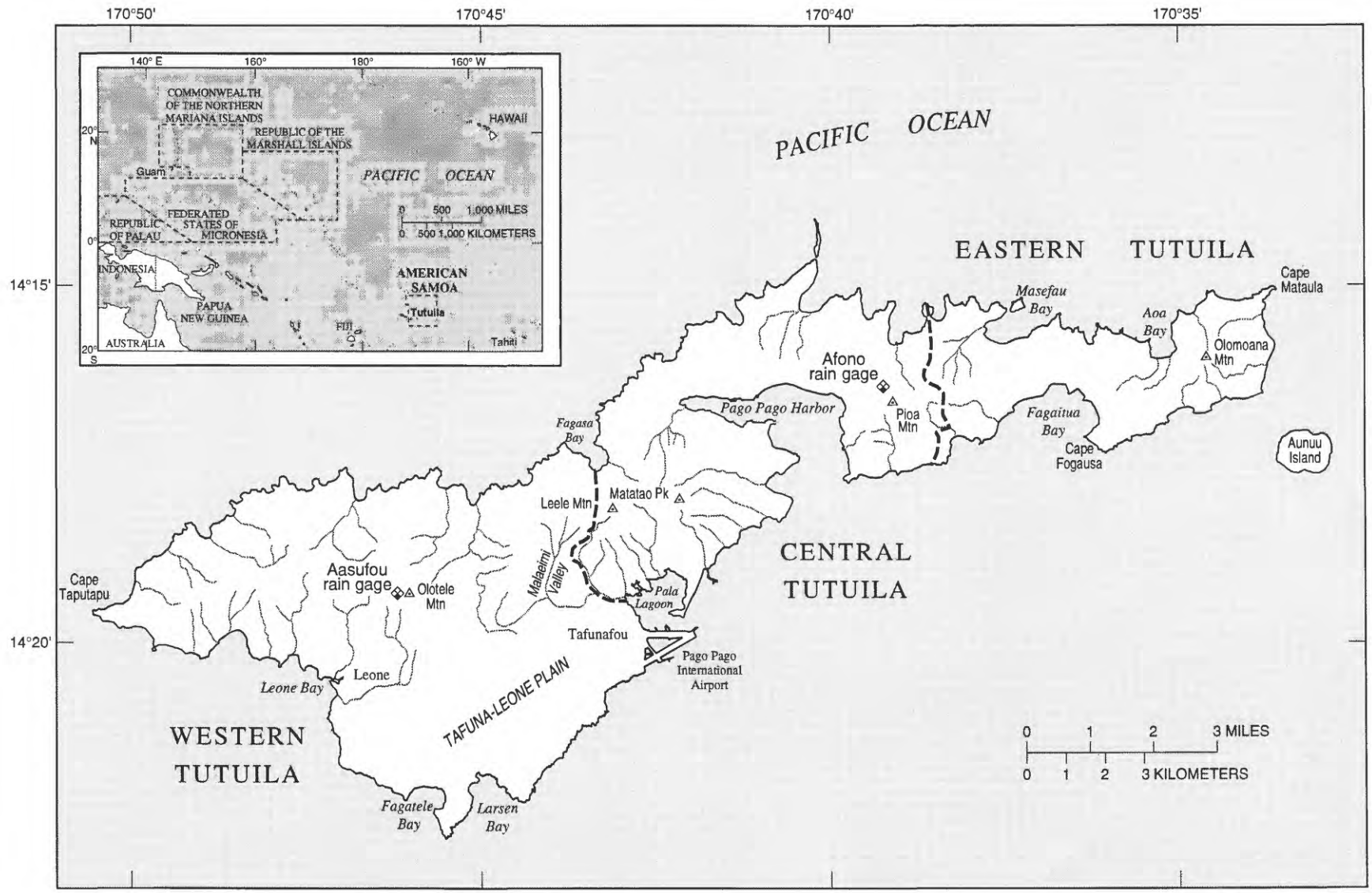


Figure 1. Tutuila and Aunuu Islands, American Samoa and geographic divisions used in this report.

This report summarizes pumpage data from 49 wells on Tutuila and 3 wells on Aunuu that were in production during the period October 1985 through September 1996. Records for 11 of the production wells on Tutuila indicate no pumpage in the 12-month period ending with September 1996, but are included in this report for historical purposes. Chloride concentrations in the pumped water at each production well also are summarized for this period. In this report, the concentration of chloride ions is used as an indicator of the salinity of ground-water pumped at wells. Salinity is a principal factor limiting the availability of ground water on midocean islands. Rainfall data from two gages also are summarized in this report to allow comparisons with the ground-water data. Water-level measurements from 9 observation wells on Tutuila also are summarized.

For convenience of discussion, the wells on Tutuila are grouped into three regions (fig. 1). Western Tutuila includes all of the Tafuna-Leone Plain and the wells in Aoloaufou. Central Tutuila includes all the wells surrounding Pago Pago Harbor, as well as in Fagasa on the north coast and in Laulii on the south coast about 0.5 mi beyond the mouth of the harbor. Eastern Tutuila includes all of the wells east of Laulii.

Setting

Tutuila is a volcanic island of about 53 mi^2 located in the tropical South Pacific (fig. 1). The island is narrow and elongate in the east-west direction and characterized mostly by steep, deeply eroded mountains that rise abruptly from the ocean to elevations as high as 2,140 ft. The exception to this general topography is the relatively flat Tafuna-Leone Plain in the southwest which stretches from Tafunafou to Leone. The mountainous part of Tutuila is composed of Pliocene- to Pleistocene-age shield-volcano alkalic basalts, andesites, and trachytes that have relatively low permeabilities (Stearns, 1944; Macdonald, 1944, 1968; Davis, 1963; Bentley, 1975). The Tafuna-Leone Plain is composed of younger (Holocene age), more permeable lava flows and pyroclastic cones (Stearns, 1944; Davis, 1963; Bentley, 1975). Ground-water production is high on the Tafuna-Leone Plain. Elsewhere on Tutuila, wells are located in small valleys in the rugged mountains or other low-lying areas near the coast. Wells drilled on the top of Olotele Mountain near Aoloaufou are the only exception.

The small island of Aunuu (0.6 mi^2), less than 1 mi off the southeastern shore of Tutuila, is a tuff (consolidated volcanic ash) cone with a coastal plain on its western side. The coastal plain is about 2,000 ft wide in the east-west direction and 4,000 ft long in the north-south direction and is composed of partly consolidated marine and terrigenous sediment. Two marshes are present on Aunuu: one in the center of the tuff cone and the other at the inland edge of the coastal plain where it abuts the slope of the tuff cone. All of the ground-water development on Aunuu comes from wells in the coastal-plain sediments.

Acknowledgments

This report was produced under a cooperative agreement with the ASEPA. Data were collected by the ASPA. The author gratefully acknowledges Togipa Tausaga (Director, ASEPA), Abe Malae (Director, ASPA), Sheila Wiegman (ASEPA), and Wilfredo Carreon (ASPA), for their assistance.

RAINFALL

Rainfall averaged 17.1 in/mo at the rain gage in Aasufou and 13.2 in/mo at the rain gage in Afono near Pioa Mountain (fig. 1) during the period January 1985 through September 1996 (the Pioa gage in the first ground-water data summary [Izuka, 1996] is called the Afono gage in this report because it more correctly identifies its geographic location). The plots of the monthly departures from the mean show a seasonal pattern of rainfall with peaks in January to March and troughs in July to August (fig. 2). Plots of the departure of the 3-month and 6-month backward-looking moving average also show the seasonal cycle. Late 1987 to early 1992 was a relatively long dry period with below-average rainfall, whereas rainfall in 1994 through September 1995 was higher than average.

Trends over the 12-month period ending September 1996.--Rainfall in the 12-month period from October 1995 through September 1996 was lower than average at both the Afono and Aasufou gages. Rainfall averaged only 12.5 in/mo at the Aasufou gage and only 10.1 in/mo at the Afono gage during this period.

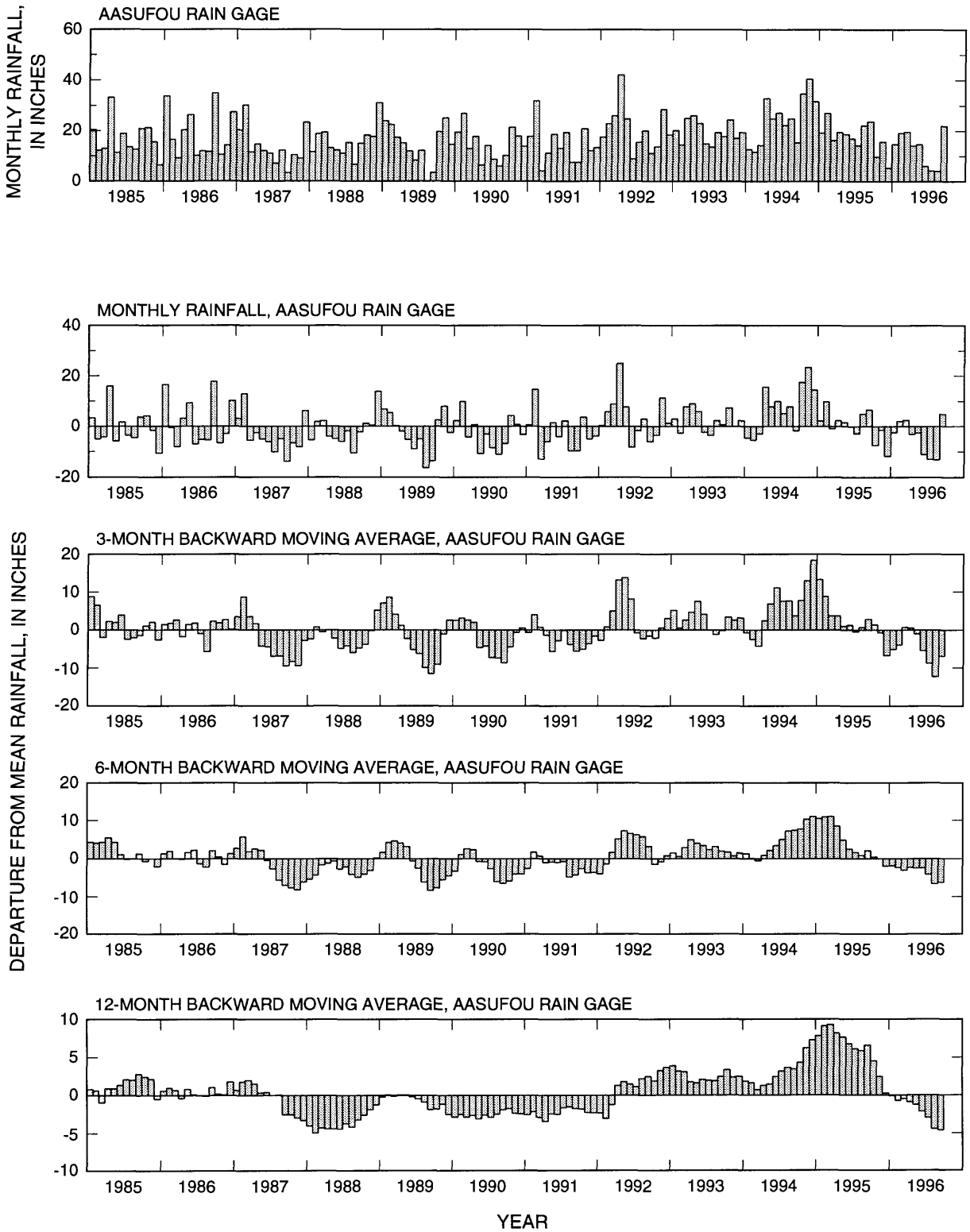


Figure 2. Monthly rainfall, departure of monthly from mean rainfall, and departure of 3-month, 6-month, and 12-month backward-looking moving averages from mean rainfall recorded at the Aasufou and Afono rain gages, Tutuila, American Samoa.

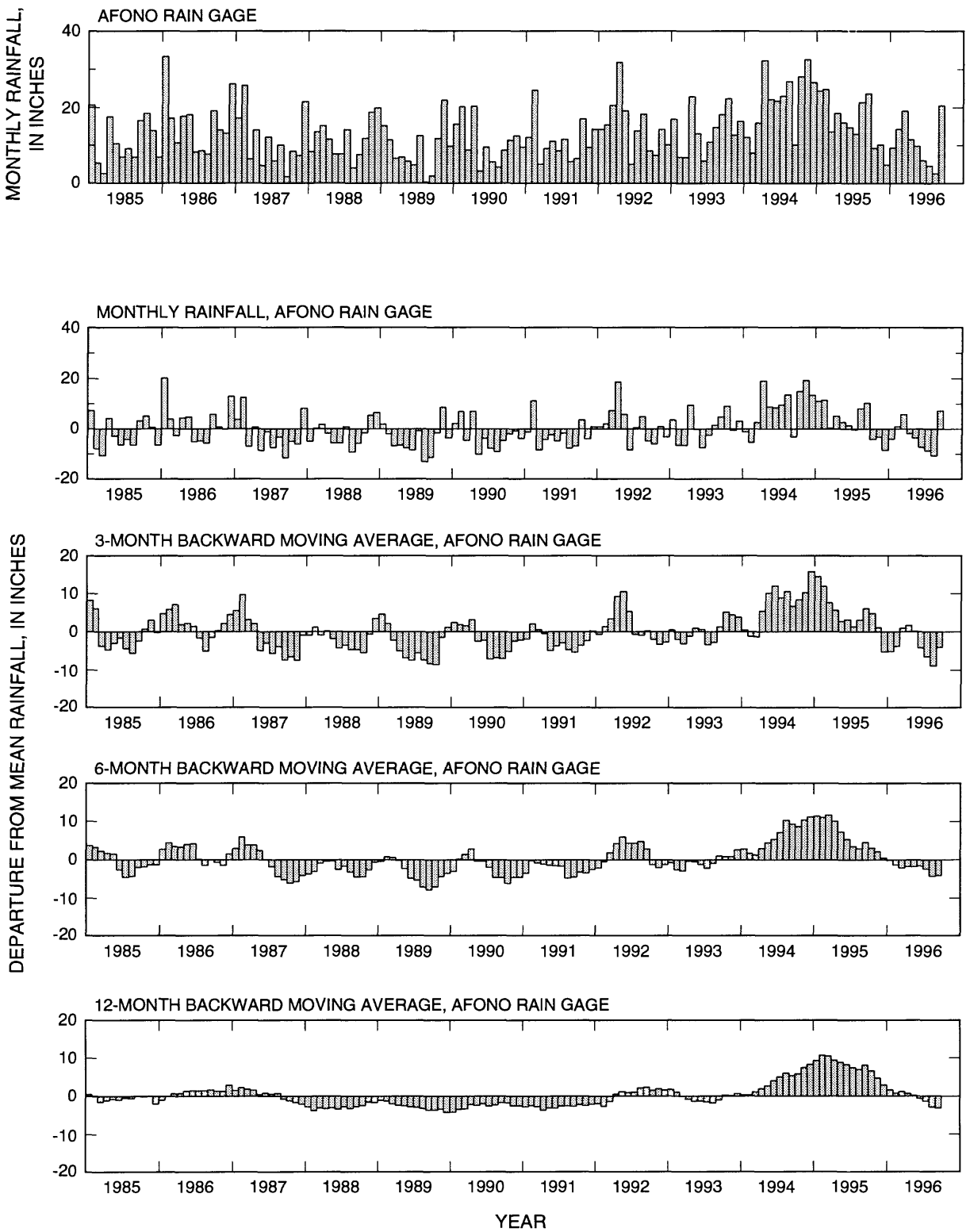


Figure 2. Monthly rainfall, departure of monthly from mean rainfall, and departure of 3-month, 6-month, and 12-month backward-looking moving averages from mean rainfall recorded at the Aasufou and Afono rain gages, Tutuila, American Samoa--*Continued.*

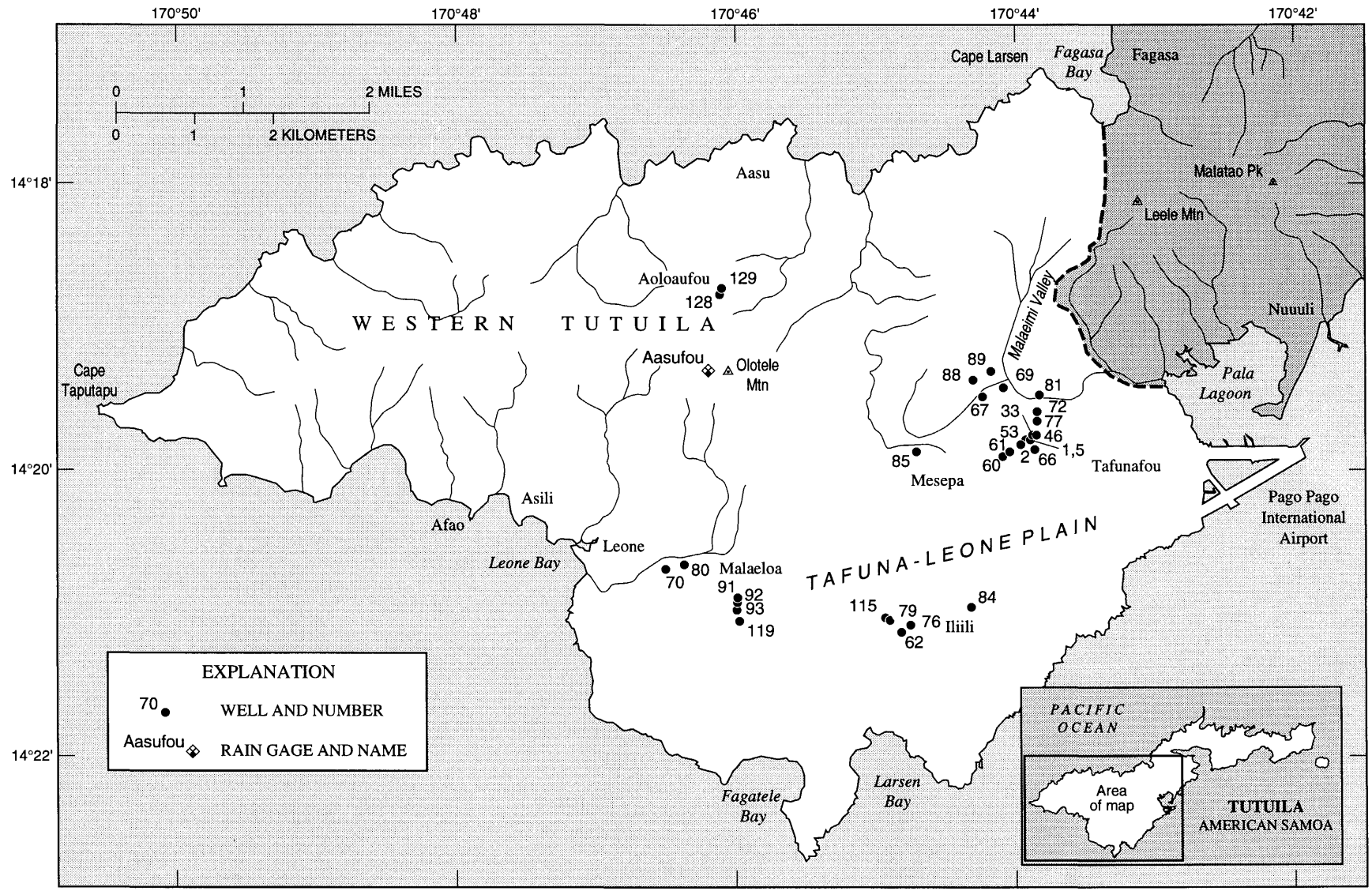


Figure 3. Wells in western Tutuila, American Samoa.

WESTERN TUTUILA GROUND-WATER DATA

Western Tutuila is the site of the most productive wells on Tutuila, including the highly productive wells on the Tafuna-Leone Plain, which include wells in Tafunafou, Malaeimi, Mesepa, Iliili, and Malaeloa (fig. 3). Also included in western Tutuila are the wells in Aoloaufou near the summit of Olotele Mountain. The wells of western Tutuila are grouped on the basis of proximity to each other in five sections: (1) Tafunafou, (2) Malaeimi-Mesepa, (3) Malaeloa-Leone, (4) Iliili, and (5) Aoloaufou.

Tafunafou

The wells in Tafunafou are among the most productive on Tutuila (fig. 4). Wells 33, 46, 60, 61, 72, and 81 are part of a dense cluster of wells produced a total of about 1.6 to 2.4 Mgal/d since 1985. Chloride concentrations at Tafunafou wells varied over a large range from 15 to more than 1,500 mg/L (fig. 4). Brief increases in chloride concentration display a saw-tooth pattern, with gradual rises during dry periods and sharp drops when rainfall returns. Water levels in non-pumping monitor wells in Tafunafou varied mostly within 1 or 2 ft above and below the mean-sea-level datum, with brief rises in water level as much as 20 ft above mean sea level (fig. 4).

Trends during the 12-month period ending September 1996.-- Since October 1995 no pumpage was reported from well 46; the well had been producing about 0.2 Mgal/d prior to October 1995. Since October 1995, pumpage at the other wells in the cluster remained about the same as in previous months, except at well 60 where pumpage more than doubled in the early part of 1996, then was reduced substantially for the remainder of the period. The average pumpage for well 60 over the 12-month period ending September 1996 was 0.4 Mgal/d, about equal to the average pumpage for the period of record of this well. All Tafunafou wells for which data are available showed rises in chloride concentrations in this period. Water levels at monitor wells 1, 2, and 5 have continued the long-term trend, varying within 1 or 2 ft of mean sea level.

