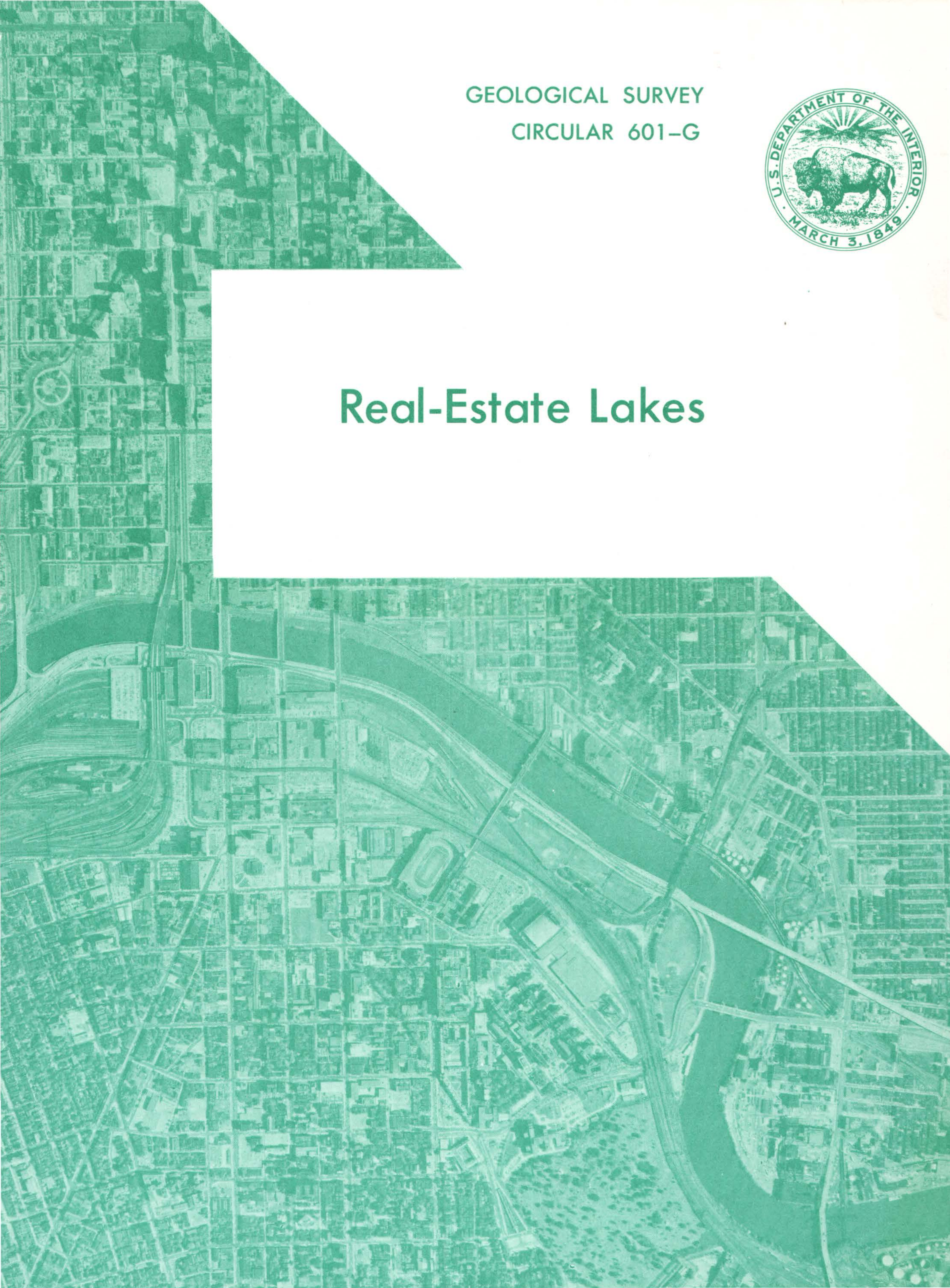

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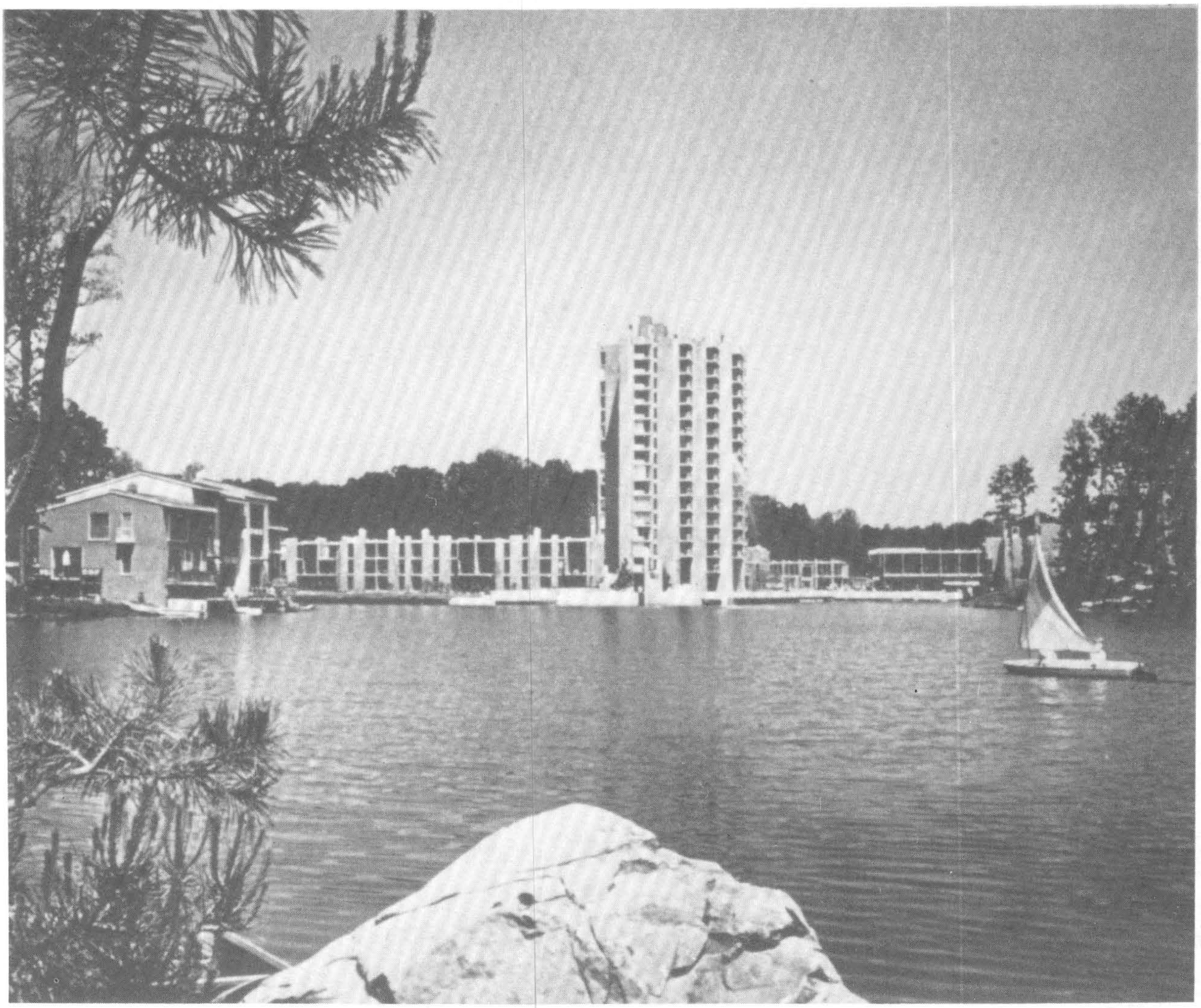
Real-Estate Lakes

REAL-ESTATE LAKES



Real-estate lakes can increase the value and enjoyment of our urban outdoors. (Photograph by William A. Graham.)

Real-Estate Lakes

By David A. Rickert and Andrew M. Spieker

WATER IN THE URBAN ENVIRONMENT

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FOREWORD

Urbanization—the concentration of people in urban areas and the consequent expansion of these areas—is a characteristic of our time. It has brought with it a host of new or aggravated problems that often make new demands on our natural resources and our physical environment. Problems involving water as a vital resource and a powerful environmental agent are among the most critical. These problems include the maintenance of both the quantity and quality of our water supply for consumption, for recreation, and general welfare and the alleviation of hazards caused by floods, drainage, erosion, and sedimentation.

A prerequisite to anticipating, recognizing, and coping intelligently with these problems is an adequate base of information. This series of reports is intended to show the relevance of water facts to water problems of urban areas and to examine the adequacy of the existing base of water information.

E. L. Hendricks

E. L. Hendricks,
Chief Hydrologist

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INTRODUCTION

Since the dawn of civilization waterfront land has been an irresistible attraction to man. Throughout history he has sought out locations fronting on oceans, rivers, and lakes. Originally sought for proximity to water supply and transportation, such locations are now sought more for their esthetic qualities and for recreation. Usable natural waterfront property is limited, however, and the more desirable sites in many of our urban areas have already been taken. The lack of available waterfront sites has led to the creation of many artificial bodies of water.

The rapid suburbanization that has characterized urban growth in America since the end of World War II, together with increasing affluence and leisure time, has created a ready market for waterfront property. Accordingly, lake-centered subdivisions and developments dot the suburban landscape in many of our major urban areas. Literally thousands of lakes surrounded by homes have materialized during this period of rapid growth. Recently, several "new town" communities have been planned around this lake-centered concept.

A lake can be either an asset or a liability to a community. A clean, clear, attractively landscaped lake is a definite asset, whereas a weed-choked, foul-smelling mudhole is a distinct liability. The urban environment poses both problems and imaginative opportunities in the development of lakes. Creation of a lake causes changes in all aspects of the environment. Hydrologic systems and ecological patterns are usually most severely altered. The developer should be aware of the potential changes; it is not sufficient merely to build a dam across a stream or to dig a hole in the ground. Development of a successful lake requires careful planning for site selection and design, followed by thorough and continual management.

