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RELATION OF WATER LEVELS IN THE RED RIVER ALLUVIAL AQUIFER TO RAINFALL AND STAGES OF THE RED RIVER, POOL 2, RED RIVER WATERWAY, ALEXANDRIA AREA, LOUISIANA, 1971-91

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96-4053

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Relation of Water Levels in the Red River Alluvial Aquifer to Rainfall and Stages of the Red River, Pool 2, Red River Waterway, Alexandria Area, Louisiana, 1971-91

By Ronald C. Seanor, John K. Lovelace, and Charles W. Smoot

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Baton Rouge, Louisiana

1996

U.S. DEPARTMENT OF THE INTERIOR

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PLATE

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FIGURES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
inches per year (in/yr)	25.4	millimeters per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer

Temperature in degrees Celsius (˚C) can be converted to degrees Fahrenheit (˚F) as follows: ˚F = 1.8(˚C) + 32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Relation of Water Levels in the Red River Alluvial Aquifer to Rainfall and Stages of the Red River, Pool 2, Red River Waterway, Alexandria area, Louisiana, 1971-91

By Ronald C. Seanor, John K. Lovelace, *and* Charles W. Smoot

ABSTRACT

The Red River alluvial aquifer is a relatively undeveloped source of large amounts of freshwater in the pool 2 area of the Red River waterway navigation project in Louisiana. Infiltration of rainfall provides the primary source of recharge to the alluvial aquifer. In general, ground-water levels are highest during December through May, when most of the rainfall occurs and evapotranspiration is low. Ground-water levels are lowest during September and October, when the least rainfall occurs and evapotranspiration is high. Water levels in the alluvial aquifer typically fluctuate 10 feet or less. However, these fluctuations can be much larger in wells near the river. The Red River is hydraulically connected to the alluvial aquifer, and ground-water levels near the river fluctuate in response to changes in river stage.

Movement of water in the aquifer generally is lateral and downvalley. Lateral movement of water in the aquifer is typically from topographic highs, created by natural levees in the valley, toward the Red River and toward low backswamp areas along the valley margins. The filling of the navigation pool at Lock and Dam 2 caused the stage of the Red River at Alexandria to rise about 24 feet. Water levels in wells near the river rose in response to the rise in river stage, and ground-water gradients toward the river declined. However, water levels in wells at distances greater than about 2 miles from the river experienced little change when the pool was filled.

INTRODUCTION

The Red River alluvial aquifer, in the pool 2 area of the Red River waterway navigation project, is a relatively undeveloped source of large amounts of freshwater within the Red River Valley in Louisiana. Even though small amounts of water are withdrawn from the alluvial aquifer for irrigation and domestic use, the water is not suitable for public-supply or some industrial uses without treatment for hardness and iron removal (Smoot and others, 1995, p. 1). However, the water has a relatively low and constant temperature, which makes it suitable for other uses such as industrial cooling.

The U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, began a study in 1962 to systematically collect water-level data from the Red River alluvial aquifer to document water-level fluctuations in the aquifer. The objective of this study in 1991 was to compare water levels in the Red River alluvial aquifer, rainfall at Chambers, La., and stages of the Red River at Alexandria, La. The stage of the Red River varies due to the natural hydrologic cycle, but the stage, in the study area, underwent a substantial rise due to the completion and operation of Lock and Dam 2, which began filling the navigation pool in 1988. Some farmers (in the study area) have expressed concern about the potential effects of higher water levels in the alluvial aquifer on crops; much of the land is used for cotton and soybean cultivation.

Purpose and Scope

This report describes the relation of ground-water levels to rainfall and river stage in the pool 2 area of the Red River Valley. Included in this report are hydrographs of (1) water levels measured 1971-87 (pre-pool period) and 1988-91 (full-pool period) for wells completed in the Red River alluvial aquifer, and one well completed in the upland terrace aquifer, (2) rainfall at the Louisiana State University (LSU) Dean Lee Research Station at Chambers, Louisiana, and (3) stages of the Red River (1971-91) at Alexandria, Louisiana.

Many of the wells used in this study were installed during 1957-58 for an earlier evaluation of ground-water resources in Rapides Parish. Additional wells were installed during 1968-72 to improve water-level data coverage within the rural parts of the study area and in 1978 to improve water-level data coverage for the urban parts.

Description of Study Area

The study area includes parts of Grant Parish and Rapides Parish (fig. 1) and is mostly within the Red River Valley; a small part is in the upland terrace, adjacent to the valley. This area extends from just south of Lock and Dam 2 in southeastern Rapides Parish, along the Red River, upvalley to 3 mi south of Lock and Dam 3 in Natchitoches Parish. Lock and Dam 2 is located about 12 mi downvalley from Alexandria. Lock and Dam 3 is located about 45 realigned miles upstream from Lock and Dam 2. The flood plain between these two structures ranges from 5 to 12 mi wide and is characterized by low relief, meandering old and present-day river courses, and oxbow lakes. The altitude of the valley above sea level generally ranges from 65 ft at Lecompte, La., to 95 ft at Colfax, La. The altitude of the adjacent upland terrace ranges from 100 to 160 ft above sea level. The primary land use is agriculture; however, the suburban areas of Alexandria, Boyce, and Lecompte occupy parts of the valley.

Climate

The climate of the study area is humid and subtropical. Average annual rainfall for a 20-year period (1971-91) is 62.5 in. at the LSU Dean Lee Research Station (National Oceanic and Atmospheric Administration, 1971-91). Annual rainfall ranged from 47.6 in. in 1978 to 79.4 in. in 1991. The wetter months generally are during late winter and early spring. The drier months generally are during late summer and early fall. The average annual temperature for the study area is about 19 °C. The coldest months are December to February, during which the average daily temperature is about 9 °C. The warmest months are July and August, during which the average daily temperature is about 28 °C (National Oceanic and Atmospheric Administration, 1971-91).

Previous Studies

Hydrologic conditions of the Red River alluvial aquifer are described in the following references. Newcome and Sloss (1966) described the hydrogeology of Rapides Parish and aquifer characteristics of the Red River alluvial aquifer. Ludwig (1979a, b) defined the average preconstruction ground-water levels and determined the effects the proposed lock and dam structures of the Red River waterway navigation project would have on the ground-water levels in the proposed pool 2 area. Whitfield (1980) described chemical characteristics of water in the Red River alluvial aquifer. Rogers (1983) determined the potential effects of Lock and Dam 2 on the ground-water levels within the urban and suburban areas of the pool 2 area. Smoot and others (1995) described the effects of construction and operation of the Red River waterway Lock and Dam 2 on the quality of water in the Red River alluvial aquifer in the pool 2 area.

Figure 1. Location of study area in parts of Grant Parish and Rapides Parish, Louisiana.

Data Collection

Water-level data were collected from 101 wells during 1971-91 by the U.S. Geological Survey and U.S. Natural Resource Conservation Service (pl. 1). Water levels were measured monthly in most wells; however, during 1988-89 some wells were measured less frequently. Total monthly rainfall data were collected at LSU Dean Lee Research Station during 1971-91 (National Oceanic and Atmospheric Administration, 1971-91). Daily stage data for the Red River at Alexandria were collected by the U.S. Army Corps of Engineers during 1971-91 (U.S. Army Corps of Engineers, 1971-81, 1982-86; Betty McBroom, U.S. Army Corps of Engineers, Vicksburg District, written commun., 1993).

HYDROGEOLOGY

The present valley has been eroded into deposits of Tertiary age. Subsequent deposits have partly refilled the valley with alluvial sediments. The alluvial sediments grade upward from coarse sand and gravel to fine sand, silt, and clay. The sand and gravel deposits of Pleistocene age in the lower part of the alluvium form the Red River alluvial aquifer. The upper fine-grained sediments of Holocene age comprise a confining unit, which ranges in thickness from a few feet to more than 50 ft (Whitfield, 1980, p. 6). The thickness of the alluvial aquifer is variable, but averages 50 ft within the study area with a maximum of 110 ft (Rogers, 1983, p. 8). Hydrogeologic units within the study area are shown in figure 2.

<table>
<tr><th>System</th><th>Series</th><th colspan="2">Stratigraphic unit</th><th>Aquifer or confining unit</th></tr>
<tr><td rowspan="2">Quaternary</td><td>Holocene
?</td><td colspan="2">Unnamed flood plain deposits</td><td>Unnamed confining unit</td></tr>
<tr><td>Pleistocene</td><td colspan="2">Red River alluvial deposits

Northern Louisiana terrace deposits</td><td>Red River alluvial aquifer or surficial confining unit
Upland terrace aquifer or surficial confining unit</td></tr>
<tr><td rowspan="7">Tertiary</td><td>Pliocene
?</td><td rowspan="4">Fleming Formation</td><td>Blounts Creek Member</td><td>Evangeline aquifer or surficial confining unit</td></tr>
<tr><td rowspan="3">Miocene
?</td><td>Castor Creek Member</td><td>Castor Creek confining unit</td></tr>
<tr><td>Williamson Creek Member
Dough Hills Member
Carnahan Bayou Member</td><td>Williamson Creek aquifer
Dough Hills confining unit
Carnahan Bayou aquifer</td></tr>
<tr><td>Lena Member</td><td>Lena confining unit</td></tr>
<tr><td rowspan="2">Oligocene</td><td colspan="2">Catahoula Formation</td><td>Catahoula aquifer</td></tr>
<tr><td colspan="2">Vicksburg Group, undifferentiated</td><td rowspan="2">Vicksburg-Jackson confining unit</td></tr>
<tr><td>Eocene</td><td colspan="2">Jackson Group, undifferentiated</td></tr>
</table>

Modified from Stuart and others, 1994

Figure 2. Hydrogeologic units in the Alexandria area, Louisiana.

Sediments of sand, silt, and clay of Miocene age, underlie the alluvial deposits and crop out along the valley wall. Terrace deposits of gravel, sand, silt, and clay of Pleistocene age, which are remnants of older and higher flood plains, overlie the Miocene deposits. The terrace deposits may be in direct hydraulic connection with the alluvial aquifer (Ludwig and Terry, 1980, p. 12).

The Red River alluvial aquifer is considered to be confined. This interpretation is supported by the low coefficients of storage calculated from aquifer tests (Whitfield, 1980, p. 7). Locally, however, confining units may be absent and water-table conditions prevail. In other local areas where confining units are relatively thin, water-table conditions may prevail during periods of low water level (Whitfield, 1980, p. 6).

Recharge to the Red River alluvial aquifer primarily occurs by the infiltration of rainfall through the confining unit to the aquifer, and through the unsaturated zone to the aquifer in areas where the confining unit is absent (Ludwig, 1979a, p. 4). Annual recharge from precipitation averages from 3 to 4 in/yr, but may be as high as 12 in/yr in areas where sand and silt are present from land surface to the top of the aquifer, or as low as 1 in/yr in backswamp areas where clay dominates the upper sediments (Whitfield, 1980, p. 8). The present bed of the Red River is incised into the aquifer throughout its course in the study area (Ludwig, 1979a, p. 4). Whitfield (1980, p. 8) noted that water from the Red River and its major tributaries may provide recharge to the aquifer during periods of high river stages, but the water only moves short distances into the aquifer, and is discharged back to the river when the stage falls. Minor recharge may also occur from lateral movement of water from adjacent aquifers of Pleistocene and Miocene age and from upward movement of water from underlying aquifers of Miocene age (Whitfield, 1980, p. 8). Virtually all inflow to the aquifer is discharged to the Red River and its tributaries or by evapotranspiration (Rogers, 1983, p. 8).

RELATION OF GROUND-WATER LEVELS TO RAINFALL AND RED RIVER STAGES

Water levels in selected wells along sections A-A' through D-D', monthly rainfall collected at the LSU Dean Lee Research Center at Chambers, and stages of the Red River at Alexandria during 1971-91 are shown in figures 3, 5, 7, 8, 10, and 11. Profiles along sections A-A' through D-D' showing land-surface altitude and water levels at selected wells for selected pre-pool and full-pool periods are shown in figures 4, 6, 9, and 12. Locations of sections A-A' through D-D' are shown on plate 1.

Infiltration of rainfall provides the primary source of recharge to the Red River alluvial aquifer. In general, ground-water levels are highest during December through May, the months in which most rainfall occurs (figs. 3, 5, 7, 8, 10, and 11). During this period, evapotranspiration is low and stream stages are high, reducing the rate of ground-water discharge. Ground-water levels are lowest during September and October, the months of least rainfall. The rate of ground-water discharge increases during these months because stream stages are low and evapotranspiration is high. Even though rainfall occurs throughout most of the year in the study area, increased evapotranspiration during the summer months prevents most infiltrating rainfall from exceeding root-zone depths (Rogers, 1983, p. 10). For example, the water level in wells R-965 (fig. 3), R-722 (fig. 5), and R-724 (fig. 8) continued to decline through August 1978, although 10.3 in. of rain was recorded during the month. Water levels in the alluvial aquifer typically experience fluctuations of 10 ft or less. However, these fluctuations can be much larger in wells near the Red River, which are affected by stage fluctuations.

The effect of precipitation on water levels was indicated during a period of deficient rainfall, July 1980 through May 1982. Almost all of the hydrographs in figures 3, 5, 7, 8, 10, and 11 show that water levels were lower than normal during this period. However, because stage fluctuations of the Red River were fairly normal during the period, water levels in wells very close to the river, such as R-1014B (fig. 3), R-723 (fig. 5), and R-739 (fig. 10), were less affected by the deficient rainfall.

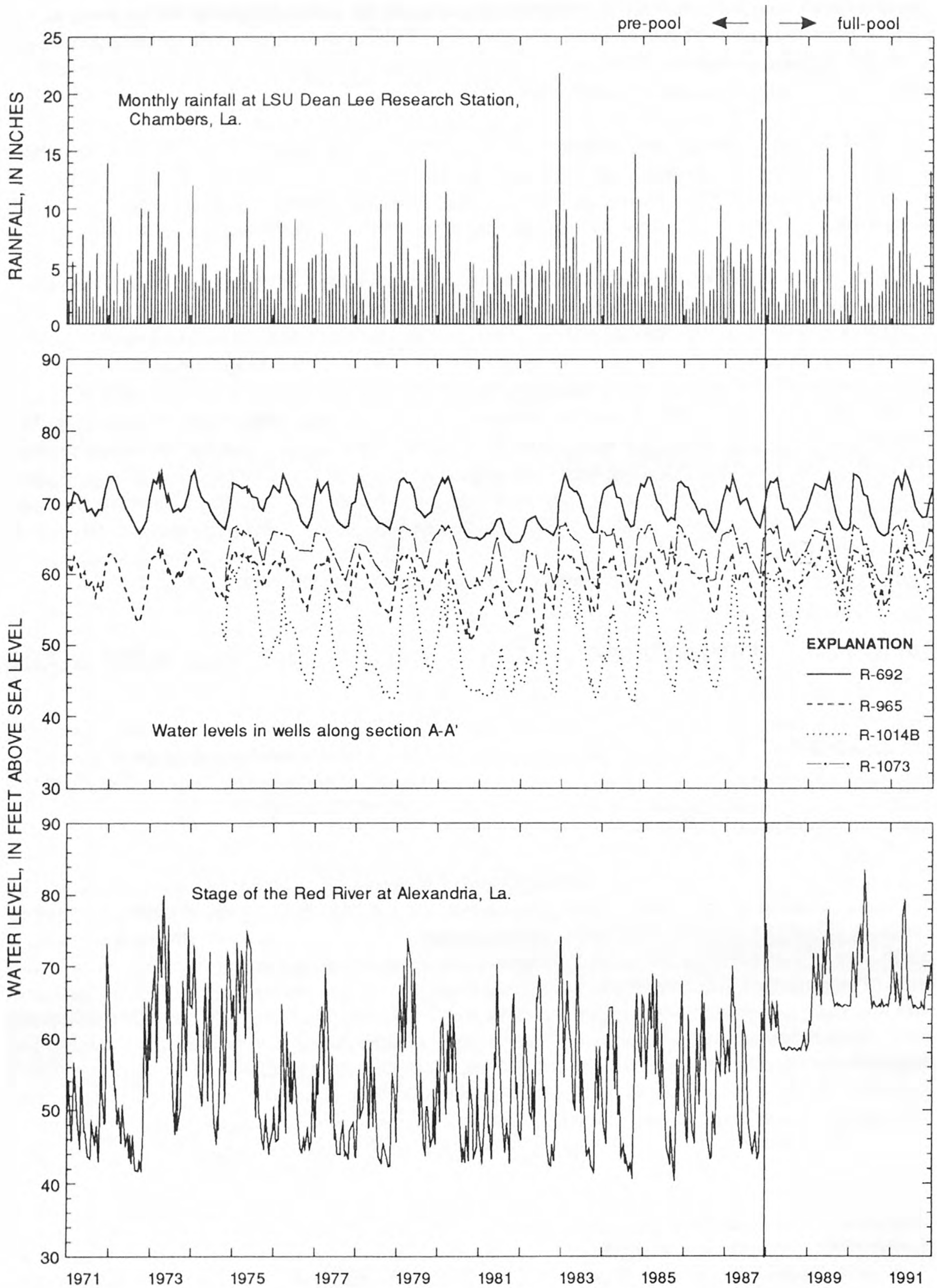


Figure 3. Monthly rainfall, water levels in wells R-692, R-965, R-1014B, and R-1073 completed in the Red River alluvial aquifer along section A-A', and stage for the Red River at Alexandria, Louisiana, 1971-91.

