NOAA Technical Memorandum NWS ER-66

CONTRIBUTING FACTORS TO THE 1980-81 WATER SUPPLY DROUGHT, NORTHEAST U.S.

Hydrology Division
Eastern Region Headquarters
June 1981

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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Solomon G. Summer

Hydrology Division
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UNITED STATES DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
James P. Walsh, Acting Administrator

National Weather Service
Richard E. Hallgren, Director

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1. INTRODUCTION

On June 1, 1980, the New York City Water Supply Reservoir levels were near 97 percent of capacity (Fig. 1). Reservoirs in northern New Jersey and southeastern Connecticut were also near capacity at the start of the high usage season. The Water Supply Outlook for the upcoming season was encouraging. Following a dry winter, a very wet March and April resulted in abundant runoff for area reservoirs. (Central Park, New York City, reported 10.41 inches and 8.26 inches, respectively, during March and April 1980.)

Just 6 months later, the Northeast was gripped with severe water shortages. By mid-November, the NYC reservoir system dropped to less than 40 percent of capacity (Fig. 1). An even more abrupt decline is shown in these figures supplied by the Hackensack Water Company in New Jersey. The Hackensack System, with a capacity of 13.2 Billion Gallons (BG) as compared to NYC's 547.5 BG, represents a much smaller system and thus reacted more quickly to the drought's effects.

Hacksensack Reservoir System

1980	Percent of Capacity
June 1	96
July 1	85
August 1	67
September 1	41
October 1	26
November 1	25

2. CONTRIBUTING FACTORS AND DROUGHT DEFINITIONS

Three main factors contributed to the abrupt change in Water Supply Storage from May to November 1980:

1. Large precipitation deficiencies in the area watersheds.

2. High water consumption rates during the period.

3. Much above normal temperatures during the summer season.

3. DROUGHT DEFINITIONS

The World Meteorological Organization has defined six types of drought as follows (Subrahmanyan, 1967):

1. Meteorologic drought - defined only in terms of precipitation deficiencies in absolute amounts, for specific durations.

2. Climatological drought - defined in terms of precipitation deficiencies, not in specific quantitites but as a ratio to mean or normal values.

3. Atmospheric drought - definitions involve not only precipitation, but possibly temperature, humidity, or wind speed.

4. Agricultural drought - definitions involve principally the soil moisture and plant behavior, perhaps for a specific crop.

5. Hydrologic drought - defined in terms of reduction of streamflows, reduction in lake or reservoir storage, and lowering of ground-water levels.

6. Water-management drought - this classification is included to characterize water deficiencies that may exist because of the failure of water-management practices or facilities such as integrated water supply systems and surface or subsurface storage to bridge over normal or abnormal dry periods and equalize the water supply through the year.

Drought types 1, 3, 5, and 6 were all evident during the 1980-81 Northeast Drought.

4. PRECIPITATION DEFICIENCIES

1980 annual and November 1979 - April 1981 precipitation departures from normal (Figs. 2a and 2b) show deficiencies in the range of 10 inches over the drought area. Most of the deficiencies occurred from May through October 1980. As an example, here is the precipitation data from Hackensack Water Company precipitation records at New Milford Plant, Oradell, New Jersey:

Month	Average	1980	Departure
May	3.61	2.03	-1.58
June	3.48	2.09	-1.39
July	4.31	1.78	-2.53
August	4.35	1.14	-3.21
September	3.65	1.67	-1.98
October	3.31	3.33	-1.02
6-Month Totals	22.71	12.05	-10.67

5. WATER CONSUMPTION

Water consumption increases during May through September 1980 period may have been due to three factors: a general trend towards increasingly annual per capita water consumption, the same trend with respect to demands made by outside suburban communities, and the above-normal temperatures experienced during the 1980 summer months in the Northeast.

