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Continued Operation of a 25-Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 2006

by
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Prepared for the
U.S. Army Corps of Engineers, Chicago District

January 2007

Illinois State Water Survey
Center for Atmospheric Science
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

CONTINUED OPERATION OF A 25-RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 2006

FINAL REPORT

To

U.S. Army Corps of Engineers, Chicago District

Contract

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ABSTRACT

A dense raingage network has operated in Cook County since the fall of 1989, to provide accurate precipitation measurements for use in simulating runoff for Lake Michigan diversion accounting. This report describes the network design, the operations and maintenance procedures, the data reduction and quality control methodology, a comparison of rainfall amounts obtained via analog chart and data logger, and an analysis of precipitation for Water Year 2006 (October 2005 - September 2006). The data analyses include 1) monthly and Water Year 2006 amounts at all sites, 2) Water Year 2006 amounts in comparison to patterns from network Water Years 1990-2005, and 3) the 17-year network precipitation average for Water Years 1990-2006. Also included are raingage site descriptions, instructions for raingage technicians, documentation of raingage maintenance, and documentation of high storm totals.

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by

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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 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 1900, 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 (USACE), Chicago District, is the accurate representation of the precipitation that falls over portions of Cook County, Illinois.

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 discharged into the water courses. 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 two facilities located at the lakefront: the Chicago River Controlling Works, and the O’Brien Lock and Dam.

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 groundwater 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 function is to model runoff. The second function is to aid in determining the inflow, infiltration, 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 are 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 cubic feet per second (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; Peppler, 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 toward 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 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, air flow-restricting

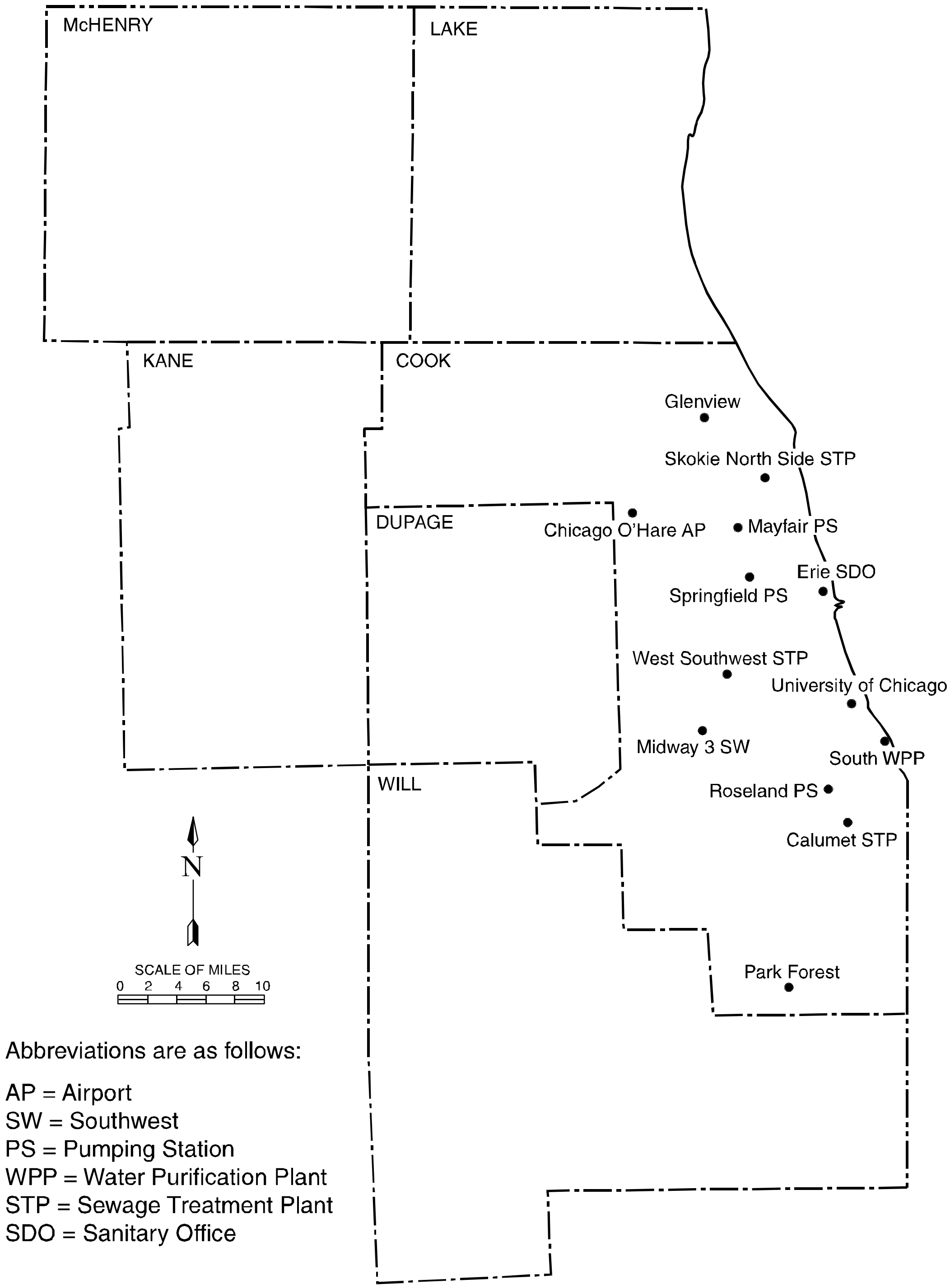

Figure 1. Raingage locations used for diversion accounting purposes prior to Water Year 1990. These include National Weather Service gages located at Chicago O'Hare AP, Midway 3 SW, University of Chicago, and Park Forest; City of Chicago gages located at Mayfair PS, Springfield PS, South WPP, and Roseland PS; and Metropolitan Water Reclamation District of Greater Chicago gages located at Glenview, Skokie North Side STP, Erie SDO, West Southwest STP, and Calumet STP.

obstructions) and 2) different observing, 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, was tedious to implement, and the adjusted precipitation values may not have completely captured the actual precipitation regime, although the data produced were much improved over the original values. This procedure also illuminated difficulties experienced when trying to merge data observations from different 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 USACE jointly decided in late 1988 to devise, install, and operate a new raingage network, funded by the USACE. The purpose of the new network was to produce consistent, accurate data for the diversion accounting, which would require little or no adjustment. 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 2006, year 17 of network operation.

2. 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 precipitation (typical in spring and summer) was found to require nearly twice as many gages as required for more widespread, continuous precipitation (fall and winter). With that in mind, and opting for 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 the 10 to 15 gages Vogel had originally envisioned, have provided adequate coverage for precipitation catchment during Water Years 1990-2005, the first 16 years of network operation (Peppler, 1991b, 1991c, 1993b, 1994, 1995; Westcott, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003 2004, 2005, 2006), 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 reduces 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. As of September 30, 2006, 11 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). Appendix I contains complete site descriptions for each network location, accurate as of September 30, 2006. Each universal weighing-bucket raingage used throughout the network was fitted with a battery-powered electric chart drive that rotated the 24-hour charts approximately once per day. The SWS provided all raingages from its inventory. To improve the accuracy and reliability of the raingages, as of February 1, 2001, the 25 raingages were redeployed, fitted with linear potentiometers and data loggers, in addition to the battery-powered chart drive. The chart drive was altered to use 8-day charts instead of 24-hour charts to accommodate monthly instead of weekly servicing.

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. In October 1996, an Alter shield was installed at site #14, a very windy lakefront location.

3. NETWORK OPERATION AND MAINTENANCE

Each raingage in the network was fitted with a linear potentiometer and a data logger, as of February 1, 2001, in addition to an 8-day chart drive and chart cylinder gears that rotate the chart cylinder approximately once every week. The timing resolution of the charts is somewhat reduced, but still adequate for hourly measurements, and the rainfall accuracy for the 8-day charts is comparable to the 24-hour charts (Westcott, 2002). The data logger records the date, time (Central Standard Time), and an accumulated precipitation total every 10 minutes. These data are downloaded to a laptop computer and 3.5-inch diskette during the first week of each month, every 28-37 days. These data are brought to SWS for processing and quality

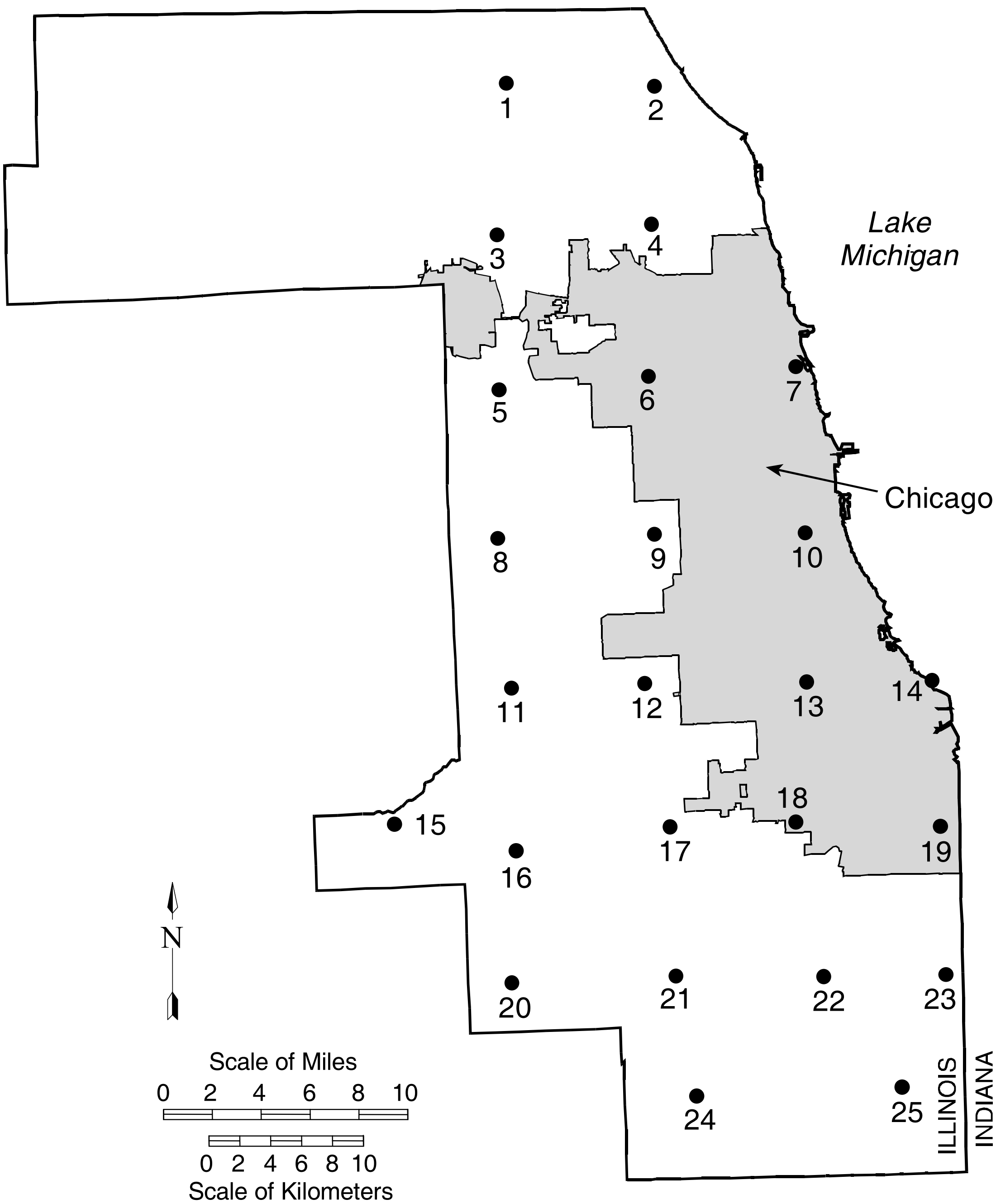

Figure 2. The Cook County 25-site raingage network for Water Years 1990-2006.

