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GEOLOGICAL SURVEY

THE EFFECTS OF PLUGGING A DEEP ARTESIAN WELL ON THE CONCENTRATION OF CHLORIDE IN WATER IN THE WATER-TABLE AQUIFER AT HIGHLAND ESTATES, LEE COUNTY, FLORIDA

By

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Open-File Report

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INTRODUCTION

Upward leakage of saline water from deep artesian wells has caused widespread deterioration in quality of water in the shallow artesian aquifers underlying Lee County. The water-table aquifer has been affected similarly when saline water from the deep artesian wells has been allowed to discharge at the surface, or when corroded well casings have developed leaks at shallow depth.

A program is underway (1972) in Lee County and adjacent areas to minimize or eliminate these problems by plugging deep artesian wells. The Florida Department of Natural Resources has for many years maintained a strong interest and support of a well plugging program. In addition, the Department has provided valuable technical advice and assistance including the development of detailed logging and cement plugging procedures to effectively eliminate surface discharge or subsurface leakage from deep artesian wells. Although a large number of wells has been plugged in Lee County as well as in other areas, little documentation has been obtained concerning the residual effects on quality of the water in the intruded aquifers after elimination of the discharge or leakage.

The purpose of this report is to present the results of an investigation wherein the quality of water in the water-table aquifer improved after a deep artesian well was plugged.

ACKNOWLEDGMENTS

The investigation was made in cooperation with the Florida Department of Natural Resources, Bureau of Geology, and the Board of County Commissioners of Lee County. The cooperation of the residents at Highland Estates in permitting periodic sampling of wells and other measurements is greatly appreciated. The cooperation of H. J. Woodard and C. R. Sproul of the Florida Department of Natural Resources also is gratefully acknowledged.

DESCRIPTION OF THE AREA

Highland Estates is a small residential community at Bonita Springs, in the southern part of Lee County as shown in figure 1. The land is generally flat although relatively well drained. Surface altitudes range from 10 to 12 feet above mean sea level. Most of the land under development was part of a citrus grove; these are common to the area. Many of the remaining citrus trees continue to bear but they are not maintained for commercial production.

Before 1972, domestic water supplies for nearly all the homes at Highland Estates were obtained from individual wells 20 to 25 feet deep. A central water supply and distribution system for Bonita Springs serves Highland Estates. Wells of the central system were constructed in a water-yielding zone about 60 feet below land surface. Most of the homes in Bonita Springs probably will continue to use wells to irrigate lawns.

Numerous deep artesian wells in the area flow. Many of these, drilled to irrigate citrus, are no longer used, presumably because the concentration of chloride in water was so great that the water was injurious to plants.

