Water in Urban Planning, Salt Creek Basin, Illinois

WATER MANAGEMENT AS RELATED TO ALTERNATIVE LAND-USE PRACTICES

By ANDREW M. SPIEKER

Prepared in cooperation with the
Northeastern Illinois
Planning Commission

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2002

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, Secretary

GEOLOGICAL SURVEY

William T. Pecora, Director

Library of Congress catalog card No. 79-605466

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1 (paper cover)

Water in Urban Planning, Salt Creek Basin, Illinois

Flooded farmland south of Elk Grove Village at the Cook and Du Page County line illustrates the problem of water management in future urban planning in Salt Creek basin, Illinois. Photograph taken on June 12, 1967, after the flood of June 10. Photograph courtesy of Soil Conservation Service, U.S. Department of Agriculture.

CONTENTS

ILLUSTRATIONS

TABLES

WATER IN URBAN PLANNING, SALT CREEK BASIN, ILLINOIS

Water management as related to alternative land-use practices

By Andrew M. Spieker

ABSTRACT

Water management can be an integral part of urban comprehensive planning in a large metropolitan area. Water both imposes constraints on land use and offers opportunities for coordinted land and water management. Salt Creek basin in Cook and Du Page Counties of the Chicago metropolitan area is typical of rapidly developing suburban areas and has been selected to illustrate some of these constraints and opportunities and to suggest the effects of alternative solutions. The present study concentrates on the related problems of ground-water recharge, water quality, management of flood plains, and flood-control measures.

Salt Creek basin has a drainage area of 150 square miles. It is in flat to gently rolling terrain, underlain by glacial drift as much as 200 feet thick which covers a dolomite aquifer. In 1964, the population of the basin was about 400,000, and 40 percent of the land was in urban development. The population is expected to number 550,000 to 650,000 by 1990, and most of the land will be taken by urban development.

Salt Creek is a sluggish stream, typical of small drainage channels in the headwaters area of northeastern Illinois. Low flows of 15 to 25 cubic feet per second in the lower part of the basin consist largely of sewage effluent.

Nearly all the public water supplies in the basin depend on ground water. Of the total pumpage of 27.5 million gallons per day, 17.5 million gallons per day is pumped from the deep (Cambrian-Ordovician) aquifers and 10 million gallons per day is pumped from the shallow (Silurian dolomite and glacial drift) aquifers. The potential yield of the shallow aquifers, particularly glacial drift in the northern part of the basin, far exceeds present use. The largest concentration of pumpage from the shallow aquifers is in the Hinsdale–La Grange area. Salt Creek serves as an important source of recharge to these supplies, particularly just east of Hinsdale. The entire reach of Salt Creek south and east of Elmhurst can be regarded as an area of potential recharge to the shallow aquifers. Preservation of the effectiveness of these potential recharge areas should be considered in land-use planning.

Salt Creek is polluted in times of both low and high flow. Most communities in the basin in Du Page County discharge their treated sewage into the creek, whereas those in Cook County transfer their sewage to plants of the Metropolitan Sanitary District outside the basin. During periods of high runoff, combined storm runoff and overflow from sanitary sewers enter the creek. Such polluted water detracts from the stream's esthetic and recreational potential and poses a threat to ground-water supplies owing to induced recharge of polluted water to shallow aquifers. Alternative approaches to the pollution problem include improvement of the degree of sewage treatment, detention and treatment of storm runoff, dilution of sewage through flow augmentation, or transfer of sewage from the basin to a central treatment plant. To result in an enhanced environment, the streambed would have to be cleansed of accumulated sludge deposits.

The overbank flooding in Salt Creek basin every 2 to 3 years presents problems because of encroachments and developments on the flood plains. Flood plains in an urban area can be managed by identifying them, by recognizing that either their natural storage capacity or equivalent artificial capacity is needed to accommodate floods, and by planning land use accordingly. Examples of effective flood-plain management include (1) preservation of greenbelts or regional parks along stream courses, (2) use of flood plains for recreation, parking lots, or other low-intensity uses, (3) use of flood-proofed commercial buildings, and (4) provision for compensatory storage to replace natural storage capacity. Results of poor flood-plain management include uncontrolled residential development and encroachment by fill into natural storage areas where no compensatory storage has been provided.

Flood-control measures may consist of either enlarging channel capacity to accommodate flooding within the affected area or providing upstream storage in detention facilities. Widespread channeling may create problems by transferring the flooding downstream. Furthermore, trees are endangered along the flood plains where the channels are widened and straightened. Altered channels require constant maintenance, or they will revert to their original configuration. Ground-water recharge can be impaired by rushing storm runoff out of the drainage basin faster than the soils of the streambed and flood plain can absorb it. However, limited channel improvements and channel maintenance can be beneficial.

In general, retention of storm runoff within the basin offers greater opportunities for water management than channeling. Runoff can be retained in valley reservoirs, upground reservoirs, or storage facilities created, for example, on rooftops or in parking lots. A good reservoir site exists in the Ned Brown Forest Preserve near Elk Grove Village. It has been proposed to develop a multipurpose reservoir there by excavating below the water table to create a permanent recreational pool for boating and fishing. Other possible storage facilities could be developed in abandoned quarries or in underground tunnels.

Flood plains already developed could be reclaimed through Federal Urban Renewal and Open Space Programs. A comprehensive flood-control strategy would include many or all of the above techniques, each applied to its best advantage within a framework of comprehensive planning.

Present development trends threaten to consume most undeveloped land and to continue pressures for further development of the flood plains. Better water-management opportunities are offered in compresensive plans which provide for preservation of additional open space.

INTRODUCTION

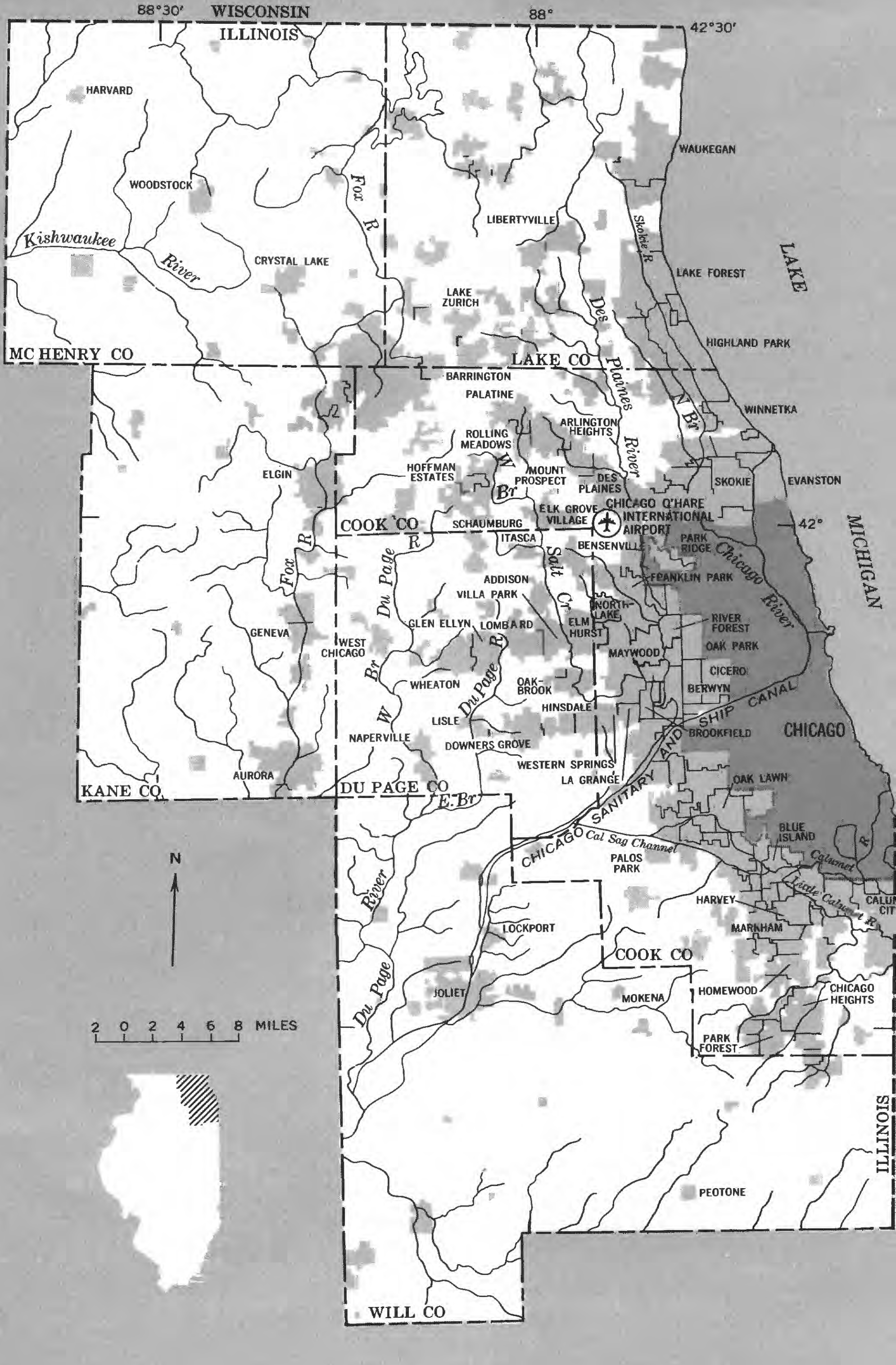
WATER IN LAND-USE PLANNING

Water takes up space and can either enhance or detract from the environment. Therefore, it must be an essential part of any land-use plan. As people and activities become increasingly concentrated in the Nation's large metropolitan areas, the urban planner assumes an ever more important role in planning for the orderly development of these areas. Whereas in the past, local governmental units have, to a large extent, been able to solve their problems individually, the tremendous expansion of the last 20 years has brought about a need for close coordination among communities. The actions of one community in a densely developed area are more and more likely to affect adjacent communities. The principal functions of the urban planner are to solve regional problems and to assist communities in solving local problems for the maximum public benefit. Because many of these problems are water related, urban planners will become involved in water management.

In the past and to some extent at present, water management has largely been the domain of single-purpose agencies having limited operational and territorial jurisdictions. As water problems have arisen, the appropriate agency has been called on to solve them, usually as quickly as possible. This approach of piecemeal solutions to individual problems without consideration of the whole environment (an approach which might be called the "quick fix"), can bring about unforeseen and dangerous results in a complex, rapidly urbanizing area.

The increasing concentration of people and activities in our vast urban complexes is bringing about a multiplication of water-related problems. As these areas become more densely developed, more problems will be created, and the effects of any one problem will be more widely felt. Flooding problems will increase as pressures on land force the uneconomic development of flood plains. Disposal of increasing volumes of sewage without regard to the receiving stream's capacity for assimilation will increase pollution. Water-oriented recreation is more and more in demand as both population and leisure time increase; however, pollution renders much of the water in urban areas unfit for recreational use.

The Northeastern Illinois Planning Commission was created by the Illinois Legislature in 1957 to "encourage sound and orderly development" of the six-county northeastern Illinois metropolitan area (fig. 1) centered around Chicago. This metropolitan planning agency has recognized the importance of water in urban planning and has assumed



88°30′
WISCONSIN
ILLINOIS
88°
42°30′
HARVARD
WOODSTOCK
Kishwaukee
River
CRYSTAL LAKE
Fox R
LIBERTYVILLE
WAUKEGAN
Skokie R
LAKE FOREST
LAKE
LAKE ZURICH
Des Plaines River
HIGHLAND PARK
MC HENRY CO
LAKE CO
BARRINGTON
PALATINE
ARLINGTON HEIGHTS
N Br
WINNETKA
ROLLING MEADOWS
HOFFMAN ESTATES
MOUNT PROSPECT
DES PLAINES
SKOKIE
EVANSTON
ELGIN
W Br
ELK GROVE VILLAGE
CHICAGO O'HARE INTERNATIONAL AIRPORT
42°
MICHIGAN
COOK CO
SCHAUMBURG
ITASCA
BENSENVILLE
PARK RIDGE
Chicago River
Fox R
Du Page R
Salt Cr
ADDISON
FRANKLIN PARK
VILLA PARK
NORTHLAKE
RIVER FOREST
GENEVA
GLEN ELLYN
LOMBARD
ELMHURST
OAK PARK
WEST CHICAGO
MAYWOOD
CICERO
W Br
Du Page R
WHEATON
OAK-BROOK
BERWYN
HINSDALE
CHICAGO SANITARY AND SHIP CANAL
LISLE
BROOKFIELD
CHICAGO
NAPERVILLE
DOWNERS GROVE
WESTERN SPRINGS
AURORA
LA GRANGE
OAK LAWN
KANE CO
DU PAGE CO
E. Br
BLUE ISLAND
Cal Sag Channel
N
PALOS PARK
Calumet R
River
HARVEY
Little Calumet R
CALUMET CITY
LOCKPORT
MARKHAM
COOK CO
Du Page
JOLIET
MOKENA
HOMEWOOD
CHICAGO HEIGHTS
2 0 2 4 6 8 MILES
PARK FOREST
ILLINOIS
PEOTONE
WILL CO

an active role in planning for water management. In 1961, a flood-mapping program was started in cooperation with the six metropolitan counties and the U.S. Geological Survey. Forty-four 7½-minute quadrangles, each with an area of about 57 square miles, at a scale of 1 inch = 2,000 feet, on a topographic base, were completed by mid 1966. When the second phase of the program was finished in 1969, 19 additional quadrangles had been completed. Flood maps are now available for almost the entire northeastern Illinois metropolitan area. Mapping of the remainder of the area is now in progress. The flood-mapping program and the uses of flood maps in urban planning are discussed in a report by Sheaffer, Ellis, and Spieker (1970).

This was the first comprehensive flood-mapping program of its kind in the United States. The maps, which delineate the principal areas known to have been flooded in recent historic time, are being used by governmental agencies, planners, developers, and financial institutions to prevent unwise development of such areas.

Broadening the scope of its interest in water management, the Northeastern Illinois Planning Commission completed in 1966 a comprehensive report on water problems and water-management opportunities entitled "The Water Resource in Northeastern Illinois: Planning Its Use" (Sheaffer and Zeizel, 1966). This report is an analysis of the quantity and quality of the area's water resource and opportunities for its management. A wide range of management alternatives is presented, but no single plan is endorsed. Legal, administrative, and technical aspects of water management are considered.

A summary of principal findings and a statement of water-management policies precedes the text of the report. The first stated policy is that "Water resource management facilities should be planned in accordance with desired patterns of development as set forth in the comprehensive plan for Northeastern Illinois. Water resource management must be integrated with and be an integral part of comprehensive land use planning." The principle stated in the second sentence of this policy led to the investigation summarized in the present report.

PURPOSE OF THIS REPORT

The purpose of this report is twofold. First, it seeks to demonstrate how hydrologic data can be applied in urban planning, what kinds of hydrologic data are most useful, and how the hydrologist can best present these data so that they will be useful to the planner. Second,

---

◀ FIGURE 1.—Northeastern Illinois metropolitan area.

it seeks to evaluate the mutual interaction of water management and alternative land-use practices in a metropolitan area—that is, it evaluates both the effects of alternative land-use practices on the hydrologic system and the role of the hydrologic system in the implementation of these alternative land-use practices.

Inasmuch as the application of hydrologic information to land-use planning is a relatively new subject, the present report should be regarded as a pilot study, giving direction to areas and subjects which will require more detailed study in the future. This is a complex and wide-ranging field, far too broad to cover fully in an investigation of rather modest scope. For this reason, the present study focuses on three aspects of the hydrology of urban areas: water quality in the urban environment, the interrelationship of surface water and ground water, and management of the flood plains and the hydrologic effects of alternative flood-control measures in the urban environment. The report concludes with a brief resume of the implications of the interaction of these components of the hydrologic system in long-range comprehensive metropolitan area plans. All these problems are important aspects of the newly emerging science of urban hydrology.

One effective way to achieve these objectives is to select a small part of the northeastern Illinois metropolitan area as a study area in order to explore the interrelationships between land use and hydrology. The entire metropolitan area is too large and complex for such a study. From the hydrologist's point of view, a drainage basin is the most convenient unit. For this reason, the Salt Creek basin was selected as the study area for the present report.

SALT CREEK BASIN — A STUDY AREA

Salt Creek basin was selected as the area for the present study for several reasons. First, its size—about 150 square miles—is conveniently small, yet large enough to present a variety of water-management problems. Second, Salt Creek is typical of rapidly urbanizing suburban northeastern Illinois, where most of this area's urban development is taking place. The water- and land-related problems of Salt Creek are typical of those of the metropolitan area as a whole. Third, the basin is relatively close to Chicago and is squarely in the path of urban expansion, as is dramatically shown on a map of the area (fig. 2). Four of the area's principal corridors of development, which generally follow commuter rail lines, pass through this basin. In 1964, about 40 percent of the land in Salt Creek was in urban development. Planners at the Northeastern Illinois Planning Commission estimate that by 1990, 70 percent of the area will be urbanized.

Finally, several alternative measures to deal with flooding and related problems have been proposed or studied, resulting in widespread interest and a relative abundance of hydrologic data.

Water pollution is a serious problem in that it complicates flood-control plans for the beneficial use of floodwaters, it conflicts with water-oriented recreation, and it potentially endangers public water supplies. Although these problems have been studied individually, the need exists for a comprehensive study of their effects, in terms of land and water management.

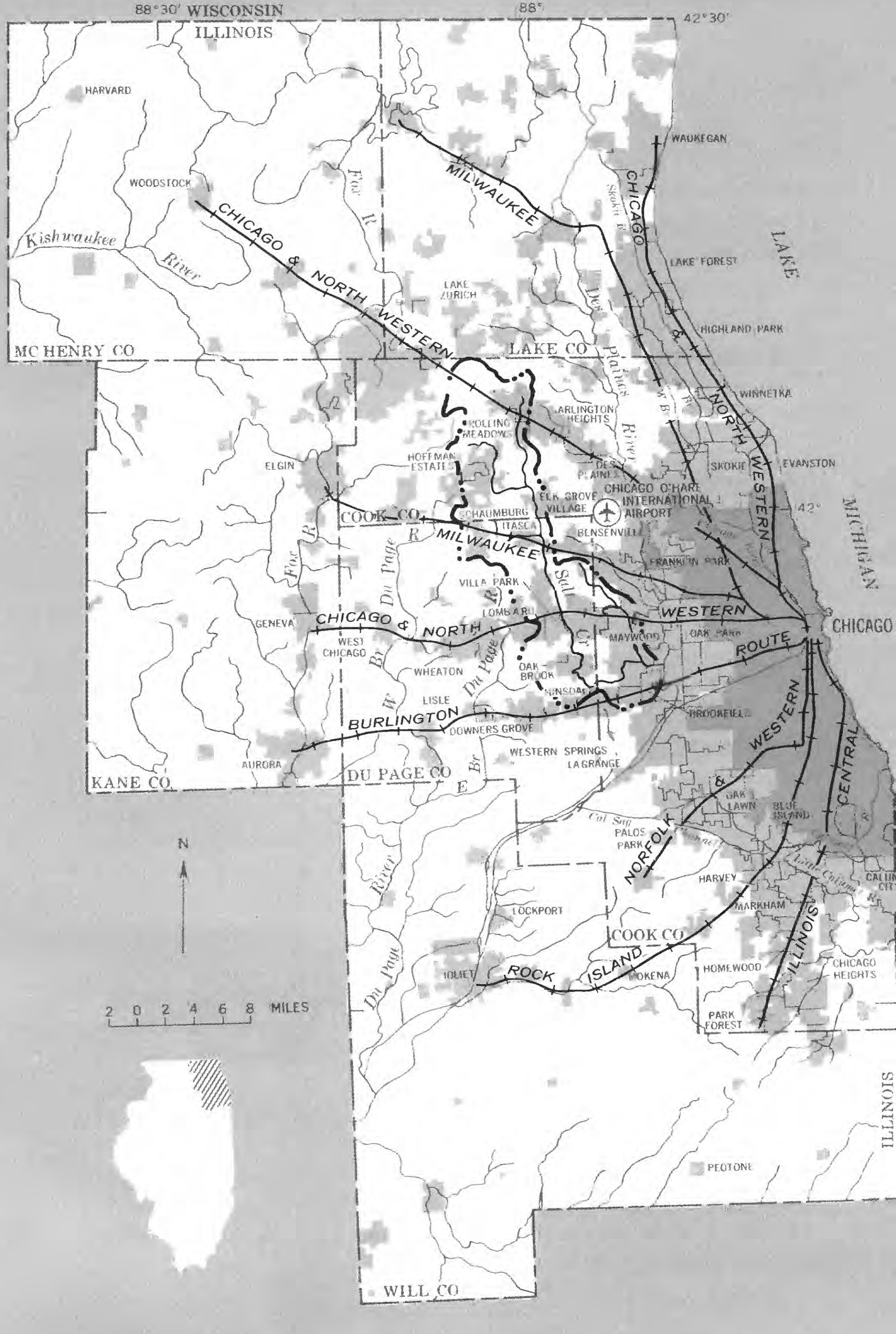
These problems are approached in four steps. The first step is a definition of the hydrologic system and its relation to urban development. Second, a closer look is taken at the problems of flooding and the management of flood plains. Illustrative examples of desirable and undesirable land-use practices as they relate to the potential for flood danger in Salt Creek basin are cited. Third, a study of the hydrologic and land-use implications of several alternative flood-control measures is made. Finally, the water-management implications of three alternative long-range land-use plans for the area are discussed.

HYDROLOGIC SYSTEM IN SALT CREEK BASIN

Water occurs in a closely connected system, called the *hydrologic system,* that includes both the water and the physical environment in which it occurs. Both the water and the physical environment can be separated into various components, all closely interrelated. Water occurs in the atmosphere, on the surface of the earth in streams and lakes, and below the ground surface in the pore spaces and fractures in rocks and in sand and gravel deposits. The physical environment of water consists of the atmosphere, the soils on the surface, the geologic formations beneath the surface, and the works of man.

Water moves freely back and forth among the various components of the hydrologic system in a process known as the *hydrologic cycle.* Precipitation is the source of the water. As the water falls on the ground, some of its runs off overland, contributing to streamflow. Some of it infiltrates into the ground. Most of it evaporates, and some is transpired by vegetation into the atmosphere. Of the water that infiltrates into the ground, some goes into temporary storage in water-bearing formations from which it may be pumped by wells or discharged into streams as base flow. The remainder is accounted for by evapotranspiration from the ground.

370-926 O—70——2



88°30' WISCONSIN
ILLINOIS
88°
42°30'
HARVARD
WOODSTOCK
Kishwaukee
River
Fox R
MILWAUKEE
CHICAGO & NORTH WESTERN
WAUKEGAN
CHICAGO & NORTH WESTERN
LAKE FOREST
HIGHLAND PARK
WINNETKA
EVANSTON
SKOKIE
LAKE
MICHIGAN
LAKE ZURICH
MC HENRY CO
LAKE CO
Des Plaines River
ARLINGTON HEIGHTS
ROLLING MEADOWS
HOFFMAN ESTATES
ELGIN
DES PLAINES
CHICAGO O'HARE INTERNATIONAL AIRPORT
ELK GROVE VILLAGE
SCHAUMBURG
ITASCA
BENSENVILLE
COOK CO
42°
MILWAUKEE
FRANKLIN PARK
Du Page R
VILLA PARK
LOMBARD
WESTERN
CHICAGO
GENEVA
CHICAGO & NORTH
WEST CHICAGO
MAYWOOD
OAK PARK
ROUTE
WHEATON
OAK BROOK
HINSDALE
LISLE
BURLINGTON
DOWNERS GROVE
BROOKFIELD
WESTERN SPRINGS
LA GRANGE
AURORA
KANE CO
DU PAGE CO
E Br
W Br
Salt Cr
NORFOLK & WESTERN
CENTRAL
OAK LAWN
BLUE ISLAND
Cal Sag
PALOS PARK
HARVEY
MARKHAM
N
LOCKPORT
River
Du Page
COOK CO
JOLIET
ROCK ISLAND
MOKENA
HOMEWOOD
ILLINOIS
CHICAGO HEIGHTS
PARK FOREST
2 0 2 4 6 8 MILES
PEOTONE
ILLINOIS
WILL CO

The components of the hydrologic system exist in a delicate balance. Therefore, any manmade change in one component of the system will alter its balance with the other components. In Salt Creek basin, the most profound manmade change is the highly complex transformation known as urbanization in which undeveloped or agricultural area is changed into a concentrated center of people, buildings, and activities. Urbanization is, in reality, an important influence on the hydrologic system.

PHYSICAL SETTING

NATURAL ENVIRONMENT—TOPOGRAPHY, DRAINAGE, AND SOILS

Salt Creek basin, or the natural drainage area of Salt Creek and its tributaries, an area of 150 square miles, is an elongated crescent-shaped unit about 30 miles long and 5 to 8 miles wide (fig. 3). The concave side of the crescent is roughly parallel to the shoreline of Lake Michigan. Salt Creek basin owes its shape and location to the Wisconsin ice sheet, the last of the great continental glaciers to cover the area, about 10,000 years ago. The basin lies between two morainal ridges deposited by the retreating ice sheet—the Valparaiso Moraine to the west and south, and the Tinley Moraine to the east. These moraines are part of a network of several concentric ridges around Lake Michigan.

The main stem of Salt Creek rises west of Palatine and flows southeast to Rolling Meadows, then generally southward to Hinsdale, where it turns abruptly east to its confluence with the Des Plaines River near Brookfield.

Salt Creek is parallel to the Des Plaines River through most of its course (fig. 3). Prior to the Wisconsin Glaciation, Salt Creek continued south along what is now Flag Creek. Deposition of the Valparaiso Moraine blocked this southerly course, forcing Salt Creek to flow east from Hinsdale to the Des Plaines River.

Unlike Salt Creek in Nebraska, the Salt Forks of the Arkansas and Red Rivers in Oklahoma, and the Salt River in Arizona, northeastern Illinois' Salt Creek does not contain salt water. Rather, it owes its name to an incident early in the history of the area. Salt Creek was, in fact, originally known as the Little Des Plaines River, according to early maps. In 1867, John Reid, a teamster, was hauling a load of salt to Galena. The wagon became mired in the muddy bottom at Brush

---

FIGURE 2.—Salt Creek basin is squarely in the path of growth in the northeastern Illinois metropolitan area.

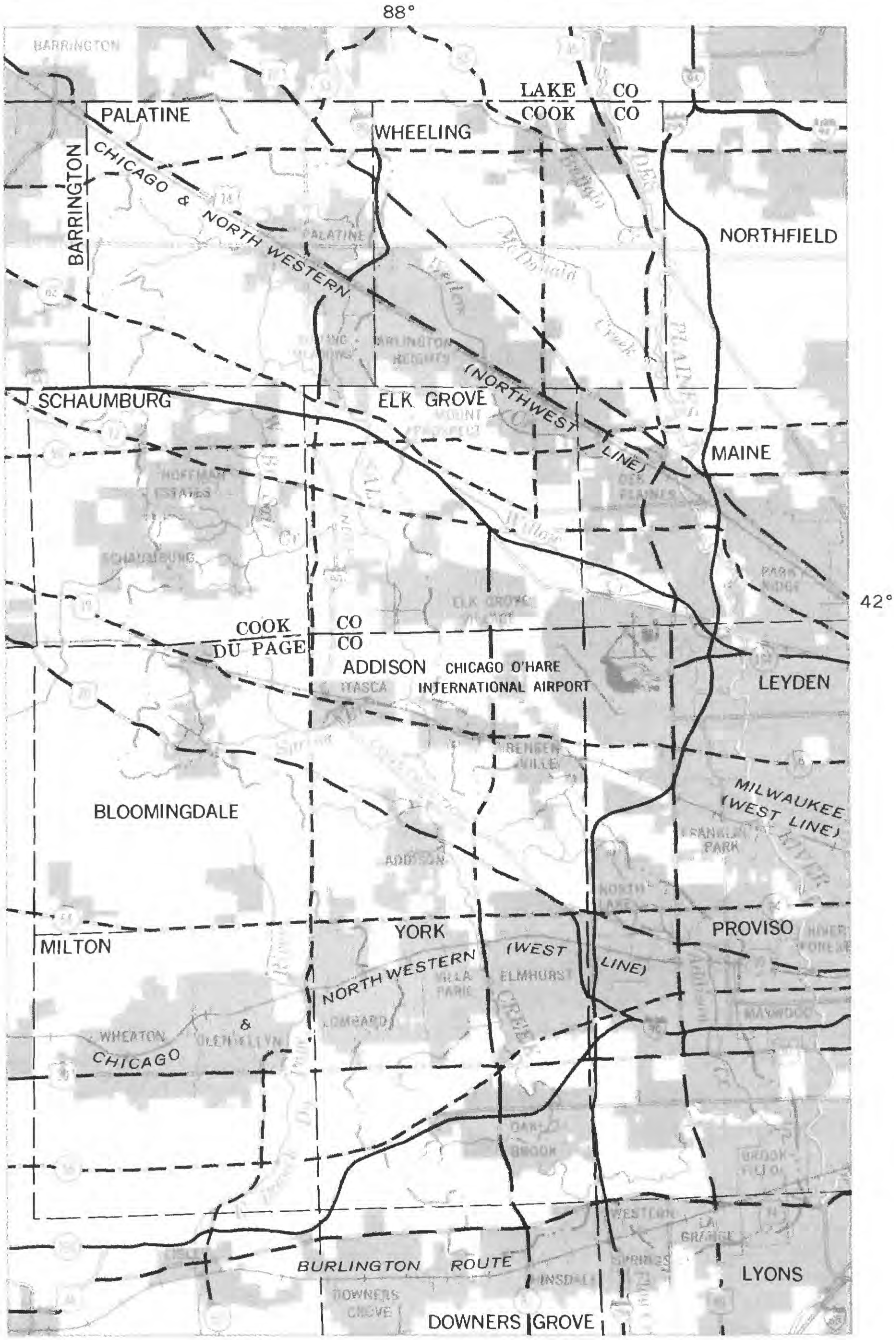
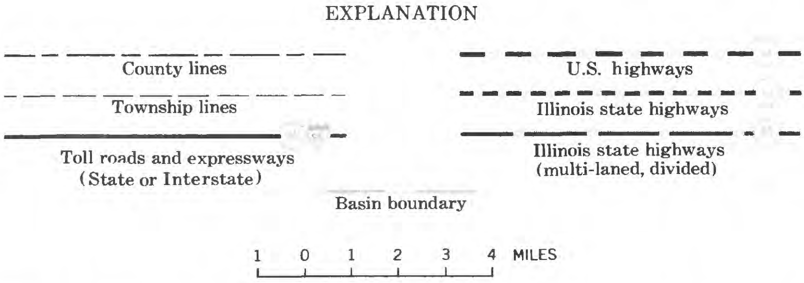


FIGURE 3.—Principal towns, highways, railroads, and drainage in Salt Creek basin.



Hill, now Hinsdale. As the horses tried to pull the wagon out, much of the salt dumped into the creek and dissolved. Apparently, this early instance of pollution made a sufficiently strong impression on local residents that they began referring to the stream as Salt Creek. The name has remained to this day (Dugan, 1949, p. 5).

The terrain of Salt Creek basin is flat to gently rolling, except in the northwestern part near the headwaters where it is hilly. Most of the basin ranges in elevation from 675 to 775 feet above sea level. The highest elevation is 873 feet at Inverness, in the northwestern part of the basin, and the lowest is 610 feet at the mouth, near Brookfield. The slope of the land is generally to the east; Salt Creek hugs the east side of its drainage basin through much of its course.

The largest tributary is Addison Creek, which rises in Bensenville and flows into Salt Creek near Broadview. Several other tributaries, some unnamed and many intermittent (flowing only part of the time), flow eastward into the main stream. The most prominent of these are Spring Brook, which rises in the vicinity of Roselle and Bloomingdale and enters Salt Creek near Itasca, and the West Branch of Salt Creek.

Salt Creek basin is, in general, poorly drained. Its drainage would be characterized by a physiographer as "youthful"—that is, it is still dominated by the constructional features resulting from the last ice sheet. There has not been sufficient time since the end of this glaciation for the drainage to adjust fully to the terrain. This poor drainage is evidenced by many swamps and local depressions, particularly in the northern part of the basin. The drainage divides forming the boundaries of Salt Creek basin are not distinct and are therefore difficult to recognize. Owing to the flat terrain, relatively minor works of man, such as highway or railroad fills as little as 5 feet high, can alter these divides. Many of the straight-line segments of the drainage boundary (fig. 3) are the result of such alterations.

The main stem of Salt Creek is 45 miles long from its source near Inverness to its mouth near Brookfield. The gradient of the lower reach, from the mouth to river mile 34 north of Elk Grove Village (river miles are measured upstream from the mouth), is flat, about 2 feet per mile. From river mile 34 to river mile 41 in Palatine, the gradient is somewhat steeper, averaging 7 feet per mile. Above river mile 41, it becomes much steeper, averaging 22 feet per mile. The steeper gradient in the headwaters area reflects the more pronounced relief associated with the Valparaiso Moraine.

The soils in Salt Creek basin are characteristic of those derived from the glacial drift of northeastern Illinois. Three general types were recognized and mapped (fig. 4) .The first two were formed on the glacial tills, which cover most of the area, and the third was formed on the moderately permeable sand and silt deposits.

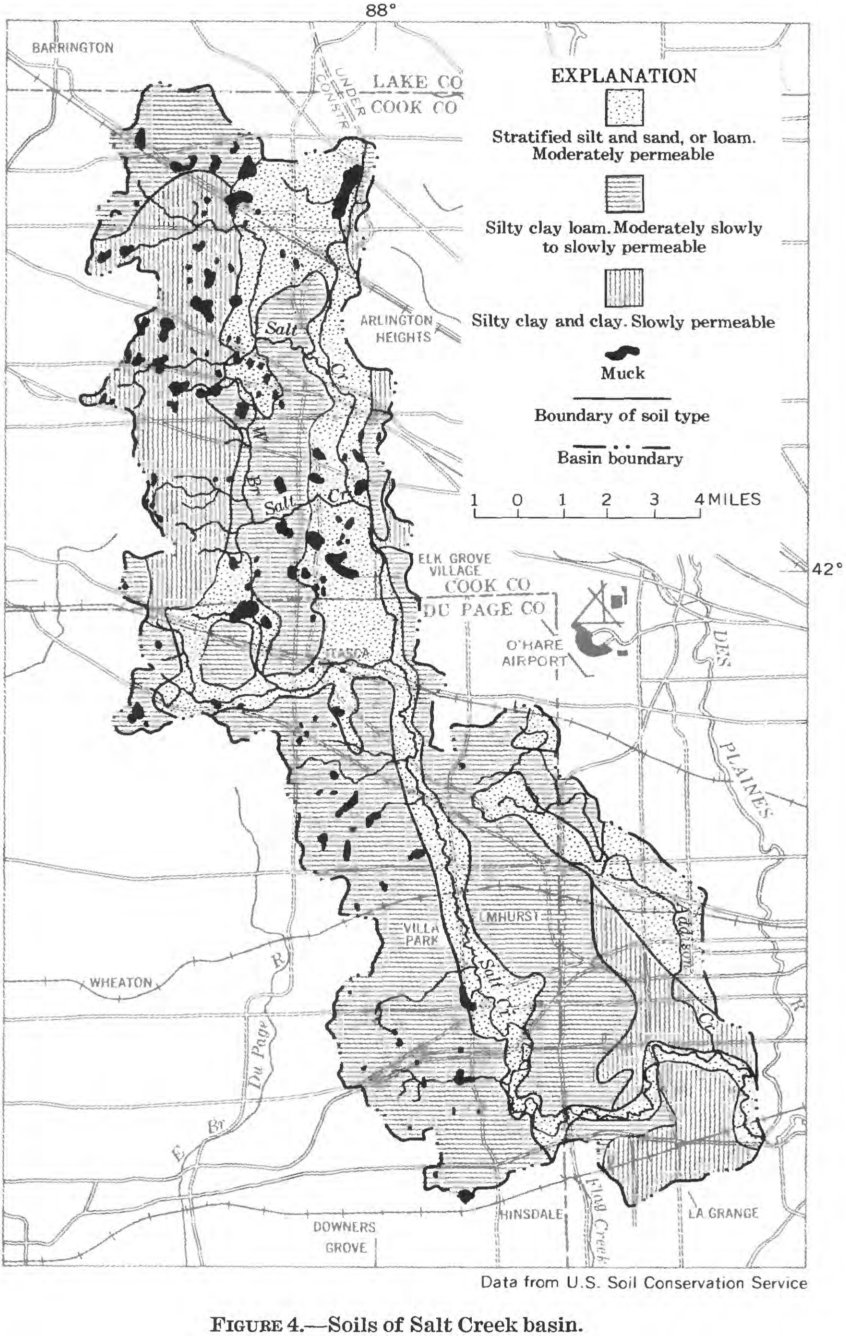
Most of the area is covered by a moderately fine textured silty clay loam derived from till. This soil is moderately slowly to slowly permeable (fig. 4), resulting in a fairly high runoff rate. Approximately the northwestern quarter of the area is underlain by a fine-textured silty clay, even less permeable than the silty clay loam. Such soils are referred to as "heavy" in the terminology of the soil scientist. Inasmuch as this silty clay is nearly impervious and is generally in an area of steep slopes, it is potentially the most erosive soil in the area and produces a high rate of runoff.

A narrow strip along Salt Creek and its tributaries is underlain by moderately permeable glacial outwash, consisting primarily of sand, silt, and some gravel. This strip is about half a mile wide downstream from Elk Grove Village. It is considerably wider upstream from Elk Grove Village.

Areas of muck, unstable soil rich in organic matter and similar to peat, abound in Salt Creek basin, especially in association with the heavy soils of the northwestern part of the area.

NATURAL VERSUS POLITICAL BOUNDARIES

Natural drainage divides, for better or worse, seldom coincide with political boundaries, although rivers themselves in many places form the boundaries between States, counties, or cities. Such is not the case with Salt Creek. The greater part of Salt Creek basin is in Cook and Du Page Counties. A minute fraction of the headwaters area, less than half a square mile, is in Lake County. As a result of the peculiar inverted L-shaped configuration of Cook County (fig. 2), Salt Creek rises in Cook County, its middle section passes through Du Page County, and it flows back into Cook County for the last 10 miles of its course toward its confluence with Des Plaines River. Thus, actions taken in either county may strongly influence events in both counties.



Data from U.S. Soil Conservation Service

FIGURE 4.—Soils of Salt Creek basin.

In Salt Creek basin, this peculiar relation of drainage to political boundaries has far-reaching implications for water management. The effective management of the hydrologic system in a river basin requires close coordination and cooperation among all units of government. Cook and Du Page Counties have followed somewhat different, though not necessarily incompatible, management practices. Most of Cook County, including nearly all the Cook County parts of Salt Creek basin, is in the Metropolitan Sanitary District of Greater Chicago, which takes all sewage to several large treatment plants. Thus, most of the sewage from the Cook County parts of Salt Creek basin is transported out of the basin. In Du Page County, however, several small sewage plants of individual communities discharge their effluent into Salt Creek. These diametrically opposite sewage-disposal practices create a potential conflict in the management of water in Salt Creek basin.

URBAN DEVELOPMENT

POPULATION

Salt Creek basin has been in the process of urbanization—the conversion from rural to urban activity and land use—for more than 100 years. Chicago's first railroad, the Chicago & Galena Union, now the Galena Division (commonly known as the West Line) of the Chicago & North Western, was built in 1849. This line passes through Salt Creek basin at what is now the city of Elmhurst. During the remainder of the 19th century, as Chicago developed into the Nation's foremost rail center, several other railroads, notably the Burlington, the Milwaukee Road, and the Northwest Line of the Chicago & North Western, crossed Salt Creek basin (fig. 3). Many communities grew up along these rail lines, which provide commuter service to downtown Chicago.

Until the building boom which started after World War II, most of the urban development in Salt Creek was concentrated in corridors along these commuter rail lines. By 1930, the area's population had reached 95,000. In the following decade the increase was modest; Salt Creek basin's population in 1940 was only 107,000 (fig. 5).

The end of World War II triggered a building boom which resulted in both a substantial population increase and a significant change in the pattern of urban development. The increasing dependence on the automobile as the principal means of transportation in the postwar era has lessened dependence on public transportation. Whereas urban development prior to the war was concentrated along rail lines, the trend in the postwar era has been toward a more dispersed pattern of urbanization that fills in the spaces between the corridors. Planners refer to such a pattern of uncontrolled growth as "urban sprawl."

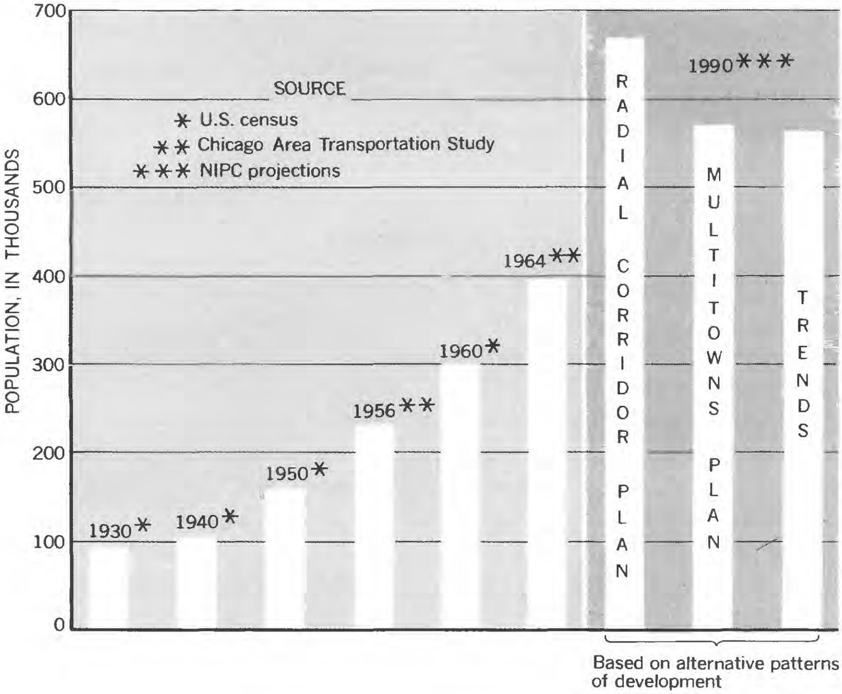


FIGURE 5.—Population of Salt Creek basin, past, present, and future. NIPC, Northeastern Illinois Planning Commission.

By 1950, the population of Salt Creek basin had increased to 160,000, a substantially greater rate of increase than in the decade preceding World War II. The building boom blossomed forth in the following decade and is still continuing; the estimated 1964 population was nearly 400,000.

The greater part of the postwar population expansion in Salt Creek basin has taken place in the northern part of Cook County. Much of this growth can be attributed to the proximity of Chicago's O'Hare International Airport, the world's busiest airport. The population of Palatine, for example, increased from 2,222 in 1940 to 4,079 in 1950, and then to 11,504 in 1960. Entirely new communities, such as Hoffman Estates, Schaumburg, and Elk Grove Village, have been established since 1950.

Predicting future population changes is risky, owing to the large number of variables over which the residents of an area have no control. For example, if a large industry decides to build at a given location, this event results in a substantially increased population in its vicinity. The reverse is true if an industry or other large employer leaves the area. However, most planners agree that the northeastern Illinois metropolitan area will continue to grow. The Northeastern Illinois Planning Commission estimates that by 1990 the population of Salt Creek basin will have increased to between 550,000 and 665,000, depending on the pattern of development (fig. 5). These alternative patterns of development are explained in the following section on land use.

CHANGING LAND USE

As the population of Salt Creek basin has increased, land has been in a steady process of change from rural to urban uses. A comparison of figures 6 and 7 shows the changes that took place between 1940 and 1964, an interval when Salt Creek basin was urbanized on a large scale. Although quantitative land-use data for 1940 are not available, the generalized map presented here indicates that most of the land was in rural (vacant or agricultural) use at that time. Urban land uses were largely concentrated along the corridors which followed commuter rail lines.

The corridor pattern of land use had changed by 1964 (fig. 7). By this time 42 percent of the land was in urban development, which had spread to the areas between the corridors.

