DETERMINATION OF WATER USE IN ROCKFORD AND KANKAKEE AREAS, ILLINOIS

by John K. LaTour

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 90-4166

Prepared in cooperation with the

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

Urbana, Illinois

1991

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
4th Floor
102 E. Main Street
Urbana, IL 61801

Copies of the report can be
purchased from:

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GLOSSARY

BLOWDOWN.--Periodic discharge of water from boilers to lower dissolved-solids concentration and to remove sludge.

COMMERCIAL USE.--Water for motels, hotels, restaurants, office buildings, and other commercial facilities and institutions--both civilian and military. The water may be obtained from a public supply or may be self supplied.

COMMUNITY.--An incorporated town in the Rockford area or Kankakee area. They are Loves Park, North Park, and Rockford for the Rockford area; and Bourbonnais, Bradley, and Kankakee for the Kankakee area.

CONSUMPTIVE USE.--That part of withdrawn water that is evaporated, transpired, incorporated into products, consumed by people, or otherwise removed from the immediate water environment.

CONSUMPTIVE-USE RATIO.--The average of consumptive-use estimates from the consumption-budget and (or) types-of-use methods divided by the deliveries and (or) self-supply withdrawals.

CONVEYANCE LOSS OR GAIN.--Water that is lost or gained through faulty pipes, joints, and valves, or water gained from runoff directed to the conveyance system.

COOLING SYSTEM.--Device used to cool air or products by transferring heat to water and evaporating the water.

DELIVERY.--The amount of water received by water users after being conveyed by public suppliers. See water user.

DELIVERY RATE.--The average delivery to water users by category. See water user.

GLOSSARY

DIRECT RETURN.--Water discharged to ground- or surface-water sources by commercial, industrial, domestic, or municipal users. See return.

DOMESTIC USE.--Water for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. The water may be obtained from a public supply or may be self supplied. See household.

DRIFT.--Water droplets or mist that are emitted from cooling systems into the air.

ESTABLISHMENT.--A commercial, industrial, or municipal water user at a single physical location or one that is billed by a public supplier.

EVAPORATION.--Process by which water is changed from the liquid into vapor.

EVAPOTRANSPIRATION.--A collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and by plant transpiration.

GROUND WATER.--Generally all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water) where the water is under pressure greater than atmospheric.

HOUSEHOLD.--A house, an apartment unit, a group of rooms, or a single room occupied as a separate living quarters where occupant(s) live and eat separately from other persons. For example, a single-family household or an apartment unit within an apartment complex (U.S. Bureau of Census, 1980, p. B-1). Also referred to as occupied housing unit by the U.S. Bureau of Census.

INDUSTRIAL USE.--Water used for industrial purposes such as fabrication, processing, washing, and cooling, and includes such industries as steel, chemical and allied products; and paper and allied products. The water may be obtained from a public supply or may be self-supplied.

MAJOR WATER USER.--An establishment that can be categorized as commercial or industrial and typically uses more than 1 million gallons of water per month for two or more consecutive months.

MUNICIPAL USE.--Water supplied from a public supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools. This is also referred to as "PUBLIC WATER USE" by the Branch of Water-Use Information, U.S. Geological Survey.

PER CAPITA USE.--The average amount of water used per person per day.

PLANT MANAGER.--Someone who monitors the water usage of a commercial, industrial, or municipal water user(s). This person typically is employed by the water user. See water-utility manager.

GLOSSARY

PUBLIC SUPPLY.--Water withdrawn by public and private water suppliers and delivered to groups of users.

PUBLIC-WATER SYSTEM.--A public water-supply and (or) sewage-treatment network.

RELEASE.--Water discharged after use to a sewer and eventually treated by a sewage-treatment plant.

RETURN.--Water that reaches a ground- or surface-water source after being used and thus becomes available for further use. The water may be returned by sewage-treatment plants (sewage-treatment return) or by commercial, industrial, domestic, or municipal users (direct return).

SELF-SUPPLIED WATER.--Water withdrawn from a ground- or surface-water source by a user rather than being obtained from a public supply.

SEPTIC-SYSTEM USER.--A water user that releases water to a septic system instead of to a sewage-treatment plant.

SEWAGE-TREATMENT RETURN.--Water discharged to ground- or surface-water sources by sewage-treatment plants.

SEWER FEE.--An assessment paid by water users for the treatment of wastewater. The fees are typically determined according to the water users deliveries and (or) self-supply withdrawals unless the water user can verify by meters that releases are less than deliveries.

SURFACE WATER.--An open body of water, such as a stream or a lake.

WATER USE.--The quantity and the distribution of water from the point it is withdrawn from a source to the point it is consumed or returned.

WATER-USE CATEGORY.--Water use grouped by type of use. The categories in this report are commercial, industrial, domestic, municipal, public supply, and sewage treatment.

WATER USER OR USER.--An establishment or household at a single physical location or one that is billed by a public supplier.

WATER UTILITIES.--Public-supply or sewage-treatment plants that are publicly or privately owned.

WATER-UTILITY MANAGER.--A person who operates a public-supply and (or) sewage-treatment plant.

WITHDRAWAL.--Water removed from the ground or diverted from a surface-water source by public or self-suppliers.

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To Obtain
	Length	
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09294	square meter (m^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per month (Mgal/mo)	0.0014132	cubic meter per second (m^3/s)
million gallons per year (Mgal/yr)	0.0001177	cubic meter per second (m^3/s)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

DETERMINATION OF WATER USE IN ROCKFORD AND KANKAKEE AREAS, ILLINOIS

by John K. LaTour

ABSTRACT

Amounts of water withdrawn, delivered, consumed, released, returned, and lost or gained during conveyance were determined for six communities--Rockford, Loves Park, North Park, Kankakee, Bourbonnais, and Bradley--served by the public-water systems in the Rockford and the Kankakee areas of Illinois. Water-use categories studied were commercial, industrial, domestic, and municipal uses; public supply; and sewage treatment. The availability and accuracy of water-use data are described, and water-use coefficients and methods of estimating water use are provided to improve the collection and the analysis of water-use information.

Water-use data were obtained from all the water utilities and from 30 major water users in the Rockford and the Kankakee areas. Data were available for water withdrawals by water suppliers; deliveries by water suppliers to water users; returns by sewage-treatment plants and water users; releases by water users to sewers; and sewer-conveyance losses.

Accuracy of the water-use data was determined from discharge measurements or reliability tests of water meters, or was estimated according to the completeness of the data. Accuracy of withdrawal and sewage-treatment-return data for the Rockford area and of withdrawal, delivery, industrial release, and sewage-treatment-return data for the Kankakee area was considered to be at least 90 percent.

Where water-use data were inadequate or unavailable, various methods were used to estimate consumptive uses; releases; returns by commercial, domestic, and municipal users; and conveyance losses and gains. The methods focused on water budgeting to assure that water uses balanced. Consumptive uses were estimated by use of the consumption-budget method, the types-of-use method, consumptive-use ratios, the winter base-rate method, and the maximum lawn-watering method. The winter base-rate method provided the best domestic consumptive-use estimates, whose ratios (consumptive use from the winter base-rate method divided by deliveries and self-supply withdrawals), by community, ranged from 0.03 to 0.136 and averaged 0.068. The consumption-budget and types-of-use methods, as well as consumptive-use ratios, were used to estimate consumptive use for commercial, industrial, and municipal categories. Water budgeting was generally used to estimate releases, and conveyance losses and gains. Estimates of nonconsumptive uses by cooling systems, boilers, and lawn watering; data of deliveries to septic-system owners; and (or) water budgeting were used to estimate commercial, domestic, industrial, and municipal returns.

Proportions of water use were similar in the Rockford and the Kankakee areas. Of the public-supply withdrawals in each area, about one-half was

delivered for commercial and industrial uses; about one-third for domestic use; and about one-sixth for municipal use and public-supply conveyance losses. Consumptive use by all water users in the Rockford and the Kankakee areas was 13 ±1 percent, releases were 78 ±2 percent, and returns were 9 ±2 percent of deliveries and self-supply withdrawals. Total returns were greater than total withdrawals in the two areas because of sewer-conveyance gains, which amounted to about 34 percent of the sewage-treatment returns for each area.

Delivery rates (deliveries divided by the number of users [establishments or households]) and domestic per capita use were similar for all six communities. At a 95-percent confidence level, domestic delivery rates for each community range from 0.067 to 0.075 million gallons per household per year. Commercial delivery rates range from 0.277 to 0.535 million gallons per establishment per year. Delivery rates for all categories combined range from 0.100 to 0.192 million gallons per user per year. Domestic per capita use, which ranged from 67.2 to 71.0 gallons per day, averaged 69.2 ±1.1 gallons per day.

INTRODUCTION

Reliable *water-use*[1] data are needed to help resolve supply problems arising from competing uses of water and shortages of water attributed to *withdrawals* and drought. Supply problems resulting from declining ground-water levels and (or) poor quality of water, particularly in northeastern Illinois, have forced politicians to reallocate water from various sources. Although their decisions on allocation and (or) conservation have been based on water-use data, the accuracy of the data is generally unknown. As water resources continue to diminish, deteriorate, and (or) become more costly, sound allocation and use policies, based on reliable water-use data, will become increasingly important.

Managers of some *public-water systems* have had to estimate water use because of insufficient data. Water-use data for Illinois (Solley and others, 1988; Kirk, 1987) have generally been limited to those for withdrawals and *returns* of water. Knowledge of amounts of water delivered to and *released* by *water users* (*establishments* and *households*), and amounts withdrawn from and returned to water sources is essential for estimating *consumptive uses* and *conveyance losses and gains*. *Water-utility managers* of public-supply and sewage-treatment facilities need water data to determine whether supplies and capacities for conveyance are adequate for current and future demands.

Reliable water-use data and methods for estimating water use can be obtained from studies of water use at specific sites. A study of water use in the Rockford and the Kankakee areas of Illinois by the U.S. Geological Survey, in cooperation with the Illinois Environmental Protection Agency, was done to devise methods and techniques for improving collection and analysis of water-use data.

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[1] Italicized terms are defined in the Glossary.

Purpose and Scope

This report (1) describes the water-use data available from water-utility managers and water users in the Rockford and the Kankakee areas of Illinois during 1984, (2) presents an evaluation of the accuracy of these data, and (3) describes methods and water-use coefficients for estimating water use.

The report contains data and estimates on water withdrawal, *delivery*, consumptive use, release, return, and conveyance loss and gain for six communities served by the public-water systems of the Rockford and the Kankakee areas. The *water-use categories* studied were *commercial*, *industrial*, *domestic*, and *municipal uses*; *public supply*; and sewage treatment. Water-use information for the first four categories is limited to water users that receive water from a public-water supplier and (or) release water to a sewage-treatment plant in the Rockford and the Kankakee areas.

Description of the Study Areas

Rockford Area

The Rockford area, in northern Illinois, is about 88 mi (miles) northwest of Chicago (fig. 1). Its total population is 168,710: 1.5 percent of Illinois' 1980 population of 11.4 million (U.S. Bureau of Census, 1980). In this report, "Rockford area" refers to the incorporated communities of Rockford, Loves Park, and North Park. The populations of Loves Park and North Park, primarily residential communities north of Rockford (fig. 1), are 13,192 and 15,806 (U.S. Bureau of Census, 1980).

The Rockford area has three public-water suppliers (one for each *community*). *Ground water* is supplied through 31-, 30-, and 111-year-old conveyance systems in Loves Park, North Park, and Rockford. There are 1,212 self-suppliers that withdraw from ground-water sources.

The entire Rockford area is served by one sewage-treatment plant. The plant and the sewer-conveyance system for the community of Rockford are about 50 years old; however, the sewer-conveyance systems for Loves Park and North Park are newer. Water treated at the sewage-treatment plant is returned to the Rock River.

Kankakee Area

The Kankakee area, in northern Illinois, is about 64 mi south of Chicago (fig. 1). Its total population is 54,429: 0.5 percent of Illinois' 1980 population (U.S. Bureau of Census, 1980). In this report, "Kankakee area" refers to the incorporated communities of Kankakee, Bourbonnais, and Bradley. The populations of Bourbonnais and Bradley, primarily residential areas north of Kankakee (fig. 1), are 13,280 and 11,008 (U.S. Bureau of Census, 1980).

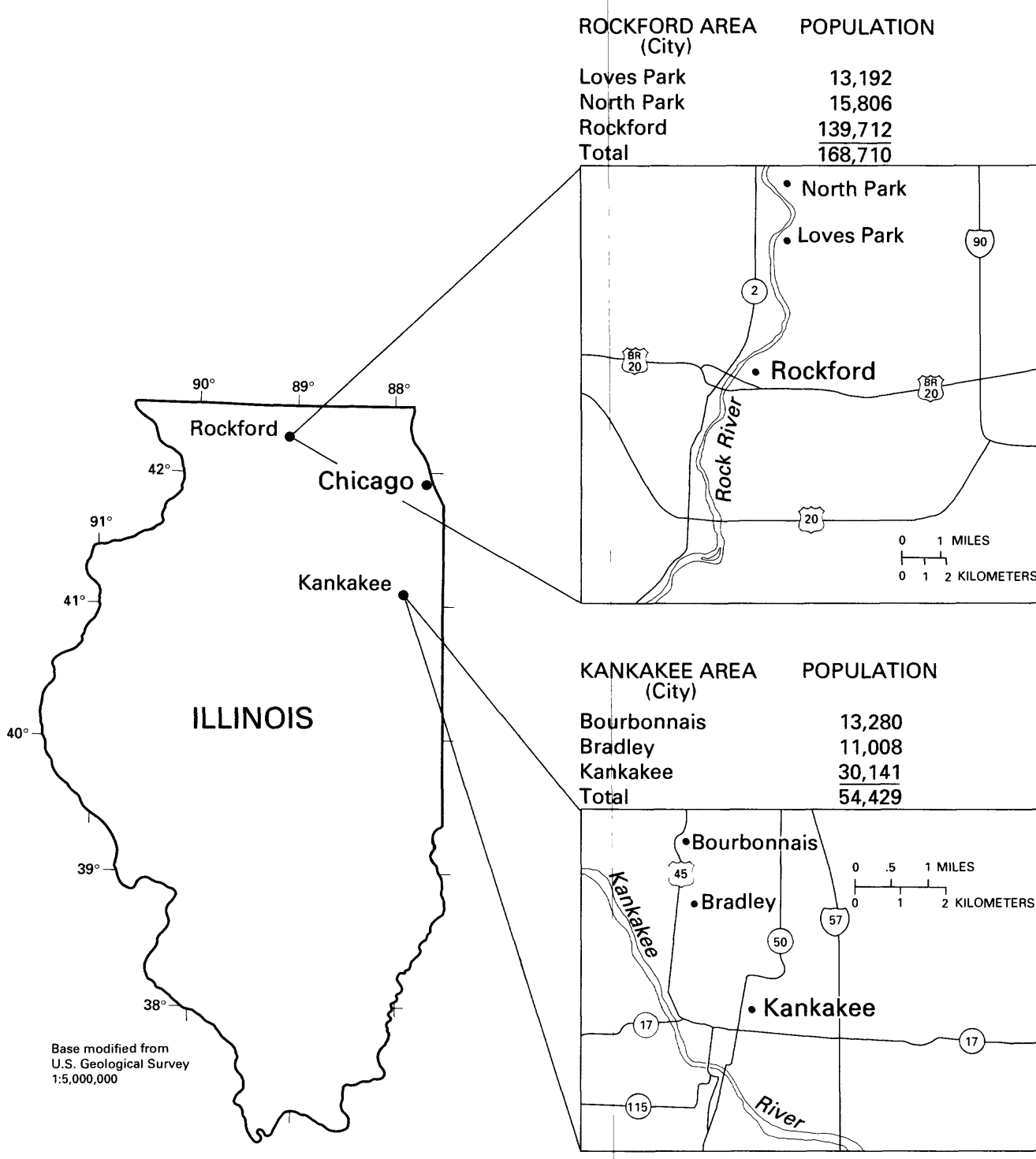

Figure 1.---Locations and populations of Rockford and Kankakee areas, Illinois, 1984 (populations from U.S. Bureau of Census, 1980).

The Kankakee area has one public-water supplier and three self-suppliers. *Surface water* from the Kankakee River is delivered to various users in the area through a 99-year-old conveyance system. Self-suppliers withdraw ground water.

There are three sewage-treatment plants in the area (one for each community). Unlike the Rockford area's distinct storm and sanitary sewer-conveyance systems, the Kankakee area has a combined system. In general, sewage and precipitation runoff are routed through one conveyance system from each community to the sewage-treatment plants. However, when rainfall exceeds roughly one-half inch, water discharges from the six overflow weirs in the system to the Kankakee River. Although the sewer-conveyance system is about 50 years old, several sewer additions, overflow weirs, and pumps were added about 1950. All three sewage-treatment plants return treated water to the Kankakee River downstream from the public supply.

Acknowledgments

Cooperation from city officials, water-utility managers, and water users was essential for obtaining water-use data. The following city officials cooperated with the effort: Mayor Kenneth Hayes of Bradley; Mayor John McNamara of Rockford; Mayor Ernest Mooney of Bourbonnais; Mayor Tom J. Ryan, Jr. of Kankakee; and Mayor Joseph Sinkiawic of Loves Park.

Most water-use data were collected from *water utilities*. The following water-utility managers contributed water-use data:

Jerry Pombert, Wastewater Treatment Plant, Bourbonnais;
Robert Cullins, Wastewater Treatment Plant, Bradley;
Jack Dewgan, Water Department, Bradley;
James Clarno, Department of Water Pollution Control, Kankakee;
Charles H. Smith and Joseph F. Donovan, Kankakee Water Company;
Steve Urbelis, Water Department, Loves Park;
Dennis Leslie, Public Water District, North Park;
George Brettrager, Water Department, Rockford; and
John Olson and Richard Eick, Sanitary District, Rockford.

The cooperation of the following water-utility personnel was helpful in the study:

Robert E. La Fontaine, Sherri Gessner, and Cliff Evans, Kankakee Water Company;
Patricia Schatz, Department of Water Pollution Control, Kankakee;
Pat Smith, Water Department, Loves Park;
Sharon Sherwood, Public Water District, North Park;
Ella Fromm, Katherine Paolucci, and Betty Schulz, Water Department, Rockford; and
Doris Brady, Cal Kahl, Diane Scales, and Dee Kudzma, Sanitary District, Rockford.

Finally, the cooperation of all the *plant managers*, plant engineers, and maintenance supervisors of major water users was helpful, and a special thanks is extended to Steven C. Anderson for his suggestions and time.

METHODS OF STUDY

The general criteria for selection of study areas were cities with populations greater than 50,000 in northern or central Illinois. The availability of water-use data and the cooperation of water-utility managers were essential. Water-utility managers from the Rockford and the Kankakee areas were contacted first. After an initial meeting, Rockford and Kankakee were chosen as the two study areas.

Data Collection and Review

Water-use data were collected in six incorporated communities served by public-water systems (public-supply and (or) sewage treatment) in the Rockford and the Kankakee areas. Data were also collected for all unincorporated subdivisions served by the public-water systems in the two areas. The small residential water uses in these subdivisions were included in the communities of Rockford or Kankakee.

Managers of all water utilities and several *major water users* were asked to provide data on withdrawals, deliveries, consumptive uses, releases, returns, and conveyance losses and gains. Major water users included commercial and industrial establishments that use more than 1 Mgal (million gallons) of water per month for two or more consecutive months. All water utilities were visited, and plant managers of the major water users were contacted for information that the water utilities could not provide.

Conceptual water-use models (figs. 2 and 3) showing the association of water withdrawals, deliveries, consumptive uses, releases, returns, and conveyance losses and gains were developed for the study areas. These models were used as guides to balance water uses and to identify unreasonable water-use data or estimates.

Review of the data revealed that estimating techniques were needed. The techniques are described, along with the estimated results, in the subsections of "Determination of Water Use."

Water-Utility Data

Water-use data were obtained from all water utilities. These data were entered into computer files and were reviewed for (1) missing information, (2) overlapping and inconsistent dates, (3) large deviations (20 percent) between monthly measurements, and (4) reporting units (cubic feet, gallons, million gallons). All the data were converted to million gallons per time. Water-utility managers were contacted to resolve questions on the data or to provide estimates of the water use.

