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Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1993

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CONTINUED OPERATION OF A RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 1993

Randy A. Peppier

FINAL REPORT

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CONTENTS

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1. 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 U.S. Supreme Court Order of 1967, 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 systems with the runoff, and this water then goes to the treatment plants or, during major flood events, becomes surcharge 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, groundwater supply whose effluent is discharged into the canal, water used by federal facilities, and 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, groundwater, 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,

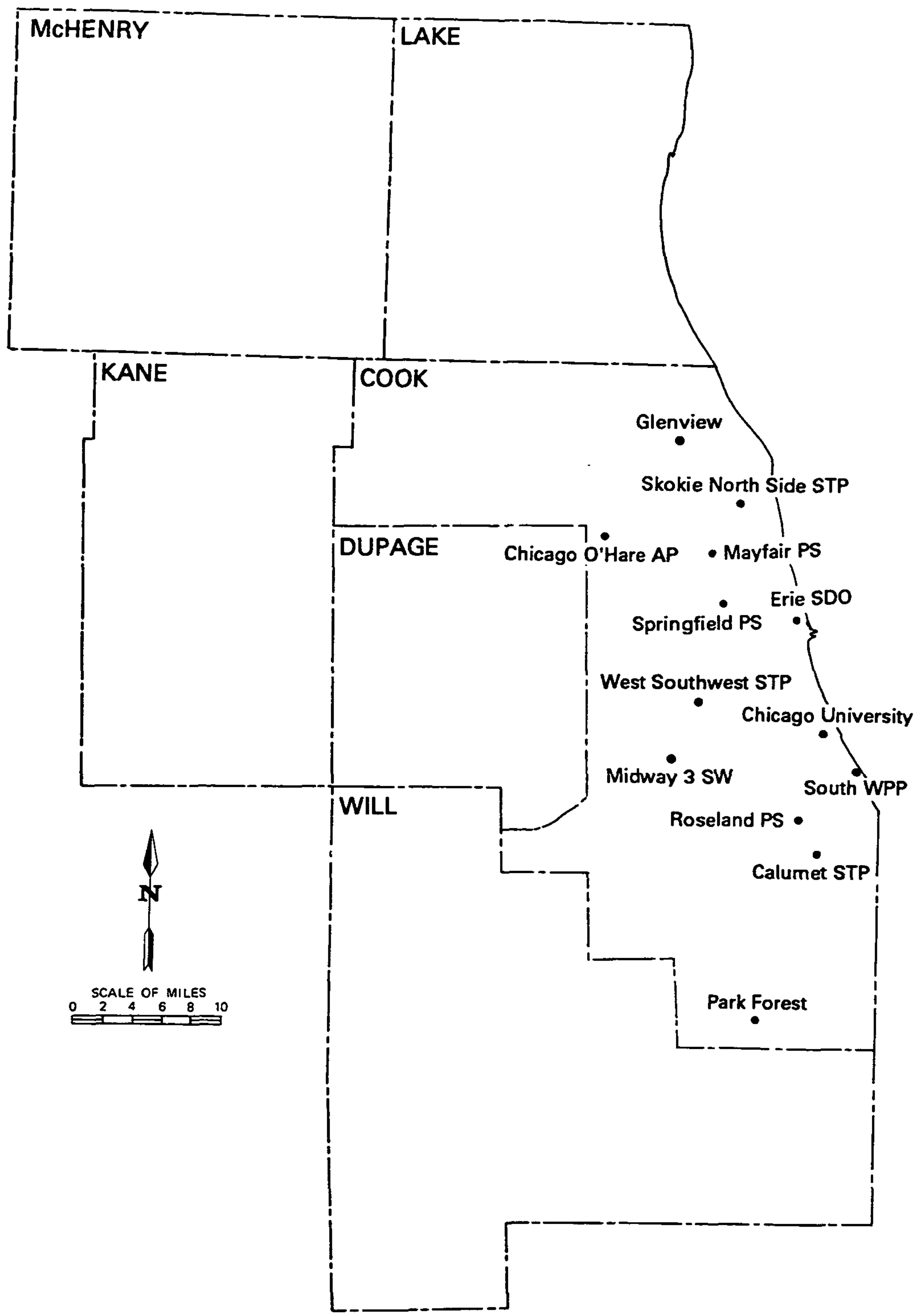


Figure 1. Raingage locations used for diversion accounting purposes prior to Water Year 1990. These include the National Weather Service gages located at Chicago O'Hare AP, Midway 3 SW, Chicago University, and Park Forest; the City of Chicago gages at Mayfair PS, Springfield PS, South WPP, and Roseland PS; and the Metropolitan Water Reclamation District of Greater Chicago gages at Glenview, Skokie North Side STP, Erie SDO, West Southwest STP, and Calumet STP. Abbreviations are as follows: AP = Airport, SW = Southwest, PS = Pumping Station, WPP = Water Purification Plant, STP = Sewage Treatment Plant, and SDO = Sanitary District Office.

data reduction, and quality control practices used by the individual 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 mat 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 1993, the fourth year of the network's operation.

2. NETWORK DESIGN

The SWS has operated dense raingage networks in the past (e.g., Huff, 1970, 1979), which tested gridded raingage spacings 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 mat 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 1990-1992, the first three years of network operation (Peppier 1991b, 1991c, 1993b), 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 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 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, only four sites have been relocated since the network began operating 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. Table 1 lists the property owner and address for each site. Appendix I contains more complete site descriptions for each network location as of September 30, 1993.

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.

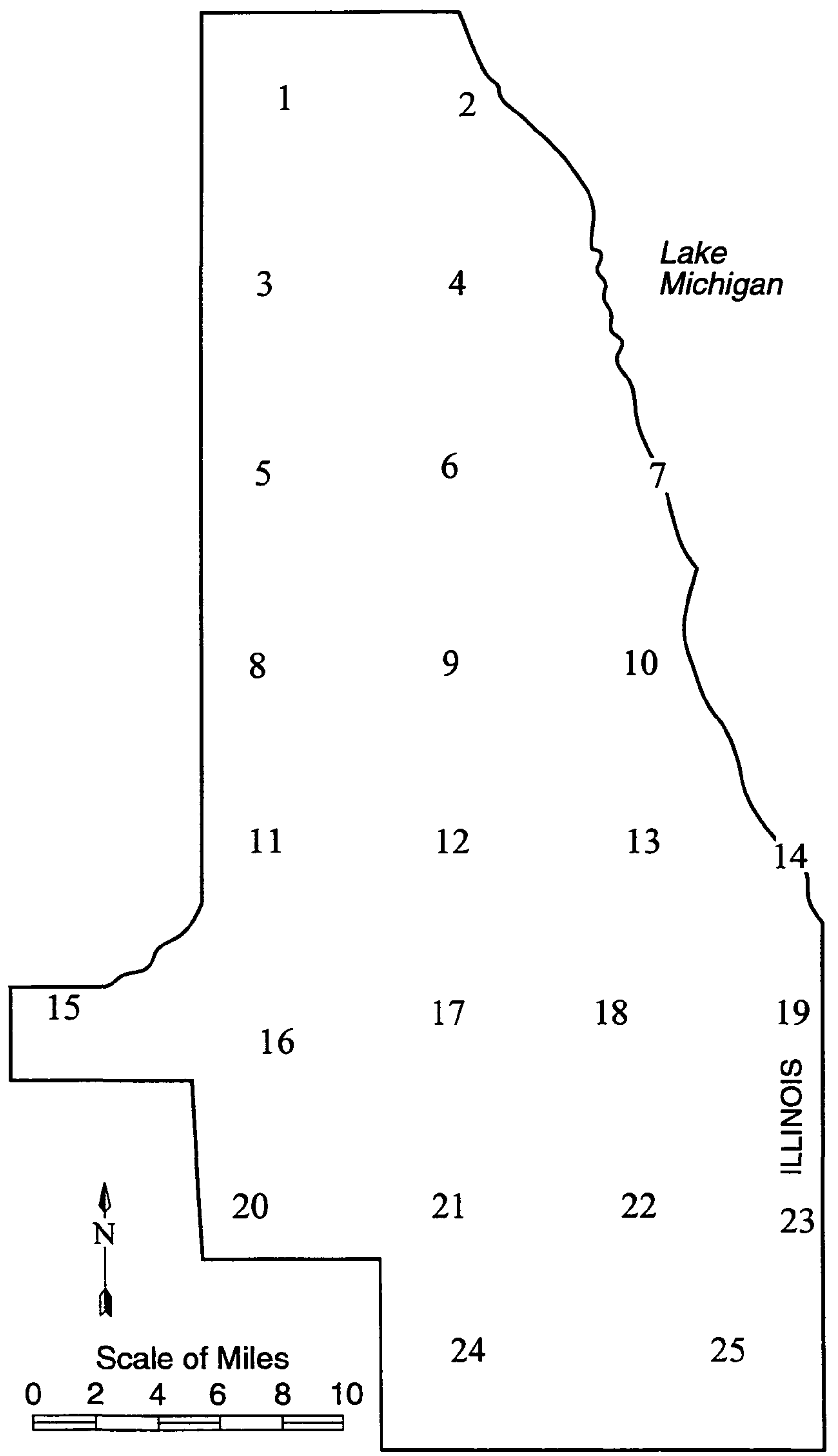


Figure 2. Configuration of the 25-site raingage network used during Water Years 1990-1993.