Figure 8 is a graph, based on available data, showing land-use changes between 1956 and 1964 and projected land use in 1990, according to three alternative patterns of development which future growth might follow.[1] During the 1956–64 period, the percentage of land in urban development (not including public open space) changed from 27 to 42 percent. Most of this increase is due to residential development. A surprisingly large proportion of urban land is used for streets, alleys, and parking places. There was relatively little change in public open space during this period. Although Salt Creek is generally thought of as an urban basin, 47 percent of its land was still in agricultural use or vacant in 1964.

How Salt Creek basin will develop in the future depends largely on which growth pattern is followed. Figure 9 shows generalized sketches of three plans future growth might follow. These drawings are not plans for the area in the accepted sense, but rather are planners' concepts of how the area might look in about 50 years if alternative development patterns are followed.

---

[1] Figure 8 is based on a total land area for Salt Creek basin of 100,000 acres, or about 155 square miles, which differs slightly from the computed drainage area of 150 square miles. The difference exists because the land-use analysis is based on a grid-system approximation of the actual drainage area.

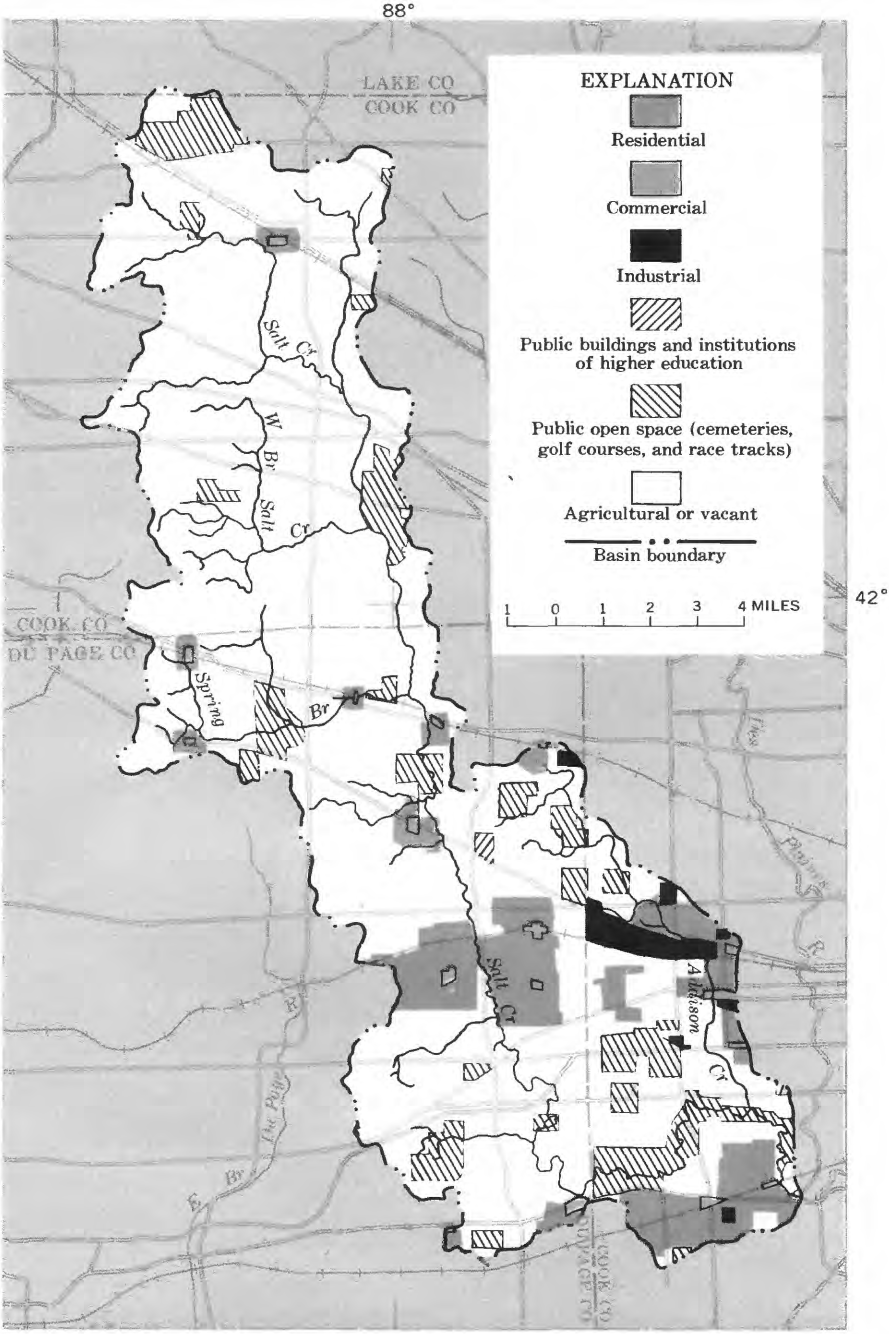


FIGURE 6.—Land use in Salt Creek basin, 1940.

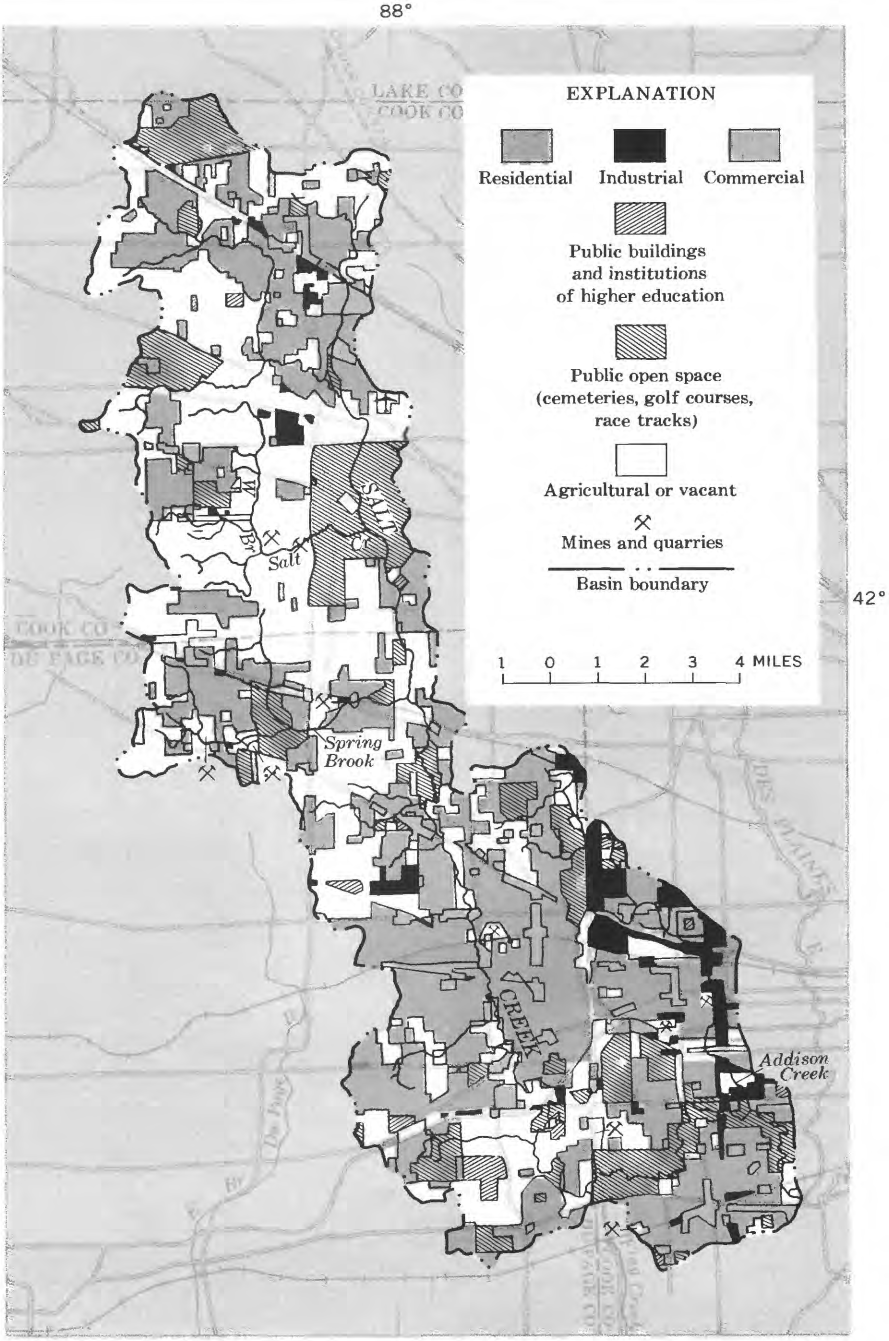


FIGURE 7.—Land use in Salt Creek basin, 1964.

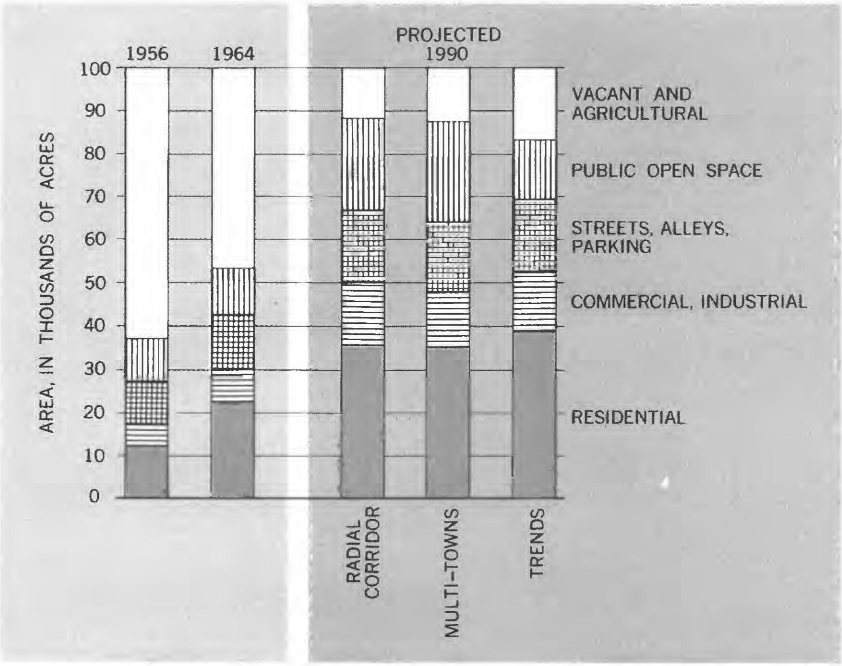


FIGURE 8.—Land use in Salt Creek basin, past, present, and future. Based on total area of 100,000 acres, or 155 square miles.

The first such alternative, the "Radial Corridor" plan, is based on a strengthened rapid-transit network radiating from the central city. Development would be concentrated in fairly high densities in radial corridors along these transit lines. Space between the corridors would be largely reserved for public open space and low-density residential development, such as estates. In a sense, this pattern represents a resurgence of the pre-World War II pattern of concentration of development along commuter rail lines.

The second development pattern, referred to as the "Multi-Towns" plan, is more dispersed than the radial corridor plan and places more emphasis on automobile transportation. This growth pattern would concentrate development in clusters of towns, many of them new towns, around several regional commercial centers.

The third alternative, the "Trends" plan, is not a comprehensive plan; rather, it is a planner's concept of how the region will look in the future if present growth trends continue. In effect, a continuation of these trends would result in greater urban sprawl, which would eventually engulf most of the metropolitan area. This does not imply that the "Trends" alternative is based on a total absence of planning.

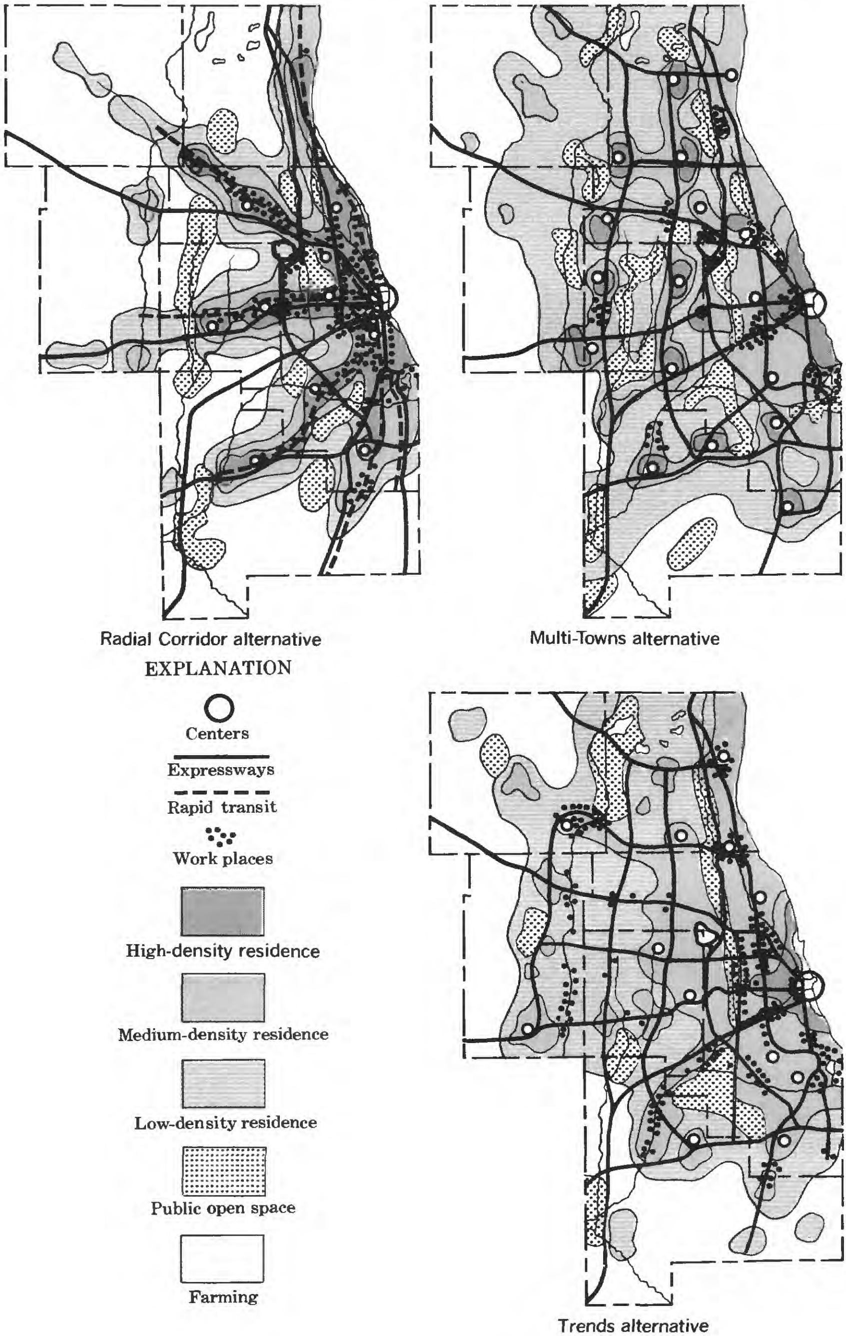


FIGURE 9.—Three alternative growth patterns for the northeastern Illinois metropolitan area. Population density increases with pattern density.

It is based on the present absence of a coordinated and comprehensive plan. Both Cook and Du Page Counties have plans, as do most of the individual communities in Salt Creek basin. The "Trends" alternative emphasizes the lack of coordination among these many plans and the tendency to perpetuate the present development pattern of urban sprawl.

In spite of distinct differences in these three growth patterns, relatively little difference would exist in the percentage of various land uses in 1990 in Salt Creek basin. The only significant difference (fig. 8) would be that, if present trends were continued, less land would be reserved for public open space than if either of the two planned alternative growth patterns were followed. The population of Salt Creek basin in 1990 (fig. 5), however, would be substantially greater if the "Radial Corridor" pattern of development were followed. The three alternative plans of development and their water-management implications for Salt Creek basin are discussed in detail in a later section of this report.

WATER IN SALT CREEK BASIN

The flow characteristics of Salt Creek are the result of the interaction of precipitation and water stored in the ground, which eventually discharges into the stream by natural seepage and by man's use. (Man pumps water from wells and then discharges it into the stream as sewage effluent.) For this reason, precipitation and ground water are discussed prior to the discussion of streamflow characteristics.

PRECIPITATION AND EVAPOTRANSPIRATION

The mean annual precipitation for Chicago, based on records from 1871, when the U.S. Weather Bureau began measurements, through 1966, is 33.06 inches. Figure 10 shows annual precipitation for the period 1931–66 at Chicago Midway Airport, the weather station with the longest period of record in the northeastern Illinois metropolitan area. Although precipitation during a single storm or over a short period of time may vary considerably throughout this area, over a longer period of years the record of any one station is representative of the area as a whole. Annual precipitation varies considerably from year to year, ranging from 22 to 46 inches for the period of record given in figure 10.

Precipitation in the northeastern Illinois metropolitan area is distributed fairly evenly through the year, although slightly less generally occurs during the winter months. Figure 11 shows minimum, mean, and maximum monthly precipitation for the same period of record. Although the mean indicates a fairly uniform distribution throughout the year, the extremes vary over a wide range.

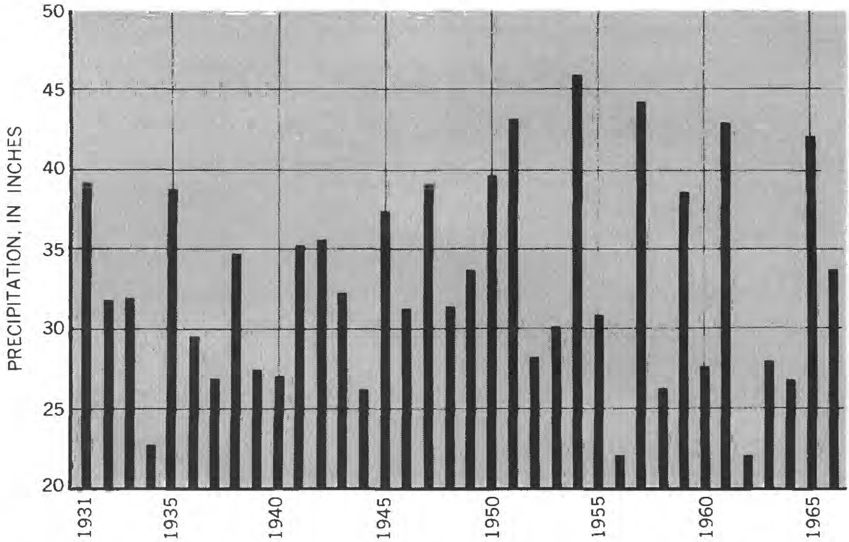


FIGURE 10.—Annual precipitation at Chicago Midway Airport, 1931–66.

Although precipitation is fairly evenly distributed throughout the year, much of it, particularly in the spring and summer, occurs in thunderstorms of relatively short duration and high intensity. These storms cause much of the flooding in Salt Creek basin.

Not all precipitation is available for use by man. Approximately 75 percent of total precipitation in a typical year is consumed by evaporation into the atmosphere and by transpiration by plants, collectively referred to as *evapotranspiration*. Mean annual evapotranspiration for the northeastern Illinois metropolitan area has been estimated to be 25.2 inches (Sheaffer and Zeizel, 1966, p. 11). Thus, only about one-fourth of the water that falls on the area is available for use.

A more accurate determination of evapotranspiration within Salt Creek basin cannot be made, owing to the lack of long-term precipitation and evaporation records for the basin. Some generalizations can be made, however, by comparison of rainfall and runoff relations in Salt Creek basin with the metropolitan area as a whole. Based on the period of record from 1951 through 1965 at the gaging station on Salt Creek at Western Springs, the mean annual runoff is 9.71 inches. This is somewhat greater than the average runoff of 8.5 inches for this part of Illinois, as determined by the Illinois State Water Survey (1958, p. 5). The 1951–65 period is used as a standard period because it it the longest period for which records are available for both gaging stations on Salt Creek. Precipitation (at Chicago Midway Airport) for this same period is 33.18 inches. Subtracting runoff from rainfall

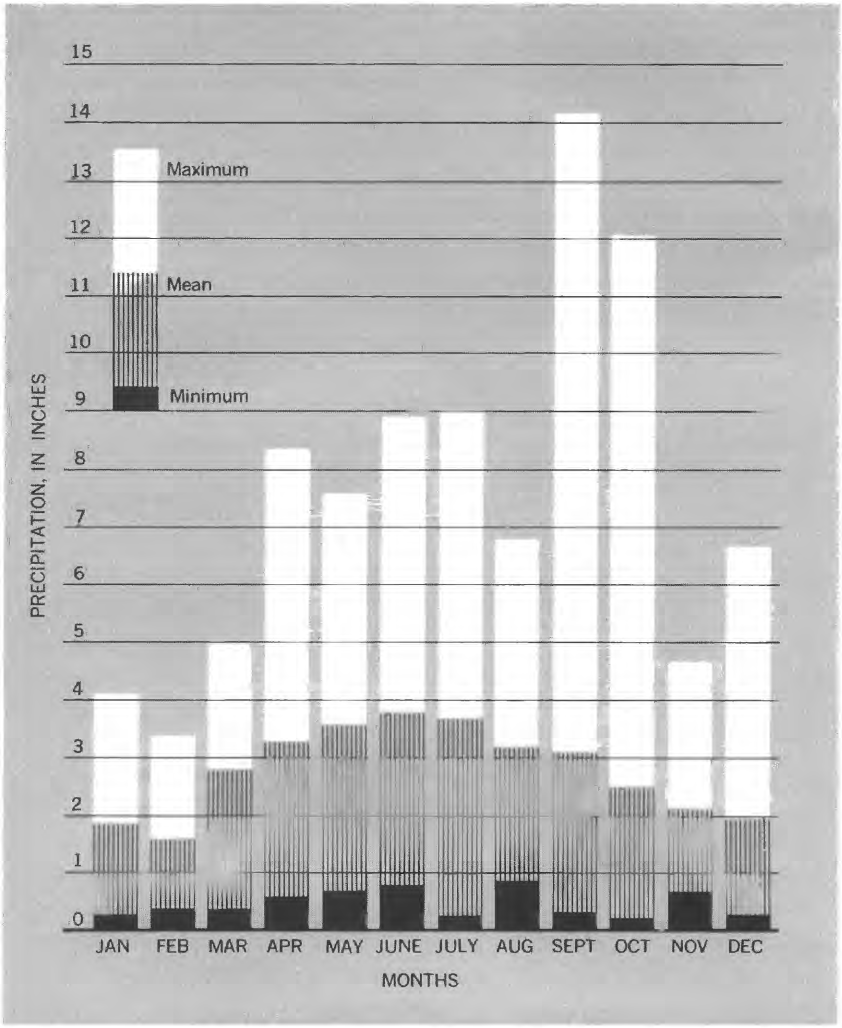


FIGURE 11.—Monthly precipitation (minimum, mean, and maximum) at Chicago Midway Airport, 1931–66.

yields a remainder of 23.72 inches, slightly less than the mean annual evapotranspiration estimated by Sheaffer and Zeizel (1966, p. 11). The two calculations are remarkably consistent, considering that different methods and different areas were used.

This difference might be attributed to use of the ground-water resource and its subsequent discharge into Salt Creek as sewage effluent, a process which would tend both to increase runoff and to diminish evapotranspiration. As a general rule, on a long-term basis evapotran-

370-926 O—70——3

spiration is approximately equal to rainfall minus runoff. This relationship is only approximate because some of the rainfall goes into ground-water storage. The diversion of sewage effluent from Salt Creek basin would tend to further complicate the rainfall-runoff relationship. In humid regions, such as the northeastern Illinois metropolitan area, ground water eventually moves toward streams into which it discharges, making up much of the streams' dry-weather flow, or *base flow*. Most of the communities in Salt Creek basin depend on wells for their water supplies. Pumping from these wells affects runoff and evapotranspiration in two ways. First, by lowering the water table, pumping from shallow wells tends to reduce evapotranspiration. Second, most of the water pumped from the ground is returned to the stream as sewage effluent at a greater rate than if this water were allowed to flow toward the stream on its natural course; this process tends to increase runoff.

GROUND WATER

AQUIFERS AND CONFINING BEDS

The materials that underlie Salt Creek basin are saturated below a water surface known as the *water table*. The water table ranges in depth from 2 to 50 feet beneath the land surface. The saturated subsurface materials serve both as storage reservoirs for ground water and as conduits through which ground water moves. The movement of ground water in the absence of pumping in a humid area, such as Salt Creek basin, is from recharge areas, where precipitation infiltrates through soils and into the underlying materials, toward the streams, where it discharges.

Not all earth materials transmit water equally. Water moves much more easily through highly permeable materials, such as sand, gravel, and fractured or creviced rock, than through relatively impermeable, or "tight," materials, such as clay, dense shale, or dense limestone. Permeable materials capable of yielding water economically to wells are known as *aquifers* (water-bearing materials), and impermeable materials are generally known as *confining beds*. The movement of water through these two contrasting kinds of materials can be compared to the flow of the same volume of traffic over a six-lane expressway on the one hand and over a narrow road full of potholes on the other hand.

UNCONSOLIDATED DEPOSITS

The bedrock in Salt Creek basin is covered by unconsolidated deposits commonly known as glacial drift. These drift deposits were laid down by the great continental ice sheets which covered much of North America 10,000 to 25,000 years ago. Figure 12 shows the generalized character of the drift materials. The thickest drift cover, in places more than 200 feet thick, is in the northern part of the basin. Toward the south it thins to 50 feet or less. Most of the drift consists of till, a dense aggregate of clay containing pebbles and boulders. Some sand and gravel deposits are interbedded with the till in all parts of the basin. A fairly widespread layer of sand and gravel is at the base of the drift. In the northern part of the basin, this layer is 50 feet or more thick and is used as an aquifer. At present, only the villages of Palatine and Addison use these unconsolidated deposits to any great extent for public water supplies. The potential yield of the sand and gravel aquifers, however, far exceeds their present use (Sheaffer and Zeizel, 1966, p. 31–32).

The glacial drift is thin in the southern part of Salt Creek basin. In places, bedrock is within a few feet of the land surface. The basal sand and gravel is generally too thin to be used as an aquifer; however, it forms a hydraulic connection between Salt Creek and the underlying bedrock aquifer. This relationship is a critical factor in groundwater recharge in the southern part of Salt Creek basin and is discussed in greater detail in the section on "Interrelationship of Surface Water and Ground Water."

BEDROCK AQUIFERS

There are three bedrock aquifers in the northeastern Illinois metropolitan area, all of which are present in Salt Creek basin; however, only the upper two units (fig. 13) are extensively used for water supplies. The uppermost bedrock aquifer consists of fractured and creviced dolomite of the Niagara and Alexandrian Series of Silurian age, a carbonate rock similar to limestone, but rich in magnesium. Some water-yielding dolomite is also present in the underlying Maquoketa, which consists largely of shale. These deposits are known as the Silurian Dolomite Aquifer, or the "shallow dolomite aquifer." The term "shallow dolomite aquifer" is used in this report. The overlying drift and the dolomite are collectively referred to as the "shallow aquifer." Water occurs in joints, cracks, and crevices of the dolomite. Inasmuch as these openings are irregularly distributed, much test drilling is generally required before a producing well can be completed. It is quite possible to drill a dry hole only a few feet away from a well yielding as much as 1,000 gallons per minute. The shallow dolomite aquifer ranges in thickness from 100 to 300 feet.

The second major aquifer system, known as the Cambrian-Ordovician Aquifer, consists of the Glenwood Shale and St. Peter Sandstone, the dolomites of the Trempealeau and Franconia Formations, and the Ironton and Galesville Sandstones (fig. 13). This aqui-

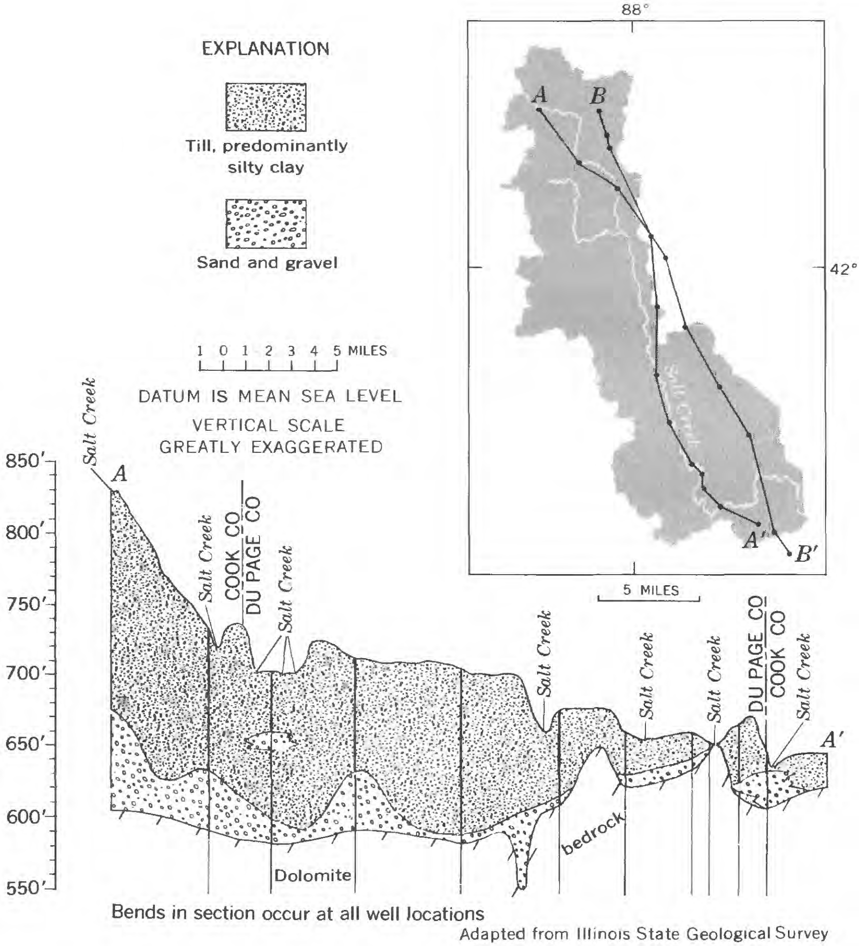
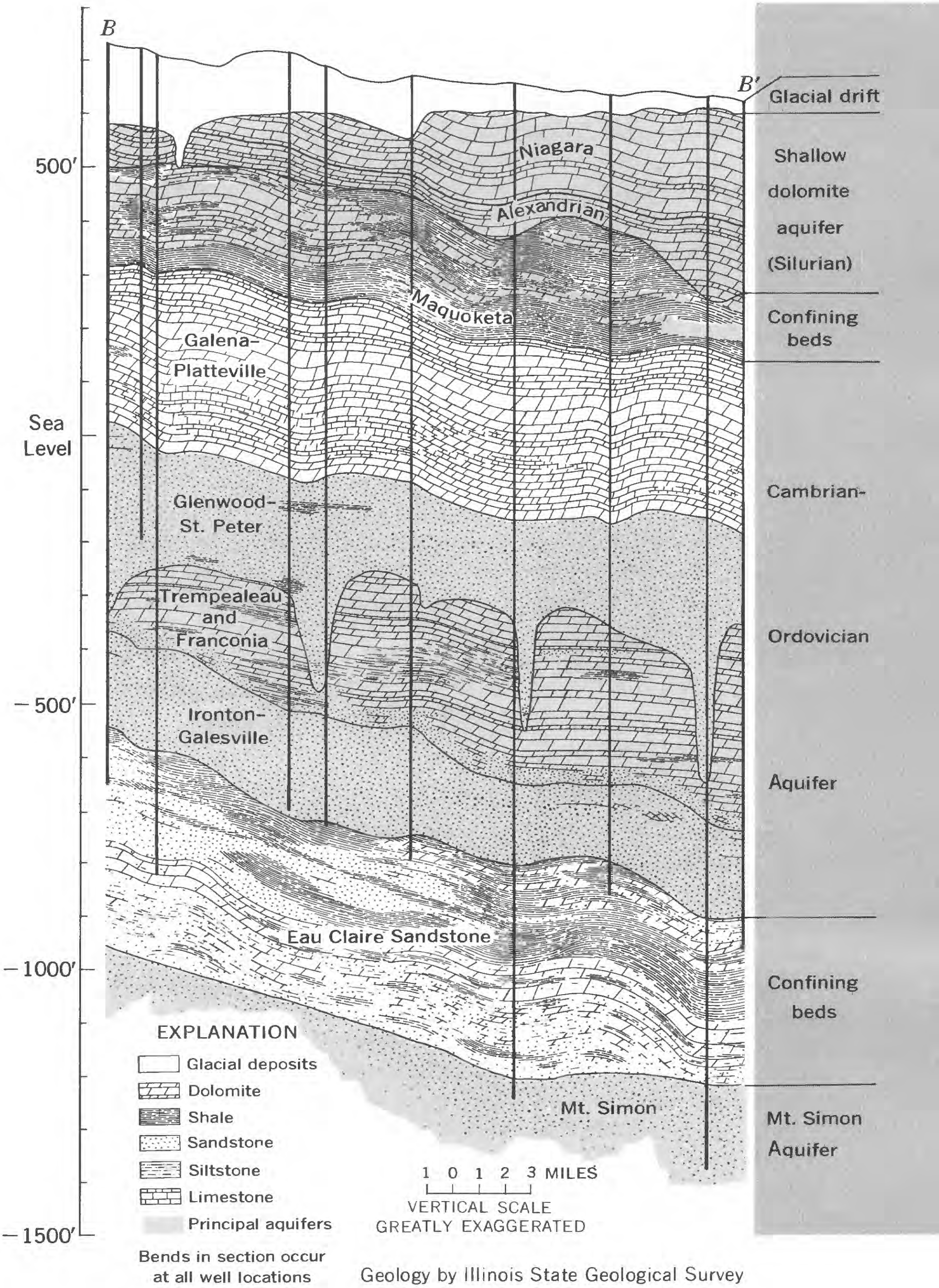


FIGURE 12.—Generalized lithologic section of the unconsolidated deposits in Salt Creek basin.

fer system is 500 to 700 feet thick, and its top is 500 to 800 feet below the surface. It is separated from the shallow dolomite aquifer by confining beds of the Maquoketa Shale and the Galena and Platteville Formations. The Ironton and Galesville Sandstones form the most productive unit of this system, accounting for 50 percent of its yield. The water-bearing characteristics of the Cambrian-Ordovician Aquifer are much more uniform than those of the shallow dolomite aquifer.

FIGURE 13. Geologic section of bedrock formations in Salt Creek basin. Line of section shown in figure 12.


B
B′
500′
Sea Level
−500′
−1000′
−1500′
Niagara
Alexandrian
Maquoketa
Galena-Platteville
Glenwood-St. Peter
Trempealeau and Franconia
Ironton-Galesville
Eau Claire Sandstone
Mt. Simon
Glacial drift
Shallow dolomite aquifer (Silurian)
Confining beds
Cambrian-Ordovician Aquifer
Confining beds
Mt. Simon Aquifer
EXPLANATION
Glacial deposits
Dolomite
Shale
Sandstone
Siltstone
Limestone
Principal aquifers
Bends in section occur at all well locations
1 0 1 2 3 MILES
VERTICAL SCALE GREATLY EXAGGERATED
Geology by Illinois State Geological Survey

Where it has not been possible to obtain water from the shallow aquifer or where assured yields are required, many wells have been drilled into the Cambrian-Ordovician Aquifer.

The Mt. Simon Aquifer (fig. 13) is separated from the Cambrian-Ordovician Aquifer by confining beds of the Eau Claire Sandstone. The Cambrian-Ordovician and the Mt. Simon Aquifers are collectively referred to as the "deep aquifer." Only the upper part of the Mt. Simon is shown in figure 13, as very little is known about its water-bearing characteristics. Few wells have been drilled into the Mt. Simon because adequate water supplies can almost everywhere be developed in the Cambrian-Ordovician Aquifer. The Mt. Simon Formation is believed to be about 2,000 feet thick and is underlain by crystalline granitic rock. Brackish and saline water occur in the deeper strata of the Mt. Simon.

In this report, the studies of the interrelationship of surface water and ground water are concerned primarily with the shallow aquifer. Recharge to the shallow aquifers occurs locally, whereas recharge to the deep aquifer occurs in north-central Illinois and in southern and central Wisconsin, where it is closest to the surface. For all practical purposes, the deep aquifer is hydraulically isolated from the shallow aquifer by confining beds. An effective interconnection between the deep aquifer and Salt Creek and (or) the shallow aquifer has been created by man, who has drilled uncased wells which penetrate both aquifers and allow interchange of water between the two. Some of the water pumped from the deep aquifer is discharged as sewage effluent into Salt Creek.

GROUND-WATER PUMPAGE AND SEWAGE DISPOSAL

Most of the communities in Salt Creek basin depend on the ground water for their public supplies. The exceptions are a few towns in Cook County, mostly in the Addison Creek basin, that purchase water from the city of Chicago and return their sewage to the Metropolitan Sanitary District of Greater Chicago.

Total public supply pumpage in 1966 was 27.5 mgd (million gallons per day). Of this amount, 17.5 mgd was pumped from the deep aquifer system and 10 mgd from the shallow aquifer. Nearly all pumping from the shallow aquifer is from the shallow dolomite aquifer; the towns of Palatine and Addison pump a total of 1.9 mgd from glacial drift.

Most water pumped for domestic or public use must be disposed of as sewage. Two general patterns of sewage disposal prevail in Salt Creek basin. The major pumping centers, where more than 1 mgd is pumped, and the direction of sewage disposal for each community are shown in figure 14. The sewage of communities in Cook County

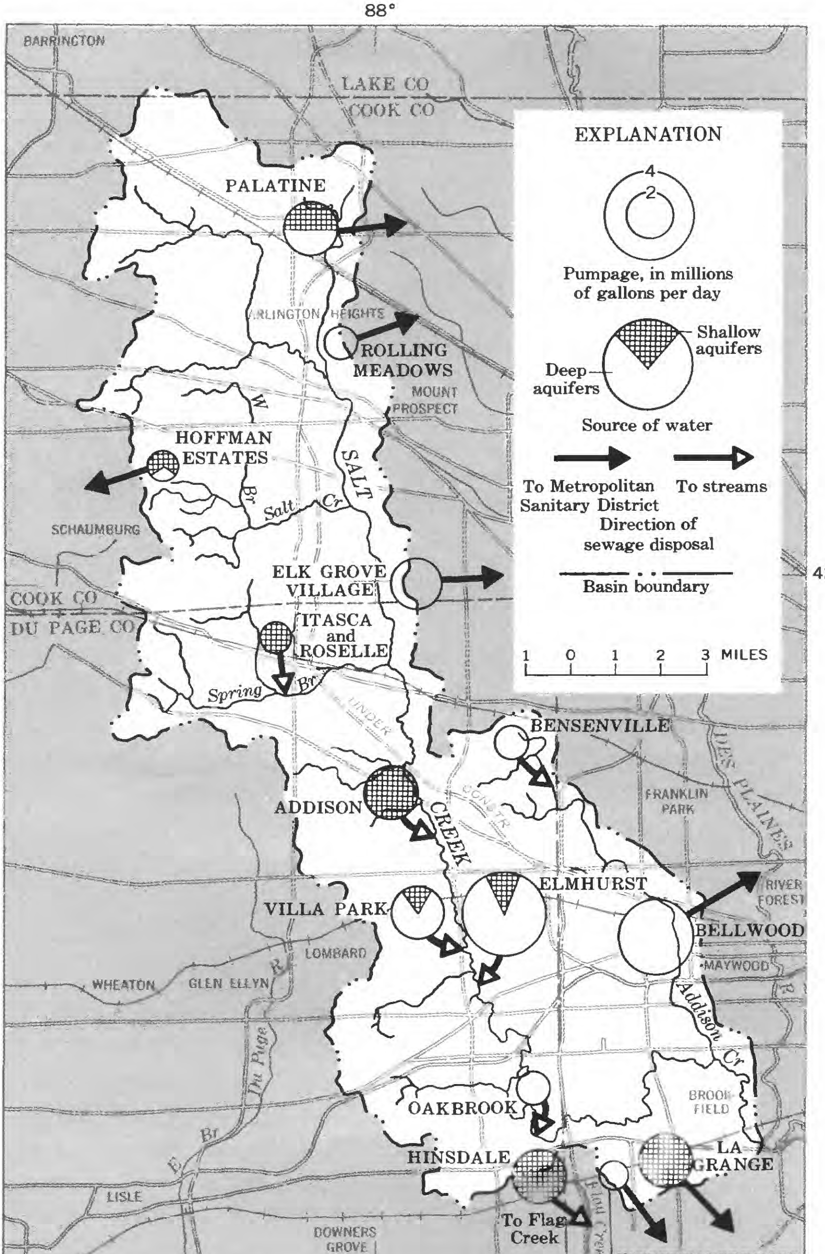


FIGURE 14.—Municipal ground-water pumpage and sewage disposal in Salt Creek basin, 1966.

is taken out of the basin through interceptor sewers of the Metropolitan Sanitary District and is treated at its large treatment plants. Most communities in the basin in Du Page County, on the other hand, have their own treatment plants from which the effluent is discharged into Salt Creek or its tributaries. Of the 27.5 mgd pumped from aquifers in Salt Creek basin, 16.1 mgd is disposed of outside the basin by the Metropolitan Sanitary District, and 11.4 mgd is discharged into Salt Creek or its tributaries. These amounts do not take into account the slight losses due to consumptive use.

Many residents of Salt Creek basin live in areas not served by public water or sewage systems. A survey conducted by the Northeastern Illinois Planning Commission and based on the results of the 1960 Census of Housing shows that 11,300 individual septic systems and 10,400 individual domestic wells existed in Salt Creek basin in 1960. Assuming an average of four residents per household and an average per capita domestic water use of 60 gallons per day, this would result in an additional 2.5 mgd of ground-water pumpage.

Ground-water pumping and the resulting volume of sewage have increased in relation to the population growth of Salt Creek basin. In 1940, total pumpage was estimated at 9 mgd, of which 5.5 mgd came from the deep aquifer and 3.5 mgd from the shallow aquifers. These figures indicate that, in addition to the trend of increasing water use, there has been a shift in recent years toward greater use of the shallow aquifers.

Urbanization of Salt Creek basin has increased the demand on the shallow aquifers and, at the same time, reduced the potential for natural recharge of these aquifers. Urbanization covers much of the area with impervious surfaces, such as pavement and roof tops, and thus reduces the surface area through which water can infiltrate. As previously stated, about 42 percent of Salt Creek basin was urbanized in 1964. Perhaps as much as 25 percent of the urbanized area has been rendered nearly impervious. Therefore, a little over 10 percent of the natural recharge capacity may have been lost.

The most important source of recharge to water supplies in the shallow aquifers, however, is induced stream infiltration. This is true, in large part, because the materials underlying the streambed and the adjacent flood plain are much more permeable than the materials underlying most of the area. Induced stream recharge is discussed more fully in the section on "Conditions Necessary for Induced Recharge."

STREAMFLOW CHARACTERISTICS

Streamflow is variable because it results from a combination of runoff caused by precipitation and ground-water seepage. In an urban area, a third and highly important factor influencing streamflow is sewage effluent. For some time, the importance of measuring streamflow has been recognized. Streamflow, or discharge, measurements are useful in the design of culverts, bridges, and flood-control works and in the planning of urban development. Three continuous stream-gaging stations are in Salt Creek basin (fig. 15); two are on Salt Creek, and one is on Addison Creek. In recent years, the need for additional records of flood stages has been recognized, and 17 crest-stage gages have been installed on Salt Creek and its tributaries. Detailed records of the continuous recording stations and annual maximum readings for the crest-stage gages are published annually by the U.S. Geological Survey. At 5-year intervals the annual records are compiled into single reports.

The following discussion of streamflow is confined to Salt Creek above the gaging station at Western Springs (fig. 15). Figure 16 shows hydrographs of the two continuous gaging stations on Salt Creek for the water year ending September 30, 1966. (The hydrologist's accounting period begins on October 1, which is about the end of the growing season, and ends the following September 30.) These graphs illustrate the typical range of flows that occur on Salt Creek, although the only extended period of low flow occurred in September 1966. For 17 consecutive days in September, there was no flow at the Arlington Heights gaging station.