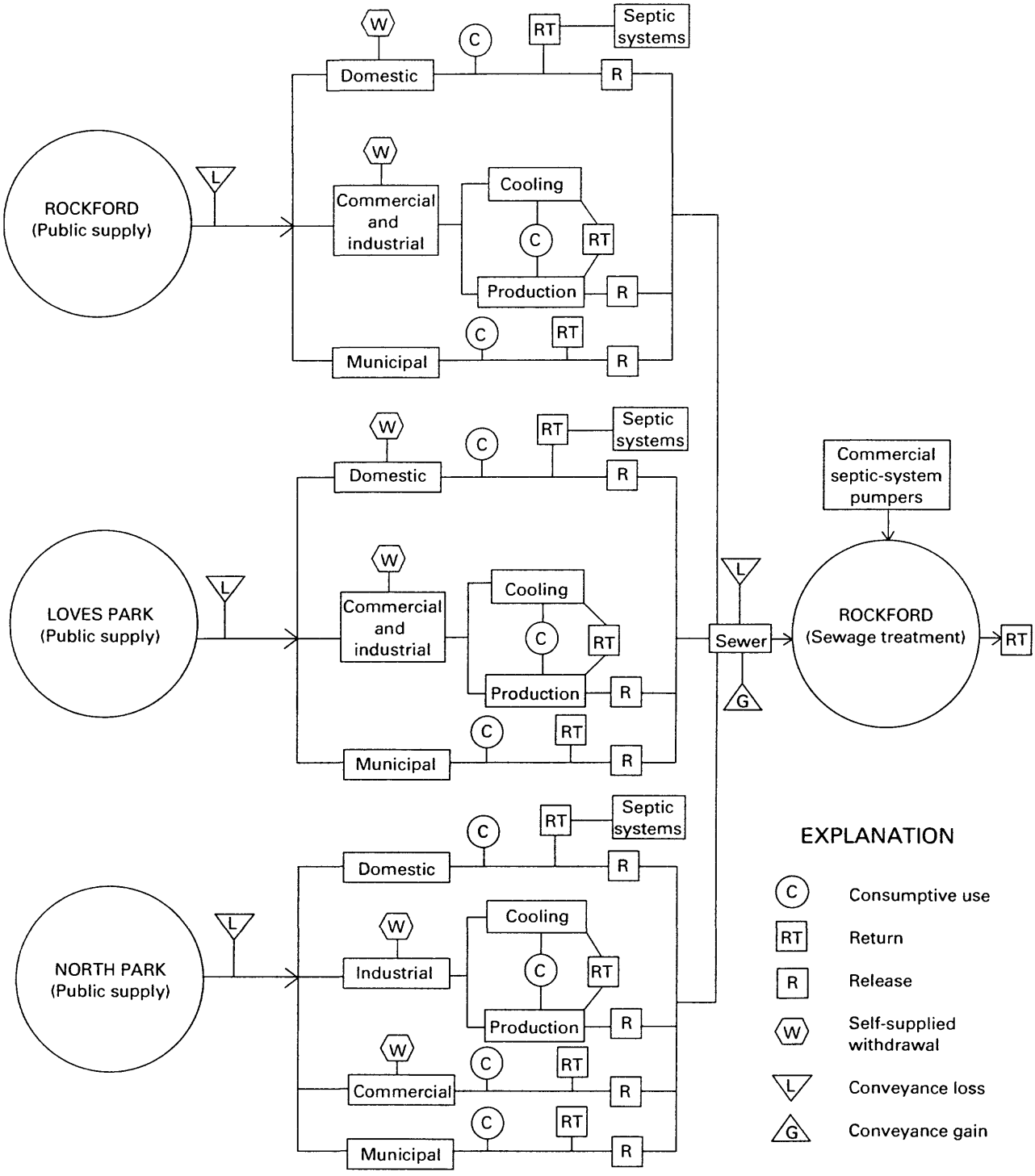

Figure 2.---Water-use model for Rockford area.

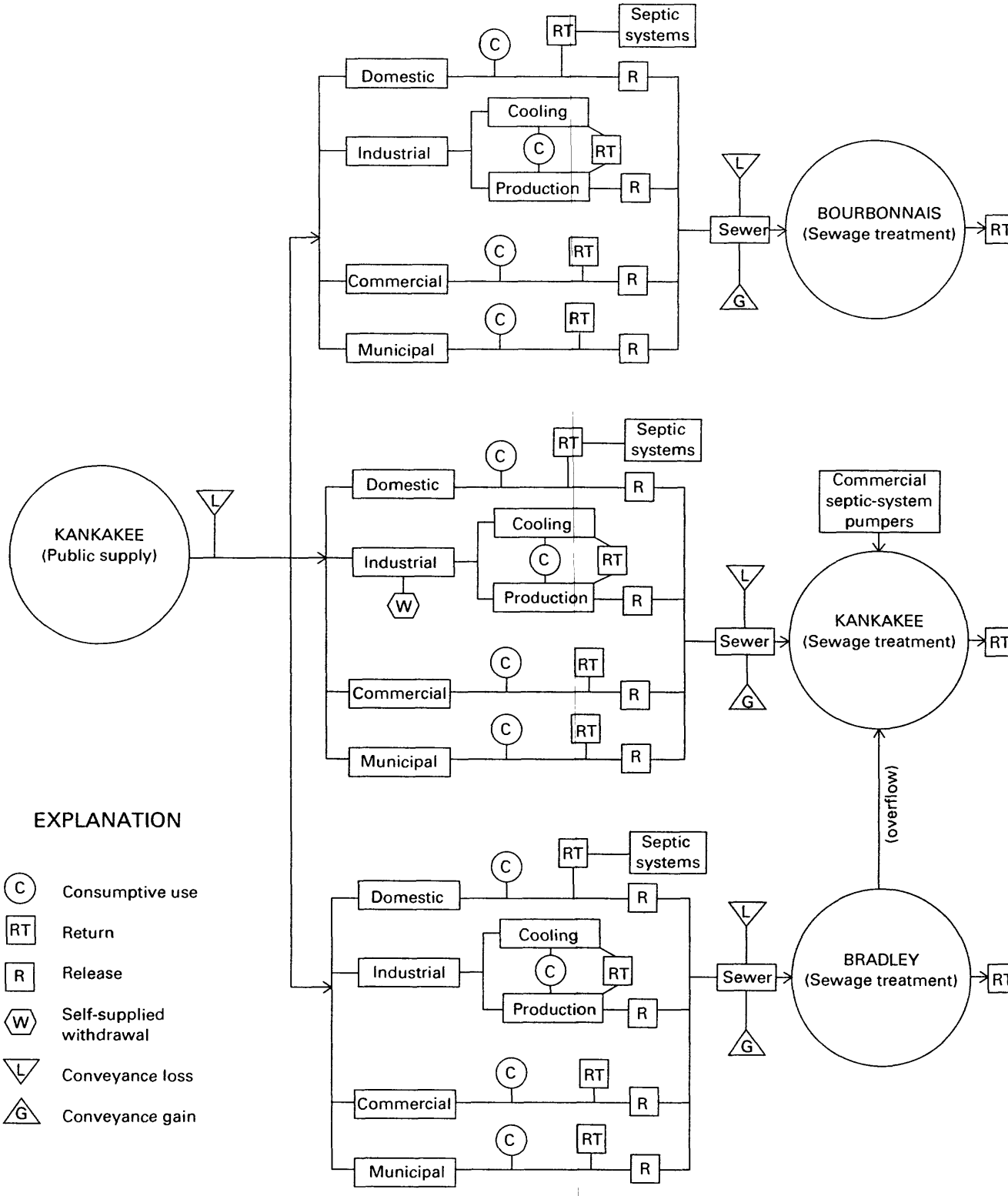

Figure 3.---Water-use model for Kankakee area.

Rockford area

Water utilities in this area maintain records of withdrawals, deliveries, releases, some returns, and some public-supply conveyance losses. The frequencies and the types of water-use data obtained are listed in table 1.

Table 1.--Frequency of collection and types of water-use data obtained from water utilities in the Rockford area, Illinois, 1984

[D, daily; M, monthly; B, bimonthly; Q, quarterly; V, variable; dash indicates no records available; records may not be complete]

Types of water-use data	Loves Park	North Park	Rockford
Withdrawals:			
Public-supplied[1]	D	D	D
Self-supplied[2]	Q	Q	Q
Public-supply conveyance losses[1]:	M	-	M
Deliveries[3]:			
Commercial	M	M	Q
Domestic	M	B	Q
Industrial	M	M	Q
Municipal	M	B	M
Releases[2]:			
Commercial	Q	Q	Q
Domestic	Q	Q	Q
Industrial	Q	Q	Q
Municipal	Q	Q	Q
Returns:			
Commercial[2]	-	-	Q
Domestic[2]	-	B	Q
Industrial[2]	-	-	V
Municipal[3]	Q	B	-
Sewage treatment[2]	D	D	D

[1]Data collected by public suppliers.
[2]Data collected by sewage-treatment plants.
[3]Data collected by sewage-treatment plants and public suppliers.

Water-use data obtained from the Rockford Water Department included public-supply withdrawals, deliveries per category for 150 meter-reading routes, deliveries to individual major water users, updates to delivery records, percentages of commercial and industrial usage per route, and public-supply conveyance losses (table 1).

Loves Park Water Department and North Park's Public Water District provided public-supply withdrawal and delivery data. Estimates of public-supply conveyance losses also were obtained from Loves Park Water Department.

The Rockford Sanitary District provided the following data:

1. Billing summaries, which included metered or estimated water releases by category (commercial, domestic, industrial, and municipal).

2. Individual commercial and industrial releases, which included location number (location of establishment), date of water-meter-reading, category of use, meter reader, two-digit Standard Industrial Classification (SIC) code (Office of Management and Budget, 1987), name of establishment, and quantity of water released by establishment.

3. Plant data, which included water returns by the Rockford Sanitary District and precipitation.

In addition, information compiled from the Sanitary District's files included self-supplied withdrawals; and deliveries used for *cooling systems*, boilers, lawn sprinklers, swimming pools, and septic systems that became consumptive uses and (or) *direct returns*. These data are available because the Sanitary District bills water users, who release water to the District, according to their self-supply withdrawals, deliveries, and (or) releases. Therefore, water users with large consumptive uses and (or) direct returns will meter these uses so they are not billed for water not released to the Sanitary District.

Kankakee area

The frequency and the types of water-use data for this area are listed in table 2. Public-supply withdrawal and delivery data were obtained from the Kankakee Water Company. The data included withdrawals by the water company, deliveries to various major water users, total deliveries in the Kankakee area for municipal uses, and deliveries by meter-reading route for commercial, domestic, industrial, and school categories. In this report, water use by schools is a commercial use.

The Kankakee Department of Water Pollution Control provided data on *sewage-treatment returns*, self-supply withdrawals, releases and returns for 14 of the 29 industrial establishments, releases for some commercial establishments, and precipitation. Data on sewage-treatment returns for the communities of Bourbonnais and Bradley were obtained from their sewage-treatment plants.

Table 2.--Frequency of collection and types of water-use data obtained from water utilities in the Kankakee area, Illinois, 1984

[D, daily; M, monthly; V, Variable; dash indicates no records available; records may not be complete]

Types of water-use data	Bourbonnais	Bradley	Kankakee
Withdrawals:			
Public-supplied[1]	D	D	D
Self-supplied[2]	-	-	M
Deliveries[1]:			
Commercial	M	M	M
Domestic	M	M	M
Industrial	M	M	M
Municipal	M	M	M
Releases[2]:			
Commercial	-	-	V
Domestic	-	-	-
Industrial	M	M	M
Municipal	-	-	-
Returns[2]:			
Commercial	-	-	-
Domestic	-	-	-
Industrial	M	-	M
Municipal	-	-	-
Sewage treatment	D	D	D

[1]Data collected by public suppliers.
[2]Data collected by sewage-treatment plants.

Major Water-User Data

Thirty-two major water users--20 in the Rockford area, 12 in the Kankakee area--were asked to provide data on the amounts of water:

1. Withdrawn from surface- and (or) ground-water sources (self-supplied withdrawals);

2. Received from a public supplier (deliveries);

3. Lost by *evaporation* or by incorporation into product (consumptive uses);

4. Released to sewers and eventually treated by sewage-treatment plants (releases); and

5. Returned by water users to surface water sources (direct returns).

Because of the large number of major water users in the Rockford area, 20 were randomly contacted. In the Kankakee area, all 12 were contacted. Most of the data were provided as meter readings. These data were converted to flow by taking the difference between beginning and ending readings. Of the 32 major water users, 30 provided adequate data for at least one of the preceding five items. Data were considered to be adequate if more than 2 months of data were available.

Some water uses for major water users were estimated from partial data. If at least 2 months of data were available, monthly estimates were based on the average monthly use for the period represented by the data. The average was applied to the months lacking data. This technique was used only for major water users that were in production year round.

Although water-meter readings were taken daily, weekly, monthly, bimonthly, or quarterly by the cooperating major water users, all data were converted to monthly estimates for analysis. For bimonthly and quarterly data, a daily average was determined and then was multiplied by the number of days in each month of the period. In this method, any seasonal change is assumed to be represented by the bimonthly and quarterly data; and daily use is assumed to be constant during the period represented by the data.

Accuracy of Water-Use Data

The accuracy of withdrawal, delivery, release, and return data is indicated by ratings of good, fair, or poor. "Good" signifies that the data have an error less than 10 percent; "fair" signifies an error between 10 and 25 percent; and "poor" signifies an error greater than 25 percent. Ratings of accuracy were not assigned to estimates.

Initially, discharge measurements by the U.S. Geological Survey were used to determine the accuracy of data. Discharge was measured at several major water-user release sites and at all sewage-treatment-return sites. At least two measurements were made at water-metered sites equipped with open-water flumes, weirs, or dams. Discharge was measured by conventional current-meter methods (Rantz and others, 1982, p. 79-151) or, where possible, by the volumetric method (Rantz and others, 1982, p. 262-263). The discharge measurements were started and were stopped with digit changes on the water meter in order to relate the

measurements to the water-meter readings. Percentage differences between the meter readings and the discharge measurements were calculated. Percentage differences for each site were averaged and then were multiplied to the metered data as an adjustment to the data. The percentage difference between total adjusted data and total unadjusted data of all measured sites indicated the accuracy of the data. Data were adjusted temporarily to show accuracy only, not to correct them. A percentage difference was used only if a discharge measurement was rated as good or fair and if the adjusted temporary value balanced with other related water uses.

Where available, reliability tests of meters made by water utilities were used to determine the accuracy of data. The overall accuracy was determined by the average percentage difference between the water-meter readings and the test-meter readings of all meters tested at typical flow rates.

If neither discharge measurements nor meter tests were available, the accuracy of data was estimated by the completeness of the data. If data were available for all water users (establishments and households), a rating of "good" was assigned. If data were available for at least three-fourths of the water users, but some estimation was required, a rating of "fair" was assigned. If data were available for less than three-fourths of the water users and most water uses were estimated, a rating of poor was assigned. Water-utility managers were consulted to determine the approximate percentage of water users that were documented by data.

DETERMINATION OF WATER USE

The number of commercial and industrial establishments per person in the Rockford and the Kankakee areas is the same (0.02); however, the number and type of establishments in the two areas differ. In the Rockford area, there are 3,352 commercial and industrial establishments, 61,865 households (domestic), and 64 municipal establishments on public supplies. There are 113 commercial, 1,056 domestic, and 43 industrial users that are self-supplied. In the Kankakee area, 1,127 commercial, 29 industrial, 16,657 domestic, and 33 municipal users are on public supplies. Only three industries are known to be self-supplied. The water users in the Rockford and the Kankakee areas are listed by SIC code in table 3.

Water Uses

Data and estimates of water use in the Rockford and the Kankakee areas are presented in the order that water is used, except for conveyance losses and gains, which are presented last. Also presented are the source and the accuracy of the data, the methods of estimation (if applicable), and water-use coefficients (if determined). Accuracy was not determined for estimates.

Table 3.--Water users by Standard Industrial Classification (SIC) code in the Rockford and the Kankakee areas, Illinois, 1984

SIC code	Description
07	Agricultural services
15-17	Construction/contractors
20	Food and kindred products
23[r]	Apparel and other finished fabric products
24[r],25[r],26	Wood products (lumber, furniture, and paper)
27	Printing and publishing
28-29[r]	Chemical and petroleum products
30	Rubber and miscellaneous plastics
32	Stone and concrete products
33	Primary metal industries
34	Fabricated metal products except machinery and transportation equipment
35[r]	Industrial and commercial machinery and computer equipment
36	Electronic and other electrical machinery except computer equipment
37[r]	Transportation equipment
38[r]-39[r]	Measuring, analyzing, and controlling instruments and miscellaneous manufacturing
40	Railroad transportation
41	Local and suburban passenger transportation
42	Motor-freight transportation and warehousing
43	U.S. Postal Service
45[r]	Air transportation
47	Transportation services
48	Communications
49	Electric, gas, and sanitary services
50-53	Wholesale trade; retail trade including building materials and general merchandise stores
54	Food stores
55-57	Automobile dealers, service stations, apparel stores, and home furnishings
58	Eating and drinking places
59	Miscellaneous retail
60-65	Finance, insurance, and real estate
67	Investment offices
70	Lodging establishments
72	Personal services
73	Business services
75	Automotive-repair services
76	Miscellaneous-repair services
78	Motion pictures
79	Amusement and recreation services
80	Health services
81	Legal services
82	Educational services
83	Social services
84	Museums
86	Membership organizations
88	Domestic
89	Miscellaneous services
91-96	Governmental services
97[r]	National security
99	Nonclassifiable

[r] Rockford area only.

Withdrawals

The public suppliers in the Rockford and the Kankakee areas document all public-supply withdrawals (table 4). Withdrawal data for all known *self-supplied water* users were available from sewage-treatment plants because self-supplied water users that release water to the sewer-conveyance systems are assessed sewage-treatment fees based on their withdrawals (table 5). Self-supplied withdrawals not included in this study are by self suppliers that do not release to a sewage-treatment plant or are unrecognized or are illegally connected to the sewer-conveyance systems. Total withdrawals (public and self supply) for the Rockford and the Kankakee areas are listed in table 6. In the Rockford area, public-supply withdrawals were 97 percent of that area's total withdrawals. In the Kankakee area, public-supply withdrawals were 99 percent of that area's total withdrawals.

Because data were available for all public-supply withdrawals and self-supplied withdrawals served by the public-water systems in the Rockford and the Kankakee areas, the accuracy of the withdrawal data in both areas is considered to be good (refer to "accuracy of water-use data" section). Furthermore, public-supply withdrawals in the Rockford area are metered by propeller flowmeters whose expected accuracies are ±2 to ±5 percent (Walski, 1984, p. 223). In the Kankakee area, public-supply withdrawals are metered by Venturi and Dall flowmeters whose expected accuracies are ±1 percent (Walski, 1984, p. 223).

Deliveries

The public-water suppliers in the Rockford and the Kankakee areas collect delivery data for all known commercial, industrial, and domestic uses (table 7). Public suppliers also collect some municipal delivery data (table 7).

Although delivery data were available for the Rockford area, some deliveries by category had to be estimated. For the community of Rockford, data for commercial, domestic, and industrial deliveries were available; however, to determine water use by category would have required manually aggregating (from countless pages of computer printouts) the amounts of water used per household and establishment, each quarter, for each meter-reading route. Therefore, the commercial and the industrial deliveries were estimated as follows: The percentages of first-quarter deliveries that were commercial and industrial for each meter-reading route were determined from the total of the first quarter's (January through March) commercial and industrial deliveries. The total quarterly deliveries per meter-reading route were then multiplied by the percentages and aggregated to estimate quarterly commercial and industrial deliveries. The remaining deliveries were assumed to be domestic. For the community of Loves Park, the pipe size of water meters was used to determine categories of use. Deliveries recorded by water meters with pipes smaller than 1 in. (inch) were assumed to be domestic deliveries, and deliveries recorded by water meters with pipes equal to or greater than 1 in. were assumed to be commercial and industrial deliveries. In North Park, because of the small number of commercial and industrial establishments, the name of the establishment was used to distinguish between commercial and industrial deliveries.