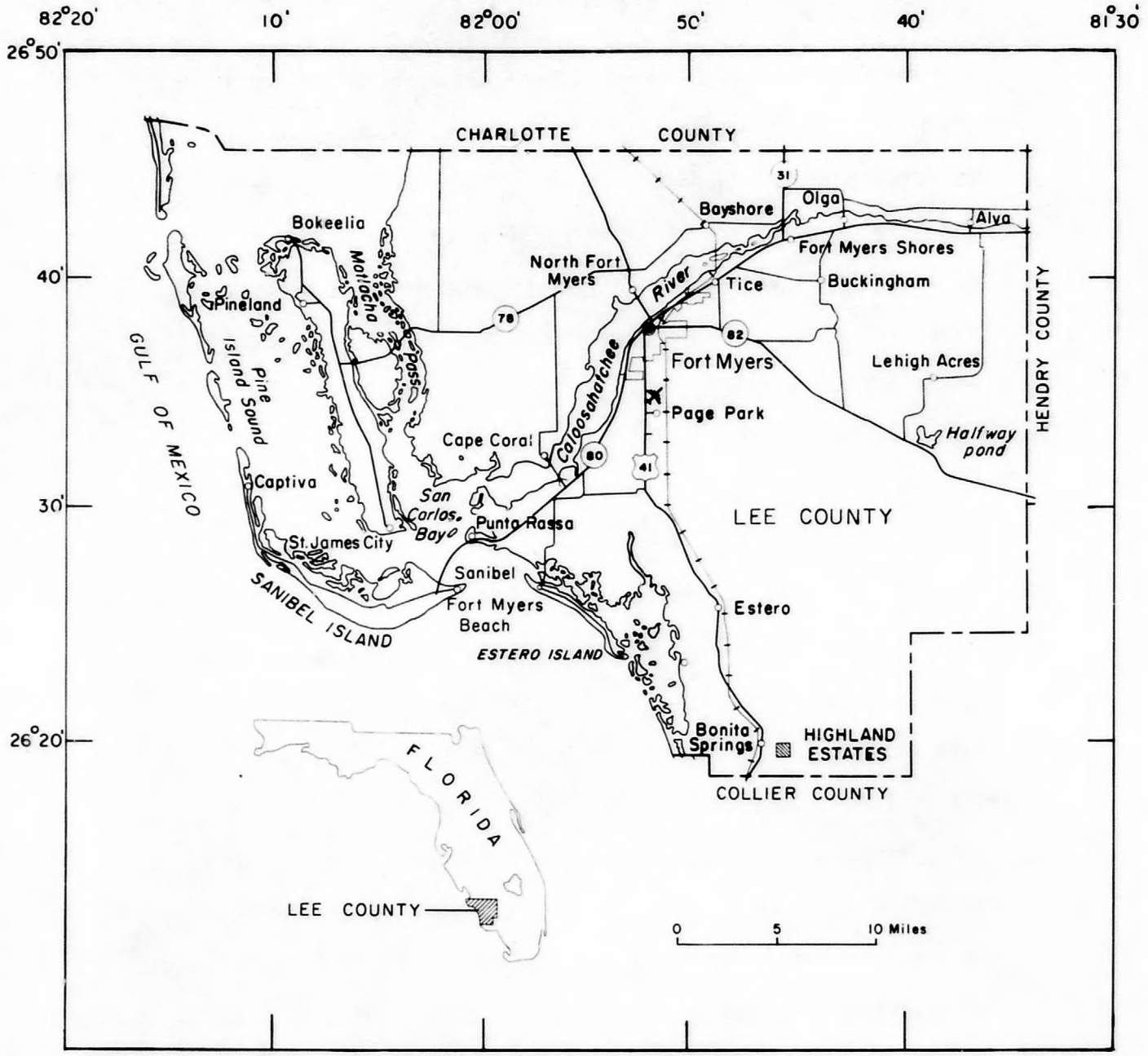

Figure 1.--Map of Lee County showing location of Highland Estates.

WATER-BEARING FORMATIONS

The uppermost water-bearing unit that underlies Highland Estates is called the water-table aquifer. It consists of tan colored medium sand and some shell fragments (fig. 2). It extends from the land surface to a depth of about 30 feet. The aquifer is recharged directly by rainfall. The water table fluctuates from 2 to 6 feet below the land surface (6-10 feet above sea level) during the rainy season and from 9 to 10 feet (2-3 feet above sea level) during the dry season. The chloride concentration in water from the aquifer generally ranges from 20 to 40 mg/l (milligrams per liter).

A second water-bearing unit, the "sandstone aquifer," occurs at a depth of about 70 feet beneath the land surface and extends downward to about 250 feet. The aquifer consists chiefly of gray and tan limestone in the upper and lower parts and gray calcareous sandstone in the middle part. The sandstone aquifer is confined in some areas. Water levels in the aquifer fluctuate seasonally from 2 to 7 feet below the land surface (5-10 feet above sea level). Although this aquifer is the principal source of water for the central water-supply system for Bonita Springs, no further discussion is warranted within the scope of this report.