control. 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. The data logger also is calibrated to 12 inches. 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. Use of the latter traverse occurs infrequently, but 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 for long periods.

A raingage technician residing in Champaign, Illinois, travels to Cook County and services each gage during the first week of each month, which means that 4-5 traces are drawn on each chart. Servicing includes downloading data from data loggers, removing and replacing the current chart, checking the pen point, emptying the bucket in April-October (the warm season of the year), and noting any problems, including chart-drive malfunction, gage imbalance or instability, data logger malfunction, vandalism, unauthorized movement of the gage, etc. During the warm season, evaporation shields are fitted into the collection orifice above the bucket to reduce 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. Buckets are emptied and recharged with antifreeze when needed. Appendix II contains the complete set of servicing instructions followed by the raingage technician.

Each month the technician collects a complete set of 25 charts and makes a log entry regarding problems encountered at each site. The following section, describing the data reduction and quality control procedures, explains what happens to the data collected by the data loggers and on the analog charts.

Most problems encountered by the raingage technician pertain to either the data loggers or the chart drives and pens. Often, the solution is to replace the data logger or the chart drive or their batteries or the pen tips. If replaced, both the data loggers and the chart drives are cleaned and readied for reuse at the SWS. Two spare data loggers and chart drives allow for needed exchanges. Some problems, however, cannot be solved during the routine monthly servicing. If necessary, a second one-day trip is made mid-month to resolve problems that could not be handled during the routine monthly visit. 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, 2006.

4. DATA REDUCTION

Analog Charts

The data from these charts are used to assist in the quality control of the data logger precipitation amounts and as backup if a data logger fails. The charts are especially useful for verifying light precipitation events. The monthly set of charts is edited to identify the various traces on the charts and to number sequentially by date those traces showing precipitation. A running inventory of "on" and "off" chart times is 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 technician will 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 precipitation 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 also can 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 marked appropriately.

After all charts have been edited, they are ready to be digitized with a Summagraphics Microgrid II digitizer. The chart values are loaded into a personal computer with each chart 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” on each breakpoint along the respective trace. Once a chart is digitized, computer output gives details on the precipitation that was measured on the chart for each storm, with appropriate storm amounts and beginning and ending times. Also included is an analysis of whether the chart drive is running slow or fast, which helps assess whether the chart drive requires servicing. Errors made during the editing stage also can 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 stored in the computer. The time required to edit and digitize the 8-day charts is minimal in comparison to that required for 24-hour charts, approximately 4 hours instead of 3 days. This is because there are fewer charts, 25 instead of 100, and also fewer traces per chart, 4-5 traces instead of 7-14 traces.

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 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.

Data Loggers

The minimum rainfall amount recorded by the data logger is 0.01 inches every 10 minutes. Often electronic noise is present as evidenced by 10-minute values oscillating between -0.01-inch and 0.01-inch values. Noise can be caused by wind or other vibrations. Computer software was developed to set 10-minute values to zero if within ±10 minutes of a -0.01-inch value, or if within ±20 minutes of a value less than -0.01 inches. Further, if an isolated positive 10-minute value is found (no other precipitation for ±90 minutes), that value also is set to zero. These 10-minute accumulated precipitation amounts then are summed to hourly values and displayed in a format comparable to that already established for the analog chart data. Here, further elimination of noise is done. Noisy values are denoted as 88.88. Values usually are considered part of a precipitation event if more than two adjacent gages detect precipitation during the same hour. However, it has been noted that there often are “events” in the hours just after sunrise. It is believed that these frequent events, not observed by the analog charts, are related to a rapid heating of the raingage. These “a.m.” storms are deleted unless the analog charts or the NWS gages located in Cook County also report precipitation, or unless the NWS radar indicates precipitation.

Final Data Array

The precipitation data array created from the data logger data is checked for time and space consistency, storm periods are delimited, and missing values are filled in 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 was 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), Peppler (1990, 1991a-c, 1993a,b, 1994, 1995), and Westcott (1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006) to delineate storms for Water Years 1984-2005. For each storm, values are summed, plotted on maps using all available data and stations, and isohyetal patterns are drawn. During Water Year 2006, 127 such storms were defined.

After a generalized precipitation pattern is obtained for each storm, storm total values also are obtained from the analog charts. If available, the charts are used to determine hourly precipitation values if a data logger fails. Otherwise, a computer program using an objective analysis program is executed to objectively determine new values for hours designated as missing by the data loggers. The objective routine is also used to re-create values at gage sites for which questionable values were identified during the storm analysis stage. Once everything has been verified, a final computer file of hourly precipitation values for the month being analyzed is archived.

5. COMPARISON OF STORM RAINFALL FROM TWO COLLECTION METHODS

Eight-day charts and data loggers are used at the 25 refurbished gages. The 8-day chart data are digitized monthly. The largest difference between the precipitation data derived from the data loggers and that from the charts is the accuracy of the timing of storm events. The onset and end times of storms between gages are more consistent when using data loggers. This in large part is due to the elimination of the chart drive and the pen mechanism, which are known to stick unless monitored almost daily. Further, the data loggers evaluate precipitation accumulations at 10-minute intervals rather than at the standard hourly accumulations acquired from digitizing the analog charts.

Storm total precipitation amounts from the data loggers and 8-day charts for the 25 raingages are presented in Figure 3. The correlation between the 8-day charts and the data loggers is 0.99. Note that the storm total pairs are centered on the 1:1 line.

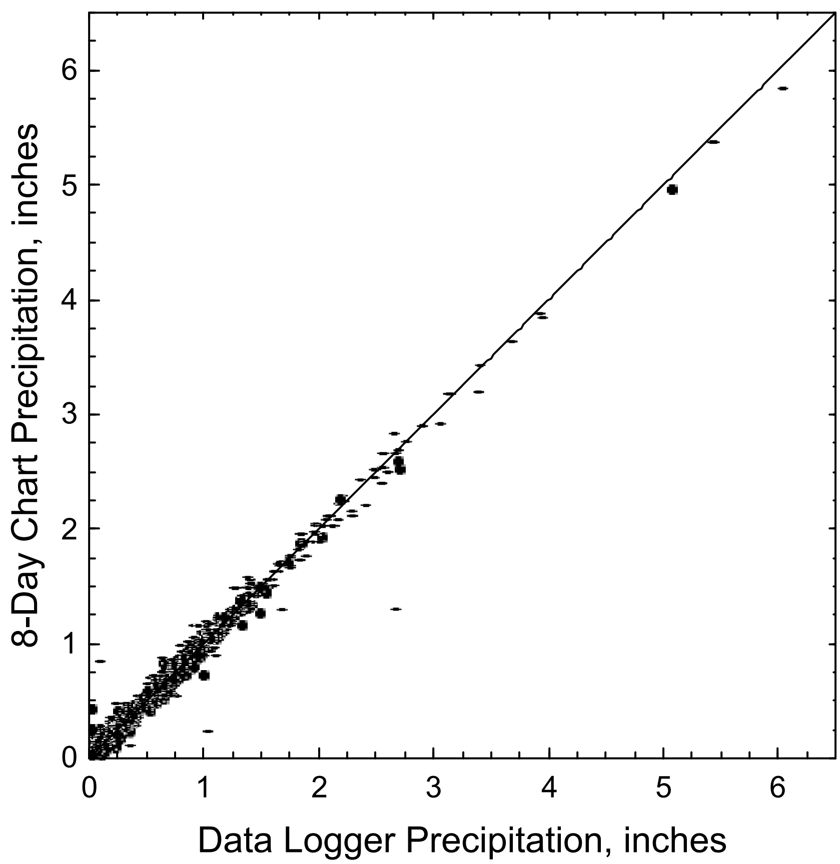

Figure 3. Storm total precipitation at individual gages for the data loggers and the 8-day chart data, October 1, 2005-September 30, 2006. (1:1 line indicated by a dashed line).

Table 1. Percent Frequency of Rainfall Values Falling within the ± 10, 20, and 30 Percent Difference Range for All Rainfall Pairs and for Logger Precipitation Values above the 0.25-, 0.5-, 0.75-, 1.0-, and 1.5-inch Thresholds.

Frequency DL vs. chart	*All N = 1559*	*≥ 0.25 N = 867*	*≥ 0.50 N = 575*	*≥ 0.75 N = 385*	*≥ 1.00 N = 213*	*≥ 1.50 N = 81*
± 10	55	77	85	89	93	98
± 20	73	93	97	98	98	98
± 30	80	98	99	99	99	99

Notes: Rainfall in each pair of gages exceeded zero inches; N indicates the number of rainfall pairs; and DL indicates data loggers.

The percent frequency of storm total precipitation pairs with differences ≤ 10, 20, and 30 percent is shown in Table 1. Only values where both the data logger and the raingage reported some precipitation are included. The percent differences were computed as [(Logger – Chart) / Logger] *100.0. When the data logger storm total value was at least 0.25 inches, only 5 of 867 8-day chart values differed by more than 50 percent from data logger values. The large differences are due mainly to the performance of the chart drive or pen mechanism.

