*TEXAS*
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Report 152

# *DEVELOPMENT OF GROUND WATER IN THE HOUSTON DISTRICT, TEXAS, 1966-69*

June 1972

SECOND PRINTING
JANUARY 1973

TEXAS WATER DEVELOPMENT BOARD

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# DEVELOPMENT OF GROUND WATER IN THE HOUSTON DISTRICT, TEXAS, 1966-69

By

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United States Geological Survey

This report was prepared by the U.S. Geological Survey
under cooperative agreement with the
Texas Water Development Board
and the cities of
Houston and Galveston

June 1972

Second Printing
January 1973

Published and distributed
by the
Texas Water Development Board
Post Office Box 13087
Austin, Texas 78711

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Cont'd.)



## TABLES



## FIGURES

## TABLE OF CONTENTS (Cont'd.)

Page

# DEVELOPMENT OF GROUND WATER IN THE HOUSTON DISTRICT, TEXAS, 1966-69

By

R. K. Gabrysch
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## ABSTRACT

Total withdrawals of ground water in the Houston district increased from about 412 mgd (million gallons per day) in 1966 to 507 mgd in 1969. Almost all of the increase occurred in the Katy, Pasadena, and Houston areas. Pumpage in the NASA area has become significant in the past few years, increasing from 5.3 mgd in 1966 to 11.2 mgd in 1969. Small increases occurred in the Baytown-La Porte and Texas City areas, but pumpage remained almost constant in the Alta Loma area.

Water-level declines continued, generally, at a greater rate than before 1966. The greatest declines in the past several years were in the Houston area, but the center of decline is still in the Pasadena area.

Although salt-water encroachment is probable in the district, no large increases in chloride were measured at the monitoring points.

# DEVELOPMENT OF GROUND WATER IN THE HOUSTON DISTRICT, TEXAS, 1966-69

## INTRODUCTION

Collection of data to define the ground-water resources in and around Houston, Texas, was begun by the U.S. Geological Survey about 1929. The present program of collection and dissemination of data is a cooperative effort by the U.S. Geological Survey, the Texas Water Development Board, and the cities of Houston and Galveston.

Many reports describing the geology and ground-water resources of the Houston district have been published. Some of the more comprehensive reports are listed in the "Selected References" at the end of this report. The most recent report summarizing the geology and hydrology of the Houston district is by Gabrysch (1967), the report also presents data on pumpage, changes in water levels, and information on land-surface subsidence.

As a result of recent studies in the coastal area of southeast Texas, it is now possible to define better the aquifer system in the Houston district. A mapping program to delineate the aquifers in the district is presently (1970) underway, and these maps will be presented in later reports.

The Houston district, as described in this report, includes all of Harris and Galveston Counties and parts of Chambers, Liberty, Montgomery, Waller, Fort Bend, and Brazoria Counties (Figure 1). Previous reports in this program described the same areas, but the ground-water conditions in Galveston County were reported separately. Galveston County is now included in the Houston district because of the related effects of extensive ground-water development in southeastern Harris County.

The author expresses his appreciation to the well drillers, industrial plant officials, municipal officials, and many well owners who contributed data used in this report. The cooperation and assistance of D. E. Van Buskirk, Superintendent of Production, Water Division, city of Houston, greatly facilitated data collection and preparation of this report.

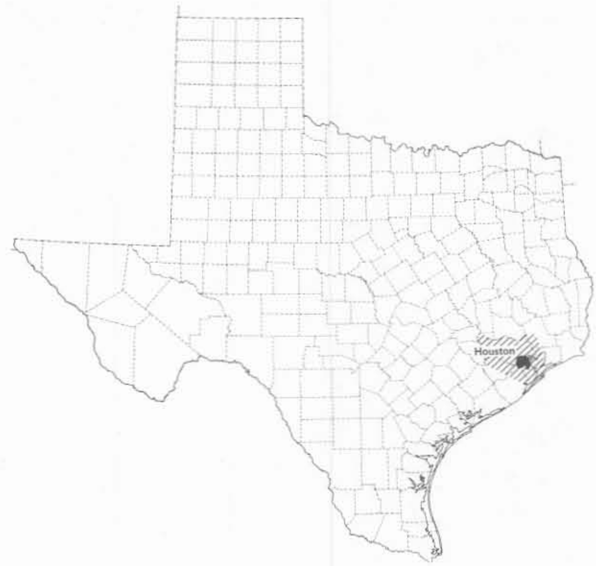


Figure 1.—Index Map Showing Area of Report

## AQUIFERS

The aquifers in the Houston district are composed of sand and clay beds that are not persistent in lithology or thickness. The beds grade into each other both laterally and vertically within short distances; consequently, differentiation of geologic formations on drillers' and electrical logs is almost impossible. However, White and others (1944, p. 146-147) and Lang and others (1950, p. 37) divided the aquifer system into seven zones based on the predominance of sand or clay. In the Houston District, water is being pumped only from sands above zone 2, a clay zone that contains some of the most continuous beds in the area.

The Alta Loma Sand of Rose (1943) (hereafter referred to as the Alta Loma Sand), which is the major aquifer in Galveston County and southern Harris County, is an exception in that it can be traced in the subsurface for great distances. The Alta Loma Sand is massive and about twice as permeable as the underlying sands, referred to by Wood and Gabrysch (1965) as the "heavily pumped layer." The Alta Loma Sand has been described as a basal sand of the Beaumont Clay, but recent work by Wesselman (1965) indicates that the Alta Loma Sand is older than the Beaumont Clay and is equivalent to at least part of the Chicot aquifer in Louisiana.

The heavily pumped layer, as defined by Wood and Gabrysch (1965), is the thick sequence of interfingering sand and clay beds between the land surface and zone 2 in part of the Houston district, between the top screens in the city of Houston water-production wells and zone 2, or, if the Alta Loma Sand is present, it is between the base of the Alta Loma Sand and zone 2. The heavily pumped layer of the Houston district is probably equivalent to the Evangeline aquifer in Louisiana.

## DEVELOPMENT OF GROUND WATER

Areas of major ground-water development discussed in this report are as follows: Houston, Pasadena, Katy, Baytown-LaPorte, NASA, Texas City, and Alta Loma (Figure 2).

Although some records of pumpage date back to the late 19th century, only the data on pumpage since 1960 are presented in this report. Tables 1, 2, and 3 show the amounts of ground water pumped in each of the areas within the district during the period 1960-69. Data on pumpage before 1960 was previously presented by Wood and Gabrysch (1965, p. 20).

Before the beginning of heavy withdrawals of ground water in the Houston district, water pressure in the sands was generally much greater than it is now, and many of the wells were flowing wells. Since the withdrawals of large supplies of ground water, water levels have been lowered considerably.