Table 1. Raingage Network Site Information

Site Number	*Name*	*Address*
1	Mission Brook Sanitary District	P.O. Box 2362 Northbrook, IL 60065
2	Winnetka Park District	510 Green Bay Rd. Winnetka, IL 60093
3	Private Residence	1885 Riverview Dr. Des Plaines, IL 60018
4	Village of Skokie	5127 Oakton St. Skokie, IL 60077
5	Private Residence	2925 N. Sarah Dr. Franklin Park, IL 60131
6	Private Residence	5346 W. Fletcher St. Chicago, IL 60641
7	Broadway United Methodist Church	3344 N. Broadway Chicago, IL 60657
8	Cook County Forest Preserve District	10400 Windsor Dr. Westchester, IL 60154
9	Mary Queen of Heaven Parish	5314 W. 24th Place Cicero, IL 60650
10	Rental Residence	527 W. 26th Street Chicago, IL 60616
11	Private Residence	10180 5th Ave. Cutoff LaGrange, IL 60525
12	C.P. Hall Company	5851 W. 73rd St. Bedford Park, IL 60499
13	Private Residence	7409 S. Eggleston St. Chicago, IL 60621
14	City of Chicago South Water Purification Plant	3300 E. Chiltenham Place Chicago, IL 60649

Table 1. (Concluded)

Site Number	*Name*	*Address*
15	Metropolitan Water Reclamation District	13 Stephen Street Lemont, IL 60439
16	Private Residence	240 Timber Edge Lane Palos Park, IL 60464
17	Sardee Industries	11900 S. Laramie St. Alsip, IL 60658
18	Ingersoll Products Company	1000 W. 120th St. Chicago, IL 60643
19	Graycor Industries	12233 Avenue O Chicago, IL 60603
20	Private Residence	10595 W. 167th St. Orland Park, IL 60462
21	Private Residence	16710 Lockwood Rd. Tinley Park, IL 60477
22	U. S. Army Reserve Center	400 E. 167th Street Harvey, IL 60426
23	City of Lansing Public Works	3300 E. 171st St. Lansing, IL 60438
24	Village of Matteson	3625 W. 215th St. Matteson, IL 60443
25	Big John's Farm Stand	1754 E. Joe Orr Rd. Chicago Heights, IL 60411

3. NETWORK OPERATION AND MAINTENANCE

Each raingage in the network was fitted with 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, 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. Refer to Appendix II for a complete listing 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 two months, or as necessary, the SWS project 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 me 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 gives a complete maintenance history, including site relocations, for each of the 25 raingages, and more fully describes the kinds of maintenance and repairs conducted. This information is current through September 30, 1993.

4. DATA REDUCTION

When a set of charts arrives at the SWS, it 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-/off-time designations, particularly when time zones change in October and March (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 Mhz personal computer. Each chart is processed separately. The four corners 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 me 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 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 me 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) to define storms for Water Years 1984-1993. For each storm, values are summed and plotted on maps using all available data and stations, and isohyetal patterns are drawn. During Water Year 1993, 122 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 me resultant direction and speed at Chicago O'Hare Airport), and known urban effects in the Chicago area (Huff and Vogel, 1976; Changnon, 1980, 1984) are taken into account when drawing isolines and interpolating values. A computer program that uses 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 with questionable values that 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.

5. DATA ANALYSIS AND METHODOLOGIES

Using the final Water Year 1993 data set, various analyses were produced. These include: (1) water year amounts (Figure 3) and comparisons to patterns from network Water Years 1990-1992 (Figure 4), (2) monthly amounts (Figures 5-10) for the network as documentation of the data collected, (3) monthly and water year totals at all sites (Table 2), (4) a special analysis of the drenching June 7-8, 1993, storm (Figure 11), and (5) an analysis of the four-year network precipitation average, 1990-1993 (Figure 12).

Figure 3 and Table 2 contain information on Water Year 1993 amounts. Isopleths in Figure 3 are labeled in inches, while values in Table 2 are to the nearest hundredth of an inch. Precipitation during this water year was exceedingly high, amounting to more than that collected in any of the other network water years (1990-1992). This was a very wet period across the entire Midwest, causing widespread flooding. In Cook County, the largest precipitation amounts occurred in the north-central region centered on Site #6 (refer to Figure 2 and Table 1 for site locations and brief descriptions, and Appendix I for complete site descriptions) and across a broad area of the south-central portion of the network centered on Sites #16, #18, and #23. Precipitation lows were generally located in the far northwestern, central, and extreme southwestern portions of the network, centered on Sites #3, #9, and #20, respectively. The general pattern noted during Water Year 1993 is reminiscent of some of the "urban high" cases noted in research conducted on other Chicago-area precipitation data (see further discussion below). Every site except Sites #1-#4 and #9 measured in excess of 50 inches during Water Year 1993, all well above the 1961-1990 Chicago O'Hare Airport annual precipitation normal of 35.82 inches.

Some areas within the network warrant further mention (see Figure 3). The broad area

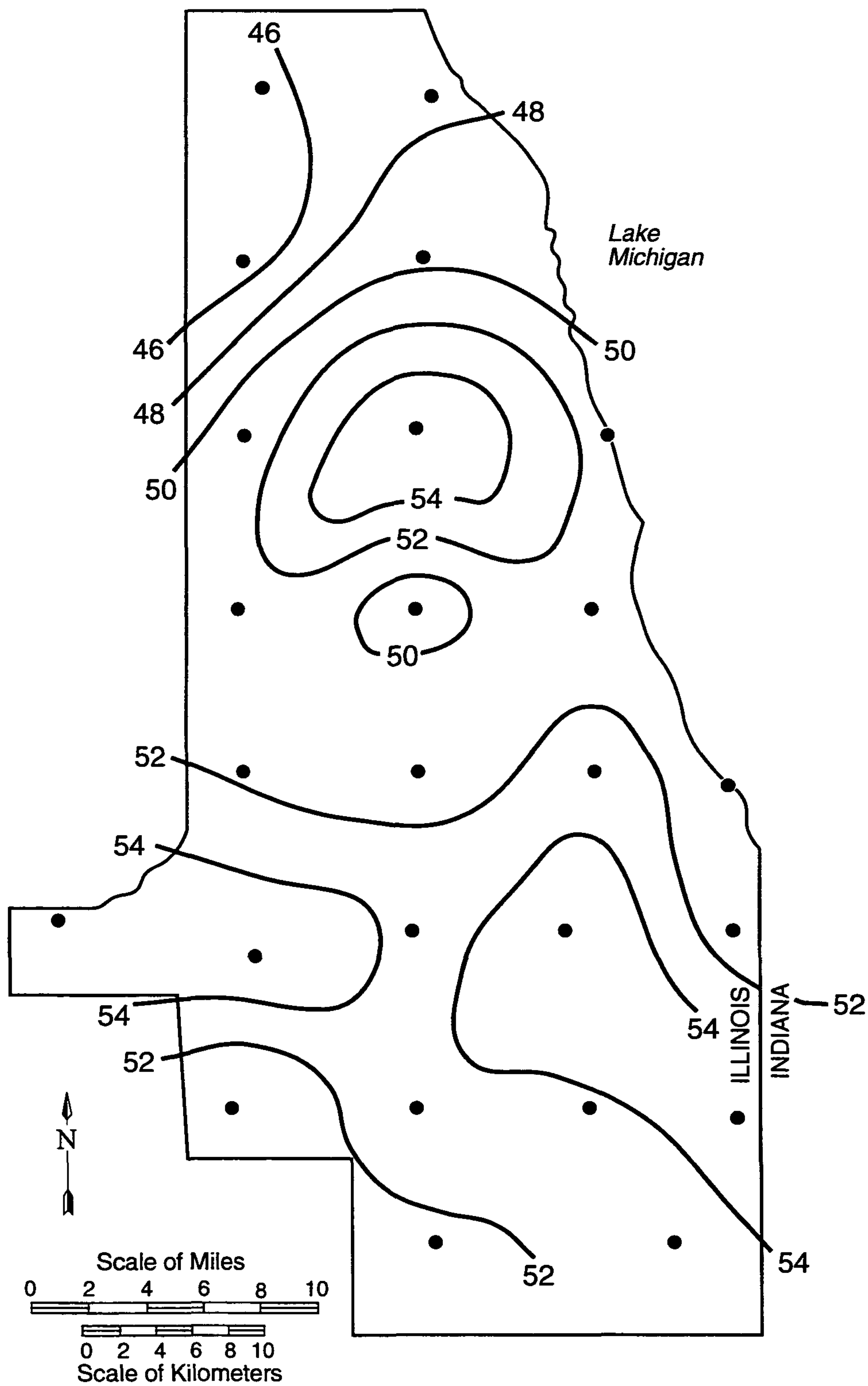


Figure 3. Precipitation pattern (inches) for Water Year 1993. Dots indicate raingage sites.

Table 2. Monthly and Water Year Precipitation Amounts for Water Year 1993 (inches)

	Site Number																								
Date	**1**	**2**	**3**	**4**	**6**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**16**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**26**
Oct-92	1.31	1.66	1.69	2.23	1.79	1.76	1.24	1.01	0.88	0.94	1.05	0.73	0.68	0.66	1.18	0.76	0.77	0.95	0.73	0.80	0.93	0.74	0.79	0.64	1.07
Nov-92	5.59	5.15	5.04	5.23	5.44	5.57	5.30	5.86	5.28	5.37	5.38	4.84	5.29	4.30	6.66	5.38	5.19	4.92	4.53	5.94	5.79	4.90	4.76	5.02	4.40
Dec-92	2.37	2.53	2.77	2.85	3.18	3.17	3.03	3.41	3.10	3.19	3.36	3.26	3.07	2.80	3.47	3.53	3.50	3.37	3.06	3.35	3.68	3.19	3.37	3.08	3.28
Jan-93	3.37	3.63	3.41	3.58	3.92	4.20	3.99	3.86	4.33	3.95	3.80	3.67	3.73	3.68	4.02	4.06	3.74	3.56	4.10	4.29	4.62	4.01	3.98	3.84	3.22
Feb-93	0.92	1.29	1.10	1.21	1.37	1.45	1.21	1.27	1.40	1.51	1.10	0.96	1.39	1.00	0.85	1.06	0.98	1.02	1.02	0.99	1.53	1.27	1.15	1.13	0.96
Mar-93	4.37	5.24	4.20	5.06	4.99	5.31	5.15	4.88	5.02	5.24	4.90	4.71	5.13	4.78	5.33	4.58	4.39	4.79	4.99	3.87	4.78	4.73	4.73	4.61	4.11
Apr-93	4.72	4.57	4.44	4.68	5.25	6.01	4.79	5.42	5.26	5.04	5.33	4.23	4.24	3.21	5.11	4.50	3.65	3.68	3.24	3.50	3.42	3.27	3.21	3.46	3.62
May-93	2.26	2.59	2.39	2.67	2.81	3.23	3.47	3.09	2.90	2.93	2.34	2.42	2.31	1.95	2.40	2.51	2.30	1.93	1.88	2.43	2.49	1.84	2.11	1.80	2.02
Jun-93	7.86	8.40	7.60	9.00	8.56	9.47	8.66	9.51	8.61	7.94	11.67	11.46	11.87	14.61	11.40	14.21	13.64	16.46	12.77	8.47	9.33	11.55	12.85	12.14	12.57
Jul-93	4.49	4.04	3.64	3.71	4.15	3.78	3.74	2.95	2.22	2.86	2.37	3.80	3.62	2.61	2.15	2.63	2.73	2.23	2.55	2.81	3.01	2.97	3.60	3.72	3.44
Aug-93	4.61	5.16	4.53	5.24	5.68	6.36	6.26	5.98	5.77	6.66	5.14	5.29	5.58	6.83	6.59	6.63	6.41	6.70	6.95	7.68	8.18	9.64	8.77	7.31	7.41
Sep-93	3.86	3.67	4.45	4.06	4.51	4.84	4.73	4.56	4.94	5.70	5.54	6.17	5.49	4.50	6.01	5.84	5.99	6.27	5.03	6.40	5.43	5.70	5.80	5.13	6.55
WY 1993	45.73	47.93	45.26	49.52	51.65	55.15	51.57	51.80	49.71	51.33	51.98	51.54	52.40	50.93	55.17	55.69	53.29	55.88	50.85	50.53	53.19	53.81	55.12	51.88	52.65