LONG-TERM TRENDS

A convenient means of analyzing long-term streamflow trends is the *flow-duration curve*, a graph showing the discharge, or streamflow, and the percentage of time that discharge is equaled or exceeded. Figures 17 and 18 are duration curves for the two Salt Creek gaging stations. For each station the period of record has been broken down into four shorter periods: 1951–53, 1954–57, 1958–61, and 1962–65 (water years). The shape of the lower end (greater than 60 percent) of a duration curve is indicative of a stream's low-flow characteristics. A relatively flat curve indicates that the stream has a sustained low flow, or dry-weather flow. A curve that drops off sharply, on the other hand, indicates a lack of sustained base flow. Many hydrologists consider the flow equaled or exceeded 90 percent of the time to be a good index of a stream's dry-weather flow, or base flow. The duration data were broken down into these four periods to show the changes that have taken place in the streamflow characteristics during the rapid urbanization of Salt Creek basin.

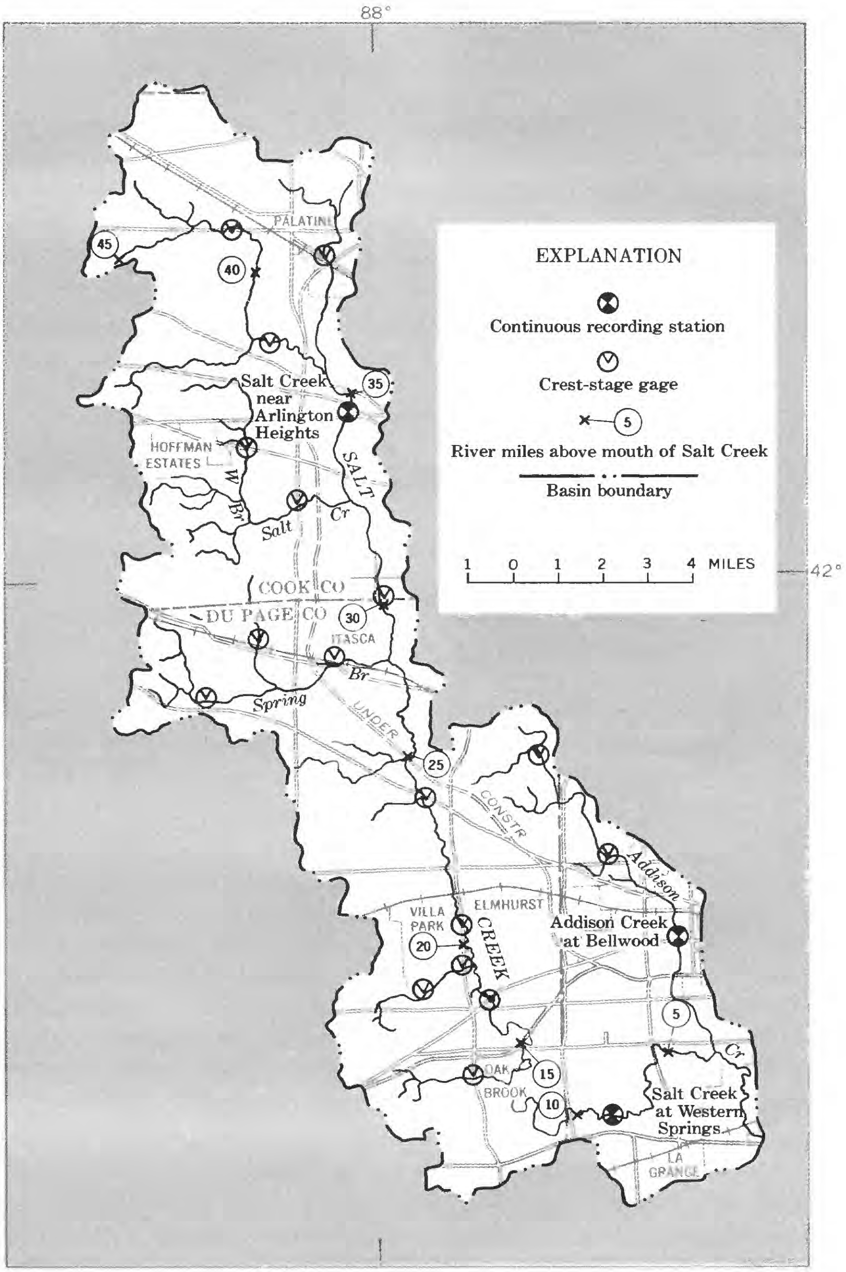


FIGURE 15.—Gaging station locations in Salt Creek basin.

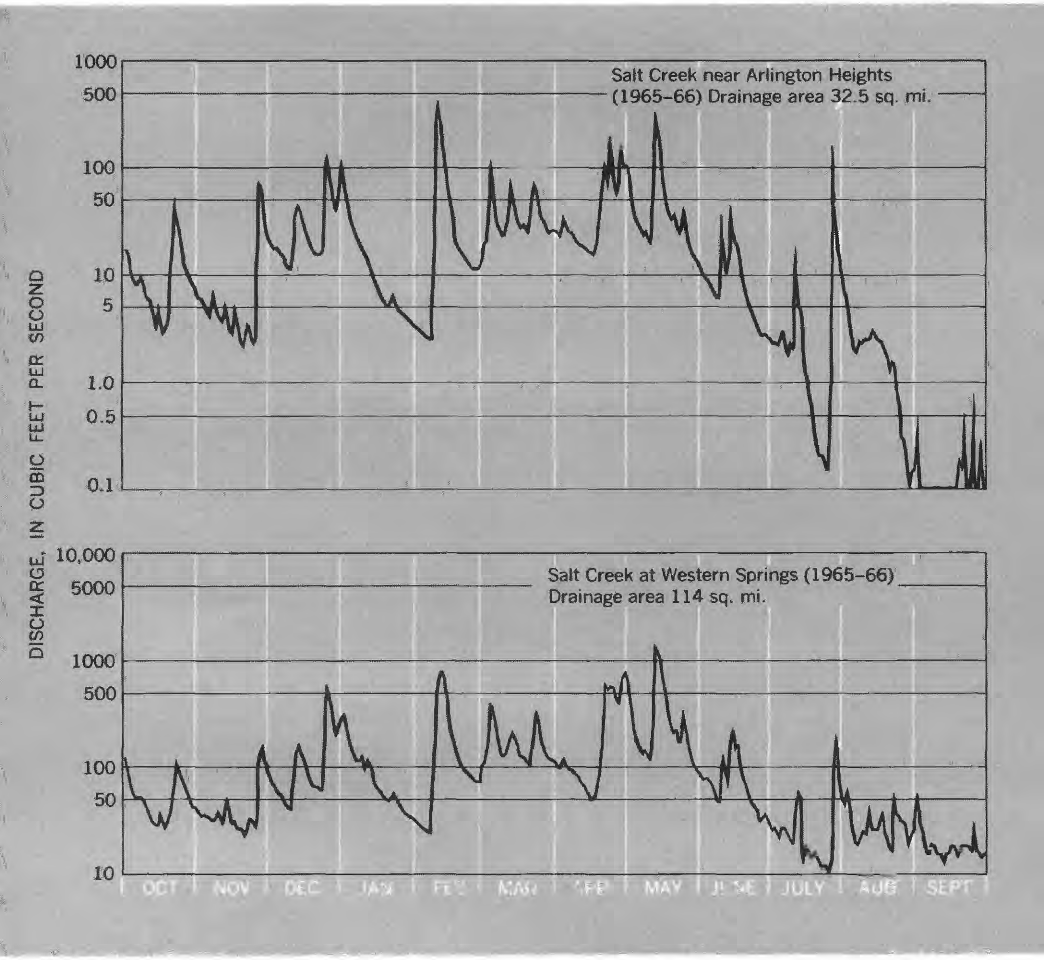


FIGURE 16.—Hydrographs of two continuous gaging stations on Salt Creek for 1966 water year.

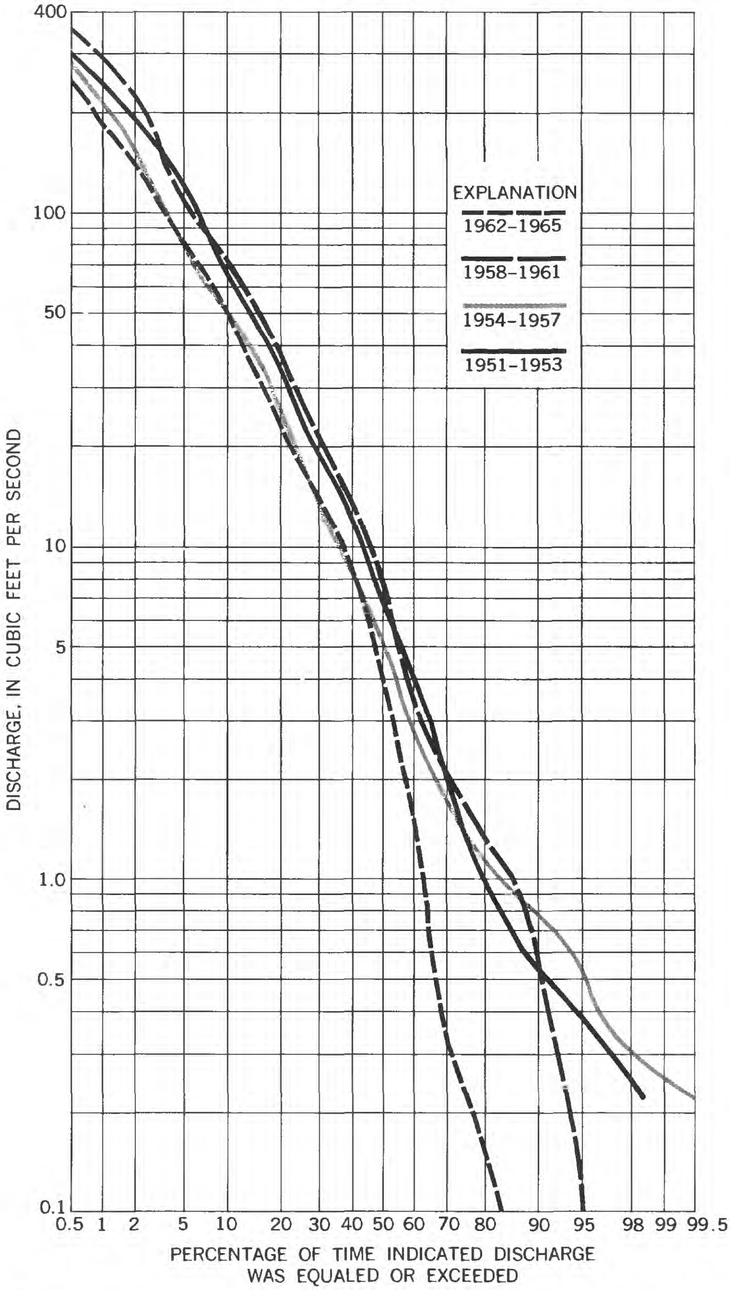


FIGURE 17.—Flow-duration curves, Salt Creek near Arlington Heights.

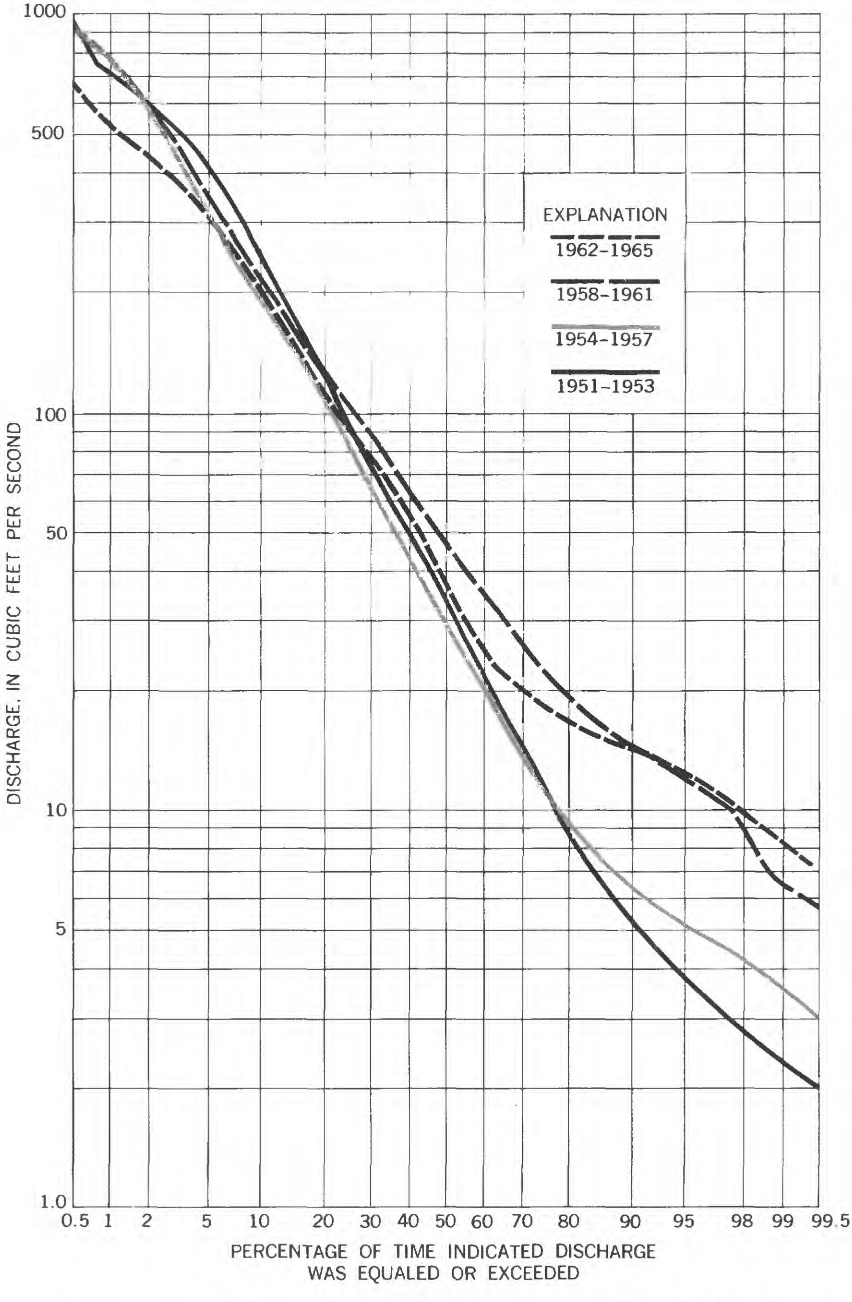


FIGURE 18.—Flow-duration curves, Salt Creek at Western Springs.

The most obvious feature of the curves for the two stations (figs. 17 and 18) is that the lower ends of the Western Springs curves are considerably flatter than the corresponding segments of the Arlington Heights curves. This indicates a generally higher base flow at Western Springs. Although relatively little deviation exists among the four periods in the middle and upper ranges of the curves, considerable deviation is evident among the lower ends of both curves.

The duration curves for the Arlington Heights station show a perceptible 90 percent flow of about 0.5 cfs (cubic feet per second) for the 1951–53 period. The 90 percent flow increased to about 0.8 cfs in the 1954–57 period. Beginning in 1958, however, the low flow dropped off sharply. During the final plotted period of record (1962–65), the flow was less than 0.1 cfs 15 percent of the time.

The increase in base flow during the 1954–57 period over the preceeding 1951–53 period can probably be attributed to a greater rate of sewage effluent from the Palatine sewage-treatment plant, resulting from increasing population of the area served by this plant. In 1958, however, the Palatine sewage system was tied into the Metropolitan Sanitary District of Greater Chicago, and its treatment plant was closed. Since that time, Palatine's sewage has been transported out of Salt Creek basin to the Metropolitan Sanitary District's North Side Treatment Plant. This change in sewage-disposal practice has caused a marked change in the low-flow characteristics of Salt Creek in its upper reaches.

The low-flow characteristics of Salt Creek at Western Springs are affected less by Palatine than by the several sewage-treatment plants in Du Page County that still discharge into Salt Creek or its tributaries. Figure 18 shows a steady increase in the low flow for the four selected periods of record. The 90-percent flow at Western Springs increased from 5 cfs for the 1951–53 period to 14 cfs for the 1962–65 period, probably as a result of increased sewage effluent. In the analysis of ground-water pumpage and its disposition as sewage, it was estimated that an average of 11.4 mgd, or 17.6 cfs, is discharged into Salt Creek. It is thus apparent that the low flow of Salt Creek consists almost entirely of sewage effluent.

Although the preceding analysis of changing low-flow conditions in Salt Creek appears convincing, the alternative possibility that these changes are due to climatic factors must be considered. Figure 19 consists of two double-mass curves, or cumulative graphs of precipitation versus runoff at the two gaging stations in Salt Creek basin. If the rainfall-runoff relationship were influenced solely by climatic factors, both these graphs would follow a straight line. The fact that they do not indicates that the change in streamflow regimen is at least in part due to nonclimatic factors. The double-mass curves for both stations, and particularly for Western Springs, plot generally to the right of the projected straight line, indicating increased runoff. This could be the result of increased sewage effluent or perhaps of increased storm sewer capacity. Another argument in support of this thesis is that, if climate were the principal factor controlling the change in the low-flow characteristics, the changes would be the same for both stations. That they are not strongly suggests that change in the sewage effluent volume is the principal factor controlling the low flow of Salt Creek.

Figure 19 shows an excess of 13 inches accumulated runoff at the Western Springs station over that at the Arlington Heights station. This excess reflects the fact that all the sewage plants discharging into Salt Creek are downstream from the Arlington Heights gage (figs. 14 and 15).

Although changes in the upper end of the duration curves are not nearly so pronounced as those at the lower end, the curve for the Western Springs station (fig. 18) does show a slight shift to the left at the upper end. This could indicate that, owing to filling of the flood plain and more rapid drainage through storms sewers, floods are now of greater intensity but of shorter duration than they were in the earlier periods. Considerably more research into this relationship is needed before a more definitive statement can be made.

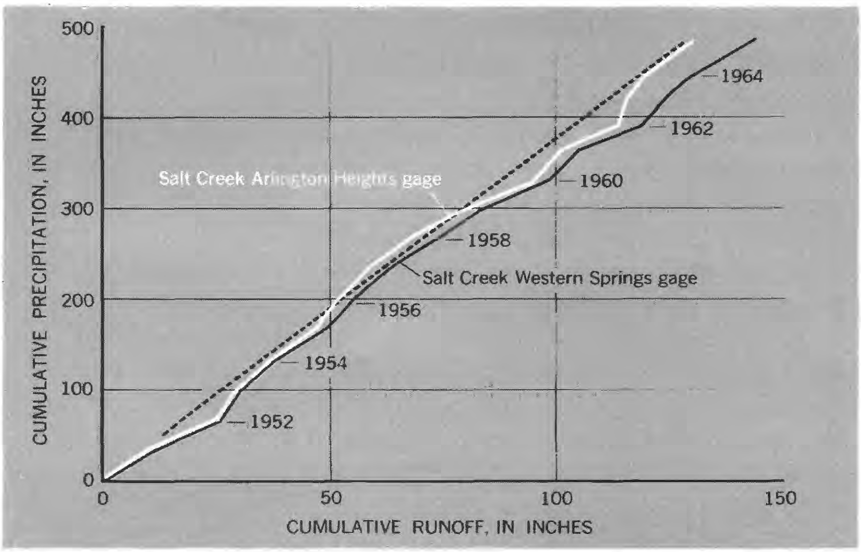


Figure 19.—Cumulative precipitation versus runoff in Salt Creek basin, 1951–65 water years.

SURFACE-WATER-DATA NEEDS IN AN URBANIZING AREA

Although the foregoing flow-duration data show some of the changes urbanization has imposed on the streamflow regimen of Salt Creek, they do not tell the whole story. The data suggest that the low flow of Salt Creek was slight before urbanization increased the load of sewage effluent. They also suggest that floodflows were less intense but of greater duration before urbanization consumed much of the natural storage capacity of the flood plains. The 1951–65 period was one of intensive urbanization, but much of the area was already urbanized before this period began. To present the entire picture would require discharge records that predate the urbanization of a significant part of the basin. For the Salt Creek basin, this would require records beginning about 50 years ago. Such records, unfortunately, are not available. This absence of data points to the need for collecting hydrologic data in areas which are not presently urbanized but which are likely to become urbanized in the future.

An alternative solution to this dilemma might be to compare the regimen of Salt Creek during this period of urbanization with the regimen of a stream in a similar geologic and climatic environment, but in a rural area. This approach is difficult because finding two basins with similar hydrologic characteristics is unlikely. Second, data are generally scarce for small drainage basins in rural areas.

NEW TOWNS—A PROMISING REALM FOR HYDROLOGIC STUDIES

The development of new towns on the fringes of the metropolitan areas offers a more promising approach for future studies of the hydrologic implications of urbanization. Such towns are entirely new communities, completely planned from the beginning. Park Forest, Ill. (fig. 1), is an example of such a community.

The use of new towns for hydrologic studies provides several unique advantages. The towns are planned, and thus the hydrologist will know where they will be located and what directions urban growth will take. He will be able to begin collecting data before actual construction begins, thus acquiring the important "base period" data prior to urbanization. Construction of such planned communities generally takes place rather rapidly. In 5 years, a hydrologist could accumulate data on the effects of urbanization that might take 10 to 20 years to accumulate in a more slowly developing area. Finally, the hydrologic data collected could help the planners take full advantage of the physical environment in designing their towns. Pitfalls, such as unwise use of flood plains, could thus be avoided.

To take maximum advantage of such new-town studies, systematic studies of land-use changes should be undertaken in conjunction with the hydrologic studies. In particular, changes in natural drainage patterns and in the storage capacity of the flood plains should be monitored.

In addition to oportunities for hydrologic studies, new towns offer opportunities for the application of the principles of coordinated water management and land use which will be discussed in following sections of this report.

Although hydrologic studies associated with the planning and development of new towns is a promising approach in theory, it may prove difficult in practice. The exact location of new towns is seldom made known by the developer until actual construction begins, to avoid speculation on the price of land. In this event, intensive data collection could begin only concurrently with construction. Only in a Government-sponsored project would the location be known sufficiently far in advance for intensive data collection to begin a significant time before the process of urbanization begins.

In spite of these limitations intensive data collection during the construction of new towns affords an excellent opportunity to gather a lot of information in a relatively short time about the hydrologic effects of urbanization.

INTERRELATIONSHIP OF SURFACE WATER AND GROUND WATER

The interrelationship between the surface-water and ground-water components of the hydrologic system should be considered in land-use planning. This is particularly important in an area, such as Salt Creek basin, where the ground-water resource is extensively used for water supplies. Some of these water supplies are taken from shallow aquifers in hydraulic connection with Salt Creek, and changes made by man, such as development on the flood plain or alteration of the channel configuration, could well affect the water-supply potential of these aquifers.

The natural movement of water in a humid environment is generally from the aquifers into the streams. During periods of low flow, Salt Creek is fed by seepage from the shallow unconsolidated deposits—mostly silt, sand, and gravel—that underlie the flood plains. The rate of seepage varies greatly at different times of the year and in different reaches of the stream. It is greatest when the soils and shallow materials are saturated and when the water table is high in relation to the water level in streams. The rate of ground-water seepage dwindles during extended dry periods.

370-926 O—70——4

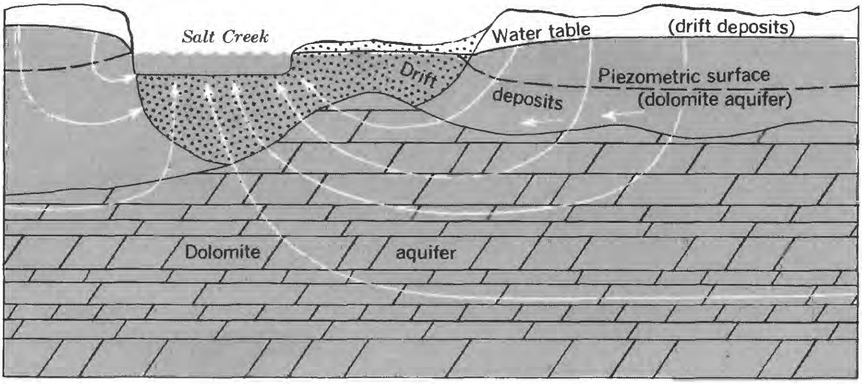
Pumping of water from wells in the shallow aquifers, when the aquifers are in hydraulic connection with a stream, can alter the natural hydraulic gradient by diverting water that under natural circumstances would feed the stream's base flow. Under these conditions, streamflow can be depleted, or the rate of seepage to the stream can be reduced. If pumping creates a sufficient change in the hydraulic gradient, this gradient can actually be reversed, causing water to seep from the streambed into the aquifers. The stream, therefore, can serve as a source of recharge to the aquifers. Recharge occurring under these conditions is referred to by hydrologists as *recharge by induced stream infiltration*, or simply as *induced recharge*. Such induced recharge is believed to sustain much of the ground-water pumpage from the shallow aquifers in the lower part of Salt Creek basin.

CONDITIONS NECESSARY FOR INDUCED RECHARGE

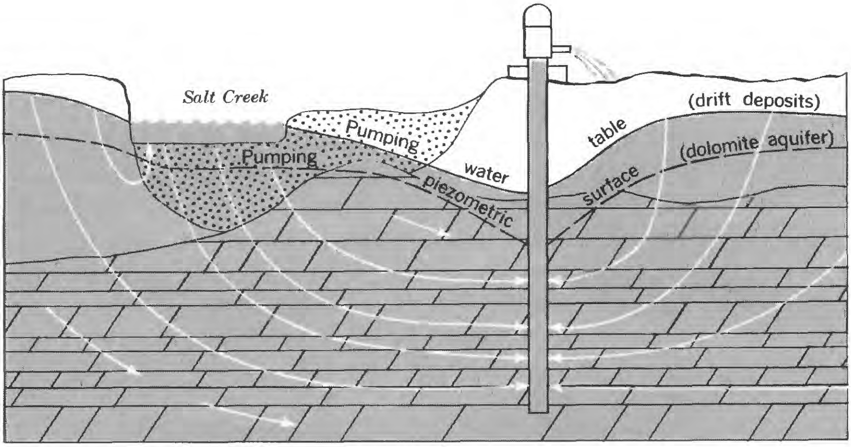
Induced recharge does not necessarily occur everywhere water is pumped from aquifers near a stream. Two conditions must exist for significant induced recharge to occur. First, the geologic conditions must be favorable. Either the aquifer being pumped must be in direct hydraulic connection with the stream, or the materials between the stream and the aquifer must be permeable enough to transmit water at a rate sufficient to recharge the aquifer. Second, the wells being pumped must be close enough to the stream to induce recharge, and they must be pumped at a rate high enough to alter the hydraulic gradient.

Figure 20 is an idealized sketch showing how such conditions might occur in a geologic-hydrologic environment similar to that of Salt Creek basin. Under natural conditions (fig. 20), ground water is recharged by precipitation and moves toward the stream. Most of the movement takes place in more permeable materials, such as the shallow dolomite aquifer and the sand and gravel underlying the streambed. In this idealized situation, the sand and gravel deposits are in direct connection with the aquifer. The level at which water stands in an open well in the shallow deposits is called the *water table*. The imaginary surface representing the level at which water stands in wells finished in the dolomite aquifer is called the *piezometric surface*.

Pumping from wells in the aquifer (fig. 20) creates a *cone of depression* around these wells. If this cone intersects the stream, the natural hydraulic gradient is reversed, and recharge is induced from the stream into the aquifer.



A



B

FIGURE 20.—Generalized movement of water between stream and shallow dolomite aquifer as it would occur in Salt Creek basin under ideal conditions for induced recharge. *A*, Natural conditions. *B*, Induced recharge caused by pumping from aquifer.

HINSDALE–LA GRANGE AREA

Conditions favorable for induced recharge are not uniform throughout Salt Creek basin (fig. 13). In general, the southern part of the basin is more favorable than the northern part. In the northern part of the basin, the shallow dolomite aquifer is covered by a thick section of glacial drift, much of which is fairly impermeable till. Thus, a good hydraulic connection does not exist between Salt Creek and the aquifer. Conditions south of Elmhurst, however, are much more favorable; here the drift cover is much thinner. Numerous bedrock highs exist, where the aquifer is virtually at the land surface. Enough sand and gravel are present in the drift to provide a hydraulic connection between Salt Creek and the aquifer. The geology and ground-water hydrology of this area have been studied by the Illinois State Geological Survey and the Illinois State Water Survey (Zeizel and others, 1962; Prickett and others, 1964, p. 75–87).

A requirement for induced recharge exists in the area around Hinsdale and La Grange, where pumping from the shallow dolomite aquifer has created an extensive cone of depression. Total ground-water pumpage from the shallow dolomite aquifer in this area in 1962, according to data of the State Water Survey (Prickett and others, 1964, fig. 118), was 8.6 mgd.

Geologic Conditions

The geologic conditions favorable for induced recharge, as illustrated in figure 20, are approximated in the Hinsdale area. Figures 21 and 22 show the thickness of impermeable drift cover, the nature of the glacial drift, and their relation to Salt Creek in this area. This illustration is part of a special study by the Illinois State Geological Survey conducted at the request of the author of the present report (Landon, R. A., written commun., January 1967). The bedrock surface crops out in the streambed of Salt Creek at three places (fig. 21). In much of the area (fig. 22), the bedrock aquifer is overlain by a permeable deposit of sand and gravel. Furthermore, the drift cover is 25 feet or less along this entire reach of Salt Creek. Although induced recharge could occur in any part of this reach of Salt Creek, it is most likely to occur either where the bedrock aquifer is exposed in the streambed or where the overlying sand and gravel are in the streambed.

Cone of Depression

Pumping from the shallow dolomite aquifer has created a widespread cone of depression which extends under the reach of Salt Creek shown in figure 21. This cone has been analyzed by the Illinois State Water Survey (Prickett and others, 1964, p. 81–83). Figure 23 is a map of this cone in 1962, prepared by the State Water Survey. The contours show the elevation of the piezometric surface of the shallow dolomite aquifer. Pumping in the La Grange area has lowered this piezometric surface by over 100 feet, creating a hydraulic gradient steep enough to induce recharge from Salt Creek. The "area of ground-water diversion" as shown in figure 23 indicates the area from which water is being diverted from its natural flow path into the Hinsdale–La Grange cone of depression.

INTERRELATIONSHIP OF STREAMFLOW, PUMPING, AND RECHARGE

Pumping that creates induced recharge from a stream will reduce the stream's flow. Most induced recharge occurs during periods of high streamflow for three reasons. First, the wetted perimeter of the stream is greater during periods of high flow, providing a greater surface area through which water can infiltrate. Second, the higher stage of the stream creates a greater head differential between the stream and the ground-water level in the underlying deposits. Third, the higher velocities associated with high streamflow cause scouring of the streambed, which removes the fine materials and thus creates a more permeable medium through which the water can infiltrate.

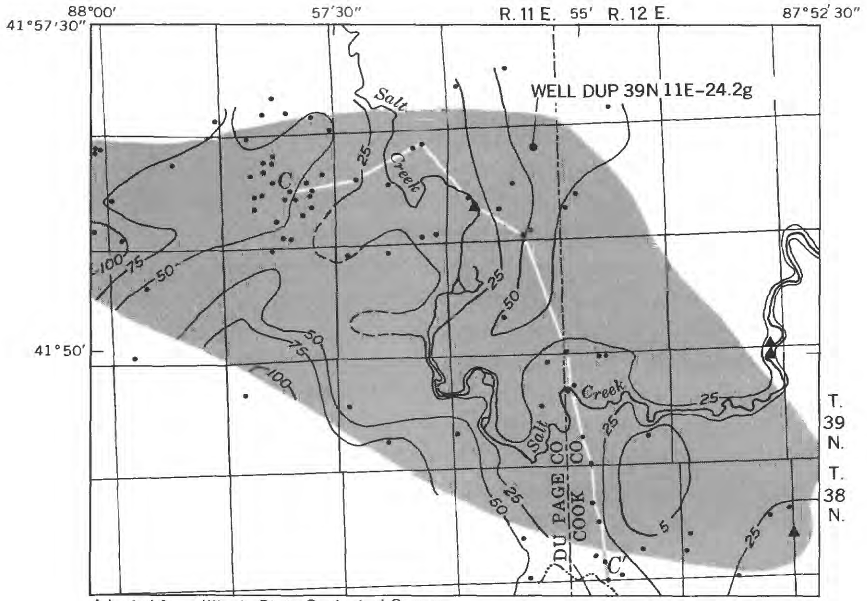
Streamflow losses during periods of high flow are difficult to measure. The percentage of total streamflow that infiltrates into the ground during these periods is usually so low that it cannot be detected by ordinary stream-gaging procedures which have an inherent margin of error of at least 5 percent. Although the percentage of streamflow infiltrating into the ground is low, the actual quantity may be very high in terms of ground-water pumpage. During a characteristic period of moderately high flow, the discharge of Salt Creek might be 500 cfs. Bearing in mind the 5 percent factor of error, a streamflow loss of 25 cfs, equivalent to about 16 mgd, could occur without being detected. Sixteen mgd is indeed a significant amount of water in terms of ground-water pumpage in Salt Creek basin. Periods of low streamflow offer a better opportunity to study streamflow losses, however, because flow is generally more stable during these periods, and the measurements can be more closely controlled. Furthermore, the loss generally makes up a greater percentage of total streamflow and is thus more readily detected.

Stream Discharge and Ground-Water Levels During High Streamflow

Stream infiltration can be detected by comparing the hydrograph of the stream with the hydrograph of a nearby well in a hydraulically interconnected aquifer. Unfortunately, records showing such an ideal relationship do not exist for Salt Creek basin. Figure 24 shows a comparison for the best available records. Well DUP 39N11E–24.2g [2] is a

---

[2] Well numbers shown in this report are based on the system used by the Illinois State Geological Survey and State Water Survey. The first three letters indicate the county: COK for Cook County and DUP for Du Page County. The next series of letters and numbers indicates the township, range, and section based on U.S. Government land surveys. The next combination of letters indicates the location within the section, based on a coordinate system which divides each 640-acre section into 64 squares of 10 acres each. Thus, well DUP 39N11E–24.2g is in Du Page County, township 39 north, range 11 east, section 24, and in square 2g. If more than one well is in a 64-acre square, the wells are identified by consecutive arabic numerals.



Adapted from Illinois State Geological Survey

1 ½ 0 1 MILE

EXPLANATION

Area of diversion for Hinsdale-La Grange cone of depression (After Prickett and others, 1964, fig.125, p. 83)

▲ Bedrock exposure

Line of equal thickness of cover material, interval 25 feet except 5-foot line (dashed where inferred)

• Control data: water well records and engineering borings

FIGURE 21.—Thickness of cover material over basal gravel or dolomite bedrock aquifer in the Hinsdale area. Cross section shown in figure 22.

continuously recording observation well open in the shallow dolomite aquifer, about 1 mile from Salt Creek and 3 miles from the Western Springs gage. The well is 350 feet deep, and the aquifer is covered by 60 feet of glacial drift. Although the log of this well does not differentiate the materials of the drift, the log of a nearby well, about 600 feet north, indicates a layer of sand and gravel 35 feet thick immediately overlying the aquifer. This basal sand and gravel layer appears to be fairly widespread in this vicinity (figs. 21 and 22) and could provide a hydraulic connection between Salt Creek and the aquifer.

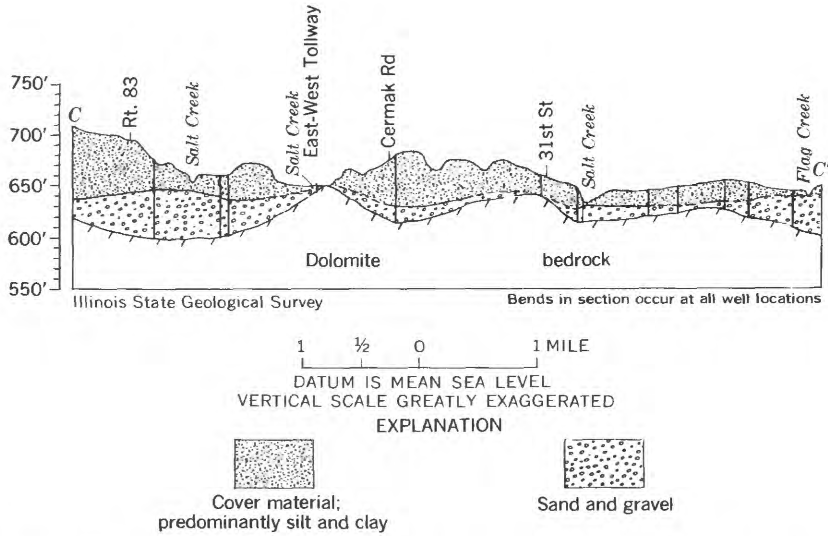


FIGURE 22.—Geologic cross section of the glacial drift and top of the bedrock surface in the Hinsdale area. Line of section shown in figure 21.

Figure 24 compares the gage height and discharge of Salt Creek, the water level in well DUP 39N11E–24.2g, and the precipitation at Wheaton for the first 24 days of July 1963. Wheaton, which is about 8 miles west of Elmhurst, is the nearest weather station that recorded the storms that affected the lower end of Salt Creek basin during this period. No measurable precipitation occurred during the first 12 days of July. Accordingly, this was a period of low streamflow, and the water level in the observation well declined. Precipitation began on July 13. During the final 12 days of the period used in this comparison, a total of 6.31 inches of rain fell at Wheaton, largely on July 13, 16, 19 and 20. Both the level of Salt Creek and the water level in the well rose in response to this rainfall. The stream hydrographs have three peaks that coincide with the three major storms of the period. The rising water level in the well was much steadier, and the sharpest rise occurred on July 13.

It is difficult to determine whether the rising water level in the well was due to direct infiltration of rainfall or to recharge from Salt Creek. Either or both of these events could cause the water level to rise. The fact that the water level in the well rose rapidly on July 13, however, suggests that the rise was due to induced stream recharge. It seems improbable that rainfall could infiltrate so rapidly through 60 feet of drift, at least 30 feet of which is relatively impermeable clay till, especially after an extended dry period. This well is near the edge of the Hinsdale–La Grange cone of depression (fig. 23), and conditions

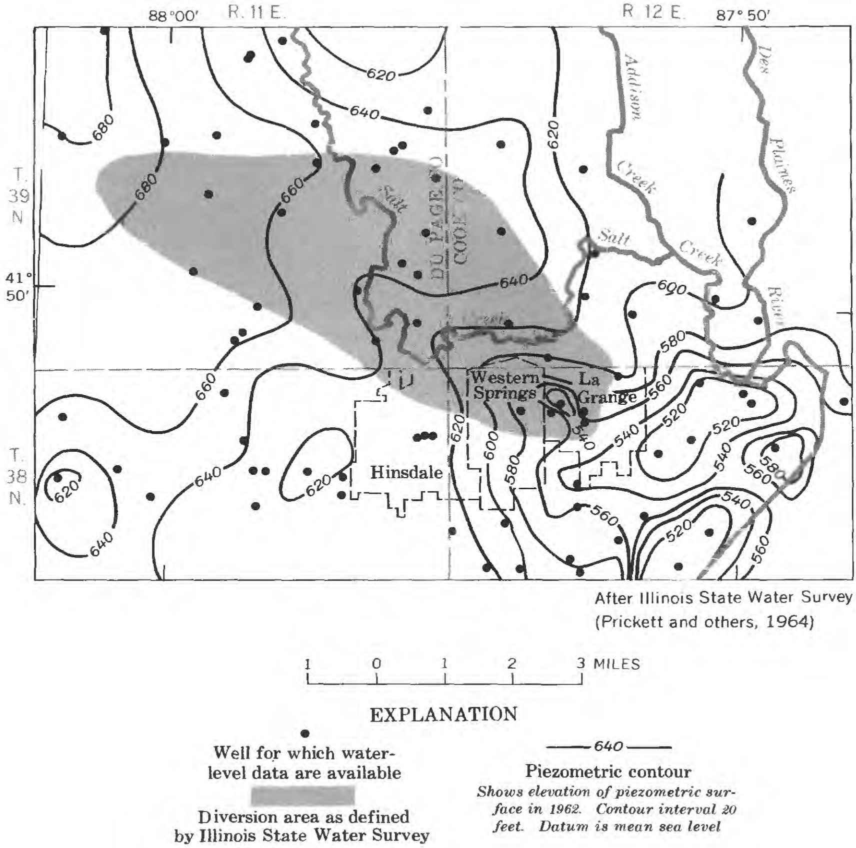


FIGURE 23.—Piezometric surface of shallow dolomite aquifer. A distinct cone of depression is in the Hinsdale–La Grange area.

were probably favorable for induced recharge on July 13, 1963. Therefore, it appears likely that at least part of the water-level rise in well DUP 39N11E–24.2g was the result of induced recharge to the aquifer. A systematic and coordinated program of ground-water-level measurements in several critically located wells, stream gaging, and precipitation measurements in the drainage basin would be required to determine the exact nature of the relation between streamflow and ground-water recharge.

Streamflow Losses During Periods of Low Flow

Although it appears that most ground-water recharge occurs during periods of high streamflow, some recharge does occur during low-flow periods. Losses are more readily detected during periods of low streamflow.

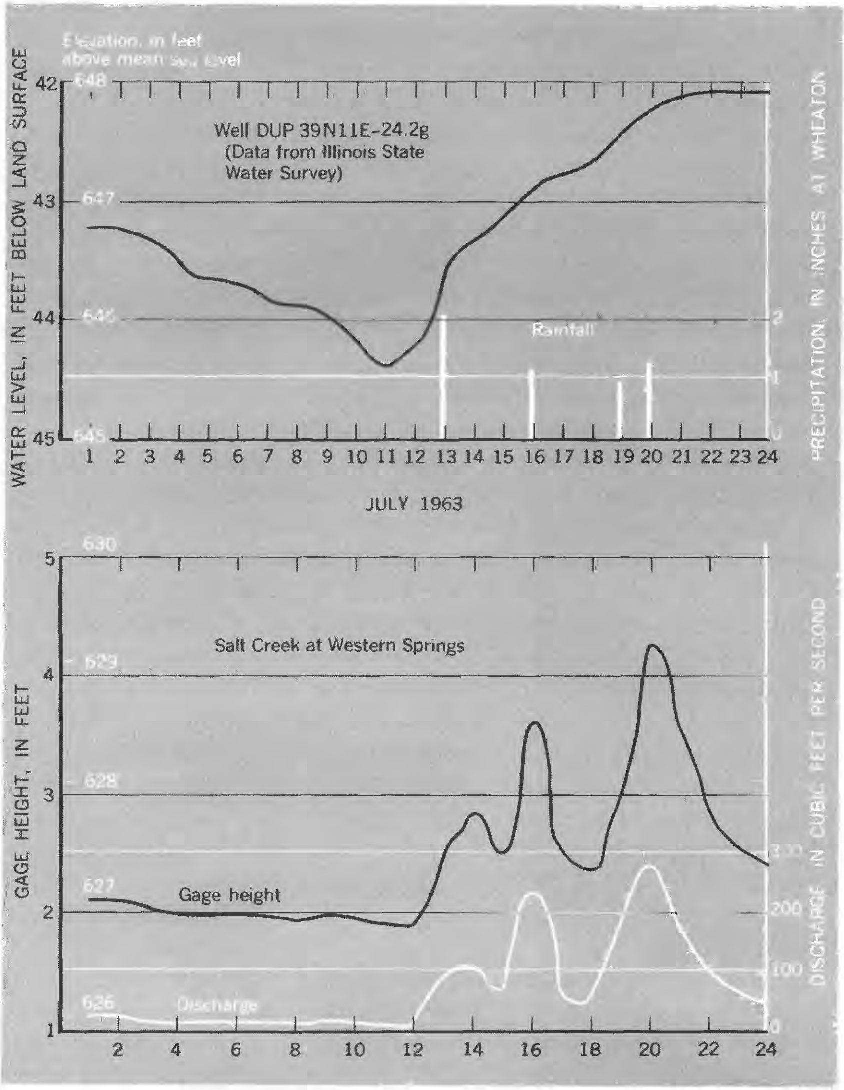


FIGURE 24.—Comparison of water level in Silurian Dolomite Aquifer, gage height and discharge of Salt Creek, and precipitation at Wheaton, July 1963.