Records of water levels and water-level declines in a large part of the Houston district are based on measurements in wells that have multiple screens. The screened sands are likely to contain water under different pressure heads; therefore, the measured water levels are composites of pressure heads in all sands screened.

Because no observation well in the Houston district completely penetrates and screens the heavily pumped layer, water-level measurements in a particular well represent the hydraulic head only in that part of the aquifer that is screened. The maps showing the altitudes of water levels in the heavily pumped layer are regional approximations and may not be exact at any particular location or depth.

Water-level measurements in wells tapping the Alta Loma Sand are representative of the true pressure within the aquifer. Most wells producing water from the Alta Loma have only one or two screens because the formation is massive and contains little clay. Vertical hydraulic continuity within the formation probably is very good.

The altitudes of water levels in wells in the heavily pumped layer and the Alta Loma Sand in the spring of 1970 are shown in Figures 3 and 5. Figures 4 and 6 show the declines in water levels in these units.

### Houston Area

The Houston area is in the central and south-central parts of Harris County (Figure 2) and consists of most of the city of Houston and closely adjoining territory. The Houston area, as designated in this report, is slightly larger than in previous reports on this program. Because of the growth of the city of Houston, additional areas to the north and northwest have been added.

#### Pumpage

Pumpage in the Houston area is principally for municipal supply, but minor amounts of ground water are used by small industries. The city of Houston is the largest single user of ground water in the district. In 1953, ground-water pumpage in the area was about 100 mgd (million gallons per day); pumpage by the city of Houston was 77.3 mgd.

In 1954, water from Lake Houston became available and 0.9 mgd of surface water in that year was used by the city of Houston for municipal supply. Until 1968, the lake furnished between 24 and 29 mgd. In November 1968, additional water mains were put into service, and municipal usage of Lake Houston water was increased to 44.4 mgd.

Ground-water pumpage by the city of Houston in 1969 was 133.4 mgd (Table 1), and the total ground-water pumpage for all uses in the area in 1969 was 160.4 mgd.

#### Decline of Water Levels

Water levels declined at least 80 feet in most of the Houston area between 1961 and 1970 (Figure 4). As much as 170 feet of decline occurred in the vicinity of the Spring Branch well field, which was activated in 1964. The rate of decline ranged from about 3 feet per year in the southern part of the area to about 19 feet per year in the northwestern part. The exceptionally rapid rate of decline in water levels in the Spring Branch field will decrease as the cone of depression expands. The rate of decline in most of the area has been at least 9 feet per year.

Table 1.--Average pumpage of ground water in areas principally in Harris County, in million gallons per day

| Area | Use | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Houston | Public supply | | | | | | | | | | |
| | City of Houston | 78.1 | 83.1 | 96.3 | 105.2 | 109.4 | 115.7 | 117.6 | 128.7 | 131.3 | 133.4 |
| | Suburban | 10.7 | 9.8 | 10.6 | 12.4 | 12.9 | 13.6 | 13.8 | 16.0 | 15.5 | 16.7 |
| | Industrial | 9.1 | 8.1 | 8.4 | 7.8 | 8.2 | 8.1 | 8.9 | 9.2 | 9.7 | 9.0 |
| | Irrigation | .5 | .6 | 1.0 | 1.0 | 1.3 | 1.2 | 1.2 | 1.3 | 1.1 | 1.3 |
| | Subtotal | 98.4 | 101.6 | 116.3 | 126.4 | 131.8 | 138.6 | 141.5 | 155.2 | 157.6 | 160.4 |
| Pasadena | Public supply | 8.6 | 8.8 | 10.0 | 11.0 | 10.7 | 11.5 | 11.8 | 13.5 | 12.7 | 14.4 |
| | Industrial | 70.0 | 75.1 | 73.1 | 72.9 | 79.2 | 82.4 | 88.5 | 94.3 | 112.9 | 108.3 |
| | Irrigation | * | * | * | .1 | .1 | .1 | .1 | .1 | .1 | .1 |
| | Subtotal | 78.6 | 83.9 | 83.1 | 84.0 | 90.0 | 94.0 | 100.4 | 107.9 | 125.7 | 122.8 |
| Katy | Public supply | 1.6 | 1.6 | 1.7 | 1.9 | 1.6 | 2.5 | 2.1 | 2.4 | 2.3 | 2.8 |
| | Industrial | 5.8 | 5.8 | 9.4 | 9.8 | 10.6 | 10.0 | 11.1 | 10.7 | 10.1 | 10.2 |
| | Irrigation | | | | | | | | | | |
| | Rice | 80.0 | 89.0 | 141.0 | 136.0 | 128.0 | 126.0 | 104.0 | 159.0 | 147.0 | 142.0 |
| | Other | .4 | .4 | .5 | .7 | .6 | .6 | .3 | .4 | .4 | .4 |
| | Subtotal | 88.0 | 97.0 | 153.0 | 148.0 | 141.0 | 139.0 | 118.0 | 172.0 | 160.0 | 155.0 |

See footnotes at end of table.

Table 1.--Average pumpage of ground water in areas principally in Harris County, in million gallons per day--continued

| Area | Use | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Baytown- | Public supply | 3.8 | 4.0 | 4.8 | 5.0 | 5.4 | 5.5 | 5.4 | 5.7 | 5.9 | 7.0 |
| La Porte | Industrial | 17.9 | 18.3 | 17.2 | 18.9 | 18.0 | 16.1 | 17.3 | 17.7 | 18.1 | 20.8 |
| | Subtotal | 21.7 | 22.3 | 22.0 | 23.9 | 23.4 | 21.6 | 22.7 | 23.4 | 24.0 | 27.8 |
| NASA 1/ | Public supply | 0.8 | 0.9 | 0.8 | 1.3 | 2.0 | 3.2 | 3.6 | 4.3 | 4.6 | 4.9 |
| | Industrial | .3 | .6 | 1.0 | .9 | .6 | .6 | .8 | 2.1 | 2.4 | 5.5 |
| | Irrigation | .1 | .1 | .2 | .2 | .2 | .1 | .9 | .9 | .8 | .8 |
| | Subtotal | 1.2 | 1.6 | 2.0 | 2.4 | 2.8 | 3.9 | 5.3 | 7.3 | 7.8 | 11.2 |
| | Total (rounded) | 288 | 306 | 376 | 385 | 389 | 397 | 388 | 466 | 475 | 477 |

* Less than 50,000 gpd.

1/ Previously included in Baytown-La Porte area.

