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Water

EPA

Our Nation's Lakes

Cover: Late afternoon at the Nature Conservancy's Santanoni Preserve in the Adirondack Mountains of New York

Back Cover: The belted kingfisher, common resident of lakeshores and streambanks over much of North America

Contents Page: Cool swim on a steamy summer day at Monroe Lake, Indiana

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EPA

Our Nation's Lakes

United States Environmental Protection Agency July 1980
Prepared by the Clean Lakes Program under the direction of Robert J. Johnson

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Illustrated by Sandra Gold and Allen Carroll

Contents

Foreword

This Nation has an estimated 100,000 lakes that are 100 acres or greater of which 37,000 are publicly owned. The public uses these lakes for a variety of purposes. water supply for municipal, industrial and agricultural use; recreation including boating, swimming and fishing; flood control; and aesthetic enjoyment as centerpieces for public parks. The value of these resources is hundreds of millions of dollars.

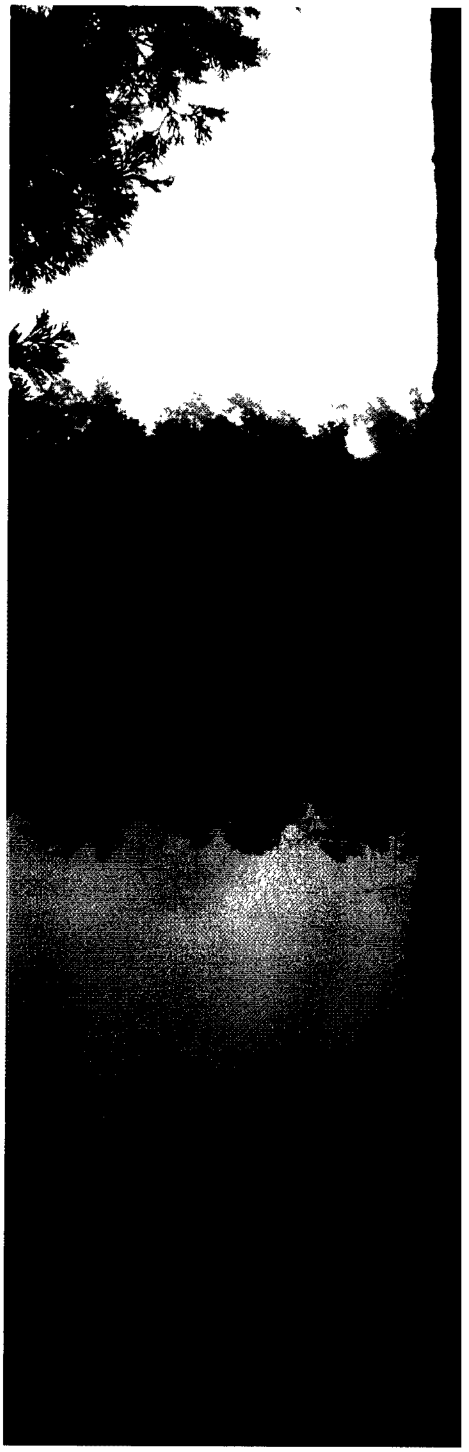
Lakes are vital parts of the freshwater ecosystems of this country. Their watersheds tap 42 percent of the surface area of the United States. They contribute an essential part of the fish and wildlife habitat for countless species of organisms. Pollution is destroying many of these resources and the public needs to know why That is the purpose of this book. A significant portion of lake pollution originates from mismanagement of land and wastewater at the local level. Such sources of pollution can be controlled at that level, with minimal Federal and State assistance if the public is adequately informed of lake pollution problems, sources, and effective solutions.

This book is designed to inform the general public about lakes and this problem. It presents examples of these problems and some solutions. It presents a discussion of available sources of financial and technical assistance offered by the Federal Government EPA has awarded financial assistance to States over the past 5 years to study and clean up over 200 lakes under its Clean Lakes Program.

We began this reporting project by assembling a number of people from EPA and the President's Council on Environmental Quality who know lakes. Together, we came up with an outline and suggested format for the author and illustrator Once the manuscript was drafted, some 25 persons in the scientific community carefully reviewed it, noting their suggestions and sending along additional material to the author. These reviewers' names and affiliations appear at the end.

The author, Elinor Horwitz, has tried to present the facts But beyond that, she has explained the background, and the evolution, and the unique qualities of lakes in clear, understandable terms. We hope the book encourages the general public to take an active role in lake pollution control so that we may enjoy our lakes for many years to come

Steven Schatzow
Deputy Assistant Administrator
for Water Regulations and Standards



Sunrise over Lake Nummy in New Jersey's Belleplain State Forest

Preface

It is a curious matter that widespread public concern about lake degradation is of such recent origin. All through history lakes have been used for transportation, for food supply, for bathing, and as a source of drinking water for human beings and animals. There is also no reason to believe that our unfrivolous forebears were indifferent to the recreational opportunities lakes provide. Yet, perversely, lakes have routinely been used as dumping places for trash and receptacles for sewage, their surrounding wetlands have too often been drained or filled to provide "useful" land for agriculture or construction. The 20th century's wondrous technological sophistication brought new forms of abuse to our freshwater supply as toxic, hazardous, often non-biologically degradable substances were introduced into our streams, rivers, and lakes, where they may remain for very long periods of time.

Considerable effort has been made in recent years to inform the public about the newly recognized importance of our coastal and inland wetlands—the swamps, marshes bogs, and prairie potholes that serve such useful functions in shoreline protection, pollution and flood control, and as wildlife habitats. It is difficult to learn that a swamp should be treasured, because wetlands have been viewed as unalluring, unwholesome waste places by virtually everyone except field biologists, duck hunters, and trappers. Lakes, on the other hand, have always been valued for the utilitarian and recreational bounty they provide and also for their aesthetic appeal. In both western and eastern cultures, artists, poets, naturalists, and philosophers have endowed our lakes with a romantic image. The seer of Walden Pond, Henry David Thoreau, wrote, "A lake is a landscape's most beautiful expressive feature, it is earth's eye onlooking into which the beholder measures the depth of his own nature."[1]

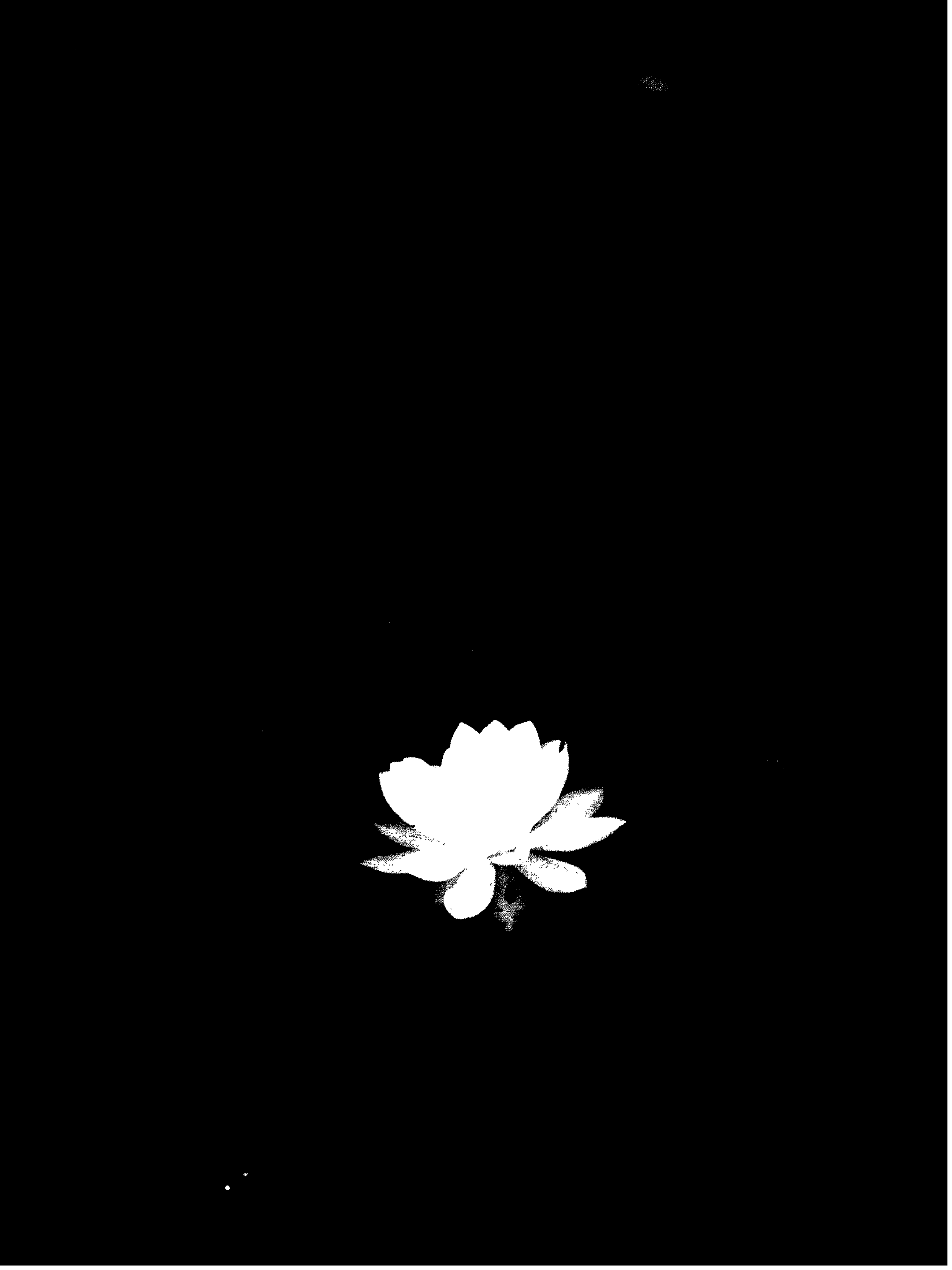
Perhaps. The fact is, it is difficult to achieve a spiritual insight by looking down into many of our lakes today. Based on the National Eutrophication Survey, an estimated two-thirds of the lakes, ponds, and artificial impoundments in this country receiving discharge from wastewater treatment facilities are thought to have serious pollution problems.[2] Some of our lakes are sick, some are in extremis. Many can, with present technology, be slowed in their degradation or even be restored to health. Others are too far advanced in their deterioration to be treatable at a reasonable cost. Although this book will consider lake restoration, it is important to realize that our lakes need restoration because we have failed to protect them. Today, we understand how to prevent further degradation of our inland waters, and lake protection must become a vital priority.

An increasingly aware and environmentally sensitized public now demands that something be done when a local lake is plagued with unsightly algal blooms, loss of game fish, unpleasant odors. Most lake protection and lake restoration projects begin at the local level with a call for action from private citizens and local agencies. A number of Federal, State, and local programs now offer financial and technical assistance for public lake cleanup and major watershed and tributary improvement activities.

Since 1976, EPA has offered cost-sharing grants for public lake rehabilitation—the Clean Lakes Program—under section 314 of the Federal Water Pollution Act Amendments (see Appendix). Original legislation was drafted and introduced in the Senate by Senators Walter F. Mondale of Minnesota and Quenton Burdick of North Dakota. Under this Act, publicly-owned freshwater lakes—including ponds, reservoirs, and impoundments with no marine water intrusion—are eligible for funding, currently limited to 50 percent of the total project cost. Eligible lakes must offer access through publicly-owned contiguous lands, enabling nonresidents to enjoy the same recreational benefits as residents.

It is difficult to relate costs and benefits in planning a lake restoration project. What is a lake worth in terms of aesthetic enjoyment and recreational potential? What is it worth if it is the source of a city's drinking water? What if it is needed for agricultural irrigation? Is a lake primarily a precious natural resource that should be, with greatest possible vigilance, protected? Or is a lake a recreational resource that should be enjoyed by as many people as possible? The two objectives are now recognized as being frequently incompatible.

One principle that is constantly reaffirmed in lake protection and restoration research is that the most effective methods generally will not bring rapid results, will require voluntary compliance and the sacrifices inherent in a long-range commitment. This book was written to inform all those concerned with the present and future quality of our Nation's lakes about the causes and nature of lake degradation and current ways of dealing with the problem.



Chapter 1 Where We Stand

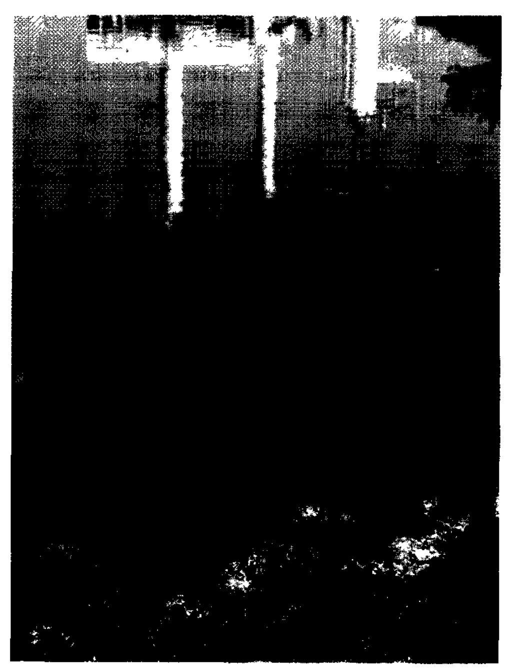
Official recognition of the fact that our natural resources are both finite and threatened dates from the establishment of the earliest national parks in the latter part of the 19th century. With the official closing of the frontier in 1891, timberland was first federally reserved under President Grover Cleveland despite the objections of Joseph Cannon, Speaker of the House, who voiced a widely endorsed sentiment when he asked, "Why should I do anything for posterity? What has posterity done for me?"[3]

The question reflected not only an arrogant lack of concern for future generations but also peculiarly American convictions that natural resources are inexhaustible. Guided by this certainty, a nation of small farmers and a growing number of land developers—often with financial encouragement from Government agencies—drained swamps and marshes, and leveled forests. Our history of environmental abuse began with the first settlers. Although our forebears were noted for their pervasive thrift and the care they took to guard possessions that might be handed down to succeeding generations, their attitude toward the natural world was profligate.

The gradual westward movement was given impetus not only by rapid increases in population and rising land prices in the east, but also by environmental devastation. Visitors from Europe in pre-Revolutionary War decades were horrified by the exploitative land practices of the pioneers, who knew that as land eroded and streams and harbors silted in they could always pick up and move farther west.

During the first half of the 20th century, the pollution of our lakes, rivers, and streams was accorded infinitely less notice than the destruction of woodlands and cropland. Until recent decades, water pollution was considered regrettable only insofar as it constituted a public health menace. Devastating epidemics of such waterborne diseases as typhoid, paratyphoid, and cholera occurred through the late 19th and early 20th centuries, and control of pathogens became a research priority. By 1908, as the result of the first generation of clean water campaigns in this country, chlorine was introduced as a purifying agent for drinking water supplies in large cities.[4] In more recent decades, bacterial, viral, and fungal infections that lead to eye and ear irritation or intestinal disturbances in swimmers have caused concern from time to time about the purity of water used for recreation. Public health measures of the 1970's resulted in bans on the consumption of fish from polluted waters as scientific understanding was brought to bear on the way toxic substances in our waters have entered the food chain.

Aesthetic deterioration of our lakes was scarcely noted until after World War II when a combination of elements—increased affluence, new highway construction, widespread car ownership, and the shortening of the work week—brought more and more people to lakeside recreation areas. Exploitative development of lake shores and the introduction of phosphate-based detergents were



Lake waters pristine and polluted: water lilies, Chippewa National Forest, Minnesota: factory stacks reflected in polluted water (right).

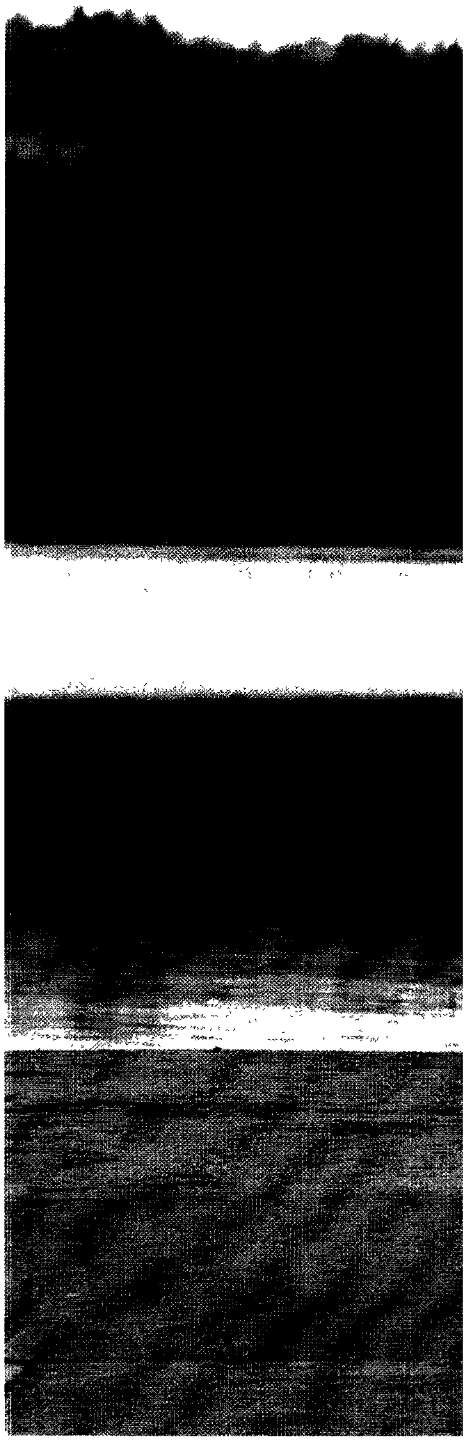
Where We Stand

major factors in accelerating lake degradation and as early as the 1940's some States initiated the first lake cleanup programs.

In the past decade, international concern about inland water quality has led to extensive research into the causes of lake degradation and the development of many effective and financially feasible methods to control or reverse these processes. Lake restoration technology is still in its early stages, but the critical necessity for clean lake policies and programs is now broadly recognized.

As in other conservation issues, a decision to save a lake often means that public interest must do battle with private gain, with the "right" of the owner of a lakeside lot to site a house as he or she chooses, the "right" of the farmer to plow to the edge of the stream, the "right" of the factory owner to discharge wastes into the waters. Today we have regulatory measures that impinge on some of these choices, other controls depend on voluntary cooperation and an enlightened surrender of short-term private gain for long-term public benefit.

Partial surveys have been made, but we do not know for certain how many lakes we have. The most reliable estimates have set the figure at 100,000 lakes larger than 100 surface acres excluding Alaska, which has several million.[5] As we enter the ever more populous, urbanized, and energy short 1980's, the need for clean lakes—right nearby—becomes more urgent. Although we have 3,700 urban lakes in this country that can be used for recreation by millions of people, an estimated 80 percent have significant water quality problems.[6] Unlike our ancestors, we can no longer leave the mess we have created behind and move west; we cannot all live upstream from an ecological disaster. Fuel shortages threaten to restrict trips of hundreds of miles to that pristine blue lake of happy childhood memory which, in fact, may now look distressingly like the murky pond 5 miles away, where people also swam, fished, sailed, strolled, and quoted from Walden . . . only yesterday.