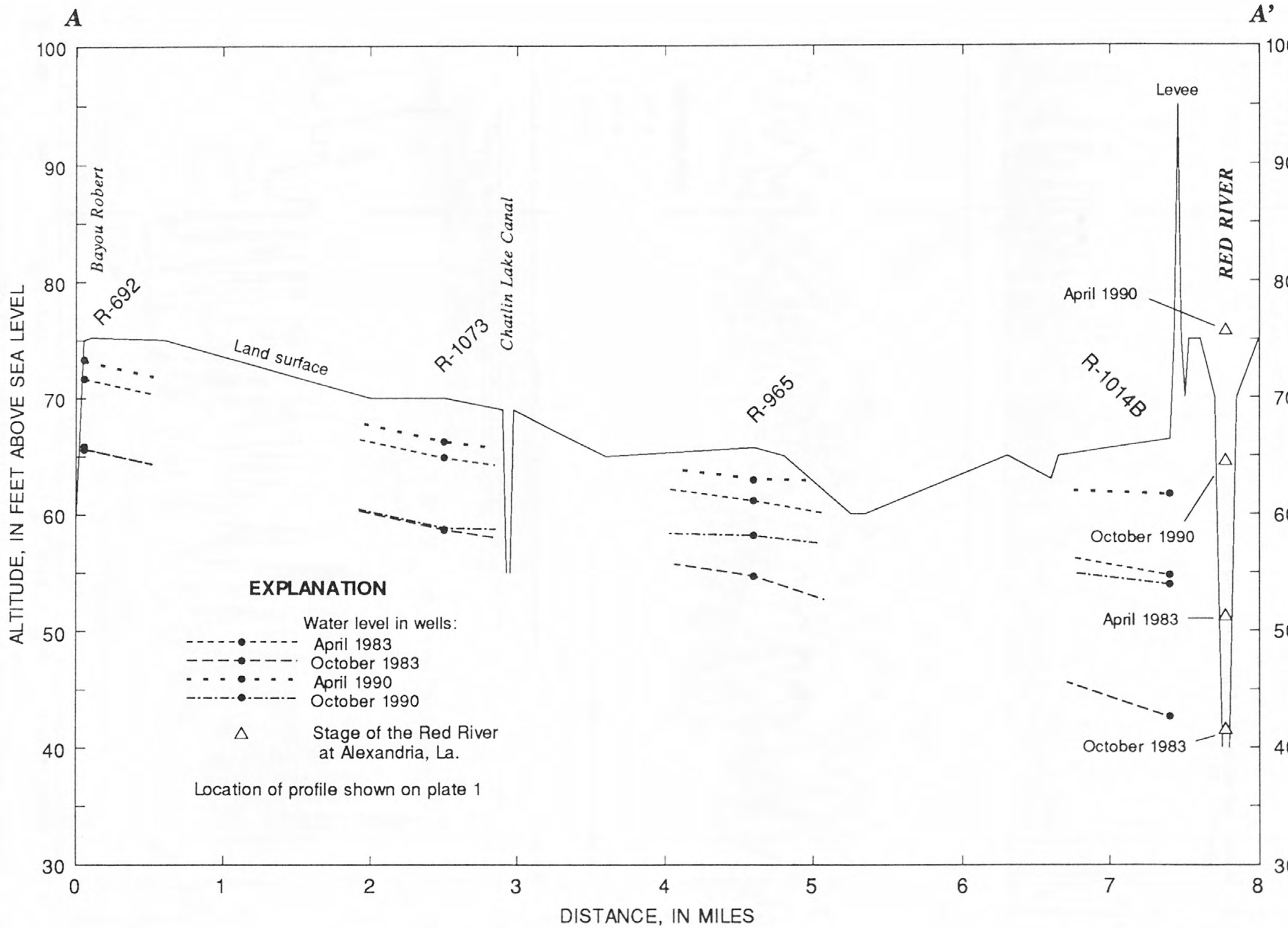


Figure 4. Water-level profile A-A' of the Red River alluvial aquifer and stages of the Red River for selected pre-pool (1983) and full-pool (1990) conditions, Red River waterway, Alexandria area, Louisiana.

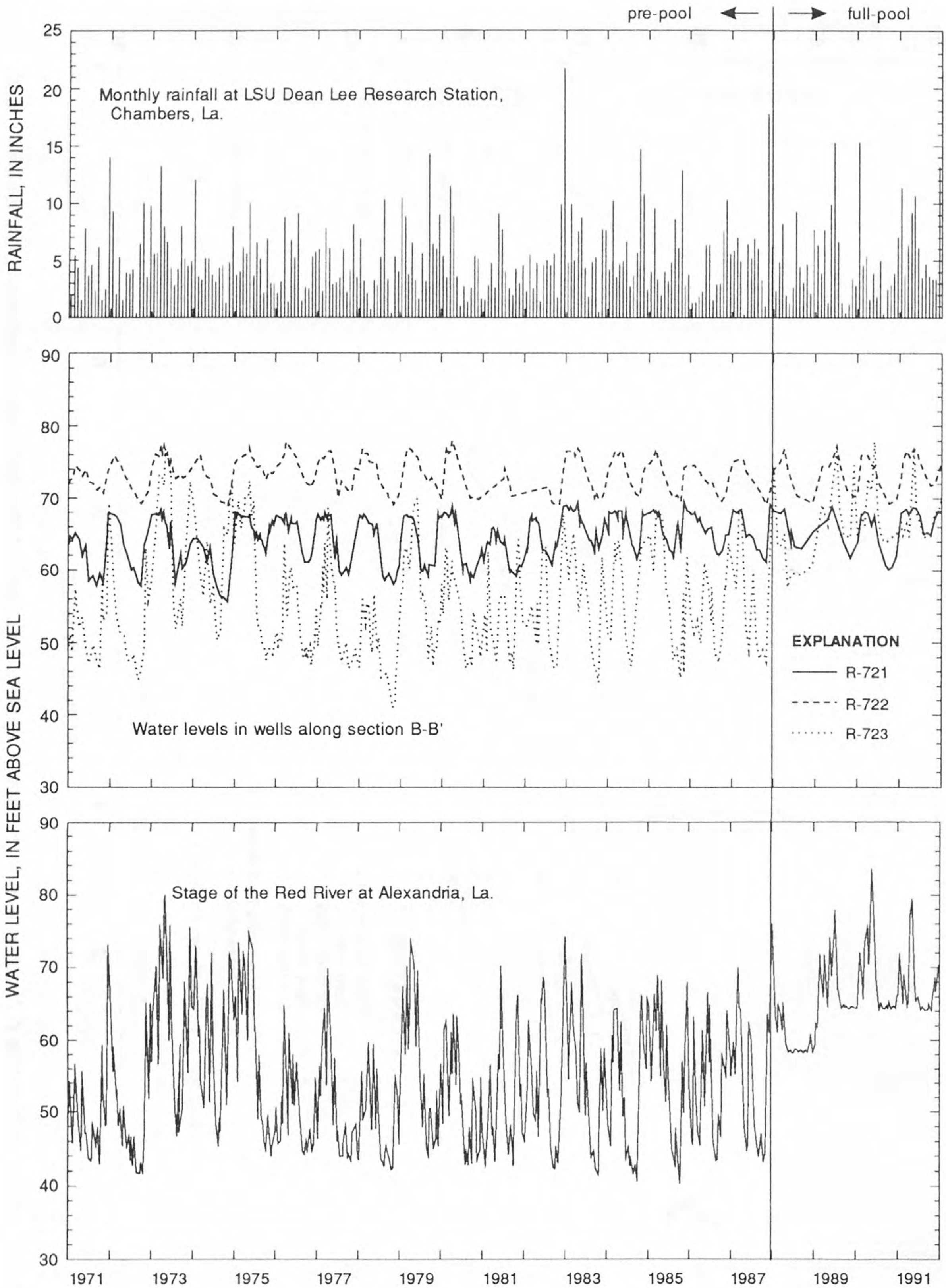


Figure 5. Monthly rainfall, water levels in wells R-721, R-722, and R-723 completed in the Red River alluvial aquifer along section B-B', and stage for the Red River at Alexandria, Louisiana, 1971-91.

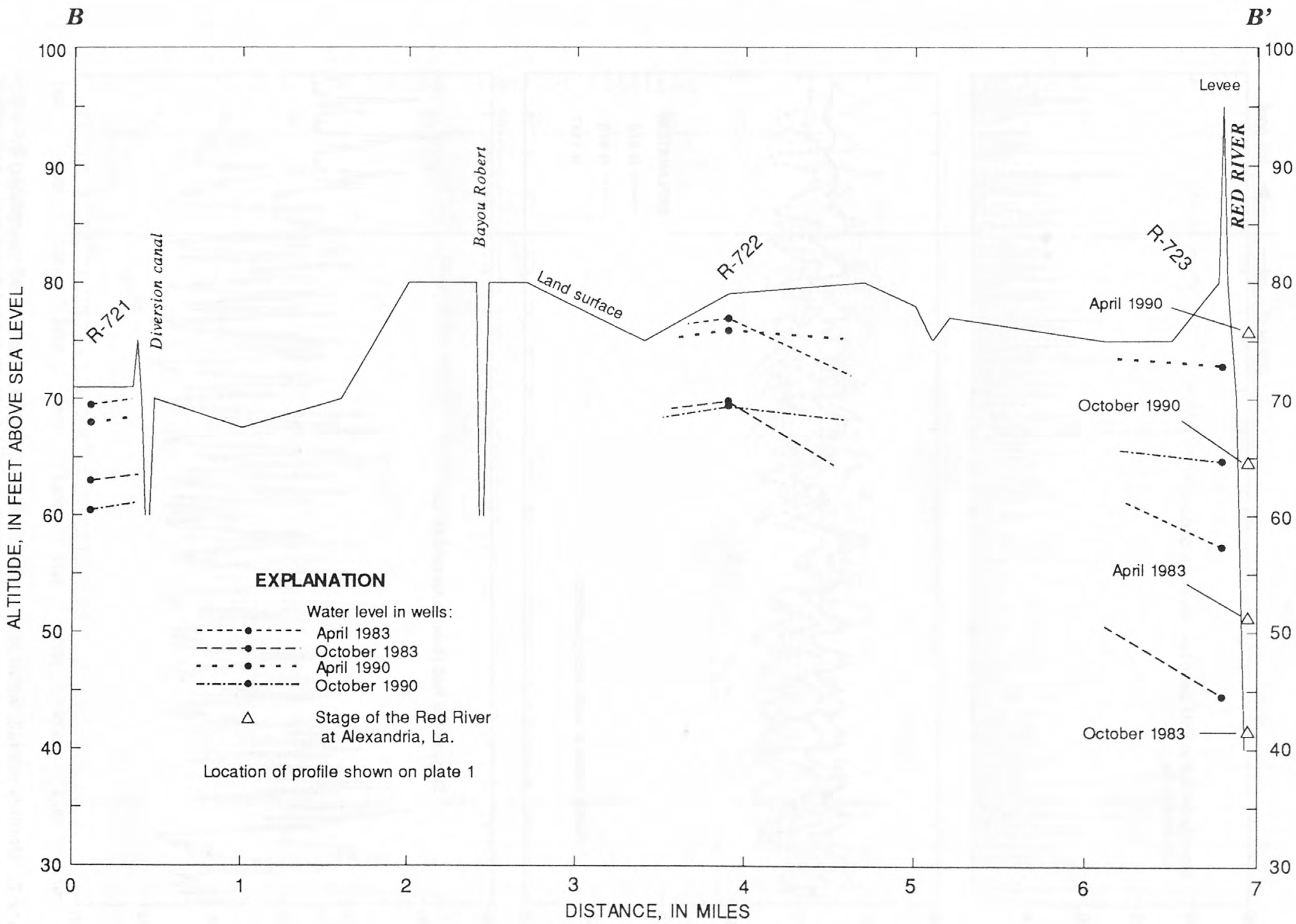


Figure 6. Water-level profile B-B' of the Red River alluvial aquifer and stages of the Red River for selected pre-pool (1983) and full-pool (1990) conditions, Red River waterway, Alexandria area, Louisiana.

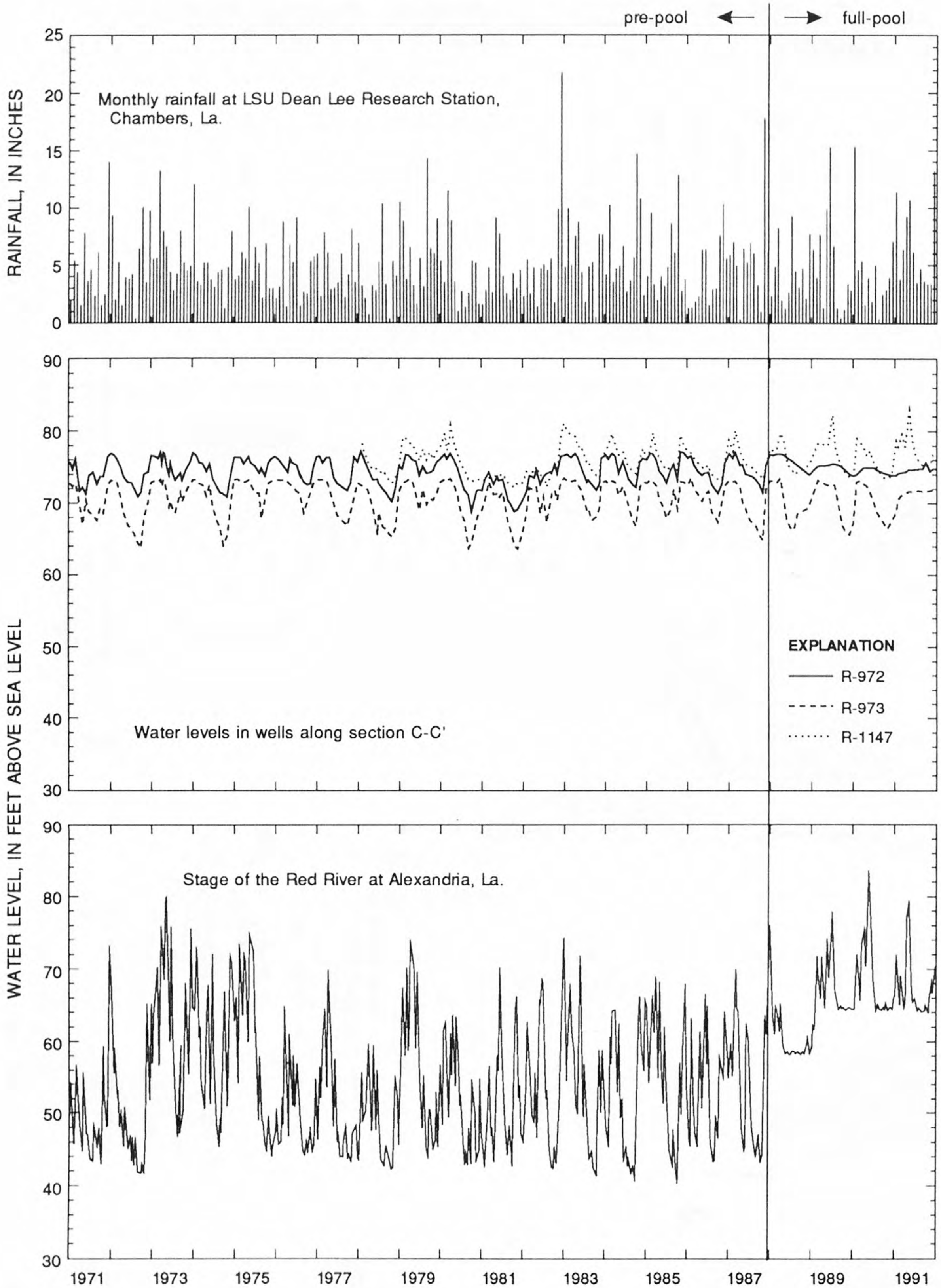


Figure 7. Monthly rainfall, water levels in wells R-972, R-973, and R-1147 completed in the Red River alluvial aquifer along section C-C', and stage for the Red River at Alexandria, Louisiana, 1971-91.

