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A Research Report for
Rockwell Hanford Operations

Hanford Site Water Table Changes 1950 Through 1980 - Data Observations and Evaluation

D. A. Zimmerman
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G. D. Black
M. A. Young

April 1986

Prepared for the U.S. Department of Energy
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SUMMARY

The basalt formations underlying the Hanford site are being considered for characterization and evaluation as a deep geologic repository for defense and commercial radioactive wastes. To understand the hydrology of the Hanford area, we need to know if the ground-water system is in steady state and what impact a change in surface stress from artificial recharge may have on the underlying basalt aquifers. Researchers at Pacific Northwest Laboratory are supporting efforts to understand these issues by illustrating how changes in wastewater disposal activities at the Hanford site have altered the configuration of the water table surface with time. The objective of this work was to determine the magnitude and direction of changes in the elevation of the water table across the Hanford site from 1950 to 1980.

Plots of the magnitudes of water-level changes occurring over 5-year intervals from 1950 through 1980 are presented. The water-level changes that occurred during each 5-year interval are related to water discharges from nuclear fuel reprocessing facilities or other discharge sources. Chronological and spatial correlations between wastewater discharges and unconfined ground-water mounding demonstrate that cause-and-effect relationships can be inferred for large-scale hydrologic phenomena with a high degree of confidence. This result indicates that it is feasible to make qualitative predictions of the water table's response to future changes in wastewater disposal practices.

The plots of water-level changes show large water-level increases in the vicinity of the Separations Area (200 East and 200 West) from 1950 to 1960; the rate of increase of water-level changes grows more slowly from 1960 to 1970, while the areal extent of the mounding continues to expand. Only small changes occur from 1970 to 1980; during this time period, the unconfined system appears to be in approximate equilibrium with the sources. Based on previous experience, it is believed that an increase in ground-water mounding will begin to appear near the 200 East Area B Pond as a result of the increased discharges from the restart of PUREX in 1983.

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INTRODUCTION

A major goal of the Basalt Waste Isolation Project (BWIP) is to develop an understanding of the hydrology of the Pasco Basin, particularly within the Cold Creek syncline where the reference repository location (RRL) is sited. Hydrologic models of the Pasco Basin have been developed by three organizations: Pacific Northwest Laboratory (PNL), Rockwell Hanford Operations, and the U.S. Geological Survey (USGS). Differences in the conceptualization of the hydrology among these groups raised concern about how much is known and how much can be inferred about the hydrology of the Pasco Basin. In response to these concerns, BWIP established the Interagency Hydrologic Working Group (IHWG), composed of staff from the three organizations, to provide a technical forum for identifying the important differences and for developing a means for their resolution.

An important issue confronting the IHWG concerns the impact changes in surface stresses in the unconfined aquifer may have on confined aquifers within the basalt formations. Large volumes of water are routinely discharged to the ground surface at various locations in the vicinity of the RRL. As part of the Hanford site characterization process, BWIP intends to perform large-scale aquifer pumping tests on selected hydrologic units of the basalt formations within the RRL. To properly interpret the data from these tests, it is necessary to determine if surface stresses can influence the water level/pressure readings taken from wells and piezometers monitoring in the basalt aquifers.

This report describes, in a general sense, the history of water loads that have been applied to the ground surface at the Hanford site and the response of the water table to those loads. This work is limited to an analysis of data for the unconfined system only; it does not address confined/unconfined aquifer dynamics. The intention is to provide a historical perspective of how water discharges to ground have changed the configuration of the water table with time. This work will benefit another ongoing study that is designed specifically to examine how the effects of surface stresses may propagate laterally and vertically through the ground-water system.

The data presented here show the magnitude of the effect that surface-water discharges have had on the Hanford site unconfined aquifer with time. Point data of water-level changes at specific wells are plotted on background (plan view) maps of the Hanford site. In addition, hydrographs for selected wells show historical water levels at specific locations.

BACKGROUND

During FY 1984, the IHWG reviewed data on measured water levels for wells in the Quincy Basin. The Quincy Basin is an area adjacent to and north of the Hanford site, where unconsolidated sediments are underlain by Wanapum Basalt. Artificial recharge from the Columbia Basin Irrigation Project has been applied to the Quincy Basin since the early 1950s. The Quincy Basin data showed increases in water levels (caused by irrigation) for wells in the unconsolidated deposits followed by much larger increases in water levels for wells penetrating the Wanapum Basalt. Although no cause-and-effect relationship has been established between the Quincy Basin alluvial water-level observations and basalt water-level observations, the question was posed as to whether this same phenomenon might occur at the Hanford site. The artificial recharge that is applied to the unconsolidated deposits on the Hanford site results from the disposal of liquid wastes from chemical separations processing of spent nuclear fuel elements. Approximately 1.9 million acre-ft/yr of water is applied to 450,000 acres in the Quincy Basin (Tanaka et al. 1974); this is equivalent to 4 ft/yr per unit area. In 1983, ~19,500 acre-ft (Aldrich 1984) of wastewater was discharged over ~180 acres on the Hanford site or greater than 100 ft/yr per unit area.

RELEVANT HISTORICAL EVENTS

Large volumes of process cooling water have been discharged to ponds in or near the 200 Areas since 1944. Smaller volumes of low- and intermediate-level radioactive liquid wastes such as steam condensates, process condensates, scavenged process waste supernatants, and plutonium processing wastes have been or are being discharged to subsurface disposal cribs within the 200 Areas. Significant changes in the configuration of the water table can be related to the stresses imposed on the unconfined aquifer via wastewater discharges from the chemical processing facilities. Relatively small volumes of water discharges to ground have occurred in the 100 Areas where nine plutonium production reactors are sited. A map of the Hanford site, which shows the 200 Areas and the reprocessing facilities, the major disposal ponds, and the production reactor sites, is shown in Figure 1.

REPROCESSING FACILITIES

The major facilities that have been discharging large volumes of water to ground surface since the early 1940s are listed below. Also listed are the ponds and cribs that receive the largest quantities of wastewater; other cribs are grouped together (Tables 1 and 2) because they are often located in one area, thereby concentrating the 'load' on the unconfined system. Figure 2 shows a plan view of the 200 Areas and the locations of the reprocessing facilities, the major wastewater receiving ponds, and the crib groups identified in Tables 1 and 2.

200-East Area

- B Plant - One of the original fuel separations facilities, operated between 1945 and 1952. In 1968 it was converted to a waste fractionization plant and is in operation.
- A Plant or PUREX Plant - An irradiated fuel-processing plant, operated between 1955 and 1972. The PUREX plant resumed operations in 1983 and is continuing to operate.

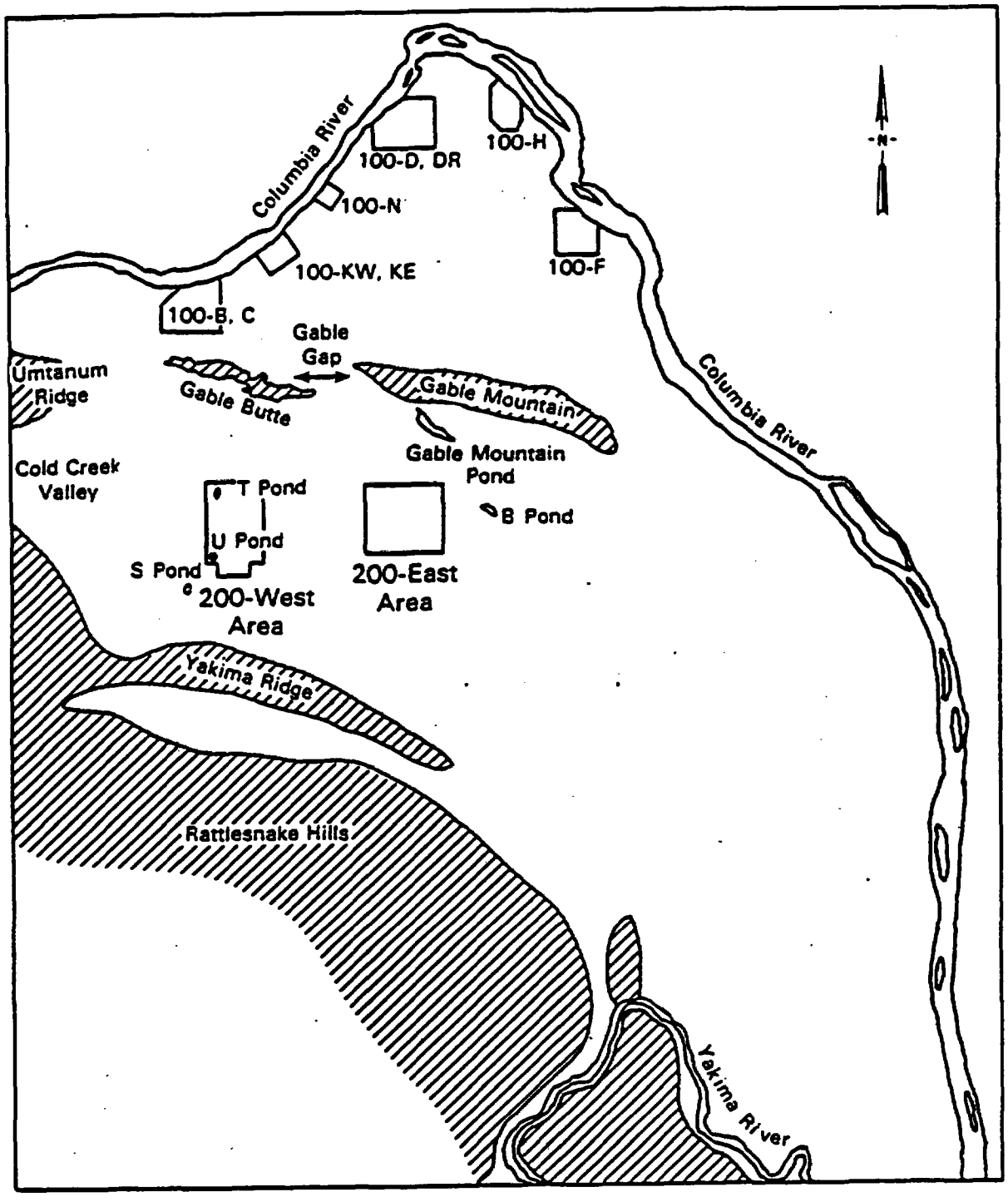


FIGURE 1. Hanford Site Map Showing 200 Areas and Reprocessing Facilities, the Major Disposal Ponds, and the Production Reactor Sites (S Pond and U Pond have not been in service since October 1984 and December 1984, respectively.)

TABLE 1. Wastewater Discharges to 200-East Area Ponds and Cribs[a] (L)

	1943 to 1950	1951 to 1955	1956 to 1960	1961 to 1965	1966 to 1970	1971 to 1975	1976 to 1980	1943 to 1980
Gable Mountain Pond	0.000E+00 0.00 PCT[b]	0.000E+00 0.00 PCT	2.453E+10 38.74 PCT	6.200E+10 79.33 PCT	5.387E+10 71.53 PCT	3.716E+10 60.55 PCT	4.598E+10 67.26 PCT	2.235E+11
B Pond	9.950E+09 98.91 PCT	8.398E+09 91.14 PCT	3.149E+10 49.73 PCT	1.170E+10 14.96 PCT	1.784E+10 23.69 PCT	2.097E+10 34.17 PCT	1.944E+10 28.44 PCT	1.198E+11
PUREX Cribs Area	0.000E+00 0.00 PCT	5.261E+07 0.57 PCT	4.372E+09 6.90 PCT	3.973E+09 5.08 PCT	2.600E+09 3.45 PCT	6.711E+08 1.09 PCT	6.755E+08 0.99 PCT	1.234E+10
B Plant Area	6.455E+07 0.64 PCT	3.023E+08 3.28 PCT	8.103E+07 0.13 PCT	0.000E+00 0.00 PCT	5.234E+08 0.69 PCT	2.408E+09 3.92 PCT	4.238E+08 0.62 PCT	3.803E+09
A Tank Farm Cribs	0.000E+00 0.00 PCT	8.166E+07 0.89 PCT	2.492E+09 3.93 PCT	8.170E+07 0.10 PCT	1.973E+08 0.26 PCT	5.664E+07 0.09 PCT	4.606E+05 0.00 PCT	2.910E+09
B Tank Farm Cribs	4.491E+07 0.45 PCT	1.031E+08 1.12 PCT	0.000E+00 0.00 PCT	5.600E+06 0.01 PCT	1.416E+08 0.19 PCT	1.074E+08 0.17 PCT	1.825E+09 2.67 PCT	2.228E+09
C Cribs	0.000E+00 0.00 PCT	2.680E+08 2.91 PCT	2.524E+08 0.40 PCT	3.978E+08 0.51 PCT	1.414E+08 0.19 PCT	6.669E+03 0.00 PCT	1.640E+07 0.02 PCT	1.076E+09
B-C Cribs	0.000E+00 0.00 PCT	8.710E+06 0.09 PCT	1.101E+08 0.17 PCT	1.574E+06 0.00 PCT	4.022E+05 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	1.207E+08
Total Discharges	1.006E+10	9.214E+09	6.333E+10	7.815E+10	7.531E+10	6.137E+10	6.836E+10	3.658E+11

(a) Information taken from internal Hanford site contractor reports concerning radioactive liquid wastes discharged to ground in the 200 areas from 1943 to 1980.

(b) PCT = Percent of total discharge for the 5-year time interval.

TABLE 2. Wastewater Discharges to 200-West Area Ponds and Cribs[a] (L)

	1943 to 1950	1951 to 1955	1956 to 1960	1961 to 1965	1966 to 1970	1971 to 1975	1976 to 1980	1943 to 1980
U Pond	6.790E+09 30.30 PCT[b]	4.006E+10 59.15 PCT	3.936E+10 68.11 PCT	1.279E+10 29.26 PCT	1.519E+10 59.98 PCT	1.815E+10 78.65 PCT	2.592E+10 94.71 PCT	1.583E+11
S 16, S 17 Ponds	0.000E+00 0.00 PCT	6.437E+09 9.50 PCT	1.118E+10 19.35 PCT	2.337E+10 53.46 PCT	4.608E+09 18.20 PCT	1.565E+09 6.78 PCT	0.000E+00 0.00 PCT	4.716E+10
T Pond	1.398E+10 62.39 PCT	1.512E+10 22.32 PCT	2.976E+09 5.15 PCT	4.830E+09 11.05 PCT	3.726E+09 14.71 PCT	1.765E+09 7.65 PCT	8.460E+07 0.31 PCT	4.248E+10
S 5, S 6, S 10, S 11 Cribs and Ponds	0.000E+00 0.00 PCT	4.658E+09 6.88 PCT	3.529E+09 6.11 PCT	2.009E+09 4.60 PCT	9.347E+08 3.69 PCT	1.063E+09 4.61 PCT	9.800E+08 3.58 PCT	1.317E+10
N Cribs Area	1.439E+09 6.42 PCT	4.857E+08 0.72 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	1.925E+09
Z Plant Area	1.000E+09 0.45 PCT	1.564E+08 0.23 PCT	2.064E+08 0.36 PCT	1.318E+08 0.30 PCT	4.197E+08 1.66 PCT	2.021E+08 0.88 PCT	5.046E+06 0.02 PCT	1.221E+09
S 19 Pond	0.000E+00 0.00 PCT	1.730E+08 0.26 PCT	1.151E+08 0.20 PCT	1.627E+08 0.37 PCT	1.731E+08 0.68 PCT	1.735E+08 0.75 PCT	2.482E+08 0.91 PCT	1.046E+09
S Tank Farm Area	0.000E+00 0.00 PCT	1.789E+08 0.26 PCT	2.941E+07 0.05 PCT	4.272E+07 0.10 PCT	8.235E+07 0.33 PCT	1.425E+08 0.62 PCT	1.285E+08 0.47 PCT	6.044E+08
Redox Plant Area	0.000E+00 0.00 PCT	6.554E+07 0.10 PCT	2.504E+08 0.43 PCT	2.086E+08 0.48 PCT	5.200E+05 0.00 PCT	5.380E+06 0.02 PCT	0.000E+00 0.00 PCT	5.304E+08
U 8, U 12 Cribs	0.000E+00 0.00 PCT	2.545E+08 0.38 PCT	1.330E+08 0.23 PCT	7.410E+07 0.17 PCT	3.990E+07 0.16 PCT	9.810E+06 0.04 PCT	0.000E+00 0.00 PCT	5.113E+08
T Plant Area	5.890E+07 0.26 PCT	2.149E+06 0.00 PCT	2.860E+05 0.00 PCT	5.130E+07 0.12 PCT	1.465E+08 0.58 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	2.592E+08
T Tank Farm Area	4.090E+07 0.18 PCT	1.185E+08 0.17 PCT	4.895E+06 0.01 PCT	4.793E+07 0.11 PCT	1.352E+06 0.01 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	2.136E+08
U Plant Area	0.000E+00 0.00 PCT	1.683E+07 0.02 PCT	2.457E+06 0.00 PCT	8.698E+04 0.00 PCT	1.671E+06 0.01 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	2.105E+07
U Tank Farm Area	0.000E+00 0.00 PCT	8.019E+05 0.00 PCT	4.730E+02 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	0.000E+00 0.00 PCT	8.024E+05
Total Discharges	2.241E+10	6.773E+10	5.779E+10	4.372E+10	2.532E+10	2.308E+10	2.737E+10	2.674E+11

(a) Information taken from internal Hanford site contractor reports concerning radioactive liquid wastes discharged to ground in the 200 areas from 1943 to 1980.

(b) PCT = Percent of total discharge for the 5-year time interval.

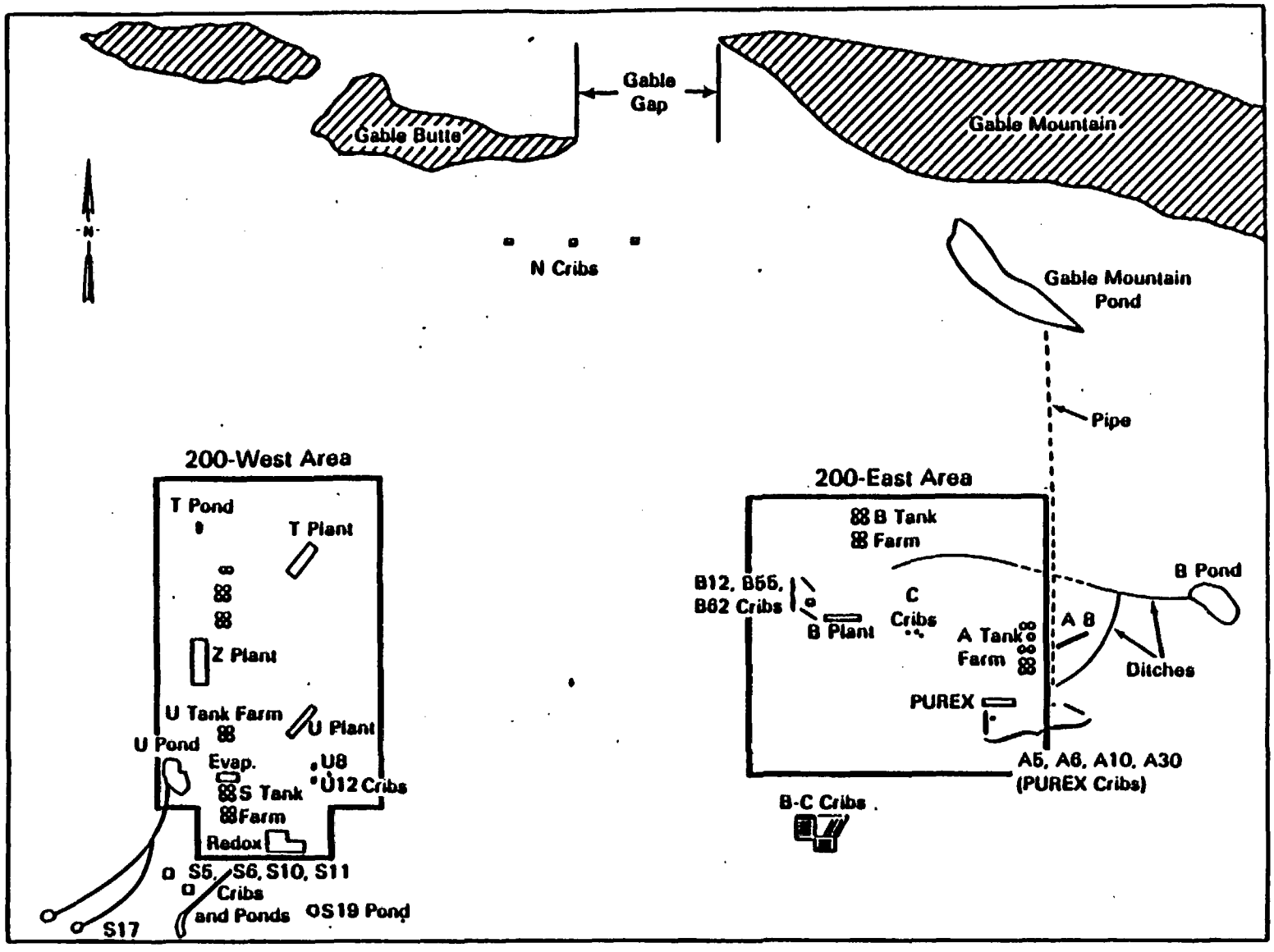


FIGURE 2. Plan View of the Separations Area Showing Locations of Reprocessing Facilities and Major Receiving Ponds and Cribs

- 200-East Evaporator - An evaporator used to reduce the volume of liquid waste stored in tank farms. This evaporator began operating in 1977 and is in operation today.
- B Pond - This pond began receiving wastewater in 1945. Two expansion ponds were constructed in 1984 adding 50% more capacity.
- Gable Mountain Pond - This pond began receiving wastewaters in 1957. Decommissioning of Gable Mountain Pond began in 1984, but it continues to receive reduced wastewater discharges.
- Other Cribs or Trenches - Certain cribs and trenches received significantly larger volumes of wastewater than others; these are shown in Figure 2 and are labeled PUREX Cribs, A8, B12, B55, and B62.

<u>200-West Area</u>

- T Plant - This fuel separations facility, similar to B Plant, operated from 1944 through 1956.
- Z Plant - This plutonium reclamation facility was constructed in 1949 and is still in operation.
- U Plant - This plant was built for fuel separations processing and was used to recover uranium from stored radioactive waste. U Plant operated from 1952 through 1958 and was placed back into operation in 1984.
- Redox Plant - This reduction-oxidation process plant for fuel separation operated between 1951 and 1967.
- The 200-West Evaporator - This evaporator, used to reduce the volume of liquid waste in the storage tanks, was constructed in 1975 and operated until (about) 1980.
- T Pond - This pond received wastewater discharges from 1944 through 1975.
- U Pond - This pond began receiving waste discharges in 1944 and was decommissioned and covered over in 1984.

- S Ponds - Several ponds and cribs located outside the 200-West Area were constructed and received large volumes of water from the mid-1950s to the early 1970s.

WASTEWATER DISCHARGES

Records of wastewater discharges to ponds and cribs were examined to determine how much liquid was discharged to each of these facilities listed above. These data are presented in Table 3 to enable a comparison of the quantities and distribution of water discharges for each time interval with the plots of water-level changes occurring during each interval. Table 3 shows the volumes and relative percentages of water discharged to the ground in each of the Separations Areas (200 East and 200 West) for each 5-year time interval. Table 1 shows the volumes and percentages of water discharges to each of the receiving ponds and cribs or groups of cribs for each 5-year time interval in the 200-East Area. Table 2 shows the same information for the 200-West Area.

TABLE 3. Water Discharges To The Separations Areas[a] (L)

Time Period	Volume (L)		Total Volume	% of Total	
	200 East	200 West		200 East	200 West
1943 - 1950	1.006E+10	2.241E+10	3.247E+10	31.0	69.0
1951 - 1955	9.214E+09	6.773E+10	7.694E+10	12.0	88.0
1956 - 1960	6.333E+10	5.779E+10	1.211E+11	52.3	47.7
1961 - 1965	7.815E+10	4.372E+10	1.219E+11	64.1	35.9
1966 - 1970	7.531E+10	2.532E+10	1.006E+11	74.8	25.2
1971 - 1975	6.137E+10	2.308E+10	8.445E+10	72.7	27.3
1976 - 1980	6.836E+10	2.737E+10	9.573E+10	71.4	28.6

(a) Information taken from internal Hanford Site contractor reports concerning radioactive liquid wastes discharged to ground in the 200 Areas from 1943 to 1980.

PRODUCTION REACTOR SCHEDULES

Water table changes occurring near the production reactor sites appear in some of the plots. The cooling water from these reactors was held in retention basins before being discharged into the Columbia River. Some of these retention basins had considerable leakage causing local ground-water mounds to develop (Dorian and Richards 1978). In addition, cribs and trenches were used to dispose of coolant effluent from fuel element ruptures and other radioactive waste streams. At the N Reactor, flow to the 1301-N crib and trench totals ~2 1/2 million gal/day. Changes in the water table at these sites appear to be correlated with the operating schedule of these reactors (Table 4).

TABLE 4. Reactor Status Summary (from ERDA 1975)

Reactor	Operation	
	Start	Shutdown
100-DR	Oct 1950	Dec 1964
100-F	Feb 1945	Jun 1965
100-H	Oct 1949	Apr 1965
100-D	Dec 1944	Jun 1967
105-B	Sep 1944	Feb 1968
105-C	Nov 1952	Apr 1969
100-KW	Jan 1955	Feb 1970
100-KE	Apr 1955	Jan 1971
100-N	Dec 1963	Operating

DATA PREPARATION

Pacific Northwest Laboratory routinely collects and stores water-level and chemical contaminant data for wells penetrating the unconfined aquifer at the Hanford site. This information is stored on a computerized data base. An initial scan of the data base was made to determine the number of different wells that were measured for each year of record. An arbitrary 5-year interval beginning in 1950 was chosen to extract the data for all wells at which water levels were measured (i.e., data for 1950, 1955, 1960, 1965, etc., were retrieved from the data base). A search of these data sets for wells common to both 'time planes' for each 5-year interval was made; this reduced the number of data points. For example, if 30 wells were measured in 1950 and 50 wells were measured in 1955 and of those wells 15 corresponded to identical wells for both sets of measurements, then 15 data points would be available for calculating the water-level changes that occurred between 1950 and 1955. One set of data was generated that shows the water-level changes that took place across the entire 30-year time span from 1950 through 1980.