For precipitation amounts greater than 0.25 inches, the data logger and gages performed very well. At smaller precipitation amounts, there is more uncertainty in both the data loggers and the 8-day charts. Electronic noise resulting from wind or other vibrations is common for data logger measurements, and sometimes poor connections also can result in noise. While much of the electronic noise is eliminated by computer software and manual checks, not all can be eliminated with assurance. Noise will have the greatest impact upon the smaller precipitation values. However, usually even small amounts of a few hundredths of an inch can be read on the 8-day charts. The 8-day charts will continue to be digitized both for backup purposes and to evaluate the performance of the potentiometer, data logger, and the pen mechanism.

6. DATA ANALYSIS

The Water Year 2006 dataset was used to produce various analyses, including: 1) monthly and Water Year 2006 amounts at all sites, 2) water year amounts and comparisons to patterns from network Water Years 1990-2005, 3) monthly amounts as documentation of the data collected, and 4) an analysis of the 17-year network precipitation average for Water Years 1990-2006.

Table 2 and Figure 4 show Water Year 2006 precipitation amounts. Isopleths in Figure 4 (and remaining figures) are labeled in inches, while values in Table 2 are given to the nearest hundredth of an inch. Water Year 2006 was average in precipitation amount**.** Network average precipitation for Water Years 1990-2005 were 40.00, 39.19, 36.56, 51.78, 29.23, 34.68, 36.88, 34.09, 36.12, 36.33, 33.33, 36.39, 33.37, 29.03, 35.24 and 27.09 inches, respectively. The 16-year (1990-2005) network average precipitation was 35.46 inches. The Water Year 2006 network average of 35.66 inches was nearly the same as the 16-year network average (101%) and the 1971-2000 Chicago O'Hare Airport annual precipitation normal of 36.27 inches (98%). There were 127 precipitation events in Water Year 2006. Ten of the 127 precipitation events included at least one site at which the storm total exceeded the one-year recurrence interval (Appendix IV). On average, seven heavy precipitation events occurred annually in Water Years 1990-2005.

Table 2. Monthly and Annual Precipitation Amounts for Water Year 2006 (inches)

Gage	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Total*
1	0.42	2.32	1.17	2.56	1.63	2.65	3.10	2.57	3.51	2.27	3.33	4.90	30.43
2	1.43	2.08	1.73	3.06	1.66	2.52	3.32	3.33	2.46	2.33	3.21	6.29	33.42
3	0.95	2.30	1.12	2.30	1.52	2.25	2.93	2.67	3.28	2.54	3.24	5.53	30.63
4	1.72	2.14	1.48	3.35	1.43	2.30	3.55	2.48	2.60	2.28	3.70	4.66	31.69
5	1.36	1.93	0.74	2.29	1.47	2.16	3.49	2.43	3.23	3.33	3.81	4.05	30.29
6	1.62	2.07	1.22	2.20	1.35	2.49	3.36	2.49	3.14	3.41	4.41	3.78	31.54
7	2.07	2.09	1.55	2.29	1.14	2.33	4.18	2.02	2.40	2.97	5.77	2.86	31.67
8	0.96	1.92	1.11	2.43	1.47	2.52	3.94	1.87	3.08	2.52	3.87	4.33	30.02
9	0.54	1.88	1.09	3.21	1.39	2.39	3.46	2.21	4.12	3.97	4.49	4.38	33.13
10	2.74	2.13	1.97	3.40	1.44	2.82	4.39	4.13	3.14	4.42	4.24	5.60	40.42
11	0.63	1.87	1.28	3.22	1.31	2.53	3.98	2.07	3.64	2.77	7.13	3.57	34.00
12	1.02	1.70	1.24	2.34	1.16	2.33	3.28	2.50	3.24	3.08	5.41	3.45	30.75
13	2.30	1.61	1.59	2.88	0.87	2.82	4.01	3.84	2.53	4.02	5.27	7.09	38.83
14	3.32	2.00	1.31	2.54	0.65	2.55	3.75	3.21	2.70	4.86	5.43	6.37	38.69
15	0.40	1.95	1.24	2.79	1.31	3.02	3.85	2.39	4.55	3.82	6.08	4.32	35.72
16	0.56	1.63	1.46	2.94	1.03	3.20	3.67	2.97	3.86	5.25	7.64	5.15	39.36
17	1.18	1.65	1.20	3.05	0.88	2.74	3.36	3.55	2.54	4.45	8.43	4.60	37.63
18	2.23	1.72	1.24	2.56	0.63	2.77	3.84	4.75	2.35	4.81	5.74	5.75	38.39
19	3.27	1.63	1.05	2.78	0.66	2.82	3.35	2.94	2.18	4.16	6.17	4.28	35.29
20	1.05	1.43	0.92	2.05	0.66	3.11	4.43	2.41	2.81	3.11	5.77	5.76	33.51
21	1.60	1.97	1.25	3.07	0.76	3.13	5.22	3.42	3.57	3.16	8.44	4.97	40.56
22	2.83	1.97	1.24	2.81	0.84	3.02	5.27	4.36	2.53	3.50	7.17	3.59	39.13
23	3.37	2.27	1.33	2.89	1.26	2.96	4.41	4.25	2.72	4.20	5.78	4.30	39.74
24	2.19	2.06	1.50	2.81	0.88	3.37	7.58	3.59	2.67	5.12	9.03	4.37	45.17
25	3.30	2.02	1.11	2.86	1.13	2.94	6.80	2.59	2.50	4.40	7.48	4.44	41.57
Avg	1.72	1.93	1.29	2.75	1.14	2.71	4.10	3.00	3.01	3.63	5.64	4.74	35.66

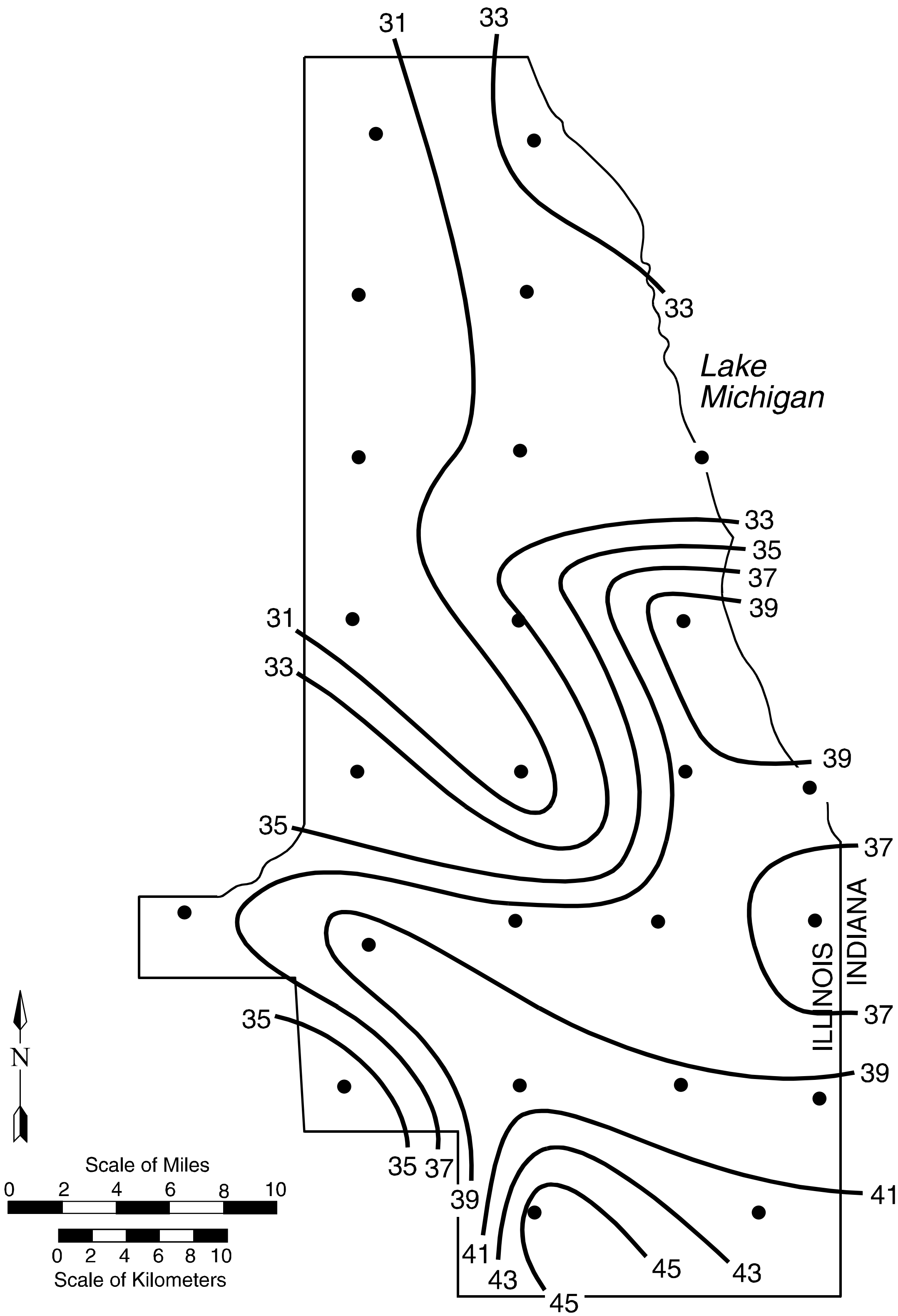

Figure 4. Precipitation pattern (inches) for Water Year 2006.

The largest precipitation amounts during Water Year 2006 occurred in the southern portion of the network (sites #21, #22, #23, #24, and #25) and in the north-central region (#10, #13, #14, #16, #17, #18; Figure 4). See Figure 2 and Appendix I for site information. The lightest amounts occurred in the northern and western portions of the network (sites #1, #3, #4, #5, #6, #7 #8 and #12). The heaviest precipitation in the network during Water Year 2006 (45.2 inches) fell at site #24, while the lightest fell at site #8 (30.0 inches).

Figure 5 provides maps of precipitation amounts for individual Water Years 1990-2005. The general pattern of high values for Water Year 2006 is similar to that of 1991, 1998 and 2005, with the largest precipitation in the south-central portion of the network. The "urban high" of the near lake, central Chicago area noted in other network water years and in other Chicago-area research (e.g., Huff and Vogel, 1976) may be evidenced in the finger of higher values (sites #10, #13, and #14) in east-central Cook County (Figure 2) in the 2006 rainfall pattern.