of precipitation values exceeding 51 inches in the north-central part of the network, centered on Site #6, and the large area of high values in the southern part of the network (most in excess of 52 inches) both coincide with the highs, "urban" and otherwise, noted in historical 1949-1974 data (e.g., "north-central high" from Huff and Vogel, 1976) and by data from other water years in the 1980s and 1990s, including data collected by this network (e.g., Peppier, 1991a, 1991b, 1991c). The possible stabilizing effect exerted by Lake Michigan on convective rainfall (e.g., Huff and Vogel, 1976), which can result in lower values near the lakeshore, was not particularly evident during this water year. The northern minimum that appears in Water Year 1993 also appears in other network water years (e.g., Peppier 1993b). Like the other three network water year patterns, the spatial pattern for Water Year 1993 is in great contrast to the unusual anomalies associated with the precipitation amounts from the NWS, MWRDGC, and CC raingages used to generate precipitation information for Water Years 1984-1989 (see Peppier 1993b for those patterns). Analyses for the other network water years, 1990-1992, are contained in Figure 4.

During Water Year 1993, amounts ranged from 45.26 inches at Site #3 in the northeast to 55.88 inches in the east-southeast (Table 2). Amounts during other water years were much lower, as mentioned previously. During Water Year 1990, totals ranged from 36.24 inches at Site #4 in the extreme northeast to 45.89 inches at Site #13 in the east. In Water Year 1991, the amounts ranged from 33.79 inches at Site #1 in the extreme northwest to 47.54 inches at Site #24 in the extreme southwest, and during Water Year 1992 totals ranged from 33.63 inches at Site #8 in the west to 40.00 inches at Site #10 just south of the Loop.

Figures 5-10 contain monthly analyses for Water Year 1993 (see also Table 2). Heavier precipitation occurred during November, June, August, and September, with June clearly being

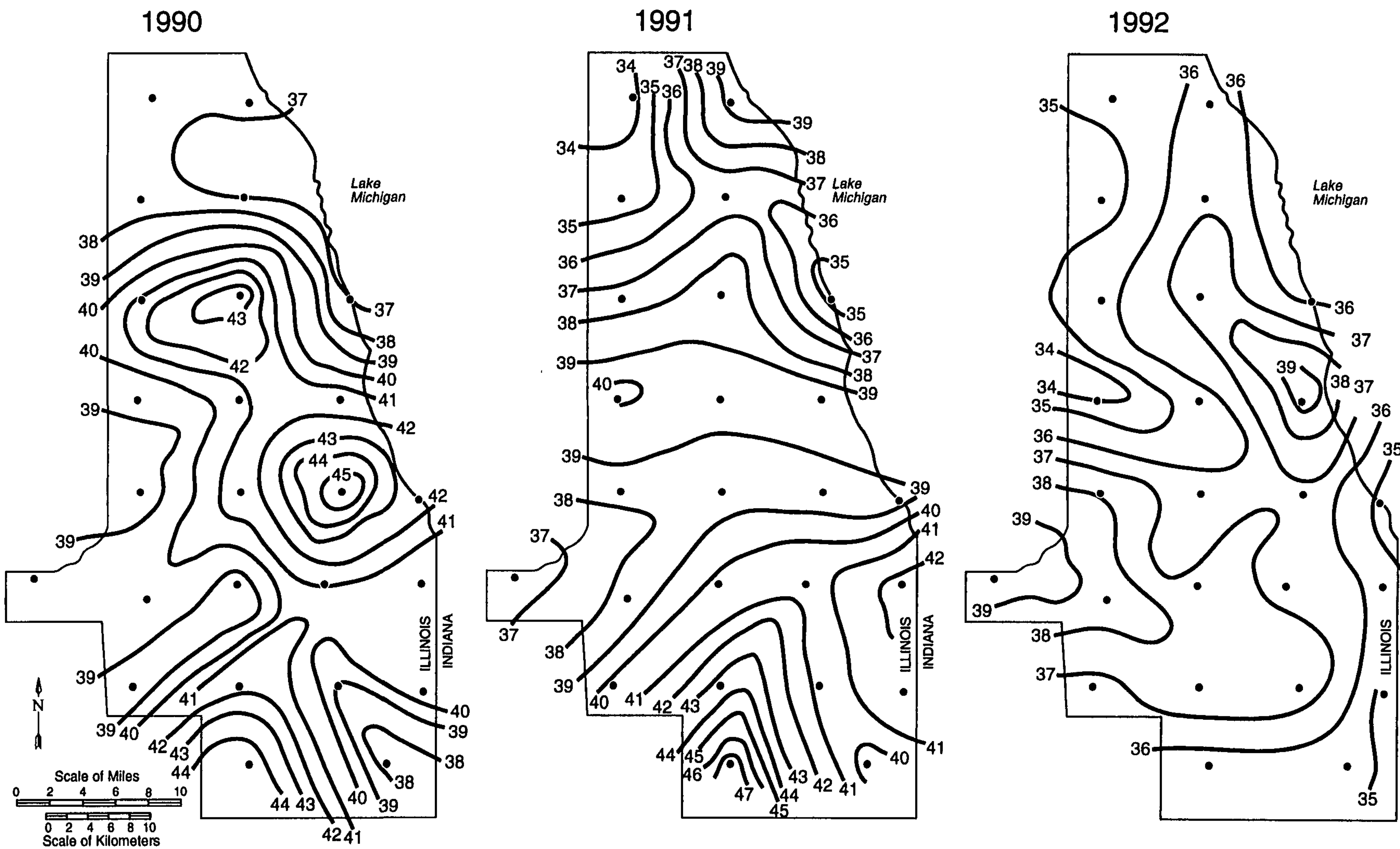


Figure 4. Precipitation patterns (inches) for Water Years 1990, 1991, and 1992 from network raingages.

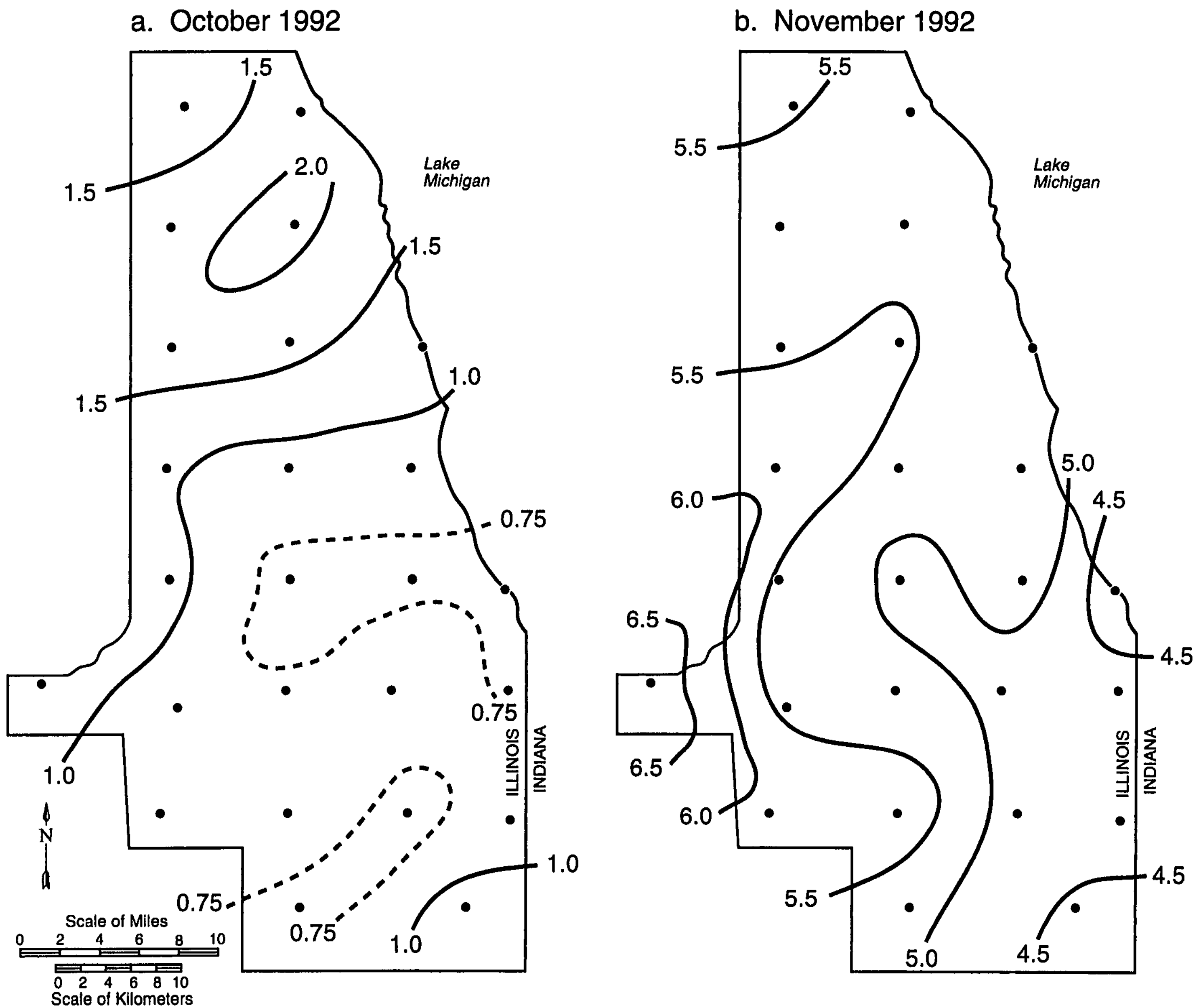


Figure 5. Precipitation pattern (inches) for October 1992 (Panel a) and November 1992 (Panel b). Dots indicate raingage sites.