An estimated 80 percent of the Nation's 100,000 lakes have water quality problems. At right, sunbathers at Walden Pond in Massachusetts, site of Thoreau's cabin.

Chapter 2 How Lakes Form

Most of the lakes now extant in the northern United States were formed 10,000 to 12,000 years ago as the glaciers moved across large areas of North America, Europe, and Asia in the geological era commonly known as the Great Ice Age. As the earth warmed, these basins gradually became habitat for a myriad of plant and animal species. As dead plants and animals decomposed, the nutrients released fostered the growth of new generations of life.

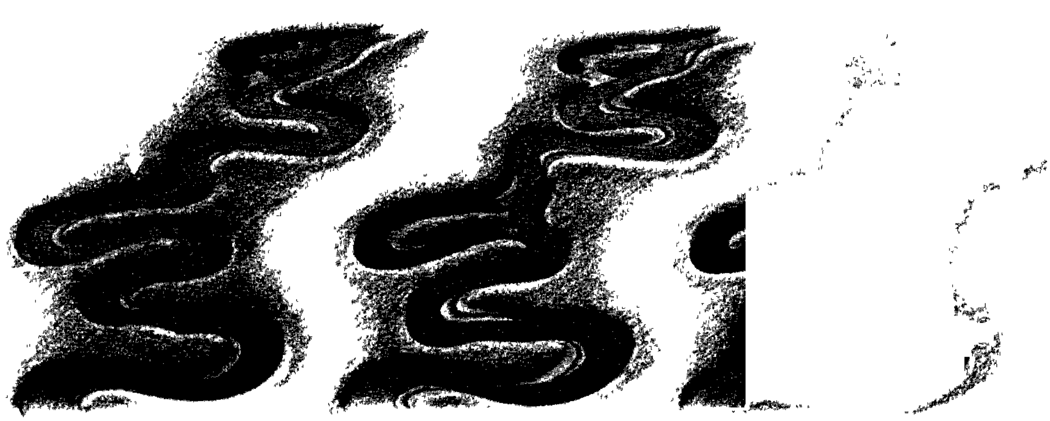
Lakes have also originated in other great natural events such as earthquakes and volcanos. Lake Baikal in Siberia and Lake Tanganyika in equatorial Africa, the world's deepest lakes, originated much earlier and were formed by movements of the earth's crust too deep to be classified as earthquakes.[7] Lake Baikal, 1,738 meters deep (5,700 feet), contains 20 percent of the world's supply of fresh water[8] and has approximately 600 species of plants and 1,200 types of animals, three-quarters of which are found in no other lake in the world.[9]

Earthquakes were responsible for the formation of many lakes in North America including Reelfoot Lake in Tennessee, which was created by the New Madrid earthquake of 1811. Crater Lake in Oregon was formed when the center of a volcanic cone collapsed.[10] Spirit Lake in Washington was formed by the volcanic action of Mount St. Helens In May of 1980 the volcano erupted again, virtually destroying the lake.

Lakes can also be created by gradual forces such as the corrosive movements of rivers and the cutting off of meander channels to form oxbow lakes. These lakes are seldom permanent. Shallow lake basins known as sand dune lakes such as Moses Lake in the State of Washington were created when winds built up areas of dunes leaving depressions below.

The shape of a lake basin is determined by the manner in which it was created and will, to a large extent, affect its degree and type of productivity. Some lakes are deep with steeply sloping sides. Others are shaped like shallow soup bowls with a large littoral zone—the region extending from the edges to the depth at which sunlight can no longer penetrate and permit rooted plants to grow. In lake terminology the profundal area is the central, deep, dark, lower region of the body of water below which light penetration is insufficient to support the production of green plants. The limnetic region is the large expanse of open water above. The percentage of water volume in littoral, profundal, and limnetic regions of individual lakes, which varies greatly according to basin shape, is an important factor influencing plant and animal communities, lake flushing time, and other natural processes.

The sinkhole lakes of central Florida (left) are formed as water seeping through fractures in the limestone bedrock slowly dissolves the rock to form round depressions. In this satellite photo, infrared film makes vegetation appear magenta. At upper right is the Atlantic Ocean. Right: a meandering, silt-laden river often forms broad bends which are cut off by erosive action to form oxbow lakes.



1 2 3

How Lakes Form

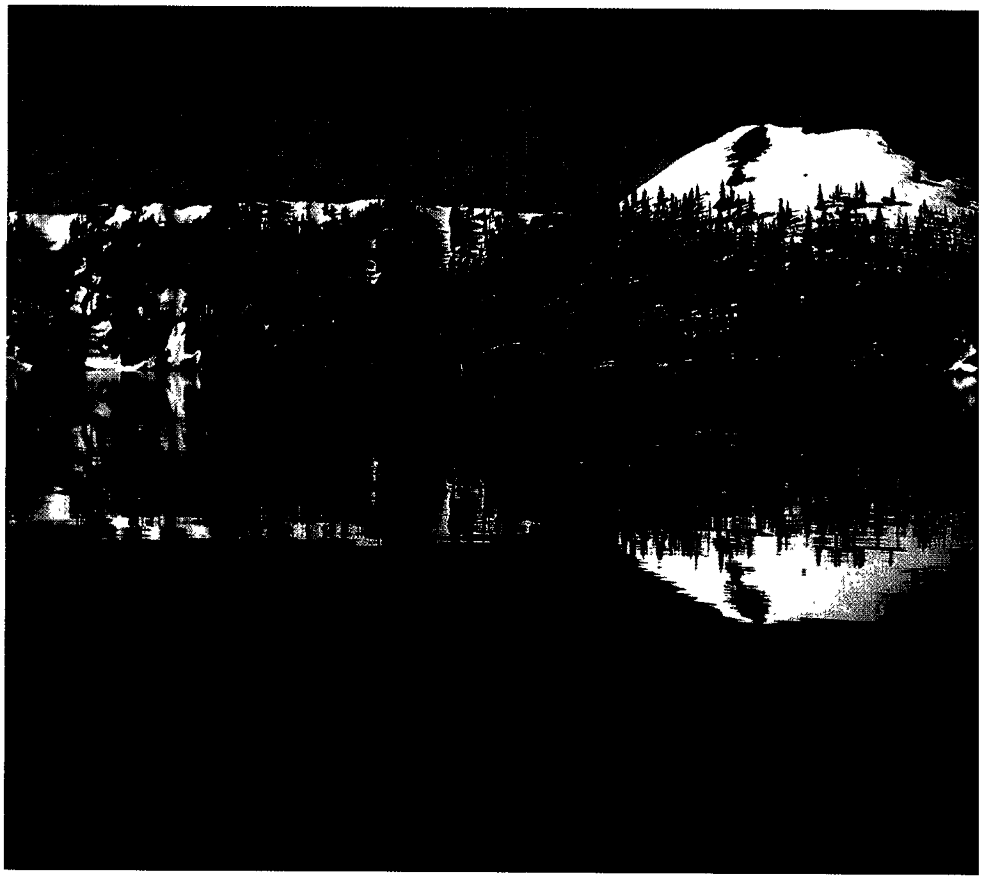
12,000 B.C.

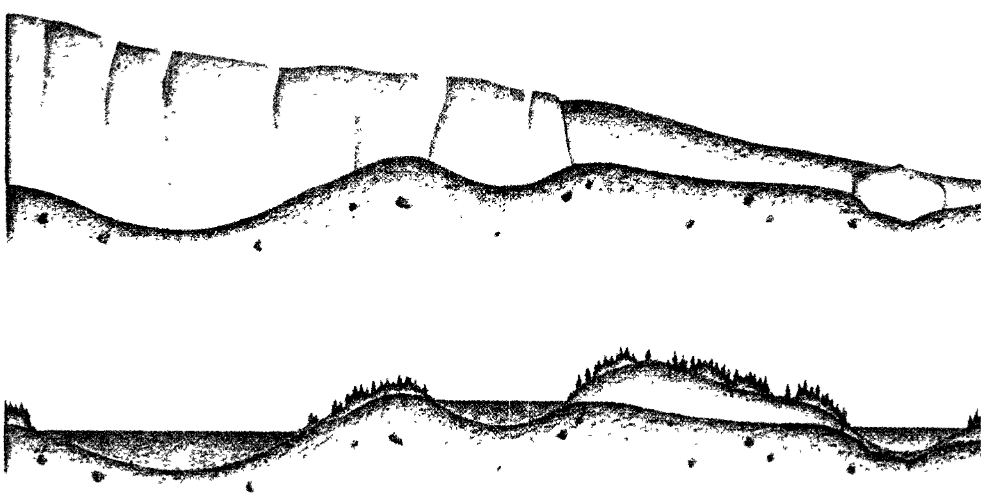
11,700 B.C.

9,500 B.C.

8,800 B.C.

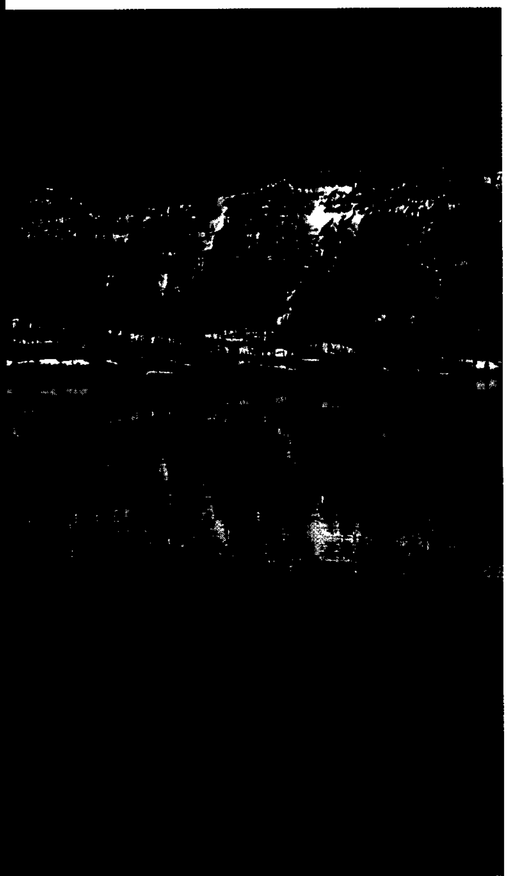
The scouring action of successive ice sheets formed the giant rock basins that contain the Great Lakes. From 12,000 B.C. (above) to the present (far right) the lakes have changed in size and shape as glaciers advanced and retreated and as water drained through various channels to the southwest and east. Today the Great Lakes drain northeastward via the Lawrence River.

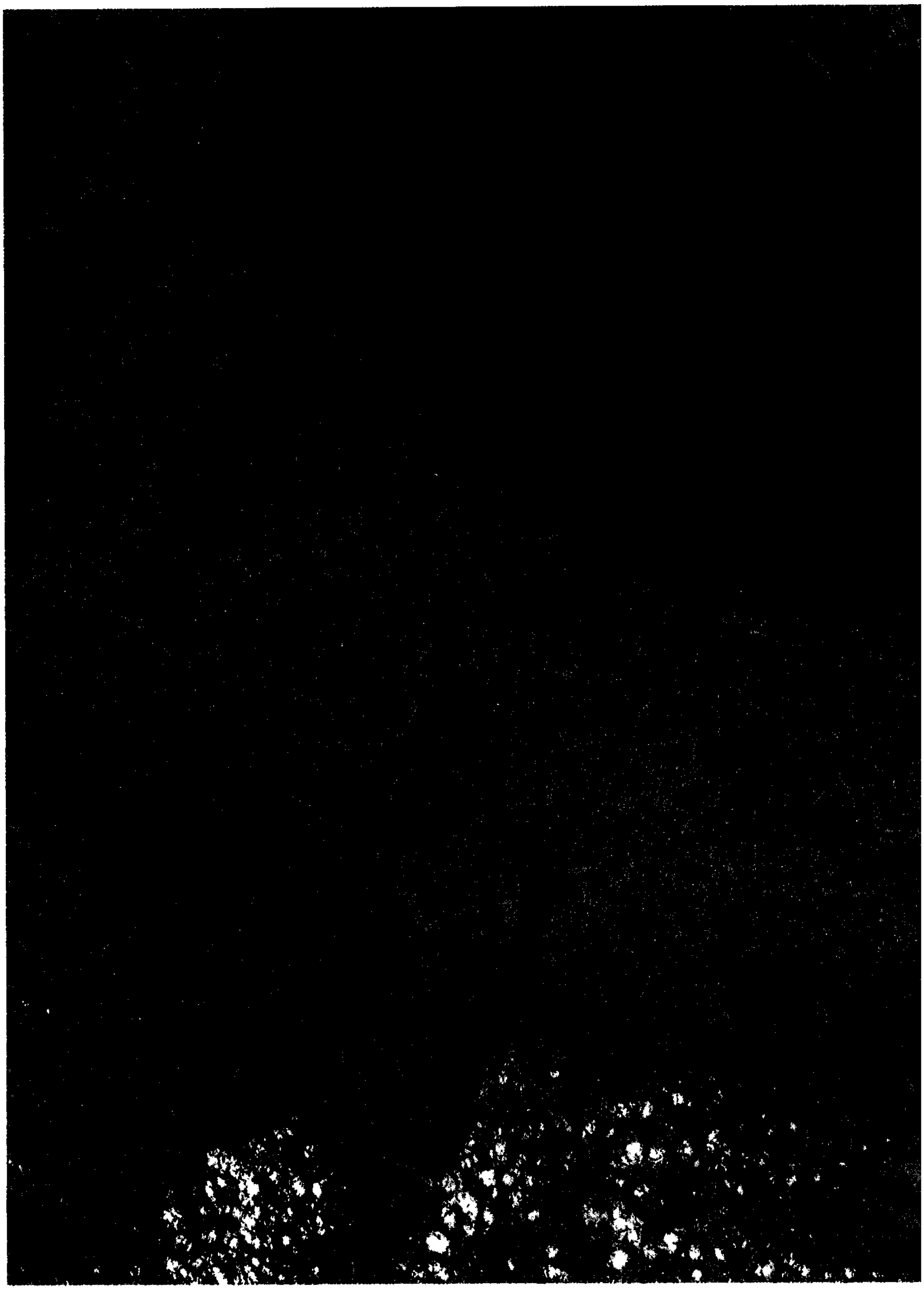




In mountainous areas (above), lakes may form behind landslide debris acting as a natural dam. The diagram at right shows three types of glacially formed lakes. At left, a lake basin is scoured out of till or bedrock; center, a lake forms behind material deposited at the glacier's terminus; right, "kettle" lakes form in depressions left by melting ice blocks.

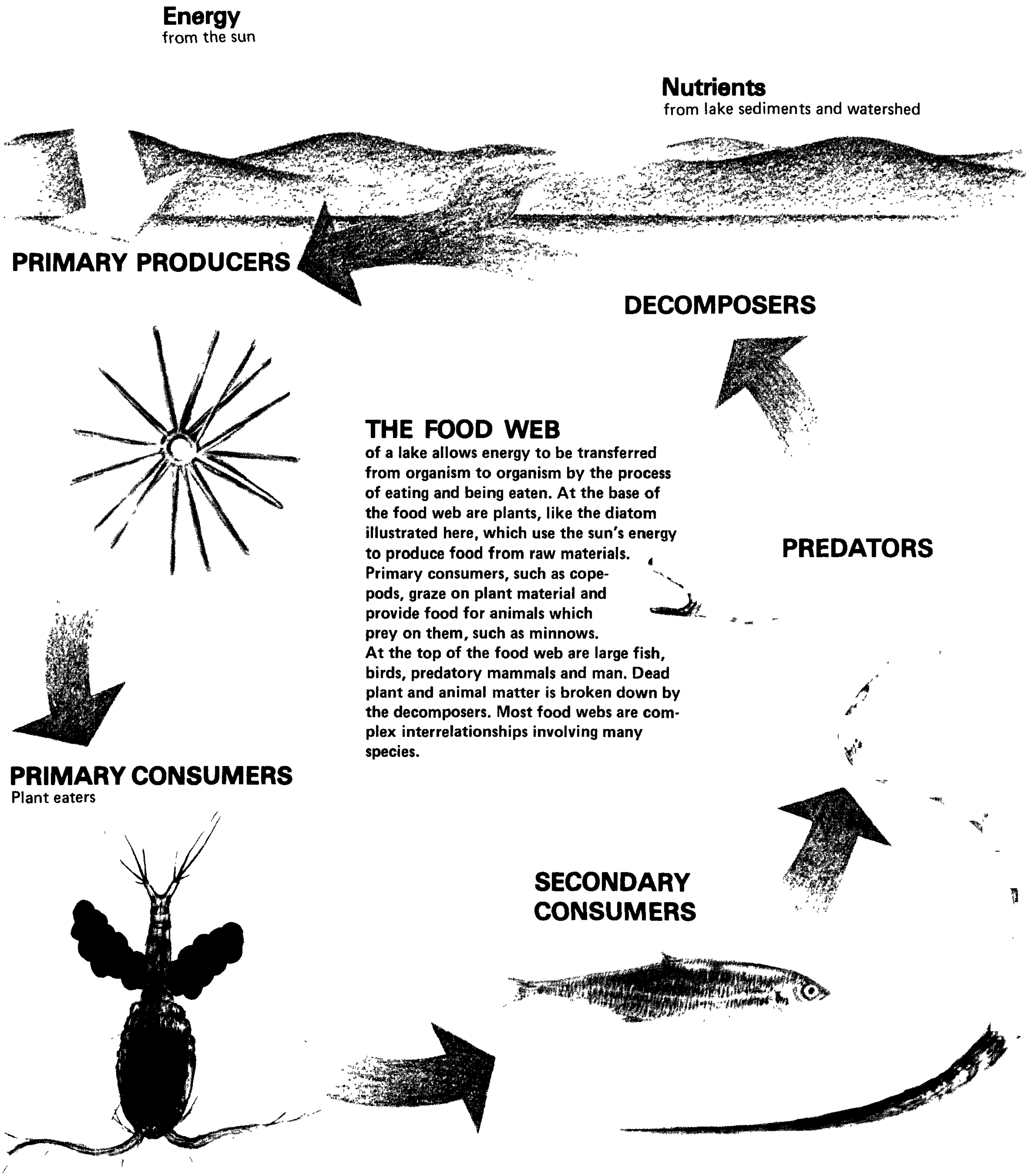
6,000 B.C. | 3,200 B.C. | 3,000 B.C. | Present





Oregon's Crater Lake (above), the Nation's deepest, fills a cavity created by the collapse of a volcano about 6,500 years ago. At right, a satellite view of the finger lakes of New York. The lakes were formed by the damming of long, narrow valleys by glacial deposits. At top is Lake Ontario.