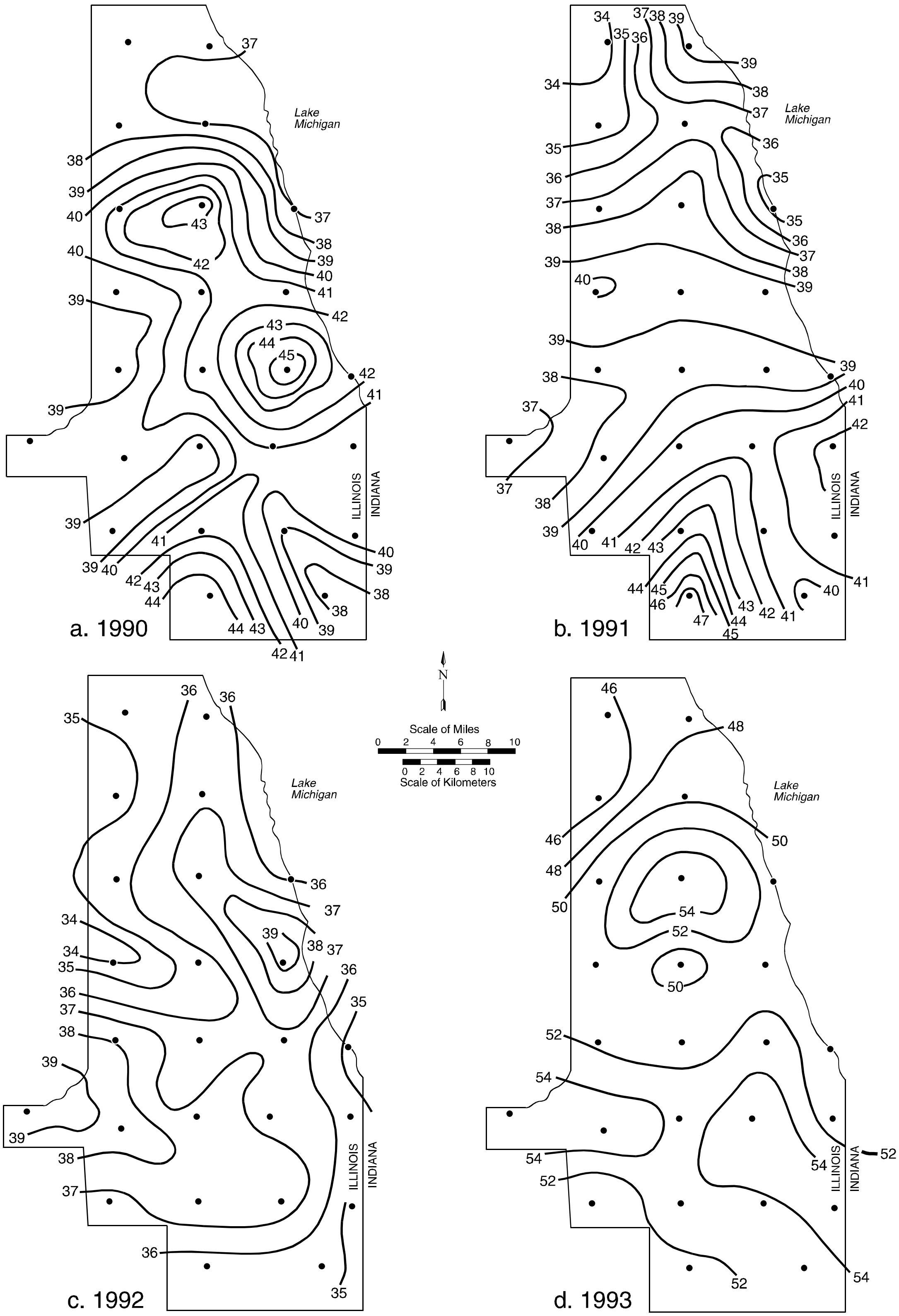

Figure 5. Precipitation pattern (inches) for Water Years 1990-2005.

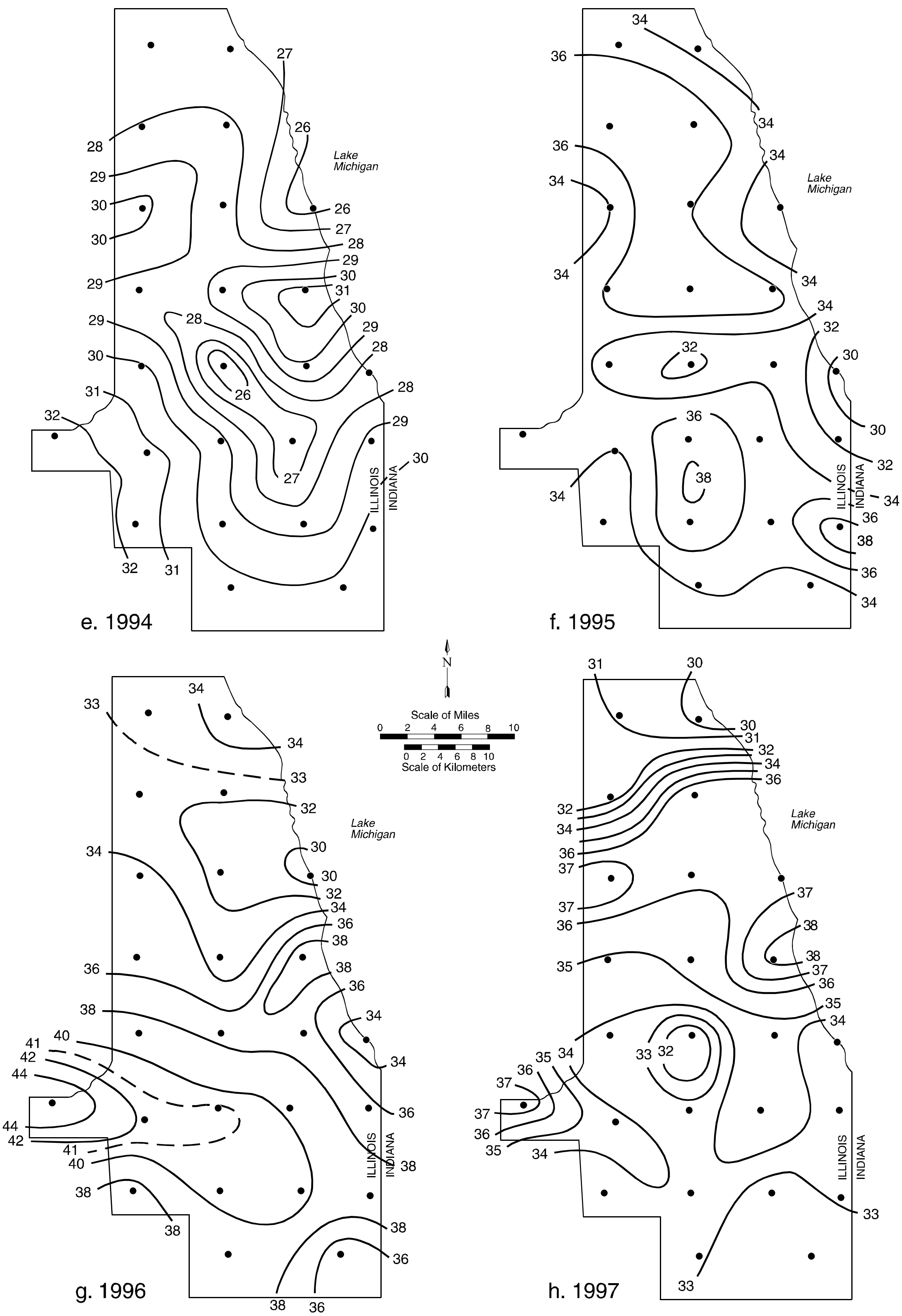

Figure 5. Continued.

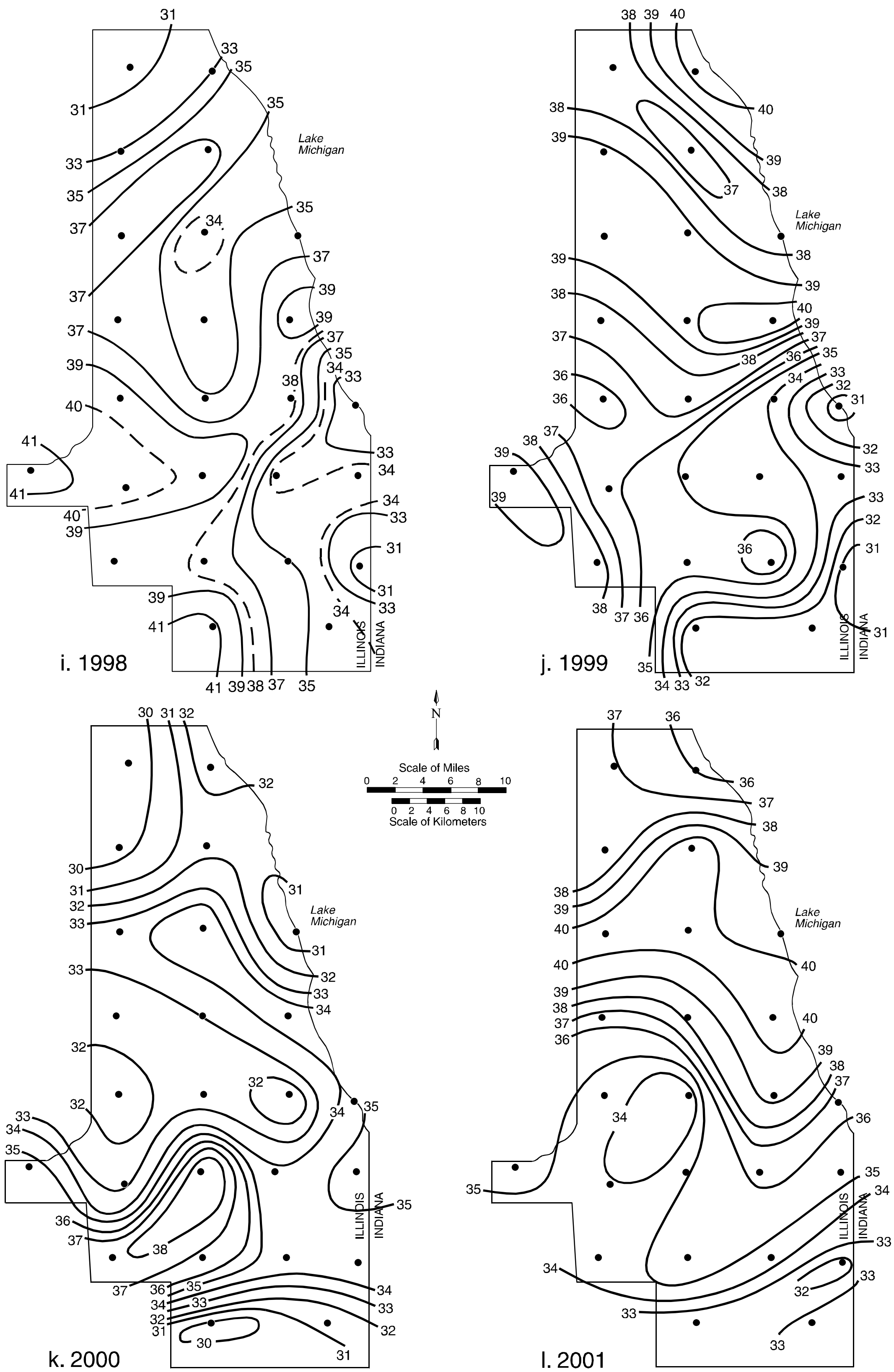

Figure 5. Continued.