The purpose of this report is to describe the characteristics of real-estate lakes, to pinpoint potential problems, and to suggest possible planning and management guidelines for their solution. It is not intended as a construction manual nor is it intended to supplant on-site engineering planning. Rather, the report is an appraisal of the wide range of potential water and water-related problems that arise in making real-estate lakes attractive visually and functional environmentally. It is written to acquaint developers, property owners, and citizen groups with these problems so that they may be more knowledgeable in seeking adequate planning and engineering advice. The report should also be useful to various regulatory agencies because it relates lake problems to basic hydrologic components.

Most of the general information in this report was obtained from the 47 district offices of the Water Resources Division, U.S. Geological Survey. Detailed information on specific hydrologic problems came largely from a continuing study of the effects urbanization has had on real-estate lakes. Additional detailed information was provided by several short-term studies conducted by local Survey offices expressly for this report.

TYPES AND CHARACTERISTICS OF REAL-ESTATE LAKES—WHAT IS A REAL-ESTATE LAKE?

A real-estate lake, for the purposes of this report, is any body of water in the urban environment created or developed for the enhancement of real-estate value. Most real-estate lakes were built in conjunction with urban development. Some, however, were in existence long before they became surrounded by urbanization. Many farm ponds have become real-estate lakes as urban sprawl has engulfed agricultural land. Water-supply reservoirs have on occasion been converted into real-estate lakes. Lake Barcroft in Fairfax County, Va., was formerly a reservoir for the Alexandria municipal water supply. In 1950 its use for water supply was discontinued, and it was sold to a developer. The lake is now surrounded by high-quality residences, some of them valued at more than $100,000.

Real-estate lakes may range in size from small ponds of an acre or less to considerably larger lakes, some measuring several hundred acres in area. The most common sizes range from 5 to 50 acres. Typical lakes are surrounded by single-family dwellings, usually on quarter-acre or half-acre lots, but some lakes are surrounded by a mixture of single-family units, townhouses, and apartments. Lake Anne at Reston, Va., and Lake Kittamaqundi at Columbia, Md., are built as the focus of town activity and are surrounded by residential and commercial developments.

A few real-estate lake developments are rather unusual departures from the common methods of development. The Washingtonian, a development north of Rockville, Md., consists of a high-rise apartment building located beside a small lake that is in the middle of a golf course. Four Lakes, an apartment complex west of Lisle, Ill., is built around four abandoned limestone quarries. The lakes are used for swimming, boating, and water skiing in summer and for ice skating in winter.

HOW REAL-ESTATE LAKES ARE MADE

A lake can be created by either of two means, or by a combination of the two. The most common way is to impound a stream with a dam. An impoundment requires some topographic relief, either natural or artificial (relief can be created in flat terrain by diking and filling). Impounded lakes abound in the suburbs of many cities which have humid climates and rolling or hilly terrains. This type of artificial lake is very common in the Washington-Baltimore area.

In areas where terrain is flat and the water table is high, lakes can be created by excavating below the water table. Many lakes have been developed from borrow pits used for fill in highway construction or from abandoned gravel pits and rock quarries. Excavated lakes are most common in the flat glaciated terrain of the Midwest and in the Atlantic and Gulf Coastal Plains.

PURPOSES AND USES OF REAL-ESTATE LAKES

Real-estate lakes are created for three basic reasons: property value enhancement, esthetic attractiveness, and water-oriented recreation. In a sense the first reason underlies the other two. When any developer plans and builds a lake, he does so basically to increase the value of his property. Its value is increased largely as a result of the added attractiveness and recreational opportunities. Furthermore, a lakeside residence has a certain "status value" in our society.

Lakefront property indeed does have a higher monetary value than nonlakefront property (David, 1968). At Lakewood, a development near Des Moines, Iowa, for example, typical lakefront homes sold for $25,000 to $35,000, and most of them were close to the higher figure; similar homes located away from the lake sold for $17,500 to $25,000. The value of a lakeside location to both the developer and the resident is self evident.

A clear, blue lake surrounded by green forest and grass can be one of the most visually pleasing features of the urban and suburban landscape. A lake provides a pleasing accent in the suburban environment, and with resourceful planning, it is possible to create a lake with esthetic quality even in the urban environment.

Water-oriented recreation has become increasingly popular in recent years as a result of increasing affluence and leisure time. Swimming, boating, fishing, and, in the winter, ice skating are some of the activities that lure potential homeowners to lake-centered communities. Because these activities are not always compatible, however, conflicts may develop which require some sort of control. In fact, intensive recreational use, such as large numbers of motorboats on a small lake, can detract from the very esthetic values which attracted many homeowners in the first place.

CLIMATE AND GEOGRAPHY INFLUENCE LOCATIONS

Real-estate lakes are not found in all parts of the United States. As a rule, they are confined to the more humid parts of the country, that is, to those areas which receive an average of 30 or more inches of rainfall annually. They are virtually nonexistant in the arid Southwest. The greatest concentration is in the East and Midwest. Some are found on the West Coast.

The few real-estate lakes found in California and other semiarid to arid environments are largely excavated water-table lakes. Impounded lakes are rare in these areas because of the scarcity of perennial streams. Any impounded real-estate lake in such a climatic environment would probably be dry for more than half the year. Lake Lagunita, an impounded lake of about 150 acres on Los Trancos Creek, Stanford University Campus, Palo Alto, Calif., fills during the rainy winter season—from about December to March. During the spring it is used for such recreational activities as canoeing and sunbathing and hiking. By summer, the lake is dry. Lake Lagunita is not, strictly speaking, a real-estate lake, but its regimen illustrates the problems of impounded lakes in semiarid to arid areas having a pronounced pattern of seasonal rainfall.

The abundance of natural lakes in certain areas of the United States, especially in northern New England, upper New York State, northern Michigan, Wisconsin, Minnesota, and Florida, provides sufficient natural lakes for real-estate development, so artificial lakes are seldom needed. Florida, however, also has an abundance of artificial lakes that have been built to fill the need created by the Floridian life style, which places heavy emphasis on recreation and the outdoor life.

PLANNING OF REAL-ESTATE LAKES

A successful real-estate lake requires (1) careful planning prior to construction and (2) thorough management after it is built. Unless planning and management are well conceived and coordinated, problems will inevitably develop.

The more important planning considerations for real-estate lakes are discussed as two categories: (1) regional and (2) local, or onsite.

REGIONAL CONSIDERATIONS

"BLUE-GREEN" DEVELOPMENT

In most conventional urban developments, the land is stripped of much of its vegetation and divided into rectangular lots in a regular grid pattern. This method of development obliterates many of the smaller natural drainage channels, and they must be replaced by enclosed storm sewers. While the storm sewers are generally adequate to handle the runoff from minor and moderate storms, the sewers overflow during the occasional severe storm and flood streets and basements.

Planners and engineers have come to recognize that preserving the natural drainage is in many places preferable to replacing it with enclosed storm sewers, for the natural channels can accommodate more runoff during extreme storms than the artificial storm drainage. Also, as a result of increasing concern over quality of the environment, urban planners have been breaking away from the former patterns of development. Many now advocate the preservation of as much as possible of the natural environment—in particular, the trees, the natural ground cover, and natural drainage patterns. The preservation of *open space* to break the monotony of urban sprawl is becoming more commonly used in urban design.

The concept of "blue-green" development not only enhances the quality of the urban environment, but at the same time provides for more effective storm drainage. "Blue-green" development is the "planned integration of permanent water areas in open spaces, with provision for flood storage" (Jones, 1967, p. 60). Rather than constructing large artificial drainage channels in urbanizing areas, the developer preserves the natural drainage channels and flood plains and creates artificial lakes by impoundment or by a combination of impoundment and excavation. These lakes serve the purposes of providing recreation, an esthetically pleasing environment, and space for the temporary storage of storm runoff. Temporary storage eases the demand on storm-drainage capacity and often results in systems which are considerably less costly than those designed by conventional means.

Use of the "blue-green" concept in new communities affords numerous opportunities for developers to plan lake-centered residential developments. By thus coordinating real-estate lake developments with the natural drainage system, the developer may avoid many of the potential pitfalls of unplanned or haphazard lake development.

RECLAIMING ABANDONED QUARRIES AND PITS—SEQUENTIAL DEVELOPMENT

Bulk construction materials such as earthfill, crushed rock aggregate, and sand and gravel are in great demand in urban areas. The cost of these bulk materials increases greatly if they must be hauled long distances. Long hauls are becoming increasingly common, however, because valuable deposits are being covered by urban development and are thus lost for use. Sand and gravel are particularly scarce in some areas.

Urbanization can take place without the loss of these construction materials if thoughtful planning precedes development. The appropriate planning strategy is known as *sequential use* of land, and real-estate lakes can play an important role in its realization. An abandoned pit or quarry is an eyesore and detracts from land values in its vicinity. In areas where the water table is near the land surface, these abandoned pits contain water. With landscaping and a little imagination, they can be converted into esthetically pleasing real-estate lakes, and the surrounding land can be developed for urban use. If sequential use of land is applied, a developer can first profit from sale of the construction materials and then profit from selling the land for residential development. Thus sequential land development should be a desirable investment.

A regional appraisal of mineral resources and ground water should be made prior to sequential land development in order to facilitate the effectiveness of such development. Areas underlain by recoverable construction materials and areas with a high water table need to be defined. Areas where these two characteristics coincide will be suited for sequential land use ending in real-estate lake development.