Table 2.--Average pumpage of ground water in Galveston County,

in million gallons per day

| Area | Use | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Texas City | Public supply | 3.7 | 3.9 | 4.4 | 4.5 | 4.5 | 4.7 | 4.7 | 5.6 | 5.9 | 6.8 |
| | Industrial | 6.1 | 5.1 | 5.2 | 5.4 | 6.2 | 5.9 | 7.1 | 6.5 | 6.8 | 6.1 |
| | Subtotal | 9.8 | 9.0 | 9.6 | 9.9 | 10.7 | 10.6 | 11.8 | 12.1 | 12.7 | 12.9 |
| Alta Loma | Public supply | 11.9 | 10.7 | 10.9 | 11.5 | 11.5 | 11.3 | 11.0 | 11.2 | 11.6 | 11.9 |
| Other Galveston County areas | Public supply and industrial | 1.4 | 1.5 | 1.5 | 1.6 | 1.8 | 1.9 | 2.5 | 3.1 | 3.6 | 4.5 |
| | Total (rounded) | 23 | 21 | 22 | 23 | 24 | 24 | 25 | 26 | 28 | 29 |

Table 3.--Average pumpage of ground water in the Houston district, in million gallons per day

| Use | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|---|---|---|
| Public supply 1/ | 121 | 124 | 141 | 154 | 160 | 170 | 171 | 189 | 192 | 200 |
| Industrial | 109 | 113 | 114 | 116 | 123 | 123 | 135 | 142 | 162 | 162 |
| Irrigation | 81 | 90 | 143 | 138 | 130 | 128 | 106 | 162 | 149 | 145 |
| Total (rounded) | 311 | 327 | 398 | 408 | 413 | 421 | 412 | 493 | 503 | 507 |

1/ Other Galveston County pumpage from table 2 is equally divided between public supply and industrial.

The history of water-level declines in the Houston area is shown by the hydrographs in Figure 7. The rate of decline between 1961 and 1970, as indicated by these hydrographs, was about 6 to 8 feet per year (wells LJ-65-21-402 and LJ-65-13-927).

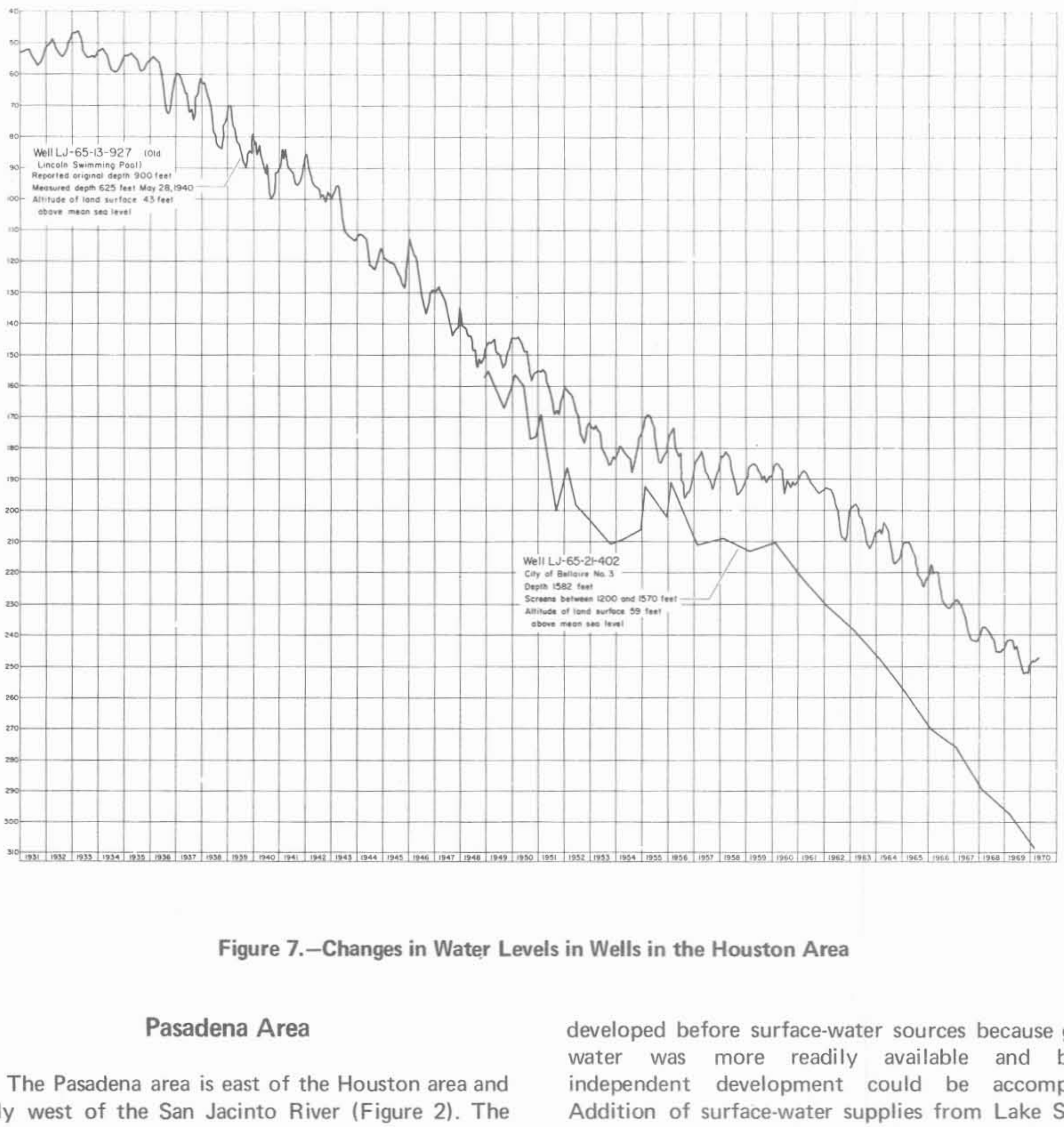


**Figure 7.—Changes in Water Levels in Wells in the Houston Area**

## Pasadena Area

The Pasadena area is east of the Houston area and mostly west of the San Jacinto River (Figure 2). The area includes a heavily industrialized zone along the Houston Ship Channel. Large ground-water withdrawals began in the Pasadena area after 1937.

### Pumpage

The principal use of water in the Pasadena area is industrial. Of about 197 mgd (surface and ground water) used in 1969 for all purposes in the area, 182 mgd was for industrial use. The phenomenal growth of industry has been due in part to the availability of large quantities of good quality water. Ground-water sources were developed before surface-water sources because ground water was more readily available and because independent development could be accomplished. Addition of surface-water supplies from Lake Sheldon and the San Jacinto River in 1942, and Lake Houston in 1954, relieved the draft of ground water for a short time. Ground-water pumpage in the Pasadena area in 1953 averaged 87 mgd; in 1969, pumpage averaged 122.8 mgd.