How Lakes Form



THE FOOD WEB

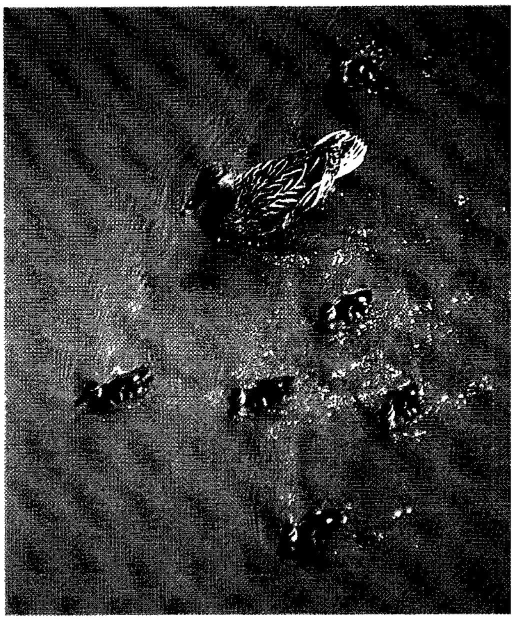
of a lake allows energy to be transferred from organism to organism by the process of eating and being eaten. At the base of the food web are plants, like the diatom illustrated here, which use the sun's energy to produce food from raw materials. Primary consumers, such as copepods, graze on plant material and provide food for animals which prey on them, such as minnows. At the top of the food web are large fish, birds, predatory mammals and man. Dead plant and animal matter is broken down by the decomposers. Most food webs are complex interrelationships involving many species.

Lake Ecosystems

To understand lake protection and lake restoration, it is essential to know how lakes form and function. A lake is an inland body of water, naturally or artificially impounded. As opposed to a moving channel, a lake is essentially a collecting basin, with biological, chemical, and physical qualities very different from those of a stream or a river in which the water moves continually in one direction. Within these large, small, shallow, deep, warm, cold, alkaline, acidic, highly individual and complex bodies of water, an awesome diversity of plant and animal life exists in a delicate state of balance. It is the nature of what we call an ecosystem that all parts—the communities of plant and animal life that make up the biomass together with the nonliving environment—function in a united interdependent fashion. The well-being of the microscopic phytoplankton and the waterlilies cannot be separated from the well-being of the worms, insects, snails, frogs, and fish.

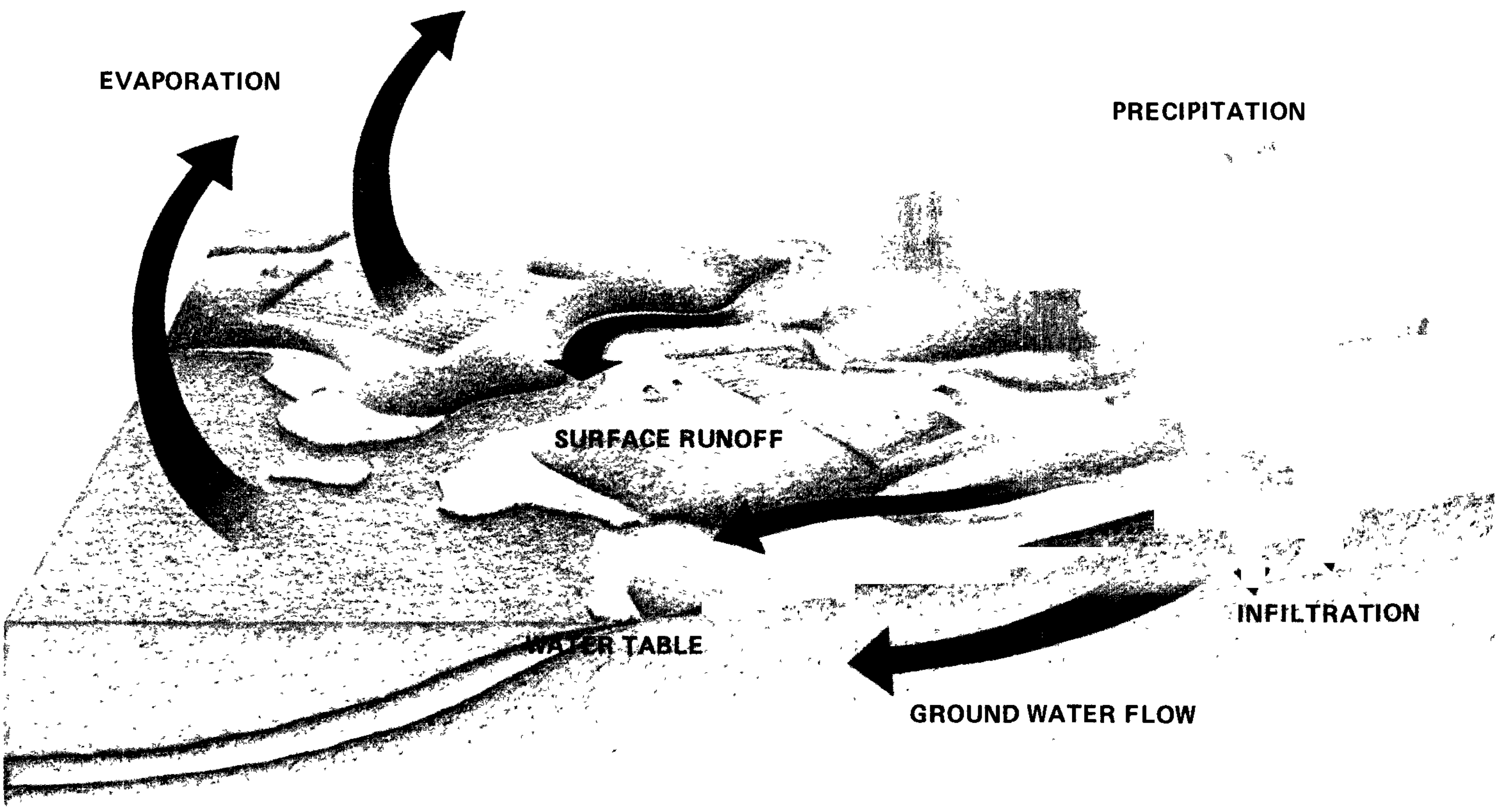
From the variety of plants and animals occurring in a region—the species pool—those present in a given lake and their abundance will be determined by the surrounding geology and the structure of the lake, the chemical content and turbidity of the water, climatic conditions, and other natural forces. Those species tolerant of the physical and chemical environment of the lake will survive and multiply. And although the organisms joined in a lake ecosystem form a little world, this world is highly vulnerable to alteration in water quality. Both numbers of organisms and diversity of species can be affected by changes in chemical and physical water properties, such as temperature and turbidity; severe alterations can eliminate all life.

As the sunlight penetrates the water, plants, through a complex process called photosynthesis, transform radiant energy into the chemical energy of food, combining carbon dioxide with water to produce sugars and giving off oxygen in the process. The maintenance of a balanced exchange of carbon dioxide and oxygen and the production of sufficient oxygen for the needs of animal life in the lake are processes as essential to life as the food supply. The chain of consumption in which aquatic animals eat plants and big fish eat little fish extends out of the lake ecosystem when fish are consumed by birds, by human beings, or by other mammals. Dead plants and animals, which sink to the bottom, are decomposed by bacteria and fungi, recycling nutrients to the water in which they live and to the sediments in the lake basin. Death and decomposition are as necessary to the chain of nutrient exchanges as is any other part of the organic cycle.

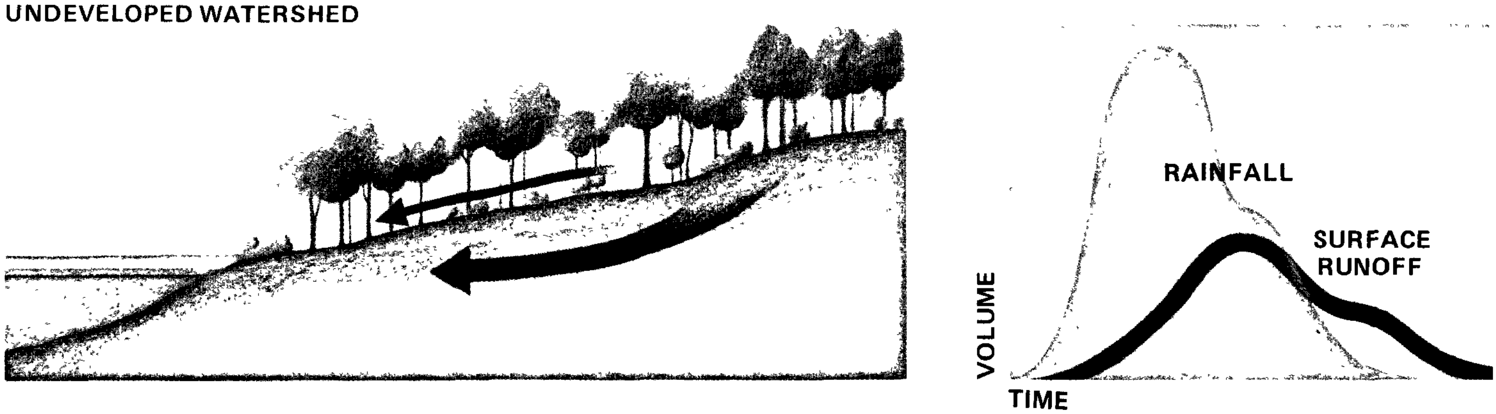


Mallard ducks and bullfrog: familiar members of lake food webs

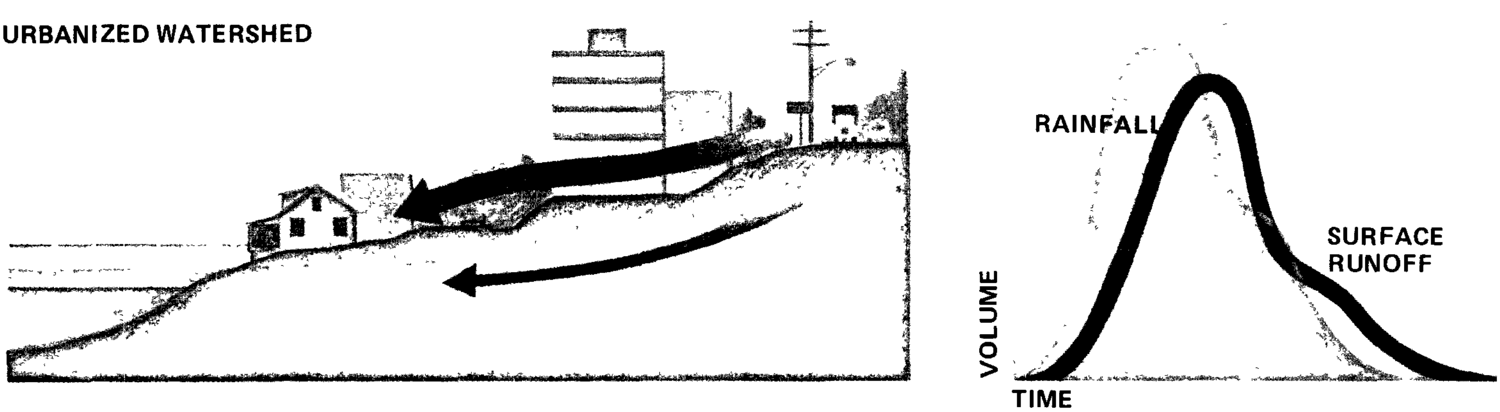
How Lakes Form



UNDEVELOPED WATERSHED



URBANIZED WATERSHED



The Water Cycle

Water can enter a lake from a number of different sources. Some lakes are fed entirely by springs or groundwater and direct precipitation. Many lakes are fed by rivers and/or streams that bring water to the basin by channeled routes. Water enters other lakes overland, by runoff, and through precipitation. All these seemingly separate routes are intimately joined in the universal natural process known as the water cycle.

In the first phase of the cycle, water is taken up into the atmosphere by evaporation from the oceans and to a much lesser degree from land and inland waters and by transpiration from plants. It then condenses and is returned to the earth in the form of rain or snow. Water that falls on the land nourishes the growth of plants and is absorbed into the soil. Some of this moisture percolates down to the water table, increasing the groundwater flow. Excess water that cannot be absorbed moves toward rivers, streams, and lakes by overland flow or runoff. In highly developed cities, where concrete and asphalt have replaced porous land areas, street runoff from rain and snow melt is very heavy compared with runoff in undeveloped areas. Eventually the water returns to the ocean so that the finite supply of water on our planet is never lost but is constantly recycled.

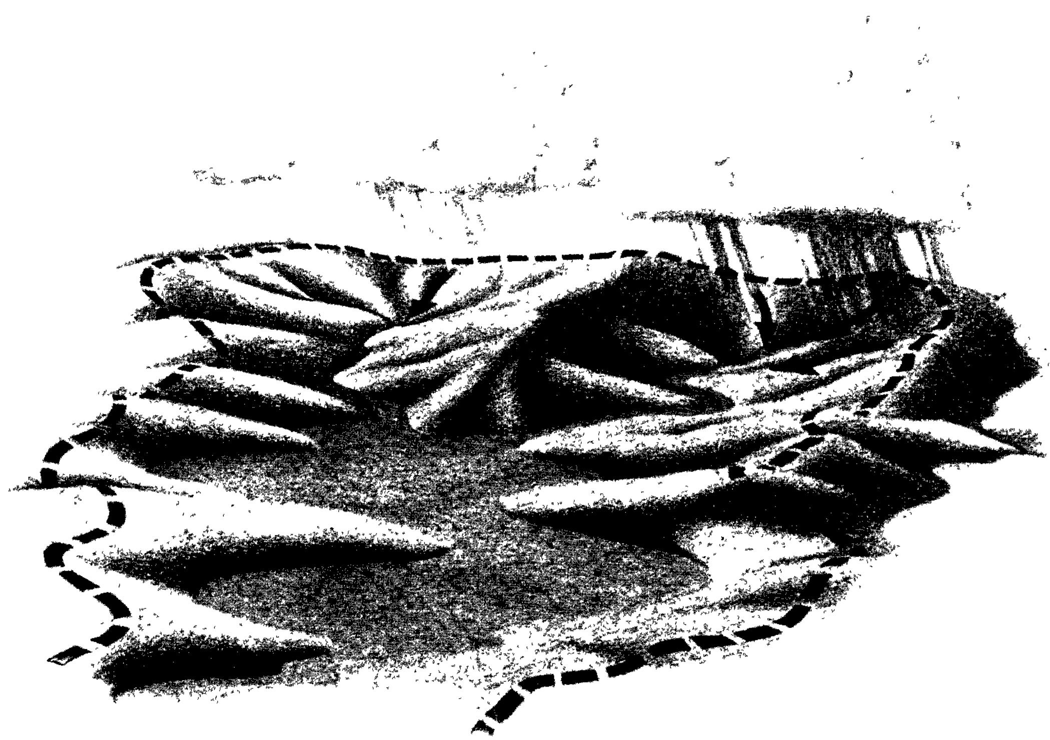
The Lake and Its Watershed

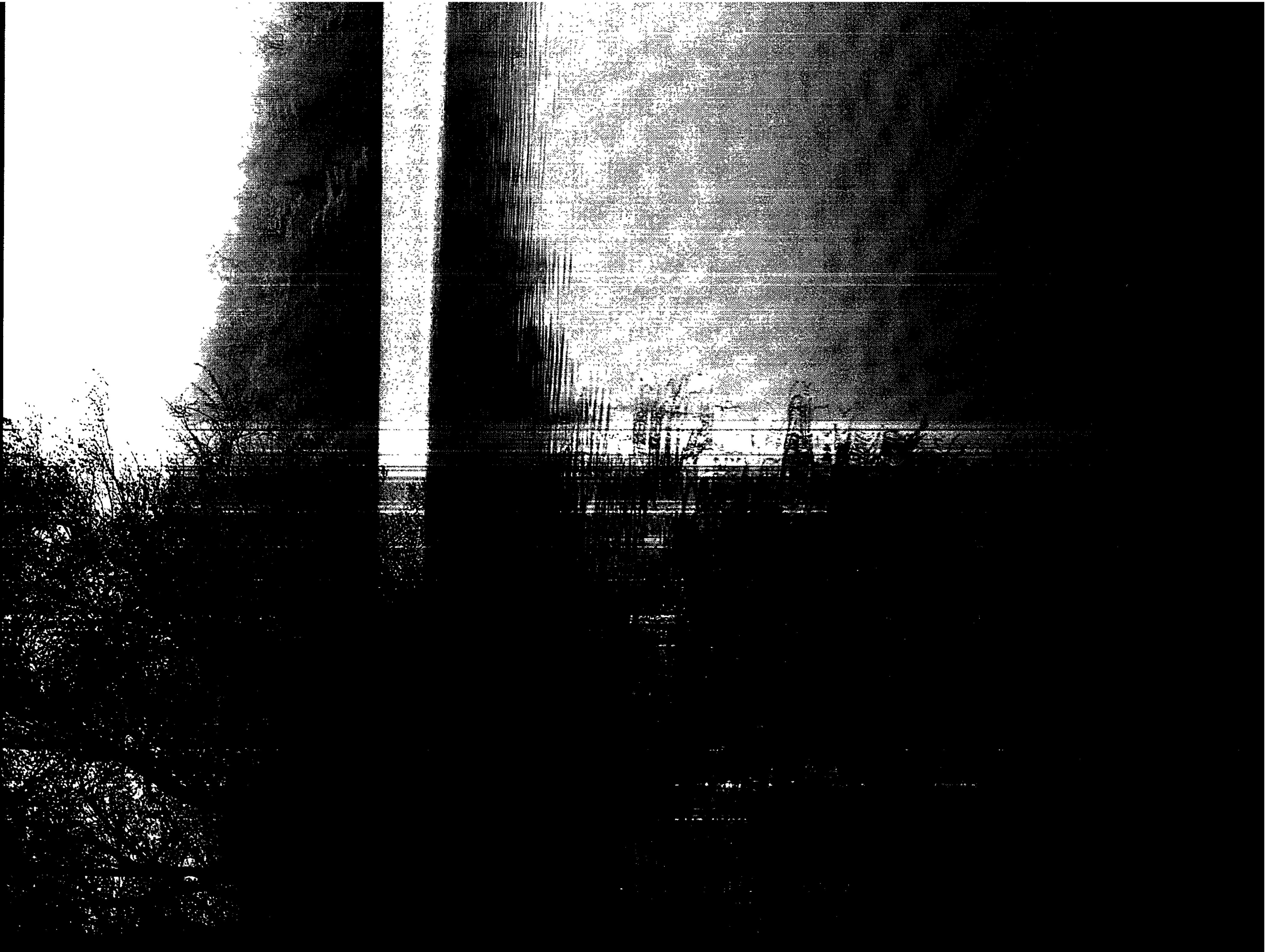
Although the vast and interconnected oceans are only gradually affected by what happens on land, everything that happens in a lake intimately reflects activity in the watershed. The watershed comprises not only the streams and rivers that flow directly into the lake; it also includes wetlands and the dry land areas, both adjacent to and upland from the lake. The water supply for a specific lake will be determined by topography as water moves by gravity from higher to lower elevations.

Although all drainage systems lead, through the unifying water cycle, back to the great reservoir, the ocean, the appearance of a lake, its physical and chemical properties, and the nature of its ecosystem, will to a very large extent be determined by the quality of the waters received from the drainage area. Most lake problems—evidenced by excessive plant growth or shallowness from siltation—have their source on land. Nutrients and sediments are brought into the lake by water, whether the water reaches the lake by channeled flow, runoff, seepage, or precipitation.

The precipitation that nourishes plants and fills rivers and lakes is one stage of the global process called the water cycle (above, left). Water that reaches the earth enters the ground through infiltration or flows over the surface as runoff to lakes and streams. Evaporation--from oceans, lakes and rivers, and from land--completes the cycle. In urbanized areas (left), proportionally less rainwater can enter the soil to slowly seep into rivers and lakes. The resulting increase in surface runoff may worsen erosion and pollution. As the graphs show, surface runoff is greater in volume and peaks more rapidly in urbanized areas, increasing danger and severity of floods.