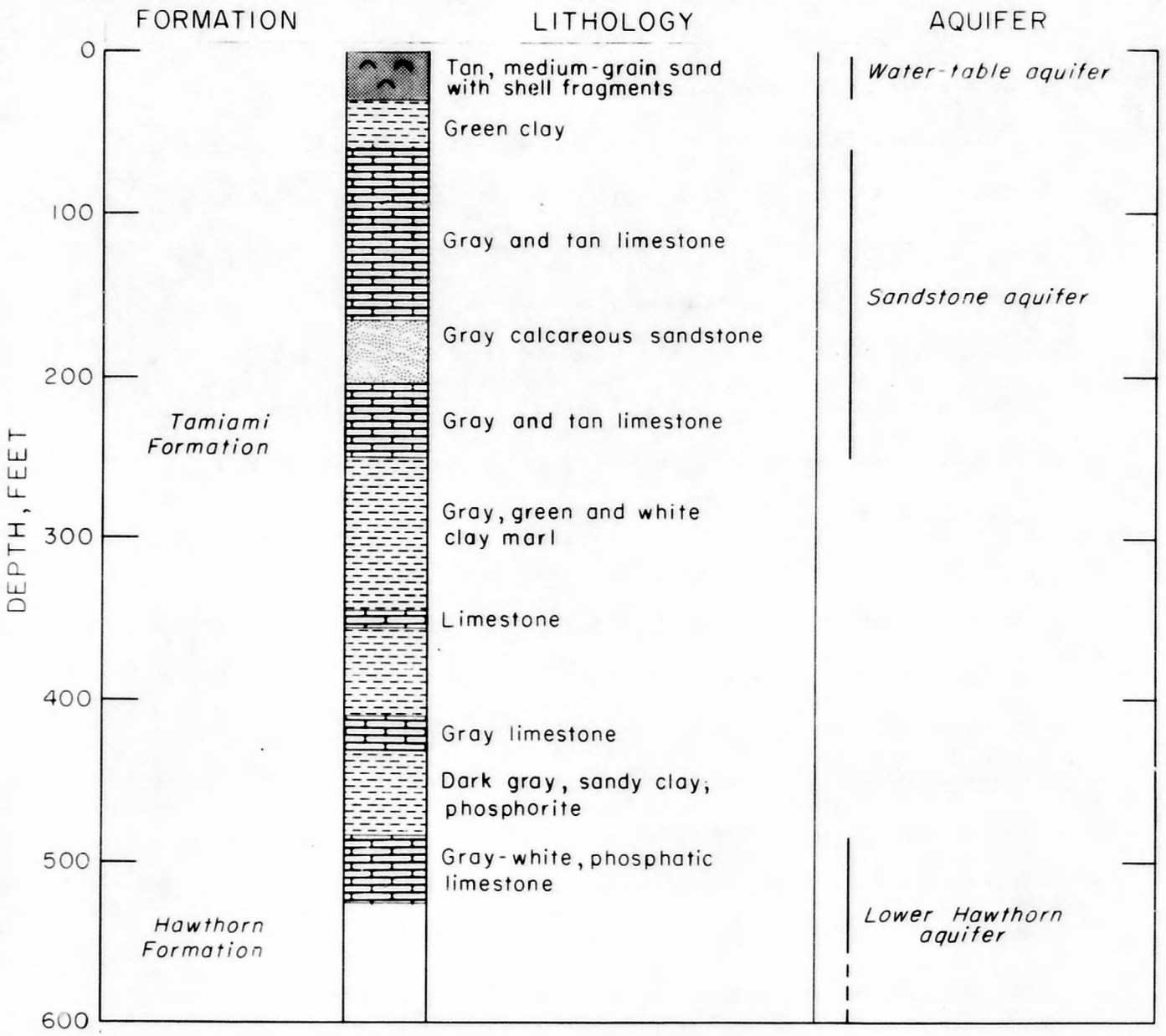

Figure 2.--Composite log of formations, lithology, and aquifers underlying Highland Estates.

Thin water-bearing zones are present within the depth range 250-485 feet below land surface. The next major water-bearing formation is at a depth of about 485 feet and probably extends downward several hundred feet. This latter unit, consisting chiefly of gray-white, phosphatic limestone, is termed the lower Hawthorn aquifer. It is under higher artesian pressure than any of the aquifers occurring at shallower depths, having a water level of about 19 feet above land surface (31 feet above sea level). Several wells in and adjacent to Highland Estates and which tap this aquifer yield water ranging in chloride from 1,500 to 2,000 mg/l. Generally, the temperature of water in this aquifer is higher than in the shallower aquifers.

RESULTS OF PRELIMINARY INVESTIGATION

In July 1967, several residents of Highland Estates reported that water from shallow wells on this property tasted salty. Because of continued reports that the water seemed salty, a preliminary investigation was begun in January 1968 to identify the wells that were acting as conduits for the saline water.

Figure 3 shows the location of 15 wells in the Estates and the chloride content in water samples collected from them on January 28, 1968. Except the samples from well 15, all were from wells 20 to 25 feet deep constructed in the water-table aquifer. As shown on figure 3, chloride concentrations in water from the shallow wells ranged from 25 mg/l in well 4 to 590 mg/l in well 2. Four shallow wells, numbers 1, 2, 6, and 8, alined northward, yielded water much higher in chloride than from similar wells in adjacent areas.