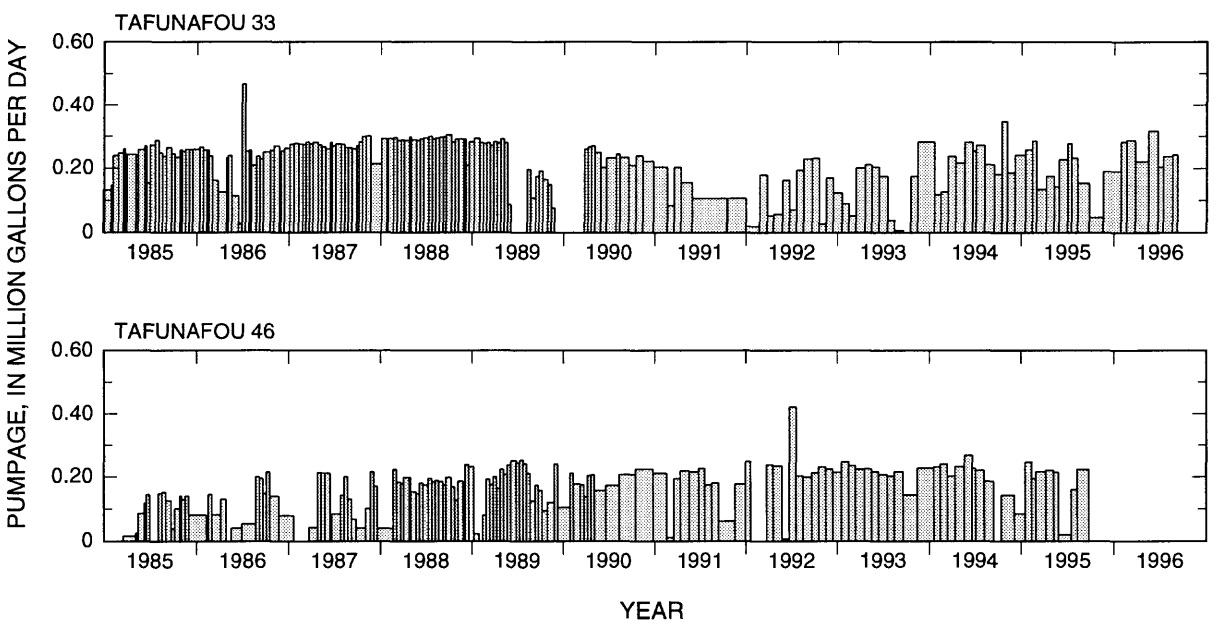
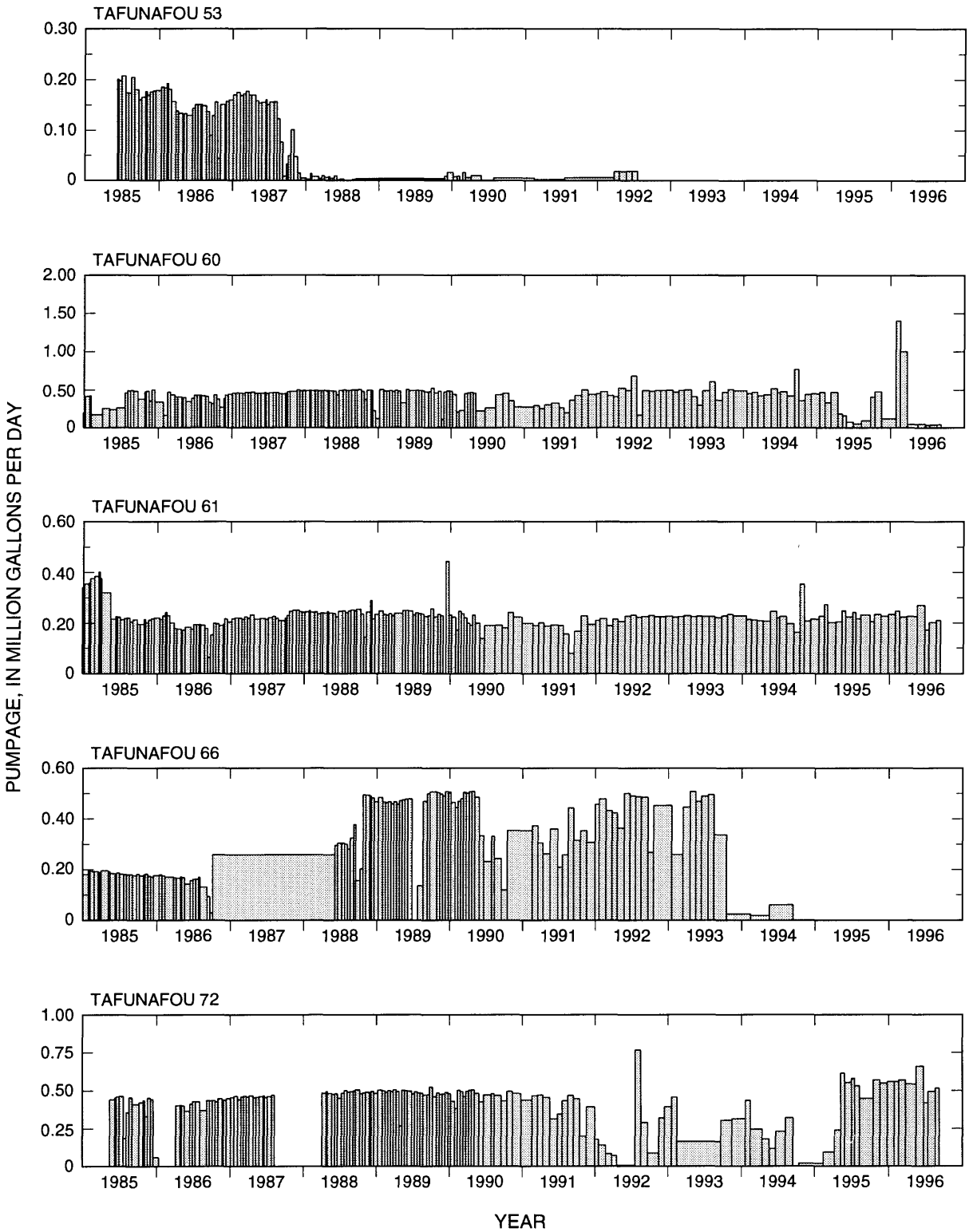


Figure 4. Pumpage, chloride concentrations, and water levels for wells in Tafunafou, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)



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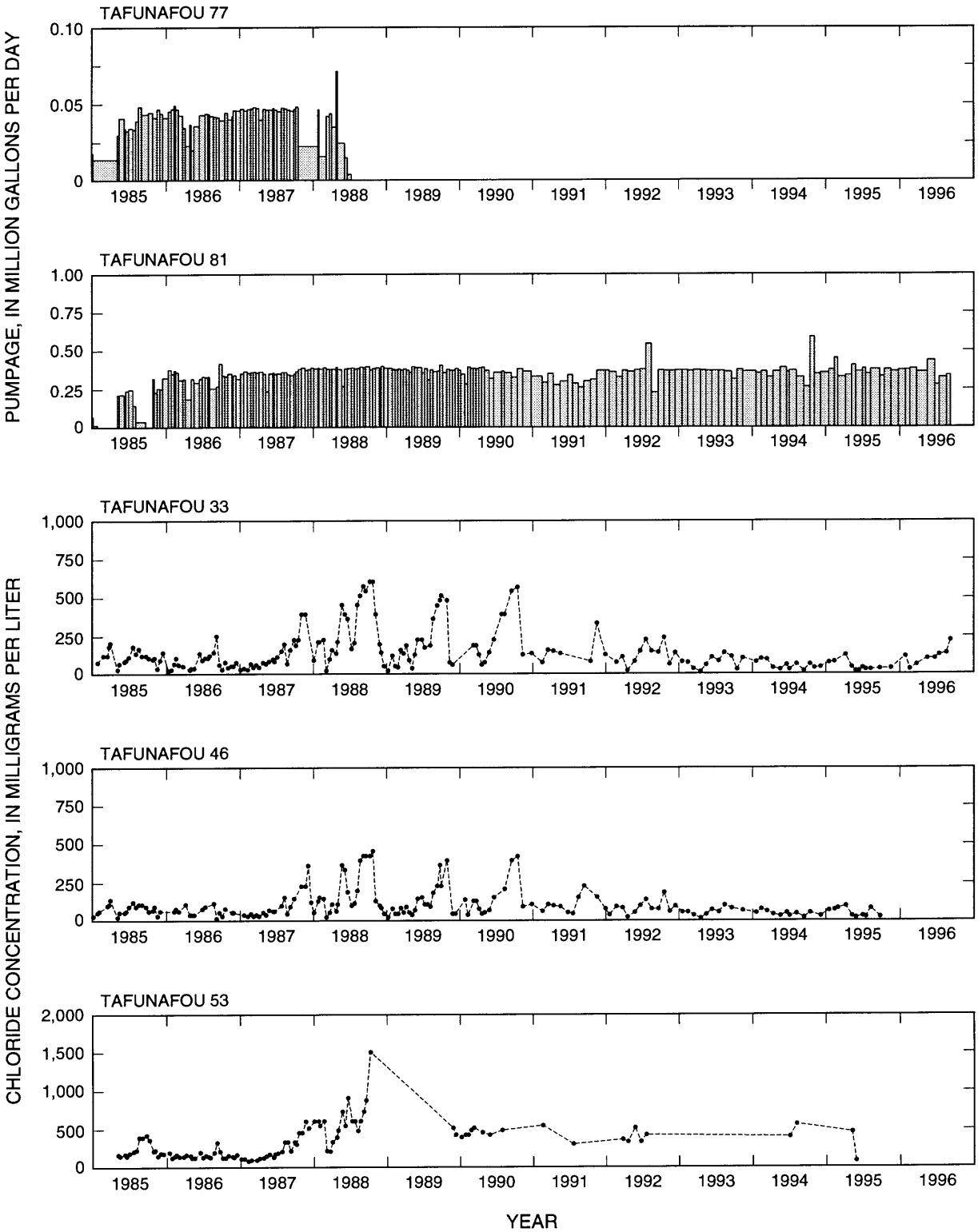

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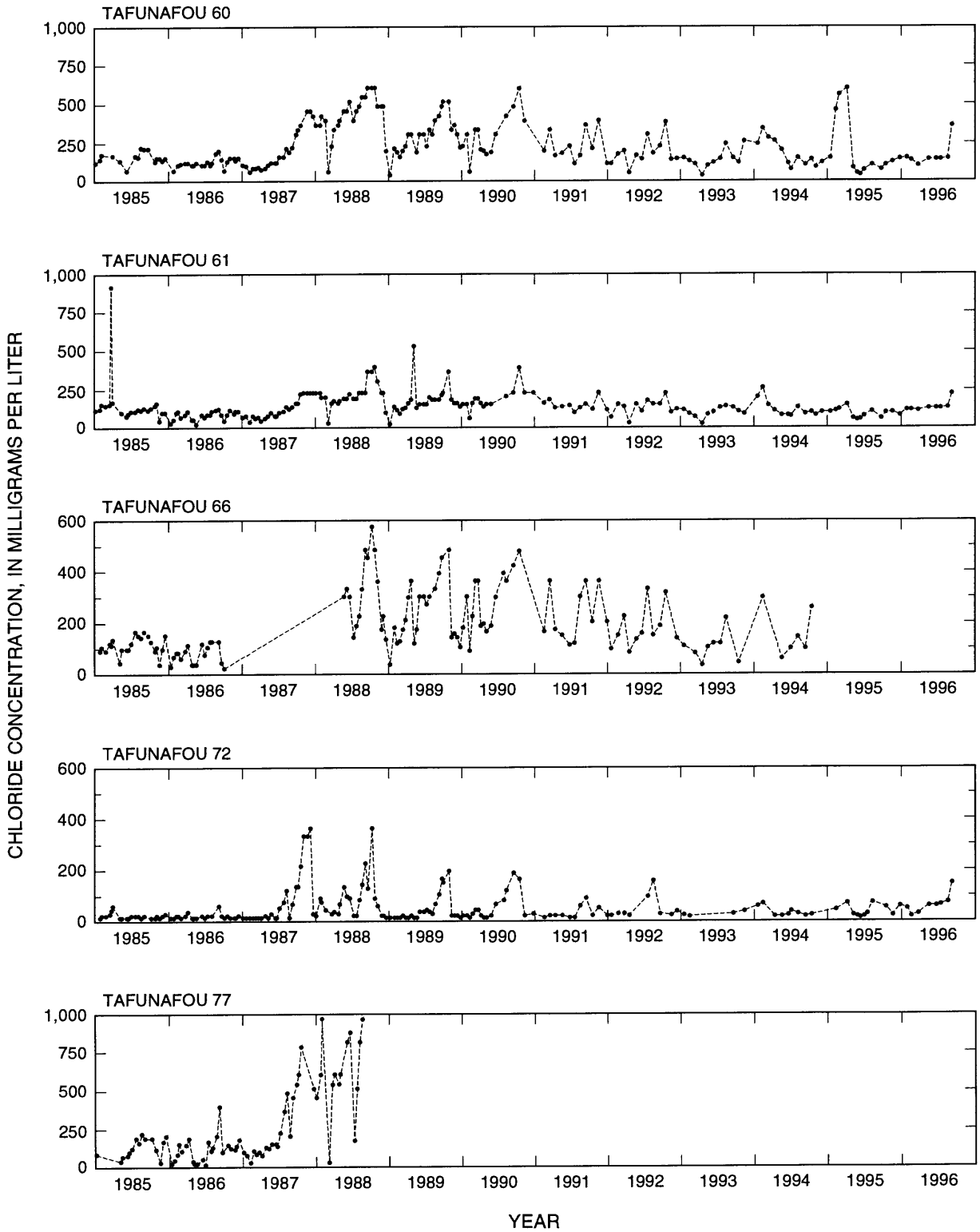

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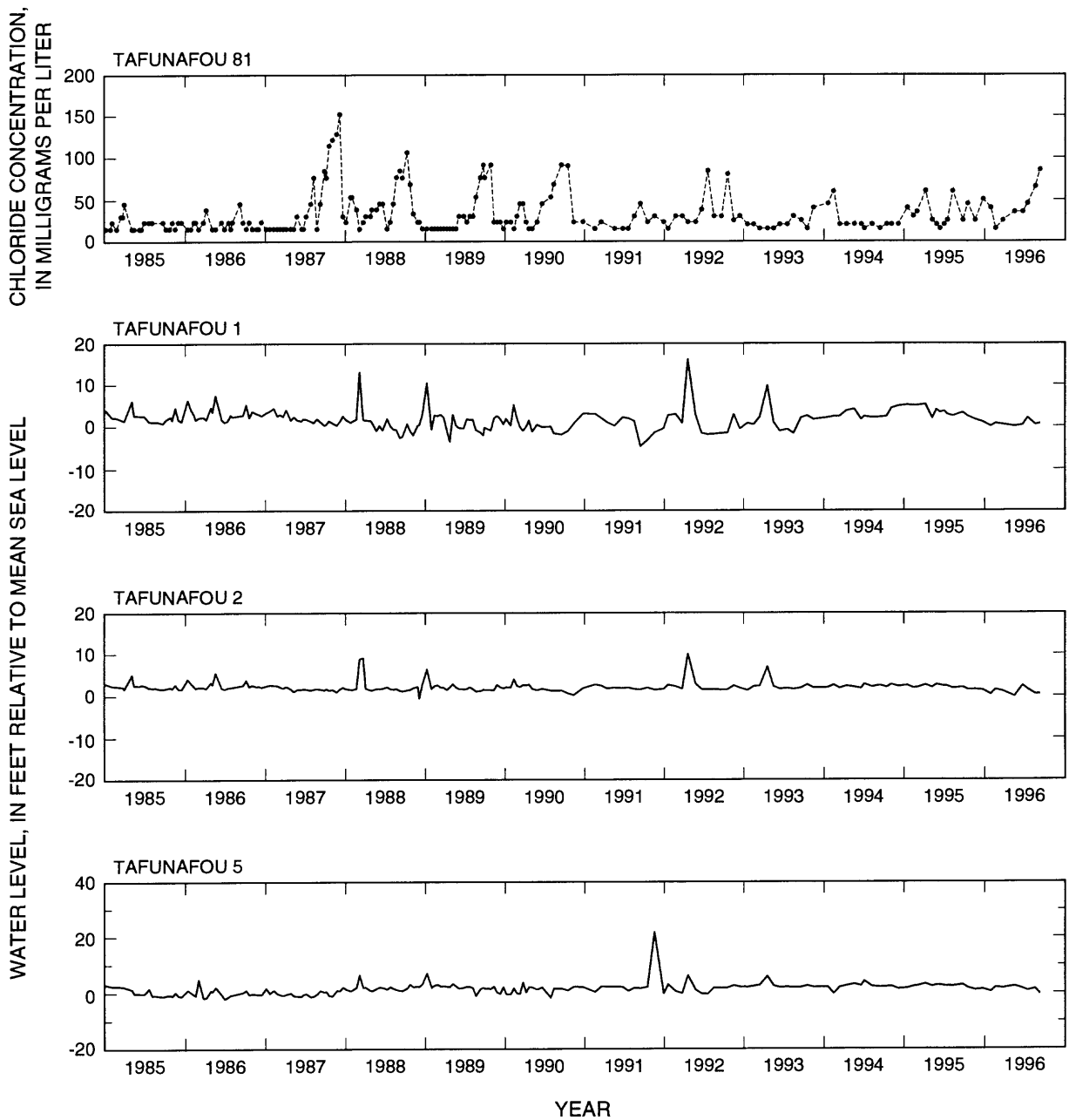

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Malaeimi-Mesepa

Wells 67, 69, 88, and 89 are in Malaeimi Valley, and well 85 is in the village of Mesepa (fig. 3). Well 67 has been pumping since 1984 at 0.3 to 0.4 Mgal/d (fig. 5). Well 85 also began pumping in 1984 at about 0.3 Mgal/d, but pumpage was increased to about 0.5 Mgal/d in 1986. Pumpage at well 89 began pumping at about 0.4 Mgal/d and increased to 0.5 Mgal/d in 1989. Well 69 produced about 0.01 Mgal/d until early 1990, but chloride concentrations rose to more than 500 mg/L despite the low pumping rate. Well 88 produced about 0.2 to 0.4 Mgal/d between 1991 and 1994, but has had no reported pumpage since then. Chloride concentrations in all of the wells in Malaeimi and Mesepa, except well 69, were less than 50 mg/L and showed little variation (fig. 5). These low chloride concentrations were maintained even during periods when wells 67, 85, 88, and 89 were each pumping 0.4 to 0.5 Mgal/d.

Water-level monitoring began at well 88 in 1991, while it was still a production well. Water levels measured during pumping dropped more than 50 ft below sea level. The well stopped production in late 1994, at which time water levels began to rise above sea level (fig. 5).

Trends during the 12-month period ending September 1996.--Wells 67, 85, and 89 continued pumping at rates close to their long-term average rates of 0.3 to 0.6 Mgal/d in the 12-month period ending September 1996 (fig. 5). Chloride concentrations in well 67 rose to their highest levels (40 mg/L) in late 1996, but this concentration is low compared to wells outside Malaeimi Valley. Chloride concentrations in well 85 in Mesepa continued on a gradual rising trend that began in 1990, but did not exceeded 50 mg/L.

Water levels in well 88 in the 12-month period ending September 1996 continued on a rising trend that began after pumping at the well was discontinued in 1994. On August 20, 1996 water level was measured at 90 ft above sea level, the highest water level on record at this well since monitoring began.