A lake's watershed (right) includes all wetlands, streams and upland areas from which water flows into the lake (dark arrows).





Chapter 3

How a Healthy Lake Functions

Characteristics of Water

No one disputes the fact that water is essential for all creatures that live on land, but in a lake or a pond, water is everything. It is the medium in which the plants and animals of the ecosystem live and move, breathe, and are nourished. It is because of special characteristics such as transparency, the ability to retain heat, and the ability to dissolve matter, that water is able to sustain the life in a lake.

Plant production, the basis of the food web, is dependent on light, heat, and nutrients. A healthy ecosystem begins with the penetration of the lake's waters by sunlight, and the degree of penetration depends on the degree of transparency. Turbidity in a lake or reservoir, caused by suspended silt or other inorganic material or by excessive plant or animal matter, can interfere dramatically with productivity by impeding light penetration. When plant life, which can be rooted in the bottom or freely floating, is diminished in quantity or radically altered in species, higher organisms are deprived of food, shelter, and sites for reproduction.

One of the simplest instruments employed in measuring lake water quality is a white disk 20 centimeters (8 inches) in diameter invented in 1865 by an Italian physicist. The Secchi disk, as it is now known, is lowered into a lake to the depth at which it can no longer be seen by the investigator. In water with high turbidity it may disappear within a few centimeters, but, in 589-meter (1,932-foot) deep Crater Lake in Oregon, Secchi disk readings of 40 meters (131 feet) have been recorded.[11] These readings are virtually unequalled except in Lake Tahoe in California-Nevada.

The ability of water to dissolve substances makes essential elements available to living organisms. The two major nutrients essential for aquatic plant growth, nitrogen and phosphorus, dissolve readily in water in a number of different compounds. The rate and variety of algal growth will usually be closely related to the concentration of nutrients in the lake.

Because of water's unique physical qualities the temperature in freshwater below ice rarely drops below 4 degrees Centigrade (39 degrees Farenheit). It seldom goes above 27 degrees Centigrade (80 degrees Farenheit) during the summer.[12] Under normal conditions, changes in water temperature are gradual and organisms living in water need to adapt to a much narrower range of fluctuations than many land animals.

Temperature layering or stratification in lakes occurs because of differences in water density related to temperature. As every lake swimmer knows, the water may seem inviting near the surface but suddenly a few feet lower a chill is felt. The upper layer of a stratified lake is known as the epilimnion. The circulating waters of the epilimnion are separated from the dark, non-circulating, lower, colder waters of the hypolimnion by a central layer of rapid temperature transition known as the thermocline.

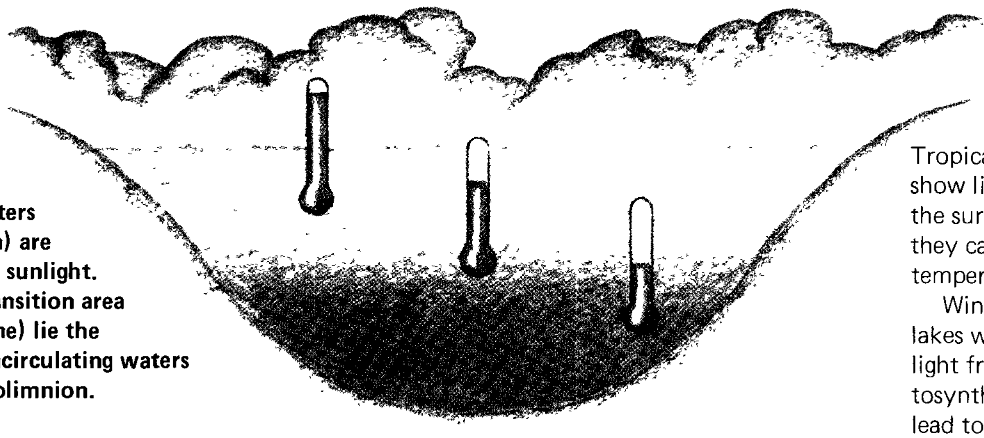
In most North American lakes several changes in heat distribution take place over the seasons. When the air temperature drops in the autumn, epilimnion and hypolimnion water temperatures equalize and achieve the same densities. As surface waters become cooler and heavier, they begin to mix with the water below, and the movement of winds and currents results in a total overturn with reoxygenation of the lower levels, previously depleted of oxygen. Another overturn occurs in the spring in northern regions when ice melts and water temperatures become uniform throughout the lake. Both the autumnal and the spring overturns bring nutrients that have accumulated in the lower levels to the surface, where they stimulate development of algal populations.

In shallow lakes, the action of winds and currents may prevent thermal stratification and in subtropical, warm temperate, or deep temperate lakes that do not freeze, the entire lake circulates throughout the winter.

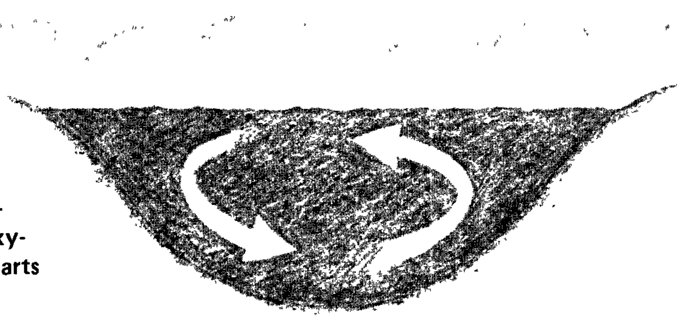
Powers Lake, Connecticut

How a Healthy Lake Functions

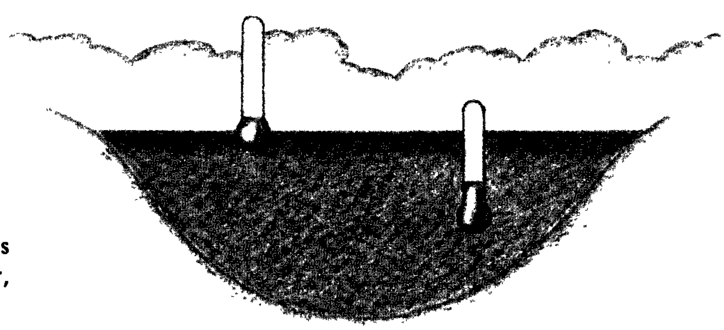
SEASONAL TEMPERATURE LAYERING



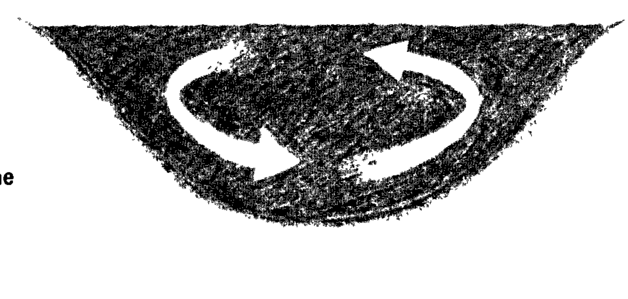
SUMMER
Surface waters (epilimnion) are warmed by sunlight. Below a transition area (thermocline) lie the cooler, noncirculating waters of the hypolimnion.



FALL
In many lakes, surface water cools until an overturn occurs, supplying oxygen and nutrients to all parts of the lake.



WINTER
When ice covers the lake, a layer of water just above freezing lies above slightly warmer, denser water.



SPRING
Another overturn occurs when ice melts and water temperature becomes uniform from the surface to the bottom.

Tropical lakes with high water temperature show little seasonal temperature change at the surface or in the depths, even though they can become just as stably stratified as temperate lakes.

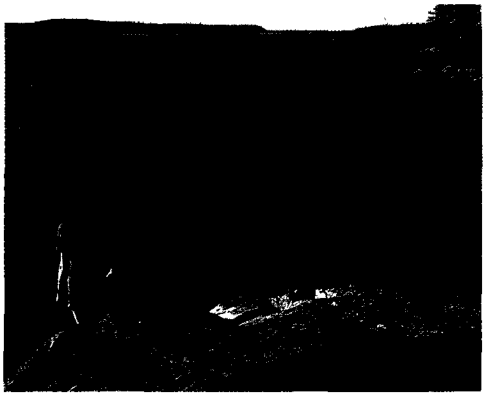
Winter fish kills can happen in shallow lakes when snow covers ice preventing sunlight from reaching plants. The loss of photosynthesis and the decay of dead plants lead to oxygen depletion in the water belo Summer oxygen depletion can be caused b excess amounts of decaying material, with highly productive lakes particularly subject to oxygen depletion. A measurement of co siderable significance in lake studies is the D.O., or dissolved oxygen concentration, which varies with the changing balance of photosynthesis and respiration.

Classifying Lakes

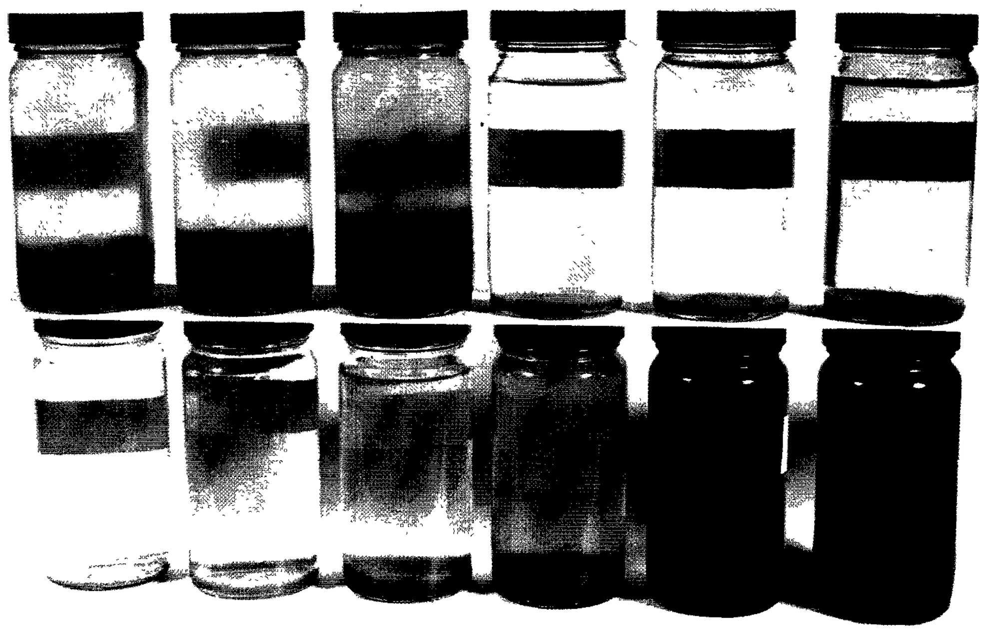
Numerous ways have been devised for classifying lakes by physical qualities, by chemical characteristics, by age. One physical means of classification is by thermal characteristics.

Another classification relates to the source of water supply. Seepage lakes are f entirely by groundwater, drainage lakes are fed by overland sources. The chemical qual ty of water in a seepage lake is strongly affected by the length of time the water ha been in contact with surrounding soils before reaching the lake and by the nature of those soils.

Lakes also may be classified by such ph sical characteristics as basin shape and by whether or not they have an outlet. Water flowing into a deep lake with no outlet or with a very limited outlet will have a longe "residence time" than it would have in a shallow lake with rapid flow-through. The extraordinarily deep Lake Tahoe has an est mated residence time of 700 years. The res dence time of water in other lakes with strong flushing action may be measured in days or months. In reservoirs, which are co



Above, an aging, eutrophic pond in Connecticut supports many aquatic plants. At right, plankton samples from 12 New York lakes vary from oligotrophic (clear samples) to eutrophic (bottles at lower right).



structed for purposes of flood control, power production, irrigation, water supply, recreation, or several of these uses, water residence time is controlled to serve these functions.

The most common way of classifying lakes in discussions of water quality is by their productivity. This is determined by the nutrients brought in from the watershed and by direct fallout from the atmosphere, the chemistry of the bottom sediments, and the geological nature of the drainage basin, as well as by the climate and the depth and shape of the basin. Based on organic cycles, which in turn are based on "trophic" or nutritional characteristics, lakes are commonly divided into three categories: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic (poorly fed) lakes are those in which plant growth is limited by a low chemical concentration of nutrients. Consequently, such lakes have few aquatic weeds and algae or other plant life. The number of species is usually high but the number of individuals low. Oligotrophic lakes are usually large and deep and clear with high levels of dissolved oxygen and Secchi disk visibility of 6 meters (20 feet) or more.

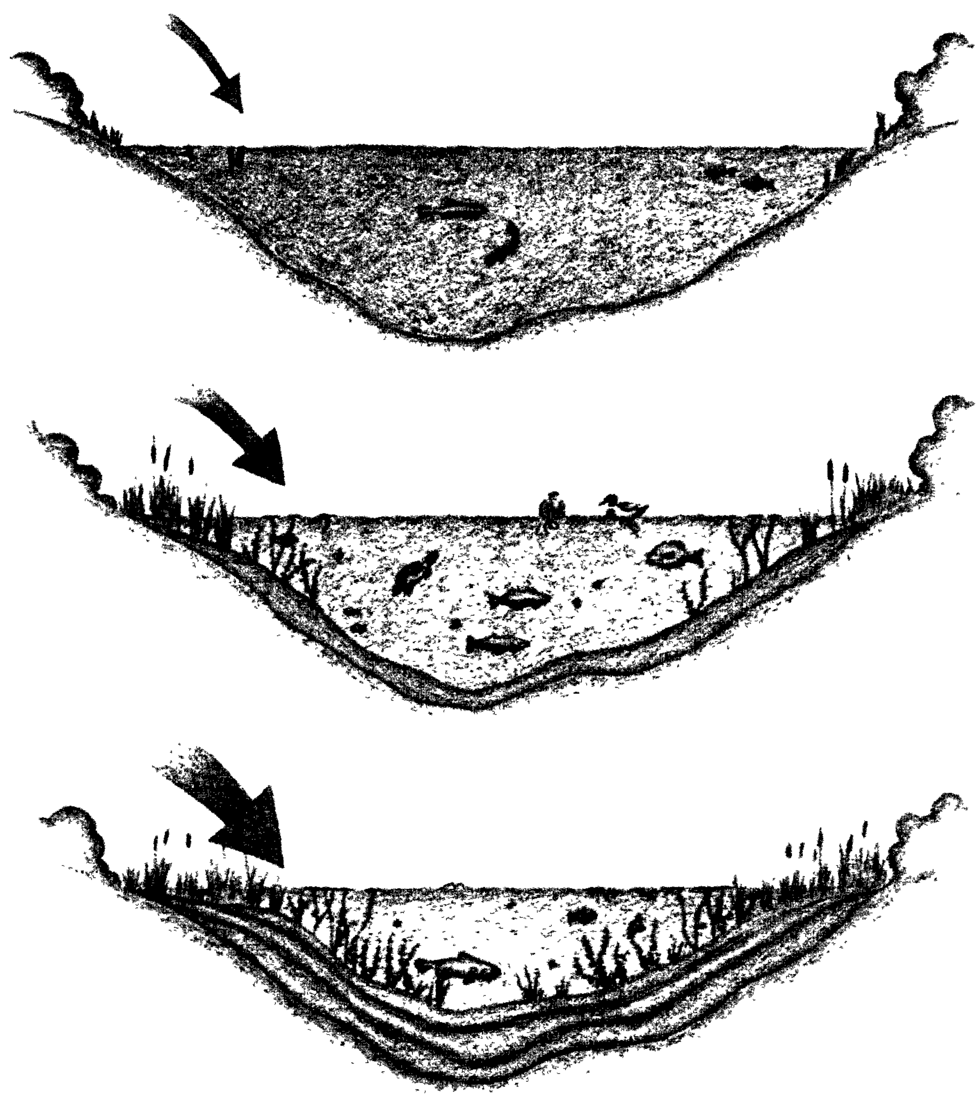
Eutrophic (well fed) lakes have large supplies of nutrients and heavy layers of organic sediments on their bottoms. Inflow of sediments makes the lake shallow and turbid. Secchi disk visibility may be as little as one-half meter (2 feet) or less and because of shallowness and high nutrient levels there may be extensive weed and algal growth. Although during the summer photosynthesis, particularly by blue-green algae, is extremely high on sunny days, when sunlight is absent species diversify and numbers in the animal kingdom may be limited by low dissolved oxygen levels. This results from the high rates of both algal respiration and bacterial action required to decompose dead vegetation. As a lake becomes increasingly eutrophic the number and type of bottom creatures will change. The high rate of decomposition produces excessive demand on the oxygen supply by decomposing organisms, with subsequent low oxygen levels. This critical problem may cause distress or death of organisms. Fish populations in temperate oligotrophic lakes can include species such as trout and salmon, which live in the cool, well-oxygenated hypolimnion during the warmer months. But in warmer eutrophic lakes with low oxygen in the hypolimnion, these fish are replaced by warmwater species such as perch, pike, bass, panfish, and bullheads which are capable of living in the warm epilimnion

Mesotrophic lakes are at an in-between stage nutritionally, with ecosystems functioning in a stable fashion, supporting a diverse community of aquatic plant and animal life. Many of our most popular recreational lakes are at this mesotrophic stage of evolution.

Although paleolimnologists, who study the history of lakes, have found examples in the eons of geological time that counter this theory, in general, lakes evolve naturally from oligotrophic to eutrophic stages. Eutrophic lakes are common in regions of

How a Healthy Lake Functions

Below, top to bottom: Oligotrophic lakes, with clear waters, few bottom sediments, and low biological activity may evolve (through cumulative or increased influx of nutrients, represented by arrows) into mesotrophic and finally eutrophic lakes, characterized by turbid waters, sediment buildup and large numbers of aquatic plants.



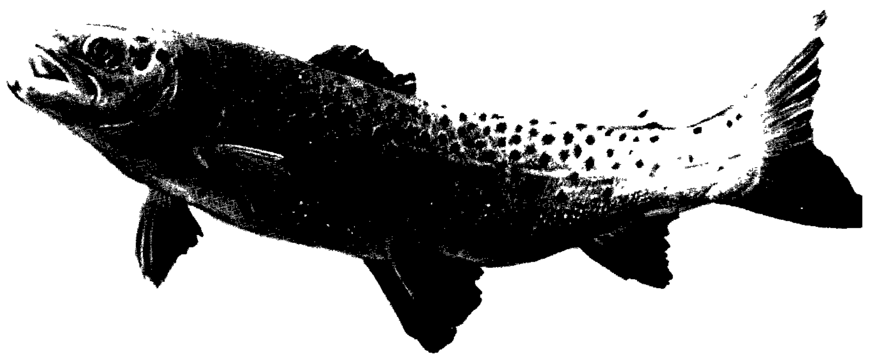
fertile soils, but in less fertile soils attaining this level of productivity may take many thousands to millions of years. The eutrophication process, however, is accelerated by man, who through urbanization and agricultural practices may increase the supply of nutrients and sediments to the lake.