POLLUTED STREAMS

A real-estate lake, to be successful, must be esthetically pleasing and must provide opportunity for recreation. Thus the water must be of good quality and free of harmful pollutants. It follows that the source of water for impoundment in the lake must be relatively pure and uncontaminated. Polluted streams cannot be developed into successful real-estate lakes. In fact, lakes serve as traps for nutrients and sediments, so the very development of a lake on a polluted stream will serve to intensify the degree of pollution. Pesticides and toxic metals are a further concern, for these materials are concentrated by adsorption on sediments and by biological magnification in the food chains.

In an urbanized area, a pollutional survey is necessary to determine which streams are suitable for real-estate lake development. A regional survey of a watershed should be made to locate the sources—both existing and potential—of pollution. Streams which receive significant quantities of sewage effluent are obviously poor choices for development of real-estate lakes. Similarly, streams which receive large quantities of storm runoff from heavily urbanized areas may also be poor choices. If an urban area contains waste-generating industries and a high population density, the storm runoff to streams may be more heavily polluted than sewage effluent and sometimes even more polluted than raw sewage. Suburban and rural streams which drain heavily fertilized croplands and lawns are also poor choices for lake development. Streams which are suspect should be studied in detail to determine the level of nutrient loading.

A further regional consideration is the future development potential of the area above the lake site. Intense urban development at a future date would probably contribute pollution to the lake. The undesirable deterioration might lead to costly management or possibly result in loss of the lake for the intended purposes of esthetics and recreation.

SITE SELECTION

Site selection is perhaps the most important planning consideration in the development of a lake-centered community. Drainage area should be adequate to supply the necessary water, and relief and slope should be sufficient to provide an appropriate depth and surface area. Also of prime consideration is the esthetic appeal of the site. Hilly, wooded areas or those with exceptional panoramic views are especially desirable.

It is impossible to set adequate rule-of-thumb guidelines for the size of drainage area needed to sustain an artificial lake. The minimum satisfactory size from place to place depends upon such factors as rainfall, topography, geology, and soils. For example, in the humid climate of North Carolina, a lake covering 5 to 7 acres generally requires a supporting drainage area of 25 to 30 acres; a ratio of about 5 to 1 (Burby, 1967). However, in parts of the Piedmont in Virginia, a ratio as high as 20 to 1 is sometimes necessary. Much larger ratios are required in less humid areas.

The inflow that can be expected at a potential site can be computed from data on runoff, precipitation, and evapotranspiration. Such data are available from the U.S. Geological Survey, the U.S. Weather Bureau, or the U.S. Soil Conservation Service. Real-estate lakes, however, need not depend entirely on natural inflow. Lake levels can be maintained by supplying water from other sources, notably from municipal supplies or from wells. To do so, however, may be costly, and the increase in cost must be considered in the planning. These aspects are discussed in more detail in the section "Model For Real-Estate Lake Planning and Management."

LOCAL OR ONSITE CONSIDERATIONS

INCOMPATIBILITY OF USES

Planning for a real-estate lake should include careful consideration of the purposes and uses of the lake, for some uses may not be compatible with others. One purpose common to all real-estate lakes is the creation of an esthetically attractive environment. The value of the surrounding area is greatly enhanced by the beauty of a lake. A lake is a fragile ecosystem, however, and intensive lake use and overdevelopment of shoreline property are certain to disrupt the system. Eventually, the ecological disruption will blight the very esthetic qualities which initially induced the overuse.

From the outset, intended purposes and use of the lake need to be identified and ranked in priority. Regulations must then be designed to enforce protection of the priority usage. For example, if esthetic appearance is important, regulations banning the use of outboard motors on boats might be necessary.

Two-cycle outboard motors are a source of oil and gasoline pollution. Once in a lake, a small amount of oil can spread into a thin unsightly film across an extensive area of lake surface. Moderate amounts of petroleum products can upset the entire ecological balance of a lake. In addition, the noise assault created by outboard motors diminishes the esthetic quality of a small lake.

Some incompatibilities between esthetic quality and lake uses are less obvious but far more difficult to reconcile. Fishing is a high priority use for real-estate lakes. Fish require food, however, and most new lakes lack the biological productivity needed to support a large fish population. Plant nutrients in the form of commercial fertilizer can be added to a lake to stimulate production of the small organisms which fish feed upon. Unfortunately, these same nutrients accelerate eutrophication and contribute to the growth of aquatic weeds and unwanted forms of algae.

Eutrophication is a natural aging process that affects every lake from the day of its formation. Real-estate lakes, because of their nature and manner of creation, are more susceptible to eutrophication than are most natural lakes. In fact, much of the work involved in the planning and the management of a real-estate lake is devoted to preserving the esthetic quality of the lake. Intentional enrichment is incompatible with this goal, for enrichment accelerates the aging process and thus shortens the time span over which the lake can be maintained in a state of high esthetic quality.

Not only are esthetic appearance and recreational use sometimes incompatible, but several recreational uses of real-estate lakes may conflict with each other. Possible conflicting uses include boating versus swimming, fishing versus water skiing, and motorboating versus canoeing and sailing. Planning of desired uses during the design and creation of the lake can eliminate many of the problems which might arise in later years.

EROSION AND SEDIMENTATION

The Problems

The erosion-sedimentation cycle is the most widespread problem with real-estate lakes. Normal background erosion aggravated by both small- and large-scale construction yields a ready supply of transportable sediment in a new development. The rapid increase of sediment carried by streams during land development is primarily the result of the earth moving involved in grading, road building, and installation of utilities. The earthwork is normally done in the most expedient manner without concern for loss of material from the site or subsequent damage to downstream property. After each rainstorm the streams and lakes in most new developments are stained by their loads of sediment. The greatest amount of sediment is deposited at the times of heavy storm runoff. Normal streamflow contributes only a small portion of the total sediment load to most real-estate lakes.

Following a rainstorm, a real-estate lake can remain muddy for many days. Because the muddy appearance reduces the esthetic value of the lake and the selling power of the property, it results in a monetary loss. Potentially, however, a far greater monetary loss can result from sediment deposition. Sediment removal operations are costly, but in their absence sediment often accumulates to form unsightly mudflats and sometimes accumulates rapidly enough to fill the entire lake. A sediment-choked lake is shown in figure 1. When a lake reaches this condition, it may be more of a detriment than an asset to a real-estate community.

Large lakes in large developments generally have the greatest problems with sediment accumulation. The drainage area of a large real-estate lake is usually larger than the actual development. Riparian rights aside, the owners have little means of controlling erosion and sediment on outside property. Even when the entire drainage basin is owned, lakes in the larger developments generally have greater sediment problems because of the methods usually employed in real-estate lake development. Generally, the larger the development, the larger the area graded at one time and the longer the period the graded areas are left exposed to the forces of erosion.

Controls

Sediment-control planning can encompass a large number of separate and integrated concepts. The most basic concept, and the one of first importance, is the prevention of soil erosion. The most fundamental plan for preventing erosion is development zoning based on the potential erodibility of the landscape. Erodibility maps can be prepared for any area by combining information on landscape slopes with information on the properties of the surficial geologic material. Once prepared, the map can be used to assess what type and density of development each parcel of land can accommodate without being exposed to severe erosion. In this manner, most of the natural landscape can be preserved, and rapid sedimentation of the lake can be prevented.

Sedimentation problems during development can be greatly reduced by doing a large part of the heavy earthwork prior to construction of the lake. It is generally preferable to complete the heavy grading, the installation of sewerlines and gas lines, and the building of roads, parking lots, and walkways before the lake is created. Initially this practice might reduce the selling power of the property, but, in the long run, it should provide for a more trouble-free lake and greater property value.

The planning and design of the configuration of land around a lake's shoreline is an important factor in preventing soil erosion. Gentle slopes are generally

Figure 1.—Sediment accumulation, the most common problem of real-estate lakes, can turn lakes into mudflats. (Photograph courtesy of Soil Conservation Service.)

preferable, because steep slopes are susceptible to erosion by wave action and overland flow. Steep slopes are likely to cause both a maintenance problem on the banks and a sedimentation problem in the lake. In many places the problem of bank erosion can be combated by leaving a natural-habitat buffer zone 25–50 feet wide around the lake and along all contributing streams.

Where it is necessary to grade the entire landscape, the shoreline and streambanks must be quickly stabilized. A steep slope can be maintained by lining it with a hard substance, such as concrete or riprap. A gentle slope can usually be successfully stabilized with sod.

Even with the best planning, some types of land undergo considerable erosion during development, and discharge large quantities of soil into watershed streams. In such situations, a major method of sediment control is the construction of sedimentation basins on streams above the lake. If properly located and designed, sedimentation basins can greatly reduce the amount of sediment which reaches the lake. To provide worthwhile results, a basin must be designed large enough and must be periodically cleaned to be kept large enough to have the needed sediment-trapping capability. Basin design must also include proper access for sediment-removal equipment. This aspect is often overlooked in the planning of these basins.

A second method of reducing intransit sediment loads is the construction of temporary storage basins within the storm-drainage system. This method is especially important where storm sewers drain large, incompletely developed areas. Like the instream basins, the temporary storage basins must be carefully designed and periodically emptied to provide efficient sediment removal.

In some developments, the combination of zoning, onsite, and intransit controls may be insufficient to prevent large quantities of sediment from entering the proposed lake. Where this situation is predicted, an inlet sedimentation basin may be built at the upstream end of the normal pool of the lake. Properly constructed, this basin can intercept and remove much of the incoming sediment at the point of entry and thereby prevent it from accumulating throughout the lake. The primary basin is generally excavated to a depth below the existing streambed which is sufficient to provide volume for 3 or 4 years of accumulation. A secondary basin can be constructed farther upstream to remove coarse materials from floodflows.

Design of an inlake sedimentation basin must include provision for periodic excavation by dragline or similar equipment. Access for the equipment must be provided, and the basin must be narrow enough at all points to be accessible for excavation from preconstructed roads.

The use of inlake basins is predicated on the capability of these basins to concentrate sediment where removal is relatively easy and inexpensive. If sediment is allowed to accumulate throughout the lake, the difficulty and cost of removal will increase sharply.