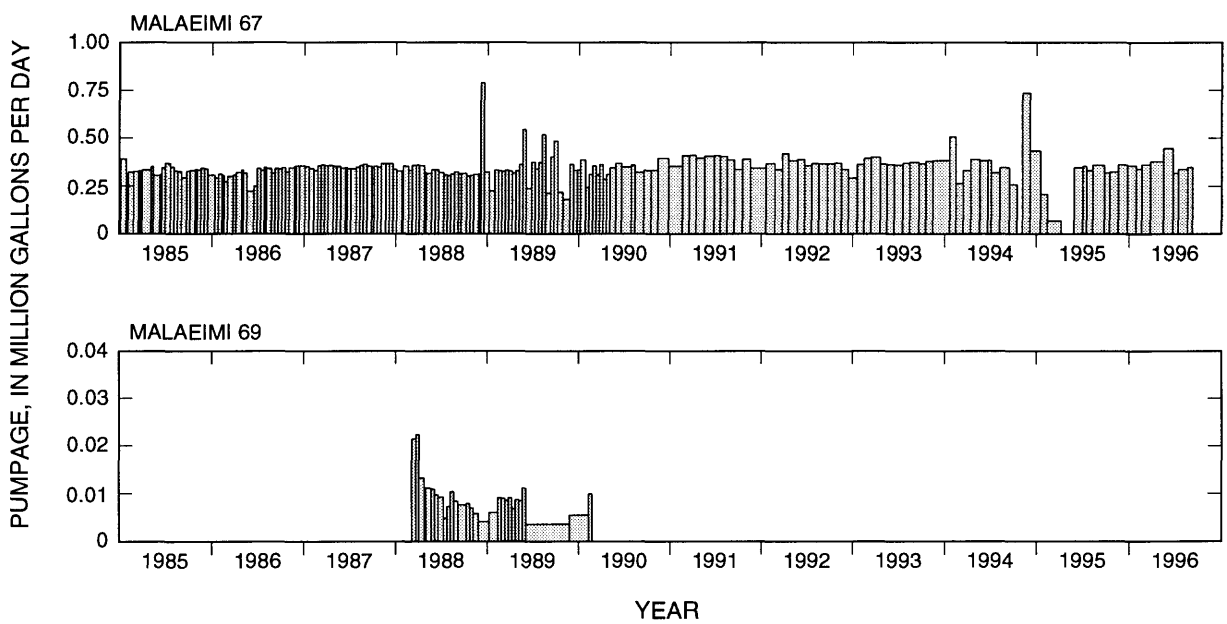
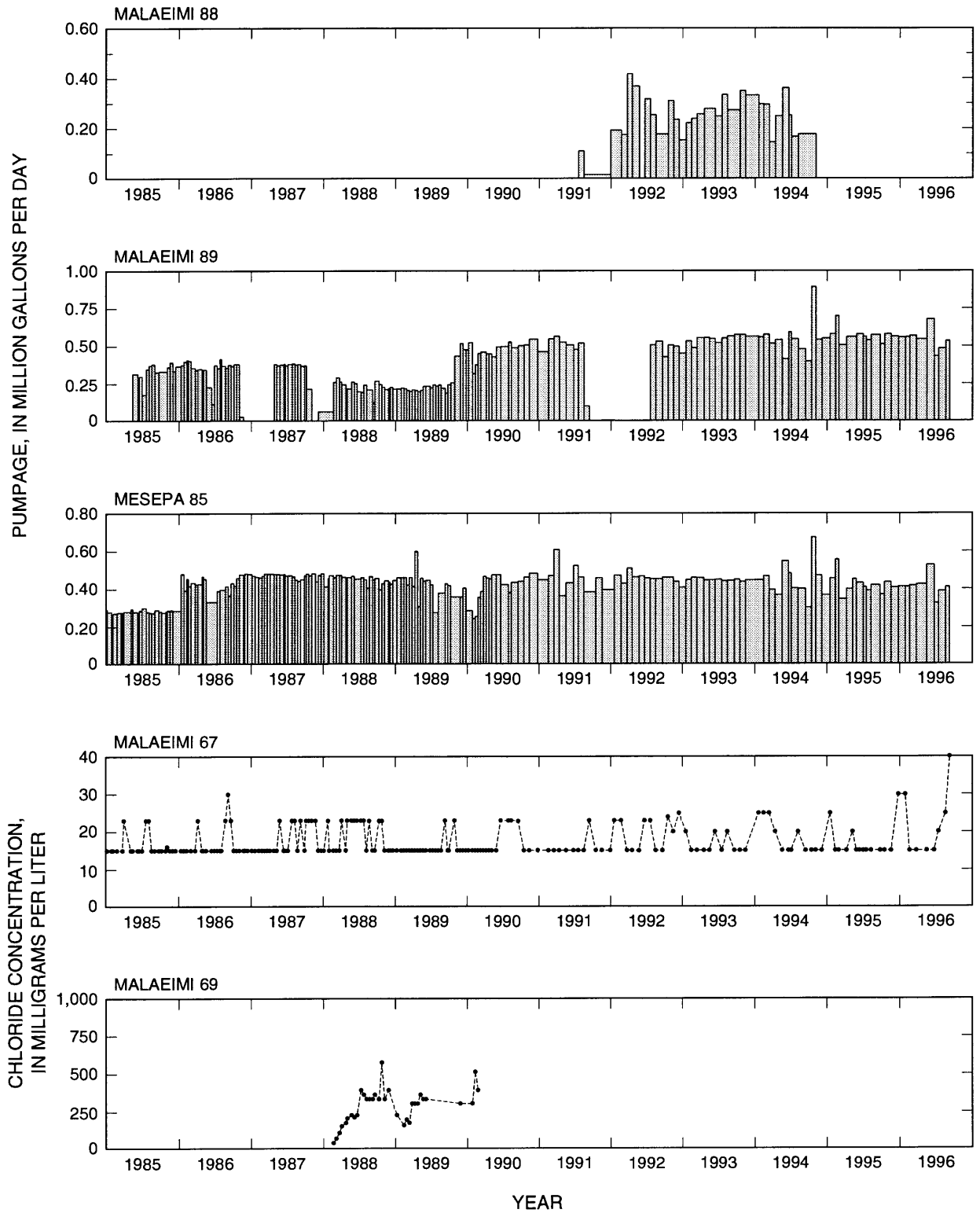


Figure 5. Pumpage, chloride concentrations, and water levels for wells in the Malaeimi-Mesepa area, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)



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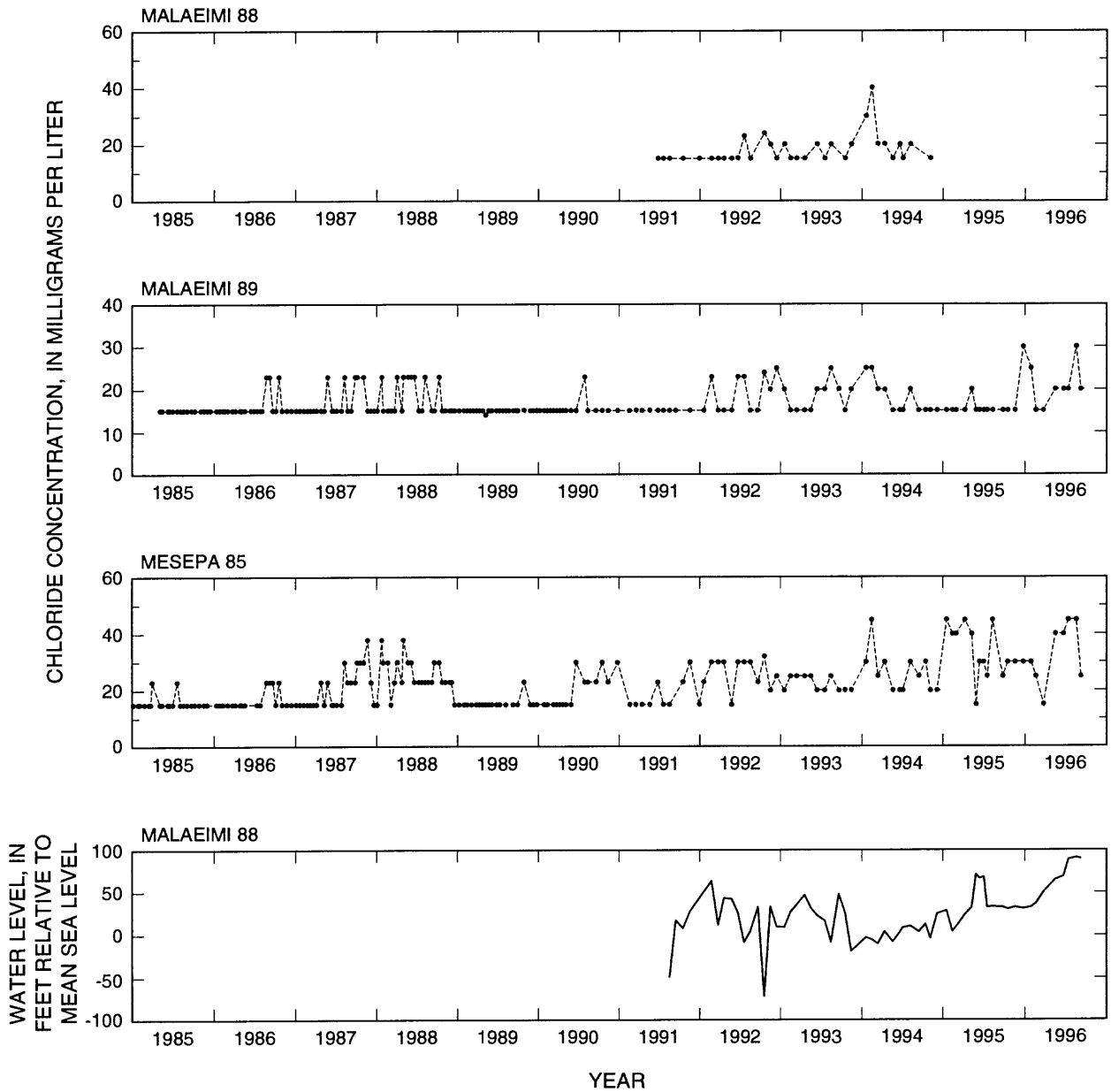

Figure 5. Pumpage, chloride concentrations, and water levels for wells in the Malaeimi-Mesepa area, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Iliili

The village of Iliili is located on the Tafuna-Leone Plain less than 1 mile from the southern coastline of Tutuila (fig. 3). Four wells, 62, 76,79, and 84 have produced a total of about 1.2 Mgal/d since 1985 (fig. 6). Chloride concentrations at wells 76 and 79 remained near 100 mg/L over the entire pumping period. Chloride concentrations at well 62 rose to as high as 200 mg/L. Chloride concentrations in well 84 frequently exceeded 500 mg/L over the period of record. Water levels, monitored at well 115, were about 5 ft above sea level, and varied by about plus or minus 2 ft. The Iliili water levels were higher than in Tafunafou by about 2 to 3 ft, and lower than in Malaeimi by about 80 ft.

Trends during the 12-month period ending September 1996.--Well 76 had been pumping about 0.3 Mgal/d prior to August 1995, but pumpage dropped to an average of less than 0.02 Mgal/d between August 1995 and March 1996 (fig. 6). In April 1996, well 76 resumed pumping at about 0.3 Mgal/d. Pumpage at wells 62, 79 and 84 during the 12-month period ending September 1996 remained about the same as in previous years. Chloride concentrations in all of the wells in Iliili showed an increase during most of this period, but decreased sharply in September 1996. Water levels at well 115 during this period have shown the same variation of 1 to 2 ft about a mean of 5 ft above sea level, as in previous years.

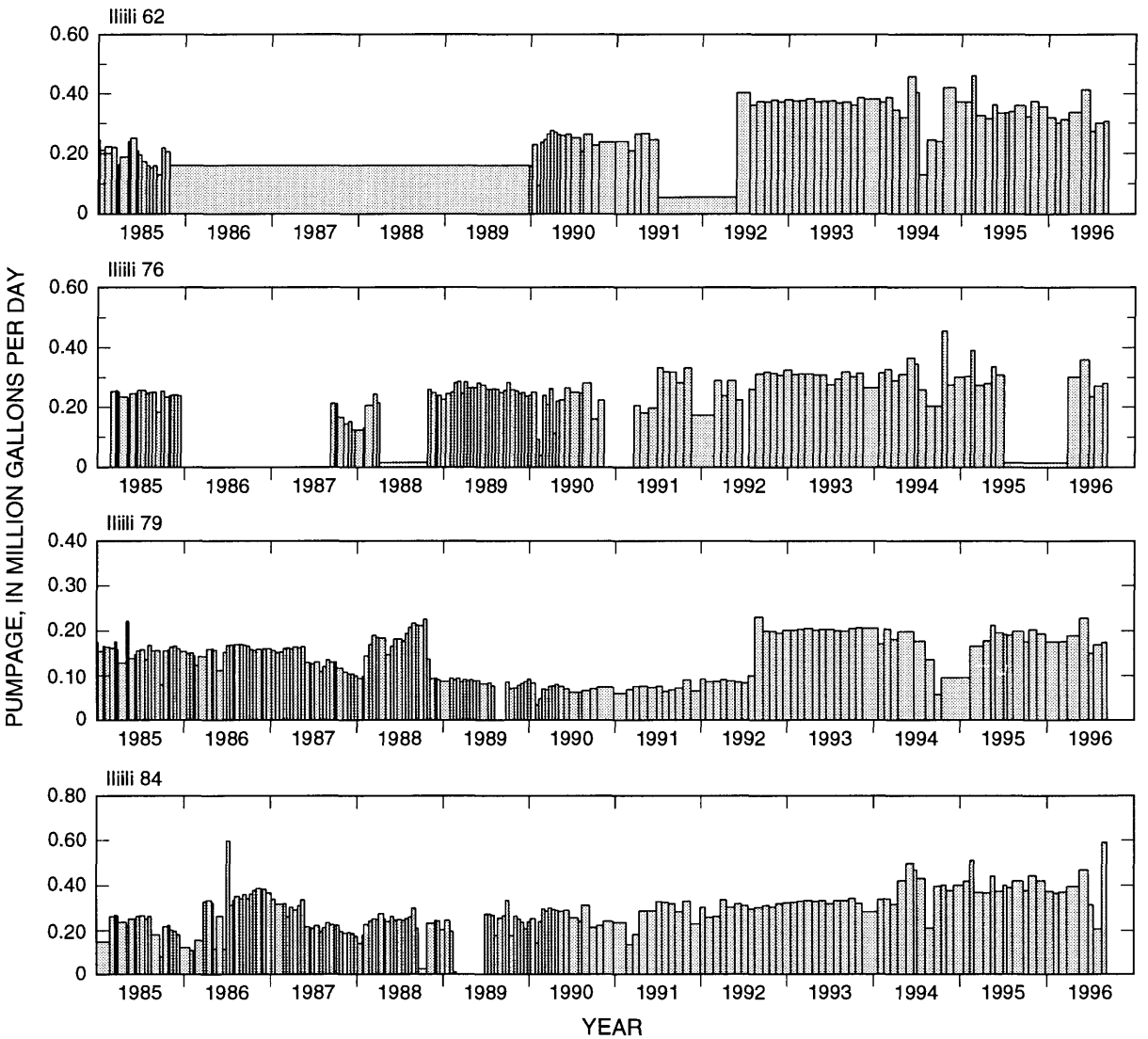

Figure 6. Pumpage, chloride concentrations, and water levels for wells in Iliili, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

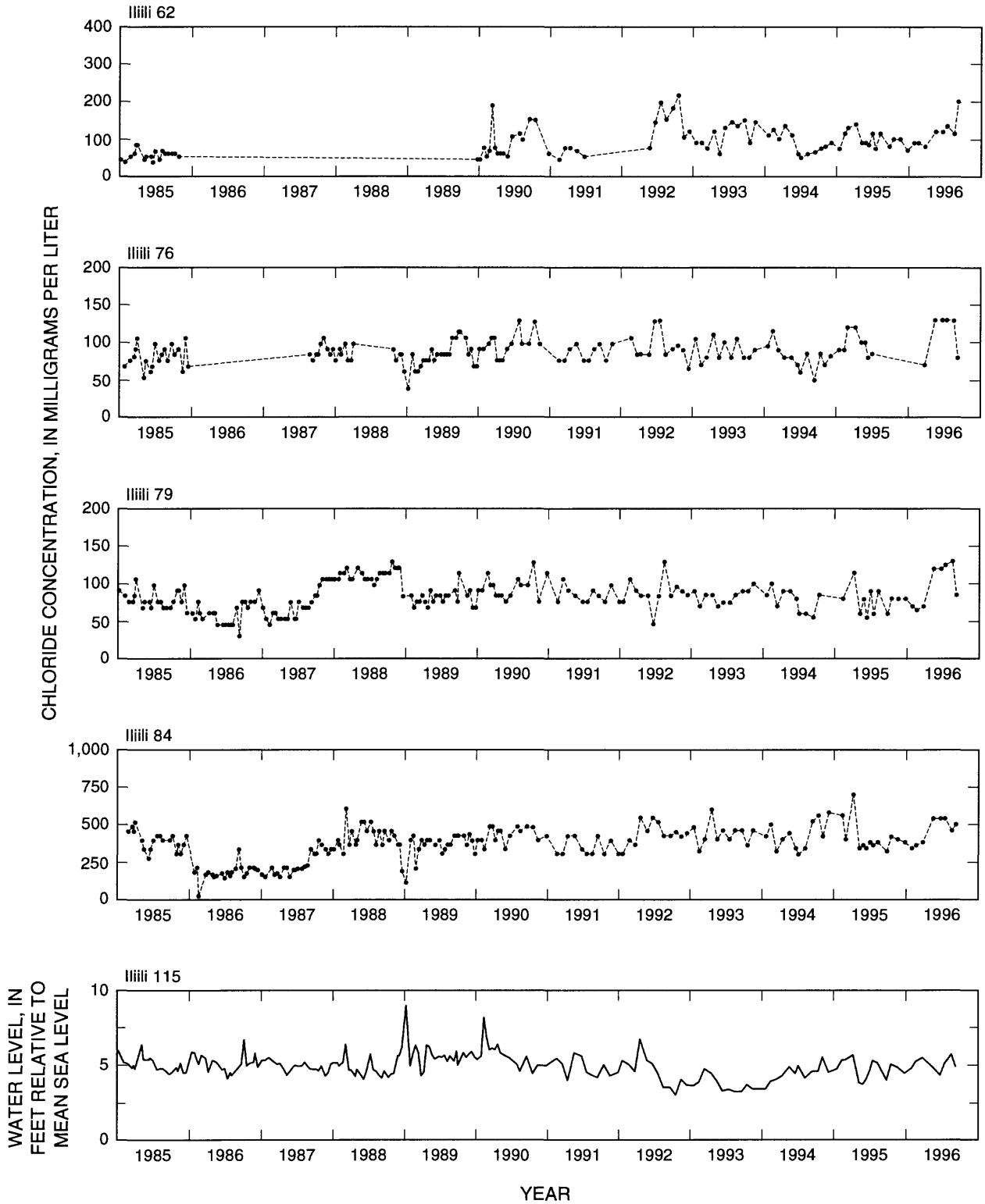

Figure 6. Pumpage, chloride concentrations, and water levels for wells in Iliili, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Malaeloa-Leone

The Malaeloa-Leone area (fig. 3) has 6 production wells, 70, 80, 91, 92, 93, and 119, which have pumped a total of about 2.2 Mgal/d (fig. 7). Chloride concentrations in wells 70, 80, 91, and 92 have remained under 100 mg/L over the entire period of pumping; chloride concentrations in well 93 have risen periodically to about 100 mg/L but remained below 50 mg/L over most of the pumping period. Chloride concentrations of well 93 peaked during periods of lower-than-average rainfall in the Aasufou rainfall record (fig. 2). In well 119, chloride concentrations have been higher, exceeding 500 mg/L several times during the period of record. As in well 93, the chloride concentrations in well 119 peak during periods of lower-than-average rainfall, except that the peaks are more frequent and rise to higher concentrations at well 119. Peaks in chloride concentration in both well 93 and well 119 show a saw-tooth pattern similar to the pattern seen in the Tafunafou chloride-concentration record. Water levels were monitored at well 92 from 1985 to 1990, during which time water levels fluctuated 1 to 10 ft above sea level (fig. 7). Water levels have not been monitored in this area since 1990.

Trends during the 12-month period ending September 1996.--During the 12-month period ending September 1996, pumpage at the Malaeloa-Leone wells remained about the same as in previous years (fig. 7). Chloride concentrations in all wells except 119 remained below 100 mg/L during this period, but well 93 showed an upward trend in 1996 and the chloride concentration measured at well 91 on December 26, 1995 (40 mg/L) was the highest in the last 12 years of record for that well. Chloride concentrations in well 119 showed an increasing trend in 1996, rising to 480 mg/L in September 1996.