Table 4.--Public-supply withdrawals in Rockford and Kankakee areas, Illinois, 1984

[All figures are in million gallons]

Month	Rockford area				Kankakee area
	Loves Park	North Park	Rockford	Total	
January	80.178	48.542	807.669	936.389	335.224
February	68.742	42.903	736.608	848.253	297.394
March	72.823	46.420	765.410	884.653	306.277
April	66.145	46.285	735.825	848.255	278.082
May	75.712	50.256	824.071	950.039	308.388
June	89.474	57.621	932.099	1,079.194	327.831
July	93.539	76.753	1,010.588	1,180.880	322.144
August	98.527	73.256	1,121.881	1,293.664	367.646
September	80.962	52.220	888.573	1,021.755	323.630
October	73.804	46.473	795.563	915.840	323.328
November	66.146	41.998	708.083	816.227	297.092
December	61.247	43.144	688.577	792.968	300.700
Total	927.299	625.871	10,014.947	11,568.117	3,787.736
Number of households and establishments	4,942	5,291	55,170	65,403	17,867

Table 5.--Self-supply withdrawals in the Rockford and the Kankakee areas, Illinois, 1984

[Dashes indicate no data; all figures are in million gallons]

Month	Rockford area										Kankakee area
	Loves Park[1]			North Park[1]			Rockford[1]			Total	
	Commercial	Domestic	Industrial	Commercial	Domestic	Industrial	Commercial	Domestic	Industrial		Industrial
January	0.731	0.012	0.060	0.011	--	0.030	7.085	3.174	13.915	25.018	0.981
February	.684	.012	.056	.010	--	.028	6.629	2.969	13.018	23.406	4.222
March	.732	.013	.060	.011	--	.030	7.086	3.175	13.915	25.022	4.383
April	1.182	.014	.095	.008	--	.032	7.443	3.890	17.978	30.642	3.699
May	1.221	.015	.098	.009	--	.033	7.690	4.020	18.578	31.664	3.062
June	1.182	.014	.096	.009	--	.033	7.443	3.891	17.978	30.646	3.045
July	2.508	.016	.571	.012	--	.043	9.014	6.146	19.568	37.878	1.747
August	2.509	.017	.571	.012	--	.043	9.015	6.147	19.569	37.883	3.440
September	2.427	.016	.552	.011	--	.042	8.724	5.948	18.937	36.657	3.627
October	1.700	.015	.353	.008	--	.041	7.384	3.959	17.812	31.272	5.528
November	1.646	.015	.342	.008	--	.039	7.146	3.832	17.238	30.266	1.113
December	1.700	.015	.353	.008	--	.040	7.384	3.959	17.812	31.271	2.773
Total	18.222	.174	3.207	.117	--	.434	92.043	51.110	206.318	371.625	37.620
Number of households or establishments	28	7	6	3	--	2	82	1,049	35	1,212	3

[1]Derived from quarterly records of sewage-treatment plants.

Table 6.--Total withdrawals in the Rockford and the Kankakee areas, Illinois, 1984

[All figures in million gallons]

Month	Public supply	Self supply[1]	Total
	Rockford area		
January	936.389	25.018	961.407
February	848.253	23.406	871.659
March	884.653	25.022	909.675
April	848.255	30.642	878.897
May	950.039	31.664	981.703
June	1,079.194	30.646	1,109.840
July	1,180.880	37.878	1,218.758
August	1,293.664	37.883	1,331.547
September	1,021.755	36.657	1,058.412
October	915.840	31.272	947.112
November	816.227	30.266	846.493
December	792.968	31.271	824.239
Total	11,568.117	371.625	11,939.742
	Kankakee area		
January	335.224	0.981	336.205
February	297.394	4.222	301.616
March	306.277	4.383	310.660
April	278.082	3.699	281.781
May	308.388	3.062	311.450
June	327.831	3.045	330.876
July	322.144	1.747	323.891
August	367.646	3.440	371.086
September	323.630	3.627	327.257
October	323.328	5.528	328.856
November	297.092	1.113	298.205
December	300.700	2.773	303.473
Total	3,787.736	37.620	3,825.356

[1]Derived from quarterly records of sewage-treatment plants (Rockford area only).

Table 7.--Deliveries by public suppliers in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons]

Month	Rockford area								
	Loves Park				North Park				
	Commercial and industrial[1]	Domestic[1]	Municipal	Total	Commercial	Domestic[2]	Industrial	Municipal[2]	Total
January	44.224	25.495	3.992	73.711	3.462	26.947	0.818	0.859	32.086
February	38.179	23.266	4.278	65.723	3.269	25.209	1.325	.804	30.607
March	44.295	23.973	4.448	72.716	3.063	25.447	1.347	.825	30.682
April	36.988	25.190	2.511	64.689	3.156	24.626	1.569	.798	30.149
May	49.872	28.488	2.391	80.751	3.170	35.243	1.370	.788	40.571
June	43.765	31.170	3.547	78.482	4.236	34.107	2.285	.762	41.390
July	44.442	38.638	2.448	85.528	5.584	44.292	2.661	.866	53.403
August	50.272	35.344	2.497	88.113	5.833	44.293	2.503	.867	53.496
September	42.270	28.926	2.406	73.602	4.728	34.248	1.674	1.147	41.797
October	44.368	27.647	3.518	75.533	3.805	35.390	1.174	1.185	41.554
November	31.859	24.612	4.178	60.649	3.509	29.012	.741	.871	34.133
December	34.327	26.257	2.957	63.541	3.265	29.979	.572	.900	34.716
Total	504.861	339.006	39.171	883.038	47.080	388.793	18.039	10.672	464.584
Number of households or establishments	237	[3]4,693	12	4,942	135	[3]5,003	15	16	5,169

Table 7.--Deliveries by public suppliers in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Rockford area				Kankakee area				
	Rockford				Bourbonnais				
	Commercial and industrial[4]	Domestic[4]	Municipal	Total	Commercial	Domestic	Industrial	Municipal[5]	Total
January	432.823	271.792	2.551	707.166	4.377	23.489	8.947	2.020	38.833
February	404.899	254.257	2.387	661.543	4.708	23.730	7.745	1.897	38.080
March	432.823	271.793	2.552	707.168	3.784	21.232	8.612	2.506	36.134
April	487.971	289.279	1.908	779.158	4.681	24.811	8.703	1.632	39.827
May	504.237	298.921	1.972	805.130	4.138	22.462	9.305	2.228	38.133
June	487.972	289.279	1.908	779.159	5.025	26.012	10.396	1.969	43.402
July	529.989	344.681	3.607	878.277	4.627	25.687	10.011	1.965	42.290
August	529.989	344.681	3.607	878.277	4.558	29.357	10.479	2.174	46.568
September	512.892	333.562	3.491	849.945	4.430	26.648	7.730	2.395	41.203
October	340.993	256.754	7.545	605.292	4.361	24.487	7.511	2.724	39.083
November	329.994	248.471	7.302	585.767	4.086	23.752	6.147	2.408	36.393
December	340.994	256.753	7.545	605.292	4.137	23.255	6.745	2.614	36.751
Total	5,335.576	3,460.223	46.375	8,842.174	52.912	294.922	102.331	26.532	476.697
Number of households or establishments	2,965	[3]52,169	36	55,170	126	3,967	1	5	4,099

Table 7.--Deliveries by public suppliers in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Kankakee area									
	Bradley					Kankakee				
	Commercial	Domestic	Industrial	Municipal[5]	Total	Commercial	Domestic[6]	Industrial	Municipal[5]	Total
January	3.642	25.978	0.351	4.040	34.011	37.704	49.252	88.417	7.407	182.780
February	3.439	20.695	.941	3.793	28.868	37.538	46.251	90.077	6.954	180.820
March	3.204	21.652	1.637	5.011	31.504	36.278	46.642	92.519	9.187	184.626
April	3.369	21.393	2.017	3.263	30.042	40.090	47.550	94.814	5.983	188.437
May	3.080	23.602	2.205	4.456	33.343	40.692	49.517	97.013	8.171	195.393
June	3.716	23.585	3.018	3.938	34.257	45.738	51.016	99.351	7.220	203.325
July	3.743	24.948	3.158	3.929	35.778	44.437	53.461	83.211	7.204	188.313
August	4.004	25.594	3.107	4.348	37.053	47.813	56.770	98.144	7.973	210.700
September	3.477	24.690	2.577	4.790	35.534	40.183	49.031	114.048	8.783	212.045
October	3.790	22.212	2.229	5.448	33.679	37.673	46.273	94.693	9.988	188.627
November	3.309	23.142	1.987	4.816	33.254	33.145	43.374	98.043	8.830	183.392
December	3.758	21.176	1.766	5.228	31.928	35.382	43.985	78.242	9.584	167.193
Total	42.531	278.667	24.993	53.060	399.251	476.673	583.122	1,128.572	97.284	2,285.651
Number of households or establishments	141	3,915	2	10	4,068	860	8,775	26	18	9,679

[1]Estimated from data where water meters equal to or greater than 1 inch were assumed to be commercial and industrial, and meters smaller than 1 inch were assumed to be domestic.
[2]Derived from bimonthly data.
[3]U.S. Bureau of Census, 1980.
[4]Estimated from a sampling of quarterly data and the percentage of total deliveries that were commercial and industrial. The remainder were domestic.
[5]Municipal deliveries for the Kankakee area were separated into communities by percentages determined from the number of municipal establishments in each community.
[6]Contains several unincorporated subdivisions.

The overall accuracy of delivery data for the Rockford area is considered fair (10- to 25-percent error) because some deliveries by category had to be estimated. The accuracy of the municipal delivery data is considered to be poor (greater than 25-percent error) because data were available for about one-half of the deliveries (George Brettrager, Rockford Water Department, oral commun., 1985).

For the Kankakee area, delivery data were available for all categories. However, delivery data for municipal use were not available by community. Municipal deliveries by community for the Kankakee area were determined based on the number of municipal establishments in each community.

The overall accuracy of delivery data for the Kankakee area is good; however, the accuracy of municipal delivery data should be considered poor, because data were available for about one-half of the deliveries (C.H. Smith, Kankakee Water Company, oral commun., 1985). In reliability tests of water meters, the Kankakee Water Company (Cliff Evans, Kankakee Water Company, written commun., 1986) found that the meters registered 83.9, 99.9, and 100.1 percent of the flows for introduced flows of 0.25, 2.0, and 12.0 gal/min (gallons per minute). The Kankakee Water Company has tested nearly 400 propeller- and diaphragm-type meters used by all categories since 1978. According to Hudson (1964), 77 percent of domestic uses are at flow rates of 0.25 gal/min or greater. On the basis of Hudson's percentages of domestic use at the three flow rates tested, the average domestic delivery for Kankakee, and the test results; domestic-delivery data were estimated to be underregistered by only 2 percent. The test results also indicate that delivery data from flows equal to or greater than 2.0 gal/min should be within 1-percent error. Because flow rates of domestic uses are typically smaller than flow rates of other categories of use, the flow rates of other categories of use should be greater than 2 gal/min and thus data accuracy would be expected to be less than 1 percent.

The use of *delivery rates* (deliveries divided by the number of water users [establishments or households] by category) as coefficients in the estimation of deliveries for other water systems was evaluated. Delivery rates are listed by category and community in tables 8 and 9.

The standard deviation for domestic-delivery rates is 0.005 (Mgal/H)/yr (million gallons per household per year) or about 7 percent of the mean domestic rate 0.071 (Mgal/H)/yr. For all categories--commercial and industrial, domestic, and municipal--the standard deviation is 0.056 (Mgal/user)/yr (millions gallons per user per year) or about 38 percent of the mean rate 0.146 (Mgal/user)/yr. On the basis of the confidence intervals of the mean rates for each community, typical domestic deliveries for these communities should be 0.071 ±0.004 (Mgal/H)/yr; and typical delivery rates for all categories should be 0.146 ±0.046 (Mgal/user)/yr. At 95-percent confidence, domestic deliveries should range from 0.067 to 0.075 (Mgal/H)/yr, and deliveries for all categories should range from 0.100 to 0.192 (Mgal/user)/yr for water systems in Illinois that are similar to those in the Rockford and the Kankakee areas.

Commercial and industrial deliveries could be distinguished from each other for the communities of North Park, Bourbonnais, Bradley, and Kankakee. The average commercial delivery rate for these communities was 0.406 (Mgal/est)/yr

Table 8.--Delivery rates[1], by category, in the Rockford and the Kankakee areas, Illinois, 1984

[(Mgal/est)/yr, million gallons per establishment per year; (Mgal/H)/yr, million gallons per household per year; (Mgal/user)/yr, million gallons per user per year]

Community	Commercial and industrial [(Mgal/est)/yr]	Domestic [(Mgal/H)/yr]	Municipal[2] [(Mgal/est)/yr]	All categories [(Mgal/user)/yr]
Loves Park	2.130	0.072	3.264	0.179
North Park	.434	.078	.667	.090
Rockford	1.800	.066	1.288	.160
Bourbonnais	1.222	.074	5.306	.116
Bradley	.472	.071	5.306	.098
Kankakee	1.812	.066	5.405	.236
Mean	1.312	.071	3.539	.146
Standard deviation	.727	.005	2.150	.056
Confidence interval	±.598	±.004	±1.769	±.046

[1]Delivery rates equal public-supply deliveries to each category divided by the number of establishments or households per category.

[2]Kankakee area municipal delivery rates are similar among the communities because the total municipal use was separated into communities on the basis of the number of municipal establishments in each community.

Table 9.--Delivery rates for commercial and industrial categories in North Park and the Kankakee area, Illinois, 1984

[All figures are in million gallons per establishment per year]

Community	Commercial	Industrial
North Park	0.420	102.331
Bourbonnais	.302	12.496
Bradley	.554	43.407
Kankakee	.349	1.203
Mean	.406	39.859
Standard deviation	.110	45.308
Confidence interval	±.129	±53.314

(million gallons per establishment per year); the standard deviation was 0.110 (Mgal/est)/yr or 27 percent of the mean (table 9). On the basis of the confidence interval, typical commercial deliveries should be 0.406 ±0.129 (Mgal/est)/yr. For other similar systems in Illinois, the probable range for commercial deliveries is from 0.277 to 0.535 (Mgal/est)/yr. Industrial delivery rates among the communities vary widely.

Consumptive Uses

Consumptive-use data were not available for the Rockford or the Kankakee areas. Therefore, consumptive uses (table 10) were estimated by various methods.

Consumptive use can best be estimated as the difference between water acquired and water released by each establishment and household (water user). On the basis of this concept, a water user's consumptive use could be estimated by the consumption-budget method:

$$CONS = (DEL + SSWD) - (REL + DRT), \quad (1)$$

where CONS is annual consumptive uses;
DEL is annual deliveries;
SSWD is annual self-supply withdrawals;
REL is annual releases to sewage-treatment plant; and
DRT is annual direct returns to surface- and ground-water sources.

This method was used to estimate consumptive use by water user where data and (or) estimates were available for all variables. Consumptive use by category can be determined by summing the estimates of consumptive use by water user. Some of the data used in this equation were estimated, so some CONS are estimated from estimates.

Where water-use data or estimates were not available, the consumption-budget method could not be used. In those cases, the types-of-use method was used to estimate consumptive use. By this method, consumptive use is estimated from data of water used for cooling systems, boilers, and lawn watering.

Data for the types-of-use method, available from the Rockford Sanitary District, consist largely of consumptive uses and (or) direct returns. These data are the result of water users metering their large consumptive uses and (or) direct returns so that they are not billed for the water withdrawn or delivered that does not get released to the Sanitary District. Because of the significant cost of purchasing and installing water meters, these data probably represent the largest consumptive uses and (or) direct returns in the Rockford area.

In the types-of-use method, consumptive use was determined as a percentage of use by cooling systems, boilers, and lawn watering. On the basis of previous investigations, the following percentages seem to explain consumptive use for these types of use in Illinois:

Table 10.--Estimates of consumptive use in the Rockford and the Kankakee areas, Illinois, 1984

[DEL and SSWD, deliveries and(or) self-supply withdrawals; all figures are in million gallons per year]

Category	Consumptive use[1]	DEL and SSWD	Consumptive use[1]	DEL and SSWD	Consumptive use[1]	DEL and SSWD
	Rockford area					
	Loves Park		North Park		Rockford	
Commercial and(or) industrial[2]	112.887	526.290	[3]4.531 5.863	47.197 18.473	990.201	5,633.937
Domestic	[4]33.147	339.180	[4]53.082	388.793	[4]227.714	3,511.333
Municipal	[3]11.125	39.171	[3]3.031	10.672	10.692	46.375
Total	157.159	904.641	66.507	465.135	1,228.607	9,191.645
	Kankakee area					
	Bourbonnais		Bradley		Kankakee	
Commercial	[3]5.080	52.912	[3]4.083	42.531	[3]45.761	476.673
Industrial	3.240	102.331	6.459	24.993	228.925	1,128.572
Domestic	[4]12.240	294.922	[4]8.477	278.667	[4]23.210	583.122
Municipal	[3]7.535	26.532	[3]15.069	53.060	[3]27.629	97.284
Total	28.095	476.697	34.088	399.251	325.525	2,285.651

[1]Estimated by use of the consumption-budget method and(or) the types-of-use method except where indicated otherwise.
[2]Consumptive-use estimates for Loves Park and Rockford are for commercial and industrial combined because deliveries for the two categories could not be separated.
[3]Estimated by use of the minimum consumptive-use ratio per category--Table 12 (commercial = 0.096, municipal = 0.284).
[4]Estimated by use of the winter base-rate method.

Types of use	Consumptive use as a percentage of use[1]
Cooling systems	80
Boilers	90
Lawn watering	80

The remaining 10 to 20 percent, considered to be nonconsumptive use by cooling systems, boilers, and lawn watering, was designated direct returns (water returned by commercial, domestic, industrial, and municipal establishments). Refer to "Direct Returns" section.

The annual consumptive-use estimates by water user, determined from the consumption-budget and types-of-use methods, were combined to estimate most consumptive uses for the Rockford and the Kankakee areas. The combined estimates are listed in table 11 by two-digit SIC code and in table 12 by category of use. The negative values in table 11 indicate that some users released more water than they were delivered. Negative values could result from the consumption-budget method for users that receive and process materials such as milk, which contains water. For those water users, and others that could be identified, their deliveries were increased to prevent negative values. Negative values that could not be prevented (as in table 11) are those resulting from underregistering delivery meters and (or) overregistering release meters. Negative values were assumed to be zero when consumptive uses by water user were summed to determine consumptive use by category.

The estimates summed were considered to be adequate consumptive-use estimates based on the amount of deliveries in the sample estimated by use of the two methods. For adequate definition of consumptive uses, the deliveries of the sample estimated must be more than 50 percent of the population deliveries. The consumptive-use estimates (table 10) that were considered to be adequate are commercial and industrial (Loves Park and Rockford), industrial (North Park and Kankakee area), and municipal (Rockford). They were derived from the estimate of the sample whose deliveries made up 63 to 100 percent of population deliveries (table 13).

Consumptive-use ratios (the average of consumptive-use estimates from the consumption-budget and (or) the types-of-use methods divided by deliveries and (or) self-supply withdrawals) by SIC code and category of use were determined (tables 11 and 12). Although these ratios may be used as coefficients to estimate consumptive uses for systems whose water uses and climate are similar, they should be used with caution. Some of the ratios were estimated from types-of-use data that probably represent the largest consumptive use in the study areas, and many were derived from a small number of water users sampled.

[1]Refer to Appendix for details on determination of consumptive use as a percentage of use by cooling systems, boilers, and lawn watering.