Following are statistics furnished by the NYC Department of Environmental Protection showing the year-to-year changes in New York City Consumption of Water - 1940 to 1979: (Table 1)

Table 1

NEW YORK CITY CONSUMPTION OF WATER - 1940 to 1979

Year	Consumption in City proper Mgd *	Gallons per capita per day	Furnished to outside communities mgd	Total mgd	billion gallons
1940	922.7	124	21.6	944.3	345.614
41	964.2	130	24.8	989.0	360.985
42	906.7	124	21.5	928.2	338.793
43	942.7	133	21.5	964.2	351.933
44	1,004.9	144	26.5	1,031.4	377.492
1945	1,056.2	146	22.0	1,078.2	393.543
46	1,117.1	146	24.1	1,141.2	416.538
47	1,159.0	149	30.4	1,189.4	434.131
48	1,172.3	150	31.5	1,203.8	440.591
49	1,166.9	149	36.2	1,203.1	439.132
1950	953.3	121	29.1	982.4	358.576
51	1,041.9	131	28.1	1,070.0	390.550
52	1,087.0	136	32.7	1,119.7	409.810
53	1,093.9	135	44.6	1,138.5	415.552
54	1,063.4	131	46.3	1,109.7	405.040
1955	1,109.9	136	45.3	1,155.2	421.648
56	1,111.3	136.2	48.9	1,160.2	424.633
57	1,169.0	143	57.2	1,226.2	447.563
58	1,152.9	140.8	49.6	1,202.5	438.912
59	1,204.3	146.8	60.3	1,264.6	461.579
1960	1,199.4	153.9	58.9	1,258.3	460.529
61	1,221.0	156.0	64.0	1,285.0	469.022
62	1,207.6	153.5	68.8	1,276.4	465.896
63	1,218.0	154.1	76.7	1,294.7	472.582
64	1,189.2	149.8	79.4	1,268.6	464.295
1965	1,052.1	131.9	71.2	1,123.3	409.995
66	1,044.9	130.4	73.2	1,118.1	408.128
67	1,135.3	141.0	71.0	1,206.3	440.302
68	1,242.0	153.6	78.2	1,320.2	483.175
69	1,328.7	163.5	80.1	1,408.8	514.229
1970	1,400.3	177.9	90.4	1,490.7	544.116
71	1,423.6	180.0	87.9	1,511.5	551.695
72	1,412.4	178.3	83.0	1,495.4	547.340
73	1,448.9	182.7	95.4	1,544.3	563.681
74	1,441.8	181.5	96.3	1,538.1	561.409
1975	1,415.0	177.9	92.1	1,507.1	550.093
76	1,435.0	180.1	95.8	1,530.8	560.264
77	1,483.0	185.9	104.7	1,587.7	579.510
78	1,479.4	185.1	103.0	1,582.4	577.566
79	1,513.0	189.0	104.6	1,617.6	590.426

Data furnished by
New York City
Department of Environmental Protection
Bureau of Water Supply

* Mgd (Million gallons per day)

An analysis of the data shows a steady increase in per capita water consumption and amount of water furnished to outside communities, except for the 1965-1966 drought period when conservation water restrictions were imposed in the City. NYC's water supply statistics are similar to others in the eastern United States. Little increase in water supply storage has occurred since the last major drought in the 1960's. An increase in per capita water use has been created through the advent of more technological uses of water; for example, the use of water cooling towers for air conditioning.

The expansion of suburban communities and spread of industries outside of major cities have created water demands beyond the capacity of existing local systems. As a result, major city reservoirs have had to make up this slack through an increased allocation to outside communities.

