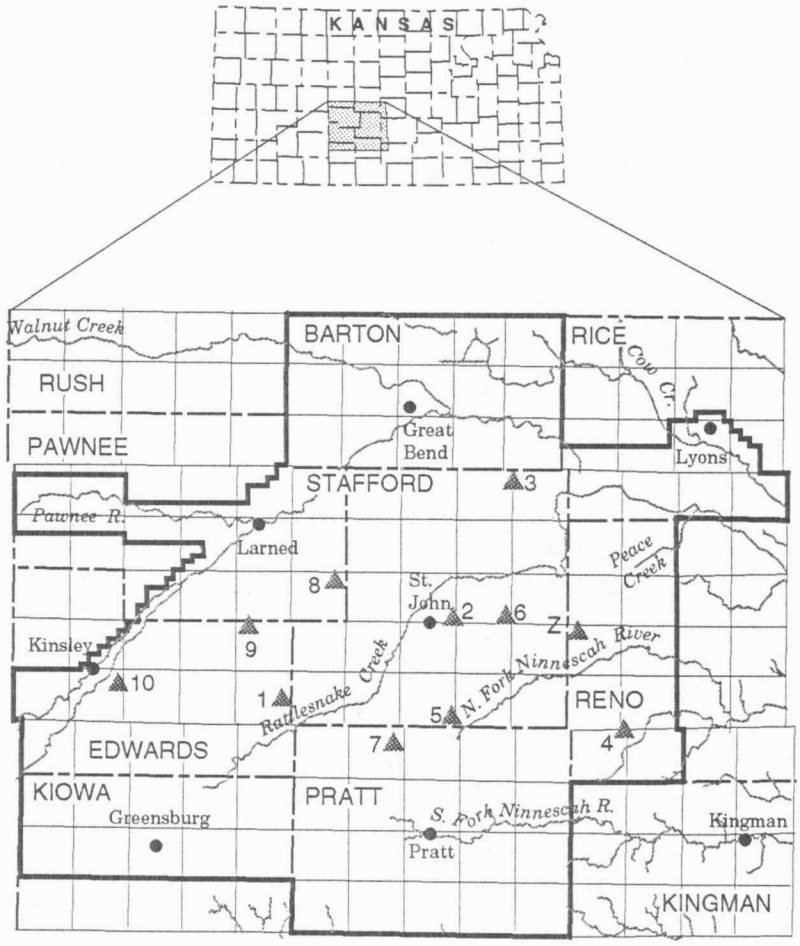
Kansas Geological Survey

Pictorial synthesis of 2,922 days (1985-1992) of continuous water-related data recording for the Big Bend Ground-water Management District No. 5 of south-central Kansas

(A short water atlas of 30 figures)



Marios Sophocleous

Open-File Report 93-22

GEOHYDROLOGY

The University of Kansas, Lawrence, KS 66047 Tel. (913) 864-3965

Pictorial synthesis of 2,922 days (1985–1992) of continuous water-related data recording for the Big Bend Ground-water Management District No. 5 of south-central Kansas

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August 1993

Guided by the motto "A picture is worth a thousand words," I present a series of water-related graphs from the Big Bend Ground-water Management District No. 5 (GMD5) region. These graphs are based on a recently completed 8-year (1985–1992) study of GMD5 ground-water recharge assessment (Sophocleous, 1991, 1992, 1993). These graphs are classified in the following manner:

1. Map of the region and recharge sites (1 figure).
2. Multiple-depth ground-water-level and precipitation daily series for recharge sites 1–10 (10 figures). The numbers in the legend indicate total depth of the well in feet; the screened length, always at the lower end of the well, is shown in parentheses. BR indicates bedrock well.
3. Total soil-profile water storage (on an approximately weekly basis) and daily precipitation for recharge sites 1–10 (10 figures).
4. Daily Rattlesnake Creek streamflow and baseflow at Macksville and Zenith stream-gaging stations and daily precipitation series of the closest rain-gage stations (2 figures).
5. Minimum and maximum daily air temperature and precipitation series for the Sandyland Experiment Station near St. John, Stafford County (1 figure).
6. Daily potential evapotranspiration (based on the Penman equation) and precipitation series for the Sandyland Experiment Station near St. John, Stafford County (1 figure).
7. Calculated annual ground-water recharge and precipitation histogram for recharge sites 1–10 (1 figure).
8. Cumulative monthly precipitation, recharge, and Rattlesnake Creek baseflow time series (2 figures).
9. Cumulative monthly Rattlesnake Creek streamflow and baseflow and ground-water recharge versus cumulative monthly precipitation (2 figures).

The interested reader should also consult our companion report, "Fifteen GIS hydrologic maps of the Big Bend Ground-water Management District No 5 (GMD5)" (Sophocleous and Stern, 1993) as well as the Sophocleous (1991, 1992, 1993) recharge-related papers.

Some comments on some of the figures are warranted.

Figure 2: The highest ground-water levels (shallowest depth to water table) occurred during 1987. Note the 1987–1991 declining water-level trends. Piezometer 2, screened in the deeper unconsolidated aquifer, shows a pronounced impact of irrigation wells because irrigation wells are usually screened at the deeper part of the aquifer. Bedrock well (BR) water levels are hydraulically connected to the overlying aquifer and fluctuate in tandem with the unconsolidated aquifer water levels, albeit in subdued fashion. Note the reversals of hydraulic gradients during irrigation seasons, implying brine intrusion potential.

Figure 3: Note the generally declining soil-profile water storage trends during the 1987–1991 period. These coincide with the ground-water-level declines shown in fig. 2. Site 7, which is an irrigated field site, shows the least soil-water-content fluctuations.

Figure 4: Rattlesnake Creek is indeed a "baseflow stream", i.e., the bulk of Rattlesnake Creek streamflow comes from baseflow. To obtain these graphs, we used the USGS baseflow separation program HYSEP2 (White and Sloto, 1990) employing the local minimum technique for daily streamflow hydrograph separation.

Figures 5 and 6: Note the coinciding periods of daily temperature and evapotranspiration.

Figure 7: Note that similar yearly rains produced different recharge amounts; this can be attributed to differences in the timing of rains. Spring rains are the most effective in recharging the aquifer. The unusually high recharge estimates for site 4 in Reno County, which received the highest precipitation among all sites during the study period, are due to the site being located on the streambank of a tributary to Wolf Creek, where the depth to the water table is shallow, approximately 2–4 ft. Also note the drought effect of 1988, which resulted in the lowest overall amount of recharge over the measurement period. Sites 8, 9, and 10 received no detectable recharge during the 1988–1992 period of record.

Figure 8: The graphs are mass curves, i.e., cumulative plottings of measured monthly rainfall and estimated monthly recharge and baseflow. The slope of a mass curve at any time is a measure of the rainfall, recharge, and baseflow rates at that time. Note the 1987 steepness of the slope, especially for cumulative recharge and baseflow, indicating increased rates of these quantities at the time. Also note the amplification factor of 10 (for display purposes) for cumulative recharge.

Figure 9: The graphs are double-mass curves of cumulative monthly Rattlesnake streamflow, baseflow, and recharge versus cumulative monthly rainfall. The theory of double-mass curves is based on the concept that a graph of the cumulative data of one variable versus the cumulative data of another is a straight line so long as the relationship between the variables is a fixed ratio (i.e., the data are proportional; the slope of the line represents the constant of proportionality between the variables). Note the steepness (change in slope) of the recharge, streamflow, and baseflow mass curves during 1987, emphasizing the importance of that above-average-wetness year, which caused a change in the constant of proportionality. Also note the close correspondence among the mass curves of streamflow and particularly of recharge and baseflow versus the precipitation mass curve. (The horizontal position of the year designation indicates the starting of the calendar year for all displayed variables.)

Acknowledgments

The cooperation and data-collection assistance of the GMD5 personnel is gratefully acknowledged. Several Kansas Geological Survey graduate research assistants assisted with data collection and processing over the duration of the project. Tain-Shing Ma, the last in the sequence of project student assistants, assisted with the data displays presented here. Sandyland Experiment Station climatic data were provided by the Kansas State University Weather Library.

References

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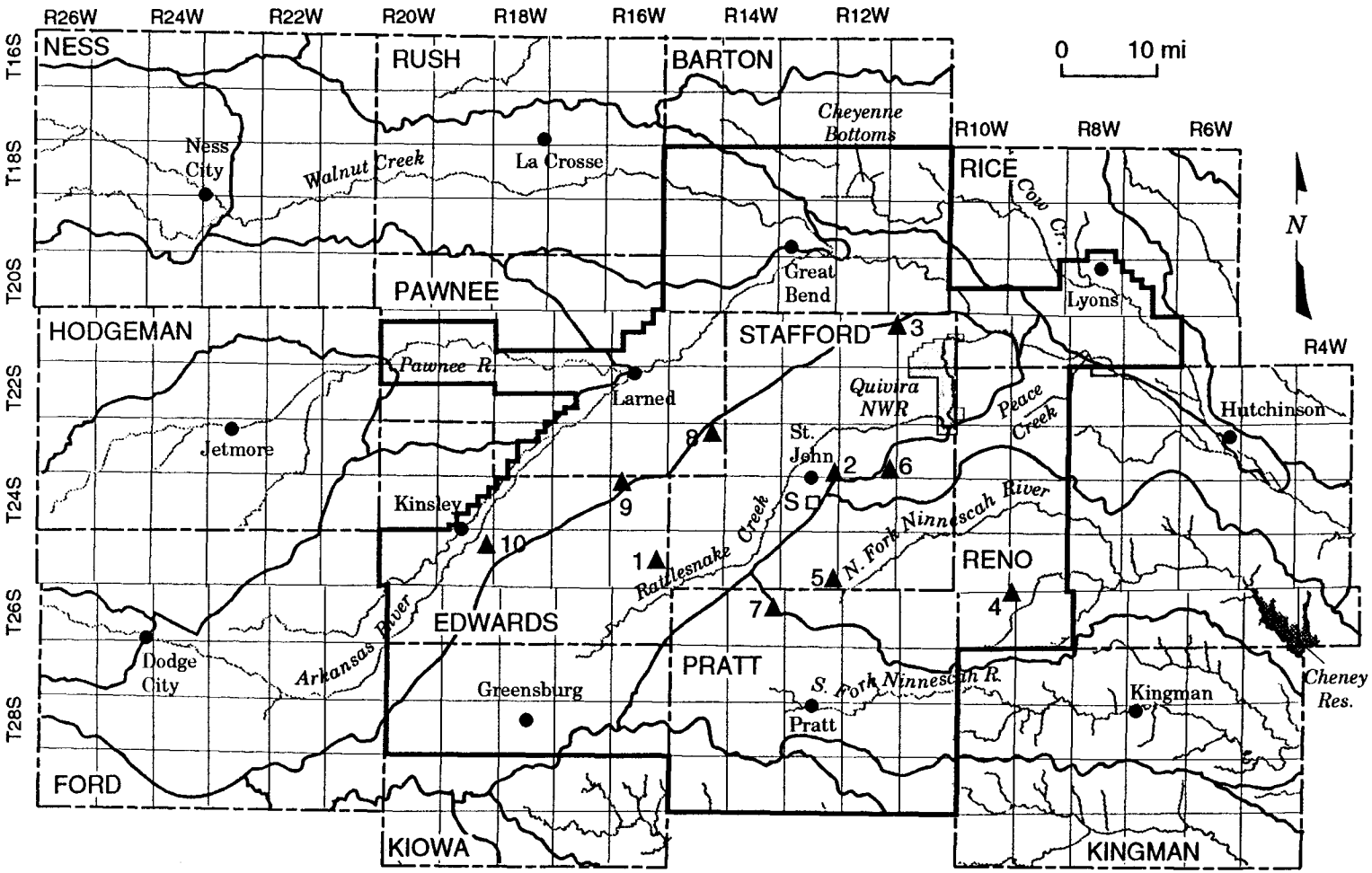
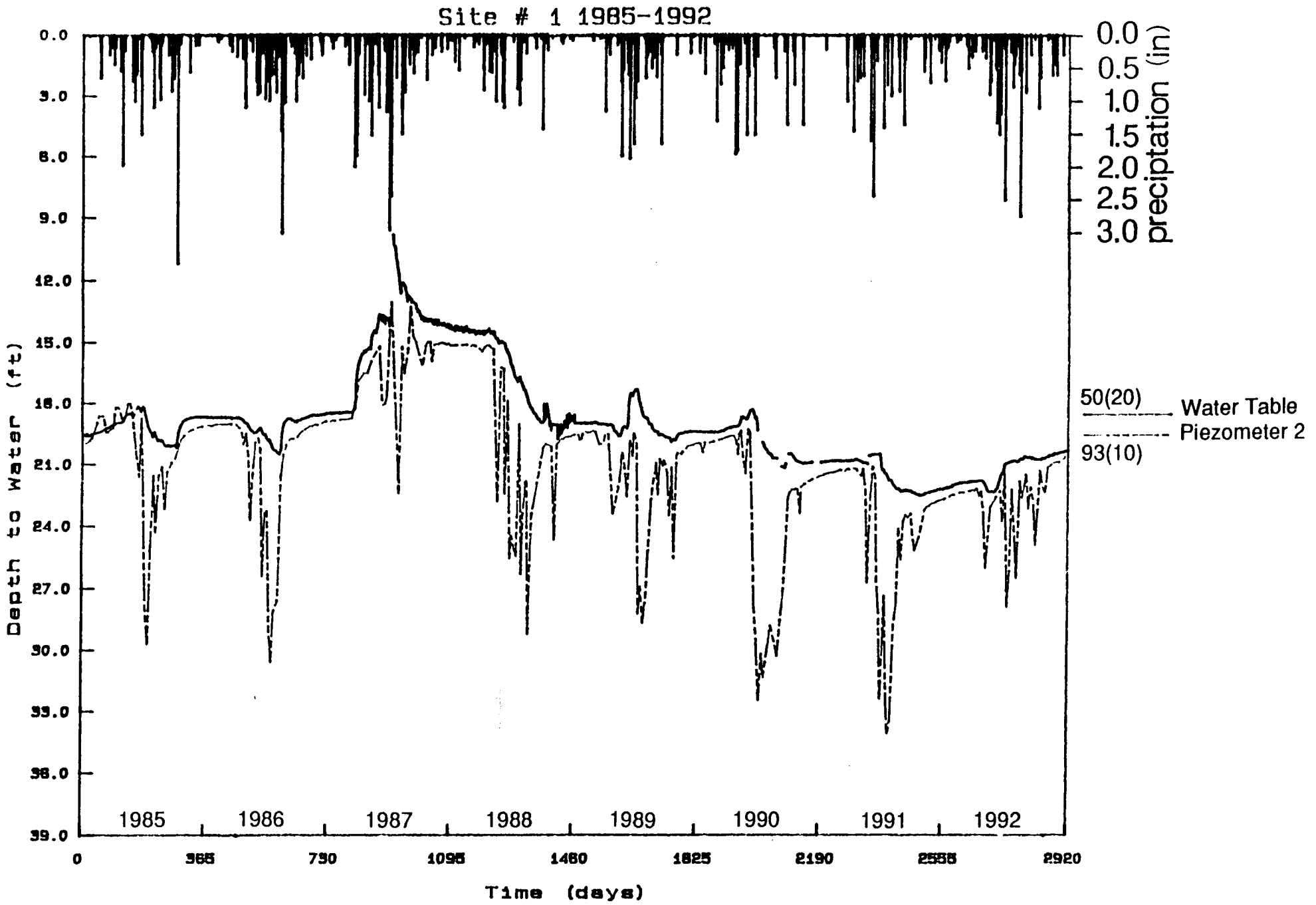