Table 11.--Estimates of consumptive uses and ratios, by SIC code, from the consumption-budget and the types-of-use methods, Rockford and Kankakee areas, Illinois, 1984

[SIC, Standard Industrial Classification; Category, C = Commercial, D = Domestic, I = Industrial, and M = Municipal; Water user, establishment or household; Mgal/yr, million gallons per year; DEL and SSWD, deliveries and(or) self-supply withdrawals; dashes indicate no data]

SIC code	Category	Sample (number of water users)	Range of consumptive uses by water user (Mgal/yr)	Total consumptive use[1] (Mgal/yr)	Consumptive-use ratio (average consumptive uses divided by DEL and SSWD)
15-17	C	2	0.061 to 1.265	1.326	0.798
20	I	12	.041 to 101.630	268.177	.322
23	I	2	.327 to 2.885	3.212	.192
24-26	I	6	-6.323 to 13.096	18.869	.544
27	I	6	.051 to 4.151	7.079	.364
28-29	I	9	.000 to 65.788	120.991	.277
30	I	4	.000 to 2.179	3.044	.266
32	I	2	.085 to 11.779	11.865	.116
33	I	10	.000 to 124.916	173.553	.318
34	I	23	.002 to 80.570	201.254	.318
35	I	18	-.001 to 21.685	104.220	.350
36	I	8	-9.951 to 87.169	118.149	.364
37	I	2	2.175 to 184.768	186.942	.454
38-39	I	4	.284 to 2.497	4.185	.371
43	C	1	--	.324	.096
48	C	1	--	.618	.273
50-53, 55-57,59	C	33	-.008 to .818	4.368	.271
54	C	11	-.016 to 3.441	8.325	.332
58	C	31	-.241 to 2.683	10.155	.266
60-65	C	14	.003 to 3.041	11.515	.482
67	C	6	.014 to 6.187	9.321	.313
70	C	5	-.002 to 7.903	10.618	.256
72	C	6	.005 to 13.674	15.661	.096
73	C	2	.507 to .764	1.271	.531
75	C	3	-.001 to .009	.018	.172
79	M[2],C	6	.001 to 2.756	5.792	.386
80	C	10	.230 to 26.460	48.203	.267
81	C	2	-.045 to .216	.216	.215
82	M[2],C	2	.966 to 3.166	4.132	.434
83	M[2],C	5	-.033 to 20.897	21.822	.343
86	C	13	-.010 to 1.057	3.780	.174
88	D[2]	1,033	.000 to .759	25.921	.423
89	C	2	.003 to .105	.107	.400
91-96	M[2],C	6	.027 to 4.835	6.136	.284
Total		1,300		1,411.169	
Mean					.325

[1]Negative consumptive use is assumed to be zero.
[2]Estimated from types-of-use method only.

Table 12.--Estimates of consumptive uses and ratios, by category, from the consumption-budget and the types-of-use methods, Rockford and Kankakee areas, Illinois, 1984

[Mgal/yr, million gallons per year; water user, establishment or household; SIC, Standard Industrial Classification; dashes indicate no data]

Category	Sample (number of water users)	Range of consumptive uses by water user (Mgal/yr)	Total consumptive use[1] (Mgal/yr)	Range of consumptive-use ratios[1] (by SIC code)	Mean consumptive-use ratio[1]
Commercial	149	-0.045 to 26.460	153.016	0.096-0.798	0.292
Industrial	106	-9.951 to 184.768	1,221.540	.116- .554	.336
Domestic[2]	1,033	.000 to .759	25.921	--	.423
Municipal[2]	12	-.033 to 4.835	10.692	.284- .434	.336

[1]Negative consumptive use is assumed to be zero.
[2]Estimated from types-of-use method only.

Table 13.--Deliveries of the sample estimated by use of the consumption-budget and the types-of-use methods, as a percentage of population deliveries, Rockford and Kankakee areas, Illinois, 1984

[<, less than; water users, establishments or households]

Category	Sample estimated (percent of deliveries)	Water users sampled	Total water users	Sample estimated (percent of deliveries)	Water users sampled	Total water users	Sample estimated (percent of deliveries)	Water users sampled	Total water users
	Rockford area								
	Loves Park			North Park			Rockford		
Commercial and(or) industrial[1]	68	22	237	43 93	50 6	135 15	63	158	2,965
Domestic	<1	2	4,693	0	0	5,003	2	1,031	52,169
Municipal	0	0	12	1	1	16	78	11	36
Total		24	4,942		57	5,169		1,200	55,170
	Kankakee area								
	Bourbonnais			Bradley			Kankakee		
Commercial	0	0	126	0	0	141	18	1	860
Industrial	100	1	1	100	2	2	98	15	26
Domestic	0	0	3,967	0	0	3,915	0	0	8,775
Municipal	0	0	5	0	0	10	0	0	18
Total		1	4,099		2	4,068		16	9,679

[1]Percentages for Loves Park and Rockford are for commercial and industrial combined because deliveries for the two categories could not be separated.

Consumptive uses (excluding domestic consumptive uses) that could not be derived from the consumption-budget or types-of-use methods, were estimated from the minimum consumptive-use ratio by SIC code in each category as generated by the consumption-budget and the types-of-use methods. The data used to create the consumptive-use ratios (tables 11 and 12) are assumed to be positively biased and assumed to represent the largest consumptive uses.

Estimates of commercial and municipal consumptive uses for North Park and the Kankakee area and municipal consumptive uses for Loves Park (table 10) are the product of the minimum consumptive-use ratios (commercial = 0.096; municipal = 0.284) and the amount of deliveries and (or) self-supply withdrawals by category.

Domestic consumptive use also was estimated by means of the winter base-rate and the maximum lawn-watering methods. In the winter base-rate method, inside domestic use is assumed to remain constant throughout the year (DiNatale, 1981, p. 14). And any total domestic use (domestic deliveries and withdrawals) greater than inside use are attributed to outside uses. Most outside domestic use was assumed to be lawn watering--a predominantly consumptive use due to *evapotranspiration* (Linaweaver and others, 1967, p. 14-48). Lawn watering was assumed to make up most domestic consumptive use.

The winter base-rate method (fig. 4) was used to determine the outside domestic use. First, domestic use was averaged during the months November through April (when outside use in Illinois is minimal) to determine the winter base rate. Outside use was calculated as the differences between the winter base rate and the domestic use for the months May through October. Roughly 80 percent of the water applied to lawns was assumed to be domestic consumptive use because of evapotranspiration (evapotranspiration factor), and the remaining (20 percent) is a direct return to ground water (refer to Appendix).

Following is an example of how domestic consumptive use was determined for Loves Park by use of the winter base-rate method:

$$\text{Winter base} = \Sigma_i \text{ domestic use}^1 \div 6 \text{ months} =$$
$$24.812 \text{ million gallons per month (Mgal/mo)},$$

where i refers to the months of November through April.

	Domestic water use, in million gallons per month				
Month	Domestic use[1]	(-)	Winter base	(=)	Outside domestic use
May	28.503		24.812		3.691
June	31.184		24.812		6.372
July	38.654		24.812		13.842
August	35.361		24.812		10.549
September	28.942		24.812		4.130
October	27.662		24.812		2.850
				Annual outside domestic use =	41.434
				Evapotranspiration factor (dimensionless) =	0.80
				Loves Park annual domestic consumptive use =	33.147

[1]Data from tables 5 and 7.

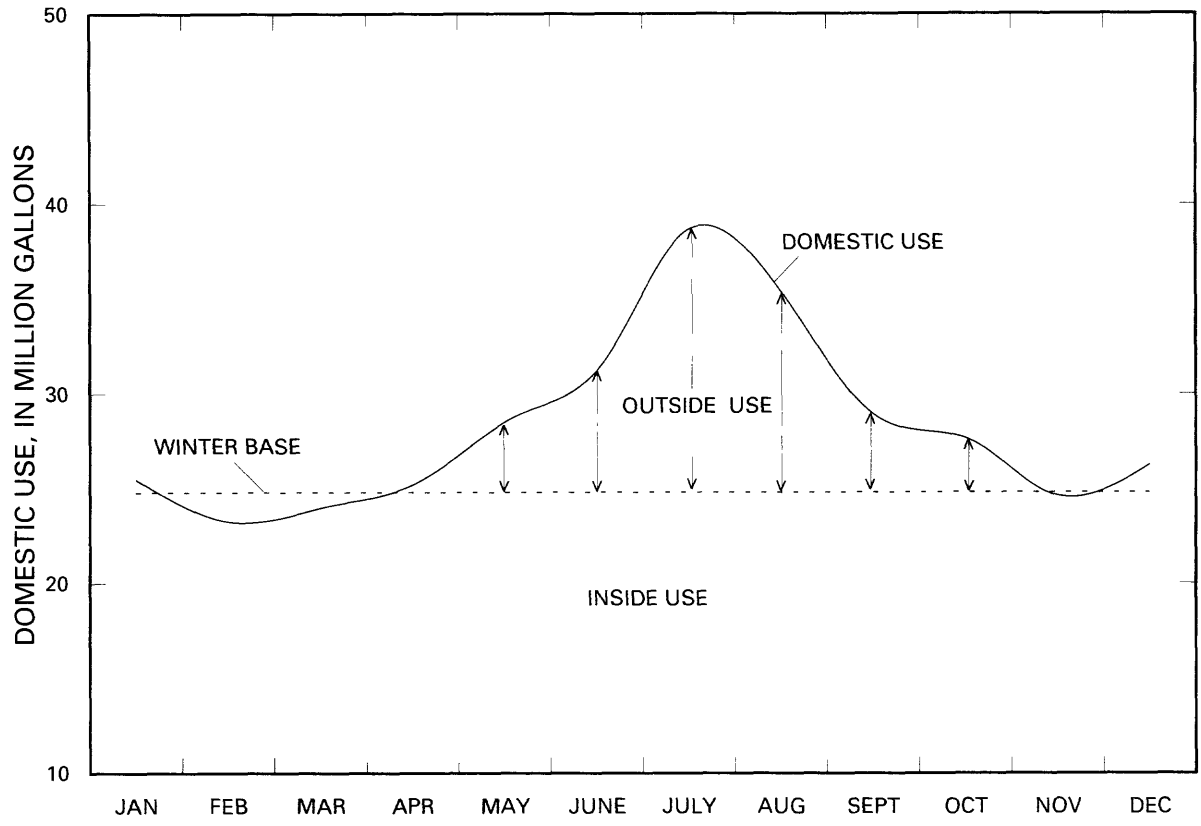

Figure 4.---Use of winter base-rate method for determination of outside domestic use of water, Loves Park, Illinois, 1984.

The maximum lawn-watering method was used to determine the maximum possible domestic consumptive use. Linaweaver and others (1967, p. 38-48) developed a method similar to this one for estimating lawn watering. Linaweaver's method, however, is used to estimate typical, not maximum, lawn-watering rates. The maximum lawn-watering method is

$$MLW = \Sigma_i \, (PE - [P - R]) \times LS, \qquad (2)$$

where MLW is annual maximum lawn watering estimate per lawn;
i is months when lawns are typically watered (May through October);
PE is monthly potential evapotranspiration;
P is monthly precipitation;
R is monthly runoff; and
LS is average lawn size.

In this method, lawn watering is assumed to become mostly domestic consumptive use and is assumed to be done when grass seems to be dying or, similarly, when PE exceeds precipitation minus runoff. In the months (typically May through October in Illinois) when PE is greater than precipitation minus

runoff, precipitation is inadequate to meet PE; so precipitation does not meet the lawn requirements. As in the winter base-rate method, domestic consumptive use was assumed to be 80 percent (evapotranspiration factor) of the maximum lawn-watering estimate. The resulting estimates of domestic consumptive use per lawn are multiplied by the number of households in a community to estimate the maximum domestic consumptive uses for a community.

The data used to estimate values for the variables in equation 2 were obtained from previous investigations, except for monthly P, which was obtained from sewage-treatment plants in both study areas. The PE was computed by the Thornthwaite method, and R was computed by the rational method (Chow, 1964, p. 11-27, 11-28, 14-6, 14-7). The LS [0.155 acre/lawn (acres per lawn) or 6,752 ft^2/lawn (square feet per lawn)] was determined from average lot size (0.25 acre), and imperviousness (38 percent) documented by Mills and others (1985, p. 222). The maximum domestic consumptive use for Loves Park is calculated as follows:

Rockford area

Month	PE (inches)	P (inches)	R (inches)
May	2.76	3.95	0.00
June	5.24	3.99	.00
July	5.32	2.92	.00
August	5.22	1.63	.00
September	3.04	1.54	.00
October	2.00	5.93	.00
	23.58 -	(19.96 -	.00) = 3.62 in/lawn
			= 0.30 ft/lawn

MLW = 0.30 ft/lawn x 6,752 ft^2/lawn
= 2,025 ft^3/lawn (cubic feet per lawn)

Evapotranspiration factor (dimensionless) = 0.80

Estimate of maximum domestic consumptive use per lawn for the Rockford area (RDCU):

RDCU = 2,025 ft^3/lawn x 0.80 = 1,620 ft^3/lawn or 0.012 Mgal/lawn (million gallons per lawn)

Loves Park's maximum domestic consumptive use
= RDCU x number of households in Loves Park
= 0.012 Mgal/lawn x 4,693 households
= 56.316 Mgal/yr

The estimates calculated from the types-of-use and winter base-rate methods were compared with the estimates obtained from the maximum lawn-watering method to identify the most reasonable domestic consumptive-use estimate. Because the maximum lawn-watering estimates represent maximum domestic consumptive use, reasonable domestic consumptive-use estimates should be less than or similar to estimates calculated from the maximum lawn-watering method. For comparison, all

estimates were converted to a common ratio (domestic consumptive-use ratio): consumptive use divided by deliveries and self-supply withdrawals (table 14). The winter base-rate method seems to be a more reasonable means of estimating domestic consumptive use than the types-of-use method because its ratios do not exceed the maximum lawn-watering ratios. The types-of-use method is considered to be unreasonable because its ratios exceed the maximum lawn-watering ratios by a factor of two. Furthermore, when domestic consumptive-use estimates from the types-of-use method or the maximum lawn-watering method were subtracted from the deliveries in each community, during the high consumptive use period (May through October), the resulting release estimates seemed to be unreasonably small.

Table 14.--Domestic consumptive-use ratios[1] derived from various estimating methods, Rockford and Kankakee areas, Illinois, 1984

Community	Ratios from the types-of-use method	Ratios from the maximum lawn-watering method	Ratios from the winter base-rate method
	Rockford area		
Loves Park	0.423	0.166	0.098
North Park	.423	.154	.136
Rockford	.423	.178	.065
Mean	.423	.166	.100
	Kankakee area		
Bourbonnais	.423	.282	.042
Bradley	.423	.295	.030
Kankakee	.423	.316	.040
Mean	.423	.298	.037
Overall mean	.423	.232	.068

[1]Domestic consumptive-use ratio is consumptive-use estimates divided by deliveries and self-supply withdrawals.

In the Rockford area, ratios (table 14) from the winter base-rate method ranged from 0.065 to 0.136 and averaged 0.1. In the Kankakee area, the ratios ranged from 0.030 to 0.042 and averaged 0.037. The overall average for the two study areas was 0.068. A study of water use in central Pennsylvania showed that the ratio of lawn watering to domestic deliveries for eight households ranged from 0.01 to 0.16 and averaged 0.06 (Seaker and Sharpe, 1988). Linaweaver and others (1967, p. A-2, A-6) found that the ratio of lawn watering to domestic deliveries in Des Moines, Iowa, was 0.09. Oak Ridge National Laboratory (1980) developed consumptive-use ratios by SIC code and State from U.S. Geological Survey water-use information. The ratio for Illinois was 0.12 (Oak Ridge National Laboratory, 1980).

The winter base-rate method provided better domestic consumptive-use estimates (table 10) than other methods for the following reasons:

1. Estimates are determined from all domestic delivery data, not just a sample.

2. The delivery data applied in the method include the effects of socioeconomic behavior on water demand, such as cost of water, cost of living, income levels, and lawn-watering practices.

3. The ratios did not exceed maximum lawn-watering ratios.

4. The ratios agreed with those in previous studies.

Releases

Release data and estimates for the Rockford and the Kankakee areas are listed in table 15. Industrial release data were available from the sewage-treatment plants in the Rockford and the Kankakee areas. According to water-utility managers from both areas, the industrial-release data that were available represent most of the industrial releases in the areas (Richard Eick, Rockford Sanitary District, and James Clarno, Kankakee Department of Water Pollution Control, oral commun., 1985). In the Kankakee area, the industrial release data represented industries whose deliveries accounted for 95 percent of all the industrial deliveries in that area. Partial commercial-, domestic-, and municipal-release data for the Rockford area were available from the Rockford Sanitary District.

When partial-release data were available for more than 50 percent of the water users, nonrecorded releases for each establishment or household in a category were assumed to equal their deliveries. The aggregated release data and estimates were adjusted, where necessary, to balance with other annual water uses: self-supply withdrawals, deliveries, consumptive uses, and direct returns. The annual adjustment needed to balance annual water use was applied equally, by day, to monthly releases. Adjustments were applied to releases, instead of to estimates of consumptive uses or direct returns, because the adjustment would have the least effect on releases, which are significantly larger than the other estimates. Commercial and municipal releases for the Rockford area, and industrial releases for North Park and Kankakee were estimated by this method of adjustment.

Releases also were estimated for categories, except for municipal, with few or no release data--less than 50 percent of the establishments or households--by the following equation:

$$REL_c = (DEL_c + SSWD_c) - (CONS_c + DRT_c) \quad (3)$$

where REL_c is monthly releases to sewage-treatment plant;
DEL_c is monthly deliveries;
$SSWD_c$ is monthly self-supply withdrawals;
$CONS_c$ is monthly consumptive uses; and
DRT_c is monthly direct returns to surface- and ground-water sources.
Subscript "c" refers to categories of use.

Table 15.--Releases in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons; dashes indicate releases are minimal]

Month	Rockford area									
	Loves Park[1]					North Park[1]				
	Commercial[2]	Domestic[3]	Industrial	Municipal[2]	Total	Commercial[2]	Domestic[3]	Industrial[2]	Municipal[2]	Total
January	8.362	23.414	23.096	1.483	56.355	2.500	12.103	0.847	0.553	16.003
February	7.859	21.563	21.606	1.405	52.433	2.395	11.322	.794	.522	15.033
March	8.362	22.100	23.095	1.482	55.039	2.501	11.072	.848	.553	14.974
April	8.489	23.356	21.616	1.475	54.936	2.143	10.715	.968	.602	14.428
May	8.753	23.075	22.336	1.516	55.680	2.185	11.048	.999	.620	14.852
June	8.490	24.035	21.616	1.477	55.618	2.143	10.959	.968	.603	14.673
July	10.335	25.251	25.963	1.499	63.048	2.997	11.989	.768	.251	16.005
August	10.336	24.671	25.963	1.499	62.469	2.997	11.990	.768	.252	16.007
September	10.019	23.556	25.125	1.459	60.159	2.928	12.200	.744	.244	16.116
October	9.232	23.282	26.009	1.798	60.321	3.024	12.299	.770	.631	16.724
November	8.952	23.005	25.170	1.748	58.875	2.954	13.198	.745	.612	17.509
December	9.231	24.394	26.009	1.797	61.431	3.023	13.637	.770	.631	18.061
Total	108.420	281.702	287.604	18.638	696.364	31.790	142.532	9.989	6.074	190.385

Table 15.--Releases in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Rockford area					Kankakee area				
	Rockford[1]					Bourbonnais				
	Commercial[2]	Domestic[3]	Industrial	Municipal[2]	Total	Commercial[3]	Domestic[3]	Industrial	Municipal	Total
January	164.452	268.051	188.611	2.613	623.727	3.954	23.070	8.797	--	35.821
February	156.136	250.758	176.443	2.484	585.821	4.285	23.311	7.575	--	35.171
March	164.453	268.053	188.612	2.614	623.732	3.361	20.815	8.412	--	32.588
April	147.461	273.985	157.087	2.318	580.851	4.258	24.392	8.463	--	37.113
May	151.191	257.621	162.324	2.374	573.510	3.714	22.043	9.045	--	34.802
June	147.461	255.806	157.087	2.318	562.672	4.601	23.483	10.046	--	38.130
July	164.032	258.969	163.843	2.847	589.691	4.203	23.419	9.591	--	37.213
August	164.032	258.970	163.843	2.847	589.692	4.134	24.152	10.069	--	38.355
September	159.889	279.316	158.557	2.776	600.538	4.007	23.611	7.370	--	34.988
October	187.395	226.337	169.152	3.054	585.938	3.938	23.180	7.221	--	34.339
November	182.497	235.216	163.695	2.975	584.383	3.663	23.333	5.947	--	32.943
December	187.395	243.054	169.151	3.054	602.654	3.714	22.836	6.555	--	33.105
Total	1,976.394	3,076.136	2,018.405	32.274	7,103.209	47.832	277.645	99.091	--	424.568

Table 15.--Releases in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Kankakee area									
	Bradley					Kankakee				
	Commercial[3]	Domestic[3]	Industrial	Municipal	Total	Commercial[3]	Domestic[3]	Industrial[2]	Municipal	Total
January	3.302	25.974	0.432	--	29.708	33.891	47.069	62.887	--	143.847
February	3.099	20.691	.958	--	24.748	33.725	44.116	72.431	--	150.272
March	2.864	21.650	1.111	--	25.625	32.465	44.586	77.114	--	154.165
April	3.029	21.389	1.352	--	25.770	36.277	45.361	61.726	--	143.364
May	2.740	22.588	1.700	--	27.028	36.878	44.541	79.304	--	160.723
June	3.375	22.586	1.953	--	27.914	41.924	44.846	76.273	--	163.043
July	3.402	22.857	1.851	--	28.110	40.623	45.135	62.142	--	147.900
August	3.663	22.986	1.949	--	28.598	43.999	45.855	70.327	--	160.181
September	3.137	23.352	1.702	--	28.191	36.369	44.402	71.540	--	152.311
October	3.450	21.765	1.744	--	26.959	33.860	43.952	75.207	--	153.019
November	2.969	23.138	1.694	--	27.801	29.332	41.110	70.267	--	140.709
December	3.418	21.171	2.088	--	26.677	31.569	41.987	69.062	--	142.618
Total	38.448	270.147	18.534	--	327.129	430.912	532.960	848.280	--	1,812.152

[1]Derived from quarterly records.
[2]Release data were available but needed adjusting to balance water uses.
[3]Estimated by use of equation 3.