Water-level measurements are usually taken in the spring and fall. Therefore, the spring and fall water-level data were examined separately so that seasonal fluctuations in the water table would not be included in the calculations of water-level change. However, during the 1950s and 1960s many of the wells were measured once a year; this significantly reduced the number of data points that could be used to track the changes taking place. Further examination of the data showed that, relative to the changes occurring across a 5-year time interval, the seasonal variation in water levels was insignificant. Therefore, when both spring and fall water-level measurements were available, they were averaged to provide one data point per well per year.

DISCUSSION OF PLOTS

The point data of water-level changes across each 5-year time interval are plotted on background (plan view) maps of the Hanford site (Figures 3 through 7 and Figure 9; Figure 8 shows a hydrograph plot of the well with the plus 25 value in the southeast corner in Figure 7). The number of data points available for plotting was often so great that closely spaced data points similar in magnitude were removed to make the plots readable. Occasionally, apparent 'flyers' or anomalously large data values appear on the plots; in these instances, the hydrograph of the well was plotted, and the history of the well (boring record, maintenance record) was examined in order to find an explanation or form a hypothesis about the cause of the anomalous data point. Compare each of the plots with the discharge volumes listed in Tables 1, 2, and 3.

1950 TO 1955

Figure 3 shows the water table changes that occurred between 1950 and 1955. The large increases south of Gable Butte corresponded to the discharges from T Plant, U Plant, Z Plant, and the Redox facilities, all in the 200-West Area. The small increases in the 200-East Area, south of Gable Mountain, resulted from B Plant discharges. These increases reflect the outer fringe of the mound under the B Pond. The minus six value, located in the immediate vicinity of the B Pond, reflects the B Plant shutdown prior to the PUREX Plant startup. Table 3 shows that the 200-West Area received almost 90% of the total water discharges during this time period.

1955 TO 1960

Figure 4 shows the water table changes that occurred between 1955 and 1960. In the 200-West Area, large decreases are observed; these correspond with the shutdown of T Plant and U Plant. The outer fringe of the 200-West Area mound continued to spread north toward Gable Butte and south toward the Yakima Ridge. In the 200-East Area, increases in water levels corresponded with the startup of the PUREX Plant and the discharge of waters into Gable

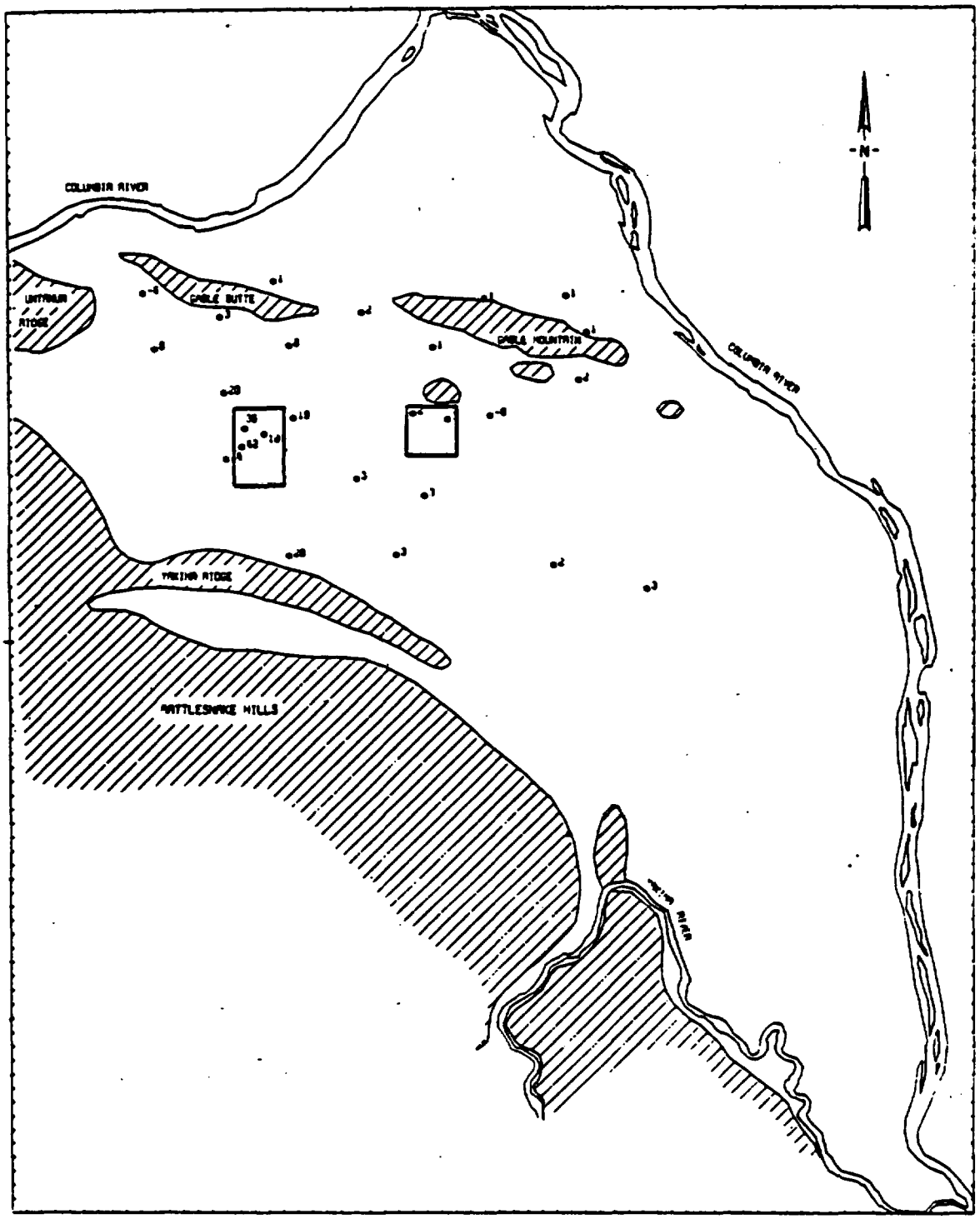


FIGURE 3. Water Level Changes (in feet) from 1950 to 1955

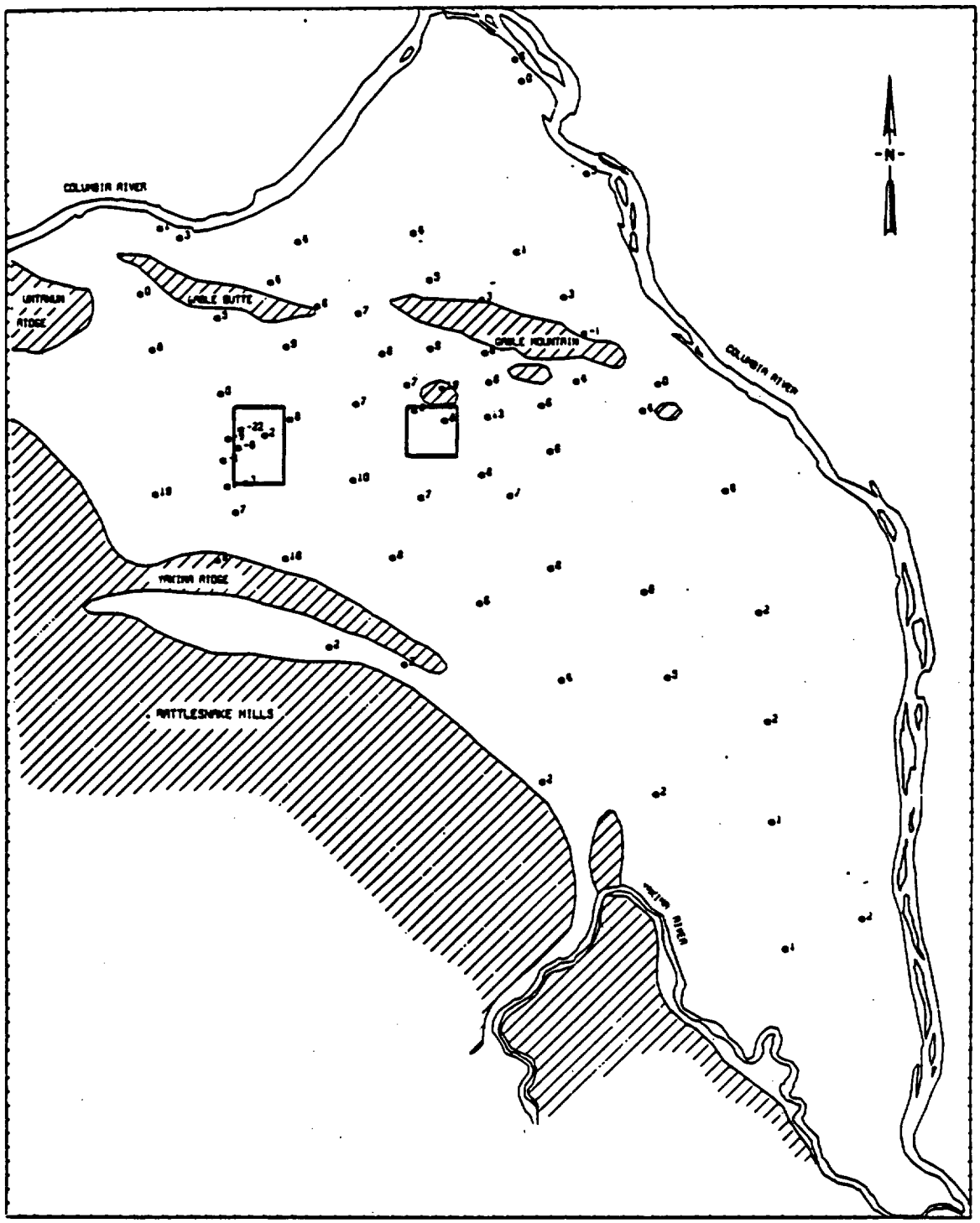


FIGURE 4. Water Level Changes (in feet) from 1955 to 1960

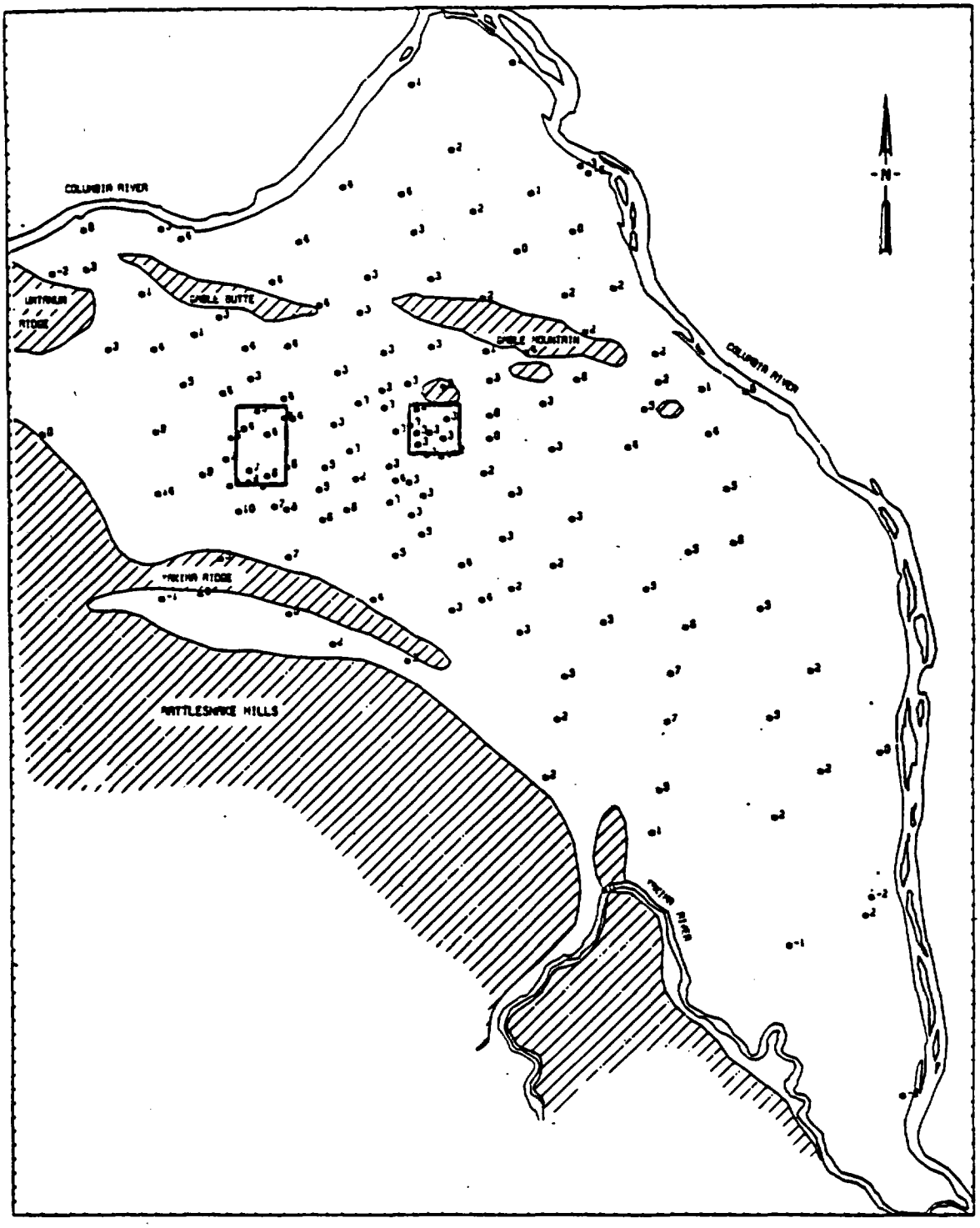


FIGURE 5. Water Level Changes (in feet) from 1960 to 1965

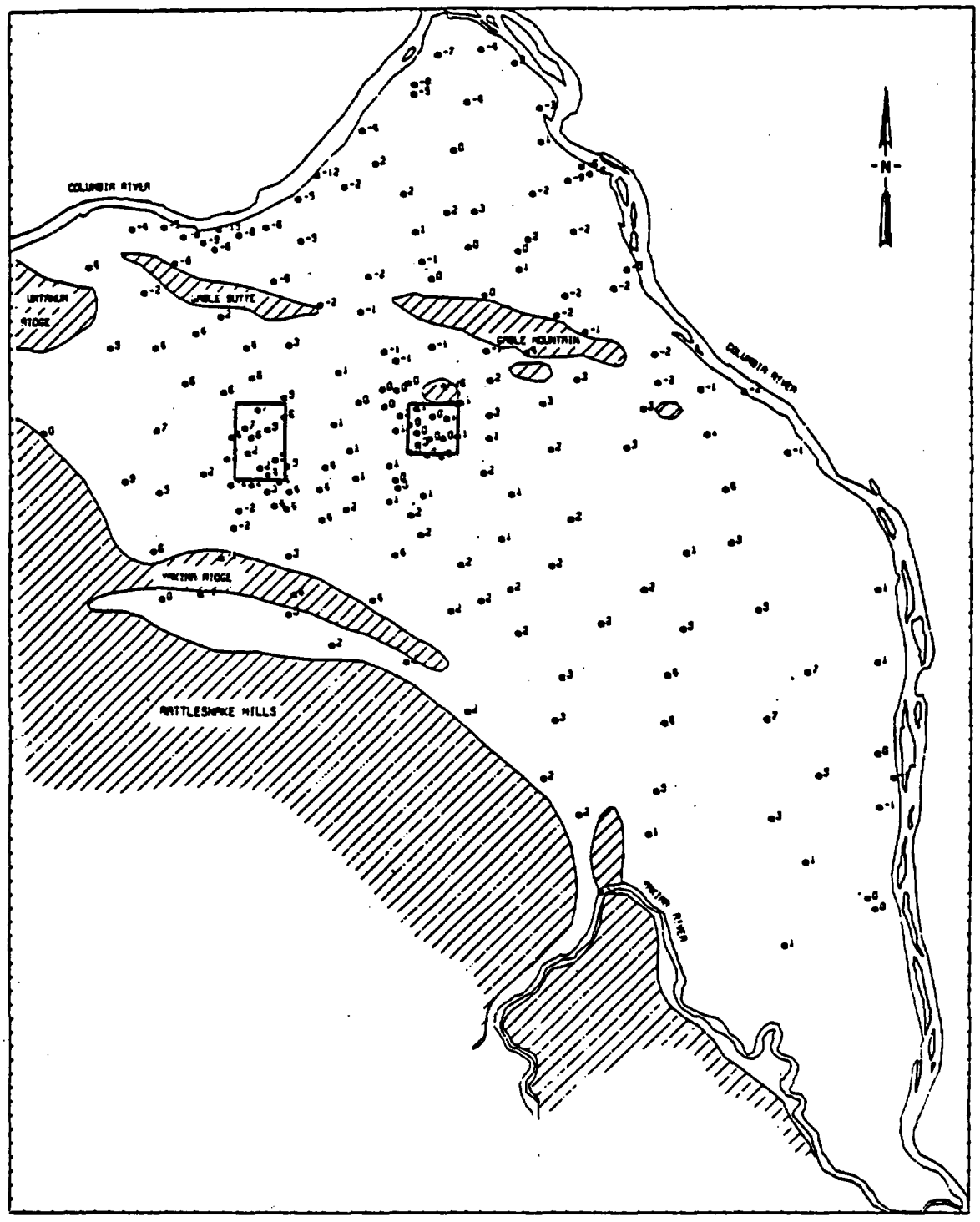


FIGURE 6. Water Level Changes (in feet) from 1965 to 1970

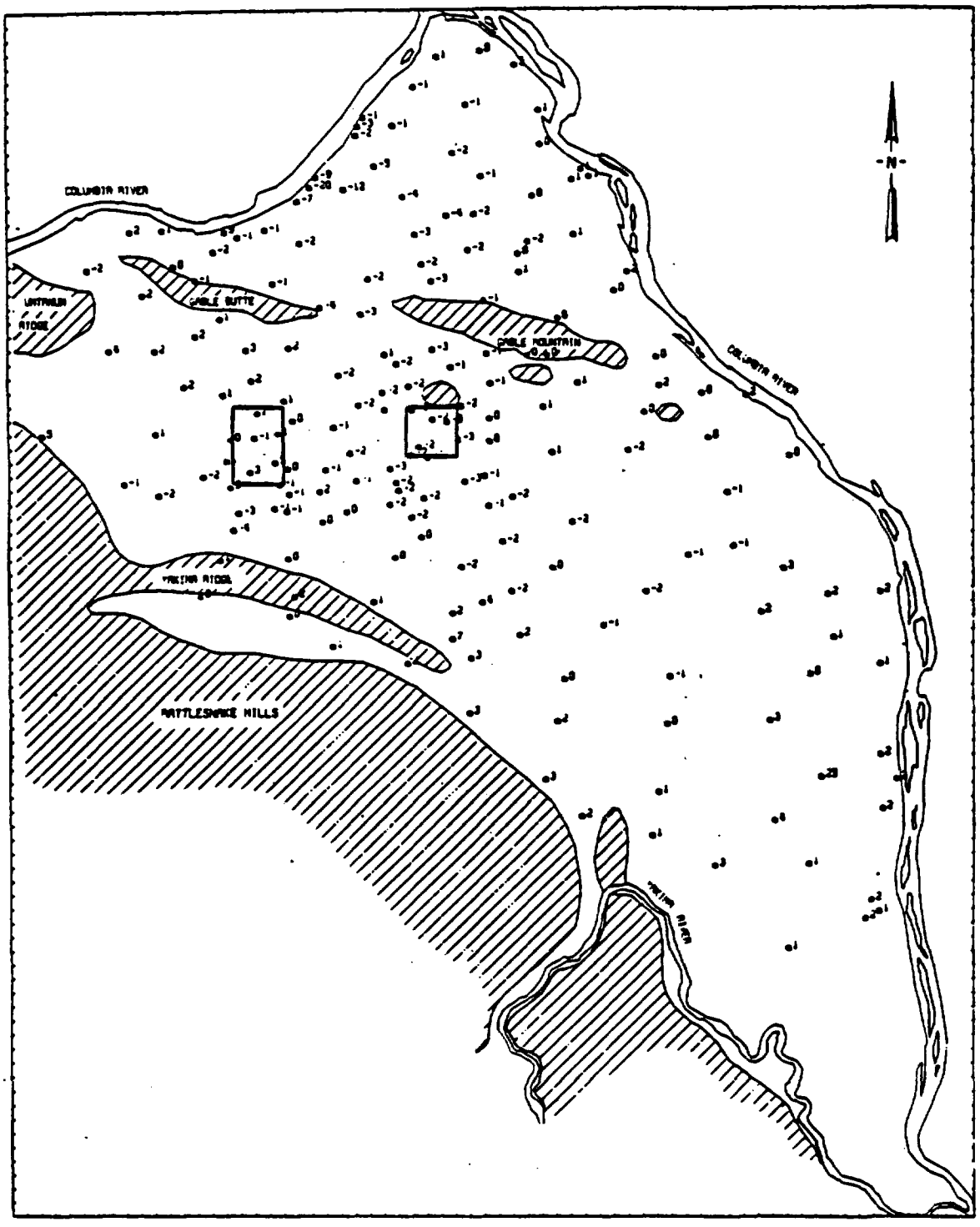
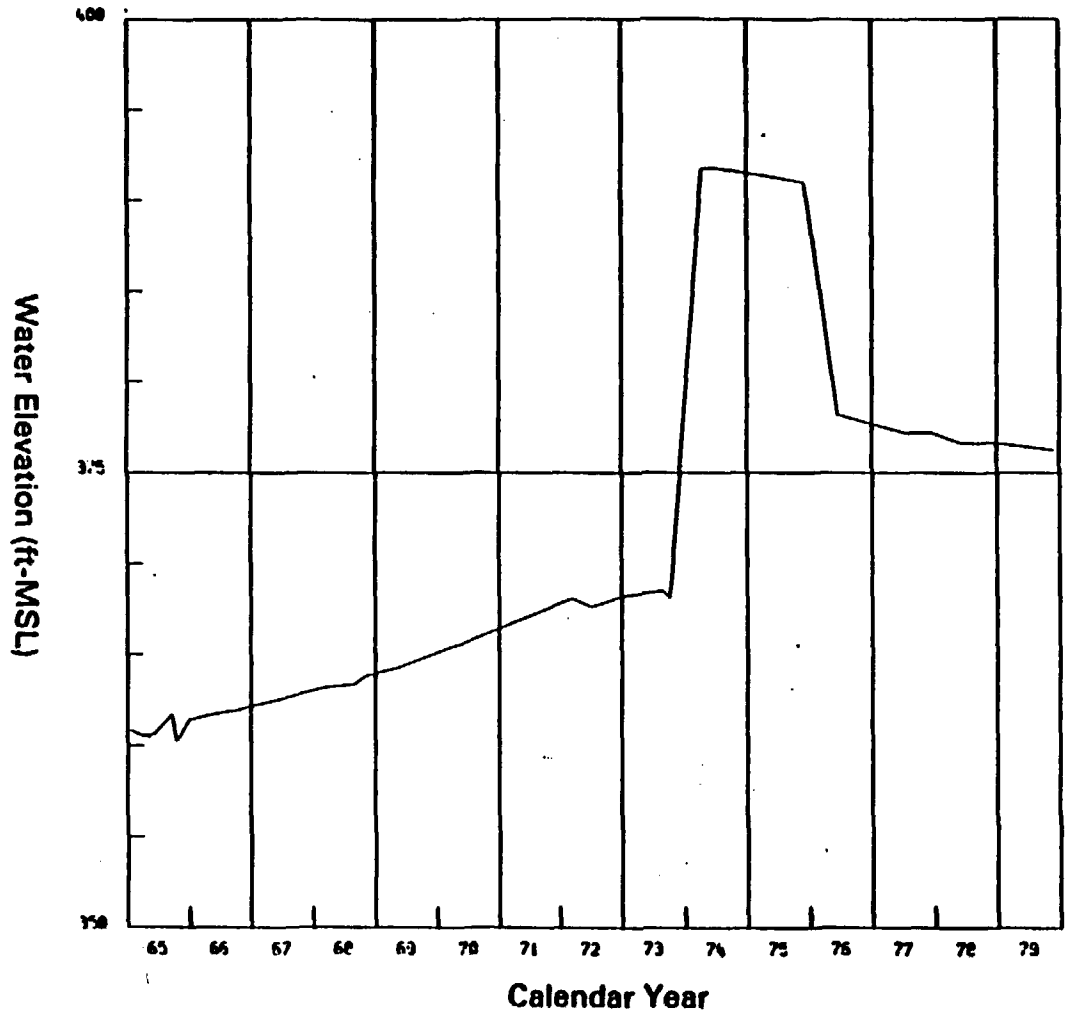