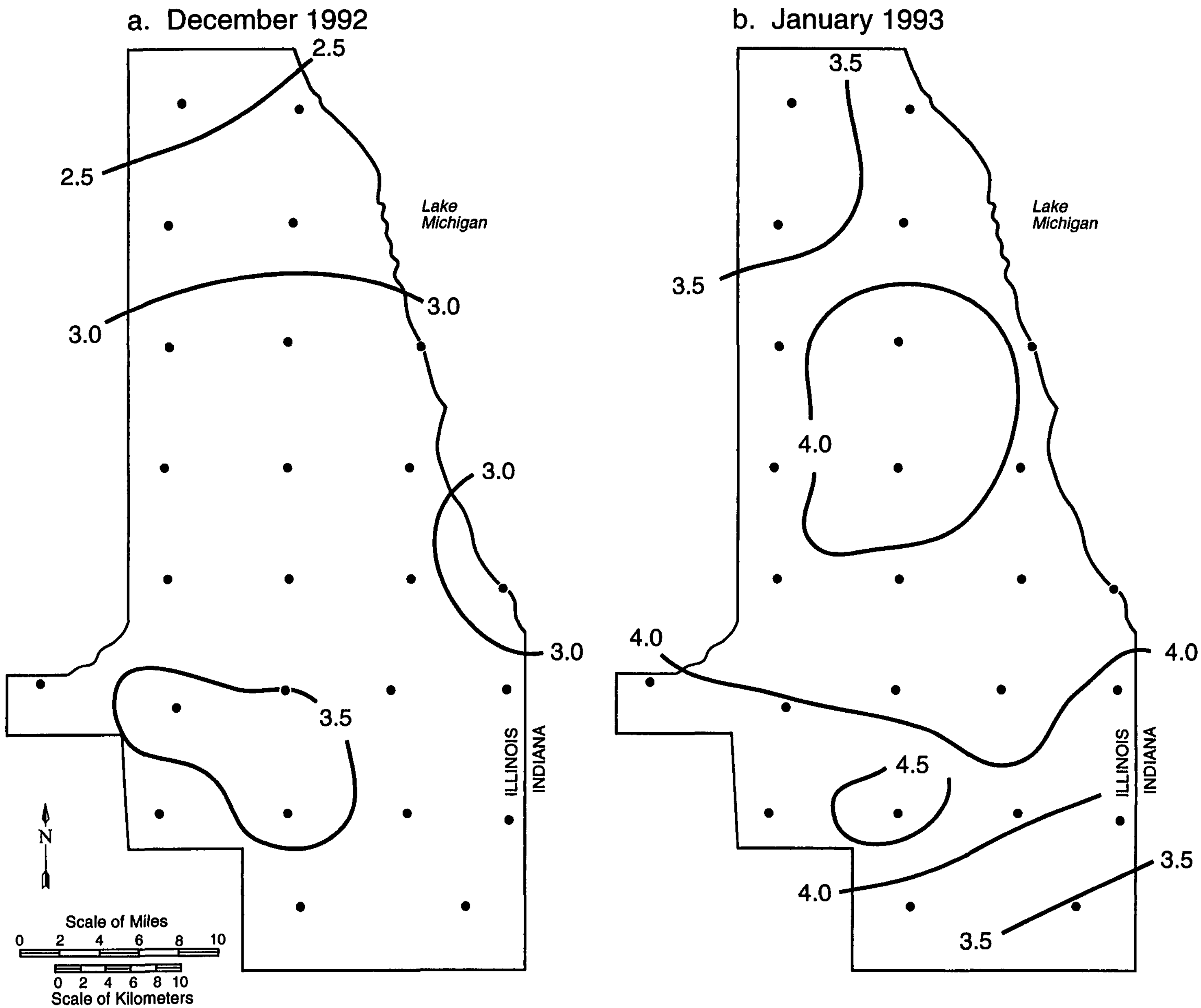


Figure 6. Precipitation pattern (inches) for December 1992 (Panel a) and January 1993 (Panel b). Dots indicate raingage sites.

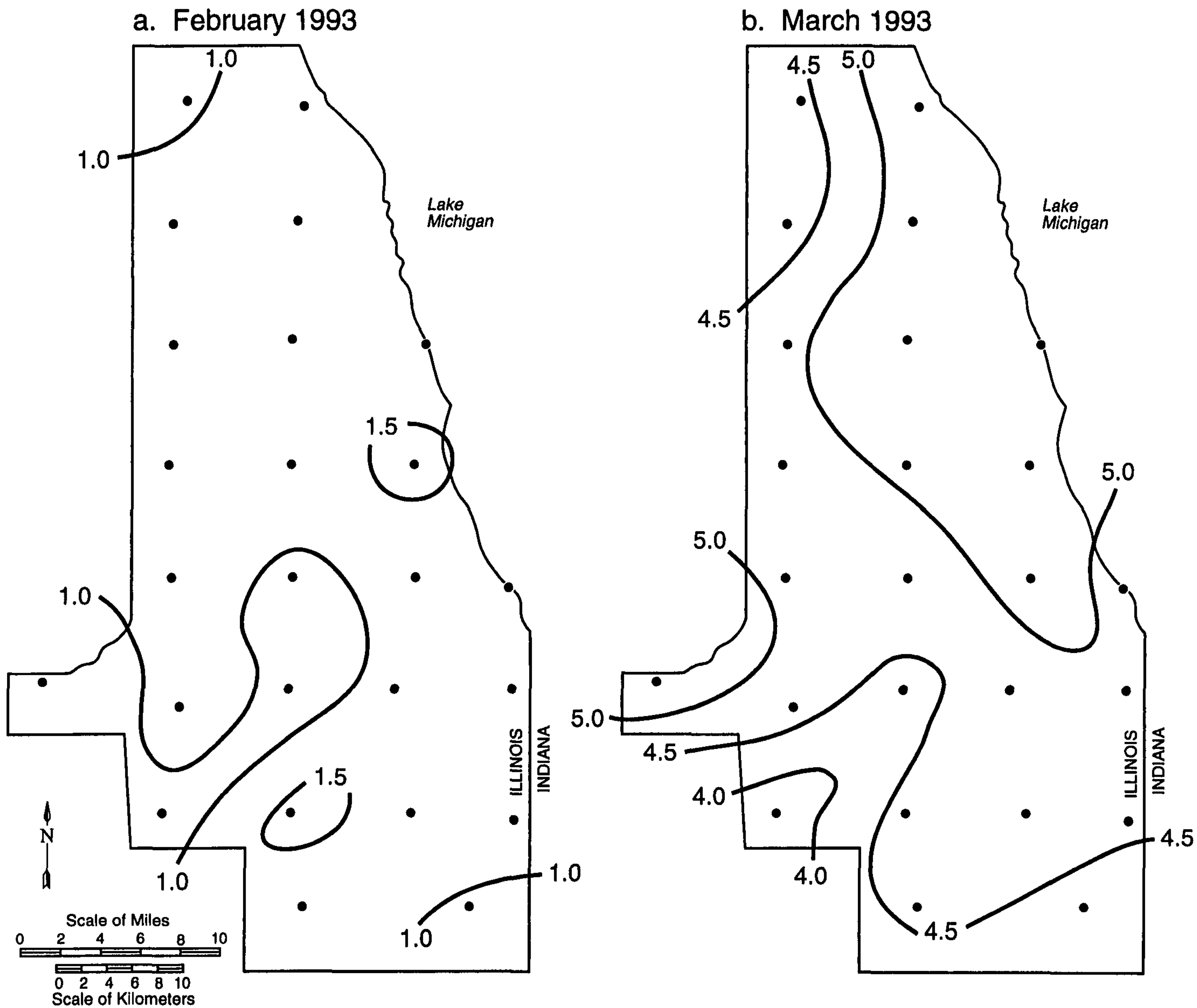


Figure 7. Precipitation pattern (inches) for February 1993 (Panel a) and March 1993 (Panel b). Dots indicate raingage sites.

