Contract Report 618

Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1996

by
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Office of Cloud & Precipitation Research

Prepared for the
U.S. Army Corps of Engineers, Chicago District
and the U.S. Geological Survey

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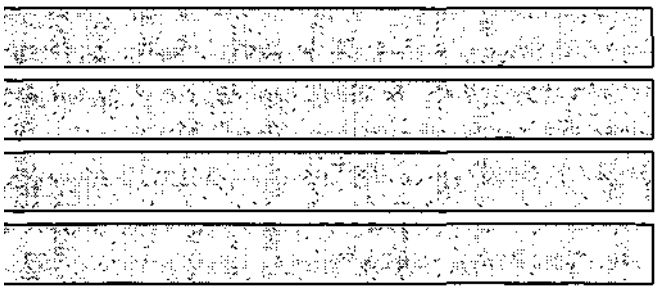

Illinois State Water Survey
Atmospheric Sciences Division
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

CONTINUED OPERATION OF A RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 1996

Nancy E. Westcott

FINAL REPORT

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U.S. Army Corps of Engineers, Chicago District
and
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by

Nancy E. Westcott, Meteorologist

INTRODUCTION

The volume of water diverted from Lake Michigan into the state of Illinois is monitored to ensure that the diversion does not exceed a long-term average of 3,200 cubic feet per second (cfs) as imposed by a 1967 U.S. Supreme Court Order, which was updated in 1980. This diversion has a long history, dating back to the mid-1800s with the completion of the Illinois and Michigan Canal. Over the years, it has been affected by such events as the reversal of the flow of the Chicago River and completion of the Chicago Sanitary and Ship Canal in 1901, and has weathered various legal proceedings that attempted to ensure that the diversion could be monitored and did not exceed certain limits. One of the key components of the monitoring procedure, administered by the U.S. Army Corps of Engineers (COE), Chicago District, is the accurate representation of the precipitation that falls over portions of the Cook County, Illinois region.

The primary components of Illinois' diversion from Lake Michigan are as follows: (1) water is pumped directly from Lake Michigan as the source of potable water supply and discharged into the river and canal system in the greater Chicago area as treated sewage; (2) storm runoff is discharged from the diverted watershed area of Lake Michigan, draining to the river and canal system; and (3) water enters the river and canal system directly from Lake Michigan.

The storm runoff from the Lake Michigan watershed basin enters the combined and separate sewer systems and watercourses. The combined sewers mix sanitary system flow with runoff, and this water then goes to the treatment plants or, during major flood events, becomes surcharged into the watercourses. When large storm events are predicted (and greater than normal storm runoff is anticipated), the canal system is drawn down prior to the event to prevent flooding. If the event fails to materialize, canal system levels are restored using a direct diversion from Lake Michigan through three facilities located along the shoreline: the Chicago River Controlling Works, O'Brien Lock and Dam, and the Wilmette Controlling Works.

The method for computing the diversion involves the direct measurement of diversion flow at Romeoville, Illinois, as measured by an acoustic velocity meter. Flow at Romeoville consists of both diversion and nondiversion flows (deductions). The theory behind diversion accounting is to use the flow at Romeoville and deduct from it flows not

attributable to diversion. Diversion flows that bypass Romeoville are added to the resultant flow, yielding a net computed diversion of water from Lake Michigan. The deductions to the Romeoville record include runoff from 217 square miles of the Des Plaines River watershed that is discharged into the canal, the ground-water supply whose effluent is discharged into the canal, water used by federal facilities, and the Indiana water supply that is discharged into the canal via the Calumet River system and the Calumet Sag Channel.

The diversion is approximated by adding the Lake Michigan water-supply pumpage, direct diversions from Lake Michigan, and runoff from 673 square miles of diverted Lake Michigan watershed. This approximation is performed to cross-check the computed diversion.

In both of these procedures, it is necessary to estimate runoff from the Des Plaines River and the Lake Michigan watersheds. Hydrologic simulations of runoff perform two functions. One is to model runoff. The second is to aid in determining the runoff, ground water, and sanitary proportions of treatment plant discharge. Inputs into the simulation model consist of land-use and climatological data. Of the latter, the most significant is precipitation data.

Accurate precipitation data, thus, are essential to properly simulate the runoff process. Runoff can constitute a significant portion of the diversion. For example, from Water Year 1986 through Water Year 1989 (a water year extends from October 1 through September 30 of the following calendar year), runoff from the Des Plaines River watershed constituted a 142 cfs (4 percent) deduction from the Romeoville measurement record in the diversion computations. In the cross-check approximations, the Lake Michigan watershed runoff constituted a 729 cfs (23 percent) share of the total diversion.

However, the precipitation data available for use by the accounting procedure prior to Water Year 1990 (particularly Water Years 1984-1989) displayed patterns inconsistent with known, long-term Chicago-area patterns (e.g., Changnon, 1961, 1968; Huff and Changnon, 1973; Vogel, 1988,1989; Peppier, 1990,1991a, 1993a). These patterns also diverge from the known urban effects found within the precipitation patterns for the Cook County region for heavier rainfall distributions from 1949-1974 (Huff and Vogel, 1976), particularly towards the south, and within patterns observed during the operation of a dense raingage network and radar system in the Chicago area during the late 1970s (Changnon, 1980, 1984).

The recent unusual patterns were caused by abnormally low precipitation totals at a select number of the 13 sites used by the accounting procedure (Figure 1). Inspection of these sites (Vogel, 1988), which are irregularly distributed over the region, revealed that the low precipitation totals were caused by 1) inadequate raingage exposure (e.g., gages situated on rooftops or too near natural or artificial, flow-restricting obstructions) and 2) different observing, data reduction, and quality control practices used by the individual

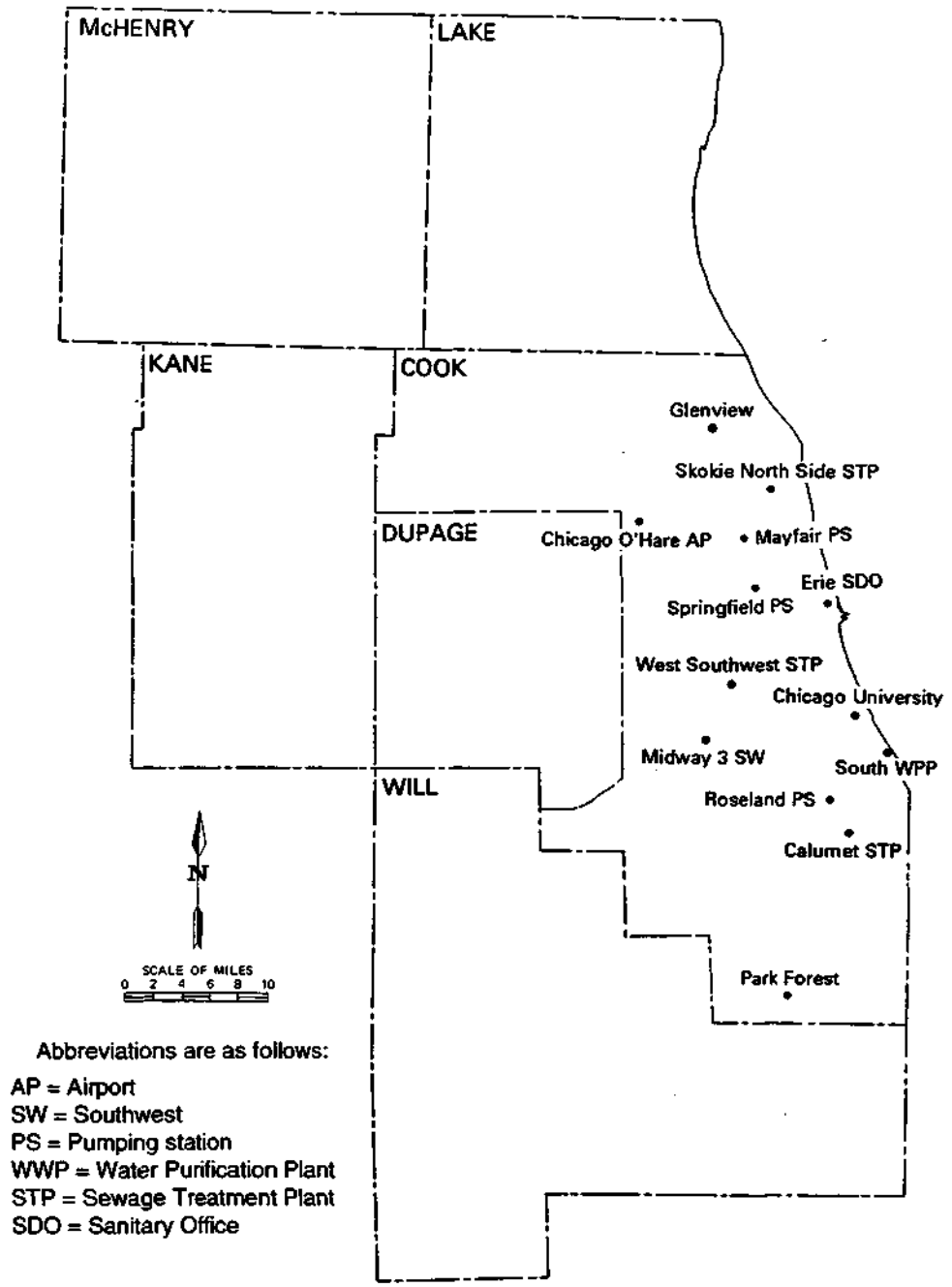

Figure 1. Raingage locations used for diversion accounting purposes prior to Water Year 1990. These include National Weather Service gages located at Chicago O'Hare Airport, Midway 3 Southwest, University of Chicago, and Park Forest; city of Chicago gages located at three pumping stations (Mayfair, Springfield, and Roseland) and the South Water Purification Plant; and Metropolitan Water Reclamation District of Greater Chicago gages located at Glenview, three sewage treatment plants (Skokie North Side, West Southwest, and Calumet), and Erie Sanitary District Office.

groups responsible for raingage operation and data collection (National Weather Service - NWS, Metropolitan Water Reclamation District of Greater Chicago - MWRDGC, and city of Chicago - CC). Vogel (1988) established that the unusual precipitation patterns began occurring in the late 1960s when some changes were made in data collection and reduction.

Vogel (1988) devised a procedure to adjust the questionable values, thus making the data suitable for use in the accounting procedure. This procedure, however, is tedious to implement, and the adjusted precipitation values may not completely capture the actual precipitation regime, although the data produced are much improved over the original values. This procedure also illuminated difficulties experienced when trying to merge data observations from different observing agencies and equipment into one data set. Vogel (1988) gave the following recommendation at the end of his report on the reduction and adjustment of the Water Year 1984 data and on field evaluations of the NWS, MWRDGC, and CC sites:

> With these types of differences it will always be hard to maintain a consistent set of high-quality precipitation observations for the Chicago urban region. A precipitation network which must produce a set of high-quality observations should have a consistent set of gages; should be managed by one group with fixed quality control procedures, exposure criteria, and a set operating procedure. Management by one group would allow for consistent 1) observations, 2) quality control, and 3) spatial and temporal precipitation patterns.
>
> To achieve this, it is recommended that a raingage network be established to monitor the precipitation over northeast Illinois relevant to the diversion of Lake Michigan waters. This network should consist of 10 to 15 weighing-bucket recording raingages. The raingages should be reasonably spaced across the affected area. The network should be managed by one group to ensure that the best possible exposures are obtained initially, and that these exposures are inspected at least annually. The data from such a network should all be quality-controlled in a consistent manner.
>
> Weighing-bucket raingages with daily charts would be capable of obtaining hourly or smaller time increments if daily charts are used. To reduce costs and to increase security, it is recommended that these raingages be located on private property, and that the observers be given a modest annual stipend. The charts from the observers should be mailed to a central location for data processing, quality control, and extraction of hourly precipitation totals. Raingages should be evenly spaced, as much as possible, and sites would be found after consulting with the agencies involved (pp. 41-42).

Using Vogel's recommendation as a model, the State Water Survey (SWS) and the COE jointly decided in late 1988 to devise, install, and operate a new raingage network, funded by the COE. The purpose of the new network was to produce consistent, accurate data for the diversion accounting, which would require little or no adjustment. The implementation and operation of such a network would have to be justified on the grounds of both long-term cost savings and greater accuracy.

This report describes the maintenance and operation of the network, along with the data reduction and analysis techniques employed, and brief data analyses, for Water Year 1996, the seventh year of network operation.

NETWORK DESIGN

The SWS has operated dense raingage networks in the past (e.g., Huff, 1970, 1979), which tested gridded raingage spacing of 6 feet to 6 miles. Adequate sampling of convective-type precipitation (spring and summer) was found to require nearly twice as many gages as required by more widespread, continuous precipitation (fall and winter). With that in mind, and opting for an optimum grid spacing, an initial attempt at creating a grid resulted in an array of 40 raingages located in the Cook County region within the Lake Michigan and Des Plaines River watersheds of the MWRDGC North, Central, South, and Lemont basins. Due to cost considerations, however, some spring/summer catchment ability was sacrificed, and a 25-site grid was devised using a 5- to 7-mile grid spacing between gages. Also due to cost considerations, raingages were not installed outside the watershed boundaries to better define isohyetal patterns at those boundaries. These 25 raingages, more than Vogel had originally envisioned (10-15), have provided adequate coverage for precipitation catchment during Water Years 1990-1995, the first six years of network operation (Peppier 1991b, 1991c, 1993b, 1994, 1995; Westcott, 1996), and are consistent with the "best current engineering practice" as specified in the 1967 and 1980 Supreme Court decrees.