FIGURE 7. Water Level Changes (in feet) from 1970 to 1975



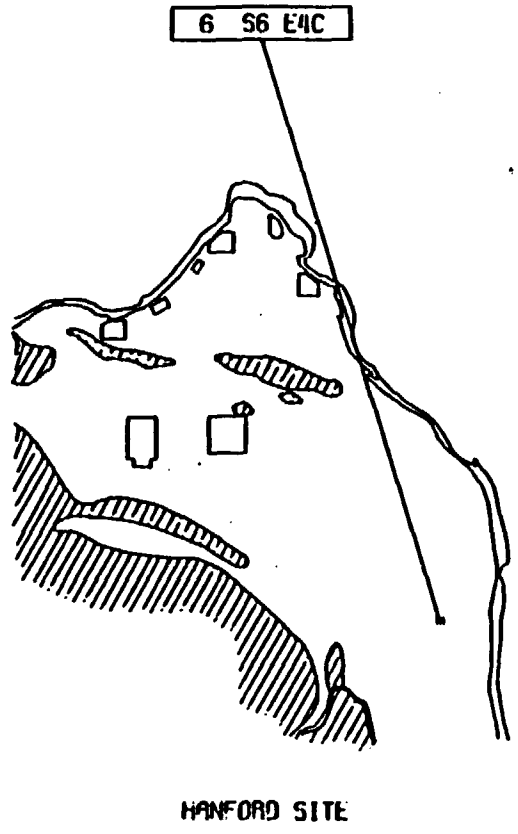


FIGURE 8. Water Level History in Well 699-S6-E46

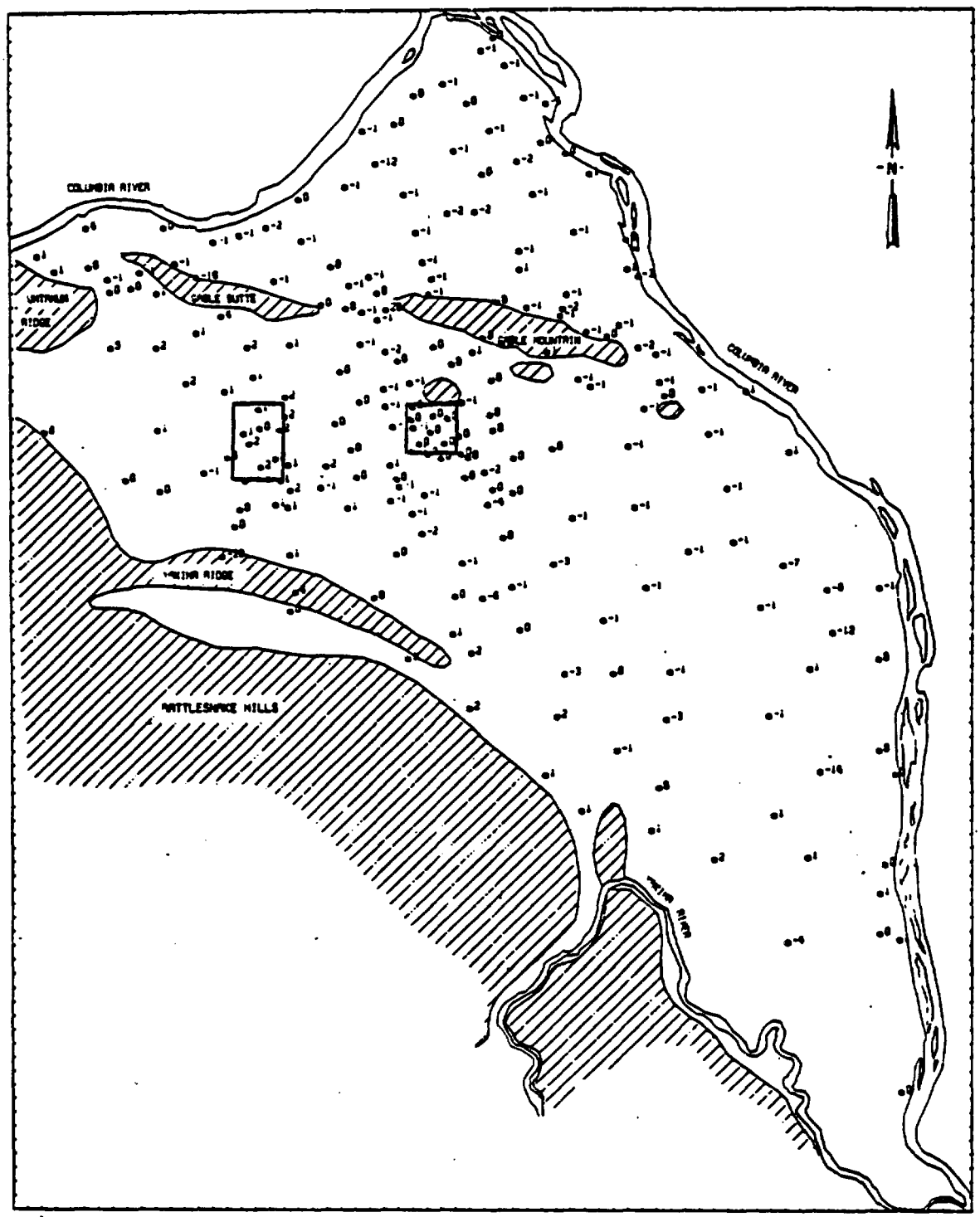


FIGURE 9. Water Level Changes (in feet) from 1975 to 1980

Gable Mountain pond during this time period. Larger rises occurred in the 200-West Area than in 200-East Area because materials in the 200-West Area have a lower transmissivity. The transmissivity 'interface' between the East and West Areas occurs along an imaginary line extending from the east end of Gable Butte to the east end of the Yakima Ridge; the West Area mound is consistent with this geometry. The large plus 19 value north of the Yakima Ridge is probably due to the continued spreading of the 200-West Area mound onto these low transmissive materials together with irrigation water from the upper Cold Creek area moving eastward into the basin. Small rises in water levels to the southeast reflect the continued spreading of both 200-East and 200-West ground-water mounds.

1960 TO 1965

Figure 5 shows the water table changes that occurred between 1960 and 1965. In the 200-West Area, Redox and Z Plant continued to operate, and the mound continued to spread. Irrigation water from the Upper Cold Creek Valley added to the rising levels (plus 9 and plus 14 values) to the west of the 200-West Area. In the 200-East Area, PUREX Plant discharged water into various cribs near the PUREX facility. Water from the PUREX Plant can be diverted into either B pond or Gable Mountain Pond or both. Table 1 shows that the Gable Mountain Pond received ~80% of the water discharges during this time period (2.5 times more water than the previous 5-year interval), while flows into the B Pond were decreased from the previous 5-year interval. Water levels continued to rise to the south and east of the 200 Areas as the ground-water mounds continued to spread outward.

1965 TO 1970

Figure 6 shows the water table changes that occurred between 1965 and 1970. In the 200-West Area, small decreases corresponded with the shutdown of the Redox Plant in 1967; Table 1 shows that total discharges to 200-West Area fell to almost half the volume discharged during the previous 5-year time interval. In other areas farther away from the U Pond, the 200-West Area mound continued to spread. In the 200-East Area, few changes in water levels

discharges from the 200-East Area facilities and the aquifer's ability to transmit the water away. The minus 26 value occurs in well 699-49-48, which was deepened to 1165 ft and penetrated the basalt; therefore, this data point does not reflect a water-level change in the unconfined system. The large decreases that occurred north of Gable Butte corresponded with the shutdown of 100-B and 100-C reactors. Other decreases along the Columbia River north of Gable Mountain appear to have corresponded with the shutdown of 100-KW, 100-D, 100-H, and 100-F reactors.

1970 TO 1975

Figure 7 shows the water table changes that occurred between 1970 and 1975. The small changes that occurred throughout the Hanford site indicate that the unconfined aquifer system was beginning to approach equilibrium with the sources. The small decreases in the 200-West Area, occurring several miles from the U Pond, were probably due to the slow propagation of the effects from the shutdown of the Redox Plant finally reaching the outer fringes of the mound. The decreases in the 200-East Area corresponded with the shutdown of the PUREX Plant. Large decreases along the Columbia River north of Gable Gap (the gap between Gable Butte and Gable Mountain) corresponded with the shutdown of 100-KW and 100-KE reactors. The small negative values at the 100-N reactor location are probably related to the shutdown of 100-KW and 100-KE reactors, which are 2 miles upgradient from the 100-N reactor.

A plus 25 value appears on Figure 7 near the river in the southeast corner of the Hanford site. This well, 699-S6-E4C, had four piezometers (O, P, Q, R) installed to various depths in 1964. The deepest piezometer (P) was open from 439 to 449 ft; the driller's log shows basalt from 435 to 461 ft. It is believed that measurements of the 'P' tube piezometer were mistakenly recorded for the shallow piezometer (the 'O' tube) during 1974 and 1975. Thus the higher basalt water levels are reflected in the hydrograph plot of well 699-S6-E4C, which is shown in Figure 8. A listing of the water levels measured for the 'O' and 'P' tubes shown in Tables 5 and 6 support this theory. In January 1976 the piezometers were removed. Thus, measurements made after 1976

TABLE 5. Hydrograph Data (in feet) for Well 699-S6-E4CP (The 'P-Tube')

20-SEP-65	389.65	5-NOV-68	390.03	4-OCT-72	390.94
30-SEP-65	389.67	23-APR-69	390.36	3-JAN-73	389.81
18-OCT-65	389.83	21-NOV-69	388.72	10-AUG-73	391.07
27-DEC-65	389.96	1-DEC-69	388.64	15-JAN-74	391.82
22-MAR-66	389.54	17-DEC-69	388.77	15-APR-74	391.67
5-APR-66	389.32	5-JAN-70	388.63	15-JUL-74	391.69
11-APR-66	389.51	26-JAN-70	388.96	14-OCT-74	391.70
16-MAY-66	389.72	2-FEB-70	388.74	7-JAN-75	391.13
24-JUN-66	389.89	16-FEB-70	389.04	14-APR-75	391.21
20-JUL-66	389.56	1-APR-70	389.01	15-JUL-75	391.22
13-OCT-66	389.21	20-MAY-70	388.71	15-DEC-75	390.99
30-DEC-66	389.55	7-AUG-70	388.86	1-JUL-77	377.45
5-APR-67	389.53	13-SEP-71	388.70	7-DEC-77	377.45
17-OCT-67	389.59	7-MAR-72	390.93	1-JUN-80	376.54
28-AUG-68	389.65	3-JUL-72	390.83		

TABLE 6. Hydrograph Data (in feet) for Well 699-S6-E4C (The 'O-Tube'). (Data within borders show P-Tube measurements were mistakenly recorded for the 'O-Tube' during 1974 and 1975.)

13-JAN-65	360.84	30-DEC-66	362.19	30-SEP-73	368.13
1-APR-65	360.54	5-APR-67	362.39	11-OCT-73	368.85
18-MAY-65	360.59	17-OCT-67	362.84	10-APR-74	391.73
10-JUN-65	360.67	13-MAR-68	363.21	8-JUL-74	391.75
8-JUL-65	360.98	28-AUG-68	363.38	7-JUL-75	391.22
20-SEP-65	361.71	5-NOV-68	363.85	3-DEC-75	390.99
18-OCT-65	360.24	23-APR-69	364.22	15-JUN-76	378.15
27-DEC-65	361.42	1-APR-70	365.47	15-JUL-77	377.19
2-MAR-66	361.53	20-MAY-70	365.59	15-DEC-77	377.19
5-APR-66	361.61	7-MAR-72	368.09	1-JUN-78	376.65
11-APR-66	361.65	3-JUL-72	367.63	1-DEC-78	376.65
16-MAY-66	361.70	4-OCT-72	367.92	1-DEC-79	376.24
20-JUL-66	361.82	3-JAN-73	368.22		
13-OCT-66	361.96	27-AUG-73	368.50		

reflect the head in the entire open interval rather than any particular zone. This explains the elevated level of the heads observed after 1976 (caused by the contribution from the deepest zone).

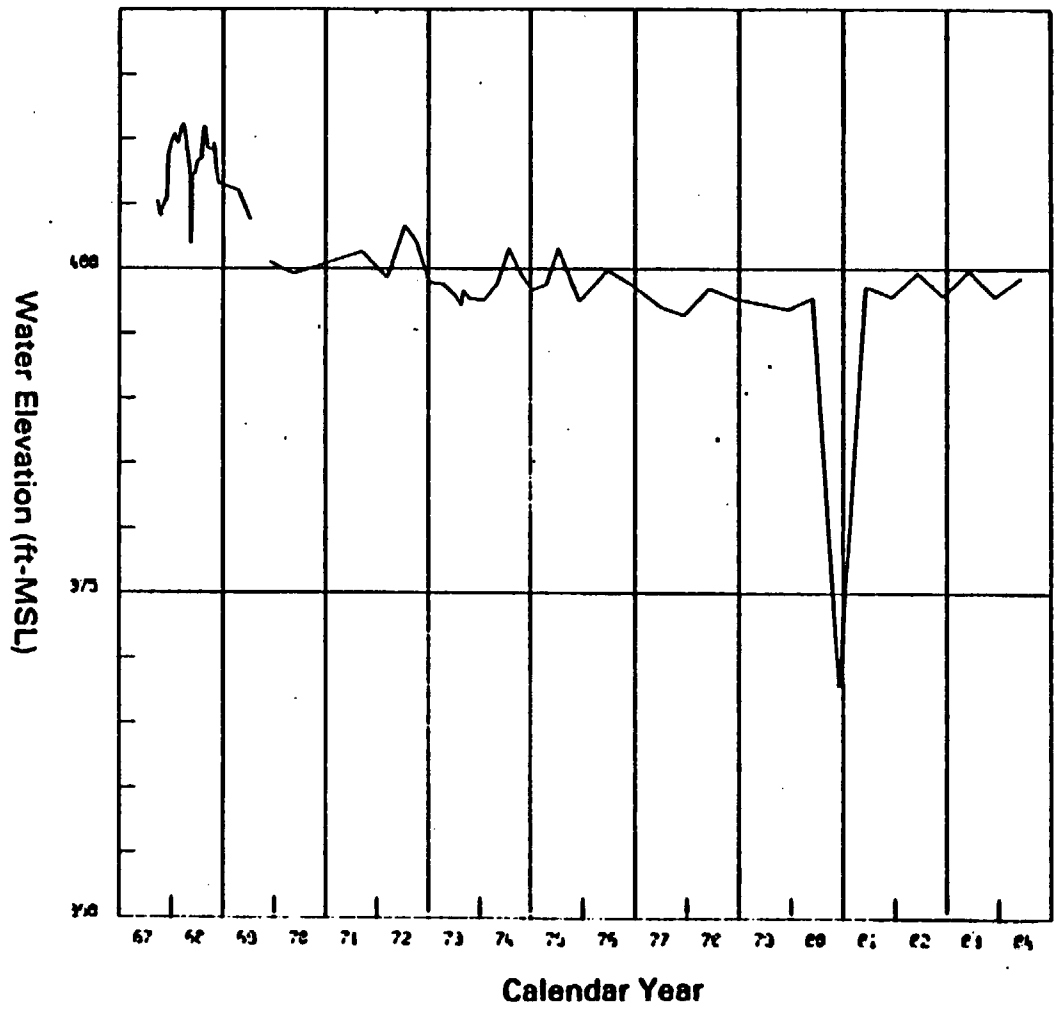
1975 TO 1980

Figure 9 shows the water table changes that occurred between 1975 and 1980. The preponderance of low and zero values throughout the 200 Areas suggests that the unconfined system was in approximate equilibrium with the discharges being applied to it. Figure 9 has several anomalously large data points that require explaining.

The hydrograph of well 699-65-83 (Figure 10) shows that the minus 16 value on the north edge of Gable Butte is probably a 'flyer'.

North of Gable Gap near the Columbia River, a minus 12 value appeared for well 699-81-58. An examination of the original records used to input water-level data into the computer data base showed that an incorrect casing elevation was recorded for this well in 1981 and 1982. The data base has since been corrected. The hydrograph for this well is shown in Figure 11.

The other minus 12 value, located along the Columbia River at the eastern edge of the Hanford site, occurs in well 699-14-E6R. There are five 699-14-E6 wells (P, Q, R, S, and T) spaced about 40 ft apart at this location, all drilled to different depths. The R well was drilled deeper than the S and T wells, indicating that it measured water levels from the deeper system as opposed to the shallow system. It is postulated that the aquifer to which this well is open was under confined or semiconfined conditions and was responding to pumping from wells that are located ~1.5 miles to the west. During construction of the Washington Public Power Supply System reactor, WNP-2, nearby wells were pumped for dust control. The hydrograph of the shallowest well, the T-well (Figure 12), is relatively flat, while the hydrograph of the deeper R-well (Figure 13) drops and fluctuates at a lower level after 1975.



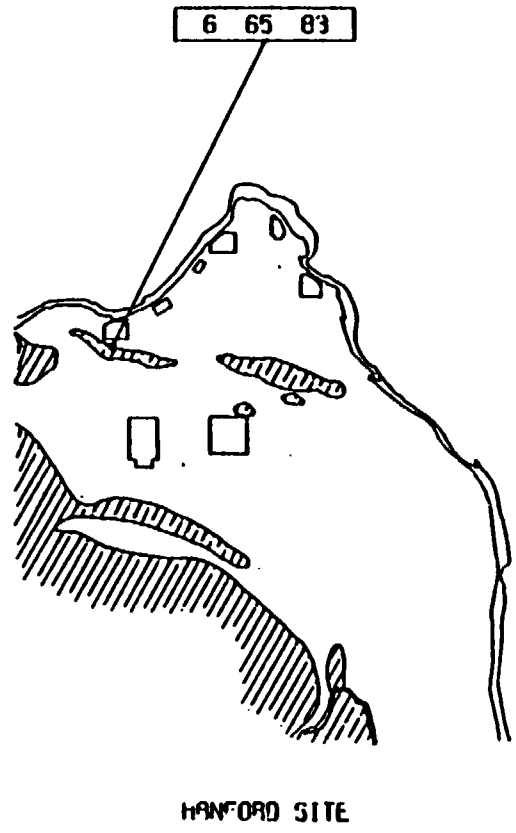


FIGURE 10. Water Level History in Well 699-65-83

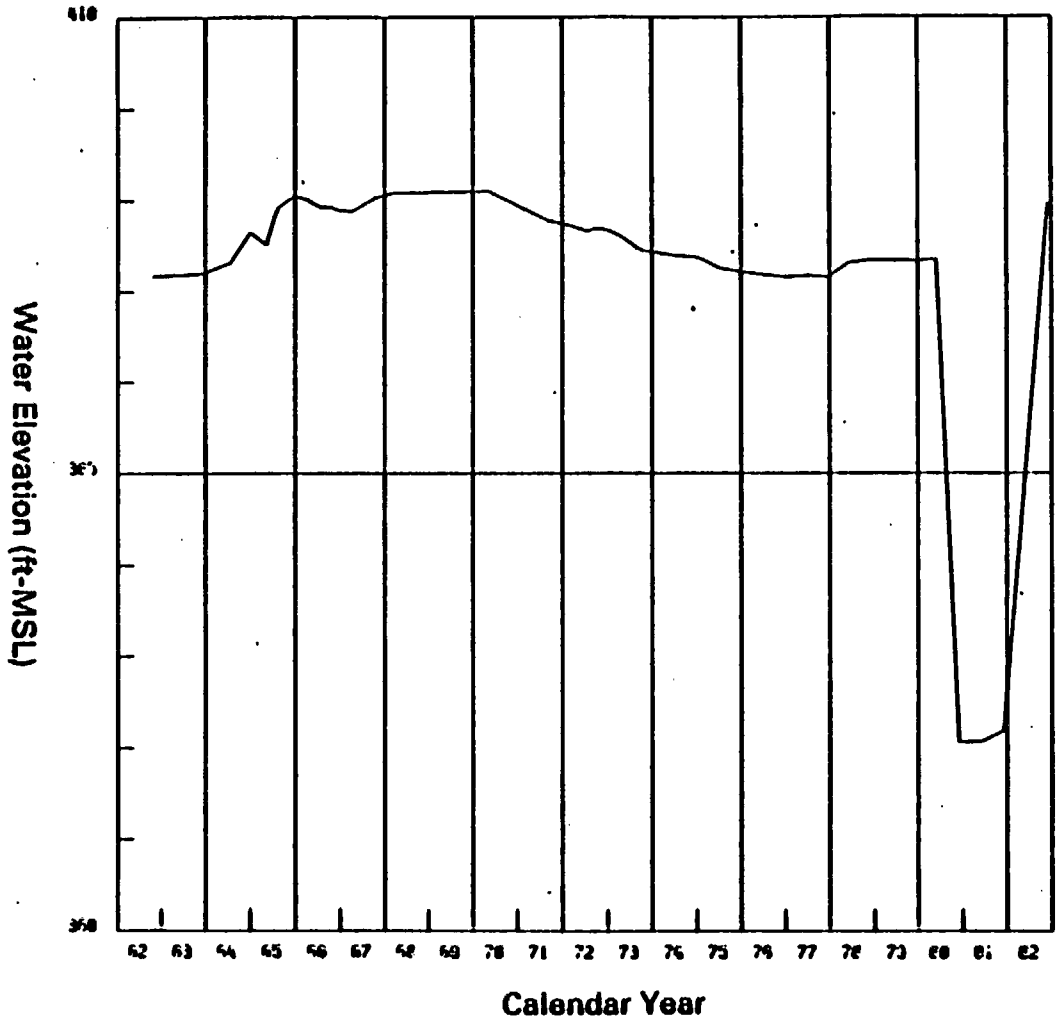
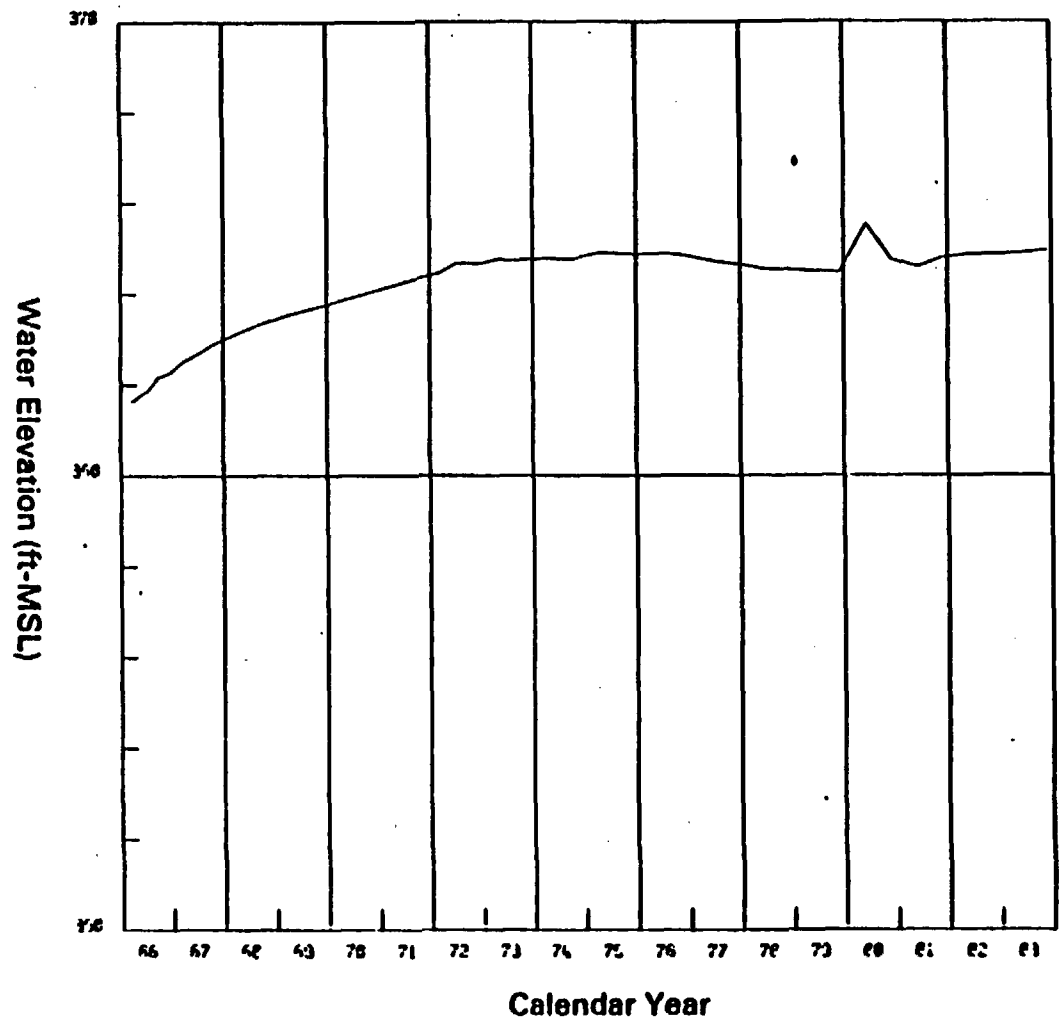


FIGURE 11. Water Level History in Well 699-81-58



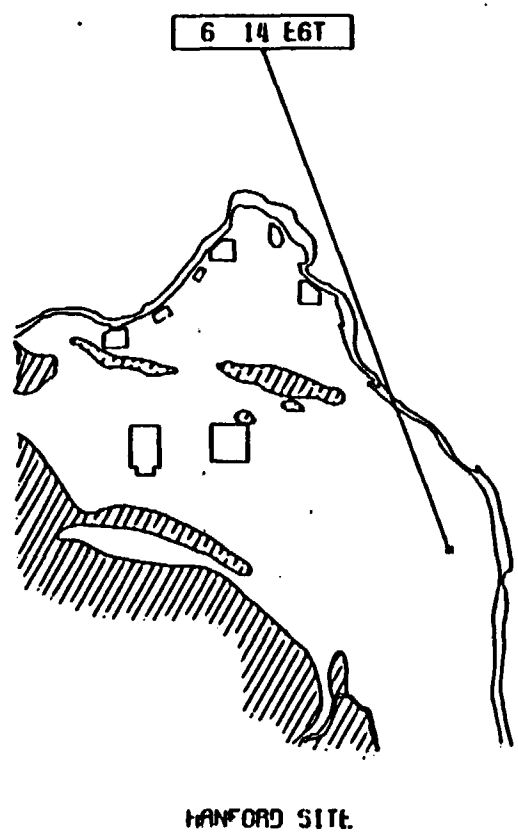


FIGURE 12. Water Level History in Well 699-14-E6T

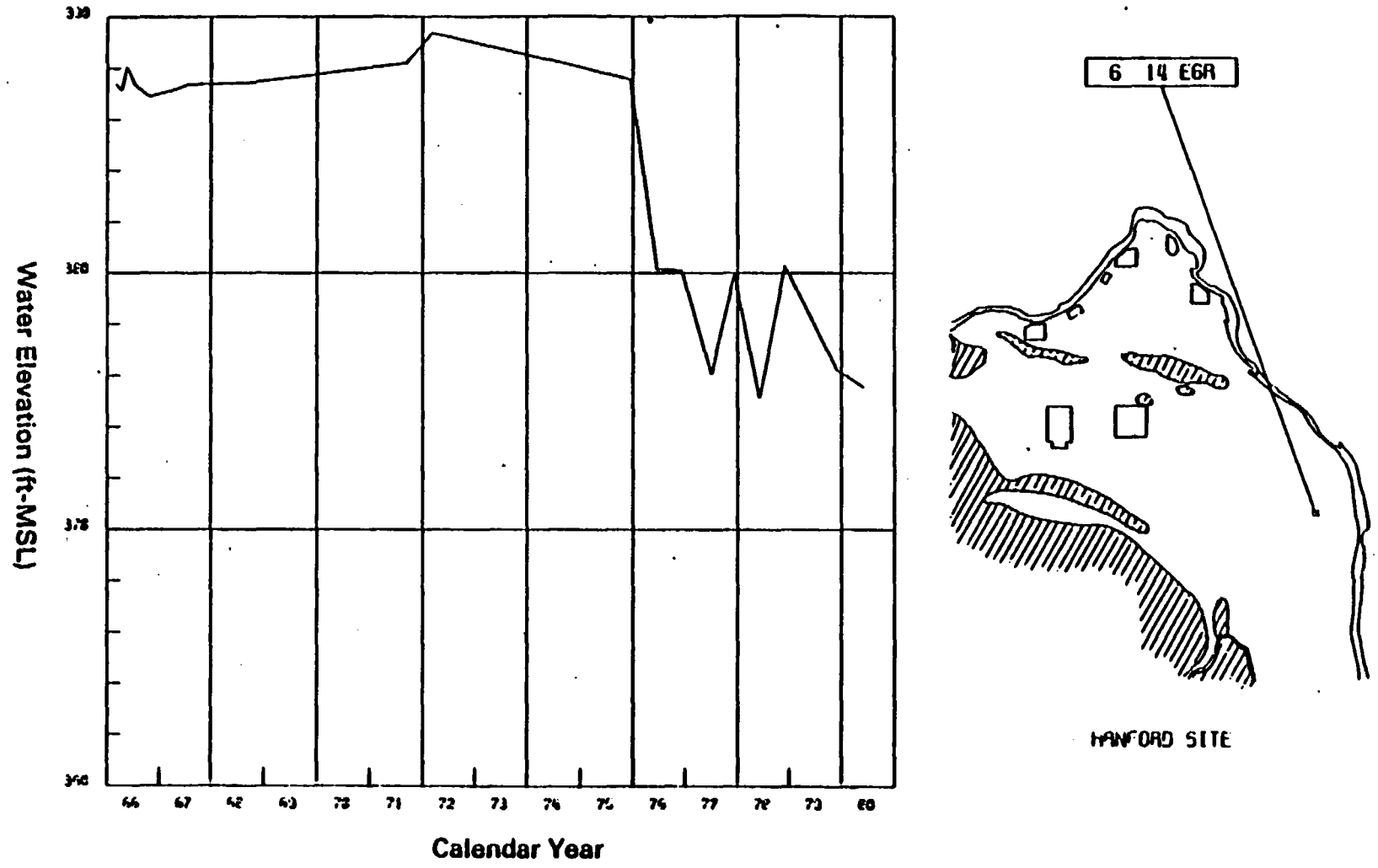


FIGURE 13. Water Level History in Well 699-14-E6R

Also near the Columbia River, at the east end of the Hanford site but farther to the south, is a minus 14 data value. This drop in water level (Figure 8) occurred in well 699-S6-E4C, probably because the wrong piezometer tube was measured in 1974 and 1975 as discussed previously.