Figure 1. Ground-water recharge assessment area and recharge study sites (triangles) (S is Sandyland Experiment Station). Darker outline denotes GMD5 boundary. River basins are outlined in red.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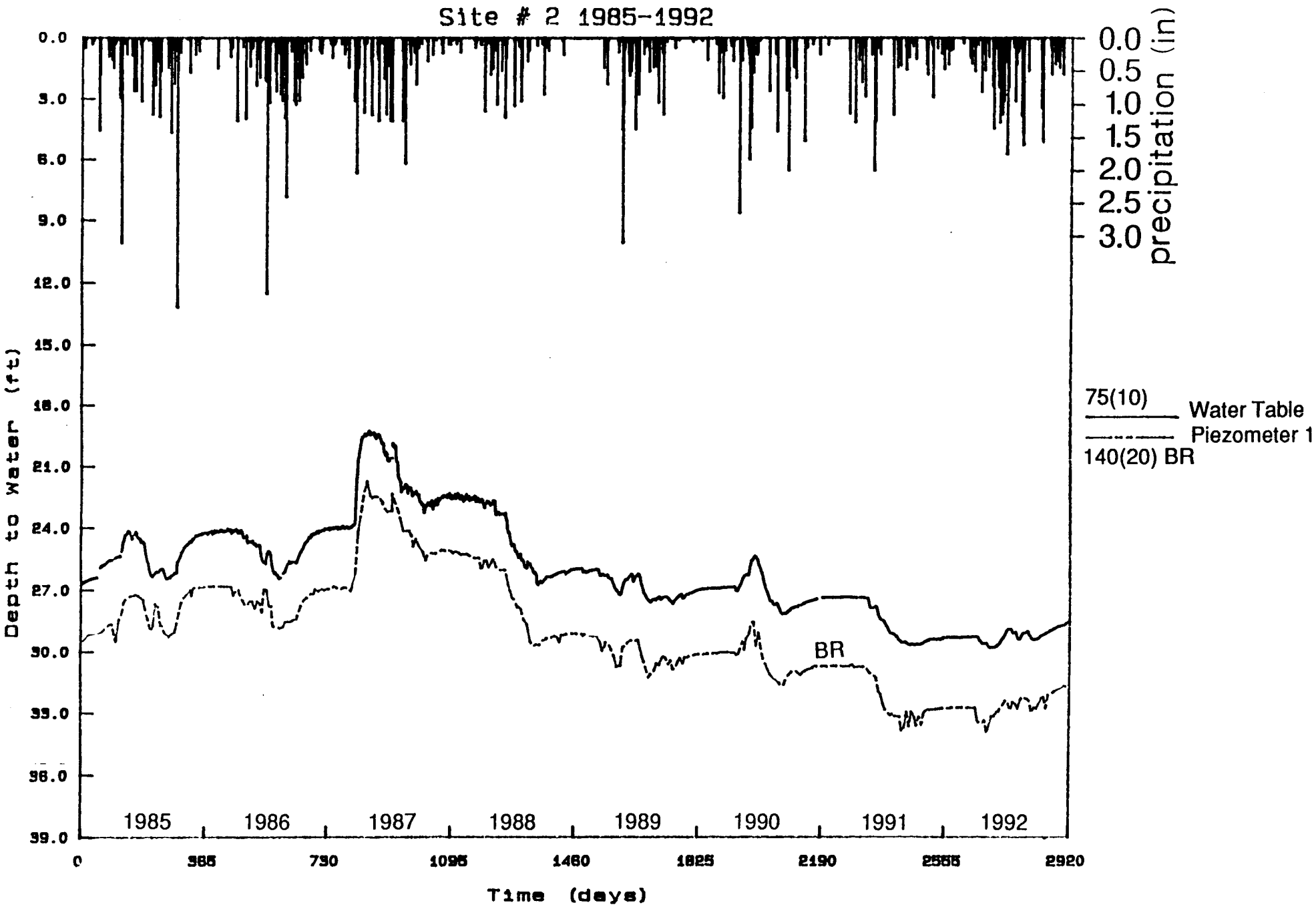
0.0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
50(20)
93(10)
Water Table
Piezometer 2
1985
1986
1987
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
2190
2555
2920
Time (days)

Figure 2.1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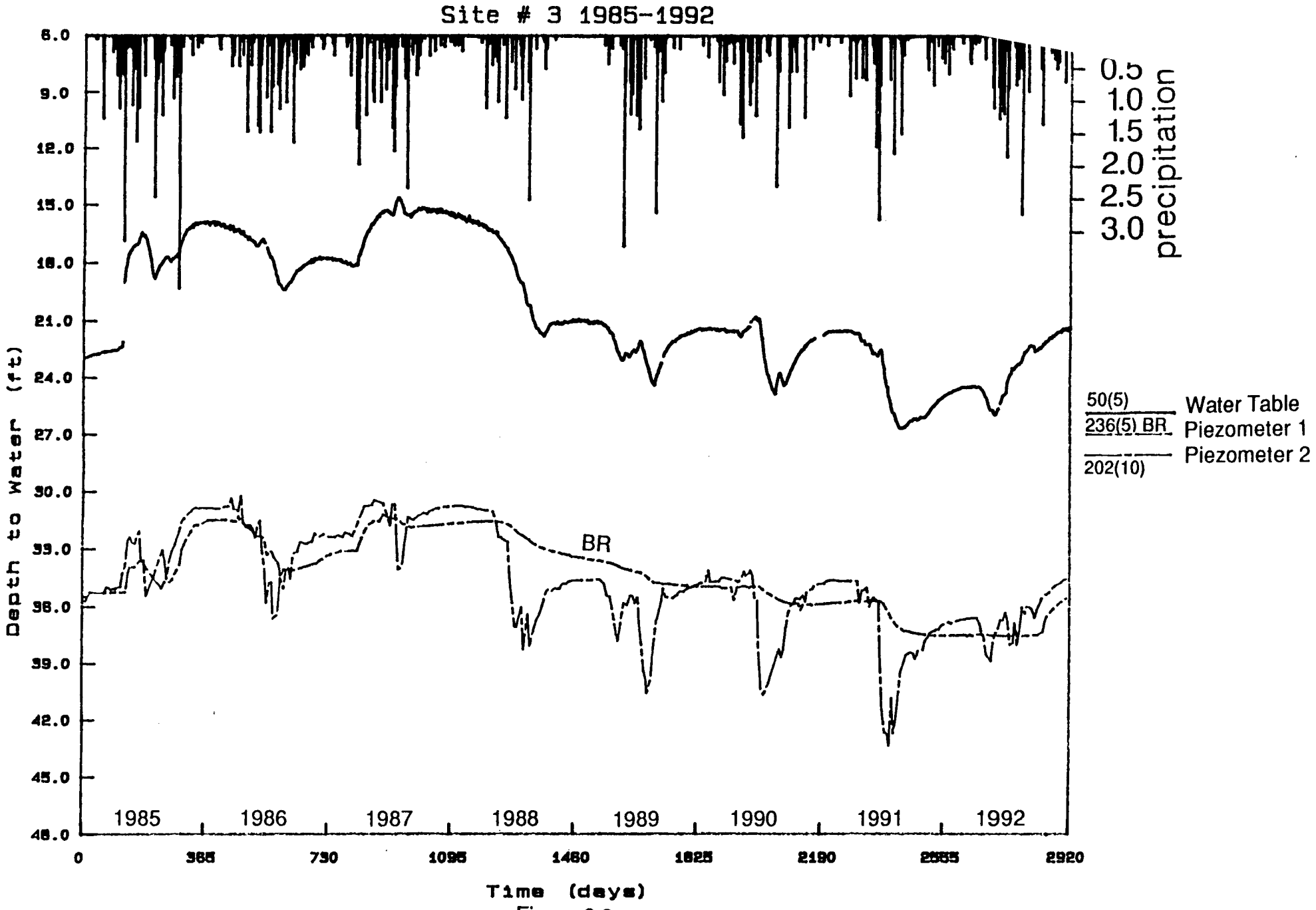
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
precipitation (in)
75(10)
Water Table
Piezometer 1
140(20) BR
BR
1985
1986
1987
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
2190
2555
2920
Time (days)
Figure 2.2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6.0
9.0
12.0
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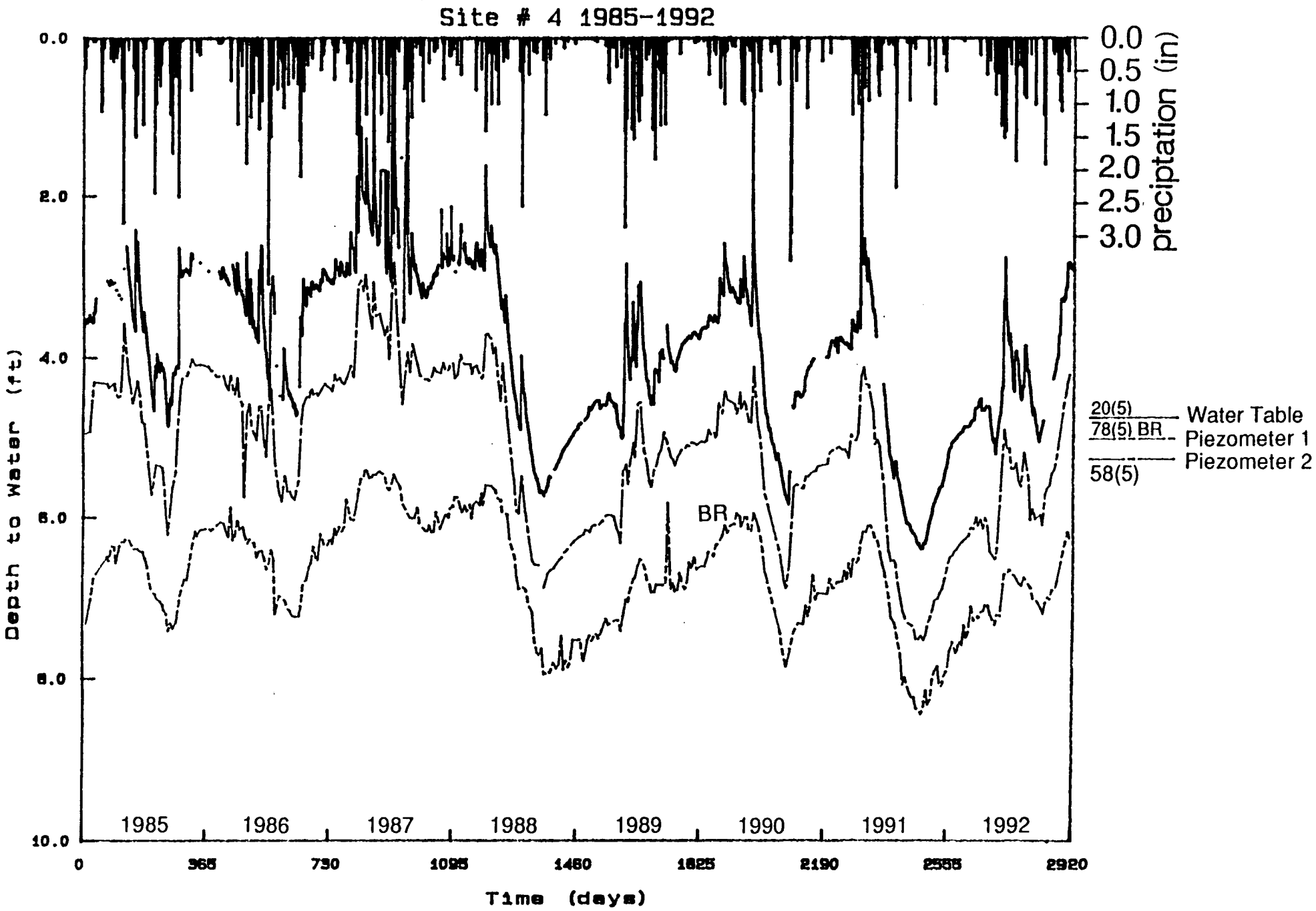
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
42.0
45.0
48.0
Depth to Water (ft)
0.5
1.0
1.5
2.0
2.5
3.0
precipitation
50(5) Water Table
236(5) BR Piezometer 1
202(10) Piezometer 2
BR
1985
1986
1987
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
2190
2555
2920
Time (days)
Figure 2.3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Depth to Water (ft)
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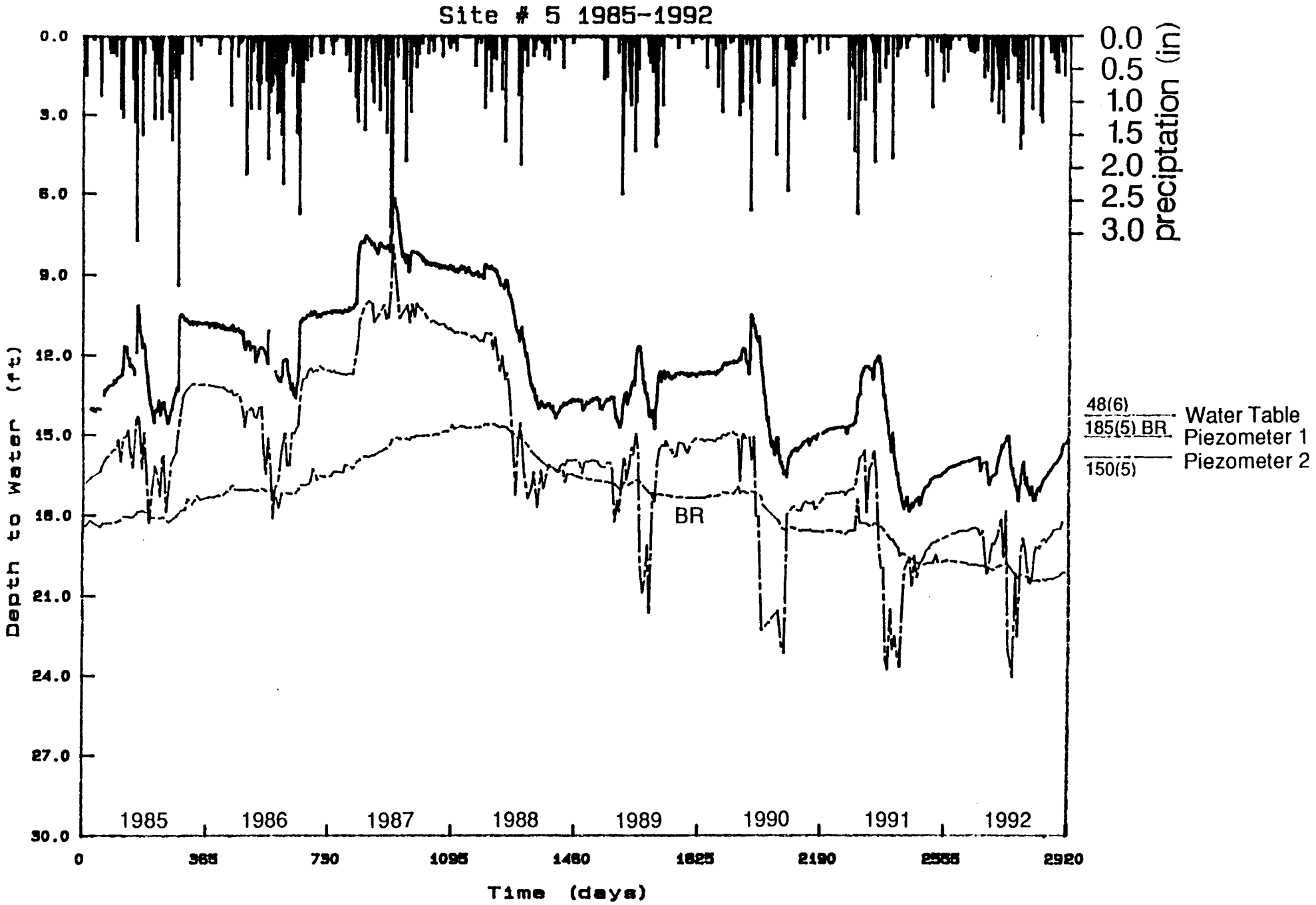
2.0
4.0
6.0
8.0
10.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
20(5)
78(5) BR
58(5)
Water Table
Piezometer 1
Piezometer 2
BR
1985
1986
1987
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
2190
2555
2920
Time (days)