Sediment Disposal

The several types of sedimentation basins can greatly reduce the accumulation of sediment within a lake. The basins serve only as temporary repositories, so sediment disposal areas must be provided. For economy, the disposal areas must be as near as practicable to the basins. In some developments the sediment can be used in certain locations to improve the grading and to reduce steep slopes. In other developments, the sediment can be used to fill unwanted gullies and ravines. Regardless of the type, disposal sites must be located and reserved at the time the sedimentation basins are constructed.

Debris and Trash

Control and removal of debris and floating trash is of considerable importance to the esthetic appearance of a real-estate lake and to the sanitary quality of its water. As in the case of sedimentation accumulation, prevention is of the first importance. Enforcement of anti-littering measures and provisions for trash disposal in open-space areas must be provided. Roadside and pavement cleanup will also be necessary in shopping centers and other heavily used areas. In many areas, prevention will not be entirely successful, and a considerable quantity of debris will find its way to the headwaters of the lake.

Floating debris may be collected by skimming barriers designed to float on the water. The barriers are normally positioned to remove the debris just before it enters the lake. Where an inlet sedimentation basin is constructed, the skimming device is generally located just upstream from the basin. Debris retained by the device must be regularly collected by maintenance personnel.

Nonbouyant debris will accumulate throughout the lake where an inlet sedimentation basin is not provided. If a basin is constructed, most of this debris will collect there and be periodically removed with the soil sediment.

Some lakes will need large capital investments for the control of sediment and trash. With proper planning, however, the cost of keeping a lake esthetically pleasing may be more than returned by the increased value of real estate.

DOMESTIC SEWAGE

The collection, treatment, and disposal of domestic sewage is a major problem in any real-estate development. The problem is particularly acute where a lake is involved, because both raw and treated sewage must be prevented from entering the lake.

Raw sewage will despoil a lake by depleting the oxygen resources of the water, by adding disease-carrying organisms which render the water unfit for recreation, and by adding plant nutrients which stimulate prolific growths of algae and aquatic weeds. Standard biological treatment greatly reduces the oxygen-consuming power and disease potential of sewage. The same treatment, however, removes only a small portion of the plant nutrients. Since the treated sewage is nutrient laden, it can accelerate the eutrophication and destruction of a lake to nearly the same extent as raw sewage. The weed growth shown in figure 2 is only one of a number of undesirable conditions that develop when treated sewage is discharged into a lake.

Sewage is generally treated and disposed by two means: individual septic tanks and sewage treatment plants. Septic tanks are a distinct hazard in real-estate lake developments. Septic tank leachates can enter a lake directly through surface or subsurface seepage and indirectly through stream or ground-water flow. Even in low density developments built on soil that is highly suitable for septic tanks, some effluent from septic tanks may eventually reach the lake. Septic tank effluents are so nutrient laden that once seepage enters a lake, the process of eutrophication is greatly accelerated and the lake is quickly despoiled. Hasler and Ingersol (1969) note the unfortunate case of Cochran Lake in the northern Wisconsin wilds. In 10 years, septic tank leachate from cottages reduced Cochran Lake from a pure gem to a 300-acre caldron of pea soup.

A real-estate lake is most effectively protected if sewage is disposed of through a municipal sewerage system. Great care is required, however, in the location and construction of the sewerlines. A leaky, poorly

Figure 2.—Nutrients from sewage effluent contribute to the growth of aquatic weeds and greatly accelerate the aging of a lake.

designed system can quickly lead to severe pollution of the lake. Combined sanitary and storm-sewer systems represent a potential hazard in real-estate lake-developments. Even if normal overflow is designed to circumvent the lake, heavy runoff may cause overflow at junctions and manholes, possibly spewing untreated sewage into the lake.

Where circumstances permit, the local sewerage system should be tied into a large regional system which has a central treatment plant. This manner of final disposal dispenses with the difficult tasks of locating, constructing, and effectively operating a new and often small sewage treatment plant. To be completely suitable, a location for a new treatment plant should be downstream from the lake, or in another drainage basin, and at a site where the receiving stream can safely assimilate the treated sewage. Each State has recently adopted a new and fairly stringent code of water-quality criteria. These codes will greatly limit the number of small streams into which sewage effluent can be legally discharged. Therefore, future urban planning will probably call for regionalized sewerage systems in which treatment plants are constructed only on the rivers and larger streams which have fairly high and consistent flows. To comply with the water pollution laws, more and more real-estate lake developments will have to dispose of their sewage through these regional systems.

STORM DRAINAGE

Storm runoff can be as potent a source of pollution as domestic sewage. Runoff from an urban area typically contains oils, fertilizers, pesticides, animal droppings, and many other wastes which result from community living. Roads and parking lots for high density housing are a prime source of oils and other petroleum based pollutants. Partly completed developments are a source of copious quantities of sediment. If the storm-drainage system leads to the lake, various amounts of these contaminants will enter the lake and may seriously degrade its quality. Thus, from the standpoint of water quality, it would seem preferable to plan and design the storm-drainage system to circumvent the lake.

The diversion of storm drainage to prevent pollution, however, will mean that less water is available to maintain the lake. Thus the cure could be worse than the disease. Even though in some areas the storm-drainage water will not be needed, in others the water will be essential for the mere development of a lake.

In the remaining areas the need for the water will be somewhere between the two extremes. In these locations, the decision to use or not to use storm-drainage water will be difficult to reach. Use of the water will reduce the cost of water-level maintenance, but will also necessitate the periodic cleaning of roads and parking lots to reduce the pollution load entering the lake. Even with cleaning, it is possible that the contaminants which remain will eventually lead to noticeable pollution of the lake. Some of these conflicting aspects are further discussed in the section "Model for Real-Estate Lake Planning and Management."

FLOODING AND WATER-LEVEL MAINTENANCE

Any lake, especially an impounded one, is likely to experience high levels of water during times of intense rainfall. This potential for lakefront flooding must be anticipated and accommodated in the design of the outlet structures. Where water is to be discharged over a concrete dam, lakefront flooding can be minimized by designing a wide spillway. Where water is to be discharged through a standpipe, flooding can be reduced by emplacement of auxiliary spillways at a level slightly higher than the standpipe. Flooding could also be reduced by designing the outlet structures to permit a water-level drawdown. With this potential, the lake level could be lowered somewhat when large storms are predicted for the area.

Property damage from flooding can be minimized through the judicious location of houses. In rolling or hilly terrains, houses can be built sufficiently high above lake level that flood damage is unlikely. In flat terrain, flood damage is more difficult to prevent; basement flooding is a particularly bothersome problem. Houses should not be built where the flood hazard is large and cannot be managed.

Water-level recessions in a real-estate lake can decrease the esthetic and recreational value of the lake and thereby diminish property values within the community. In many locations, water-level lowering can be prevented merely through the selection of a drainage area of sufficient size to sustain the lake. In some locations, however, the maintenance of a desired water level will require planning and design for inflow augmentation.

Any technique of supplying additional water represents an additional cost in the development and management of a lake. If the estimated amount of water required for lake-level maintenance is small, and rather infrequently required, augmentation from wells and municipal supplies may be suitable. However, if large amounts of water will frequently be required, other sources of augmentation should be explored. For some developments, it might be possible to divert large quantities of water from a nearby nontributary stream.

Design of outflow structures to permit controlled lowering of lake stage is a desirable feature in any real-estate lake. Many lakes will need periodic drawdown to permit dredging and shoreline maintenance. In the northern latitudes, it may be desirable to drop the lake stage during winter to prevent ice damage, which can occur during ice conditions and also during ice breakup.

In the development of a real-estate lake the cost factor may limit the design for drawdown to one fixed level. In this situation, the level should be selected only after thorough consideration of all possible purposes for drawdown. The final decision should also be tempered by a realization of the degree to which drawdown will temporarily diminish the landscape's esthetic appeal.

JURISDICTIONAL, SAFETY, AND "PEOPLE PROBLEMS"

Not all the problems of planning and developing real-estate lakes are of an environmental nature. Many problems can arise over jurisdictional rights, safety regulations, and the general attitude of the people concerning the lake. In fact, in the absence of anticipation and planning, the people-oriented problems can, at times, far outweigh the environmental problems.

Decision on what portion of the community will have lake access is an important aspect of lake planning. The greater the number of people with access, the more restrictive the regulations on lake use may have to be. For example, a large real-estate lake might be able to accommodate powerboats if the number of people with lake privileges is small. On the other hand, if the entire community has lake rights, powerboat use may be out of the question.

Jurisdictional rights to the lake may vary from open use for the entire community to exclusive use by shoreline owners. Open use is usually handled by planning a "green space" around the entire perimeter of the lake. All residents are then given equal access to the lake and to all of its facilities. This right is guaranteed through zoning or through deeding the lake and adjacent "green space" area to a community organization. When properly incorporated and administered, deeding has the same desirable effects as zoning regulations.

Deed restrictions are the common method of regulation when lake privileges are given only to people who own lakefront property. In many lakes, a combination of private and community access is practiced. A fairly large part of the perimeter of the lake may be open to community access, or perhaps only a small funnel access is made available. In the funnel access procedure, the nonriparian members of the community become part owners of a small access tract and therby gain legal access to the lake.

All gradations can exist between open community and exclusive access. Cases exist where lake use is restricted to a definite residential subdivision or to a few of a large number of subdivisions. In other cases, lake privileges are granted to all homeowners but denied to renters.

Most of the potential safety problems of a real-estate lake can be eliminated through anticipation and planning. Safety in recreation requires consideration of swimming, boating, and ice skating. If swimming is permitted, constant checks are required on the sanitary quality of the water. In addition, regulations are needed to specify whether swimming is restricted to designated beaches or is permitted anywhere on the lake and to state the length of the swimming season.