Seepage Run of November 8, 1965

On November 8, 1965, a seepage run was conducted on Salt Creek and its tributaries. A seepage run is a series of discharge measurements made at several selected sites within as short a time interval as possible to detect gains or losses of streamflow. Discharge on this day was 4.65 cfs at the Arlington Heights gaging station and 34.0 cfs at the Western

Springs gaging station. Both these flows are in the moderately low range. Although scattered showers occurred on November 7 and 8 (0.05 inch at O'Hare Airport on Nov. 7; 0.04 inch at O'Hare Airport and 0.03 inch at Midway Airport on Nov. 8), no significant amounts of precipitation had occurred since October 22, 16 days before the seepage run. Therefore, these measurements can be considered fairly representative of base-flow conditions. Figure 25 shows the measuring sites and the results of the seepage run. The principal sources and estimated rates of sewage effluent entering the stream also are shown. The following discussion is confined to that part of Salt Creek basin upstream from the confluence with Addison Creek, near Brookfield.

Under natural conditions a stream, such as Salt Creek, in a humid environment would generally gain in flow downstream. This was generally true on November 8, 1965. Streamflow increased from 1.53 cfs at the measuring site farthest upstream at Palatine to 36.5 cfs at the Roosevelt Road measuring point.

Streamflow losses were measured in two reaches of Salt Creek—one between Addison and Elmhurst, and the other between Roosevelt Road and Brookfield. A loss of 2.3 cfs, compensating for the 2 cfs inflow from the Addison sewage-treatment plant, was measured in the reach between Addison and Elmhurst. The loss of flow in this reach is considered questionable for several reasons. The measuring site at Addison has a poor channel cross section and low velocity; thus, the measurement there might be significantly in error. A better measuring site was found for use in subsequent seepage runs. The reach between Addison and Elmhurst was found to be a gaining reach in these later runs. Finally, the geologic environment near Addison is not generally favorable for induced recharge. The basal sand and gravel and dolomite aquifers (fig. 13) are overlain by a thick section of relatively impermeable till.

The loss of flow measured between Roosevelt Road and Brookfield, however, is considered to be much more significant. Taking into account the inflow of 1.2 cfs from the Oakbrook sewage plant, this loss was 6.4 cfs. Of this amount, 3.8 cfs was lost between Roosevelt Road and the Western Springs gaging station, and the remainder was lost between the Western Springs station and Brookfield. There, the measuring sections were all good, and the geologic conditions are favorable for induced stream recharge.

The streamflow losses in Salt Creek south of Roosevelt Road correlate with favorable geologic and hydrologic conditions, as described in the preceding sections. This reach is in the area where bedrock is near the surface and is generally covered by a layer of sand and gravel

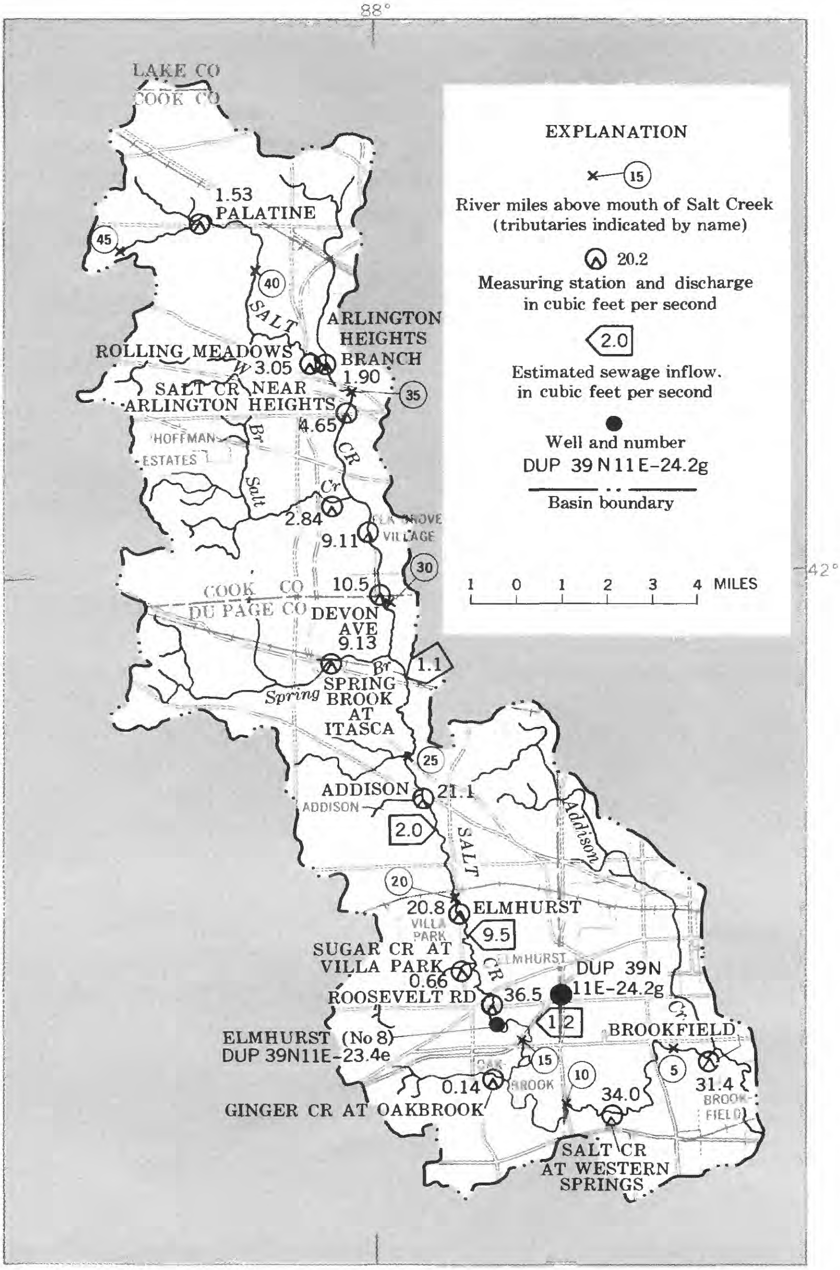


FIGURE 25.—Discharge measurements, November 8, 1965.

(fig. 22). Also, this reach is in the Hinsdale–La Grange cone of depression and virtually coincides with the area of ground-water diversion, as defined by the Illinois State Water Survey (fig. 23). Elmhurst well 8 (DUP 39N11E–23.4e), on the bank of Salt Creek about half a mile south of Roosevelt Road (fig. 25), produces from the dolomite aquifer. This well is pumped intermittently and could account for at least part of the loss of flow between Roosevelt Road and Western Springs. Based on the results of the November 8, 1965, seepage run, it appears that these favorable conditions do at times cause induced recharge and a corresponding loss of streamflow.

Additional Seepage Runs

Once the principal losing reach of Salt Creek was defined, several additional seepage runs were conducted in this reach to define its flow characteristics under a wide range of conditions. Table 1 is a summary of these seepage runs, including the original run of November 8, 1965. Streamflow losses do not occur at all times in Salt Creek between Roosevelt Road and Brookfield. For that matter, only on October 10, 1966, and in the original seepage run was a loss measured between Roosevelt Road and Western Springs. Even this loss was less than 5 percent of the total discharge (discharge measurements are considered to be accurate within 5 percent), and is thus open to question. Again, the fact that Elmhurst well 8 is not pumped much of the time may partly explain the irregularity of streamflow losses.

Streamflow losses occurred between Western Springs and Brookfield on 3 of the 7 days. On 2 days, gains of flow were recorded, one of them major, the other slight. Two of the measurements show apparent gains that are less than the 5-percent error factor.

These apparent discrepancies can perhaps be explained by the existence of factors other than natural seepage and induced infiltration in the lower reaches of Salt Creek. One such factor is pumping of water from the creek for irrigation in the vicinity of the Western

TABLE 1.—*Seepage runs in the lower reach of Salt Creek*

Date	Discharge (cfs)		
	Roosevelt Road	Western Springs	Brookfield
November 8, 1965	36. 5	34. 0	31. 4
June 23, 1966	34. 9	44. 5	42. 6
July 26, 1966	10. 8	12. 2	12. 5
August 18, 1966	21. 5	21. 7	26. 4
September 9, 1966	11. 0	14. 6	15. 4
October 10, 1966	12. 7	12. 4	6. 5
November 17, 1966	24. 5	25. 2	25. 5

Springs gage. Such pumping, which is difficult to monitor, may have affected the measurements made during the summer, but is not likely to have affected those made in October and November. Another factor, which could cause apparent gains in flow in spite of any induced infiltration that might occur, is discharge from sewage inlets. Although no sewage-treatment plants discharge into Salt Creek between Western Springs and Brookfield, numerous storm sewers do discharge into the creek. Little storm runoff is expected during periods of low flow. However, all sewers in this area are combined. A heavy load of sanitary sewage, thus, could partly spill over into the storm sewer outlets into Salt Creek. Therefore, accurate measurements of seepage in this reach would require monitoring of irrigation and storm sewers.

Still another potential source of error in these discharge measurements is evapotranspiration. Four of the seven seepage runs shown in table 1 were during the growing season and, thus, especially susceptible to evapotranspiration losses.

On November 17, 1966, measurements were made at two additional sites between Western Springs and Brookfield. Table 2 shows the results. Although a gain was recorded over the entire reach, a loss of flow did occur in the 3.2-mile reach between Western Springs and La Grange Road. This suggests that most of the loss of streamflow, when it does occur, occurs in this reach. Geologic and hydrologic conditions, as illustrated in figures 22 and 23, are favorable for induced recharge between Western Springs and La Grange Road. Additional seepage runs would be required, however, to determine whether it is in this reach that most induced recharge takes place under varying conditions of streamflow.

The differences in streamflow losses from Western Springs to Brookfield between the November 8, 1965, and the November 17, 1966, seepage runs may be related to differences in antecedent precipitation. The previous significant rainfall before the 1965 seepage run was 0.3 inch (measured at Midway Airport) and occurred 17 days before the run. In 1966, however, a rainfall of 2.69 inches occurred only 8 days before the seepage run. This suggests the possibility of more subsurface seepage into the stream in 1966, and could account for

TABLE 2.—*Discharge measurements on Salt Creek, November 17, 1966*

Measuring site	River miles above mouth	Discharge (cfs)
Western Springs	8. 8	25. 2
La Grange Park (31st St.)	6. 9	24. 7
Westchester (La Grange Road)	5. 6	23. 9
Brookfield	3. 6	25. 5

both the gain in the total reach and the relatively slight loss between Western Springs and La Grange Road.

In summary, the seepage runs on Salt Creek indicate that a significant loss of flow occurs at some, but not all, times in the Hinsdale–La Grange area. There appears to be no consistent pattern as to when such losses occur. Variations in this flow regimen are probably due to evapotranspiration, antecedent precipitation, changes in ground-water pumping, or changes in the condition of the streambed. The losses are probably related to induced recharge to pumping wells. Additional studies are needed to determine more precisely when and why these streamflow losses occur.

NEED FOR ADDITIONAL DATA AND RESEARCH

The reach of Salt Creek between Hinsdale and La Grange is clearly an important source of induced recharge to municipal water supplies in the shallow dolomite aquifer. Although this reach is presently the only place in Salt Creek basin where such recharge regularly occurs, favorable geologic conditions for induced recharge extend as far upstream as Elmhurst. Future pumping from the shallow aquifer may well create favorable hydrologic conditions for induced recharge in this additional reach. Also, increased pumping in the Hinsdale–La Grange area may necessitate artificial recharge to prevent an excessive decline of the water level. McDonald and Sasman (1967) indicated that this area has good potential for artificial recharge studies.

A much more thorough knowledge of the geology and hydrology of induced recharge under natural conditions is highly desirable before meaningful studies for artificial recharge are undertaken. Those areas most favorable for induced recharge under existing conditions would likewise be the best areas for artificial recharge operations. The geology and hydrology of this important recharge area is known only in general terms. More detailed studies are needed to define precisely where and when recharge does occur or would occur if additional ground-water supplies are developed. Furthermore, the implications of land use in these recharge areas must be considered. Most of the flood plains in the lower reach of Salt Creek are not presently developed, and much of this area is reserved as public open space. Development of part of this area might adversely affect recharge to the shallow aquifers.

Detailed geologic and hydrologic information is of critical importance to land-use planning in Salt Creek basin. Important recharge areas to the shallow aquifer exist in the reach of Salt Creek south of Roosevelt Road. Land use compatible with preservation of these recharge areas is essential for the continued use of ground water from the shallow aquifers as the area's principal source of water supply. Possible alternative land uses compatible with preserving ground-water recharge include the preservation of recharge areas as open space and the design of storm water drainage systems to channel runoff into these recharge areas. The exact location of these recharge areas, however, is not known and can be determined only by detailed hydrogeologic studies. Planning for the development of this part of the area will thus be more effective if the extent of these recharge areas is known.

The greatest single need in analyzing the recharge potential of Salt Creek is a coordinated study of the relation of surface water and ground water and the relation of both to land-use practices. The absence of coordinated studies related to land use has been due in part to limited agency objectives.

What is needed, then, is a comprehensive and coordinated program of data collection and analysis including land-use plans and all components of the hydrologic system, stream discharge measurements, ground-water-level measurements and pumpage records. Chemical, bacteriological, and biological analyses of the quality of ground and surface waters should be made over a period of 2 to 3 years and under a wide range of hydrologic conditions. A summary of the most important needs for data and research follows.

A better knowledge of the geology of the area must be obtained before detailed hydrologic studies can be undertaken. The geology of the dolomite aquifer is fairly well known. The main data gap is in the thickness and character of the glacial drift overlying this aquifer. To obtain an adequate understanding of these deposits for recharge studies would require drilling a large number of test holes along the flood plains of Salt Creek. Such a program would identify those places where a good hydraulic connection exists between the stream and the aquifer. This information could then provide a basis for measurement sites in recharge studies.

The ground-water hydrology of the Hinsdale–La Grange cone of depression has been studied. The main gaps of knowledge are in water-level and stream-gaging records and in the hydrology of the shallow unconsolidated deposits, or glacial drift. Although periodic water-level measurements are made in wells in the dolomite aquifer, only one continuously recording well (DUP 39N11E–24.2g) is maintained in this cone. This well actually is at the fringe of the cone. Several additional recording wells located between Salt Creek and the pumping centers of La Grange and Hinsdale would be needed in a detailed recharge study. A detailed soil survey would help identify areas of permeable soil, and would provide a further clue to the location of the best recharge areas.

Little is known about the flow patterns in the unconsolidated materials that overlie the dolomite aquifer. To gain an understanding of these patterns would require water-level measurements at different depths in small-diameter wells installed both in the streambed and on the adjacent flood plain. The wells would be located in those areas where the geologic conditions are determined to be most favorable for induced recharge. These wells could be measured periodically, under varying conditions of streamflow, to determine changes in head with varying depth and distance from the stream. These measurements of head differential in the unconsolidated deposits, in conjunction with the measurements from recording wells in the dolomite aquifer, could be used to determine the direction of ground-water movement from Salt Creek toward the pumping centers.

The exact number of observation wells cannot be determined on the basis of existing information. From 20 to 50 small-diameter wells (measured periodically) and five to 10 recording wells might be required. The installation of these wells would be preceded by the test drilling program to determine in detail the character of the unconsolidated deposits.

Additional stream discharge measurements, or seepage runs, should be made under a wide range of conditions and in conjunction with ground-water-level measurements. These measurements are needed to establish the relation between surface-water and ground-water flow patterns. During these runs, sewage inflow and irrigation should be monitored. An additional gaging station downstream from the present Western Springs gage, preferably at the crossing of La Grange Road, is desirable to provide spatial amplification of record. Rain gages should be maintained at all continuous stream-gaging stations to provide adequate control for determining the water budget.

The quality of water is every bit as important as the direction of its flow. Samples for analysis should be taken in conjunction with the seepage runs at all streamflow measuring sites, from selected wells in the unconsolidated deposits, and from wells in the dolomite aquifer between Salt Creek and the major pumping centers. The analyses should include at the minimum such constituents as ABS (detergents), phenols, nitrates, phosphates, BOD (biochemical oxygen demand), DO (dissolved oxygen), coliform bacteria, and chlorides, to detect any evidence of ground-water pollution. Periodic measurements of the temperature of surface water and ground water might provide additional evidence to define flow paths between Salt Creek and the pumping centers.

Once the nature of induced recharge in the lower part of Salt Creek basin is better understood, consideration can be given to increasing the yield of the dolomite aquifer by artificial recharge. The most favorable locations for artificial recharge pits or spreading basins are where a good hydraulic connection exists between Salt Creek and the aquifer. The location of these recharge areas could best be determined by a comprehensive program of investigation as outlined in the preceding paragraphs.

In summary, a more thorough knowledge of recharge characteristics is needed in the lower part of Salt Creek basin. Before any further hydrologic studies are begun, the hydrogeology of the shallow unconsolidated deposits should be studied in greater detail. Then, a comprehensive and coordinated study of induced recharge, including ground-water-level measurements, stream discharge measurements, and water-quality sampling under a wide range of conditions, could be undertaken. It is important that all such programs be coordinated if the study is to achieve its maximum effectiveness in comprehensive planning for future growth of the region.

WATER QUALITY

The quality of water is of prime importance in regional planning. Clear and clean streams can enhance the environment and increase land values, whereas polluted streams are a blot on the landscape and can be a major cause of urban blight. Furthermore, the quality of water used for public supplies, largely ground water in Salt Creek basin, must be protected. One area of emphasis in the present report is management of the flood plains and the effects of alternative flood-control measures. Water quality is critical in such planning. Many multiple-purpose flood-control plans are based on the storage of flood waters for later beneficial use, and water of poor quality is a liability rather than an asset in any such plans.

QUALITY OF SURFACE WATER

Samples for water-quality analysis were taken at several sites on Salt Creek on several occasions during the present study. For the purpose of comparison, three sampling runs were selected: November 8, 1965, during a period of relatively low flow, and April 30 and May 12, 1966, during floods. Figure 26 shows the sampling sites on which the following discussion is based.

All naturally occurring water contains some mineral matter dissolved from the earth materials with which the water has come in contact. In addition, most streams in urban areas contain some sewage effluent.

370-926 O—70——5

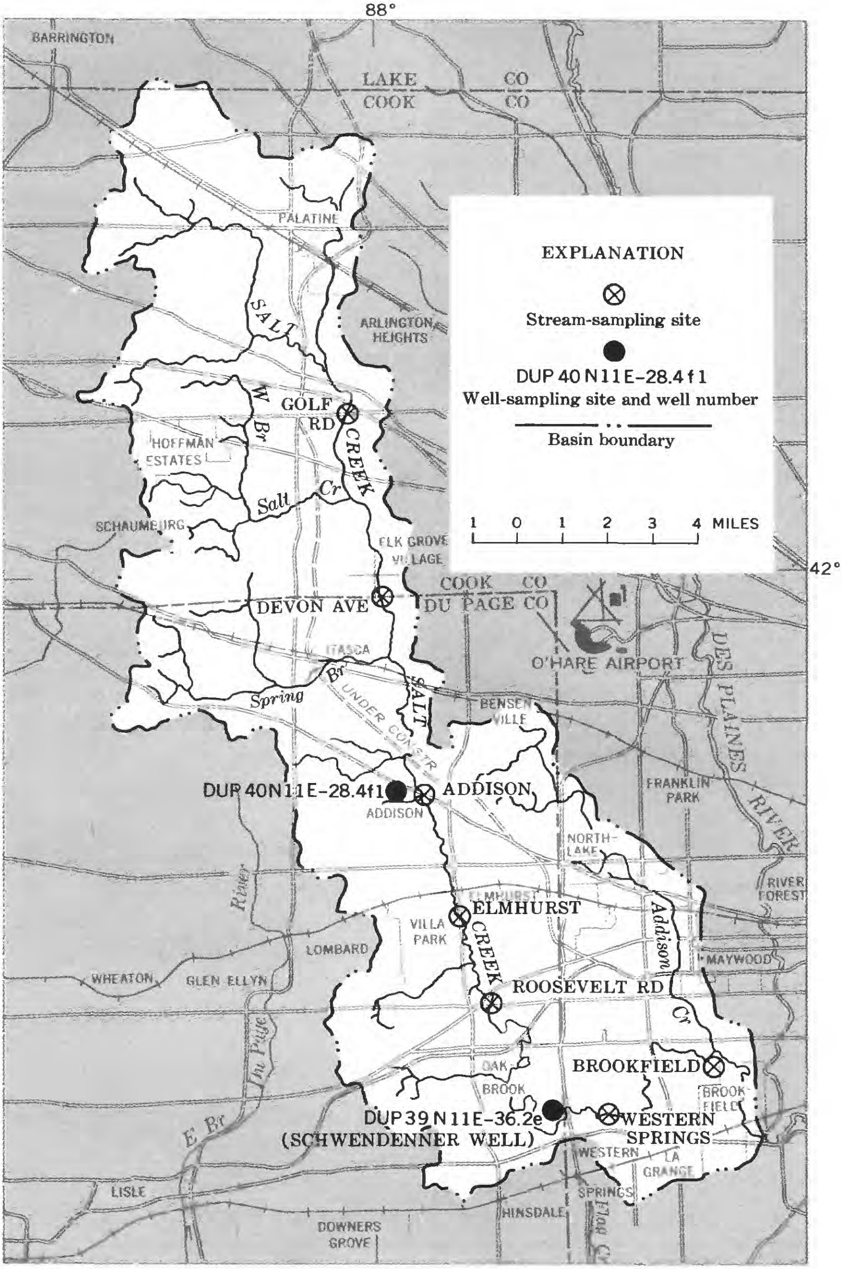


FIGURE 26.—Location of water-quality sampling sites in Salt Creek basin.

Salt Creek is no exception. Table 3 shows water-quality analyses of water from Salt Creek at three representative sampling sites on November 8, 1965. Discharge at the Western Springs gage on that day was 34 cfs, in the moderately low range (fig. 18). Discharge at the Arlington Heights gage (same location as the Golf Road sampling site) was 4.65 cfs, also in the moderate range. The chemical analyses show rather high concentrations of mineral constituents, generally becoming progressively greater downstream. As far as the inorganic constituents are concerned, the analysis of water from the Golf Road site is similar to an analysis of water from a typical well in the Silurian Dolomite Aquifer. (See table 4.) The concentrations of most of these constituents increase downstream as more sewage effluent enters the stream. The presence of coliform bacteria, "hard" or nondegradable detergents (ABS), and biochemical oxygen demand (BOD) ranging from 2 to 13 mg/l (milligrams per liter) indicates that Salt Creek has become polluted by sewage effluent.

A somewhat more comprehensive view of water quality in Salt Creek can be attained by examining changes in concentration of certain selected constituents at different points under different flow conditions. For this purpose, the analyses of November 8, 1965, during a period of moderately low flow, are compared with analyses taken during two floods in 1966, on April 30 and May 12. Figure 27 shows detailed hydrographs of these floods at the Western Springs gage and the times at which the samples were taken. The flood of April 27 to May 2 crested rather gradually in three stages. The samples were taken shortly after the final crest and after 3 days of high water. The samples of May 12, on the other hand, were taken shortly after the crest of a

TABLE 3.—*Water-quality analyses of Salt Creek, November 8, 1965*

[Analysis of BOD, DO, and coliform bacteria by Illinois Dept. of Public Health. All other analyses by Illinois State Water Survey. All values except temperature and coliform bacteria in milligrams per liter, nominally equivalent to parts per million]

Quality parameters	Sampling sites		
	Golf Road	Addison	Western Springs
Temperature (°C)	12	12	13
Iron	0.4	1.6	0.7
Sulfate	218	331	251
Chloride	52	71	165
Nitrate	0.9	7.7	26.0
Phosphate	0.2	1.4	6.8
Dissolved solids	623	860	925
Suspended solids	10	58	36
Hardness as $CaCO_3$	460	580	496
Biochemical oxygen demand (BOD)	2.0	7.3	13
Dissolved oxygen (DO)	8.5	9.2	7.1
Detergents (ABS)	0.1	0.1	0.3
Coliform bacteria (MPN/100 ml)	40,000	41,000	5,000

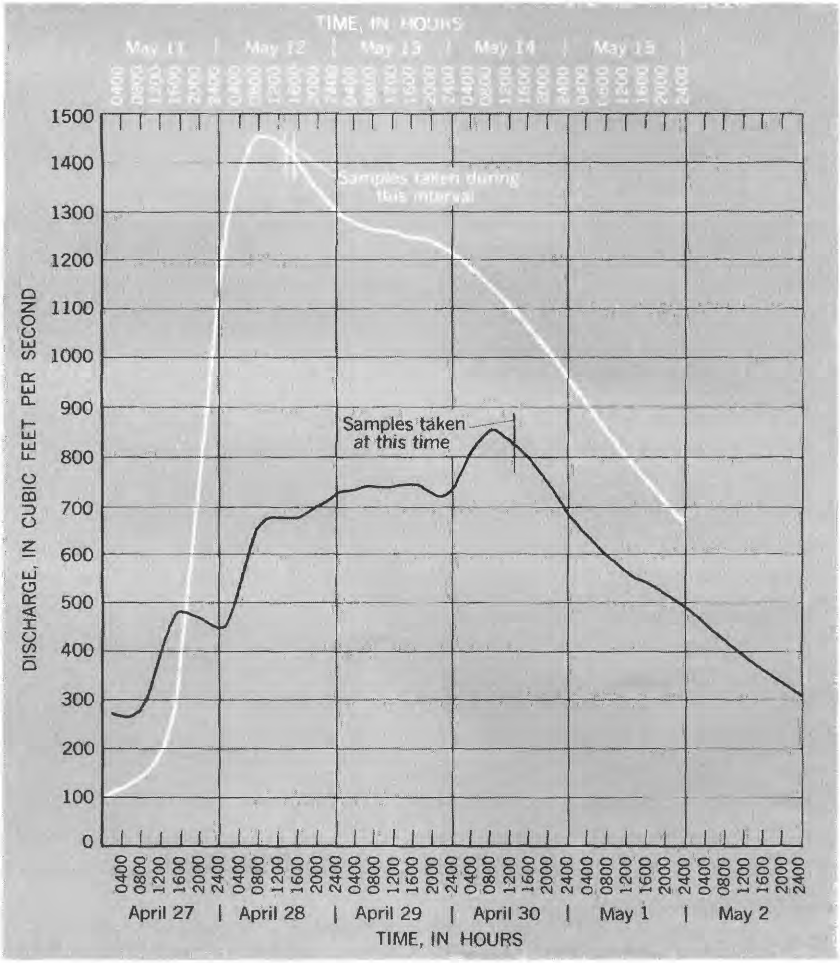


FIGURE 27.—Hydrographs of two floods on Salt Creek in 1966.

flood which rose rapidly, from 100 cfs at 2 a.m. on May 11 to 1,455 cfs at 8 a.m. on May 12.

DO and BOD are indicators of the extent of a stream's organic pollution. BOD is not a substance but rather a measure of the amount of oxygen required to assimilate the organic matter in the stream. A minimum of 5 mg/l of DO is considered necessary for the maintenance of aquatic life, except such pollution-tolerant organisms as carp and sludge worms. An excess of BOD over DO indicates degraded conditions.

Figure 28 shows DO and BOD plotted against river miles above the mouth of Salt Creek at three different times. On November 8, 1965,

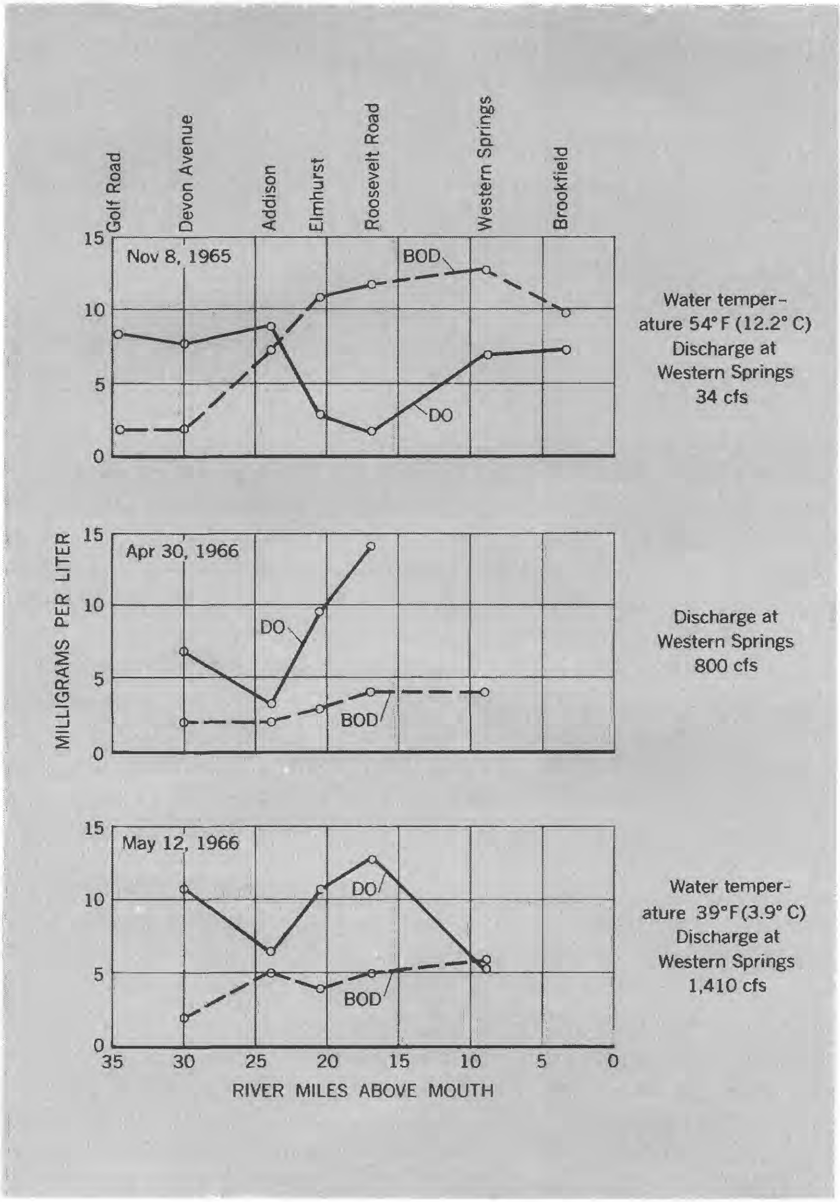


FIGURE 28.—Dissolved oxygen and biochemical oxygen demand versus river miles along Salt Creek.

the DO level dropped below Addison, then recovered at Western Springs. The lowest reading was 1.7 mg/l at Roosevelt Road. BOD exceeded DO at all sampling sites below Addison. Most of the sewage effluent discharged into Salt Creek is in the degraded reach between Addison and Western Springs. Another major source of effluent is Spring Brook, which is upstream from the Addison sampling site. This tributary receives sewage effluent from Itasca, Roselle, and Bloomingdale; and the inflow is reflected in the increase in BOD between the Devon Avenue and Addison sampling stations. Apparently, sufficient oxygen was present in this reach, however, to prevent any excess BOD.

DO exceeded BOD at all sampling sites in the floods of April 30 and May 12, except at Western Springs on May 12. (No DO analysis was run at Western Springs on April 30.) This indicates that the greater rate of flow at higher velocities characteristic of floods is generally sufficient to assimilate much of the stream's organic matter. DO was depleted at Addison during both floods and at Western Springs on May 12. Whereas the oxygen deficiency at low flow at Roosevelt Road on November 8 is probably due to upstream sewage effluent loads, the deficiencies which occurred during the two floods may have resulted from another cause. The Addison and Western Springs sampling sites are associated with sluggish reaches of Salt Creek. The Addison sampling site is in a particularly sluggish reach, and the Western Springs site is slightly over 2 miles downstream from Fullersburg Dam, which creates a pond during low flow. Through the years, deposits of sludge from the suspended matter in sewage effluent have accumulated in these stagnant pools. These sludge deposits are stirred up during periods of high flow, creating an oxygen demand.

A general downstream increase in dissolved solids on November 8 and the peak at Addison on May 12 (fig. 29) are probably indicative of pollution loads. Except for the peak at Addison, the pollution load was generally lower during the May 12 sampling run, a period of high streamflow. The Addison peak probably is the result of discharge from combined sewers into Spring Brook, which enters Salt Creek just above Addison.

Coliform bacteria are commonly used as indicators of pollution. Although these organisms are not themselves necessarily harmful, their presence does indicate pollution from fecal wastes. Figure 30 shows concentrations of coliform organisms at different points along Salt Creek during the three previously discussed sampling periods. Coliform bacteria are generally reported as the most probable number of organisms per 100 ml. The most striking feature of figure 30 is that the coliform counts were generally higher during both the floods sampled than during the relatively low-flow period of November 8, 1965. In all three sampling runs, concentrations generally increased downstream, reaching a peak at Elmhurst or Roosevelt Road. The lower reaches of Salt Creek generally had coliform counts of over

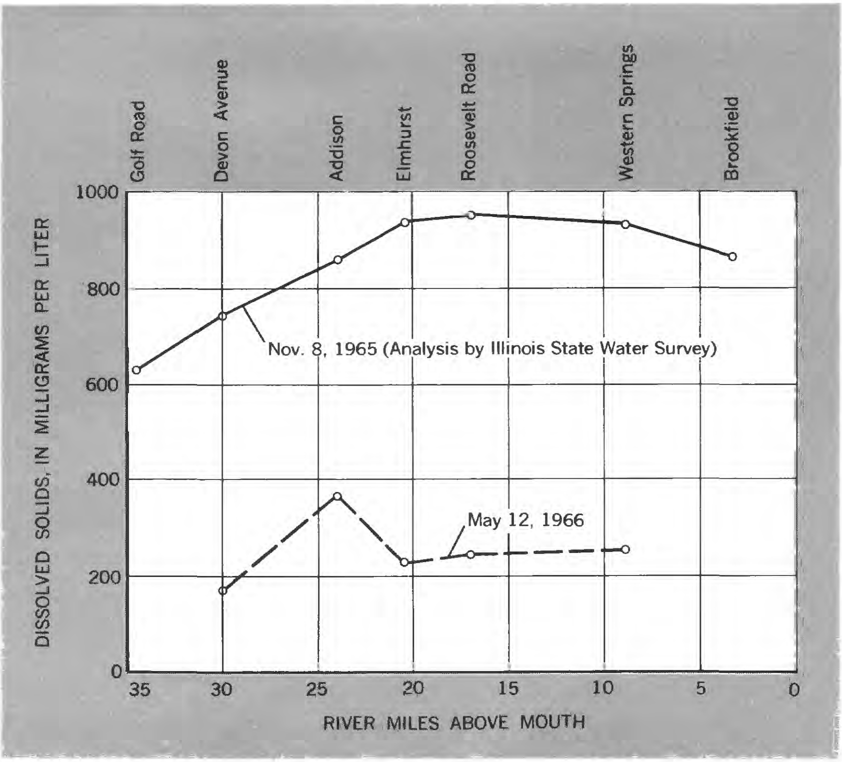


FIGURE 29.—Total dissolved solids in Salt Creek, November 8, 1965, and May 12, 1966.

100,000 organisms per 100 ml. Water is considered safe for recreation only when the coliform count is under 1,000.

Several general observations can be made concerning these results. There are no sewage treatment plants discharging into Salt Creek upstream from Devon Avenue. The presence of coliform organisms at both Devon Avenue and Golf Road, however, indicates that the water at these sites is polluted. This pollution might be a result of overflow from combined storm and sanitary sewer systems in the Cook County communities normally tied into interceptor sewers of the Metropolitan Sanitary District. During low-flow periods, however, no such overflow should occur unless the sewers are overloaded. Pollution during periods of low flow could result, in part, from the discharge of the many individual septic systems in the area. There were an estimated 3,600 septic systems in the part of Salt Creek basin in northern Cook County in 1960. Some of these systems near Salt Creek or its tributaries discharge directly into the streams.

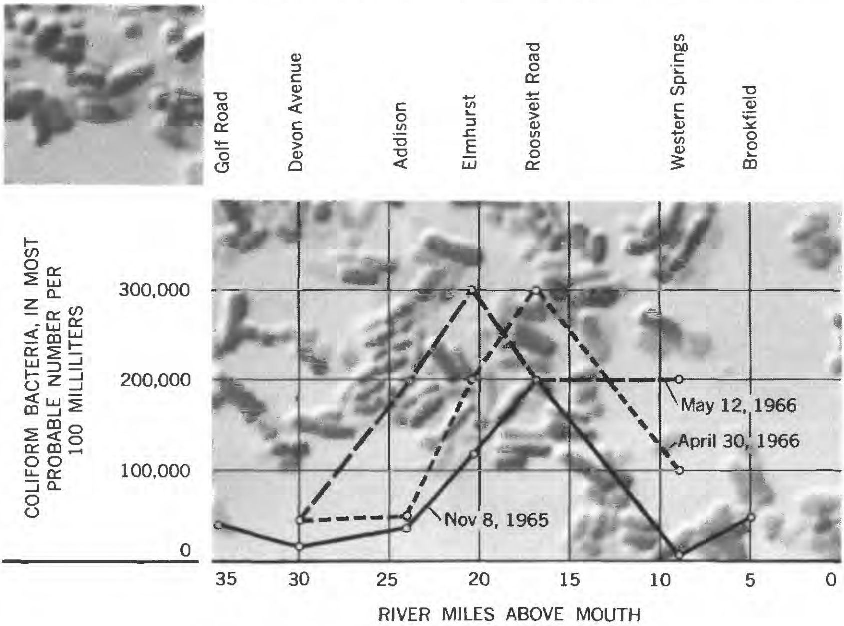


FIGURE 30.—Coliform bacteria in Salt Creek.

Coliform bacteria counts were generally higher during the two floods than during the period of low flow. This is probably true for three reasons. First, many of the communities in Salt Creek basin have combined sewers. During periods of high runoff, much of the sewage bypasses the treatment plants and enters the receiving streams untreated. Second, accumulated sludge in the streambed, in which coliform bacteria thrive, is stirred up by floods. The two greatest such accumulations are probably in slack water reaches in the vicinity of Addison and in the pond upstream from Fullersburg Dam, near Oakbrook. Third, a storm flushes the land surface; accumulated wastes are carried in the runoff and account for relatively high counts in streamflow crests.

The implications of the foregoing water-quality characteristics for flood control and water management are far reaching. Recent research (Sheaffer and Zeizel, 1966, p. 73 and fig. 31) suggests that, at least for some streams, only the initial flush of a flood is polluted. After a few hours, the water is of sufficiently good quality to be stored for later beneficial use. In sluggish streams such as Salt Creek where sludge has accumulated through the years and where combined sewers discharge untreated sewage during storms, this generalization does not necessarily apply. The samples of April 30, 1966, were collected after 3 days of high water (fig. 27) and still contained large numbers of coliform bacteria.

QUALITY OF GROUND WATER

Ground water in Salt Creek basin is generally hard, reflecting the abundance of carbonate rock in the area. The quality of ground water of Du Page County was discussed by Zeizel, Walton, Sasman, and Prickett (1962, p. 77–81).

The quality of water in the shallow aquifers, especially in the shallow dolomite aquifer, is of particular interest because of pollution problems caused by induced recharge. A map in the Northeastern Illinois Planning Commission's water-management report (Sheaffer and Zeizel, 1966, fig. 21), based on data provided by the Illinois State Water Survey, indicates that the hardness of water in the shallow dolomite aquifer ranges generally from 300 to 600 mg/l in Salt Creek basin. Table 4 shows a chemical analysis of water from a well in this aquifer.

TABLE 4.—*Chemical analysis of water from a well in the shallow dolomite aquifer*

[Well owned by village of Addison. Analysis by Illinois State Water Survey. Results in milligrams per liter except where indicated]

Well DUP 40N11E–28.4fl			
Depth of well (ft)	155	Alkalinity	326
Date of collection	5–16–47	Sulfate	200
Temperature (°C)	11.2	Chloride	6.0
Silica	24.0	Fluoride	0.2
Iron	1.4	Nitrate	1.0
Calcium	108	Hardness as $CaCO_3$	505
Magnesium	56.7	Dissolved solids	625
Sodium and potassium	18.2		

There is an area in the lower reach of Salt Creek where hardness of water in the shallow aquifer is generally higher, from 600 to 1,000 mg/l (Sheaffer and Zeizel, 1966, fig. 21). This has been identified in the present study as an important area of induced recharge to the La Grange cone of depression. In view of the close interrelationship between surface water and ground water in this area, it appears that the greater hardness of ground water can be attributed to the infiltration of polluted water from Salt Creek.

Another indication of pollution of the shallow aquifer comes from an analysis by the Illinois State Water Survey of water from a well at the Schwendenner office building at Hinsdale (well DUP 39N11E–36.2e; see fig. 26 for location). This well is 347 feet deep, is cased to bedrock, and yields water from the shallow dolomite aquifer. The reported hardness is 830 mg/l. The sample contained 0.3 mg/l of ABS, a substance which does not occur naturally in water. While ABS itself is not believed to be harmful and the quantity reported is negligible, it is an indicator of pollution. Because this well is about 1,000 feet from Salt Creek and is in the Hinsdale–La Grange cone of depression, induced recharge from Salt Creek appears to be the most likely source of the pollutants.

The foregoing examples are merely indications of ground-water pollution in the Hinsdale–La Grange area. Further study is required to document fully the nature and extent of pollution. The mere suggestion that ground-water pollution exists as a result of surface-water pollution, however, should be a strong argument in favor of improving the quality of water in Salt Creek.

DEFINING THE POLLUTION PROBLEM

Pollution is a vastly complex phenomenon. It cannot be fully defined in terms of only DO, BOD, dissolved solids, hardness, ABS, and coliform bacteria. The studies outlined in the two preceding sections are intended only to show that pollution does exist in Salt Creek and to identify in general terms some of the broader relations among parameters. These study methods could serve as examples of the kinds of analyses which should be undertaken in the future, over a longer period of time, and under a wider range of conditions. For example, samples could be taken at 2-hour intervals from the beginning to the end of a flood. This sampling procedure would better define the changes in water quality that take place during a flood. Continuous monitoring of DO, temperature, and dissolved solids at one or more stations would better define the relation of water-quality changes to streamflow.

Most water-quality studies have either concentrated on the chemical aspects of pollution or do not include indicators of pollution at all. For example, the typical "complete" chemical analysis of a ground-water sample does not always include such constituents as ammonia nitrogen, ABS, coliform bacteria, DO, BOD, and phenols, any of which may be an indicator of pollution. Furthermore, pollution is not a purely chemical phenomenon. A complete study of pollution of a stream should include analyses of the nature and extent of polluted bottom deposits and the nature and extent of aquatic life. Some aspects of pollution relating to solid wastes are almost impossible to evaluate in quantitative terms. For example, the entire length of Salt Creek contains such objects as discarded tires, shopping carts from supermarkets, beer cans, and an abundance of paper and cardboard refuse. Although these objects do not show up in any water-quality analysis, they do constitute visual pollution that detracts from the environment.

Another aspect of pollution that needs further study is the growth of algae. These organisms thrive on nutrients, mostly nitrates and phosphates which are not completely removed by existing sewage treatment plants. Fertilizers and livestock excrement may be other sources of nutrients. These algae cause an unsightly green scum on the surface of the stream. During warm weather, they enrich the stream in dissolved oxygen while the sun is shining (by the process of photosynthesis), while at night the organic matter in the stream consumes the oxygen, sometimes causing unpleasant septic odors. Research is being conducted into the extent of growth of algae, means of controlling these organisms, and advanced sewage treatment techniques to prevent or reduce the quantity of nutrients in effluent released to the streams. The results of this research have not yet been applied in northeastern Illinois.

Sediment is another aspect of the pollution problem intensified by urbanization. The almost perpetual construction which takes place in a rapidly urbanizing area results in accelerated erosion of soils and increased sediment loads in the streams.

The Soil Conservation Service of the U.S. Department of Agriculture has developed a series of construction practices, based on research in Montgomery County, Md. that will reduce sediment loads (American Society of Planning Officials, 1966). A summary of these practices follows:

1. Construction at any given time will be confined to the smallest practical area. and for the shortest practical period of time;
2. Temporary vegetation and mulching will be used to protect critical areas;
3. Basins will be installed to retain sediment from land undergoing development;
4. Channels will be provided or installed to accommodate sharp changes in runoff;
5. Permanent vegetation and structures will be installed as soon as practical;
6. Development plans will be suitably fitted to the peculiar requirements of the soils and topography found at each site;
7. Where feasible, natural vegetation will be retained and protected as cover for land under construction.