Figure 2.4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Depth to Water (ft)
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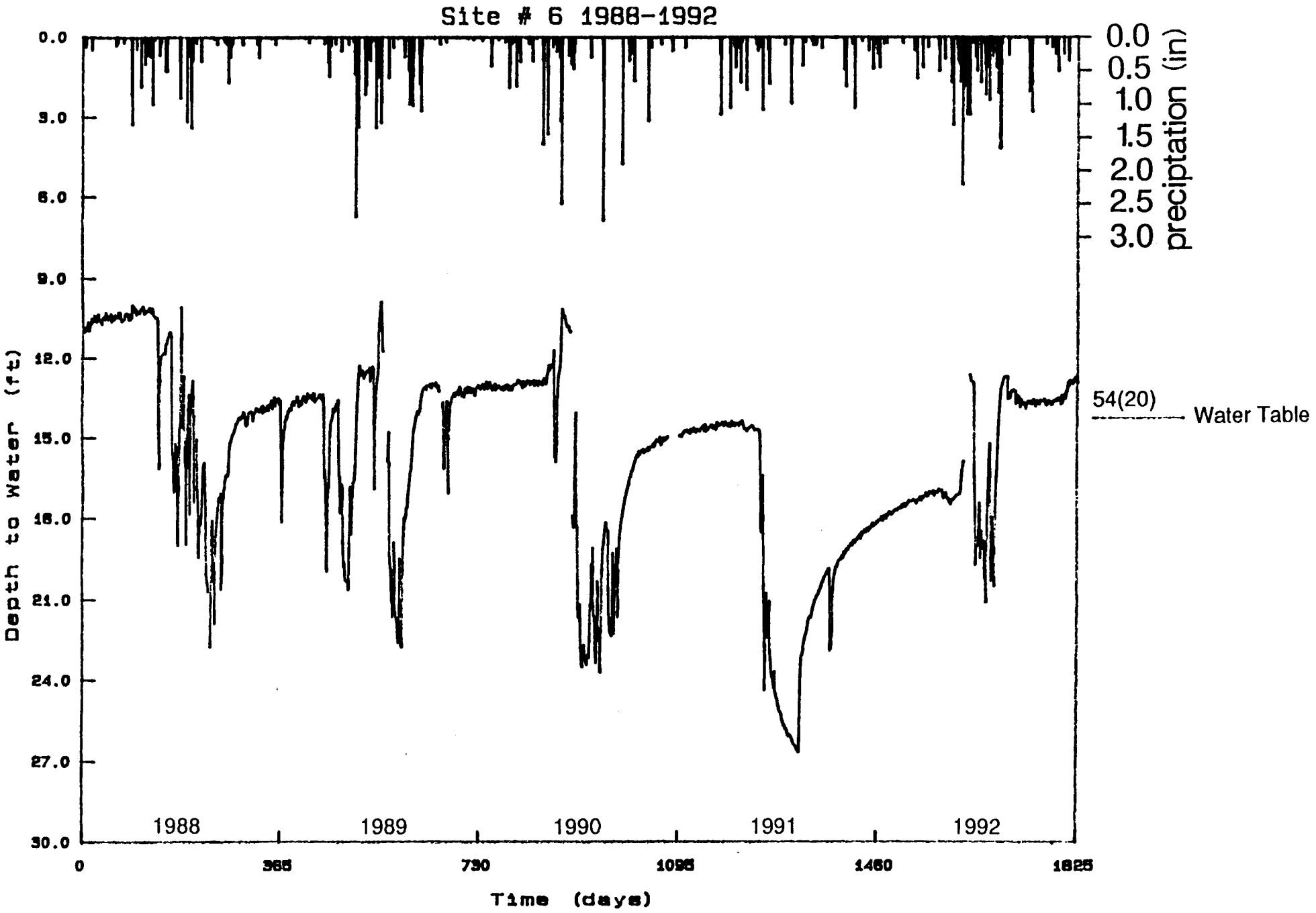
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
1985
1986
1987
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
2190
2555
2920
Time (days)
BR
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
48(6) Water Table
185(5) BR Piezometer 1
150(5) Piezometer 2

Figure 2.5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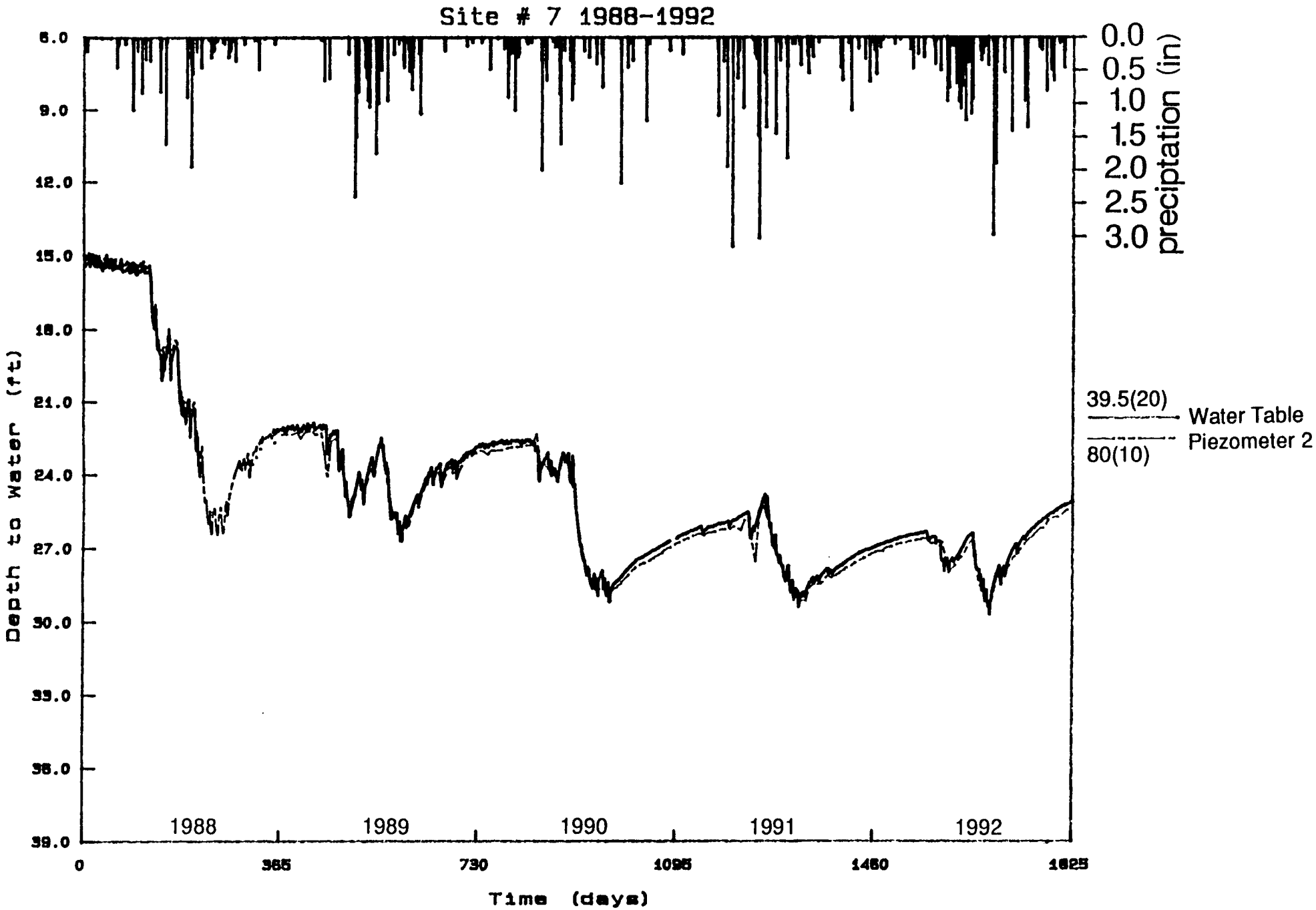
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
54(20)
Water Table
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
Time (days)

Figure 2.6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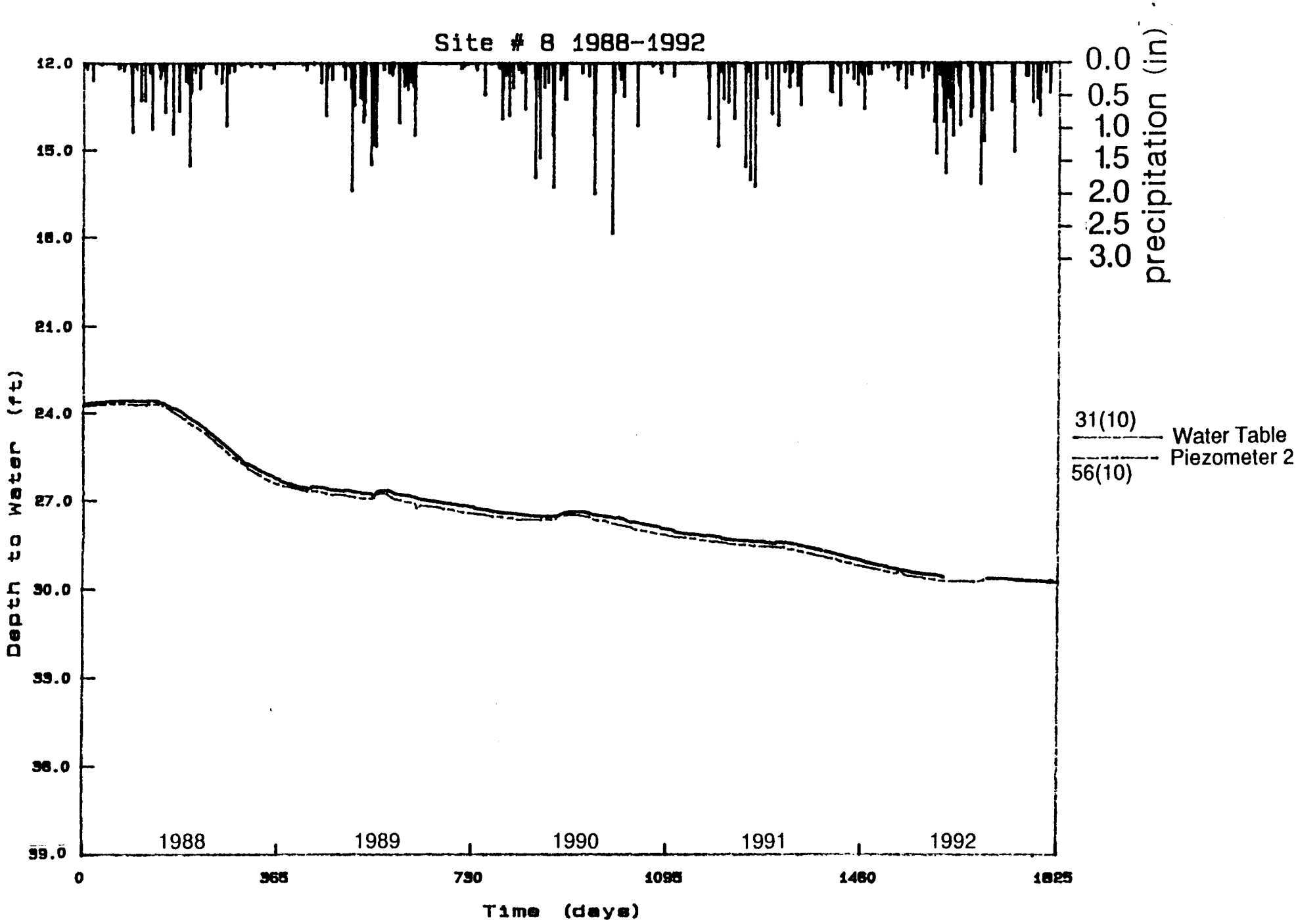
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
39.5(20)
Water Table
Piezometer 2
80(10)
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
Time (days)

Figure 2.7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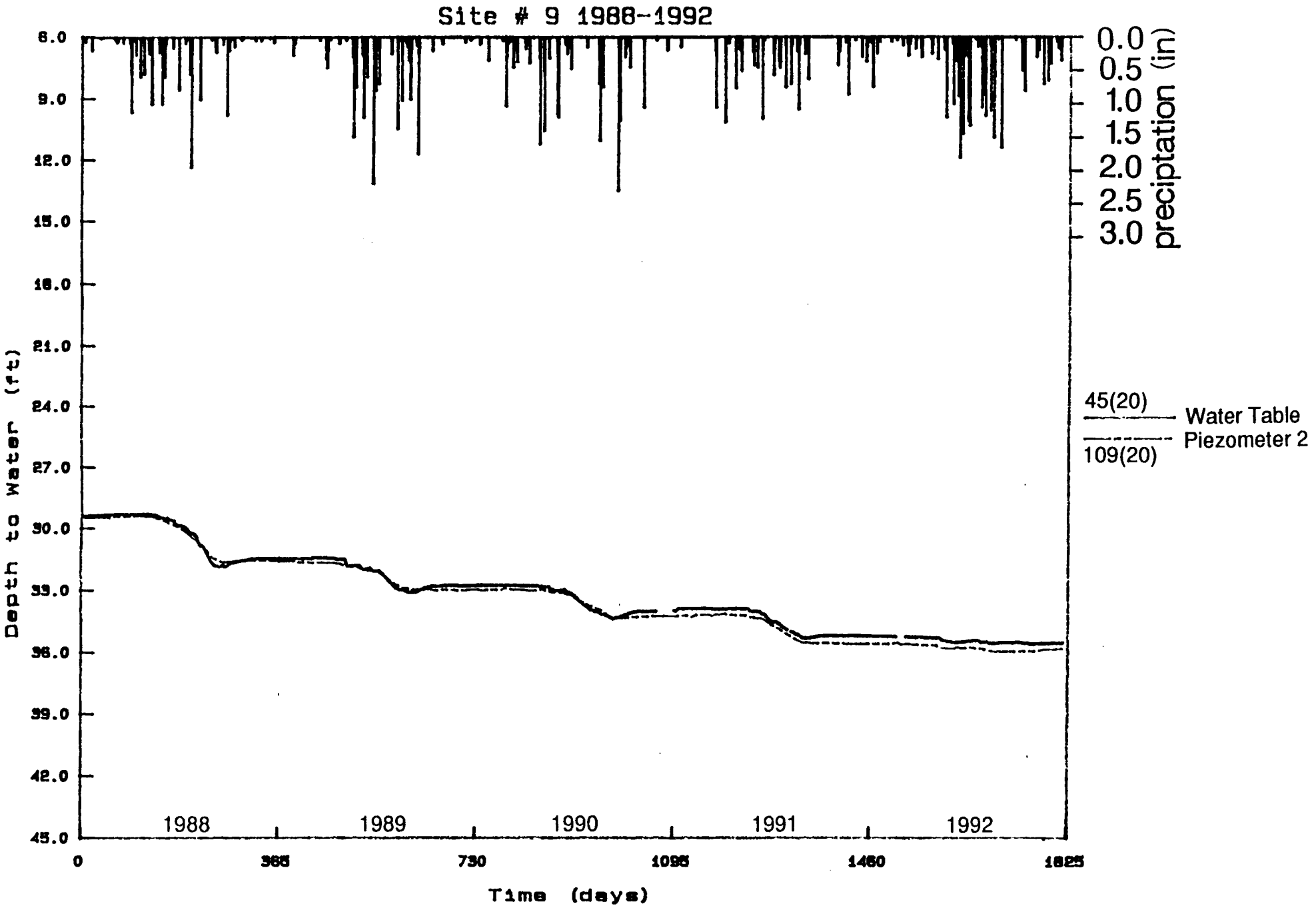
15.0
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
precipitation (in)
31(10)
Water Table
Piezometer 2
56(10)
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
Time (days)
Figure 2.8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Depth to Water (ft)
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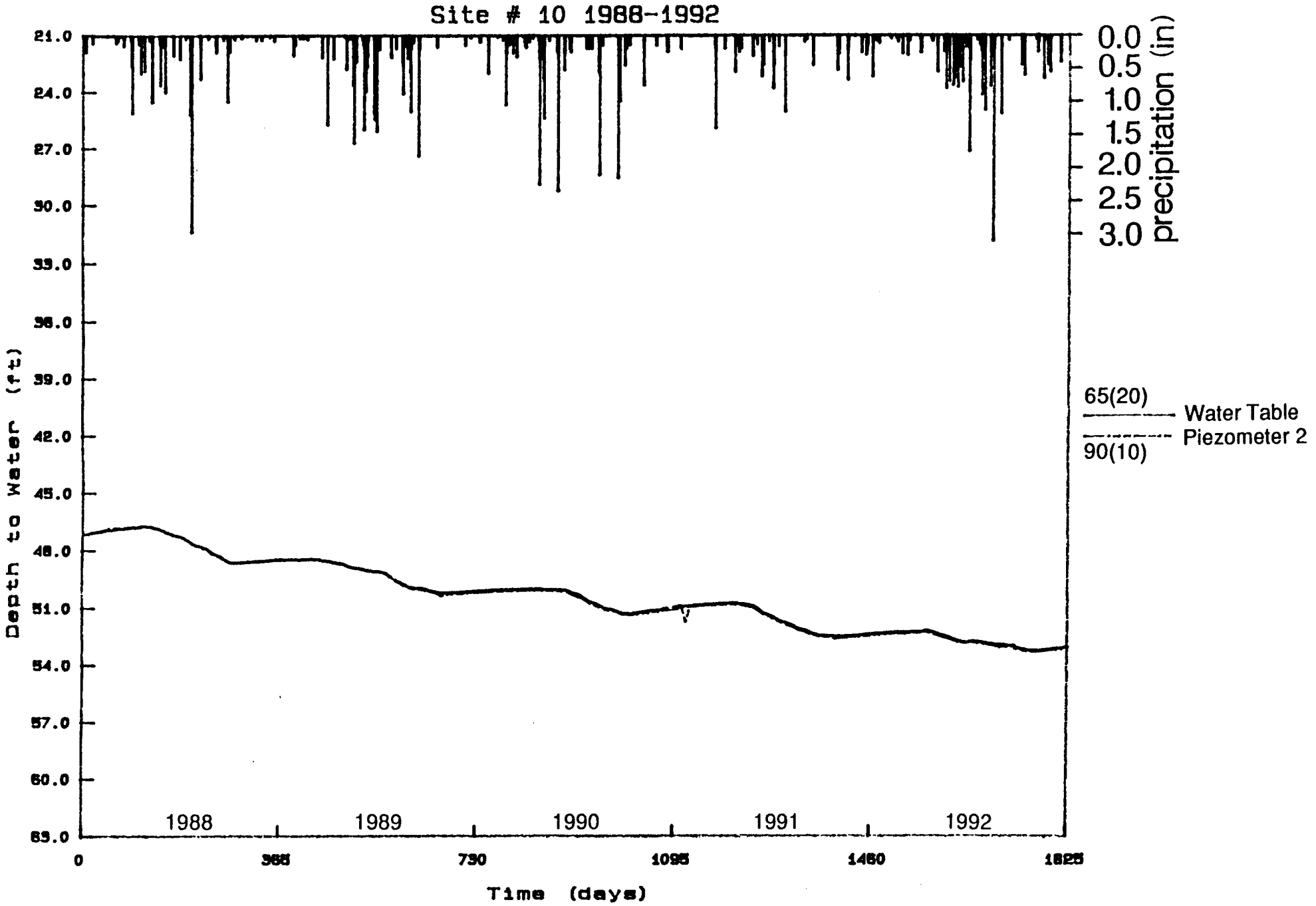
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0
33.0
36.0
39.0
42.0
45.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
preciptation (in)
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
Time (days)
45(20)
Water Table
109(20)
Piezometer 2