Topographic maps of the Cook County region were used to approximate the location of each of the 25 sites and fine-tune their placement to best position the sites with respect to residential areas, industrial facilities, or municipal grounds. Since terrain effects are fairly minimal in northeastern Illinois, gridding was possible. Gridding also allows the use of simple arithmetic averaging to compute areal depths instead of other labor-intensive methods such as the Thiessen polygonal method.

Once candidate locations were found, several preliminary field trips were made to the Cook County region, and letters were written by the SWS in summer 1989 seeking permission to use the selected locations as raingage sites. Due to the urbanization of the region, site selection was sometimes a frustrating venture, as it was difficult in many instances to identify good catchment areas free of barriers for ground-level placement. When selecting sites, highest priority was given to those at ground level in relatively open, secure areas, since obstructions and local wind eddies produced by flow barriers present

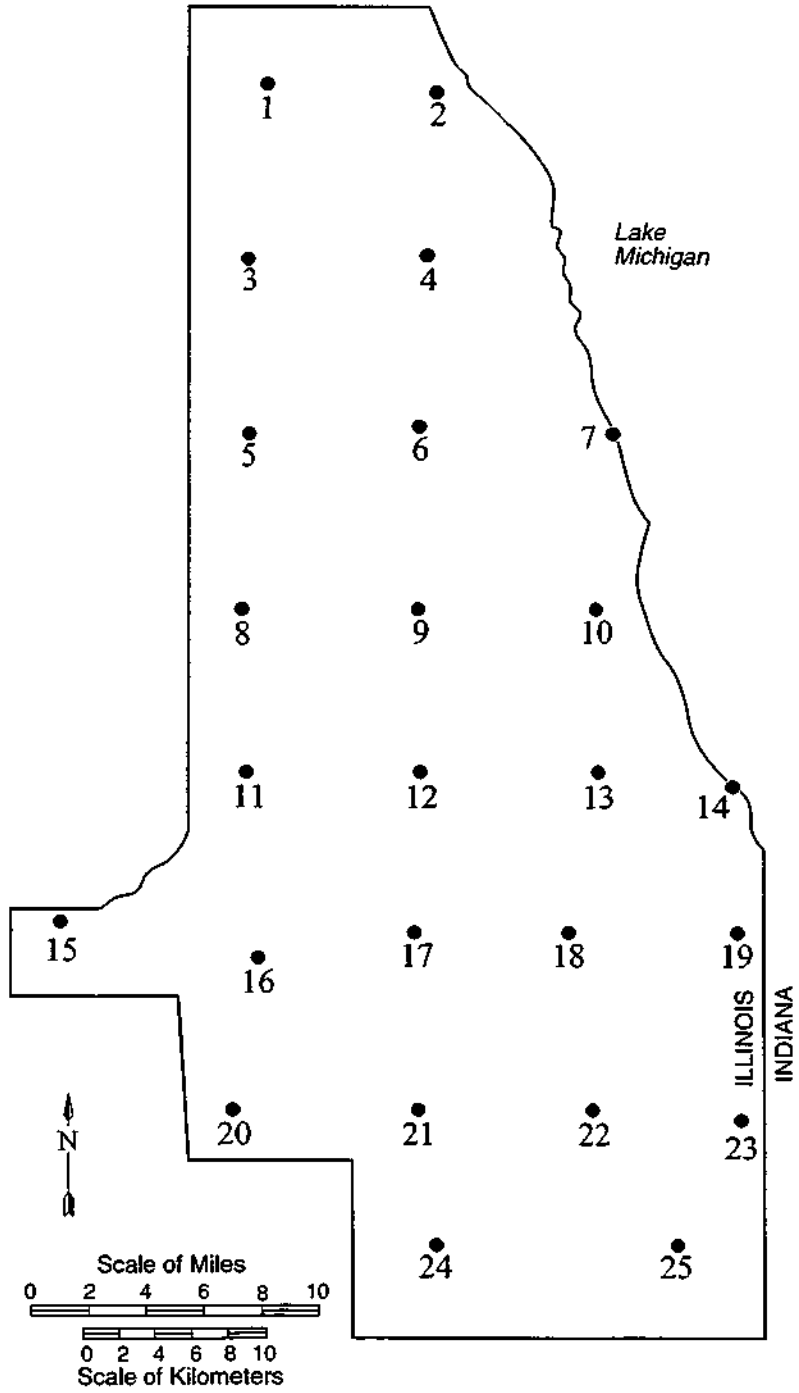

Figure 2. The 25-site raingage network used during Water Years 1990 to 1995.

the largest sources of error in collecting precipitation data. Placing the collector at ground level mitigates wind effects on catchment and represents the ideal exposure (Legates and Willmott, 1990), but it is not practical in wintertime when snow is measured. Thus, as has been standard SWS practice, each raingage was to be placed on stakes with its base approximately 8 inches above ground level and the top of its orifice at about 4 feet. When asked for permission to site a raingage on their property, most individuals, businesses, and municipalities were extremely receptive. In fact, as of September 30, 1996, only seven sites have been relocated to a different property since the network began collecting data in October 1989.

In late September and early October 1989, the entire 25-gage network was installed (Figure 2). Each universal weighing-bucket raingage used throughout the network was fitted with a battery-powered electric chart drive for more consistent and reliable operation. The SWS provided all raingages from its inventory. Appendix I contains complete site descriptions for each network location, accurate as of September 30,1996.

The weighing-bucket recording raingages used are as reliable as any others available (see Jones, 1969, for a complete description of tests of different raingages). All raingages are subject to catchment errors due to winds, wetting losses, evaporation, splashing into or out of the gage, and blowing snow (Legates and Willmott, 1990). Koschmieder (1934) noted that as wind speed increases, gage catch decreases. Legates and Willmott (1990) found that raingage errors "tend to be proportional to total precipitation and amount to nearly 11 percent of the catch." To prevent loss due to blowing snow during the winter, the Nipher shield and the shield used by Lindroth (1991) are helpful, but were not considered for the new network due to cost and vandalism considerations.

NETWORK OPERATION AND MAINTENANCE

Each raingage in the network was fitted with a 24-hour chart drive and chart cylinder gears that rotate the chart cylinder once every 24 hours. The 24-hour chart allows resolution down to 15-minute periods. Because a chart can measure up to 12 inches of precipitation, each gage is fitted with a galvanized bucket capable of holding 12 inches of precipitation in calibration with the 8-inch orifice opening used on the raingage collector. An upward pen traverse on a chart measures the first 6 inches the bucket catches, and a reversed, downward pen traverse measures inches 7-12. The latter traverse, though often unnecessary, is vital whenever more than 6 inches of precipitation occurs between chart periods, or during winter when the antifreeze-charged buckets are allowed to accumulate precipitation without dumping for long periods of time.

A single team of observers, living in Cook County, services each gage every 6-8 days, which means that 6-8 traces are drawn on each chart. Servicing includes removing and replacing the current chart, checking the pen point, dumping the bucket from April-October (the warm season of the year), and noting any problems, including chart-drive malfunction, gage imbalance or instability, vandalism, unauthorized movement of the gage,

etc. During the warm season, evaporation shields are fitted into the collection orifice above the bucket to mitigate evaporation. During the cool season (November-March), these shields are removed and a 1-quart charge of antifreeze is added to each bucket. This allows frozen precipitation to melt in the bucket as it is caught, allowing the weighing mechanism to give a proper reading. Appendix II contains a complete set of servicing instructions provided to the raingage observers.

Each week a complete set of 25 charts collected by the observers is mailed to the SWS, along with notations about problems. The following section, describing data reduction, explains what happens to the data collected on the charts.

Approximately once every four months, or when necessary, the SWS raingage service leader visits the network to perform routine maintenance and repairs for which the observers do not possess adequate expertise. These activities include a site assessment of an observer-noted problem and the determination of a solution. Because most problems pertain to the chart drives, the solution is often to replace the drive or its batteries. If replaced, a chart drive is cleaned and readied for reuse at the SWS. Two spare chart drives allow for flexibility here. Other typical problems (mentioned above) can be solved on these trips as well. Appendix III provides a complete maintenance history, including site relocations, for the raingage network, and more fully describes the kinds of maintenance and repairs conducted. This information is accurate through September 30, 1996.

DATA REDUCTION

Each set of charts that arrives at the SWS is edited to identify the various traces on the charts and to number sequentially by date those showing precipitation. This is perhaps the most important step in the reduction procedure. A running inventory of "on" and "off" chart times is also maintained to ensure that the on-times on the newly received charts match the off-times on the last set of charts analyzed. Occasionally, the observers make inadvertent errors in the on-time/off-time designations, particularly when time zones change in October and April (charts are always kept on Central Standard Time). The on- and off-times are marked on the charts, with the on-time revolution designated as " 1 " , and the last revolution designated as appropriate. Then, the various rain periods (storms) are identified and numbered based on their sequence in relation to the first and last revolutions. This editing procedure also acts as a trouble-shooting exercise to identify chart-drive problems (running slow, fast, or not at all). Raingage instability can also be identified from a shaky pen trace. Skipping or unusually heavy traces indicate problems with the pen tip. Calibration problems can be noted if a trace reverses before the 6-inch line is reached. Finally, the editing stage permits the identification of missing periods of data on the charts, and these are appropriately marked. After all charts have been edited, they are ready to be digitized with a Summagraphics Microgrid II digitizer.

All values are fed into a 486/33 megahertz (MHz) personal computer. Each chart is processed separately. The four comers of a chart are digitized to set the grid, then on- and off-times are entered and their locations digitized. The number of revolutions on each

chart is noted. Each trace indicating precipitation is digitized by "clicking-in" each breakpoint along the respective trace. Once a chart is digitized, computer output gives details on the precipitation that was measured on the chart, in storm amount format, with appropriate beginning and ending times. Also included is an analysis of whether the chart drive is running slow or fast, which helps assess whether a chart drive requires servicing. Errors made during the editing stage can also be caught during digitization. If a chart drive stops during a collection period, the beginning and ending points of the missing period are digitized and appropriately stored in the computer.

Once a calendar month of data is logged into the computer, a C-language computer program, written at the SWS, calculates hourly precipitation values at all 25 sites for each hour of the month in question. These calculations are based on a linear interpolation between digitized breakpoints on the traces. The newly computed hourly values are compared to the digitized storm values during program execution to ensure consistent precipitation amounts. A printout of the entire monthly data array contains data for all 25 stations for all hours of the month. Monthly totals appear at the bottom of the printout. Missing values are denoted as 99.99.

This data array is then used to check for time and space consistency, to divide the data into storm periods, and to fill in missing values with interpolated information. A storm is defined as a precipitation period separated from preceding and succeeding precipitation periods by approximately 6 hours at all stations in the network. This definition has been used by Huff (1967) for an area of similar dimensions in central Illinois, by Vogel (1986) to define extreme storm events in the Chicago area, and by Vogel (1988,1989) and Peppier (1990, 1991a, 1991b, 1991c, 1993a,b, 1994, 1995; Westcott, 1996) to define storms for Water Years 1984-1995. For each storm, values are summed and plotted on maps using all available data and stations, and isohyetal patterns are drawn. During Water Year 1996, 128 such storms were defined.

After a generalized precipitation pattern is obtained for each storm, interpolated storm totals are manually estimated from the pattern for each site having missing information during that storm. Wind information, if available (usually the resultant direction and speed at Chicago O'Hare Airport), and known urban effects in the Chicago area (Huff and Vogel, 1976; Changnon, 1980,1984) may be taken into account when drawing isolines and interpolating values. A computer program using an objective analysis program from the International Mathematical and Statistical Library (IMSL) is then executed to objectively determine new values for hours designated as missing. The objective routine is also used to re-create values at data sites for which questionable values were identified during the storm analysis stage. After execution of the program, the new values are compared to the manually estimated ones, and any unrealistic objective values are adjusted. Once everything has been verified, a final computer file of hourly precipitation values for the month being analyzed is archived.

DATA ANALYSIS

The final Water Year 1996 data set was used to produce various analyses, including: (1) monthly and water year amounts at all sites (Table 1), (2) water year amounts (Figure 3) and comparisons to patterns from network Water Years 1990-1995 (Figure 4), (3) monthly amounts (Figures 5 -10) as documentation of the data collected, and (4) an analysis of the seven-year network precipitation average for Water Years 1990-1996 (Figure 11).

Table 1 and Figure 3 show Water Year 1996 precipitation amounts. Isopleths in Figure 3 (and Figures 4-10) are labeled in inches, while values in Table 1 are to the nearest hundredth of an inch. In considering the total annual network precipitation amount, Water Year 1996 was an average year. The Water Year 1996 network average of 36.88 inches was above but close to the 1961-1990 Chicago O'Hare Airport annual precipitation normal of 35.82 inches. Network averages (inches) for the network Water Years 1990 to 1995 were 40.00, 39.19, 36.56, 51.78, 29.23, and 34.68 inches, respectively. However, in Water Year 1996, there were nearly the same number of heavy rainstorms as in the extremely wet Water Year of 1993 when 11 storms exceeded the one-year recurrence interval. There were 128 storms in Water Year 1996, and ten of these included sites where the storm totals exceeded the one-year recurrence interval (Appendix (IV). The other five water years had between four and seven heavy rainstorms.