Safety regulations for boating revolve about the initial and highly important decision of whether or not to permit powerboat use. This decision requires close consideration of lake size, the number of people with lake privileges, and the priority of environmental esthetics. Where powerboats are permitted, the community usually sets regulations on maximum boat size and on speed limits and decides whether or not water skiing is allowed.

Safety planning for ice skating will eliminate the dangers of thin ice. Potential accidents are prevented in some communities by permitting skating activities only after designated, qualified individuals have inspected the ice surface.

Real-estate-lake "people problems" include the littering of the lake and general access land with trash and the lack of concern by the community for preserving the quality of the lake. Where these problems prevail, community pride and a sense of participation are lacking. Community pride can be fostered by educating people about the nature of the lake and introducing people to the many enjoyments it can provide.

Lack of a sense of participation is most prevalent in those developments which restrict lake access to a small proportion of the community. Most individuals, once denied lake access, are less interested in how their actions affect the long-term quality of the lake. These people find little reason to care if the runoff from their parking lots and lawns and the flow in the stream adjoining their properties will eventually pollute the lake. Thus, fostering a sense of participation requires careful consideration during the planning of jurisdictional rights to lake use.

MANAGEMENT OF REAL-ESTATE LAKES

In almost all aspects of life, management is truly successful only if it is preceded by proper planning. This fact has time and time again become regretably clear in the development of real-estate lakes. No amount of management can save a lake if the major physical systems are misdesigned at the outset. Preservation of a lake depends more upon good planning and practical land zoning than upon the more frequently considered management control aspects.

Lake management, however, does play a vital and necessary role. Proper management can lessen the number and magnitude of problems that arise from minor mistakes in planning. Moreover, even well planned lakes require constant management in order to be maintained at a desirable level of physical, chemical, and esthetic quality.

SEDIMENTATION

SOIL SEDIMENT

Most sediment problems in real-estate lakes arise directly or indirectly from construction activities. Areas under active construction are usually the largest contributors of sediment to lakes. However, the erosion of improperly stabilized surfaces, such as hillsides, streambanks, and shorelines, can also contribute large amounts of sediment, and in addition they simultaneously despoil the esthetic quality of the landscape.

The effect of construction on sediment production is well documented by experience at Lake Barcroft in Fairfax County, Va. During the pre-urbanization period from 1915 to 1945, about 120 acre-feet of sediment was deposited in the lake. On a yearly basis this amount equals 19 cubic feet per acre of drainage area. Between 1945 and 1955, however, urbanization rocketed the sediment accumulation to 160 acre-feet, equal to 75 cubic feet per acre per year. During the 1945–55 period, 9.5 square miles of the watershed was urbanized. With allowances for erosion on the remaining land, each square mile that passed through the construction cycle contributed about 17 acre-feet of sediment to the lake.

The basic principle of sediment-control management is the complete stabilization of soil particles or, at least, the containment of eroded particles on an individual development site. Once sediment is in transit, the processes of erosion accelerate, and the costs of control rapidly increase. Complete sediment control during development is impossible, but the severity of problems can be lessened by minimizing the potential for erosion. This management concept involves minimizing both the areal extent that is laid bare to erosional forces and the length of time that the land is exposed. Developmental practices to achieve this goal include the leaving of vegetation in place until just before construction, the disturbance of only as much area as is needed at one time, the early installation of storm drains, and the restabilization of the land surface as quickly as possible.

Immediate stabilization of natural channels, hillsides, and roadbanks is of the utmost importance. Most natural channels can be stabilized with grass through seeding or sodding, but some channels may require stone or concrete linings. Gentle slopes can usually be stabilized by the simple seeding of grass. Likewise, most steep slopes can be stabilized with grass, but many will also require mechanical protection from erosion until the grass is established. Techniques for mechanical protection include the use of straw mulch, light asphalt sprays, and jute matting.

During construction, the use of sediment traps on individual sites is a vital step in sediment control. If properly located and sized, sediment traps effectively hold the flow of overland water long enough to settle a large part of the suspended soil particles. Sediment traps keep soil on the individual site and out of the drainageways where it is much more difficult to manage.

Once sediment reaches a stream, control procedures increase in cost and decrease in efficiency. However, in many drainage areas, sedimentation basins on streams above the lake may be quite effective in reducing the potential contribution of sediment. As mentioned in the section on planning, sedimentation basins should be constructed prior to creation of the lake. However, if necessity dictates, these basins may be built at any point during the life of a lake.

Although active construction contributes the largest amount of sediment, shoreline erosion is the second largest source of sediment in a real-estate lake. Even with the best planning, shoreline erosion can easily occur. Such erosion can seriously blight the landscape and lead to the creation of shoreline mudflats. These mudflats are unsightly and greatly interfere with recreation. Constant surveillance and maintenance are required to keep shoreline erosion to an acceptable level. In many places incipient erosion can be suitably stabilized with grass. Particularly troublesome areas may require the addition of a considerable amount of riprap or, if erosion is severe, the building of concrete walls.

Once sediment reaches the lake, the cost of management increases sharply. Hopefully, if the rate of sedimentation is high, the problem will have been envisioned during planning, and a sedimentation basin will exist where the stream enters the lake. Management can then focus on maintenance of the basin, which must be emptied periodically.

In the absence of an inlet basin, sediment will accumulate throughout the lake. Then the real headaches begin. As sediment deposits build up, the esthetic quality of the lake is impaired and potential recreational use of the lake is diminished. Management of the problem may require sediment removal from many areas of the lake. Unfortunately, nearshore areas, such as coves, are often virtually inaccessible to heavy equipment. Open-water areas often require the building of underwater roads in order to place the dragline and to move the sediment hauling trucks.

Thus, in the absence of proper planning, the management of sediment problems can be very expensive. This point is well illustrated by the case of Lake Barcroft. During the first 10 years of development as a real-estate lake, about one-third of a million dollars was spent for sediment removal (fig. 3). Today, after the expenditure of even more money, the lake still has numerous sediment problems.

LEAVES

Not only soil particles, but leaves can cause sediment problems in real-estate lakes. In forests most leaves remain in the vicinity of where they originally fall, ultimately decomposing and adding to the forest litter. In contrast, in a real-estate lake development, the leaves fall on lawns, roadways, and parking lots. Very often a large portion of these leaves ends up in the streams and storm-drainage systems. The lake then becomes the final settling place of the leaves as they are deposited in a

Figure 3.—Sediment removal is expensive; at Lake Barcroft, in Virginia, over one-third of a million dollars was spent in just 10 years. (Photograph courtesy of Soil Conservation Service.)

mixture with soil sediment. Where the volume of leaves reaching the lake is large, the deposition may rapidly fill the discharge areas of the stream. Rapid filling and clogging is often especially bad in developments where the storm-drainage system is routed to the lake.

Good management practices can minimize the deposition of leaves in a real-estate lake. Periodic cleaning of parking lots and roadways during autumn can greatly reduce the potential loading. On individual properties, leaves will decompose if left in place, but if raked, they should be disposed of in such a manner that they will never reach the lake. This rules out the disposal of leaves along streambanks and drainage ways.

EUTROPHICATION

NATURE OF THE PROCESS

Eutrophication is a natural aging process which affects every lake and dooms it to eventual extinction. Eutrophication of a lake consists of the gradual progression from one life stage to another based upon increases in the degree of nourishment. Enrichment and sedimentation are the principal contributors to the aging process. As described by Greeson (1969):

> The shore vegetation and higher aquatic plants utilize part of the inflowing nutrients, grow abundantly, and, in turn, trap the sediments. The lake gradually fills in, becoming shallower by the accumulation of plants and sediments on the bottom and smaller by the invasion of shore vegetation, and eventually becomes dry land. The extinction of a lake is, therefore, a result of enrichment, productivity, decay, and sedimentation.

The sequence of events leading to the extinction of a lake are summarized in figure 4.

Under natural conditions, eutrophication is a slow process, but artificial enrichment resulting from man's activities can accelerate it to the degree that only a few years are needed for the complete destruction of a lake. The hastening of eutrophication by artificial enrichment is portrayed in figure 5.

Some real-estate lakes have been marred by a prolific growth of algae within 1 year of development. A dense algal growth or bloom is usually the first visual indication that a lake is in ecological trouble. A bloom imparts a greenish-yellow or brownish color to the water and often physically hinders swimming, boating, and fishing in the lake. The decay of dead algal cells may release materials with disagreeable odors to the water. Of greater importance is the fact that the decay process consumes life-giving oxygen. Thus, the decomposition of