Figure 2.9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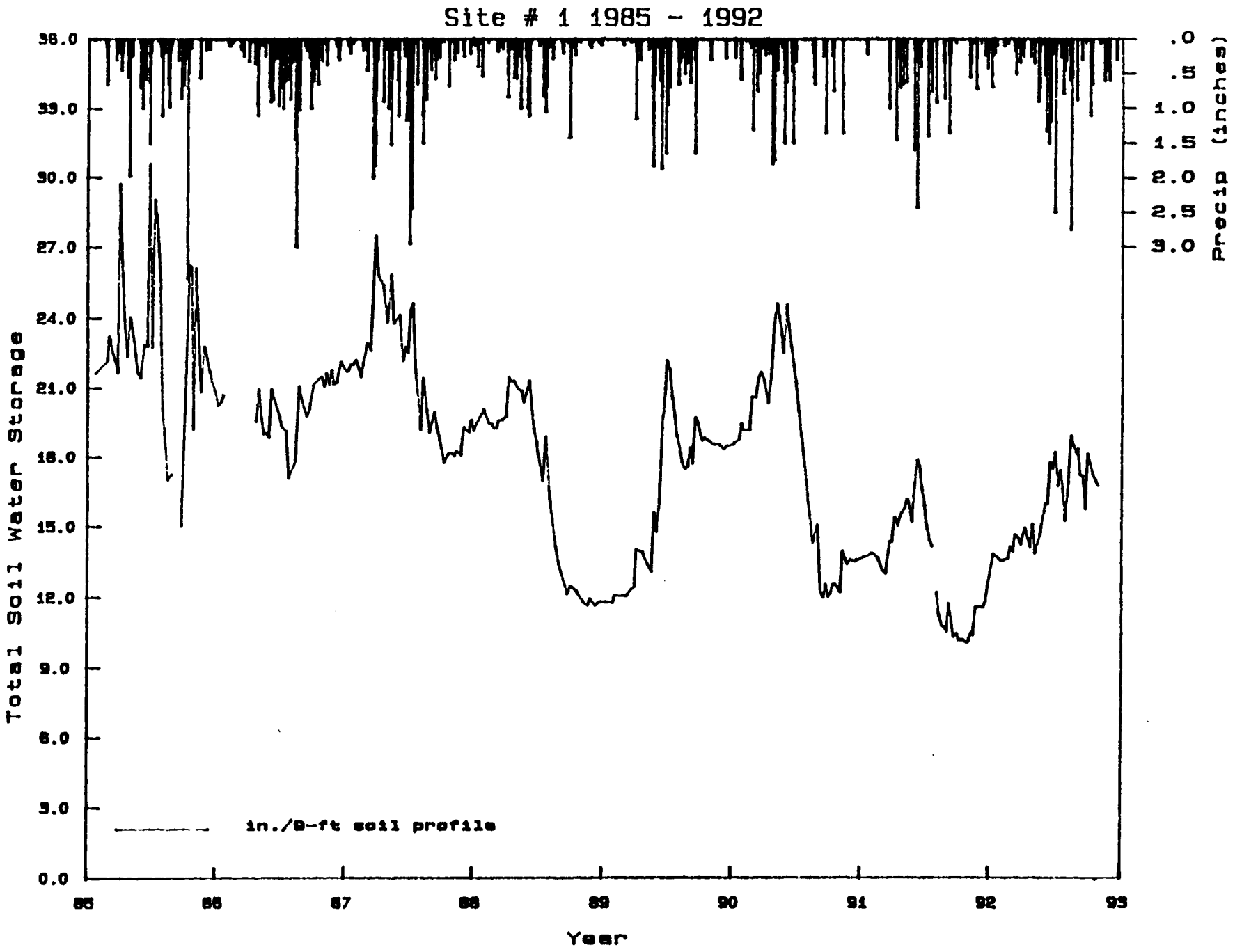
33.0
36.0
39.0
42.0
45.0
48.0
51.0
54.0
57.0
60.0
63.0
Depth to Water (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
precipitation (in)
65(20)
Water Table
Piezometer 2
90(10)
1988
1989
1990
1991
1992
0
365
730
1095
1460
1825
Time (days)
Figure 2.10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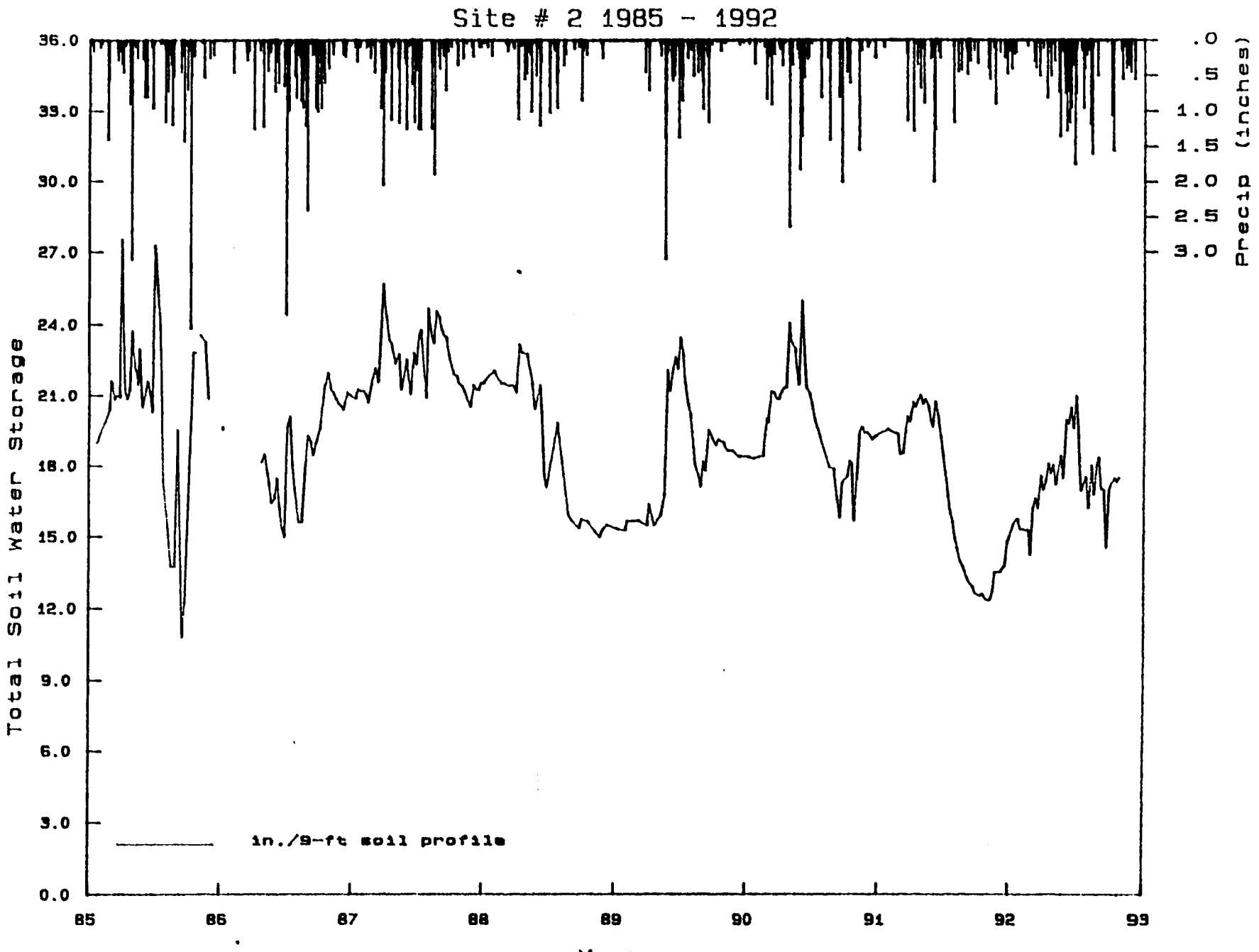
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
.0
.5
1.0
1.5
2.0
2.5
3.0
Precip (inches)
in./3-ft soil profile
85
86
87
88
89
90
91
92
93
Year
Figure 3.1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27.0
24.0
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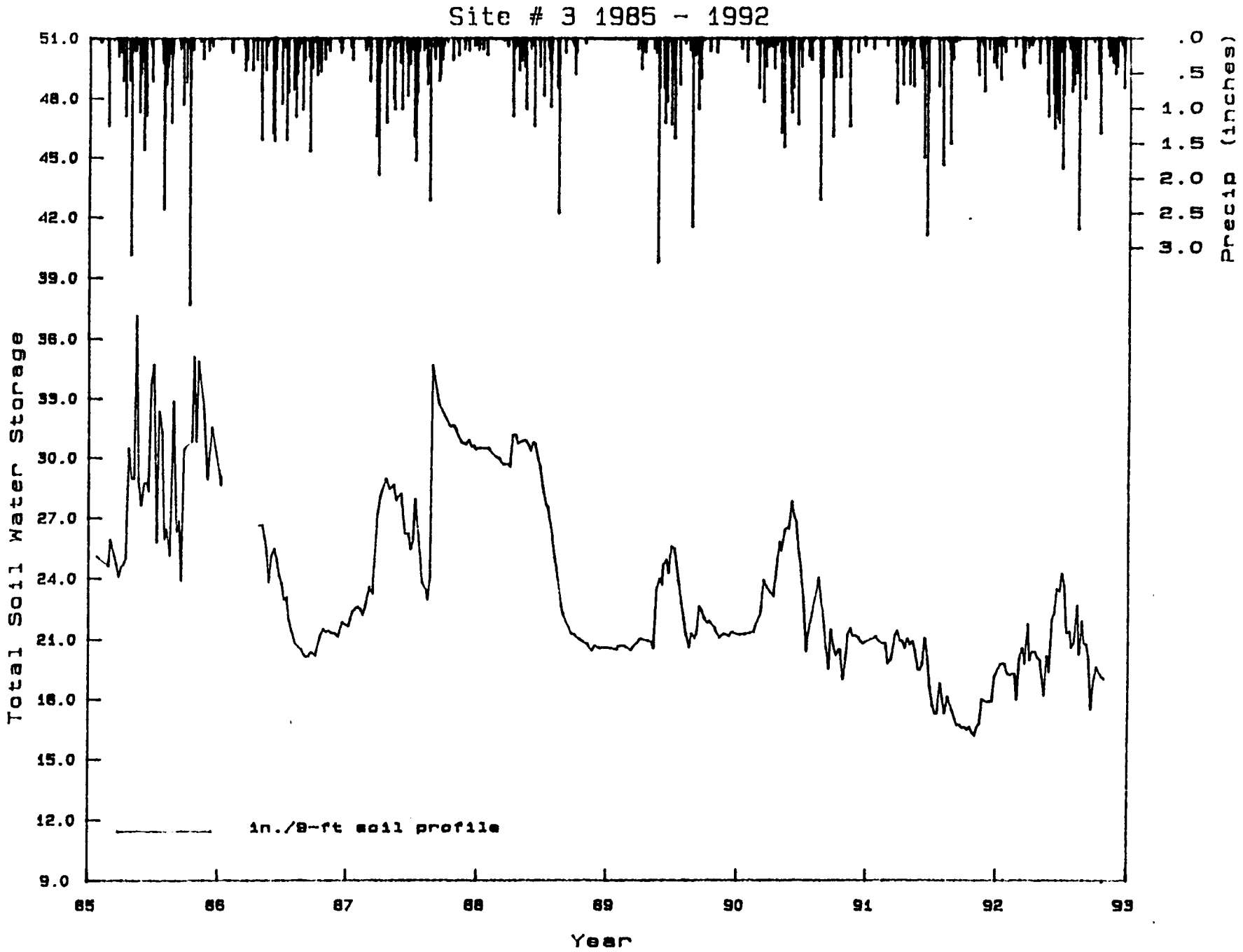
15.0
12.0
9.0
6.0
3.0
0.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
in./3-ft soil profile
85
86
87
88
89
90
91
92
93
Year