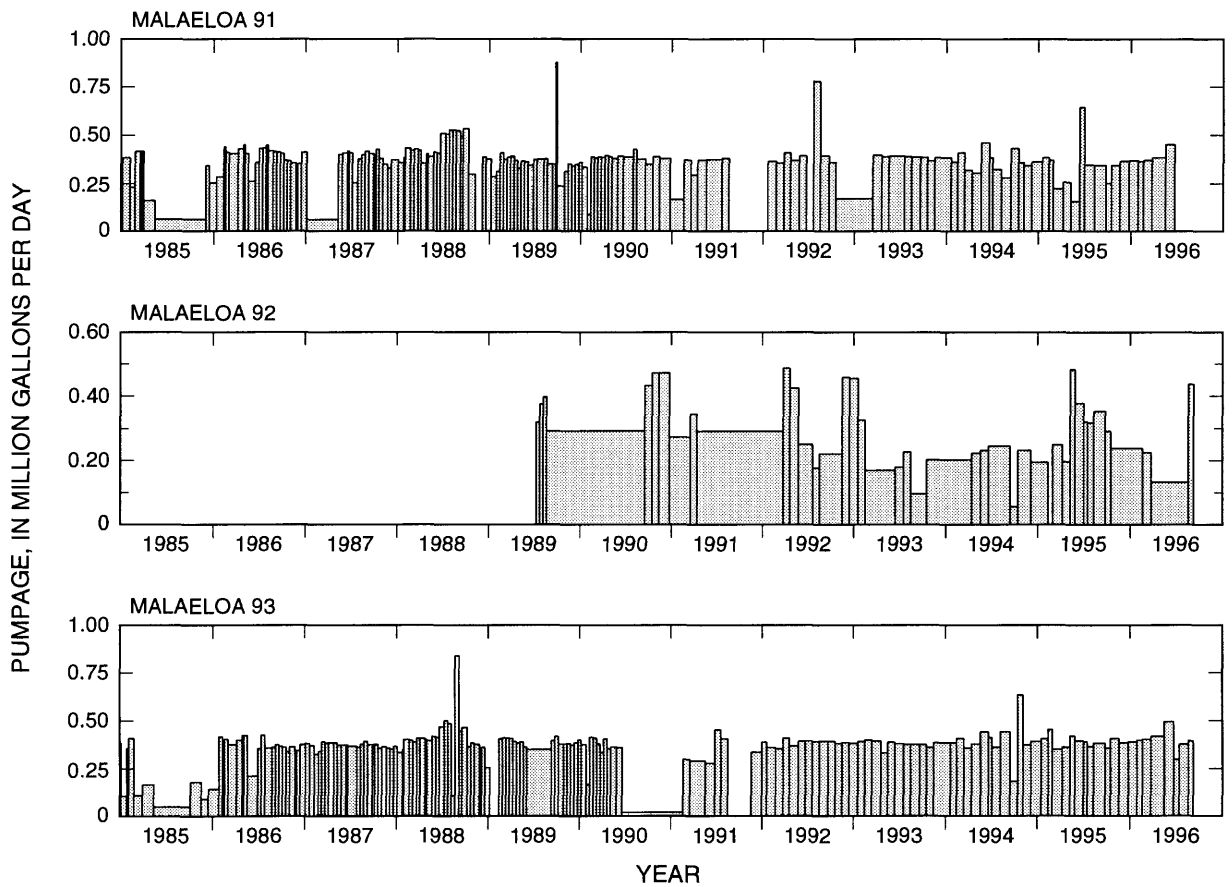

Figure 7. Pumpage, chloride concentrations, and water levels for wells in the Malaeloa-Leone area, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

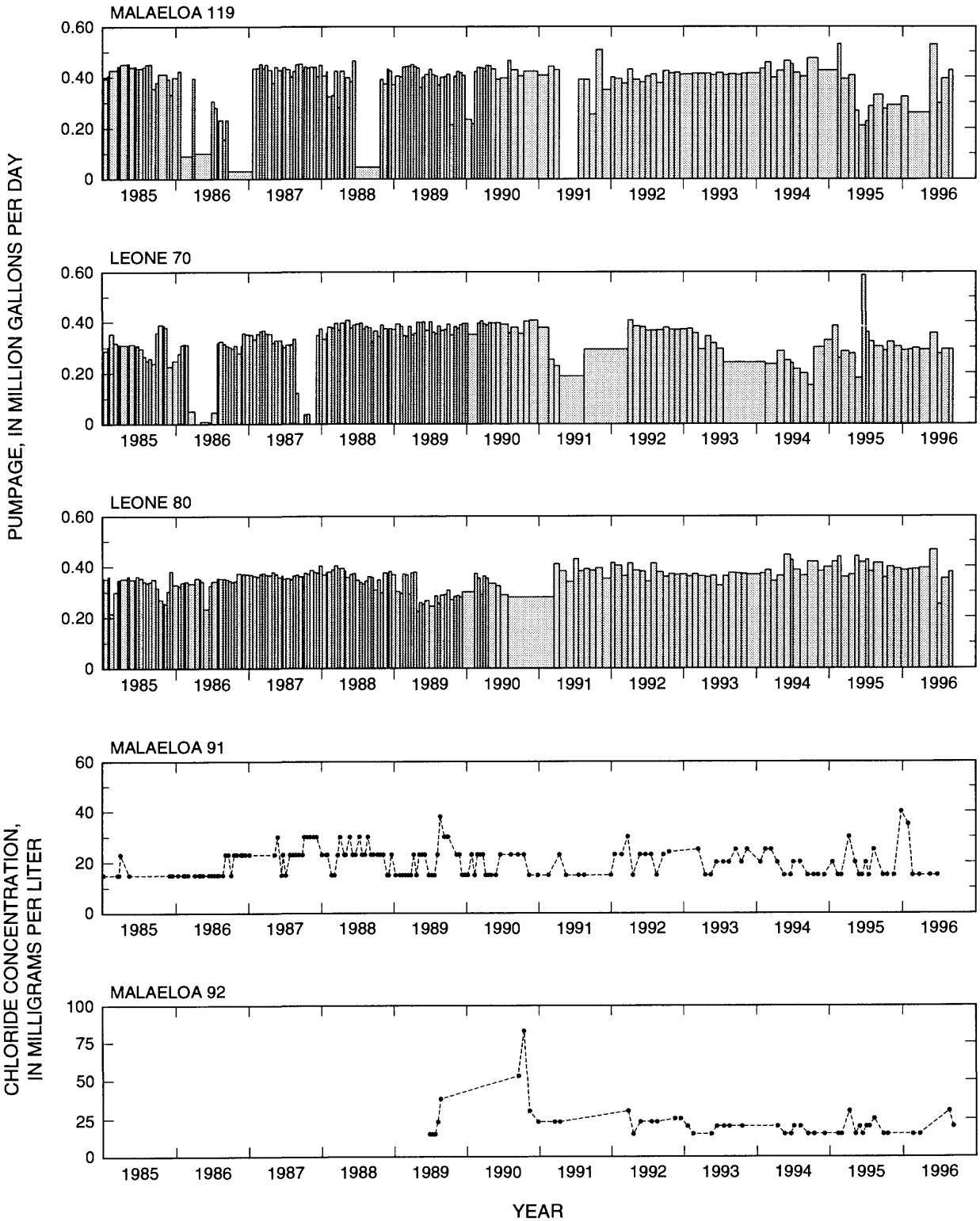

Figure 7. Pumpage, chloride concentrations, and water levels for wells in the Malaeloa-Leone area, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

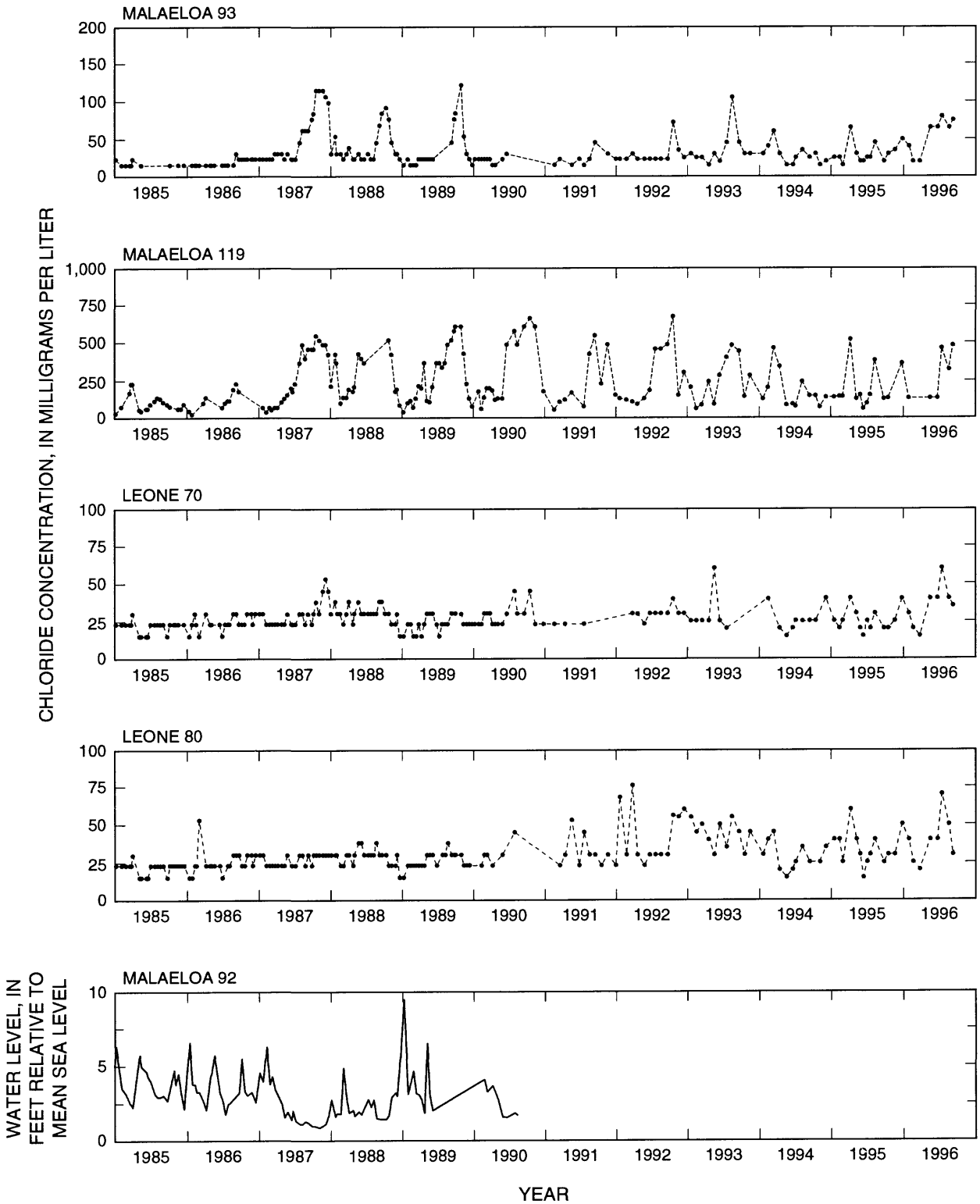

Figure 7. Pumpage, chloride concentrations, and water levels for wells in the Malaeloa-Leone area, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Aoloaufou

Wells 128 and 129 in Aoloaufou pump water from pyroclastic deposits that mantle the crest of Olotele Mountain (fig. 3). The wells were put into production in 1994 at about 0.03 to 0.05 Mgal/d each (fig. 8). Chloride concentrations have remained at 15 mg/L throughout most of the pumping period. No water levels have been reported for Aoloaufou.

Trends during the 12-month period ending September 1996.--In late 1995 and early 1996, pumpage at wells 128 and 129 continued on an upward trend that began in early 1995. The pumpage peaked at both wells in mid 1996, and declined from that time through September 1996. Chloride concentrations in both wells have remained at about 15 mg/L throughout the 12-month period ending September 1996.

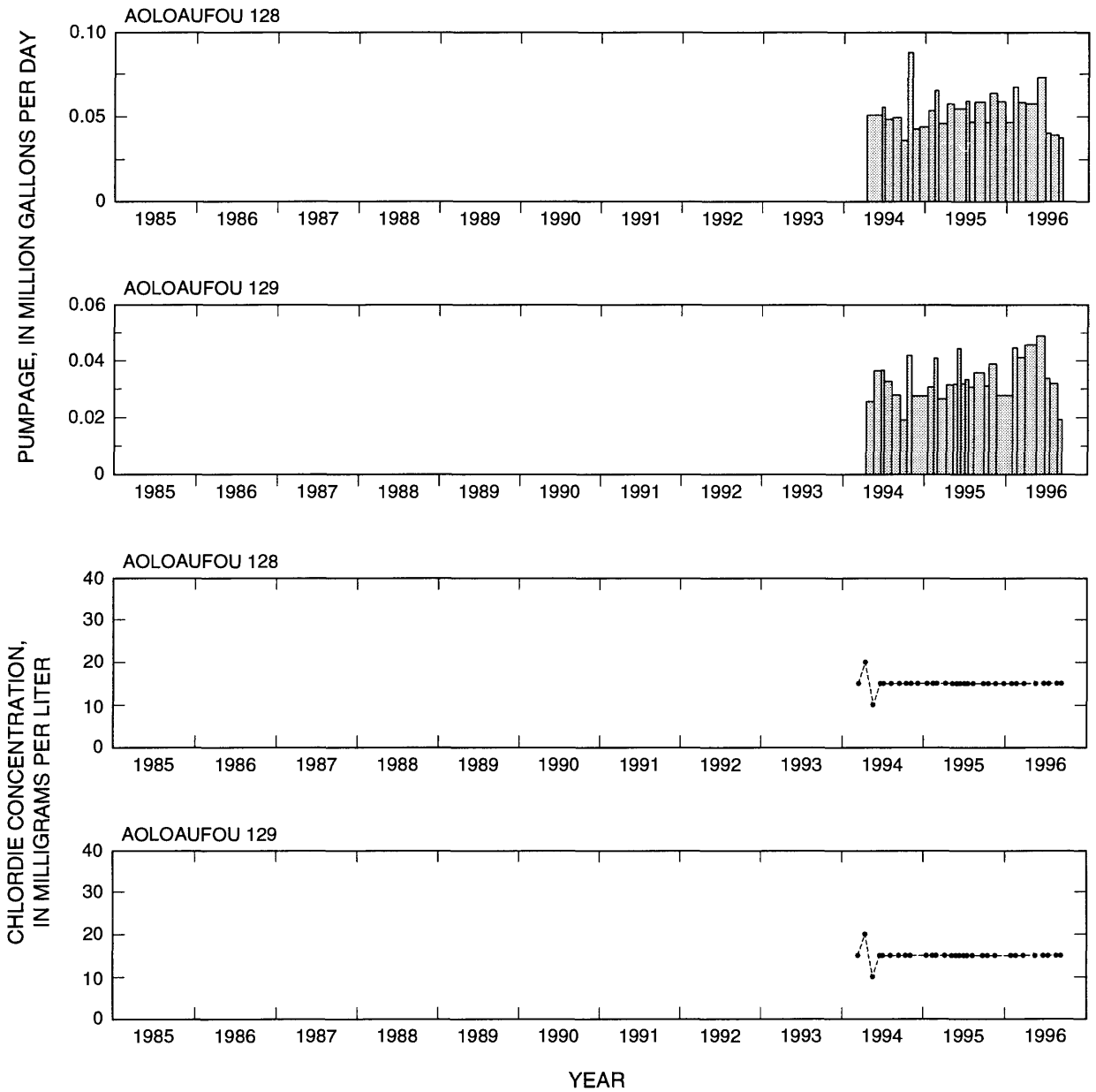

Figure 8. Pumpage and chloride concentrations for wells in Aoloaufou, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

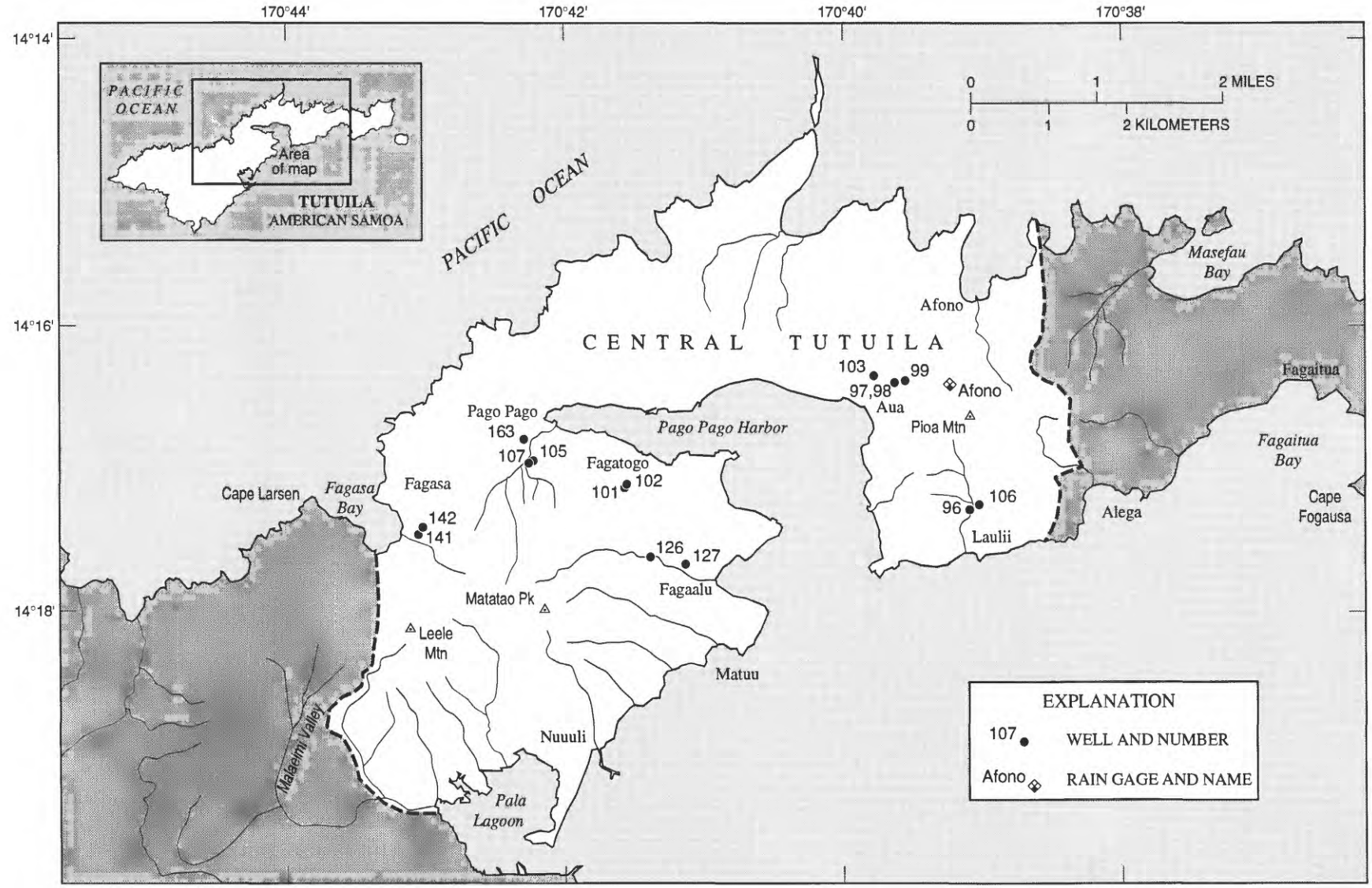

Figure 9. Wells in central Tutuila, American Samoa.

Central Tutuila Ground-Water Data

Central Tutuila in this report includes the section of the island east of Pago Pago International Airport up to and including the village of Laulii (fig. 9). Most of the wells in central Tutuila lie in small valleys surrounding the large embayment of Pago Pago Harbor. Wells in Fagaalu, Fagatogo, Pago Pago, and Aua lie in valleys whose mouths open toward the harbor to form smaller embayments nested within the larger embayment of Pago Pago Harbor. To the north of the harbor a sheer cliff stretches eastward from Pago Pago to Aua. Fagasa and Laulii lie in valleys outside the drainage area of Pago Pago Harbor.

Because of the large natural harbor in Pago Pago, central Tutuila is the industrial center on the island. The population lives in villages located mostly on the relatively flat valley floors and coastal plain and extending a short distance up the adjoining hillsides. Ground water is developed mostly from wells in the valleys, but a pipeline connects the southern shore of central and eastern Tutuila with the highly productive wells of western Tutuila. Fagasa is not connected to this pipeline but has its own wells.

Fagaalu

Ground-water development in Fagaalu Valley on the western side of Pago Pago Harbor (fig. 9) consists of well 127, which has been pumped only intermittently at an average of about 0.06 Mgal/d since late 1992 (fig. 10). Chloride concentrations from this well have remained below 100 mg/L, and usually below 50 mg/L for the entire period of record.

Water levels in Fagaalu have been monitored at well 126 since 1987 (fig. 10). Before 1989, water levels at well 126 were between 70 and 80 ft above sea level. When the well was deepened in 1989 and the upper portion sealed to prevent seepage from a nearby stream, the water level dropped to about 25 ft above sea level, then climbed to about 60 ft above sea level between 1989 and 1991. Between 1991 and 1995, water levels remained near 60 ft above sea level.

Trends during the 12-month period ending September 1996.--Pumpage at well 127 rose sharply in mid 1996 from a mean pumpage of about 0.02 Mgal/d in previous years to 0.1 Mgal/d in June-August 1996 (fig. 10). At about the same time, chloride concentrations in water from the well rose to as high as 65 mg/L, and water levels in monitor well 126 dropped nearly 20 ft to about 25 ft above sea level where it remained through September 1996.