### Decline of Water Levels

Water levels in wells in the heavily pumped layer have declined at least 90 feet between 1961 and 1970 in almost all of the area (Figure 4). The greatest decline, as much as 120 feet, occurred in the center of the area. The rate of decline ranged from about 9 to about 13 feet per year. The rate of decline since 1961, indicated by the composite hydrograph of water levels in wells LJ-65-23-139 and LJ-65-23-106 near the Houston Ship Channel (Figure 8), is about 11.4 feet per year.

Figure 9 shows the hydrographs of water levels in observation wells LJ-65-23-804 and LJ-65-23-805 located within a few hundred feet of each other, which are screened in two different sands in the heavily pumped layer. Although there is no ground-water development near these wells, seasonal effects of pumping are reflected in the water levels. The rate of water-level decline since 1966 in well LJ-65-23-804, the deeper well, is about 8.6 feet per year; the rate of decline in well LJ-65-23-805 is about 11.3 feet per year.

Pumping from the Alta Loma Sand has caused as much as 70 feet of water-level decline between 1960 and 1970 in this aquifer in the Pasadena area (Figure 6). Water levels in wells completed in the Alta Loma Sand in the eastern part of the area are as much as 300 feet below sea level (Figure 5). Although the deepest part of the cone of depression is still in the Pasadena area, the greatest decline of water levels during the 1960-70 period was in the Baytown-La Porte and NASA areas (Figure 6).

Figure 10 shows a hydrograph of water levels in a well completed in the Alta Loma Sand. The hydrograph shows an almost steady rate of decline of about 7 feet per year for the years 1954-69.


**Figure 8.—Changes in Water Levels in Harris County Wells LJ-65-23-139 and LJ-65-23-106**


**Figure 9.—Changes in Water Levels in Two Single-Screened Deep Wells in the Southern Part of the Pasadena Area**

## Katy Area

The Katy area includes much of the northern and western parts of Harris County, southeastern Waller County, and northern Fort Bend County (Figure 2). This area, which is mostly agricultural, is the largest area in the Houston district.

### Pumpage

All water used in the Katy area is pumped from the ground, and more than 90 percent of the water is used for the irrigation of rice. Estimates of the amount of water used for irrigation are based on the amount of water pumped per acre and the total acreage in cultivation. The amount of water pumped per acre was estimated from the results of tests using selected wells. The yield of water per unit of power consumption was determined two or three times during the season for

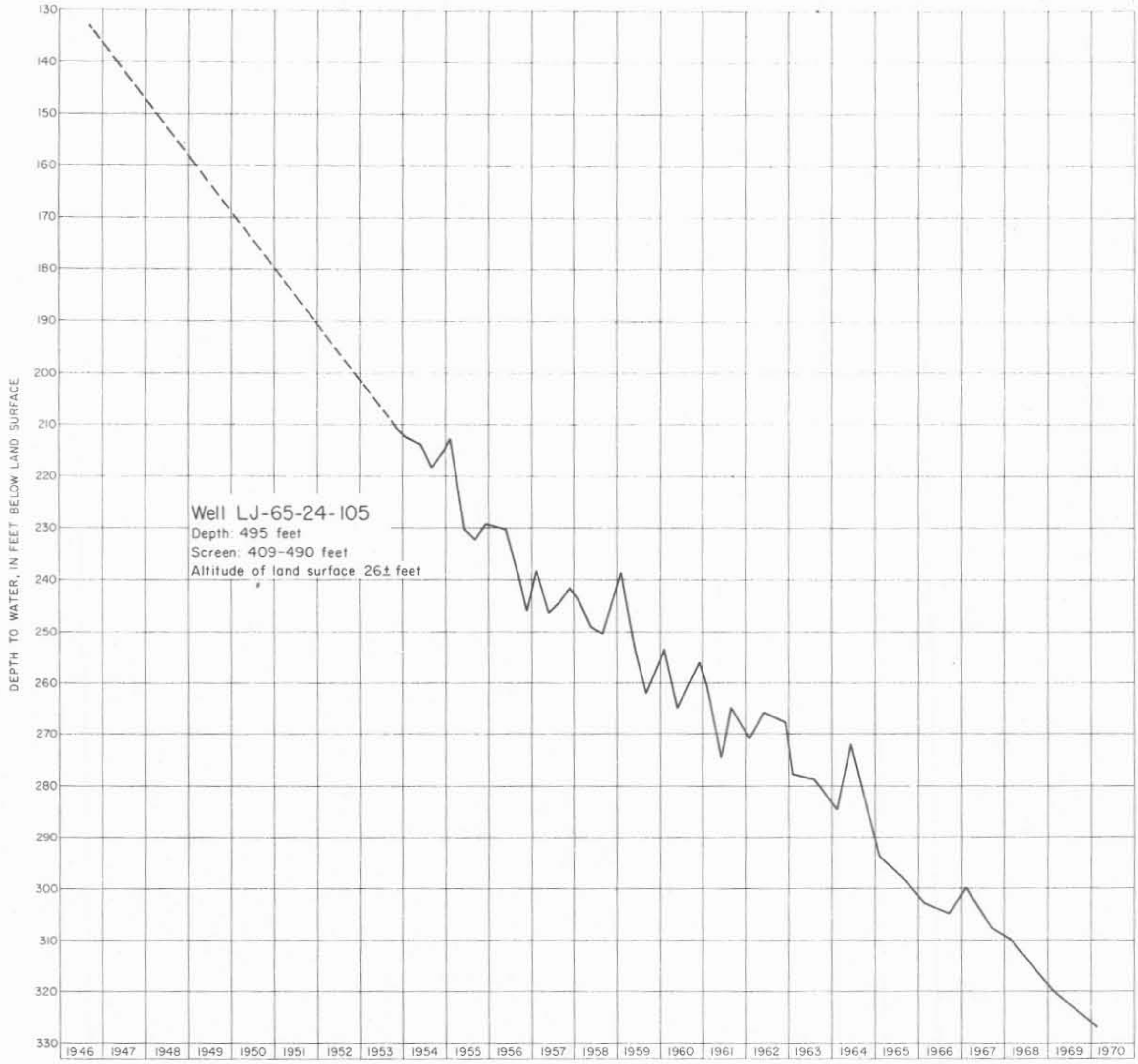


**Figure 10.—Changes in Water Levels in a Well Completed in the Alta Loma Sand in the Pasadena Area**

each of the selected wells. The average yield per unit of power times the total power used for the irrigation season provides a good estimate of the total pumpage. The number of acres planted in rice each year was obtained from the allotment records of the U.S. Department of Agriculture. The acreage planted and the estimated pumpage for the 1966-69 period are as follows:

| YEAR | ACREAGE | PUMPAGE (ACRE-FEET PER ACRE) | TOTAL ACRE-FEET |
|---|---|---|---|
| 1966 | 55,131 | 2.12 | 116,878 |
| 1967 | 57,606 | 3.09 | 178,003 |
| 1968 | 67,426 | 2.44 | 164,519 |
| 1969 | 60,827 | 2.62 | 159,367 |

Pumping for irrigation occurs during a period of about 150 days, but for comparison, the annual pumpage was divided by 365 days to obtain an average daily rate of a 12-month basis. Estimates of pumpage for 1960-69 are shown in Table 1.