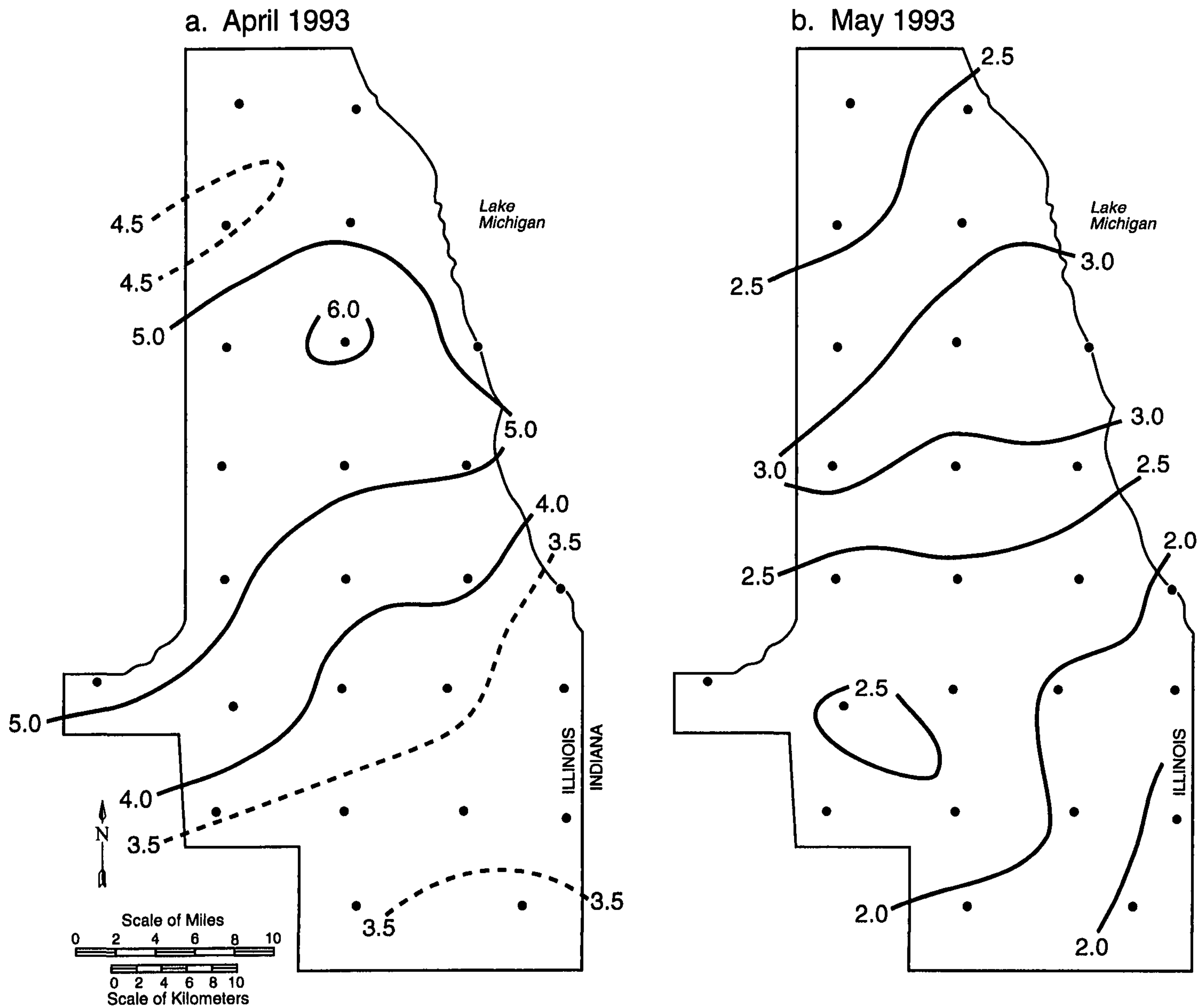


Figure 8. Precipitation pattern (inches) for April 1993 (Panel a) and May 1993 (Panel b). Dots indicate raingage sites.

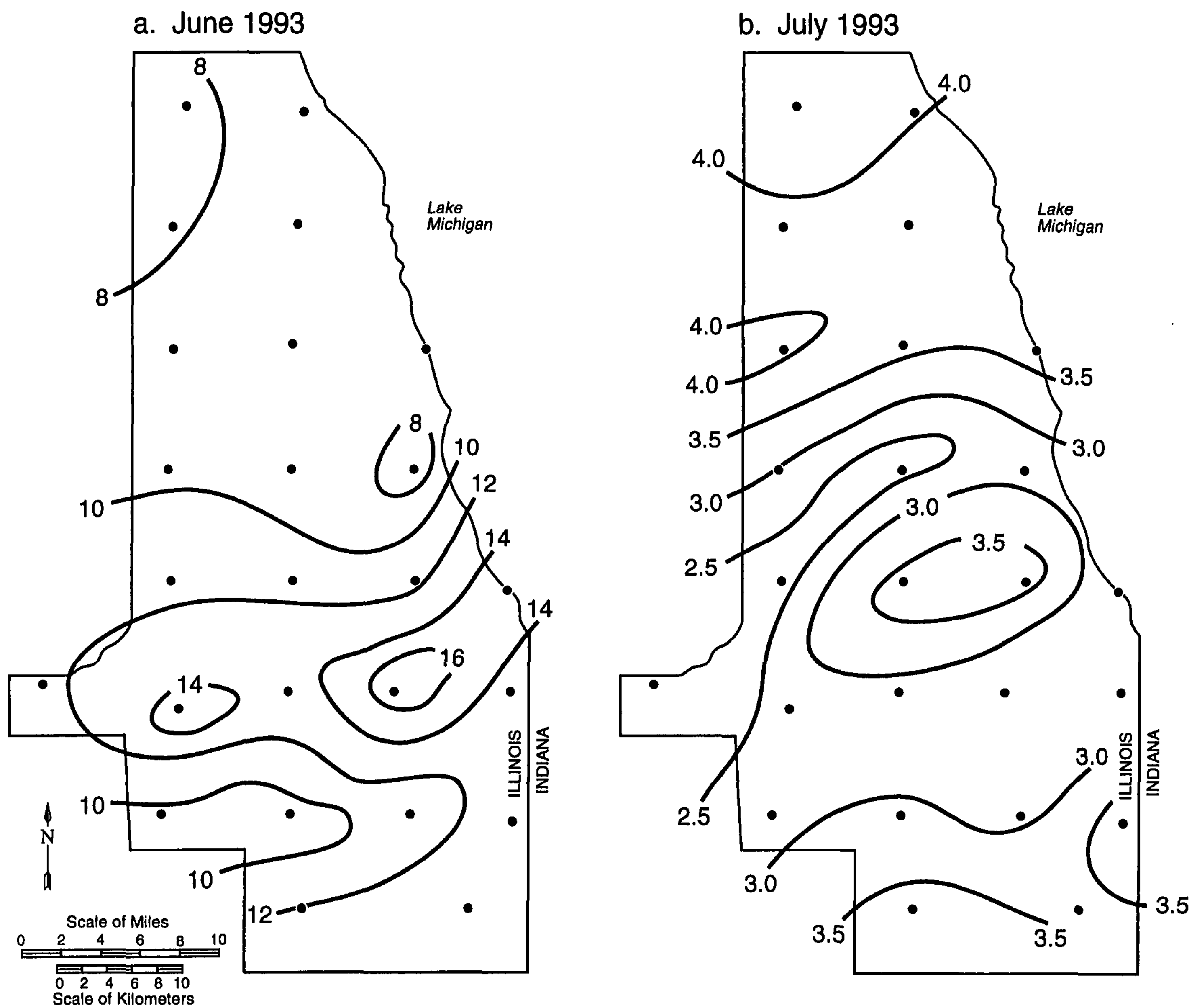


Figure 9. Precipitation pattern (inches) for June 1993 (Panel a) and July 1993 (Panel b). Dots indicate raingage sites.