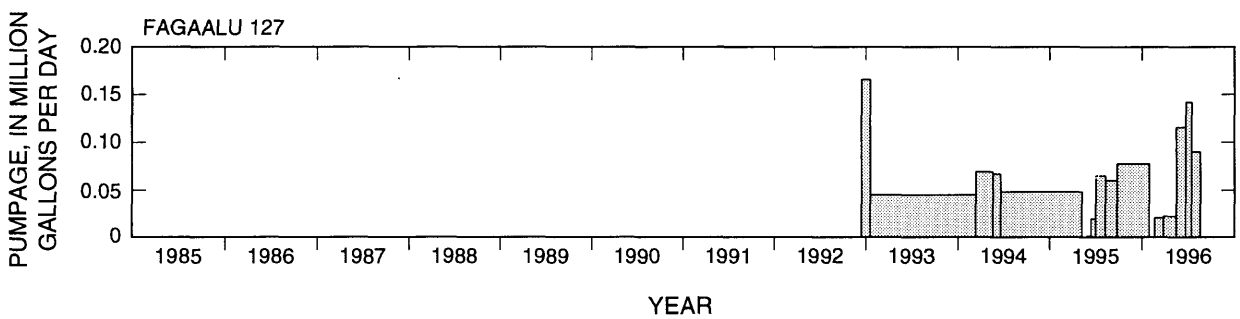

Figure 10. Pumpage, chloride concentrations, and water levels for wells in Fagaalu, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

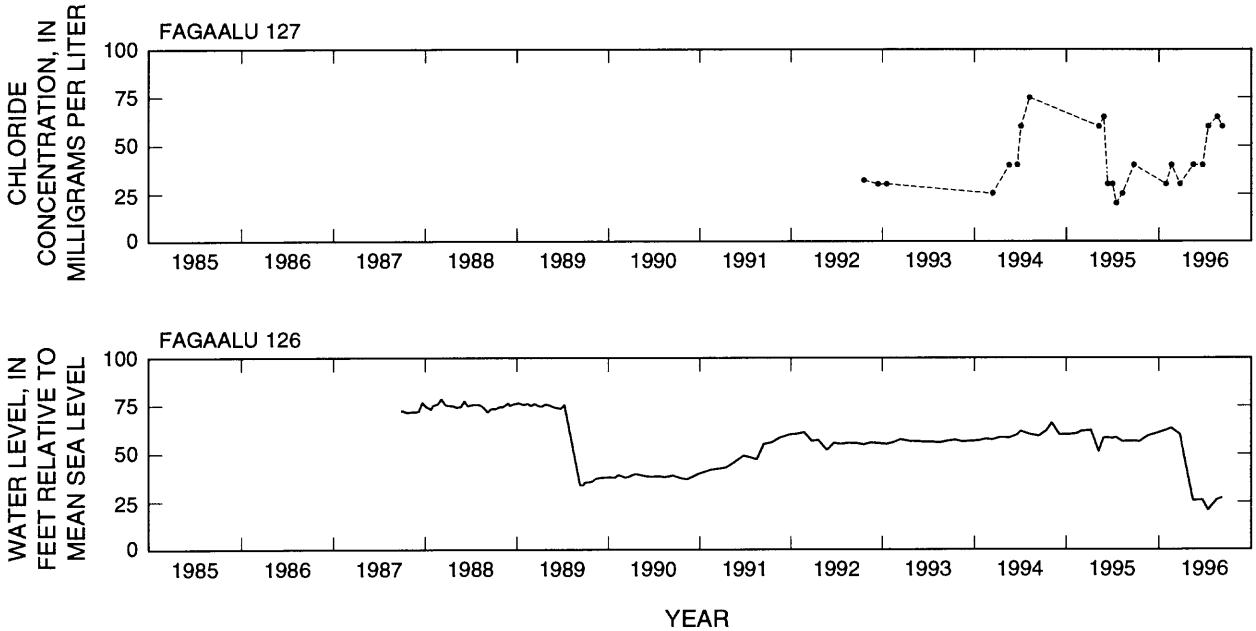

Figure 10. Pumpage, chloride concentrations, and water levels for wells in Fagaalu, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Fagatogo

Pumpage in the Fagatogo area has alternated between wells 101 and 102 (fig. 9). Well 101 produced about 1 Mgal/d from 1986 to 1988. From 1988 to 1992, well 101 was shut off and well 102 was pumped at a rate of 1 Mgal/d (fig. 11). Pumpage was switched back to well 101 in 1992 but reduced to about 0.5 Mgal/d. Chloride concentrations at both pumped wells remained mostly below 50 mg/L throughout the period of record. Water levels monitored in well 101 in 1986 prior to the beginning of pumping were about 20 ft above sea level. Between 1988 and 1992, when well 102 was being pumped and well 101 was used only for water-level monitoring, water levels in well 101 were near sea level, and occasionally dropped 2 to 3 ft below sea level (fig. 11). For a brief period in mid-1992, pumping at both 101 and 102 ceased, and water levels in well 101 began to rise. No water-level records are available for this area after pumping resumed at well 101 in late 1992.

Trends during the 12-month period ending September 1996.--Pumping at well 101 during the 12-month period ending September 1996 continued at about 0.5 Mgal/d, which is about the same rate as in previous years (fig. 11). No water was reportedly pumped at well 102 during this period. Chloride concentrations at well 101 rose to 30 mg/L in 1996.

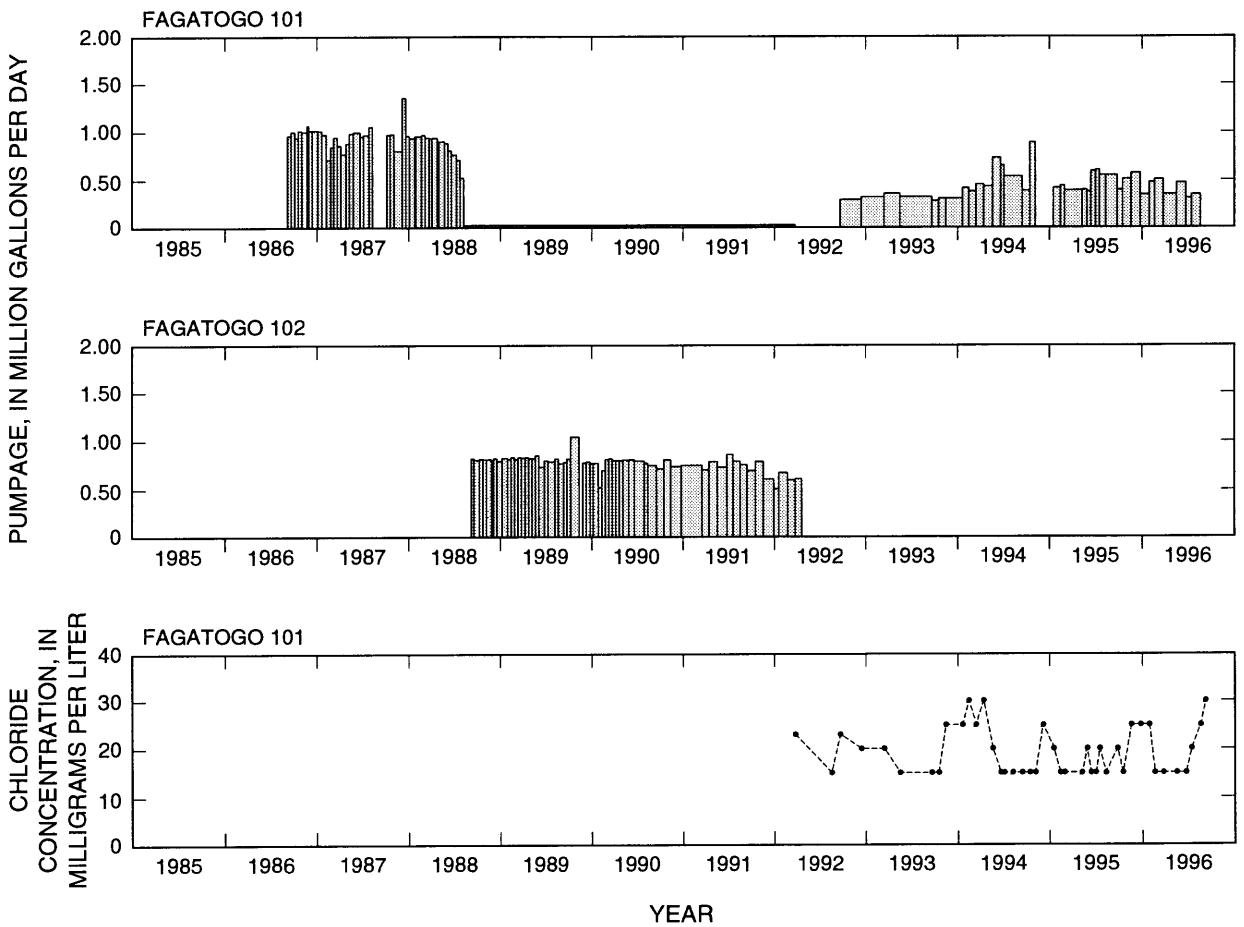

Figure 11. Pumpage, chloride concentrations, and water levels for wells in Fagatogo, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

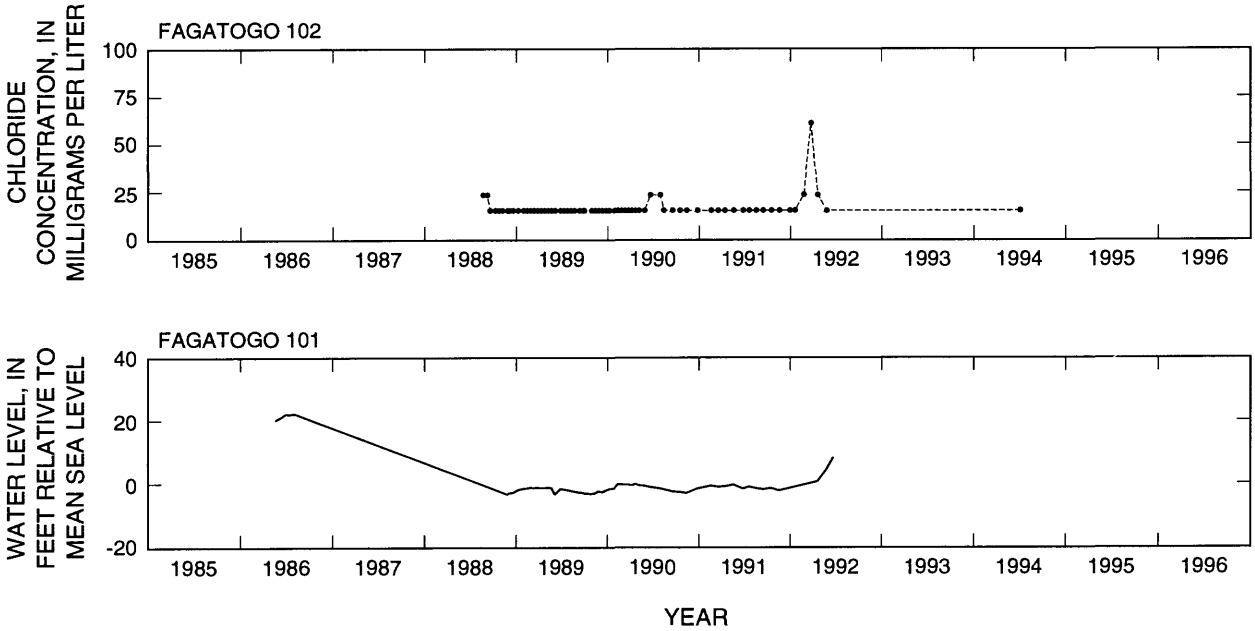

Figure 11. Pumpage, chloride concentrations, and water levels for wells in Fagatogo, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Pago Pago

Pago Pago is located at the farthest inland extension of the Pago Pago Harbor embayment (fig. 9). Three production wells are located in this area. Well 105 has been pumped since late 1988 at rates of about 0.2 Mgal/d, while well 107 has been pumped about 0.5 Mgal/d (fig. 12). Well 163 began pumping in mid-1995 at about 0.4 Mgal/d. All of the Pago Pago wells have maintained chloride concentrations of less than 60 mg/L throughout the period of record. Pre-pumping water levels at well 105 fluctuated between 47 and 50 ft above sea level. Pumping water levels are not available at well 105. Water levels at well 107 during pumping initially declined to about 3 ft above sea level and dropped as low as 1 ft below sea level between 1989 and 1990, but have remained at about 5 ft above sea level since then.

Trends during the 12-month period ending September 1996.--In mid-1995, the pumping rate at well 105 changed from its steady pre-1995 average of about 0.2 Mgal/d (fig. 12). Pumpage at this well stopped between July and November 1995, then resumed in December 1995 and continued to the end of the period of record at fluctuating rates. Pumpage at well 107 during the 12-month period ending September 1996 remained at about 0.4 to 0.5 Mgal/d, which is about the same as in previous years. Pumpage at well 163 averaged 0.3 Mgal/d since production began in mid 1995.

Chloride concentrations in well 105 rose sharply in 1996 to the highest concentration ever measured at the well (45 mg/L in September 1996). Chloride concentrations in wells 107 and 163 during the 12-month period ending September 1996 have remained near 20 mg/L with fluctuations of about 10

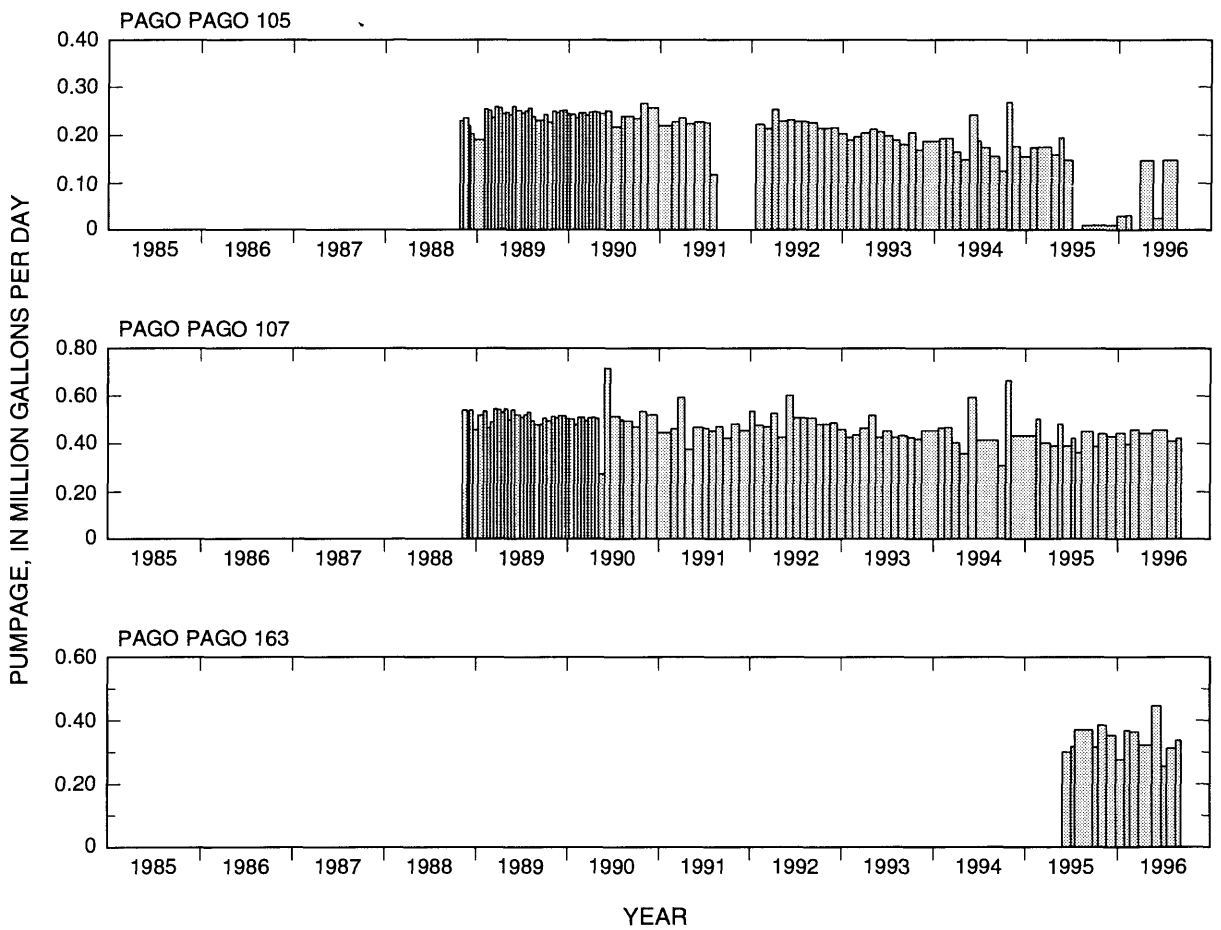

Figure 12. Pumpage, chloride concentrations, and water levels for wells in Pago Pago, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

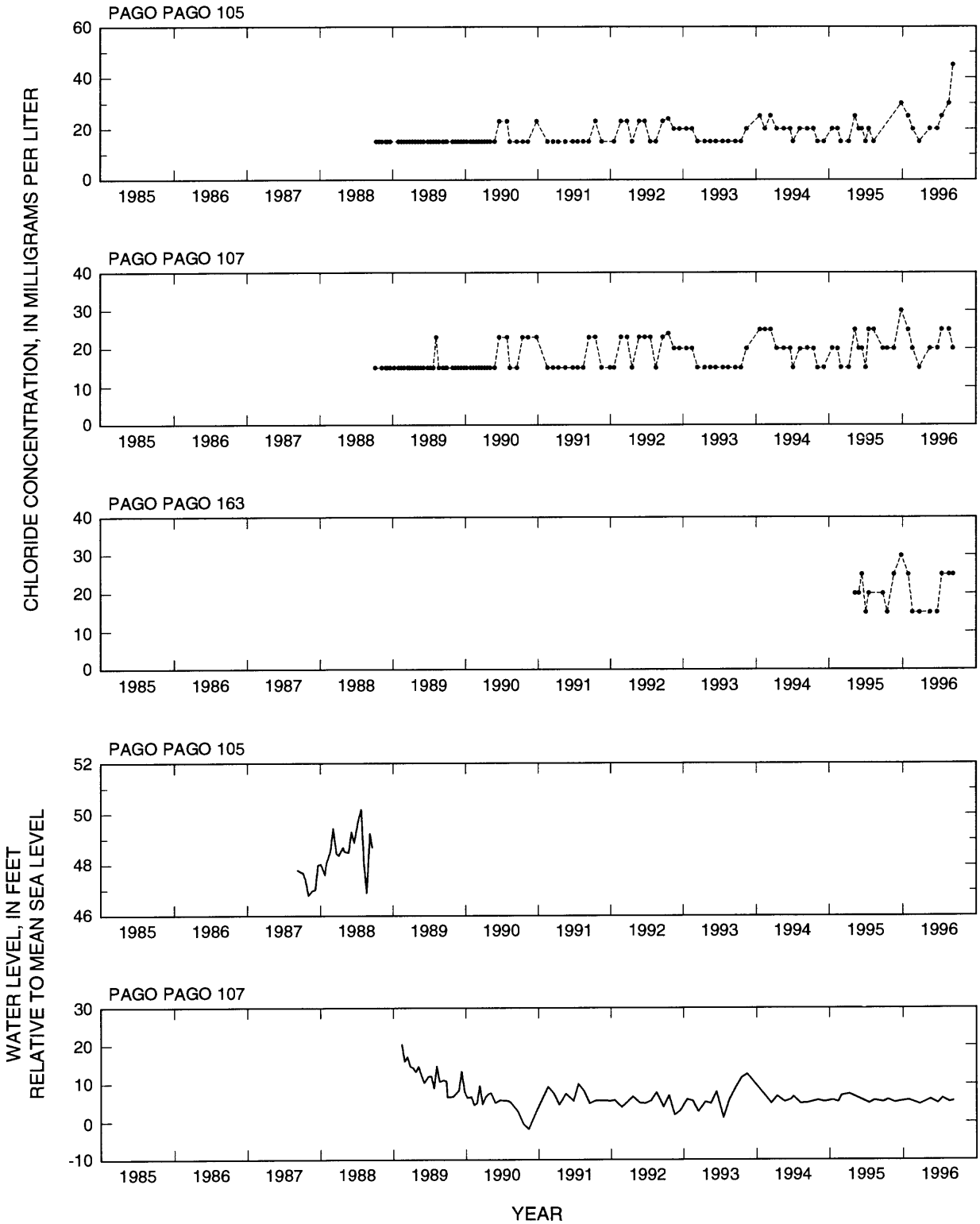

Figure 12. Pumpage, chloride concentrations, and water levels for wells in Pago Pago, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Aua

Aua has three wells that have pumpage records between 1985 and September 1996 (fig. 9). Wells 97 and 98 began pumping in 1984 and well 99 began pumping in 1985 (fig. 13). Well 97 and 99 are still in production, whereas well 98 has not been pumped since 1987. Pumpages and chloride concentrations at the wells have varied greatly over the 12-year period of record. Pumpage at each of the three wells began at about 0.3 to 0.4 Mgal/d in 1985 and initial chloride concentrations were below 100 mg/L. After about 2 years of steady pumping, chloride concentrations at all three wells began rising sharply. During the period of intermittent pumpage between 1987 and 1990, chloride concentrations at well 97 decreased slowly while pumpage was lowered or halted, but quickly rose again when pumpage resumed. In 1991 pumping resumed at a more constant rate of about 0.4 Mgal/d, and chloride concentrations rose to over 500 mg/L, occasionally exceeding 800 mg/L. Pumping at well 98, which is near well 97, was stopped in 1987 after chloride concentrations rose to nearly 400 mg/L.

Pumpage in well 99 remained relatively constant at about 0.3 Mgal/d from 1985 to mid-1989. At the beginning of this period, chloride concentrations in this well were below 100 mg/L, but in 1986 after about 1.5 years of continuous pumping, chloride concentrations began to rise. In 1987 chloride concentrations rose to 500 mg/L. Chloride concentrations remained near 400 mg/L but began declining in 1990, about a year after pumpage was reduced to less than 0.2 Mgal/d. By 1991, the chloride concentrations were near 200 mg/L. Chloride concentrations stayed at 100 to 200 mg/L until mid-1994 when pumpage was again increased to 0.5 Mgal/d and chloride concentration rose to more than 500 mg/L.

Water levels monitored in pumping well 99 in late 1985 through 1989 (most measurements were made while the pump was on) are nearly all below sea level, some by as much as 60 ft. Water levels measured in the non-pumping well 98 since 1989 have also been below sea level since nearby well 97 was returned to constant production in 1991. Water levels measured at non-pumping well 103 have remained a few feet above sea level but occasionally dropped a few feet below sea level during the period of record (fig. 13).

Trends during the 12-month period ending September 1996.--During the 12-month period ending September 1996, pumpage at well 97 averaged about 0.4 Mgal/d, which is an increase compared to pumpage in 1994 and 1995. Pumpage at well 99 varied from 0 to 0.5 Mgal/d, and averaged about 0.2 Mgal/d. Chloride concentrations in well 97 on September 10, 1996 reached 820 mg/L, the third highest concentration reported since the well began pumping in 1984. Chloride concentrations in well 99 ranged from 80 to 360 mg/L during the 12-month period ending September 1996. Water levels in well 98 varied between 9 and 15 ft below sea level during this period.