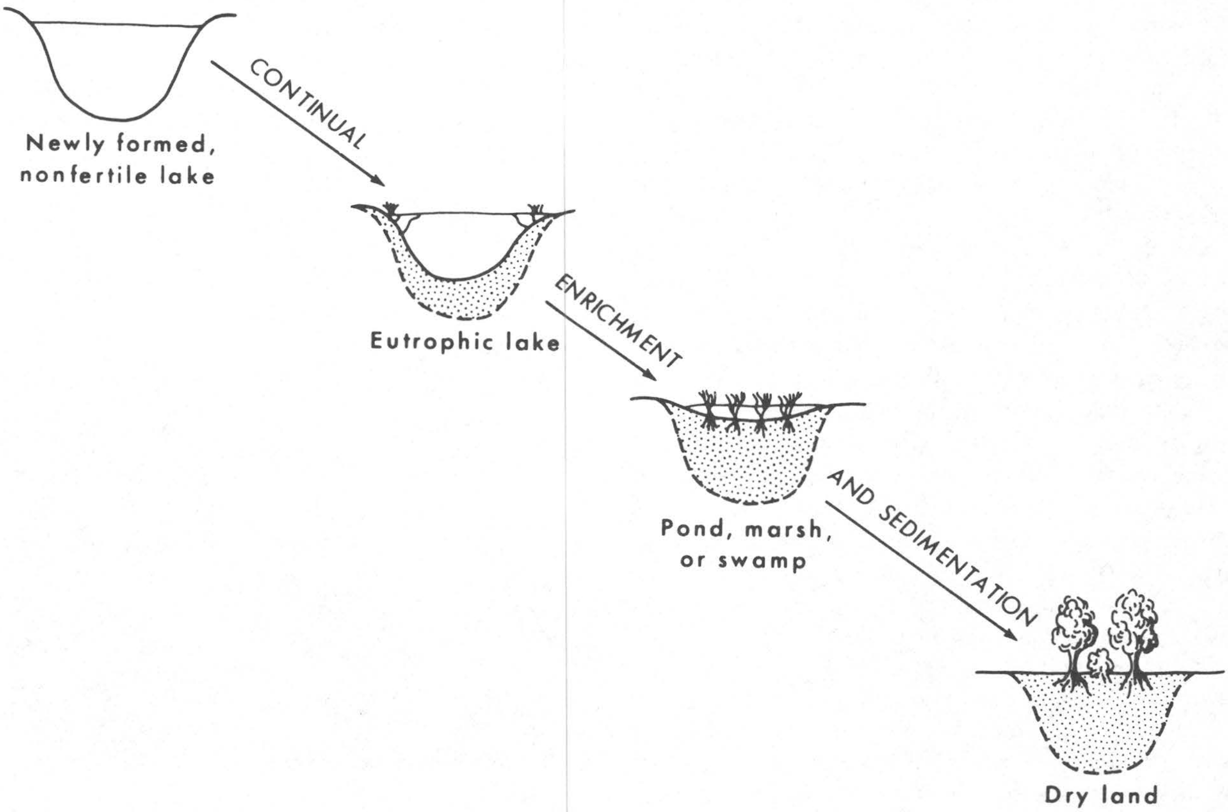

Figure 4.—Eutrophication—the process of aging by ecological change. (Modified from Greeson, 1969.)

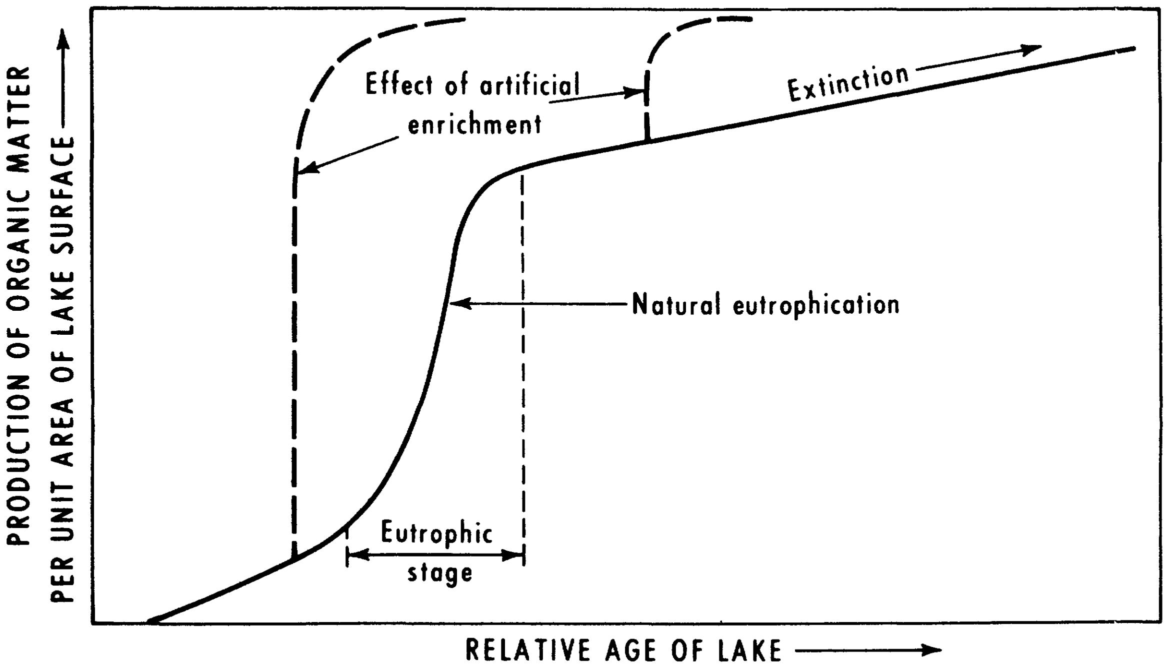

Figure 5.—Hypothetical curve of eutrophication showing the effect of artificial enrichment. (Modified from Hasler, 1947.)

dead cells in large blooms may substantially reduce the oxygen level of the lake. Moderate reductions in the oxygen level, if sustained for several days, will result in numerous disruptions in lake ecology. Severe depletions of oxygen often result in fish kills.

CONTROL OF NUTRIENT SOURCES

Although nutrient enrichment of a real-estate lake is inevitable, careful management can usually prevent it from occurring at a rapid rate. To be successful, a program for eutrophication control must minimize the potential nutrient contributions from both acute and chronic sources. Acute sources are those which can rapidly add large quantities of nutrients to the lake; the main sources are poorly operating sewage disposal systems. Chronic sources are those which continually add small quantities of nutrients to the lake. Chronic sources usually result from the normal day-to-day and year-to-year activities of urban living.

The most frequent acute source of nutrients is septic tank seepage. Many older real-estate lake communities disposed of sewage exclusively through septic tank systems. The systems were often unwisely located, poorly designed, and improperly installed. Nutrients from many of these systems quickly reached the lakes and resulted in massive growths of algae.

A seepage-contaminated lake can usually be improved in quality if the flow of nutrients is stopped. However, since a lake entraps nutrients, the process of recovery or nutrient cleansing may be slow, and complete recovery is usually impossible. Furthermore, where seepage has badly polluted a lake, worthwhile improvement will generally require the complete banning of septic tanks and their replacement with a sewerage system.

Planning is the key to effective eutrophication control. From this standpoint, the use of septic tanks is not recommended for real-estate lake communities. However, if septic tanks are already installed and the systems are properly located and designed, periodic inspection of performance may prevent large quantities of nutrients from entering the lake. If faulty systems are detected, immediate redesign is necessary.

Rapid eutrophication of a lake can also be caused by nutrient influx from a stormwater-drainage system. In this case, the rate of nutrient enrichment can be reduced through a coordinated program to periodically clean the roads and parking lots which contribute to the stormwater flow. The stormwater pollution problem can be entirely solved, however, only by rerouting the drainage system to circumvent the lake. This action is not always possible, because the stormflow may be needed to maintain the desired water level of the lake. Seepage from a faulty sewerage system is another potential cause of rapid eutrophication. This problem requires quick repair or relocation of the sewer pipes in order to protect the lake.

Lawn fertilizer is the most prevalent chronic source of nutrients in real-estate lake developments. After a heavy storm, water will flow overland into streams or directly into the lake. As it passes over fertilized lawns and around fertilized shrubs, the water becomes charged with nutrients and eventually carries them into the lake.

Nutrient influx from lawn fertilizer can never be entirely controlled, but it can be minimized. Most homeowners have a tendency to overfertilize their lawns. For a given soil type each section of lawn and each shrub has an exact fertilizer requirement for optimum growth. These requirements can be routinely determined at low cost to the public by many universities and governmental agencies.

It is possible for a concerned community to help preserve its lake by developing a fertilizer control program. The first step is a determination of the fertilizer requirements of the entire community. The second step is a program of community-wide application of fertilizer to insure that only those amounts actually needed are applied. The program can also seek to minimize the total fertilizer requirements of the development. This goal is attained, first, by keeping as much of the open space as possible in natural habitat, and second, through the planting of altered landscape with grasses and shrubs which have low fertilizer needs.

Other chronic nutrient sources are leaves and nutrient-rich sediments. The amounts of these materials which enter the lake can be minimized by controlling the sources. Some of the possible measures for sediment and leaf control are discussed in the section "Sedimentation."

TREATING THE EFFECT

Preventing the development of undesirable conditions is the goal of eutrophication control. However, in lakes where massive algal blooms already occur, it is sometimes necessary to treat this effect of eutrophication at the same time that attempts are being made to control the nutrient sources. The most common method of treatment is the application of copper sulfate ($CuSO_4$), a chemical which kills the algae. Algal blooms are caused by an over abundance of the wrong kinds of algae. Copper sulfate can control the growth of these species of algae, but its addition to water also causes undesirable effects.

Nonselectivity in toxic effect is the major problem caused by the use of $CuSO_4$. The chemical kills almost all forms of plankton, not merely the massive growths of undesirable forms which constitute an algal bloom. Because plankton are vital links in the food chains, their mass destruction results in less food for the fish population. Fish normally do not feed upon the species of algae which predominate during blooms. If these species were used as food, fish would be the ideal control for algal blooms.

A second problem with $CuSO_4$ is the buildup of copper concentration in bottom sediments. This accumulation can cause the concentration of copper in water to remain high throughout the year. If this condition arises, algaecidal effects of the copper may become a permanent feature of the lake.

The use of $CuSO_4$ is a stopgap measure, for as the dead algae cells undergo decay, large quantities of nutrients are recycled to the water. Quite often the recycled nutrients stimulate a new bloom as soon as weather conditions are favorable and the copper concentration of the water has decreased below the algaecidal level. In any event, most of the nutrients are entrapped by the lake and are held available for future algal growth.

Because algal blooms are cyclic, extremely large blooms are usually of short duration. Thus, $CuSO_4$ can be regarded as an extreme measure, to be used only when a bloom is becoming prolific enough to be intolerable even for a short period of time. Algal blooms can be prevented or limited permanently only by minimizing the nutrient influx.

SANITARY QUALITY

The sanitary quality of water is determined on the basis of tests for indicator bacteria. When the indicator bacteria are present in concentrations above certain levels, it is probable that the water also contains disease-causing bacteria.