The largest precipitation amounts during Water Year 1996 occurred in a band across the southern part of the network (sites #15-#17, #21, and #22, respectively; and at central Chicago site #10 (see Figure 2 and Appendix I for site information). The lightest amounts, occurred along the lake shore (sites #7 and #14), and in the northern half of the network (sites #1-#9) and in the southeast comer of the network (site #15). The heaviest precipitation during the water year fell at site #15 the westernmost gage in the network (45.87 inches), while the lightest fell at site #7 near Lake Michigan (30.02 inches).

At first glance, one might think that this rainfall pattern was largely determined by the extremely heavy storm occurring on July 17-18, 1996, which averaged 5 inches over the network. A total of 10.99 inches of rain fell at site #15, 7.75 inches at site #16, between 1.8 and 4.5 inches at sites #1 -#9, and between 5.0 and 7.0 inches was observed at most other sites in that 30-hour period. However, after subtracting the extreme rainfall case from the annual gage totals, the same basic pattern remained. While the gradients were smaller, the heaviest rain fell at sites #15-#18, #22 and extended up to site #10. The lightest precipitation fell at the nine northern sites and sites #14 and #25. The stabilizing influence of Lake Michigan noted in previous years was again apparent.

Figure 4 provides a map of precipitation amounts for network Water Years 1990 to 1995. The general pattern for Water Year 1996 is somewhat reminiscent of Water Year 1992 with an east-west band of heavier precipitation across the southern half of the region and lighter precipitation along the eastern edge of the network. The "urban high" of the near lake, central Chicago area noted in other network water years (especially 1990,1992,

Table 1. Monthly and Water Year Precipitation Amounts for Water Year 1996 (inches)

Site	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Total*
1	3.51	3.13	0.73	1.58	0.51	0.75	2.67	8.16	4.17	4.12	1.89	2.40	33.62
2	3.72	3.18	0.79	1.76	0.56	1.14	2.58	6.42	4.22	4.93	1.24	3.95	34.49
3	3.62	3.09	0.66	1.67	0.52	0.77	2.20	6.99	4.53	3.82	1.29	3.08	32.24
4	3.31	3.00	0.63	1.58	0.57	0.89	2.46	7.27	4.95	3.80	1.03	3.13	32.62
5	3.61	3.25	0.55	1.67	0.67	0.88	2.71	6.12	4.22	4.51	2.36	4.65	35.20
6	3.38	2.93	0.64	1.58	0.76	0.81	2.27	5.97	4.37	3.56	1.96	3.39	31.62
7	2.87	3.19	0.43	1.27	0.72	1.26	2.39	5.66	3.60	3.42	1.44	3.77	30.02
8	3.74	3.36	0.58	1.87	0.98	0.98	2.48	5.51	4.15	6.28	2.71	2.94	35.58
9	3.37	4.04	0.36	1.40	0.62	1.15	2.26	5.65	3.74	5.63	2.90	2.69	33.81
10	3.37	4.79	0.57	1.83	0.69	1.55	2.55	5.32	4.52	6.82	2.56	3.48	38.05
11	3.82	4.34	0.47	1.62	0.62	1.02	2.79	6.49	5.91	8.48	0.89	2.78	39.23
12	3.34	4.60	0.27	1.34	0.52	1.00	3.17	6.75	4.66	8.31	0.77	3.10	37.83
13	3.36	4.51	0.52	1.52	0.63	1.55	2.71	5.95	4.69	7.13	1.02	3.56	37.15
14	2.82	3.95	0.31	1.18	0.78	0.90	2.45	6.66	5.16	5.29	0.81	3.53	33.84
15	4.52	4.77	0.32	1.59	0.87	0.98	3.17	6.04	5.28	13.24	0.61	4.48	45.87
16	3.88	4.25	0.47	1.36	0.72	1.40	3.21	5.99	4.27	11.98	0.89	3.61	42.03
17	3.48	5.06	0.42	1.45	0.97	1.72	3.28	5.83	4.71	10.05	0.56	3.68	41.21
18	3.52	4.14	0.28	1.36	1.08	1.15	2.76	6.43	5.20	8.46	1.01	4.44	39.83
19	2.98	3.82	0.29	1.01	0.87	1.17	3.50	6.00	4.78	6.94	1.43	3.39	36.18
20	3.68	3.74	0.36	1.34	1.22	1.16	3.90	5.47	4.43	8.04	0.69	3.02	37.05
21	3.45	3.92	0.38	1.29	1.52	1.29	3.71	6.59	3.90	9.67	1.00	3.46	40.18
22	3.33	4.11	0.25	1.37	1.85	1.29	4.18	6.90	5.05	8.18	0.62	3.30	40.43
23	2.91	4.57	0.37	1.11	2.00	1.60	3.83	7.55	4.08	7.71	0.97	2.03	38.73
24	3.12	3.57	0.17	1.16	2.63	1.08	3.55	8.39	3.99	8.59	0.19	2.91	39.35
25	2.64	3.76	0.14	0.69	1.36	1.10	2.89	7.56	3.81	8.87	0.46	2.56	35.84
Avg.	3.41	3.88	0.44	1.42	0.97	1.14	2.95	6.47	4.50	7.11	1.25	3.33	36.88

and 1994) and in other Chicago-area research (e.g., Huff and Vogel, 1976) was again present in 1996.

As in the case of the other network water year patterns, the spatial pattern for Water Year 1996 does not contain the wildly varying anomalies found in an analysis using the Metropolitan Water Reclamation District of Greater Chicago, the National Weather Service, and the City of Chicago raingages for Water Years 1984-1989, which were the precipitation input for diversion accounting before construction of the present network (see Peppier, 1993b for those patterns). While there is a 8-inch gradient in the annual amount between sites #7 and #10, gradients of 15 to 20 inches were common in the 1984-1989 analysis.

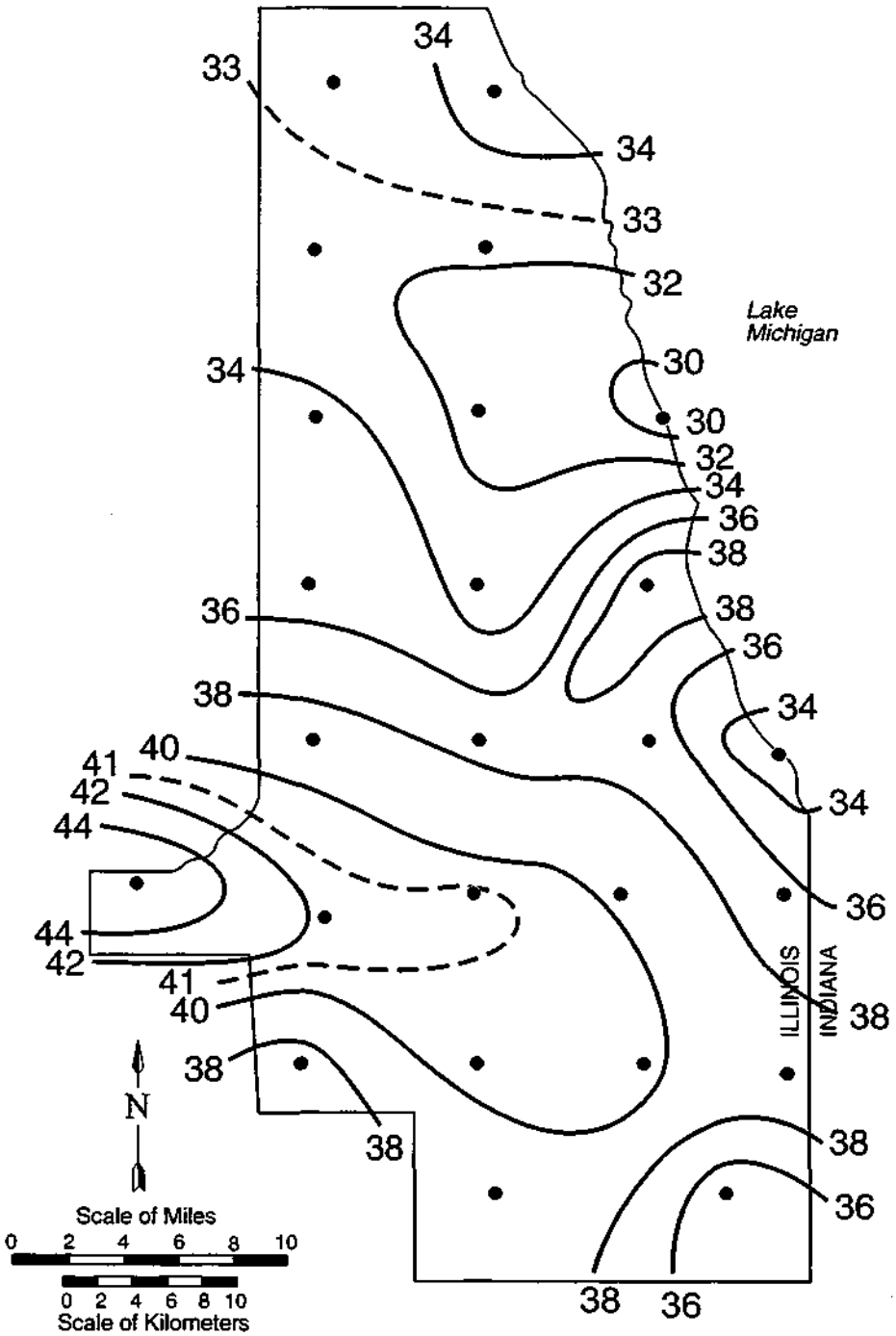

Figure 3. Precipitation pattern (inches) for Water Year 1996.

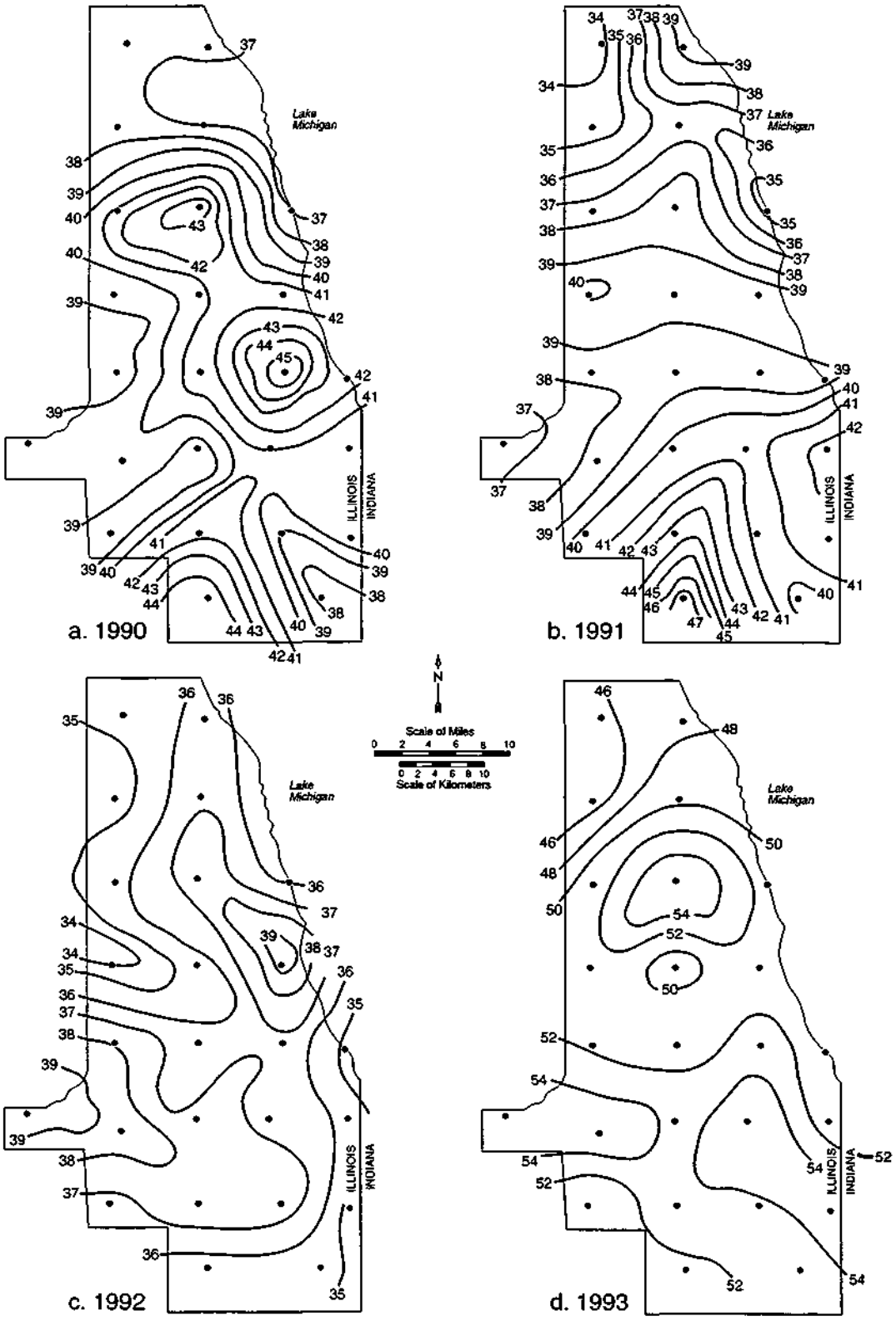

Figure 4. Precipitation pattern (inches) for Water Years 1990 -1995.