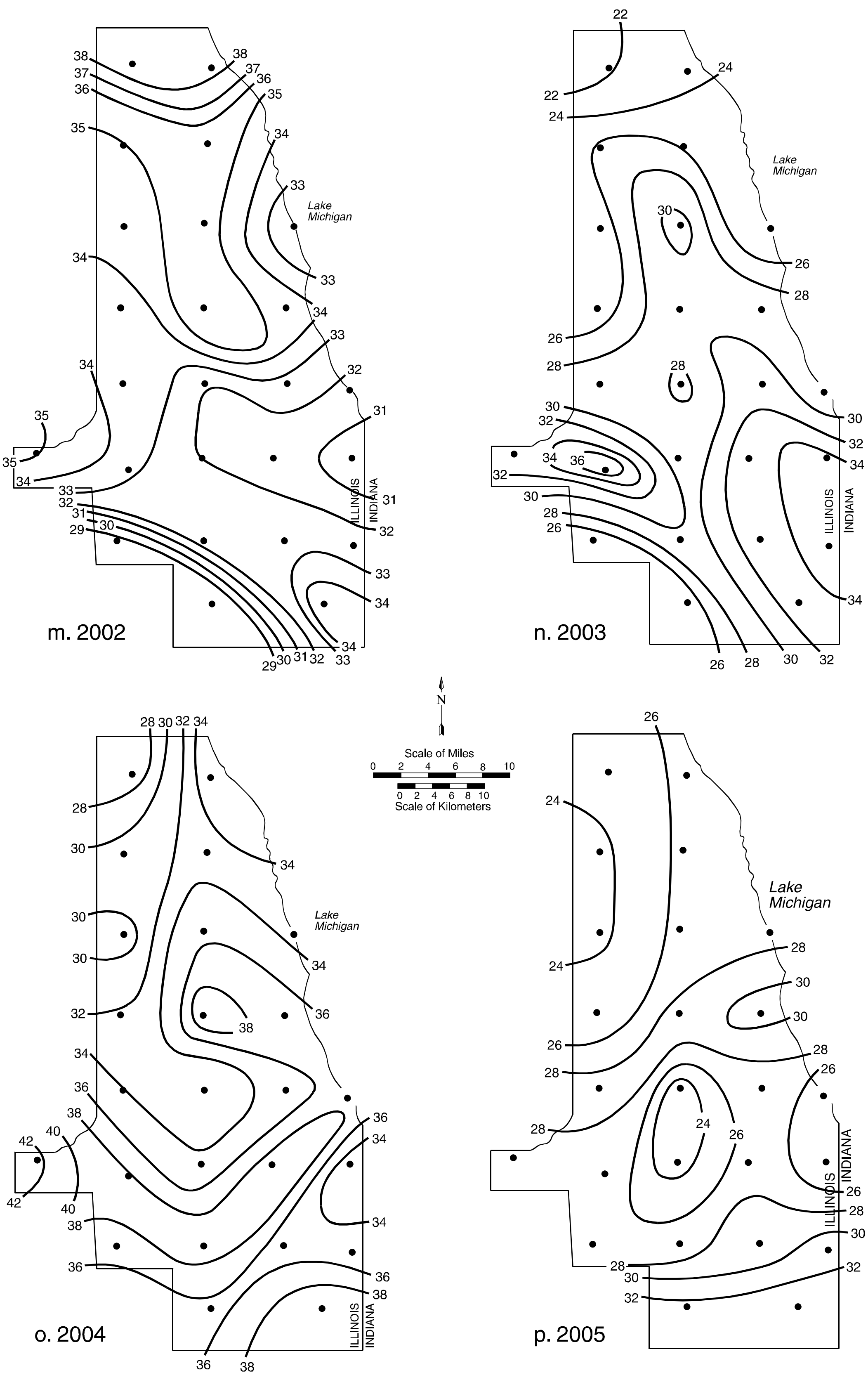

Figure 5. Concluded.

As in the case of the other network water year patterns, the spatial pattern for Water Year 2006 (Figure 4) does not contain the anomalies found in an analysis using sites operated by the MWRDGC, the NWS, and Cook County for Water Years 1984-1989 (Vogel, 1988; Peppler, 1993b). Gradients of 15 to 20 inches were common in those analyses. Precipitation data from those sites were the input for diversion accounting before construction of the present network (Peppler, 1993b). For Water Year 2006, there is a 10.6-inch gradient between sites #10 and #12. However, these values are supported somewhat by values at nearby sites.

Figure 6 presents monthly precipitation patterns for Water Year 2006. Monthly network precipitation amounts were less than 65 percent of the 16-year average for the first two months October and November 2005 in Water Year 2006, and greater than 135 percent of the 16-year network average during the last 2 months in Water Year 2006. Less than 3.0 inches of precipitation fell in each of the first 6 months in Water Year 2006, and 3.0 or more inches of precipitation fell in each of the last 6 months during the warm season. Precipitation amounts and the spatial gradient in precipitation amount generally were small in magnitude during the cold season months of October 2005 through March 2006.

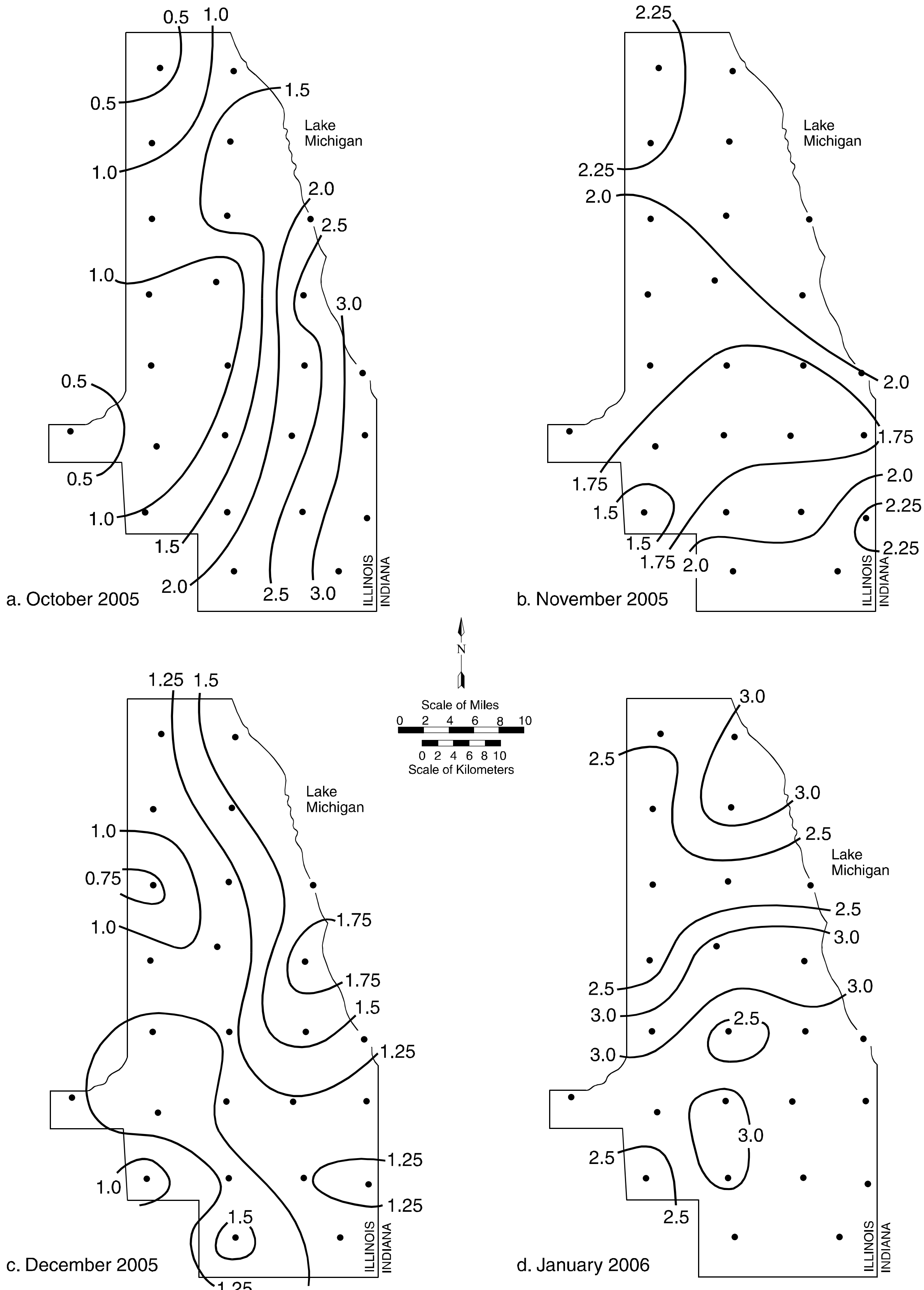

Figure 6. Precipitation pattern (inches) for October 2005-September 2006.