Not all "healthy" lakes are clear, blue, deep bodies of fresh water. Desert salt lakes, such as the Great Salt Lake in Utah, occur in arid climates. Salt concentrations build up because of an imbalance in which evaporation is greater than precipitation Prairie potholes and bogs are sometime classified with lakes and sometimes wit wetlands. Potholes are seasonal bodies of water, shallow depressions which range size from less than ½ to over 40 hectares (1 to 100 acres). Like many floodplain lakes which have formed in old ox-bows they are usually dry durin some months of the year. Most are foun in the northern Great Plains area extend ing into south central Canada. Bog lakes are most commonly found in the north eastern and north-central States. Becaus they have almost no inflow or outflow they retain decayed humic material, mak ing their water brown in color and highl acidic.[13]

A word about ponds. Although the ter pond is loosely used to refer to small shall bodies of fresh water, including natural phenomena and those made by man or beaver, it may also indicate, as in the ca of Walden Pond, a body of considerabl size. Particularly in New England, becau of traditional regional usage, the word po should not be assumed to indicate dimer sion. Ponds that become dry during the summer as water tables fall may support mobile organisms such as insects and frog which can find other temporary refuge, or those that have special mechanisms enabling them to survive in a state of dor ancy.

Reservoirs

As opposed to a natural lake, a reservoir constructed for purposes of flood co trol, drinking water supply, irrigation, c electric power generation, has a natural inlet—i.e., a stream or river—and an arti ficial outlet—the control gate of a dam. Although reservoirs have ecosystems sir ilar to those of natural lakes, because of their different morphology and waterflow characteristics, they present special problems.



The bullhead (left) is tolerant of warm water and is a common resident of the surface waters of eutrophic lakes. The river trout (right) often occurs in the cooler bottom waters of temperate oligotrophic lakes.

A reservoir is an impoundment formed by a dam. It has shallow water at the inlet and deep water near the dam, unlike a natural lake, which is more likely to have a shallow littoral zone with deeper waters toward the middle. Although a reservoir may be very deep, the residence time of its water can vary from a few days to a few years, depending on the size of the lake relative to its watershed area, the purpose for which the dam is used, and the seasonal rises and dips in the quantity of waters it receives.

Reservoirs tend to have greater siltation and turbidity problems than natural lakes because they are fed by rivers, which carry high loads of matter held in suspension. Essentially, the reservoir becomes a settling basin for the river

Waters drawn from an anaerobic hypolimnion of a reservoir may contain noxious gases, including hydrogen sulfide, which is highly toxic to aquatic life. The Corps of Engineers has found that these waters corrode outlet mechanisms, and that high levels of hydrogen sulfide have often made workers at reservoir dams feel ill.[14] These gases, which result from decomposition of organic matter, may also be accompanied by high concentrations of iron and manganese in periods of low flow, all lead to unpleasant odors, tastes, and discoloration of water downstream—and high costs for removal of these pollutants if water is to be used for consumption.

Releases of turbid water can interfere with downstream fishing and other recreation When water is withdrawn from the hypolimnion of the reservoir, discharge waters often bring cold water with lowered dissolved oxygen concentrations to receiving streams, damaging fisheries downstream or altering other components of stream ecology Fisheries might also suffer damage from waters drawn from the epilimnion which are warmer than normal stream temperatures. In some instances, however, cold "tail waters" provide excellent trout fishing.

Management of reservoirs must take into consideration the velocity of releases as well, since large pulses of water rushing downstream may utterly destroy habitats simply by their force rather than by their incompatible chemistry and temperature. Other management problems involve providing fish passage around hydroelectric dams and considering the results of fluctuating water levels and velocity on fish spawning habitats at appropriate times of year. Drops in water level in reservoirs and seasonal fluctuations in natural lakes cause problems with public use turbidity from bank erosion, unaesthetic views of mud banks, and problems of access to docks and other recreational facilities. In parts of the West, irrigation drawoffs have completely dried up reservoirs as well as stream beds.

Lake Powell, a reservoir on the Colorado River, sprawls behind the Glen Canyon Dam in Arizona.

Chapter 4 How Lakes Change

Utah's Great Salt Lake has been altered by the construction of a railroad causeway which separates the less saline waters of the southern portion of the lake, which receives more freshwater inflow, from the saltier waters of the northern portion.

Sedimentation

Lakes are not permanent features of the landscape. Eventually, even without human influences, lakes will change and may disappear. The process may be relatively fast because of rapid siltation, or it may be slow, occurring over hundreds of thousands of years.

A primary natural cause of the death of lakes is accumulation of sediments. This occurs as fragments from dry land are, by the forces of water, wind, and gravity, moved to waterways, or as the remains of organic matter accumulate within the lake. As sediments build up, lakes become increasingly shallow, the light of the sun penetrates to the bottom, and plant life proliferates. Eventually the lake will become a wetland. Over a long period of time the wetland will fill in completely and appear to become dry land except for intermittent wetness.

Sedimentation is generally a slow process in a wilderness and in undeveloped countries, but it is hastened by the activities of man. Development markedly speeds siltation as earth is cleared and moved for highway, residential, or industrial construction Deep and surface mining speeds the introduction of materials that belong on land into waterways. Precipitation and snow melt runoff carries sediments from urban parks and gardens through storm sewers and into rivers and streams. Tree roots hold water and restrain erosion, but when woodland is converted to farmland the dynamics are altered. Four billion tons of sediment are washed into lakes and streams in this country each year, of which an estimated 50 percent comes from agriculture [15] When cultivated land is left without vegetative cover, it is extremely vulnerable to erosion by water and by wind. The loss of billions of tons of topsoil annually reduces land productivity while simultaneously supplying the major water pollutant. Sediments entering lakes may also carry nutrients, toxic chemicals, and pathogens.

Runoff carrying solid materials from the watershed may create unaesthetic lake water conditions—or a serious public health problem. Concern about contracting infecttious disease from water is low in this country since few people have known anyone who suffered more serious consequences from unclean swimming water than something a doctor cheerfully labeled "swimmer's ear" or "summer diarrhea." It is important, however, to note that several outbreaks of typhoid contracted from drinking water have taken place here and in developed nations around the world in the past three decades, proving that the dread diseases of our grandparents' time are not extinct.[16]

Nutrient Enrichment

Among the essential ingredients in any chemical mixture designed to stimulate plant growth on land are nitrogen, phosphorus, and potassium. For gardens, these nutrients may be added in the form of commercial fertilizers, or by recycling animal manure and composted vegetable wastes. The nutrients are soluble in water and therefore penetrate the soil with rainfall. An excess of nutrients can enter waterways and lakes from this source alone in "sheet" runoff from gardens, cities, parks, and farmlands.

Nutrient enrichment of a lake and sediment loading lead to eutrophication. To understand the management of lake problems, a distinction must be made between natural eutrophication, which occurs as nutrients wash from undeveloped watersheds, build up in lakes, and are recycled by the sediments, and "cultural eutrophication," an accelerated enrichment process caused by human activities.

Cultural eutrophication occurs in developed areas as essential plant nutrients,

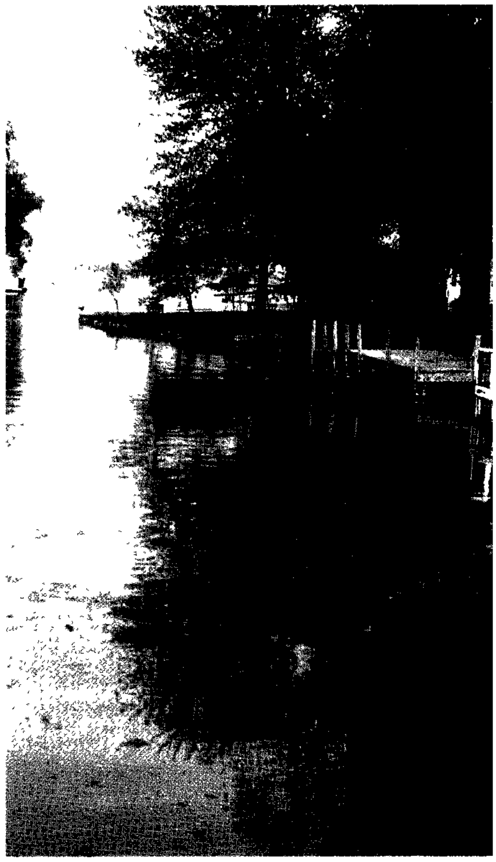
How Lakes Change

Photos (above) taken in 1920 and 1936 document the death of Lake Como in Hokah, Minnesota. The lake was filled with sediment from steep slopes that had been cleared of timber and cultivated without erosion controls. At right, sediment fills a ditch at a Virginia construction site.

particularly nitrogen and phosphorus, enter the lake from a variety of specific and diffuse sources. Organic wastes enter waterways from inadequate or faulty sewage treatment plants, from septic tank seepage, from cattle feedlots, and from a variety of food, paper, and textile industries. Municipal wastewater carries high concentrations of phosphorus from two major sources—human feces and phosphorus-based detergents. Industrial wastes may contain nutrients and a wide spectrum of toxic and hazardous materials. Storm sewers carry soil, lawn fertilizers, salt, pet droppings, sand, lead, and many other materials.

The National Eutrophication Survey, conducted on lakes receiving municipal wastewater by the Environmental Protection Agency from 1971 to 1977, found eutrophic conditions in 68 percent of the 800 lakes surveyed. Four percent of these lakes were classified as hypereutrophic. Not all the problems are recent or controllable. Oneida Lake in upstate New York was known to the local Indians in the 18th century by a name that means "stinking green," because of its algal blooms.[17]

Eutrophication is unmistakable. Overstimulation of plant growth occurs, with consequent deterioration in water quality and changes in fish species. Heavy growth of blue-green algae makes the lake green and murky, with seasonal algal blooms and scums and mats formed by deteriorating plants. Excessive growth of macrophytes—rooted aquatic plants—may clog the lake, making it unattractive for swimmers, boaters, and fishermen. Unpleasant odors and tastes are noticed as decomposition of plants results in depleted oxygen supply. Mosquito populations thrive when shallow wind-protected waters stagnate. Fish may, in some instances, die and populations change as those species that require good oxygen supply and cool waters, such as trout, salmon, black bass, and walleye, disappear and are replaced by species which are tolerant of warm water and low oxygen such as bullheads, carp, and mudminnows. Some eutrophic lakes do support excellent bass fisheries.



Algae and aquatic weeds, symptoms of eutrophication, can be an aesthetic nuisance and a hindrance to recreation. At right, eutrophication in Lake Mendota, Wisconsin.

Other Pollutants

Pollutants, in ordinary terms, are silt and biologically degradable substances. The term includes human and animal wastes as well as many other types of foreign matter that may enter a lake as, for example, vegetable wastes from a cannery. Such wastes become troublesome pollutants only if they produce undesirable alterations of the plant or animal life or result in uninviting conditions for recreation. When organic wastes enter a lake they are greeted by a host of biological organisms designed to cope with the problem. Natural cleansing forces go to work as microorganisms metabolize pollutants into carbon dioxide and water. Problems come from overload, which exerts a high biochemical oxygen demand for decomposition and this may decrease dissolved oxygen to concentrations too low for higher plants and animals. Decomposition also adds nutrients to the lake that are available for algal blooms.

Today a range of synthetic chemical contaminants for which there are few or no decomposer organisms have found their way into our lakes. Runoff from both urban and rural areas and discharges from industry carry to the lake such substances as toxic pesticides, PCB's (polychlorinated biphenyls), asbestos, and toxic metals such as arsenic, mercury, lead, zinc, and copper. Even in rivers, where self-cleansing action disperses pollutants more rapidly than in lakes, grave pollution problems may persist. Kepone-contaminated substances in the James River in Virginia are expected to remain there beyond the year 2000.[18] Materials carried into lakes may recycle within the system for generations.

How Lakes Change

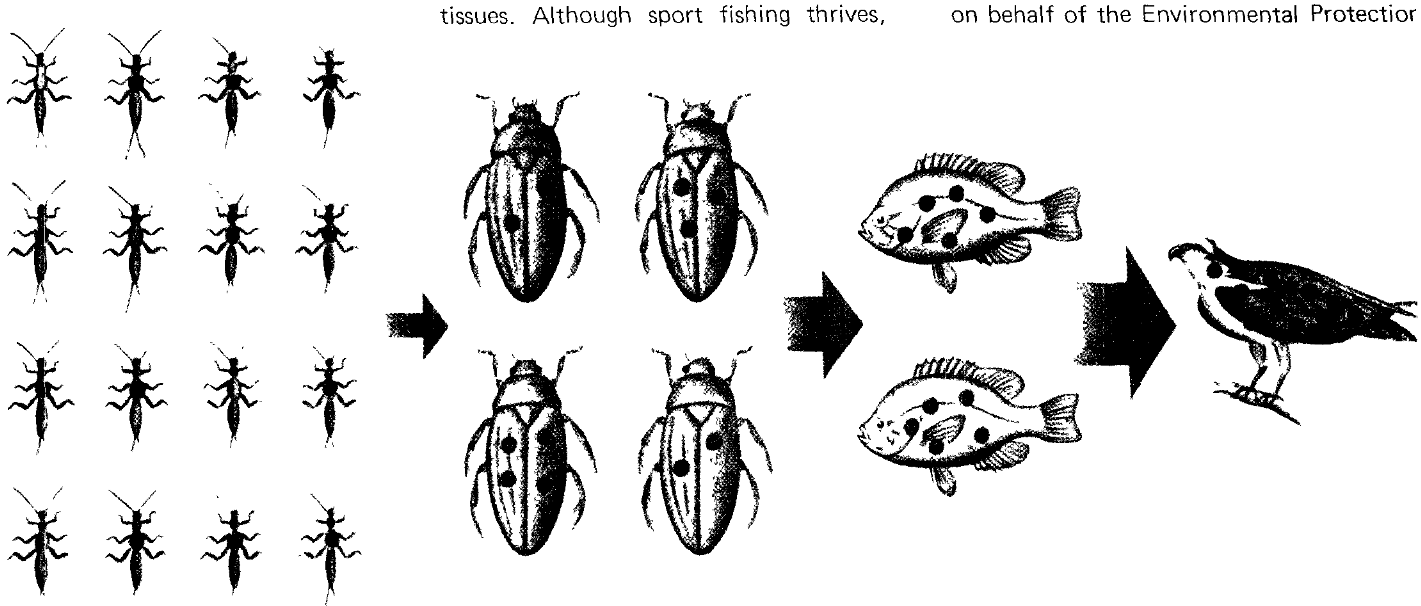
Pollutants such as the insecticides Kepone and DDT can remain in the lake and become toxic to animals and to humans as a result of "biological magnification." Toxic substances tend to become concentrated in the tissues of organisms by this process as smaller animals are consumed by larger ones. Ironically, the very qualities that made DDT such an exciting discovery in the 1940's—the fact that it worked fast, attacked a wide range of pests, and was persistent—resulted in widespread ecological damage. The fact that it was also cheap resulted in flamboyant overuse. Although DDT was banned in the United States in 1972, in 1976 fish in Lake Michigan were still found to have concentrations of the chemical in their bodies in excess of those permitted for human consumption.[19]

Fish in Lake Michigan were also discovered to be high in concentrations of PCB's, a group of industrial chemicals now usable only under strict control and no longer manufactured in the United States.[20] Like DDT, PCB's degrade extremely slowly and accumulate in animal tissues. Women who lived near the Great Lakes and consumed fish from the lakes were found to have PCB's in breast milk and in fatty tissues. Although sport fishing thrives, trout and salmon from Lake Michigan are prohibited from being commercially harvested because of high PCB levels.[21] The Food and Drug Administration considers unfit for human consumption any fish containing two parts per million of PCB's since these chemicals have caused fish kills and been implicated in human mutation.[22] Approximately 400 million pounds of PCB's have been discarded already and are present in the environment while an added 30 million pounds are still in use.[23] In Lake Superior there is concern about concentrations of asbestos in parts of the lake from which drinking water supplies are taken, this resulted from direct dumping of tailings from a mining operation [24] In a number of States not bordering the Great Lakes, consumption of fish from certain waters is also restricted because of unacceptable levels of PCB's and pesticides, particularly DDT and Dieldrin.[25]

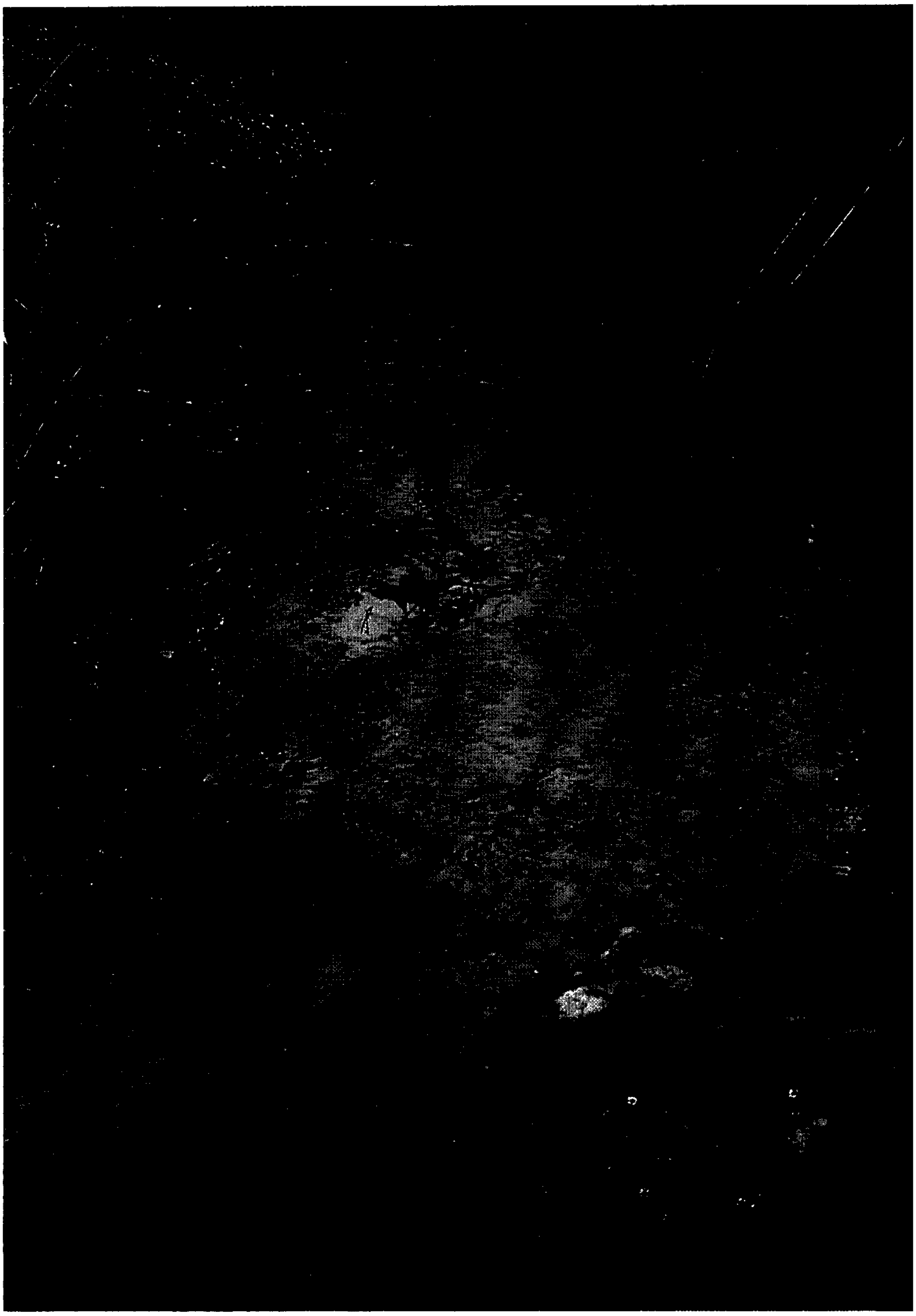
Case Report: Alcyon Lake

In March of 1980 the Justice Departmen on behalf of the Environmental Protectior

Toxic substances can reach dangerous levels in animals near the top of the food chain through a process called biological magnification. Small animals with low concentrations of toxins are consumed by larger animals, in whose tissues the toxins accumulate.