### Decline of Water Levels

Water-level declines in the heavily pumped layer in the Katy area between 1961 and 1970 ranged from about 10 feet to more than 80 feet (Figure 4); however, declines were less than 40 feet in most of the area. The rate of decline ranged from about 1 foot per year to more than 4 feet per year in most of the area. Although pumpage in the Katy area was greater than in any other area, the rate of water-level decline was less. There are at least two principal reasons for the lesser rate of water-level decline:

1. Hydraulic properties of the aquifer in the Katy area are more favorable for ground-water withdrawal with less decline in the water level than eleswhere in the district. The coefficient of storage, even though still in the artesian range, is greater than in the other areas; therefore, larger amounts of water can be withdrawn with less decline in pressure. The permeability of the sands in the heavily pumped layer in the Katy area is also greater than the permeability of sands in the heavily pumped layer in the other areas. Because of the greater capacity to transmit water, the declines are less.

2. Pumping in the Katy area is not as concentrated as in other areas of the district. Each well can furnish enough water for the irrigation of large plots of land; therefore, the wells are generally spaced so that they cause only minor mutual interference.

Figure 11 illustrates the decline of water levels in the Katy area. The hydrographs of the water levels indicate a nearly steady decline of about 1.5 to 2.5 feet per year.

## Baytown-La Porte Area

The Baytown-La Porte area extends eastward from the Pasadena area to the Chambers County line (Figure 2). Previously, the area extended southward to the Galveston County line; however, extensive development in the southern part of the area has necessitated a division into two parts. For purposes of discussion, the northern part is now called the Baytown-La Porte area and the southern part the NASA (National Aeronautics and Space Administration) area. Records have been reworked and pumpage distributed to show development in the two areas since 1960.

### Pumpage

Ground-water pumpage in the Baytown-La Porte area is principally from the Alta Loma Sand. In 1969, pumpage was about 75 percent for industrial use and 25 percent for municipal supply. Ground-water pumpage has increased from 21.7 mgd in 1960 to 27.8 mgd in 1969 (Table 1).

### Decline of Water Levels

Water levels in the Baytown-La Porte area have declined as much as 80 feet during the 1960-70 period (Figure 6). The greatest decline has occurred in the southwestern part of the area. Based on the water-level decline map, the rates of decline range from less than 2 feet per year at the northern edge of the area to about 8 feet per year in the southwestern part. Figure 12, a hydrograph of water levels in a well in the area, indicates a rate of decline of less than 7 feet per year before 1968, and a rate of about 14 feet per year since 1968. This increased rate of decline is probably due to increased pumpage in the nearby NASA area.

Figure 5 shows that water levels in wells in the Alta Loma Sand range from less than 120 feet below sea level in the northern part of the area to more than 280 feet below sea level near the western edge of the area.

## NASA Area

The NASA area is bounded on the north by the Baytown-La Porte area, on the west by the Pasadena and Houston areas, on the south by Galveston County, and on the east by Galveston Bay. The NASA area was previously included as part of the Baytown-La Porte area, but because of the increased development beginning in 1962 with construction of the Manned Spacecraft Center of the National Aeronautics and Space Administration (NASA), the area is now considered separately.

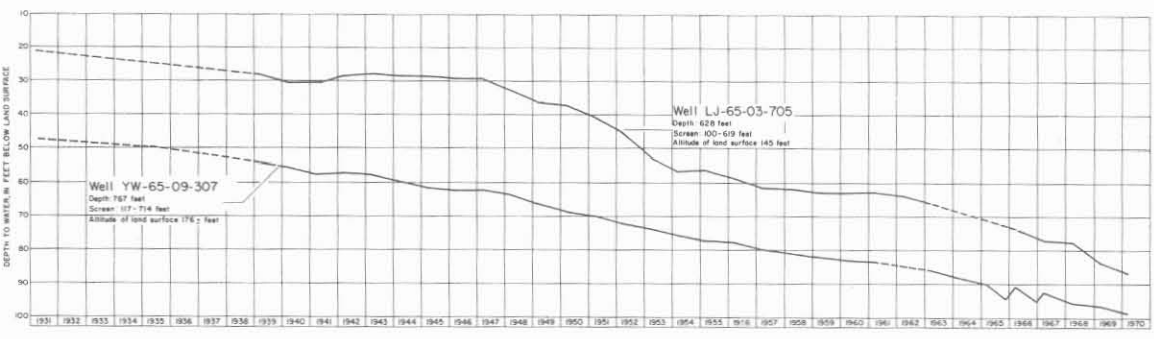


**Figure 11.—Changes in Water Levels in Wells in the Katy Area**


**Figure 12.—Changes in Water Levels in a Well Completed in the Alta Loma Sand in the Baytown-La Porte Area**

#### Pumpage

Pumpage of ground water since 1960 in the NASA area is given in Table 1. Nearly all pumpage is from the Alta Loma Sand. Pumpage in the area before 1962 was about 2 mgd. Since 1962, the use of water has gradually increased to 11.2 mgd in 1969.

#### Decline of Water Levels

Water levels in the area have declined as much in the NASA area as in the Baytown-La Porte area during the 1960-70 period (Figure 6). The decline in water levels ranged from about 40 feet in the southwestern part of the area to about 80 feet in the northeastern part. The rate of water-level decline, as determined from data given on Figure 6, range from about 4 to about 8 feet per year.

The hydrograph shown in Figure 13 indicates a rate of decline of about 5.3 feet per year until 1967. From 1967 until 1970, the indicated rate of decline is about 9.6 feet per year. Depth to water ranges from 120 feet below sea level in the extreme southwestern part of the area to about 230 feet below sea level in the northern part (Figure 5).

### Texas City Area

The Texas City area in the southeastern part of Galveston County (Figure 2) includes the cities of Texas City and La Marque and the adjoining area. The economy of the area is industrial.

#### Pumpage

Pumpage for industrial use in the Texas City area remained almost constant for the 10-year period from 1960 through 1969 (Table 2). Pumpage for public supply increased from 3.7 mgd to 6.8 mgd. Total pumpage in the area increased from 9.8 mgd in 1960 to 12.9 mgd in 1969. The aquifers in the area are the Alta Loma Sand and the sand beds above the Alta Loma.