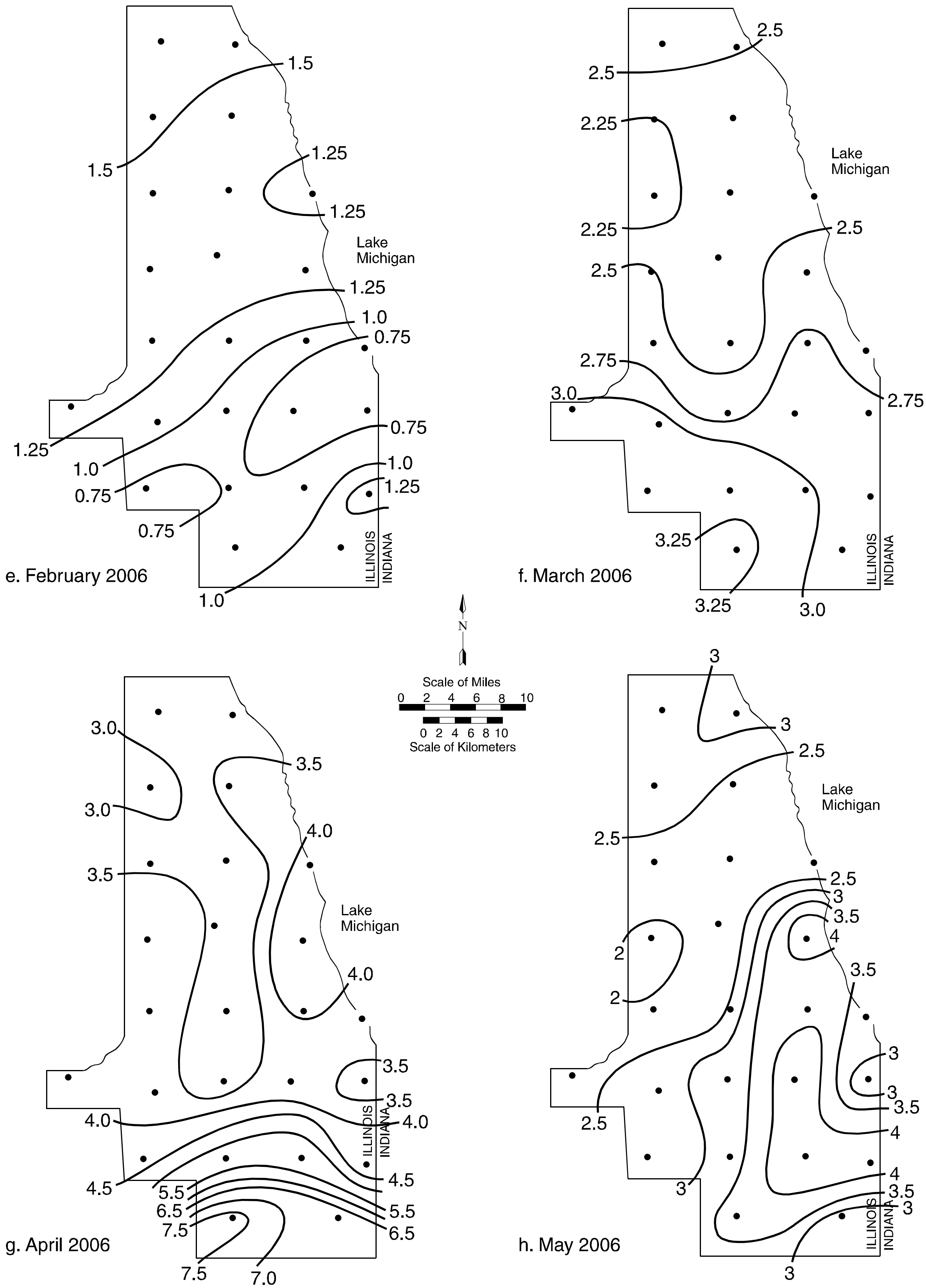

Figure 6. Continued.

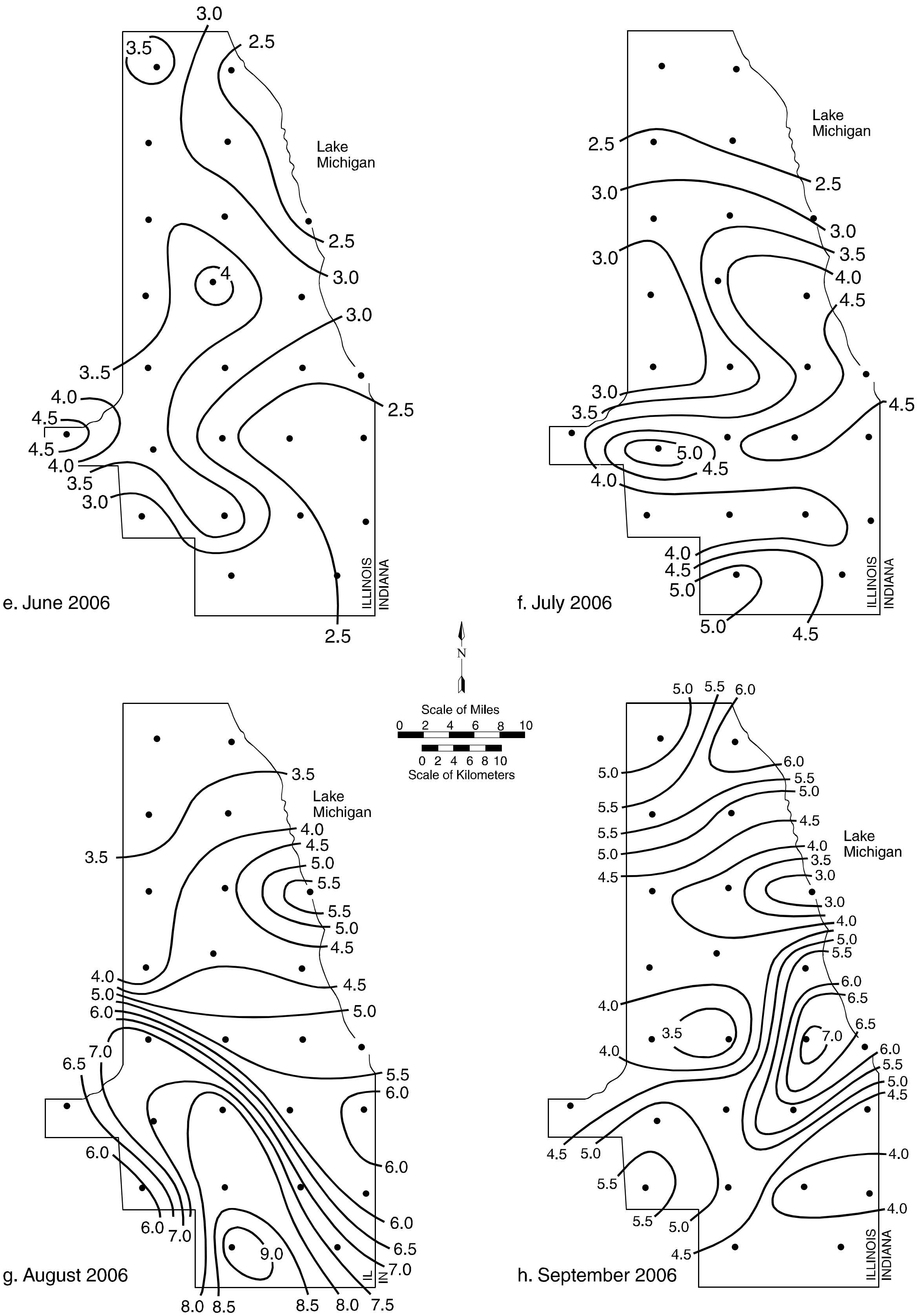

Figure 6. Concluded.

The 17-year (1990-2006) average precipitation pattern (Figure 7) shows, as in previous years, an area of higher values across southwestern Chicago (sites #15, #16, and #21), and northward at Chicago (site #10). Lower values are found at northern sites #1, #2, #3, and #7, at central sites #8 and #12, and at lake site #14. The 17-year networkwide average is 35.59 inches.

For high precipitation events, 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). Of the 127 precipitation events identified during Water Year 2006, ten had at least one gage for which the amount surpassed the one-year recurrence interval for the given storm duration. Within these ten storm events, 42 gages exceeded at least the one-year recurrence interval: 18 gages (one-year recurrence interval category), 13 gages (2-year category), 6 gages (5-year category), 3 gages (10-year category), and 2 gages (25-year category).

The ten heavy precipitation events of Water Year 2006 occurred during the warm months of April, June, July, August and September. The storm event with gages exceeding the 25-year recurrence interval (5.0 inches in this case) occurred on April 16-17, 2006. Appendix IV contains specific information concerning these Water Year 2006 precipitation events with gages that exceeded the one-year recurrence interval.