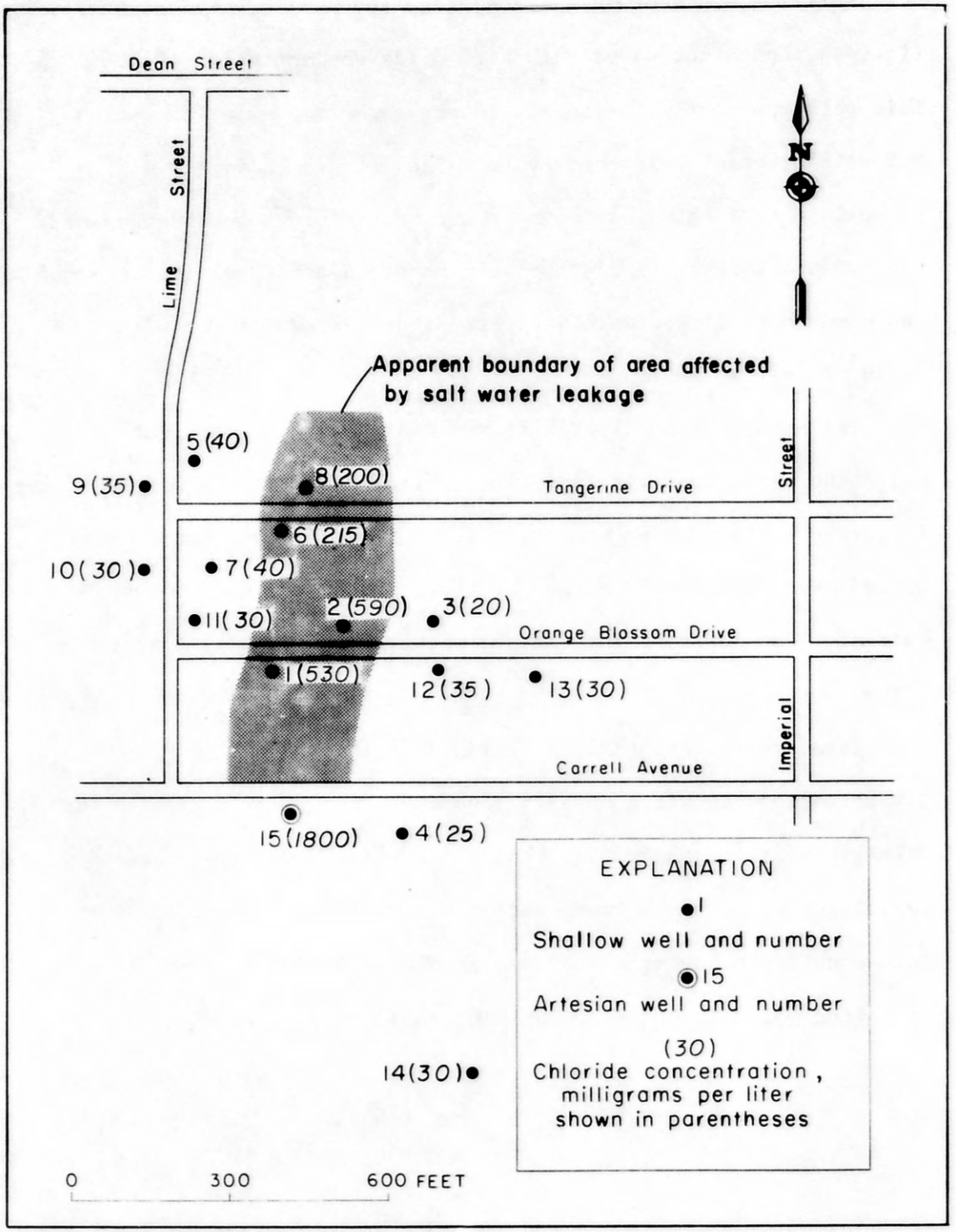

Figure 3.--Map showing location of wells at Highland Estates and chloride concentrations in water on January 24, 1968.