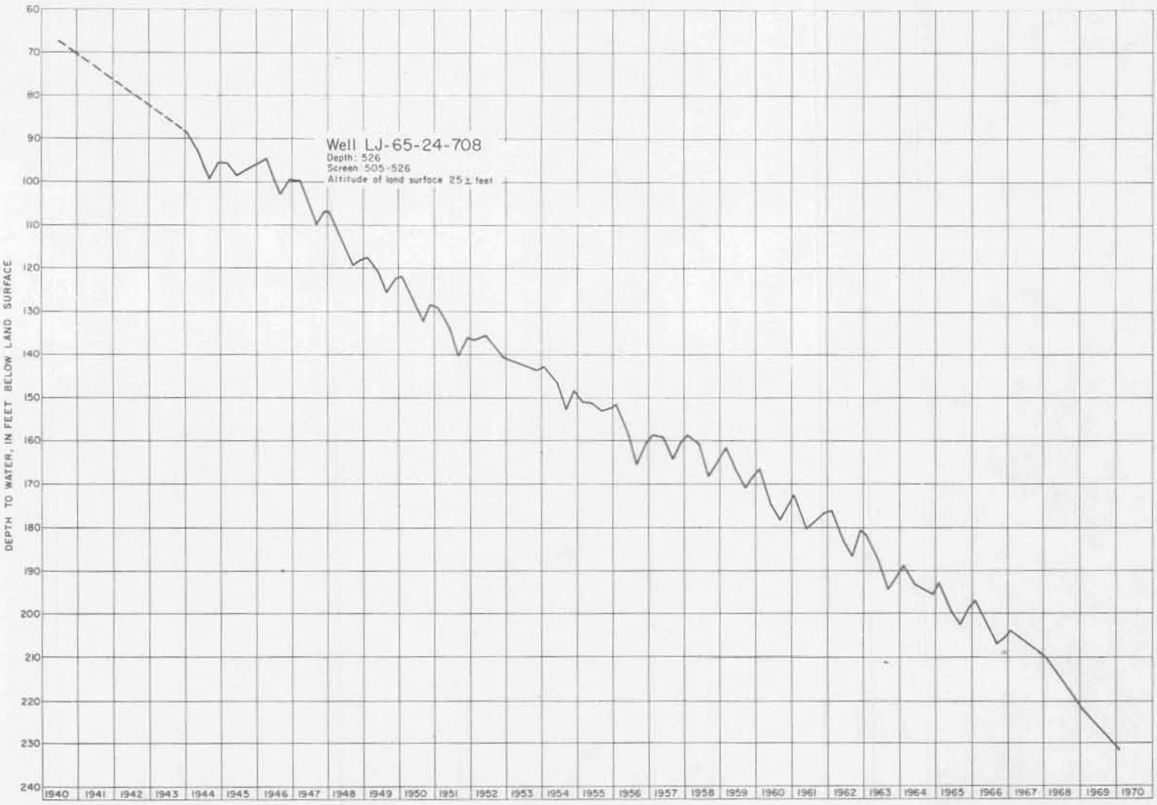


**Figure 13.—Changes in Water Levels in a Well Completed in the Alta Loma Sand in the NASA Area**

More than 50 percent of the water is pumped from sands above the Alta Loma.

#### Decline of Water Levels

Water-level declines in wells completed in the Alta Loma Sand were generally less than 20 feet for the 1960-70 period (Figure 6). The hydrograph of well KH-64-33-805 (Figure 14) shows the rate of decline since 1967 to be about 4 feet per year. Before 1967, the rate of decline was about 2 feet per year.

The change in water levels in wells producing from sand beds above the Alta Loma is shown by the hydrograph of well KH-64-33-903. Before and after the 1963-67 period, the rate of water-level decline was about 3 feet per year.

Depth to water in wells in the Alta Loma Sand ranged from about 70 to 90 feet below sea level. Data are not available to prepare a map of depth to water in wells in the upper sand beds.

### Alta Loma Area

The Alta Loma area is in the west-central part of Galveston County (Figure 2). The well fields for the town of Alta Loma and the city of Galveston are in this area.

#### Pumpage

All pumpage in the Alta Loma area is for public supply, which is mostly for the city of Galveston, and nearly all pumpage is from the Alta Loma Sand. Table 2 shows that pumpage remained almost constant for the past 10 years. In 1969, pumpage in the area was 11.9 mgd.

#### Decline of Water Levels

Decline of water levels of more than 10 feet and as much as 40 feet occurred in the area during the 1960-70 period (Figure 6). The rate of decline was less than 4 feet per year.

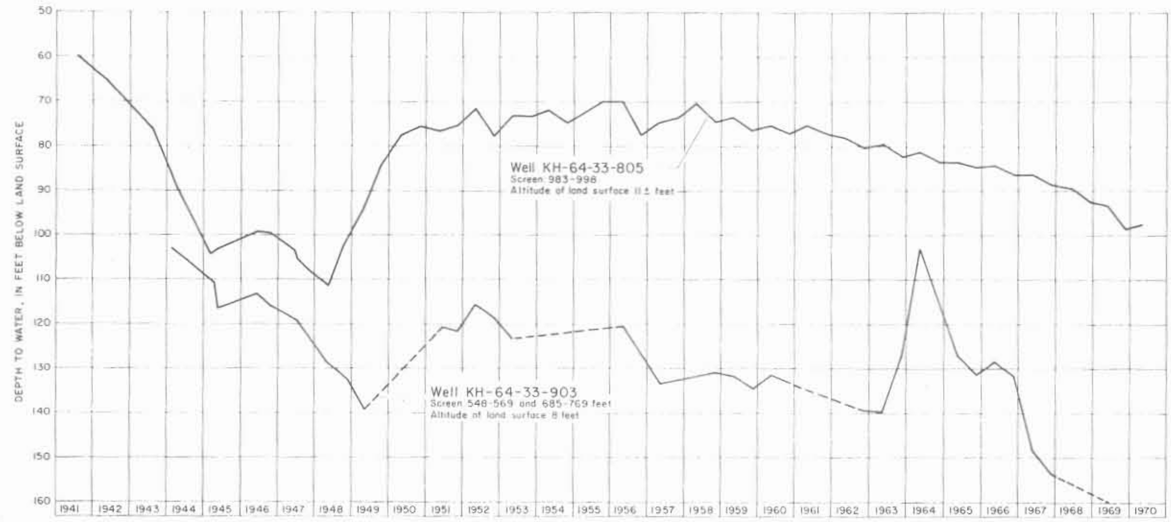


**Figure 14.—Changes in Water Levels in Wells in the Texas City Area**

Figure 15, a hydrograph of the water level in well KH-65-40-707, shows that the rate of water-level decline has been about 3.1 feet per year since 1962.