Although the pollution problem in Salt Creek basin is complex and data are insufficient, some important conclusions can be drawn. Salt Creek has become degraded, especially in the nearly stagnant reaches upstream from Fullersburg Dam and near Addison. This condition is the result of decades of abuse. Until about 15 years ago, most sewage discharged into the stream received only minimal treatment, and much of it was discharged untreated. At present, nearly all sewage discharged into Salt Creek receives "secondary" treatment, which removes 80 to 90 percent of the BOD and suspended solids. Population increase, however, threatens to outpace increases in the degree of sewage treatment. The population of towns presently discharging sewage into Salt

Creek has increased fivefold, from about 30,000 in 1930 to about 150,000 in 1965. A continuation of this trend will result in little or no improvement of the quality of sewage effluent in Salt Creek.

The two or three floods, or periods of high runoff, which typically occur annually, are not sufficient to scour and remove the accumulated bottom deposits. Furthermore, the quality of flood runoff is degraded by the discharge of untreated wastes from combined sewers. For these reasons, any flood-control plans which feature the detention and storage of flood runoff for beneficial use are not realistic unless steps are taken to improve the quality of the stored water.

Pollution of a stream can detract from the value of adjacent land. Houses along a polluted stream are likely to decline in value because people are not willing to put up with odors and other unpleasant byproducts of polluted water. In addition, polluted water may detract from the recreational and esthetic potential of adjacent forested land. A park or forest preserve through which a polluted stream flows has been likened by one prominent public official in northeastern Illinois to "a shiny red apple with a rotten core."

Finally, the polluted water in Salt Creek poses an ever-increasing threat to the quality of ground-water supplies in the shallow aquifers that receive induced stream recharge. At present, these supplies are mainly in the Hinsdale–La Grange area. In the future, however, it is quite possible that additional towns may develop water supplies in the shallow aquifers adjacent to Salt Creek. If this should occur, these new supplies will be in danger of becoming polluted, unless the quality of Salt Creek is improved.

ALTERNATIVE APPROACHES TO THE POLLUTION PROBLEM

The pollution problem in Salt Creek could be managed by one or more of several alternative approaches. A few of the more obvious alternatives follow. These courses of action are not mutually exclusive; some of them could be undertaken in conjunction with certain features of other approaches.

1. Leave conditions as they are.—This is the approach that has been taken to date (1969). Although there has been a general improvement in the degree of sewage treatment, it has not always kept pace with the population increase. Little has been done about the degraded condition of the streambed, and few communities have dealt effectively with the problem of untreated wastes from combined sewer systems or from urban runoff. A continuation of past practices and present trends will probably result in increased pollution of Salt Creek.

The public is becoming increasingly aware and increasingly intolerant of polluted conditions in general. Likewise, the public is demanding more facilities for outdoor recreation and an esthetically pleasing living environment. For these reasons, the residents of Salt Creek basin, or any other urban area for that matter, are not likely to tolerate existing conditions for long. Public officials will thus be forced to take actions to improve these conditions.

2. Improve degree of sewage treatment and consolidate treatment plants.—Another approach to the pollution problem is to increase the degree of sewage treatment to the point that the effluent is virtually pure. "Tertiary" treatment is coming into widespread use in combatting ever-increasing pollution loads. This type of treatment usually removes 98 to 99 percent of BOD and suspended solids and chlorinates the effluent to inhibit bacterial growth.

Improving the degree of sewage treatment can be accomplished either by upgrading existing treatment plants or by consolidating treatment facilities in a large plant. The strongest argument in favor of the latter approach is economy of scale; one large treatment plant can do the job more efficiently and more economically than can several smaller plants.

Consolidation of treatment plants is not a new concept. It was attempted in Salt Creek basin as far back as 1928, when the Salt Creek Drainage Basin Sanitary District was created. This district included the villages of Addison, Elmhurst, and Villa Park, and adjacent unincorporated areas. It was proposed to consolidate the sewage systems of these three villages into a single treatment plant on Salt Creek.

The plan for the Salt Creek Drainage Basin Sanitary District was never activated, owing largely to local opposition to the initial cost of construction and the inability to agree on plans, regardless of the long-term economies of such plans. Addison withdrew from the district in 1930, and Elmhurst in 1932. The district still exists but, in effect, operates only the sewage treatment system for Villa Park. Today the separate sewage treatment plants of Elmhurst and Villa Park exist side-by-side along the banks of Salt Creek.

Consolidation of the sewage plants in Salt Creek basin in Du Page County is presently under consideration as part of a master plan to improve the degree and efficiency of sewage treatment. The sewage of all Du Page County communities in the basin would go into an interceptor sewer parallel to Salt Creek and then to a centralized tertiary treatment plant near Hinsdale. The effluent from this plant would be either discharged into Salt Creek or diverted out of the basin into Flag Creek.

A recent study by the U.S. Committee on Intergovernmental Relations (1963, p. 202–203) points out the economy of scale in the construction and operation of sewage treatment plants. Comparative construction costs per million gallons per day for plants of various capacity providing secondary treatment follow:

Capacity (mgd)	*Cost (per mgd)*
100	$230,000
10	400,000
1	720,000

Operation and maintenance costs for the same plants would be as follows:

Capacity (mgd)	*Cost (per mgd)*
100	$35
10	39
1	62

These figures do not include the cost of land, interceptor sewers, or engineering fees. For widely extended sewage treatment districts, the economy of scale would have to be balanced against the cost of extensive interceptor sewer lines. Nevertheless, these comparative costs suggest that several adjacent communities would save considerably by pooling their sewage treatment facilities rather than by constructing separate plants.

Tertiary treatment may be only half the answer to the pollution problem in Salt Creek basin. If the quality of the effluent were greatly improved, the stream would clean itself up in time. The question is, how much time? For a sluggish stream like Salt Creek that has been subjected to decades of abuse, it might require a few more decades to undo the damage already done. Another problem is the thousands of individual septic systems, some of which discharge directly into the stream. Improving the degree of sewage treatment might be a wasted effort unless the quality of the receiving stream is likewise improved.

3. Augment low flow.—An alternative to improving the quality of sewage effluent is to increase the receiving stream's low flow, which would provide for greater dilution. However, reservoir sites with storage capacity adequate for flow augmentation are scarce in urban areas of low relief such as Salt Creek basin. Sheaffer and Zeizel (1966, p. 97–98) discussed the concept of flow augmentation and many of the problems involved, using Salt Creek as an example. To maintain a base flow of 50 cfs, or 35 mgd, which is considered to be an adequate rate for the dilution of existing sewage effluent, would require reservoirs with a storage capacity of 30,000 acre feet. Surface storage capacity to maintain such a flow is not available within the basin. Therefore, maintenance of a base flow of 50 cfs in Salt Creek would require either interbasin transfer of water or use of ground water.

Low-flow augmentation alone would not solve the problems of bottom conditions and untreated sewage from combined sewers during storms any better than would improved sewage treatment. Thus, the same limitations that apply to tertiary treatment would likewise apply to flow augmentation as a means of improving water quality.

4. Transport sewage from basin.—A fourth alternative is to intercept the sewage from all communities in Salt Creek basin and transport it to a central treatment plant outside the basin. This is already being done to a large degree by the Metropolitan Sanitary District, which serves most of the basin in Cook County. The effects of this approach have already been demonstrated by the reduction of low flow at the Arlington Heights gage (fig. 17). Presumably, if Du Page County were to adopt a similar approach, the low flow in the lower reaches of the stream would also be reduced. Whether it is better to have a moderately low base flow of polluted water or a lower base flow of less polluted water is subject to debate. To compare the effects of this plan with the effects of flow augmentation or improved sewage treatment would require a detailed economic analysis of the costs and benefits of each approach. Again, interbasin transport of sewage would not solve the problem of the already degraded condition of the streambed. Furthermore, discharge of untreated sewage from combined sewers during storms would continue unless all storm-drainage systems in the basin were separated from sanitary sewers. Also, interbasin transfer of sewage is only a partial solution to the problem. While it may alleviate conditions in one basin, it would merely transfer the problem to another basin.

Future Sewage-Treatment Practices

The present pattern of sewage disposal practices may change in the future. Du Page County, as mentioned, is considering a plan for the consolidation of sewage-treatment plants. Under this plan, the effluent from communities in Salt Creek basin might be diverted to Flag Creek. Furthermore, the Metropolitan Sanitary District is planning to construct a tertiary treatment plant which, according to the original plan, would discharge into the West Branch of Salt Creek, upstream from a proposed flood-control reservoir in the Ned Brown (Busse Woods) Forest Preserve. However, arrangements are being worked out between the Sanitary District and the Cook County Forest Preserve District to discharge the effluent from this plant into Salt Creek below the proposed dam, thus preventing the effluent from entering the reservoir. This plant would serve much of the rapidly growing northwestern part of Cook County. Effluent from this plant would probably exceed in volume the combined output of all the sewage plants on Salt Creek in Du Page County. Construction of a new plant is necessary because the capacity of existing plants and the interceptor sewers feeding them cannot keep pace with the area's rapid growth. The Metropolitan Sanitary District has concluded that it would be more economical to construct the new facilities close to the most rapidly growing areas rather than to enlarge both the existing plants and the long network of interceptor sewers.

These changes in sewage disposal practices are bound to influence the quality of water in Salt Creek. Although a greater volume of sewage effluent will result from these practices, the effluent might be of considerably better quality than that presently being discharged.

A More Comprehensive Approach To Water-Quality Control

No plan for the improvement of sewage disposal practices can be wholly effective unless two important steps are taken: first, cleaning of the streambed, and, second, some provision for the treatment of wastes during periods of high runoff. Cleaning the bed of a stream of Salt Creek's size would be a fairly simple matter. Aquifers, however, to the extent that they may be already polluted, will simply have to be flushed out once the sources of pollution are removed.

The problem of treating wastes and runoff during storms is more complex. Many communities in Salt Creek basin, particularly the older ones, have combined sewer systems. The cost of separating these systems in an entire community could be great. However, the city of Elmhurst, one of the largest communities in Salt Creek basin, with an estimated 1965 population of 41,000, completed the separation of all its sewers in 1968. Another community that has come to grips with this problem is Elk Grove Village. Elk Grove Village is a fairly new community, built entirely since 1950, which in 1965 had a population of about 12,000. Here planners recognized from the outset the desirability of separate storm and sanitary sewers and planned the community accordingly. Figure 31 shows how storm runoff channels can be an esthetic asset, utilizing the median strip of boulevards. This method of providing for storm drainage, furthermore, is less costly than conventional storm sewer construction.

It is likely, in view of current policy at all levels of government, that most new residential developments will be built with separate sewer systems. But the problem remains as to what to do with combined systems in older communities. If the cost of separation should turn out to be prohibitive, an alternative approach is to detain and route storm runoff to a series of reservoirs or detention basins, and later to release it at a sufficiently low rate that it can be treated. Various types of detention facilities are further discussed in the section on alternative flood-control measures.

FIGURE 31.—Storm drainage channel in median strip of parkway in Elk Grove Village is an alternative to conventional storm sewer design.

In summary, the pollution problem is a complex one and cannot be solved by any single line of action. First, the nature and extent of pollution need to be better defined with respect both to time and to place. One this has been done, a comprehensive program, perhaps utilizing several of the techniques discussed here, could be undertaken. In the meantime, steps should be taken in the planning and construction of new development to prevent the existing situation from becoming worse.

FLOODING, AND MANAGEMENT OF THE FLOOD PLAINS

THE FLOODING PROBLEM IN SALT CREEK BASIN

The flooding problem in Salt Creek basin is aggravated by the basin's location in the headwaters of the Illinois River basin and its poorly developed drainage system. The narrow channels and the incompletely developed and poorly defined flood plains of Salt Creek

370-926 O—70——6

and its tributaries are not able to handle the runoff resulting from a heavy or intense rain, particularly if the ground is frozen. Urbanization has further aggravated the flooding problem by substituting impervious roofs and pavements for the more permeable soil cover and by reducing natural storage through filling of depressions.

Flooding in Salt Creek basin, as in much of the northeastern Illinois metropolitan area, is not hazardous in terms of loss of life and property, as compared with flooding on the Mississippi or Ohio Rivers. A typical flood on Salt Creek might inundate the flood plain to a depth of 1 to 3 feet. The damage from such flooding is often more of a nuisance or an inconvenience than a hazard. It can be, however, a rather expensive nuisance. A damage survey of the 1962 flood on the Des Plaines River near Libertyville was conducted by the U.S. Army Corps of Engineers. Flooding along this stream is hydrologically similar to flooding along Salt Creek. The average damage to each house on the flood plain was $1,000. Future flood damages are likely to be even more costly, because new houses generally have basement recreation rooms with expensive furnishings and appliances.

The seriousness of this problem can be illustrated by a survey of developments on the flood plain of Salt Creek in Du Page County (Sheaffer and Zeizel, 1966, p. 82–83). In 1954, five houses and two commercial structures were on the reach of the flood plains of Salt Creek in Du Page County. By 1964, developments on the flood plains in this same reach had increased to 409 houses, three industrial buildings, three commercial buildings, and two schools. At an average damage of $1,000 per structure, the damage from a typical flood in this reach would be at least $417,000. Damages to the commercial and industrial buildings and schools would most likely exceed $1,000 each.

Figure 32 shows areas that have been flooded in recent history in Salt Creek basin. This map is a generalization for illustrative purposes only and should not be used for detailed planning. For planning purposes, the U.S. Geological Survey flood-inundation maps (Hydrologic Atlases), on which this generalized map was based, should be used. These maps, at a scale of 1 inch=2,000 feet, show on a topographic base the areas inundated by various floods of record. Detailed profiles and frequency graphs for each flood are included in these atlases. A report by Sheaffer, Ellis, and Spieker (1970) explains how these flood-inundation maps can be used in urban planning and development to prevent unwise use of the flood plains and to reduce flood damages.

The total area of the flood plains as shown on the U.S. Geological Survey maps is 14.6 square miles, or 9.8 percent of the basin's drain-

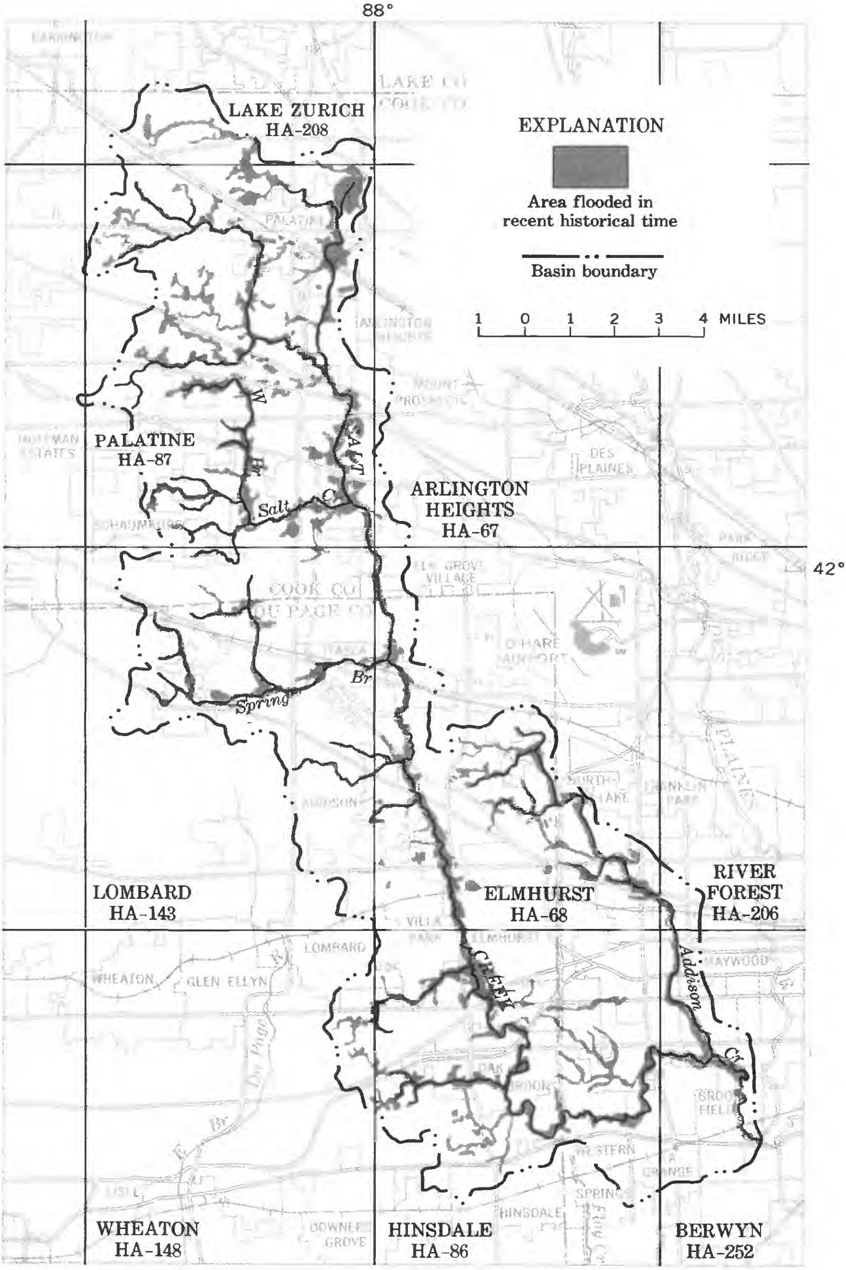


FIGURE 32.—Areas of Salt Creek basin known to have been flooded in recent historical time, and coverage by U.S. Geological Survey flood-inundation maps (Hydrologic Atlases).

age area.[3] Flood plains that constitute nearly 10 percent of a rapidly urbanizing 150-square-mile basin are a significant part of that basin and must be given consideration in planning. The largest concentration of flood plains is in the northern half of the basin. This part of the basin also includes the largest concentration of unstable muck soils (fig. 4). It is this part of the basin that is today under the greatest pressure from urbanization.

The inundated areas shown in figure 32 are those areas subject to what is generally known as *overbank flooding*. This type of flooding has been defined by Leopold and Maddock (1954, pp. 249–51) as "Any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream." In addition, many closed depressions are subject to inundation during periods of heavy rainfall. Although some of the larger depressed areas are shown in figure 32, those not related to river stages and flood frequencies are not always included.

The flooding of basements, underpasses, and other street depressions is a common occurrence in urban areas. This type of flooding is usually the result of inadequately sized or designed storm drainage systems and is not necessarily associated with overbank flooding of a stream. Therefore, the nature and extent of this type of flooding cannot be portrayed on a flood-plain map such as figure 32.

It is difficult to define "flood stage" at any or all points in the basin in terms of a specific elevation at a given gaging station because the height of the stream's banks varies throughout the basin. Figure 33 shows annual flood peaks above the elevation of 632 feet at the Western Springs gage, equivalent to a gage height of about 7 feet, for the period of record 1946–66. During the 21-year period, floods higher than 632 feet occurred in 9 years, or an average of once every 2.33 years. The maximum flood discharge recorded at the Western Springs gage was 1,920 cfs on March 20, 1948. At the Arlington Heights gage, the maximum recorded discharge for the period of record 1951–66 was 721 cfs on March 30, 1960. A flood discharge of 1,050 cfs occurred at Arlington Heights on June 11, 1967, however.

Some flooding does occur when the gage height at Western Springs is below 7 feet; minor flooding occurs when the gage height is as low as 6 feet. Gage heights of greater than 6 feet occurred in 14 out of the 21 years, or in an average of 2 years out of 3. Thus, flooding in Salt Creek basin is a rather frequent occurrence.

[3] This figure differs slightly from the figure of 11.49 square miles, or 10.0 percent as shown in the Northeastern Illinois Planning Commission report (Sheaffer and Zeizel, 1966, table 23). The latter figure is for the 114-square-mile drainage area above the Western Springs gage, whereas the figure used in the present report is for the entitre drainage area of 150 square miles.

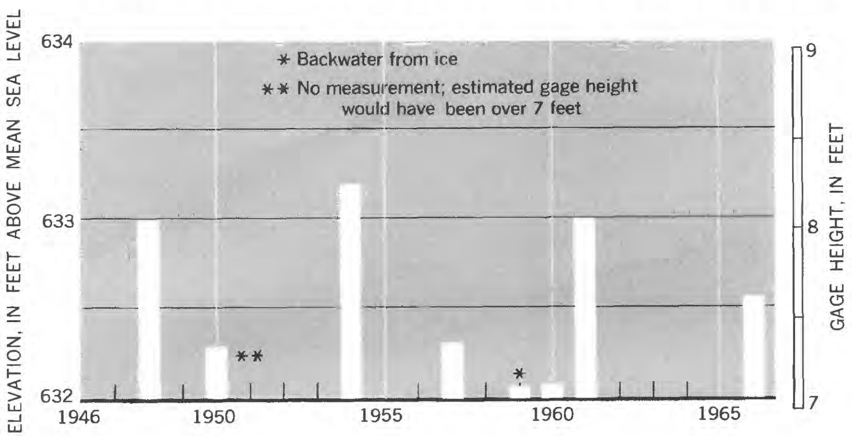


FIGURE 33.—Annual floods above 632-foot elevation, 1946–66, Salt Creek at Western Springs.

Figure 34 is a flood-frequency graph for Salt Creek at Western Springs, based on the 21-year period of record. Although a flood of about 7.3 feet gage height is expected to occur once every 3 years, a 9-foot flood, only 1.7 feet higher, is expected only once in every 50 years. It must be emphasized that recurrence intervals are average figures—the average number of years that will elapse between occurrences of floods that equal or exceed a given magnitude. The fact that a major flood occurs in one year does not reduce the probability of that flood being exceeded in the next year or even in the next week.

MANAGEMENT OF THE FLOOD PLAINS

A flood plain is defined (Hoyt and Langbein, 1955, p. 12) as "the lowland that borders a river, usually dry but subject to flooding." Thus, the flood plain is as much a part of a stream as its channel. It simply is not used as often as the channel. To the planner, flooding can be regarded as a temporary land use that must be accommodated. Effective management of the flood plains is therefore an integral part of urban planning.

Flooding does not become a problem until the areas subject to flooding are developed and damage to buildings or other structures occurs. Unfortunately, the pressure for development of land in urbanizing areas is so great that these flood plains have been built upon in many places, in part owing to ignorance of the flood hazard. Thus damage inevitably occurs, and flooding becomes a problem.

All effects of flooding are not undesirable. As discussed earlier in this report, the flood plains of lower Salt Creek are valuable recharge

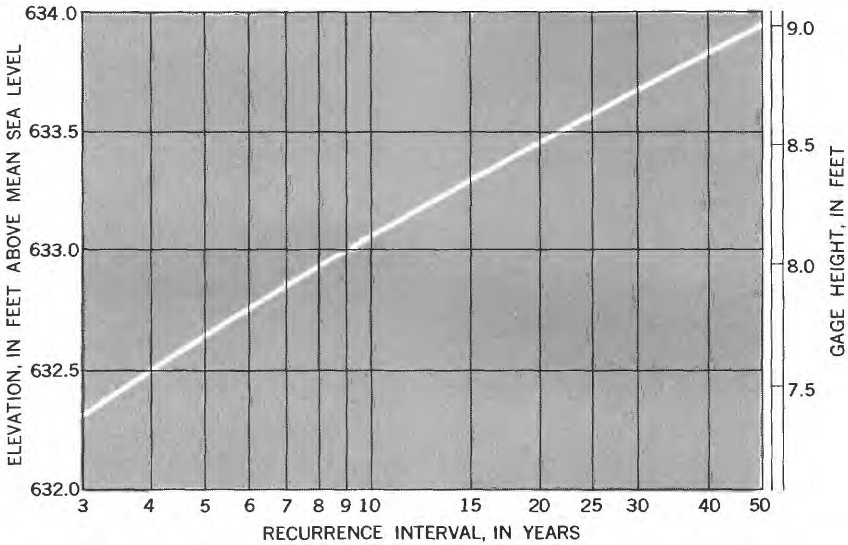


FIGURE 34.—Frequency of flood stages on Salt Creek at Western Springs.

areas to ground-water supplies in the shallow aquifers. If such areas are properly managed, flooding can be regarded as a benefit.

Flood-plain management is a complex endeavor. First, the areas subject to flooding must be identified. This has been accomplished in the northeastern Illinois metropolitan area by the cooperative U.S. Geological Survey-Northeastern Illinois Planning Commission flood-mapping program. These maps identify areas that have been flooded in the past, based on the best available information. Because of the rapid growth of the metropolitan area, these maps should be periodically revised to show the effects of changes in land use and to reflect more recent floods as recorded by the crest-stage network.

Where municipalities are served by water from shallow aquifers, existing and potential recharge areas in the flood plains should be identified. These areas in Salt Creek basin have been defined in general terms, but a more detailed study is needed. Once the recharge areas are mapped and the infiltration capabilities determined, steps can be taken to preserve favorable recharge conditions.

Flood-plain management can be accomplished by prohibiting or restricting developments on flood plains, by allowing limited development of flood-proofed industrial or commercial buildings, or by constructing flood-control works to reduce the flood hazard. Alternative flood-control measures are discussed later in the report. The following section describes several examples of existing uses of the flood plains in Salt Creek basin together with their benefits and liabilities.

EXAMPLES OF EFFECTIVE FLOOD-PLAIN MANAGEMENT

GREENBELTS

The maintenance of greenbelts, tracts of land reserved as public open space generally contiguous to streams, has long been recognized as a desirable goal by city and metropolitan planners. Examples of such greenbelts are to be found in Washington D.C., Philadelphia, Chicago, and in many other metropolitan areas throughout the world. The esthetic appeal of a meandering stream surrounded by forest maintained in essentially its natural state can provide a pleasant break in the otherwise monotonous sprawl of a large metropolis.

Greenbelts have been established primarily for their esthetic and recreational appeal; however, they may have additional and equally important benefits to land-use planning from the standpoint of water management. The development of greenbelts along streams serves to prevent unwise development of flood plains and can, at the same time, preserve ground-water recharge areas. The importance of these water-management benefits of greenbelt areas has not been fully recognized in the past. Such benefits, however, can be as important as recreation and esthetics as justification for maintaining open space.

The desirability of establishing a greenbelt in the northeastern Illinois metropolitan area was recognized before 1900. The earliest detailed expression of this concept, however, was in the ambitious "Plan of Chicago," by Burnham and Bennett (1909). One of the major features of this plan, and the one which has been most effectively implemented, was the development of the unique natural features of the Chicago region for use and enjoyment by the public. The Burnham plan called for the development of an extensive park system along the front of Lake Michigan and a greenbelt surrounding the city of Chicago. The recommendation of the Burnham plan for greenbelts (Burnham and Bennett, 1909, pp. 52–54) follows:

> The opportunity for a park area entirely surrounding the city is to be found in the extension of the lake entrance at Glencoe, westward until it reaches the valley of the Des Plaines; thence, the park stretch would extend south along the valley to Riverside, and, taking in the valleys of Salt and Flag Creeks, still southerly to the drainage canal. Turning to the east, the line would extend along the Calumet feed, Stone Creek, and Lake Calumet River to and including Lake Calumet, and thence to the Lake front.

This ambitious concept has never been fully realized. However, extensive greenbelts have been developed along the North Branch of the Chicago River, the Des Plaines River, and Salt Creek.

The Illinois Legislature in 1913 passed the Forest Preserve Act, providing for the organization and operation in any county of regional forest preserve districts, which are corporate entities. In counties with more than 500,000 population, these districts have taxing and bonding powers. The act states that a forest preserve district has power to "acquire lands containing forests and lands connecting such forests, and to maintain, preserve, restore, and restock such lands together with their flora, fauna, scenic beauties in their natural condition as nearly as may be for the education, recreation and enjoyment of the people." In 1961, the act was amended to give taxing and bonding powers to counties with less than 500,000 population. The act was further amended in 1963 to provide that "Any such district may also acquire lands * * * along or enclosing water courses, drainage ways, lakes, ponds, planned impoundments or elsewhere which * * * are required to store flood waters, or control other drainage and water conditions necessary for the preservation of ground water * * *."

The Cook County Forest Preserve District was organized in 1915 under the provisions of this act. During the period between 1915 and 1930, the district acquired considerable land in Salt Creek basin (fig. 35). Although it probably never occurred to the founders of the district, much of the land they acquired was to become extremely useful for water management in later years. The forest preserve in the lower part of the basin includes most of the flood plain of Salt Creek between the Du Page County line and Brookfield. Much of this flood plain is a favorable area for recharge to the shallow aquifers. Although the remainder of this lower part of the basin has become completely urbanized (fig. 7), the flood plain has been kept largely out of development, and an important recharge area has been preserved.

Another early acquisition of the Cook County Forest Preserve District is the Ned Brown Preserve south of Palatine (fig. 35). This preserve includes a large valley reservoir site. A proposal for a multipurpose reservoir at this site is discussed in the following section on alternative flood-control measures.

The full effects of urbanization were felt in Du Page County much later than in Cook County. Although Du Page County organized a forest preserve district in 1920, land acquisition on a large scale did not begin until the 1960's. By this time, the eastern half of the county, which includes Salt Creek basin, was already considerably urbanized. Thus, acquisition of large tracts of land in Salt Creek basin, as had been done in Cook County, was not practical. The Fullersburg Preserve (fig. 35) near Hinsdale, however, contains 132 acres of wooded land that borders Salt Creek. The historic Old Graue Mill is located in this preserve, and the mill dam provides a reservoir for boating. The flood plains in this preserve are also a potentially favorable recharge area to the shallow aquifers. Because much of the flood plain in the

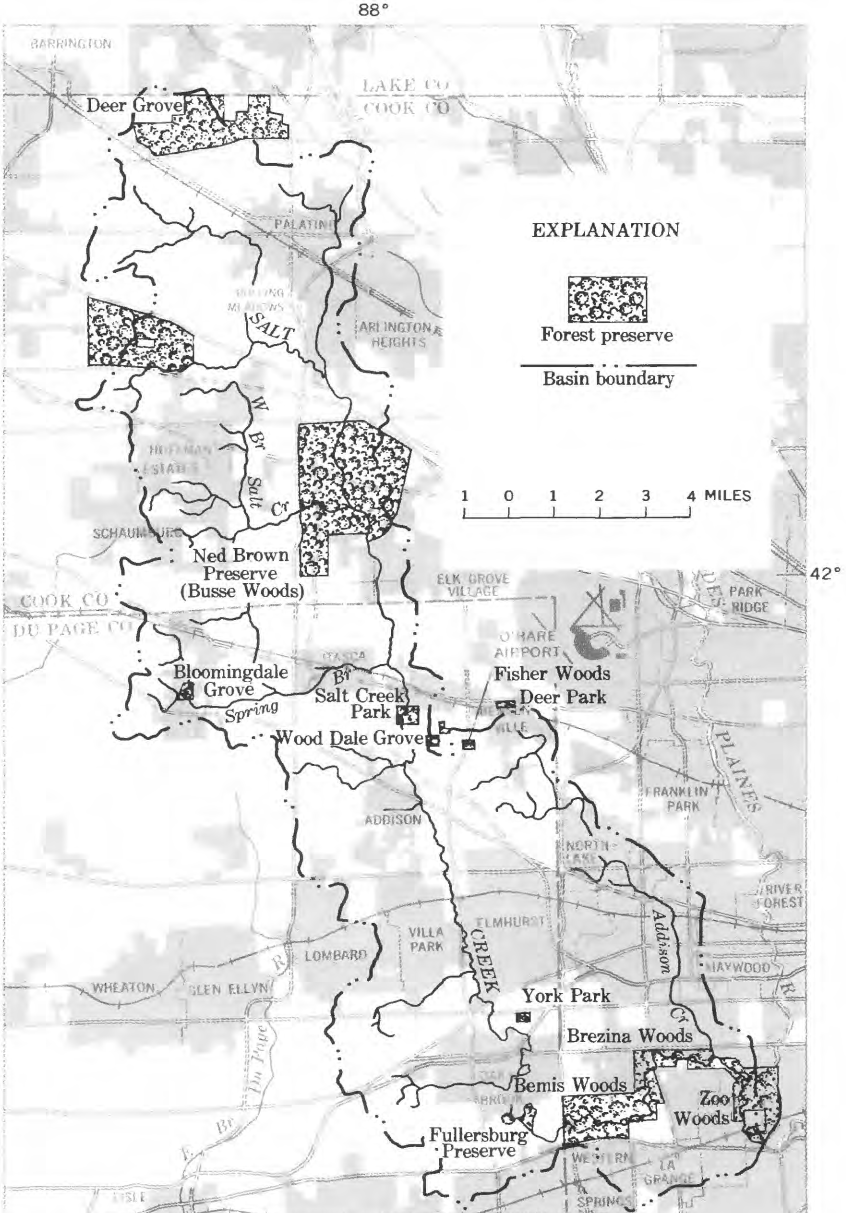


FIGURE. 35.—Forest preserves in Salt Creek basin and adjacent areas.

village of Oakbrook, just upstream from Fullersburg Preserve, has been kept open for outdoor recreational uses, this reach of Salt Creek in Du Page County reflects good planning principles and can be regarded as a favorable recharge area. Although the Fullersburg Preserve is not large in total area, it represents as excellent example of the management of a stream, its adjacent flood plain, and surrounding wooded land to take full advantage of their esthetic potential. As the metropolitan area becomes more intensely urbanized, the value of such scenic land materially increases.

The land within a metropolitan area is a fixed resource; only a finite land area is available. As land values increase in response to pressures for urban development, every possible benefit must be demonstrated to preserve land as open space in an urban area. Recreation, esthetic appeal, and enhancement of the environment are the usually cited justifications for maintaining public open space. These benefits are indeed important; however, the additional water-management benefits of preserving flood plains, potential reservoir sites, and recharge areas can be cited as further justification for maintaining greenbelts along streams.

Owing to the foresight of the planners of 50 years ago, much of Salt Creek in Cook County has been preserved in essentially its natural state. This policy has enhanced the area's esthetic appeal, provided badly needed recreational areas, and afforded the opportunity for water management by preserving flood plains and potential reservoir sites and by maintaining natural recharge areas. On the basis of available information, it appears that ground-water recharge conditions in lower Salt Creek would be less favorable today had this area been developed. This approach to management of the flood plains is cited as an example which can be used in planning the growth of presently undeveloped parts of the northeastern Illinois metropolitan area or in other urbanizing regions.

The desirability of reserving large areas of public open space in Du Page County was not recognized until much of the land was no longer available. This was partly because Du Page County was not faced with urban problems until fairly recently. The late start in land acquisition is also due in part to the fact that the Du Page County Forest Preserve District did not have taxing and bonding authority until 1961. That such land is no longer available, however, has become an important lesson. The Du Page County Forest Preserve District has undertaken a long-term program of land acquisition along the West Branch of the Du Page River, in the western part of the county (fig. 1). Land is also being acquired along the East Branch of the Du Page River. Much of western Du Page County is presently in a rural state. The eventual goal of this program is to create a greenbelt along the West Branch, similar to the greenbelt created 50 years ago along the Des Plaines River and Salt Creek. The same principles of preserving flood plains, reservoir sites, and ground-water recharge areas can be put into practice in the West Branch, just as they were applied in Salt Creek many years ago. The program for developing a greenbelt in western Du Page County can potentially be even more effective, however, because of a greater availability today of geologic and hydrologic data and a better understanding of the relation between hydrologic principles and land-use practices.

FLOOD-PLAIN MANAGEMENT BY MUNICIPALITIES

The maintenance of extensive greenbelts in forest preserve or regional park districts is not the only approach to flood-plain management in an urban area. Effective and economic use of the flood plains can be accomplished by individual communities, provided that the extent of the flood plain is defined and the communities are planned to accommodate flooding. Two villages in Salt Creek basin, Elk Grove Village and Oakbrook are examples of effective flood-plain management. Both these villages include part of the flood plain of Salt Creek and have been developed essentially since 1950. In both places, the basic approach has been to keep the flood plain essentially free from structural development. These two communities, however, are of quite different character and have achieved the objective somewhat differently.

Elk Grove Village is typical of the new suburbs that have grown since World War II in the northeastern Illinois metropolitan area. Salt Creek passes through this community. The planners of Elk Grove Village recognized that a strip along Salt Creek about 300 to 500 feet wide was subject to flooding and therefore held this strip out of development, as shown in figure 36. Thus, badly needed space was made available for recreational activity, while at the same time potential flood damages to buildings were prevented.

Oakbrook is a community consisting largely of low-density and high-quality residential development surrounding private recreational facilities; it has a commercial core that includes one of the largest regional shopping centers in the Chicago area. Most of the flood plain of Salt Creek in Oakbrook is taken up by a polo field, golf courses, and related facilities. A limited amount of low-density commercial development on the flood plain has been permitted, as shown in figure 37. This building is of particular interest in that it is *flood proofed;* that is, it is designed to minimize or eliminate flood damage. (For a complete discussion of flood proofing, see Sheaffer, 1967.)

FIGURE 36.—Flood plain of Salt Creek in Elk Grove Village is reserved largely for nonstructural uses.

The floor of this building is about 3 feet above the flood plain, nearly a foot higher than the flood level of 1961. The building was built in 1964; in the flood of 1966, the parking lot behind the building was inundated by "a few inches" of water, according to the building manager.

The type of flood-plain management employed at Oakbrook can be regarded as an acceptable alternative to simply keeping all structural development off the flood plains. The entire area is landscaped, and well maintained and has a generally pleasing appearance. Recreational facilities in open space present a good opportunity to make use of the flood plain while at the same time avoiding severe damage; the inconvenience caused by flooding a few days each year is slight. Likewise, commercial and industrial development can constitute economic uses of flood plains, provided the buildings are built to withstand flooding and the owners are cognizant of the risk involved. The developments on the flood plain at Oakbrook are of low density. Higher density development should be accompanied by provision for compensatory storage to make up for the lost natural storage capacity of the flood plains.

FIGURE 37.—Low-density commercial development on flood plain of Salt Creek at Oakbrook is an effective form of flood-plain management.

EXAMPLES OF POOR FLOOD-PLAIN MANAGEMENT

RESIDENTIAL DEVELOPMENT ON FLOOD PLAINS

The undesirability of residential development on flood plains has been thoroughly documented (Sheaffer and Zeizel, 1966, p. 80–83; White and others, 1958). Even where flooding does not result in costly damage, it is an inconvenience with which the public is becoming increasingly less tolerant. Most people do not wish to live where their streets, yards, driveways, or basements are subject to flooding, even though the houses themselves are not damaged. Therefore, property values are likely to decline in residential developments built on flood plains.

Much of past development of flood plains can be attributed simply to lack of knowledge of the flood hazard. As the flood-plain mapping program in the northeastern Illinois metropolitan area approaches completion, however, public awareness of the flood hazard increases. Financial institutions are likewise becoming reluctant to finance residential developments on flood plains.

One means of developing an area that includes a flood plain is by maintaining a median strip, thus keeping the flood plain out of development, as in the previously cited example of Elk Grove Village. Another approach is to make channel improvements or other engineering changes such as culverts to lessen or eliminate the flooding problem. This approach may be satisfactory if the magnitude of expected flooding is known, if the improvements are designed to accommodate a flood that might be expected to occur fairly frequently, and if the improvements are adequately maintained.

In some residential developments on flood plains, improvements have been made without adequate knowledge of the extent of flooding; it has been erroneously assumed that any "improvement" will eliminate the flood risk. An example of such a situation can be found in Salt Creek basin along Sugar Creek in Villa Park. The case history of this development and the flooding problems encountered was documented in detail by Pearson (1962, p. 46–85).

The development and the area inundated by the flood of 1961 are shown in figure 38. The land was purchased by a developer in 1956. In 1958, it was annexed to Villa Park and zoned for residential development. Nearby residents knew that the lower part of this tract along Sugar Creek, generally below an elevation of 670 feet, was subject to flooding, even though the flood inundation map was not available until 1962. Village officials and the developer were also aware of this problem. The developer proposed to enclose the stream in dual corrugated metal culverts, starting with dimensions of 58 inches by 36 inches at the upper end and enlarging to 72 inches by 44 inches at the outlet. The village approved this proposal, and development of the area began in 1959.

A flood occurred in January 1960, inundating the lower parts of the subdivision and causing damage, particularly to basements. A greater flood occurred in September 1961. It then became apparent that the two metal culverts were not adequate to handle expected flood runoff. Pearson (1962, p. 55), states that the capacity of the culverts has been exceeded "at least two times a year, on the average." After the flood of 1961, the village passed an ordinance prohibiting any residential building on land below an elevation of 670 feet in this area.

Several homeowners in 1962 brought suit against the developer and the village for damages and for permitting the development of land not suitable for habitation. A settlement was reached whereby the owners were compensated for damages, and the flooding problem was to be relieved by rerouting Sugar Creek around the development either in a larger concrete culvert with an adequate inlet structure or in an open ditch. The culverts were enlarged in 1967. These improvements appear to have significantly reduced the flood hazard.

The foregoing is an example of what can happen when an area subject to flooding is developed without adequate knowledge of the flood hazard or adequate engineering safeguards. In this particular

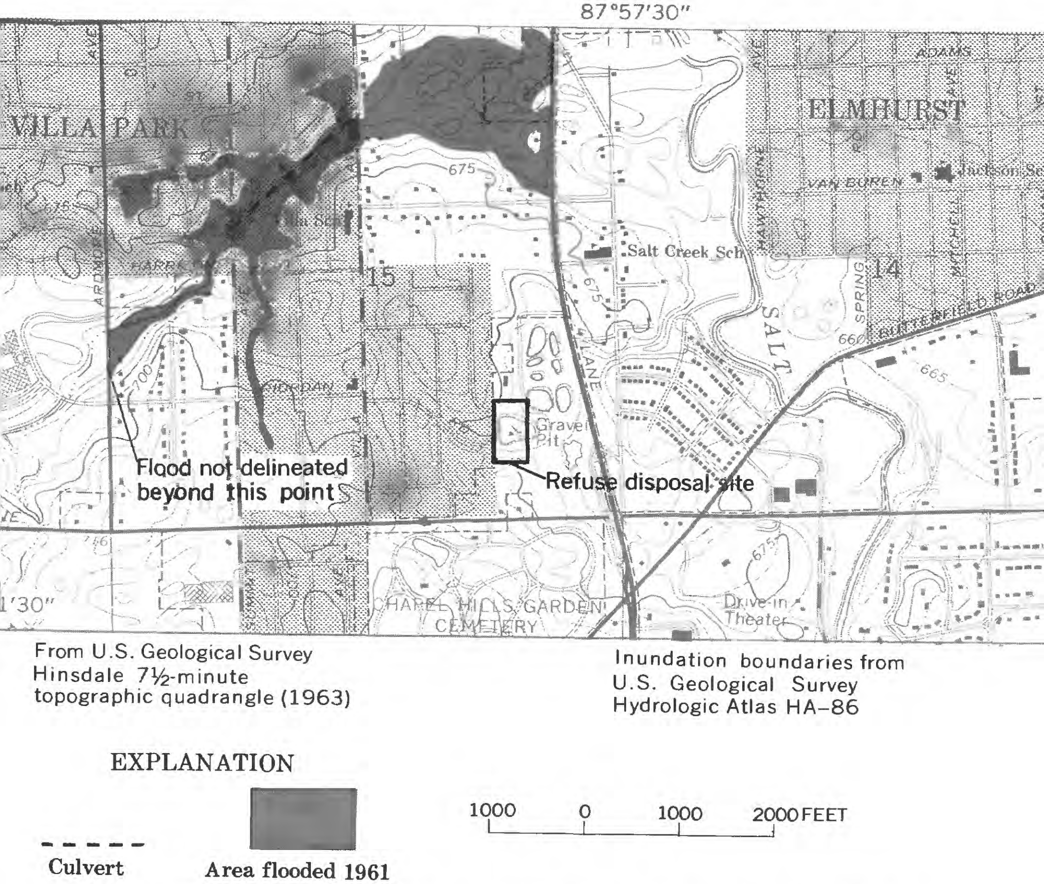


FIGURE 38.—Subdivision along Sugar Creek at Villa Park, and area inundated by the 1961 flood.

example, the hazard was known to exist, but the steps taken to prevent flooding proved to be inadequate. Ordinarily, flooding in such a situation results in a widespread exodus of homeowners, who usually are forced to take a loss on their property. Because many developments on flood plains are marginal to begin with, they may end up as virtual slums only a few years after they are built.

In the development on Sugar Creek at Villa Park, however, the homes are of good quality, and many of the residents have remained and kept their property in good condition in the hope that relief will be forthcoming.