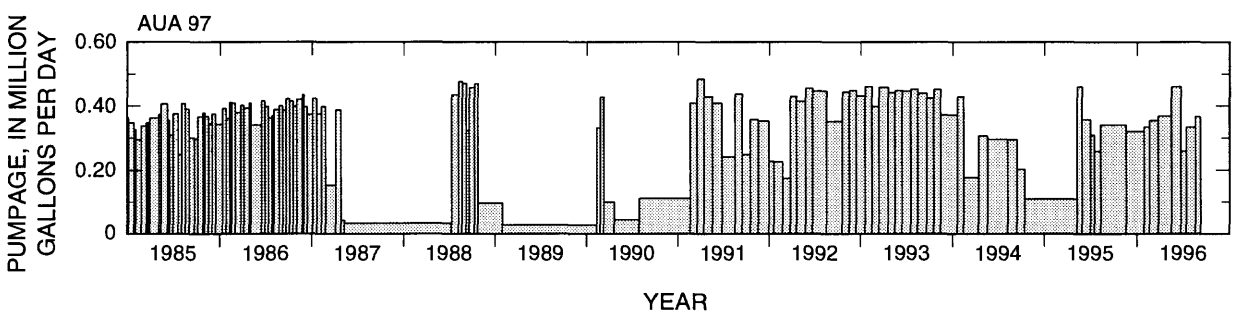

Figure 13. Pumpage, chloride concentrations, and water levels for wells in Aua, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

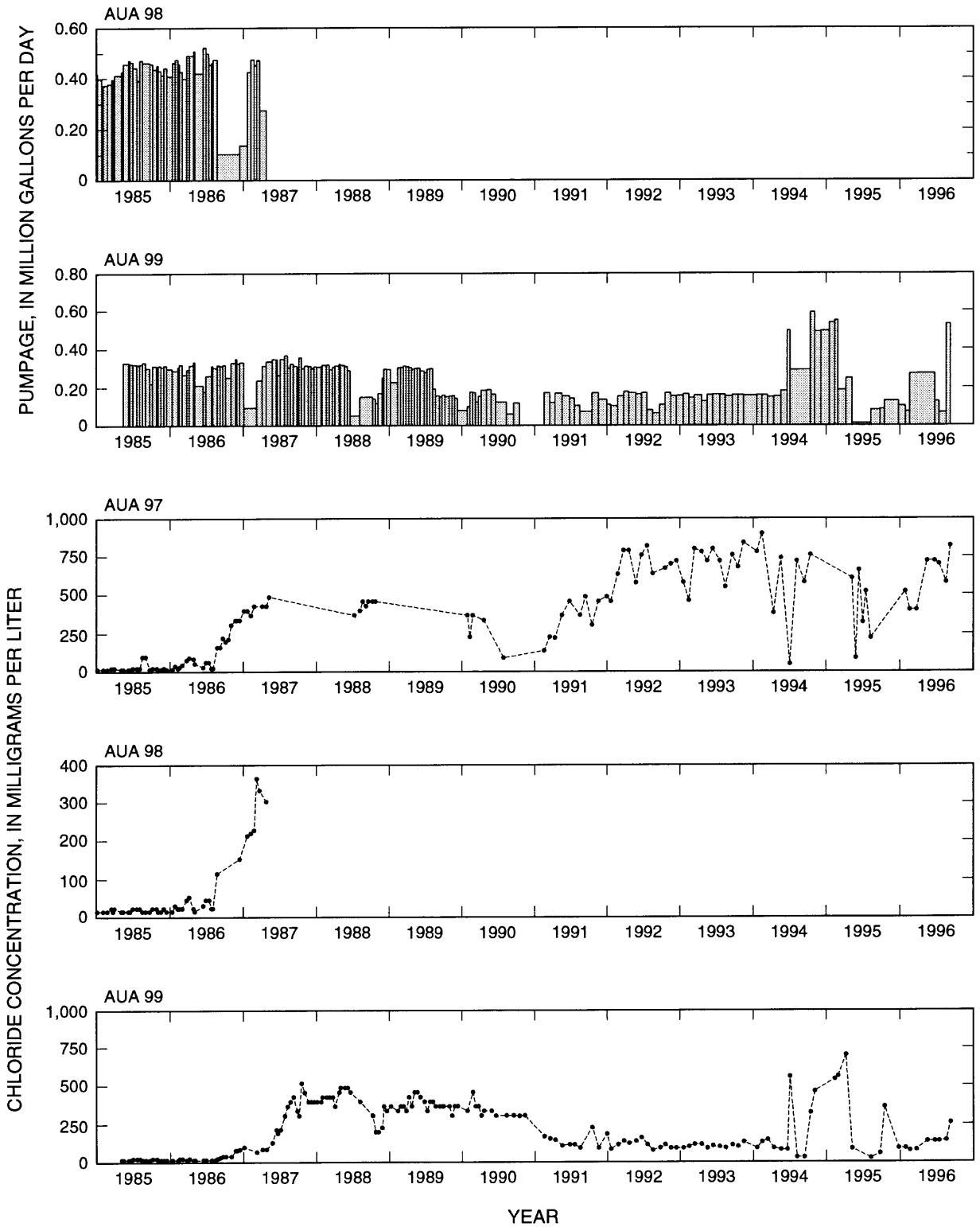

Figure 13. Pumpage, chloride concentrations, and water levels for wells in Aua, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

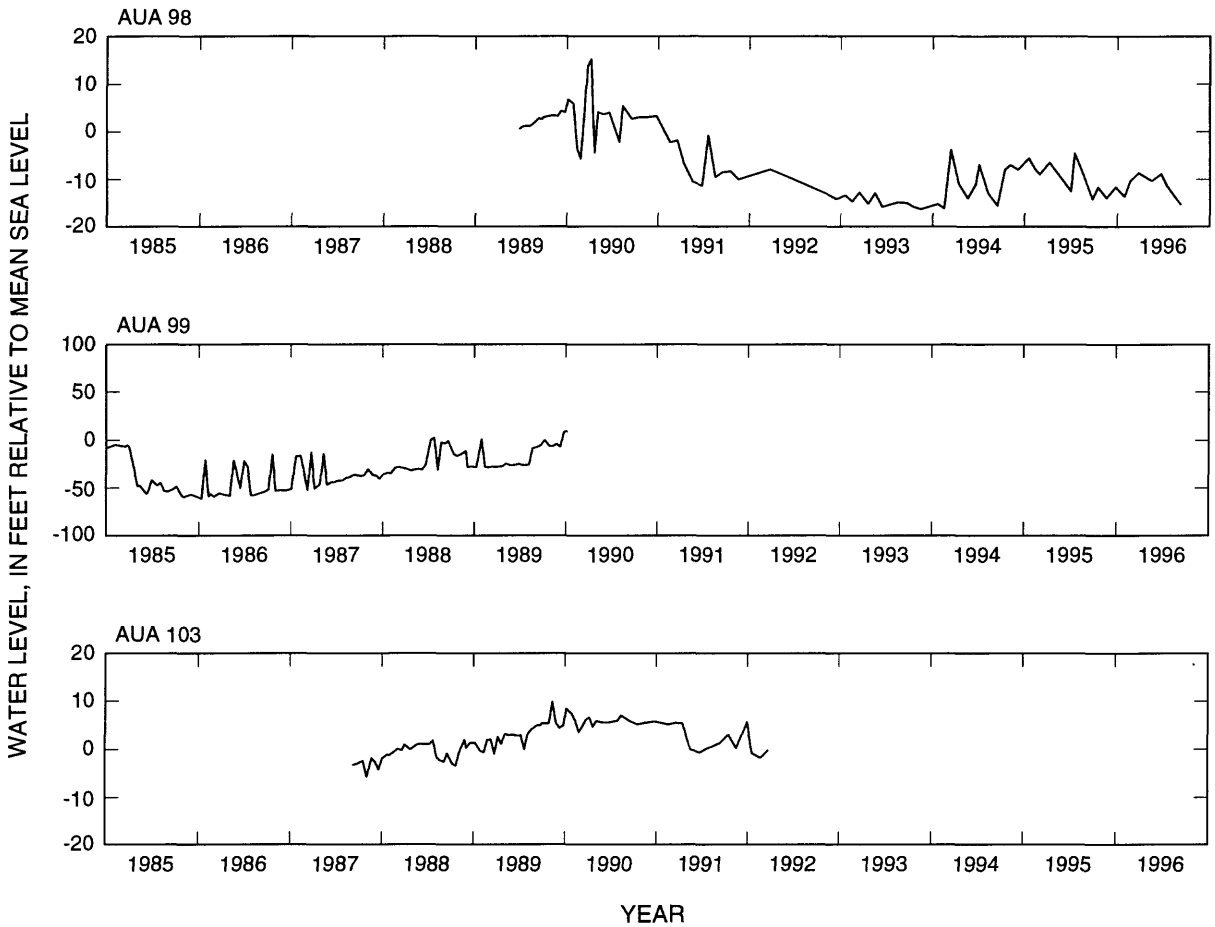

Figure 13. Pumpage, chloride concentrations, and water levels for wells in Aua, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Laulii

Laulii on the south coast of Tutuila about 0.5 mi east of Pago Pago Harbor has one pumping well (96) and one monitor well (106, fig. 9). Pumpage at well 96 averaged 0.08 Mgal/d from late 1988 through 1994 (fig. 14). There are no pumpage data for the well after February 1995 because of a meter malfunction, but pumpage continued at the well at about the same rate (0.08 Mgal/d) as in previous years (W. Carreon, ASPA, oral commun., 1997). Chloride concentrations in this well have remained less than 100 mg/L over the period of record, but show more variability and a gradual upward trend since 1992. Water levels at well 96 prior to pumping varied between 18 and 21 ft above sea level. Water levels at well 106 have fluctuated between 16 and 27 ft above sea level.

Trends during the 12-month period ending September 1996.--Pumpage at well 96 during the 12-month period ending September 1996, probably averaged about the same rate (0.08 Mgal/d) as in previous years (W. Carreon, ASPA, oral commun., 1997). During the 12-month period ending September 1996, chloride concentrations at well 96 continued to rise along the trend that began in 1992. The highest chloride concentration measured in well 96 in the 12-month period was 80 mg/L on January 30, 1996. Water levels in monitor well 106 during the 12-month period ending September 1996, varied by 4 ft around a mean of about 22 ft, which is about the same mean and variation of previous years.

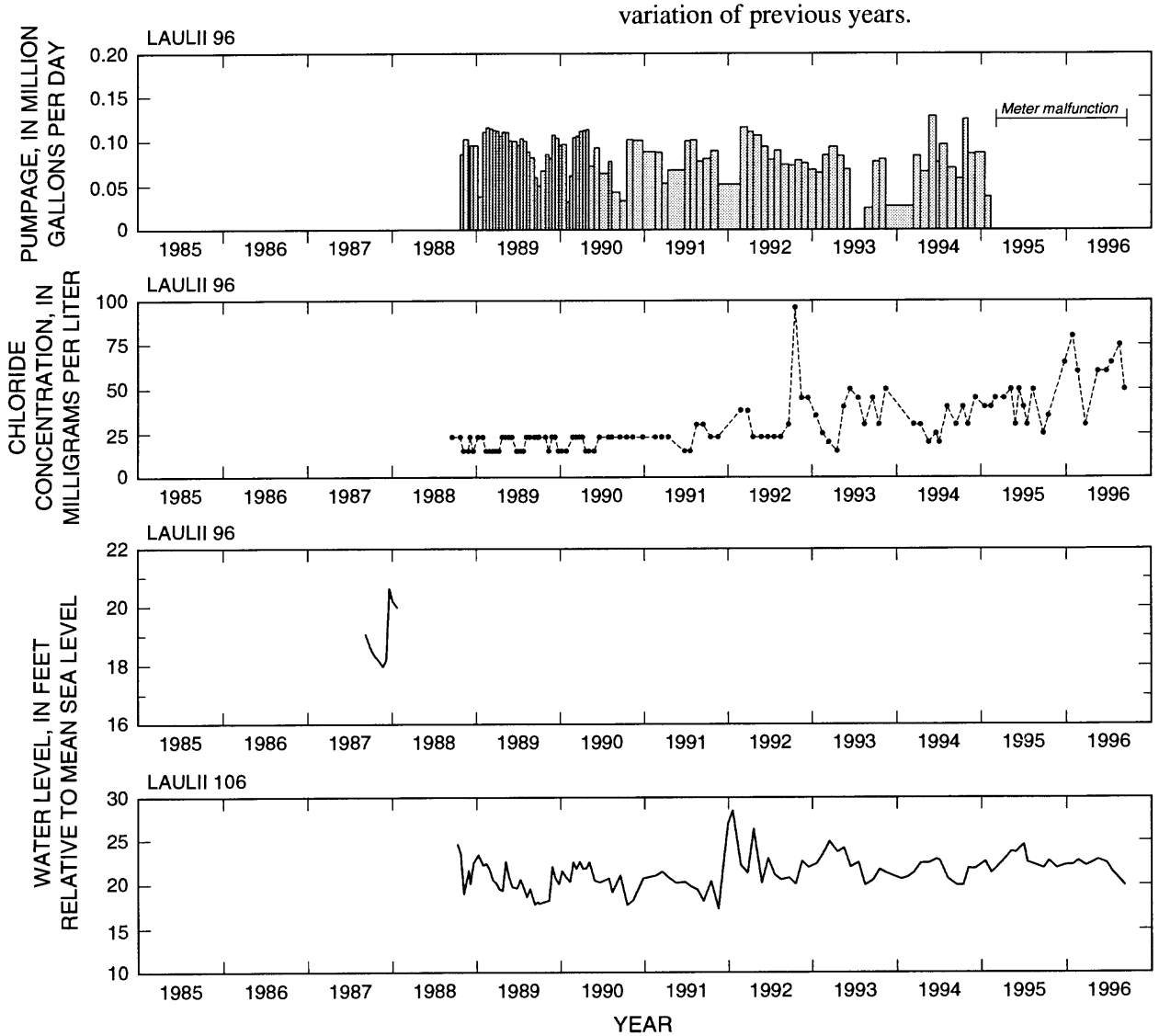

Figure 14. Pumpage, chloride concentrations, and water levels for wells in Laulii, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Fagasa

Fagasa on the northern coast of central Tutuila has two production wells in small valleys that do not extend far from the sea coast (fig. 9). Well 141 has pumped at various rates between 0 and 0.04 Mgal/d with an average of about 0.01 Mgal/d since 1991 (fig. 15). Well 142, which is shallower than well 141, has also been pumping since 1991, but only intermittently and at a lower rate. Chloride concentrations at well 141 rose gradually but remained below 100 mg/L from 1991 through early 1995. Chloride concentrations at this well fluctuated greatly since then, exceeding 200 mg/L on occasion. Since the beginning of pumpage in 1991, chloride concentrations at well 142 were higher on average, varied over a greater range, and increased more steeply than at well 141.

Trends during the 12-month period ending September 1996.--Pumpage at well 141 showed a decline from 0.02 Mgal/d in October 1995 to less than 0.01 Mgal/d in January 1996, but pumpage rose back to 0.02 Mgal/d by May 1996. Between May and September 1996, pumpage at well 141 declined again to less than 0.01 Mgal/d. Pumpage in well 142 in 1995 averaged less than 0.01 Mgal/d, but rose to more than 0.01 Mgal/d in 1996. During the 12-month period ending September 1996, chloride concentrations in both wells 141 and 142 varied by hundreds of mg/L. Chloride concentrations in well 141 continued on an upward trend that began in 1995, but dropped sharply in July 1996.

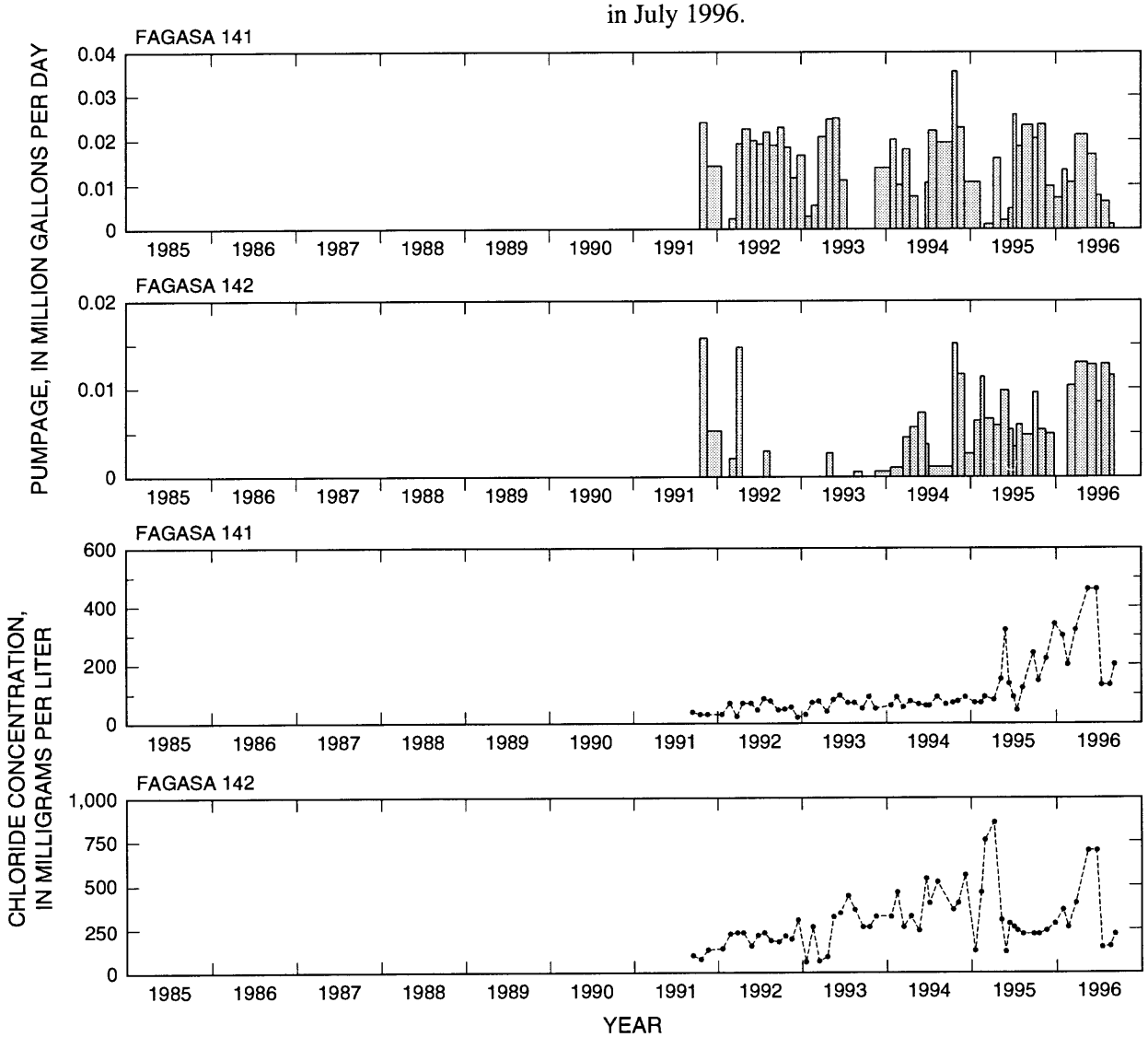

Figure 15. Pumpage and chloride concentrations for wells in Fagasa, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

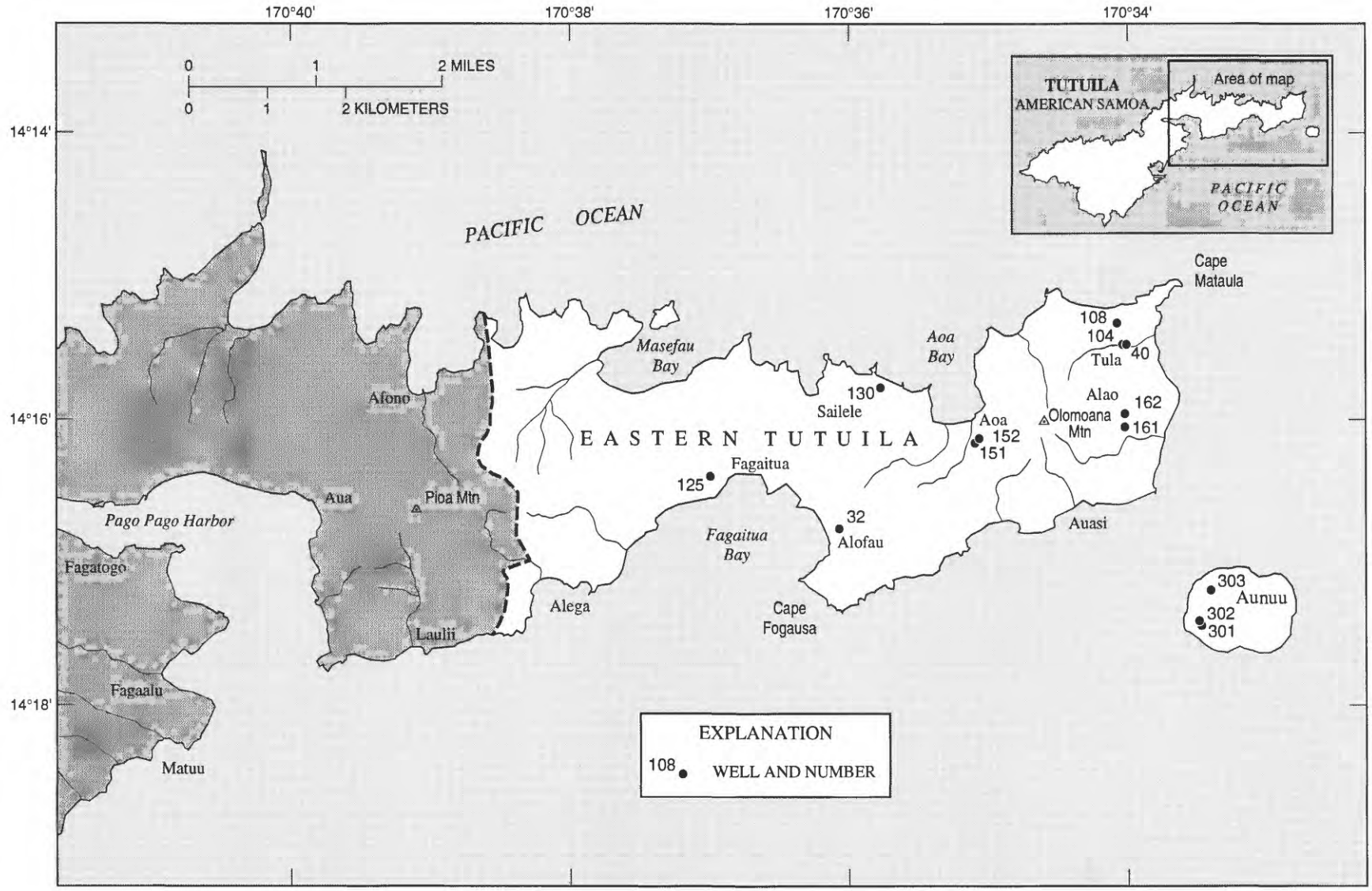

Figure 16. Wells in eastern Tutuila and Aunuu, American Samoa.