Under current law, each State is free to define the levels of indicator bacteria which constitute health hazards for different uses of water. For recreational uses, most States define two categories of standards according to the degree of bodily contact with the water. The category of primary contact uses includes swimming, diving, water skiing, and dabbling by children. These uses involve considerable risk of ingesting water in quantities sufficient to impose a health hazard. The category of secondary contact includes fishing, boating, and other activities in which contact with water is either incidental or accidental.

Lakes used for swimming must be continually tested and found to meet those standards established for primary contact recreation. Furthermore, even if the lake is intended only for fishing and boating, it is usually impossible to keep the many children in a development from playing in the water. In this light, a goal of meeting the primary contact standards would provide a much greater assurance of public health than merely meeting the secondary contact standards.

In a lake development the possible sources of sanitary contamination are stormwater drainage, sewer overflow, seepages from faulty sewerlines, and septic tanks and, if planning has been very poor, sewage treatment plant effluent. In the last case, the contamination is best stopped by rerouting the effluent. If seepage from a faulty sewerline is a problem, partial rebuilding of the line will probably be required. Similarly, if contamination is coming from septic tank seepage, the faulty systems will have to be redesigned and rebuilt or entirely replaced with a sewerage system.

When the source of contamination is either sewer overflow or stormwater drainage, some management options are available. These sources of contamination are intermittent. Furthermore, disease-causing bacteria fare poorly in most surface waters and generally die rapidly. If testing shows that these intermittent sources are contaminating a lake for only a few weeks of the year, a management decision could be made simply to live with the situation, provided the community can accept the fact that the lake will be periodically closed to recreation. Alternatively, of course, a sewerline could be partially rebuilt and a stormwater drainage system could be rerouted.

PESTICIDES

Lakes act as highly efficient traps for persistent pesticides. Once a pesticide, such as DDT, enters a lake it accumulates in the sediments and in biological food chains.

A food chain within a lake begins with the plant life and progresses upward to the largest carnivorous fish. Biological accumulation of DDT throughout the chain is often capable of magnifying many thousandfold the initial concentration in the water. The concentration of DDT residues in a simple food chain is shown schematically in figure 6. Even small amounts of DDT in the water of a lake may present a potential threat to the ecosystem of the lake. Furthermore, if recreational fishing is pursued, both the food chain and the high pesticide concentrations are extended to man.

Recently, (1970), the U.S. Geological Survey began testing for pesticides in a few real-estate lakes. Results are inconclusive as yet, but one lake was found in which monthly sampling has shown the surface water to contain measureable concentrations of DDT. When the DDT was initially noted, a survey was conducted to determine the possible sources of the pesticide. A small portion of the drainage basin lies outside the real-estate community, but no pesticides were being applied on the outside land. Appreciable contributions from rainfall were also ruled out because analyses from a second real-estate lake, 1 mile away but in a currently undeveloped basin, showed a complete absence of DDT. Thus, it was tentatively concluded that the source of DDT was the application of the pesticide within the real-estate lake community.

Because very few real-estate lakes have been analyzed for pesticides, no one knows how common the condition described may be. The studies suggest, however, that some real-estate lakes may be endangered by pesticide contamination.

If concerned, a real-estate lake community can easily develop a pesticide-management program. Ideally, the basic goal of such a program would be to minimize the use of pesticides, especially the persistent or so-called hard pesticides such as DDT. The need for pesticide use in the community can be reduced from the outset by leaving as much of the open land as possible in its natural habitat. All vegetation undergoes periodic pest infestation, but generally the native plants are more resistant to attack than are nonindigenous plants. Pesticides are rarely needed to protect the shrubs and trees in natural wooded areas. In contrast, large doses of chemical disease and pest controls are usually required to maintain grass in a desirable and pleasing condition. Where the natural habitat must be disturbed, landowners can be alerted to plant the grasses, shrubs, and trees which have wide resistance to the pests most common in the local area.

A community program can also seek to eliminate or at least minimize the use of insecticides for mosquito control. The major keys to natural control of mosquitoes are a weed-free lake and shoreline and the absence of organic pollution such as septic tank seepage. Large growths of aquatic and shoreline weeds are an open invitation to the breeding of mosquitoes. A weed-free lake and shoreline discourages female mosquitoes from depositing eggs and, at the same time, permits easy access of predators to any eggs that are laid. The control of weeds also decreases the amount of vegetable matter and, thereby, the food supply for bottom dwelling insects such as blind mosquitoes and midges. These insects, although nonbiting, are nuisances in many areas.

Aquatic weed growth can be limited in a lake through design to minimize the amount of shallow water. Rooted aquatic plants usually grow poorly at water depths greater than 2--3 feet. Lake management for weed control may involve periodic cutting of shoreline weeds and periodic dredging to maintain designed water depths in the nearshore areas. Costs incurred in the natural control of mosquitos are usually minimal compared with the relief provided from large scale infestations and the consequent need for pesticides.

Regardless of the purpose, if pesticides must be used in a lake community, the pesticide should be selected with great care and applied sparingly. If spraying is necessary over a large area, it should be done by a person who is very knowledgeable in the art.

"PEOPLE PROBLEMS"

To foster full and proper use of a real-estate lake, some communities have hired an individual who is trained in both planning and ecology. This individual generally develops educational programs on lake and community environment, while providing professional planning expertise to all management programs related to the environment.

Perhaps the most difficult task of the planner-ecologist is persuading people to cooperate in order to implement the management programs. Lack of cooperation is sometimes a roadblock to extremely important, hydrologically sound programs. More often, however, the lack of cooperation manifests itself in such nagging problems as litter and trash.

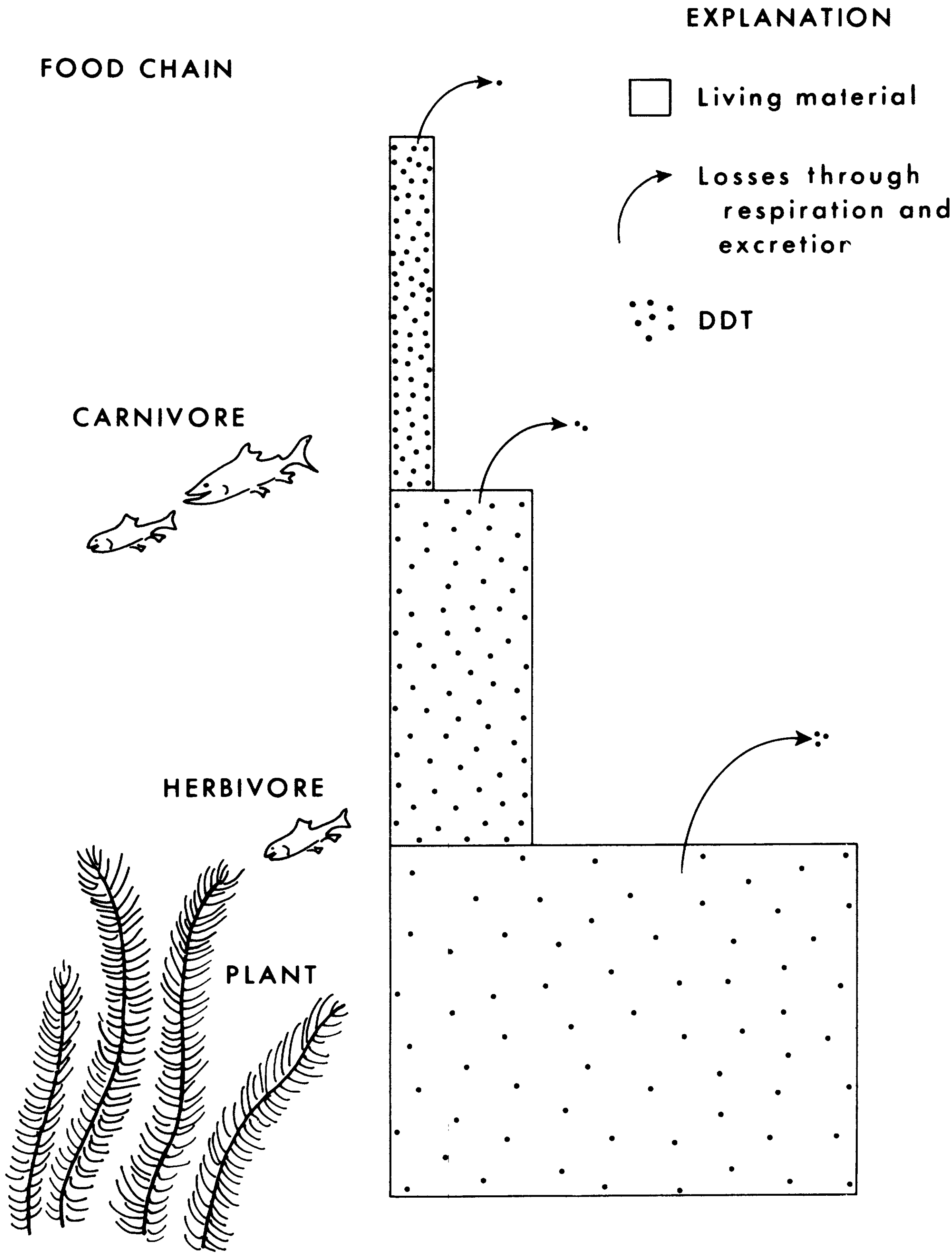

Figure 6.—Schematic diagram of the concentration of DDT residues being passed along a simple food chain. The concentration increases with each link and is highest in the ultimate carnivore. (Modified from Woodwell, 1967.)

Littering of the lake, shoreline, and tributaries is a "people problem" which requires constant consideration. Where public concern is lacking, a shoreline quickly becomes littered with paper, bottles, and cans. Some of this trash is thoughtlessly discarded in place, but much of it is usually blown or washed from nearby lawns and parking lots.