Domestic releases for the two study areas and commercial releases for the Kankakee area were estimated by use of equation 3. For domestic releases, $CONS_c$ values were obtained from the winter base-rate method and were applied during the high consumptive-use months May through October. Estimation of domestic releases in Loves Park is shown in table 16. For commercial releases, $CONS_c$ values were applied to all months because commercial uses are less seasonal.

Table 16.--Estimation of domestic releases by use of equation 3 for Loves Park, Illinois, 1984

[DEL, deliveries; SSWD, self-supply withdrawals; CONS, consumptive use, DRT, direct returns to septic systems; REL, releases; all values in million gallons]

Month	[DEL + SSWD] -	[CONS[1] + DRT] =	REL
January	25.495 0.012	0 2.093	23.414
February	23.266 .012	0 1.715	21.563
March	23.973 .013	0 1.886	22.100
April	25.190 .014	0 1.848	23.356
May	28.488 .015	2.953 2.475	23.075
June	31.170 .014	5.097 2.052	24.035
July	38.638 .016	11.074 2.329	25.251
August	35.344 .017	8.439 2.251	24.671
September	28.926 .016	3.304 2.082	23.556
October	27.647 .015	2.280 2.100	23.282
November	24.612 .015	0 1.622	23.005
December	26.257 .015	0 1.878	24.394

[1]CONS was derived by use of the winter base-rate method.

Municipal releases were assumed to be insignificant where release data were not available because most water used for municipal purposes is returned (direct returns) to ground- or surface-water sources or is consumed. Water used for firefighting and at parks, for example, generally is returned or evaporated. Municipal releases for the Kankakee area were assumed insignificant because data were not available.

On the basis of discharge measurements at 19 major-water-user release points, the accuracy of industrial release data is poor (25-percent error) for the Rockford area and good (less than 10-percent error) for the Kankakee area. Discharge measurements and related information in the Rockford and the Kankakee areas are given in table 17. On the basis of the percentage differences between total unadjusted and total adjusted releases, release meters were overregistering by about 41 percent in the Rockford area and were underregistering by about 3 percent in the Kankakee area. The release data were adjusted temporarily by the percentage differences to determine overall accuracy only, not to correct them.

Table 17.--Discharge measurements and related information at major-water-user release sites, Rockford and Kankakee areas, Illinois, 1984

[ID, identification number; Mgal/yr, million gallons per year]

Major-water-user site ID	Number of release points measured	Average percentage difference[1]	Percentage of all area releases measured	Percentage of all area industrial releases measured	Releases (Mgal/yr)	
					Unadjusted	Adjusted[2]
			Rockford area			
1	1	-23.6	1.2	4.2	97.701	74.644
2	2	-93.8	1.2	4.3	99.450	6.166
3	3	-63.8	2.3	7.9	183.811	66.540
4	1	13.2	.3	1.0	23.920	27.077
5	5	-.6	1.1	3.9	89.743	89.205
6	2	13.0	.7	2.4	56.402	63.734
Total	14		6.8	23.7	551.027	327.366
			Kankakee area			
1	1	12.6	4.1	10.8	104.548	117.721
2	1	-3.1	3.2	8.6	82.804	80.237
3	1	-.4	2.0	5.2	50.327	50.126
4	1	2.8	.6	1.6	15.710	16.150
5	1	-87.4	.2	.5	4.605	.580
Total	5		10.1	26.7	257.994	264.814

[1]Average percentage difference between flows from meter readings and discharge measurements (negative number indicates meter was reading too high).

[2]Determined by correcting the metered (unadjusted) releases by the average percentage differences.

The negative percentage differences in table 17 indicate overregistering water meters. Debris and (or) foam at the throat of the measured flumes seemed to have caused overregistering at most sites.

Measured releases in the Rockford area consisted of 7 percent of all releases and 24 percent of the industrial releases (table 17). Measured releases in the Kankakee area consisted of about 10 percent of all releases and 27 percent of industrial releases.

Returns

Returns were classified as sewage-treatment returns or direct returns by commercial, domestic, industrial, and municipal users.

Sewage-treatment returns

These returns are waters discharged to ground- or surface-water sources by sewage-treatment plants. Sewage-treatment-return data from sewage-treatment plants are listed in table 18. Sewage-treatment returns in table 18 represent the flows entering each plant, except for Bourbonnais, which represent flows exiting the plant.

Table 18.--Sewage-treatment returns in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons]

Month	Rockford area	Kankakee area			
		Bourbonnais	Bradley	Kankakee	Total
January	1,003.850	33.344	38.055	190.635	262.034
February	988.570	35.740	59.879	297.011	392.630
March	1,009.770	44.186	67.696	364.184	476.066
April	979.830	54.029	68.445	244.797	367.271
May	1,054.850	50.222	64.094	311.556	425.872
June	1,092.620	47.140	62.760	216.910	326.810
July	1,131.560	39.368	44.866	190.994	275.228
August	1,028.150	37.366	34.569	193.231	265.166
September	885.290	35.895	28.968	174.222	239.085
October	976.460	29.449	33.906	201.324	264.679
November	970.910	25.150	40.452	226.748	292.350
December	943.970	25.877	51.861	228.869	306.607
Total	12,065.830	457.766	595.551	2,840.481	3,893.798

Discharge measurements at the four sewage-treatment plants in the two study areas indicate that the overall accuracy of these data is good (less than 10-percent error). On the basis of the differences between total unadjusted and total adjusted sewage-treatment returns (table 19), sewage-treatment-return meters were overregistering by about 6 percent in the Rockford area and by about 9 percent in the Kankakee area. Sewage-treatment returns in the city of Kankakee, which accounted for about 73 percent of all sewage-treatment returns in the Kankakee area, were overregistered by about 7 percent.

Direct returns

Direct returns are waters discharged by commercial, domestic, industrial, and municipal users to ground- or surface-water sources. Water is "directly returned" typically from boilers, cooling systems, lawn watering, swimming pools, and septic systems.

Partial direct-return data were obtained (tables 1 and 2) from sewage-treatment plants for most categories in the study areas. Direct-return data were also obtained from some public suppliers. These direct returns by public suppliers from overflows and backwashing filters were considered to be municipal returns.

Direct-return data and estimates for the Rockford and the Kankakee areas are listed in table 20. Only the municipal returns for Loves Park and the industrial returns for Bourbonnais and Kankakee are solely from direct-return data. Most others listed in table 20 include a combination of direct-return data and estimates.

The nonconsumptive-use estimates (10 to 20 percent) from the types-of-use method (refer to "Consumptive Uses" section and Appendix) were used to estimate direct returns for water users without direct-return data. In table 20, commercial and industrial returns listed for the Rockford area and domestic and municipal returns listed for the community of Rockford include these estimates.

When direct-return data or nonconsumptive-use estimates were not available for a water user, direct returns were assumed to be negligible. The reasoning is that water users with significant returns would meter them to reduce *sewer fees*. The assumption is not valid for water users that do not release water and, consequently, do not pay sewer fees. All commercial water users in the Kankakee area and industrial users in Bradley were assumed to have negligible returns.

Water users with septic systems do not pay sewer fees; therefore, delivery records to *septic-system users* were also used to estimate the direct returns that were undefined by direct-return data and (or) nonconsumptive-use estimates:

$$DRTSS_c = DSS_c - (DSS_c/DEL_c \times CONS_c), \qquad (4)$$

where $DRTSS_c$ is monthly direct returns by septic-system users;
DSS_c is monthly deliveries to septic-system users;
DEL_c is monthly deliveries; and
$CONS_c$ is monthly consumptive uses.
Subscript "c" refers to category.

Table 19.--Discharge measurements and related information at sewage-treatment-return sites, Rockford and Kankakee areas, Illinois, 1984

[Mgal/yr, million gallons per year]

Community	Average percent difference[1]	Number of discharge measurements	Range of measured return flows (Mgal/yr)	Percentage of all sewage-treatment returns	Sewage-treatment returns (Mgal/yr)	
					Unadjusted	Adjusted[2]
			Rockford area			
Total	-5.8	2	13,450-13,700	100	12,065.830	11,366.012
			Kankakee area			
Bourbonnais	-57.4	3	386-395	11.8	457.766	195.008
Bradley	22.5	2	237-395	15.3	595.551	729.550
Kankakee	-7.4	2	3,130-3,170	72.9	2,840.481	2,630.285
Total		7		100	3,893.798	3,554.843

[1]Average percentage difference between flows from meter readings and discharge measurements. (Negative number indicates meter was reading too high.)

[2]Determined by correcting the metered (unadjusted) returns by the average percentage differences.

Table 20.--Commercial, domestic, industrial, and municipal returns in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons; dashes indicate no record or negligible returns]

Month	Rockford area									
	Loves Park					North Park				
	Commercial[1]	Domestic[2]	Industrial[1]	Municipal[3]	Total	Commercial[1,2]	Domestic[2,4]	Industrial[1,2]	Municipal[2,4]	Total
January	0.064	2.093	0.956	1.192	4.305	0.687	14.844	0.103	0.005	15.639
February	.059	1.715	.894	.447	3.115	.710	13.887	.084	.007	14.688
March	.064	1.886	.956	.576	3.482	.612	14.375	.066	.006	15.059
April	.087	1.848	1.142	.358	3.435	.684	13.911	.151	.007	14.753
May	.089	2.475	1.180	.178	3.922	.750	17.497	.257	.042	18.546
June	.087	2.052	1.142	2.121	5.402	1.289	17.358	.206	.122	18.975
July	.374	2.329	1.493	.520	4.716	1.561	18.365	.483	.384	20.793
August	.374	2.251	1.493	.232	4.350	1.565	18.365	.464	.392	20.786
September	.362	2.082	1.446	.280	4.170	1.040	16.146	.378	.527	18.091
October	.285	2.100	1.439	1.149	4.973	.836	16.275	.172	.060	17.343
November	.275	1.622	1.393	1.715	5.005	.550	15.814	.133	.010	16.507
December	.285	1.878	1.440	.640	4.243	.592	16.342	.124	.005	17.063
Total	2.405	24.331	14.974	9.408	51.118	10.876	193.179	2.621	1.567	208.243

Table 20.--Commercial, domestic, industrial, and municipal returns in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Rockford area					Kankakee area				
	Rockford					Bourbonnais				
	Commercial[1,3]	Domestic[1,2,3]	Industrial[1,3]	Municipal[1]	Total	Commercial	Domestic[2]	Industrial	Municipal[5]	Total
January	0.324	6.915	53.613	0.163	61.015	--	0.419	0	1.382	1.801
February	.303	6.468	50.758	.153	57.682	--	.419	0	1.300	1.719
March	.324	6.915	53.144	.163	60.546	--	.417	0	1.868	2.285
April	2.557	19.184	46.125	.193	68.059	--	.419	0	1.014	1.433
May	2.641	18.080	52.295	.200	73.216	--	.419	0	1.590	2.009
June	2.557	17.941	52.265	.193	72.956	--	.422	0	1.351	1.773
July	5.256	26.309	53.112	.425	85.102	--	.421	0	1.327	1.748
August	5.256	26.309	53.384	.425	85.374	--	.422	0	1.536	1.958
September	5.087	28.161	48.222	.411	81.881	--	.421	0	1.777	2.198
October	1.937	16.456	53.691	.365	72.449	--	.420	0	2.086	2.506
November	1.874	17.087	54.973	.353	74.287	--	.419	0	1.790	2.209
December	1.937	17.658	47.302	.365	67.262	--	.419	0	1.976	2.395
Total	30.053	207.483	618.884	3.409	859.829	--	5.037	0	18.997	24.034

Table 20.--Commercial, domestic, industrial, and municipal returns in the Rockford and the Kankakee areas, Illinois, 1984--Continued

Month	Kankakee area									
	Bradley					Kankakee				
	Commercial	Domestic[2]	Industrial	Municipal[5]	Total	Commercial	Domestic[2]	Industrial	Municipal[5]	Total
January	--	0.004	--	2.764	2.768	--	2.183	4.048	5.067	11.298
February	--	.004	--	2.599	2.603	--	2.135	6.548	4.765	13.448
March	--	.002	--	3.735	3.737	--	2.056	6.339	6.847	15.242
April	--	.004	--	2.028	2.032	--	2.189	9.464	3.718	15.371
May	--	.004	--	3.180	3.184	--	2.303	10.714	5.831	18.848
June	--	.002	--	2.703	2.705	--	2.298	10.089	4.955	17.342
July	--	.004	--	2.652	2.656	--	2.498	5.714	4.864	13.076
August	--	.004	--	3.071	3.075	--	2.440	7.173	5.633	15.246
September	--	.004	--	3.554	3.558	--	2.345	9.464	6.518	18.327
October	--	.002	--	4.172	4.174	--	2.243	5.089	7.648	14.980
November	--	.004	--	3.581	3.585	--	2.264	7.381	6.565	16.210
December	--	.005	--	3.952	3.957	--	1.998	6.964	7.244	16.206
Total	--	.043	--	37.991	38.034	--	26.952	88.987	69.655	185.594

[1]Estimates of nonconsumptive use from the types-of-use method (see "Consumptive Uses" section and Appendix).
[2]Estimated by use of equation 4.
[3]Data recorded quarterly.
[4]Data recorded bimonthly.
[5]Estimated by use of equation 5.

The weighing expression, $DSS_c/DEL_c \times CONS_c$, is used to estimate consumptive use by water users with septic systems. The expression was used to compensate for $CONS_c$, which represents consumptive use by all water users. The resulting consumptive use is subtracted from DSS_c to determine the part of DSS_c that is direct returns by septic-system users ($DRTSS_c$).

If deliveries to septic-system users (DSS_c) were less than 5 percent of the total domestic deliveries, consumptive use by septic-system users would be overestimated with equation 4. In those cases, consumptive use was assumed to be negligible. All deliveries to those septic-system users were assumed to become direct returns.

Equation 4 was used to estimate domestic returns for all communities, and commercial, industrial, and municipal returns for North Park. These returns were included with the other direct returns previously determined. Table 21 is an example of how domestic returns by septic-system users were estimated for Loves Park.

The estimating procedure outlined in table 21 was also used to estimate returns by commercial, industrial, and municipal septic-system users. However, because their consumptive use was considered to be year round, the ratio and CONS were applied to all months, instead of just the summer months.

Where direct-return data or nonconsumptive-use estimates were not available for municipal use, the direct returns could not be assumed to be negligible. The reason for this is that most municipal establishments do not release water or pay sewer fees. Therefore, where deliveries to municipal septic-system users also were unknown, direct returns by municipal users were estimated by the equation:

$$DRT = DEL - CONS, \qquad (5)$$

where DRT is monthly direct returns;
DEL is monthly deliveries; and
CONS is monthly consumptive uses.

This equation, in which municipal deliveries are assumed to become either consumptive use or direct returns, was used to estimate municipal returns for the Kankakee area.

The accuracy of commercial, domestic, industrial, and municipal return data in table 20 is considered to be poor (greater than 25-percent error) because most direct returns were estimated. Of the categories with direct-return data, the water-utility managers believe that roughly one-half to three-fourths of the direct returns are being metered (Richard Eick, Rockford Sanitary District, and James Clarno, Kankakee Department of Water Pollution Control, oral commun., 1985).

Total returns for the Rockford and the Kankakee areas (table 22) were determined by combining sewage-treatment returns and direct returns. Sewage-treatment returns accounted for 92 percent of the total returns in the Rockford area and 94 percent in the Kankakee area.

Table 21.--Estimation of domestic returns in Loves Park, Illinois, 1984

[A, monthly deliveries to septic-system users; B, ratio x domestic consumptive use; N/A, not applicable; all figures are in million gallons]

Month	Total domestic deliveries[1] (DEL)	Deliveries to septic-system users (A)	Ratio[2] $\left(\frac{A}{DEL}\right)$	Domestic consumptive use[3] (CONS)	Consumptive use by septic-system users (B)	Domestic returns (A - B)
January	25.507	2.093	N/A	N/A	N/A	2.093
February	23.278	1.715	N/A	N/A	N/A	1.715
March	23.986	1.886	N/A	N/A	N/A	1.886
April	25.204	1.848	N/A	N/A	N/A	1.848
May	28.503	2.761	0.097	2.953	0.286	2.475
June	31.184	2.455	.079	5.097	.403	2.052
July	38.654	3.259	.084	11.074	.930	2.329
August	35.361	2.951	.083	8.439	.700	2.251
September	28.942	2.350	.081	3.304	.268	2.082
October	27.662	2.289	.083	2.280	.189	2.100
November	24.627	1.622	N/A	N/A	N/A	1.622
December	26.272	1.878	N/A	N/A	N/A	1.878

[1]Includes domestic self-supply withdrawals.
[2]Applied only during the high consumptive-use period.
[3]Derived from the winter base-rate method.

Table 22.--Estimates of total returns in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons]

Month	Sewage treatment	Commercial, domestic, industrial, and municipal returns[1]	Total
	Rockford area		
January	1,003.850	80.959	1,084.809
February	988.570	75.485	1,064.055
March	1,009.770	79.087	1,088.857
April	979.830	86.247	1,066.077
May	1,054.850	95.684	1,150.534
June	1,092.620	97.333	1,189.953
July	1,131.560	110.611	1,242.171
August	1,028.150	110.510	1,138.660
September	885.290	104.142	989.432
October	976.460	94.765	1,071.225
November	970.910	95.799	1,066.709
December	943.970	88.568	1,032.538
Total	12,065.830	1,119.190	13,185.020
	Kankakee area		
January	262.034	15.867	277.901
February	392.630	17.770	410.400
March	476.066	21.264	497.330
April	367.271	18.836	386.107
May	425.872	24.041	449.913
June	326.810	21.820	348.630
July	275.228	17.480	292.708
August	265.166	20.279	285.445
September	239.085	24.083	263.168
October	264.679	21.660	286.339
November	292.350	22.004	314.354
December	306.607	22.558	329.165
Total	3,893.798	247.662	4,141.460

[1]Estimates.