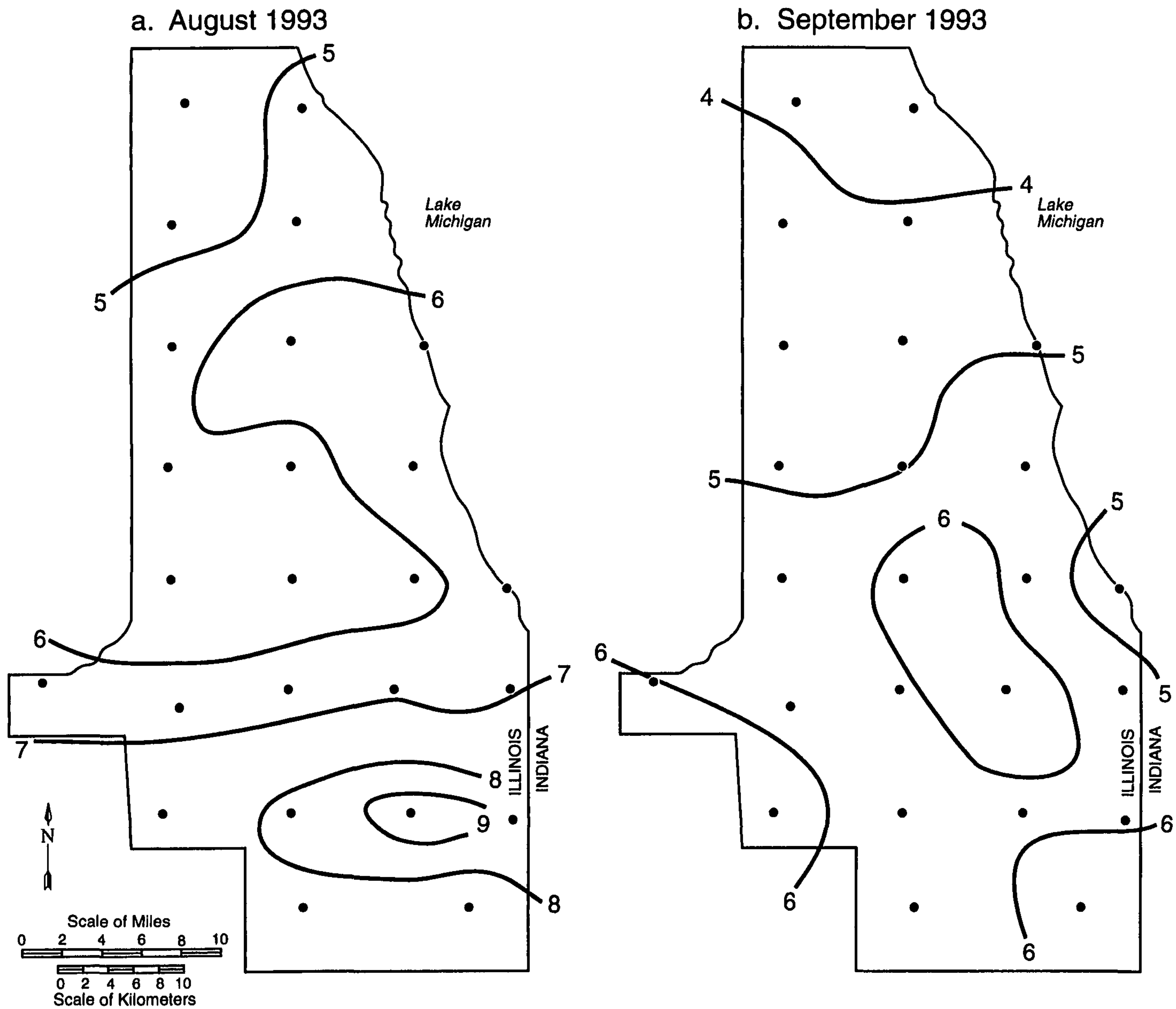
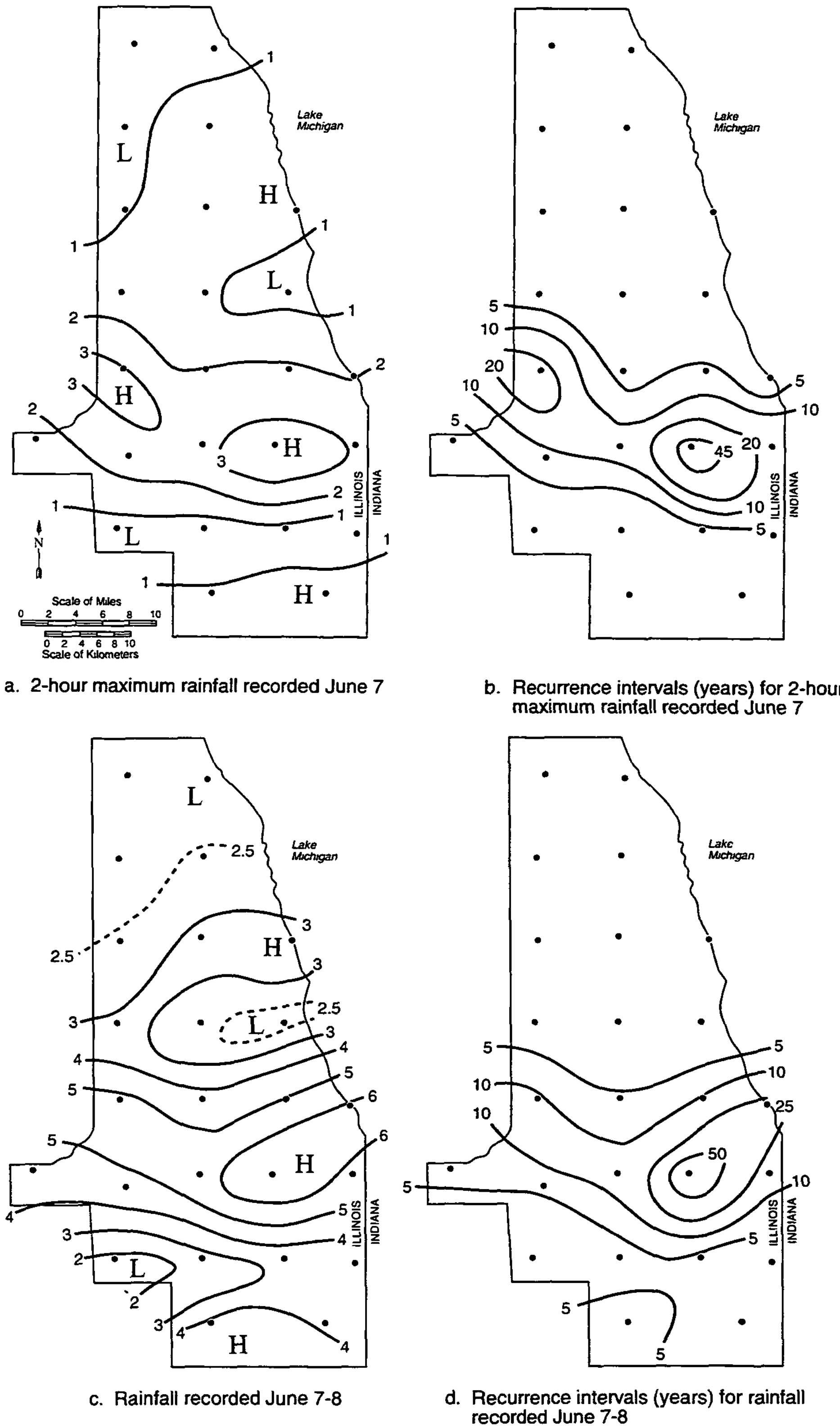


Figure 10. Precipitation pattern (inches) for August 1993 (Panel a) and September 1993 (Panel b). Dots indicate raingage sites.

the wettest month, while lighter precipitation generally occurred during October, February, and May, with October and February being the driest months.

June values (Figure 9, Table 2) ranged from a whopping 16.46 inches at Site #18 in the east-southeast (the water year monthly high) *to just* 7.60 inches at Site #3 in the northwest. All but two sites located south of Sites #8-#10 received in excess of 11 inches of rain during the month. June precipitation was highlighted by a series of thunderstorms that occurred from the 7th through the 8th, causing widespread flash flooding in the southern half of Cook County. The June 7-8 period is documented in Figure 11, and was Storm 76 during the water year. Between 3.2 and 3.5 inches of rain fell during a two-hour maximum storm-burst late in the morning on June 7 at Site #11 in the west and at Site #18, while nearly 3 inches fell during this period at Site #19 in the east-southeast, and more than 2 inches fell at Sites #12, #13, #14, #16, and #17. The amounts recorded at Sites #11 and #18 during that short period have a recurrence interval of between 23 and 45 years (i.e., amounts of that magnitude during a two-hour period should happen only once every 23 to 45 years) based on long-term climatological statistics for northeastern Illinois (Huff and Angel, 1989). During about a 36-hour period on June 7-8, more than 6 inches of rain fell at Sites #14 and #18, while more than 5 inches were recorded at Sites #11, #13, #17, and #19. The 6.86-inch amount recorded at Site #18 during a 38-hour period has a recurrence interval of just over 50 years. The June 1993 network-wide average was 10.82 inches, 8.35 inches above the 1990-1992 network average of 2.47 inches.

A look at the driest cases, October (Figure 5, Table 2) and February (Figure 7, Table 2), indicates that amounts in October ranged from just 0.64 inches at Site #24 in the southwest, the water year low, to 2.23 inches at Site #4 in the north, and in February ranged from 0.85 inches at Site #15 in the west-southwest to 1.51 inches at Site #20 in the southwest. October



a. 2-hour maximum rainfall recorded June 7

b. Recurrence intervals (years) for 2-hour maximum rainfall recorded June 7

c. Rainfall recorded June 7-8

d. Recurrence intervals (years) for rainfall recorded June 7-8

Figure 11. Analysis of the June 7-8, 1993 storm (network storm #76).

had been the wettest month in Water Year 1992.

Of the 122 storms identified during Water Year 1993, 11 produced amounts that surpassed an annual event (one-year recurrence interval) for the given storm duration, considering storm durations of one hour to ten days in northeastern Illinois (values from Huff and Angel, 1989). These included Storms 6 (October-November 1992); 76, 78, 79, 80, and 85 (June 1993); 98 (July 1993); 108, 110, and 111 (August 1993); and 116 (September 1993). Storm 76 in June, as previously documented, was by far the most potent of all, with amounts at five sites exceeding a ten-year event and amounts at ten sites exceeding a five-year event. Other storms/recurrence intervals of significance included Storm 108 in August, during which amounts at two sites exceeded a ten-year event, and Storm 110 in August, when amounts at one site exceeded a five-year event. Appendix IV contains specific information about all network-defined storms that exceeded an annual event, considering storm periods of one hour to ten days, with special notation given to storms that exceeded a two-year event.

Finally, a four-year composite (1990-1993) average analysis (Figure 12) generally shows lower values in the north and higher values in the south. Lows exist in me northwest, west, along the lakeshore, and in the southwest and extreme southeast, while highs emanate in the extreme south and west-southwest and push northward to the north-central portion of the grid at Site #6. The four-year network average is 41.88 inches.

6. SUMMARY

The Cook County raingage network has now collected precipitation data for Water Years 1990-1993, and appears to be doing so accurately. The exposure and areal coverage of me network are superior to those of previously-used sites administered by the NWS, CC, and