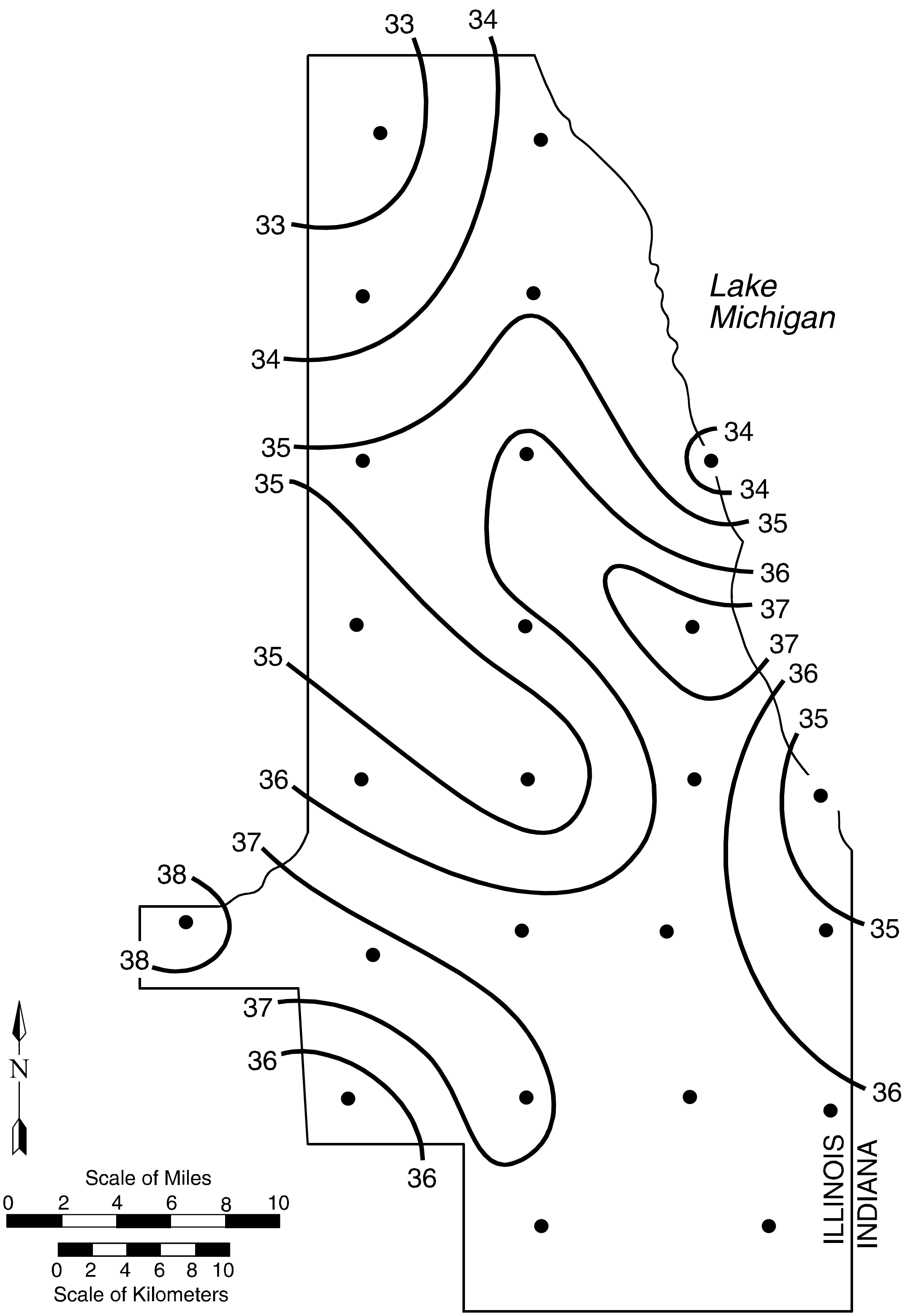

Figure 7. Seventeen-year average precipitation pattern (inches), Water Years 1990-2006.

7. SUMMARY

The Cook County raingage network has collected precipitation data during 17 water years, 1990-2006. Precipitation amounts in Water Year 2006 were moderate, with a network average of 35.66 inches, nearly the same as the 16-year network average of 35.46 (101%) and the 1971-2000 Chicago O'Hare Airport annual precipitation normal of 36.27 inches (98%). Ten heavy precipitation events occurred during the warm season of Water Year 2006. Siting of the raingages, areal coverage of the network, installation of potentiometers and data loggers, and careful quality control of the data allow the U.S. Army Corps of Engineers, Chicago District, to accurately estimate the storm runoff portion of the diversion of water from Lake Michigan into Illinois. Because of the relatively dense spacing of the raingages, the network also provides high-quality data for research on the precipitation variability of the Cook County region.

8. 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, 2006. Sites that have been relocated since the network began operation in October 1989 are noted in the "Placement" section of the descriptions. Note that there are slight differences in latitude and longitude values from previous years. More accurate GPS readings were obtained for all sites during the summer of 2006.

This appendix has been eliminated to protect the privacy of the site owner.

APPENDIX II: INSTRUCTIONS FOR RAINGAGE TECHNICIANS

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

    - A supply of 8-day rotation raingage charts (Belfort number 5-4047-B)
    - A supply of spare felt-tipped pen points
    - A roll of paper towels or similar absorbent material
    - A ball-point pen or pencil
    - Grass clippers and/or sickle
    - A clipboard
    - A spare 12-quart bucket
    - Batteries for the 25 data loggers
    - A spare data logger
    - A set of weights for calibration
    - A laptop computer and an a/c adapter

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 WGN, 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:

    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 pulling 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 attach the chart to the drum cylinder, making sure the horizontal lines are properly aligned, 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 precipitation event. Make a small mark with your pen or pencil on the chart at the half-inch line to indicate the ON time. Reinstall the chart cylinder onto the electric chart drive, making sure the chart cylinder and drive gears mesh. Set the pen point at the ON time.

4) Quickly remove the collector assembly (top cap) from the top of the gage by rotating the collector assembly 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). During the warm season, pour the water into the 2-inch measuring tube and record the amount of precipitation collected for use in checking the calibration. During wintertime operations when a charge of antifreeze is in the bucket, leave the antifreeze until the chart reading passes the 6-inch mark. At that point, pour the bucket contents into a sealed container and dispose of properly. DO NOT POUR SOLUTION ONTO THE GROUND! If wintertime conditions prevail, recharge the empty bucket with one quart of antifreeze. Reposition the dry bucket on the platform and reinstall the collector assembly by setting it on top of the raingage case and turning counterclockwise until the tongue-and-groove assembly meshes. At any time of the year, once the collector is repositioned, check the gage to make sure the collector orifice top edge is level.

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 is a good idea to "zero" the pen near the 0.25-inch mark to prevent evaporation from taking the pen point below the zero line.

6) Unplug the data logger from the connection to the potentiometer. Plug the data logger into the laptop computer and download data. Save data to a file on the laptop and to a file on a three-inch diskette. Check the battery voltage. Change the batteries in the data logger if necessary. After changing the batteries, check the battery voltage again, reload the program, plug the data logger into the connection with the potentiometer, and complete a five-point calibration of the gage.

7) To make a five-point calibration of the gage, set three weights at a time into the center of the bucket. As each set of weights is added, enter that point as instructed by the data logger software, and note the position of the pen on the chart. After the calibration is complete, be sure that the pen on the chart agrees with the data point indicated as each set of weights is removed from the bucket.

8) 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. Observe 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 month, place them in numerical order. Note any serious problems encountered during servicing. Situations worthy of immediate attention include chart-drive stoppages, unauthorized movement of the raingage, vandalism, and theft. Make minor repairs (e.g., pen point stuck under drum cylinder, debris in the collection bucket, etc.). Major repairs will be scheduled as soon as possible.

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, alert the project director so that contact can be made with 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 they have concerning the project and your job that you are unable to answer to the Project Principal Investigator. Remind them of the toll-free number, (866) 292-7305.

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 from Water Year 1990 through Water Year 2006. Any unusual gage activity performed by non-Water Survey staff also is included. The technician normally replaces pen points and chart drive batteries, and relevels and trims vegetation around the gages when required, but those instances are not listed. Also calibration checks and gage cleaning activities that were conducted at various times throughout the water year are not listed here unless some other servicing was required at a particular site. Organized chronologically by site number, this documentation is accurate through September 30, 2006.

SITE #1: NORTHBROOK - MISSION BROOK SANITARY DISTRICT

10-95: Replaced gage at same location.

04-97: Moved gage about 10 feet to the northwest of the pumping station due to bulldozer activity in the property immediately adjacent to previous location.

05-08-97: Moved gage about 20 feet to the northwest of the pumping station.

09-10-98: Replaced chart drive.

06-26-99: After two instances of vandalism, replaced and moved gage about 20 feet to the north so that it is more visible at night. Added lock to gage.

02-01-01: Replaced old gage with rebuilt gage with data logger.

03-02-01: Replaced potentiometer.

08-01-02: Installed redesigned data logger.

11-04-04: Replaced gage housing after vandalism. Replaced chart drive.
Installed co-located gage and data logger to south of Gage 1.

01-01-05: Co-located gage becomes primary gage. Removed original primary gage.

04-06-05: Reinstalled original (02-01-01) primary gage and data logger.

SITE #2: WINNETKA

09-10-97: Moved gage about 20 feet to the east of its previous location.

09-10-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

08-10-01: Replaced chart drive.

06-06-02: Installed redesigned data logger.

08-01-02: Installed another redesigned data logger.

08-01-06: Replaced data logger.

SITE #3: DES PLAINES

09-10-98: Replaced chart drive.

11-12-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

09-18-02: Installed redesigned data logger.

05-02-06: Replaced data logger.

SITE #4: VILLAGE OF SKOKIE

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

10-21-93: Replaced gage at same location after 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 necessitated a recalibration. Replaced chart drive and one support stake.

05-29-94: Replaced chart drive.

10-95: Replaced gage at same location.

09-10-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

11-02-01: Removed trash from gage.

05-02-01: Removed trash from gage.

07-18-02: Installed redesigned data logger.

07-02-03: Replaced data logger.

06-06-05: Replaced data logger.

01-07-06: Replaced top cap.

09-06-06: Replaced chart drive. Removed trash from top cap.

SITE #5: FRANKLIN PARK

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

11-12-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

11-01-01: Replaced chart drive.

08-20-02: Installed redesigned data logger.

02-05-03: Replaced data logger.

08-19-04: Replaced gage and data logger.

11-04-04: Replaced chart drive.

07-07-05: Replaced data logger.

SITE #6: NORTH CENTRAL CHICAGO, NEAR BELMONT

07-12-93: Moved gage about 60 feet to the west-northwest to a backyard.

11-12-98: Replaced chart drive.

09-10-99: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

08-01-02: Installed redesigned data logger.

04-01-04: Replaced data logger.

05-06-04: Replaced data logger.

02-02-05: Replaced data logger. When the replaced data logger was cleaned, an old spider web was found inside, causing intermittent noise problems.

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.

11-12-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

04-04-01: Removed considerable amount of gravel from the gage.

07-18-02: Installed redesigned data logger.

02-02-06: Replace chart drive.

SITE #8: WESTCHESTER - FOREST PRESERVE

06-02-95: Replaced chart drive.

09-11-97: Replaced gage at same location, due to vandalism damage.

10-30-97: Replaced gage at same location, due to vandalism damage (sword passed through cylinder).

12-11-97: Moved gage to more secure location, about 300 feet west-northwest of its previous location. It is just south of the end point of the Forest Preserve entrance road on west side of the Forest Preserve property, with the garages of two private homes about 30 feet to the southeast and northeast.

11-12-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

08-20-02: Installed redesigned data logger.

10-07-02: Because of vandalism, replaced and moved gage about 100 feet south-southwest of old location. New location is more open and more visible from nearby houses and further from Forest Preserve Path.

11-21-02: Replaced data logger.

02-05-03: Replaced data logger.

03-04-04: Replaced data logger.

06-04-04: Removed ants from gage.

04-08-05: Used ant bait.

09-18-05: Replaced batteries in data logger.

SITE #9: BERWYN

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.

09-11-97: Replaced gage at same location.

04-09-98: After three instances of vandalism, replaced and relocated gage to the Cicero Water Station about 1.3 miles north of the old location. The gage is in the center of a 1-acre field, with a 150-foot tower 150 feet to the south, a 75-foot tree 100 feet to the north, a 20-foot building 100 feet to the east, and a 20-foot building 200 feet to the west.

04-30-98: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

07-01-01: Moved gage to a protected area east of the service area, about 5 feet from a building, due to the construction of a new water tower.