The 1980 summer season was one of the warmest on record in the United States, and the Northeast was no exception. Following are representive summer monthly departures from normal at selected stations: (Table 2)

Table 2

1980 SUMMER MONTHS DEPARTURES

FROM NORMAL TEMPERATURES

Station	June	July	Aug	Sep
New York City	-1.3	2.7	5.4	2.4
Newark	-1.2	2.5	4.0	3.0
Trenton	-1.6	2.3	4.3	3.1
Allentown	-1.3	3.2	6.5	5.6
Scranton	-2.6	1.0	5.2	3.2
Albany	-4.2	.2	1.1	.7
Hartford	-1.4	1.5	2.8	2.1
Boston	-1.7	2.5	2.9	2.5
Philadelphia	-1.7	1.7	5.2	4.1

Monthly temperatures from July to September were well above normal. Comparing the monthly temperature with corresponding monthly water consumption figures at New York City (Fig. 3 and Table 3 below) illustrates the following:

Table 3

NYC SUMMER TEMPERATURES/WATER CONSUMPTION

	Average Temperatures			Average Daily Water Consumption MGD*		
Month	1980	Norm	Departures	1980	Base Period 1977-79	Increased Consumption 1980 vs Base Period
June	70.3	71.6	-1.3	1,490	1,480	+ 10
July	79.3	76.6	+2.7	1,620	1,540	+ 80
August	80.3	68.4	+5.4	1,630	1,530	+100
September	70.8	68.4	+2.4	1,530	1,470	+ 60

*MGD (Million Gallons per Day)

The increases in water consumption during the summer months of 1980 closely parallel the above normal temperatures during those months. Additionally, during 1980, because of high summer temperatures, evapotranspiration rates were excessive. As an example of the increase over normal conditions, the Class A pan evaporation figures for Canoe Brook, a representative station for northern New Jersey, were examined for the 1980 Growing Season and compared to long term normals for this station. As an additional check, the years 1960 to 1966 were examined. The summer of 1960 was an unusually cool season, and the period 1961-1966 represents the last major drought period in the northeast. (Table 4)

Table 4

CANOE BROOK, NEW JERSEY

(PAN EVAPORATION - GROWING SEASON MAY-SEPT)

Year	Apr	May	Jun	Jul	Aug	Sep	Seasonal	May-Sep Departure From Norm	Percentage of Norm
1960	---	3.13	4.12	4.56	3.57	3.07	18.45	-2.92	86%
1961	---	3.70	4.74	4.90	3.84	3.60	20.78	- .59	97%
1962	---	3.90	4.97	5.67	4.48	3.40	22.42	1.05	105%
1963	---	4.22	5.24	6.50	6.16	3.65	25.77	4.40	121%
1964	---	5.66	5.51	5.80	5.32	5.01	27.30	5.93	128%
1965	2.70	6.07	5.62	5.95	5.52	3.24	26.40	5.03	124%
1966	0.67	4.09	5.39	7.44	5.51	3.60	26.03	4.66	122%
1979		4.80	5.35	5.69	4.79	3.81	24.44	3.07	114%
1980		4.88	6.24	7.02	5.97	4.73	28.84	7.47	135%
NORM		4.56	4.54	5.11	4.18	2.98	21.37	---	100%

An examination of the statistics for Canoe Brook reveals the following:

1. The 1980 growing season had an excess in pan evapotranspiration of 7.47 inches over normal. (135 percent)

2. The cool 1960 growing season had 86 percent of normal pan evapotranspiration.

3. The 1961-1966 Drought Period showed an increase in seasonal pan evapotranspiration with the maximum amounts occurring during the 1963-1966 seasons corresponding to the years of greatest water supply deficiencies.

4. Using the Canoe Brook 1980 pan evaporation departure from normal, and assuming a pan-coefficient of .75, the 1980 seasonal evaporation excess from free water surfaces is computed as follows:

   Evaporation Excess = Pan Evap excess x Evap Coeff = 7.47 x .75 = 5.6 inches

THE EFFECTS OF THE COLD DRY WINTER OF 1980-1981 ON RESERVOIR LEVELS

The New York City Reservoir system and others in the Northeast reached their lowest storage levels around February 1, 1981.

