

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 91-9**

**RECHARGE ESTIMATION FOR THE GROUNDWATER  
MANAGEMENT DISTRICT NO. 5:  
A SIX-YEAR RECORD**

by

Marios Sophocleous

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## Recharge estimation for the Groundwater Management District No. 5: A six-year record

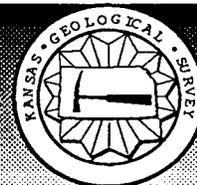
A report to the Big Bend GMD5

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***GEOHYDROLOGY***



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Quantifying the rate of natural groundwater recharge is a basic prerequisite for efficient groundwater resource development. It is the quantity of groundwater recharge that may in the long term be available for extraction, and is therefore of prime importance in assessing groundwater resources. False assumptions about groundwater recharge, especially when evaluating water rights applications, may lead to overdevelopment of an aquifer and to the serious consequences accompanying such overdevelopment. However, the rate of aquifer recharge is one of the most difficult factors to measure or derive in the evaluation of groundwater resources. Therefore recharge estimation must be seen as an iterative procedure; initial estimates need to be revised and refined as more data become available and new techniques are employed.

For groundwater recharge assessment in the GMD5 we are focusing on quantifying recharge for the region by combining 1) the hydrologic or soil-water balance on a storm-by-storm year-round basis, and 2) the resulting water table rises. For this assessment we are measuring, on an approximately weekly basis, the soil-profile water storage using a neutron probe, and we are continuously monitoring climatic and water-level data using various data recorders at 10 sites distributed throughout the GMD5 (Fig. 1). Each site is equipped with a weighing and recording rain gauge, a neutron-probe access tube, a water table well with a water-level recorder, and two deeper piezometers. Two of the sites are also equipped with weather stations that record solar radiation, air temperature, relative humidity, barometric pressure and wind speed. A schematic layout of site instrumentation is shown in Fig. 2. Using the data collected at these stations, we calculate a soil-water balance for each recharge-producing storm period. By associating the result with the consequent water table rise, which is tied to specific precipitation events, we obtain reliable effective recharge values for different storm periods.

Table 1 and Fig. 3 summarize the results of our recharge estimates for all our sites and for all the years for which measurements have been collected. For the original five recharge sites 1 through 5 we have data since 1985, whereas for sites 6 through 10 we have data since 1988. We find that for the GMD5, groundwater recharge is indeed highly variable from year to year and from one area to another, with a 6-year (1985–1990) average of  $2\frac{1}{4}$  inches of "effective" recharge (i.e., recharge that caused measurable water table rise) over the district. The average precipitation over this same period in the area was approximately  $23\frac{1}{4}$  inches. Thus this recharge estimate represents almost 10% of the annual precipitation. Note that the unusually high recharge estimates for site 4 in Reno County are due to the site being located on the stream bank of a tributary to Wolf Creek; the depth to the water table there is very shallow, approximately 2–4 ft (Table 1).

The preexisting soil-moisture conditions and the thickness and nature of the vadose or unsaturated zone are major factors affecting recharge; also the timing and amount of precipitation is crucial in aquifer recharge. As can be seen in Fig. 3, similar yearly rains produced different recharge amounts; this is because of differences in timing of rains. Spring rains are the most effective in recharging the aquifer. Also note the drought effect of 1988, which resulted in the lowest overall amount of recharge during the 6-year study period. Sites 8, 9, and 10 received no measurable effective recharge during the 3-year period of record (1988–1990). The 1990 estimated average recharge values for all sites ( $1\frac{1}{4}$ " of recharge;  $22\frac{1}{4}$ " of precipitation) are well below the 1985–1990 average. This resulted in the lowest groundwater levels in the 1985–1990 period of continuous groundwater level record (Figs. 4a–c).

It is interesting to note in Fig. 4 that the bedrock-well water levels (piezometer 1) have become higher than the deeper alluvial aquifer water levels (piezometer 2) for progressively longer periods as time progresses. The implication of these observations is that the bedrock brine waters have an increasing tendency to intrude into the freshwater alluvial aquifer directly overlying Permian bedrock, thus adversely affecting the water quality of the Great Bend aquifer. This water quality degradation can be seen in Fig. 5, which depicts the water salinity changes, expressed as specific conductance, near the fresh-saltwater interface (shown in Fig. 6) underlying the freshwater

aquifer. As the aquifer water level is slightly decreased or increased, the water salinity is increased or decreased, correspondingly (Fig. 5) because of the underlying saltwater intrusion into or retreat from the freshwater aquifer. The data depicted in Figs. 5 and 6 are from a monitoring site (Sittner) approximately 5 miles to the south of recharge site 3 in Stafford County.

Estimates of recharge are normally subject to large uncertainties. In addition, determination of the high variability of recharge in space and time, shown in Table 1 and Fig. 3, creates a number of problems. To reduce such uncertainties, we must monitor aquifer behavior on a continuous or periodic basis district-wide to ensure that an adequate multi-year database is collected, from which representative averages can be taken. Table 2 provides a measure of the district-wide variability of the volume of aquifer recharge. For example, if we only estimated recharge in the district based on the wettest year of the 1985-90 period of record (i.e. 1987), then the average recharge based on the original 5 sites would be 5.22" (which is 77.6% higher than the 1985-90 average for the 5 original sites). Given that the approximate district acreage is 2,511,104 acres, this would correspond to 1,092,330 acre-ft of aquifer replenishment. However, if we only estimated recharge based on the driest year of the 1985-90 period of record (i.e. 1988), then the average recharge for the original 5 sites would only be 1.1" (or 62.6% less than the 1985-90 average), which corresponds to 230,184 acre-ft of aquifer replenishment district-wide. The total water appropriation in the district as of January 1, 1988 amounted to 824,732 acre-ft, which is more than 3.5 times the amount of dry-year natural groundwater recharge. The 6-year average recharge amount of 2.23" for all 10 sites corresponds to 466,647 acre-ft of aquifer replenishment, which is 1.75 times less than the previously-mentioned total water appropriation for the district.