Figure 5 shows that the water level in wells in the Alta Loma Sand is between 130 and 140 feet below sea level in the deepest part of the cone of depression in the Alta Loma area.

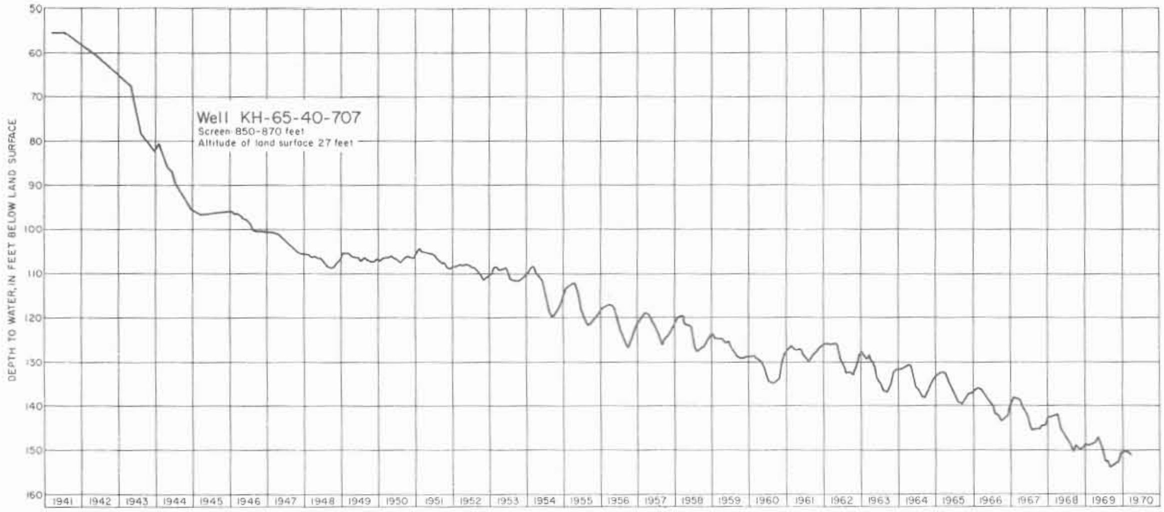


**Figure 15.—Changes in Water Levels in Well KH-65-40-707 in the Alta Loma Area**

## CHEMICAL QUALITY OF GROUND WATER

In general, ground water of good chemical quality can be obtained in most of the Houston district. Lang, Winslow, and White (1950, p. 48) state "The shallow aquifers as a rule contain calcium bicarbonate type waters that are hard; whereas, the deeper aquifers contain sodium bicarbonate type waters that are soft. Waters from these aquifers contain only moderate amounts of mineral matter." Sand beds containing fresh water are present at greater depths in the Houston area than elsewhere in the district.

Several reports have presented maps of the approximate base of fresh water in the district. The latest map showing the base of fresh to slightly saline water appears as plate 5 in the report by Wood, Gabrysch, and Marvin (1963). Chemical analyses of water from many wells in the district are presented in the reports by White, Rose, and Guyton (1944) and by Petitt and Winslow (1955). The reader is referred to these and more recent publications for more specific information on quality of water.

The fresh water-salt water interface in the sand beds of the heavily pumped layer lies along a line approximately parallel to the coastline in the southern part of Harris County. In the Alta Loma Sand, the interface is probably along a line between Alta Loma and Texas City.

The lower part of the Alta Loma Sand at Texas City and at Alta Loma contains more highly mineralized water than the upper part. Monitoring points in the Alta Loma Sand and the heavily pumped layer are insufficient for determination of the exact locations of the interfaces or the rate of updip movement of the saline water toward the cones of depression.

Figure 3 shows the altitude of water levels in wells in the heavily pumped layer. This figure shows that water is moving from the area of the salt-water interface in southern Harris County toward the areas of heavy pumping to the north. Although the salt water evidently is moving toward the heavily pumped areas, an extensive program of resampling of wells has indicated no significant increase in mineralization of the pumped water. Unfortunately, sampling points are not available in the critical areas in southern Harris County where the advancement of the salt water should be monitored. Observation wells should be installed in the critical areas and the movement of salt water toward the areas of ground-water withdrawals should be monitored.

Figure 16 shows the increase in chloride in water from the city of Galveston's "old" well field at Alta Loma. The chloride content of the water from well KH-65-48-211 has remained fairly constant between 800 and 850 mg/l (milligrams per liter) since 1958, except for one sample collected in 1968 which contained 785 mg/l of chloride. The chloride content of the water from well KH-65-48-214 ranged between 710 and 775 mg/l since 1965. The chloride content of water from well KH-65-48-201 has increased from 275 to 520 mg/l since November 1965. Well KH-65-48-201 is the most northwesterly of these three wells. The increase in chlorides may indicate an advancement of the salt water-fresh water interface or it may indicate movement of water upward from the saline water in the lower part of the Alta Loma Sand.

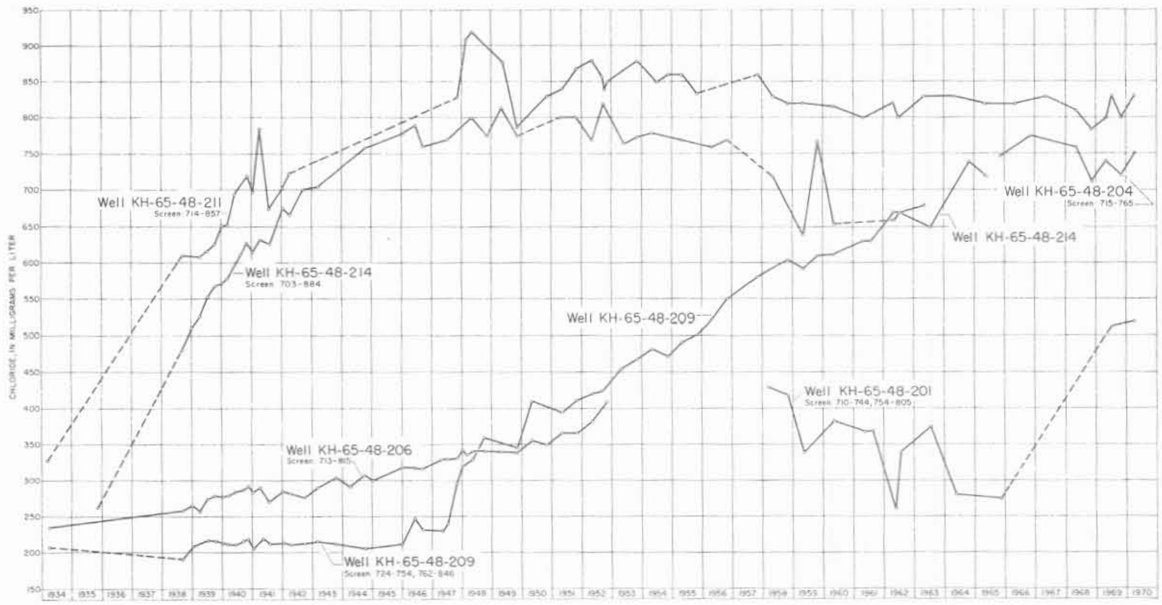


**Figure 16.—Changes in Chloride Content of Water From Wells in the City of Galveston's "Old" Well Field in the Vicinity of Alta Loma**