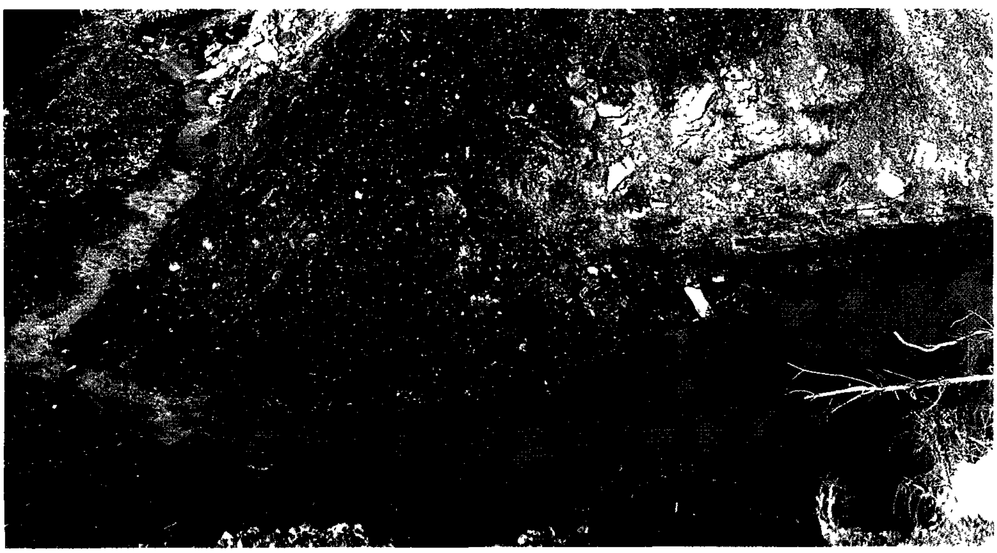
The waters of Alcyon Lake (left) in Mantua Township, New Jersey have been contaminated by chemicals dumped at the LiPari Landfill, 1,000 feet upstream from the lake. Below, leachate from the landfill contains dangerous chemicals such as benzene, lead, and cadmium.



Agency, filed suit against the owner of the LiPari Landfill in Mantua Township, New Jersey, to force cleanup of the inactive chemical disposal site from which dangerous chemicals are leaking into nearby streams. Chemicals such as benzene, lead, cadmium, and others—some of which are suspected of causing cancer—were dumped on this site starting in 1958 and have worked their way through adjoining soils and waterways. Now they are threatening the public. Two streams adjacent to the landfill are contaminated and are bringing contaminants to Alcyon Lake, half a mile away in Pitman, New Jersey.

Leaching from the chemical dump is the most dangerous assault to this lake, which has had severe pollution problems for over 20 years. This formerly popular recreational lake was once the site of an amusement park and annual agricultural fairs. It was described in 1928 as a beautiful swimming, fishing, and boating spot and the town's major asset, but it was closed to swimming in 1958 because heavy loads of fecal matter were entering the waters from a malfunctioning privately owned treatment works in nearby Glassboro. The malfunction, in turn, was attributed to intake of wastes at the treatment works from a metal-plating plant. In 1972, new regional sewage collection and treatment facilities cut off one source of pollution, but in addition to the critical chemical leachates, five storm sewers now empty into the lake and runoff from surrounding agricultural areas carries high levels of fertilizers, pesticides, herbicides, and fungicides. Inflow of sediment has reduced average depth in the lake from 2.7 to 1.2 meters (9 to 4 feet) and has sealed freshwater springs.

The LiPari Landfill, only 305 meters (1,000 feet) upstream from Alcyon Lake, accepted a wide variety of industrial, hazardous, and toxic materials as well as municipal refuse through mid-1977. Careless storage of these wastes created dangerous conditions and the necessity for the costly cleanup. New EPA regulations, announced in May, 1980, represent the first attempt



Acid drainage from a coal mine stains the water of a small stream.

to effectively control the disposal of hazardous wastes [26]

Regional Problems

Chemical pollution is not the sole problem: salinity and acidity in lake waters now stand at unacceptably high levels in many regions of the country. Acid precipitation is a major environmental concern. In some States in the South and the West, the disposal of brine from oil fields contributes to salinity of lake water. Predominantly in western States, irrigation return flows are a major source of salt, while in some of the northern States runoff of highway de-icing compounds is a troublesome problem.

Acid Mine Drainage

Acidity in lake waters is often traced in mining areas to acid mine drainage. Mine drainage is associated with both deep and surface mining of coal and a number of metals. Acid drainage is a mixture of iron salts, other salts, and sulfuric acid in runoff from mining wastes. Acid from mining operations can extract heavy metals present in small quantities in soil.

Currently, an EPA clean lakes restoration project at Missouri's Finger Lakes State Park is expected to provide considerable information about the reclamation of surface mined lands. The park, on land that was formerly a coal strip mine, has many small lakes formed by surface drainage in mining trenches. Eighteen of these lakes will be formed into one large lake by constructing dams and canals; acid leaching control methods will be used to improve water quality for recreational use.

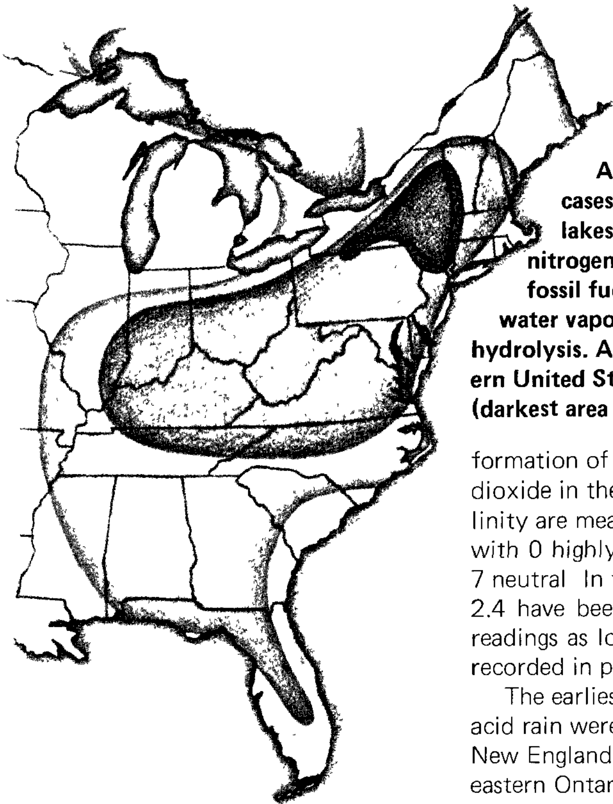
Irrigation Return Flow

The major water pollution problem in many western river basins is salinity caused by irrigation. The water diverted into irrigation systems from mountainous watersheds is of excellent quality. During irrigation procedures, however, one-half to two-thirds of this water is lost to evaporation or transpiration from plants. As the water evaporates, the salts dissolved in it stay behind and then percolate into the soils. This soil water may become more saline by dissolving salts in the ground as it passes through.

Since crop production is also reduced by salt in the soils, efforts have been made to develop crops more tolerant of this salinity Adoption of new methods, such as trickle irrigation and lining canals to minimize seepage, depends on the success of educational programs designed to demonstrate benefits that will accrue from irrigation return flow management

Acid Rain

It is only since the 1960's that those concerned with lake quality have realized that in certain cases airborne pollutants may



Acid rain, which in severe cases can effectively sterilize lakes, is caused when sulfur and nitrogen oxides from the burning of fossil fuel combine with atmospheric water vapor to become acids through hydrolysis. Acidity of rain in the eastern United States is greatest in New York (darkest area of map).

be more damaging—and certainly more difficult to control—than substances carried along our watercourses. Although most of us still enjoy the old poetic images, it is not unduly skeptical to question the gentleness of rain, the purity of the driven snow. Our rain is sullied, our snow, ditto One of the most alarming and pervasive causes of lake pollution in the Northeast today is acid rain—a phenomenon brought about by the increasing emission of nitrogen and sulfur oxides into the atmosphere from the burning of fossil fuels, especially coal. The United States discharges approximately 50 million tons of sulfur and nitrogen oxides into the atmosphere annually.[27]

Acid rain results when these gases, released by combustion, combine in the atmosphere with water vapor and are hydrolized to become acids. The acidified vapor is carried by prevailing winds and may come to earth hundreds of miles from the source of the contamination. Efforts to improve local air quality by increasing the height of smoke stacks—some to a towering 500 feet—have increased the problem by shooting noxious fumes high into the prevailing winds. Plans to increase coal use in the coming years are expected to exacerbate the problem.

Chemically, even the purest rain is slightly acidic because of dissolved carbon dioxide Rain is considered normal when its pH level is 5.6, although the level for distilled water is pH 7. This is caused by the formation of carbonic acid from the carbon dioxide in the atmosphere. Acidity and alkalinity are measured on a pH scale of 0 to 14, with 0 highly acid, 14 highly alkaline, and 7 neutral In the 1970's pH values in rain of 2.4 have been recorded in Scotland and readings as low as 3 0 are now routinely recorded in parts of New England

The earliest and most pervasive effects of acid rain were noted in Norway and Sweden, New England, northern New York State, and eastern Ontario. By the middle of the 1960's changes were being noted in fish populations in lakes in the Adirondacks. A 1975 study of 214 lakes in the region found that 82 with a pH under 5.0 had no fish. A followup study in 1979 found that 170 were sterile.[28] Half the lakes in the Adirondack region at altitudes above 2,000 feet now have an average pH of 4.2 and are devoid of fish.[29]

The relationship between acid rain and sterile lakes is a matter of international concern. At a 1979 conference on the subject in Toronto, the Canadian Minister for the Environment referred to it as "a catastrophe of a leisurely kind," because, unlike great natural disasters, the effects of acid rain on delicate lake ecosystems are *slow and pervasive*.

In addition to reducing pH readings in water to unacceptable levels, toxic heavy metals such as lead, mercury, cadmium, aluminum, zinc, beryllium, and nickel can be released by acid rain from lake bottom sediments and leached from surrounding soils.[30] High concentrations of aluminum in lake water can lead to fish mortality [31]

Little is known about the effect of acid precipitation on trees, plants, and agricultural products although studies are being conducted in all these areas. Its threat to aquatic communities, however, is becoming well understood. What happens in a lake when the waters become increasingly acid? Although many lakes in Florida, for instance, naturally have pH levels of 4.5 to 5.5 with a variety of flora and fauna, the pH levels of most healthy lakes are usually in the range of 6 to 8. When these levels begin to drop because of acid precipitation, the effects may be dramatic.

In an ecosystem damage to one tiny cog signals trouble for the entire tidy little world. At pH 6.6 most freshwater snails do not survive and the eggs of certain salamanders fail to hatch. Tadpoles and shrimp die in waters below pH 6.0. Many species of microscopic zooplankton and phytoplankton which form the lowest rungs of the food chain die out along with a number of higher species as the pH level continues to drop. When pH slips below 5.5 northern pike, perch, and other fishes disappear. Species die out for two reasons· either adult fish die or eggs fail to hatch. When pH levels reach 4 5 in lakes, most frogs and insects, and all fish are dead.[32] Acid-loving plants, such as sphagnum moss, commonly found in highly acidic bog waters, take over.

The lake looks beautiful—completely clear and blue—and as clean and lifeless as a swimming pool.

Recognizing the acid rain problem, President Jimmy Carter in August 1979 called for programing $10 million per year *for research to be co-chaired during the* next 10 years by the Environmental Protection Agency and the Department of Agriculture.[33] Acid rain research is also being carried on by a research arm of the electric industry, the Electric Power Research Institute, at Hubbard Brook Experimental Forest in the White Mountains of New Hampshire, by the National Atmospheric Administration, and by the Department of Interior's Office of Water Research and Technology. A broad spectrum of EPA programs is currently investigating effects of acid rain on aquatic systems, forests, and agricultural lands.

Current proposals for dealing with the source of the problem center on installing stack "scrubbers," on fuel desulfurization, modified combustion procedures, and alternative energy sources.[34]

Chapter 5 Lake Restoration

Lake restoration begins with knowledge of lake processes and problems. At left, Cornell University researchers collect plankton samples from Cayuga Lake, New York.

The subject of lake restoration, and lake protection, is explored and debated today in national and international conferences, in academic sessions, at Federal, State, and local governmental agencies, at meetings of lake-shore owners' associations and other community groups Although the need to do something about our degraded lakes is beyond dispute, the science of lake restoration is still in its early stages, and even the terminology can be obscure What do we mean by lake restoration? Restoration to what? To some ideal of pristine beauty? To an oligotrophic condition that may have existed in the lake's ancient past? To accepted levels for projected use? A lake with extensive growth of aquatic weeds may be a good fishing pond and yet not look inviting to swimmers. A perfectly clear lake may be blue and transparent because high levels of acidity have killed off both plant and animal life.

Clean lakes projects are generally instituted to alleviate the effects of excessive siltation or cultural eutrophication. Decisions about how far to go in cleaning up a lake that has become shallow and overgrown may be a matter of philosophy or a matter of economics Often a judgment must be made about feasible limits of expenditure and effort without the reassurance of a solid basis for predicting results.

Once a project for lake restoration is undertaken the results of this effort must be carefully monitored, evaluated, and recorded. Lake management requires careful planning based on the best scientific and technical advice, direct action, and community cooperation, particularly as regards revised land use practices and priorities

In restoring the aquatic balance of a lake by a program of lake management, all plans must be made on a lake-watershed basis. Although actual water use can alter water quality—an obvious example is fuel lost from motor boats—it is the uses of the watershed that will determine the condition of the lake in the most significant ways.

The approaches to treating a degraded lake can be divided into two broad categories. watershed measures and those methods that intrude into the lake itself to clean up the results of natural and accelerated processes. Although sometimes viewed as opposite or alternative approaches, lake restoration projects often involve both watershed and in-lake methods.

Identification of watershed sources of pollution should be the first step in any rehabilitation project. Treating the sources of lake degradation may be expensive and results not as dramatic as hoped for, but effects are likely to be lasting and, for this reason, more cost-effective in the long run. In-lake methods may also be required to speed improvements in the appearance and quality of the water. Although lakes differ biologically, chemically, and physically, so that one method may bring gratifying results in one lake and not in another, permanent lake rehabilitation begins with halting the entrance of undesirable substances. Unless this is done, weed harvesting, for example, will prove about as permanent as lawn mowing, chemical treatments will have to be repeated frequently with possible danger to the ecosystem, dredging will become a recurring expense.

Liberty Lake, in the State of Washington, is a prime example of this principle. In 1974, alum was used extensively with apparent success to precipitate phosphorus and control algal bloom, but algae reappeared profusely in 1976, 1977, and 1978. Since then, in conjunction with an EPA clean lakes grant and with a high level of community action and cooperation, sewers have been installed to replace faulty septic systems. An adjoining marsh, formerly used as pasture, has been diked to halt nutrient leaching to the lake.

A second alum treatment, scheduled for this year, is expected to be the last, now that nutrient supply to the lake has been cut back greatly.

Reducing the input of contaminants is accomplished by three general methods point source nutrient removal and control, nutrient diversion, and sediment control.

Point Source Control

In water pollution parlance "point" sources are those that are discrete and definable such as factory or sewage treatment plants that empty wastes into waterways through discharge pipes.

"Nonpoint" sources, such as urban and rural runoff, septic tank seepage, and acid rain, are diffuse. Many of the nonpoint source pollutants result from agricultural and silvicultural activities, mining practices, land development, and urbanization in general.

Discharges from point sources are, for obvious reasons, more amenable to control.

Because water polluters are now bound to a schedule of pollution abatement under the National Pollutant Discharge Elimination System, the cost of cleaning up waste products before channeling them into rivers, streams, and lakes is now considered part of the expense of running a manufacturing plant.

But despite regulations on industrial discharges, 72 percent of the drainage basins in the country are still tainted by both conventional and toxic pollutants from industrial sources.[35]

Adverse effects on water quality stemming from municipal discharges are found in an even higher percentage—89 percent—of drainage basins.[36]

The pollutants that most often reach unacceptable levels in such discharges are fecal coliform bacteria, oxygen-demanding wastes, and the major plant nutrients, nitrogen and phosphorus.

Domestic waste water carries large quantities of plant nutrients that are, to some extent, removed by conventional waste treatment methods.

Primary treatment, which eliminates suspended solids by settling tanks and filtration, reduces phosphorus by only 5 to 15 percent.

Secondary treatment systems which use biological processes to break down organic material can remove up to 50 percent of the phosphorus in waste water

Because the quantity of phosphorus is usually the main factor limiting plant growth in fresh water, reducing phosphorus loadings into waterways is essential.

Currently, approximately 1,200 waste water treatment plants which utilize some degree of advanced waste treatment technology are either in operation or in construction.

These new plants and reduction of phosphorus in detergents which was achieved in 1973 in some States and in Canada, are the major reasons for improved water quality in the Great Lakes.

Combined sewer systems, which collect domestic wastes from homes and excess water from storms, are common in our cities built before 1870, and are a major source of water pollution.

In dry weather the combined waste waters travel to the treatment plant efficiently. During seasonal storms or rapid snow melt, some of this waste water, including quantities of raw sewage, bypasses the treatment plant and flows untreated into waterways.

Raw sewage may enter our lakes carrying heavy loads of nutrients and disease-causing microorganisms.

Many lakes have been polluted by seepag from septic tanks, the most conventional waste treatment method in lake and pondside communities. The problem is avoidable when systems are correctly sited, designed, and maintained if there are the right kinds of soils in adequate amounts for drainfields to function.

A major Federal public works program in this country is EPA's construction grants program for waste water treatment. Congressional authorization has been $4.5 billion per year, but appropriations have been lower recently.

Although faulty or inadequate means of sewage disposal have, without question, been a major source of water pollution, the theory that, in all cases centralized collector sewers should replace individual systems has recently come under critical scrutiny. The Clean Water Act Amendments of 1977 provide for raised levels of Federal funding for upgrading and managing individual and multi-family systems, and new funding guides of 1978 and 1979 authorize construction of collector sewers only if severe water quality problems or threats to public health exist.

In many sparsely settled communities, the projected costs of installing conventional treatment plants bordering lakes range from high to staggering. A recent study in Wisconsin indicates that in one area the population to be served by a new system would have been faced with local and private costs ranging up to two and a half times the value of the average house.[37]

Attempts to reduce phosphorus loading to lakes include utilizing the natural cleansing effects of our wetlands. In Minnesota's Lake Minnetonka it was demonstrated that a major source of phosphorus was storm water runoff from an urban area. When this storm water was routed through a large wetlands region, 78 percent of the phosphorus and 94 percent of the total suspended solids were trapped before entering the lake, subsequently reducing algae.[38]

Considerable attention has been focused in recent years on an obvious measure to reduce nutrient loadings in waterways—the banning of phosphorus-based detergents. Since these detergents were first introduced to consumers in the 1940's they have been responsible for 50 to 70 percent of the phosphorus in our municipal sewage. Phosphate-based detergents are now banned in many lake areas, in States such as Indiana, New York, and Michigan, and in other parts of the world Some legislation bans detergents with higher than 8.7 percent phosphorus, other legislation totally bans phosphates in laundry detergents for household use.