Similarly, if we reduced the number of recharge-assessment sites we would come up with still different recharge values. For example, eliminating site 4 in Reno Co. (the highest-estimated recharge-value site) would reduce the original sites average (2.94"; Table 2) by 35%, while eliminating site 3 (the lowest-estimated recharge-value site) near the Stafford-Barton Co. boundary line would increase it by 17%. It is therefore important to realize that in order to reduce such recharge-estimation uncertainties, a long-term and spatially-representative database is required.

Table 1. 1985-1990 Groundwater Recharge Estimates for GMD5

| Site No. | County and Legal Description                         | Land Owner             | Year | Total Precipitation (inches) | Minimum and Maximum depth to Water Table (feet) | Estimated Groundwater Recharge (inches) |
|----------|--|------------------------|------|------------------------------|---|---|
| 1        | Edwards Co<br>Sec. 13, T. 25 S.,<br>R. 16 W.         | Grizzell               | 1985 | 23.30                        | 18.2-20.2                                       | 1.3                                     |
|          |  |                        | 1986 | 26.54                        | 18.5-20.5                                       | 1.1                                     |
|          |  |                        | 1987 | 34.05                        | 9.8-18.5  | 5.2                                     |
|          |  |                        | 1988 | 14.91                        | 14.2-19.6                                       | 0.7                                     |
|          |  |                        | 1989 | 21.90                        | 17.3-19.6                                       | 1.4                                     |
|          |  |                        | 1990 | 20.32                        | 18.3-21.2                                       | 0.5                                     |
| 2        | Stafford Co.<br>Sec. 36, T. 23 S.,<br>R. 13 W.       | Bliss                  | 1985 | 26.47                        | 24.2-26.7                                       | 2.8                                     |
|          |  |                        | 1986 | 27.86                        | 24.0-26.5                                       | 1.7                                     |
|          |  |                        | 1987 | 26.10                        | 19.2-24.1                                       | 3.9                                     |
|          |  |                        | 1988 | 14.52                        | 22.3-26.8                                       | 0.2                                     |
|          |  |                        | 1989 | 20.50                        | 26.2-27.3                                       | 0.9                                     |
|          |  |                        | 1990 | 21.19                        | 25.4-28.2                                       | 1.3                                     |
| 3        | Stafford-Barton Co.<br>Sec. 7, T. 21 S.,<br>R. 11 W. | Schlocktermeier        | 1985 | 29.83                        | 16.4-23.0                                       | 2.8                                     |
|          |  |                        | 1986 | 22.17                        | 15.9-19.4                                       | 0.7                                     |
|          |  |                        | 1987 | 28.11                        | 14.6-18.3                                       | 1.3                                     |
|          |  |                        | 1988 | 15.66                        | 15.5-21.9                                       | 0.0                                     |
|          |  |                        | 1989 | 21.80                        | 21.5-24.5                                       | 0.6                                     |
|          |  |                        | 1990 | 21.26                        | 20.9-25.0                                       | 0.4                                     |
| 4        | Reno Co.<br>Sec. 1, T. 25 S.,<br>R. 9 W.             | Bradshaw and<br>Sherow | 1985 | 31.19                        | 2.4-4.9   | 6.7                                     |
|          |  |                        | 1986 | 32.96                        | 2.6-4.7   | 8.3                                     |
|          |  |                        | 1987 | 37.09                        | 0.5-3.3   | 11.9                                    |
|          |  |                        | 1988 | 18.00                        | 1.6-5.7   | 3.7                                     |
|          |  |                        | 1989 | 27.39                        | 3.6-5.0   | 6.5                                     |
|          |  |                        | 1990 | 25.65                        | 1.9-5.8   | 5.3                                     |
| 5        | Stafford-Pratt Co.<br>Sec. 36, T. 25 S.,<br>R. 13 W. | Harrison               | 1985 | 30.15                        | 10.1-14.6                                       | 5.9                                     |
|          |  |                        | 1986 | 32.51                        | 10.4-13.7                                       | 4.1                                     |
|          |  |                        | 1987 | 30.69                        | 6.2-10.5  | 3.8                                     |
|          |  |                        | 1988 | 14.95                        | 8.6-14.4  | 0.9                                     |
|          |  |                        | 1989 | 23.86                        | 11.7-14.8                                       | 2.9                                     |
|          |  |                        | 1990 | 22.84                        | 10.9-16.6                                       | 1.5                                     |
| 6        | Stafford Co.<br>Sec. 36, T. 23 S.,<br>R. 12 W.       | Wendelburg             | 1988 | 16.27                        | 10.0-22.8                                       | 0.6                                     |
|          |  |                        | 1989 | 22.49                        | 9.9-22.8  | 1.7                                     |
|          |  |                        | 1990 | 23.43                        | 10.2-23.7                                       | 1.1                                     |
| 7        | Pratt Co.<br>Sec. 11, T. 26 S.,<br>R. 14 W.          | Moore                  | 1988 | 14.95 <sup>a</sup>           | 15.1-26.5                                       | 0.5                                     |
|          |  |                        | 1989 | 22.53                        | 21.9-26.8                                       | 5.6                                     |
|          |  |                        | 1990 | 20.86                        | 22.6-29.2                                       | 2.4                                     |
| 8        | Pawnee Co.<br>Sec. 14, T. 23 S.,<br>R. 15 W.         | Tranbarger             | 1988 | 14.36                        | 23.6-26.3                                       | 0.0                                     |
|          |  |                        | 1989 | 20.77                        | 26.3-27.2                                       | 0.0                                     |
|          |  |                        | 1990 | 23.99                        | 27.3-27.8                                       | 0.0                                     |
| 9        | Edwards Co.<br>Sec. 5, T. 24 S.,<br>R. 16 W.         | Schartz                | 1988 | 14.73                        | 29.3-31.9                                       | 0.0                                     |
|          |  |                        | 1989 | 18.37                        | 31.5-33.1                                       | 0.0                                     |
|          |  |                        | 1990 | 20.97                        | 32.7-34.4                                       | 0.0                                     |
| 10       | Edwards Co.<br>Sec. 1, T. 25 S.,<br>R. 19 W.         | Olsen                  | 1988 | 15.02                        | 46.7-48.7                                       | 0.0                                     |
|          |  |                        | 1989 | 21.54                        | 48.5-50.2                                       | 0.0                                     |
|          |  |                        | 1990 | 22.05                        | 50.0-51.3                                       | 0.0                                     |