The foregoing example could have far-reaching legal implications. In the past, a municipality was generally not held responsible for the consequences if it allowed development of an area subject to flooding. The ancient common-law doctrine of *caveat emptor* (let the buyer beware) applied. In ruling that the village of Villa Park was responsible for permitting development where the flood hazard was recognized and inadequate improvements were made, the court set a precedent. If this precedent is followed, municipalities could be held responsible for flood damages to houses in areas known to be subject to flooding. The ruling sets forth the principle that the buyer of a house has an implied warranty from the builder and the governmental jurisdiction granting a building permit that the house is habitable. A house subject to periodic flooding is not considered habitable. With the increasing availability of flood-plain information, such a ruling could have far-reaching consequences.

The planner can perform a real public service by seeing that studies are undertaken, as they have been in northeastern Illinois, to define the extent and magnitude of flooding. After these studies have been completed, the planners can be of further service by seeing that the results are made known to governmental officials, developers, and financial institutions. Adequate knowledge of the flood hazard can avert such unfortunate occurrences as the development on Sugar Creek at Villa Park.

FILLING OF FLOOD PLAINS

The most common method used to develop flood plains is to fill them to a height above that of an expected flood. Much of the flood plain of Salt Creek has been filled in this manner, especially in the vicinity of Elmhurst, Villa Park, and Addison. Figure 39 is a photograph of such a fill. In some places fill has been built right up to both banks on the creek.

Filling of the flood plains is a prime example of the quick fix or piecemeal approach to management of the flood plains. Although this technique solves one landowner's flooding problem, it transfers the same problem to someone else, either upstream or downstream. Filling removes part of the flood plain's natural storage capacity. The flood water that would be stored in the filled area must now be stored elsewhere. This water takes up the same amount of space regardless of where it is stored. Thus, filling will either force the floodwater downstream, cause it to back upstream from the filled site, or both. In any event, storage capacity is lost and the flooding problem is transferred rather than solved.

Filling can be considered a satisfactory technique of flood-plain management if compensatory storage is provided. In other words, for every cubic foot of fill, a cubic foot of land should be excavated to provide space for the floodwater. Thus, the configuration of the flood plain is modified but no storage capacity is lost. Some municipalities have provided in their zoning ordinances that filling of the flood plain must be accompanied by compensatory storage.

FLOODING CAUSED BY EMBANKMENTS

Some flooding problems are created or aggravated by the erection of embankments or other structures that constrict the flow of floodwaters. An example of such a constriction is at a railroad embankment across the Arlington Heights Branch of Salt Creek east of Palatine. Figure 40 is a map showing the extent of the flooding which resulted.

This railroad was built many years ago, when the area was still rural and flooding was not a problem. The design of embankments being con-

FIGURE 39.—Fill on flood plain of Salt Creek near Elmhurst.

370-926 O—70——7

structed at the present time generally takes flooding into consideration. It is standard practice for engineers to design culverts to accommodate at least the greatest flood of record. In many instances, these culverts are designed with a generous safety factor. The design of bridges and culverts again emphasizes the need for adequate data on the frequency and magnitude of flooding.

The problem of the railroad embankment east of Palatine has been recognized by local and State officials. Funds were appropriated by the 1967 Illinois Legislature for channel improvements on the Arlington Heights Branch from its junction with Salt Creek to about 10,000 feet upstream. Additional funds will be required, however, to extend these improvements to the railroad embankment and into Palatine.

USE OF FLOOD PLAINS FOR REFUSE DISPOSAL

Inasmuch as flood plains are unsuitable for most structural land uses, the temptation frequently exists to use this land for such "marginal" uses as junk yards and refuse disposal sites. The suitability of various geologic environments for refuse disposal has been discussed in detail in a report by the Northeastern Illinois Planning Commission (Sheaffer and others, 1963, p. 27–39). Flood plains are generally not favorable environments for refuse disposal because the refuse is likely to fill the flood plain and thus reduce its storage capacity and because of the probability of pollution of floodwaters by the refuse. A further pollution hazard is created where the flood plain is underlain by alluvial sand, gravel, or silt deposits. In this geologic environment, a high potential exists for ground-water pollution. Much of the flood plain of Salt Creek is in just such a geologic environment.

An example of the problems encountered with refuse disposal operations on flood plains is the site at the corner of Roosevelt Road and Illinois Highway 83, south of Villa Park. The location of this site is shown in figure 38. This site is on the margin of the flood plain of Salt Creek; originally it was a gravel pit. While the pit was in operation, ground water was pumped to keep the pit dry. After the pit was mined out, the use of this site was approved for the disposal of "clean" fill, consisting mainly of building material. When pumping in the abandoned pit was stopped, the water table recovered to its natural level, about 5 feet below the land surface.

The dumping of this "clean" fill into the abandoned gravel pit filled with ground water created a situation that resulted in both pollution of the water itself and air pollution. The chemistry of the water was such that it reacted with gypsum in the fill, much of which consisted of discarded pieces of drywall material. According to public-health officials, this reaction may have been triggered by bacteria that seeped

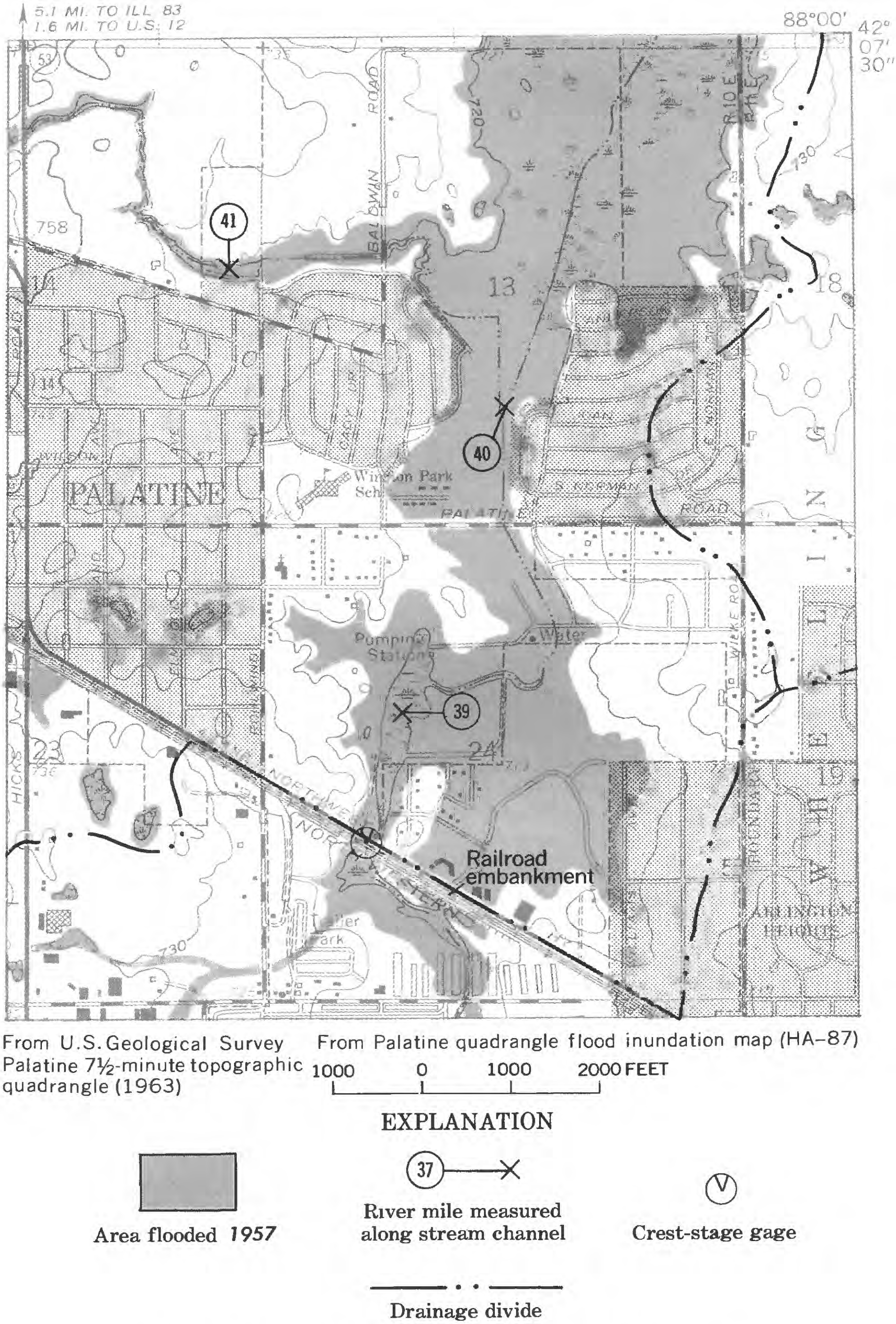


FIGURE 40.—Flooding caused by embankment east of Palatine.

into the ground water from septic systems in a nearby subdivision. In any event, the reaction caused release to the atmosphere of hydrogen sulfide gas in such quantity that it caused peeling of paint from houses in the nearby subdivision, to say nothing of the unpleasant odor.

Eventually the pit was sealed off, greatly reducing the air pollution problem. The ground water in the pit remains polluted, however. Because the natural hydraulic gradient in the flood-plain deposits is from the pit toward Salt Creek, the polluted water can be expected eventually to seep into the creek.

After the pit was sealed off, the operator continued to use the site for disposal of refuse, building up a high mound (fig 41). Because the mound is on the edge of the flood plain, it presents little problem as far as consuming space needed for the storage of flood waters. However, even though the pit was sealed off, some odor remains. This odor and the mound's unsightly appearance are testimony to an unfortunate use of the flood plain of Salt Creek.

SUMMARY

Management of the flood plains poses a challenge to planners in a large metropolitan area. In northeastern Illinois, these flood plains make up about 10 percent of the total land area, a percentage that is destined to become ever more significant as pressures increase for development of land. One approach to flood-plain management, successfully applied in Salt Creek basin, is to reserve the flood plains in essentially their natural state as regional greenbelts. Flood plains need not necessarily be kept out of structural use, however. Some land uses are compatible with flood plains, whereas others are not. Depending on how

FIGURE 41.—Refuse disposal site on flood plain of Salt Creek.

they are managed, the flood plains can be either an asset or a liability to a community or a metropolitan area.

Generally speaking, land uses that consume much of the flood plain's natural storage capacity will aggravate the flooding problem. Filling the flood plains thus merely transfers the flooding problem, unless compensating storage is provided. Residential development on flood plains usually becomes a liability to the community, because homeowners will tolerate neither the damages nor the inconvenience caused by flooding. Thus, residential developments on flood plains tend to decrease in quality and become prematurely blighted.

The use of flood plains for refuse disposal is likely to cause pollution of both surface water and ground water, in addition to detracting from the esthetic appeal of the stream and its surroundings.

Flood plains can be put to nonstructural uses such as parks, recreational facilities, or parking lots. Low-density commercial or industrial development may be a compatible land use, provided that the flood hazard is recognized and buildings are flood proofed. Parts of the flood plain, however, may be prime recharge areas to existing or potential ground-water supplies. If these recharge areas are paved or otherwise covered, much of their recharge potential may be lost. In Salt Creek basin, most of these areas fortunately have been preserved. The identification of such recharge areas is of prime importance to the planner in areas where shallow aquifers are an important source of water supply.

ALTERNATIVE FLOOD-CONTROL MEASURES AND THEIR EFFECT ON THE HYDROLOGIC SYSTEM

PHILOSOPHIES OF FLOOD CONTROL

Flood damage in a metropolitan area is a problem created by man, for no problem exists unless the areas subject to flooding are occupied. The previous section illustrates several alternative means of managing land subject to flooding, including examples of poor management of such land. Unfortunately, some lands subject to flooding have already been developed. It has not generally been considered feasible to remove developments from the areas and restore the areas to their natural state, although this practice could possibly be economically justified. The protection of existing development on flood plains generally necessitates the application of some flood-control measures, although flood proofing also can reduce flood losses.

For the purpose of the present discussion, flood-control measures are defined as any physical and relatively permanent measures taken to reduce or eliminate the damage or inconvenience caused by flooding.

Measures of adjustment to floods such as bearing the loss, public aid or relief, emergency measures (sandbagging, for example), and flood insurance are therefore outside the scope of the discussion. Measures of this type were discussed by White (1964).

Within this context, all flood-control measures, or flood damage reduction measures (as some prefer), can be classified into three categories. First, there are measures based on preserving the natural storage capacity of the flood plains as nearly as possible. Second, there are measures based on reducing flood flows by retaining much of the runoff in upstream areas. Third, there are measures based on enlarging drainage capacity to route flood runoff out of the area concerned for storage downstream.

Flood-control projects in the past have been undertaken largely as single-purpose endeavors. It is now widely believed that, for a flood-control project to be undertaken, the benefits should exceed the costs on an average annual basis. Benefits can be increased by planning for multiple purpose rather than single purpose projects. In other words, if a project can yield benefits of recreation, flow augmentation, and increased ground-water recharge in addition to flood damage reduction, its benefits will most likely exceed those of a project whose sole purpose is flood control. To maximize these benefits, planners in recent years have made it a practice to consider alternative solutions to problems rather than adopt a single plan approach.

Little attention has been given in the past to the effects of flood-control projects on the hydrologic system. Earlier in this report it was shown that a close connection exists between surface water in Salt Creek and ground water in the shallow aquifers. Furthermore, it is believed that an increase in the recharge rate to these shallow aquifers takes place during flood stages. Changes in the intensity and duration of flood stages caused by some flood-control projects would very likely have an effect on the rate of ground-water recharge. The effects of water quality on various flood-control measures and the effects of such measures on water quality also merit consideration.

The Northeastern Illinois Planning Commission, through its Technical Advisory Committee on flood control, in 1959 issued a policy statement on flood-control measures. The following criteria quoted from this statement recommend:

1. That where practicable, flood control and drainage facilities be planned on the basis of controlling the flows resulting from the most severe storm of record for the area concerned. Factors such as economics, state of development of the area and other planning considerations will often preclude the construction of facilities of such magnitude. In these instances, the constructed facilities, when feasible, should be designed to permit future enlargement at a minimum of cost.

2. That flood control and drainage facilities be planned on the basis of full development in accordance with the master plan of the area, although this may require "stage" construction contingent on future development of the area.
3. That flood control and drainage facilities be planned so as to minimize adverse effects on adjacent or downstream areas.
4. That flood control and drainage planning weigh the comparative engineering and economic aspects of alternate means of accomplishing the prevention or reduction of flood damages; e.g., channel improvements, levees, cutoff, diversions, retarding basins, land use management, flood proofing, stream maintenance, storm warnings, and flood insurance.
5. That flood control projects be as multi-purpose as practicable, including, besides means of flood damage reduction, provisions for recreation, conservation of fish and wild life, water supply, low water stream fow and navigation.
6. That flood control projects generally yield tangible and intangible benefits in excess of the costs incurred.
7. That no flood control project impair the condition of existing public lands, nor impair their use and enjoyment of the public without compensating public benefits.
8. That the expenditure of public funds for flood control and drainage be considered together with the needs and costs for other public works so that the over-all program for public works in an area will result in a maximum of benefits to the public. The over-all program for public works must be well balanced and properly coordinated.

A preliminary evaluation of the probable effects of alternative flood-control measures on the hydrologic system in Salt Creek basin follows. This discussion is concerned primarily with the implications of hydrology and land use. Detailed economic analysis is beyond the scope of this report.

ALTERNATIVE APPROACHES TO FLOOD CONTROL

PRESERVING THE NATURAL STORAGE OF FLOOD PLAINS

The first approach to flood control discussed in this report is the preservation of as much of the natural storage capacity of the flood plains as possible. Various means of attaining this objective are discussed at some length in the immediately preceding section on management of the flood plains. Preservation of this storage can be accomplished by creation of regional parks or greenbelts, by planning of communities to keep flood plains out of development, or by limiting development of flood plains.

Management of the flood plains can be implemented through a number of procedures such as creation of forest preserve or regional park districts, establishment of zoning or flood-plain regulations, and planning of communities to avoid uneconomic use of the flood plains.

From a hydrologic standpoint, maintaining the flood plains in as nearly their natural state as possible is an effective means of preserving natural recharge areas to the shallow aquifers. Such areas exist in the lower part of Salt Creek basin, and fortunately they have been, to a large degree, preserved in their natural state. Studies of the recharge potential of the flood plains in any area would be helpful in evaluating the desirability of restricting their development as opposed to alternative flood-control techniques. If such potential recharge areas are found to exist, this is an additional argument in favor of keeping these areas out of urban development. There are parts of the flood plains, however, that might be economically unfeasible to keep out of development, owing to the high value of land in an urban area.

Furthermore, there is the problem of what to do about existing developments on flood plains. Such developments, however ill advised they may be, represent a considerable investment. Flood-control works may prove to be more economical than paying the cost of damages year after year.

UPSTREAM STORAGE

Upstream storage is one of the classic approaches to flood control. This approach consists of retaining most of the flood runoff in reservoirs and detention basins in the upstream reaches of streams, thereby reducing the magnitude and frequency of flooding downstream. The concept of retention of floodwaters is compatible with the Northeastern Illinois Planning Commission's third stated criterion for flood-control works and with Policy 5 as stated in the Planning Commission's water-management report (Sheaffer and Zeizel, 1966, p. iv):

> Reclaimable flood waters should be regarded as a resource out of place and stored where practicable for such later beneficial uses as low-flow augmentation of streams, artificial recharge of ground-water supplies, water-oriented recreation, and water supply.

Thus, the principal advantages of upstream storage are reduced damage to downstream communities and the multiple-use aspect of the plan. The main argument against this approach in an urban area stems from the scarcity and generally high cost of suitable land. Although it may be argued that suitable valley reservoir sites do not exist, upstream storage can be accomplished by more imaginative and less land consuming means than the traditional valley reservoir on the main channel of the stream.

VALLEY RESERVOIRS

The oldest and most common approach to upstream storage is the valley reservoir usually, but not always, on the stream's main stem. Such reservoirs have a large capacity and thus provide a major reduction in downstream flooding.

Space allocation in a rapidly urbanizing metropolitan area is a problem that complicates the use of valley reservoirs. This problem is especially acute in an area with relatively flat terrain, such as northeastern Illinois. Few suitable reservoir sites are available. Furthermore, many good potential reservoir sites were covered by urban development before they could be set aside for reservoir use. Sheaffer and Zeizel (1966, fig. 37) showed most of the remaining sites in the northeastern Illinois metropolitan area. Even some of the sites shown in that report have since become urbanized.

Several potential reservoir sites for flood control are still available in Salt Creek basin (fig. 42). One is a fairly large site at Busse Woods, in the Ned Brown Forest Preserve; a smaller site is on Spring Brook at Itasca. Two other sites on unnamed tributaries of Salt Creek west of Rolling Meadows (fig. 42) have been proposed by the U.S. Soil Conservation Service (U.S. Dept. Agriculture, 1968, map facing p. 12).

Busse Woods Reservoir Site

The most favorable site for a valley reservoir in Salt Creek basin is a low, partly swampy meadow in the Busse Woods (sometimes known as Busse Forest) part of the Ned Brown Forest Preserve, north of Elk Grove Village. This site is especially favorable because it is almost wholly on public land owned by the Cook County Forest Preserve District, and only moderate land acquisition costs would be involved in developing the reservoir.

The Cook County Forest Preserve District has been interested for about 10 years in developing a reservoir at this site. In 1959, an engineering feasibility study was made (Consoer and others, 1959), as an alternative to a channel improvement plan presented a year earlier by the Illinois Division of Waterways (1958). At the time the 1958 Division of Waterways report was being prepared, part of the Busse Woods reservoir site was in private ownership. The Division of Waterways did not consider building the reservoir because of the high cost of the land. Later in 1958, the Cook County Forest Preserve District acquired most of the remaining privately held land at a cost of $2 million. Two additional plans for a reservoir at the Busse Woods site were prepared in 1962 by the Illinois Division of Waterways and by W. J. Bauer.

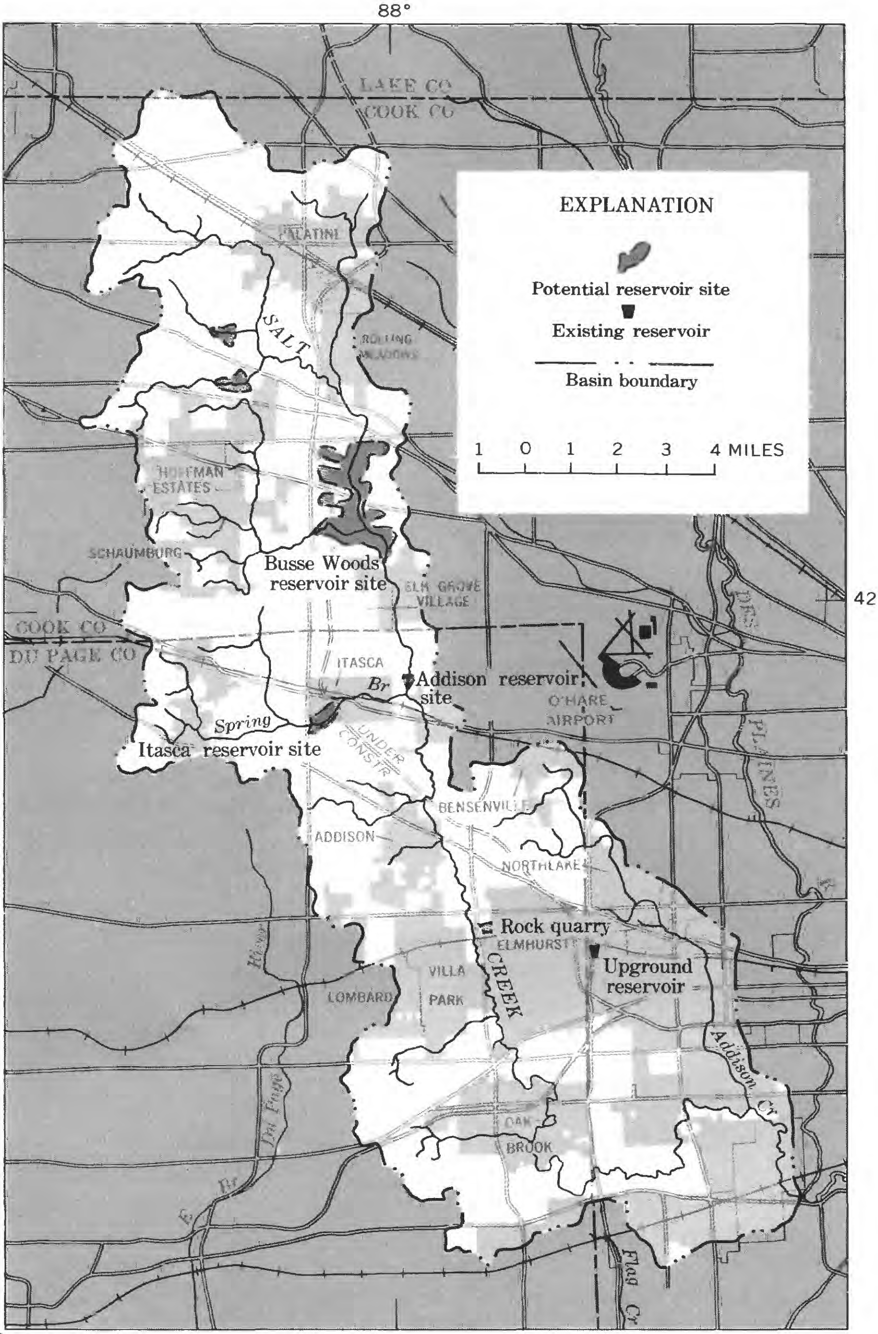


FIGURE 42.—Location of reservoir sites in Salt Creek basin.

The Consoer plan (1959, p. 10–11) calls for a reservoir with a pool elevation of 682 feet and a maximum elevation for flood control of 690 feet. A 250-acre recreational lake, 14 feet deep at the heel of the dam and tapering to about 3 feet deep, would follow essentially the present configuration of the channel. It is estimated that this reservoir would hold all runoff from a 5-inch rainfall over a 12-hour period from the 52-square-mile drainage area upstream from the dam. The consultants (Consoer and others, 1959, p. 10) calculated that this reservoir would have reduced the discharge of the flood of March 20, 1948, the greatest flood of record, from 1,920 cfs to 1,230 cfs at the Western Springs gage. Total cost of the dam construction was estimated to be $246,000.

The Illinois Division of Waterways in 1962 prepared an alternative proposal (unpublished) for a reservoir at the Busse Woods site. This proposal was intended to supplement rather than replace the Division's 1958 proposal for channel improvements. The reservoir in the 1962 proposal was intended primary for low-flow augmentation and recreation. No mention was made of flood control, but presumably any of its capacity not being used for flow augmentation could be used for this purpose. The Division's 1962 proposal calls for a permanent pool with an area of 60 acres at an elevation of 682 feet and a normal maximum pool elevation of 688 feet, with 640 acres area and 1,940 acre-feet capacity. The spillway elevation is 691 feet. The 1,770 acre-feet of storage between the elevations of 682 and 688 feet would be used to maintain, as nearly as possible, a minimum flow of 20 cfs in Salt Creek. The report says that this storage capacity is "not adequate for complete augmentation," but "adequate to provide relief over limited periods of time or partial relief over extended periods." The estimated cost of the dam and reservoir proposed by the Division of Waterways is $165,000.

Neither of these proposals was considered satisfactory by the Cook County Forest Preserve District. Although the district has legal authority to acquire lands and construct works to store floodwaters and control drainage (presumably including low-flow augmentation), it is the feeling of District officials that their primary mission is to acquire and preserve forested areas "in their natural condition as nearly as may be for the education, recreation, and enjoyment of the people," as stated in the original enabling legislation. Thus, any use of Forest Preserve lands that interferes with these stated objectives is, in their view, not compatible with this primary mission and should not be permitted.

Although the 1959 Consoer-Townsend and the 1962 Division of Waterways proposals provide for recreational pools, the Forest Preserve District felt that such provisions were inadequate. The main objection was that the depth of the pool would not be sufficient for boating or for maintaining year-round aquatic life. Furthermore, the widely fluctuating water level in these shallow pools would create unsightly mud flats and stagnant water which would lead to mosquito breeding.

Thus, in 1962, the Cook County Forest Preserve District requested a new study for a multipurpose reservoir at the Busse Woods site (Bauer, 1962). The concept of coordinated management of surface and ground waters in conjunction with land-use planning discussed by Bauer represents an imaginative approach to the problem of combining flood-control and recreational benefits in a single reservoir.

The principal objection to the earlier plans for the Busse Woods reservoir, from the standpoint of recreation, is that the permanent pool would not be deep enough for boating or aquatic life. This objection can be overcome by taking advantage of the site's generally high water table, which is on the average not more than 5 feet below the land surface. According to the plan proposed in the Bauer report, a permanent pool for recreation would be created by excavation of borrow pits below the water table for material that could be used for highway embankments at grade separations. The larger area of the permanent pool would be made possible by reshaping the contour of the land by deepening some areas and raising others (Bauer, 1962, p. 1). Thus, in effect, a permanent ground-water lake would be created and floodwater would be stored on top.

This is not a new concept. The Skokie Lagoons along the Skokie River near Northfield represent an earlier application of the same approach. Although the idea of combining a flood-control reservoir with artificially created ground-water lakes or lagoons is not new, it has not been as widely applied as it might be. Such multipurpose developments create additional benefits by enhancing the environment, in addition to their flood-control potential.

Figure 43 is a view of how this reservoir might look if the Bauer plan were carried out. The plan calls for a permanent pool, at mean elevation of 686 feet, of 470 acres area, 150 acres of which would have an average depth of 10 feet. The remainder of the lake would have an average depth of 3 feet. The deep part of the lake is intended for year-round fish habitat. The shallow parts of the lake would be planned to include feeding and spawning areas.

The reservoir would provide a capacity of 3,600 acre-feet for storage of flood runoff between the pool elevation of 686 feet and the spillway elevation of 691 feet. The reservoir is planned for a design flood of 1,125 cfs at the site, equivalent to 900 cfs at the Arlington Heights gaging station (Bauer, 1962, p. 8 and exhibit C). Such a flood could

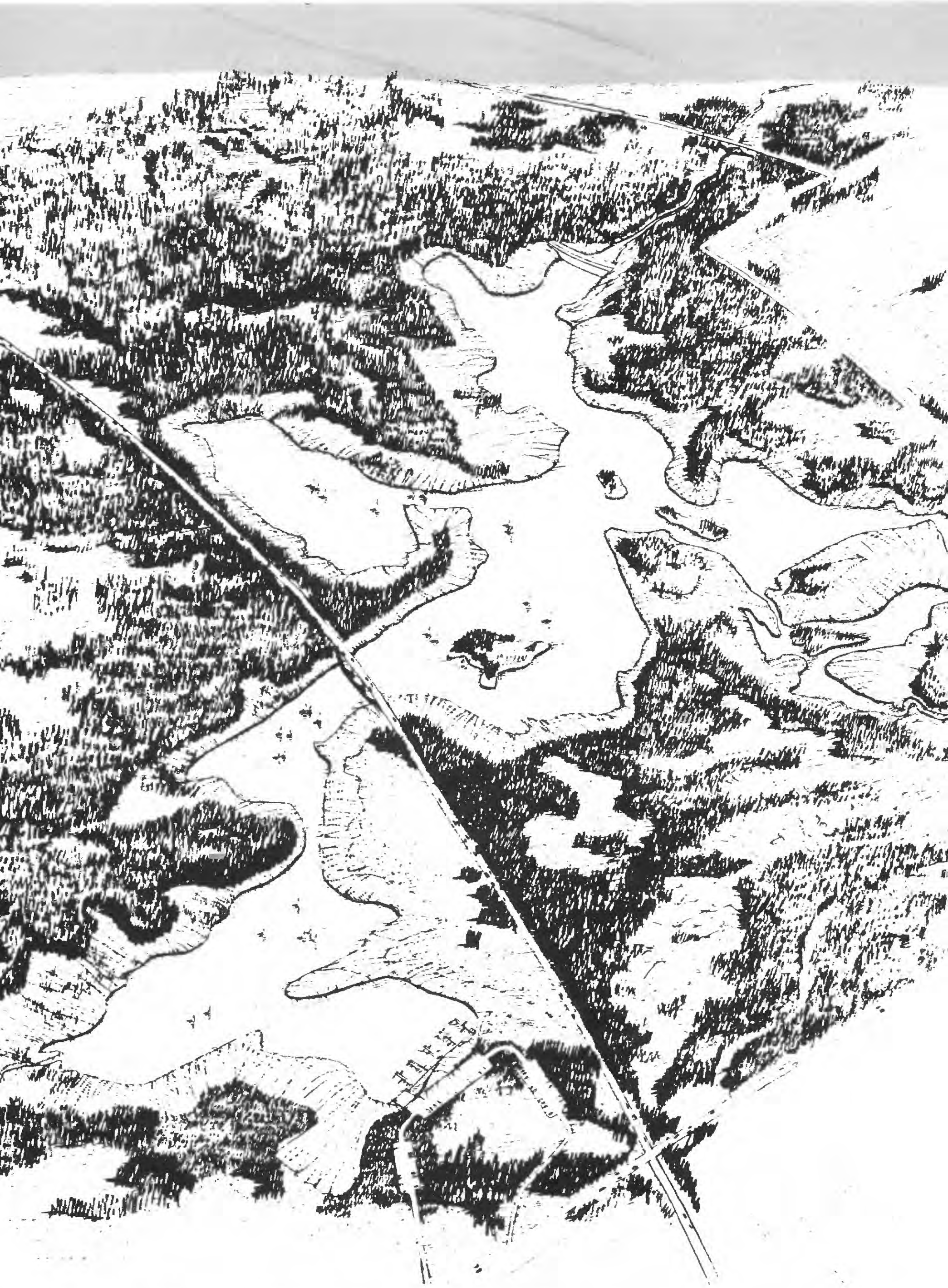


FIGURE 43.—Proposed multipurpose reservoir at Busse Woods. Courtesy of Northeastern Illinois Planning Commission.

result from 3 inches of runoff from the 52 square mile drainage area and would be greater than any flood that has occurred in the past period of record. The peak outflow from the design flood of 1,125 cfs would be about 440 cfs. Additional reservoir capacity to an elevation of 692.5 feet, the elevation of the emergency spillway, would accommodate a flood resulting from rainfall of 10 inches, greater than any ever experienced in the Chicago area.

The spillway of the proposed reservoir would be automatically controlled. It is believed that a manually controlled gate and spillway "makes possible serious errors in operation which result in claims for damages" (Bauer, 1962, p. 9). The gate would "lower automatically as the reservoir rises until a desired peak discharge is achieved, whereupon the gate rises with the reservoir until a critical elevation is reached, whereupon the discharge is automatically increased" (Bauer, 1962, p. 9). Thus, at a reservoir elevation of 690.5 feet, the discharge would be 280 cfs. Discharge would increase to a maximum of 800 cfs at the elevation of 691 feet. Bauer (1962, p. 7) estimates that 99.9 percent of the time the discharge from the reservoir would not exceed 280 cfs.

A dike and pumping station would be required to protect a nursery adjacent to the Forest Preserve holdings, unless this land were acquired. Total cost of the reservoir, including the dike and pumping station, would be $460,000. This estimated cost does not include excavation of the ground-water lake, which could be paid for by the sale of borrow material for construction of the expressway (designated FA-61) adjacent to the Ned Brown Forest Preserve. Bauer (1962, p. 12) estimated that the average annual cost of the project would be $75,000, and the average annual benefits would be $130,000, $100,000 of which would be used for recreation and conservation and $30,000 for flood control. Thus, the benefit-cost ratio would be about 2 to 1.

From the standpoint of flood control, the proposed reservoir would contain virtually all runoff from the upper third of Salt Creek basin. This would reduce, but not necessarily eliminate, the flood hazard in the lower reaches of Salt Creek. Additional measures might be required to protect those parts of the flood plain that have already been developed.

The recreational, conservation, and scenic benefits of the Busse Woods reservoir, or any other reservoir for that matter, can be realized only if the quality of water in Salt Creek is maintained at an acceptable level. Although no sewage plants discharge into Salt Creek above the reservoir site, there are individual septic systems that pollute the stream. Furthermore, combined storm and sanitary sewers that normally transport sewage to the plants of the Metropolitan Sanitary District may overflow into Salt Creek during periods of high flow. The introduction of such sewage effluent into the reservoir would materially detract from its recreational and esthetic potential. (The new sewage treatment plant being planned by the Metropolitan Sanitary District would, according to current plans, discharge into Salt Creek below the reservoir site.) These problems will have to be solved if multipurpose reservoirs are to attain their optimum effectiveness.

Other Valley Reservoir Sites

Although Busse Woods is the only suitable site for a large valley reservoir in Salt Creek basin, two other smaller sites exist, one of which could offer significant flood-control benefits. This site is on Spring Brook, a tributary of Salt Creek, at Itasca (fig. 42). Proposals for its development are discussed in a consultant's report to the village of Itasca (Bauer, 1965), which is now proceeding with a plan for developing a greenbelt within its village limits.

To control flooding on Spring Brook would require 600 to 900 acre-feet of reservoir capacity upstream from Itasca. The maximum flood of record, estimated to have been 300 cfs, would have been reduced to about 100 cfs by such a reservoir (Bauer, 1965, p. 3). A project of this magnitude would probably require action by county or State agencies. Itasca has, however, begun a multipurpose program of open space development on a more modest scale. In 1965 and 1966, the village acquired about 60 acres of land along the flood plain of Spring Brook. Most of this land was acquired through a matching Federal Open Space grant for "recreation, conservation, scenic and other amenities." A reservoir is planned for "recreation, flood control, open space preservation, and land enhancement." Among the expected benefits of this tract of open space are prevention of development on the flood plain and preservation of a natural recharge area to the shallow aquifers. The rather limited flood-control capacity of 30 to 60 acre-feet would be far from adequate for control in the entire drainage area of Spring Brook but would reduce the flood hazard locally for the village of Itasca.

Two more potential reservoir sites exist on unnamed tributaries of Salt Creek west of Rolling Meadows (fig. 42). These sites have been recommended by the U.S. Soil Conservation Service (U.S. Dept. Agriculture, 1968) for flood-control reservoirs. Each reservoir would require about 100 acres of land. The north reservoir would have a capacity of 300 acre-feet, and the south reservoir, a capacity of 530 acre-feet.

A fifth valley reservoir site shown in figure 42 is at Addison. The village of Addison plans to develop this reservoir for flood-control and recreational purposes. Its flood-control capacity would be so slight that it would have little impact on Salt Creek basin as a whole, although it might improve conditions locally.

OTHER APPROACHES TO UPSTREAM STORAGE

Valley reservoirs are not the only structures by which upstream storage can be accomplished. A large number of smaller impoundment basins can create the same storage capacity as a few larger ones. Abandoned gravel pits or quarries can provide considerable storage space. And finally, land-use and soil-conservation practices can be modified to provide storage space for floodwaters. A discussion of alternative approaches to upstream storage follows. These concepts are introduced and discussed in the Northeastern Illinois Planning Commission's water-management report (Sheaffer and Zeizel, 1966, p. 92–97).

Abandoned Gravel Pits and Quarries

Abandoned gravel pits and rock quarries can be used for the temporary storage of floodwaters. In some localities, such pits have been landscaped and developed for recreation and conservation as well as flood control. In areas such as Salt Creek basin where the water table is generally high, abandoned pits and quarries afford excellent opportunities for the development of ground-water lakes for recreation and conservation. The uses of these pits for both recreation and flood control, however, are not always compatible.

Figure 7 shows the gravel pits and quarries that existed in Salt Creek basin in 1964. Of particular interest is a large rock quarry at Elmhurst. (See fig. 42.) This quarry, in the shallow dolomite aquifer, will be mined out in a few years. It has a surface area of about 35 acres and is 200 feet deep. When this quarry is completely mined out, it will have a storage capacity of 7,000 acre-feet nearly twice the capacity of the proposed Busse Woods reservoir.

If the storage capacity of this quarry were fully utilized it could contain nearly all flood runoff for the middle third of Salt Creek's drainage area as the Busse Woods reservoir could for the upper third. An inlet could be constructed to allow floodwaters to run into the pit by gravity flow. These waters could later be pumped out at a controlled rate. Although this quarry appears promising as a flood-control reservoir detailed engineering and cost-benefit studies are required before it is used for this purpose.

A problem with the use of this site for storage of floodwaters is potential pollution of ground-water supplies. The floodwaters would, in effect, be stored in the shallow dolomite aquifer, which is widely used as a source of water supply in Salt Creek basin. Illinois law provides that water directly injected into a formation being used as an aquifer must be of drinking-water quality. The water-quality studies cited in this report show that floodwaters in Salt Creek at present do not meet this standard. Therefore, either water quality would have to be improved or measures would have to be taken to prevent movement of the stored water to ground-water supplies before this quarry could be used for flood control.

Possibly, however, hydrologic conditions in the vicinity of this quarry are such that, if it were used for storage of floodwaters, these waters would not be injected into the aquifer. The quarry is presently pumped at a rate of about 1 mgd to keep it dry. Thus a cone of depression has been created around the quarry, and ground water flows toward the quarry rather than away from it. This pumping could be continued after the quarry is abandoned. A gratuitous fringe benefit of such pumping would be a modest augmentation of Salt Creek's low flow. When the pit is filled with floodwaters, this would reverse the hydraulic gradient so that the water would flow away from the pit. The pit would be filled for such a short time, however, that the floodwaters would probably not move far into the bedrock. A resumption of pumping after the pit is emptied would probably reverse the gradient quickly enough that the floodwaters would flow back toward the pit. If this flow pattern prevails, there would be little danger to any ground-water supplies.

This example is based entirely on theory. The use of this quarry for storage of floodwaters should be preceded by a thorough study of the ground-water hydrology to determine if there would be any threat to water supplies. If the quarry is used for flood control, ground-water samples should be taken frequently from nearby observation wells to detect any possible pollution.

The use of this quarry for flood control necessarily precludes its use for water-oriented recreation, inasmuch as it would have to be kept empty to take full advantage of its large storage capacity. A steep-walled rock quarry would be of no recreational benefit unless it was kept nearly full. Keeping it full would render it virtually useless for flood control.

Abandoned gravel pits, on the other hand, could be developed through landscaping into multipurpose reservoirs. Forest preserve districts in Illinois have the authority to sell sand and gravel from their lands, making possible the creation of artificial ground-water lakes for recreation, conservation, and flood control. The possibilities for development of such facilities should challenge the imagination of planners and landscape architects. The optimum development of any

370-926 O—70——8

such facility, however, necessitates consideration of alternative plans for its development and determination of what its principal use should be. If a multiple-use facility is planned, the compatibility of uses should be evaluated.

Watershed Treatment, On-Site Storage, and Upground Reservoirs

Although large detention basins such as the proposed Busse Woods reservoir or the quarry near Elmhurst would control downstream flooding on the main stem of Salt Creek, such facilities would have no effect on flooding upstream in the tributaries or in the many closed depressions in the area. Such flooding, while generally on a smaller scale than that on the main stem, does present a problem that must be dealt with as the area becomes urbanized. Flooding of this sort can usually best be managed by small-scale approaches by local interests or governmental units.

Reservation of the areas subject to flooding for parks or low-intensity use is one approach to small-scale flooding which has been discussed earlier in the report. Another approach is the construction of small-scale detention facilities combined with land-use practices that will tend to hold runoff in the area rather than accelerate it downstream. Such practices in rural areas are commonly referred to as *watershed treatment* and are an integral part of the watershed management projects carried out by the U.S. Soil Conservation Service under Public Law 566. Construction of small detention basins or farm ponds, contour plowing, terracing, and planting of cover crops are the principal land-use practices associated with this approach.

Some of these practices could be adapted to the urban environment. For example, small detention basins could be incorporated into commercial and industrial parks, golf courses, or other tracts of open space used primarily for recreation. Steps could be taken by governmental units to assure that an adequate cover of vegetation is maintained on vacant land to minimize erosion and accelerated runoff. Programs for erosion control, such as the previously cited example from Montgomery County, Md., could be put into effect.

On-site storage of floodwaters includes creation of storage space on rooftops, in parking lots, or in excavated pits to compensate for loss of natural storage capacity due to urbanization. The storage of floodwaters in basements is a not-so-desirable form of on-site storage due to the likely damage and inconvenience. In effect, on-site storage is an urban adaptation of the watershed approach. On-site storage could be required in zoning ordinances to the extent that, if construction of a building or other development reduces an area's natural capacity for the storage of floodwaters, compensatory storage space would be mandatory.

Upground reservoirs are reservoirs for the detention of floodwaters off the main channel. Such a reservoir could be buil' on a hillside, for example. Depending on the local topography, water would either flow in and be pumped out or be pumped in and allowed to flow out. An example of such a reservoir is east of Elmhurst in an area between the embankments of two expressways, the Illinois Toll Road and the northwest extension of the Eisenhower Expressway. Water flows into the reservoir from the Elmhurst storm drainage system. After the storm it is allowed to flow out, either downstream into Addison Creek or back through Elmhurst's storm sewers into Salt Creek. The storage capacity of this reservoir is 28 acre feet, about two-thirds of which is used under normal circumstances. The remaining capacity is reserved for emergency use.

Such methods of temporary impoundment of flood runoff could be incorporated into the storm drainage systems of villages as an alternative to the usual practice of constructing larger storm sewers as more of the area becomes urbanized. By means of this alternative approach, much of the storm runoff would be retained in the area until the stream channel could accommodate it, rather than being accelerated into a downstream area for storage.

The retention of storm runoff, furthermore, would make possible its treatment and use prior to discharge into the streams. Few studies have been made of the quality of storm runoff. A recent study by the U.S. Public Health Service (Weibel, 1964), however was made in a small drainage area in suburban Cincinnati. The results of this study indicate that the quality of storm runoff may be as bad or worse than that of treated sanitary effluent. This is reasonable when one considers the debris and dead animals that may accumulate in gutters, culverts, and storm sewers during a storm. Thus, a system that would delay storm runoff until such time as a treatment plant could accommodate it would have greater benefits from the standpoint of water quality than a system which simply discharges untreated storm runoff into the receiving stream.

Practices such as watershed treatment are more effective in containing the smaller floods that occur rather frequently than infrequent floods of greater magnitude. These greater floods generally occur when the ground is saturated or frozen and would be less affected by land treatment practices. The process of urbanization results in covering much of the land with impermeable surfaces. This process would tend to create large floods where smaller ones would have occurred and must be considered in flood-control plans for urban areas. Watershed treatment applied in conjunction with other measures, however, could be an integral part of a comprehensive flood-control strategy.