Figure 3.2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45.0
42.0
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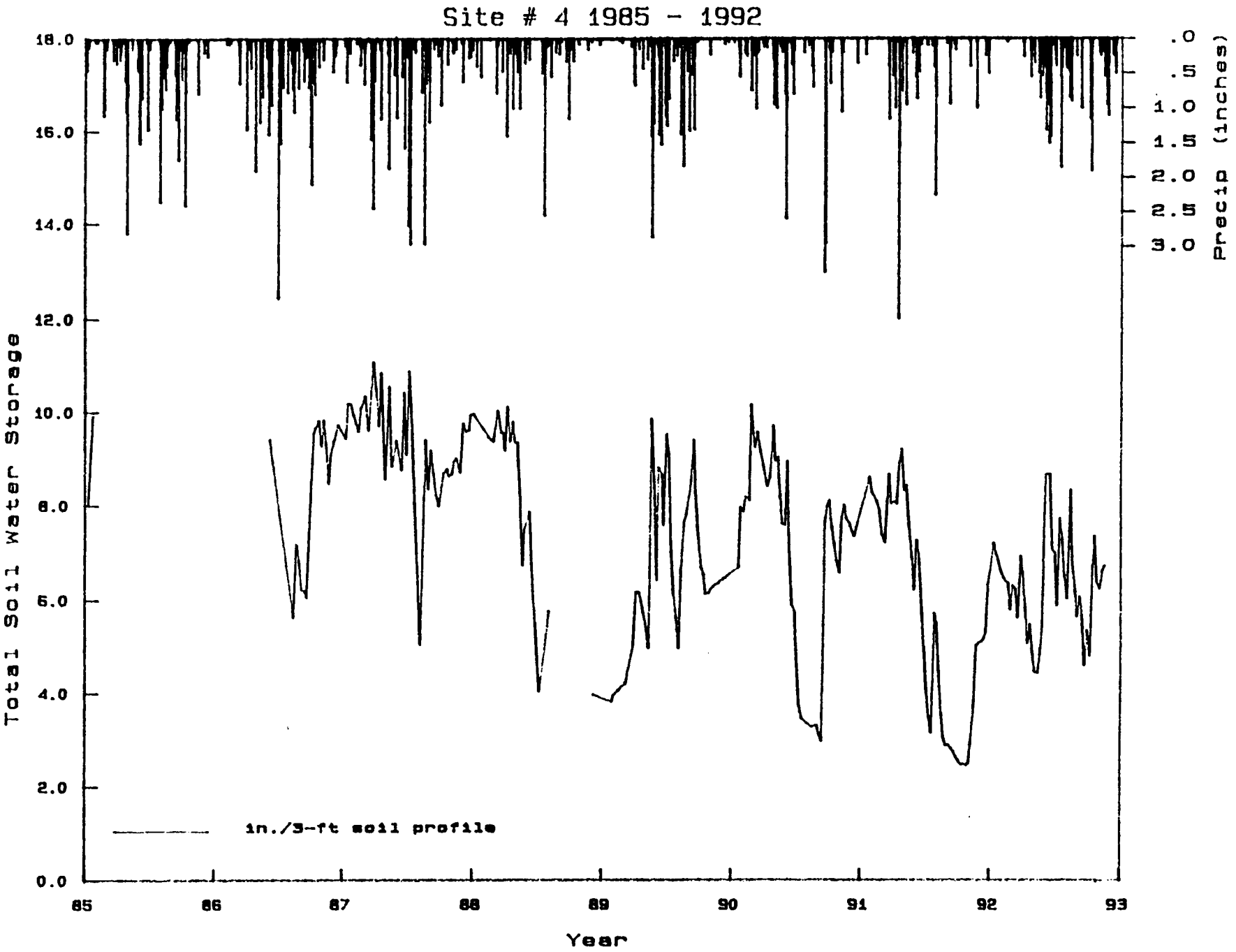
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
.0
.5
1.0
1.5
2.0
2.5
3.0
Precip (inches)
in./8-ft soil profile
85
86
87
88
89
90
91
92
93
Year

Figure 3.3


Site # 4 1985 - 1992
Total Soil Water Storage
Precip (inches)
Year
in./3-ft soil profile
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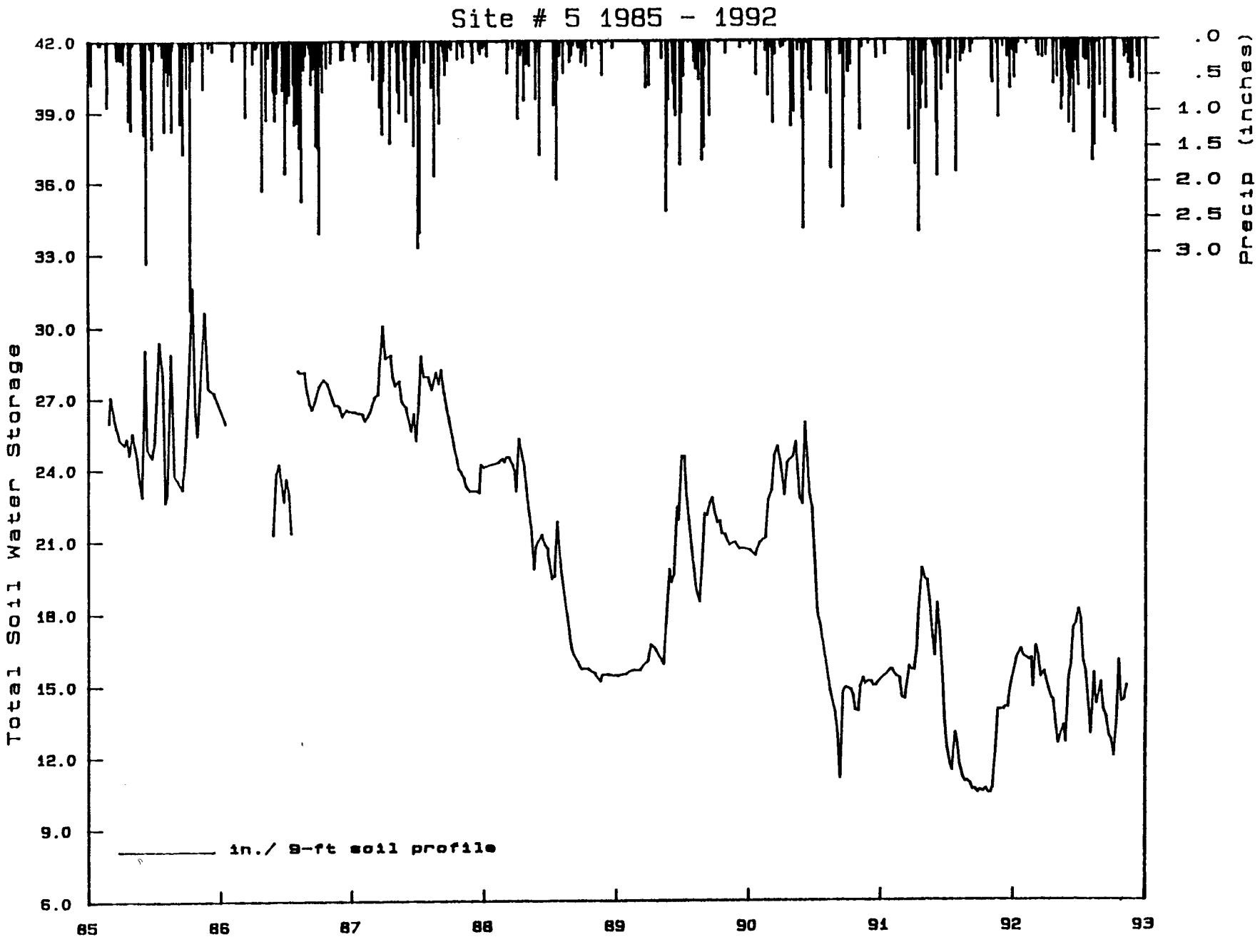
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
.0
.5
1.0
1.5
2.0
2.5
3.0
85
86
87
88
89
90
91
92
93

Figure 3.4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Total Soil Water Storage
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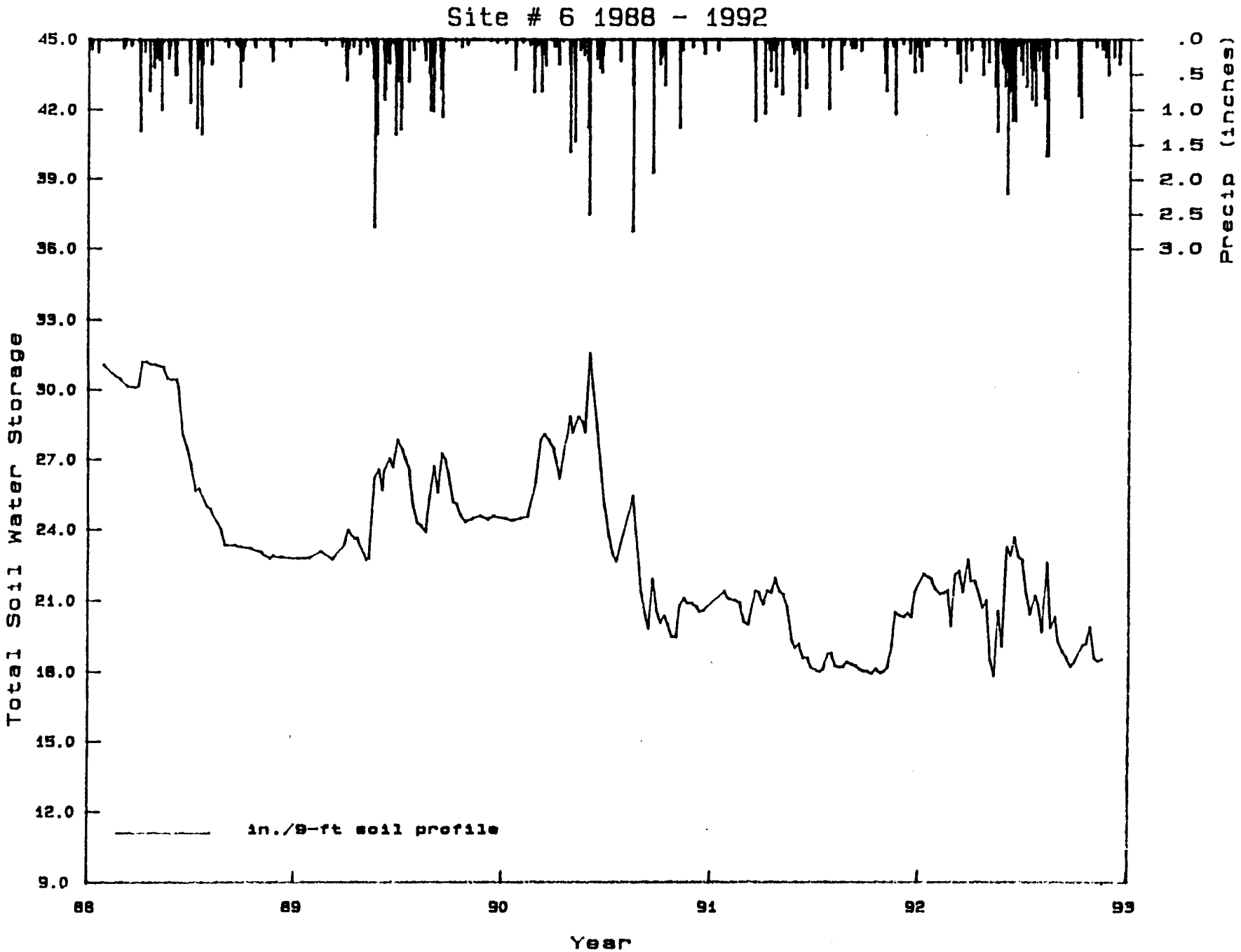
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
in./ 9-ft soil profile
85
86
87
88
89
90
91
92
93
Year

Figure 3.5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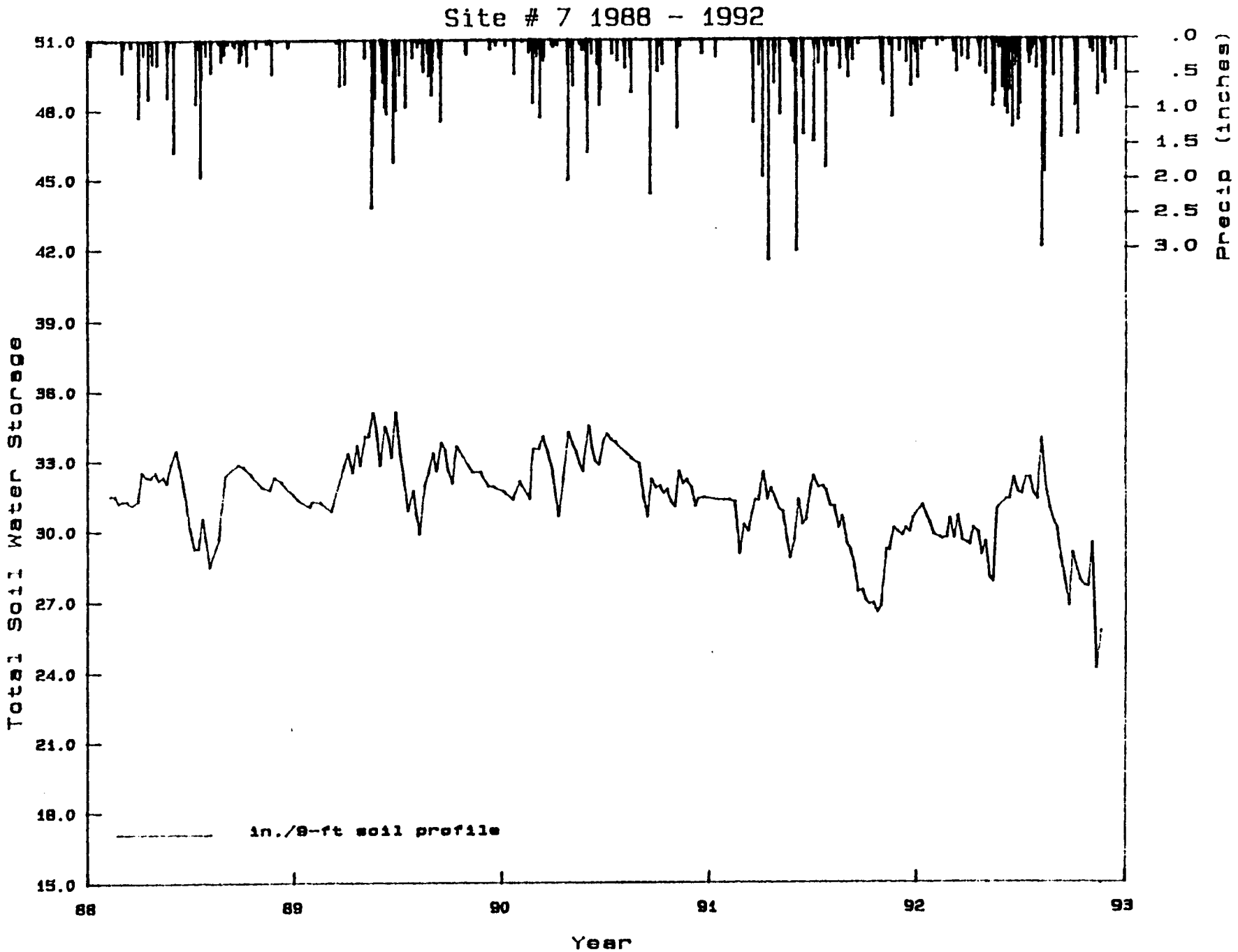
42.0
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
Total Soil Water Storage
.0
.5
1.0
1.5
2.0
2.5
3.0
Precip (inches)
in./8-ft soil profile
88
89
90
91
92
93
Year
Figure 3.6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Total Soil Water Storage
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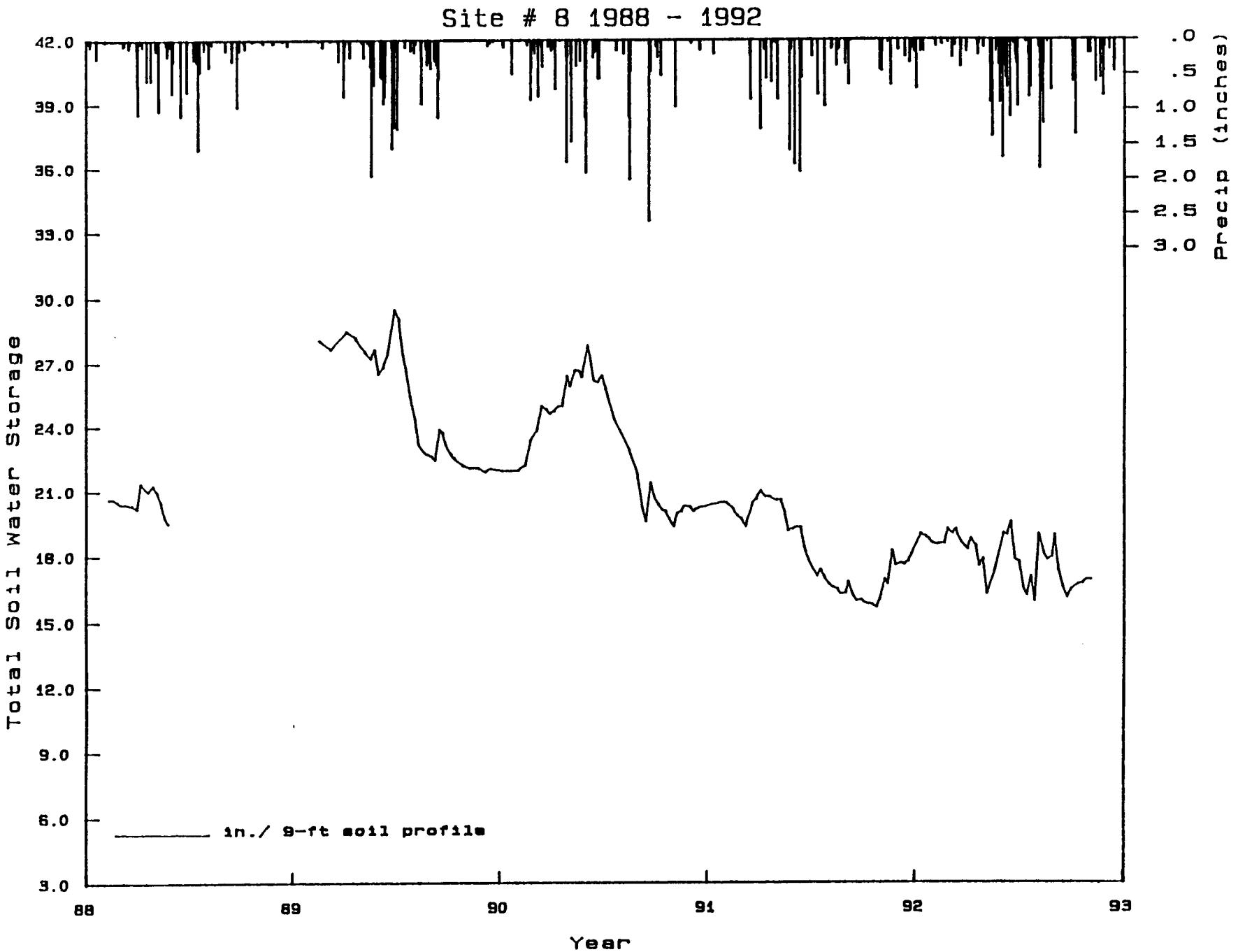
45.0
42.0
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
in./8-ft soil profile
88
89
90
91
92
93
Year