a. Precipitation taken from site 5 (the nearest site).

Table 2. District-wide variability of the volume of aquifer recharge

| 1985-90 data set<br>for the 5 original sites | Recharge<br>(inches) | District-wide volume<br>of recharge (acre-ft) |
|--|----------------------|---|
| Wettest year (1987)                          | 5.22                 | 1,092,330                                     |
| Driest year (1988)                           | 1.10                 | 230,184                                       |
| Average                                      | 2.94                 | 615,220                                       |
| Average excluding site 4                     | 1.91                 | 399,684                                       |
| Average excluding site 3                     | 3.44                 | 719,850                                       |
| 10-site average                              | 2.23                 | 466,647                                       |
| Total appropriation (1988)                   |                      | -824,732                                      |

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- Fig. 4. A 6-year (1985–1990) daily precipitation series and hydrographs for shallow (water table) and deep (piezometer 2) aquifer wells, and Permian bedrock well (piezometer 1) for (a) Site 2, (b) Site 3, and (c) Site 5.
- Fig. 5. Specific conductance and water-level changes at the Sittner site in Stafford County.
- Fig. 6. Specific conductance versus depth profile for the Sittner site in Stafford County.

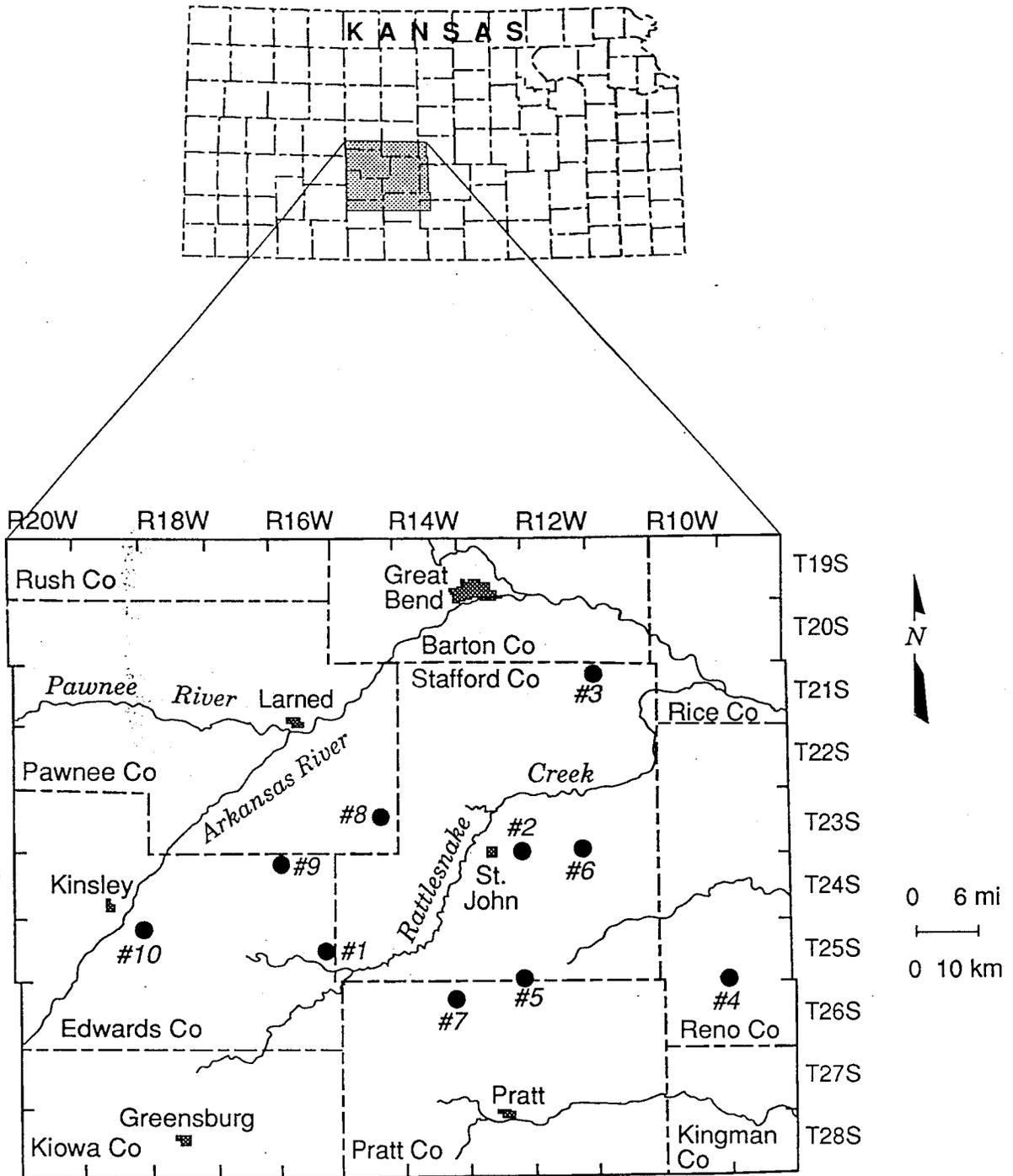


Figure 1.