EASTERN TUTUILA AND AUNUU GROUND-WATER DATA

Eastern Tutuila is formed by steep mountains that rise abruptly from the coastline. Short valleys have been cut into the island by stream erosion. Drowning of the lower parts of the valleys has created many embayments along both the northern and southern coasts (fig. 16). Valley-fill and coastal sediments create the only flat-lying areas in this rugged part of the island. Eastern Tutuila is more sparsely populated than central and western Tutuila. Most of the population is distributed in small villages on the flat-lying terrain at the mouths of valleys. Ground-water development in eastern Tutuila includes 10 pumping wells located in low-lying areas near the villages of Fagaitua, Alofau, Alao, and Tula.

Aunuu is an island off the southeastern shore of Tutuila (fig. 16). The population of Aunuu resides on a coastal plain on the western end of the island. The area is served by three infiltration galleries, also located on the coastal plain. Several small dug wells are used to obtain drinking water, but withdrawal rate from these wells is small compared to the pumpage at the infiltration galleries.

Fagaitua

One production well at Fagaitua (well 125, fig. 16) on the southern coast of Tutuila has a short pumping record between 1989 and 1991, although the chloride concentration record extends back to 1988 (fig. 17). The water meter was reported to be malfunctioning on April 24, 1989. It is not known how long prior to this date the meter was malfunctioning. At the beginning of the record, chloride concentrations were already higher than 1,000 mg/L (fig. 17). Chloride concentration rose to nearly 2,000 mg/L in 1989 during a period when the well was pumping about 0.03 Mgal/d and rainfall was lower than average (fig. 2). Pumpage was reduced in mid-1989 and stopped for a period in early 1990. Pumping resumed at about 0.01 Mgal/d in late 1990 and continued to 1991. Chloride concentrations remained at about 1,000 mg/L over this period. There are no records of pumping after 1991 nor are there any records of water levels in this area.

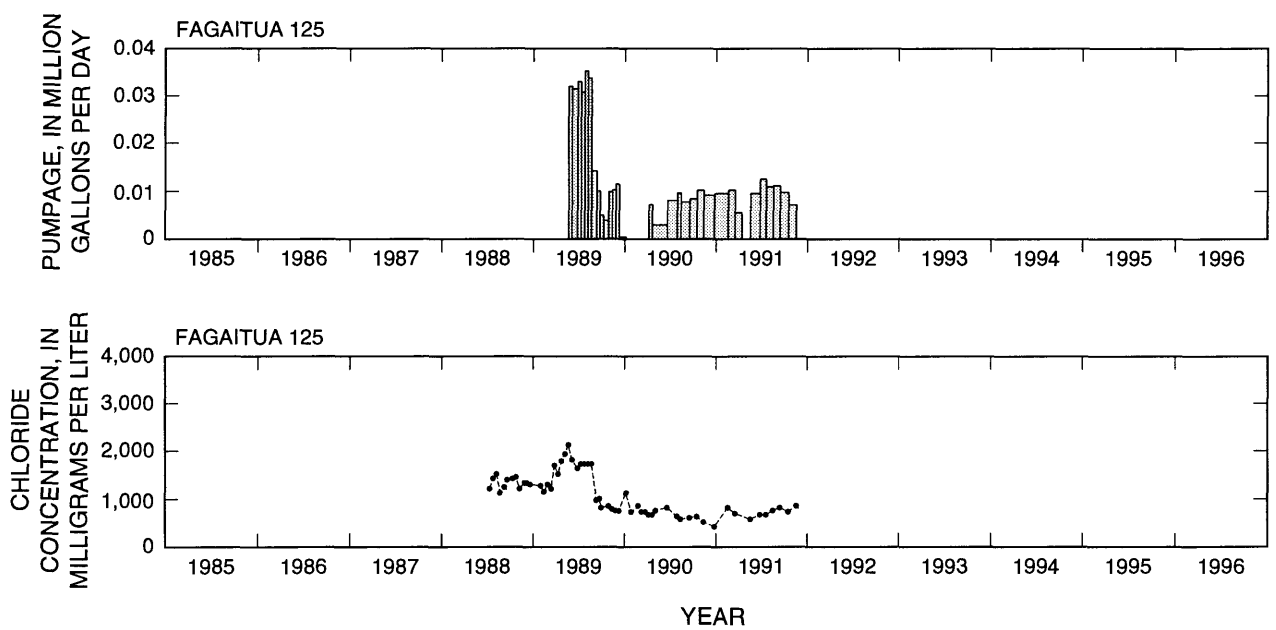

Figure 17. Pumpage and chloride concentrations for the well in Fagaitua, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Alofau

One production well (well 32) at Alofau on the southern coast of Tutuila (fig. 16) pumped at a rate of about 0.05 Mgal/d in 1988-90 (fig. 18). During this period, chloride concentrations rose from less than 1,000 mg/L to more than 2,000 mg/L. Pumpage gradually decreased to zero from mid-1990 to the end of 1991, at which time the chloride concentrations gradually returned to less than 1,000 mg/L. Pumpage resumed at a rate of 0.01 to 0.02 Mgal/d from late 1992 to late 1994. Chloride concentrations fluctuated mostly below 1,000 mg/L in 1992-94.

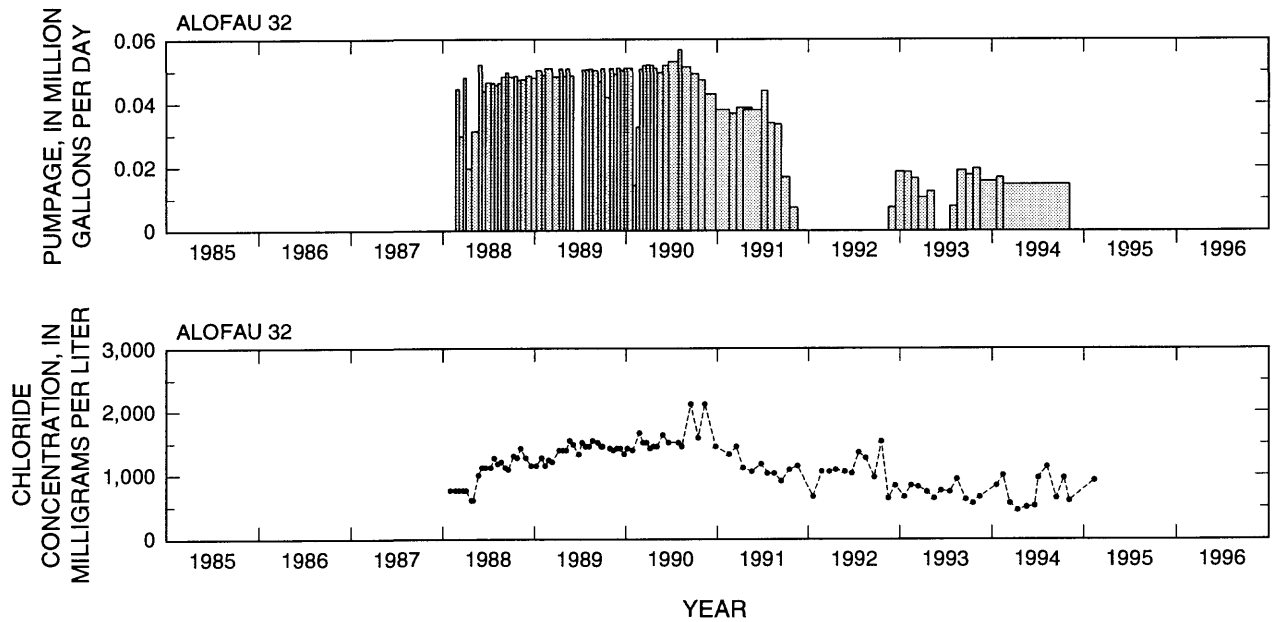

Figure 18. Pumpage and chloride concentrations for the well in Alofau, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Alao

Alao has two production wells, 161 and 162 (figs. 16 and 19). Well 161 pumped about 0.02 Mgal/d from 1994 to 1996. Chloride concentrations rose to more than 1,000 mg/L during that period. Pumpage at well 162 began in 1995 at about 0.05 Mgal/d. Initial chloride concentrations in the well were below 100 mg/L then rose to more than 500 mg/L.

Trends during the 12-month period ending September 1996.--During the 12-month period ending September 1996, well 161 was pumped at an average of about 0.02 Mgal/d. Well 162 was pumped only intermittently at an average rate of less than 0.01 Mgal/d. Chloride concentrations at well 161 remained below 150 mg/L between October 1995 and August 1996, but rose sharply to 1,160 mg/L in September 1996. Chloride concentrations in well 162 rose sharply to 360 mg/L in October 1995, increased to 520 mg/L in January and February 1996, then declined to 220 mg/L in September 1996 (fig. 19).

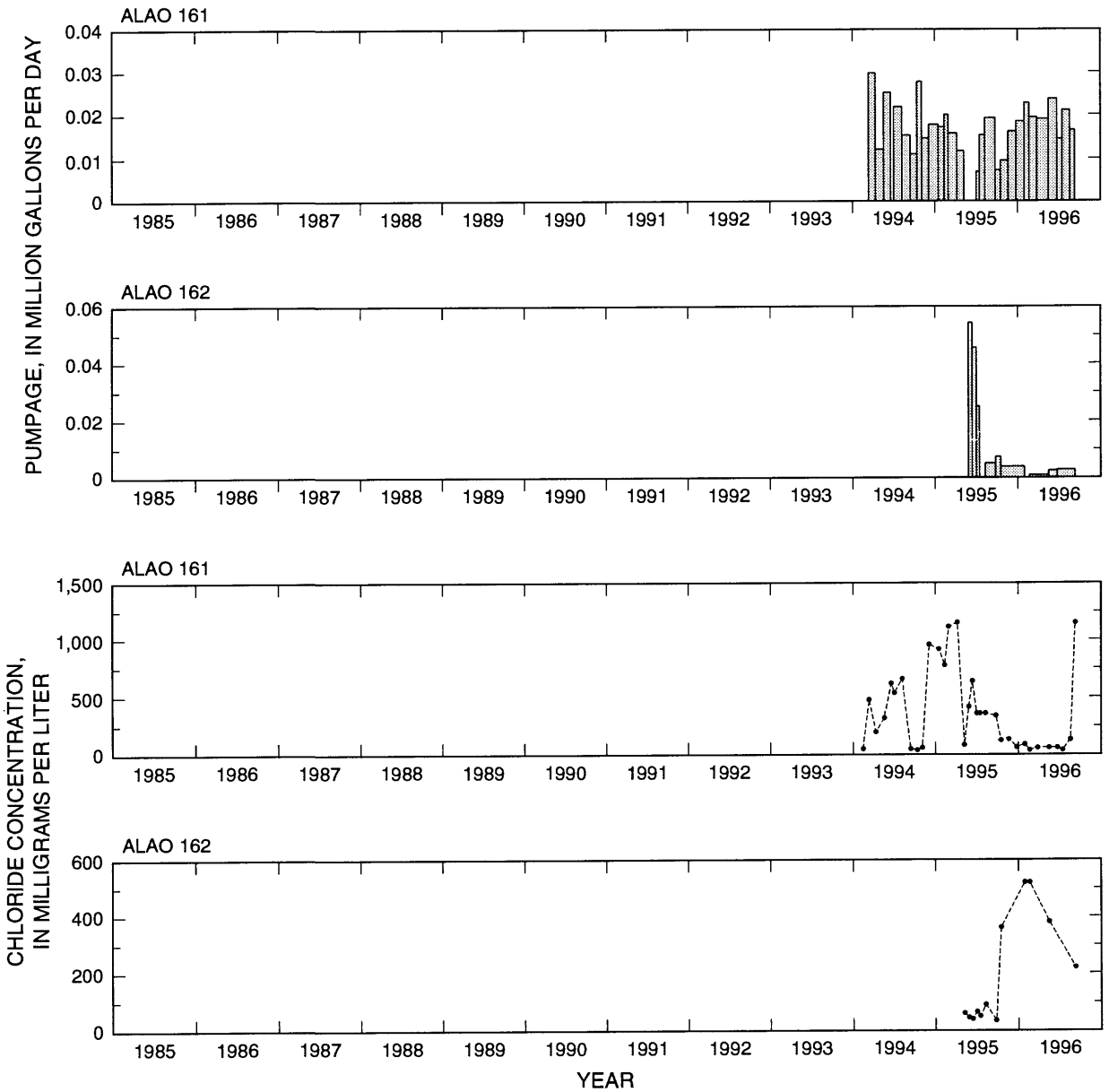

Figure 19. Pumpage and chloride concentrations for wells in Alao, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Tula

Tula on the eastern end of Tutuila has production wells 40, 104, and 108 (fig. 16). Records for well 40 began in 1991 when pumpage was about 0.04 Mgal/d (fig. 20). Pumpage was reduced to between 0.01 and 0.02 Mgal/d by mid-1991. Since 1992, the well has been pumped only intermittently at an average of less than 0.01 Mgal/d. Pumpage records for well 104 began in 1988, when the well produced about 0.07 Mgal/d. Pumpage was gradually reduced to 0.03 Mgal/d by the end of 1990 and to less than 0.02 Mgal/d beginning in 1991. Pumpage at well 108 has varied from 0 to about 0.06 Mgal/d, with an average of about 0.03 Mgal/d over the period of record.

The chloride concentration in well 40 fluctuated greatly from less than 100 to nearly 2,000 mg/L. During the period of intermittent pumpage beginning in 1992, chloride concentrations in well 40 remained mostly below 200 mg/L except on occasion when the concentration rose to more than 1,000 mg/L. Chloride concentration in the early part of the record for well 104 remained below 200 mg/L, but in July to September 1995, the chloride concentration rose sharply to as high as 420 mg/L. Chloride concentrations in well 108 in the period from 1998 to early 1990 were mostly below 200 mg/L with occasional brief rises to as high as 300 mg/L, but after mid-1990 chloride concentrations rose more frequently and to increasingly higher levels (fig. 20).

Trends during the 12-month period ending September 1996.--Pumpage at well 40 stopped in mid-1995 and resumed in September 1996 (pumpage rate in September has not yet been determined). From March through September 1996, well 104 pumped more than 0.01 Mgal/d, which is higher than the pumpage at this well in 1994 and 1995. During the 12-month period ending September 1996, pumpage at well 108 also increased relative to pumpage in 1994 to early 1995 (fig. 20).

The chloride concentration measured at well 40 when it was turned back on in September 1996 was 1,860 mg/L, the highest concentration ever measured at the well. In well 104, the record of chloride concentrations has continued to have frequent peaks as high as 400 mg/L since the first sharp rise in chloride concentration in 1995. Chloride concentrations in well 108 dropped in early 1995, but then resumed a trend of increasingly frequent and higher peaks.

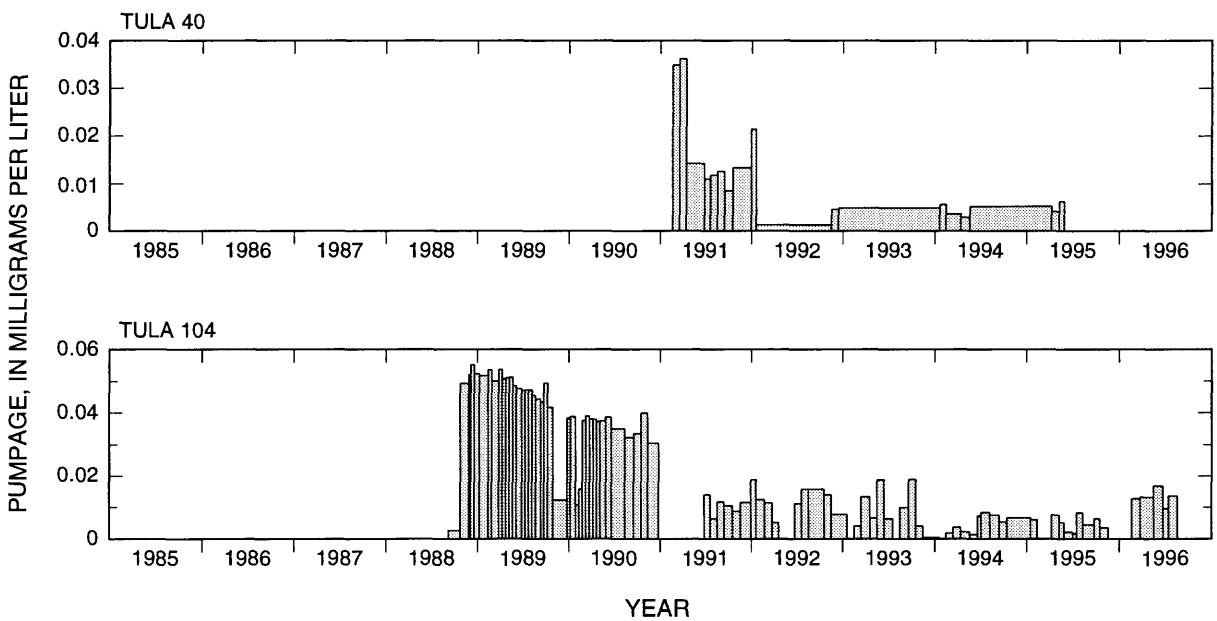

Figure 20. Pumpage and chloride concentrations for wells in Tula, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

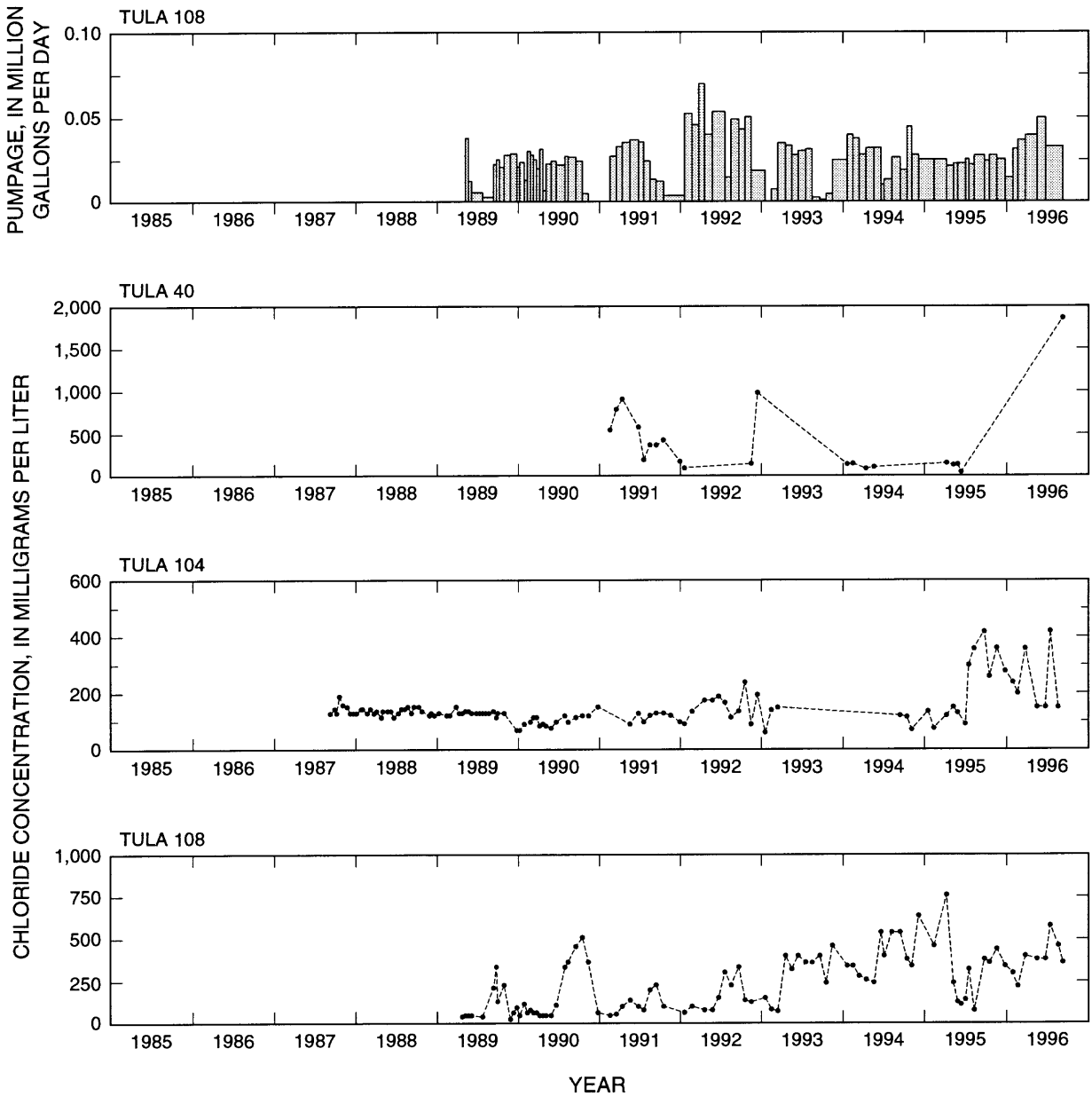

Figure 20. Pumpage and chloride concentrations for wells in Tula, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

Aoa

Aoa lies in an embayment on the northeastern shore of Tutuila (fig. 16). Two production wells in the village are sited adjacent to a low-lying swampy depression in the back of Aoa Bay. Well 151 pumped 0.02 to 0.03 Mgal/d from the end of 1992 through September 1995, and well 152 pumped between 0.03 to 0.04 Mgal/d in 1995 (fig. 21). Chloride concentrations in well 151 have remained at or below 110 mg/L since it began pumping in 1992. Chloride concentrations in well 152 were below 100 mg/L when the well began pumping in 1995.