06-07-02: Moved gage about 0.5 miles to Cicero Water Station on Roosevelt Drive. It is in a more open area, in the center of a 50 by 100- foot grassy lot, 50 feet west of a 20-foot water tank.

07-01-02: Installed redesigned data logger.

09-05: Gage, data logger and T-base stolen.

09-18-05: Installed gage at new site in Berwyn about 2 miles west of old location. Gage is in backyard of a residence, approximately 10 feet east of a 1.5-story house, and about 30 feet west of a one-story garage.

01-07-06: Replaced chart drive.

04-06-06: Replaced linear potentiometer.

SITE #10: WEST 26TH STREET

02-05-99: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

06-06-02: Replaced chart drive.

07-18-02: Installed redesigned data logger.

04-02-03: Moved gage away from encroaching spruce tree. Is about 5 feet east of 40 foot spruce, 5 feet north of 1-story garage, 15 feet west of 2-story building.

SITE #11: LA GRANGE

02-05-99: Replaced chart drive.

02-01-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

04-18-01: Moved both gages to new location along north edge of Edgewood Valley Country Club. Gages at highest point of golf course, about 60 feet from fence line separating the club from the 294 Tollway.

05-23-02: Installed redesigned data logger.

06-06-02: Tightened terminal strip pigtail connectors joining the potentiometer and data logger.

06-04-03: Removed ants and ant nest from gage.

04-02-04: Moved gage 10 feet to the east to a grassier area. Removed ants from gage.

06-04-04: Removed ants from gage.

04-08-05: Used ant bait.

SITE #12: NEAR BEDFORD PARK - CP HALL

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 southwest along a service drive in a mowed grass area.

09-11-97: Replaced gage after damaged by a truck. Its new location is about 10 feet to the southwest of its previous location, up a small incline and closer to a 6-foot chain link fence. It is approximately 35 feet east of a two-story building.

02-05-99: Replaced chart drive.

09-10-99: Replaced drum cylinder.

02-01-01: Replaced old gage with rebuilt gage with data logger.

07-01-02: Installed redesigned data logger.

02-05-03: Replaced data logger.

07-02-03: Replaced data logger.

03-01-06: Replaced data logger.

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 four blocks due west of the old position; and replaced the chart drive.

12-06-95: Replaced T-base.

5-17/19-96: Replaced T-base.

02-22-99: Replaced chart drive.

05-03-99: Found gage moved about 10 feet to the southwest, to a “well-protected” position, about 7 feet from a 10-foot wall and 30 feet from a 25-foot tall elevated-train retaining wall.

02-01-01: Replaced old gage with rebuilt gage with data logger.

07-01-02: Installed redesigned data logger.

11-04-04: Replaced chart drive.

06-04-04: Replaced data logger.

SITE #14: SOUTH WATER PURIFICATION PLANT

03-19-95: Replaced chart drive.

12-06-95: Replaced T-base.

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

10-09-96: Installed snow shield.

04-30-98: Replaced chart drive.

02-15-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

10-03-01: Replaced chart drive. Installed Alter shield on rebuilt gage, after removing old gage.

06-06-02: Installed redesigned data logger.

SITE #15: LEMONT - SAINT MARY'S SEMINARY

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.

02-05-99: Replaced chart drive.

01-13-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

11-15-01: Replaced chart drive.

06-06-02: Tightened terminal strip connectors.

06-24-02: Installed redesigned data logger.

08-01-03: Replaced data logger.

09-03-03: Replaced data logger.

12-15-03: Tightened terminal strip connectors.

04-08-05: Used ant bait.

SITE #16: PALOS PARK

02-05-99: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

11-01-01: Tightened terminal strip connectors.

06-24-02: Installed redesigned data logger.

06-17-03: Replaced data logger.

08-01-03: Replaced data logger.

06-17-04: Replaced data logger.

09-06-06: Replaced chart drive.

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 south-southeast from Sardee Industries to Alsip Fire Department Station #2.

11-21-96: Replaced gage at same location.

02-05-99: Replaced chart drive.

07-21-00: Replaced chart drive.

01-24-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

11-01-01: Replaced terminal strip connectors.

06-06-02: Installed redesigned data logger.

05-26-04: Replaced gage.

06-16-06: Replaced gage and linear potentiometer.

SITE #18: WEST 119TH STREET - HEAT TREAT CORP. OF AMERICA

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.

02-22-99: Replaced chart drive.

02-01-01: Replaced old gage with rebuilt gage with data logger.

11-15-01: Replaced chart drive.

05-23-02: Installed redesigned data logger.

06-06-02: Tightened terminal strip connectors.

03-05-03: Moved site from Ingersol to Heat Treat.

04-02-03: Moved gage to more secure position on same property after vandalism. Gage about 600 feet north-northeast of location at Ingersol in center of a fenced area, south of employees parking. Replaced chart drive and data logger.

05-01-03: Removed wasp nest from gage.

09-03-03: Replaced data logger.

06-04-04: Replaced data logger.

06-04-04: Removed ants from gage.

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.

02-22-99: Replaced chart drive.

01-13-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

12-01-01: Replaced chart drive.

10-03-01: Replaced chart drive.

11-01-01: Replaced terminal strip connectors.

06-24-02: Installed redesigned data logger. Tightened terminal strip connectors.

SITE #20: ORLAND PARK

03-16-90: Moved gage about 0.25 miles to the northwest 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.

04-30-98: Replaced chart drive.

02-15-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

03-06-02: Installed redesigned data logger.

07-02-03: Moved gage about 30 feet to south of previous location; it is about 30 feet east of a welding shop, about 60 feet east-southeast of a 30-foot pine, and about 50 feet west of a 40-foot tree line.

05-26-04: Replaced gage.

09-06-06: Top cap restored to proper position after having been vandalized.

SITE #21: TINLEY PARK

02-16-95: Replaced chart drive.

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

02-01-01: Replaced old gage with rebuilt gage with data logger.

08-10-01: Replaced chart drive.

05-02-02: Installed redesigned data logger.

11-04-04: Replaced chart drive.

05-07-04: Replaced data logger.

06-04-04: Removed ants from gage.

SITE #22: HARVEY

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

02-22-99: Replaced chart drive.

01-13-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

04-18-02: Installed redesigned data logger.

06-06-02: Tightened terminal strip connectors.

06-18-02: Replaced data logger.

08-06-03: Tightened terminal strip connectors and replaced data logger.

04-02-04: Replaced data logger.

05-05-05: Replaced data logger.

SITE #23: LANSING - POLICE DEPARTMENT

04-24-96: Moved gage 150 feet 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 south of the previous long-standing location.

04-30-98: Replaced and relocated the gage approximately 0.5 miles to the west, to a well-exposed location on the property of the Lansing Police Department.

A one-story building is 100 feet to the east, and 170th St. is about 1000 feet to the south.

01-24-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

04-18-02: Installed redesigned data logger.

08-01-03: Removed ant nest from gage.

09-06-06: Replaced ant trap. Unclogged top cap.

SITE #24: MATTESON - POLICE DEPARTMENT

06-11-98: Drum cylinder discovered stolen and subsequently replaced.

05-07-99: Moved site about 30 feet to the west, about 50 feet away from two 20-foot trees, one to the southwest and one to the southeast, about 30 feet away from a newly dug trench and building site.

01-13-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

11-01-01: Replaced terminal strip connectors.

04-04-02: Installed redesigned data logger.

05-02-02: Removed ants from gage.

07-02-03: Removed ants from gage.

06-04-04: Removed ants from gage.

09-01-05: Replaced data logger.

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

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

02-15-94: Replaced chart drive.

01-13-01: Installed rebuilt gage with data logger, while keeping the old gage for comparison purposes.

03-06-02: Installed redesigned data logger.

06-17-04: Replaced data logger.

08-04-05: Installed co-located gage and data logger.

APPENDIX IV: DOCUMENTATION OF HIGH STORM TOTALS

This appendix documents individual gage storm totals (within the 127 storms) that exceeded an annual event criteria (one-year recurrence interval) during Water Year 2006. Within the storm period, if several precipitation periods were present at an individual gage and were separated by six hours or more, only the heaviest precipitation period was considered. Leading and trailing hourly precipitation amounts of less than 0.04 inches were ignored. Storm durations of one hour to three days were evaluated. The precipitation amounts for one-year to 100-year recurrence intervals, and the aforementioned storm durations for northeastern Illinois, are given below (Huff and Angel, 1989).

Storm Duration	*Precipitation 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. If necessary, an "e" indicates a partial or full estimate for a particular site and storm, based on a spatial interpolation of the hourly precipitation values of neighboring gages. The last column indicates whether a particular gage within the given storm exceeded a precipitation value greater than an annual event criterion (2-year to 100-year recurrence intervals considered).

STORM TOTALS

Storm #	Date	Site #	Duration (hour)	Amount (inch)	Storm Recurrence Frequency
70	04 / 16-17 / 06	20	13	2.36	
		21	13	2.42	
		22	14	3.07	2-year
		23	13	2.61	2-year
		24	11	5.00	25-year
		25	15	5.39	25-year
88	06 / 09-10 / 06	11	9	2.14	
		15	9	2.55	2-year
		16	9	2.61	2-year
		17	9	2.11	
		20	8	2.25	
		21	9	2.51	2-year
		22	9	2.03	
		24	9	2.56	2-year
		25	9	2.17	
102	07 / 11-12 / 06	24	22	2.79	
111	08 / 02-03 / 06	7	14	2.65	
		13	12	2.23	
		14	11	2.55	
112	08 / 10 / 06	11	2	2.81	10-year
		12	2	1.53	
		16	2	1.80	2-year
		17	2	2.43	5-year
113	08 / 18-19 / 06	24	5	2.10	
		25	5	2.08	
114	08 / 24 / 06	15	1	1.38	

Storm #	Date	Site #	Duration (hour)	Amount (inch)	Storm Recurrence Frequency
116	08 / 28 / 06	18	8	2.42	2-year
		19	10	3.46	5-year
		20	4	1.85	
		21	5	3.25	10-year
		22	5	3.07	5-year
		23	5	2.86	5-year
		24	4	2.89	5-year
		25	5	2.84	5-year
120	09 / 12-13 / 06	13	8	3.54	10-year
		14	9	2.98	2-year
		18	6	2.46	2-year
		19	8	2.54	2-year
		20	5	2.58	2-year
		23	6	1.93	
121	09 / 22 / 06	2	2	1.70	
		3	2	2.08	2-year

Illinois State WATER Survey (1895)