Diversion

Diversion, a second lake restoration method, involves the rerouting and treatment of nutrient rich waters, usually in such a way that they are discharged into the stream below the lake.

Diversion treatments have been criticized because, although they can improve conditions in the given lake, the problem may simply be passed on to the stream or to another lake, if sewage treatment is not included in the plan.

Case Report: Lake Washington

Once an oligotrophic lake, Lake Washington, near Seattle, became significantly eutrophic over a short time because, prior to 1963, 11 secondary sewage treatment plants discharged directly into it. These effluents were found to be bringing in 56 percent of the phosphorus and 12 percent of the nitrogen that entered the lake annually. Measurements of the abundant algal growth showed that in 1962 concentrations were 15 times what they had been in 1950.[39] During that period Secchi disk readings had dropped from about 3 meters (10 feet) to 0.9 meters (3 feet).

In the 1950's, in an early lake restoration project, the Municipality of Metropolitan Seattle, assisted by Federal Water Pollution Control Act funds, formulated a plan to treat and divert this sewage from Lake Washington into Puget Sound. When the first stage was completed in 1963, 25 percent of the effluent had been diverted from the lake, by 1965 another 20 percent of the original load had been diverted. The third stage was completed in 1968, and algal growth was significantly reduced. Secchi disk measurements rapidly returned to pre-pollution levels[40]

Unvegetated slopes of construction sites are major contributors to lake sedimentation.

Control of Sedimentation

The major pollutants arriving from non-point sources are suspended solids, nutrients,

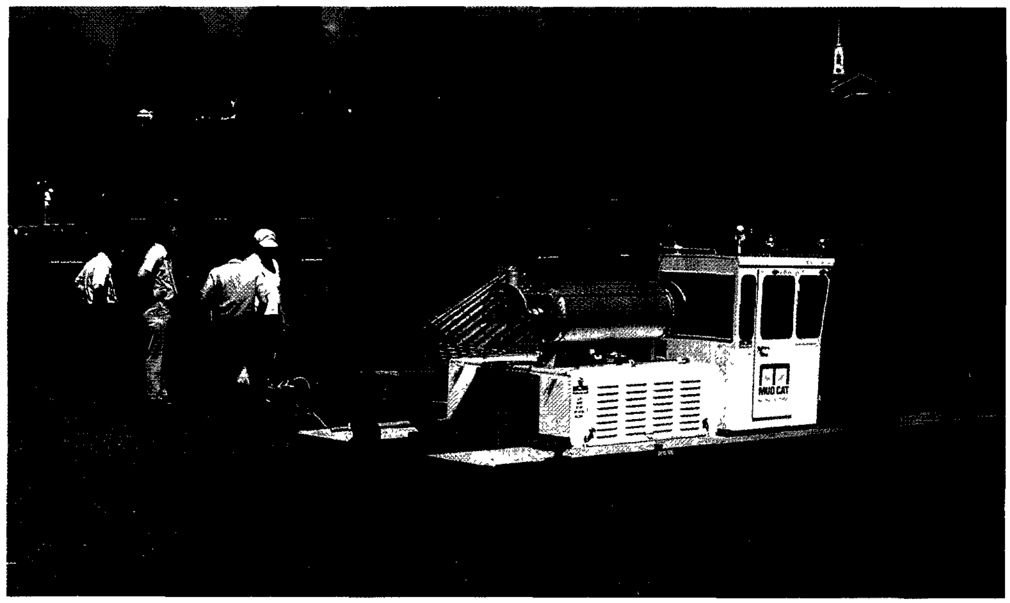
How Lakes Change

construction erodes rapidly when rain continues to fall on the ground after the soil's capacity to absorb it has been exceeded.

Sedimentation rates can be retarded only by sound land use practices within the watershed. Good agricultural conservation practices include contour plowing, crop rotation, keeping vegetative cover at all seasons, using minimum tillage methods of cultivation, and proper grazing practices that don't strip the land. Leaving buffer zones between cultivated fields and streams can also aid in retaining valuable fertile soil where it is needed and keeping it out of waterways where it becomes a major pollutant.

Since its construction in 1938 as a Works Project Administration project, the 148 hectare (300 acre) artificial Broadway Lake in Anderson County, South Carolina had provided many years of recreation in an area short of such facilities. But, in less than 40 years one-quarter of the lake had become completely silted in. Water quality was poor because of pollutants in the sediments from the 12,400 hectare (25,000 acre) hilly, red clay watershed. One-crop agriculture in the area, currently soybeans which have replaced cotton, has led to critical erosion problems. The lake is now being restored in a special Federal cost-sharing and technical assistance program sponsored by USDA and EPA and involving two State agencies. Methods include smoothing gullies and eroded roadbanks and planting grasses or trees, constructing debris basins in the watershed that will catch and store sediment, and constructing animal waste lagoons. Landowners will be assisted in developing terraces, grassed waterways, and improved timber stands, and will be instructed in the use of field borders and minimum tillage techniques.[41]

Soil erosion may also occur when builders of subdivisions leave bulldozed land without cover for years. Both construction and logging ventures should be avoided on steep slopes, and activities that leave the landscape bare should not be undertaken in rainy periods. Grassed waterways and terracing, channel lining, mulching with straw, hay, or other materials, and use of sediment traps, are all good long and short-term measures for erosion control. Lakeshore erosion can be halted both by vegetative and structural means, and retaining walls should be considered on steep grades.



A lake dredger at Collins Park, New York

In-Lake Methods of Lake Restoration

A number of mechanical, chemical, and biological methods have been employed to restore lakes that have become clogged with sediment or with overabundant plant growth. These techniques are particularly effective when used after all possible sources of pollutants have been analyzed and checked or reduced. Without in-lake restoration processes lakes with slow flushing action may show no improvement for long periods of time because nutrients already in the lake are readily recycled. Flushing time, the period it takes to completely replace one lake volume, varies from a few days for some reservoirs to a few centuries for Lake Superior. Flushing time for bottom waters may be longer than for surface waters in a stratified lake because the surface waters are replaced over and over while the deep waters can be replaced only during fall and spring overturn.

Since lakes vary so greatly, there has been considerable trial and error in experiments with in-lake restoration methods. A rapidly expanding body of information has, however, provided a basis for a higher level of predictability. Some of the more successful methods include dredging, nutrient inactivation, aeration, drawdown, and use of chemical and biological controls.

Dredging

Dredging a lake is an obvious means of removing accumulated sediments, increasing lake depth, and simultaneously removing nutrients incorporated in the sediments.

Algae and weeds choke Lilly Lake in Kenosha County, Wisconsin. Opposite: Chemical treatment begins for the eutrophic waters of Medical Lake near Spokane, Washington.

Although dredging can accomplish all these things and may show rapid and dramatic results, serious problems can arise and results may not be entirely anticipated. Studies from Japan show that when PCB-contaminated lakes are dredged, the toxic material, which adheres to the smallest particles, may be resuspended either by dredging itself or by disposal area return flow. Other studies have found that if proper techniques are not used, toxic substances such as pesticides, herbicides, and industrial wastes bound up in the sediments of a lake also may be resuspended by dredging, liberated in soluble form, and reintroduced to the food chain.[42]

Several methods have been devised for dredging a lake, and all are expensive Once the cost has been justified, finding an ecologically acceptable means of disposing of dredged material may be the limiting factor. Although dredge spoils used to be routinely dumped on adjacent wetlands, we now know that smothering useful wetlands with dredged material is damaging to needed resources and is also illegal.[43]

Case Report: Lilly Lake

In January 1976, Lilly Lake in Kenosha County, Wisconsin, received a $273,000 EPA Clean Lakes grant primarily to combat a buildup of organic detritus that had made the lake unusable for recreation. The restoration process involved removal by hydraulic dredge of 650,000 cubic meters (780,000 cubic yards) of muck. The depth of the 88-acre lake, which had been reduced to an average depth of a meter or less (2 to 3 feet), was increased to a maximum depth of 7 meters (22 feet).

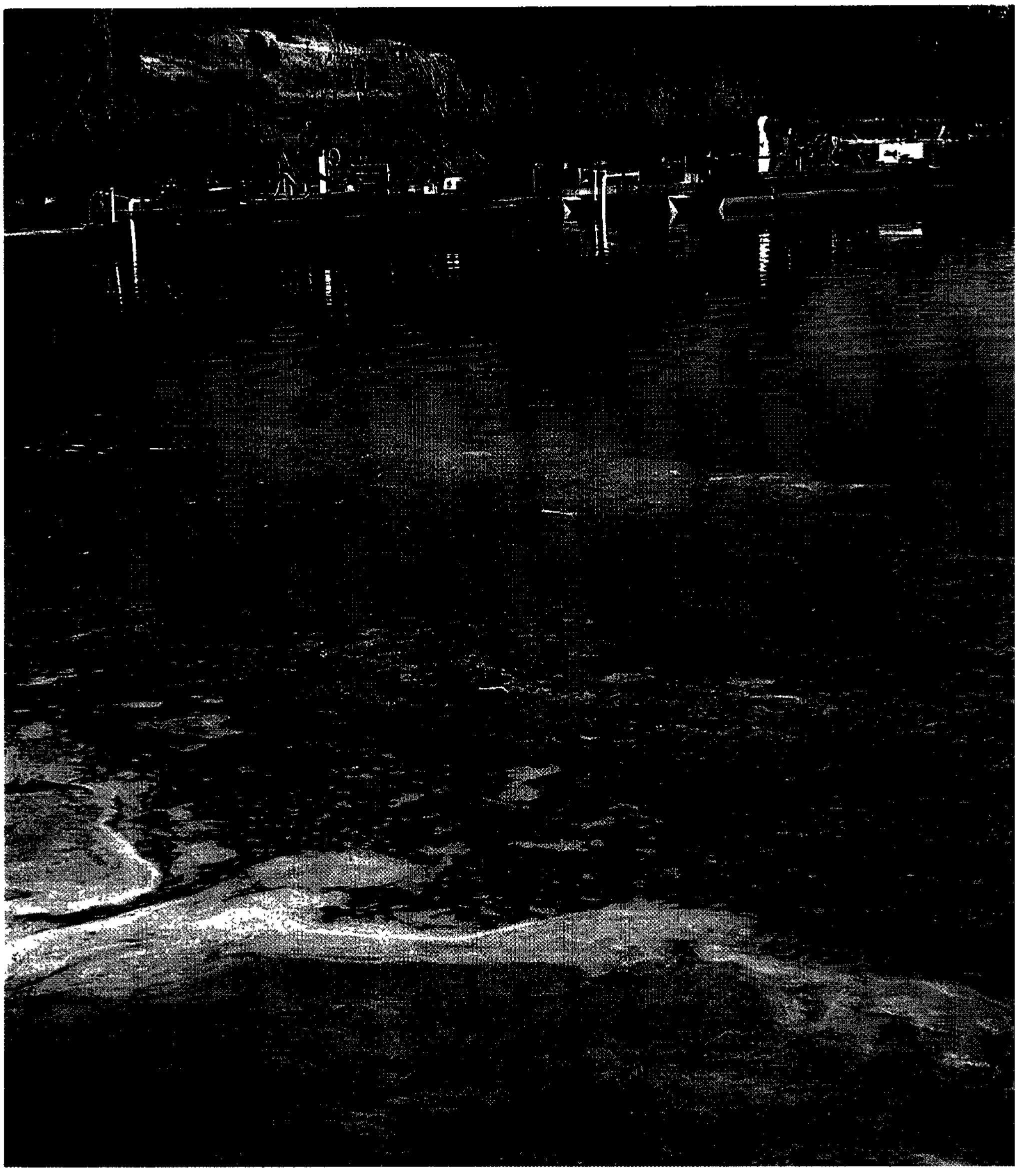
The lake is located in the southeast corner of the State and once offered attractive opportunities for boating, swimming, fishing, water skiing, and ice skating. Silting and decomposition of organic material interfered with recreation and depleted the dissolved oxygen, particularly in winter, resulting in frequent fish kills Weeds interfered with the appearance of the lake and made swimming and boating impossible.

In the restoration of Lilly Lake, local residents voted to tax themselves, State aid became available, and Federal aid was offered through a Clean Lakes grant. Emphasis was placed on using the dredged materials in an environmentally satisfactory way Some of the dredged material was piped to high land where it was spread to dry for use as a soil conditioner. Since the lake was dredged, increased depth has eliminated fish kills and the value of lakefront property has increased. Recreational use has been restored and wildlife values have been enhanced since the gravel pits to which most of the dredged materials were piped have now become two artificial perched ponds attractive to waterfowl.[44]

Nutrient Inactivation

Although the influx of nutrients from point sources may be sharply reduced by diversionary treatment and other measures, lack of evidence of improved water quality may indicate the need to control phosphorus release from the lake's sediments. The materials used, which will bond with, immobilize, or absorb nutrients and make them inaccessible to plants, are salts of iron, aluminum, and other metals commonly employed to remove phosphorus in advanced waste treatment. As opposed to dredging, nutrient inactivation presents no disposal problem and does not disrupt lake use. When it is successful, results appear very quickly and if sources of nutrients have been stopped, the effects will be long-lasting.

Aluminum sulfate, currently the chemical of choice, has been found effective in binding phosphorus and in preventing its recycling from lake sediments. Some concern is felt, however, about the unknown but possibly toxic effects of introducing a metal used as a precipitant as well as about the effect on organisms of altered pH levels.



Case Report: Medical Lake

Although the lake had been named for the supposed therapeutic quality of its waters, which are high in sodium bicarbonate, by the 1970's only the most dauntless pleasure-seekers were bold enough to swim in Medical Lake. Lying 14 miles from Spokane, Wash., the lake had spas along its shores in the early 20th century and later became a popular recreational resource for Spokane County, offering a public swimming beach and boat launching facilities. But for many years before its restoration in 1977, spring brought unsightly masses of algae to the lake's surface. When the swimming season began the lake was covered with decaying mats of green, which impeded boating and swimming for most of the summer. Fish killed by depletion of dissolved oxygen rose to the surface where they putrified and attracted thick swarms of insects. Noxious odors rose from the unwholesome water and assaulted the sensibilities of weekenders and the 2,600 inhabitants of the town, also named Medical Lake.

The lake is deep, for its region, averaging 10 meters (33 feet), with some areas as deep as 18 meters (60 feet). It is entirely spring-fed, a closed lake with small littoral area. No wastewater effluents enter the lake and the only point source of nutrients, a cooling water discharge pipe, was eliminated. The lake had been completely ringed by interceptor sewers but, because of its depth and lack of outlet and consequent slow flushing rate it was decided that further in-lake measures were needed to halt the internal recycling of nutrients. During the summer of 1977 in a plan funded through EPA's Clean Lakes Program, liquid aluminum sulfate (alum) was released on the surface and also injected directly into the hypolimnion from a barge. Because of the high alkalinity of the water, substantial doses were needed for phosphorus removal. During treatment, which lasted 41 days, over 900 metric tons of liquid alum were used.[45] The chemical combined with phosphates to produce insoluble compounds, forming a floc which then settled to the bottom. Recycling of nutrients was slowed and, with in-flow of further

How Lakes Change

The water flea, which eats algae, has been introduced in lakes as a biological control.

Drawdown was the technique used for the restoration of Steinmetz Lake in New York. Material was also dredged from the lake bottom and replaced with sand.

nutrients cut off, results should be lasting.

The increased clarity of the water and decreased algal concentrations were dramatic at Medical Lake. With autumnal turnover the total concentration of phosphorus dropped over 80 percent, with phytoplankton down 90 percent and blue-green algae replaced by green and flagellated species [46] Since completion of treatment the lake has been stocked with rainbow trout, which are notably thriving and the beach is once again inviting.

Aeration

Three methods of introducing oxygen into lakes have been devised. One involves aeration of the hypolimnion without disturbing the stratification of the lake. The second technique artificially destratifies the lake to circulate oxygen throughout the water column. A third technique keeps sections of the lake from freezing to allow uptake of oxygen from the atmosphere during winter.

Because silver salmon were dying in Erdman Lake, Washington, aeration with destratification was tried, and survival rates increased 500 percent. At Lake Roberts in New Mexico, however, aeration brought oxygen concentrations to near zero throughout the lake, killing all the fish.[47] This resulted from mixing the large volume of deep water containing no oxygen with the epilimnion.

The mechanisms designed to circulate water in the hypolimnion without disrupting natural stratification may help fish in the bottom regions. In Michigan's Hemlock Lake, rainbow trout in summer were confined to a small band of water in the thermocline by too-warm waters above and low-oxygen waters below. Aerating only the hypolimnetic regions provided adequate oxygen throughout the deep water, enabling the fish to move into the lower areas of the lake.[48]

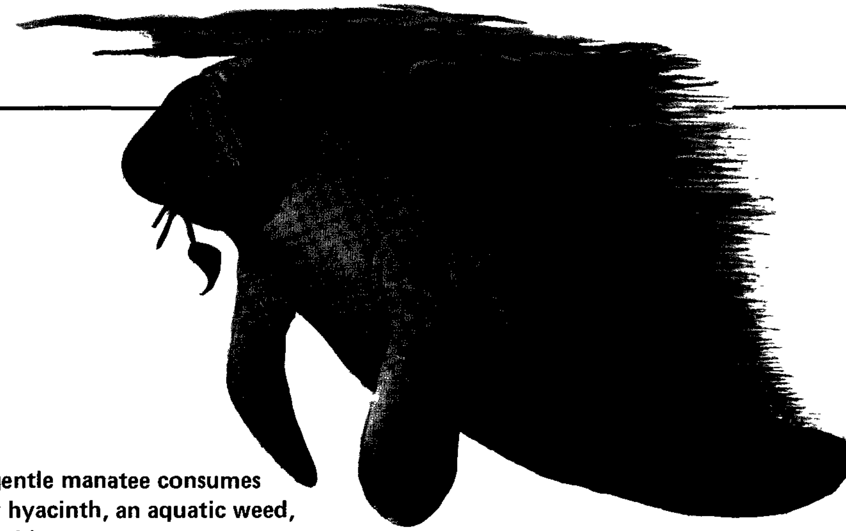
When water is required for domestic use aeration is sometimes employed to reduce the concentrations of substances that cause offensive tastes and odors. Aeration undertaken for these purposes may also solve such problems as discolored water, scaling and clogging of pipes, and high concentrations of iron, manganese, hydrogen sulfide, and ammonia.

Drawdown

Manipulating water levels can control the growth of rooted aquatic vegetation and nutrient release from the sediments. Drawdown may be used in combination with some other in-lake method such as sediment covering or harvesting. An early use of drawdown techniques was to suppre anopheline mosquito reproduction in Tennessee Valley Authority reservoirs.[49]

Observations of the biological changes accompanying natural drops in lake levels that caused sediments to dry or freeze suggested this non-toxic, relatively inexpensive, and often valuable method Water is pumped from the lake in either summer or winter, and sediments and the seeds and vegetative structures of plants are exposed to drying or freezing conditions, generally for a month or more. Drawdown may interfere with recreational uses in summer or be complicated by heavy snowfall or rainfall in winter. If drawdown is scheduled for summer, other lake work, such as improving and rebuilding docks or deepening swimming beaches or repairing shorelines, may be undertaken at the same time.