Conveyance Losses and Gains

Most water-conveyance systems lose or gain water. Conveyance losses or gains can result from water leaks in faulty pipes, joints, and valves; surface-water runoff or ground water entering the conveyance system; and unrecognized connections to the conveyance system.

Public-supply conveyances

Water in public-supply conveyance systems is conveyed under pressure, so it is typically lost, not gained. When public-supply conveyance systems are not adequately pressurized, such as when water-main breaks are being repaired, they may gain water.

Conveyance data were available from public suppliers in Loves Park and Rockford only. The data included partial estimates of known conveyance losses caused by water-main maintenance and construction for Loves Park and reservoir leakage for Rockford. In Loves Park, conveyance loss events amounted to 8.338 Mgal/yr. Losses from Rockford's public-supply reservoir amounted to 0.007 Mgal/yr.

Conveyance losses and gains for the public-supply conveyance systems in the Rockford and the Kankakee areas were estimated as the difference between public-supply withdrawals and deliveries (table 23). This method should be used cautiously because the estimates can be biased by illegal or unrecognized delivery connections and by overregistering or underregistering water meters (Kindler and Russell, 1984, p. 159). Conveyance losses or gains were assumed to be zero for self-suppliers. Using this method, the public-supply conveyance systems in the two areas lost about 5 to 26 percent of their public-supply withdrawals.

Table 23.--Estimates of public-supply conveyance losses[1] in the Rockford and the Kankakee areas, Illinois, 1984

[All figures are in million gallons]

Quarter	Rockford area			Kankakee area
	Loves Park	North Park	Rockford	
January to March	9.593	44.490	233.810	183.239
April to June	7.409	42.052	128.548	108.142
July to September	25.785	53.533	414.543	163.936
October to December	1.474	21.212	395.872	170.820
Total	44.261	161.287	1,172.773	626.137

[1]Public-supply withdrawals minus deliveries.

Although the accuracy of conveyance-loss estimates is unknown, the estimates seem to be reasonable in comparison with estimates from previous investigations. According to the American Water Works Association (1978, p. 4-10 to 4-11), estimates of public-supply conveyance loss range from 0.5 to 40.0 percent of public-supply withdrawals for most northern Illinois cities. Seidel (1985) found the national median to be 11 percent. The age and the size of public-supply conveyance systems and the extent of maintenance programs affect public-supply conveyance losses. Therefore, the estimates of public-supply conveyance losses are unique to each public-water system.

Sewer conveyances

Gain or loss data for sewer conveyance were not available. Therefore, sewer-conveyance gains or losses (table 24) were estimated as the difference between sewage-treatment returns and releases. Use of this method can result in erroneous estimates if the amount of unrecognized releases or meter errors are significant. On the basis of the estimates, the sewer-conveyance systems usually gain water.

Table 24.--Estimates of sewer-conveyance gains[1] or losses[1] in the Rockford and the Kankakee areas, Illinois, 1984

[Negative value is losses; all figures are in million gallons]

Quarter	Rockford area	Kankakee area		
		Bourbonais	Bradley	Kankakee
January to March	959.073	9.690	85.549	403.546
April to June	1,200.080	41.346	114.587	306.133
July to September	1,031.275	2.073	23.504	98.055
October to December	885.444	-19.911	44.782	220.595
Total	4,075.872	33.198	268.422	1,028.329

[1]Releases minus sewage-treatment returns.

In the Rockford area, the most probable cause of the sewer-conveyance system gain is ground-water infiltration into faulty pipes. In the Kankakee area, the sewer-conveyance gains were probably from storm-water runoff and ground-water infiltration into the combined-sewer conveyance system. The Bourbonnais sewer-conveyance system seems to have lost water (table 24) during the last quarter. Ground-water levels may have subsided below the sewer pipes during the dry summer months. This would have allowed water to escape from faulty pipes.

Donohue and Associates, Inc. (1981) evaluated Kankakee's sewer-conveyance system and reported peak gains that were 43 times the gains documented here.

Their estimates, however, do not seem to include (1) normal flow or (2) water lost from the overflow weirs. The estimating method used in this report involves sewage-treatment return data, which include the effect of normal flow and losses.

Comparison of Water Use Between Study Areas

Water use and distribution, by category, as a percentage of public-supply withdrawals in the Rockford and the Kankakee areas are shown in water-use models (figs. 5 and 6). Of the four public supplies in the two areas, domestic use (deliveries) ranged from 30.5 to 62.1 percent; commercial and industrial use ranged from 10.4 to 54.4 percent; municipal use ranged from 0.5 to 4.7 percent; and public-supply conveyance losses ranged from 4.8 to 25.8 percent (table 25). Domestic consumptive use ranged from 1.1 to 8.5 percent; commercial and industrial consumptive use ranged from 1.7 to 12.1 percent; and municipal consumptive use ranged from 0.1 to 1.3 percent. The maximum consumptive use, 12.1 percent, was for commercial and industrial uses in Loves Park. Releases by domestic users ranged from 22.8 to 30.7 percent of the four public-supply withdrawals; for commercial and industrial users, from 6.7 to 42.7 percent; and for municipal users, from 0.0 to 2.0 percent.

Table 25.--Water use, by category, as a percentage of each of the four public-supply withdrawals in the Rockford and the Kankakee areas, Illinois, 1984

[N/A, not applicable]

	Rockford area			Kankakee area
	Loves Park	North Park	Rockford	
Deliveries				
Domestic	36.6	62.1	34.6	30.5
Commercial and industrial	54.4	10.4	53.2	48.3
Municipal	4.2	1.7	.5	4.7
Public-supply conveyance losses	4.8	25.8	11.7	16.5
Consumptive uses				
Domestic	3.6	8.5	2.3	1.1
Commercial and industrial	12.1	1.7	9.9	7.7
Municipal	1.2	.5	.1	1.3
Releases				
Domestic	30.4	22.8	30.7	28.6
Commercial and industrial	42.7	6.7	39.8	39.2
Municipal	2.0	1.0	.3	0
Sewer conveyance gains	N/A	N/A	[1]35.2	35.1

[1]Includes Loves Park and North Park.

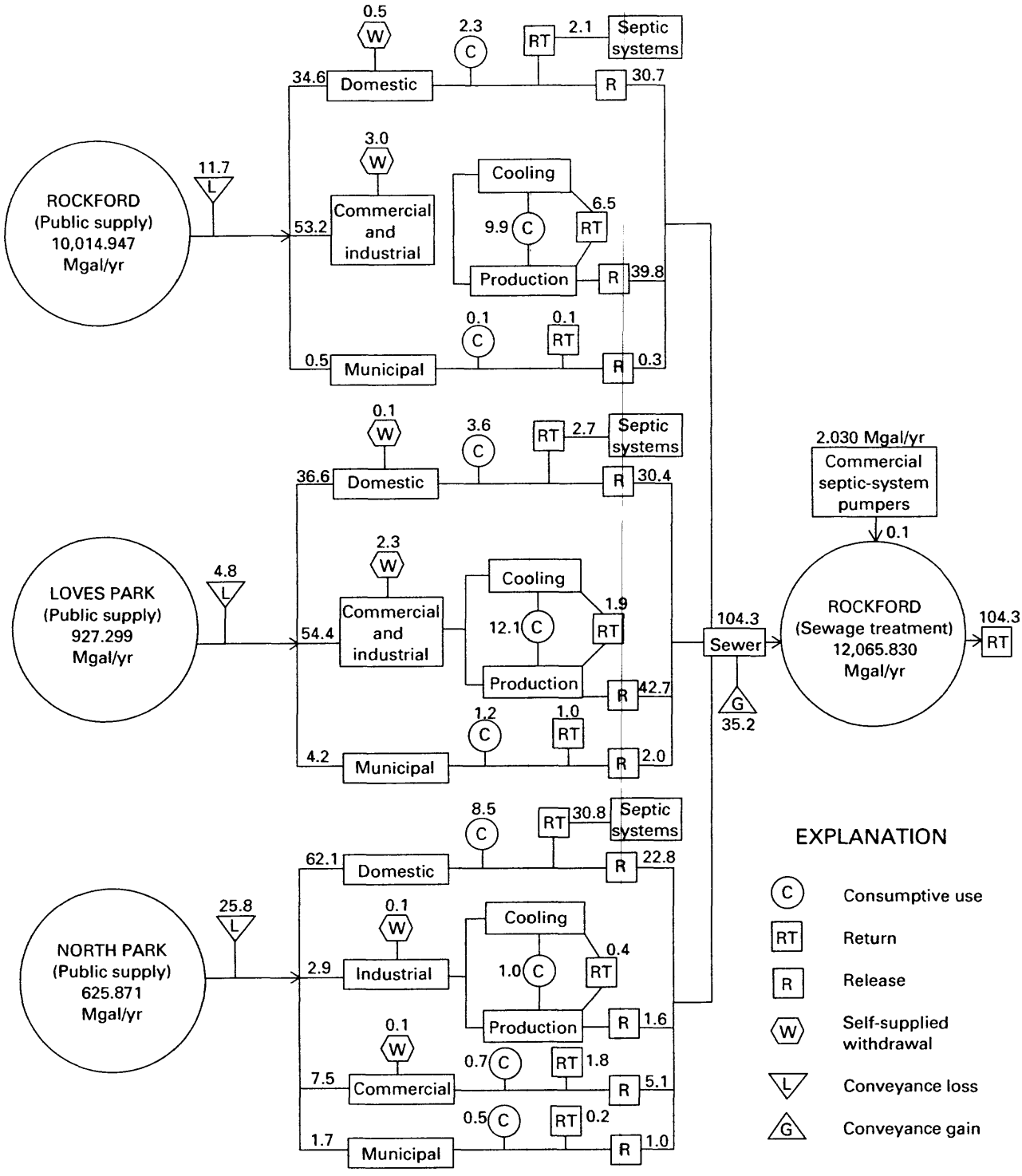

Figure 5.---Use of water, by category, as a percentage of public-supply withdrawals, Rockford area, Illinois, 1984. (Mgal/yr, million gallons per year.)

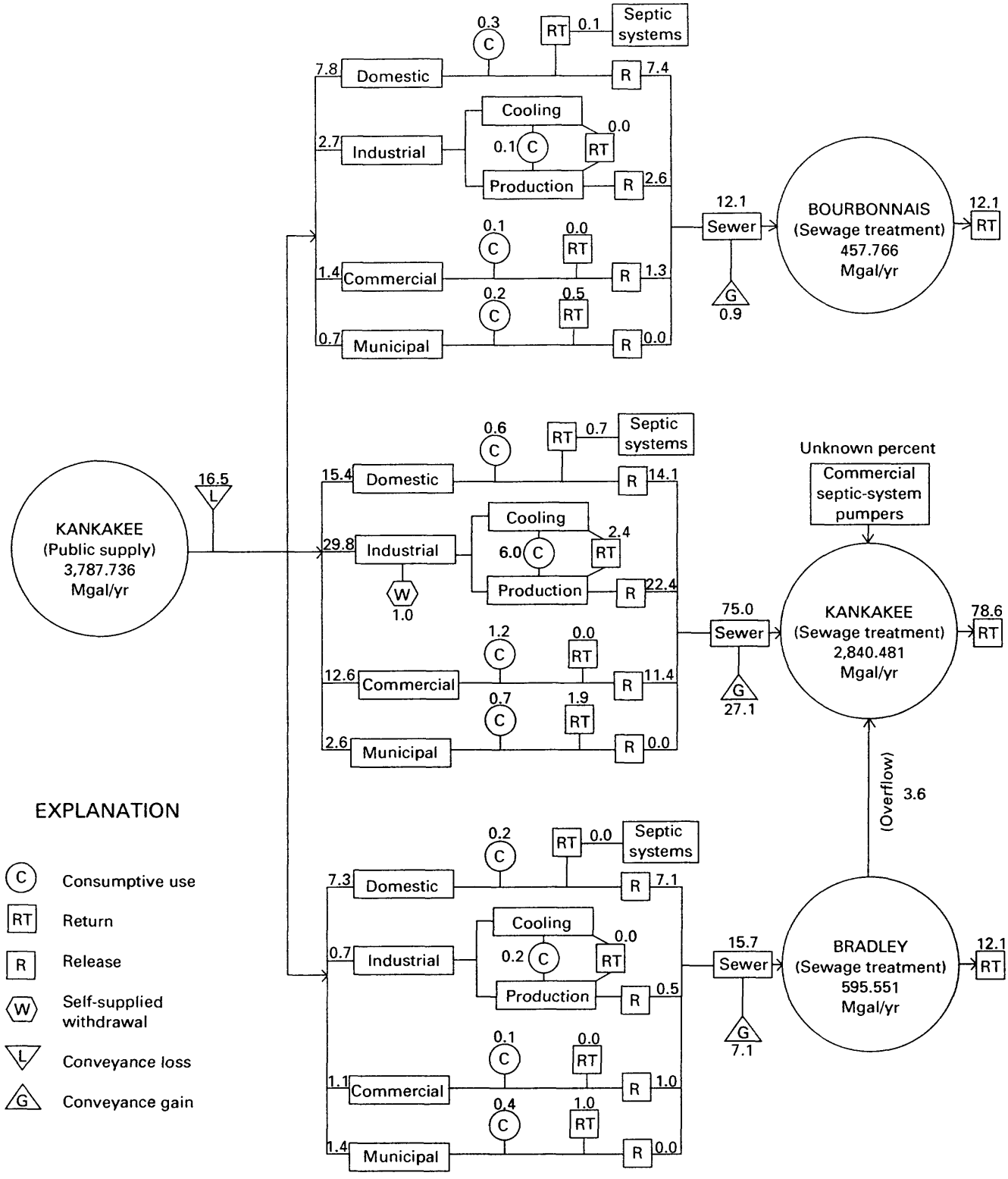

Figure 6.---Use of water, by category, as a percentage of public-supply withdrawals, Kankakee area, Illinois, 1984. (Mgal/yr, million gallons per year.)

Total deliveries, by category, as a percentage of public-supply withdrawals were similar among the two study areas (fig. 7). Commercial and industrial deliveries amounted to 51.1 percent of public-supply withdrawals in the Rockford area and 48.3 percent in the Kankakee area. Domestic deliveries were 36.2 and 30.5 percent, and municipal deliveries were 0.8 and 4.7 percent in the Rockford and the Kankakee areas. In both areas, about one-half of public-supply withdrawals were delivered for commercial and industrial uses, about one-third for domestic uses, and the remaining one-sixth for municipal uses and public-supply conveyance losses.

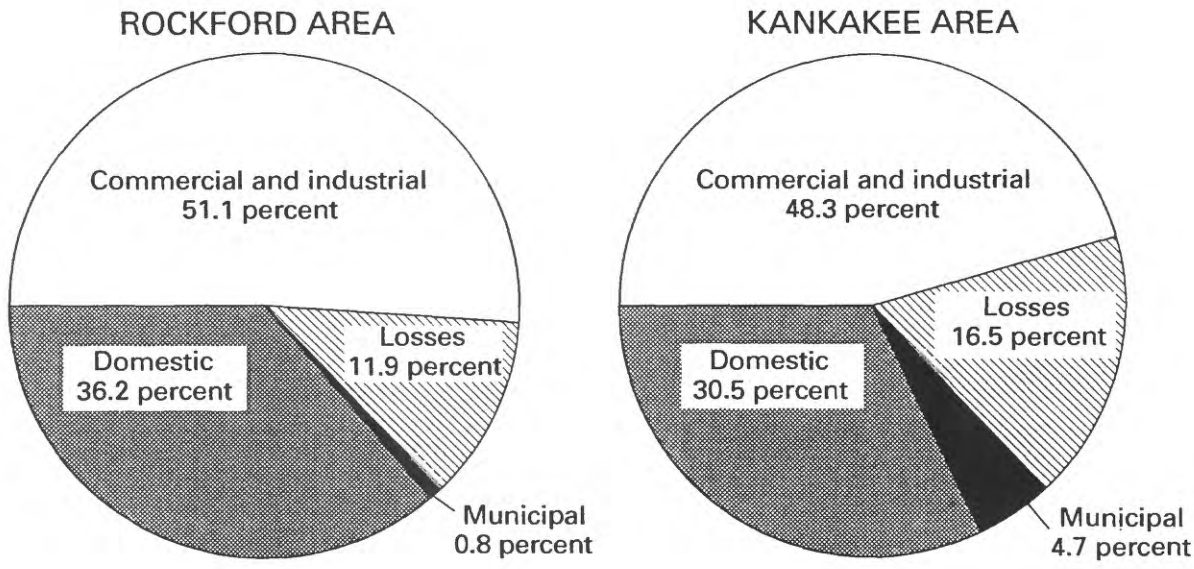

Figure 7.---Deliveries as percentages of public-supply withdrawals, Rockford and Kankakee areas, Illinois, 1984.

Conveyance losses and gains, as a percentage of public-supply withdrawals and sewage-treatment returns, were also similar in the two study areas. Public-supply conveyance losses were 11.9 percent of public-supply withdrawals in the Rockford area and 16.5 percent in the Kankakee area (fig. 7). Sewer-conveyance gains were about 35 percent of public-supply withdrawals (table 25) and about 34 percent of sewage-treatment returns in the two areas.

The distribution of used water was similar in the two study areas. In the Rockford and the Kankakee areas, commercial and industrial establishments consumed 17.9 and 15.7 percent, released 71.2 and 79.5 percent, and returned 10.9 and 4.8 percent of the deliveries and self-supplied withdrawals in each area (fig. 8). On the basis of these percentages, the commercial and the industrial consumptive uses, the releases, and the returns amounted to 17 ±1, 75 ±4, and 8 ±4 percent of their deliveries and self-supplied withdrawals in the two study areas. Domestic consumptive uses, releases, and returns amounted to 6 ±2, 88 ±5, and 6 ±4 percent of their deliveries and self-supplied withdrawals. Municipal consumptive use amounted to 27 ±1 percent of their deliveries and self-supplied

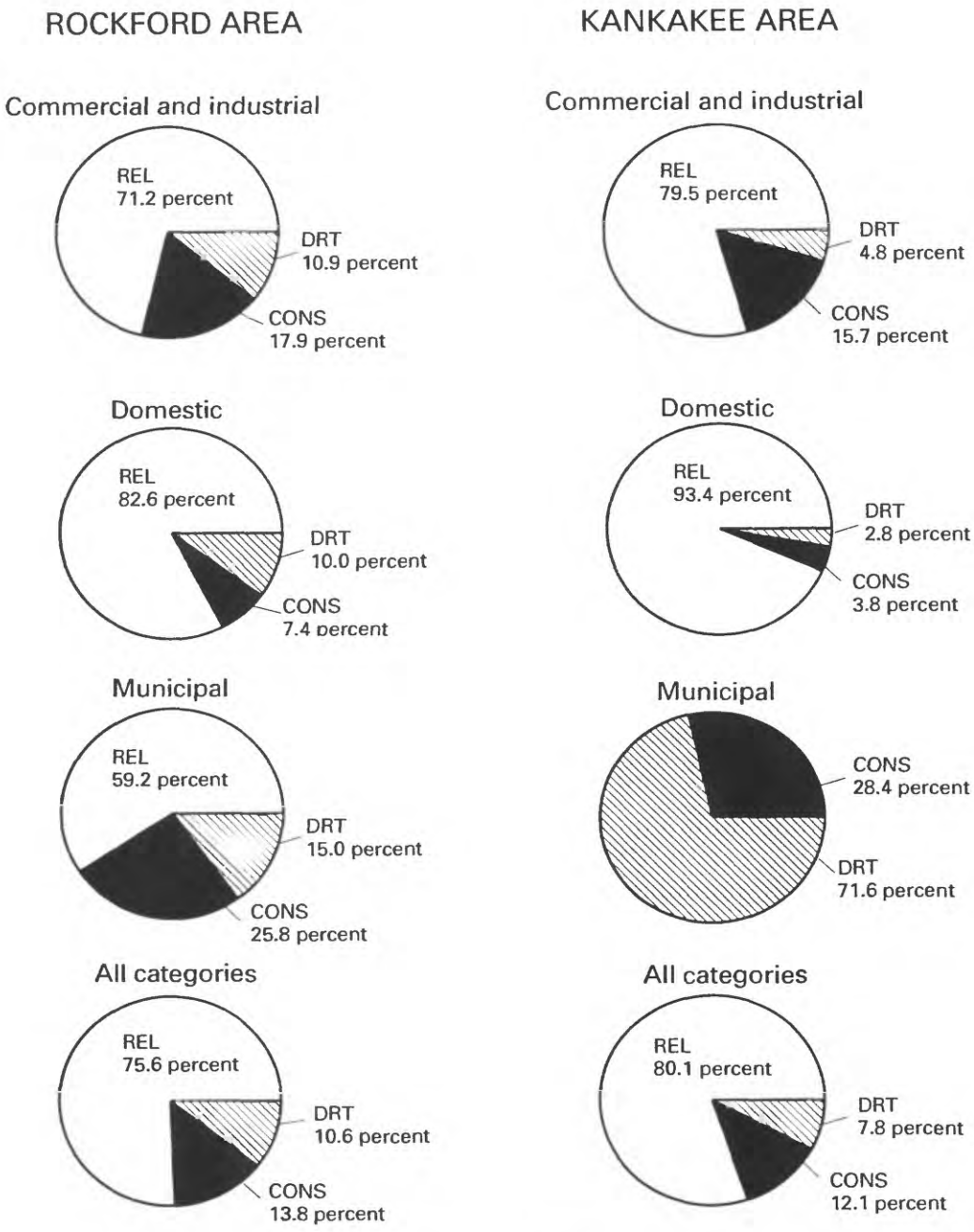

Figure 8.---Percentages of deliveries and self-supply withdrawals, by category, that became consumptive uses, releases, and direct returns, Rockford and Kankakee areas, Illinois, 1984.

withdrawals in the two areas. Municipal releases and returns in the two areas were dissimilar (fig. 8), probably because more municipal establishments were connected, or known to be connected, to the sewer-conveyance system in the Rockford area than in the Kankakee area. The consumptive uses by all water users (establishments and households) were 13 ±1 percent, the releases were 78 ±2 percent, and the direct returns were 9 ±2 percent of the deliveries and self-supply withdrawals for both areas (fig. 8).