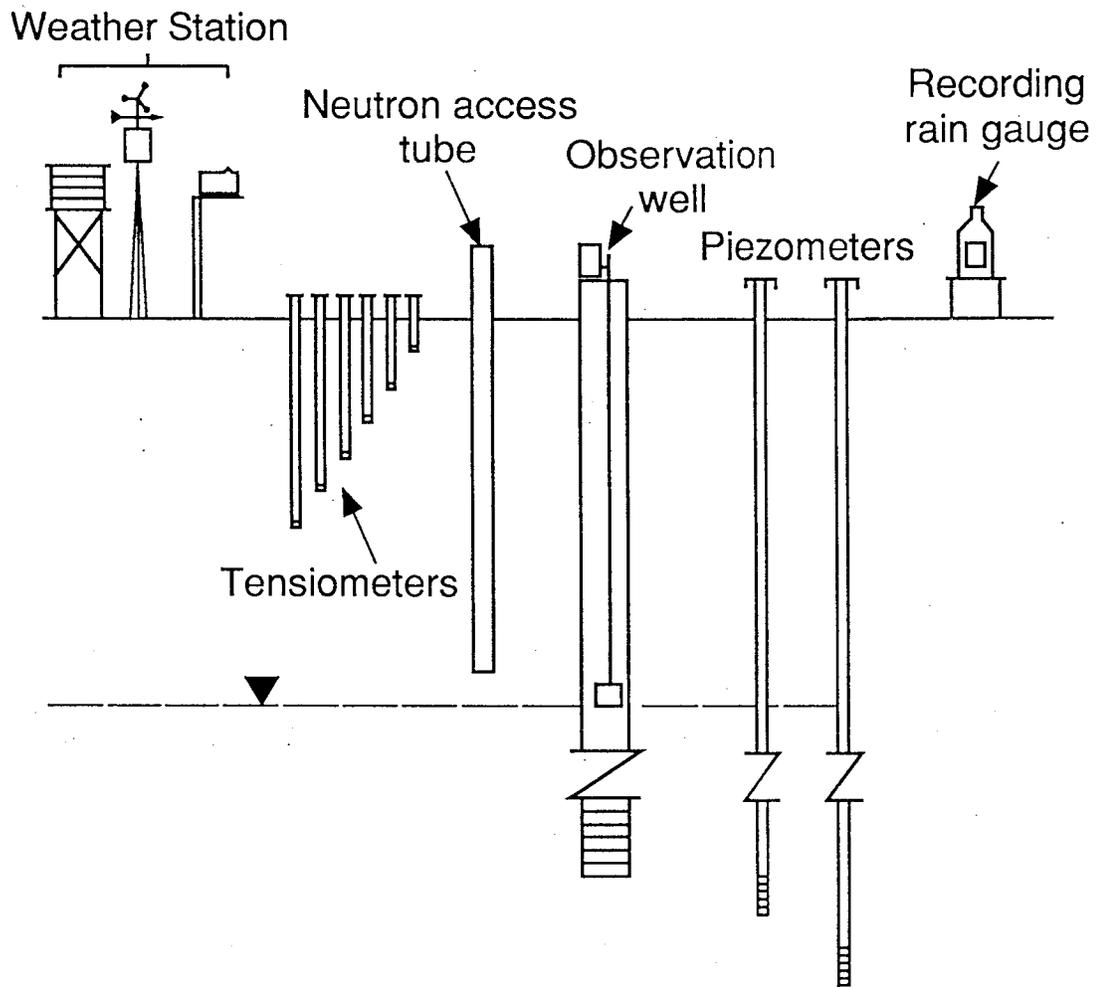


Figure 2.