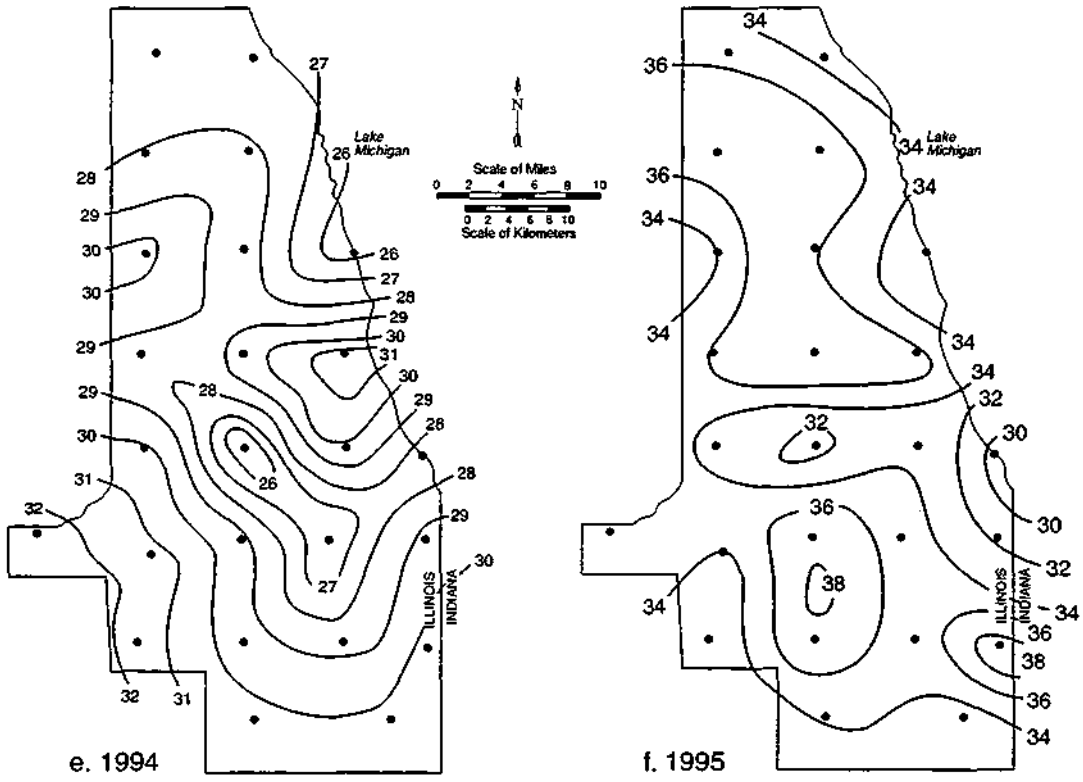

Figure 4. Concluded

Figures 5-10 contain monthly analyses during Water Year 1996 (see also Table 1). The network average precipitation in July exceeded 7.0 inches. This was largely due to the July 17-18, 1996 storm, which produced on average more than 5 inches of total rainfall. Thirteen other storms were observed in July, but only one had a network average of more than 0.5" of rainfall. Precipitation amounts exceeded 5.0 inches across the network in May, when two storms exceeded a network average of 1.0 inch, and when a total of 18 storms were observed. The June and November network averages exceeded 3.75 inches. Storms with network average rainfall of more than 1.0 inch were observed in October (1), November (1), May (2), June (1), July (1), and September (1). Precipitation was noticeably light from December 1995 through March 1996 , with the average monthly network rainfall ranging from 0.4 to 1.5 inches. Twelve or more storms per month were observed from in September 1995 and May-July 1996. Six to ten storms occurred in the remaining months.

During November, February-June, and especially July, a maximum in the southern region was noted. In October, June, July, and September, the spatial patterns indicated a maximum in the west or west central part of the network.

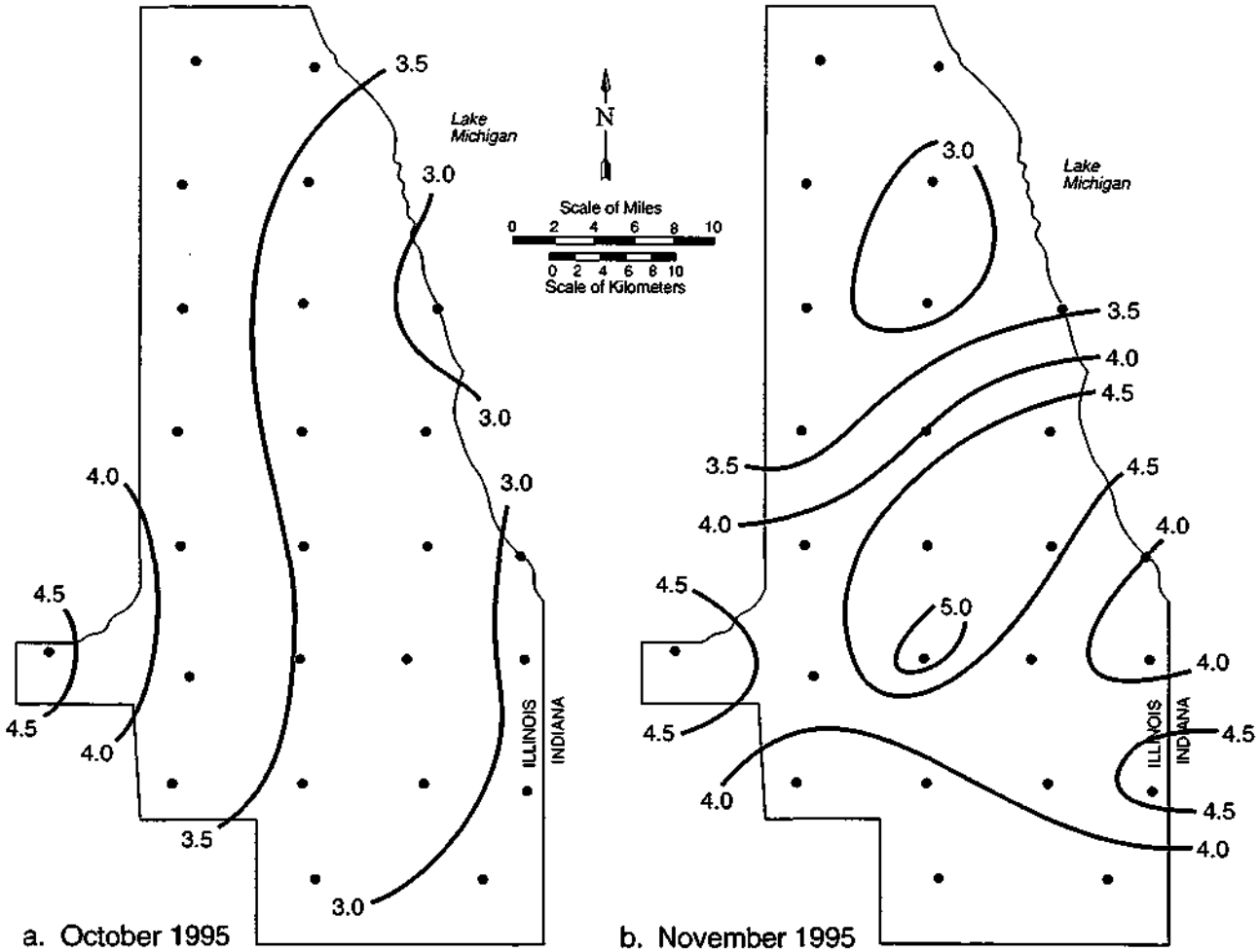

Figure 5. Precipitation pattern (inches) for a) October 1995 and b) November 1995.

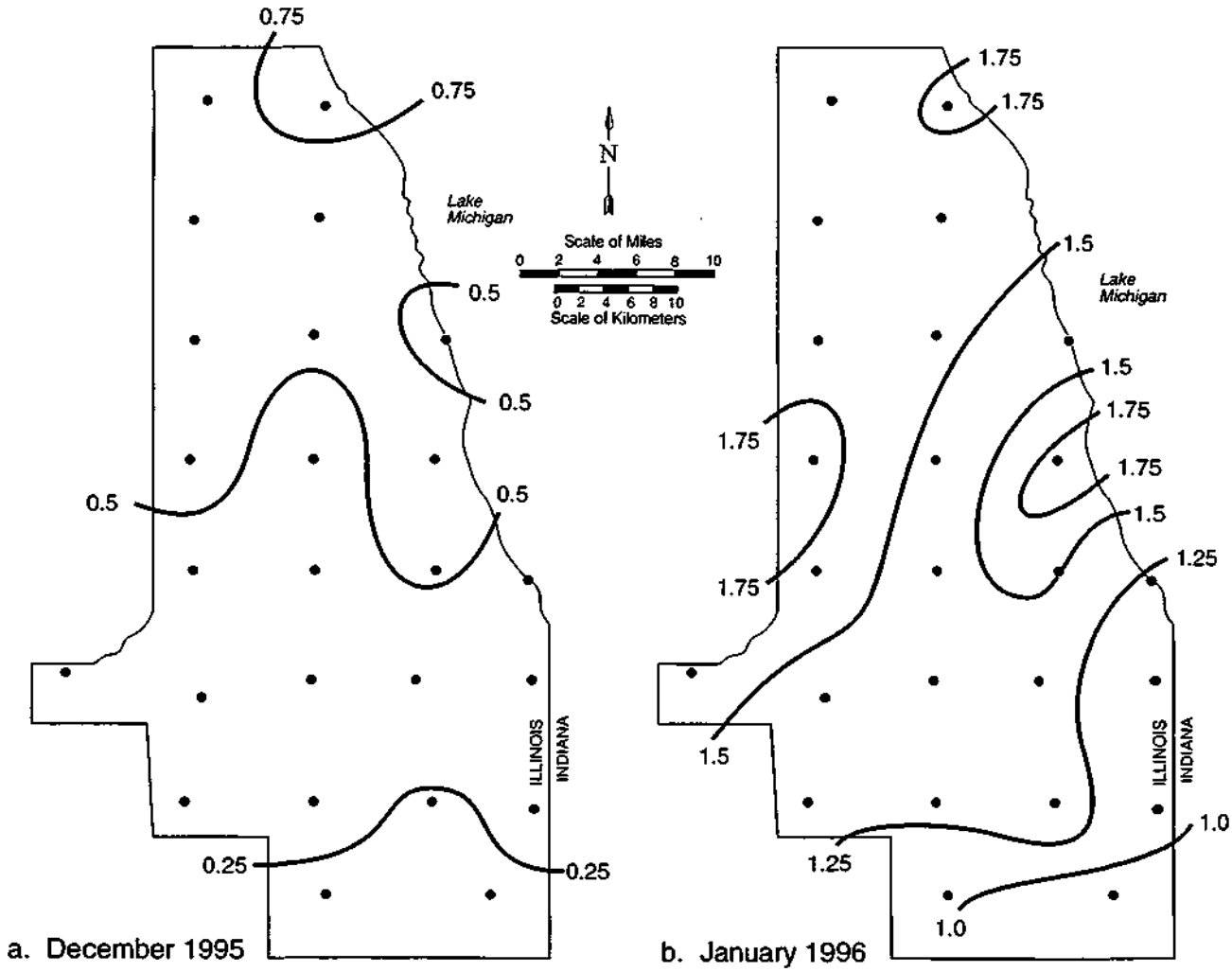

Figure 6. Precipitation pattern (inches) for a) December 1995 and b) January 1996.

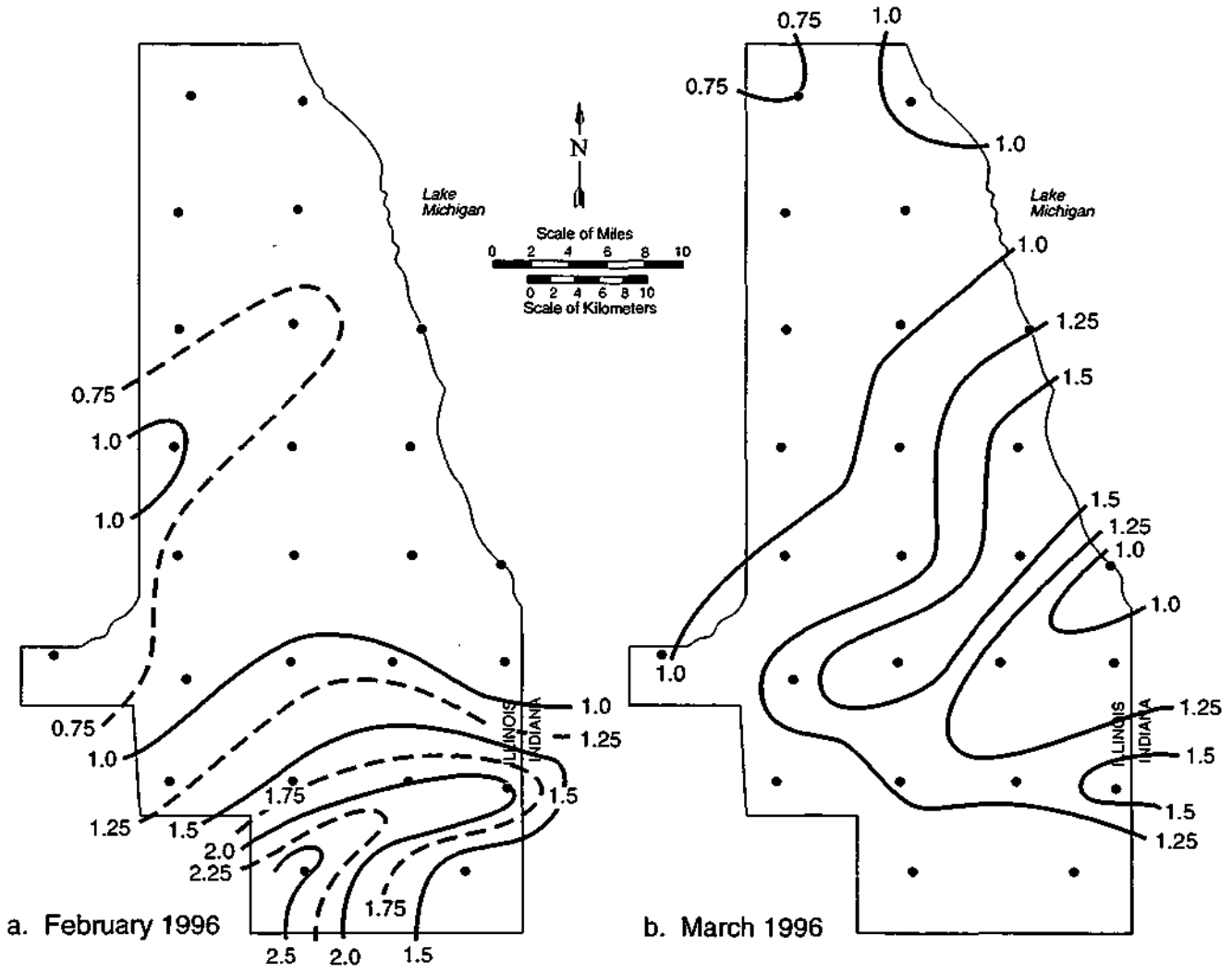

Figure 7. Precipitation pattern (inches) for a) February 1996 and b) March 1996.