Domestic *per-capita uses* (public supplied and self supplied), by community, were estimated and were compared. The population that is publicly supplied and self-supplied had to be determined to estimate these per capita uses. Public-supplied populations are typically determined from population-served information available from public suppliers. These data were available for only some of the communities studied. Self-supplied populations are typically estimated as the difference between total population and population served. In this study, the difference would overestimate the self-supplied populations, which are only those connected to the sewer-conveyance system. Therefore, the following equation was used to estimate public-supplied (PSD) and self-supplied (SSD) domestic per capita uses:

$$PSD \text{ or } SSD = DUSE/HHD/PER/366, \quad (6)$$

where DUSE is domestic use (deliveries by public supply or self-supply withdrawal),
HHD is number of households, and
PER is population per household.

Data on domestic use and number of households were obtained from most public suppliers. The number of households publicly supplied in the Rockford area, as well as the average population per household in each community, were obtained from the U.S. Bureau of Census (1980). The period of study was calendar year 1984, a leap year.

The public-supplied domestic per capita use in the six communities ranged from 67.2 to 71.0 gal/d (gallons per day). Standard deviation was 1.3 gal/d, only 1.9 percent of the mean public-supplied domestic per capita use. Per capita uses for each community in the two areas are listed in table 26. At a 95-percent confidence interval, the mean public-supplied domestic per capita use (69.2 gal/d) has an interval of only ±1.1 gal/d.

The self-supplied domestic per capita use was less than the public-supplied domestic per capita use for the communities of Rockford and Loves Park (table 26). Self-supply withdrawal data used to determine the self-supplied domestic per capita uses are of unknown completeness or accuracy. Rockford's self-supplied domestic per capita use of 51 gal/d is about 75 percent of the mean public-supplied domestic per capita use of 69.2 gal/d. The estimate for Rockford, based on data from 1,049 households, is probably reasonable. The Loves Park estimate of 24.4 gal/d is about 35 percent of the mean public-supplied domestic per capita use. That estimate was based on data for only seven households.

Table 26.--Determination of public- and self-supplied domestic per capita water use, Rockford and Kankakee areas, Illinois, 1984

[Mgal/yr, million gallons per year; gal/d, gallons per day; dashes indicate no data; N/A, not applicable]

PUBLIC-SUPPLIED

Community	Domestic deliveries (Mgal/yr)	Number of households	Persons per household[1]	Public-supplied domestic per capita use[2] (gal/d)
Loves Park	339.006	[1]4,693	2.78	71.0
North Park	388.793	[1]5,003	3.16	67.2
Rockford	3,460.223	[1]52,169	2.61	69.4
Bourbonnais	294.922	3,967	2.95	68.9
Bradley	278.667	3,915	2.78	70.0
Kankakee	583.122	8,775	2.63	69.0
Total	5,344.733	78,522	N/A	N/A
Mean	N/A	N/A	2.82	69.2
Standard deviation	N/A	N/A	.21	1.3
Confidence interval	N/A	N/A	±.17	±1.1

SELF-SUPPLIED

Community	Self-supplied domestic withdrawals (Mgal/yr)	Number of households	Persons per household[1]	Self-supplied domestic per capita use[2] (gal/d)
Loves Park	0.174	7	2.78	24.4
North Park	--	--	--	--
Rockford	51.110	1,049	2.61	51.0
Bourbonnais	--	--	--	--
Bradley	--	--	--	--
Kankakee	--	--	--	--
Total	51.284	1,056	N/A	N/A
Mean	N/A	N/A	2.69	37.7

[1]Data from U.S. Bureau of Census, 1980.
[2]Calculated by use of equation 6.

Total water returns (sewage treatment and direct) were greater than total water withdrawals (public and self supply) in the Rockford and the Kankakee areas (figs. 9 and 10) as a result of large sewer-conveyance gains. Although amounts of water should logically decrease in the order of withdrawals, deliveries, releases, and returns; returns exceeded withdrawals in the two areas. As can be seen in figures 9 and 10, consumptive use cannot be simply calculated by subtraction of returns from withdrawals because a negative consumptive-use estimate would result. A better estimate of consumptive use can be obtained by subtracting releases from deliveries.

Rainfall seems to affect water use in the Rockford and the Kankakee areas. Monthly withdrawals, deliveries, releases, and returns of water; and rainfall in the two areas are shown in figures 11 and 12. Withdrawals and deliveries seem to increase during dry periods and to decrease during wet periods. The increase in withdrawals during the summer months is generally caused by lawn watering. In general, returns seem to increase during periods of increasing rainfall. Peak returns in the Rockford area are generally caused by ground water infiltrating the sewer-conveyance system; in the Kankakee area, they are generally caused by surface-water runoff entering the combined sewer-conveyance system. The effects of rainfall (or lack of) on water use in Illinois warrant further study.

SUMMARY AND CONCLUSIONS

Amounts of water withdrawn, delivered, consumed, released, returned, and lost or gained during conveyance were determined for six communities served by the public-water systems in the Rockford and the Kankakee areas of Illinois. The six communities are Rockford, Loves Park, and North Park (Rockford area), and Kankakee, Bourbonnais, and Bradley (Kankakee area). Water-use categories studied were commercial, industrial, domestic, and municipal uses; public supply; and sewage treatment.

Water-use data were obtained from all water utilities and from several major water users (establishments that use more than 1 million gallons per month for 2 or more consecutive months) in the Rockford and the Kankakee areas. The data obtained from water utilities include (1) public-supply withdrawal, (2) self-supply withdrawal, (3) estimates of partial public-supply conveyance loss, (4) deliveries by public supply, (5) partial release, (6) partial commercial, industrial, domestic, and municipal return (direct returns), (7) sewage-treatment return, and (8) precipitation.

Of the 32 major water users, 30 provided adequate (more than 2 months of data) water-use data on self-supplied withdrawals, deliveries, consumptive uses, releases, and (or) direct returns.

Adequate data were available for all withdrawals, deliveries, and sewage-treatment returns in the two study areas. Adequate data were also available for industrial releases in both areas, municipal returns in Loves Park, and industrial returns in Bourbonnais and Kankakee.

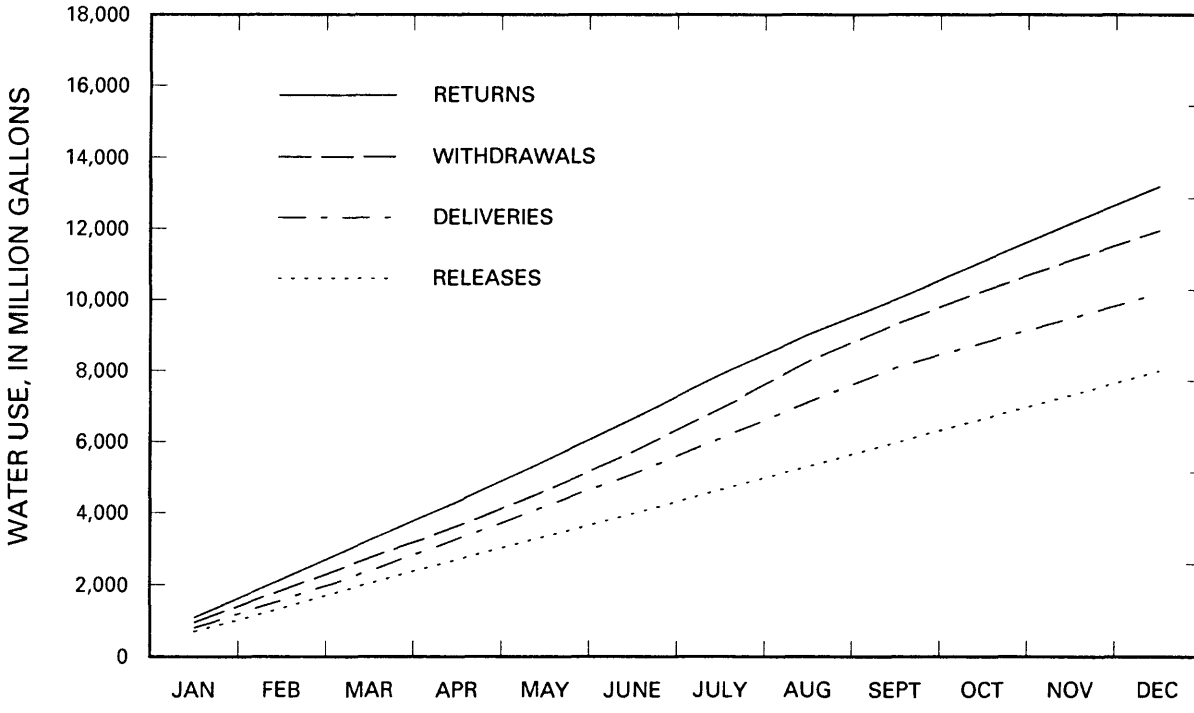

Figure 9.---Cumulative monthly withdrawals, deliveries, releases, and returns in the Rockford area, Illinois, 1984.

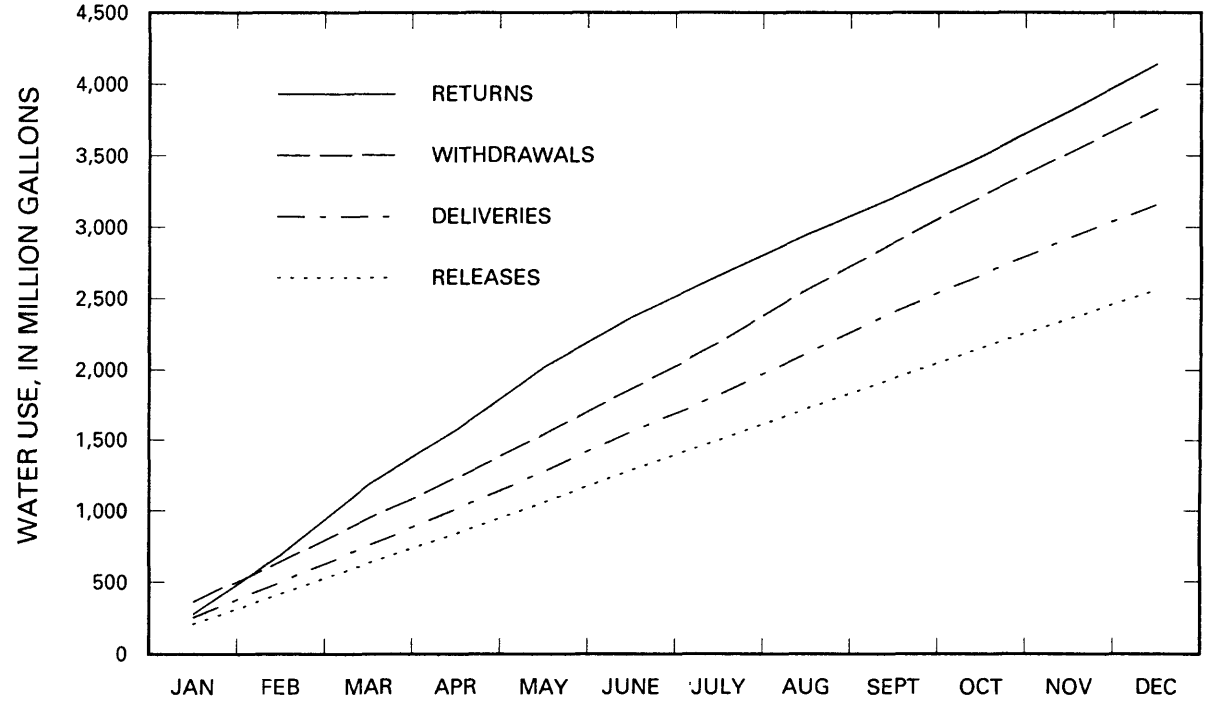

Figure 10.---Cumulative monthly withdrawals, deliveries, releases, and returns in the Kankakee area, Illinois, 1984.

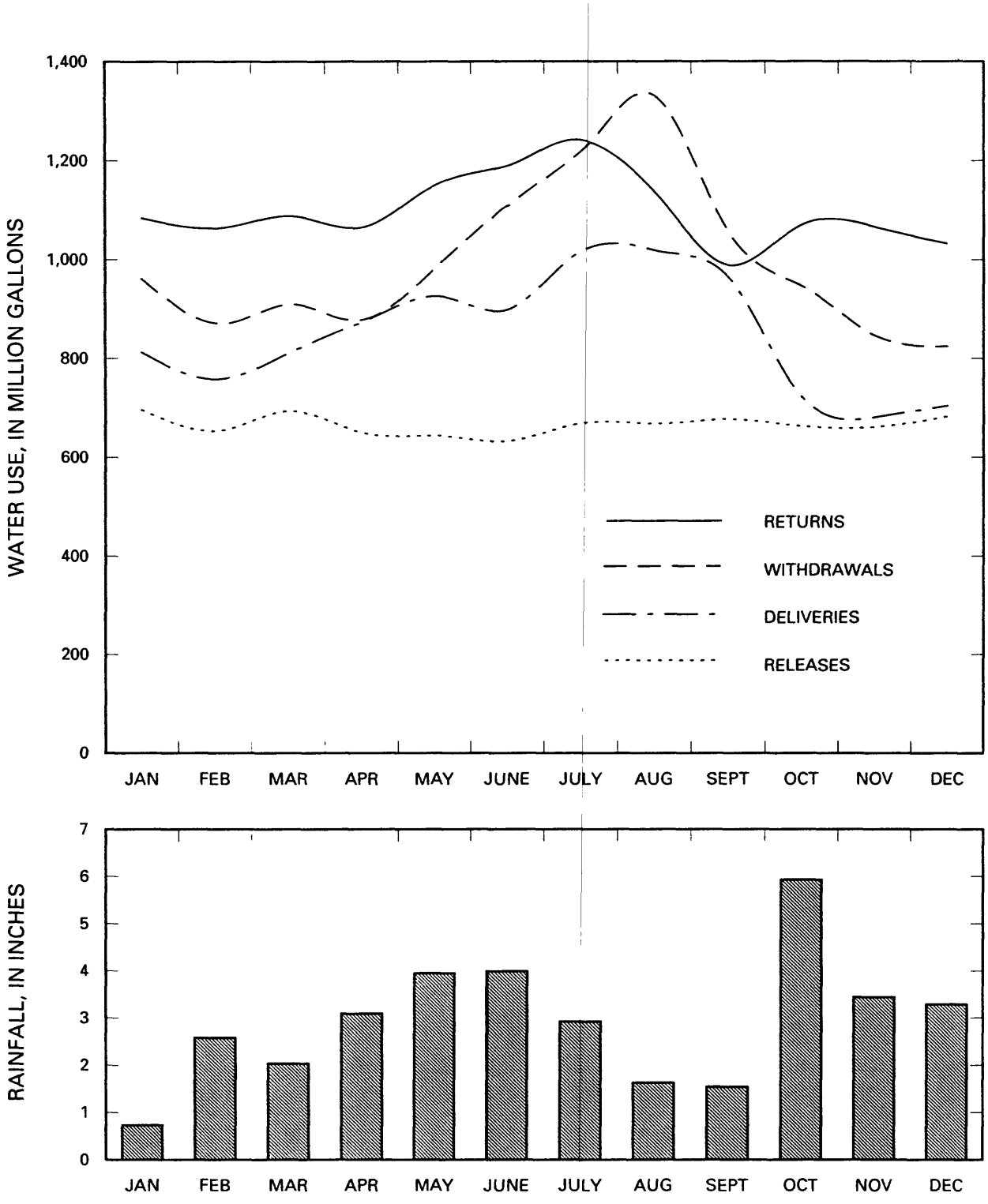

Figure 11.---Monthly withdrawals, deliveries, releases, and returns of water; and rainfall in the Rockford area, Illinois, 1984.

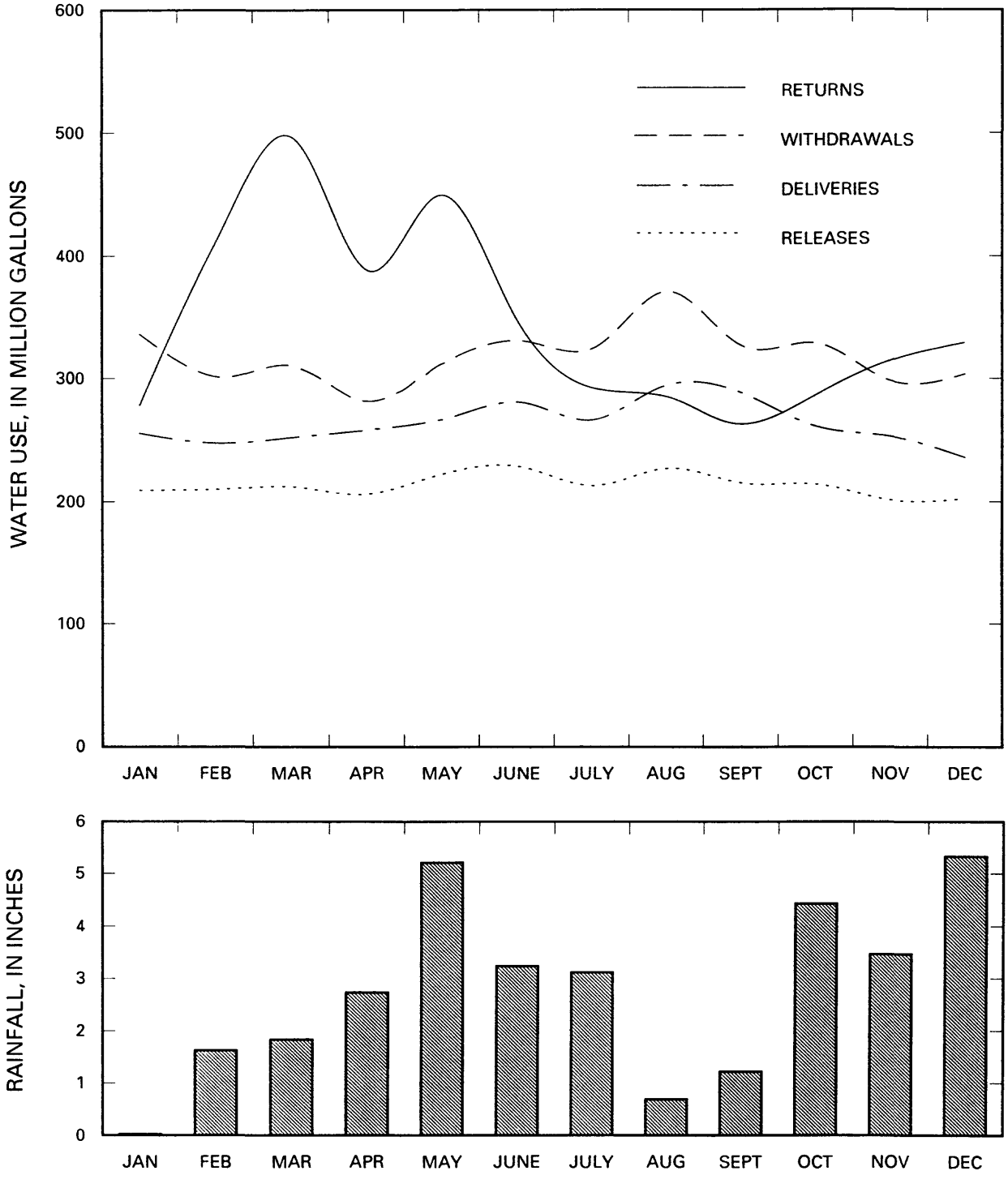

Figure 12.---Monthly withdrawals, deliveries, releases, and returns of water; and rainfall in the Kankakee area, Illinois, 1984.