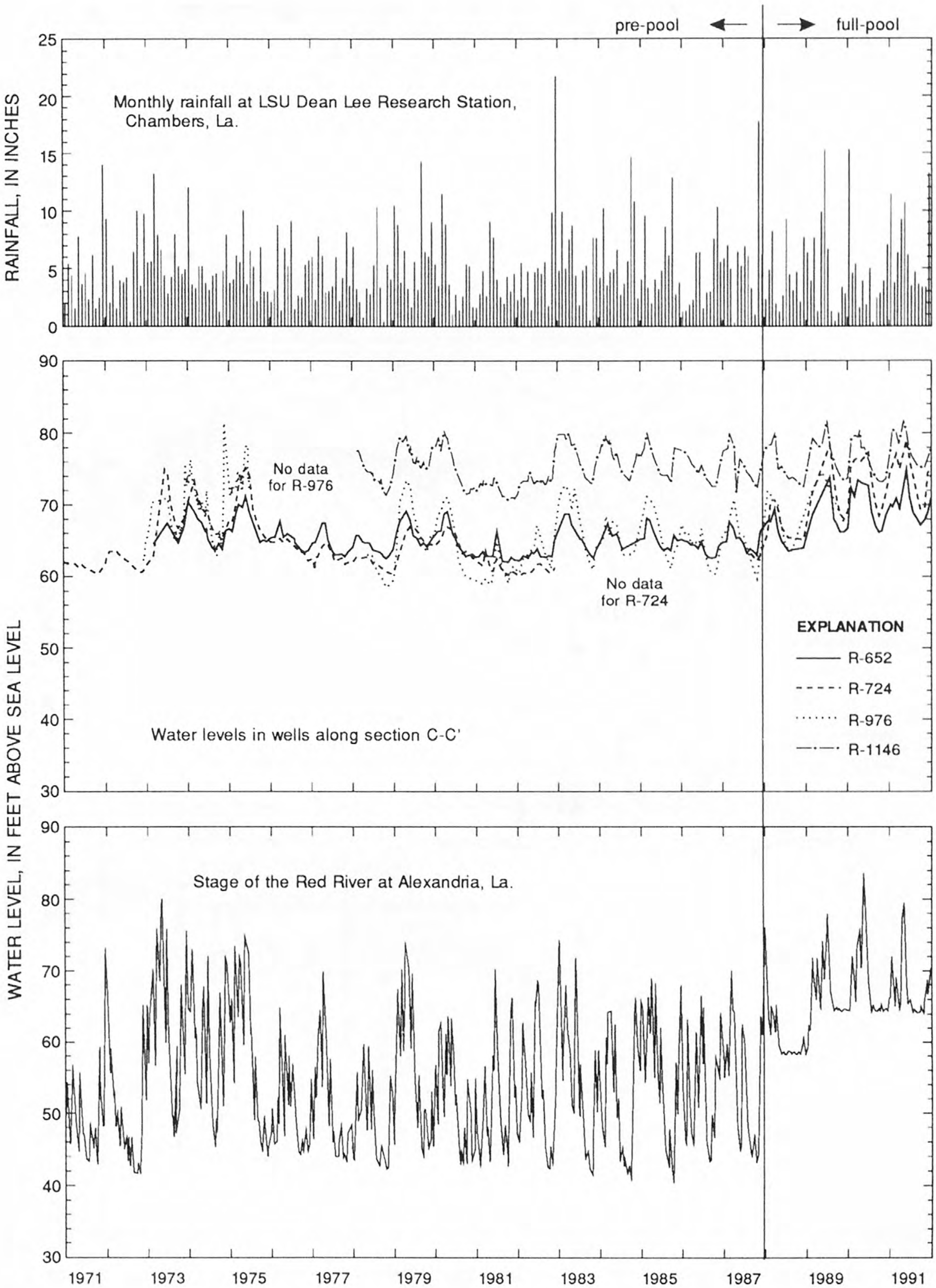


Figure 8. Monthly rainfall, water levels in wells R-652, R-724, R-976, and R-1146 completed in the Red River alluvial aquifer along section C-C', and stage for the Red River at Alexandria, Louisiana, 1971-91.

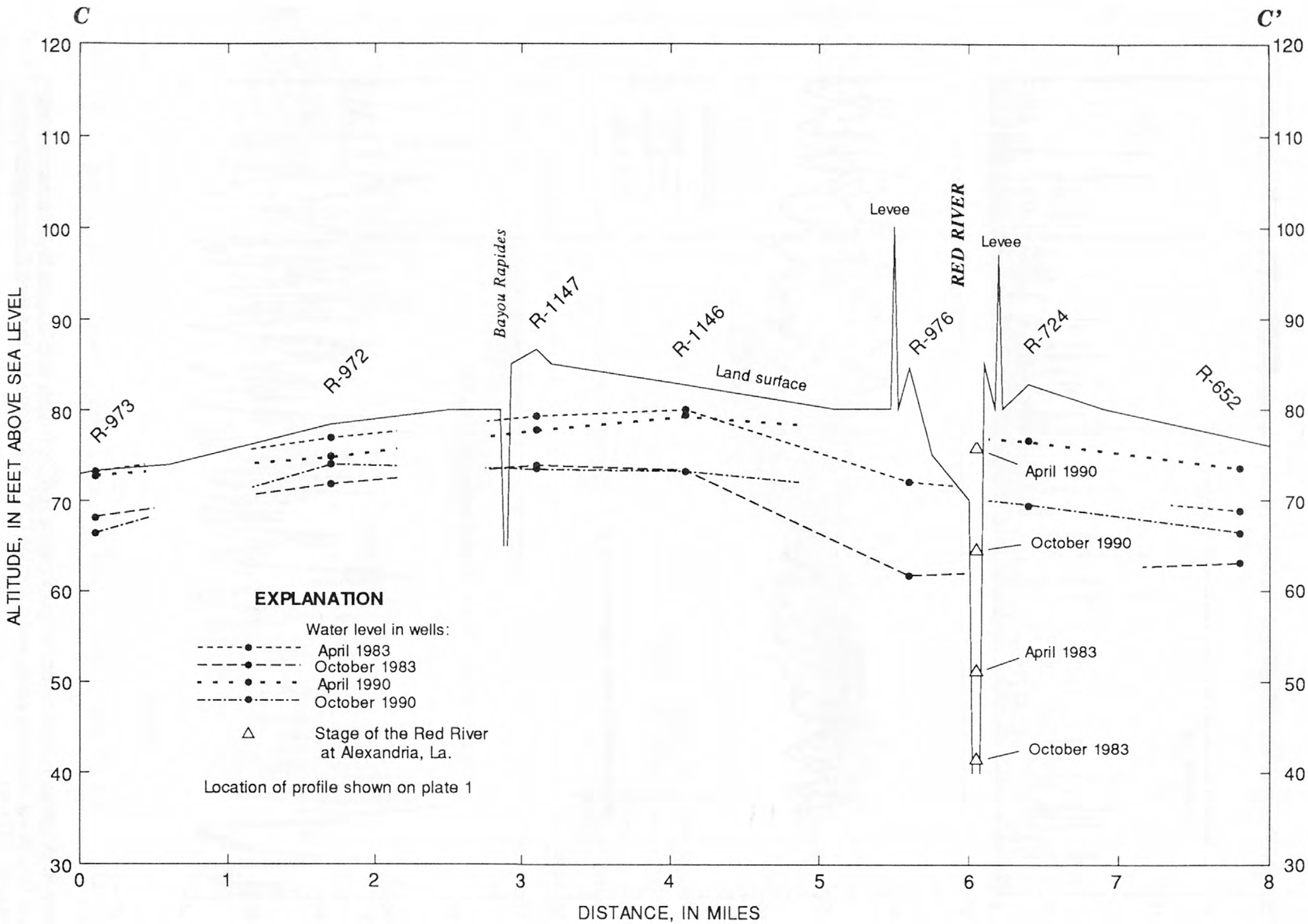


Figure 9. Water-level profile C-C' of the Red River alluvial aquifer and stages of the Red River for selected pre-pool (1983) and full-pool (1990) conditions, Red River waterway, Alexandria area, Louisiana.

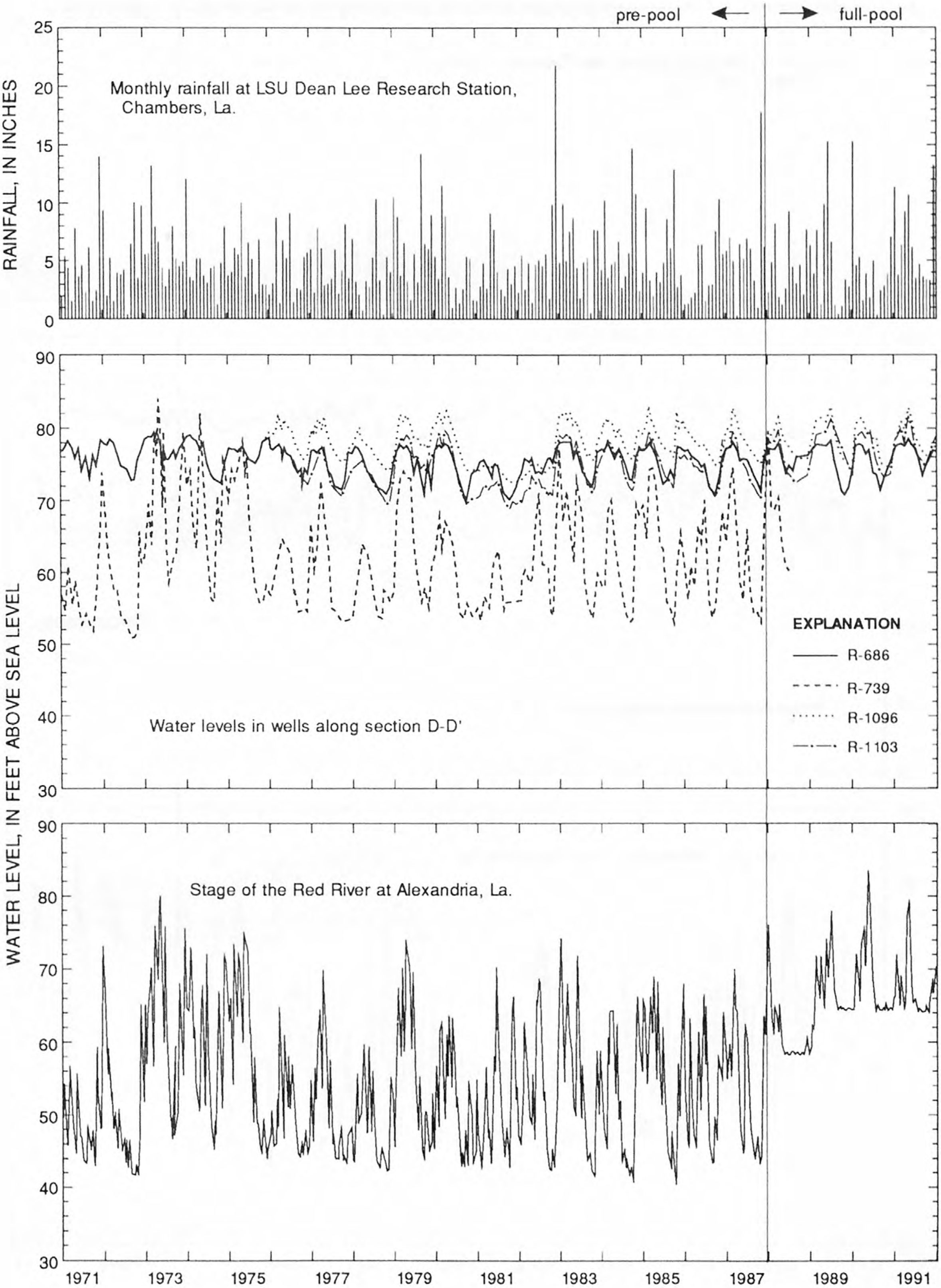


Figure 10. Monthly rainfall, water levels in wells R-686, R-739, R-1096, and R-1103 completed in the Red River alluvial aquifer along section D-D', and stage for the Red River at Alexandria, Louisiana, 1971-91.

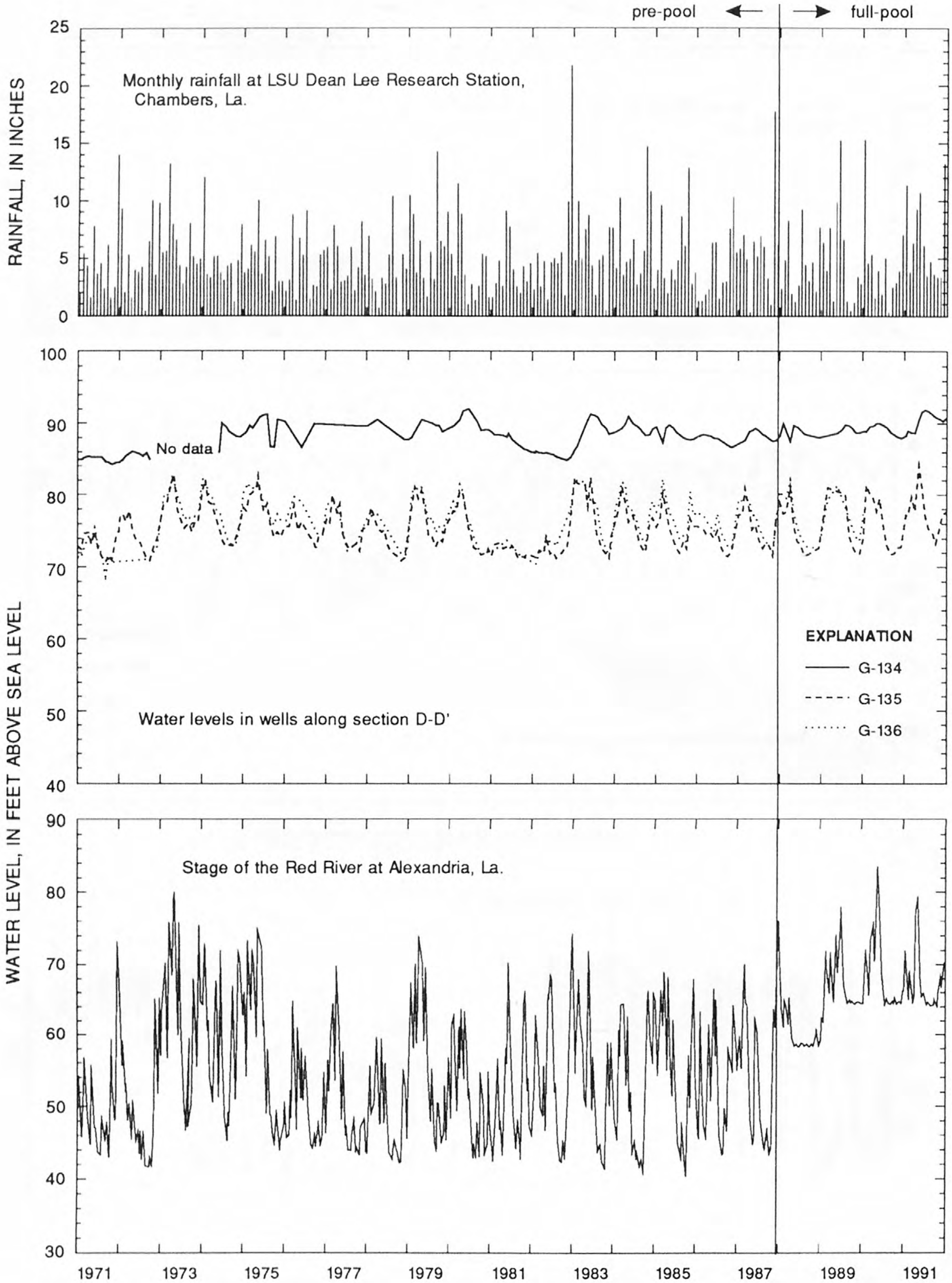


Figure 11. Monthly rainfall, water levels in well G-134 completed in the upland terrace aquifer, and wells G-135 and G-136 completed in the Red River alluvial aquifer along section D-D', and stage for the Red River at Alexandria, Louisiana, 1971-91.