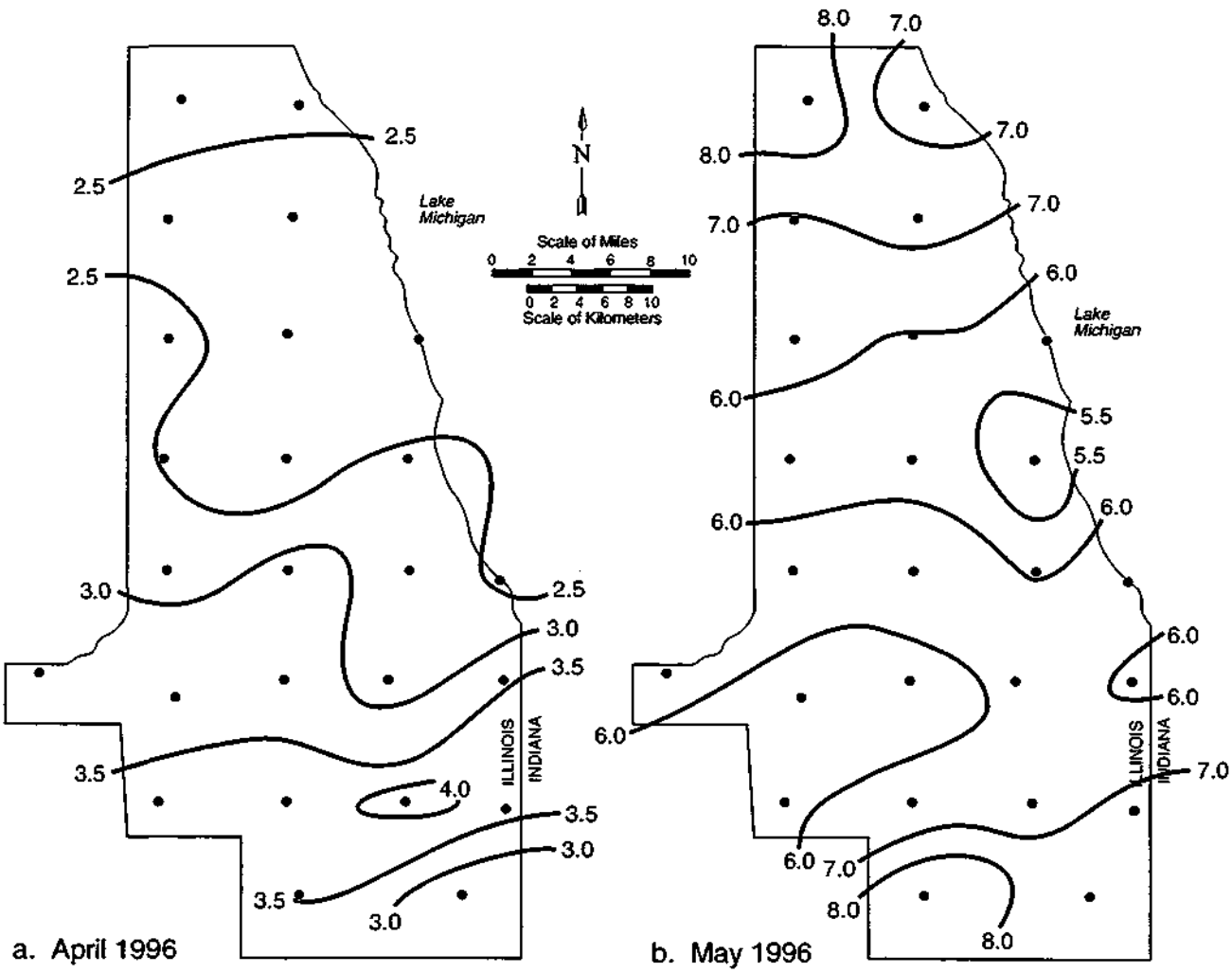

Figure 8. Precipitation pattern (inches) for a) April 1996 and b) May 1996.

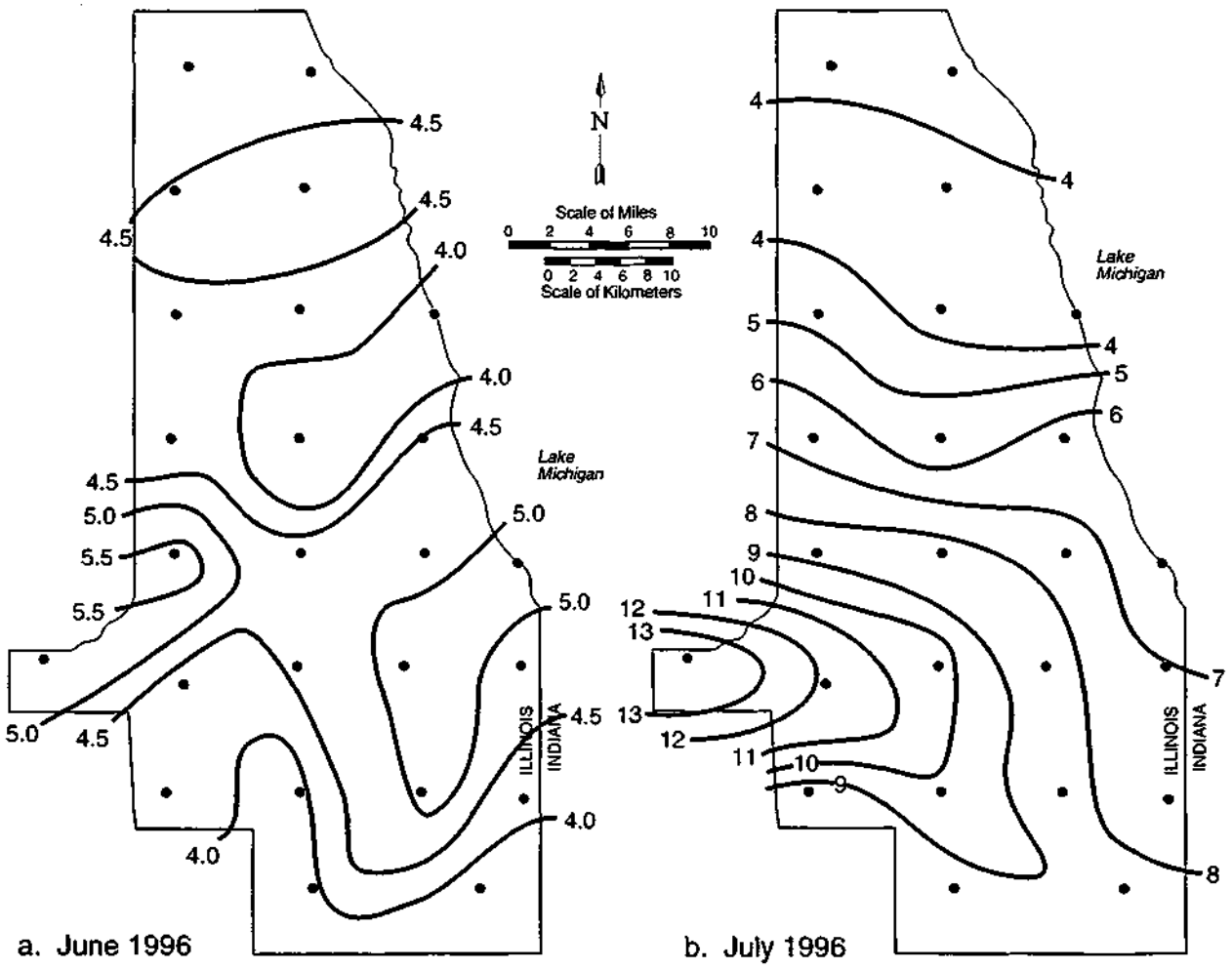

Figure 9. Precipitation pattern (inches) for a) June 1996 and b) July 1996.

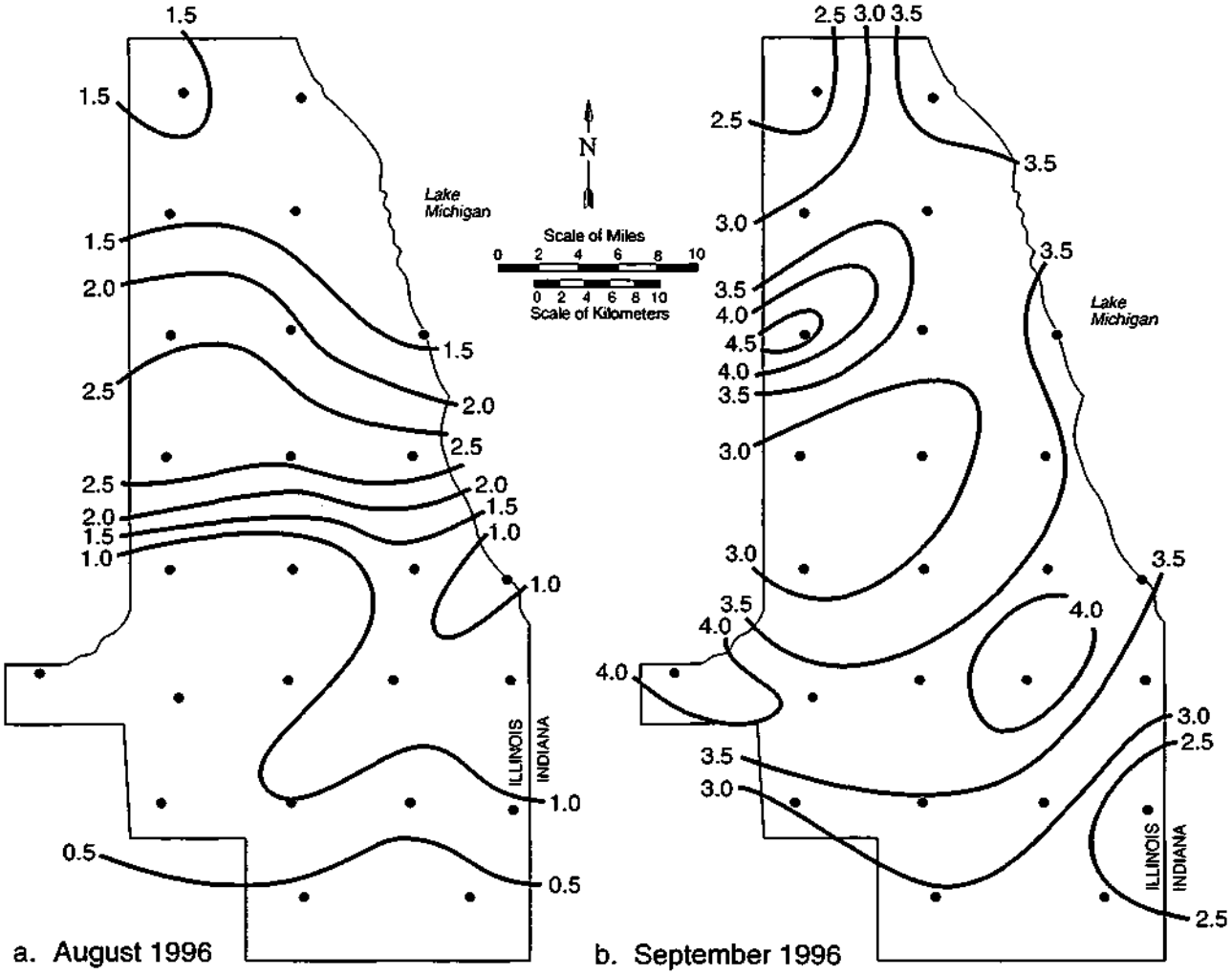

Figure 10. Precipitation pattern (inches) for a) August 1996 and b) September 1996.