As can be seen in Figure 1, following near steady storage from mid-November to mid-December, reservoir levels took a sharp drop in January. This is contrary to the normal pattern of rises for the same period.

A look at the weather regime during this period explains the reason:

> Temperatures during the latter part of December and through the month of January remained 6 to 8 degrees below normal, while precipitation was near record low values for the month of January 1981. New York Central Park records show that only .58 inches of precipitation fell in January, nearly all as snow. Thus, because of virtually no snowmelt or rain, little moisture, if any, was available as runoff for streamflow or recharge to groundwater.

As a result, the monthly streamflow on the Delaware River at Trenton was only 2429 CFS, a new January record. As a result of low streamflows, reservoirs dropped to very low levels despite the conservation cutback and seasonally low water consumption. (Table 5)

Table 5

COMPARISONS WITH THE 1960's DROUGHT - CONCLUSION

COMPARISONS OF 1980-81 DROUGHT WITH
1960's DROUGHT IN NORTHEASTERN U.S.

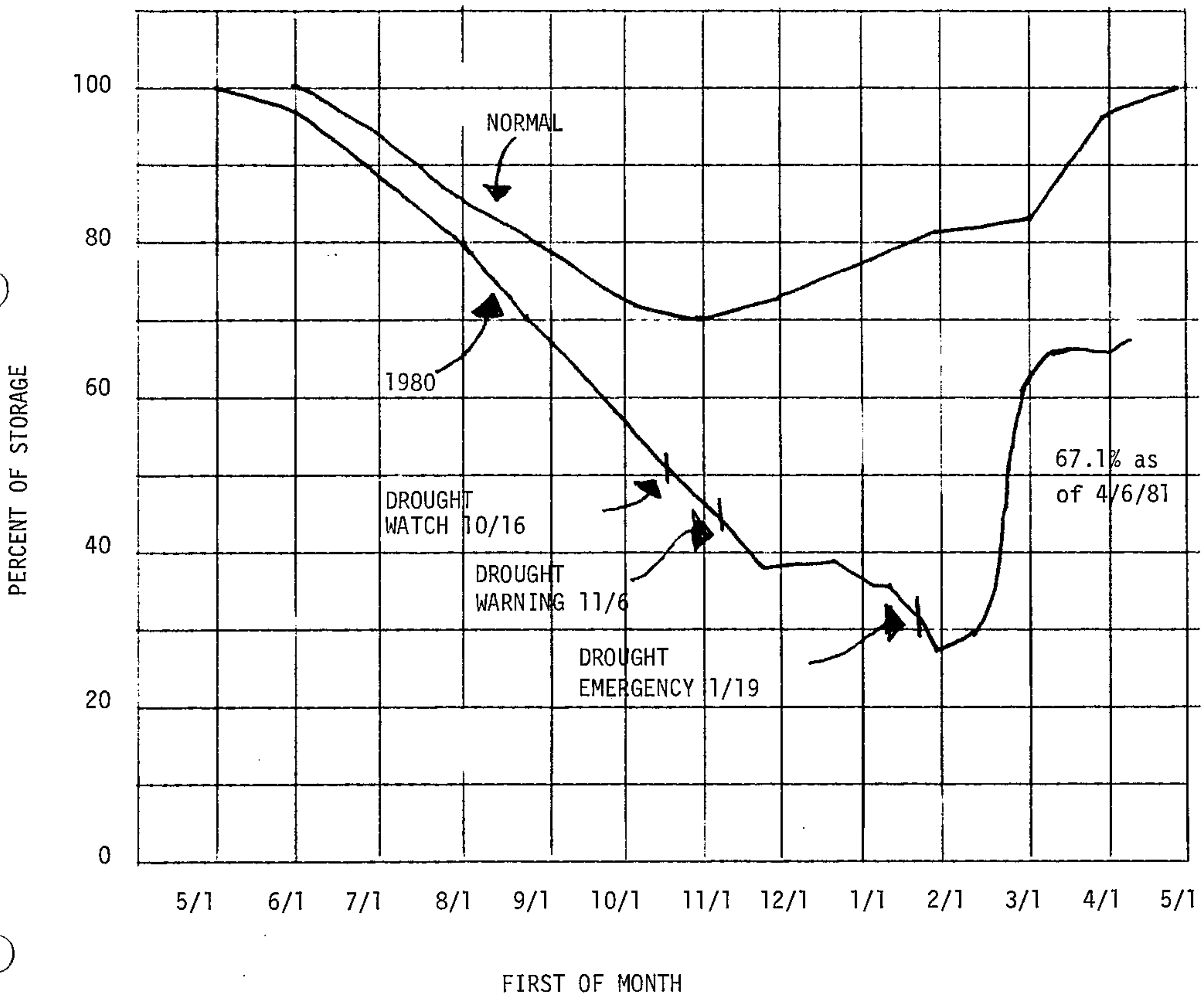
FACTOR	CURRENT	1960's