South of the 200-West Area on the northern flank of the Yakima Ridge is a minus 23 value; records for this well, 699-25-80, state that remedial work was performed from June to September 1967. In 1978, BWIP deepened the well to 1038 ft; the well is now designated DB-14 and measures water levels in basalt (McGhan and Damschen 1979). Both of these disturbances are reflected in the hydrograph of well 699-25-80, which is shown in Figure 14.

At the west end of the Hanford site is a large plus eight value; in Figure 7, this well showed an increase of 5 ft for the 1970 to 1975 time interval. It appears that this well, 699-43-104, may have been responding to irrigation practices occurring at the St. Michelle Vineyards (located at the west end of the Cold Creek Valley). The hydrograph for well 699-43-104 (Figure 15) shows little change until about 1969 when water levels began to rise linearly with time. The St. Michelle Vinyards came into operation in 1973. Before 1973, the land was owned by Pacific Coast Nursery, which began operations in 1969. Before 1969 the land was farmed using furrow irrigation. When Pacific Coast Nursery took over the property, only about 70% of the land was in production. In addition, the 'Brown well', which was the source pumping well for irrigation water, yielded only ~750 to 800 gal/min. The nursery performed well maintenance, increasing its yield to 1200 gal/min; repaired broken irrigation piping; and expanded the amount of land in production.[a] It is postulated that the irrigation practices of Pacific Coast Nursery and St. Michelle Vinyards resulted in the increased water levels that appeared in well 699-43-104 after 1969.

Finally, at the west end of Gable Mountain, a plus 26 value appears for well 699-60-57. Examination of the original records used to input the water-level measurements into the computer data base revealed that an incorrect

(a) History of Pacific Coast Nursery's operations obtained via telephone conversation with Mr. Gary Ballard, manager of Pacific Coast Nursery's Cold Creek operations.

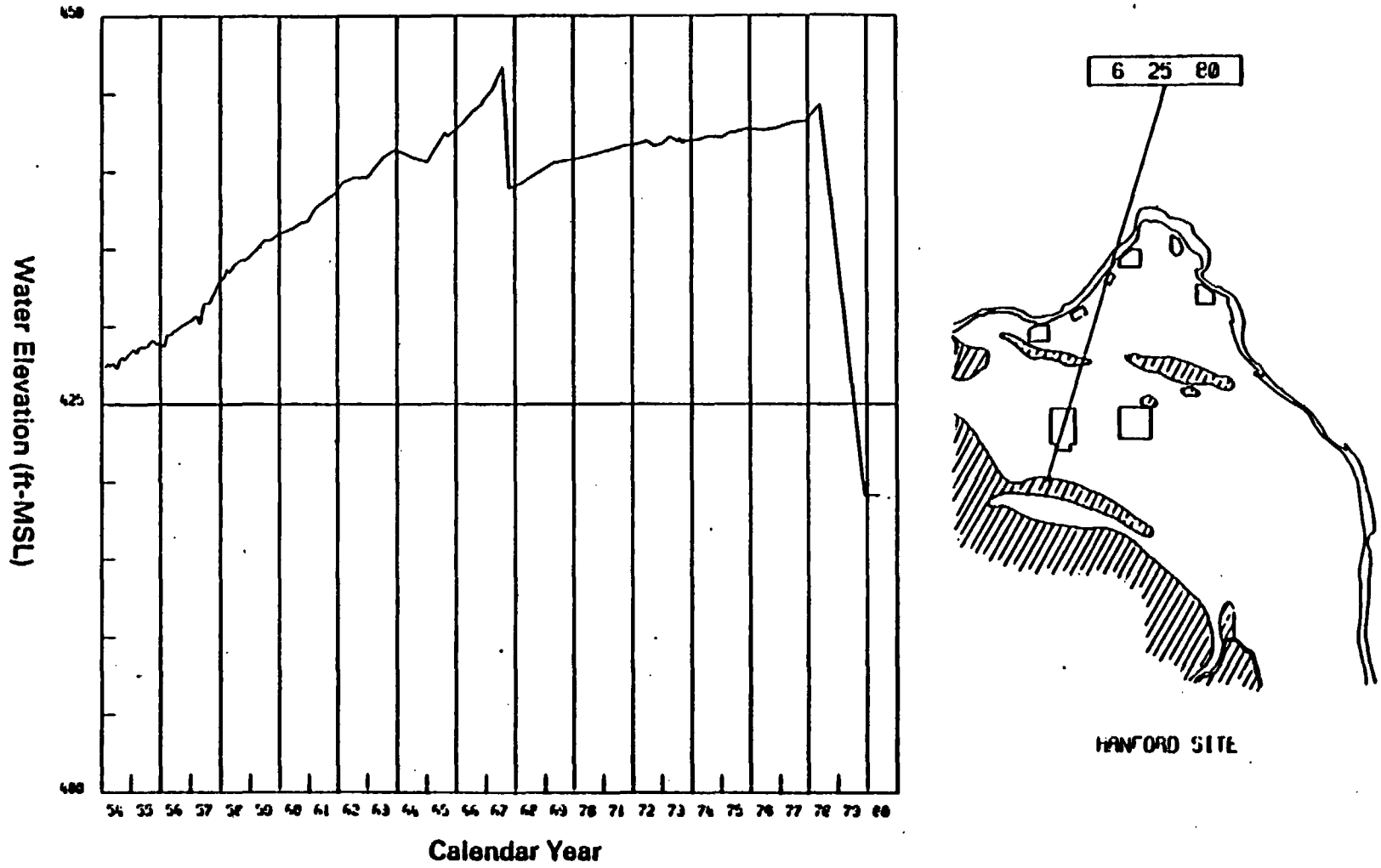
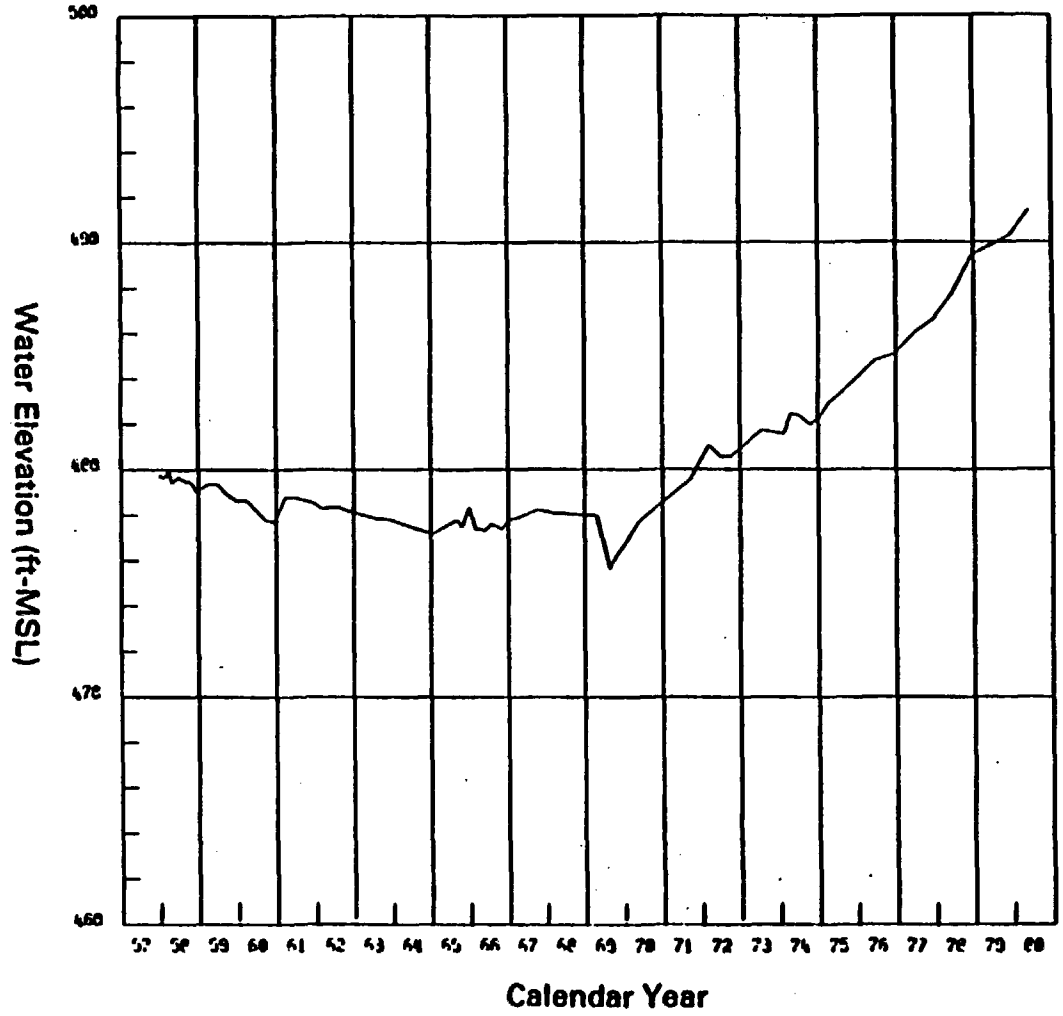


FIGURE 14. Water Level History in Well 699-25-80



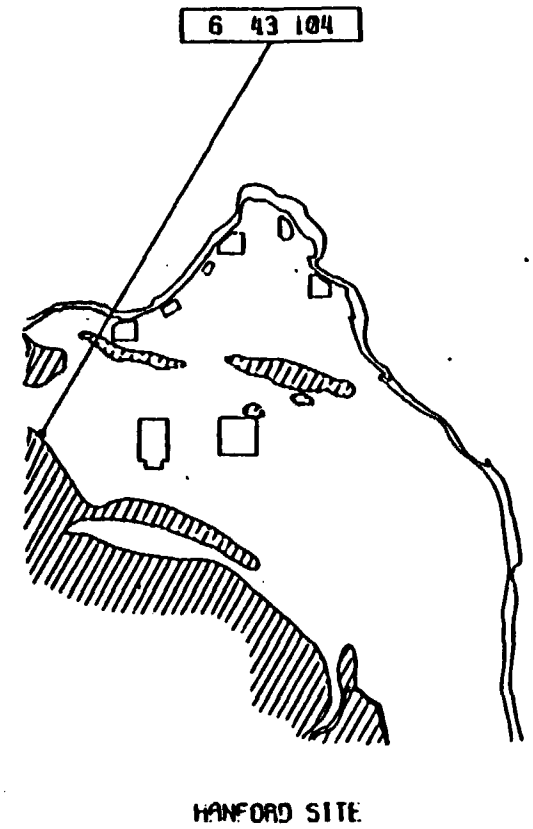


FIGURE 15. Water Level History in Well 699-43-104

casing elevation was used; the records listed 496 ft instead of 4[illegible] ft, a transposition of error resulting in a difference of 27 ft. The data base has since been corrected.

1950 TO 1980

Figure 16 shows the water table changes that occurred between 1950 and 1980. These data points show that large increases in the water table under the 200 Areas have occurred since the 1950s. The mounds are highest in the 200-West Area and spread east toward the Columbia River. The East-West transmissivity interface between the 200 East and West Areas is illustrated by the high values marked 27, 39, 15, and 20 running from the east end of Gable Butte to the east end of Yakima Ridge.

Hydrographs of the wells plotted on Figure 16 are grouped according to the key on Figure 17. The hydrographs are plotted on Figures 18 through 41. These plots show the long-term trends in a set of wells that are distributed over the major portion of the Hanford site and that span the entire time period, 1950 to 1980. Areas 5 and 6 show little or no influence of mounding from wastewater discharges originating in the 200-East and -West Areas. The remainder of the hydrographs show large increases from 1950 to 1960, followed by moderate increases from 1960 to 1970, and only small increases to stable conditions occurring from 1970 to 1980.

Evidence of the delayed response of the southeastern portion of the unconfined aquifer to changes occurring under the 200-East Area can be seen in Figures 4 through 9. In Figure 4, large rises on the order of 6 to 8 ft occurred near the outer edge of the 200-East Area mound. In Figure 5, water-level changes in the southern region reflect increases of 5 to 7 ft (5 years later). In Figure 5, water levels under the 200-East Area increased on the order of 3 ft; during the next time interval, in Figure 6, similar water-level increases are observed across the southern region. In Figure 6 water levels near the 200 East Area remained stable; this lack of increase is reflected in Figure 7, where water-level changes in the southern region range from 0 to

2 ft. The general decrease in water levels around the 200-East Area in Figure 7 is reflected by the preponderance of negative values occurring across the southern region in Figure 9.

The small changes that occurred in wells at the southeast end of the Hanford site (Figure 16) are probably not indicative of any long-term trends because of their proximity to the river. The hydrographs of these wells (Figures 38 and 39) show that water levels in these wells are strongly influenced by river stage. Two other hydrographs, shown in Figures 36 and 37, illustrate the influence that river stage can have on water level measurements: well 699-63-90 was measured biannually nearly every year since 1949 and shows large fluctuations in water levels in response to changing river stages; well 699-66-103 also shows these fluctuations but was measured less frequently. Both of these wells are located in a zone of fairly high transmissivity. The attenuation of these fluctuations beginning in 1967 is probably due to the addition of new dams upstream from the Hanford site, which provided large increases in storage capacity. Before 1967, Grande Coulee, Albeni Falls, Kerr, and Hungry Horse Dams accounted for 11,000,000 acre-ft of storage; in 1967 Duncan, Mica, and Keenleyside Dams added 10,156,000 acre-ft of storage, and in 1972 Libby Dam added 4,900,000 acre-ft of storage. Thus, the total storage capacity of dams upstream from the Hanford site was more than doubled after 1967. Other dams on the Columbia River are run-of-river dams and have relatively insignificant storage capacity.

Hydrographs in Figures 23, 24, 25, and 30 show increases in water levels beginning in 1982. These wells are located near the PUREX facility and near B Pond in the 200-East Area. The rise in water levels in these wells is believed to result from a resumption of discharges from PUREX caused by pretesting operations as part of the preparations required for the restart of PUREX in 1983.

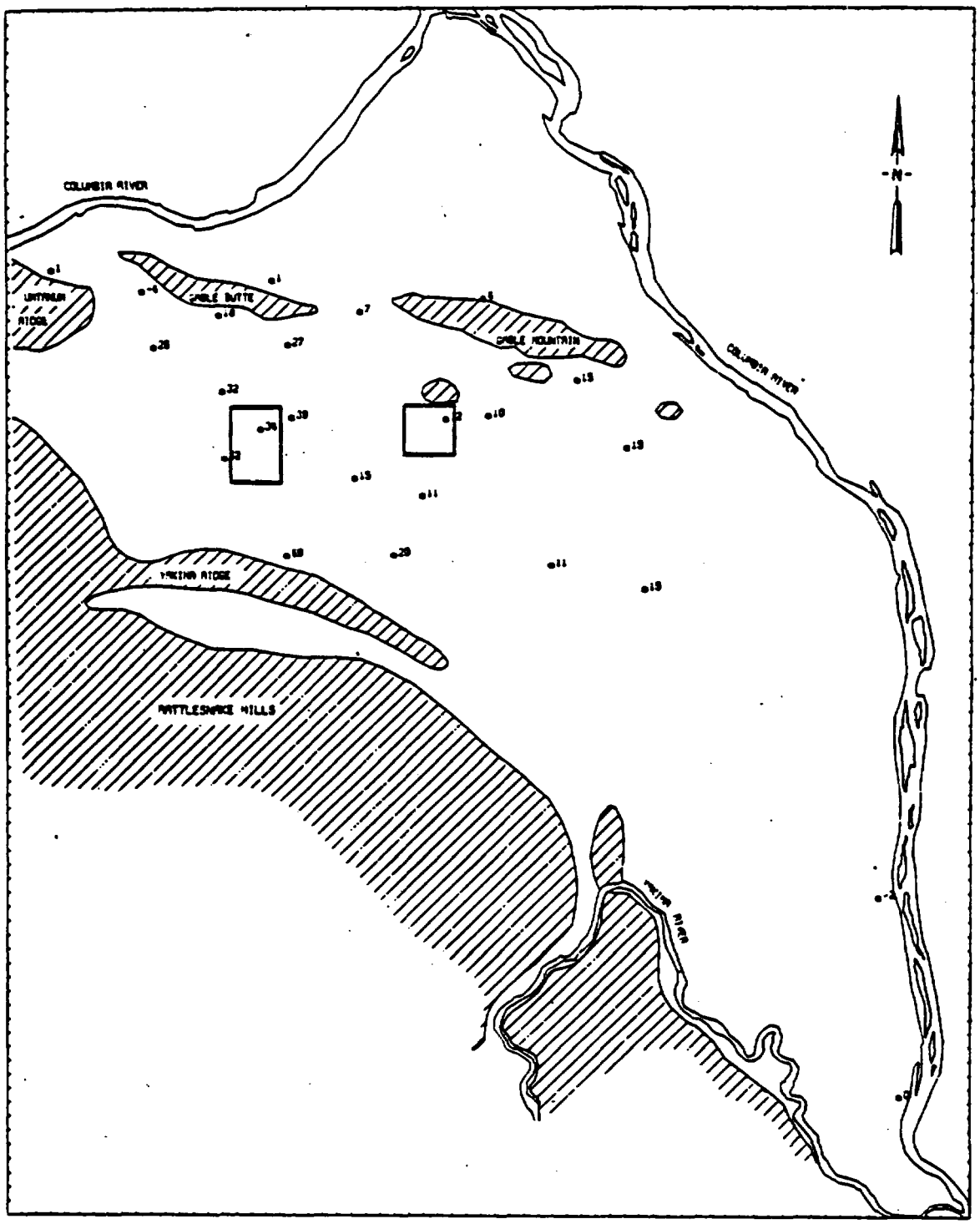


FIGURE 16. Water Level Changes (in feet) from 1950 to 1980

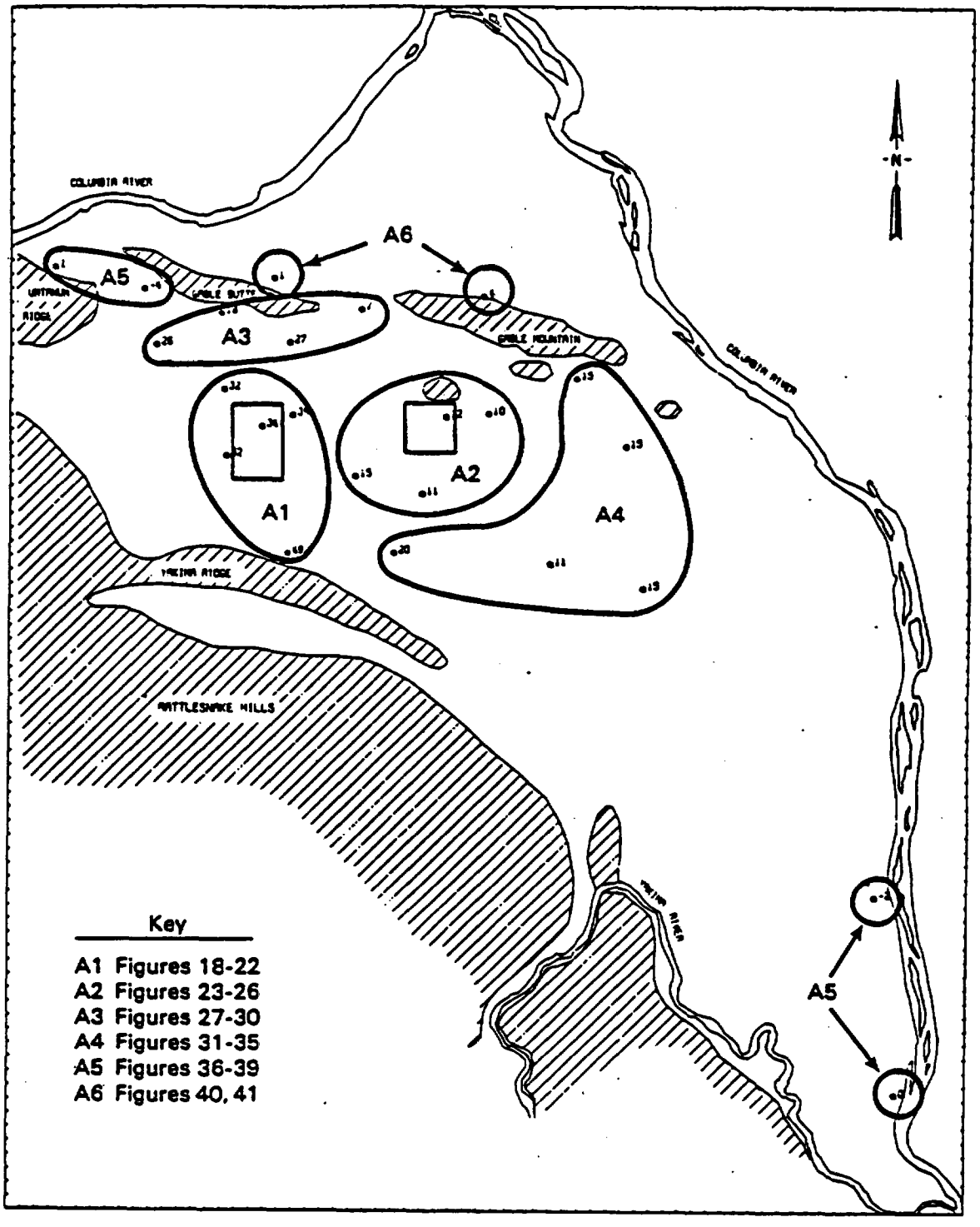
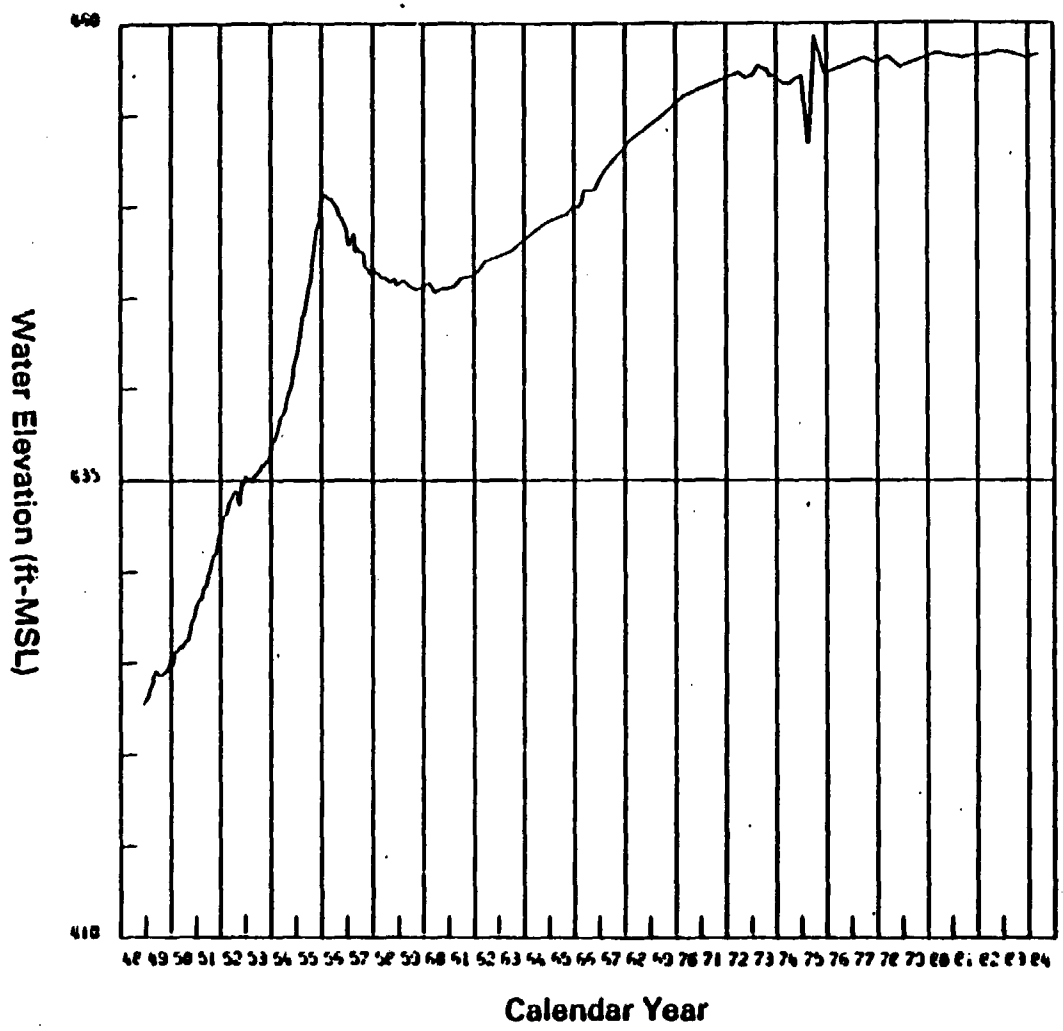