Planner-ecologists generally attempt to cope with the litter problem through education, the providing of litter cans, and where necessary, the funding of a regular cleanup program. People are informed of the consequences of thoughtless actions through pamphlets and community newspapers. Litter cans, ample in both size and number, are strategically located and regularly emptied.

Where the previous measures are insufficient, a regular cleanup program is usually scheduled for the shoreline and for the lawns and parking lots from which litter reaches the shoreline. In a few communities where the litter problem has been particularly severe, bans have been passed on the sale of nonreturnable containers.

Shoreline esthetic appearance related to private construction and landscaping is another of the "people problems." Poorly styled or unkept structures, along with poorly landscaped areas, can drastically reduce the esthetic quality of the lake. The planner-ecologist usually attempts to deal with this problem by persuading the community to adopt firm guidelines on the location, style, and upkeep of shoreline structures and on the general style of landscaping permited.

MODEL FOR REAL-ESTATE LAKE PLANNING AND MANAGEMENT

It is often difficult to determine if local hydrologic conditions can maintain a real-estate lake in a desired quantitative and qualitative form. Furthermore, if it is decided that a lake can be developed, it is practically impossible to estimate the costs of management alternatives.

Some guidelines, however, are available. One such guideline is a model for lake planning and management developed by the Geological Survey. This model provides for computerized study of local hydrologic conditions relevant to answering questions such as the following:

1. For a fixed dollar investment, what is the maximum size lake that can be supported by existing hydrologic conditions?
2. For a given lake size, what is the minimum cost required to maintain the lake under existing hydrologic conditions?

The model also permits statistical analysis of the various hydrologic components to assess their relative importance on investment decisions.

Water quality is potentially an important aspect of the model, for it may be possible to maintain a lake of a given size, yet not satisfy the desired quality requirements. The model is written to accept water quality inputs and to provide cost analysis for the management of quality problems. Unfortunately, our present knowledge of the water quality aspects of lake management is very incomplete. We are still unable to define accurately several of the cause and effect relationships of lake eutrophication. We still lack sufficient data to establish good cost estimates for management alternatives of sediment control. Thus, until science can suitably define the problems and provide the necessary data, the quality components of the model will serve only to stimulate organized thinking. For the near future, at least, the model will be used almost exclusively for the planning and management of lake hydrology.

HYDROLOGIC ANALYSIS

Potential sources of water inflow into a real-estate lake would include precipitation falling directly on the lake, influent tributary streams, storm runoff reaching the lake as overland flow and interflow, runoff from a storm-drainage system, and seepage from the ground-water reservoir. Possible categories of water removal would include evaporation from the lake surface, transpiration by aquatic and shoreline vegetation, discharge to streams, and seepage into the ground-water reservoir.

These inflows and removals are schematically shown in figure 7. Also shown are components for hydrologic management and inputs for potential control of water quality.

The parameters required for use of the model must initially be estimated from several sets of hydrologic data, with consideration given to the costs of management systems and the topography of the proposed basin. Model parameters for inflows and outflows can be obtained from actual historical data and from engineering estimates. In many cases, suitable historical data may be available for streamflow, precipitation, and evaporation, while estimates will have to be used for net seepage and the several forms of runoff. Model parameters for the management systems are based on cost estimates for initial development and for yearly operation under various sets of hydrologic conditions. Standard topographic maps are suitable for calculations of most basin parameters.

When the necessary model parameters have been estimated, flow generating programs are used to synthesize sequences of either inflows or outflows for an

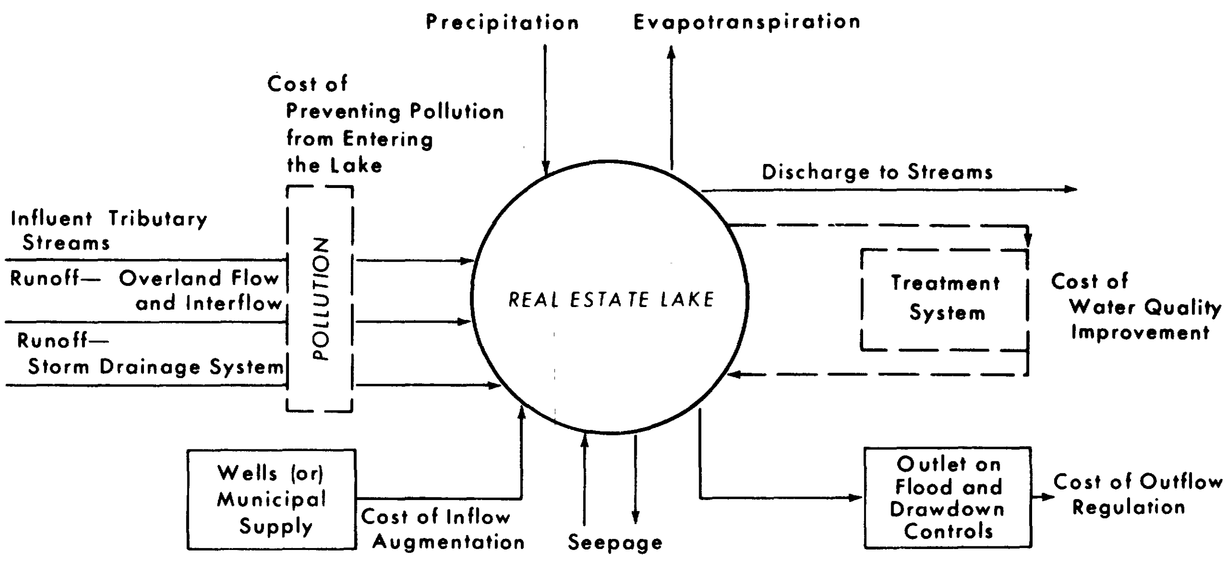

Figure 7.—Schematic diagram of a basic lake planning and management model.

idealized lake. The lake size is computed from an area to volume curve. For any condition, either natural or regulated, the lake area is defined on the basis of the long-term volume difference between incoming and outgoing flows.

The model permits rapid testing of various regulatory schemes to determine answers to management questions. Inflow augmentation and outflow regulation are the model components which provide flexibility for hydrologic management. In determining the need and (or) design of these systems, the cost of augmentation must be balanced against estimated costs for low water levels, while the cost of regulation must be balanced against estimated costs of flooding. In essence, the model will provide the user with a series of possible tradeoffs between development-operation costs and property-damage–land-devaluation costs.

The model also provides lake size and management cost analyses to help the planner decide whether or not to route the storm-drainage system to the lake. Unfortunately, at present this decision must be based entirely on hydrologic factors. We presently lack the information to quantify the pollution load potential of storm-system runoff in real-estate-lake communities. Thus, a decision to route storm drainage to the lake must be tempered by the knowledge that the water may rapidly pollute the lake if proper control measures are not used. A further point of difficulty is that costs of control measures are also unknown at this time.

Another difficult-to-measure parameter is the water loss from the transpiration portion of evapotranspiration. This component of water removal is, nevertheless, amenable to at least partial management. Control of aquatic vegetation will reduce transpiration within the lake, while selection and control of shore vegetation will reduce the terrestrial loss of water drawn from the lake. Hopefully, in the future, there will be some way to estimate the quantity of water that can be saved through these various management practices.

WATER QUALITY

The water quality components in figure 7 are portrayed in dashed lines to indicate they represent a potential, rather than a possible immediate use of the model. Polluting substances would enter the lake primarily through the tributary streams, runoff from overland flow and interflow, and runoff from a storm-drainage system. The figure thus graphically demonstrates the sources of pollution that are important to consider in planning a real-estate lake. In summary form, the development of a successful lake requires that tributary streams be unpolluted, overland flow be relatively free of fertilizer nutrients and pesticides, interflow be free of septic tank discharge, and storm drainage, if routed to the lake, be free of gross pollution.

Polluting substances can also enter a lake from springs and direct precipitation. That the amount of pollution from these sources is low is fortunate, because the sources are virtually uncontrollable. Treated and untreated sewage are not considered as inflows in the model since discharges of this type would most certainly cause severe troubles in the management of any real-estate lake.

Treatment for water-quality improvement (shown in fig. 7) is a potential component of any lake management model. Treatments currently in use are dredging for removal of sediment and spray fountains which beautify a lake while aerating the water. Although cost comparison estimates are unavailable, sophisticated treatment systems will probably cost far more than preventing pollution from initially entering a lake.

Thus, in a real-estate lake, the key to good water quality is careful planning and management to keep potential pollutants from entering the water.

CONCLUSIONS

A real-estate lake can be either an asset or a liability. With proper planning and management, it can enhance the esthetic quality of the landscape, provide water-oriented recreation, and increase the property value of the surrounding land. With poor planning and management, a lake can become a weed-choked, foul-smelling mudhole.

Proper planning is the key to success in the development of real-estate lakes. The basis for this proper planning is a thorough knowledge of the hydrology of lakes combined with an anticipation of the problems that may arise in their development and use. On this basis, preliminary planning can pinpoint the potential problems of lake development and can provide an assessment of their potential severity. This assessment of problems permits a realistic estimate of the total cost of developing a real-estate lake, rather than simply the cost of construction. In the long run, time and money can be saved by preventing or minimizing problems at the outset and by eliminating those areas where combined construction and maintenance costs would be economically prohibitive.

Management of real-estate lakes can be truly successful only if preceded by proper planning. No amount of management can save a lake if major hydrologic components are misdesigned at the outset. Proper management can, however, lessen the number and magnitude of problems that arise from minor mistakes and omissions. Moreover, even well planned lakes require constant management to be maintained at a desirable level of physical, chemical, and esthetic quality.

To be successful, the development of a real-estate lake requires the advice and guidance of experts. The necessary planning and management insights can be fully obtained only through consultation with local environmental planners and engineers. The earlier these experts are consulted, the more problem free the establishment and use of a lake will be.

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