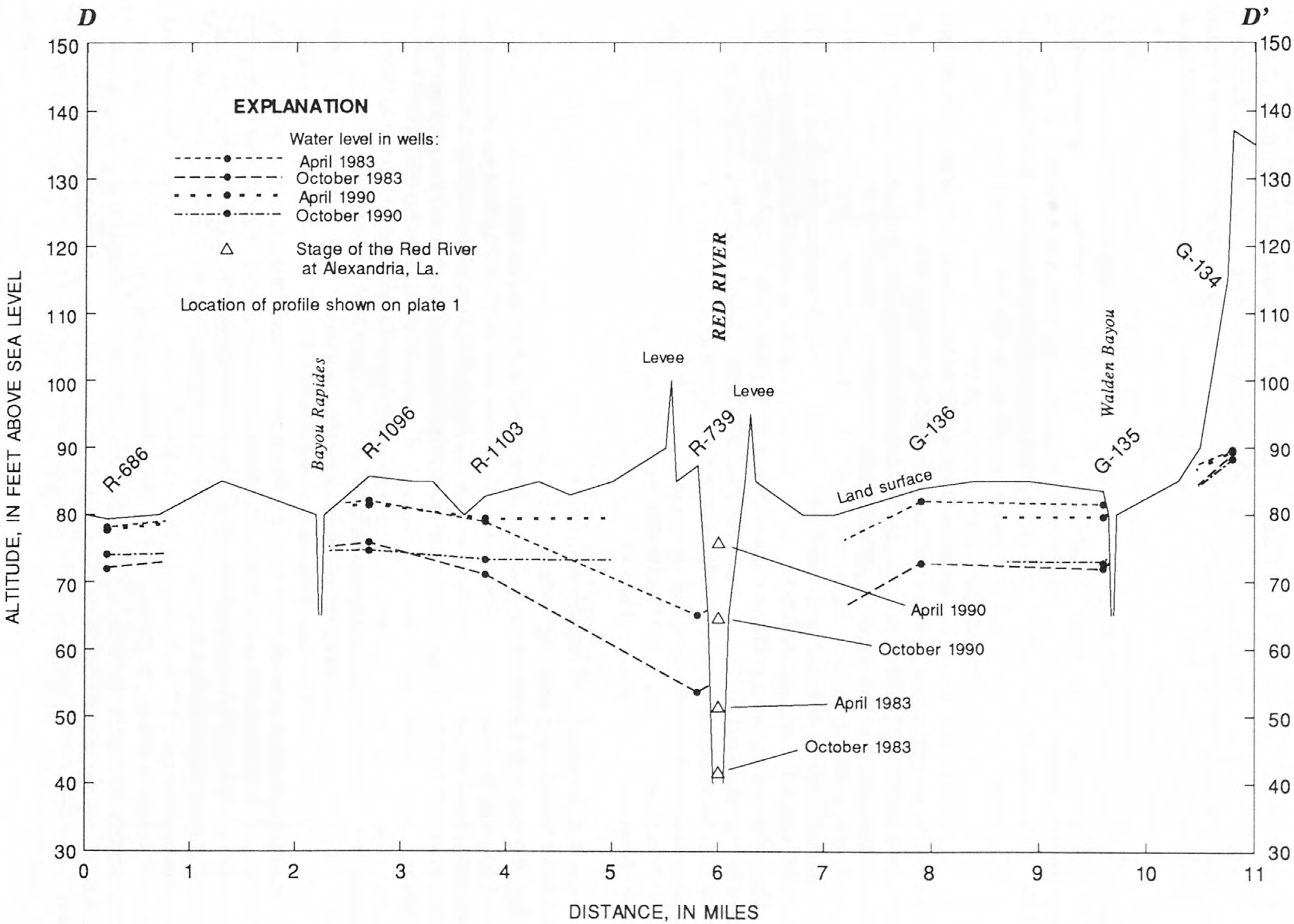


Figure 12. Water-level profile D-D' of the Red River alluvial aquifer and upland terrace aquifer (well G-134) and stages of the Red River for selected pre-pool (1983) and full-pool (1990) conditions, Red River waterway, Alexandria area, Louisiana.

Water levels in wells located near the Red River are affected by stage fluctuations and, subsequently, the filling of the navigation pool at Lock and Dam 2. The hydrographs of wells R-1014B (fig. 3), R-723 (fig. 5), and R-739 (fig. 10), which are located within 0.5 mi of the river, show water-level fluctuations similar in magnitude and duration to stage fluctuations in the Red River at Alexandria. However, the effects of river stage fluctuations on water levels are greatly attenuated at distances from the river greater than about 0.5 mi.

Rogers (1983, p. 10) showed that water movement in the aquifer generally is lateral and downvalley. During the formation of the valley, natural levees formed near river courses, and backswamp areas formed away from the river (Rogers, 1983, p. 6). Water-level profiles along sections A-A' through D-D' show that water in the aquifer typically moves from the topographic highs, created by the natural levees, toward the Red River and low backswamp areas along the valley margins (pl. 1; figs. 4, 6, 9, and 12).

The water-level profiles also show how water levels in the Red River alluvial aquifer were affected by the filling of the navigation pool at Lock and Dam 2 in 1988. The filling of the pool caused river stage to increase about 24 ft at Alexandria. Also, because the stage of the navigation pool is maintained above a minimum level, stage fluctuations were sharply attenuated.

Section A-A', located near Lock and Dam 2 (pl. 1), shows a pre-pool water-level gradient toward the Red River that is slightly steeper in the fall than in the summer, due to the seasonal difference in river stage (fig. 4). The full-pool water-level gradient is substantially less. The water level in well R-1014B is affected by changes in river stage and responded to full-pool conditions with a rise of about 10 ft and attenuated fluctuations (fig. 3). Although the water level of well R-965, located about 3 mi from the river, indicates some increase in figure 4, the hydrograph in figure 3 shows little, if any, change from pre-pool to full-pool conditions. Water levels in wells R-1073 and R-692, located farther from the river, are not discernibly affected by changes in river stage (figs. 3 and 4).

Section B-B', located about 15 mi upstream from Lock and Dam 2 (pl. 1), shows the lateral movement of ground water from a topographic high near the center of the alluvial valley toward the Red River and a low backswamp area near a diversion canal (fig. 6). Water levels in well R-723, located near the gaging station on the Red River at Alexandria, closely reflect changes in river stages during both pre-pool and full-pool conditions (figs. 5 and 6). Water levels at wells R-722 and R-721, located about 3 and 7 mi from the Red River, are not affected by the stage of the Red River and were not affected by the filling of the navigation pool (figs. 5 and 6).

Section C-C', located about 23 mi upstream from Lock and Dam 2 (pl. 1), also shows lateral movement of ground water in the area south of the Red River from a topographic high near the center of the alluvial valley toward the Red River and a low backswamp area (fig. 9). The section also shows an area north of the Red River where ground-water levels may have been affected by the filling of the navigation pool. Hydrographs for wells R-976 and R-724, located within 0.5 mi of the river, indicate that water levels at the wells are only affected by river stage during prolonged, high stages (figs. 8 and 9). Water levels at these wells showed moderate increases during 1973-75 when high stages of the Red River persisted throughout much of the period. The hydrograph for well R-972, located about 4 mi south of the river and upgradient from wells R-976 and R-724, showed no similar increases during this period, indicating the increases at wells R-976 and R-724 were caused by the river stage rather than rainfall (figs. 7, 8, and 9). Water levels at wells R-1146, R-1147, R-972, and R-973, located 2 mi or more from the river, seem unaffected by changes in river stage and showed no change in response to the filling of the navigation pool (figs. 7, 8, and 9).

However, water levels at wells R-976, R-724, and R-652, located within 2 mi of the river, increased between 5 and 10 ft due to the filling of the navigation pool (figs. 8 and 9). Hydrographs for these wells indicate that prior to the filling of the navigation pool, ground water flowed southward toward the river during low stage, and northward away from the river during high stage. Since the navigation pool was filled in 1988, ground-water flow has been northward away from the Red River at all times. Because of the paucity of water-level data from well R-976 after 1988 and the lack of stage data for the Red River at the precise point where section C-C' crosses the river, it is uncertain whether water from the river is recharging the aquifer in the area north of the river, or discharge from the aquifer to the river has simply decreased to the point that ground water is flowing northward into this area from the area south of the river.

Section D-D', located about 29 mi upstream from Lock and Dam 2 (pl. 1), also shows lateral movement of water in the area south of the Red River (fig. 12). Lateral ground-water gradients are from well R-1096 (fig. 10), northward toward the Red River and southward toward the valley margin. North of the Red River, the water level in well G-134, located outside of the alluvial valley and completed in the upland terrace aquifer, indicates southward flow of water from the upland terrace aquifer into the Red River alluvial aquifer (figs. 11 and 12). Hydrographs of water levels at wells G-135 and G-136, located about 3.5 and 2 mi north of the Red River, show that very little gradient is present between the two wells and that water levels in the wells were unaffected by the rise in river stage caused by the filling of the navigation pool (figs. 11 and 12). The hydrograph of well R-739, located about 0.1 mi from the river, indicates that water levels at the well reflect similar changes in river stages and that during pre-pool conditions, ground-water gradients were toward the river from areas north and south of the river (figs. 10 and 12). Because little water-level data for well R-739 are available for the full-pool period, it is not known how much ground-water gradients near the river were reduced by the filling of the navigation pool. Hydrographs for wells R-1103, R-1096, and R-686, located 2 mi or more from the river along section D-D' show little, if any, response to the filling of the navigation pool (figs. 10 and 12).

SUMMARY AND CONCLUSIONS

The Red River alluvial aquifer is a relatively undeveloped source of large amounts of freshwater in the pool 2 area of the Red River waterway navigation project. Water levels from selected wells completed in the alluvial aquifer, monthly rainfall collected at the Louisiana State University Dean Lee Research Station, and stages of the Red River at Alexandria, Louisiana, were compared for the period 1971-91. The stage of the Red River varies due to the natural hydrologic cycle, but the stage, in the study area, underwent a substantial rise due to the completion and operation of Lock and Dam 2, which began filling the navigation pool in 1988. Some farmers (in the study area) have expressed concern about the potential effects of higher water levels in the alluvial aquifer on crops; much of the land is used for cotton and soybean cultivation.

The Red River Valley ranges from 5 to 12 miles wide in the study area and is characterized by low relief, meandering old and present-day river courses, and oxbow lakes. The alluvium consists of coarse gravel and sand grading upward to fine sand, silt, and clay. The lower sand and gravel deposits form the Red River alluvial aquifer; the upper fine-grained sediments comprise a confining unit.

Infiltration of rainfall provides the primary source of recharge to the Red River alluvial aquifer. In general, ground-water levels are highest during December through May, when most rainfall occurs and evapotranspiration is low. Ground-water levels are lowest during September and October, when the least rainfall occurs and evapotranspiration is high. Water levels in most of the aquifer remained low during a period of deficient rainfall that occurred from July 1980 through May 1982, even though stage fluctuations in the Red River were fairly normal. Water levels in the alluvial aquifer typically experience fluctuations of 10 ft or less. However, these fluctuations can be much larger in wells near the river. Because the Red River is in direct hydraulic connection to the alluvial aquifer, ground-water levels in wells near the river fluctuate in response to changes in river stage.

Movement of water in the aquifer generally is lateral and downvalley. Lateral movement of water in the aquifer typically is from topographic highs, created by natural levees in the valley, toward the Red River and toward low backswamp areas along the valley margins. The filling of the navigation pool at Lock and Dam 2 caused the stage of the Red River at Alexandria to rise about 24 feet. Water levels in wells near the river rose in response to the rise in river stage, and ground-water gradients toward the river declined. However, water levels in wells at distances greater than about 2 miles from the river experienced little change when the pool was filled.

SELECTED REFERENCES

Ludwig, A.H., 1979a, Methods and applications of digital model simulation of the Red River alluvial aquifer, Shreveport to the mouth of the Black River, Louisiana: U.S. Geological Survey Open-File Report 79-114, 103 p.

-----1979b, Preconstruction and postconstruction ground-water levels, Lock and Dam 2, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 79-919, 18 p.

Ludwig, A.H., and Terry, J.E., 1980, Methods and applications of digital-model simulation of the Red River alluvial aquifer, Shreveport to the mouth of the Black River, Louisiana: U.S. Geological Survey Water-Resources Investigations Report 79-114, 103 p.

National Oceanic and Atmospheric Administration, 1971-91, Climatological data annual summary for Louisiana: National Oceanic and Atmospheric Administration, published annually.

Newcome, Roy, Jr., and Sloss, Raymond, 1966, Water resources of Rapides Parish, Louisiana: Louisiana Department of Conservation, Louisiana Geological Survey, and Louisiana Department of Public Works Water Resources Bulletin no. 8, 104 p.

Poole, J.L., 1961, Ground-water resources of East Carroll and West Carroll Parishes, Louisiana: Louisiana Department of Public Works, 174 p.

Rogers, J.E., 1983, Preconstruction and simulated postconstruction ground-water levels at urban centers in the Red River navigation project area, Louisiana: U.S. Geological Survey Water-Resources Investigations Report 83-4154, 33 p.

-----1988, Red River Waterway Project -- Summary of ground-water studies by the U.S. Geological Survey, 1962-85: U.S. Geological Survey Water-Resources Investigations Report 87-4261, 19 p.

Smoot, C.W., 1983, Records of water-level measurements and lithologic logs, Red River Valley, Louisiana, 1975-80: Louisiana Department of Transportation and Development, Office of Public Works Water Resources Basic Records Report no. 12, 197 p.

Smoot, C.W., and Guillot, J.R., 1988, Water-level measurements 1981-85 and chemical analyses 1978-85, Red River alluvial aquifer, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 87-541, 261 p.

Smoot, C.W., and Martin, Angel, Jr., 1991, Generalized potentiometric surfaces of the Red River alluvial aquifer, pool 1, Red River waterway area, central Louisiana: U.S. Geological Survey Water-Resources Investigations Report 91-4109, map, 7 sheets.

Smoot, C.W., Seanor, R.C., and Huff, G.F., 1995, Quality of water in the Red River alluvial aquifer, pool 2, Red River waterway area, Ruby, Louisiana: U.S. Geological Survey Water-Resources Investigations Report 94-4228, 35 p.

Stephens, J.W., 1976, Records of wells, water-level measurements, and drillers' logs, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 76-759, 335 p.

Stuart, C.G., Knochenmus, Darwin, and McGee, B.D., 1994, Guide to Louisiana's ground-water resources: U.S. Geological Survey Water-Resources Investigations Report 94-4085, 55 p.