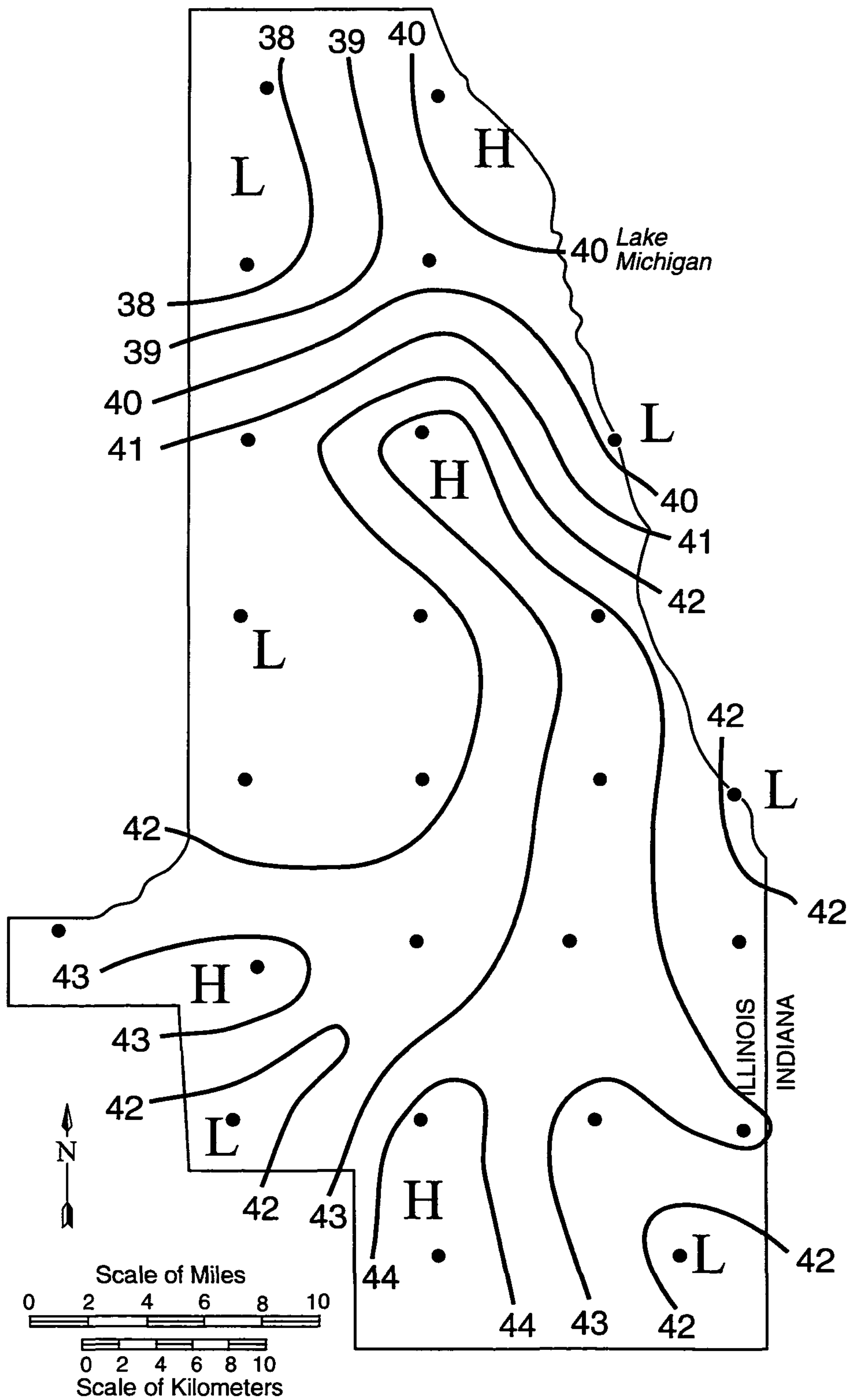


Figure 12. Four-year average precipitation pattern (inches) from Water Years 1990-1993.

MWRDGC. The present data are greatly enhancing the ability of the U.S. Army Corps of Engineers, Chicago District, to accurately assess 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 is also providing high quality data for research on the precipitation variability of the Cook County region. Network operations are now routine enough to make available final hourly, daily, and monthly precipitation totals within two to three weeks of the end of a calendar month.

7. ACKNOWLEDGMENTS

This work was contracted by the U.S. Army Corps of Engineers, Chicago District, under Grant DACW 23-92-C-0019. David Moughton, U.S. Army Corps of Engineers, Chicago District, administers the project, and also helped edit a draft version of this report. Doug Ward established the digitizing system, including software; Marv Clevenger and Roma Johnson handle all data digitizing tasks; David Cox drafted the figures for this report; and Sarah Hibbeler copy edited this report. David and Dorothy Rosenberg are the network's Cook County observers who perform weekly raingage servicing across the network.

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APPENDIX I: RAINGAGE SITE DESCRIPTIONS

Contained in this appendix are descriptions of the 25 raingage network sites representing the current siting in the Cook County, Illinois, region as of publication. 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	Range: 12E
Section: 20	Lat/Long: 42°06'39" / 87°52'06"	Quadrangle: Park Ridge
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	Range: 13E
Section: 19	Lat/Long: 42°06'29" / 87°45'06"	Quadrangle: Park Ridge
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	Range: 12E
Section: 28	Lat/Long: 42°01'21" / 87°52'39"	Quadrangle: Arlington Heights
Property Owner: Private Residence		
Address: 1885 Riverview Drive. 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 corner 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	Range: 13 E
Section: 21	Lat/Long: 42°01'37 / 87°45'20"	Quadrangle: Park Ridge
Property Owner: Village of Skokie. Attn: Eddy Nakai		
Address: 5127 Oakton 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 7415
Placement: Grassy strip between mailbox and Village payment box on east side of Floral Street near parking lot, established late 3-94 (move made by Village personnel). A previous move from the original location, which was also in a grassy strip but 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 position is 15 feet to the 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	Range: 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/Long: 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 south-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 fence.		

SITE DESCRIPTION		
Site Number: 7		
County: Cook	Township: 40N	Range: 14E
Section: 21	Lat/Long: 41°56'33" / 87°38'43"	Quadrangle: Chicago Loop
Property Owner: Broadway United Methodist Church. Attn: Pastor Fred Morris		
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 7293
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/Long: 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 7392
Placement: Southeast corner 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	Range: 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 corner 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	Range: 14E
Section: 28	Lat/Long: 41°50'42" / 87°38'27"	Quadrangle: Englewood
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 edge 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		

<table>
<tr><th colspan="3">SITE DESCRIPTION</th></tr>
<tr><td colspan="3">Site Number: 11</td></tr>
<tr><td>County: Cook</td><td>Township: 38N</td><td>Range: 12E</td></tr>
<tr><td>Section: 28</td><td>Lat/Long: 41°45'29" / 87°52'20"</td><td>Quadrangle: Berwyn</td></tr>
<tr><td colspan="3">Property Owner: Private Residence</td></tr>
<tr><td colspan="3">Address: 10180 5th Avenue Cutoff, LaGrange, Illinois 60525</td></tr>
<tr><td colspan="3">Telephone: 708/354-3161</td></tr>
<tr><td colspan="3">Permission Date: September 13. 1989</td></tr>
<tr><td colspan="3">Installation Date: September 29. 1989</td></tr>
<tr><td>Gage Mfrs. No.: 3348</td><td>Gage ID No.: 4452</td><td>Clock Mfrs. No.: E 7344</td></tr>
<tr><td colspan="3">Placement: 6 feet east of clothesline pole in center of backyard near edge of a large garden. Access from Willow Springs Road, south of Joliet Road (parcel of land is between Interstate-55 and Tri-State Tollway).</td></tr>
</table>

<table>
<tr><th colspan="3">SITE DESCRIPTION</th></tr>
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<tr><td>County: Cook</td><td>Township: 38N</td><td>Range: 13E</td></tr>
<tr><td>Section: 28</td><td>Lat/Long: 41°45'32" / 87°46'06"</td><td>Quadrangle: Berwyn</td></tr>
<tr><td colspan="3">Property Owner: C.P. Hall Company. Attn: Mark Kuklinski</td></tr>
<tr><td colspan="3">Address: 5851 West 73rd Street, P.O. Box 910, Bedford Park, Illinois 60499-0910</td></tr>
<tr><td colspan="3">Telephone: 708/594-5065</td></tr>
<tr><td colspan="3">Permission Date: November 24. 1992</td></tr>
<tr><td colspan="3">Installation Date: November 24, 1992</td></tr>
<tr><td>Gage Mfrs. No.: 4661</td><td>Gage ID No.: 5111</td><td>Clock Mfrs. No.: E 7413</td></tr>
<tr><td colspan="3">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 present location.</td></tr>
</table>

SITE DESCRIPTION		
Site Number: 13		
County: Cook	Township: 38N	Range: 14E
Section: 28	Lat/Long: 41°45'34" / 87°38'07"	Quadrangle: Englewood
Property Owner: Private Residence		
Address: 7409 South Eggleston Street, Chicago, Illinois 60621		
Telephone: 312/224-3807		
Permission Date: September 13. 1989		
Installation Date: September 29. 1989		
Gage Mfrs. No.: 4687	Gage ID No.: 5058	Clock Mfrs. No.: E 7353
Placement: Northwest of concrete patio. 3 feet from 8-foot high chain-link fence. About the only secure location in the vicinity. Entry is through a locked garage gate (observer has key). Otherwise, ring upper bell at front door. Was placed east of barbecue pit, 4 feet from fence and 7 feet southeast of present location (9-29-89 through 8-23-90), and 10 feet west of that position (8-23-90 through 4-15-92). Enter South Eggleston Street from 74th Street.		

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 Chicago - South Water Purification Plant. Attn: Robert Sambol		
Address: 3300 East Chiltenham Place, Chicago, Illinois 60649		
Telephone: 312/933-7107		
Permission Date: September 12. 1989		
Installation Date: September 28. 1989		
Gage Mfrs. No.: 3370	Gage ID No.: 4453	Clock Mfrs. No.: W00537
Placement: Center of large grassy 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: HE
Section: 20	Lat/Long: 41°40'37" / 87°59'52"	Quadrangle: Sag Bridge
Property Owner: Metropolitan Water Reclamation District of Greater Chicago. Attn: Jim Ivers		
Address: 13 Stephen Street. Lemont. Illinois 60439		
Telephone: 708/257-7371		
Permission Date: September 11. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 3373	Gage ID No.: 4421	Clock Mfrs. No.: E 7292
Placement: About 100 feet east of entrance road, and several hundred feet south of MWRDGC building. Just north of Illinois and Michigan Canal. Access from Stephen Street in downtown Lemont. Exit Interstate-55 south on Lemont Road and then downtown, or enter from east on McCarthy Road. Hours are 0700-1530 local time.		

SITE DESCRIPTION		
Site Number: 16		
County: Cook	Township: 37N	Range: 12E
Section: 28	Lat/Long: 41°39'46" / 87°52'13"	Quadrangle: 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 edge 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	Range: 13E
Section: 28	Lat/Long: 41°40'32" / 87°45'00"	Quadrangle: Palos Park
Property Owner: Sardee Industries. Attn: Andy Chakonas		
Address: 11900 South Laramie Street, Alsip, Illinois 60658		
Telephone: 708/597-7330		
Permission Date: September 11. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 4719	Gage ID No.: 5415	Clock Mfrs. No.: E 7370
Placement: About 50 feet west of last loading dock in grassy field northwest of factory. Enter Laramie Street from 122nd Street, west of Cicero Avenue. Northeast of Tri-State Tollway, just south of Restvale Cemetery.		