1) Length	Nov.1979 - Spring 1980 (present) one year +	Fall 1961 - Spring 1967 5 years +
2) Area	From Maine through Florida east of the Appalachians. Great Plains south through Texas, Rocky Mountains, portions of far west.	From central Maine through eastern Ohio and south through North Carolina [100,000 sq. miles]
3) Precipitation Deficiency	15 inches + Scattered locations in MA, CT, PA, NC, SC [Nov. 79 - Apr. 81]	50 inches + From Southwestern CT to Northern Delaware [Oct 1961 - Dec 1965]
4) Streamflow	Below normal flows Record low monthly streamflows Delaware R./Trenton [2429 CFS] [Jan 1981]	Record low all time streamflows (Delaware R. (Potomac (SRN. New Eng. Delaware R./Trenton [1180 CFS] [Oct 31,1963]
5) Groundwater Levels	4 out of 13 test wells in NJ were at record low levels during Winter 1981	Many wells at record low levels. Water table 5 to 10 feet below normal
6) Runoff	Delaware R./Trenton [14.6 inches (1980)]	Delaware R./Trenton [12.1 inches (1965)] [52 year median] [1913 - 1965 24 inches]
7) Water Supply	(25.3% of capacity - NYC Delaware Basin Water Supply) [Feb 2, 1981]	Delaware Basin reservoir storage 25% of capacity 1965
8) Hydrologic Index	[-4.5] just into extreme drought category	-6 extreme drought