FIGURE 17. Key Map Showing Groupings of Hydrograph Plots (in feet)



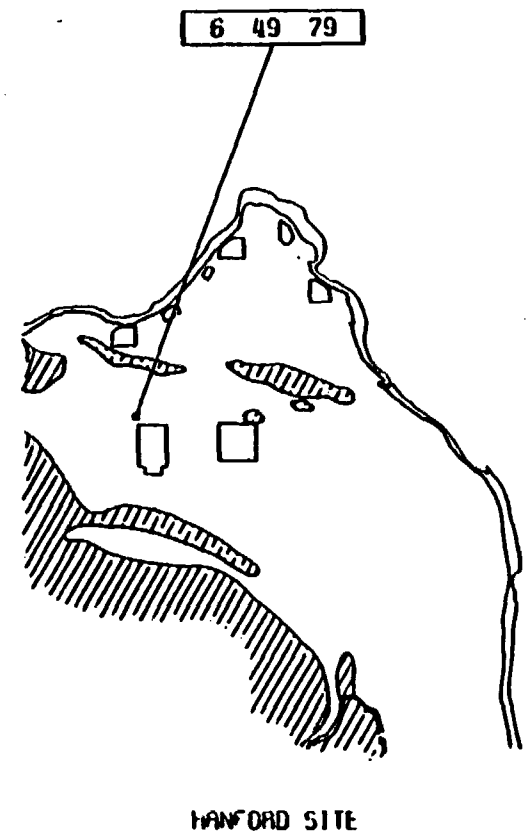


FIGURE 18. Water Level History in Well 699-49-79

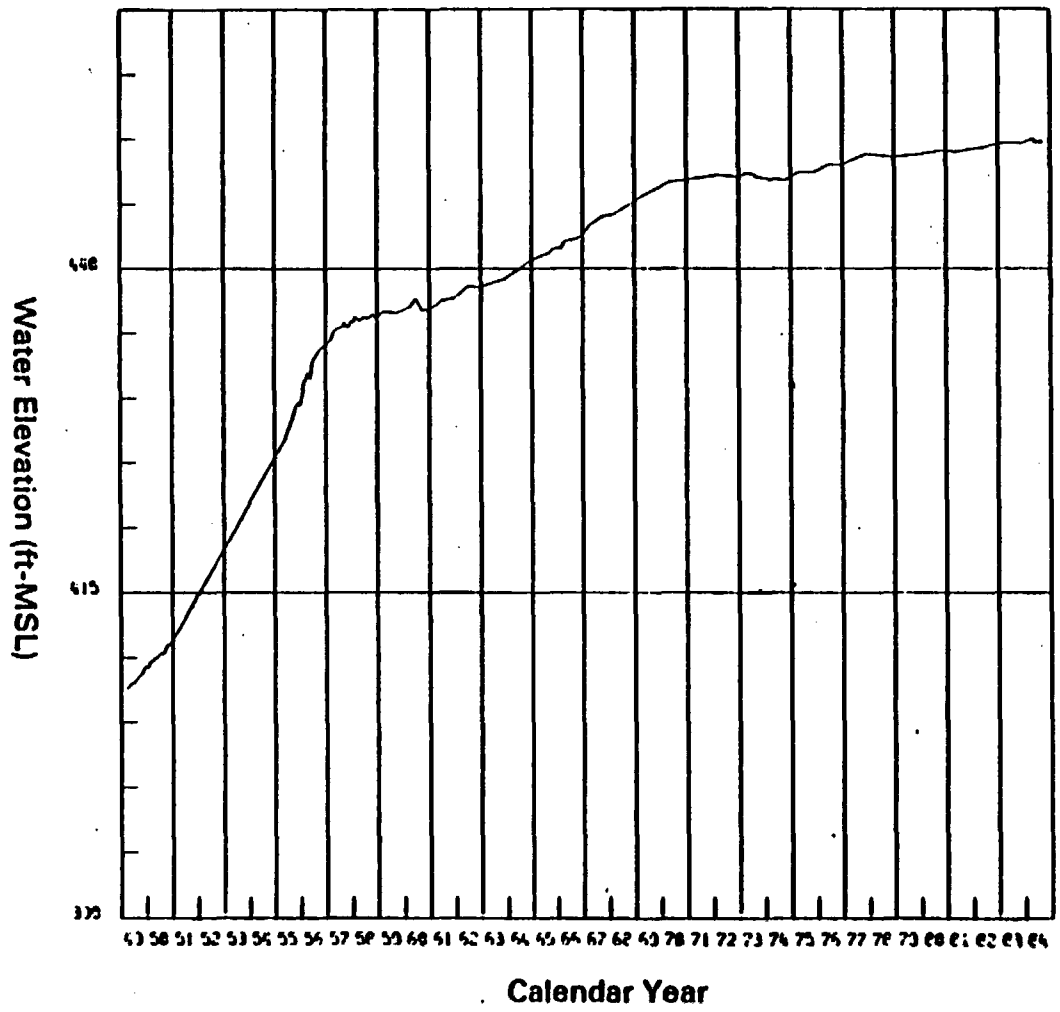
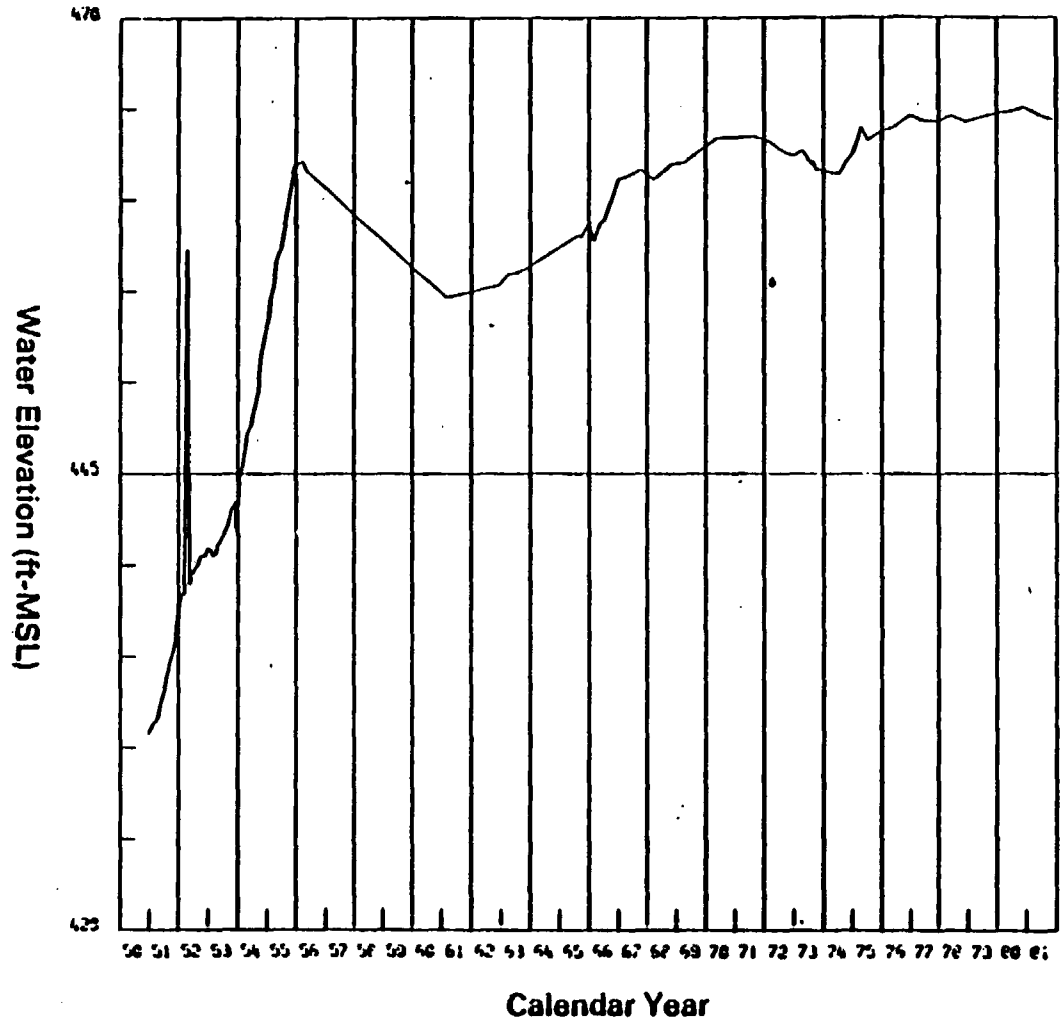


FIGURE 19. Water Level History in Well 699-45-69A



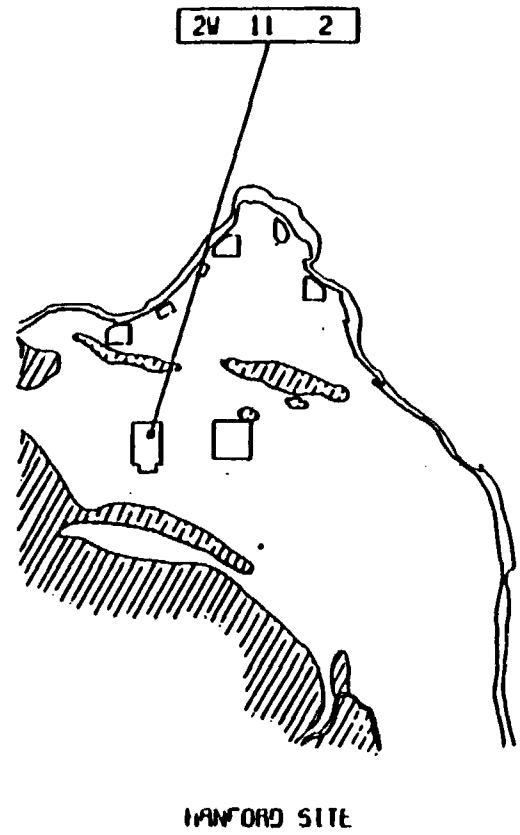


FIGURE 20. Water Level History in Well 299-W11-2

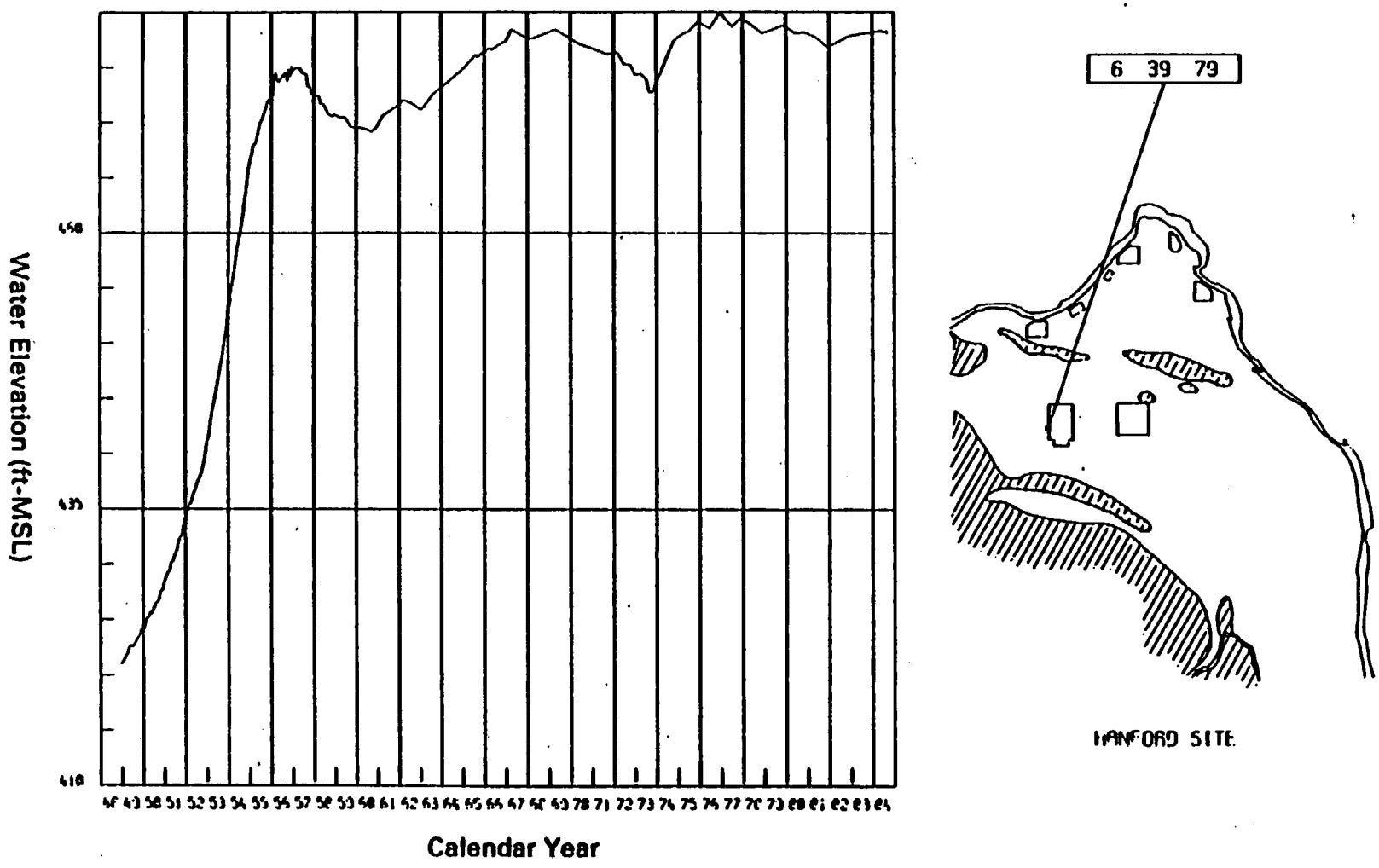


FIGURE 21. Water Level History in Well 699-39-79

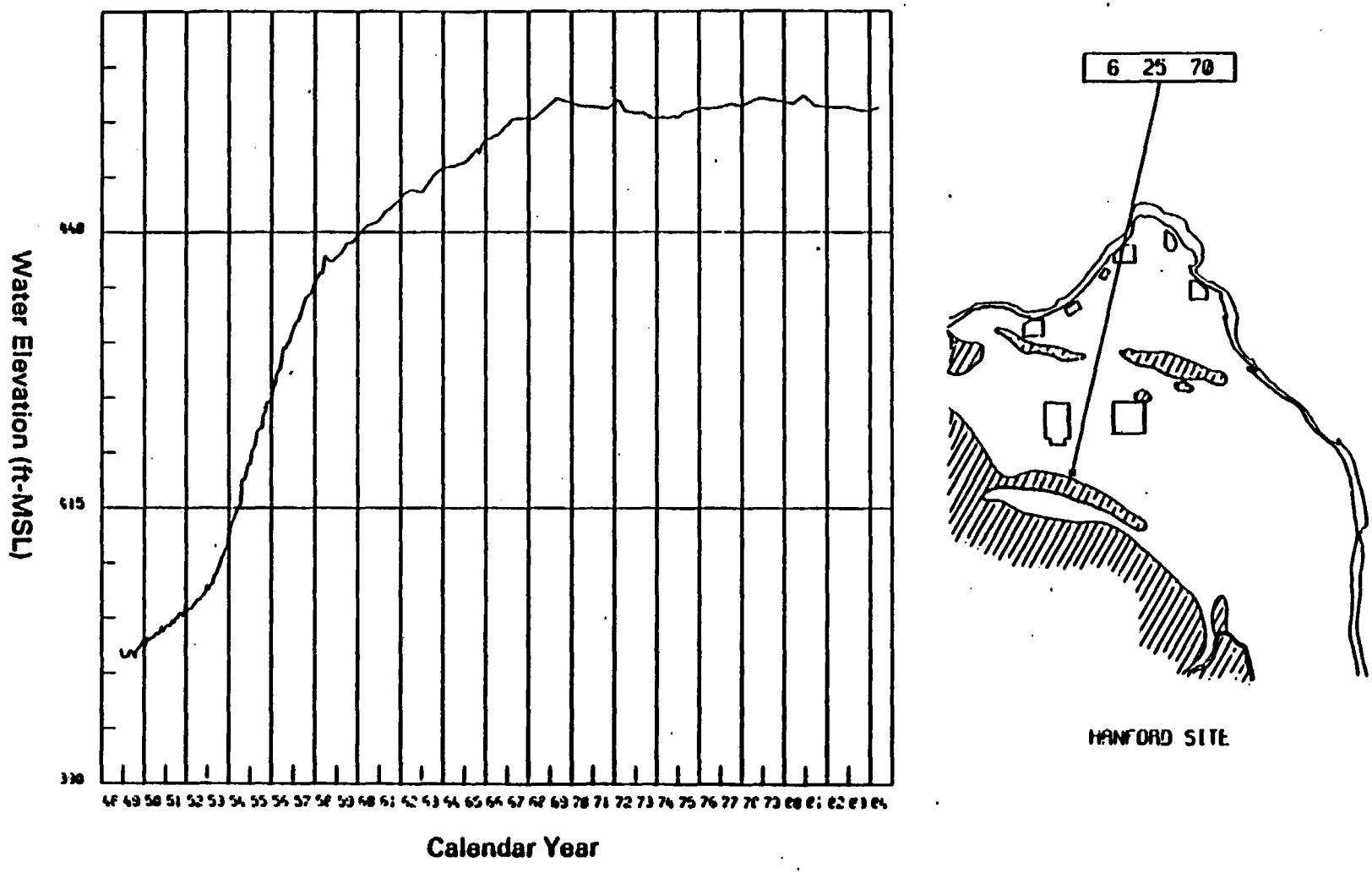
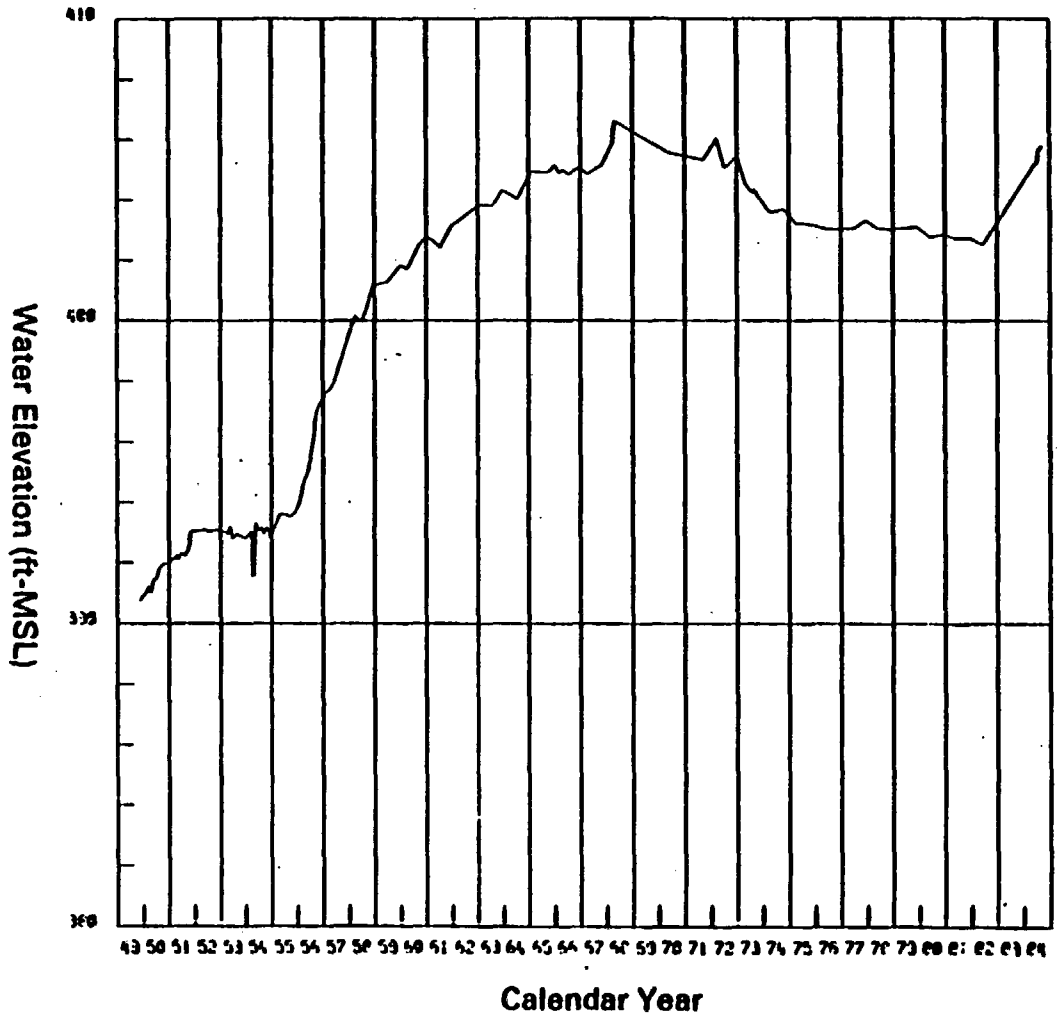


FIGURE 22. Water Level History in Well 699-25-70



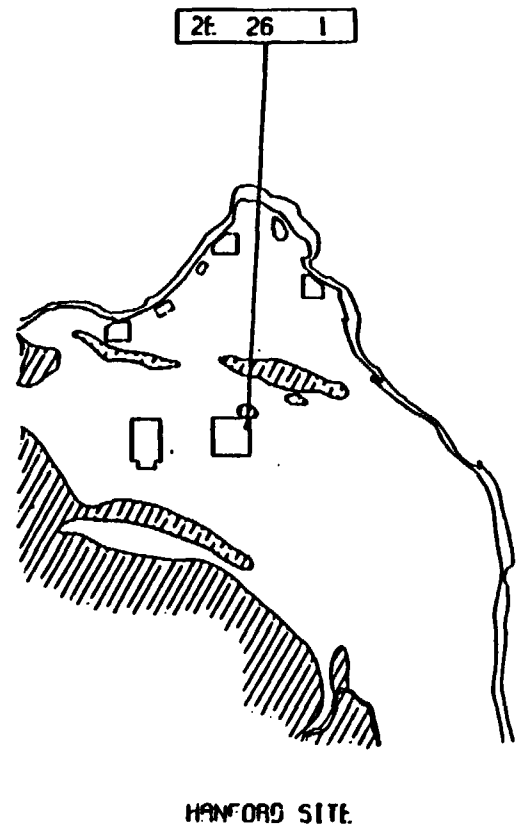
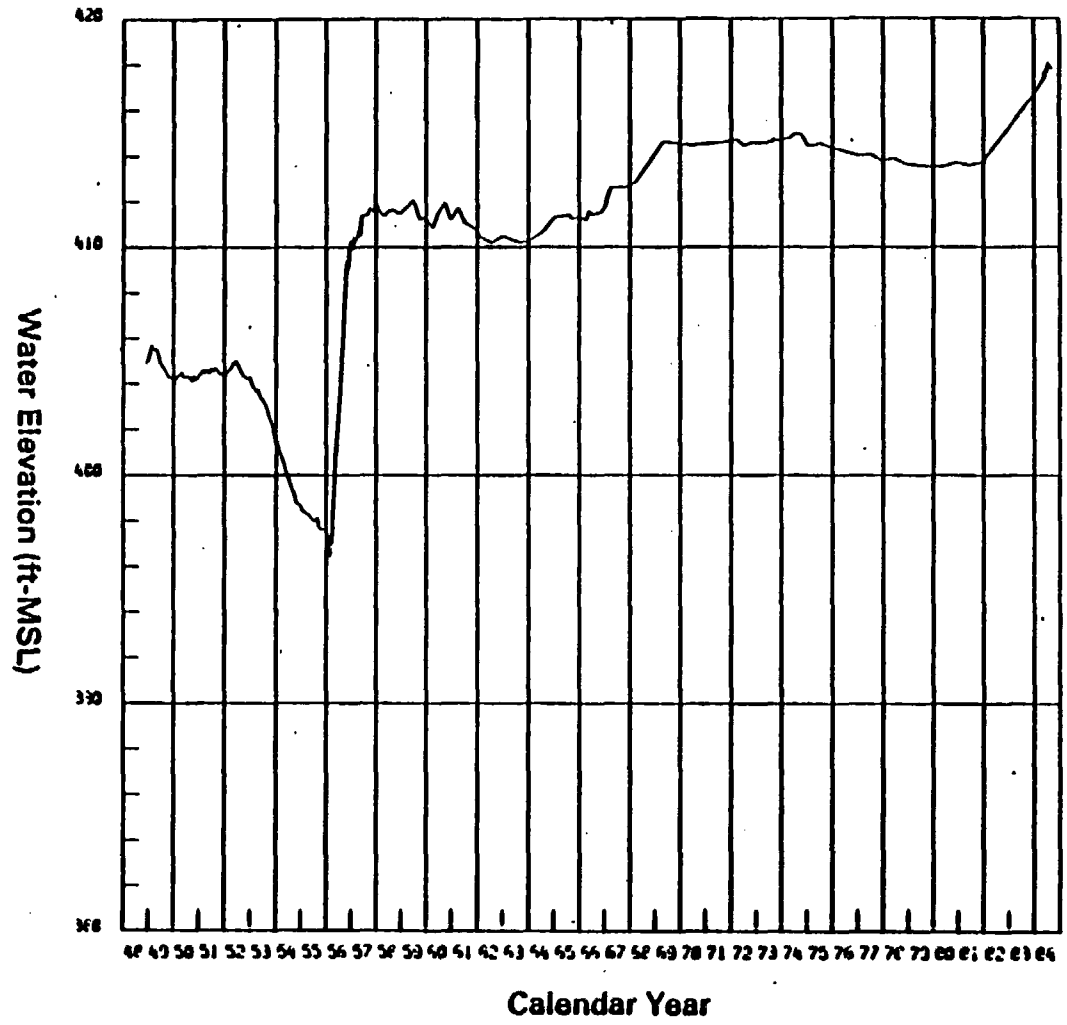