A watershed treatment project for most of Salt Creek basin under Public Law 566 is in the planning stages (U.S. Dept. Agriculture, 1968). This project would incorporate many of the techniques described above.

DOWNSTREAM STORAGE

The storage of floodwaters downstream from the area where protection is desired is another approach that has been widely advocated in urban areas. This is usually accomplished by increasing channel capacity so that the channel can accommodate the runoff from a given design storm. The floodwaters are then stored downstream, where the channel is presumably larger and therefore better able to accommodate the additional flow than the smaller headwaters streams. The argument has been brought forth that in the absence of ideal valley reservoir sites, channel improvement represents the only realistic approach to flood control.

This downstream storage approach to flood control has had particular appeal in the northeastern Illinois metropolitan area, where much of the drainage consists of small, headwaters streams of the Illinois River basin. Salt Creek is typical of such streams. The downstream storage area not only has greater capacity than headwaters streams, but it is also largely outside of the urbanized area. Therefore, flooding downstream is likely to cause less damage than flooding in the rapidly urbanizing metropolitan area. Present and future urban development downstream, however, may cast serious doubts on the value of this approach.

CHANNEL IMPROVEMENT PLAN FOR SALT CREEK BASIN

Various proposals for channel improvements in Salt Creek basin have been considered through the years. A proposal was advanced by the State of Illinois in 1958 and modified in 1962 and 1967 (Illinois Div. Waterways, 1958, [1962, unpub. rept.], 1967). Parts of the proposal, as described in the following sections have been completed.

The 1958 Division of a Waterways plan called for deepening, widening, and straightening the channel of Salt Creek from its mouth to a point about 2,000 feet upstream from Algonquin Road, or 35.5 river miles above the mouth. Figure 44 shows the approximate alinement of the channel according to this plan. In effect, two plans were presented: an "interim design plan", intended to satisfy existing flood-control requirements; and an "ultimate design plan" intended for

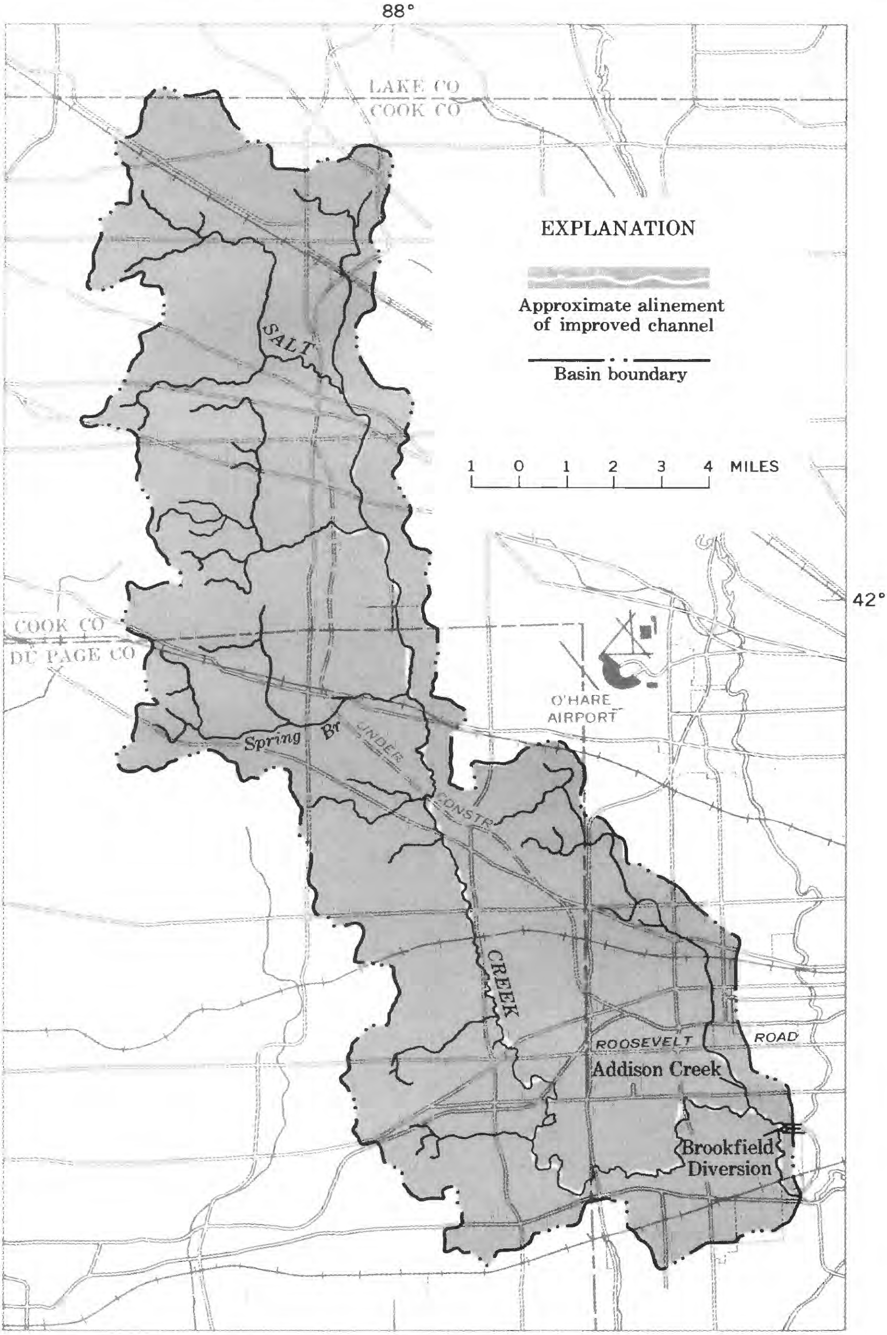


FIGURE 44.—Approximate alinement of Salt Creek according to 1958 Illinois Division of Waterways channel improvement plan.

construction in the future, when the basin presumably is completely urbanized.

The interim design plan called for a trapezoidal ditch with an average channel depth of 10 feet. The bottom width would vary from 60 feet in the upstream reaches to 70 feet in the lower reaches. The side slope would be 2 horizontal to 1 vertical. Channel capacity would range from 2,660 cfs upstream to 3,420 cfs downstream. This capacity would be more than adequate to accommodate any flood that has occurred in historical record. The gradient would vary from 4 to 5 feet per mile, somewhat steeper than the present natural gradient. Bridges and sewer outfalls would be modified to fit the enlarged channel.

According to the ultimate design plan, the channel bottom would be widened further by about 10 feet and the side slope would be increased to 1½ horizontal to 1 vertical. The channel would be paved with concrete for greater stability. Figure 45 shows a typical channel cross section under both the interim and the ultimate plans. The channel capacity thus would be increased to 7,000 cfs in the upstream reaches and 9,000 cfs downstream. This capacity, far in excess of any flood yet experienced, is justified on the basis of an estimate that runoff will greatly increase as a result of urbanization of the area (Illinois Div. Waterways, 1958, p. 7). Later studies (Illinois Div. Waterways, 1967) suggest that the 1958 proposals were overdesigned.

The cost of the interim design plan, including right-of-way and construction, was estimated to be $5,320,000 in 1958. This cost does not include maintenance. No cost estimate of the ultimate design plan was made by the Division of Waterways. According to an independent estimate (Memorandum by Engineering Department, Cook County Forest Preserve District, on 1959 report by Consoer and

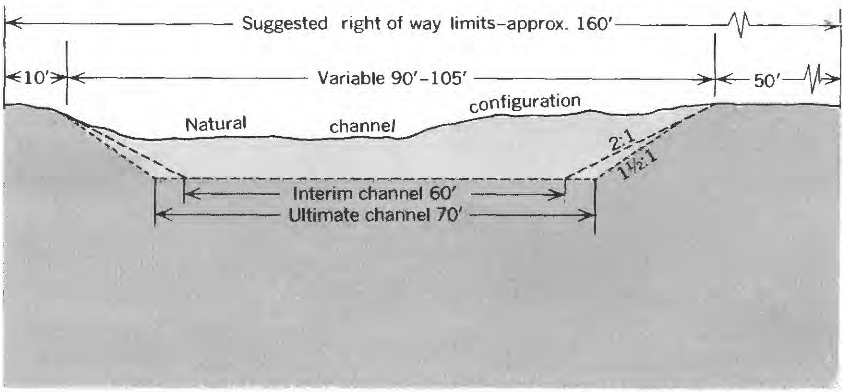


FIGURE 45.—Typical channel cross section, 1958 Illinois Division of Waterways channel improvement plan for Salt Creek.

others), the cost of the ultimate plan would be about $21 million, or $16 million more than of the cost of the interim plan.

The 1958 channel improvement plan generated widespread opposition, particularly from the forest preserve districts, conservation groups, and some communities along Salt Creek. Many communities along Salt Creek initially supported the plan in the belief that it would solve all their flooding problems, especially basement flooding, which is really the result of inadequate storm drainage systems. A number of these communities changed their position upon learning of the details of the plan.

Objections to such a proposal can be divided into six categories: esthetic considerations, hazard to safety and health, danger to downstream communities, maintenance problems, excessive cost, and adverse effect on ground-water recharge. The first five are discussed in the following paragraphs, and the sixth in a later section. ("Effects on Ground-Water Recharge of Alternative Flood Control Measures").

Conservationists raised objections to this proposal on the grounds that it would transform a visually pleasing, meandering stream, much of it flowing through forested land, into an unsightly ditch. The original 1958 proposal would have resulted in the destruction of large numbers of trees. During low-flow periods, which occur much of the time, unsightly pools of stagnant water might accumulate in the bottom of the channel and aggravate the already polluted condition of the stream.

In the minds of some, the ditches would create a safety hazard by encouraging children to play in their vicinity. This objection would be particularly valid for the concrete-lined ditch of the ultimate plan.

Another problem that has occurred with channel improvements of this type is maintenance. The legislation for such projects usually provides funds for right-of-way acquisition and construction, but none for maintenance. The need for constant maintenance is a built-in weakness of such a channel-enlargement plan. The natural meandering channel and its associated flood plain are the product of the delicately balanced processes of nature, erosion and deposition. Thousands of years were required for Salt Creek to assume its existing configuration. If man were to alter the existing balance, however, these same natural forces would tend to restore the channel to its natural state. Unless an altered channel is constantly maintained, it will through the years revert to nearly its original state, nullifying whatever benefits were to have accrued from the improvements. Concrete lining will minimize, but not eliminate, deterioration.

An example of the deterioration of improved channels is that part of Addison Creek from its mouth near Brookfield to Roosevelt Road (fig. 44). This reach was deepened and widened in 1953, much in the manner proposed for the main stem of Salt Creek. No provision was made for its maintenance. As a result, the channel has become clogged with weeds such as cattails and water willows, it has reverted to essentially its original capacity, and it has become unsightly.

At the time the Addison Creek improvements were made, the State did the construction on right-of-way provided by the communities, and the communities were held responsible for channel maintenance. The legislation has since been modified so that the State does the maintenance and bills the communities if the communities fail to do the necessary work themselves.

A fourth objection raised to the 1958 proposal is the possible adverse effect on downstream communities. The greater capacity and velocity of the improved channel would result in accelerated movement of storm runoff from Salt Creek into the Des Plaines River downstream from Brookfield. If no adequate provisions are made for the downstream storage of the accelerated runoff, flooding problems in downstream communities could be aggravated. The city of Joliet, for example, is on the banks of the Des Plaines River. The accelerated runoff from extensively deepened and widened streams in the metropolitan area upstream might require additional flood-control measures at Joliet and other downstream communities. Downstream storage problems in the northeastern Illinois metropolitan area are likely to increase in the future, as more and more of the downstream area becomes urbanized and natural storage space for floodwaters is lost. The Illinois Division of Waterways Salt Creek report (1958) is one of a series of reports which propose widespread channel improvements along the Des Plaines River and its tributaries in the Chicago metropolitan area.

To overcome the problem of adverse effects on downstream communities would require that channel improvement projects be undertaken systematically, beginning in the downstream area and working progressively upstream. There is a practical limit, however, on downstream improvements in a system as large as the Mississippi River basin. Flood-control projects are usually initiated as a result of local needs and political pressures. The planning of projects that have a potential for adverse effects on downstream areas, however, should take into account such adverse effects.

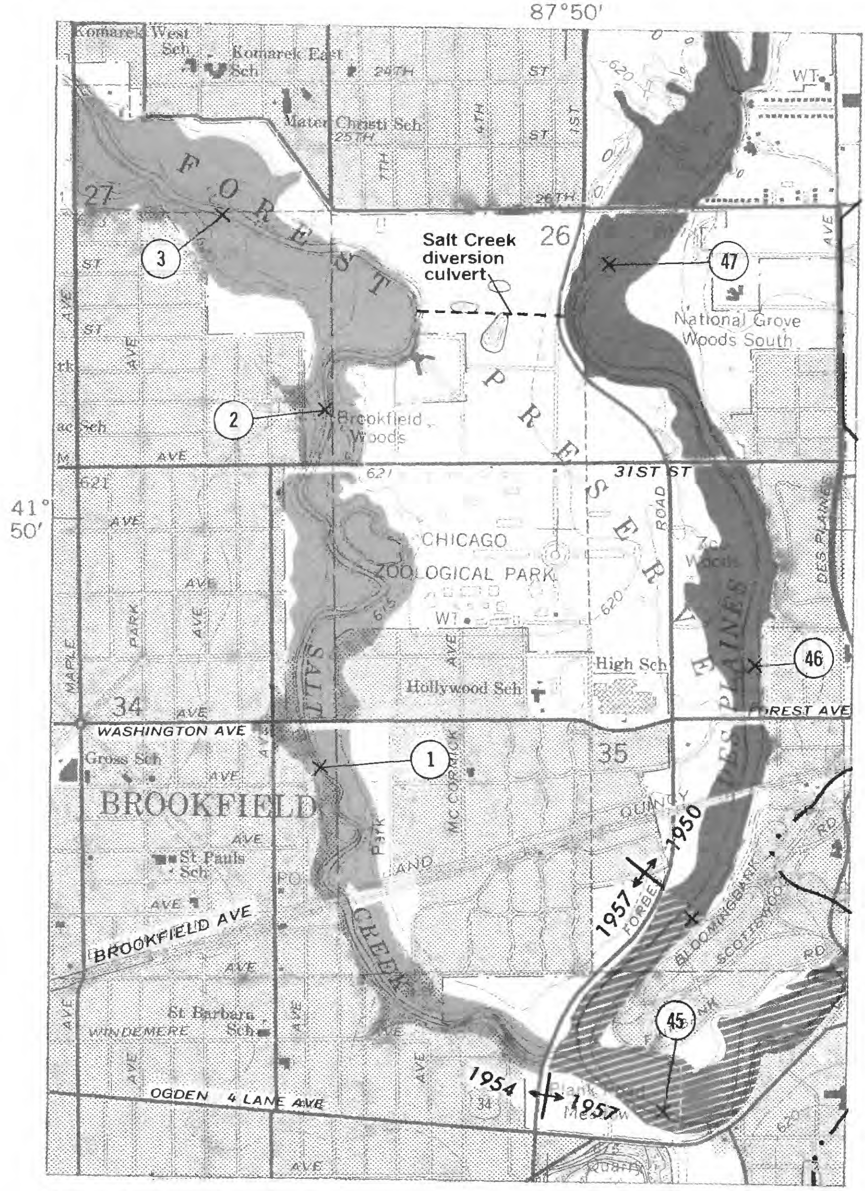
Another objection raised by opponents of the channel improvement plan is its high cost relative to anticipated benefits. Although a detailed economic analysis is not in the scope of this report, some comparative estimates can be cited. The estimated cost of the channel improvement plan is about $5 million (in 1958 dollars). A damage survey conducted for the Cook County Forest Preserve District (Consoer and others, 1959, p. 6–9) concluded that the average annual flood damage on Salt Creek was $14,360 and might increase to $21,540 as a result of future urban development. This presumably is based on the assumption that limited development of the flood plains will be permitted in the future.

In a later report (Bauer, 1962, p. 12), the average annual flood damage is estimated at $30,000. Even for a relatively long amortization period of 40 years, the average annual cost of the channel improvement plan would be $125,000, which far exceeds the average annual benefits. By way of comparison, the estimated cost of the proposed Busse Woods reservoir, for which public land is available, is $460,000. Although this reservoir alone cannot solve all the flooding problems of Salt Creek, the reservoir together with whatever channel improvements are necessary for additional flood-damage reduction would probably cost far less than the channel improvements proposed in the 1958 plan.

Certain features of the 1958 Division of Waterways plan have been implemented. Most of the improvements constructed were modified from the original plan to overcome opposition. The diversion channel north of the Chicago Zoological Park (Brookfield Zoo) (fig. 44) was built to reduce flooding downstream on Salt Creek. Figure 46 shows the location of this diversion cutoff and the areas inundated by the 1954 flood. At the insistence of the Cook County Forest Preserve District, the channel was placed underground to avoid despoiling the landscape. The diversion cutoff was intended to eliminate the need for downstream channel improvements on Salt Creek.

The diversion cutoff has not been completely effective for several reasons. First, often when flooding occurs on Salt Creek, the Des Plaines River is also at a high stage; thus, if the stage of the Des Plaines is as high as or higher than that of Salt Creek, the water backs up into the underground culverts and makes the diversion cutoff ineffective. Second, when the diversion cutoff was built, trash racks were installed at its entrance, but accumulated debris blocked the culverts; the racks were later removed, but the debris then accumulated in the cutoff and reduced its capacity. Third, the hydraulics of the intake structure do not permit the full capacity of the diversion cutoff to be used. Because the diversion cutoff has been ineffective, some channel improvements have been made downstream to remedy the flood hazard in Brookfield and to enhance the esthetic attributes of this reach.

Channel improvements have also been made in the 2-mile reach of Salt Creek upstream from the diversion cutoff (fig. 46). These im-

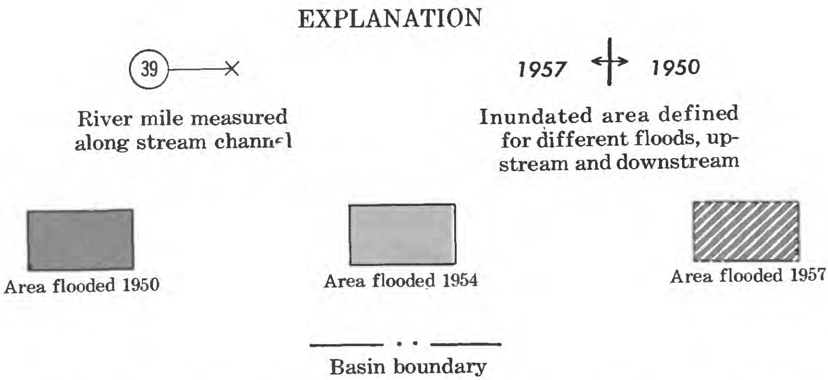


From U.S. Geological Survey
Berwyn 7½-minute
topographic quadrangle (1963)

Inundation boundaries from
U.S. Geological Survey
Hydrologic Atlas HA-252

1000 0 1000 2000 FEET

FIGURE 46.—Salt Creek diversion cutoff and areas inundated by the 1950, 1954, and 1957 floods in the Brookfield area.



provements were modified from the 1958 plan at the request of the Cook County Forest Preserve District to minimize damage to forested areas and disturbance of the landscape.

A MODIFIED APPROACH TO CHANNEL IMPROVEMENTS

The reaction of local governmental units to the 1958 Division of Waterways plan for channel improvements was generally unfavorable. In response to these criticisms, the division has modified its proposals, in part to take into consideration the eventual construction of the Busse Woods reservoir. A more recent supplement to the 1958 report (Illinois Div. Waterways, 1967, p. 4) reads:

> Studies and appraisals disclosed changes in the land development, by communities and individuals, along the stream and within its watershed that dictated the need to restudy the whole problem to achieve the most desirable and economic improvement. The original plan of improvement called for channel widths and corresponding right-of-way widths which are now considered almost prohibitive for reason of their physical and their cost requirements.

The proposal, as modified in 1967, called for (1) construction of the Busse Woods dam and multipurpose reservoir at the Ned Brown Forest Preserve, (2) continuation of the channel improvement program upstream to Elmhurst, and (3) modification of the Fullersburg Dam so that the reservoir can be used for flood control. No provision was made for the excavated permanent pool at the Busse Woods site. The automatic spillway was replaced with two manually operated sluice gates. The capacity of the downstream channel improvements was reduced as a result of greater upstream storage capacity at the reservoir.

The Division of Waterways agreed in 1969, in response to the desires of various County agencies and conservation groups, to build the Busse Woods reservoir following essentially the design proposed by Bauer

(1962). The reservoir is to include the automatic unattended spillway and the excavated permanent recreational pool, as recommended by Bauer. This project will be carried out in close coordination with the planned Public Law 566 watershed project for Salt Creek (U.S. Dept. Agriculture, 1968).

Although the disadvantages outweigh the advantages of widespread channel improvement projects such as the original 1958 plan, certain types of limited channel improvement may be a valid and even a necessary approach to flood control in an urban area. In reaches of Salt Creek, or any stream in an urban area where extensive development of the flood plain has already occurred, it may be necessary locally to increase the channel capacity to reduce flood damage. Such local improvements, which could include the enlargement of openings under bridges and removal of obstructions, may be necessary in addition to upstream storage facilities. Care should be taken in planning, however, to minimize any danger to downstream communities. With judicious planning, such local improvements can be made while maintaining the meandering character of the stream in essentially its natural state.

Another type of channel improvement that merits serious consideration is a continuing program of channel maintenance. Such a program in Salt Creek basin could logically begin with dredging of the channel to remove sludge and other debris that have accumulated through the years. The program could then continue with periodic clearing, snagging, and cleaning of the channel to maintain both its natural capacity to store floodwaters and its scenic appeal. An official of the Cook County Forest Preserve District refers to such a program as "scenic maintenance." A related approach is recommended in the 1967 supplement to the 1958 Division of Waterways plan (Illinois Div. Waterways, 1967, p. 6). This proposal, initiated at the request of the Du Page County Forest Preserve District, calls for rerouting the channel of Salt Creek to bypass Fullersburg Dam, thus permiting the lagoons to be periodically drained and cleaned.

EFFECTS ON GROUND-WATER RECHARGE OF ALTERNATIVE FLOOD-CONTROL MEASURES

One of the prime considerations of planning for flood control in Salt Creek basin, or in any basin where ground water is a potential source of supply, should be the potential effects of alternative flood-control measures on ground-water recharge. Much of the population in Salt Creek basin depends on ground water from the shallow aquifers for its public water supplies. In the lower part of the basin, many of these supplies are sustained by induced recharge from Salt Creek. It is believed that a substantial part of this recharge takes place during flood stages and other periods of high water owing to higher head and greater stream velocity. Therefore, any flood-control measures which would alter the stream regimen during periods of high streamflow would also affect ground-water recharge.

Sufficient data are not available to predict quantitatively the effects of specific flood-control measures on ground-water recharge. Based on accepted hydrologic principles and on certain assumptions, however, some qualitative generalizations can be made regarding the possible effects of alternative approaches to flood control. Figure 47 is a hydrograph of a hypothetical flood in the lower reaches of Salt Creek as it might occur under existing conditions (that is, with no flood-control measures) and as it might be affected by two alternative approaches to flood control.

The solid line represents the hydrograph of a typical flood on Salt Creek under existing conditions, with what remains of the natural storage capacity of the flood plains. The dotted line represents an estimate of what might happen if the channel capacity of Salt Creek were enlarged (by deepening, widening, and straightening) according to a plan similar to the 1958 Division of Waterways proposal. If the

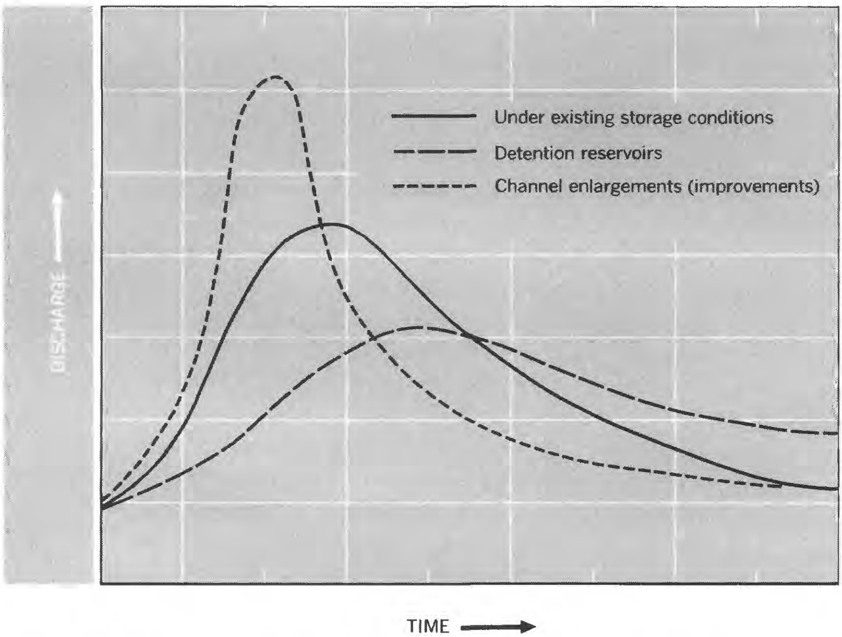


FIGURE 47.—Hydrographs of hypothetical flood in lower part of Salt Creek basin under existing conditions and as it might be affected by alternative flood-control measures.

channel were so altered, the crest would occur earlier, the peak discharge would probably be greater, and the recession would be more rapid. It is possible, though not likely in the Salt Creek channel improvement plan, that the storage capacity of the enlarged channel would be sufficient to prevent such increased discharge. Although peak discharge would probably be greater, the maximum height of the flood would probably be lower because the enlarged channel would be able to contain most flooding.

The dashed line represents a conception of how the hypothetical flood would occur in lower Salt Creek if detention reservoirs, such as the proposed Busse Woods reservoir, were constructed in the upstream areas. If much of the runoff were thus detained in the headwaters, the crest of the flood would occur later and the peak discharge would be less than under either existing conditions or proposed channel improvements. Likewise, the recession curve would be flatter and a higher rate of discharge would be maintained during the several days following the crest.

Based on these hypothetical hydrographs, predictions can be made as to the effects of these alternative flood-control measures on ground-water recharge. Under existing conditions, the channel becomes filled during a flood, and water spills over the banks onto the flood plain. Therefore, recharge occurs from both the channel and the flood plain.

Under the plan for channel improvements, the peak discharge would be greater but of shorter duration. Although some recharge would occur by seepage from the enlarged channel, the recharge areas on the flood plains would be lost. Furthermore, the period of high streamflow would be of such short duration that the soils of the streambed would probably not be able to absorb as much water. Thus, some of the water available for ground-water recharge under existing conditions would be lost if the channel improvement plan were implemented. If the channel were paved, as was proposed in the ultimate design plan of 1958, the hydraulic connection between Salt Creek and the shallow aquifers would be broken, and recharge from the stream to the aquifer could not occur, nor could water seep from the aquifer into the stream.

Detention of flood runoff in upstream storage facilities would lower both the height and the discharge of floods and extend the moderately high flows of the recession over a longer period of time. Although some recharge from the flood plains would be lost, the water would be retained in the basin long enough to increase the opportunity for recharge by seepage through the channel. The retention of floodwaters in the basin further increases the opportunities for their use in artificial recharge basins which could be developed in those parts of the flood plains not yet urbanized.

In summary, of the three alternative proposals, the plan for enlargement of the channel capacity is least favorable from the standpoint of ground-water recharge. Storage of floodwaters in upstream reservoirs would preserve some existing recharge but would probably shift some of the recharge from the flood plains to the channel. Sufficient data are not available to show whether the additional potential recharge from the channel would compensate for the loss of recharge from the flood plains.

The principal assumptions inherent in the foregoing analysis are that a substantial amount of recharge to the shallow aquifers does occur during floods and periods of relatively high streamflow, and that floods under existing conditions and under the two alternative flood-control plans will behave essentially as indicated by the hypothetical hydrographs of figure 47. To vertify the first assumption would require a program of data collection and an analysis of recharge conditions as described in the section on the interrelationship of surface water and ground water. To verify the second assumption would require detailed profiles and cross sections of the channel and flood plains of Salt Creek as they exist today and as they would exist under both the suggested alternatives. These data could be programed for analysis by a digital computer, which could synthesize hydrographs of a flood produced by a given amount of rainfall under existing conditions and as altered by either flood-control plan.

Based on these two assumptions and on the hydrologic theory as stated, the best approach to flood control in Salt Creek basin from the standpoint of maintaining ground-water recharge is a combination of upstream storage in detention reservoirs and maintenance of flood plains in their natural, undeveloped state in those reaches determined to be existing or potential recharge areas to the shallow aquifers.

NEW APPROACHES TO FLOOD CONTROL

CONJUNCTIVE USE OF SURFACE AND GROUND WATERS

The conjunctive use of surface and subsurface reservoirs for the storage of water is a possible approach to flood control which has not yet been used in the northeastern Illinois metropolitan area. The concept is not wholly new; it has been applied rather extensively in California and other Western States where the distribution of rainfall and associated high runoff varies greatly from season to season and from year to year. Todd (1959, p. 214–217) summarized some of these applications and listed the advantages and disadvantages of this water-management technique.

Applications of conjunctive use in the West have been made largely in areas with thick and extensive alluvial sand and gravel deposits. During extended dry periods, water is pumped from wells in these deposits to maintain adequate low flow in streams or to irrigate. This pumping creates storage space in the alluvial aquifers. During periods of high streamflow, the excess runoff can be diverted into these aquifers by the use of recharge pits or spreading basins, and be made available for flow augmentation in the next dry period.

Conjunctive use of surface and ground waters is practiced in suburban Nassau County on Long Island, N.Y. (Cohen and others, 1968, p. 74–75). Here storm runoff is channeled into detention reservoirs, known as "sumps," which serve as recharge pits to the alluvial sand and gravel aquifers of the Atlantic Coastal Plain. This system provides a practical and economical means of managing storm runoff and at the same time of recharging ground-water supplies. Ground water is not used, however, to augment low streamflow.

The scarcity of adequate surface storage sites in an urban area points to the attractiveness of conjunctive use as a method of flood control and low-flow augmentation. Certain problems not generally found where this approach has previously been applied exist in the northeastern Illinois metropolitan area. The greatest potential problems are the hydraulic characteristics of the shallow aquifers and the danger of introducing polluted water into aquifers used as sources of drinking water. Inasmuch as storm runoff may be highly polluted, care must be taken to prevent pollution of ground water by recharge.

Conjunctive use of surface and ground waters in Salt Creek basin would require operations largely in the upper part of the basin if maximum flow augmentation benefits are to be realized. In this part of the basin, the shallow aquifers are covered by 150 feet or more of relatively impermeable glacial till (fig. 12). Therefore, artificial recharge would have to be accomplished by injection through wells rather than by use of spreading basins or pits. Injection through wells into the dolomite aquifer might present a problem owing to the irregular distribution of the cracks and crevices that make up this rock's water-bearing capacity. Extensive basal sand and gravel aquifers exist under much of the basin, however. These aquifers would probably offer greater opportunity for conjunctive-use operations because of the greater ease of developing injection wells in a granular medium than in an irregularly creviced dolomite. Considerable research and perhaps a pilot injection well are needed before a more widespread operational program can be begun.

Inasmuch as the flood runoff in Salt Creek basin is polluted, either treatment or elimination of the major sources of pollution is required before conjunctive use operations can be put into effect. Unless the sources of pollution are eliminated or isolated, a conjunctive use operation will probably require temporary storage of flood runoff in surface reservoirs prior to treatment and injection into the shallow aquifers.

Despite these problems, conjunctive use deserves consideration as an alternative to surface storage in flood-control planning for Salt Creek basin. Future technological developments may well provide the solutions to these problems that appear to be serious at the present time.

UNDERGROUND TUNNELS FOR STORAGE OF FLOODWATERS

Construction of tunnels in underground bedrock formations for the temporary storage of floodwaters is a concept which has recently come under wide discussion in the northeastern Illinois metropolitan area. The concept was first advanced in research and discussions in the preparation of the water-management report of the Northeastern Illinois Planning Commission (Sheaffer and Zeizel, 1966, p. 167–171).

The Northeastern Illinois Planning Commission proposal calls for a regional network of tunnels and pipelines connecting all the northeastern Illinois metropolitan area's drainage basins and Lake Michigan. Lake Michigan, with its vast capacity, could be used for the temporary storage of floodwaters. During dry weather, the waters could be pumped back through the tunnel network to augment low flow in the region's streams. The tunnels could be 500 to 1,300 feet below the land surface in the Galena and Platteville Dolomites, a relatively impermeable formation. The use of this relatively impermeable formation for the tunnels would minimize the danger of ground-water pollution. It is recognized that the existing quality of floodwaters should be improved before these waters are introduced into Lake Michigan. A tunnel system, however, would not necessarily have to be connected to Lake Michigan. Water could be stored in the tunnels themselves.

Admittedly, the Northeastern Illinois Planning Commission tunnel proposal is a long-range project which would require considerable detailed feasibility study before it could be implemented. This proposal has been characterized by some observers as unrealistic and somewhat impractical. That it is ambitious and far-sighted is beyond question. Many of today's water-management projects would have been considered unrealistic 50 years ago. The Chicago Sanitary and Ship Canal, for example, was considered the seventh wonder of the engineering world at the time it was completed in 1900.

As a result of the tunnel concept advanced in the Northeastern Illinois Planning Commission's report, two different plans have been proposed for the use of tunnels in flood control and pollution control in Chicago and vicinity (Harza and Bauer, 1966; City of Chicago,

370-926 O—70——9

1967). The use of tunnels for the storage of storm runoff in an urban area has recently become an attractive alternative to more conventional approaches for a number of reasons. Using subsurface space would compensate for the lack of adequate surface reservoir sites. With the cost of land in an urban area constantly rising, the cost of tunneling may well prove to be more economical. This is especially true in light of recently developed tunneling technology. The "mole," a modern tunneling machine, is a large rotary drill (Harza and Bauer, 1966, p. V–3). Tunneling by such machines is more rapid, cheaper, and safer than by conventional drilling and blasting methods. Finally, the use of large diameter tunnels for the temporary storage of combined storm runoff and sanitary sewage in urbanized areas presents a possibly more economical alternative to the separation of storm and sanitary sewers. The combined runoff could be stored in these tunnels until the streamflow subsides and the sewage treatment plants are able to accommodate the additional loads.

One proposal (Harza and Bauer, 1966) calls for the Metropolitan Sanitary District of Greater Chicago to construct a network of tunnels in the Galena and Platteville Dolomites at a depth of about 800 feet below the land surface in a 21-square mile area near Lake Calumet. If this initial stage proves successful, the network presumably could be extended to other parts of the metropolitan area. These tunnels, 33 feet in diameter, would have a capacity to contain virtually all the combined storm runoff and sanitary sewage for the project area. The water, as it flows down the shafts into the tunnels, could be used for hydroelectric power production.

Inasmuch as the Galena and Platteville Dolomites are fairly impermeable, it is believed that lining of these tunnels would not be necessary to prevent ground-water pollution. A system of recharge wells surrounding the tunnels was proposed (Harza and Bauer, 1966, appendix D), however, to maintain ground-water levels so that the hydraulic gradient remains toward the tunnels rather than away from them. Thus, the polluted waters would be kept close to the tunnels.

A second tunnel plan was proposed by the Department of Public Works of the City of Chicago (City of Chicago, 1967). This proposal, known as the Chicago Underflow Plan, is similar to the Harza-Bauer proposal in its objectives although different in their attainment. The proposed tunnel in the Underflow Plan would be about 4 miles long below Lawrence Avenue, on Chicago's north side. Its diameter would range from 12 to 17 feet, and it would be from 140 to 200 feet beneath the surface, in part of the shallow dolomite aquifer. The tunnel would be lined with concrete to prevent polluted water from seeping into the aquifer. It is believed that the reduced tunneling cost resulting from the shallow depth would more than offset the cost of lining these tunnels. The tunnels would be kept dry when not in use and the lining could be periodically inspected to assure its effectiveness. Inasmuch as the piezometric surface is higher than the proposed tunnels, keeping the tunnels dry would assure that the hydraulic gradient in the dolomite aquifer is toward the tunnel and tend to minimize chances of pollution.

The Chicago Underflow Plan, if successful, could be extended to serve much of the metropolitan area (City of Chicago, 1967, p. 14–32), and a preliminary proposal for its expansion is presented in the same report (City of Chicago, 1967, fig. 12). The principal tunnels, according to this proposal, would be constructed under the Chicago River, the Sanitary and Ship Canal, the Cal-Sag Channel, and the Des Plaines River.

The shallow dolomite aquifer is widely used for public water supplies in much of the area that would be served by this proposed regional network of tunnels. Precautions would have to be taken to protect these supplies from pollution. The tunnels should not be built in the immediate vicinity of well fields. As long as the impermeable lining holds and the tunnels are kept dry and as long as the piezometric surface remains higher than the tunnels, the natural flow of water would be toward the tunnels rather than toward any ground-water supplies. Thus, a natural safeguard would exist that would tend to protect the supplies. Tunnels should not be planned indiscriminately, however, without regard for the protection of ground-water supplies.

Although Salt Creek is not specifically included in this proposal, the use of tunnels could be considered as an alternative to the more traditional approaches to the storage of storm runoff. The southern half of Salt Creek basin is already rather densely urbanized. By 1990, the north half probably will be urbanized with a comparable density of development. A tunnel system could thus be developed either to handle drainage within the basin or as part of a larger regional network. In such a regional network, tunnels could be planned to connect abandoned rock quarries in the Niagara Dolomite, such as the quarry near Elmhurst.

RECLAMATION OF FLOOD PLAINS

The approaches to flood-plain management and flood control discussed up to now are concerned with (1) the preservation of existing storage on flood plains, (2) the creation of storage space by surface impoundments or subsurface reservoirs, or (3) channeling of flood runoff into downstream areas. A new approach to flood control, just now gaining recognition, is the restoration of the flood plain's original storage capacity wherever the flood plain has been built or encroached upon. All or part of the natural storage capacity can be regained by flood-plain reclamation. Flood-plain reclamation consists of acquiring developed or partially developed land on flood plains, removing the offending buildings or encroachments, and redeveloping of the flood plain for open space or other low-intensity use. Federal financial assistance can be made available for such projects under the Urban Renewal and Open Space Acquisition programs.

The proposed reservoir on Spring Brook at Itasca would be built on a site acquired by the village of Itasca with assistance under the Federal Open Space Program. The Itasca site is in the partially developed category, and only a few buildings would have to be cleared before a reservoir could be built.

The Federal Open Space Program could be used for additional flood-plain reclamation in Salt Creek basin. The stream courses and their adjacent flood plains generally represent the last stands of forested land in the northeastern Illinois metropolitan area. The remaining undeveloped and partially developed lands could be considered for acquisition and development as public open space. Reaches where the natural configuration of the flood plain has been destroyed, for example by filling or by use as refuse disposal sites, could thus be acquired and restored. Reforestation could further restore part of these areas' scenic appeal.

The Federal Urban Renewal Program, administered through the Department of Housing and Urban Development, provides for the acquisition and redevelopment of blighted urban areas. In the past, this program has been most successfully realized in the central parts of cities. Few Urban Renewal projects have been completed in suburban communities, which comprise most of the communities in Salt Creek basin.

Waterfront renewal of the central business district has been a key feature of some recently undertaken Urban Renewal projects. Flood plains in many cities have been developed and protected by levees or a flood wall. The flood wall itself is usually an unsightly structure leading to blighted conditions in its vicinity. One approach to eliminating such blight through an Urban Renewal project would be to tear down the flood wall and the buildings on the flood plain. Then the flood plain could be redeveloped as a park for recreation. Parts of flood plains known not to be ground-water recharge areas could be used as parking lots. The natural storage space of the flood plain would thus be restored. Such projects for the renewal of a central business district are in progress or under consideration in Waterloo and Cedar Rapids, Iowa, both along the Cedar River.

Flood walls or levees resulting in urban blight do not exist along Salt Creek and generally do not exist along any small streams. The potential for such Urban Renewal projects may exist, however, in some communities along the larger streams in the northeastern Illinois metropolitan area. Elgin and Aurora along the Fox River and Joliet along the Des Plaines River (fig. 1) are examples of such communities. All these communities have Urban Renewal programs in progress.

In the future, conditions may be such that Urban Renewal projects along the flood plains in suburbs, such as those in Salt Creek basin, may be feasible. Many residential and commercial developments on flood plains will in time become blighted owing largely to lack of maintenance and the resulting decline in land values. These areas will become potential candidates for Urban Renewal projects.

An example is an Urban Renewal project currently under consideration in Evansdale, Iowa, a suburb of Waterloo. This suburb has considerable residential development on the flood plain of the Cedar River and its tributaries. The proposed renewal project would restore the flood plains to their original storage capacity and eliminate the flood hazard to the residential areas. Figure 48 is an artist's conception of how part of this area will look under the redevelopment plan. This drawing shows a residential development around an excavated ground-water lake, which also could serve as a temporary storage basin for storm runoff. This concept in urban development could be applied either in renewal or in new residential developments in Salt Creek basin.

A FLOOD-CONTROL STRATEGY FOR SALT CREEK BASIN

The preceding discussion summarizes various alternative approaches to flood control, how they might be applied in Salt Creek basin, and their potential effects on the hydrologic system. The flooding problem is a complex one. It cannot be eliminated or solved by any single approach. An overall strategy for flood control in Salt Creek basin or any similar basin in an urban area should include several, if not all, of the approaches discussed herein, each applied to its optimum advantage to deal with particular flooding problems. Such a strategy would be sufficiently flexible to allow for changes in the urban development of the basin and to avoid overinvestment in any facility that might become obsolete in the future. The management of flood runoff should be coordinated with other land- and water-management requirements, such as water-quality control, provision for water-oriented recreation, and open-space acquisition.

Such a strategy for managing flooding in Salt Creek basin would require close coordination and cooperation among the many govern-

FIGURE 48.—Artificial lake in proposed redevelopment of flood plain, Evansdale, Iowa. Courtesy of Urban Planning Consultants, Chicago.

mental units at local, County, metropolitan, State, and Federal levels. The time has long since passed when each community can "go it alone." Communities are so close to each other that any action taken by one community will have some effect, be it beneficial or detrimental, on adjacent communities. Various approaches to intergovernmental coordination are discussed in chapter VI of the Northeastern Illinois Planning Commission's water-management report (Sheaffer and Zeizel, 1966, p. 135–153).

Each of the previously discussed flood-control measures could have its place in such an overall strategy. The Busse Woods reservoir could be developed as a multiple-use facility to reduce downstream flood stages along the main stem of Salt Creek and to provide facilities for water-oriented recreation.

Smaller reservoirs on tributaries, such as the proposed reservoir on Spring Brook at Itasca, could be built to control flooding in the headwaters areas. Headwaters-area flooding could be controlled further by upground reservoirs and small local impoundments similar to farm ponds. Undeveloped land could be planted with corn crops, and construction could be planned to minimize erosion and runoff. Abandoned quarries, such as the large one near Elmhurst, could be used either as a supplement or as an alternative to valley reservoirs for the storage of floodwaters on the main stem of Salt Creek.

Further development of the flood plains could be controlled both by their acquisition as part of a regional open-space network and by land-use controls such as flood-plain zoning. It is particularly desirable to preserve those flood plains in the lower part of Salt Creek basin that are recharge areas to ground-water supplies.

Local channel improvements, such as widening and rebuilding of bridges and embankments to remove impediments to flow, could be made to protect existing developments from flood damage. A continuing program of "scenic maintenance," consisting of the removal of foul-smelling sludge from the stream bottom, periodic removal of unsightly vegetation, and cleaning of trash and other foreign objects, could be implemented. Such a program could be accompanied by concerted efforts to improve the quality of water in Salt Creek and its tributaries. Storm drainage systems could be improved, incorporating retention basins or ponds where appropriate, to minimize flooding in basements, underpasses, and other depressions.

Some of these approaches to flood control will be applied in the proposed coordinated programs of the Illinois Division of Waterways, the U.S. Soil Conservation Service (U.S. Dept. Agriculture, 1968), and several County and local agencies.