Figure 3.7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30.0
27.0
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18.0
15.0
12.0
9.0
6.0
3.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
in./ 9-ft soil profile
88
89
90
91
92
93
Year

Figure 3.8

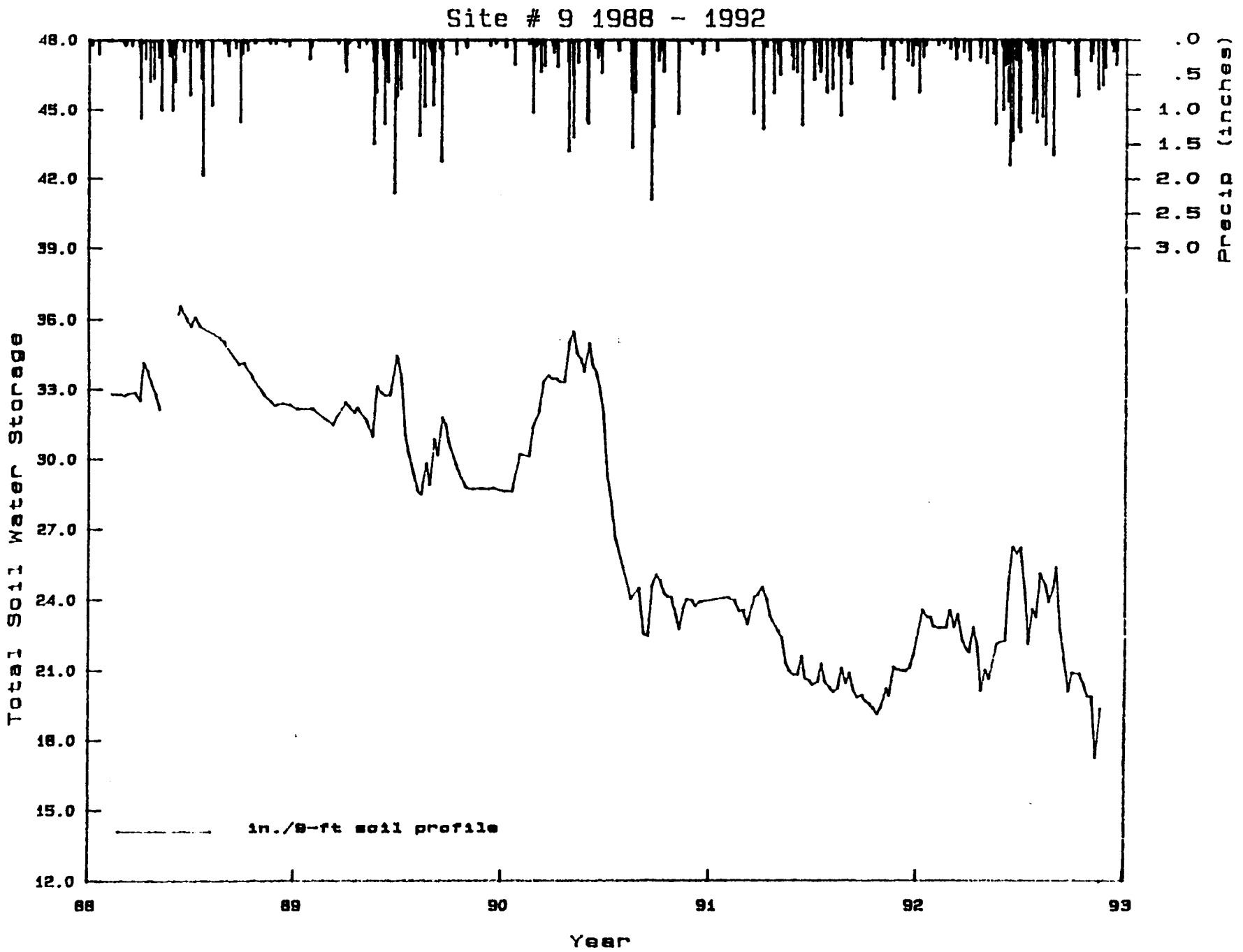
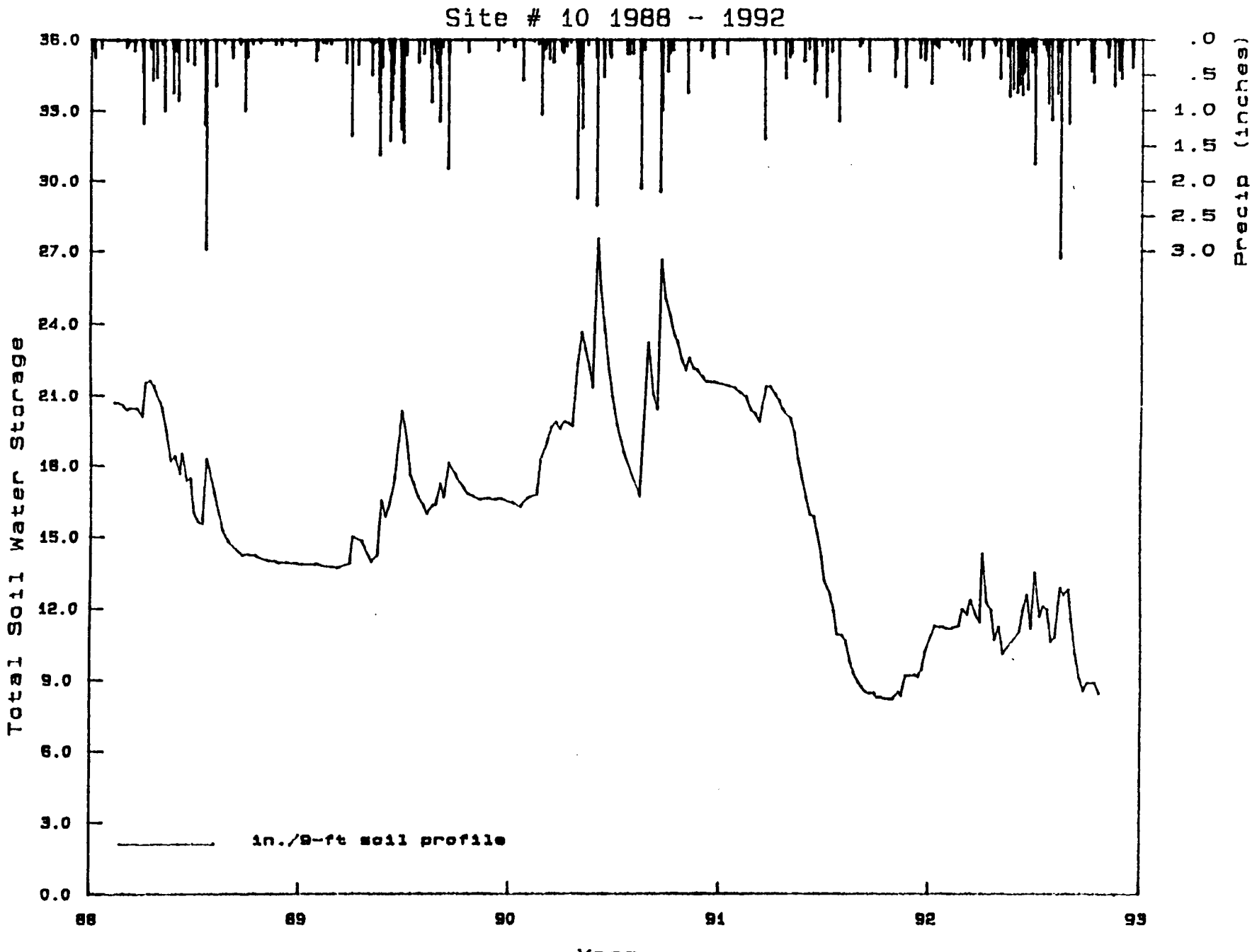

Site # 9 1988 - 1992
48.0
45.0
42.0
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
Total Soil Water Storage
.0
.5
1.0
1.5
2.0
2.5
3.0
Precip (inches)
in./8-ft soil profile
88
89
90
91
92
93
Year

Figure 3.9


Site # 10 1988 - 1992
Total Soil Water Storage
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33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
in./3-ft soil profile
88
89
90
91
92
93
Year

Figure 3.10

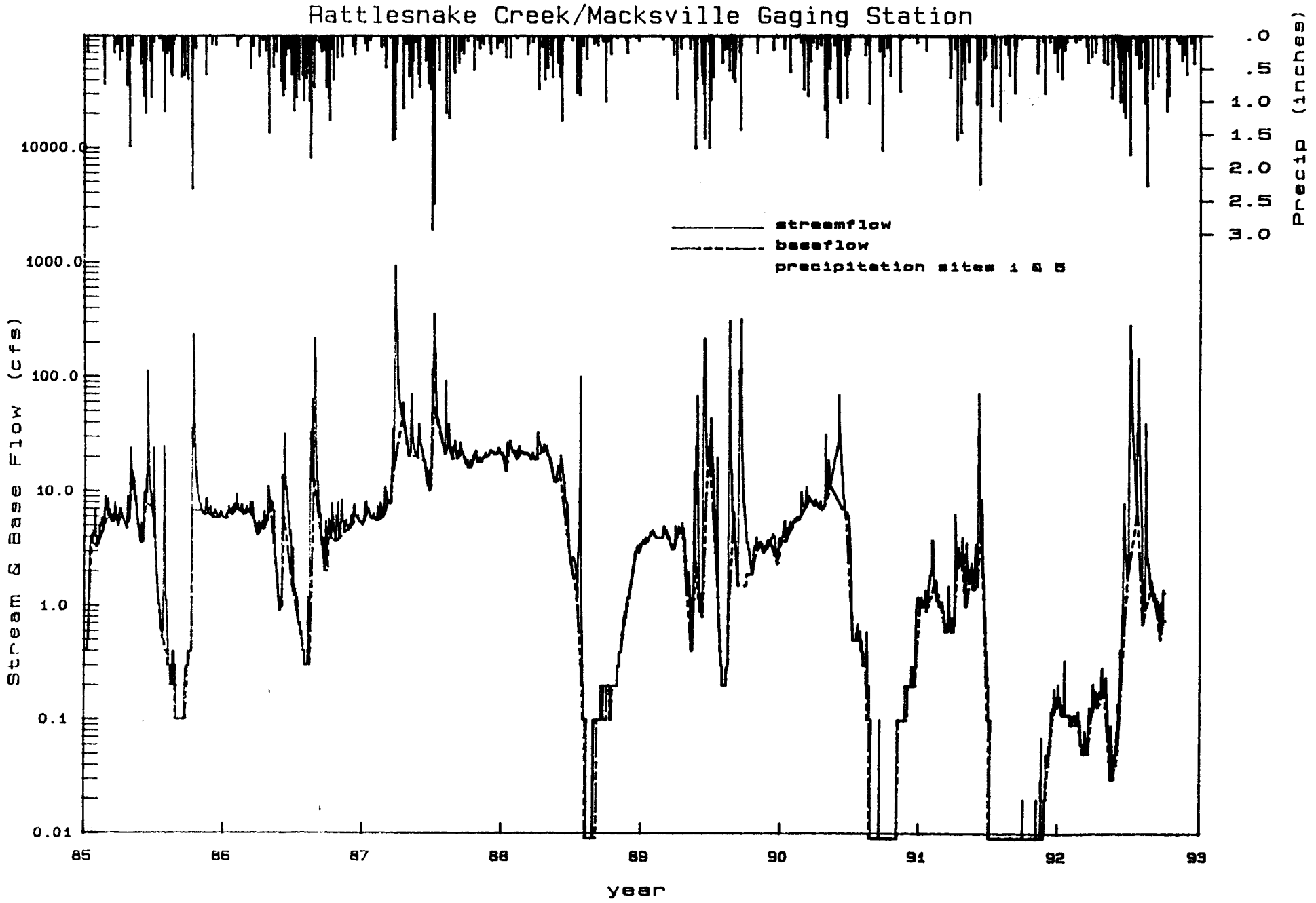
Rattlesnake Creek/Macksville Gaging Station
streamflow
baseflow
precipitation sites 1 & 5
Stream & Base Flow (cfs)
Precip (inches)
10000.0
1000.0
100.0
10.0
1.0
0.1
0.01
.0
.5
1.0
1.5
2.0
2.5
3.0
85
86
87
88
89
90
91
92
93
year