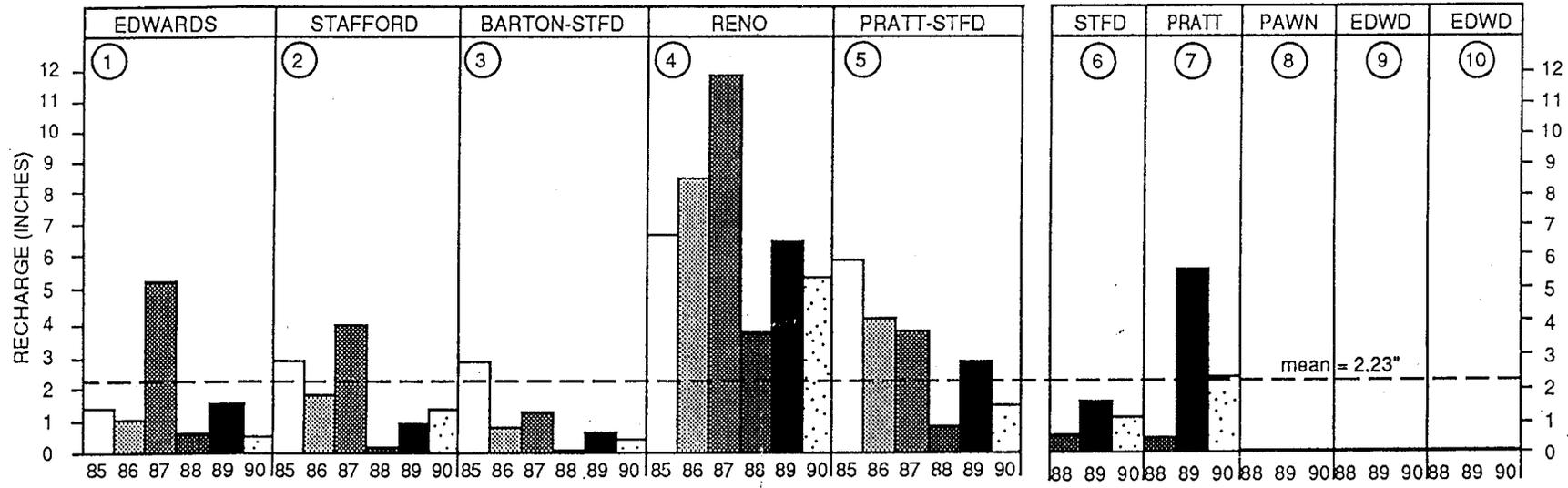
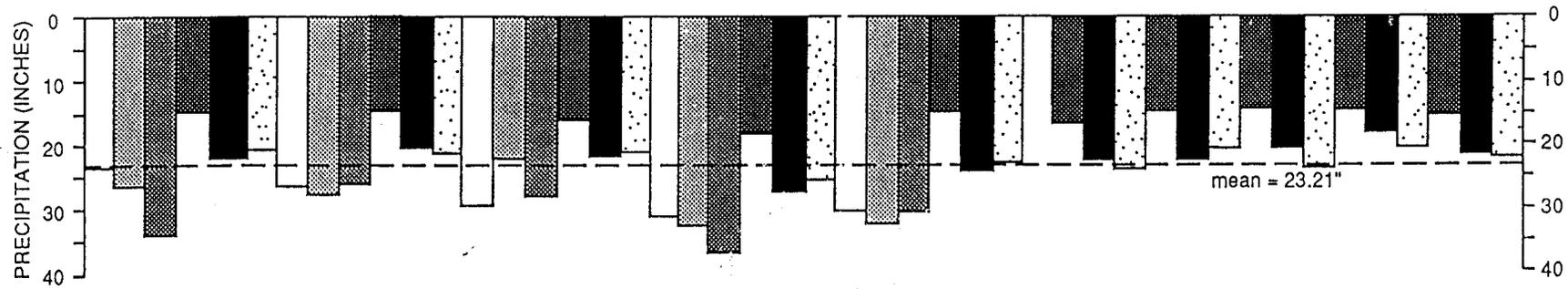


Figure 3.