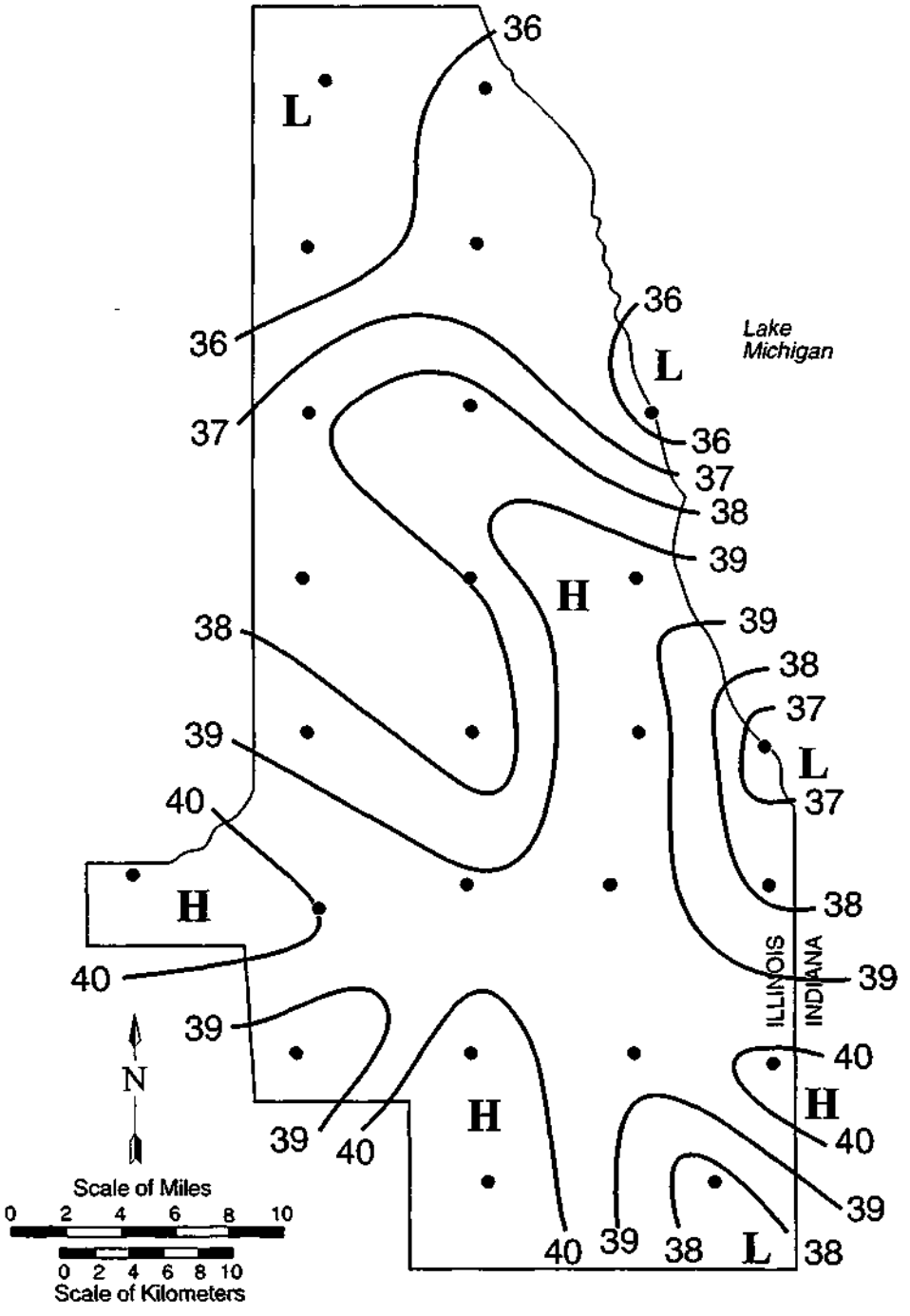

Figure 11. Seven-year average precipitation pattern (inches) from Water Years 1990 -1996.

In November, January, and March, a north-central urban high was present. Lighter shoreline precipitation values were noted in April, October, and August.

The seven-year (1990-1996) average pattern (Figure 11) reveals a star-shaped pattern of higher values across south-central Chicago (sites #15-18 and 21-23), reaching northward to sites #10 and #13, and southward to site #24. Lower values occurred in the extreme northwest at site #1, the northeast lake shore at site #7, portions of the east-southeast area of the network around sites #14 and #19. The seven-year network-wide average is 36.88 inches.

Of the 128 storms identified during Water Year 1996, ten produced amounts that surpassed the one-year recurrence interval for the given storm duration. Storm durations of one hour to three days were considered, and recurrence intervals were determined according to the standards set for northeastern Illinois (Huff and Angel, 1989). Only one of the six earlier years, the wet Water Year 1993, had a comparable number of heavy rainstorms (11). However, no other year had an event exceeding a 100-year recurrence interval as did the storm on July 17-18, 1996. This record-breaking event is documented in Changnon, et al. (1997). Of the remaining storms, one included a gage exceeding a 5-year recurrence interval and five of the storms included at least one gage exceeding the 2-year recurrence interval. Appendix IV contains specific information concerning the ten Water Year 1996 storms that exceeded the one-year recurrence interval.

SUMMARY

The Cook County raingage network has now collected precipitation data during seven water years, 1990-1996. The siting of the raingages, the areal coverage of the network, and the careful quality control of the data allow the U.S. Army Corps of Engineers, Chicago District, to more accurately estimate the storm runoff portion of the diversion of water from Lake Michigan into Illinois. Because of the relatively dense spacing of the deployed raingages, the network also provides high-quality data for research on the precipitation variability of the Cook County region.

ACKNOWLEDGMENTS

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APPENDIX I: RAINGAGE SITE DESCRIPTIONS

This appendix contains site descriptions of the 25 raingage locations in the network as of September 30, 1995. Sites that have been relocated since the network began operation in October 1989 are noted in the "Placement" section of the descriptions.

SITE DESCRIPTION		
Site Number: 1		
County: Cook	Township: 42N	Ranae: 12E
Section: 20	Lat/Long: 42°06'39'7 87°52'06"	Quadranale: Park Ridae
Property Owner: Mission Brook Sanitary District, Attn: John Tomaras		
Address: P.O. Box 2362, Northbrook, Illinois 60065		
Telephone: 708/272-2956		
Permission Date: September 14, 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 7378	Gage ID No.: 6561	Clock Mfrs. No.: E 7373
Placement: Southeast corner of pump station lawn at southwest corner of intersection of Post and Cornflower Streets. Tri-State Tollway fence is just to the west. Enter area from west at Landwehr Road (north of Willow Road) at Sunset Ridge.		

SITE DESCRIPTION		
Site Number: 2		
County: Cook	Township: 42N	Ranae: 13E
Section: 19	Lat/Long: 42°06'29"/ 87°45'06"	Quadranale: Park Ridae
Property Owner: Winnetka Park District, Attn: Richard Blust		
Address: 510 Green Bay Road, Winnetka, Illinois 60093		
Telephone: 708/446-2397		
Permission Date: September 14, 1989		
Installation Date: October 3,1989		
Gage Mfrs. No.: 1703	Gage ID No.: 261	Clock Mfrs. No.: W00534
Placement: Between maintenance building and parking lot in grassy area. Previously located 15 feet southeast in the maintenance yard (10-3-89 through 7-31-91) before the gage was destroyed. The facility closes at 1600 local time on workdays. Enter facility west off of Hibbard Street, north of Willow Road.		

SITE DESCRIPTION		
Site Number: 3		
County: Cook	Township: 41N	Ranae: 12E
Section: 28	Lat/Long: 42°01'21'7 87°52'39"	Quadranale: Arlinaton Heights
Property Owner: Private Residence		
Address: 1885 Riverview Avenue, Des Plaines, Illinois 60018		
Telephone: 708/824-1093		
Permission Date: September 14, 1989		
Installation Date: September 28, 1989		
Gage Mfrs. No.: 4730	Gage ID No.: 5062	Clock Mfrs. No.: E 7323
Placement: Northwest comer of the yard by the fence. Enter Riverview Avenue west off of Des Plaines River Road.		

SITE DESCRIPTION		
Site Number: 4		
County: Cook	Township: 41N	Ranae: 13 E
Section: 21	Lat/Long: 42°01'37/ 87°45'20"	Quadranale: Park Ridae
Property Owner: Village of Skokie, Attn: Eddy Nakai		
Address: 5127 0akton Street, Skokie, Illinois 60077		
Telephone: 708/673-0500		
Permission Date: September 18, 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 6558	Gage ID No.: 5040	Clock Mfrs. No.: E 7370
Placement: Grassy strip between mailbox and Villaqe payment box on east side of Floral Street near parking lot, established late 3-94. A previous move from the original location, on a grassy strip between another parking lot and the west side of Floral Street, was made in late 12-92. The 12-92 location was 50 feet due east of the original position in a grassy strip on the east side of Floral Street. Present site is 15 feet northeast of the 12-92 position. All locations are just north of Oakton Street (across from Village Hall).		

SITE DESCRIPTION		
Site Number: 5		
County: Cook	Township: 40N	Ranae: 12E
Section: 28	Lat/Long: 41°55'56"/ 87°52'41"	Quadrangle: Elmhurst
Property Owner: Private Residence		
Address: 2925 North Sarah Drive, Franklin Park, Illinois 60131		
Telephone: 708/455-2630		
Permission Date: September 13, 1989		
Installation Date: September 28, 1989		
Gage Mfrs. No.: 4717	Gage ID No.: 5105	Clock Mfrs. No.: W00539
Placement: Northeast corner of backyard near a fence and a hedge. Enter Schiller Avenue east off of Mannheim Road, then south on Sarah Drive (one-way). Alley access is also available in the back.		

SITE DESCRIPTION		
Site Number: 6		
County: Cook	Township: 40N	Range: 13E
Section: 28	Lat/Lono: 41°56'16"/ 87°45'39"	Quadrangle: River Forest
Property Owner: Private Residence		
Address: 5346 West Fletcher Street, Chicago, Illinois 60641		
Telephone: 312/282-9042 or 312/286-2681		
Permission Date: July 6, 1993		
Installation Date: July 12, 1993		
Gage Mfrs. No.: 5300	Gage ID No.: 5304	Clock Mfrs. No.: W00535
Placement: Original location was about 60 feet east-southeast from 9-28-89 through 7-6-93. Gage reinstalled on 7-12-93 in the west edge of a backyard 4 feet south of a one-story garage, 15 feet south of a two-story house, and 7 feet northwest of a two-story wooden stairwell/deck. Enter from an alley east off of Long Street, which is south off of Belmont Avenue. Three-car brown garage door and bright green chain link fpnce		

SITE DESCRIPTION		
Site Number: 7		
County: Cook	Township: 40N	Range: 14E
Section: 21	Lat/Long: 41°56'33'7 87°38'42"	Quadrangle: Chicaao Loop
Property Owner: Broadway United Methodist Church, Attn: Gregory Dell, Pastor		
Address: 3344 North Broadway, Chicago, Illinois 60657		
Telephone: 312/348-2679		
Permission Date: October 4, 1991		
Installation Date: October 4,1991		
Gage Mfrs. No.: 5281	Gage ID No.: 5303	Clock Mfrs. No.: E 7410
Placement: Just northeast of parking lot in grass strip between lot and black wrought iron fence. Enter parking lot from Buckingham Place (one-way westbound from Broadway). Was located at Belmont Harbor boat landing (10-1-89 through 12-27-89), on the Lincoln Park Gun Club roof (12-27-89 through 6-28-91), and just north of Diversey Harbor in a playground (6-28-91 through 10-4-91).		

SITE DESCRIPTION		
Site Number: 8		
County: Cook	Township: 39N	Range: 12E
Section: 29	Lat/Lono: 41°50'42"/ 87°52'53"	Quadrangle: Hinsdale
Property Owner: Cook County Forest Preserve District, Attn: Frank Grippo		
Address: 10400 Windsor Drive, Westchester, Illinois 60154		
Telephone: 312/562-7628		
Permission Date: September 21, 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 4669	Gage ID No.: 5070	Clock Mfrs. No.: E 7417
Placement: Southeast comer of backyard between pool and grape hedge. Enter Windsor Drive east from Belleview Drive, south from Cermak Road and into Forest Preserve residence facility. Just west of Salt Creek and parallel bike trail.		

SITE DESCRIPTION		
Site Number: 9		
County: Cook	Township: 39E	Ranae: 13E
Section: 28	Lat/Long: 41°50'47"/ 87°45'28"	Quadrangle: Berwyn
Property Owner: Mary Queen of Heaven Parish, c/o Father John Price		
Address: 5314 West 24th Place, Cicero, Illinois 60650		
Telephone: 708/863-6608		
Permission Date: May 24, 1990		
Installation Date: May 24,1990		
Gage Mfrs. No.: 7376	Gage ID No.: 6559	Clock Mfrs. No.: E 7369
Placement: Southwest comer of schoolyard about 12 feet from south fence line and along a west fence, west of the nunnery. Was located at 5530 West 24th Street (9-28-89 through 5-24-89). Enter 24th Place (one-way east) from Central Avenue, south from Cermak Road.		