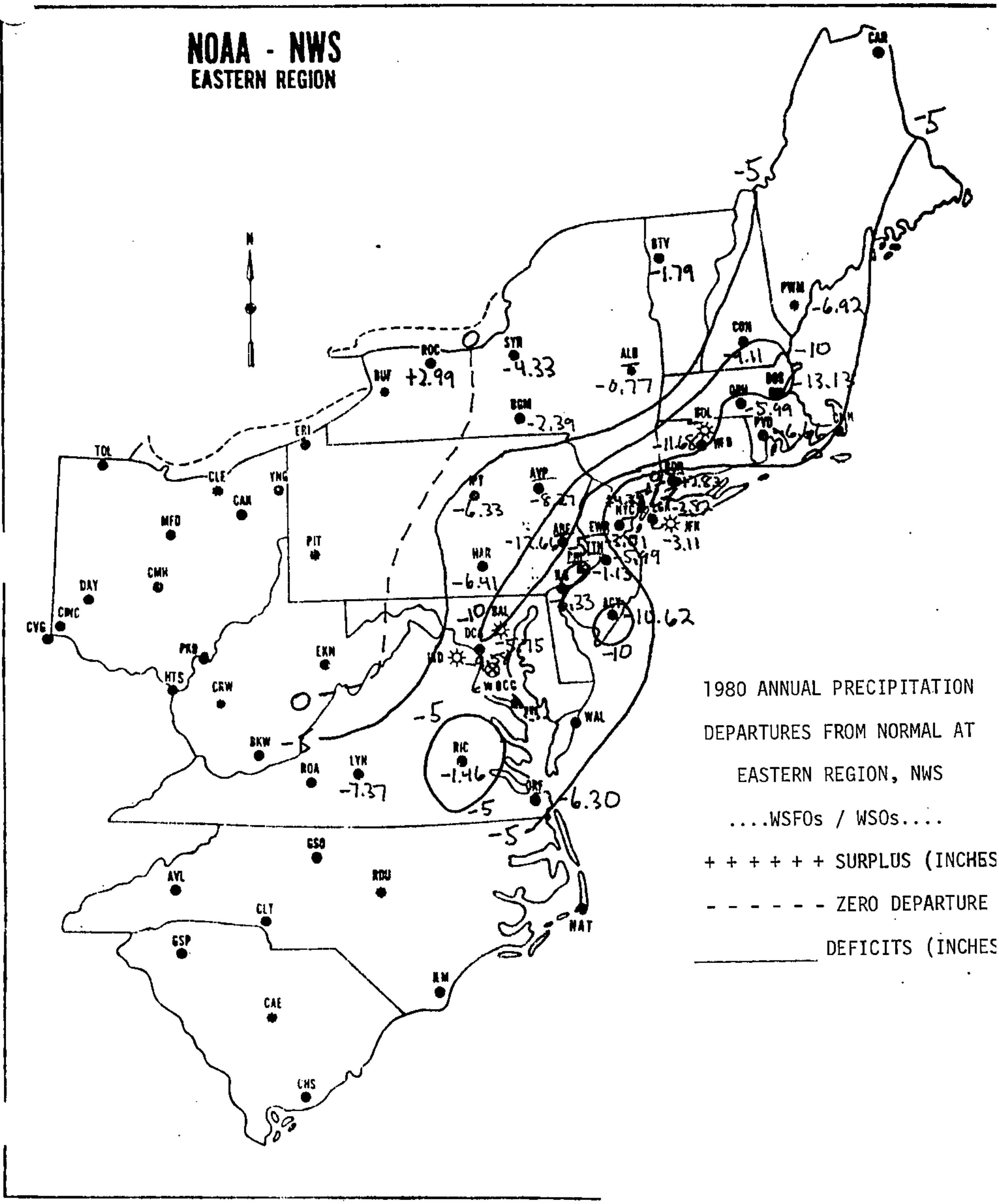
A comparison of the 1980-1981 Drought with the one in the 1960's shows that although the 1980-1981 Drought was not as severe (to this point) in terms of duration, precipitation deficiency and streamflow, the water supply storage deficiencies compared to those in the 1960's Drought. Primarily, the increase in per capita water consumption rates and wider general usage of water has resulted in more accelerated drops in water supply.