Three approaches to flood control that represent relatively new thinking could be applied in Salt Creek basin as part of a long-term strategy for managing the flooding problem. Ground water could be pumped from aquifers to maintain base flow in Salt Creek, and the space vacated by this pumping could in turn be used for the storage of flood runoff. Considerable research would be needed, and obstacles such as the presently poor quality of flood runoff would have to be overcome before such a program could become operational. Tunnels in the consolidated rock formations could be constructed for the storage of floodwaters. Such a program would probably be most effective and economical if applied to a region, rather than to a single drainage basin. Finally, the reclamation of flood plains through the Federal Urban Renewal and Federal Open Space Programs could rehabilitate parts of the blighted flood plains whose natural storage capacity has been lost.

All individual efforts or projects would have to be coordinated with other individual efforts if such a strategy is to be of optimum benefit to the entire community of Salt Creek basin.

A tabulation of the alternative approaches to flood-plain management and flood control discussed in the preceding pages follows. Each measure is related to its benefits and its degree of applicability.

TABLE 5.—*Summary of alternative approaches to flood control in Salt Creek basin*

Flood control measures	Potential benefits	Potential limitations	Application
Preservation of flood plains as open space.	Flood damage reduction. Recreation. Esthetic appeal. Ground-water recharge.	Not most economical use of flood plains everywhere.	Widespread.
Management of flood plains by municipalities:	Flood damage reduction. Recreation.		
1. Recreation facilities, parking lots.		Not economic in high-density areas.	In municipalities.
2. Controlled commercial and industrial development.		Compensatory storage necessary.	In municipalities.
Upstream storage:			
1. Valley reservoirs.	Flood control along main stem. Recreation and esthetics. Ground-water recharge.	Sites not everywhere available in urban areas.	Widespread.
2. Abandoned gravel pits and quarries.	Flood control. Esthetics and recreation. Ground-water recharge.	Precautions needed to prevent ground-water pollution.	Where sites exist.
3. Watershed treatment and on-site storage.	Control of minor flooding. Erosion control.	Cannot control major flooding.	Local.
4. Upground reservoirs.	Local flood control. Pollution control.	Benefits local. Sites not everywhere available.	Local; can be incorporated into storm drainage systems.
Downstream storage:			
1. Widespread channel improvement.	Flood control along main stem.	Transfers flooding downstream. Damage to forested areas. Requires continuous maintenance. Excessive cost relative to benefits.	Widespread.
2. Local improvements and "scenic maintenance."	Protection of existing developments on flood plains. Enhancement of environment.	Would not provide basin-wide flood protection.	Widespread and local.

TABLE 5.—*Summary of alternative approaches to flood control in Salt Creek basin*—Continued

Flood control measures	Potential benefits	Potential limitations	Application
Conjunctive use of surface and ground water.	Subsurface storage space for floodwaters and water needed for flow augmentation.	Research needed before operational program could be begun. Safeguards required to prevent ground-water pollution.	Widespread.
Storage in underground tunnels.	Regional flood control. Pollution control. More economical than surface storage.	Care needed to avoid ground-water pollution.	Widespread.
Reclamation of flood plains through Federal Urban Renewal and Open Space Programs.	Reduction of flood hazard. Provision for needed open space. Removal of blighted conditions.	Difficulty in implementation.	Widespread or local.

WATER-MANAGEMENT IMPLICATIONS OF ALTERNATIVE LAND-DEVELOPMENT PATTERNS

Land-use practices in an urban area can materially influence the functioning of the hydrologic system. Likewise, management of the hydrologic system can be used to influence patterns of land development. Three alternative patterns for future land development were introduced in the section entitled "Urban Development" and were conceptually illustrated in figure 9. A discussion follows of how the three long-range concepts might be applied in Salt Creek basin and of their water-management implications. Those aspects of water management directly related to land use are emphasized. Water-supply requirements are not discussed, except to the extent that water supply is related to land-use practices. Each alternative pattern of development is analyzed from the standpoint of both constraints and opportunities for water management. The alternative plans are discussed in more detail in two 1968 publications of the Northeastern Illinois Planning Commission (1967, 1968).

THE "TRENDS" ALTERNATIVE

The first alternative represents a planner's conception of how the region would develop if present trends continue. The most obvious trend, as illustrated in figure 9, is toward more urban sprawl. It is reasonable to assume that this tendency will continue in the absence of comprehensive regional planning. As stated earlier, however, the "Trends" alternative does not imply an absence of land-use controls or planning by counties or local governmental units.

Figure 49 shows a generalized framework for the "Trends" alternative in Salt Creek basin. The transportation network, consisting of commuter rail lines radiating from Chicago, expressways, and principal arterial highways which crisscross the basin, is the dominant factor directing future growth. The alinement of the proposed expressway designated FA–61, which will run the length of Salt Creek basin approximately parallel to Illinois Highway 53, is shown. Existing public open space and the fairly modest proposed acquisitions of the Du Page County Forest Preserve District are shown. It is assumed that the remainder of the basin will be developed.

Pressures for the development of flood plains would probably continue, though at a slower pace than in past years, under the "Trends" alternative. The trend toward developments on the flood plains is well illustrated in the previously cited example from the Water-Management Report of the Northeastern Illinois Planning Commission (Sheaffer and Zeizel, 1966, p. 82–83).

Development of the flood plains in the future is not likely to continue at a rate even approaching this rather startling pace. The availability of flood-inundation maps, such as those published by the U.S. Geological Survey, and flood-plain information studies by the U.S. Army Corps of Engineers has greatly increased knowledge of the flood hazard. County and local zoning ordinances are making it increasingly difficult to build on flood plains. Nevertheless, the pressures are likely to intensify as a result of the constantly increasing value of land.

The water-management measures discussed earlier in the present report could be implemented within the framework of the "Trends" alternative, but they would most likely achieve less than optimum results. Without coordination among communities and agencies, this alternative could lead to inefficient land use and therefore reduced op-

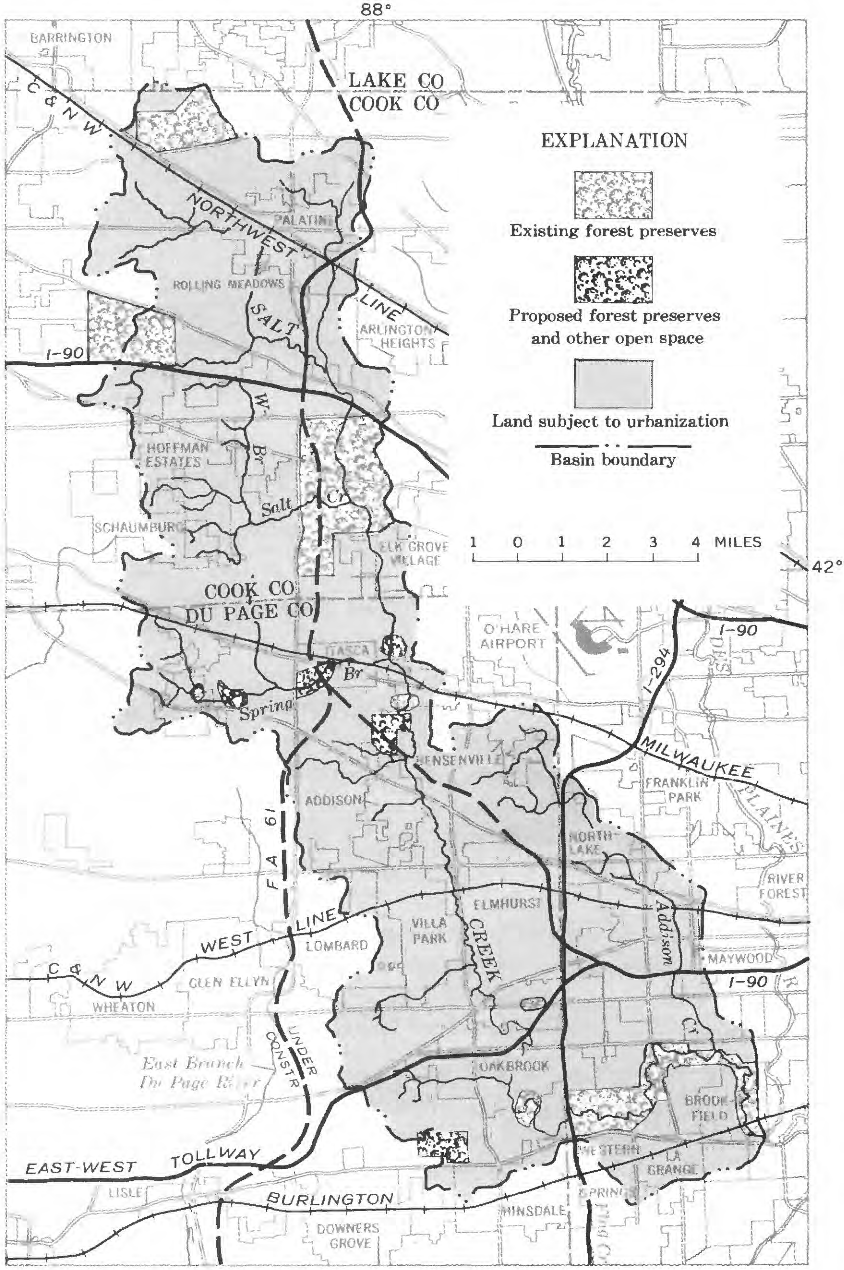


FIGURE 49.—Framework for "Trends" alternative in Salt Creek basin.

portunities for land-related water-management measures. Ground-water recharge areas in existing public open space would be preserved, but recharge areas in land not presently reserved as open space would be endangered.

THE "MULTI-TOWNS" ALTERNATIVE

The "Multi-Towns" concept (fig. 9) is, in a sense, a modification of the "Trends" alternative. This pattern of development calls for clusters of communities throughout the region. The town clusters would be separated by belts and pockets of open space that break the tendency toward uncontrolled urban sprawl. Land use under this alternative would be more efficient than under the "Trends" alternative owing to coordinated, comprehensive land-use planning. The "Multi-Towns" alternative would require more land-use controls than exist at present or than are projected under the "Trends" alternative.

Figure 50 shows the basic framework for the "Multi-Towns" alternative in Salt Creek basin. This alternative calls for the preservation or reclamation of the flood plains, where it is economic and practical as open space separating the town clusters. Federal Urban Renewal and Open Space programs could assist with the acquisition and reclamation of these flood plains. The flood plains would thus provide a system of greenbelt open space which would serve as an identifying framework to give separateness and distinctiveness to the towns. This pattern of development would not require higher residential density than the "Trends" alternative because of the more efficient land use resulting from comprehensive planning. This system could provide the first necessary step toward a program for comprehensive land and water management. Existing and proposed open-space sites could provide sites for reservoirs, preserve ground-water recharge areas, and reduce potential flooding damage to future developments.

THE "RADIAL CORRIDOR" ALTERNATIVE

The "Radial Corridor" alternative, sometimes referred to as the "Finger Plan," represents a marked departure from recent growth trends. Figure 9 shows the generalized, regional concept of this pattern of development. Urban development is concentrated in corridors along commuter rail lines, and "wedges" separating the corridors are reserved for open space and very low density residential development, such as estates. This pattern of development would require even more stringent land-use controls than the "Multi-Towns" pattern. The "Radial Corridor" alternative is the basis for the comprehensive general plan adopted in 1968 by the Northeastern Illinois Planning Commission (1968, p. 113–127).

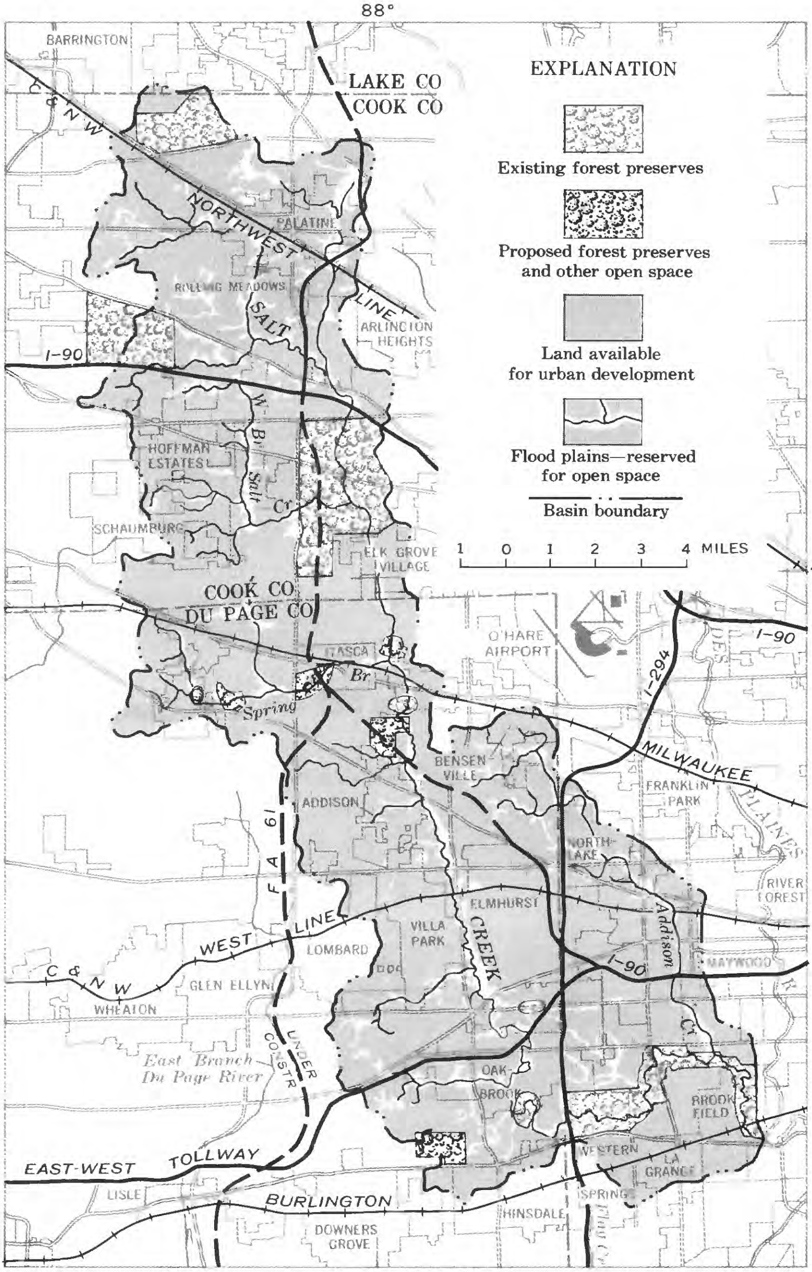


Figure 50.—Framework for "Multi-Towns" alternative in Salt Creek basin.

Figure 51 shows the basic framework for the "Radial Corridor" alternative in Salt Creek basin. Inasmuch as Salt Creek basin is relatively close to the city of Chicago and has already undergone considerable urbanization, the "Radial Corridor" plan of development cannot be applied here in its idealized form. The opportunity does exist, however, for the acquisition of relatively extensive wedges of open space. In addition, much of the flood plain areas would be reserved for open space, as in the "Multi-Towns" alternative. Four commuter rail lines cross Salt Creek basin. Corridors are already fairly well defined along both lines of the Chicago and North Western Railway and the Burlington Railroad line. The potential exists for development of a corridor along the Milwaukee Railroad through Bensenville, Itasca, and Roselle (fig. 51). The figure shows four areas, at present largely undeveloped, which might be acquired for open space to provide wedges between the corridors. Areas 1, 2, and 3 contain considerable muck and organic soils (fig. 4) which would place restraints on development. Area 2 is blocked to access from the east by O'Hare International Airport.

By preserving large tracts of open space, this alternative offers the greatest opportunity for land-related water-management facilities such as detention reservoirs, borrow-pit lakes, and gravel pits redeveloped for their esthetic and recreational potential. As is true with the "Multi-Towns" alternative, some redevelopment or reclamation of partially developed land would be required for optimum utilization of the open space.

Inasmuch as large tracts of land would be held out of development in the "Radial Corridor" alternative, a higher density of residential development than exists at present would be required within the corridors. These higher densities of development would result in higher land values and would tend to increase pressures for development of the flood plains. Such a tendency would be accentuated in Salt Creek basin by virtue of the fact that the corridors cross the basin perpendicular to the major drainage channels.

Careful planning and land-use control, however, could overcome this potential danger. Figure 52 shows an artist's conception of how a community with varying densities of development might be planned to avoid unwise development of the flood plain. The flood plain is reserved as open space, with recreational facilities, in areas of low and medium density. In the higher density commercial area, the flood plain is used as a parking lot. Thus, the flood plain is put to efficient use, and much of its natural storage capacity is preserved.

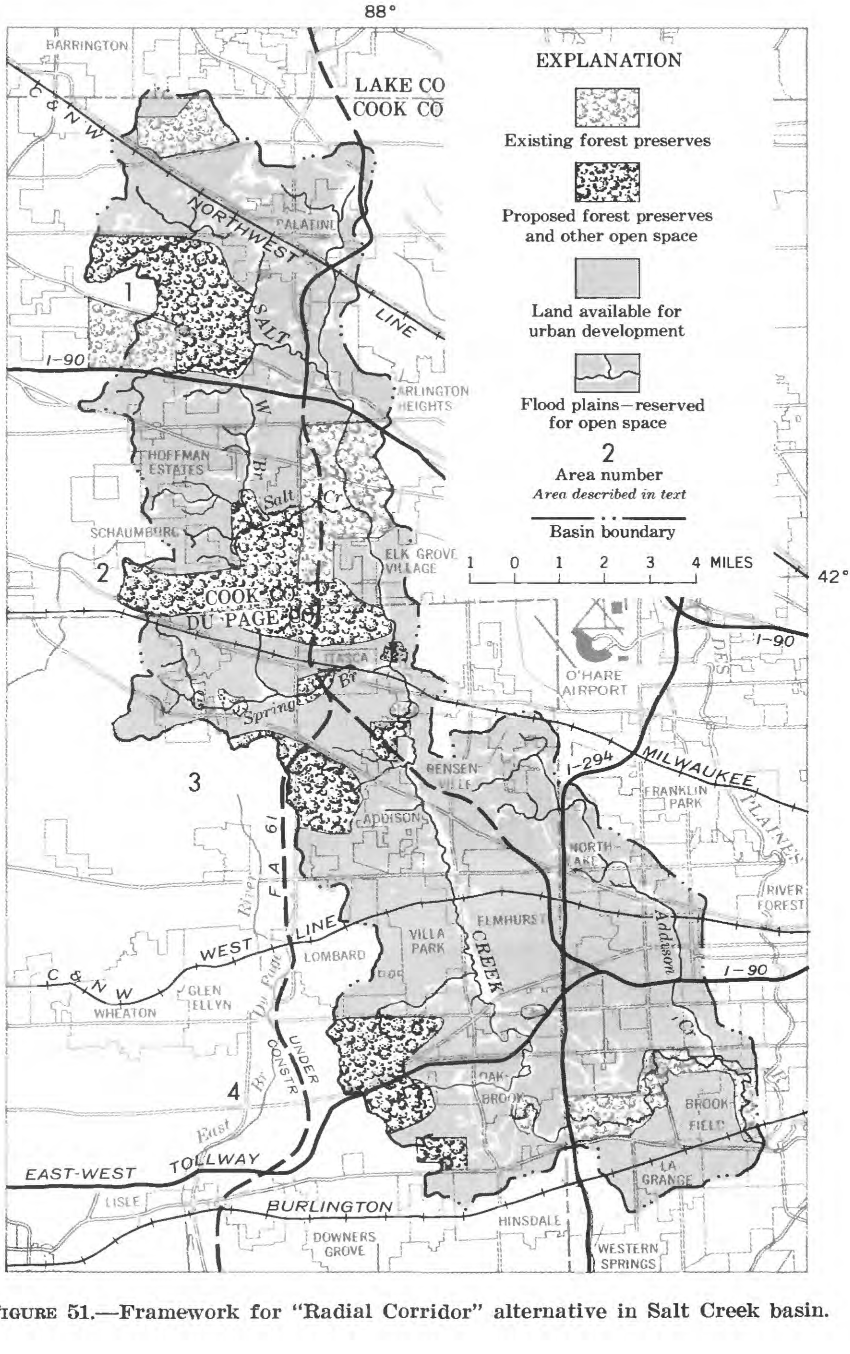


FIGURE 51.—Framework for "Radial Corridor" alternative in Salt Creek basin.

SUMMARY OF ALTERNATIVE DEVELOPMENT PATTERNS

From a realistic standpoint, future development in Salt Creek basin can be expected to follow something approaching the "Trends" alternative unless comprehensive planning is initiated and more stringent land-use controls are put in effect. The pattern of urban sprawl is already well established. To modify this pattern would require concerted, coordinated action on the part of all governmental units.

Both the "Multi-Towns" and the "Radial Corridor" alternatives offer greater opportunities for coordinated land and water management resulting from preservation of larger tracts of open space and more efficient land use. The "Trends" alternative, however, need not be regarded as the hopeless nightmare one might envision in a sprawling region developing with a total absence of planning. Some planning has already taken place. The need for open-space preservation, the danger of unwise development of flood plains, and the need for coordinated land and water management (such as more effective storm drainage systems and preservation of ground-water recharge areas) are becoming increasingly recognized. As a result, some of the desirable features of the two planned alternatives will be most likely incorporated into future development of the region.

CONCLUSIONS

Water management is an integral part of comprehensive planning for the future development of a large metropolitan area. For management to be effective, the interrelationship among the various components of the hydrologic system and their interaction with alternative land development practices must be understood. The present report uses Salt Creek basin in the northeastern Illinois metropolitan area as a study area, and emphasis is placed on such land-related water-management problems as ground-water recharge, water quality, management of the flood plains, and alternative flood-control measures. This study should be regarded as a starting point, providing a framework within which specific water-management projects can be planned and additional programs for data collection and interpretation can be carried out.

Conclusions from this study can be separated into two aspects: (1) the application of hydrologic data in urban comprehensive planning, and (2) the use of these data to evaluate the effects of alternative water-management and land-development programs, using Salt Creek basin as an example.

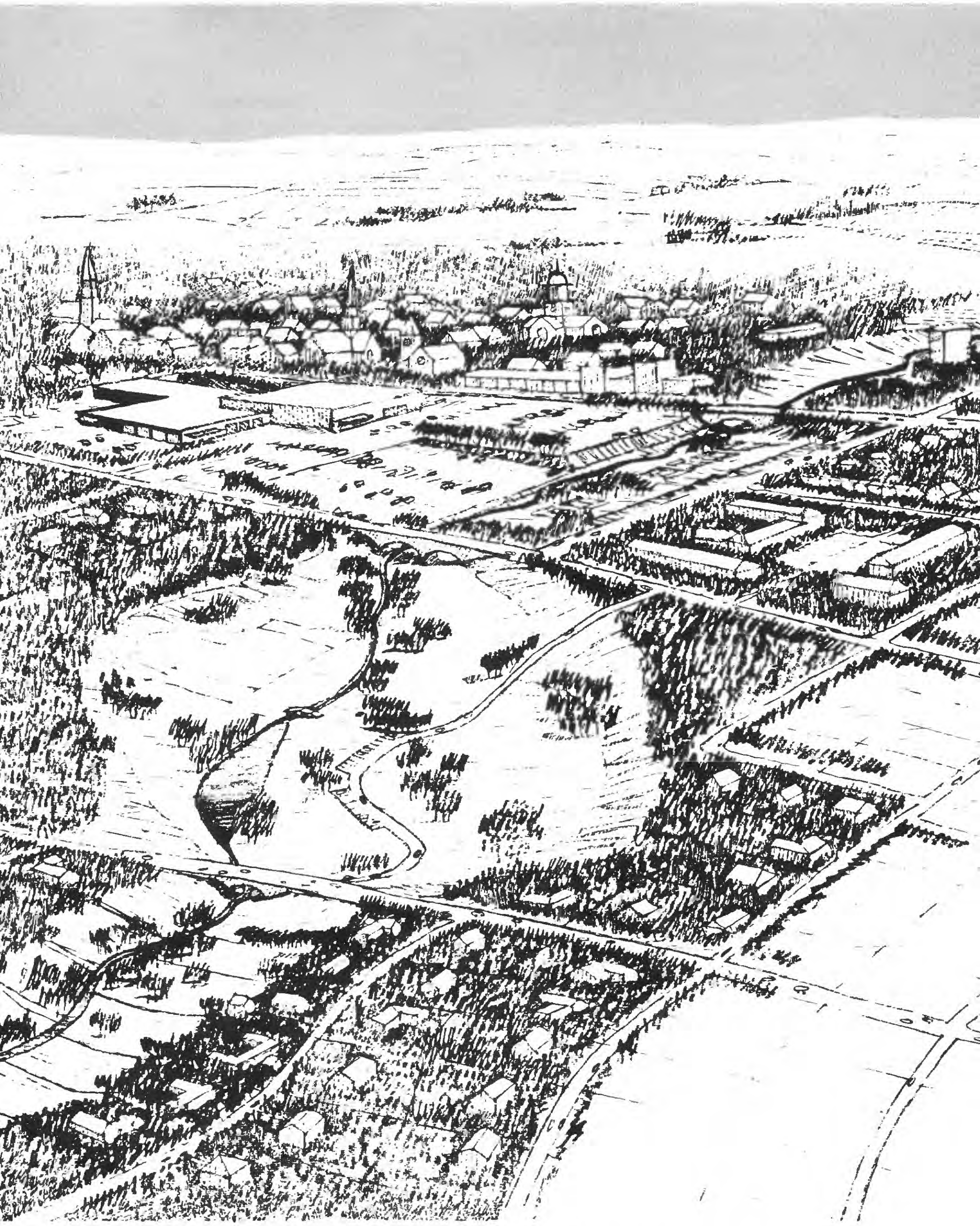


FIGURE 52.—Artist's conception of low, medium, and high density urban development around a typical flood plain.

[Courtesy of Northeastern Illinois Planning Commission.]

370-926 O—70——10

HYDROLOGIC DATA IN URBAN PLANNING

The present study has demonstrated the need for hydrologic data, both to assist in solving the water-related problems of the urban environment and to provide a sound basis for the inclusion of water-related facilities in planned urban growth. To a large extent, the kinds of data hydrologists have traditionally collected and the traditional methods of presentation of these data are not sufficient to fully meet the needs of planners. Some of these needs were met by the present study, others were only partly met, and still others could not possibly be met in a study of this scope. A summary of the data needs that became apparent in the course of this study follows. This summary is only a starting point in the study of urban hydrology and should not be regarded as an ultimate or definitive list of data needs.

Systematic and coordinated collection is needed for hydrologic data such as stream discharge measurements, ground-water levels, and water-quality analyses, to name a few. Too often in the past these data have been collected independently and haphazardly. Coordinated data collection will enable the hydrologist to better evaluate the response of the entire hydrologic system to changes imposed by the urban environment.

A greater awareness of the hydrologic impact of the urban environment is needed in planning data-collection programs. This greater awareness should influence both what kinds of data are collected and where they are collected. Changes in land-use patterns need to be documented by maps or aerial photography, in conjunction with the collection of hydrologic data, so that the hydrologic effects of these changes can be evaluated.

Hydrologic data need to be collected more intensively in areas that are not presently urbanized but are likely to become urbanized in the future, to measure the changes in the hydrologic regimen brought about by urbanization. The sites of new towns are excellent locations for such data collection. The crest-stage gage network in the northeastern Illinois metropolitan area is an excellent example of an intensive collection program in urban and urbanizing areas. The crest-stage data can be used to define changes in flood frequencies and patterns of flooding resulting from urbanization.

Changes in the hydrologic system caused by urbanization should be documented quantitatively and on maps. In addition to the usual data, such changes as modification of stream channels, encroachments on flood plains, and loss of ground-water recharge areas due to construction and paving should be measured. The use of photography, both aerial and ground based, would greatly facilitate obtaining this information.

The foregoing data needs are widely applicable in urban and urbanizing areas. One of the greatest benefits to be gained from data collection is an evaluation of the transferability of hydrologic data from one urban area to another. Whether results of data gathered in one urban environment are applicable in similar or different environments will have a major role in planning future data-collection programs.

The following are some data needs specifically applicable to Salt Creek, but whose results have considerable transfer value. The prime ground-water recharge areas need better definition so that they can be given adequate consideration in land-use plans. Additional, more closely controlled seepage runs in conjunction with ground-water and water-quality measurements are needed to define the interrelationship of surface water and ground water. Periodic synchronized sampling of water quality during floods is needed to learn of changes in water quality with respect to time which might influence treatment methods and other water-management techniques.

Data collection in urban areas should be a continuing process and should not be confined to the planning phase of urban development. Some data should be collected in the preplanning phase to serve as a base for plans. Data collection should continue during and after the plans are implemented to serve as a measure of their effectiveness.

Of equal importance as the kinds of data collected are the methods of analysis, the interpretation of data, and the presentation of results. Here again, the needs of planners may differ somewhat from the needs of engineers, who, up to the present, have been the largest users of hydrologic data. Hydrologists may need to carry their interpretations a step or two further than has been the traditional practice. For example, a map showing areal distribution of an aquifer's transmissivity and storage coefficients, parameters of significance to the ground-water hydrologist, would have little meaning to the planner. On the other hand, a map showing how much ground water can be obtained on a sustained basis would be more useful to him.

A greater use of maps would make the results of hydrologic investigations more useful to planners. In the present report, the map showing ground-water-pumping and sewage-disposal (fig. 14) sites and the map of the November 1965 seepage run (fig. 25) are examples of maps useful in planning. Flood-inundation maps are another good example. The usefulness of flood maps could be enhanced by periodic updating to show changes in the flooding pattern due to urbanization. The availability of intensive flood-stage data, such as those being obtained from the northeastern Illinois crest-stage gage network, would eventually make possible the preparation of flood-frequency maps—that is, maps showing the areas that would be inundated by floods of various recurrence intervals. Such maps would be extremely useful to planning and zoning authorities in achieving optimum utilization of the flood plains.

Other graphic presentations can be as useful as maps. Examples from the present report are the flow-duration curves (figs. 17, 18), broken down into 4-year periods, showing changes in the low-flow regimen caused by urbanization. The graphs showing downstream changes in water quality under various flow conditions (figs. 28, 29, 30) would be useful in planning for new or improved sewage-disposal facilities. Systematic collection of water-quality samples would make possible the preparation of statistical graphs showing the percentage of time given concentrations of various constituents are exceeded.

The foregoing summary is far from a definitive statement on needs for hydrologic data in planning. As more is learned about water in the urban environment, the needs for heretofore unknown or overlooked forms of data and techniques of presentation will probably become apparent.

WATER MANAGEMENT IN SALT CREEK BASIN

Selection of Salt Creek basin as a study area does not necessarily imply that water management in a metropolitan area should be planned on a basin-by-basin basis. Salt Creek basin was selected because of its convenient size for such a pilot study, its widespread public interest, and the relative abundance of data it provided. Salt Creek basin offers in one compact area many of the problems and opportunities for land-related water management in the rapidly expanding suburbs of the Nation's large metropolitan areas. It is hoped that the principles developed in this study can be applied in other areas and that the problems identified will lead to more comprehensive programs of investigation to provide the required additional data.

Urbanization has had its impact on the flow characteristics of Salt Creek. Most of the low flow consists of sewage effluent. Low flow has increased in the lower reaches as a result of increasing sewage loads from treatment plants in Du Page County. Transfer of most sewage in northwest Cook County in 1958 to the Metropolitan Sanitary District's plants outside the basin has resulted in a sharp reduction of low flow in Salt Creek's upper reaches. Periods of high flow appear to have been shifting toward higher intensity but shorter duration as a result of larger and more numerous storm-drainage systems and paving of much of the previously permeable terrain.

Most communities in Salt Creek basin depend on ground water for their public supplies. Both the shallow and the deep aquifers are used.

The shallow aquifers are recharged locally. The greatest concentration of pumping from the shallow aquifers is in the Hinsdale–La Grange area. Here the shallow dolomite aquifer is near the surface, and in places, particularly east of Hinsdale, a good hydraulic connection appears to exist between Salt Creek and the aquifer. The potential for induced recharge and artificial recharge operations exists generally along the course of Salt Creek south of Elmhurst. Detailed studies are needed to determine the most favorable specific sites.

Salt Creek carries significant pollution loads at all times. Details as to the sources and exact nature of the pollutants remain to be determined. Some pollutants, as indicated by the presence of coliform bacteria, appear to be more abundant at high flow than at low flow. This phenomenon may be due to untreated effluent from combined sewer systems, to the agitation of accumulated sludge deposits in the streambed, and to flushing of accumulated wastes from the land surface. These sludge deposits appear to be so widespread and abundant that periodic floods are not sufficient to cleanse the streambed. Traces of pollutants, probably induced from Salt Creek, have been detected in a well in Hinsdale. The extent of and potential for ground-water pollution need to be investigated, especially where ground-water supplies in the shallow aquifer are recharged by surface water.

About 10 percent of the land in Salt Creek basin consists of flood plains. The pressures of urbanization have brought about some development of these flood plains, which has proved to be uneconomical because of later substantial flood damages. The flood plains need not be kept entirely out of use, however. Some of Salt Creek's flood plains and their surrounding forested areas have been reserved as greenbelts, providing needed land for recreation and enhancing the environment in the metropolitan area. Other economic uses of the flood plains include controlled development of flood-proofed commercial and industrial buildings and provision for artificial storage to make up for the lost natural capacity to store floodwaters. Part of the flood plains constitute prime ground-water recharge areas. Further investigation is needed to identify the exact location and extent of these recharge areas. Comprehensive planning should provide for the preservation of these areas, which are likely to become even more important as urban development places greater demands on the ground-water resource.

Flood-control measures are necessary in some situations to protect existing developments on the flood plains. Owing to the high value of land in urban areas, controlled development of the flood plains and their protection by flood-control works may be more economical than prohibiting all development. In the past, the most common approach to flood control in urban areas has consisted of enlarging the channel to accommodate flood runoff. This procedure results in greater stream velocities and higher discharge rates and transfers the flooding problem to downstream areas, which themselves are becoming urbanized and losing their storage capacity. Channeling also may cause damage to the remaining forested land in the metropolitan areas.

Flood-control measures which seek to retain water in the drainage basin rather than dispose of it offer greater water-management opportunities than the traditional channeling approach. Floodwaters can be retained, for example, for ground-water recharge; channeling would result in these waters being removed from the basin faster than the materials of the streambed could absorb them.

One good valley reservoir site remains along the main stem of Salt Creek at the Ned Brown Forest Preserve near Elk Grove Village. Development of a multipurpose reservoir here would provide significant flood-control benefits and offer much-needed facilities for water-oriented recreation.

There are means of developing upstream storage facilities other than valley reservoirs, however. Upground reservoirs and smaller facilities, such as farm ponds and detention basins on parking lots and rooftops, can contribute to the storage of floodwaters. Where space is scarce, several well-distributed smaller facilities can provide the same capacity as one or two larger ones. Abandoned gravel pits and quarries can be put to use as detention facilities. A concept now being advanced is the use of underground tunnels for storage of floodwaters. Although this approach has not yet been tried in the northeastern Illinois metropolitan area, the possibility appears attractive in view of the scarcity and high land costs of suitable surface reservoir sites. Safeguards would have to be provided against ground-water pollution if such a tunnel scheme were implemented.

The reclamation of flood plains developed with marginal or substandard buildings and the redevelopment of these flood plains as parks or recreational facilities offer interesting possibilities for future consideration. Federal assistance could be made available for such projects through Urban Renewal and Open Space Acquisition Programs, administered through the Department of Housing and Urban Development.

Comprehensive land-use plans which incorporate stringent land-use controls and provide for the acquisition of large tracts of open space would provide more opportunities for water management than a continuation of the present trend toward more uncontrolled urban sprawl. Thus, the "Radial Corridor" alternative, with its broad wedges of open space preserving much of the flood plain area, would offer the greatest opportunity. The "Multi-Towns" alternative, which provides for preservation of most of the flood plains, would offer more water-managment opportunities than the "Trends" alternative, though somewhat fewer than the "Radial Corridor" alternative.

This study has stressed the interrelationships of comprehensive land-use planning and the hydrologic system and has demonstrated how effective use of the flood plains, preservation of ground-water recharge areas, and maintenance of surface and ground waters of satisfactory quality can be important elements in a comprehensive metropolitan plan. Salt Creek basin in northeastern Illinois has served as an example. The concepts presented here and the identified needs for additional data and studies can provide a starting point for effective water management that is coordinated and integrated with comprehensive urban planning in northeastern Illinois and other metropolitan areas.

ACKNOWLEDGMENTS

This report was prepared in 1966 and 1967 by the U.S. Geological Survey under the supervision of W. D. Mitchell, district chief, and in cooperation with the Northeastern Illinois Planning Commission, M. L. Rockwell, executive director. The author worked in close cooperation with the staff of the Planning Commission and wishes to thank in particular three former staff members who actively participated in planning the investigation, interpreting data, and generating ideas. These former staff members are John R. Sheaffer, Arthur J. Zeizel, and James G. Schrader. The data concerning population, land use, and future development patterns were provided by the Northeastern Illinois Planning Commission.

This report would not have been possible without the abundant data and information freely made available by many governmental agencies and individuals. Data on ground-water hydrology and chemical analyses of water samples were provided by the Illinois State Water Survey. The author wishes in particular to thank Richard J. Schicht and Robert T. Sasman of the State Water Survey for their assistance in providing data. The geological information was provided by the Illinois State Geological Survey through James E. Hackett, formerly geologist in charge of the Naperville office. Ronald J. Landon, formerly of the State Geological Survey, prepared the material on which figures 12, 21, and 22 are based. The bacterial and some of the chemical analyses of Salt Creek were run by the Illinois Sanitary Water Board. These samples were collected by Emil Oelberg of the Du Page County Health Department. Robert H. Montgomery of the U.S. Soil Conservation Service prepared the soils map of Salt Creek basin. The Division of Waterways of the Illinois Department of Public Works and Buildings made available specifications for their channel improvement plan for Salt Creek.

The author also thanks Roland Eisenbeis, superintendent of conservation, and Charles C. Estes, chief engineer of the Cook County Forest Preserve District, and C. Howard Johnson, superintendent of the Du Page County Forest Preserve District, for information concerning existing and planned open-space acquisition projects in their respective counties.

Flow-duration curves for Salt Creek were prepared by Oscar G. Lara of the U.S. Geological Survey.

Information concerning the proposed Busse Woods and Itasca reservoirs was provided by W. J. Bauer of Bauer Engineering, Inc., Chicago. The information about the residential development on the flood plain of Sugar Creek at Villa Park was made available by Thomas A. Mass, Jr., attorney, Chicago. Most of the information on reclamation of flood plains through urban renewal projects was obtained through the courtesy of Carl Landino of Urban Planning Consultants, Chicago.

SELECTED REFERENCES

American Society of Planning Officials, 1966. Montgomery County sediment control program: Am. Soc. Planning Officials Newsletter, August 1966.

Bauer, W. J., 1962, Busse Woods Forest Preserve reservoir on Salt Creek: Chicago, Bauer Engineering, Inc., report to the Cook County Forest Preserve District, 22 p., 9 figs.

———1965, Village of Itasca lake development studies: Chicago, Bauer Engineering, Inc., report to the village of Itasca, 23 p., 5 figs.

Burnham, D. H., and Bennett, Edward, 1909, Plan of Chicago: Chicago, The Commercial Club, 164 p.

City of Chicago, 1967, The Chicago underflow plan for flood and pollution control: Chicago Dept. Public Works Bur. Eng., 34 p., 12 figs.

Cohen, Philip, Franke, O. L., and Foxworthy, B. L., 1968, An Atlas of Long Island's water resources: New York Water Resources Comm. Bull. 62, 117 p.

Consoer, Townsend, and Associates, 1959, Flood control survey and report for Salt Creek: Chicago, Consoer, Townsend, and Associates Report to the Cook County Forest Preserve District, 14 p., 16 pls.

Dugan, H. G., 1949, Village on the county line—A history of Hinsdale, Illinois: Hinsdale, Ill., Friends of the Library (privately printed), 202 p.

Harza Engineering Co., and Bauer Engineering, Inc., 1966, Flood and pollution control—A deep tunnel plan for the Chicagoland area: Chicago, Report to the Metropolitan Sanitary District of Greater Chicago, 73 p., 11 exhibits, 7 appendixes.

Hoyt, W. G., and Langbein, W. B., 1955, Floods: Princeton, N.J., Princeton, Univ. Press, 469 p.

Illinois Division of Waterways, 1958, Report on plan for flood control and drainage development—Salt Creek, Cook and Du Page Counties: Illinois Dept. Public Works and Bldgs., Div. Waterways, 38 p., 26 pls.

——— 1967, Supplement report, 1967 plan for flood control and drainage development—Salt Creek, Cook and Du Page Counties: Illinois Dept. Public Works and Bldgs., Div. Waterways, 13 p., 2 figs.

Illinois State Water Survey, 1958, Water resources and climate, sec. 1 of Atlas of Illinois resources: 58 p.

Leopold, L. B., and Maddock, Thomas, Jr., 1954, The flood control controversy: New York, Ronald Press Co., 278 p.

McDonald, C. K., and Sasman, R. T., 1967, Artificial ground-water recharge investigations in northeastern Illinois: Ground Water, v. 5, no. 2, April 1967, p. 26–30.

Northeastern Illinois Planning Commission, 1965, A report on forest preserves, Du Page County: Chicago, 61 p.

——— 1967, Diversity within order—Coordinated development for a better environment: Chicago, 106 p.

——— 1968, The plan study—methodology (Metropolitan planning guidelines, phase two, the comprehensive plan): Chicago, 146 p.

Pearson, G. R., 1962, Flood plain encroachment—A factor of growing concern in the national program of flood damage reduction: Evanston, Ill., Northwestern Univ., Master's thesis in civil engineering, 110 p.

Prickett, T. A., Hoover, L. R., Baker, W. H., and Sasman, R. T., 1964, Ground-water development in several areas of northeastern Illinois: Illinois State Water Survey Rept. Inv. 47, 93 p.

Sasman, R. T., 1965, Ground-water pumpage in northeastern Illinois through 1962: Illinois State Water Survey Rept. Inv. 50, 31 p.

Sheaffer, J. R., 1967, Introduction to flood proofing: Univ. Chicago Center for Urban Studies, 61 p.

Sheaffer, J. R., Ellis, D. W., and Spieker, A. M., 1970, Flood hazard mapping in metropolitan Chicago. U.S. Geol. Survey Circular 601–C, 14 p.

Sheaffer, J. R., von Boehm, Berndt, and Hackett, J. E., 1963, Refuse disposal needs and practices in northeastern Illinois: Northeastern Illinois Planning Comm. Tech. Rept. 3, 72 p.

Sheaffer, J. R., and Zeizel, A. J., 1966, The water resource in northeastern Illinois—Planning its use: Northeastern Illinois Planning Comm. Tech. Rept. 4, 182 p.

Suter, Max., Bergstrom, R. E., Smith, H. F., Emrich, G. H., Walton, W. C., and Larson, T. E., 1959, Preliminary report on ground-water resources of the Chicago region, Illinois: Illinois State Geol. Survey and Illinois State Water Survey Cooperative Rept. 1, 89 p.

Todd, D. K., 1959, Ground-water hydrology: New York, John Wiley & Sons, 336 p.

[U.S.] Committee on Intergovernmental Relations, 1963, Performance of urban functions—Local and areawide: Washington, U.S. Advisory Com. Intergovernmental Relations Pub. M–31, 281 p.

U.S. Dept. Agriculture, 1968, Salt Creek Watershed, Cook and Du Page Counties, Illinois (preliminary investigation report): Champaign, Ill., Soil Conservation Service, 62 p.

Weibel, S. R., Anderson, R. J., and Woodward R. L., 1964, Urban land runoff as a factor in stream pollution: Jour. Water Pollution Control Federation, v. 36, no. 7, p. 914–924.

White, G. F., 1964, Choice of adjustment to floods: Chicago Univ., Dept. Geography Research Paper 93, 150 p.

White, G. F., Calef, W. C., Hudson, J. W., Mayer, H. M., Sheaffer, J. R., and Volk, D. J., 1958, Changes in urban occupance of flood plains in the United States: Chicago Univ Dept. Geography Research Paper 57, 235 p.

Zeizel, A. J., Walton, W. C., Sasman, R. T., and Prickett, T. A., 1962, Ground-water resources of Du Page County, Illinois: Illinois State Geol. Survey and Illinois State Water Survey Cooperative Rept. 2, 103 p.

INDEX

[Italic page numbers indicate major references]