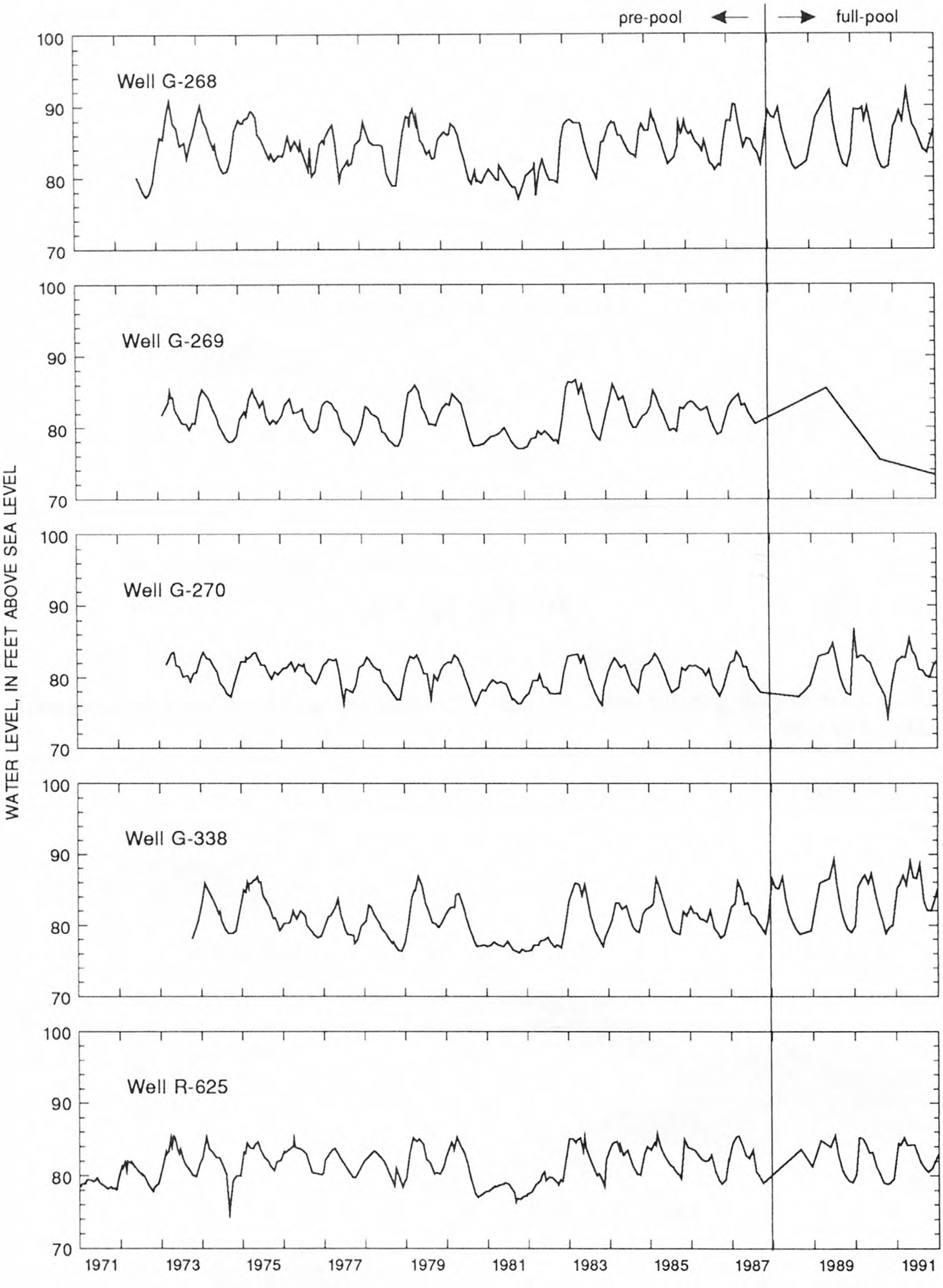
U.S. Army Corps of Engineers, 1971-81, Stages and discharges of the Mississippi River and tributaries in the New Orleans District: U.S. Army Corps of Engineers, New Orleans District, published annually.

-----1982-86, Stages and discharges of the Mississippi River and tributaries in the Vicksburg District: U.S. Army Corps of Engineers, Vicksburg District, published annually.

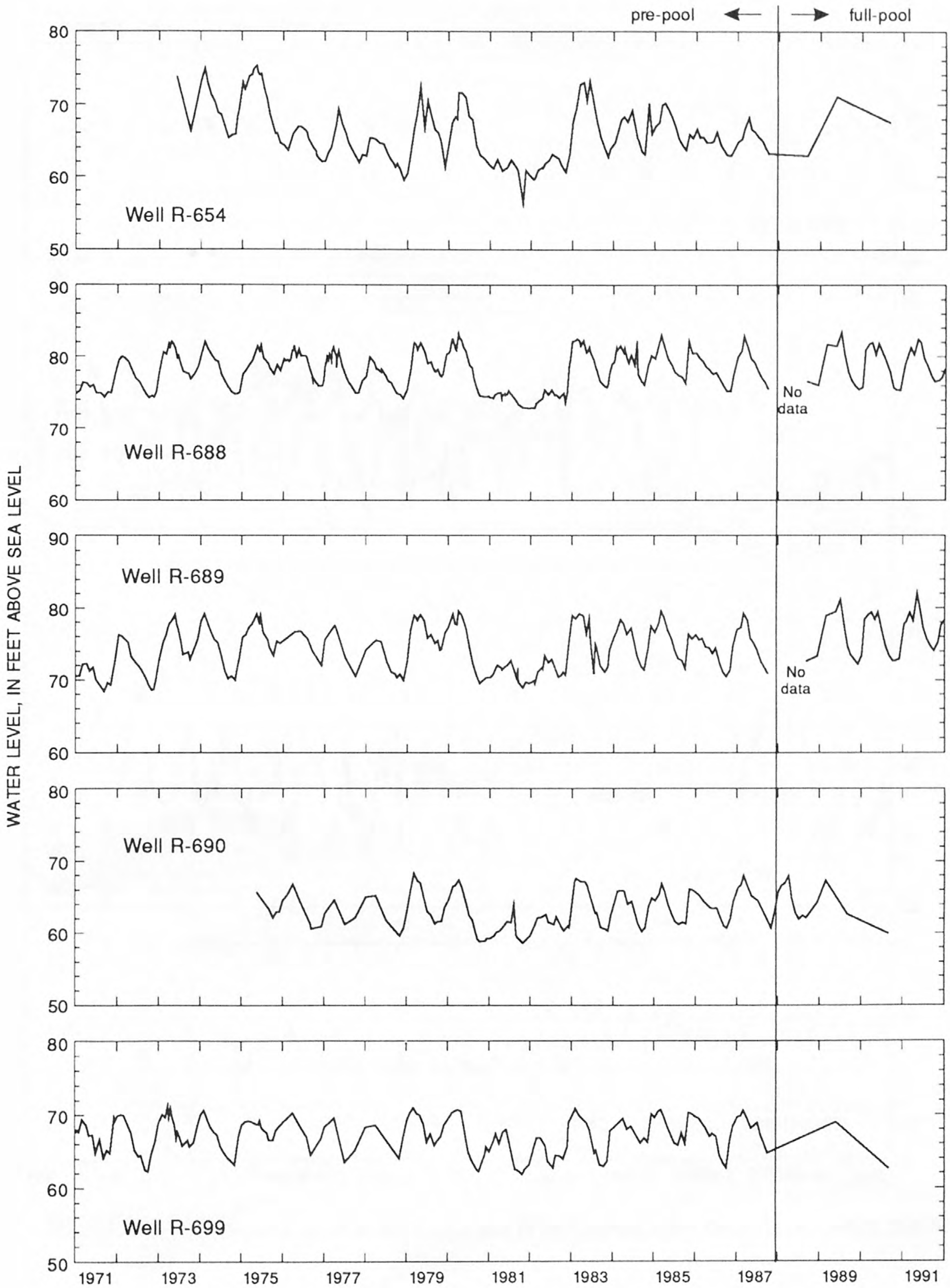
Whitfield, M.S., Jr., 1980, Chemical character of water in the Red River alluvial aquifer, Louisiana: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1018, 95 p.

APPENDIX

Hydrographs showing water levels for selected wells completed in the Red River alluvial aquifer, 1971-91



Water levels for selected wells completed in the Red River alluvial aquifer, 1971-91.



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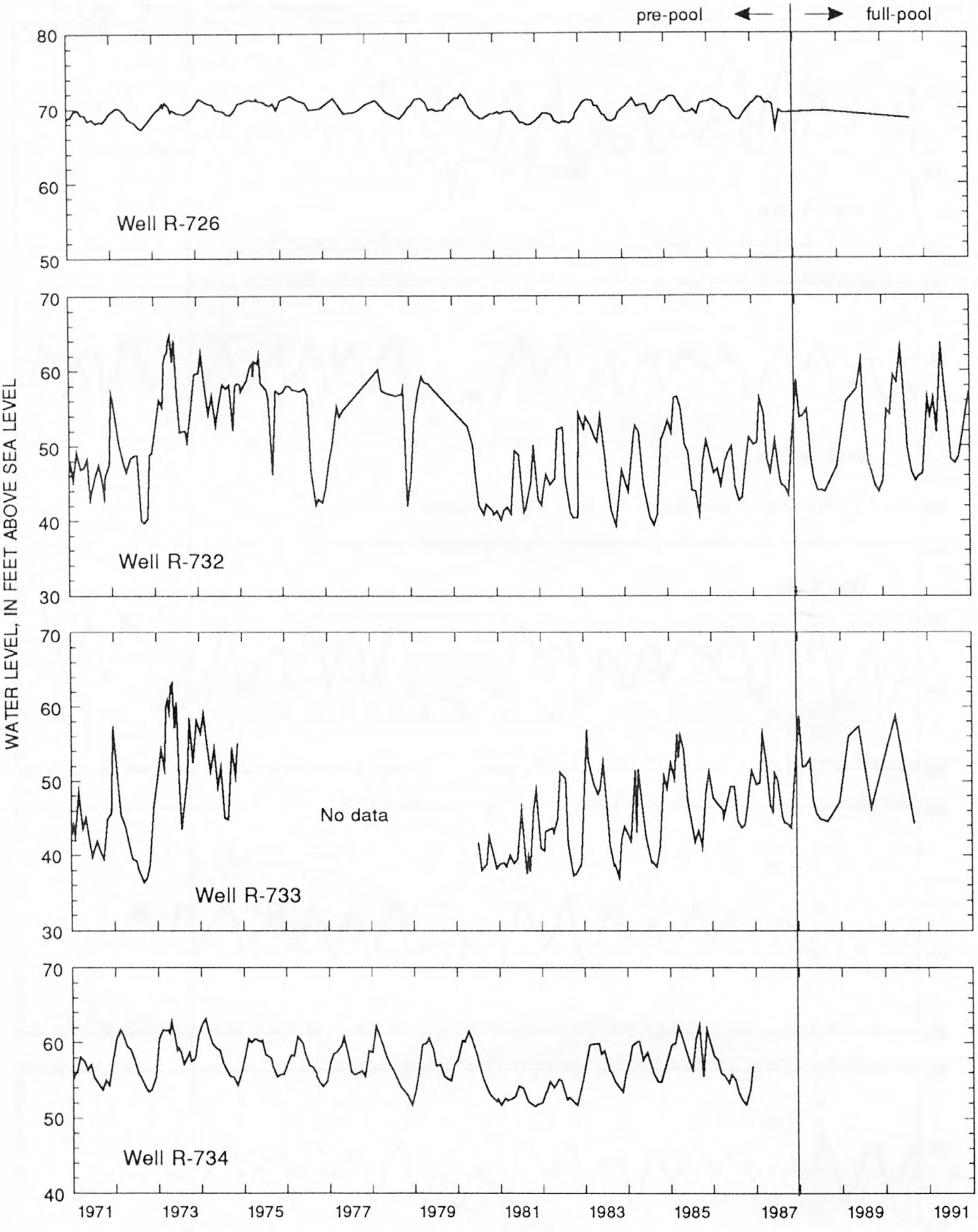

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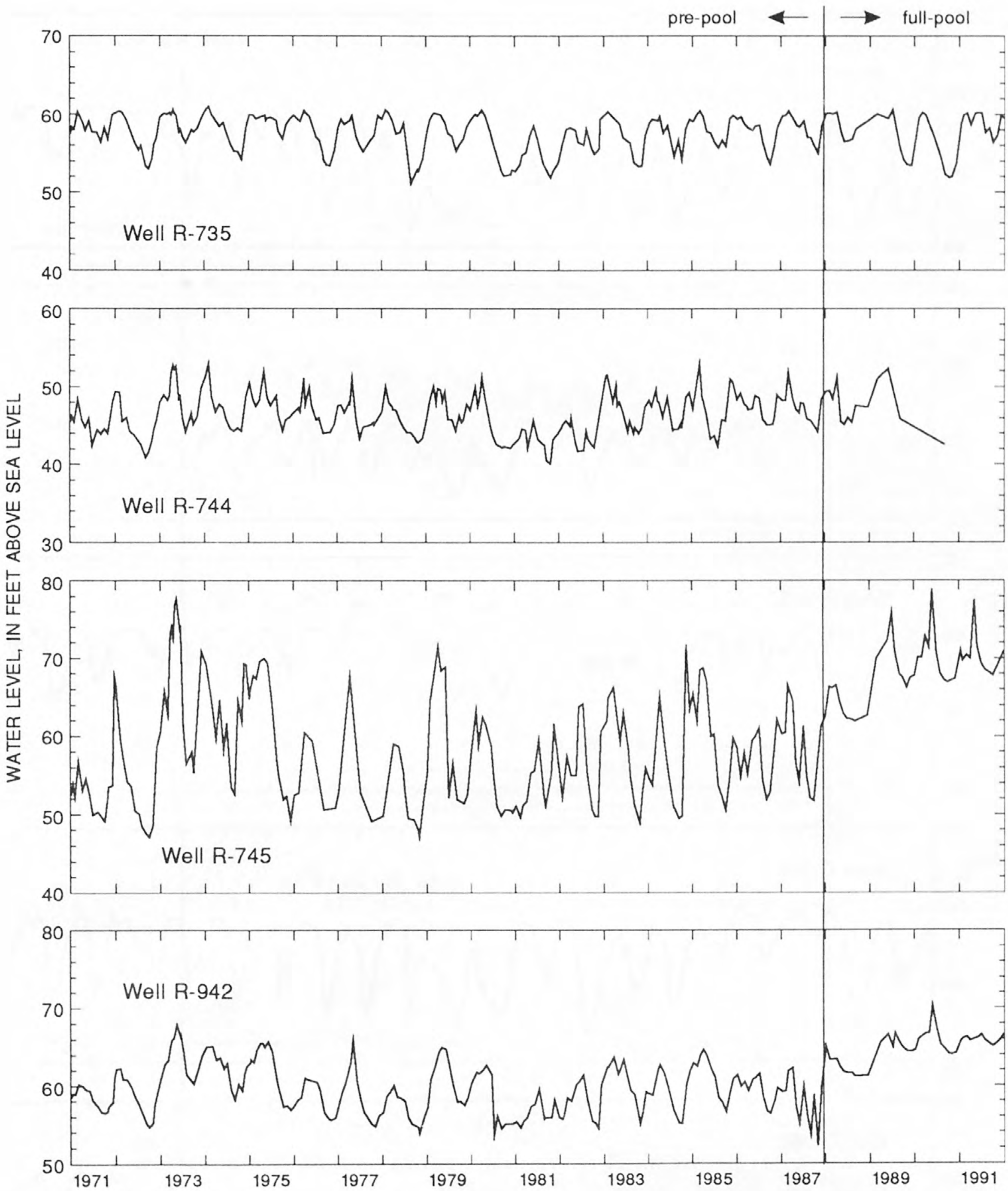