SITE DESCRIPTION		
Site Number: 18		
County: Cook	Township: 37N	Range: 14E
Section: 29	Lat/Long: 41°40'36" / 87°39'07"	Quadrangle: Blue Island
Property Owner: Ingersoll 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: Southwest end of property just southwest of a truck scale and east of property fence. Must enter at guarded gate on 119th Street.		

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: Grassy area just north of a shop building and just 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	Range: 12E
Section: 29	Lat/Long: 41°35'09" / 87°52'35"	Quadrangle: Mokena
Property Owner: Private Residence		
Address: 10595 West 167th Street, Orland 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.: W00536
Placement: About 30 feet east of welding 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	Range: 13E
Section: 28	Lat/Long: 41°35'15" / 87°44'52"	Quadrangle: Harvey
Property Owner: Private Residence		
Address: 16710 Lockwood Road, Tinley Park, Illinois 60477		
Telephone: 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 6695
Placement: North end of backyard west of (behind) garage. Enter Lockwood Road south off of 167th Street.		

SITE DESCRIPTION		
Site Number: 22		
County: Cook	Township: 36N	Range: 14E
Section: 21	Lat/Long: 41°35'll" / 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 parking lot and reserve building, 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: 6 feet from east fence in northeast corner of storage yard of Public Works complex. 75 feet east of a new recycling building. Enter north gate east off of 170th Street. Closes at 1530 local time.		

SITE DESCRIPTION		
Site Number: 24		
County: Cook	Township: 35N	Range: 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.: W00533
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, and large trees near house. Just east of Interstate-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 me sliding door on me 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 me drum cylinder to disengage it from the electric chart drive, and remove it from the instrument case. Write the OFF date and time on me chart. Carefully remove me chart from the drum to avoid smearing me fresh ink at the end of me trace.

3) Write mis OFF time as me ON time on a new chart, and apply it to me drum cylinder, making sure the crease at the right end of me chart is sharp and me 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 me 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 me 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. Rezero the pen point if necessary by turning the fine adjustment screw. It isn't 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 me 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 me 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 me sites as permanent as possible during the course of mis 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 me project director.

APPENDIX III: DOCUMENTATION OF RAINGAGE MAINTENANCE

This appendix gives documentation of the maintenance work carried out by Champaign-based Illinois State Water Survey staff at each network site during Water Year 1993, including visits when no action was taken. Any unusual gage activity performed by non-Water Survey staff is also 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 runs through November 4, 1993, when calibration checks were completed. Calibration checks and gage cleaning activities were also conducted on October 21 and 28, 1993, and are not listed here unless some other servicing was required at a particular site. A Global Positioning System (GPS) transceiver and laptop computer were used on July 12, 1993, and during the three calibration visits to refine the latitude/longitude calculations of each raingage site. The felt-tipped pens used beginning in Water Year 1992 were found to work extremely well, so their use will continue. Sites with no entries listed did not require servicing other than during the calibration visit.

SITE #1: MISSION BROOK SANITARY DISTRICT

7-6-93: Releveled gage, sprayed for ants, and reseated outer case.

10-21-93: Moved the gage about 2 feet north during calibration visit to give it firmer footing.

SITE #2: WINNETKA PARK DISTRICT

5-17-93: Releveled and fortified gage in an attempt to alleviate a shaky pen trace.

10-21-93: Replaced pen point during calibration visit.

SITE #3: DES PLAINES

10-7-92: Replaced chart drive.

2-24-93: Replaced chart drive.

7-6-93: Fixed gage door and releveled, replaced pen point.

10-21-93: Replaced pen point during calibration visit.

SITE #4: VILLAGE OF SKOKIE

12-92: Village of Skokie personnel moved gage to east side of Floral Street in a grassy strip near another parking lot.

5-17-93: Releveled gage.

7-6-93: Replaced chart drive, reseated collector.

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

SITE #5: FRANKLIN PARK

7-6-93: Met new property owner.

10-21-93: Releveled gage and replaced bucket during calibration visit.

SITE #6: WEST FLETCHER STREET

7-6-93: Removed gage from original 1989 location at the owner's request. A new location was found two homes to the west, but installation was not possible on 7-6-93.

7-12-93: Reinstalled gage at new location and checked calibration.

10-21-93: Replaced pen point during calibration visit.

SITE #7: BROADWAY UNITED METHODIST CHURCH

10-21-93: Releveled gage during calibration visit.

SITE #8: COOK COUNTY FOREST PRESERVE DISTRICT - WESTCHESTER

10-28-93: Releveled gage during calibration visit.

SITE #9: MARY QUEEN OF HEAVEN PARISH - CICERO

5-17-93: Releveled gage, trimmed a nearby bush.

7-6-93: Replaced chart drive and moved gage about 7 feet north to escape previously trimmed but growing bush.

10-28-93: Replaced chart drive during calibration visit. Gage had been vandalized.

SITE #10: WEST 26th STREET

SITE #11: LA GRANGE

10-7-92: Replaced chart drive batteries.

SITE #12: C. P. HALL COMPANY - BEDFORD PARK

11-24-92: Moved gage from previous Reckitt and Coleman position to C. P. Hall Company, still on 73rd Street, but about 0.9 mile west. New position in a grassy area on the north side of the building complex just south of 73rd Street.

5-17-93: Moved gage about 400-500 feet southwest of 11-24-92 position to a new location on C. P. Hall property. Current location is along the service drive and gives a better exposure. Checked calibration.

7-6-93: Chart drive operating properly, no action taken.

10-28-93: Releveled gage during calibration visit.

SITE #13: SOUTH EGGLESTON STREET

SITE #14: SOUTH WATER PURIFICATION PLANT

10-21-93: Releveled gage during calibration visit.

SITE #15: MWRDGC - LEMONT

10-7-92: Chart drive operating properly, no action taken.

11-24-92: Replaced chart drive and releveled gage.

5-17-93: Replaced red fine adjustment screw.

10-28-93: Releveled gage, and replaced chart drive batteries and pen point during calibration visit.

SITE #16: PALOS PARK

10-7-92: Replaced chart drive.

11-24-92: Replaced chart drive and releveled gage.

2-24-93: Replaced chart drive.

5-17-93: Replaced chart drive, releveled gage, and changed calibration.

7-6-93: Chart drive operating properly, no action taken.

SITE #17: SARDEE INDUSTRIES - ALSIP

11-24-92: Replaced chart drive and releveled gage.

7-6-93: Releveled gage.

11-4-93: Replaced chart drive during calibration visit.

SITE #18: INGERSOLL PRODUCTS - WEST 120th STREET

10-7-92: Downward-adjusted high pen arm reversal.

11-4-93: Replaced chart drive during calibration visit.

SITE #19: GRAYCOR INDUSTRIES - AVENUE O

10-7-92: Adjusted pen arm orientation to alleviate a light pen trace.

11-24-92: Reinstalled gage about 50 feet west of original position after Graycor personnel had temporarily removed it a week earlier to facilitate construction work. Rechecked calibration.

11-4-93: Replaced pen point during calibration visit.

SITE #20: ORLAND PARK

5-17-93: Replaced chart drive and releveled gage.

7-6-93: Replaced chart drive and releveled gage.

SITE #21: TINLEY PARK

5-17-93: Replaced chart drive.

SITE #22: U.S. ARMY RESERVE CENTER - HARVEY

11-4-93: Replaced chart drive batteries and pen point during calibration visit.

SITE #23: CITY OF LANSING PUBLIC WORKS

11-4-93: Replaced pen point during calibration visit.

SITE #24: VILLAGE OF MATTESON

11-4-93: Releveled gage during calibration visit.

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

7-12-93: Releveled gage.

11-4-93: Replaced chart drive and releveled gage during calibration visit.

APPENDIX IV: DOCUMENTATION OF HIGH STORM TOTALS

This appendix documents all network-defined storm totals that exceeded an annual event (one-year recurrence interval) during Water Year 1993. Storm durations of one hour to ten days were considered. The rainfall amounts for a one-year recurrence interval and the aforementioned storm durations for northeastern Illinois are given below (Huff and Angel, 1989).

Storm Duration	Rainfall Amounts (inches)
1 hour	1.18
2 hours	1.48
3 hours	1.60
6 hours	1.88
12 hours	2.18
18 hours	2.30
24 hours	2.51
48 hours	2.70
72 hours	2.93
5 days	3.25
10 days	4.12

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 storm during the water year exceeded events greater than an annual event (2-year to 100-year recurrence intervals considered).

STORM TOTALS

Storm #	Site #	Date	Duration (hours)	Amount (inches)	Other Everts Exceeded
6	15	10/31-11/2/92	41	2.72	
76	6	6/7-8/93	34	3.19	2-year
	7		35	3.31	2-year
	8		37	3.04	
	9		36	2.64	
	11		34	5.46	10-year
	12		38	4.36	5-year
	13		39	5.31	10-year
	14		38	6.31	25-year
	15		38	4.44	5-year
	16		38	4.71	5-year
	17		39	5.66	10-year
	18		38	6.86 partial E	50-year
	19		44	5.52	10-year
	22		38	3.30	2-year
	23		38	3.31	2-year
	24		48	4.45	5-year
	25		44	3.97	2-year
78	16	6/17-18/93	8	2.46	2-year
79	20	6/18-19/93	6	1.89	
	23		5	2.20	2-year
80	25	6/19/93	3	1.65	
85	18	6/27-28/93	12	2.31	
	23		11	2.38	
98	7	7/25/93	4	1.85	
108	4	8/23-24/93	4	1.71	
	5		3	2.05	2-year
	6		2	2.69	10-year
	7		2	2.71	10-year
	8		3	1.82	
	9		2	1.72	
	10		6	2.20	

STORM TOTALS (Concluded)

Storm #	Site #	Date	Duration (hours)	Amount (inches)	Other Events Exceeded
110	15	8/28-29/93	8	2.02	
	20		8	3.08	5-year
	21		7	2.22	
	22		8	2.85	
	23		8	2.09	
	24		8	2.35 E	
111	14	8/30-31/93	14	2.34	
	19		16	2.62	
	22		13	2.99	2-year
	23		15	2.53	
116	12	9/13-14/93	32	2.64	
	14		29	2.62	
	16		32	2.65	
	20		31	2.77