SITE DESCRIPTION		
Site Number: 10		
County: Cook	Township: 39N	Ranae: 14E
Section: 28	Lat/Long: 41°50'42"/ 87°38'27"	Quadranale: Enalewood
Property Owner: Rental Residence		
Address: 527 West 26th Street, Chicago, Illinois 60616		
Telephone: 312/225-8066		
Permission Date: September 13, 1989		
Installation Date: September 28,1989		
Gage Mfrs. No.: 4720	Gage ID No.: 5113	Clock Mfrs. No.: E 7416
Placement: Backyard near edqe of walk north of a garage and east of a spruce tree. Enter off of alley south of 26th Street, where locked gate is to be entered (observer keeps key). In Chinatown area, block between Wallace and Normal.		

SITE DESCRIPTION		
Site Number: 11		
County: Cook	Township: 38N	Ranae: 12E
Section: 28	Lat/Long: 41°45'29"/ 87°52'20"	Quadrangle: Berwyn
Property Owner: Private Residence		
Address: 10180 5th Avenue Cutoff, LaGranqe, Illinois 60525		
Telephone: 708/354-3161		
Permission Date: September 13, 1989		
Installation Date: September 29, 1989		
Gage Mfrs. No.: 3348	Gage ID No.: 4452	Clock Mfrs. No.: E 7344
Placement: 6 feet east of clothesline pole in center of backyard near edqe of a larqe garden. Access from Willow Springs Road, south of Joliet Road (parcel of land is between lnterstate-55 and Tri-State Tollway).		

SITE DESCRIPTION		
Site Number: 12		
County: Cook	Township: 38N	Range: 13E
Section: 28	Lat/Lonq: 41°45'32"/ 87°46'06"	Quadrangle: Berwvn
Property Owner: C.P. Hall Company, Attn: Mark Kuklins		ti
Address: 5851 West 73rd Street, P.O. Box 910, Bedford Park, Illinois 60499-0910		
Telephone: 708/594-5065		
Permission Date: November 24, 1992		
Installation Date: November 24, 1992		
Gaoe Mfrs. No.: 4661	Gaqe ID No.: 5111	Clock Mfrs. No.: E7413
Placement: Moved on 5-17-93 about 400-500 feet southwest of 11-24-92 position along service drive in a mowed grassy area. There is a security fence about 10 feet to the south. Position on 11-24-92 was in a large grassy area north of office building. Previous to 11-24-92 gage was at Reckitt and Coleman about 0.9 mile to the east of nrfisent location.		

SITE DESCRIPTION		
Site Number: 13		
County: Cook	Township: 38N	Range: 14E
Section: 28	Lat/Long: 41°45'31"/ 87°38'29"	Quadrangle: Enalewood
Property Owner: Greune Coal Company, Attn: Paul Schoeinq		
Address: 7435 South Union Street, Chicaqo, Illinois 60621		
Telephone: 312/846-4000		
Permission Date: March 1, 1995		
Installation Date: March 15, 1995		
Gage Mfrs. No.: 4687	Gage ID No.: 5058	Clock Mfrs. No.: E 5257
Placement: In southwest comer of property iust north of an elevated railroad track and just east of a concrete barrier. Gage is free-standing. Access is from south on Union Street (one-way north) north of 76th Street. Location is about four blocks directly west of previous original position (9-29-89 to 3-15-95) in Mrs. Wolfe's yard.		

SITE DESCRIPTION		
Site Number: 14		
County: Cook	Township: 38N	Range: 15E
Section: 29	Lat/Long: 41°45'27"/ 87°32'38"	Quadrangle: Jackson Park
Property Owner: City of Chicaqo - South Water Purification Plant, Attn: Robert Sambol		
Address: 3300 East Chiltenham Place, Chicaqo, Illinois 60649		
Telephone: 312/933-7107		
Permission Date: September 12, 1989		
Installation Date: September 28, 1989		
Gaoe Mfrs. No.: 3370	Gage ID No.: 4453	Clock Mfrs. No.: E 7353
Placement: Center of laroe qrassv area (turf-covered roof) over sand filtration beds. Two distant buildings are east and west of the site. Enter facility east off of 79th Street from South Shore Drive.		

SITE DESCRIPTION		
Site Number: 15		
County: Cook	Township: 37N	Range: 11E
Section: 20	Lat/Long: 41°40'47"/ 87°57'55"	Quadranale: Saa Bridae
Property Owner: St. Mary's Seminary, c/o Fr. Vendelin		
Address: 14246 Main Street, Lemont, Illinois 60439		
Telephone: 708/257-2494		
Permission Date: November 11,1994		
Installation Date: November 22,1994		
Gage Mfrs. No.: 3373	Gage ID No.: 4421	Clock Mfrs. No.: E 7292
Placement: About 250 feet along west side of a lane which extends southeasterly from the main building and drive-around, in a clearing. Previous original position (9-27-89 to 11-22-94) was at the MWRDGC site in downtown Lemont about 1.5 miles west of present position. Entrance lane is south off Main Street. Exit Interstate-55 south on Lemont Road to downtown, then proceed east on Main Street.		

SITE DESCRIPTION		
Site Number: 16		
County: Cook	Township: 37N	Ranae: 12E
Section: 28	Lat/Long: 41°39'46"/ 87°52'13"	Quadranale: Palos Park
Property Owner: Private Residence		
Address: 240 Timber Edge Lane, Palos Park, Illinois 60464		
Telephone: 708/361-0853		
Permission Date: September 11,1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 4733	Gage ID No.: 5022	Clock Mfrs. No.: E 7300
Placement: Along west edae of lawn in backyard, about 20 feet south of property line and utility. Was moved about 2 feet on 4-26-91 to facilitate landscaping. Enter subdivision from 125th Street (off of Route 45), just south of McCarthy Road. West-southwest of Papoose Lake.		

SITE DESCRIPTION		
Site Number: 17		
County: Cook	Township: 37N	Ranae: 13E
Section: 28	Lat/Long: 41°40'32'7 87°45'00"	Quadrangle: Palos Park
Property Owner: Alsip Fire	Department Station #2, Attn: Lt. John Scolum	
Address: 11946 South Laramie Street, Alsip, Illinois 60482		
Telephone: 708/385-6902		
Permission Date: August 9, 1994		
Installation Date: Auqust 9, 1994		
Gage Mfrs. No.: 4719	Gage ID No.: 5415	Clock Mfrs. No.: E 7293
Placement: Just north of parkinq lot behind (west of) Alsip Fire Department Station #2 building. Present location is about 150 yards south-southeast of previous original position (9-27-89 to 8-9-94) at Sardee Industries. Enter Laramie Street north from 122nd Street, west of Cicero Avenue. Northeast of Tri-State Tollway, south of Restvale Cemetery.		

SITE DESCRIPTION		
Site Number: 18		
County: Cook	Township: 37N	Ranae: 14E
Section: 29	Lat/Long: 41°40'36"/ 87°39'07"	Quadrangle: Blue Island
Property Owner: Inqersoll Products Company, Attn: Don Recupido		
Address: 1000 West 120th Street, Chicago, Illinois 60643		
Telephone: 312/264-7800		
Permission Date: September 12, 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 7130	Gage ID No.: None	Clock Mfrs. No.: E 7345
Placement: West end of property iust northwest of a truck scale and east of property fence. Must enter at guarded gate on 119th Street. Gage moved about 150 feet north of original position, within same property, on 8-9-94.		

SITE DESCRIPTION		
Site Number: 19		
County: Cook	Township: 37N	Range: 15E
Section: 20	Lat/Long: 41°40'21"/ 87°32'22"	Quadrangle: Lake Calumet
Property Owner: Graycor Industries		
Address: 12233 Avenue 0, Chicago, Illinois 60603		
Telephone: 312/221-8400		
Permission Date: September 11, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 5298	Gage ID No.: 5291	Clock Mfrs. No.: E 7294
Placement: Grassv area iust north of a shop buildinq and iust south of entrance drive, established on 11-24-92. Previous original position was 50 feet due east in a grassy area just south of entrance drive and just west of the main parking lot. A factory building is located 50 feet north/northeast of both locations.		

SITE DESCRIPTION		
Site Number: 20		
County: Cook	Township: 36N	Ranae: 12E
Section: 29	Lat/Long: 41°35'09"/ 87°52'35"	Quadranale: Mokena
Property Owner: Private Residence		
Address: 10595 West 167th Street, Oriand Park, Illinois 60462		
Telephone: 708/349-9388		
Permission Date: March 16, 1990		
Installation Date: March 16, 1990		
Gage Mfrs. No.: 4667	Gage ID No.: 5061	Clock Mfrs. No.: E 7627
Placement: About 30 feet east of weldina shop on rural property. Shop is east building of home/shop complex. Four dachshunds outside. Was located about 0.25 mile southeast on South 104th Avenue (9-26-89 through 3-16-90).		

SITE DESCRIPTION		
Site Number: 21		
County: Cook	Township: 36N	Ranoe: 13E
Section: 28	Lat/Lono: 41°35'15"/ 87°44'52"	Quadrangle: Harvey
Property Owner: Private Residence		
Address: 16710 Lockwood Road, Tinley Park, Illinois 60477		
TeleDhone: 708/560-0213		
Permission Date: September 16, 1989		
Installation Date: September 28, 1989		
Gage Mfrs. No.: 4686	Gage ID No.: 5037	Clock Mfrs. No.: E 5262
Placement: North end of backyard west of (behind) qaraqe. Enter Lockwood Road south off of 167th Street.		

SITE DESCRIPTION		
Site Number: 22		
County: Cook	Township: 36N	Range: 14E
Section: 21	Lat/Lono: 41°35'11"/ 87°38'00"	Quadrangle: Harvey
Property Owner: U.S. Army Reserve Center, Attn: Commander Al Dixon		
Address: 400 East 167th Street, Harvey, Illinois 60426		
Telephone: 708/339-0001		
Permission Date: September 12, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 4676	Gage ID No.: 5035	Clock Mfrs. No.: E 7334
Placement: Between parkinq lot and reserve buildinq, just north of fenced-in reserve storage lot, about 150 feet south of 167th Street. Was located about 100 feet northwest on Army property, just west of parking lot before a building was constructed on property just to the west (9-26-89 through 11-2-90). Enter 167th Street east off of Halsted Avenue.		

SITE DESCRIPTION		
Site Number: 23		
County: Cook	Township: 36N	Range: 15E
Section: 29	Lat/Long: 41°35'09"/ 87°32'14"	Quadrangle: Calumet City
Property Owner: City of Lansing Public Works, Attn: Al Poortenga		
Address: 3300 East 171st Street, Lansing, Illinois 60438		
Telephone: 708/895-7190		
Permission Date: September 12, 1989		
Installation Date: September 26,1989		
Gage Mfrs. No.: 4660	Gage ID No.: 5043	Clock Mfrs. No.: E 7357
Placement: About 40 feet east and on the south end of a 40' garage/shed, between a healthy 30' tree to the north and a 30' lightly foliated tree 15 feet south. Enter north gate east off of 170th Street. Closes at 1530 local time. Was about 150 feet north, 6 feet from east fence in northeast comer of storage yard of Public Works complex, about 75 feet east of the same recycling building.		

SITE DESCRIPTION		
Site Number: 24		
County: Cook	Township: 35N	Ranae: 13E
Section: 16	Lat/Long: 41°31'05"/ 87°44'00"	Quadrangle: Harvey
Property Owner: Village of	Matteson, Attn: Frank W. Denman	
Address: 3625 West 215th Street, Matteson, Illinois 60443		
Telephone: 708/748-1411		
Permission Date: September 12, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 7573	Gage ID No.: WMU81122	Clock Mfrs. No.: E 7564
Placement: 5 feet west of telephone terminal box on grass north of parking lot and northeast of Matteson Police Department on Cicero Avenue, 0.5 mile north of U.S. 30.		

SITE DESCRIPTION		
Site Number: 25		
County: Cook	Township: 35N	Range: 14E
Section: 13	Lat/Long: 41°31'14"/ 87°34'25"	Quadrangle: Calumet City
Property Owner: Big John's Farm Stand, Attn: John DeBoer		
Address: 1754 East Joe Orr Road, Chicago Heights, Illinois 60411		
Telephone: 708/758-2711		
Permission Date: September 12, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 7467 Gage ID No.: WMU80955 Clock Mfrs. No.: W00538		
Placement: Northeast of farm stand parking lot, northwest of house and northeast of farm stand. Small ditch between parking lot and gage, with large trees near house. Just east of lnterstate-394 and Stony Island Avenue, and west of Torrence Avenue.		

APPENDIX II: INSTRUCTIONS FOR RAINGAGE TECHNICIANS

1. Supplies required for proper servicing of the instruments in the Cook County raingage network:

   a. A supply of 24-hour rotation raingage charts (Belfort number 5-4047-B)
   b. A supply of spare felt-tipped pen points
   c. A roll of paper towels or similar absorbent material
   d. A ball-point pen or pencil
   e. Grass clippers and/or sickle
   f. A clipboard
   g. A spare 12-quart bucket

2. Make sure you have the correct time in the Central Standard Time zone:

   Please coordinate your watch with the broadcast tone from radio station WMAQ or WGN, etc., on the hour, before starting a day's servicing schedule, and recheck if possible when out in the field. Try to be within 15 seconds of the correct time.

3. Order of servicing upon arrival at a site (try to complete within 5-10 minutes of arrival):

   1) Cut the grass around the raingage if necessary or applicable. Do this to the specifications of the landowner or below the level of the raingage door, whichever is shorter.