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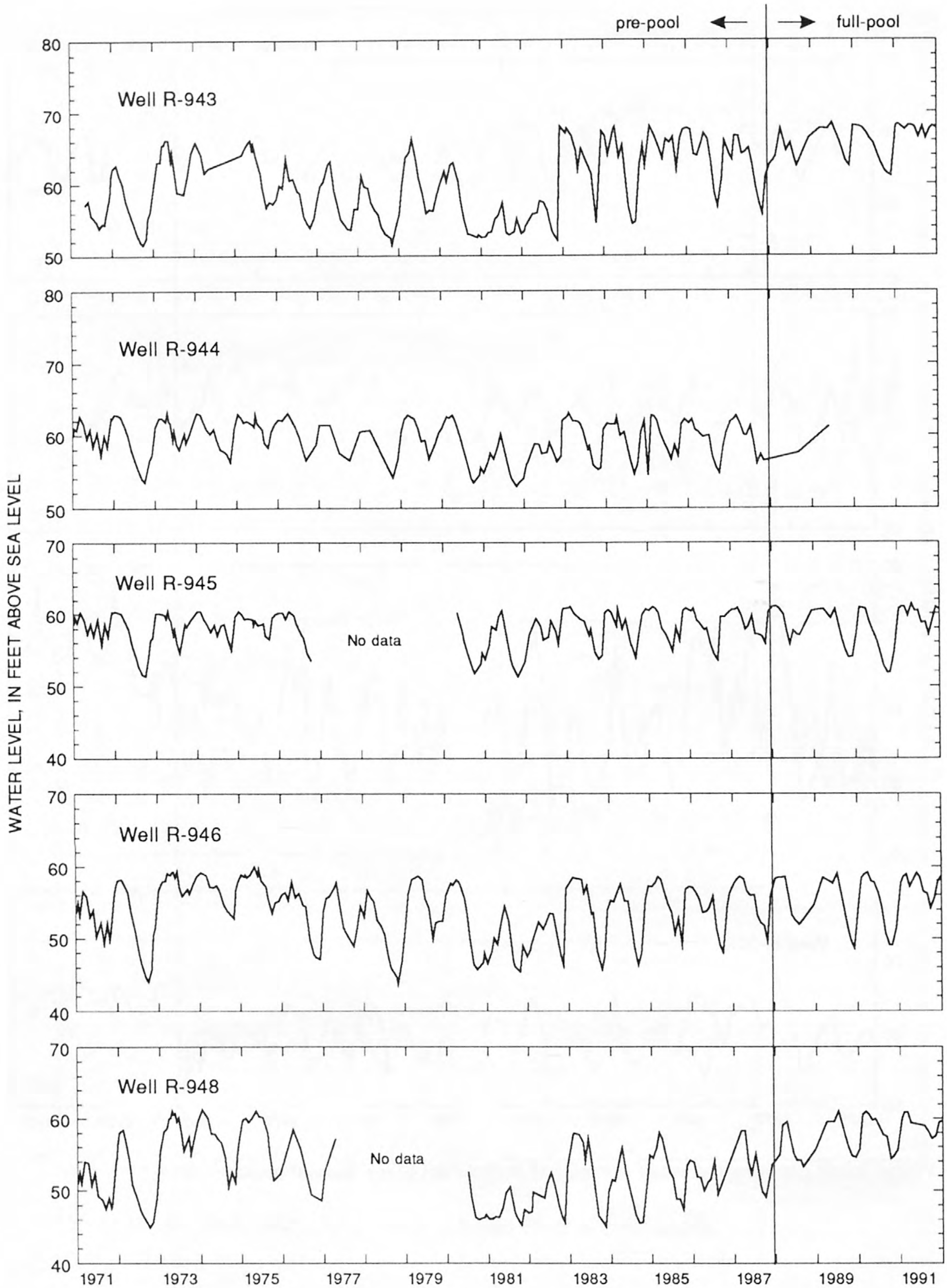

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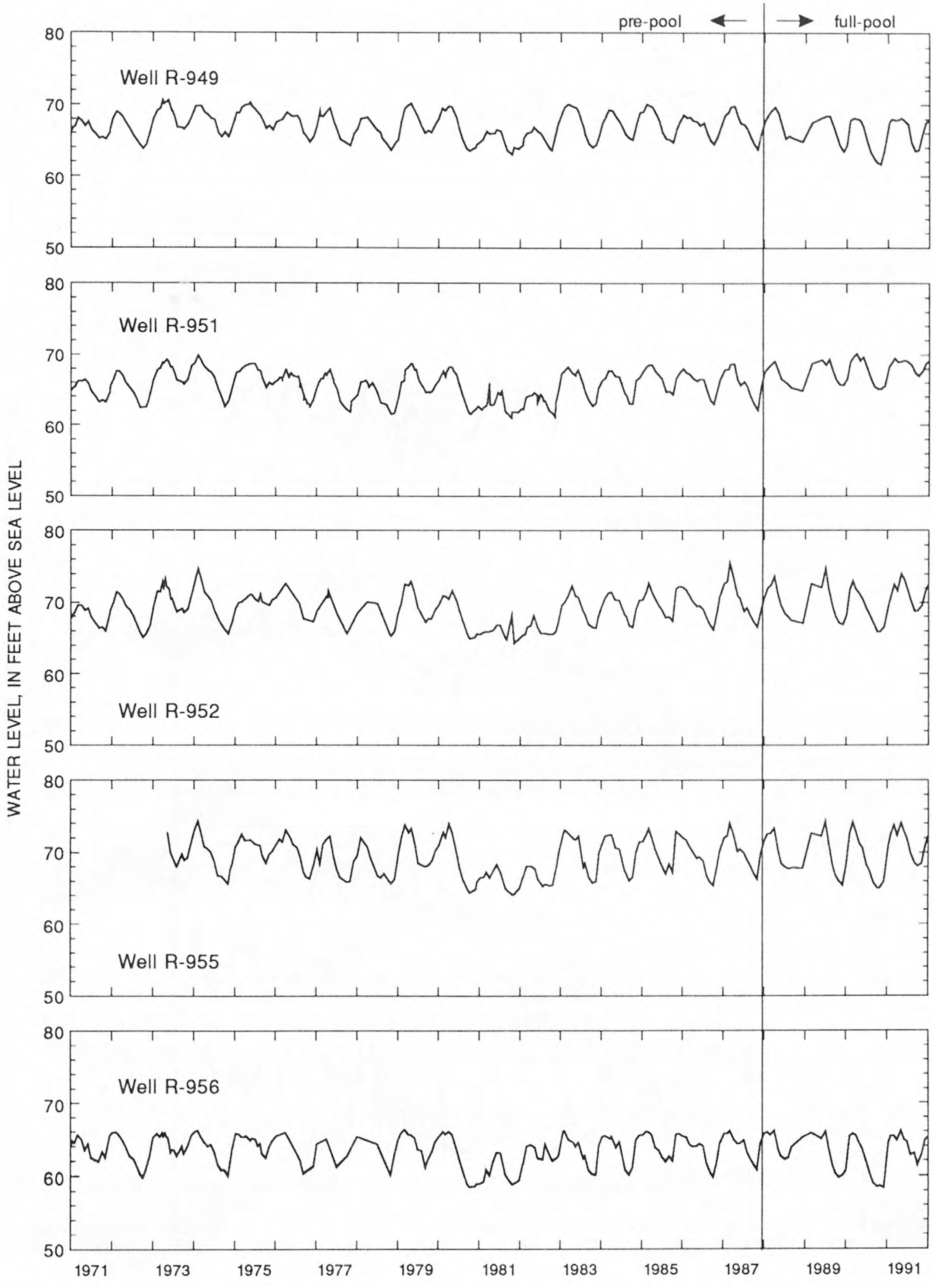

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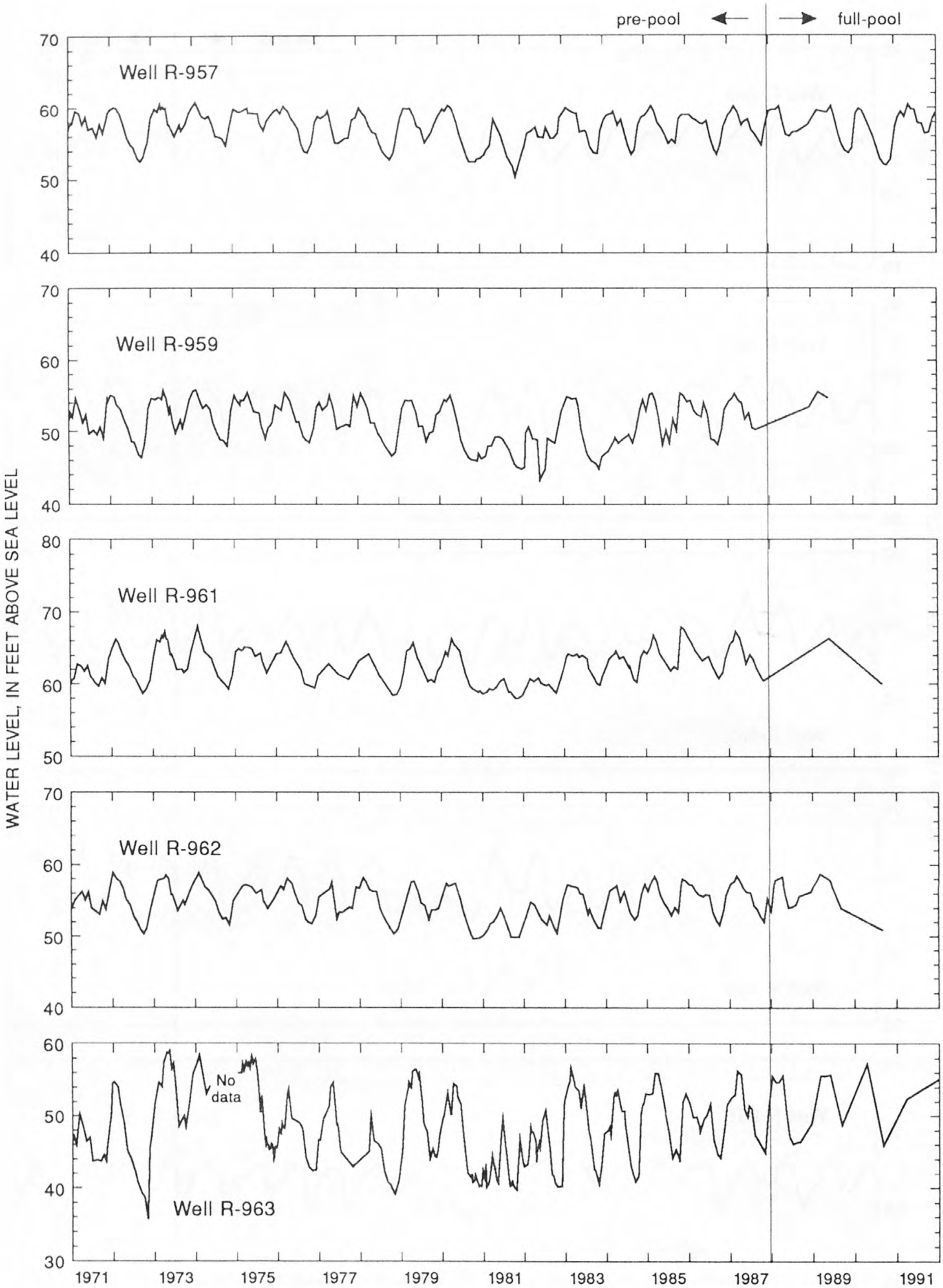

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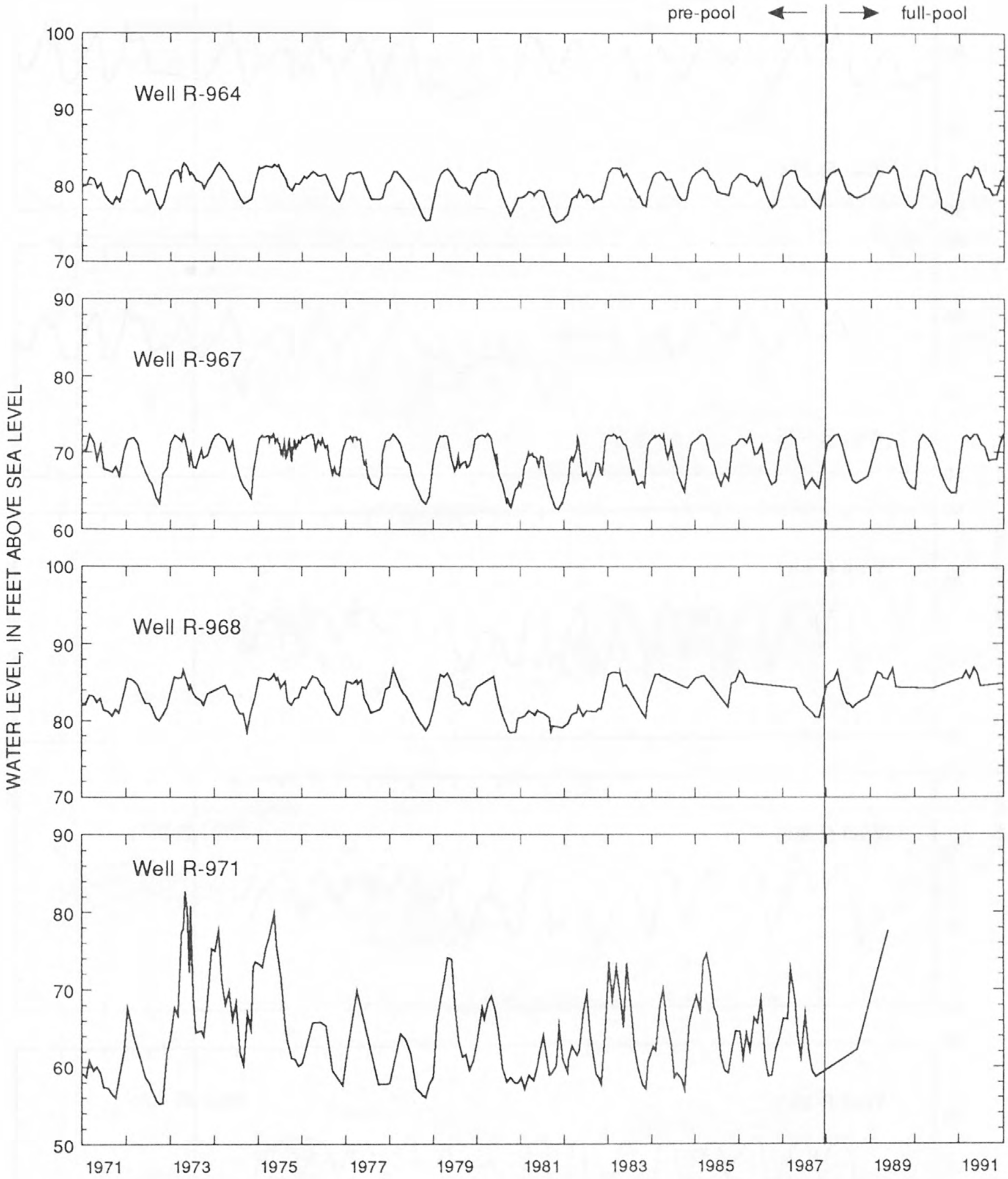

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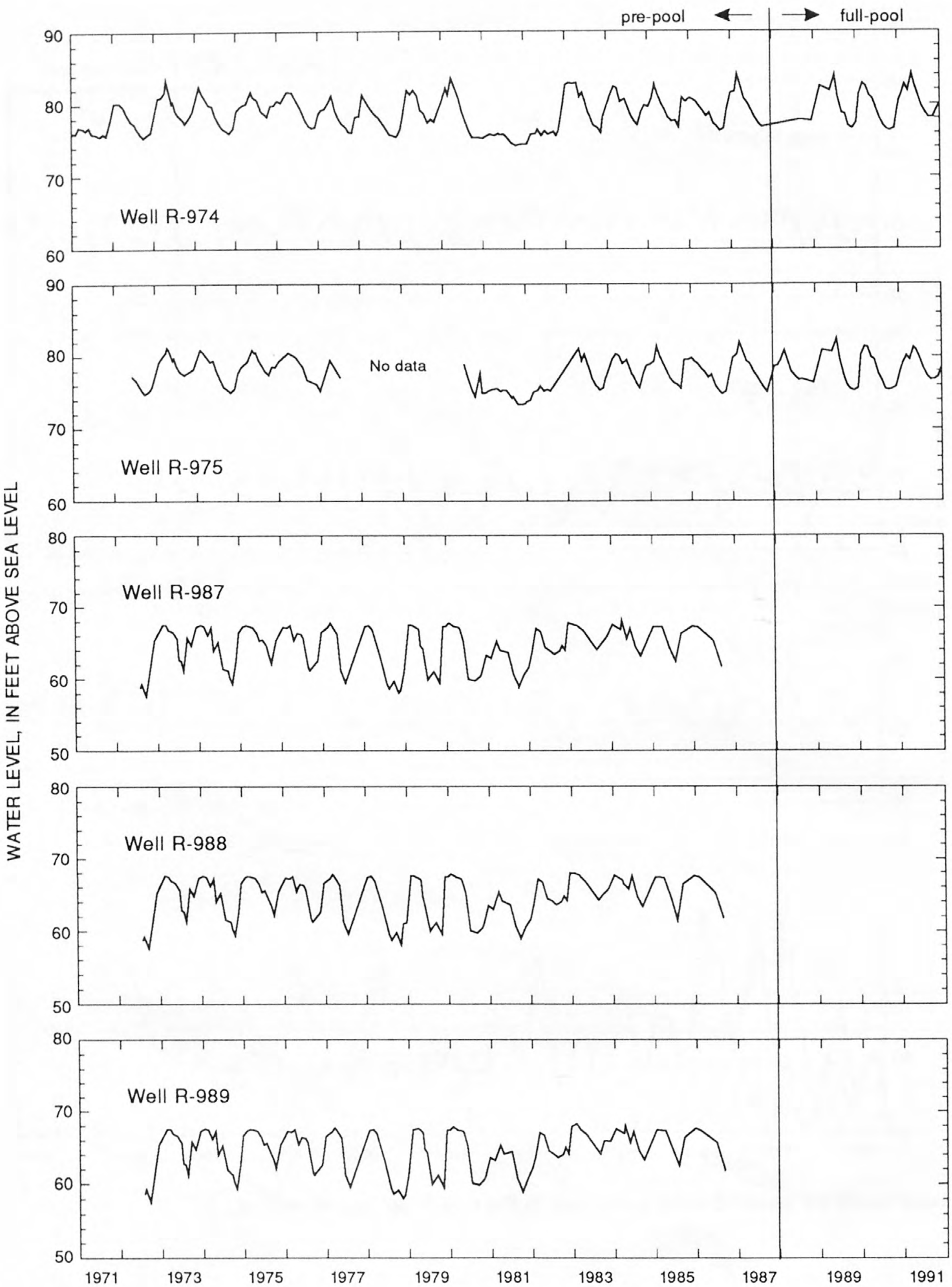