FIGURE 23. Water Level History in Well 299-E26-1



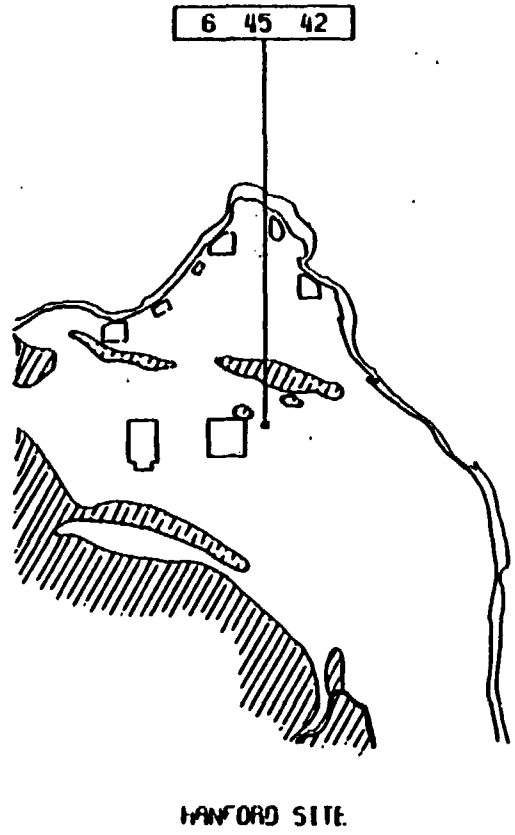
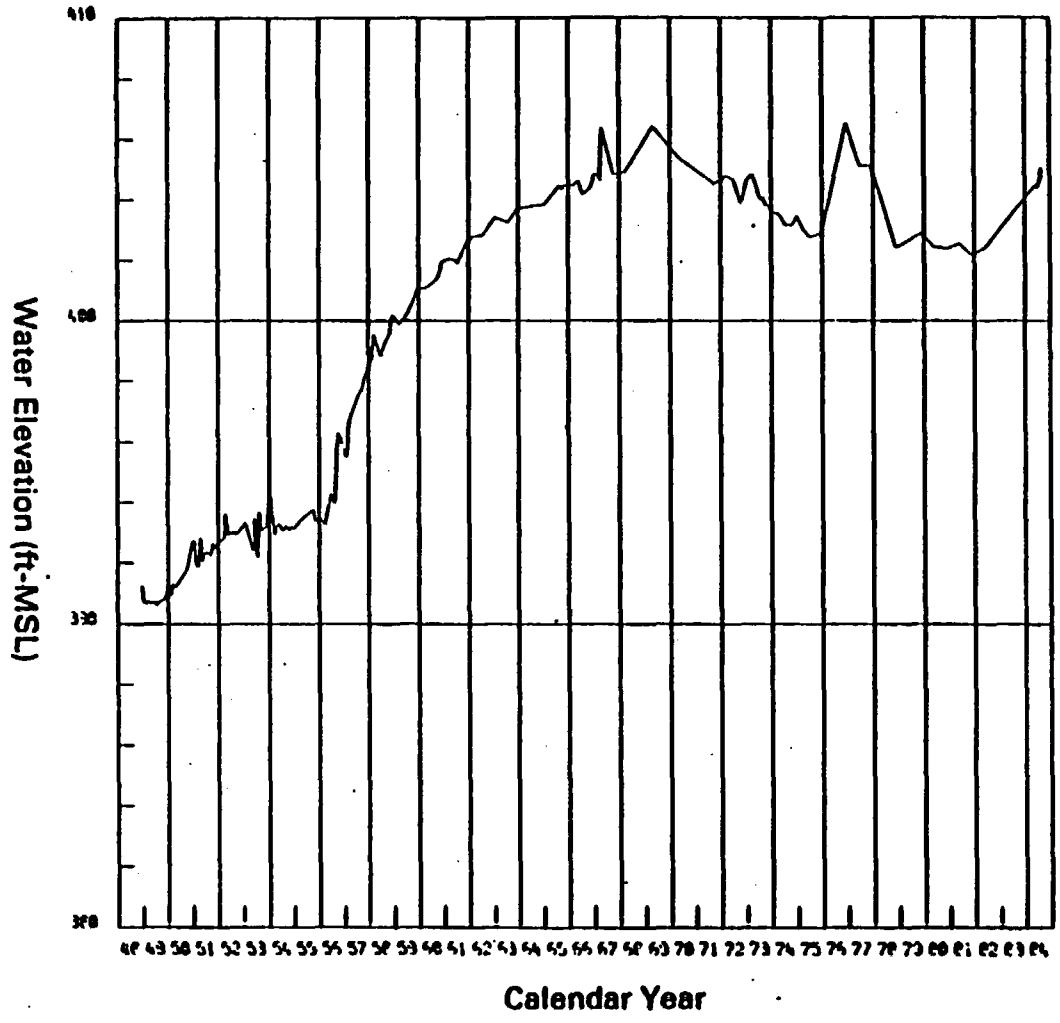


FIGURE 24. Water Level History in Well 699-45-42



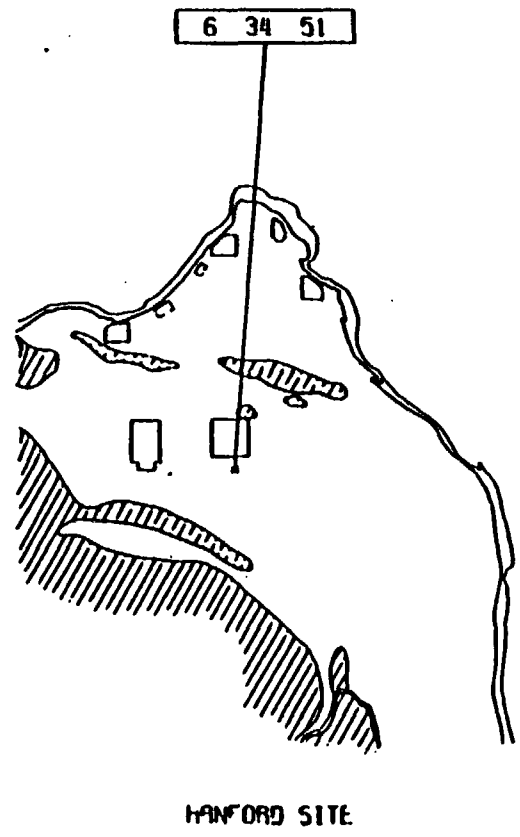


FIGURE 25. Water Level History in Well 699-34-51

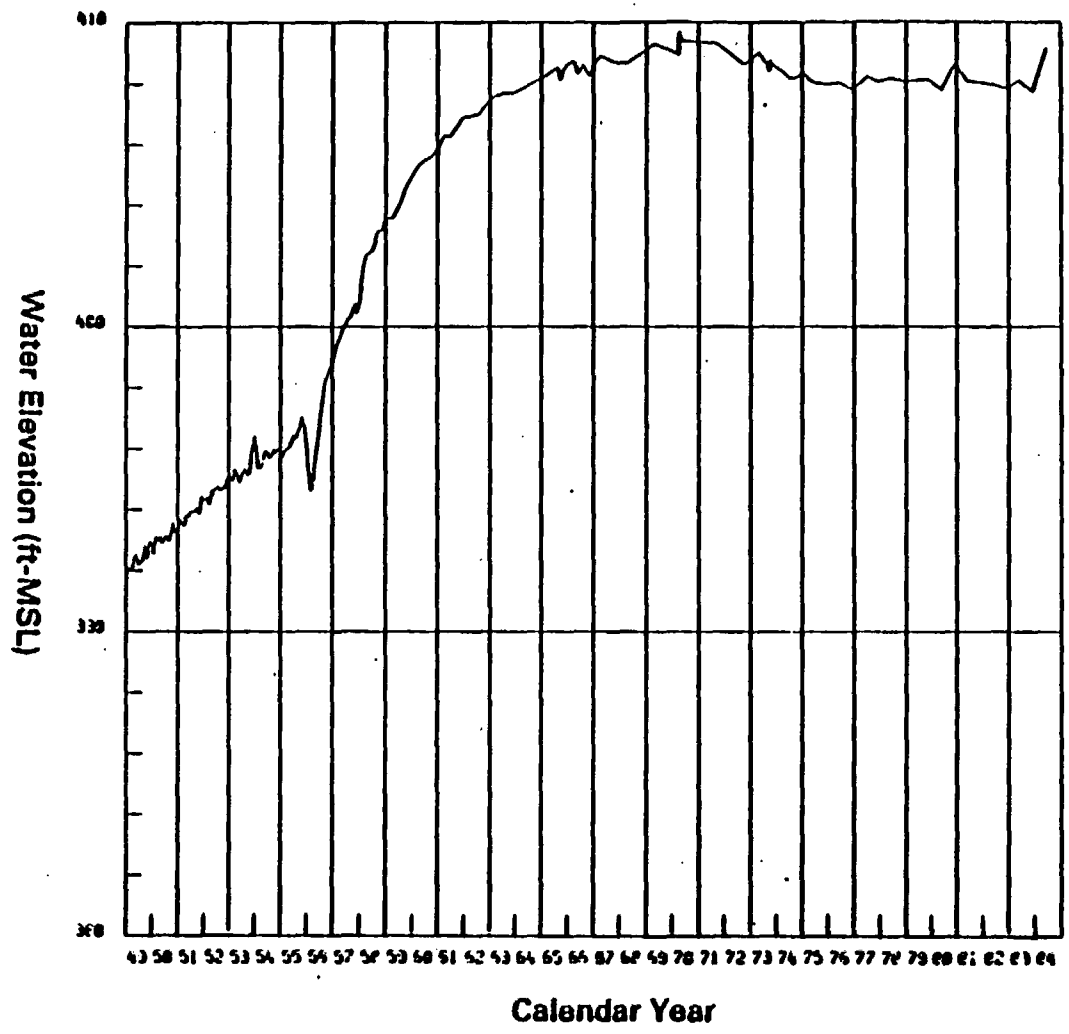
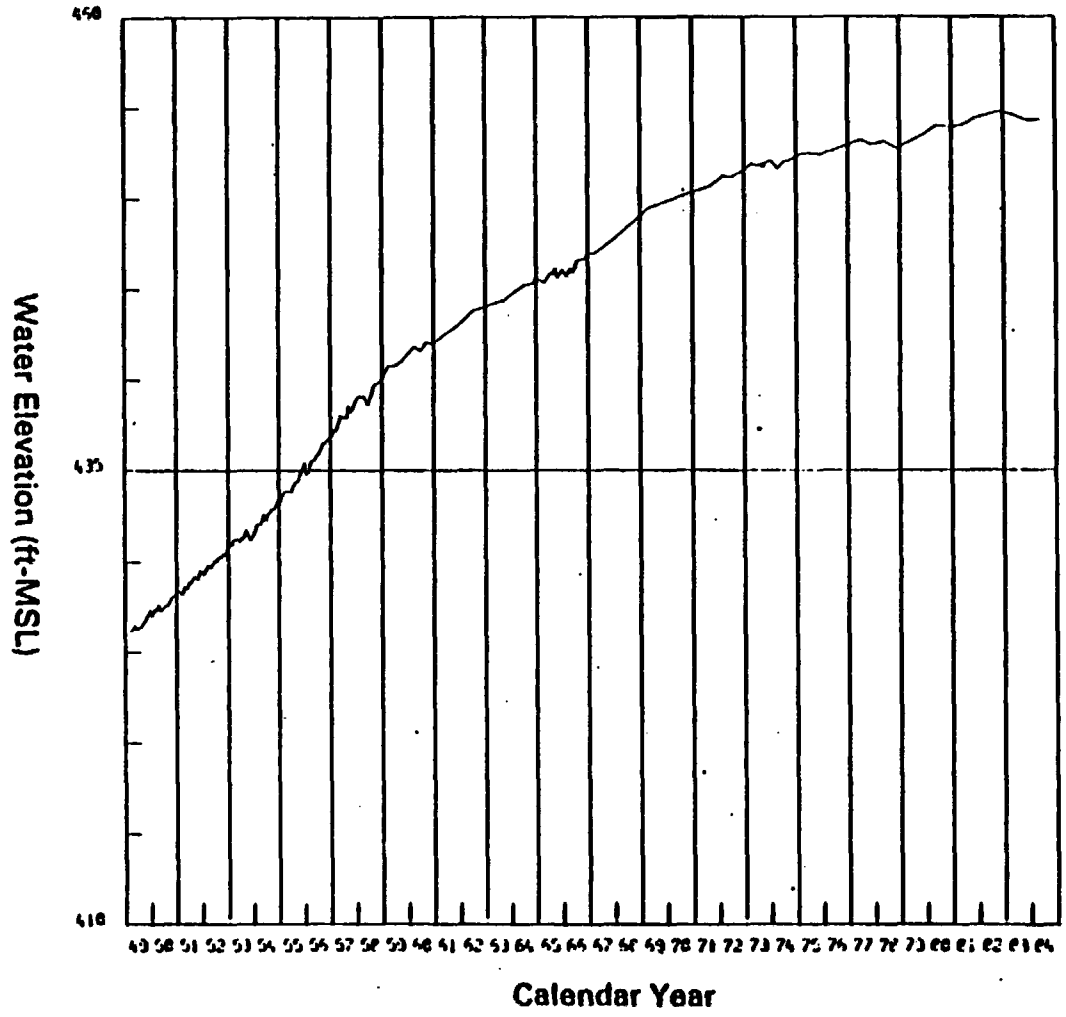