Site # 2, 1985-90

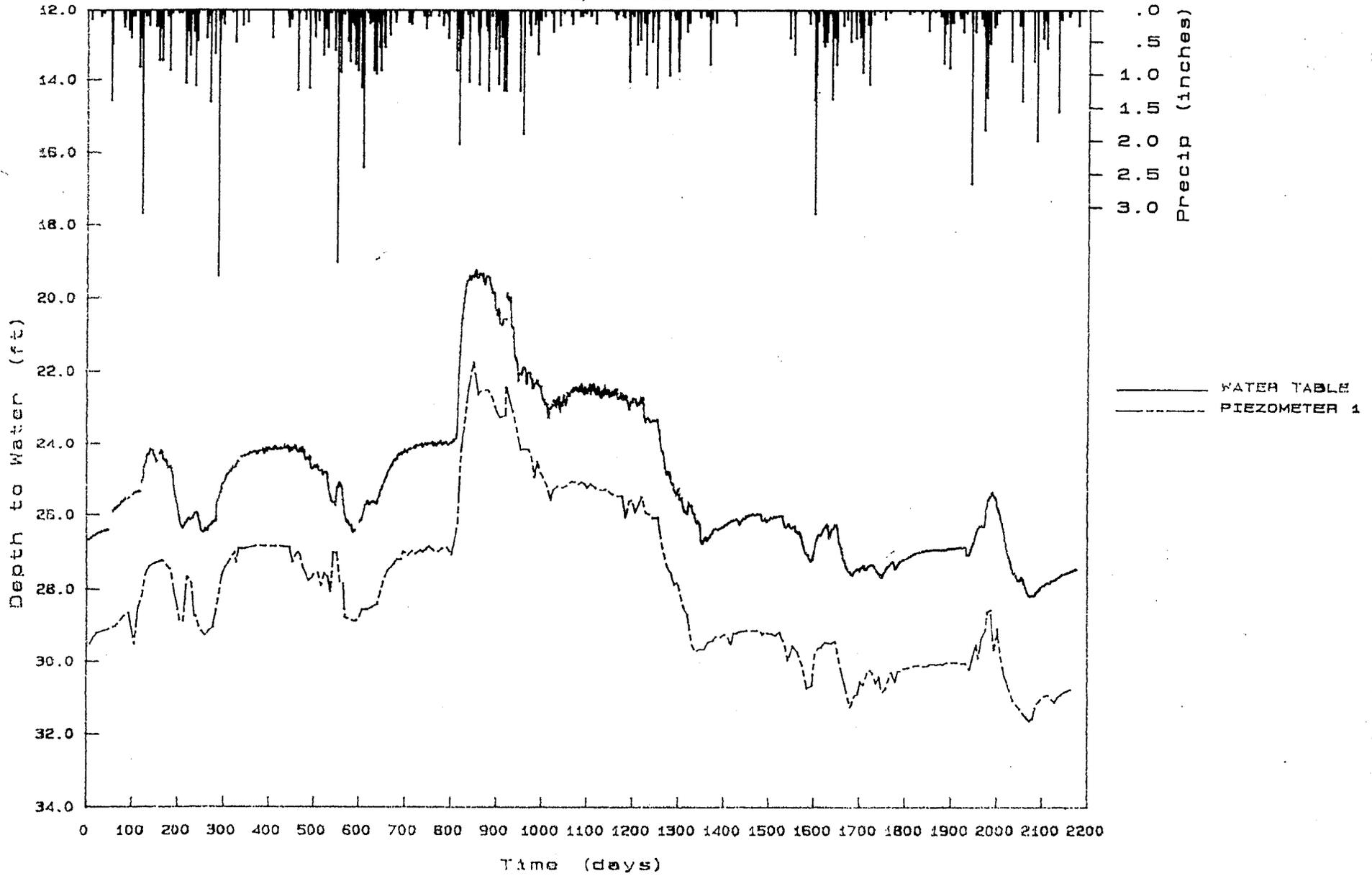


Figure 4a.

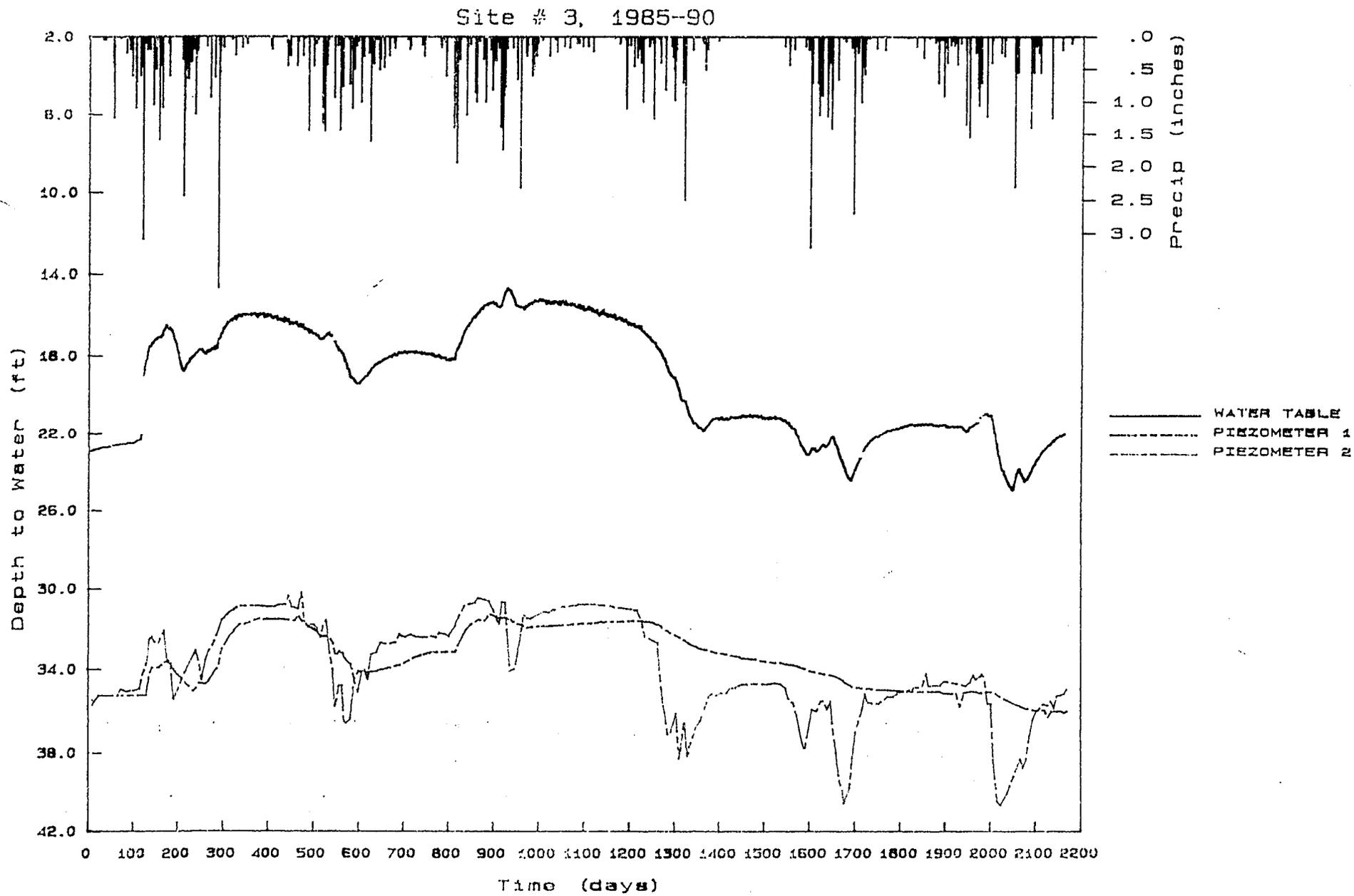


Figure 4b.