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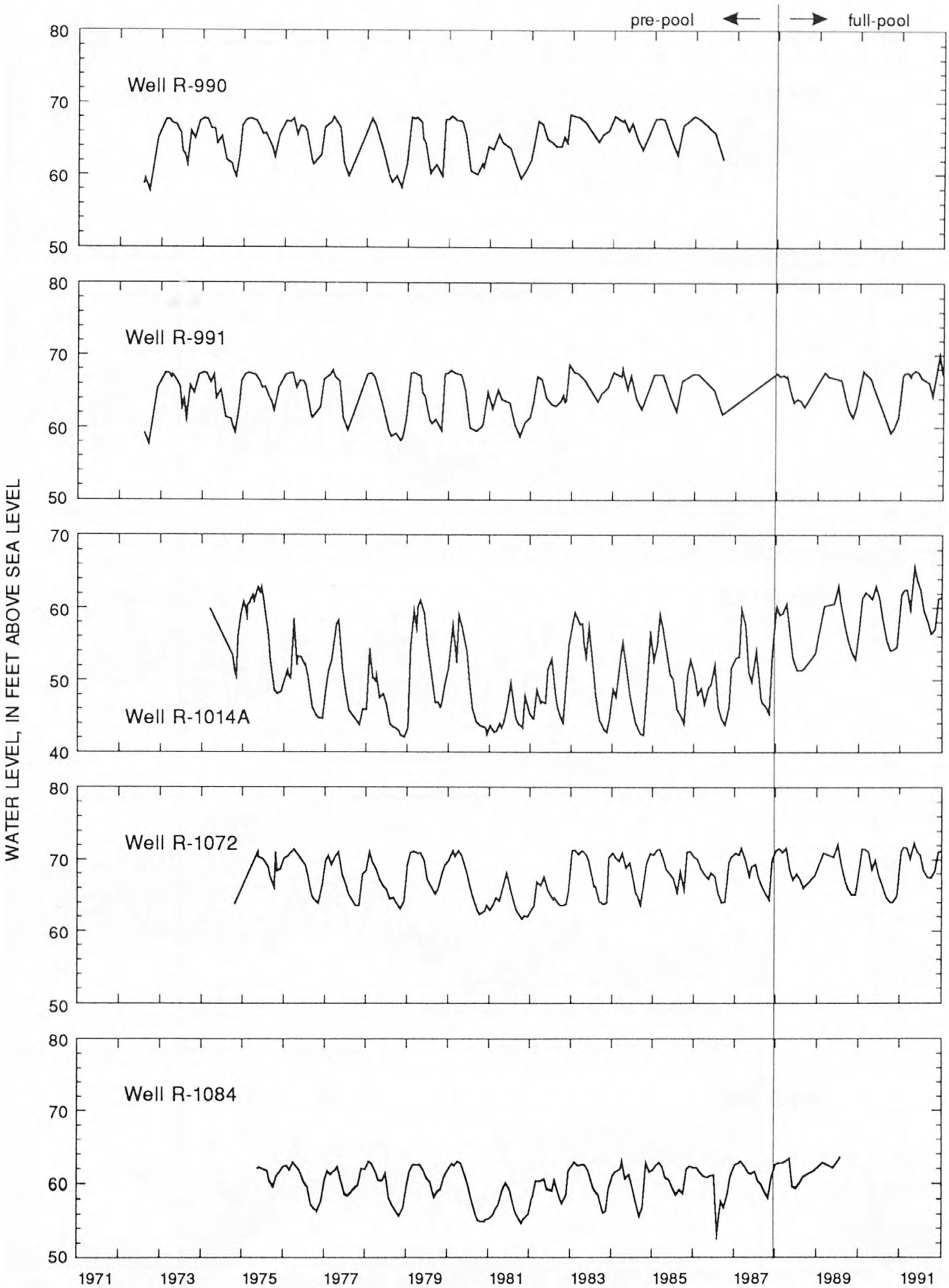

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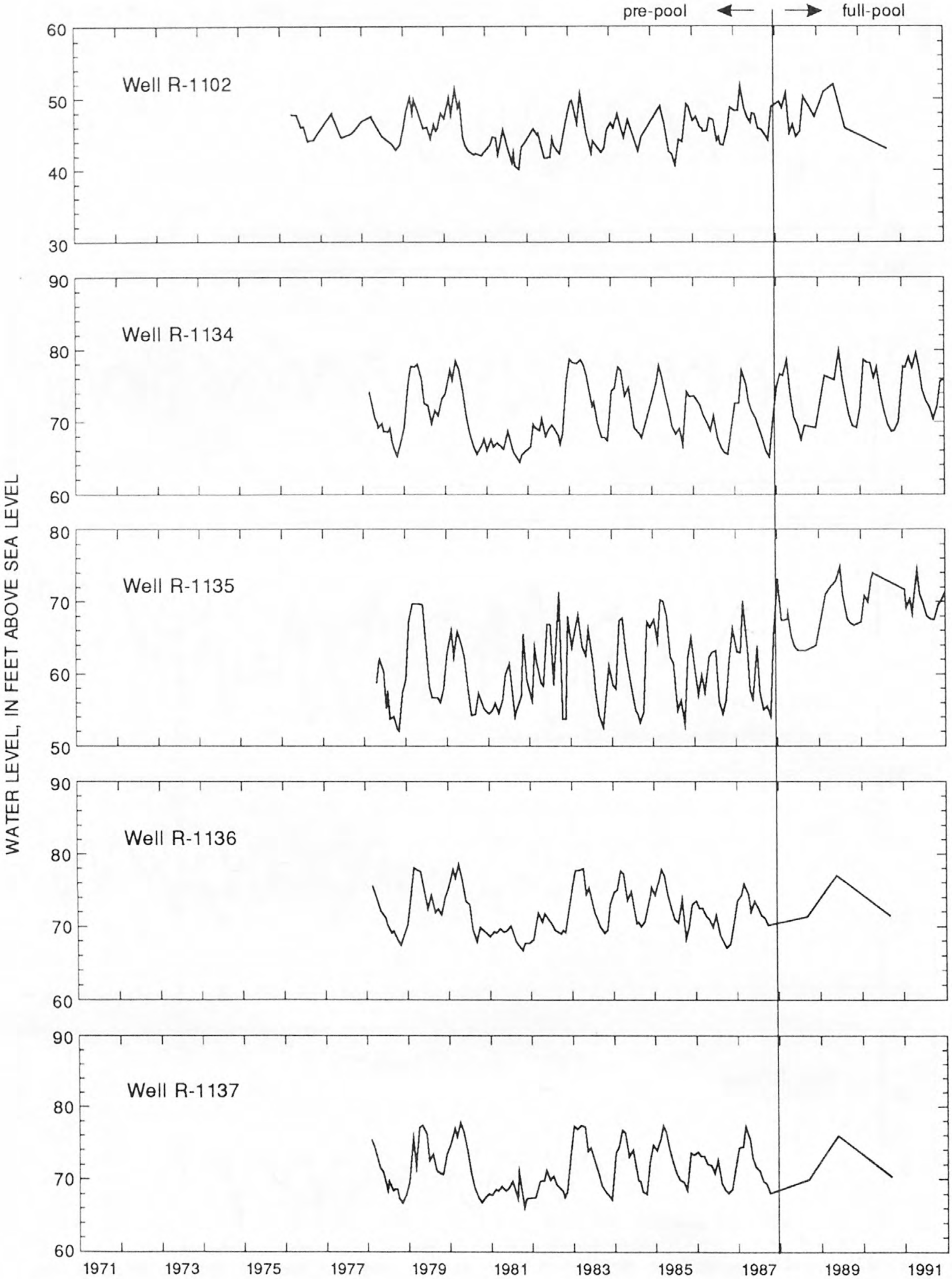

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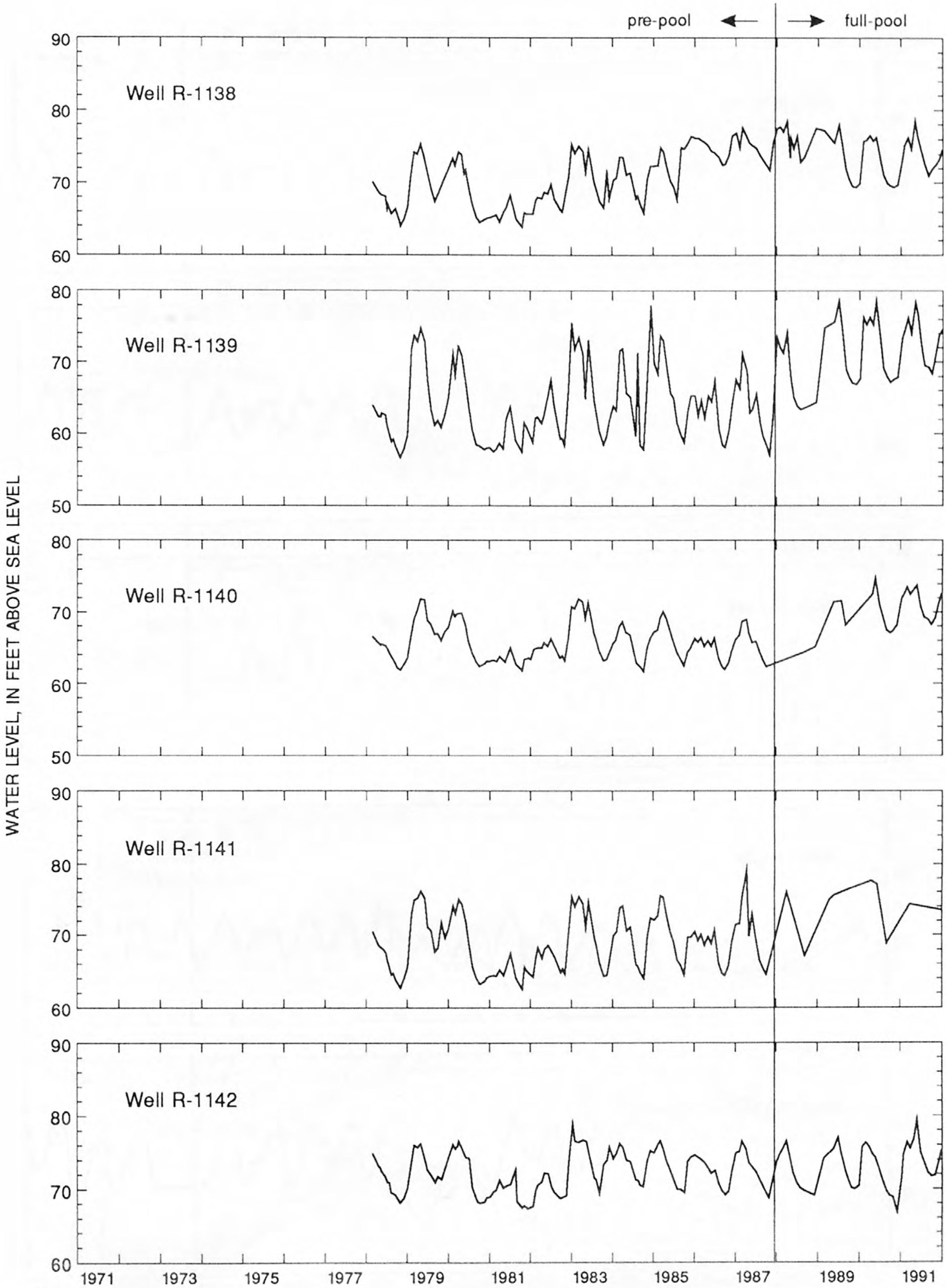

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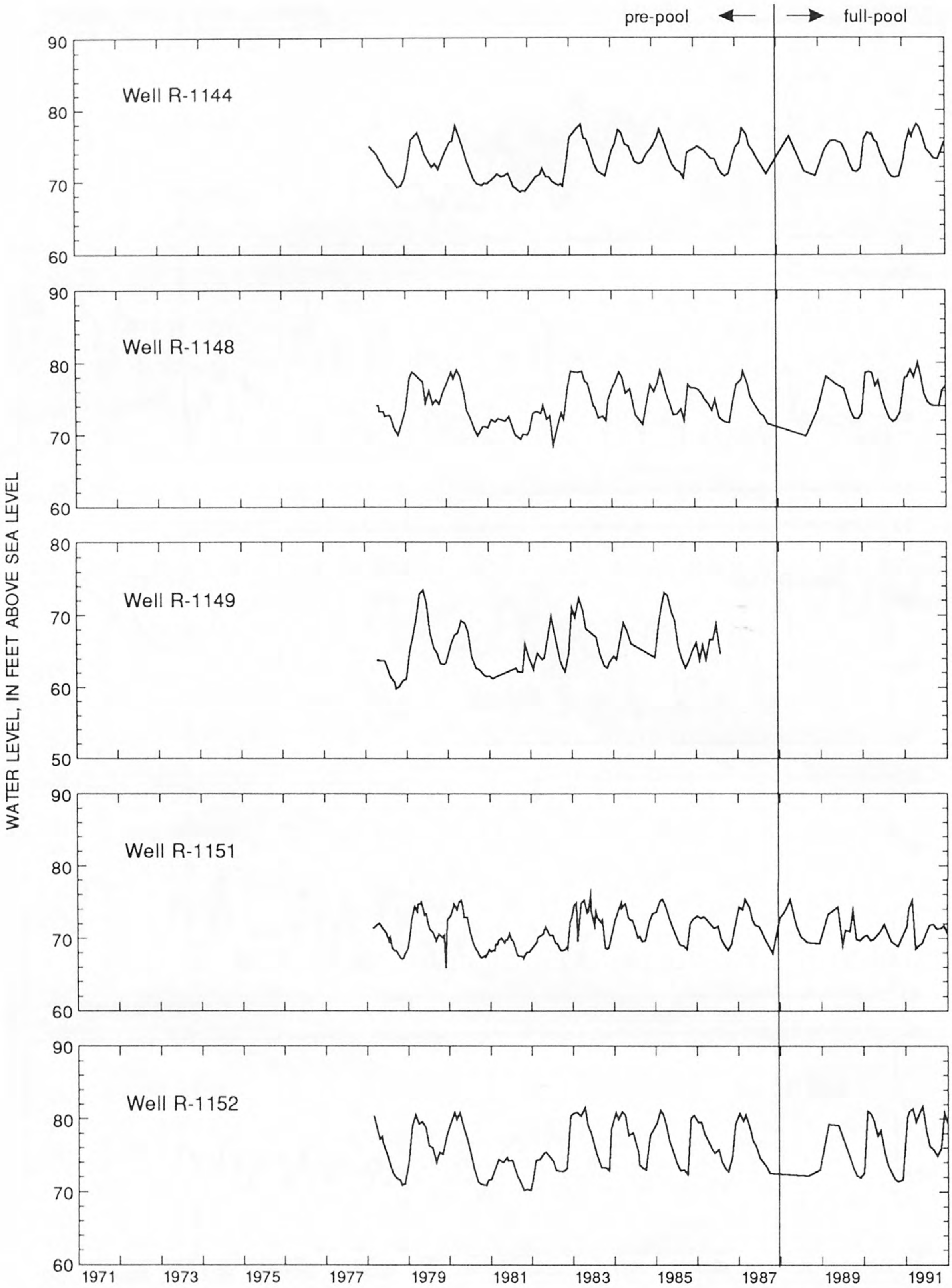