Figure 17 shows that the chloride content of water from wells in the "new" well field north of Alta Loma has remained nearly constant since about 1945, with the exception of water from well KH-65-40-401. However, the chloride content of water from well KH-65-40-401 has remained nearly constant since about 1964. Encroachment of salt water into the "new" well field since 1964 is not apparent from the data on Figure 17.

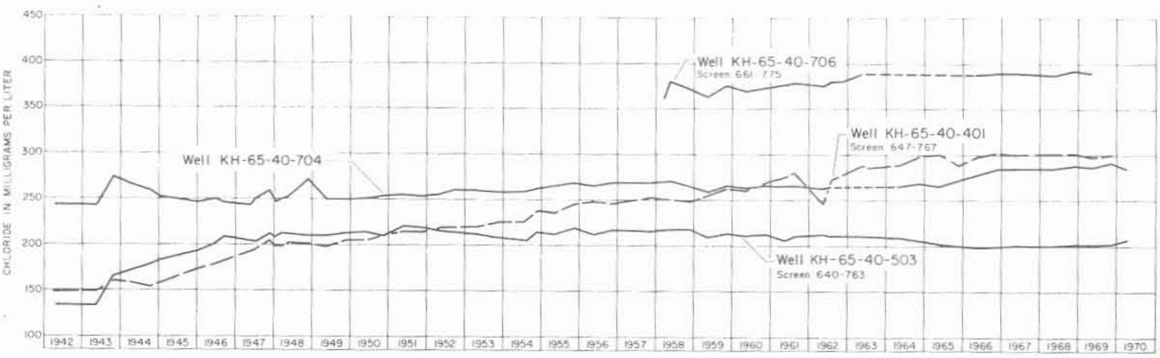


**Figure 17.—Changes in Chloride Content of Water From Wells in the City of Galveston's "New" Well Field North of Alta Loma**

Figure 18 shows the changes in chloride content of water from wells in the Alta Loma Sand (well KH-64-41-309) and from the sand beds above the Alta Loma (well KH-64-41-308) at Texas City. The concentration of chloride has remained fairly constant since 1959. The chloride concentration of water from sand beds above the Alta Loma has varied in a very narrow range since 1953. The maximum concentration of chloride in water from well KH-64-41-308 was about 220 mg/l in 1969; the minimum concentration was about 205 mg/l in 1959.

Salt water encroachment either from downdip in the aquifers or from circulation around salt domes is a threat to the fresh ground water supply in the Houston district. The location of the areas of salt water are only generally known, and extreme care should be exercised in the selection of sites for new well fields.

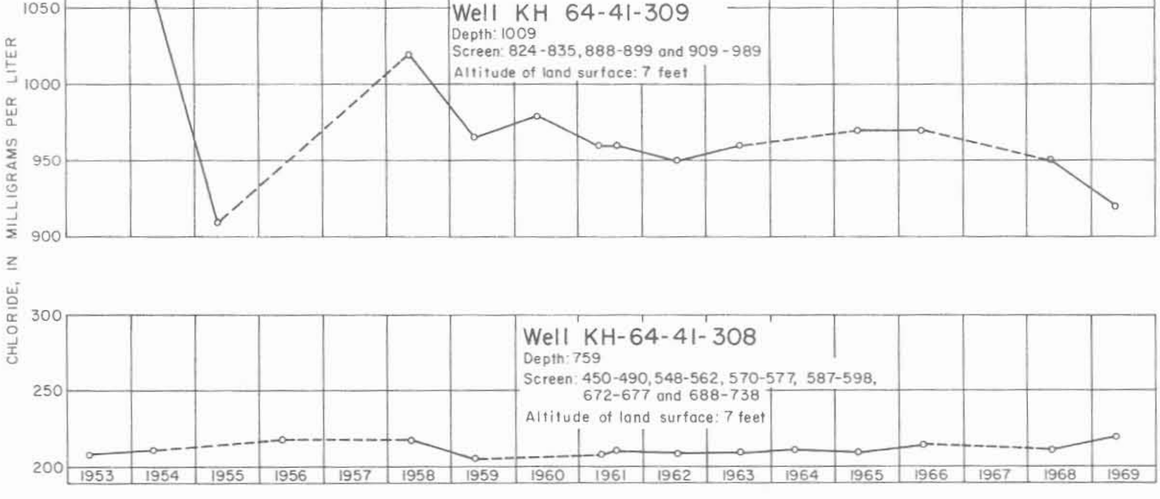


**Figure 18.—Changes in Chloride Content of Water From Wells in the Texas City Area**

## SUMMARY

Pumpage of ground water in the Houston district continues to increase. Total ground-water withdrawal for the Houston district increased from 412 mgd in 1966 to 507 mgd in 1969. From 1965 to 1969, pumpage in the Pasadena area increased from 94.0 mgd to 122.8 mgd, the largest increase in the district. Large increases in the ground-water withdrawals for municipal use in the Houston area and for irrigation use in the Katy area also occurred.

Water levels continued to decline throughout the district generally at a greater rate since 1966. The greatest decline in water levels in wells in the heavily pumped layer during the 1961-70 period occurred in the northwestern part of the Houston area. The establishment of a new well field in that part of the area resulted in as much as 170 feet of water-level decline. As much as 120 feet of water-level decline occurred in the Pasadena area where water levels are as deep as 380 feet below sea level.

Water levels in wells in the Alta Loma Sand declined as much as 80 feet in the southern part of the Baytown-La Porte area and in the NASA area from 1960 to 1970.

Although encroachment of salt water is probable in the district, the data from monitoring points do not indicate a significant increase in chlorides in the past 5 years except for water from well KH-65-48-201 in the "old" well field at Alta Loma. Observation wells should be installed to determine the fresh water-salt water interface and to monitor the movement of salt water.

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