Trends during the 12-month period ending September 1996.--Well 151 was pumped intermittently at an average rate of less than 0.01 Mgal/d during the 12-month period ending September 1996. Pumpage at well 152 remained at about 0.03 Mgal/d through September 1996.

Chloride concentrations at well 151 remained below 100 mg/L since early 1995, but rose back to as high as 110 mg/L during occasional pumping in 1996. Chloride concentrations at well 152 rose sharply in late 1995 and reached 140 mg/L in January 1996, then fluctuated between 55 and 130 mg/L through September 1996 (fig. 21).

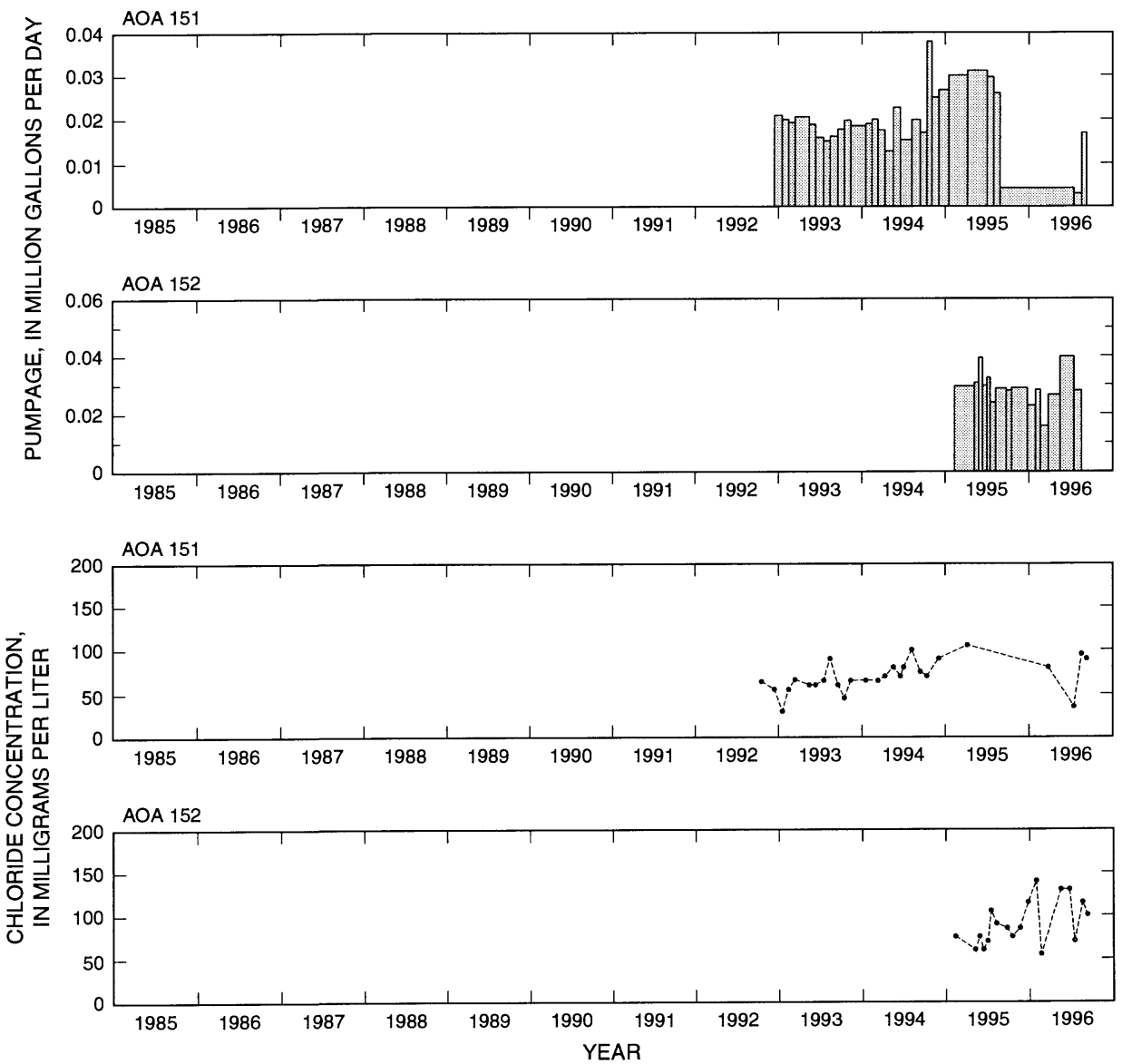

Figure 21. Pumpage and chloride concentrations for wells in Aoa, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Sailele

Sailele on the northeastern coast has one production well (well 130, fig. 16) that has produced 0.01 to 0.03 Mgal/d since 1987 (fig. 22). Chloride concentrations were about 800 mg/L through the first 4 years of pumping, then rose gradually beginning in 1991 and exceeded 1,000 mg/L in 1993. This rise in chloride concentrations occurred during a period of below-average rainfall between 1987 and 1992 (fig. 2) and after a period of high pumpage in 1992 and 1993. Chloride concentrations since then have fluctuated between 80 and 1,000 mg/L.

Trends during the 12-month period ending September 1996.--During the 12-month period ending September 1996, pumpage at well 130 continued on a declining trend. By September 1996, the well was pumping less than 0.01 Mgal/d. Chloride concentrations at well 130 during this period fluctuated between 400 and 780 mg/L.

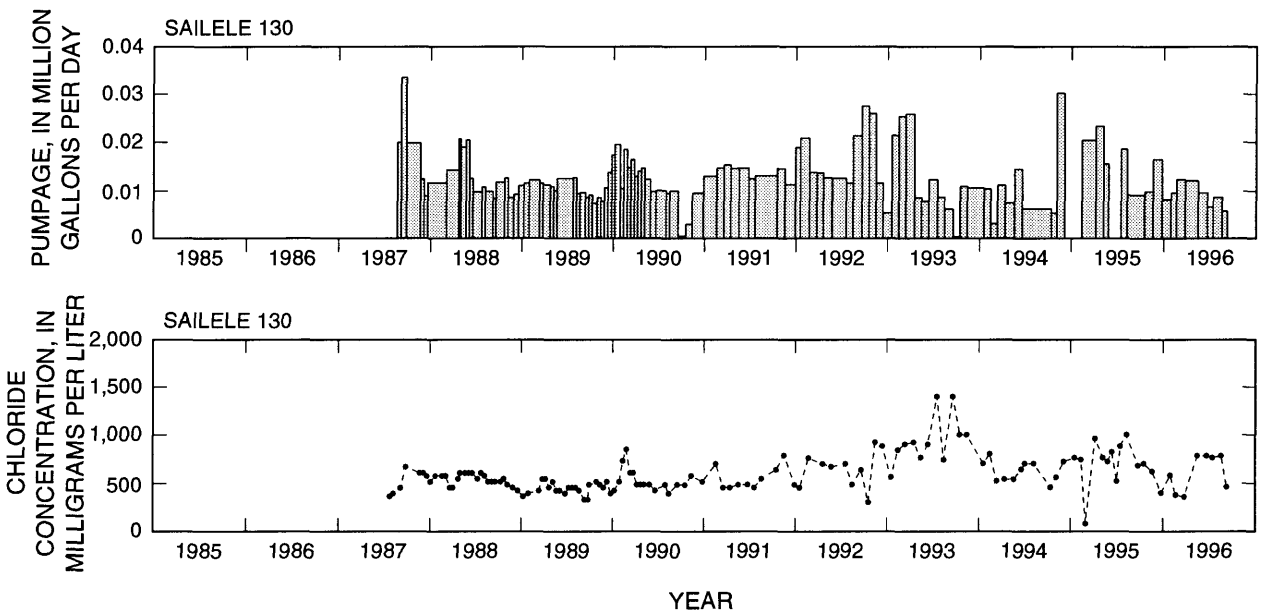

Figure 22. Pumpage and chloride concentrations for the well in Sailele, Tutuila, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

Aunuu

Ground-water production on Aunuu comes from three infiltration galleries (wells 301, 302, and 303) that began pumping in 1992 at about 0.01 to 0.05 Mgal/d each (fig. 23). Chloride concentrations were high throughout most of the period of record, varying from a few hundred to nearly 2,000 mg/L.

Trends during the 12-month period ending September 1996.--During the 12-month period ending September 1996, pumpage at well 301 continued at about 0.03 Mgal/d and well 302 continued to pump at about 0.01 to 0.02 Mgal/d. Pumpage from well 303 fluctuated from less than 0.01 Mgal/d to nearly 0.04 Mgal/d.

Chloride concentrations rose as high as 1,740 mg/L in well 301 and as high as 1,660 mg/L in well 302 (the highest concentration recorded at that well) during the 12-month period ending September 1996. Chloride concentrations in well 303 started at less than 200 mg/L in October 1995, but rose to 880 mg/L in August 1996, and then declined to 520 mg/L in September 1996.

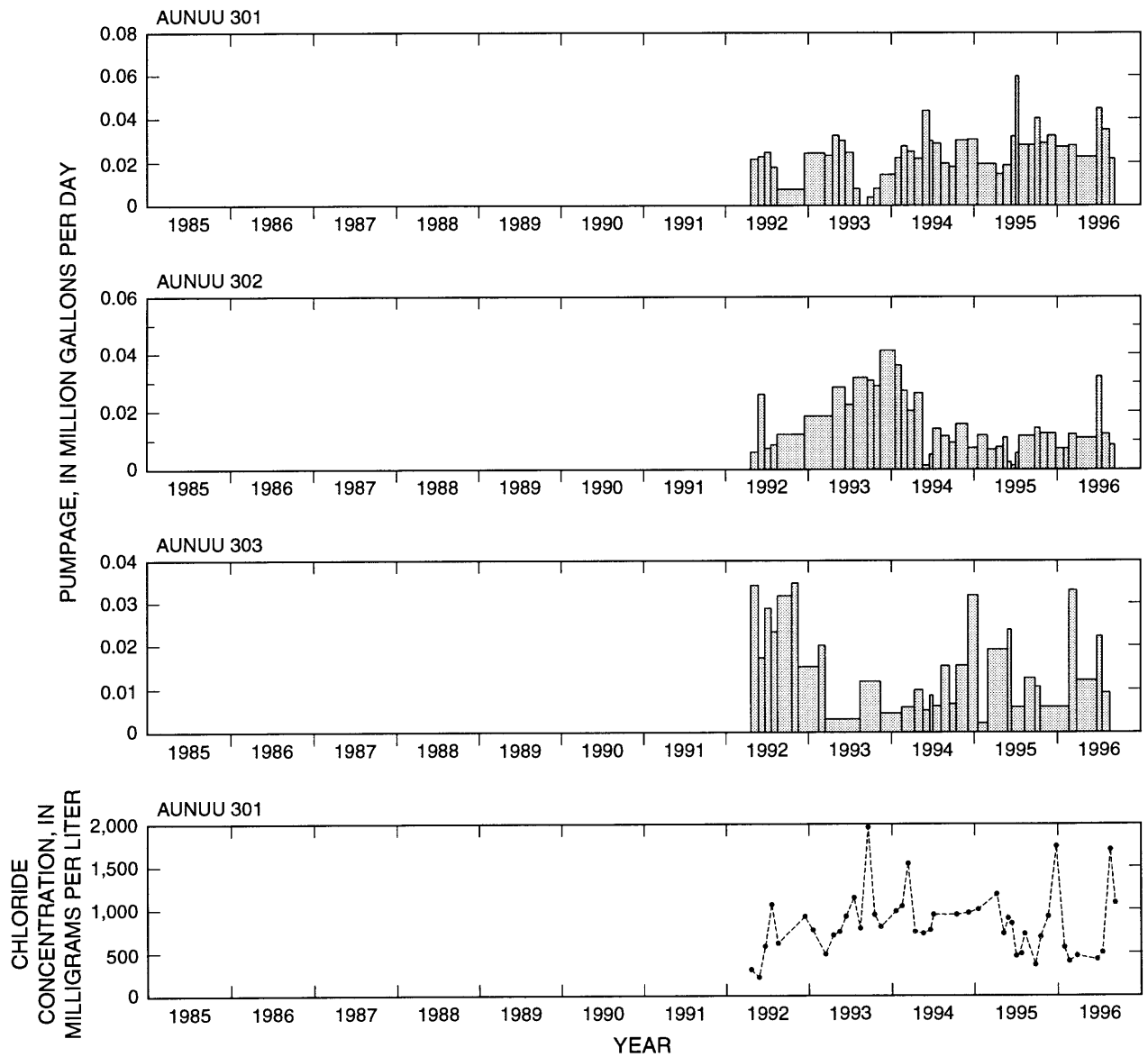

Figure 23. Pumpage and chloride concentrations for wells on Aunuu, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)

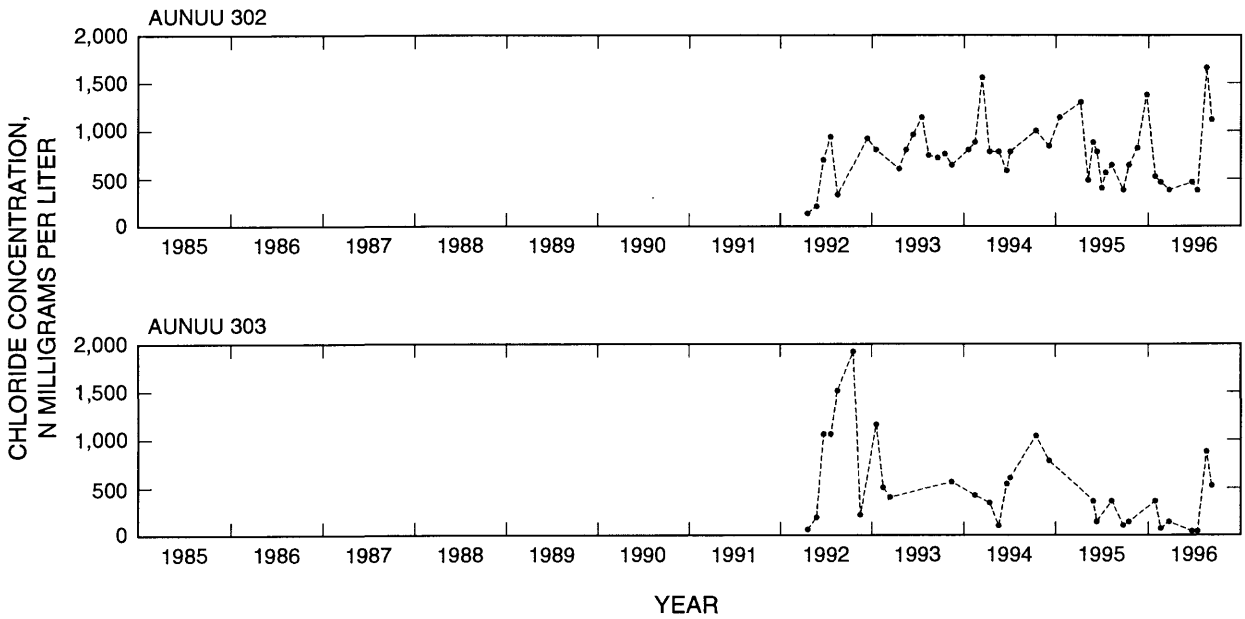

Figure 23. Pumpage and chloride concentrations for wells on Aunuu, American Samoa. (Dashed lines are intended as an aid for showing trends, but do not imply interpolation between discrete data points.)--*Continued.*

SUMMARY

Rainfall averaged 13.2 inches per month at the rain gage at Afono and 17.1 inches per month at the rain gage in Aasufou over the period from 1985 to 1996. The Tafunafou, Malaeimi-Mesepa, and Malaeloa-Leone areas in western Tutuila have had relatively constant pumpages of 0.9 to 2 Mgal/d each and chloride concentrations mostly less than 500 mg/L, although concentrations have periodically risen higher. The Iliili area has produced about 1.3 to 1.4 Mgal/d from four production wells, three with chloride concentrations less than 200 mg/L, and one with chloride concentrations that were usually under 500 mg/L. Wells in Aoloaufou produced about 0.03 to 0.05 Mgal/d each and had chloride concentrations less than 20 mg/L.

Most areas in central and eastern Tutuila, including wells in Fagaitua, Alofau, Alao, Tula, and Sailele, pumped less than 0.2 Mgal/d and each had chloride concentrations that frequently exceeded 500 mg/L. Notable exceptions are the Pago Pago and Fagatogo areas which each produced about 0.75 to 1.2 Mgal/d of water with chloride concentrations below 100 mg/L. Chloride concentrations in wells in Fagaalu, Aoa and Fagasa have usually remained below 500 mg/L, but these wells have been pumped for less than 6 years and at rates less than 0.1 Mgal/d each. Wells in Aua, which produced a total of about 0.6 to 1.1 Mgal/d, had initial chloride concentrations that were below 100 mg/L, but rose to more than 500 mg/L within 2 years of pumping and have remained high despite reductions in pumpage. Water levels in two of the three monitor wells in Aua were 9 to 15 ft below sea level. Wells on Aunuu each produced about 0.01 to 0.03 Mgal/d of water with chloride concentrations frequently in excess of 1,000 mg/L.

Trends during the 12-month period ending September 1996.--Rainfall in the 12-month period ending September 1996 was lower than average at both gages. Total pumpage for most areas remained about the same as in previous months, except in Fagaalu and Aua where pumpage increased, and in Sailele, Aoa, and Alao where pumpage decreased. Most wells showed an increase in chloride concentrations, except wells in Aoloaufou, Aoa, Sailele and well 163 in Pago Pago where chloride concentrations remained about the same as in previous months. Water levels in monitor wells in Tafunafou, Iliili, and in pumping well 107 in Pago Pago remained at about the same elevation as in previous years. Water levels in well 98 in Aua remained 9 to 15 ft below sea level as in previous years. Water levels in Laulii well 106 dropped slightly to 20 ft above sea level, and water levels in well 126 in Fagaalu dropped to about 30 ft above sea level.

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APPENDIX

DATA PROCESSING

Pumpage and chloride concentration data of all pumping wells, water levels of selected nonpumping and pumping wells, and rainfall data were collected by ASPA and sent to the USGS. Daily rainfall recorded at the rain gages in this report were summed over each month to obtain monthly totals. The departure (difference) between each month's total rainfall and the mean monthly rainfall over the period from January 1984 to September 1995 was computed and plotted in time-series graphs. Backward-looking moving averages of 3-, 6-, and 12-months were also computed and plotted. The moving averages were computed by averaging a given month's rainfall with the rainfall of 3, 6, or 12 months immediately preceding it.

All chloride concentrations were determined by a field titration kit. A quality-control check was conducted in 1984 and 1985 in which splits of 123 ground-

water samples from Samoa were analyzed using the field titration kits and laboratory titration. Comparison of the results indicated that for most of the samples, the field measurement was lower than the laboratory measurement. In four samples, the field measurement was more than 100 mg/L less than the laboratory titration. The cause of the discrepancy was not determined. More detailed records of the field titration have been kept since the 1984–85 check, but there have been no subsequent quality-control checks. Although a few measurements showed large discrepancies, 87 percent of the field determinations were within 50 mg/L of the laboratory measurement. For the purposes of this report, the accuracy of the chloride-concentration data is sufficient to track general trends in the quality of well water.

For the purposes of this report the pumpage totals were recalculated directly from meter readings supplied by ASPA. Occasional errors in the meter readings yielded negative pumpages or pumpages that were too high to have been obtained with the capacity of the pump in the well. The errors were corrected by first classifying the type and possible cause of the error and making appropriate correction (Izuka, 1996). In a few cases where the source of the error could not be determined, the reading was eliminated.

The ground-water data were initially collected on a weekly to biweekly interval but most recently the data were collected on an approximately monthly interval. Because the intervals between measurements were irregular, total pumpage in one interval was not directly comparable to total pumpage in another. The total pumpage per interval was therefore divided by the number of days in the interval to allow comparison. The irregular intervals did not affect plots of instantaneous measurements such as water level and chloride concentration, because these data can be compared regardless of the frequency at which they were collected.

This is the second in a series of ground-water data reports for Tutuila and American Samoa. Errors discovered since the publication of the first report (Izuka, 1996) have been corrected in this report.