The accuracy of water-use data is indicated by ratings of good (10-percent or less error), fair (10- to 25-percent error), or poor (greater than 25-percent error). Accuracy was determined on the basis of discharge measurements or reliability tests of meters, or estimated according to the completeness of the data. Discharge measurements were taken at 19 metered release points, which consisted of 17 percent of all releases in the two areas. Discharge measurements also were taken at all four sewage-treatment-return points. Reliability tests of meters were available for the Kankakee area. Accuracy of water-use data can be summarized as follows:

	Rockford area	Kankakee area
Withdrawals	Good	Good
Deliveries	Fair	Good
Consumptive uses	Unknown	Unknown
Releases (industrial only)	Poor	Good
Sewage-treatment returns	Good	Good
Direct returns	Poor	Poor
Conveyance losses and gains	Unknown	Unknown

Various methods were used to estimate consumptive uses; releases; returns by commercial, domestic, industrial, and municipal users; and conveyance losses and gains. The methods were focused on water budgeting to assure that water uses balanced. Consumptive uses were estimated by use of the consumption-budget method, the types-of-use method (water used for cooling systems, boilers, and lawn watering), consumptive-use ratios (consumptive use divided by deliveries and (or) self-supply withdrawals), the winter base-rate method (domestic outside use), and the maximum lawn-watering method. The winter base-rate method provided the best domestic consumptive-use estimates, whose ratios (consumptive use from the winter base-rate method divided by deliveries and self-supply withdrawals), by community, ranged from 0.030 to 0.136 and averaged 0.068. The consumption-budget and types-of-use methods, as well as consumptive-use ratios, were used to estimate consumptive use for commercial, industrial, and municipal categories. Water budgeting was used, in general, to estimate releases, and conveyance losses and gains. Estimates of nonconsumptive uses by cooling systems, boilers, and lawn watering; data of deliveries to septic-system users; and (or) water budgeting were used to estimate commercial, domestic, industrial, and municipal returns undefined by data.

Proportions of water use were similar in the two study areas. Of the public-supply withdrawals in each area, about one-half was delivered for commercial and industrial uses; about one-third for domestic uses; and about one-sixth for municipal uses and public-supply conveyance losses. Furthermore, public-supply conveyance losses were about 12 percent in the Rockford area and about 17 percent in the Kankakee area, whereas sewer-conveyance gains were about 35 percent in the two areas. The commercial and the industrial consumptive uses, the releases, and the returns in the two areas amounted to 17 ±1, 75 ±4, and 8 ±4 percent of their deliveries and self-supplied withdrawals. Domestic consumptive uses, releases, and returns amounted to 6 ±2, 88 ±5, and 6 ±4 percent of their deliveries and self-supplied withdrawals. Consumptive uses by all establishments and households were 13 ±1 percent, the releases were 78 ±2 percent, and the direct returns were 9 ±2 percent of the deliveries and self-supply withdrawals.

Total water returns (sewage treatment and direct) were greater than total water withdrawals in the two areas because of sewer-conveyance gains, which amounted to about 34 percent of the sewage-treatment returns for each area. Thus, consumptive use cannot be simply calculated by subtraction of returns from withdrawals because a negative consumptive-use estimate would result. A better estimate of consumptive use can be obtained by subtracting releases from deliveries.

Rainfall seems to affect water use in the two areas. Monthly withdrawals and deliveries seem to increase during dry periods and to decrease during wet periods. The increase in withdrawals during the summer months is generally caused by lawn watering. In general, returns seem to increase during periods of increasing rainfall, largely because surface-water runoff and (or) ground water entering the sewer-conveyance systems. Effects of rainfall (or lack of) on water use in Illinois warrant further study.

The use of delivery rates, deliveries divided by the number of users (establishments or households) by category, as coefficients in the estimation of deliveries for other water systems was evaluated. The standard deviation for domestic-delivery rates from each community is 0.005 (Mgal/H)/yr or about 7 percent of the mean domestic rate 0.071 (Mgal/H)/yr; for commercial, it is 0.110 (Mgal/est)/yr or about 27 percent of the mean rate 0.406 (Mgal/est)/yr; and for all categories, it is 0.056 (Mgal/user)/yr or about 38 percent of the mean rate 0.146 (Mgal/user)/yr. Based on the 95-percent confidence intervals of the mean rates for each community, domestic deliveries for each community range from 0.067 to 0.075 (Mgal/H)/yr; commercial deliveries range from 0.277 to 0.535 (Mgal/est)/yr, and deliveries to all categories range from 0.100 to 0.192 (Mgal/user)/yr.

Public-supplied domestic per capita use in the six communities ranged from 67.2 to 71.0 gal/d. Standard deviation was 1.3 gal/d, only 1.9 percent of the mean. At a 95-percent confidence interval, the mean public-supplied domestic per capita use (69.2 gal/d) has an interval of only ±1.1 gal/d. Rockford's self-supplied domestic per capita use (51 gal/d)--the most reasonable self-supply estimate--is about 75 percent of the mean public-supplied domestic per capita use.

In conclusion, water-use data for the Rockford and the Kankakee areas were accurate and adequate to define withdrawals, deliveries, and sewage-treatment returns. Release data were available but not always complete. Data on consumptive use; commercial, industrial, domestic, and municipal return; and conveyance loss and gain were generally unavailable. Better release data or estimates than are currently available are especially needed to quantify consumptive use and sewer-conveyance gains (or losses) by water budgeting. Field verification with meters is needed to further verify the accuracy of water-use data.

Water-use data and estimates used to plan, manage, and evaluate our water resources or public-water systems become increasingly valuable as resources continue to diminish, deteriorate, and (or) become more costly. Therefore, continued investigation of all waters withdrawn, delivered, consumed, released, returned, and lost or gained during conveyance is needed to improve the collection and the analysis of water-use information.

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APPENDIX

Determination of Consumptive Use as a Percentage of Use by Cooling Systems, Boilers, and Lawn Watering

Water used by cooling systems, boilers, and lawn watering typically becomes consumptive use or direct returns. In this section, consumptive uses as a percentage of these uses are determined for the types-of-use method.

Evaporative cooling systems constitute most of the cooling systems with significant water use in the Rockford area (Ken Linnemeir, Nelson Carlson Mechanical Contractors, oral commun., 1988); consequently, most of the data for cooling systems in the Rockford area probably represent water use by evaporative-cooling systems. Boiler-water-use data mostly represent water used by steam-generating systems because these systems use a significant amount of water but release little to the sewer.

Water used by cooling systems and boilers is commonly called make-up water. Make-up water for evaporative-cooling systems replaces water lost by evaporation, drift, and blowdown. Water lost by evaporation and drift is consumptive use. Drift is water lost by mist and small droplets, which typically evaporates. Blowdown is the occasional discharge of water to prevent scale deposits from forming in the system. Blowdown water can be directly returned to water sources, after treatment, or can be released to sewage-treatment plants. All blowdown water from cooling systems and boilers was assumed to be directly returned.

Because make-up water for the evaporative-cooling systems eventually becomes either consumptive use or direct return (blowdown), consumptive use can be determined if the quantity of blowdown is known. Estimates of blowdown (Strauss, 1978, p. 24-62; Watt, 1986, p. 109-160) range from 0 to 34 percent of make-up water. According to Watt (1986, p. 109-112), blowdown should be sufficient to maintain a dissolved-solids concentration in cooling water that is three to four times that of the make-up water. A dissolved-solids concentration of four times approaches the safe limit for most make-up waters (Watt, 1986, p. 110). In figure 13, blowdown as a percentage of make-up water is plotted against the concentration rates of dissolved solids (concentration of dissolved solids in cooling water divided by concentration of dissolved-solids in make-up water). As shown in figure 13, to maintain a concentration ratio of three to four times, 17 to 22 percent of the make-up water should be blowdown. Because roughly 20 percent of the make-up water is probably blowdown, the remaining 80 percent of the make-up water approximates consumptive use by evaporative cooling systems.

For steam-generating boilers, most make-up water replaces water lost as steam or discharged as blowdown. Water or steam can be lost as a result of the following activities:

1. Incorporation into product,
2. Operation of steam-powered machinery,
3. Discharge from leaky pipes, and
4. Discharge from safety valves.

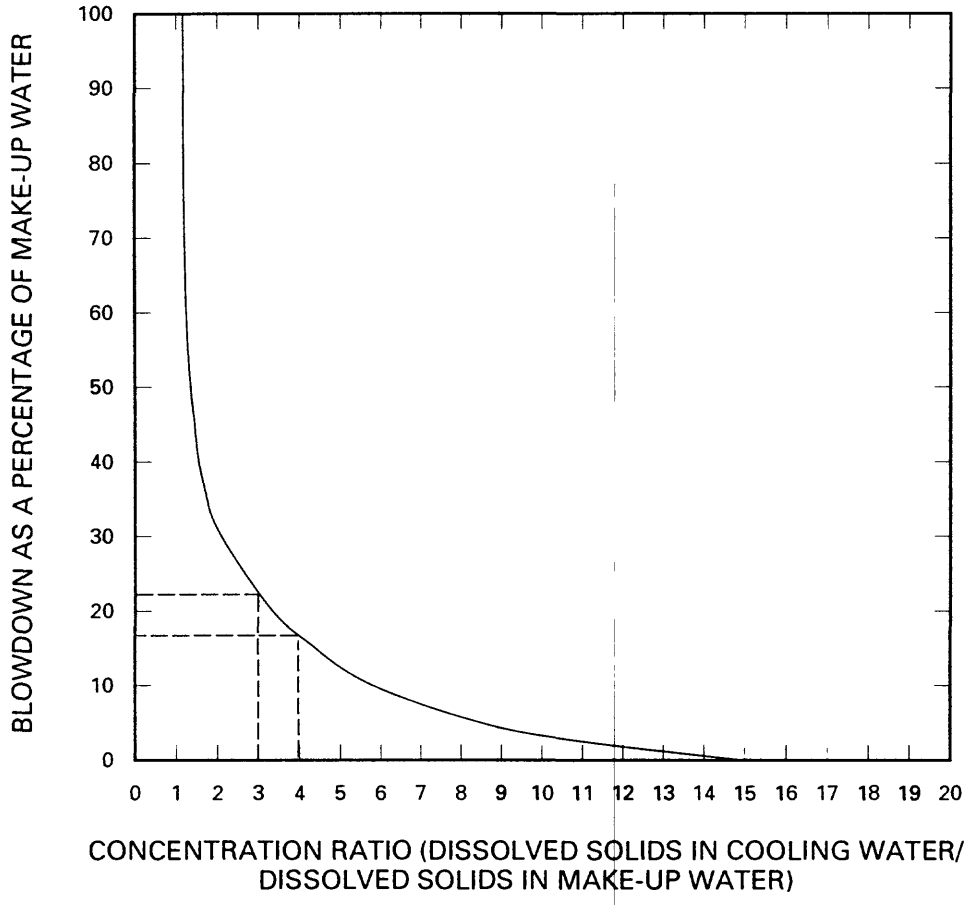

Figure 13.---The effect of blowdown on the dissolved-solids concentration of water used for cooling systems (modified from Watt, 1986, p. 112).

The incorporation of steam into products is consumptive use because the steam is removed from the immediate water environment. Steam used to operate machinery or turbines is typically lost to evaporation unless it is reclaimed. Steam discharge from leaky pipes and safety valves usually evaporates.

Blowdown from boilers generally is not consumptive use. When a blowdown valve is opened, a certain amount of the hot-water discharge will flash into steam until the pressure is relieved. Customarily, however, this steam is condensed and the blowdown water is cooled before discharge (Shields, 1961, p. 426). Therefore, water lost to blowdown was not considered consumptive use.

As in evaporative cooling systems, consumptive use by steam-generating boilers could be determined if the typical quantities of blowdown (direct return) were known. According to the American Boiler Manufacturers Association's (ABMA) recommended permissible boiler-water concentration of dissolved solids, figure 14 can be used to estimate the required blowdown percentage of make-up water (Culp/Wesner/Culp and Hughes, 1979, p. 86). In the Rockford area, boiler operating pressures ranged from 15 to 80 lb/in^2 (pounds per square inch) (Gene Mead, Nelson Carlson Mechanical Contractors, oral commun., 1989), and public-supply water concentrations of total dissolved solids averaged 417 mg/L

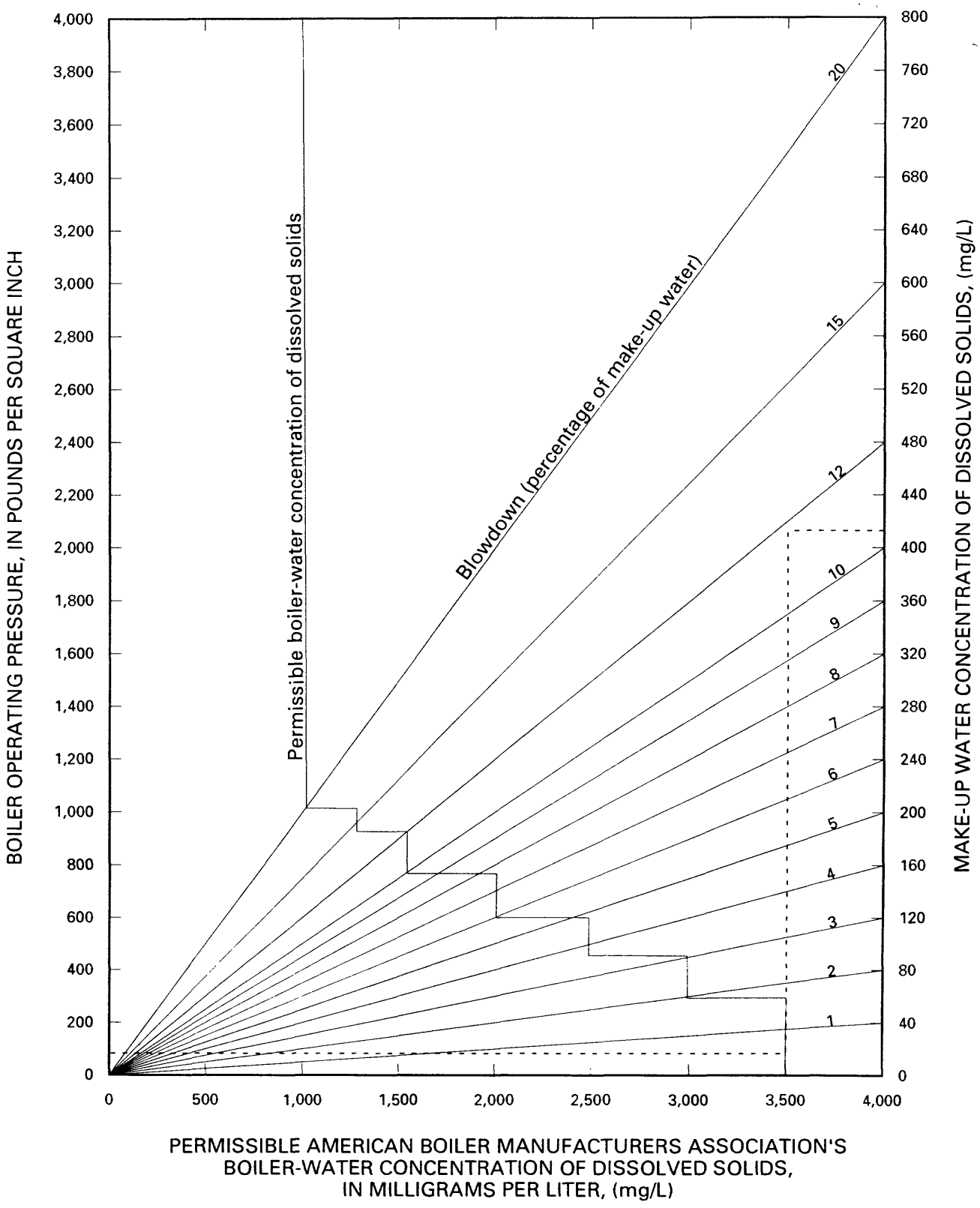

Figure 14.---Blowdown, as a percentage of make-up water, determined from boiler-operating pressure and American Boiler Manufacturers Association's recommended concentration of dissolved solids for boiler water (Culp/Wesner/Culp and Hughes, 1979, p. 86).

(milligrams per liter) (John Crooks, Rockford Water Department, oral commun., 1989). The percentage of blowdown can be determined from figure 14 by extending the operating pressure (80 lb/in^2) to the permissible boiler-water concentration of dissolved solids curve (stairstep curve = 3,500 mg/L). Then extend the permissible boiler-water-concentration value vertically to the make-up water concentration value (417 mg/L) to determine from the diagonal curves a blowdown of about 12 percent of make-up water. Because roughly 10 percent of make-up water is probably blowdown, the remaining 90 percent approximates consumptive use by steam-generating boilers in the Rockford area.

Water used on lawns is mostly consumptive use, owing to evapotranspiration. An estimate of evapotranspiration near the study areas was used to help explain the percentage of lawn watering that is consumptive use. Evapotranspiration in Sheffield, Ill., about 110 mi (miles) southwest of Rockford and 130 mi west of Kankakee, was estimated to be about 70 percent of precipitation (Ryan, 1989, p. 1). Of the average annual precipitation of 37.3 in. (inches), annual evapotranspiration averaged 25.9 in., annual runoff averaged 6.3 in., and annual recharge (to ground water) was estimated to be 5.1 in. or about 10 percent of precipitation (Ryan, 1989, p. 57). As water is generally applied to lawns at a steady, moderate rate, runoff can be assumed to be zero. Water used for lawn watering, therefore, was assumed to be evapotranspired or to be returned to the underlying ground-water aquifer. If precipitation at Sheffield was at a steady, moderate rate (like lawn watering) and runoff was zero, the runoff (6.3 in.) would instead be evapotranspired or returned. Or if roughly 10 percent of the runoff returned to ground water, similar to the amount of precipitation that returned, the remaining amount would be evapotranspired. The total annual evapotranspiration would then be about 31.5 in. (evapotranspiration + [runoff - (runoff x 0.10)]) or roughly 80 percent of precipitation. Therefore, roughly 80 percent (evapotranspiration factor) of the water used for lawn watering was considered to be consumptive use, owing to evapotranspiration, and the remaining 20 percent was considered to be returns to ground water--provided that Sheffield is climatically similar to Rockford. DiNatale (1981, p. 182) determined that probably 75 to 90 percent of lawn water evapotranspires in northern Colorado communities.

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