Well 15, south of well 1 and along the same general alinement (fig. 3), contained water with a chloride concentration of 1,800 mg/l. This well apparently tapped the lower Hawthorn aquifer at depths below 485 feet as evidenced by the high artesian head, 19.4 feet above land surface. The depth of the well could not be determined because of blockage within the well bore. Geophysical logs run on the upper part of the well indicated that the casing extended to a depth of only 80 feet.

The metal casing of well 15 was badly corroded particularly where the casing was leaking. The control valve on top of the casing, installed in 1961 to prevent flow from the well, was closed. The ground around the well was wet, although no standing water was evident. Upon opening the control valve, the well flowed about 5 gpm.

Based on the information obtained during the preliminary investigation, it was generally concluded that well 15 was the most likely conduit through which the saline water was entering the water-table aquifer near the four water-table wells at Highland Estates. This conclusion however, does not preclude the possible existence of saline water in other zones than the lower part of the Hawthorn.

THE MECHANISM OF INTRUSION

Movement of saline water from the lower Hawthorn aquifer into the water-table aquifer occurs not only in the Highland Estates area but is common throughout most of Lee County. Upon entering the bore hole of well 15 in that section of the well open to the lower Hawthorn aquifer, the saline water moved upward as a result of the head differential. Before the control valve was installed in 1961, water flowed from the top of the well casing but likely at a low rate. After the control valve was installed, the metal casing corroded, and leaked at an increasing rate immediately beneath the land surface. Whether from flow or leakage, most of the saline water upon leaving the well casing, percolated downward to the water table then moved laterally through the water-table aquifer. The direction and rate of movement was largely controlled by the permeability of the sediments and the hydraulic gradient.

The unusual distribution of higher chloride concentrations in wells 1, 2, 6, and 8 along the relatively narrow path north of well 15, probably resulted from local variations in the permeability of the sediments comprising the water-table aquifer. Most likely the path of intruding saline water marks the direction of the hydraulic gradient and the subsurface location of an accumulation of shell detritus or other material of high permeability that is similar to beds formed by wind and wave action along present shore lines.

EFFECTS OF PLUGGING WELL 15

ON CHLORIDE CONCENTRATIONS IN THE WATER-TABLE AQUIFER

On February 15, 1968, well 15 was plugged under the supervision of H.J. Woodard and C.R. Sproul of the Florida Department of Natural Resources. A water-cement mixture containing about 16 bags of cement was pumped into the well during the plugging operation. This stopped all visible leakage from the well at or near the surface and no further leakage has been noted.

After well 15 was plugged, the chloride content of water from wells 1 and 2, about 270 and 370 feet from well 15, decreased 180-200 mg/l by May 1968 as shown in figure 4. The chloride content continued to decrease until August when the total reduction was 285 mg/l in well 1 and 420 mg/l in well 2. The chloride content of water from wells 6 and 8, about 540 and 620 feet from well 15, decreased 120-130 mg/l over the same period. The reduction in chloride concentrations probably was related in part to the dilution and flushing of saline water from the aquifer by rainfall which began in May.

Analyses made in November 1968, after this initial period of decreasing concentrations, indicated that chloride in water from wells 1, 6, and 8 had increased by 65-70 mg/l. This probably represents residual contamination from saline water that had gained access to the aquifer before well 15 was plugged.