FIGURE 26. Water Level History in Well 699-36-61A



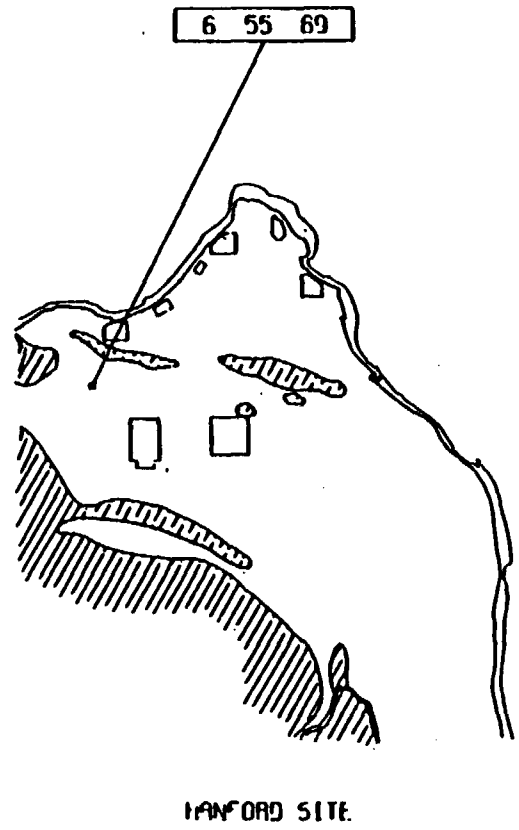


FIGURE 27. Water Level History in Well 699-55-89

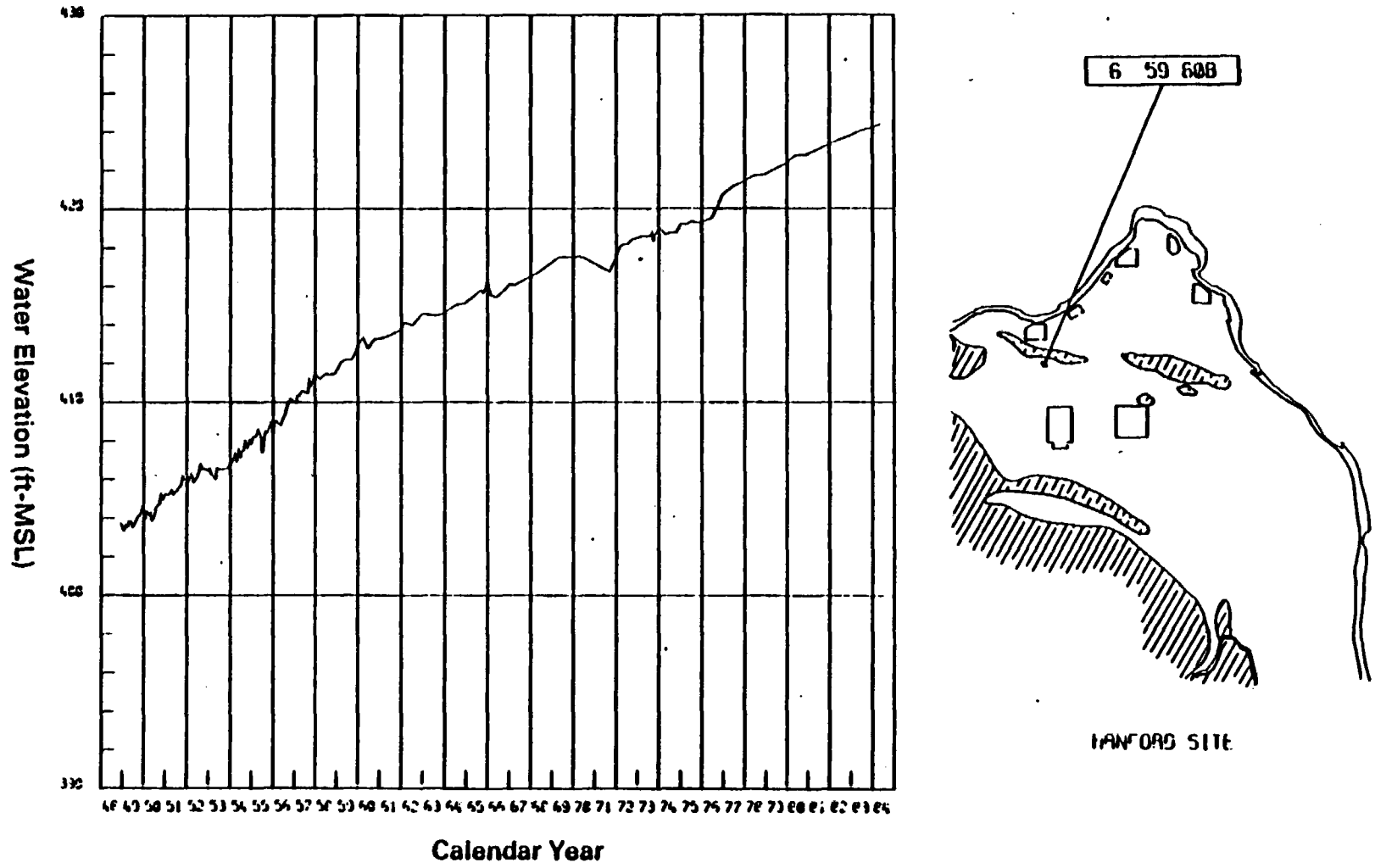


FIGURE 28. Water Level History in Well 699-59-80B

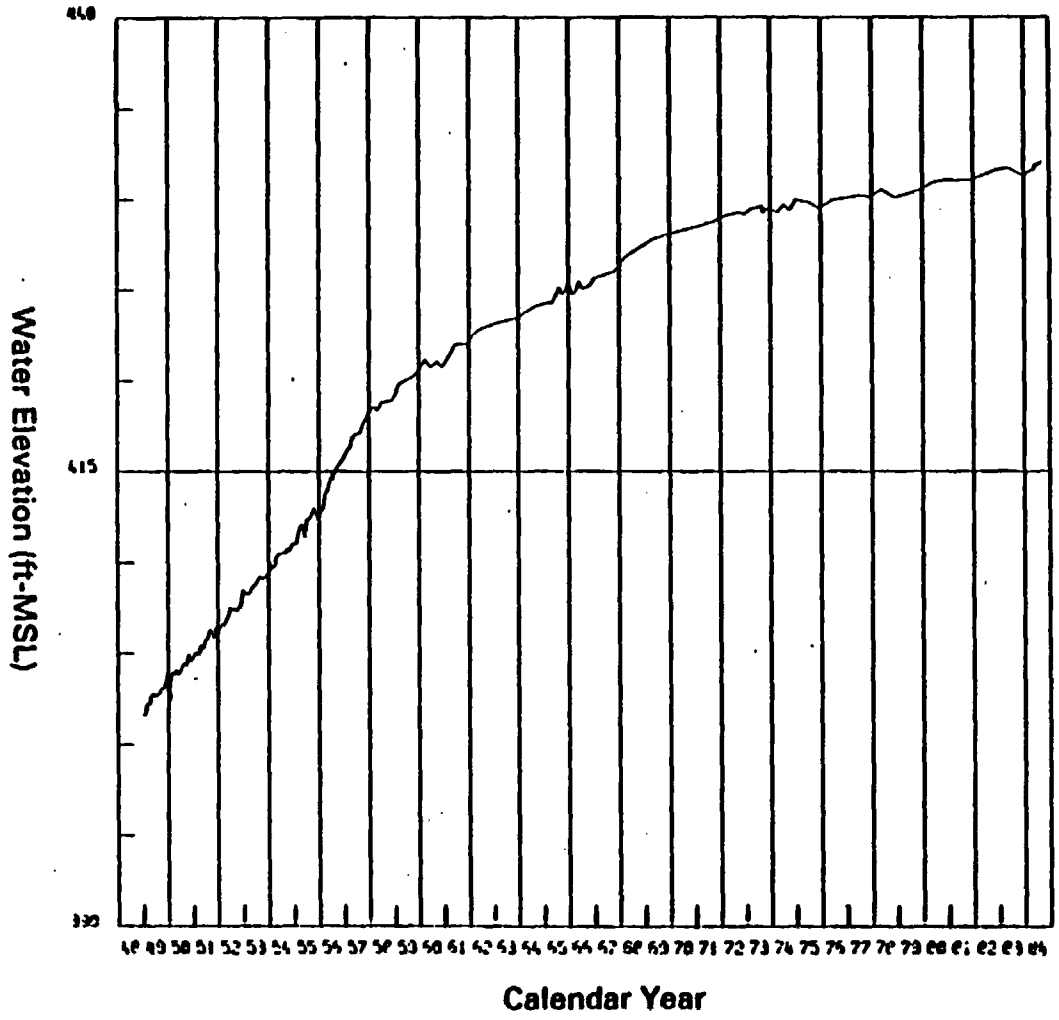


FIGURE 29. Water Level History in Well 699-55-70

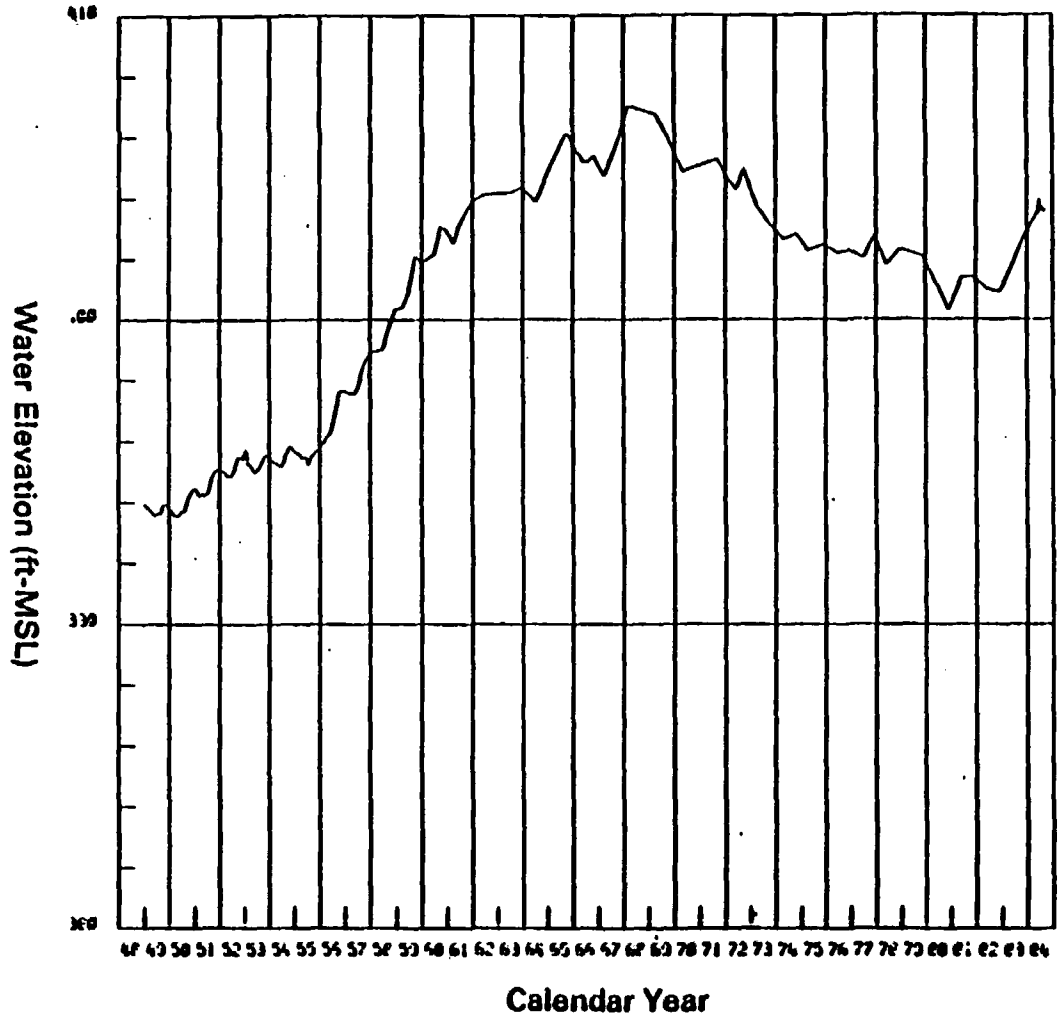


FIGURE 30. Water Level History in Well 699-60-60

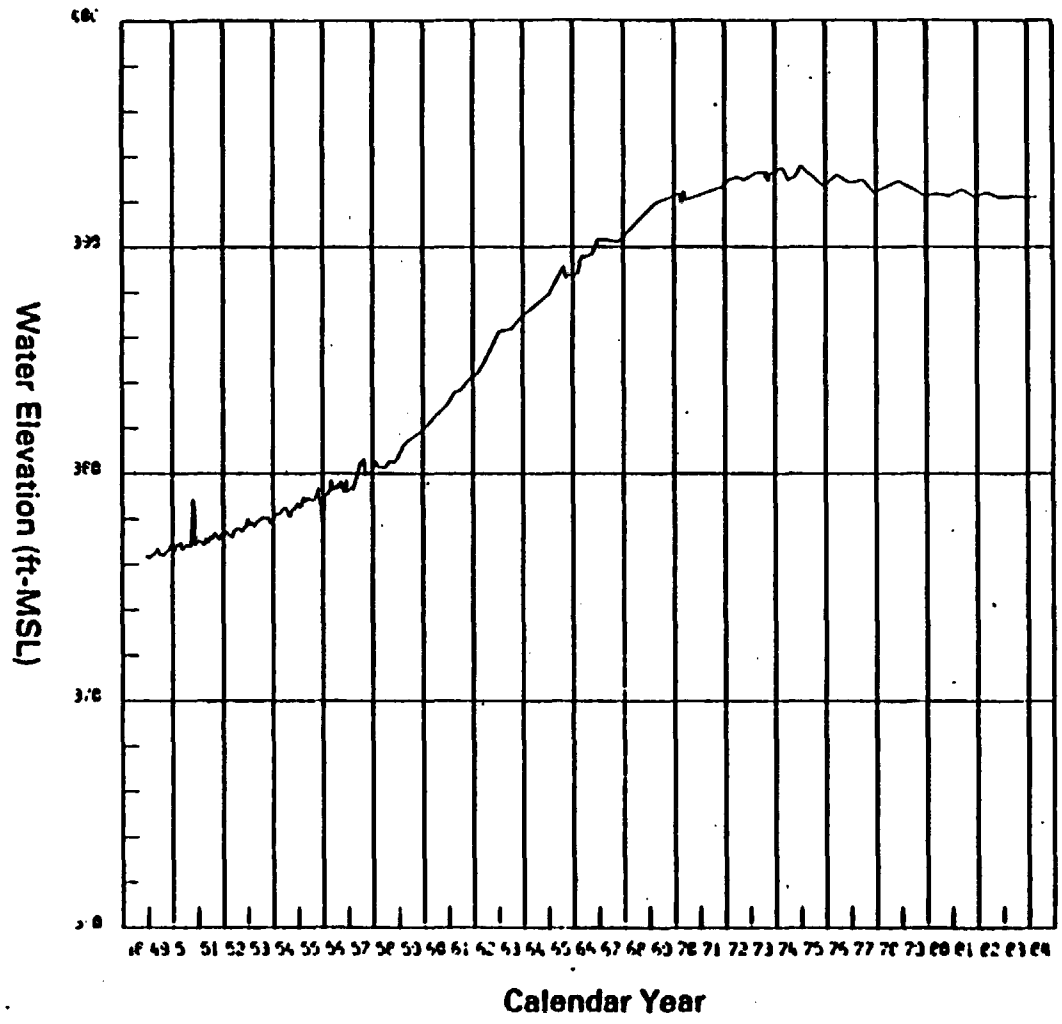
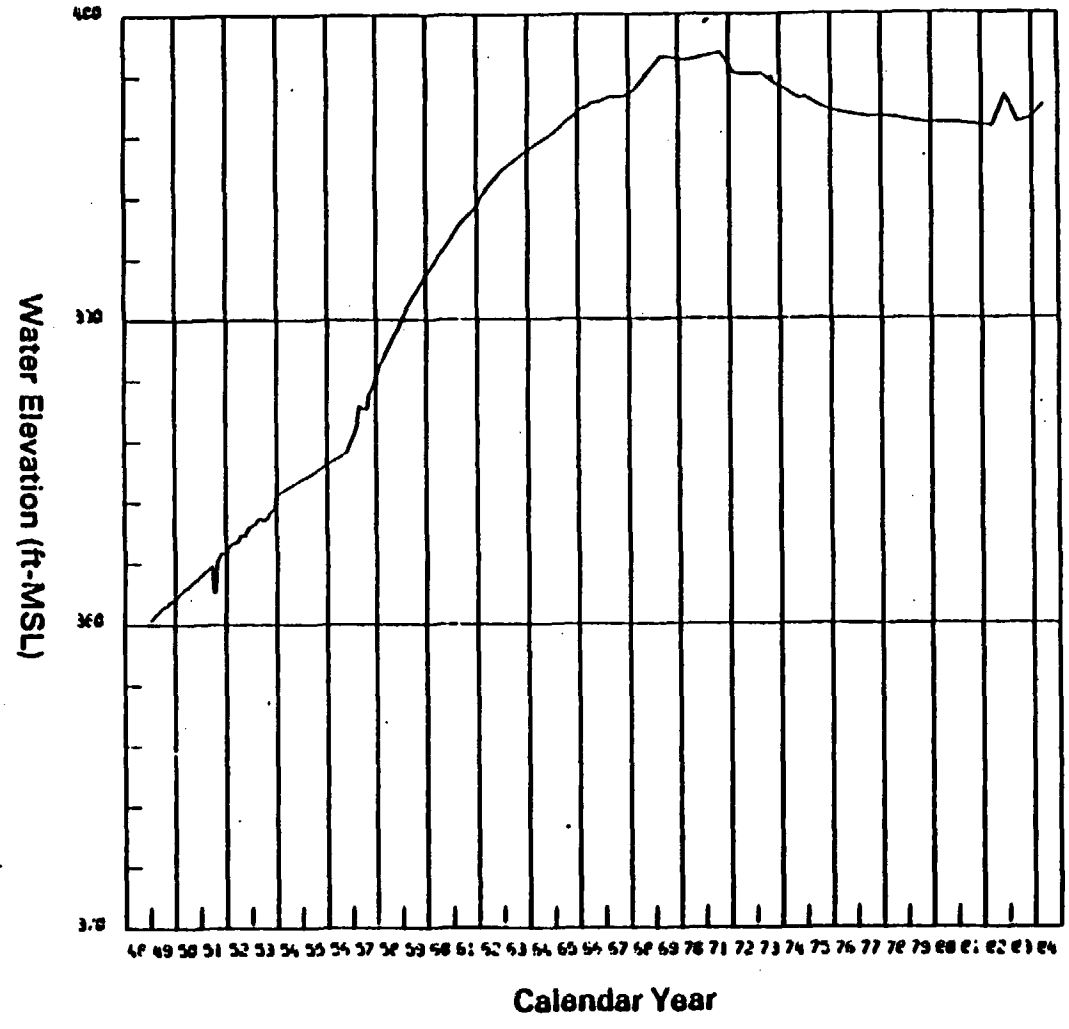


FIGURE 31. Water Level History in Well 699-50-30



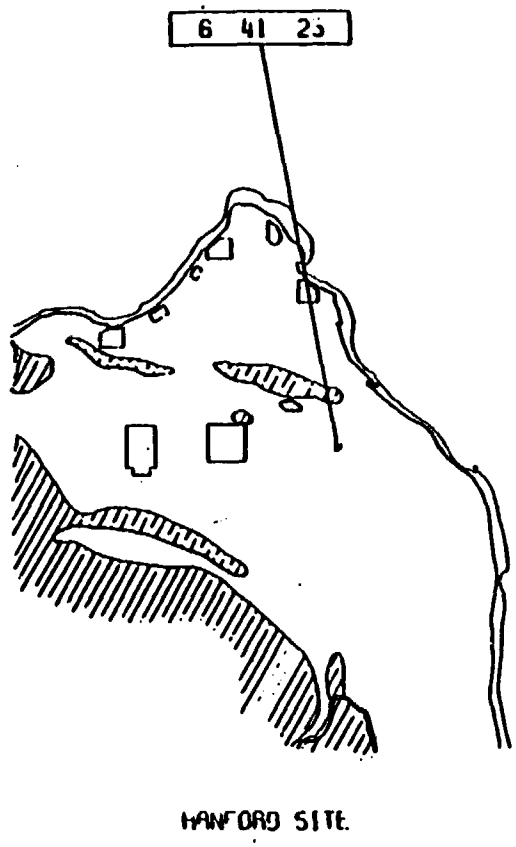
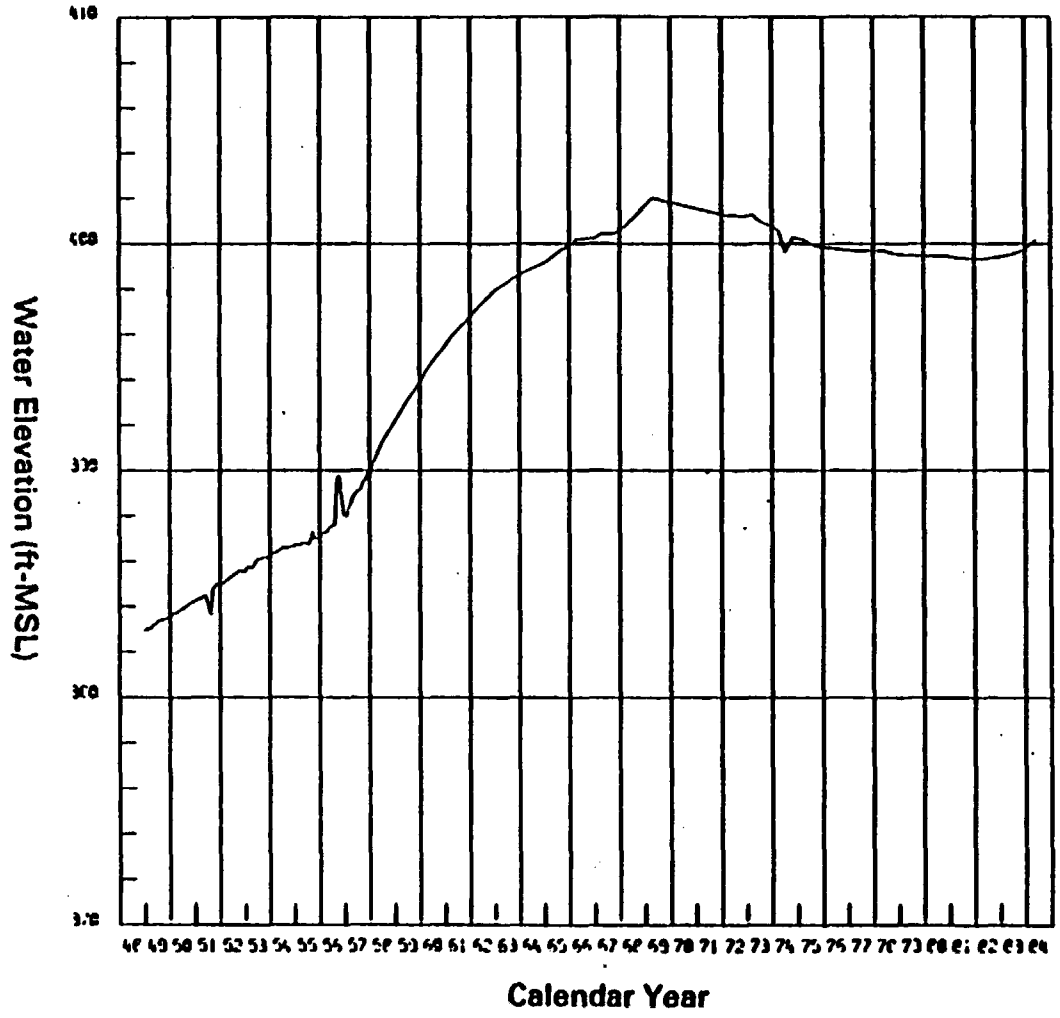


FIGURE 32. Water Level History in Well 699-41-23



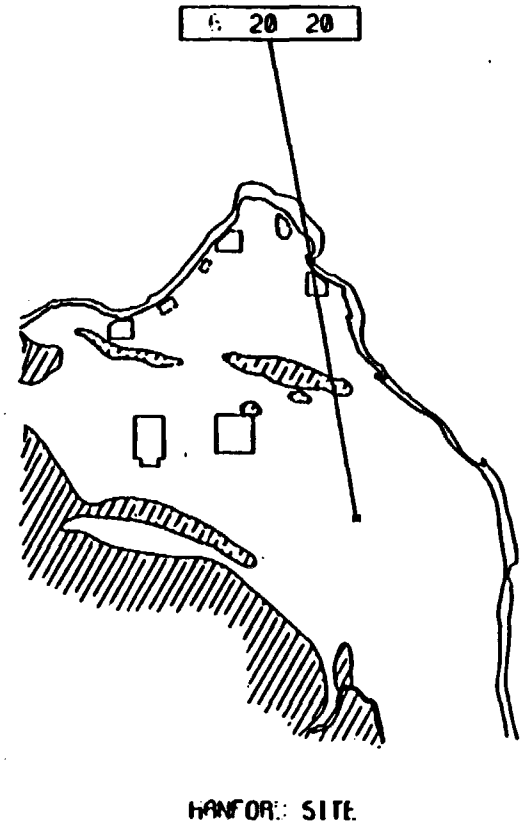


FIGURE 33. Water Level History in Well 699-20-20

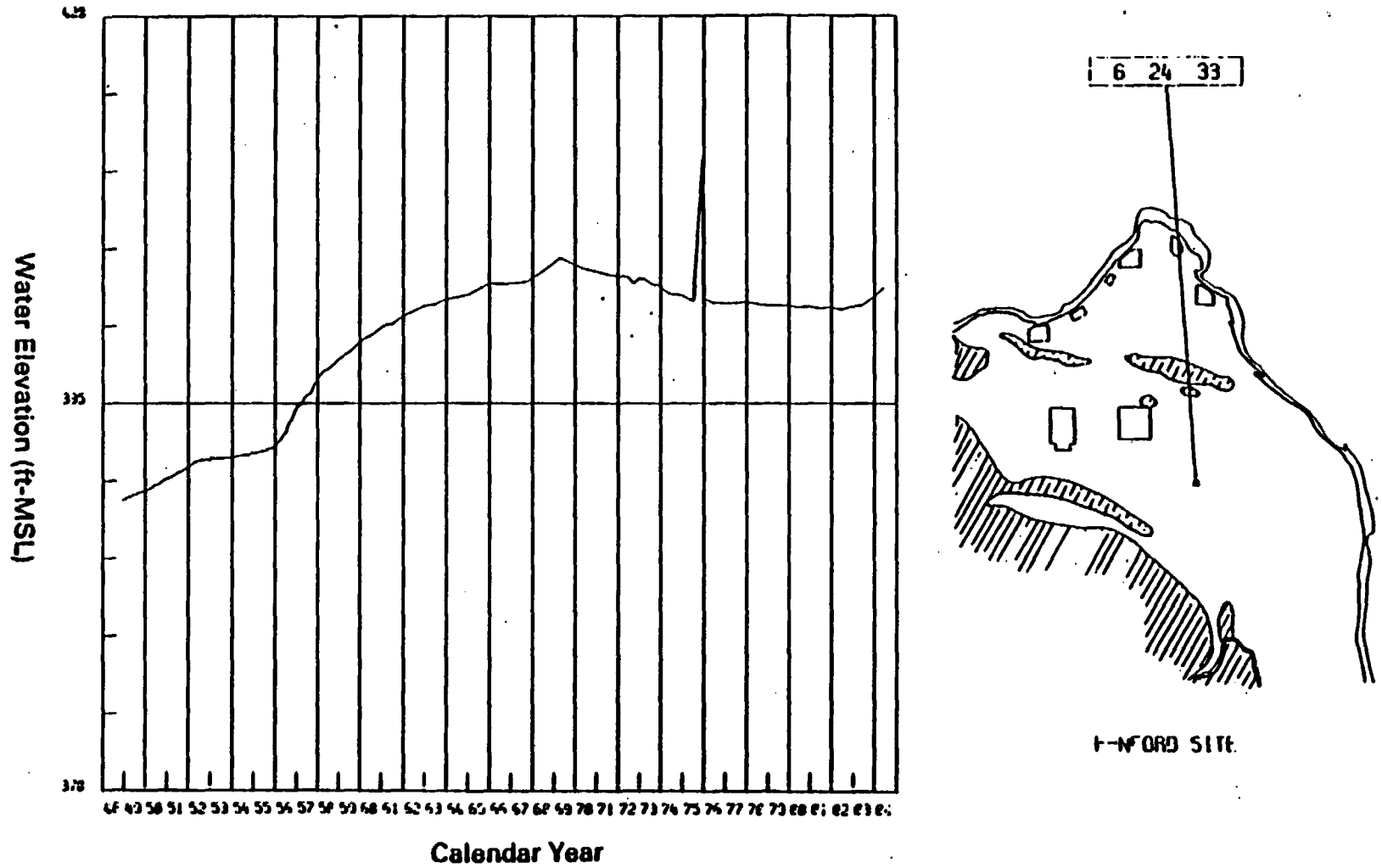
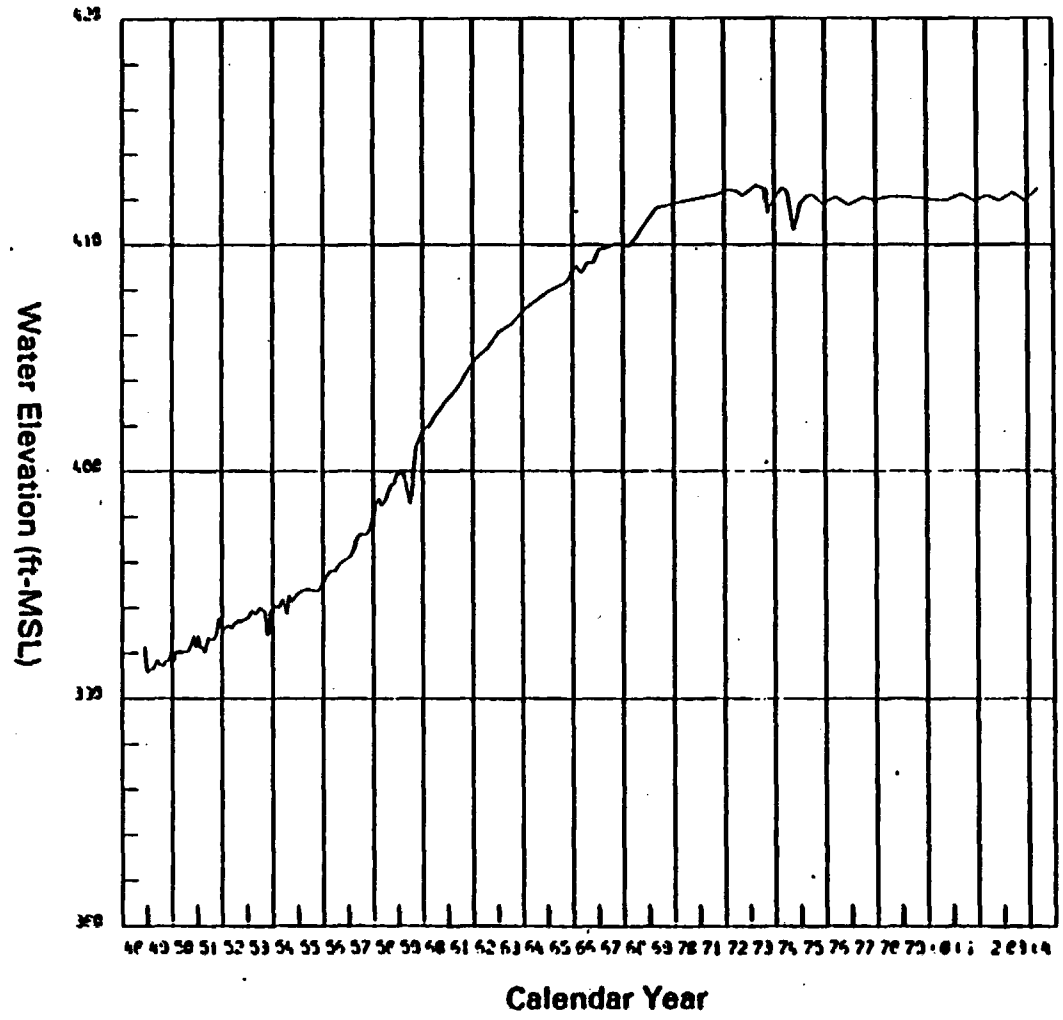