Figure 4.1

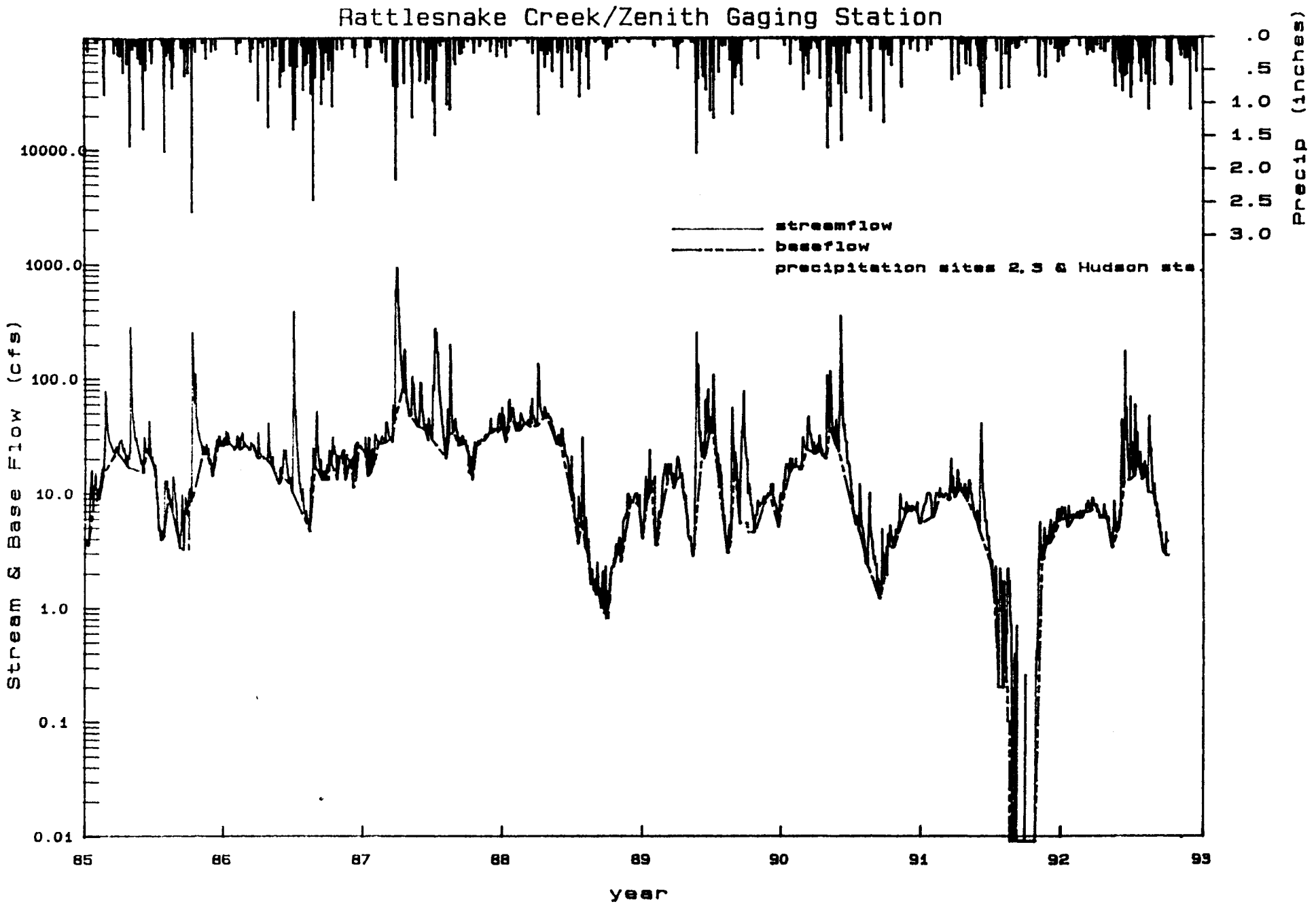
Rattlesnake Creek/Zenith Gaging Station
streamflow
baseflow
precipitation sites 2, 3 & Hudson sta
Stream & Base Flow (cfs)
10000.0
1000.0
100.0
10.0
1.0
0.1
0.01
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
85
86
87
88
89
90
91
92
93
year

Figure 4.2

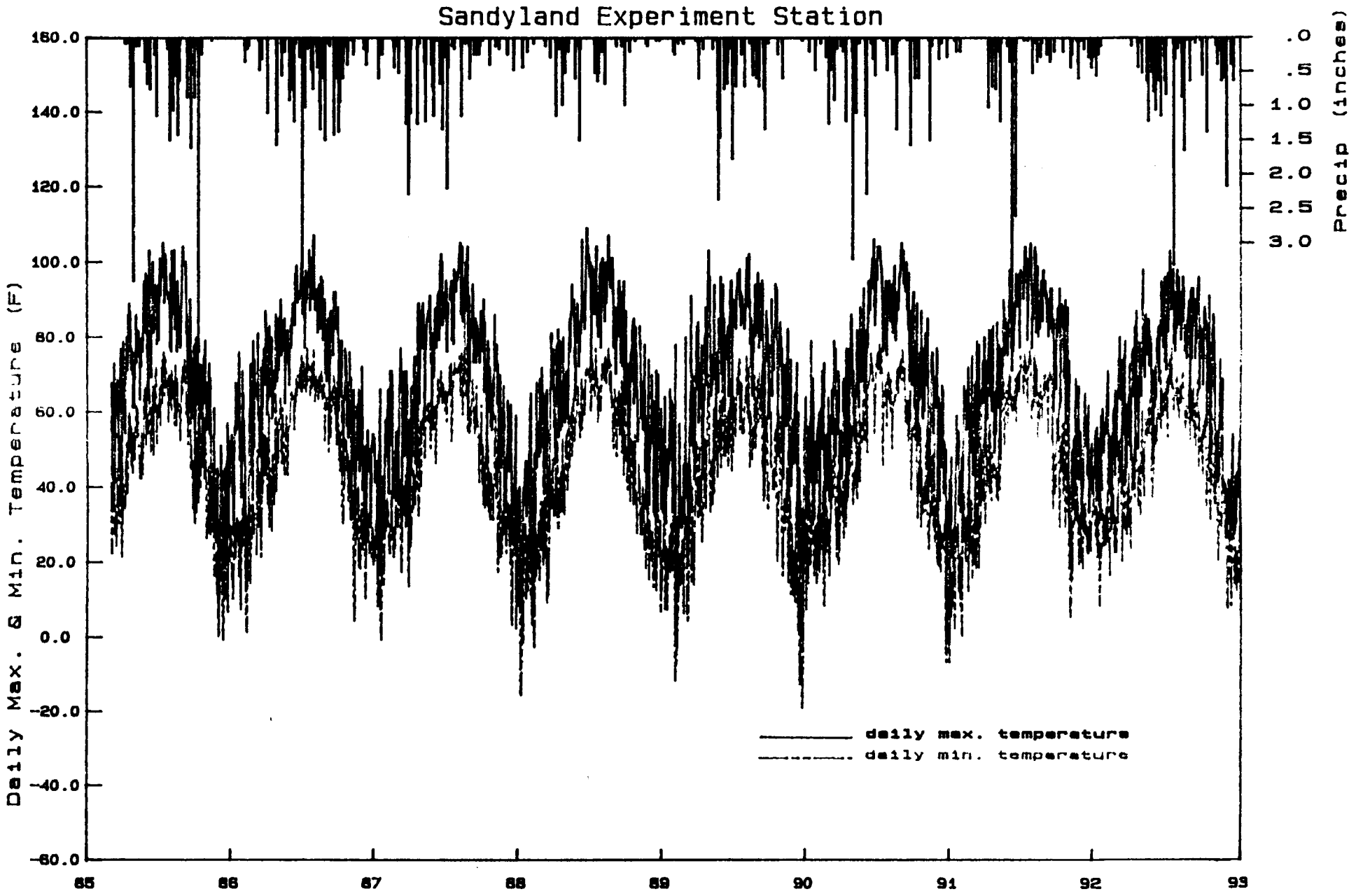
Sandyland Experiment Station
Daily Max. & Min. Temperature (F)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
Precip (inches)
.0
.5
1.0
1.5
2.0
2.5
3.0
daily max. temperature
daily min. temperature
85
86
87
88
89
90
91
92
93
year

Figure 5

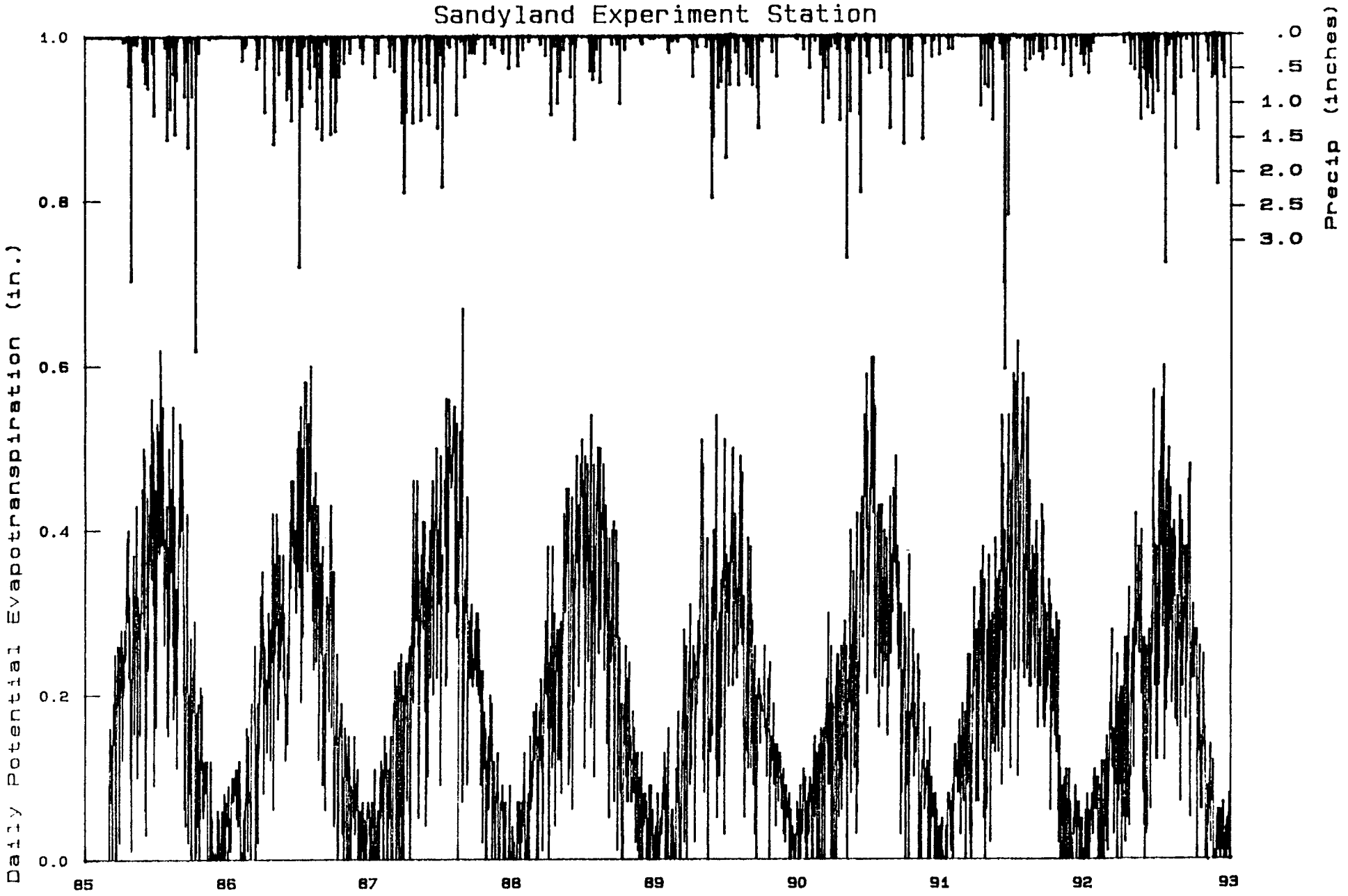
Sandyland Experiment Station
Daily Potential Evapotranspiration (in.)
Precip (inches)
1.0
0.8
0.6
0.4
0.2
0.0
.0
.5
1.0
1.5
2.0
2.5
3.0
85
86
87
88
89
90
91
92
93
year

Figure 6

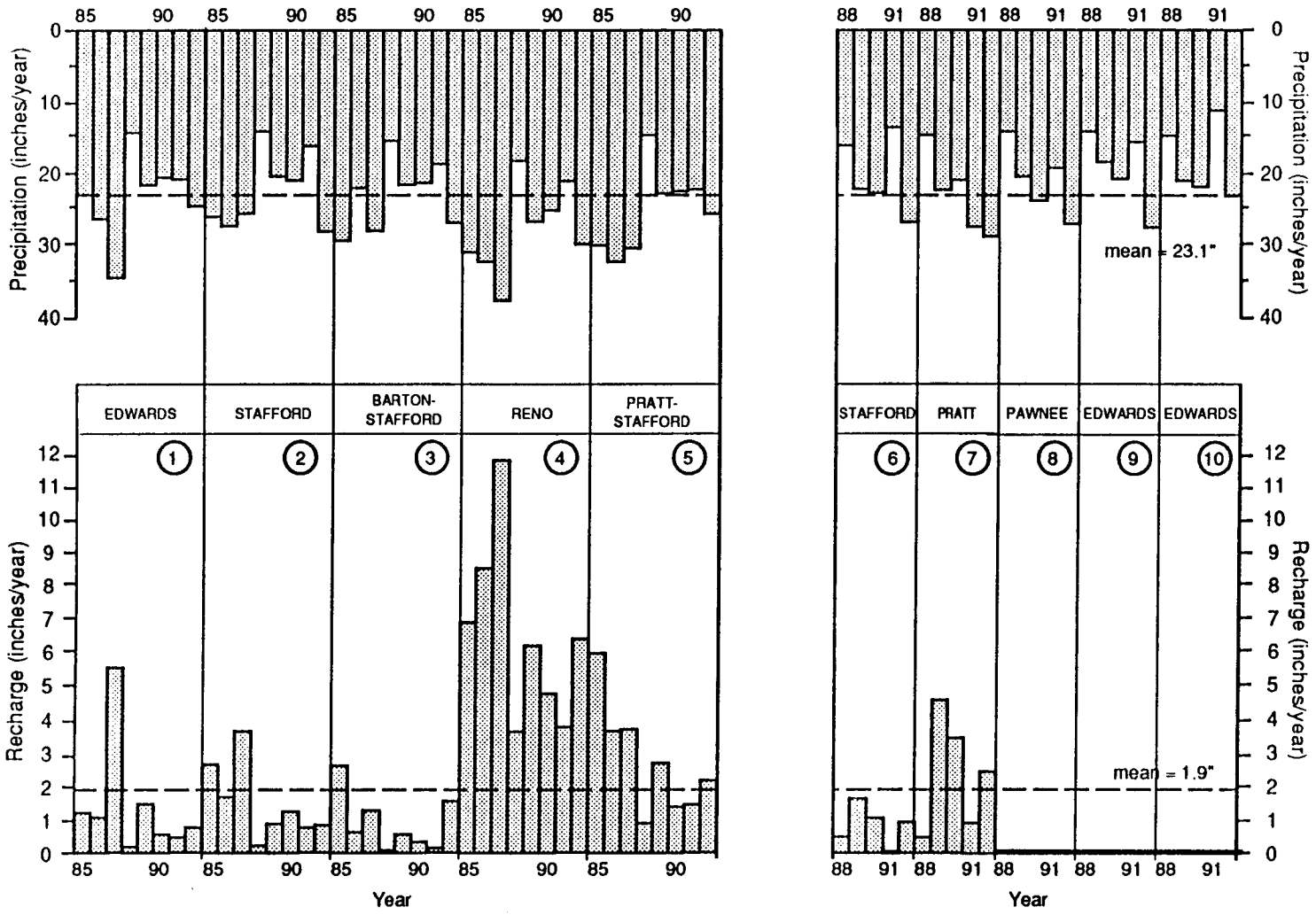

Figure 7. Annual recharge and precipitation at each site for the period 1985-1992.