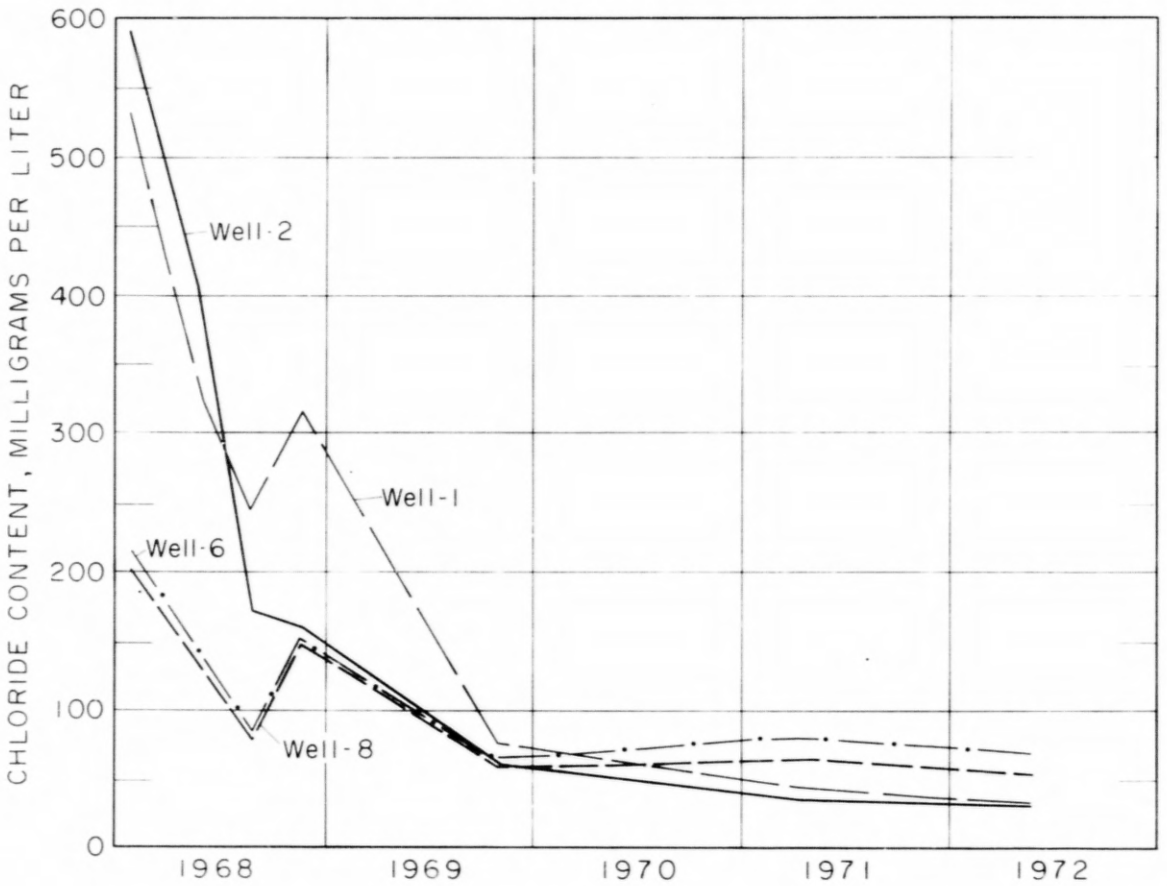

Figure 4.--Variations in chloride concentrations in wells 1, 2, 6, and 8, 1968-72.

By October 1969, about 20 months after well 15 was plugged, the chloride content of water from wells 1, 2, 6, 8 was less than 80 mg/l, indicating a decrease of 452 mg/l in well 1; 528 mg/l in well 2; 151 mg/l in well 6; and 140 mg/l in well 8. Additional observations in April 1971 and May 1972 indicated some variation in chloride content in wells 6 and 8, but a continued decrease in wells 1 and 2.

All except one of the wells sampled in January 1968 were sampled again in May 1972, more than 4 years after plugging well 15. The chloride analyses are shown in figure 5. Water from wells 1 and 2, formerly most affected by leakage of saline water from well 15, contain chloride within the normal range in water from other wells in the water-table aquifer. Wells 6 and 8 showed some residual effects of the saline water which entered the aquifer earlier.

The results of this brief investigation provides reliable evidence that surface discharge and subsurface leakage from well 15 were the primary sources through which saline water entered the water-table aquifer at Highland Estates. The results further indicate that rainfall will, in time, dissipate most of the effects of the saline water, provided the conduit remains tightly sealed.