Site # 5, 1985-90

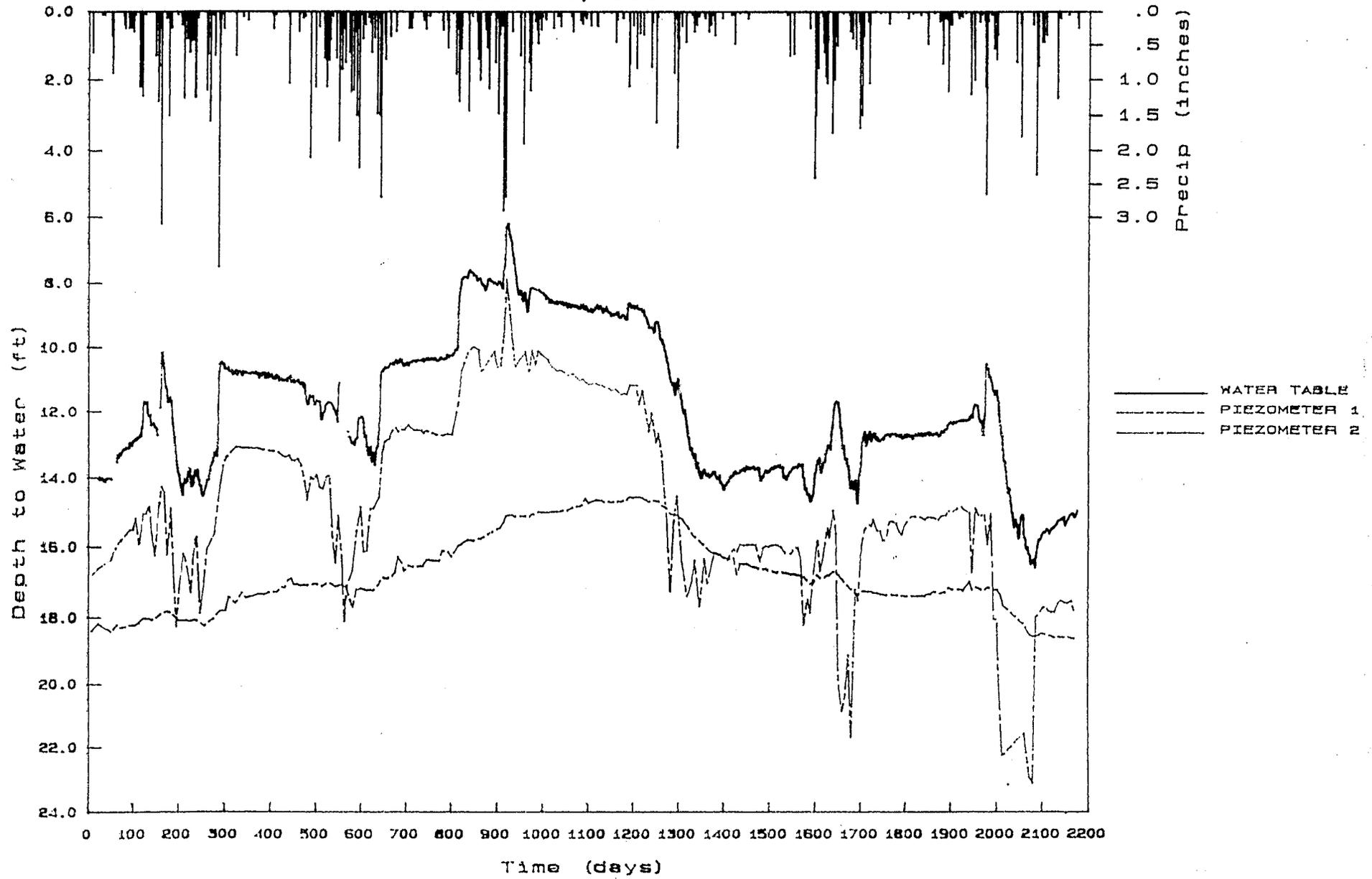
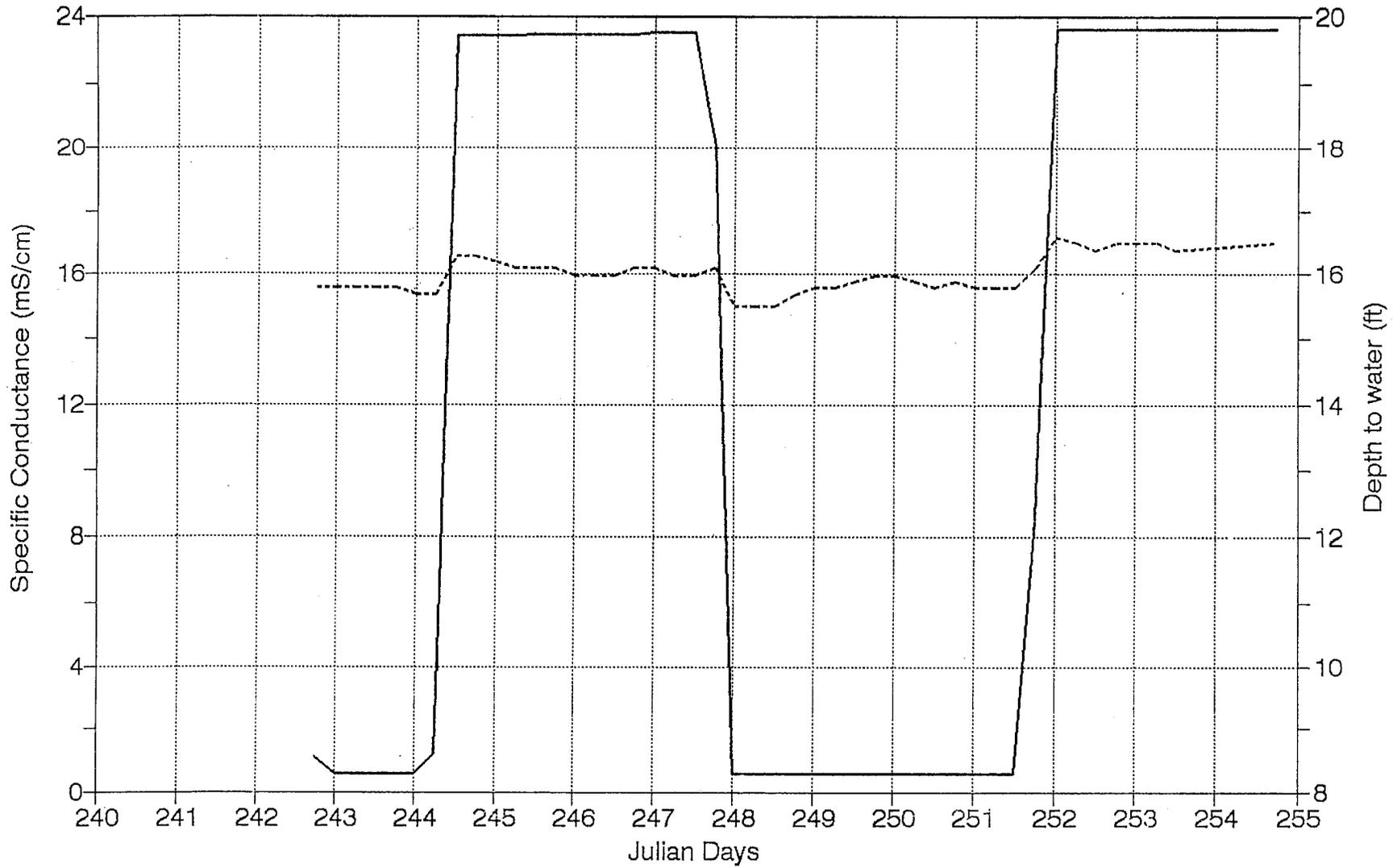