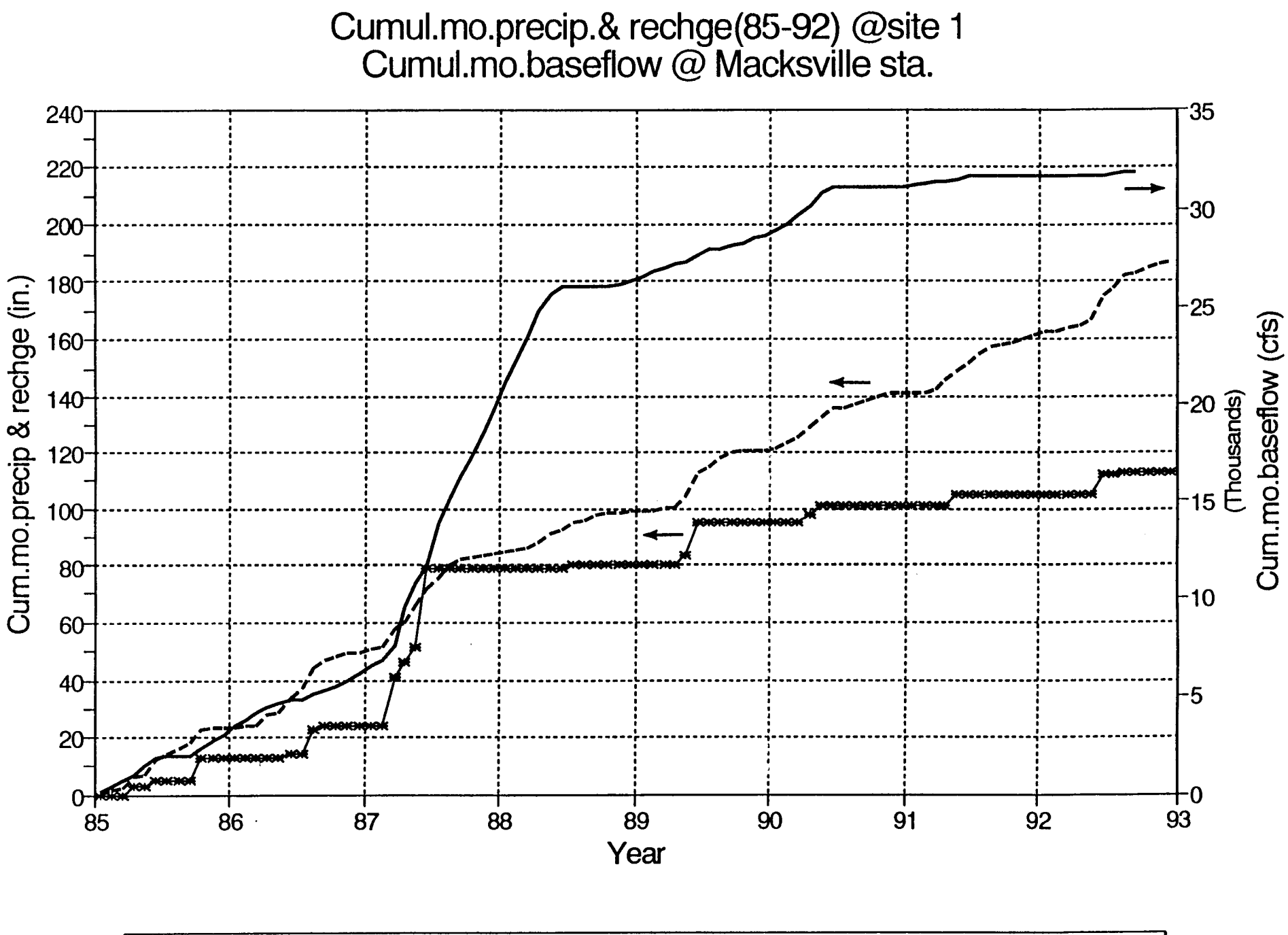
Cumul.mo.precip.& rechge(85-92) @site 1
Cumul.mo.baseflow @ Macksville sta.
Cum.mo.precip & rechge (in.)
Cum.mo.baseflow (cfs)
(Thousands)
Year
240
220
200
180
160
140
120
100
80
60
40
20
0
35
30
25
20
15
10
5
0
85
86
87
88
89
90
91
92
93
cum.mo.rechge*10 #1
cumul.mo.precip #1
cumul.mo.bsfl/Mac

Figure 8.1

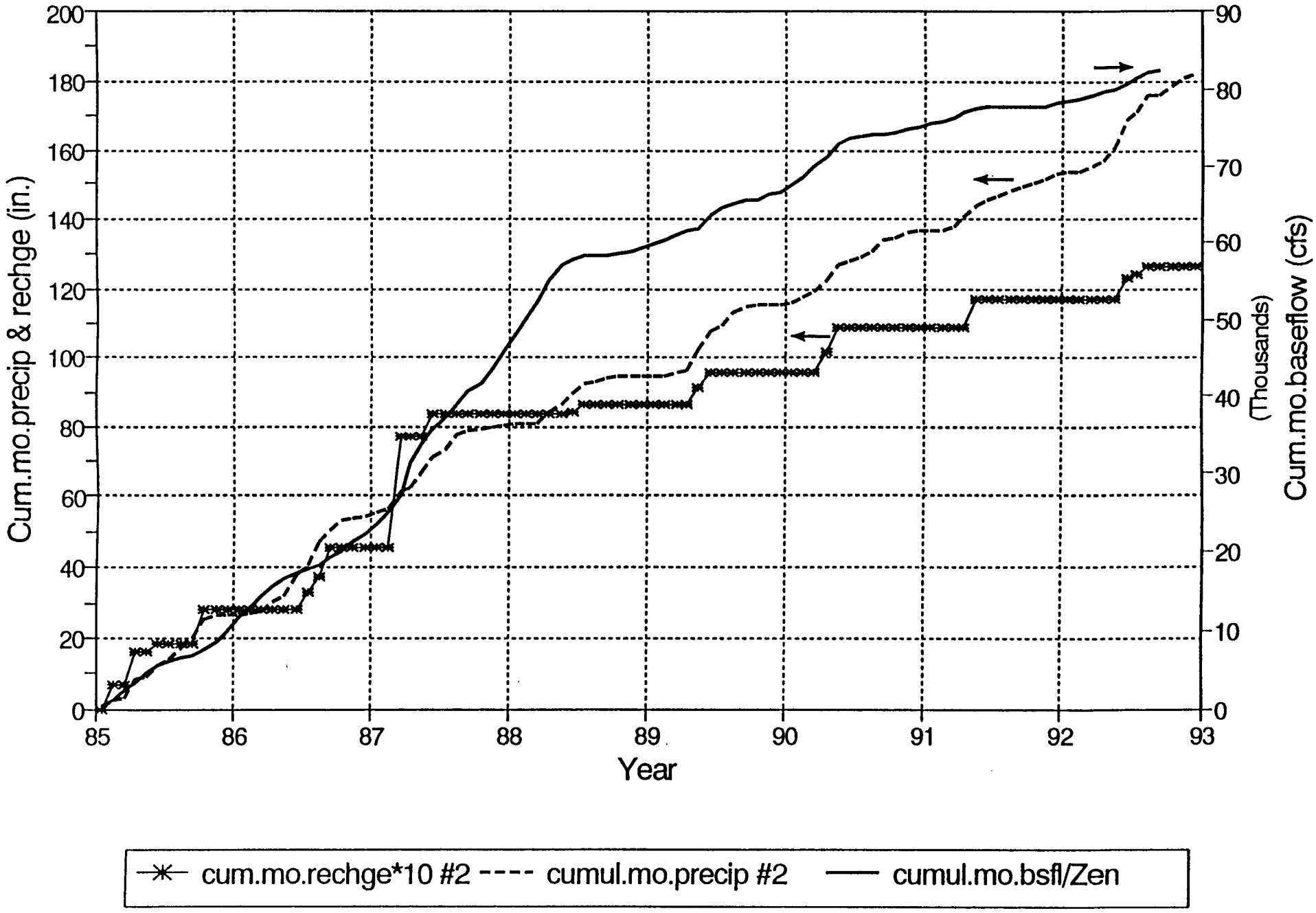
Cumul.mo.precip.& rechge(85-92) @site 2
Cumul.mo.baseflow @ Zenith sta.
Cum.mo.precip & rechge (in.)
Cum.mo.baseflow (cfs)
(Thousands)
Year
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
60
70
80
90
85
86
87
88
89
90
91
92
93
cum.mo.rechge*10 #2
cumul.mo.precip #2
cumul.mo.bsfl/Zen

Figure 8.2

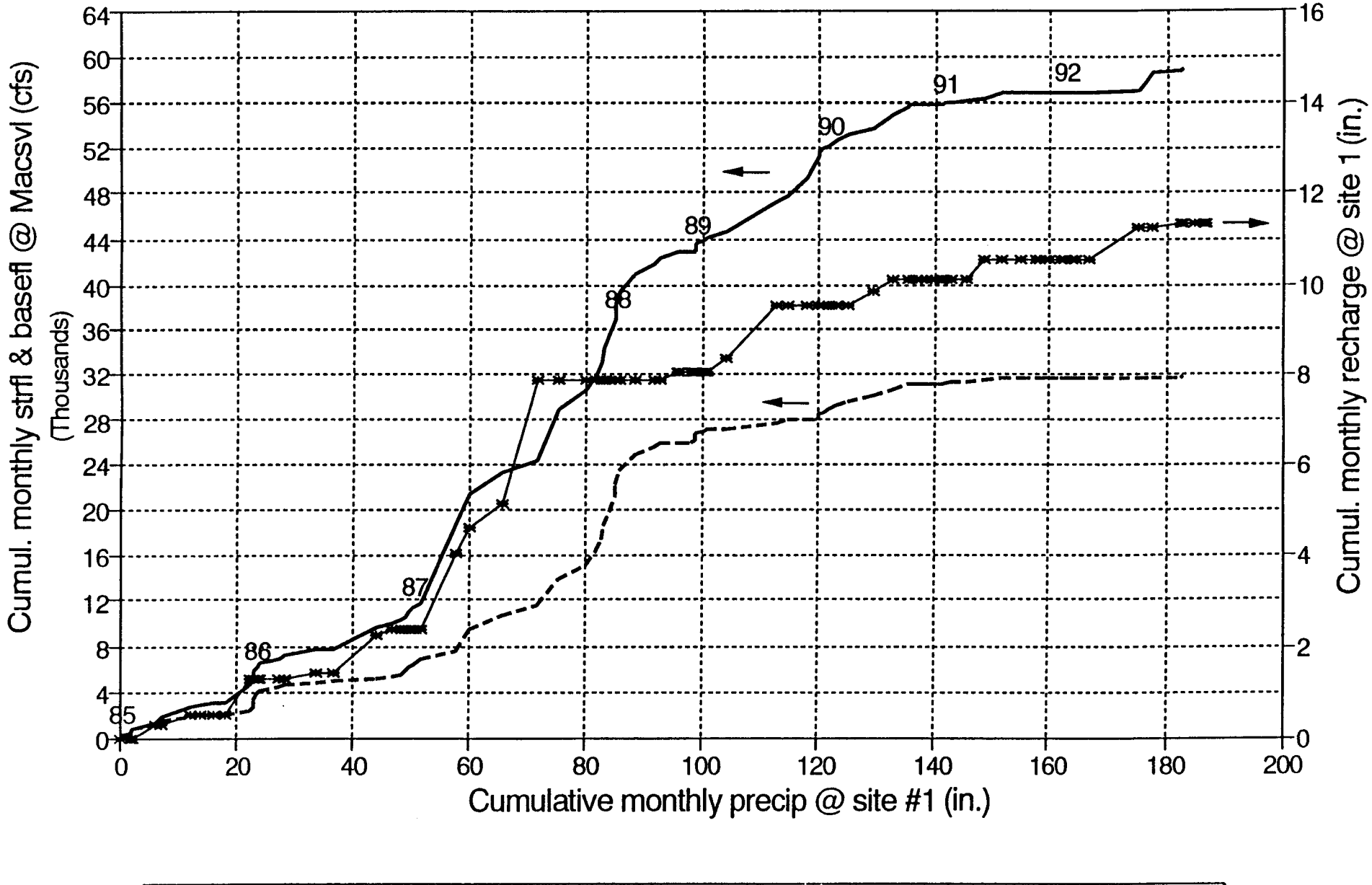
Cumulative Strflow, Baseflow & Recharge
versus Cumulative Monthly Precipitation
Cumul. monthly strfl & basefl @ Macsvl (cfs)
(Thousands)
Cumul. monthly recharge @ site 1 (in.)
Cumulative monthly precip @ site #1 (in.)
85
86
87
88
89
90
91
92
0
20
40
60
80
100
120
140
160
180
200
Streamfl @ Macksvl
Baseflow @Macsville
Recharge @ site 1

Figure 9.1

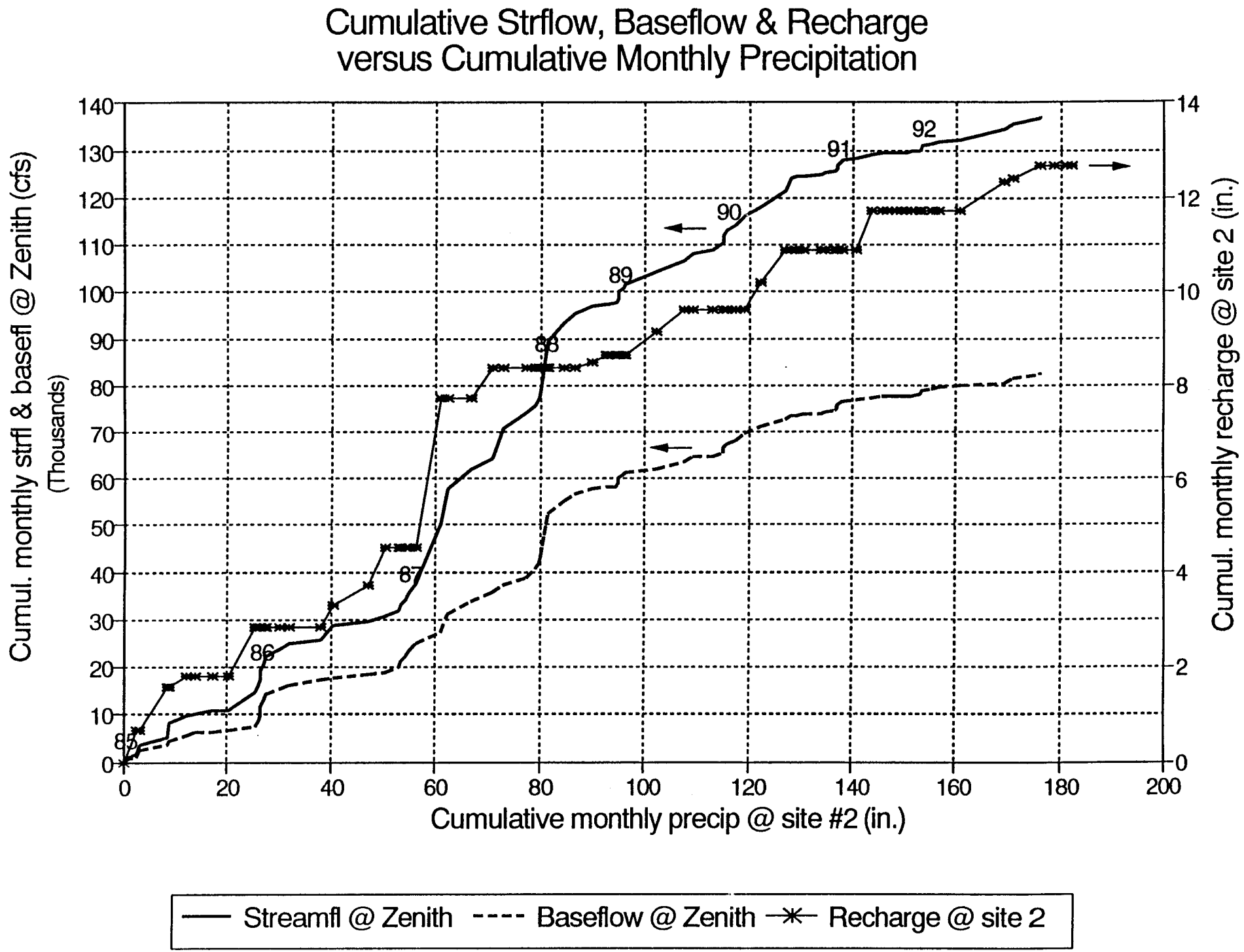
Cumulative Strflow, Baseflow & Recharge
versus Cumulative Monthly Precipitation
Cumul. monthly strfl & basefl @ Zenith (cfs)
(Thousands)
Cumul. monthly recharge @ site 2 (in.)
Cumulative monthly precip @ site #2 (in.)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
160
180
200
85
86
87
88
89
90
91
92
Streamfl @ Zenith
Baseflow @ Zenith
Recharge @ site 2

Figure 9.2