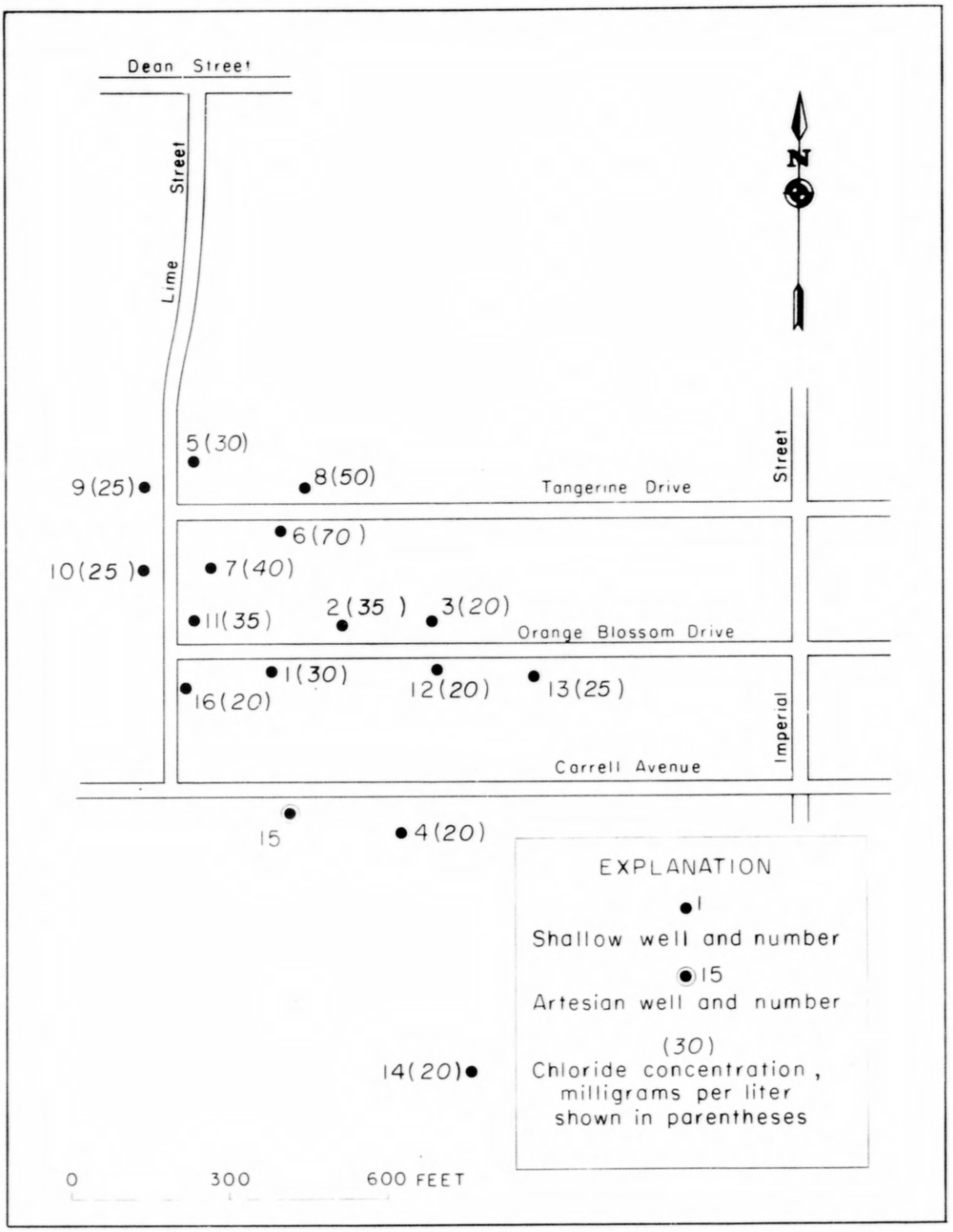

Figure 5.--Map showing chloride concentrations in wells at Highland Estates on May 24, 1972.

SUMMARY AND CONCLUSIONS

In January 1968, chloride concentrations ranging from 200 to 590 mg/l were determined in four shallow wells drilled to the water-table aquifer at Highland Estates. The chloride in water from other shallow wells in the area was 20-40 mg/l. The saline water in the aquifer was the result of leakage from a nearby artesian well drilled to the lower Hawthorn aquifer. Water from this well contained 1,800 mg/l of chloride.

After the artesian well was plugged in February 1968, the chloride in the water from the affected shallow wells decreased rapidly and by August 1968 ranged from 80 to 245 mg/l. By October 1969, the chloride concentrations had decreased to 60-80 mg/l, indicating an overall reduction in chloride concentrations ranging from 140 mg/l in the least affected to 528 mg/l in the well most affected by the intrusion of saline water.

More than 4 years after plugging, some residual effect of the saline water still remained. However, the chloride concentration in the two wells nearest the source of saline water was within the normal range of concentrations determined for the water-table aquifer in the area.

The results of this investigation provided reliable evidence that surface discharge or subsurface leakage of saline water from an artesian well, resulting in deterioration in quality of the water in parts of the water-table aquifer, could be eliminated by plugging. The natural processes of flushing and dilution likely will dissipate the effects of the saline water that already had entered the aquifer within relatively short periods if the plugging eliminated the leakage.