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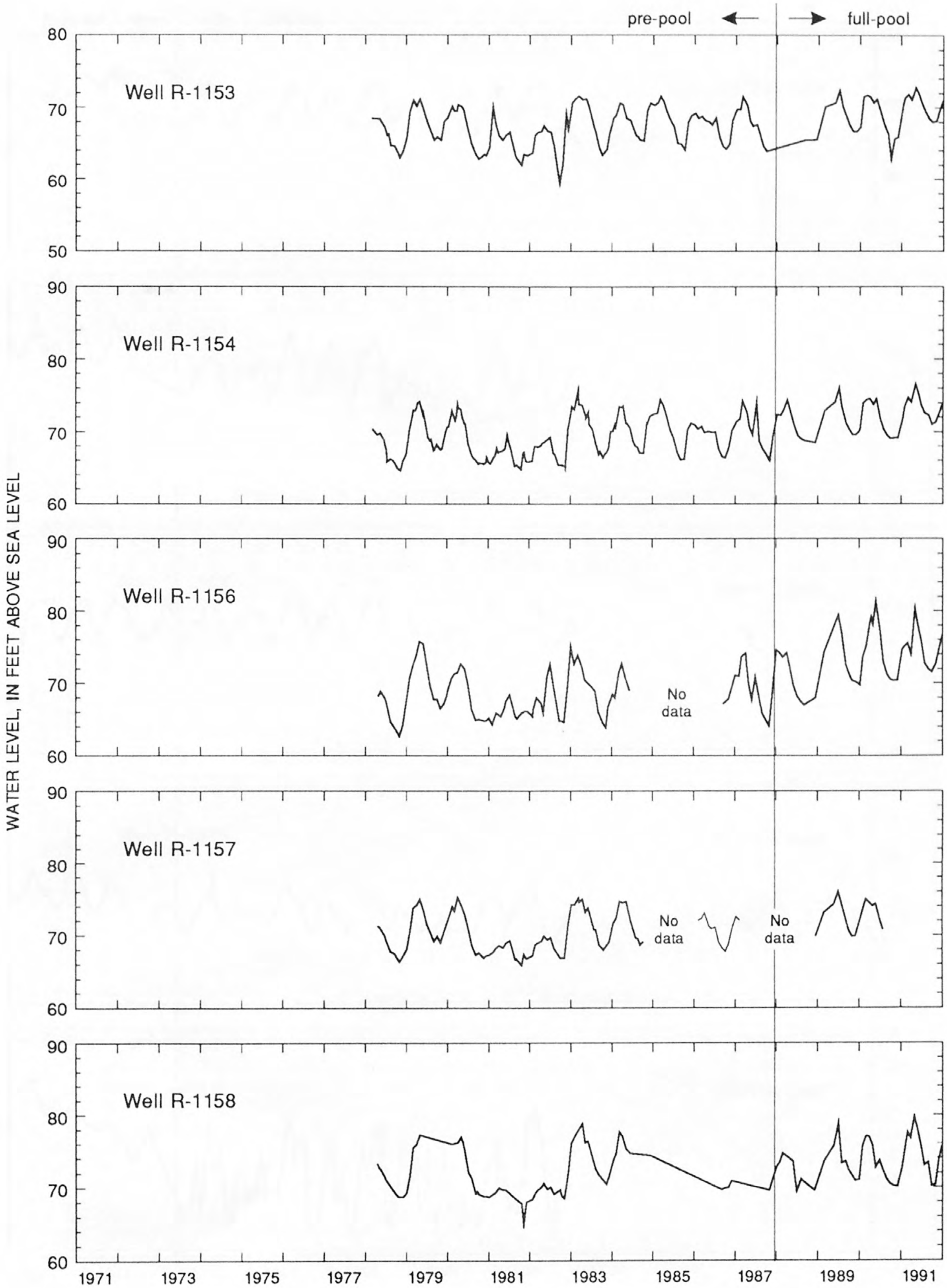

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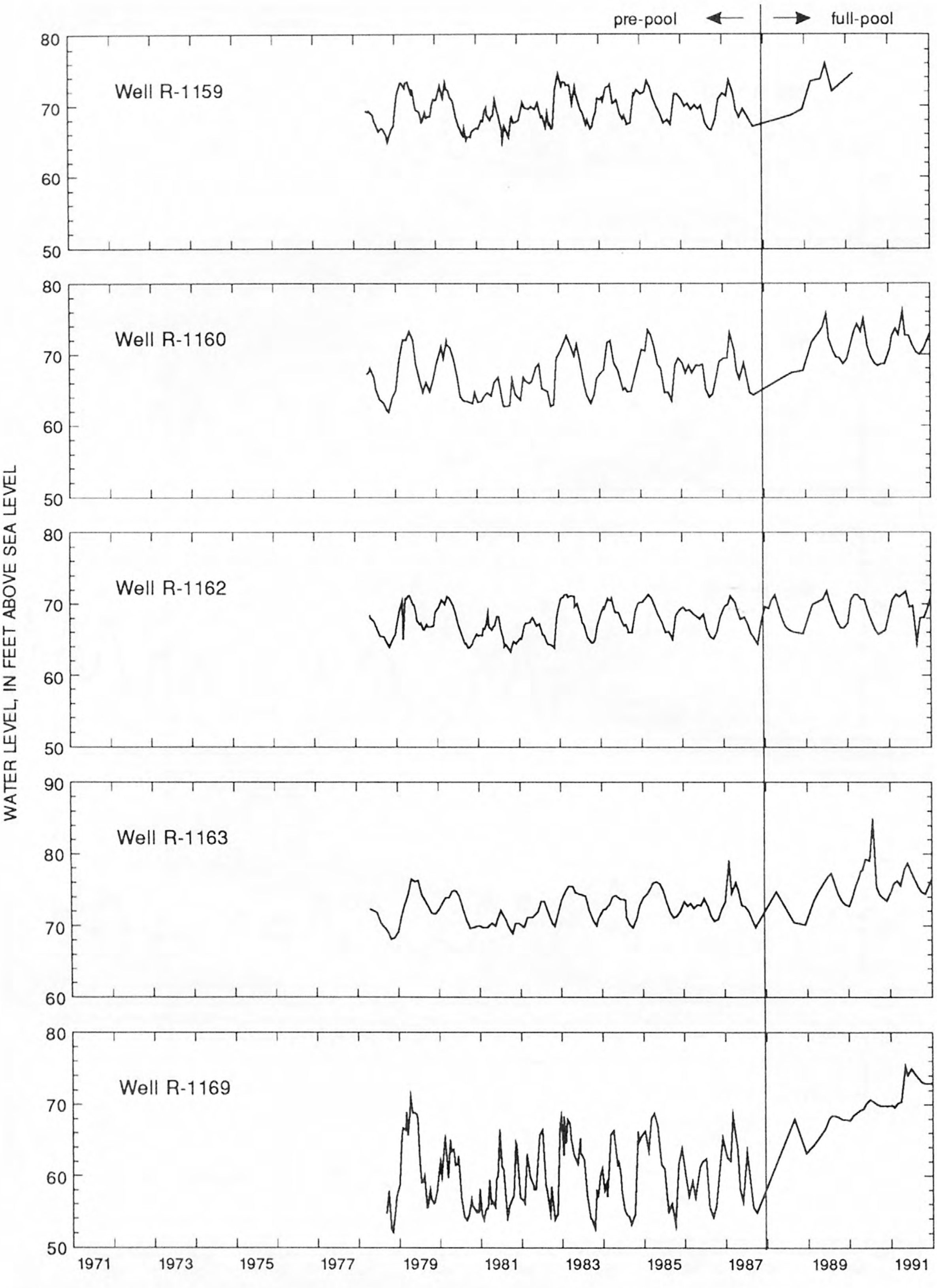

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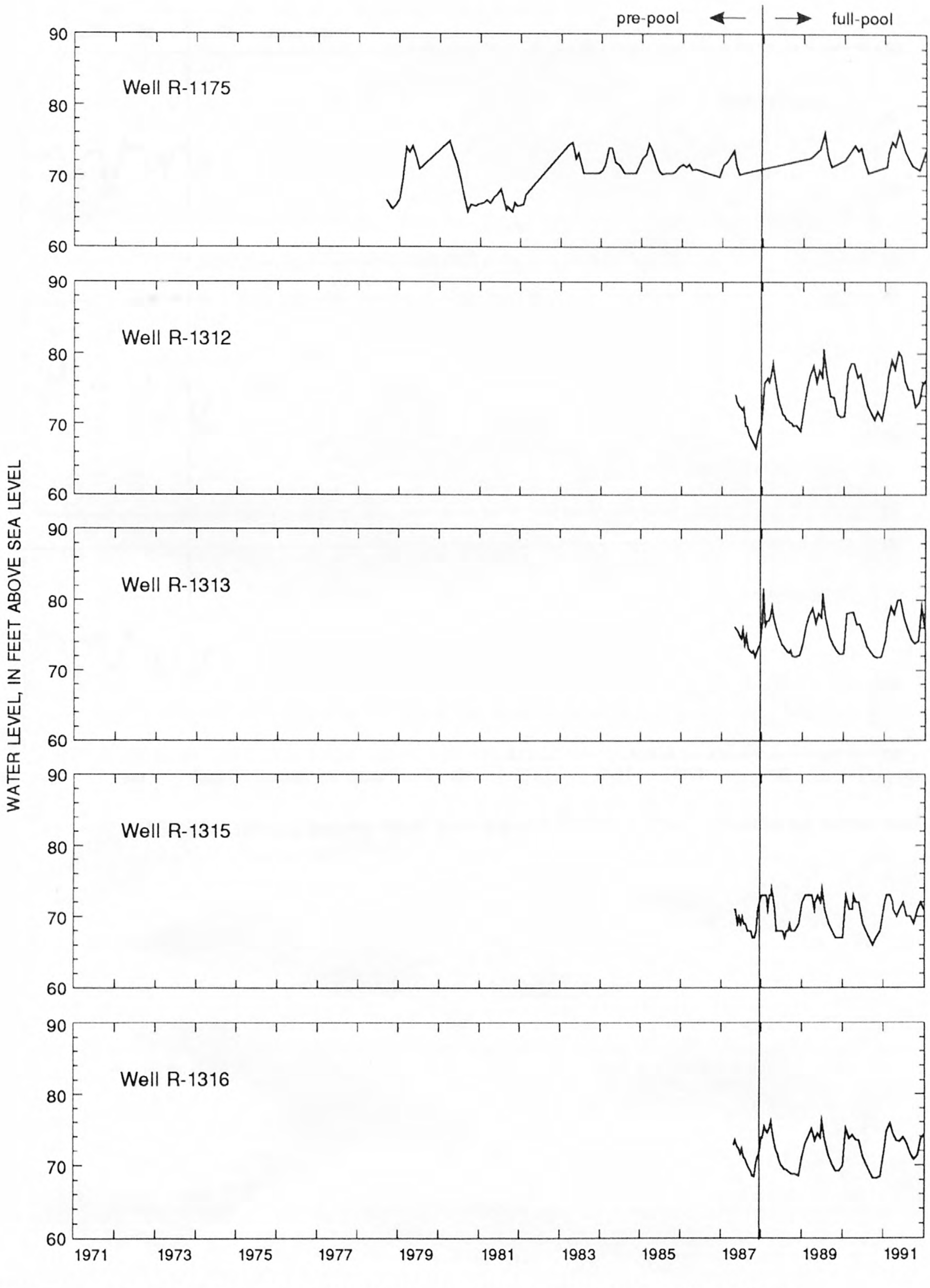

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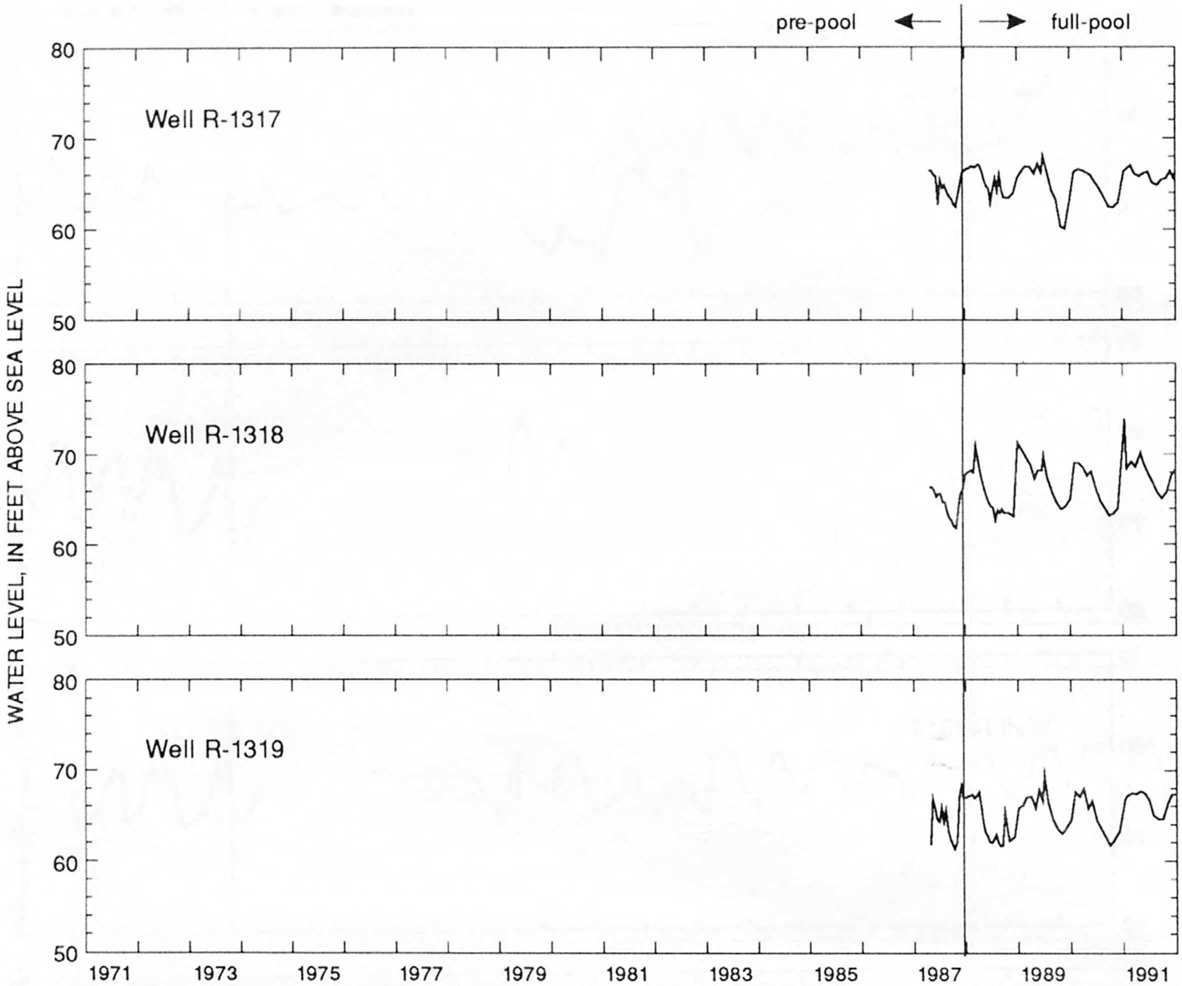

Water levels for selected wells completed in the Red River alluvial aquifer, 1971-91.

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