   2) Open the sliding door on the side of the instrument case by pushing out on the hinge lock and pulling up on the door handle, depress the bucket platform upright casting to ink the OFF time on the chart (a vertical line). Note the time on your watch, and move the pen point and arm away from the chart by pushing out on the pen bracket. Lift up on the drum cylinder to disengage it from the electric chart drive, and remove it from the instrument case. Write the OFF date and time on the chart. Carefully remove the chart from the drum to avoid smearing the fresh ink at the end of the trace.

   3) Write this OFF time as the ON time on a new chart, and apply it to the drum cylinder, making sure the crease at the right end of the chart is sharp and the chart is tight on the cylinder. This helps prevent skipping when the pen point travels over the drum clip, as well as preventing false indications of a rain event. Make a small mark with your pen or pencil on the chart near the zero-inch line to indicate the ON time. Try to match the chart reading with the ON time as closely as possible. Reinstall the chart cylinder onto the electric chart drive, making sure the chart cylinder and drive gears mesh.

4) Quickly remove the collector from the top of the gage by rotating the collector clockwise to disengage the tongue-and-groove assembly, set it down, and then carefully lift the bucket off of the weighing platform (if there is water in it) and dump the water on the ground. Reposition the bucket on the platform and reinstall the collector by setting it on top of the raingage case and turning counterclockwise until the tongue-and-groove assembly meshes. During wintertime operation when a charge of antifreeze is in the bucket, leave the antifreeze until the chart reading passes the 6-inch mark. At that point, dump the bucket contents into a large plastic bucket and dispose of properly. DO NOT POUR SOLUTION ONTO THE GROUND! If wintertime conditions prevail, recharge the empty bucket with a quart of antifreeze. At any time of the year, once the collector is repositioned, check the gage to make sure the collector orifice top edge is level. With a level positioned on the collector orifice, depress the stakes on the side(s) reading high with your shoe or boot, lightly or firmly depending on how much out of level the gage is and how soft the ground is.

5) Move the pen arm and point over near the chart cylinder and rotate the cylinder counterclockwise until the pen point coincides with the pencil mark on the chart denoting the ON time. Let the pen point rest on the chart there, and depress the platform casting again to make a vertical pen line at the ON time. This also assures that the pen point is writing correctly. If not, check the tip of the pen point to see why it is not drawing. Replace if necessary. It helps if the word "ON" is written on the chart near the ON line for later chart editing purposes. Re-zero the pen point if necessary by turning the fine adjustment screw. It isnt a bad idea to "zero" the pen near the 0.25-inch mark instead to prevent evaporation from taking the pen point below the zero line.

6) Wipe the inside base of the gage to keep it relatively clean. Check the just-removed chart for any irregularities and note them on the upper right corner. As you are doing this, keep an eye on the new chart to make sure the drum is rotating and the pen is writing. When you are sure everything is operating correctly, carefully close the gage door and push the hinge lock in to secure it. Make sure you have removed all supplies and tools from the site before moving on to the next one.

4. Completed raingage charts and site repairs:

When a complete set of 25 charts has been collected for a week, place them in numerical order, put them in one of the postage-paid envelopes provided, and mail them to the State Water Survey, noting the name of the project director on the envelope. If any serious problems were encountered during servicing, please call the project director "collect" to relay the information to him. Situations worthy of immediate attention include chart-drive stoppages, unauthorized movement of the raingage, vandalism, and theft. Repairs will then be scheduled as soon as possible. Make minor repairs (e.g., pen point stuck under drum cylinder, debris in the collection bucket, etc.). Major repairs will require the attention of the State Water Survey.

5. Change in site status:

If you become aware that there has been or will be a change of status of one of the sites in the network, or one of the landowners requests movement of the raingage, please alert the State Water Survey immediately so that the project director can contact the landowner to work out a new arrangement. It is important to try to keep the sites as permanent as possible during the course of this project.

6. Public relations:

As a representative of the State of Illinois, it is imperative that you make your contacts with the landowners and others as cordial as possible and respect their property. They are providing an important service by agreeing to have the instrumentation on their property, so please keep their good will. Refer any questions from them concerning the project and your job that you are unable to answer to the project director.

APPENDIX III: DOCUMENTATION OF RAINGAGE MAINTENANCE

This appendix documents the maintenance work carried out by Champaign-based Illinois State Water Survey staff at each network site during Water Year 1995. Any unusual gage activity performed by non-Water Survey staff also is included. The on-site observing team normally replaces pen points and chart drive batteries, and relevels and trims around the gages when required, and those instances are not listed. Organized chronologically by site number, this documentation is accurate through September 30, 1996.

Calibration checks and gage cleaning activities were conducted at various times throughout the water year and are not listed here unless some other servicing was required at a particular site. Sites that did not require servicing other than weekly chart changing or a calibration visit are not listed.

SITE #1: MISSION BROOK SANITARY DISTRICT

10-95: Replaced gage at same location.

SITE #4: VILLAGE OF SKOKIE

12-92: Moved 50 feet due East of the original location.

10-21 -93: Replaced gage at same location. Previous one accidentally destroyed by Village personnel two weeks earlier.

02-15-94: Replaced gage again. Previous one vandalized.

04-20-94: Movement in 03-94 by Village personnel precipitated a recalibration. Replaced chart drive and one support stake.

05-29-94: Replaced chart drive.

10-95: Replaced gage at same location.

SITE #5: FRANKLIN PARK

10-21 -93: Replaced bucket during a calibration visit.

SITE #6: NORTH CENTRAL CHICAGO, NEAR BELMONT

07-12-93: Moved about 60 feet to the WNW to a backyard.

SITE #7: BROADWAY UNITED METHODIST CHURCH

10-04-91: Moved to current location; was located at Belmont Harbor boat landing (10-01 -89 through 12-27-89); on the roof of the Lincoln Park Gun Club (12-27-89 through 06-28-91), and just north of Diversey Harbor in a playground (06-28-91 through 10-04-91).

04-20-94: Replaced chart drive.

5-17/19-96: Rotated gage base at the existing location to ensure a solid foundation.

SITE #8: WINCHESTER

06-02-95: Replaced chart drive.

SITE #9: MARY QUEEN OF HEAVEN PARISH - CICERO

10-28-93: Replaced chart drive during a calibration visit.

04-20-94: Replaced chart drive, repaired outer case.

06-24-94: Replaced outer case.

SITE #12: CP HALL, NEAR BEDFORD PARK

11-24-92: Moved gage West 0.9 miles, north of an office building.

05-17-93: Moved gage about 400-500 feet to the SW along a service drive in a mowed grass area.

SITE #13: GREUNE COAL COMPANY

03-15-95: Moved gage from Eggleston Street to a sheltered coal yard of the Greune Coal Company on Onion Street, about 4 blocks due West of the old position; and replaced the chart drive.

12-06-95: Gage T-base replaced.

5-17/19-96: Gage T-base reinforced.

SITE #14: SOUTH WATER PURIFICATION PLANT

03-19-95: Replaced chart drive.

12-06-95: Gage T-base replaced.

06-13-96: Gage replaced at same location. It was hit by a riding lawn mover on 06-10-96.

SITE #15: SAINT MARY'S SEMINARY - LEMONT

11-22-94: Moved gage about 1.5 miles East from MWRDGC complex in Lemont to the grounds of the Franciscan Fathers, on Main Street in Lemont.

SITE #17: ALSIP FIRE DEPARTMENT STATION #2

11-04-93: Replaced chart drive during a calibration visit.

06-24-94: Replaced chart drive.

08-09-94: Moved gage about 150 yards SSE from Sardee Industries to Alsip Fire Department Station #2.

SITE #18: INGERSOLL PRODUCTS - WEST 120th STREET

11-04-93: Replaced chart drive during a calibration visit.

08-09-94: Moved gage about 150 feet North of previous location in work yard.

Site #19: AVENUE O

11-24-92: Moved gage 50 feet due West to grassy area just north of a shop building and just south of an entrance drive.

5-17/19-96: Rotated gage base at the existing location to ensure a solid foundation.

SITE #20: ORLAND PARK

03-16-90: Moved gage about 0.25 miles to the NW to rural property about 30 feet east of a welding shop.

5-17/19-96: Rotated gage base at the existing location to ensure a solid foundation.

SITE #21: TINLEY PARK

02-16-95: Replaced chart drive.

05-22-95: Replaced chart drive, again.

SITE #22: HARVEY

11-02-90: Moved about 100 feet to the SE, between a parking lot and an Army reserve building, just north of a reserve storage area.

SITE #23: LANSING

04-24-96: Moved 150 feet to the South of the previous location at the request of the property manager.

5-15/17-96: Moved site slightly, so it is evenly spaced between two trees (one about 15 feet to the south and one about 15 feet to the north). It is close to the site where it was moved on 04-24-96, still about 150 feet to the South of the previous long standing location.

SITE #25: BIG JOHN'S FARM STAND - CHICAGO HEIGHTS

11-04-93: Replaced chart drive during a calibration visit.

02-15-94: Replaced chart drive.

APPENDIX IV: DOCUMENTATION OF HIGH STORM TOTALS

This appendix documents individual station storm totals (within the 128 storms) that exceeded an annual event (one-year recurrence interval) during Water Year 1996. Within the storm period, if several rain periods were present at an individual gage that were separated by 6-hours or more, only the heaviest rain period was considered. Storm durations of one hour to three days were considered. The rainfall amounts for one-year to one hundred-year recurrence intervals, and the aforementioned storm durations for northeastern Illinois are given below (Huff and Angel, 1989).

Storm Duration	*Rainfall Amounts (inches)*						
	1-yr	*2-yr*	*5-yr*	*10-yr*	*25-yr*	*50-yr*	*100-yr*
1 hour	1.18	1.43	1.79	2.10	2.59	3.04	3.56
2 hours	1.48	1.79	2.24	2.64	3.25	3.82	4.47
3 hours	1.60	1.94	2.43	2.86	3.53	4.14	4.85
6 hours	1.88	2.28	2.85	3.35	4.13	4.85	5.68
12 hours	2.18	2.64	3.31	3.89	4.79	5.62	6.59
18 hours	2.30	2.79	3.50	4.11	5.06	5.95	6.97
24 hours	2.51	3.04	3.80	4.47	5.51	6.46	7.58
48 hours	2.70	3.30	4.09	4.81	5.88	6.84	8.16
72 hours	2.93	3.55	4.44	5.18	6.32	7.41	8.78

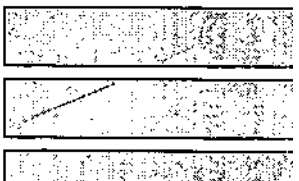
The values listed in the following table exceed the numbers above for the given storm duration. An "e" indicates a partial or full estimate for a particular site and storm. The last column indicates whether a particular gage within the given storm exceeded a rainfall value greater than an annual event (2-year to 100-year recurrence intervals considered).

STORM TOTALS

Storm #	*Date*	*Site #*	*Duration (hour)*	*Amount (inch)*	*Storm recurrence frequency*
23	11/10-11/95	8	17	2.41	
		9	14	3.01	2-year
		10	27	3.68	2-year
		11	18	3.24	2-year
		12	28	3.53	2-year
		13	20	3.42	2-year
		14	21	2.92	2-year
		15	18	3.51	5-year
		16	17	2.97	2-year
		17	25	3.73	2-year
		18	23	3.08	2-year
		19	18	2.81	2-year
		20	18	2.53	
		21	20	2.73	
		22	26	2.99	
		23	29	3.37	2-year
		24	18	2.60	
		25	20	2.65	
49	2/26-27/96	24	11	2.46	
70	5/9-10/96	34	4	3.04	
83	5/28/96	10	7	2.09	
		12	11	2.13	
		13	8	2.14	
		14	8	2.75	2-year
		15	9	2.08	
		18	8	2.39	
		19	8	1.99	
		22	9	2.54	2-year
		24	10	2.56	2-year
		25	8	2.18	

Storm #	*Date*	*Site #*	*Duration (hour)*	*Amount (inch)*	*Storm recurrence frequency*
95	6/17-18/96	12	8	2.85	2-year
		13	7	2.26	
		14	8	2.47	2-year
		17	7	1.99	
		18	7	2.25	
105	7/17-18/96	1	28	2.81	
		2	27	3.17	2-year
		4	23	2.51	
		5	24 e	3.14 e	2-year
		6	24	2.54	
		8	24	4.51	10-year
		9	24	4.31	5-year
		10	26	4.31	5-year
		11	24	6.79	50-year
		12	24	6.51	50-year
		13	24	5.19	10-year
		14	25	4.18	5-year
		15	27	10.99	100-year
		16	26	7.75	100-year
		17	23	6.54	50 year
		18	23	5.65	25-year
		19	23	4.67	10-year
		20	24	5.66	25-year
		21	24	6.50	50-year
		22	24	5.74	25-year
		23	24	5.27	10-year
		24	26	6.40	25-year
		25	24	6.31	25-year
120	8/22-23/96	5	4	1.75	
		8	6	2.09	
		9	3	2.08	2-year
		10	3	2.29	2-year
122	9/08-09/96	5	10	2.37	

Storm #	*Date*	*Site #*	*Duration (hour)*	*Amount (inch)*	*Storm recurrence frequency*
12	9/11/96	15	3	2.04	2-year
		16	5	1.82	
128	9/26-27/96	17	18	2.35	
		18	18	2.53	
		21	18	2.68	
		24	19	2.54	



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