Because of this, it is now evident that seasonal meteorological factors, i.e., the effect of above-normal temperatures resulting in increased evapotranspiration, play a more significant role in affecting existing water supply, through the interaction of runoff available to reservoirs and in the consumption rates depleting reservoirs. Forecasting seasonal or annual precipitation deficiencies, as well as predicting unusually hot summers or cold winters, becomes an important planning tool in water management.

Figure 1

NEW YORK CITY RESERVOIR LEVELS

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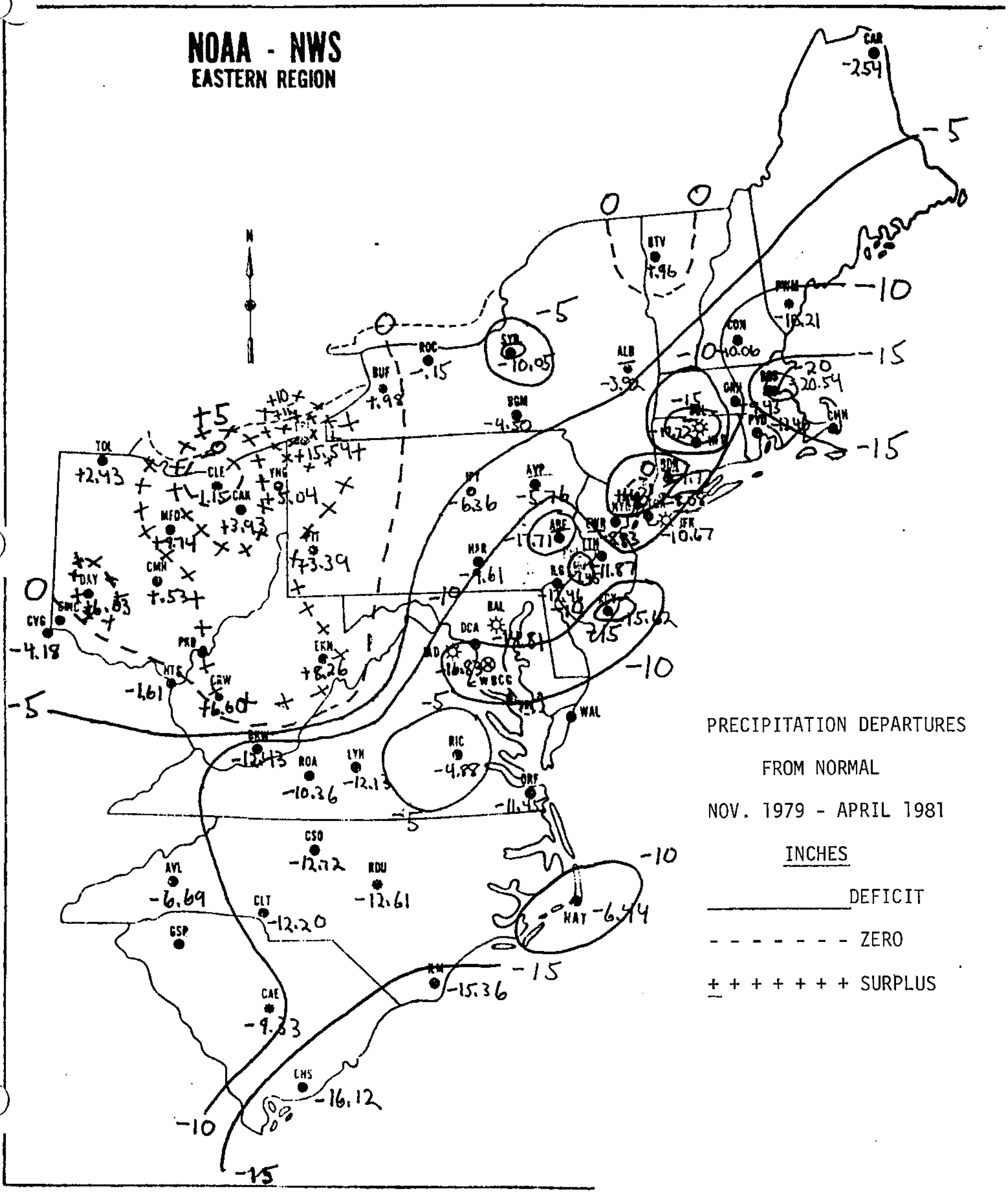
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BGM -4.30
TOL +2.43
CLE -1.15
YNG +5.04
CAK +3.93
MFD +9.74
CMH +.53
DAY +6.03
CVG -4.18
PKB
HTS -1.61
CRW +6.60
EKN +8.26
PIT +3.39
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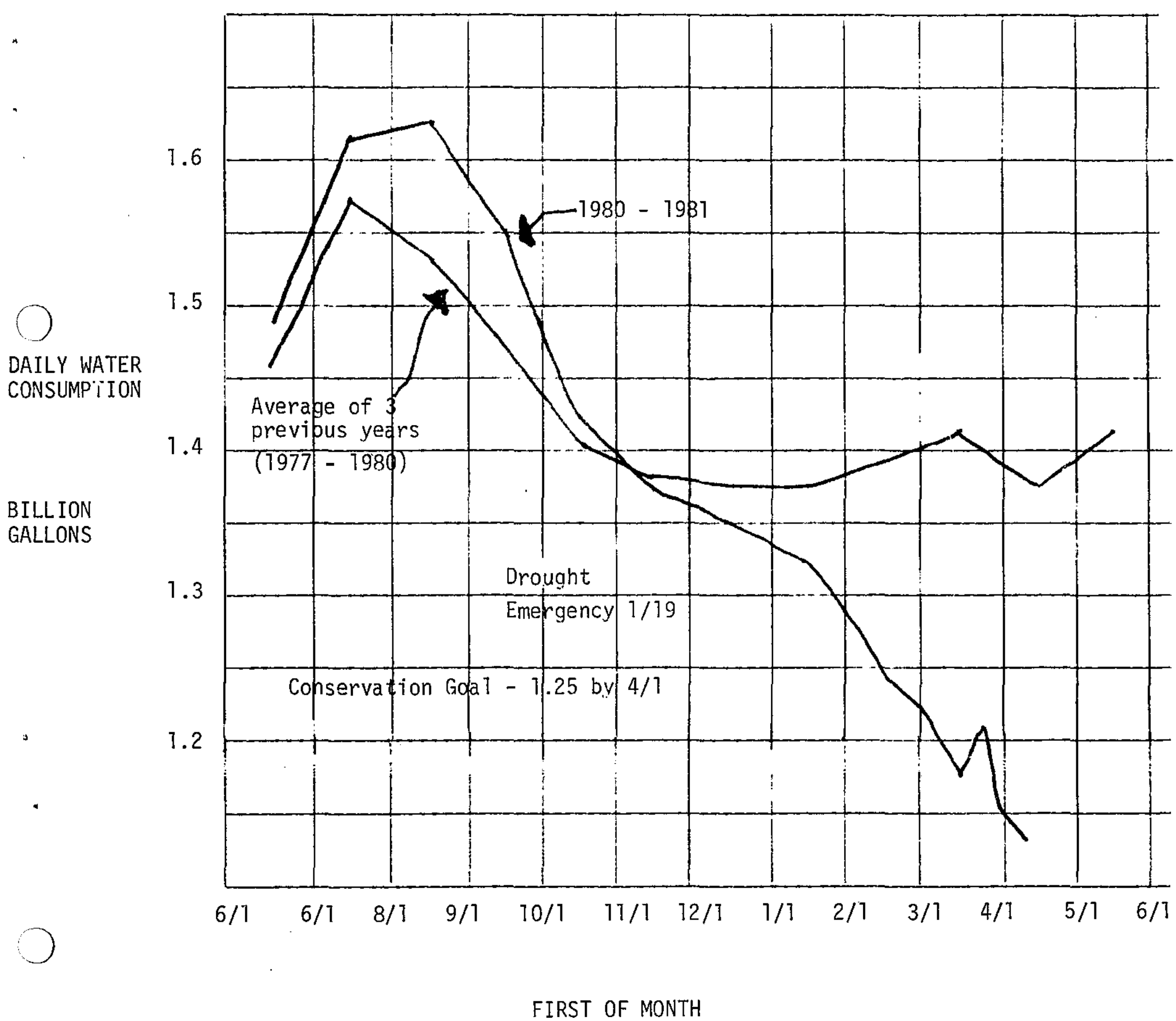
PRECIPITATION DEPARTURES
FROM NORMAL
NOV. 1979 - APRIL 1981
INCHES
DEFICIT
ZERO
+ + + + + + + SURPLUS

Figure 3

NEW YORK CITY DAILY WATER CONSUMPTION



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