FIGURE 34. Water Level History in Well 699-24-33



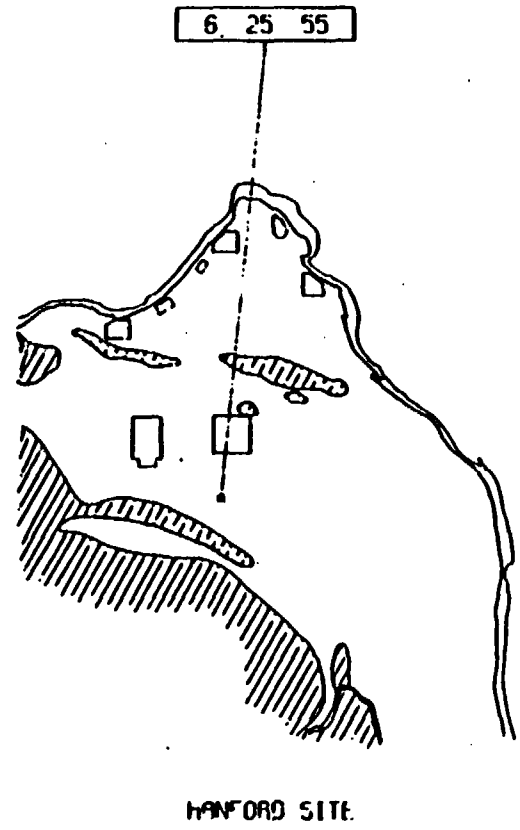


FIGURE 35. Water Level History in Well 699-25-55

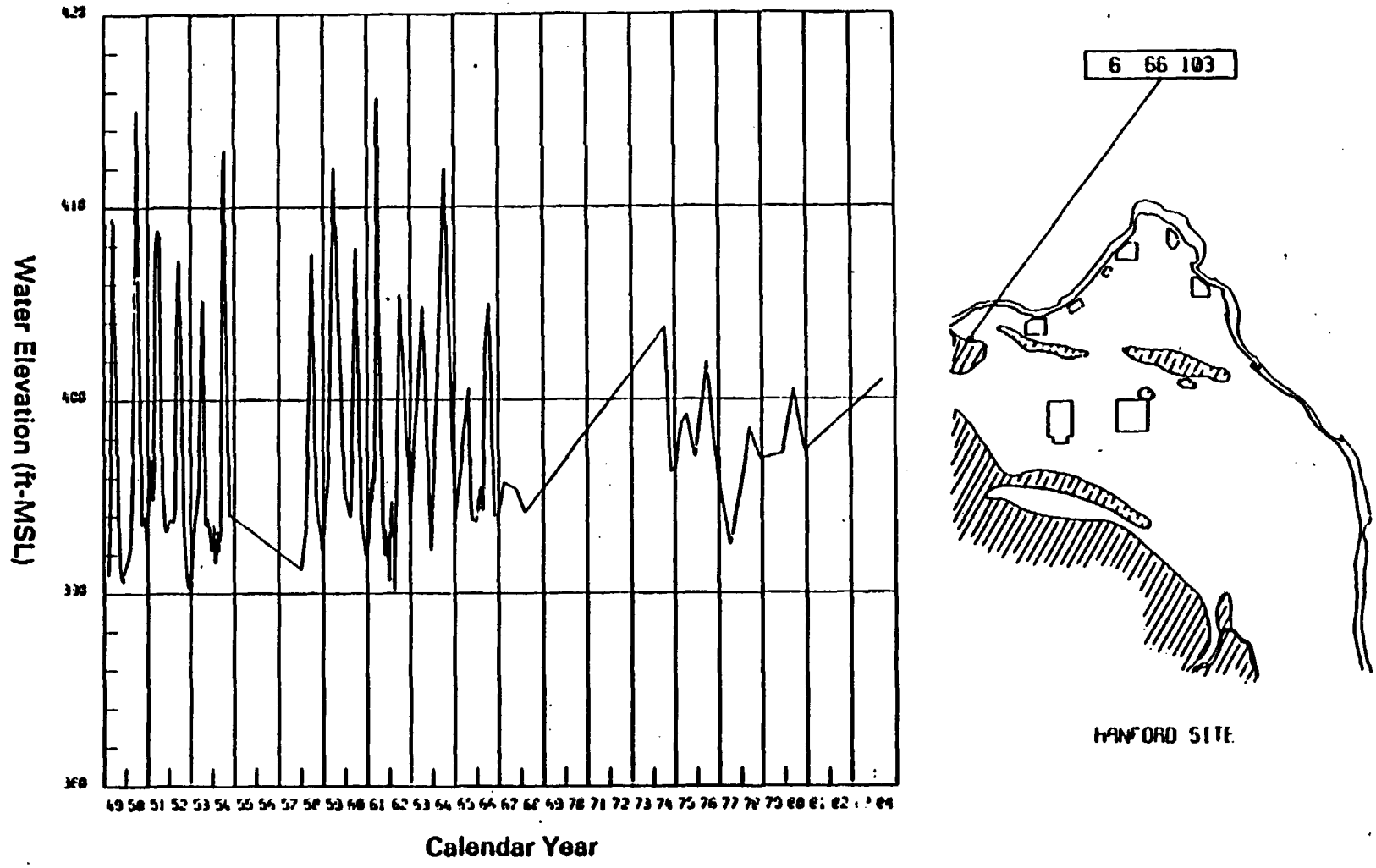
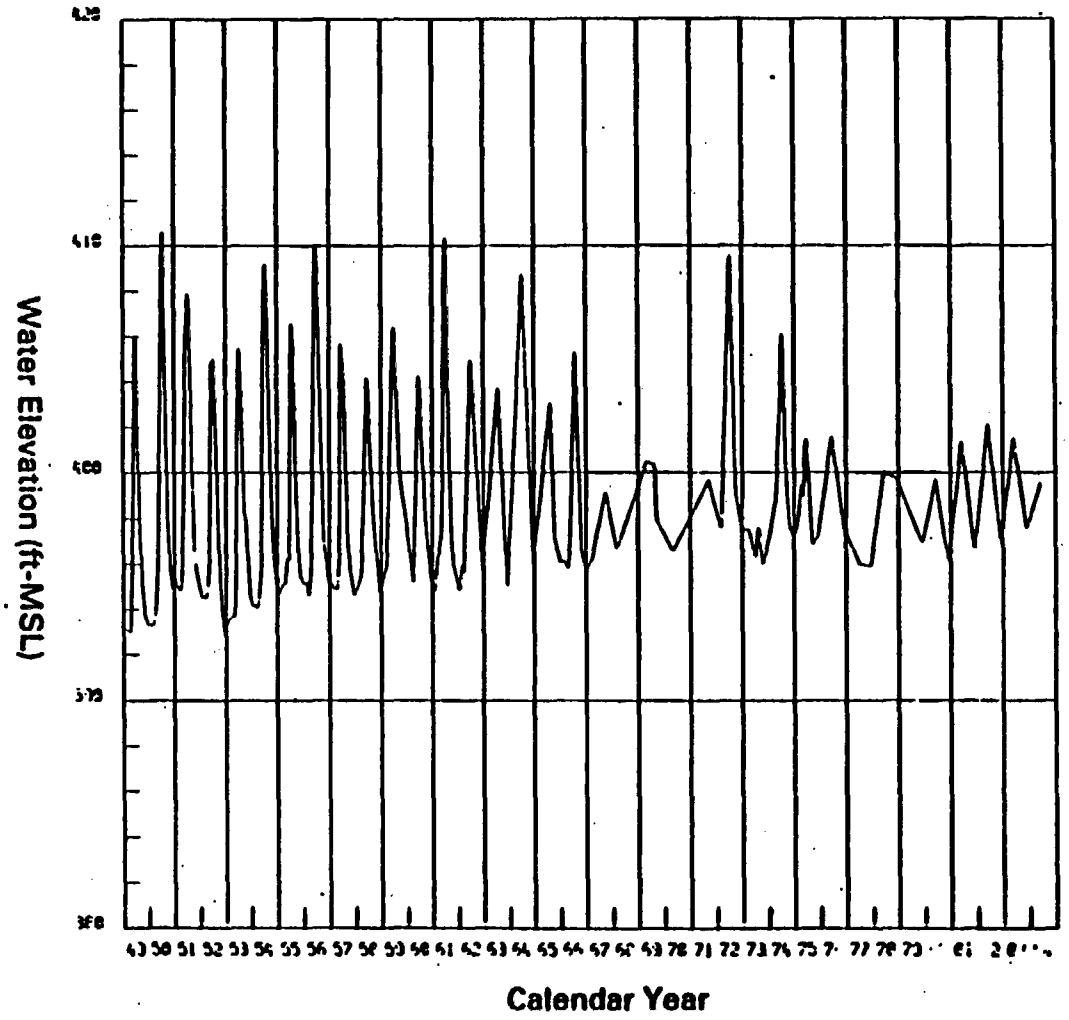


FIGURE 36. Water Level History in Well 699-66-103



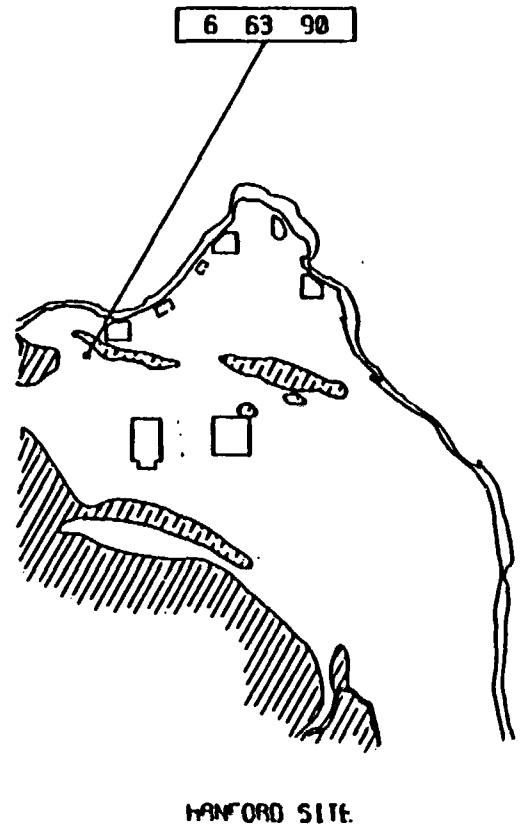


FIGURE 37. Water Level History in Well 699-63-90

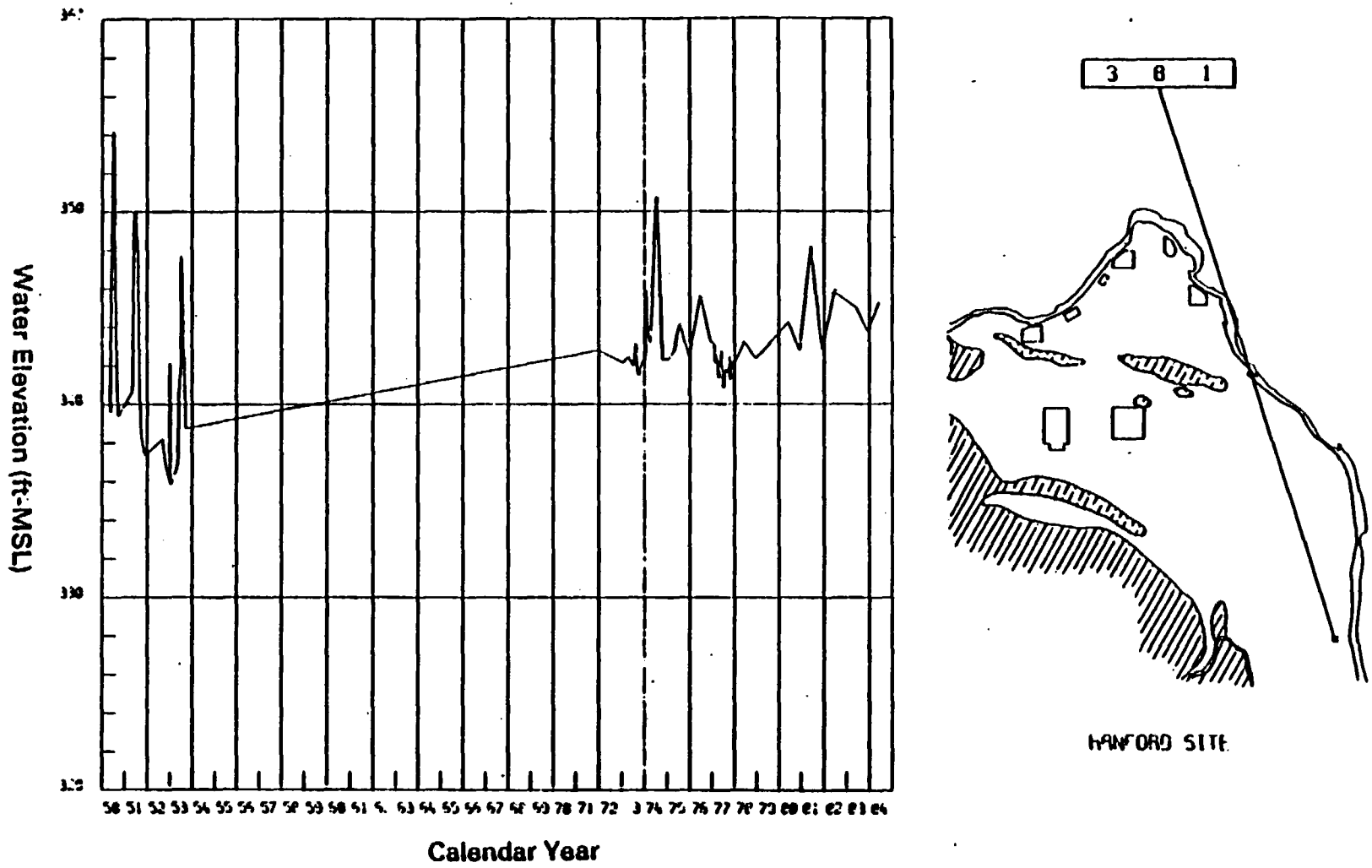
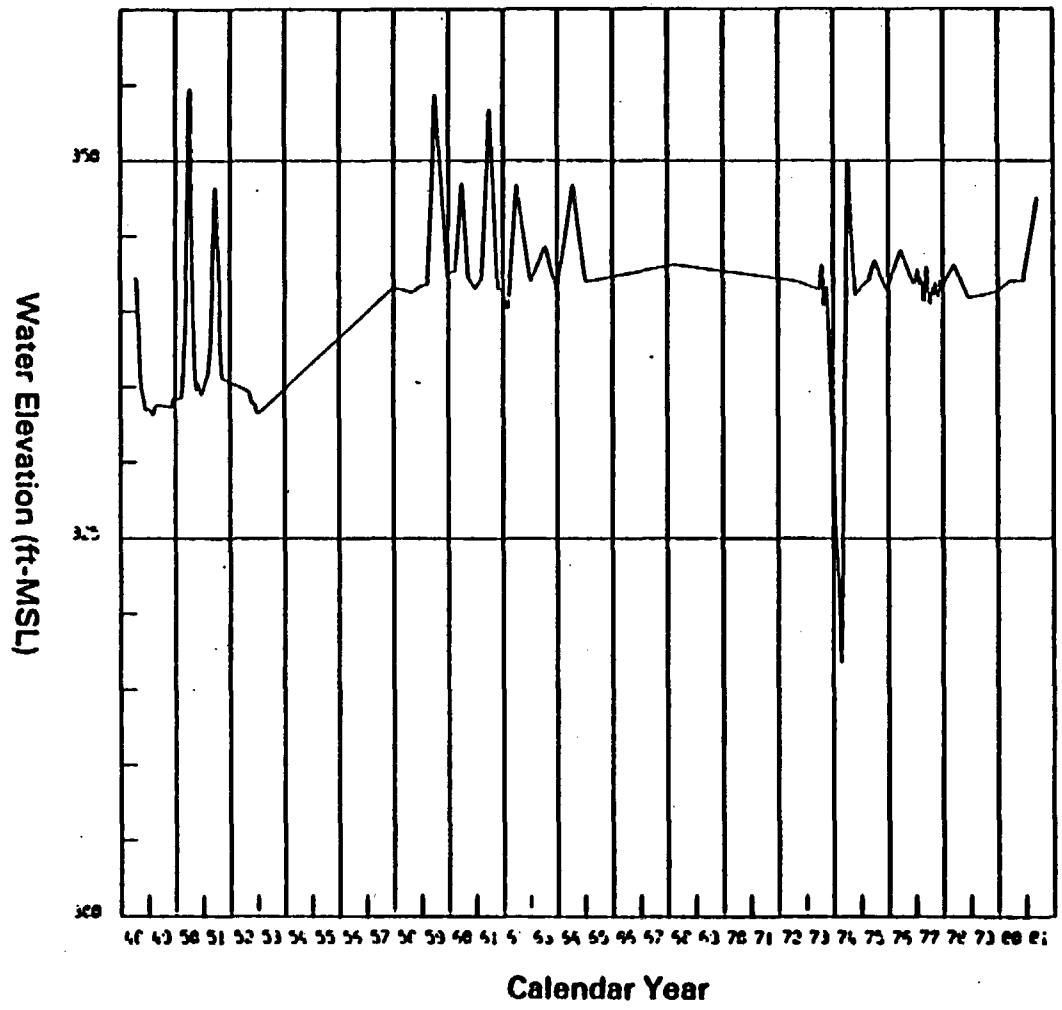


FIGURE 38. Water Level History in Well 399-8-1



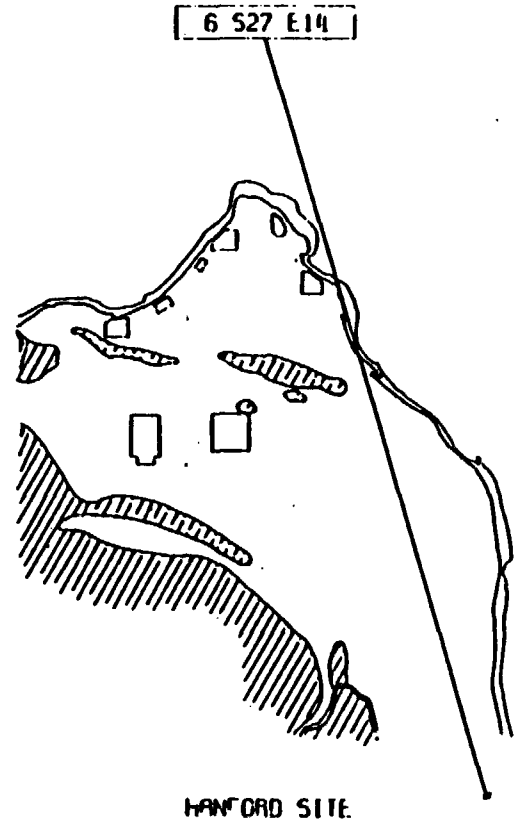
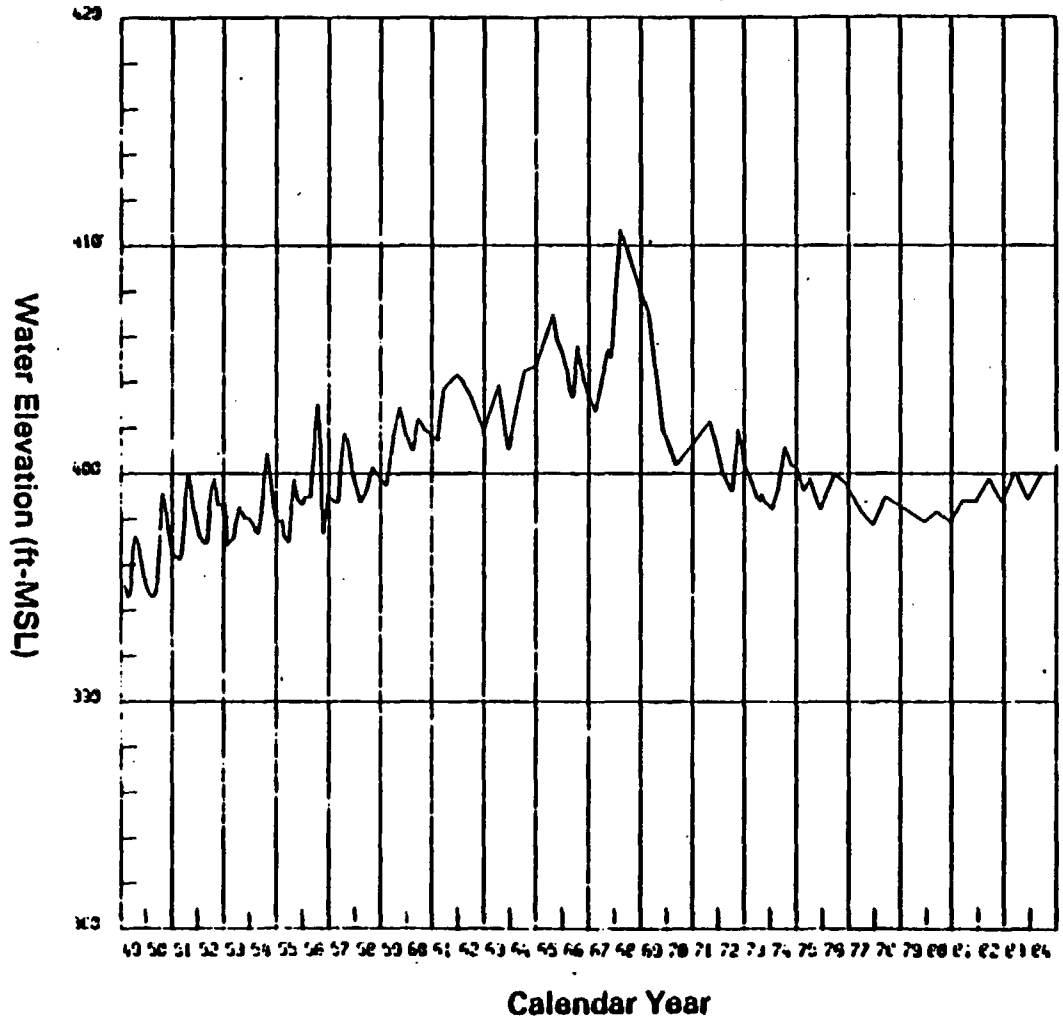


FIGURE 39. Water Level History in Well 699-S27-E14



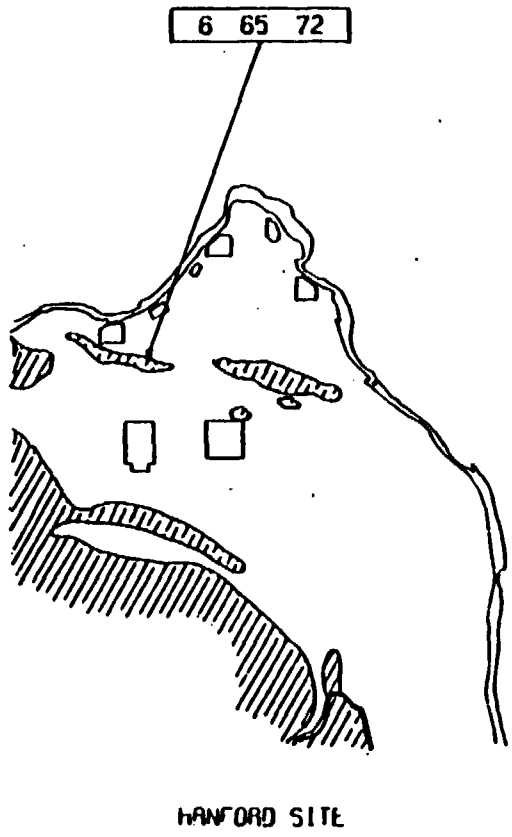
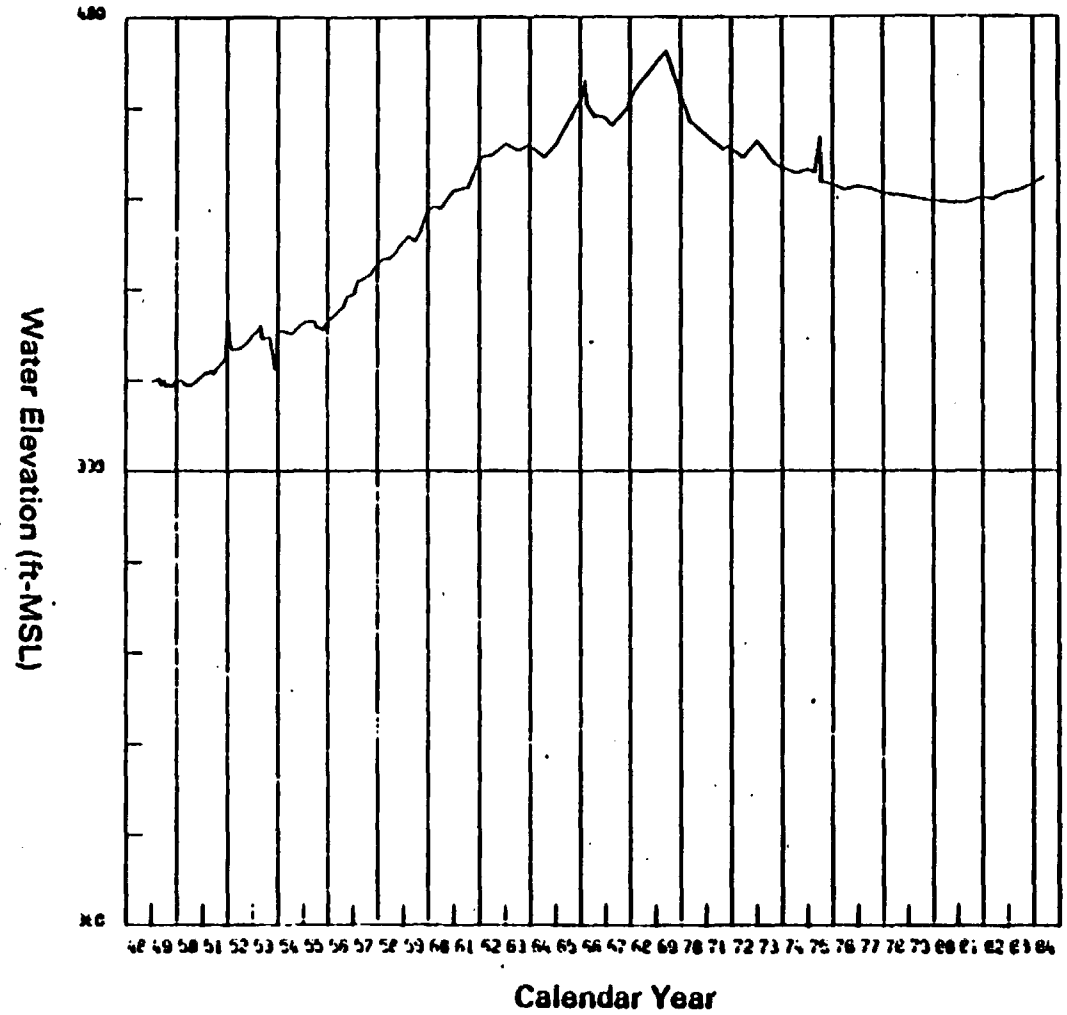


FIGURE 40. Water Level History in Well 699-65-72



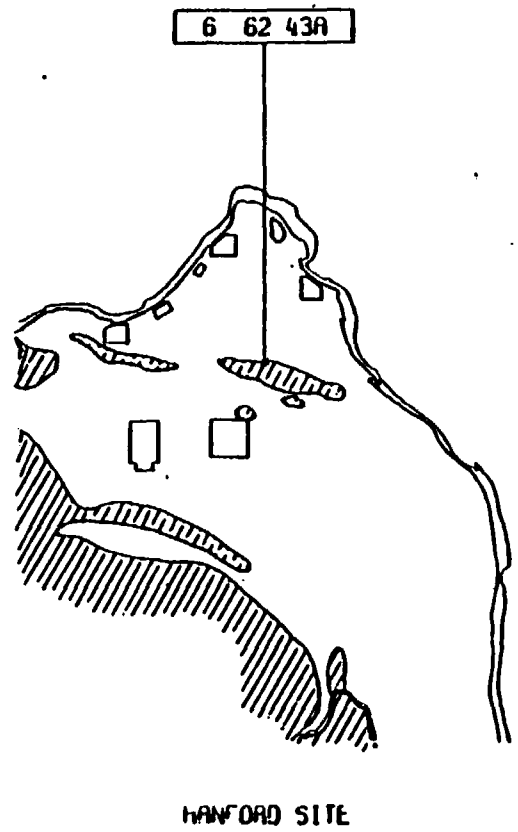


FIGURE 41. Water Level History in Well 699-62-43A

CONCLUSIONS

Discharges of wastewater from Hanford site facilities in the Separations Areas have caused significant changes in the configuration of the water table on the Hanford site since operations began in 1943. Ground-water mounds have developed under the major ponds and in the immediate vicinity of the 200 Areas where wastewater has been discharged to the ground. The mounds have grown both in height and laterally since the early 1950s and continue to maintain elevated water levels in the unconfined system throughout the major portion of the Hanford site. During the 1960 to 1970 time period, the rate of increase in water levels was sharply reduced. During the 1970 to 1980 time period, the unconfined system appears to have been in approximate equilibrium with the sources, although hydrographs of wells immediately south of Gable Butte continue to show a slight increasing trend during this time period.

Changes in the water table can be related to the waste-management activities at the Hanford site. The unconfined system appears to behave in a predictable manner; therefore, qualitative predictions of future aquifer response to future liquid-waste disposal activities can be made with reasonable certainty. An increase in ground-water mounding is predicted (based on process experience) for the area under the 200-East B Pond caused by the increased discharges from the restart of the PUREX Plant in 1983.

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