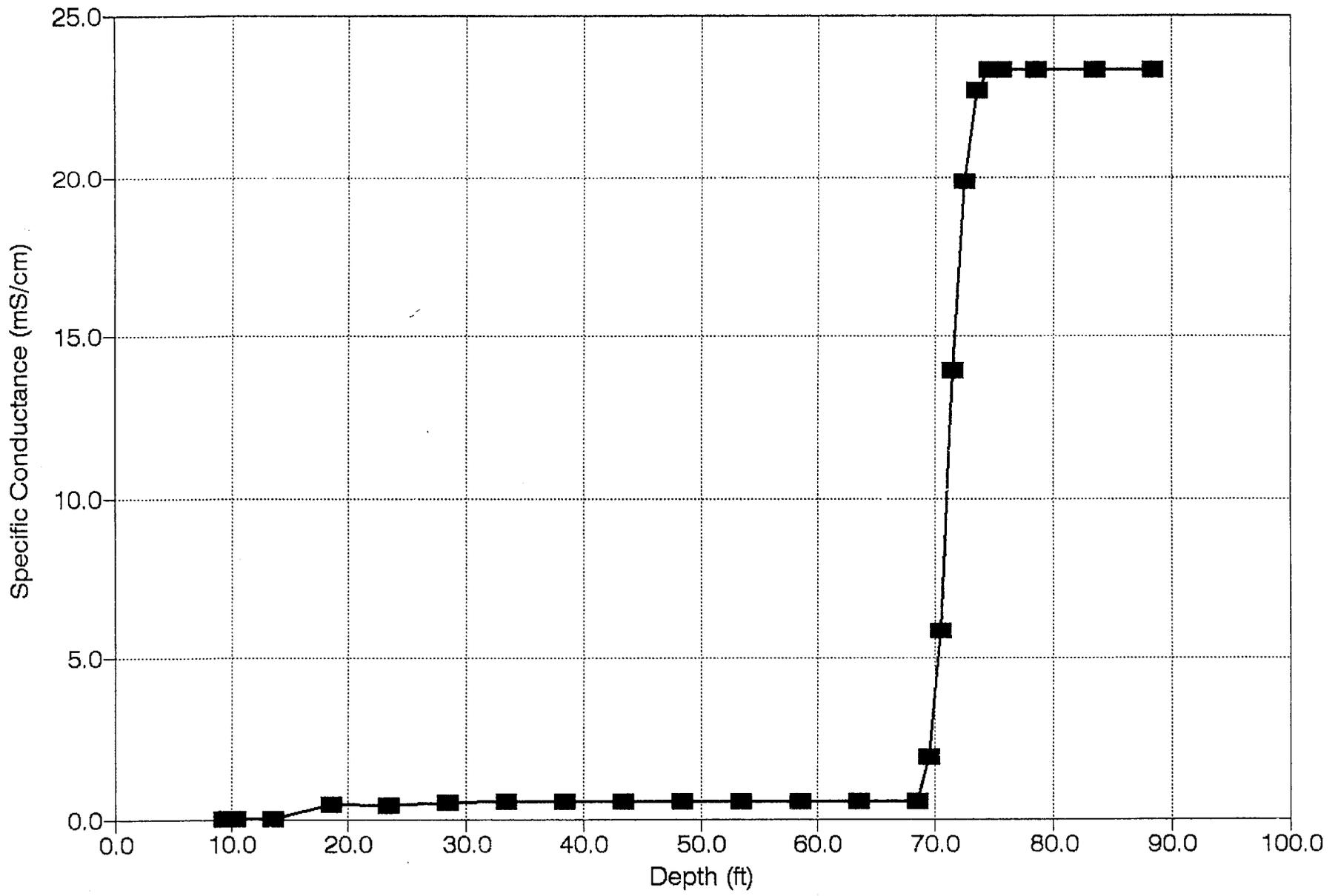
Figure 4c.

Sittner 1990  
Probe at 70.5' Below Land Surface



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Figure 5.



■ Sittner 8/30/90

Figure 6.