Although in a few cases drying and freezing processes have been found to stimulate plant growth and other undesirable growth has proven resistant, good results have been observed in Florida, TVA lakes, and lakes in Louisiana and Wisconsin in destroying the very trouble-



The gentle manatee consumes water hyacinth, an aquatic weed, in Florida waterways.

some exotic weed, Eurasian water milfoil.[50] Drawdown also deepens the lake by dewatering and compaction and provides a diffusional barrier against the passage of nutrients to the water on reflooding.

Harvesting

When lakes are heavily infested with nuisance weeds, harvesting with specialized cutting machines may be advisable in conjunction with control of point and nonpoint source pollution and before other in-lake methods, such as drawdown. Harvesting equipment has been designed to deal with floating surface plants such as water hyacinth, emergent plants that are rooted in the bottom and pierce through the surface of the lake such as rushes and weeds, and submersed macrophytes. It has been used in the Madison (Wisconsin) lakes where, early in the 1960's, the Eurasian water milfoil (*Myriophyllum spicatum*) grew so explosively that it displaced native species.[51] Harvesting may also reduce phosphorus availability, although the degree to which it does so is small and long-term results are questionable. The process is expensive and the collection and removal of debris a problem. Research is underway to find marketable use for harvested material as animal feed or compost.

Chemical Controls

One means of destroying unsightly growths of algae or rooted aquatic plants in a lake that brings almost immediate although temporary improvement is the use of algicidal chemicals. As in all other in-lake procedures, this last ditch method is recommended only after nutrient input has been tackled at the source. Although many different compounds have been developed, most contain copper. Some, however, contain highly toxic organic compounds effective on specific target organisms. Currently over 12,000 tons of chemicals are used for this purpose annually; their concentrations vary according to the severity of the problem.[52]

The major objection to chemical controls is that not enough is known at this time about the long-term effects on aquatic animals at various life stages. Breakdown rates of these chemicals have not been sufficiently investigated, and we do know that crops may be damaged if irrigated by water in which these chemicals have been used.[53]

Uneasiness about chemical controls in general is based on past experiences with insufficiently understood toxic pollutants, and has led many to favor the more benign mechanical methods

Biological Controls

A major side effect of using such broad spectrum pesticides as DDT was that they killed off both prey and predator. New emphasis on integrated pest management seeks to harness natural forces to combat one problem pest by, among other methods, introducing a predator, rather than by spraying a poison.

In lake research an area of considerable interest is the use of biological controls to combat unwanted vegetation. Various members of the animal kingdom have been experimentally introduced into eutrophic lakes where they are greeted by an alluring array of edible vegetation. Water fleas have been introduced to eat algae, a stem borer has been brought in to feast on alligator weed, and in canals in Florida the strange aquatic mammal, the manatee or sea cow, has been introduced to chew up the water hyacinths that clog waterways. Although the manatee has proven to have a virtually insatiable appetite for aquatic weeds, it is unfortunately a rare animal, difficult to catch and transport, and unwilling to breed in captivity or in fresh water.[54]

Recent experiments have centered on the white amur or grass carp, a native of Northern China. This fish will eat over 20 types of aquatic weeds although it cannot eat micro-algae. In China, where grass carp are used to keep waterways free of weeds, some fish have devoured so much vegetation that they have grown to weigh as much as 180 kilograms (400 pounds).[55] In 1963, over 100 lakes in Arkansas were stocked with grass carp in a carefully monitored experiment. Since other introduced species of carp have proven to be pest animals, the import of this fish was originally restricted to the State of Arkansas. So far no apparent harm has come to native fish from its presence since the fish is truly herbivorous, but the possible environmental impact is not fully understood and many professionals in the field fear that undesirable effects on the ecosystem may emerge. Some concern is felt that duck habitats could be damaged if plant-eating fish are permitted to denude them of vegetation.[56] It had been thought that, because of their fastidious spawning needs, which require particular river conditions, the grass carp would not reproduce in this country. But since they have now escaped from Arkansas lakes into the Ohio and Missouri Rivers, rivers in Florida and Georgia, and several in the Mississippi basin, there is a possibility that they are reproducing and careful ecological watch is in effect. Authorities believe, however, that any spawning which occurs will result in small populations with little impact, and that the fish has further potential as a food.

Other experiments in biological controls include sterilizing fish, subjecting the greenery to fatal plant diseases, and introducing new plants that compete for light and nutrients and crowd out others that are less desirable. In one California project a slender spike rush was introduced to a lake and has covered the bottom in sodlike fashion, preventing nuisance weed growth.[57]

Chapter 6

Yesterday, Today, and Tomorrow

Sunrise at Wilson Pond, Maine

Paleolimnology

A lake has a past, a present, and a future. The specialized academic field of paleolimnology concerns itself with uncovering the mysteries of a lake's distant past. Studying the lake basin, its water, and its sediments, paleolimnologists also concern themselves with the past history of the entire drainage area. Here, as in other limnological studies, the basic unit is the lake watershed.

The major objective of research in paleolimnology is to disclose the evolutionary sequences through which a lake has passed on evidence revealed by the lake's sediments. The accumulated sediments in lake basins result both from the geomorphology of the lake and materials brought into the lake through the ages from the watershed. Although paleolimnology is considered a relatively new research field which requires sophisticated methods of analyzing sediments and measuring other indications of productivity in the remote past, it is of interest that the first major and often cited investigation was geologist G.K. Gilbert's study in 1891 of the freshwater ancestor of the Great Salt Lake of Utah.[58]

The paleolimnologist, whose evidence comes from studying the mineralogy and organic and inorganic chemistry of the sediments as well as the fossil remains of organisms, interprets his or her necessarily fragmented findings by inferring that fossil organisms required environments similar to those needed by their descendants today. Incredibly, many aquatic plants and nearly all aquatic animals leave some type of identifiable remains in sediments as do terrestrial organisms, such as the pollen and spores of plants that grew in the watershed. Some remains can be identified by species, some only by genus or family, particularly when the material preserved represents one stage of the life cycle—a cocoon, larva, egg, or cyst. The various species of profundal midges, which are associated with particular levels of dissolved oxygen in the hypolimnion, are interpreted as indicating similar conditions in previous eras when found in a lake core.

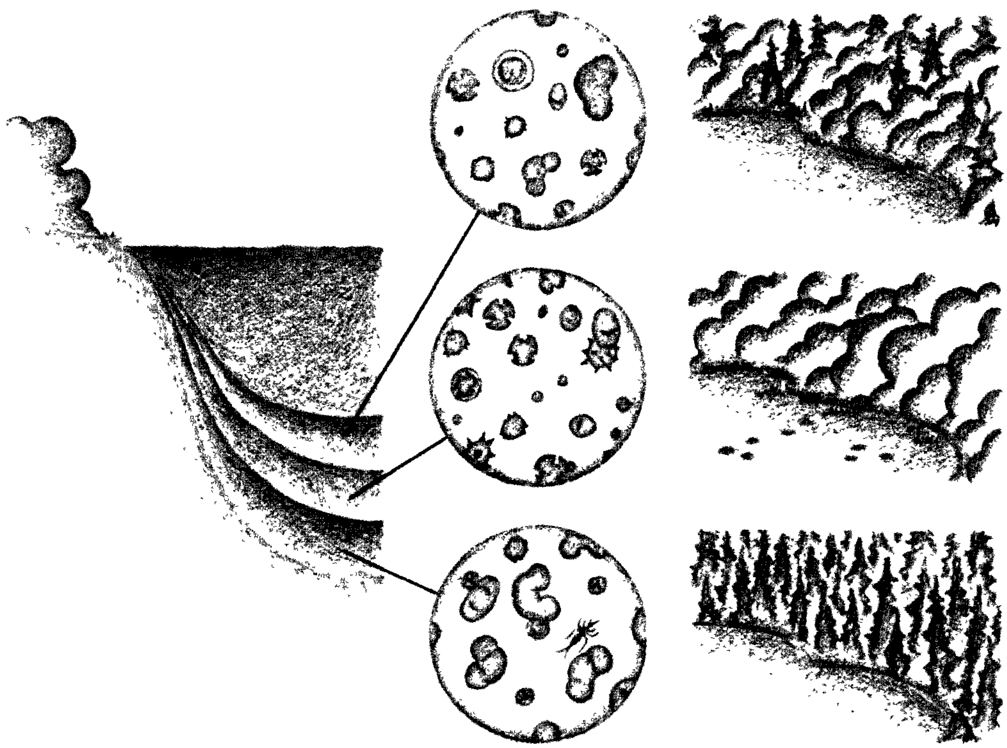
Studies in paleolimnology have demonstrated beyond question that what is generally assumed to be a one-way route from oligotrophy to eutrophy can turn in the other direction as well. Because of changes in nutrient level lakes can become less, as well as more productive over time. In the 20th century, the common route towards eutrophy is associated with man's activities. In less populous and urbanized periods of history production often declined due to changing land use practices and gradual loss of nutrients in a watershed through leaching.

Paying the Price

Most successful lake restoration projects are easily appreciated by people familiar with the "before." Although the average lake user may be unaware of phosphorus loadings and erosion problems and extremely reluctant even to consider the significance of fecal coliform counts, lake users know what they like. What they don't like is a lake choked with weeds and covered with green scum, a lake that is difficult to boat around, uninviting to swim in, and smells bad to boot. Whether they are anglers, animal lovers, or just plain squeamish they definitely find the floating corpses of dead fish distasteful. A lake restored to health and beauty is an irresistably exhilarating sight.

One attempt to more objectively evaluate the results of lake projects is to compare cost and benefits, to set up a method of placing dollar and cents values on lake improvements and relate these totals to the amount of money spent. This is an appealing approach in a society in which government expenditures are constantly under scrutiny by a public aware that action means tax money.

The Environmental Protection Agency's



Paleolimnology involves scientific detective work to trace the history of lakes and their watersheds. Use of such clues in lake sediments as fossil pollen grains and plant and animal remains enable paleolimnologists to reconstruct climatic and biological changes in the lake's past.

Clean Lakes Program, which awarded its first grant on January 6, 1976, had approved 105 grants totaling $40,097,110 by the end of the fiscal year 1979. A study was undertaken in an attempt to discover whether we—the taxpaying, lake-using public—are getting our money's worth.

The investigation examined 28 of these projects, costing $15,349,053 in Federal funding matched by equal sums from State and local governmental agencies. In summary, their answer was a resounding "yes." Although it may shiver the sensitive aesthetic timbers of nature lovers even to consider such numerical evidence—and stir skepticism in others who find calculating the joy of watching the sun set over a translucent lake arbitrary at best—the study concluded that the 10-year present value of benefits measurable in monetary terms is $127,488,500, or a return of $8.30 per EPA dollar expended and half that sum per total dollar of expenditure.[59] The project investigators also found that virtually everyone involved in tl restorations felt that the value received in terms of public benefits was indisputable. I some communities lake restoration project facilitated obtaining other grants for park improvement and similar undertakings.

Benefits measured fell into 12 categorie: recreation, aesthetics, flood control, economic development, fish and wildlife, agriculture, property value, public health, multiple use (commercial fishing and publi water supply), education and research development, pollutant reduction, and associated items such as resource recovery and reduced management cost.

Obviously, some of these categories are more easily quantified than others. Measuring the number of people who are likely to benefit from the recreational facilities of clean lakes revealed that an astonishing 99. percent of us live within an hour's drive of publicly-owned lake, with one-third of our population living 5 miles or less from such lake. Restoration projects promote increase use of lakes and also may open up uses lost through long periods of degradation. A poi scale was set up to assign a dollar value to a day of recreation at a lake. Since most lal restoration projects are undertaken to develop recreational and aesthetic enjoyment, these categories accounted for the highest share of total discounted benefits. Public health benefits were primarily reduc tion in fecal coliform counts and in turbidity, which can endanger swimmers. An example of an educational benefit was heightened awareness of and interest in environmental protection.

The restoration of Medical Lake, described earlier in this book, is one of the less complex examples. The Clean Lakes Program grant amount, awarded in December 1976, was $128,217. Total discounted benefits from the project are estimated at $931,750 over a 10-year period of time. In addition to restoring the lake to its former uses, a new benefit—trout fishing—resulted. Success of the alum treatment was unequivocable, with virtually immediate recreational, aesthetic, and fish and wildlife benefits Property values have risen, as the lake's attractiveness returned. Whereas prior to restoration, at most 100 people visited the lake for any purpose during a weekend, weekend usage now is between 750 and 1,000, even though trout fishing is not yet permitted. The summary of benefits shows $89,400 for recreation including wildlife improvement and $225,000 in terms of property values. The total is $314,400 the first year and the net value for 10 years, including $17,100 in annual fishing benefits which will begin to accrue in the third year, is $931,750 [60]

The project does not reveal what view the mayor of the town of Medical Lake might have on assigning dollar values to free swimming at the town beach, but it does quote him as enthusiastically insisting that the town's share of the project was "the best money we've ever spent."

Recreation

The relationship between clean water as an environmental goal and clean water as a resource people can use and enjoy may seem too obvious for comment. National goals as stated in the Federal Water Pollution Control Act Amendments of 1972 set forth 1983 as the year in which all waters in the United States are to be swimmable and fishable and 1985 as the year when discharge of all water pollutants will be halted. As citizens we have committed ourselves to these aims through the votes of our representatives and senators and in our support of State and local policies as well.

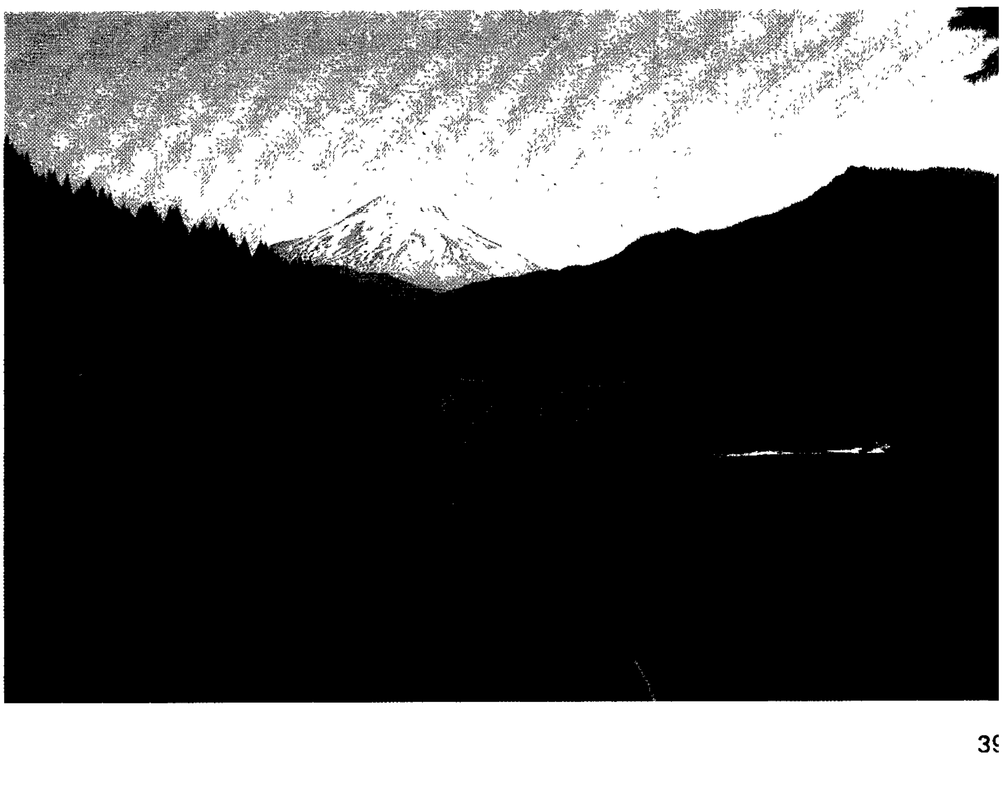
One of the provisions of the Clean Water Act of 1977 is that from that year on no town or county can be granted Federal funds for wastewater treatment facilities unless it also has "analyzed the potential recreation and open space opportunities in the planning of the proposed treatment works".[61] Wastewater treatment facilities are normally sited near a body of water and often can be integrated with such multiple uses as hiking trails, bike paths, fishing piers and boat launching areas, skating rinks, swimming areas, and greenways—corridors of open space and recreational land running along waterfronts—while still filling community sanitation needs.

Although water pollution problems and recreational opportunities have traditionally been handled by totally different Government agencies, today cooperation is the key word An enthusiastically supported urban project co-sponsored by EPA and the Heritage Conservation and Recreation Service of the Department of Interior for the restoration of the 59th Street Pond in Central Park, New York City, is currently nearing completion (see page 43). In a rural watershed in Maine, EPA and the U.S. Department of Agriculture are jointly sponsoring lake cleanup by revising agricultural methods (see page 42).

Multiple-use is far from a new idea at reservoirs. Approximately 150 hydroelectric projects now have recreational facilities or plans to create them through the cooperative efforts of Federal agencies, private electric utilities, and State or local governments. These include swimming, boat docking facilities, nature study trails, and hiking paths.[62] TVA lakes in the seven Tennessee Valley States offer recreational opportunities for millions of visitors. At Lake Mead in Nevada, considerable attention has been given to maintaining sport fisheries at the highest possible level New guidelines for combining efficient use of the dam with superior fishing opportunities involve timing drawdown to avoid spring spawning period, and providing rising levels in summer to give better living space and escape cover for the young fish[63]

Whether recreation takes place on reser-

Water skiing in southern Washington. This scene has changed dramatically since Mount St. Helens, in background, erupted in 1980.



voirs or in natural lakes, a current major problem is overuse. Excessive activity at a lake may lead to destruction of banks and increased turbidity, to excessive noise from motor boats or simple overcrowding, to the lack of peace and safety that arises from conflicting uses Everyone who has ever vacationed at a lake knows some horror story of an accident—to a swimmer, a boater, a water-skier, a snorkler—that might have been avoided

Toilets of sailboats and motor boats that empty directly into the water can bring pathogens into the lake. EPA regulations now prohibit overboard discharge of raw sewage into navigable waters of the United States. New marine sanitation devices are of two basic types those that break down and treat toilet wastes, resulting in effluent with a vastly reduced fecal coliform count, and "no-discharge" systems with holding tanks. The latter type is now required in lakes where entrance and exit by boat is not possible

At many lakes the great charm of the area and the resultant massive increase in development of the shoreline pose an ominous threat to the spectacular beauty that first attracted visitors to the scene.

Lake Tahoe, the country's second deepest lake, is invariably described as "unique" because of its extraordinary clarity, deep blue color, and exquisite mountain setting. In the past two decades development, which has raised the permanent population of the lake from 3,000 to 75,000 and the number of visitors from a few thousand per year to as many as 250,000 on a peak summer day,[64] has fostered rapidly increased productivity in the lake as the result of nutrients carried in eroded soil. Recreational facilities now include campgrounds, State

Lakes such as Walden Pond in Massachusetts provide opportunities for recreation and contemplation for people of all ages.

Lake Tahoe, straddling the California-Nevada border, is, despite its pristine appearance, beset by problems associated with development of its shoreline.

parks, boat ramps, ski areas, and such non-lake related entertainment as gambling casinos and nightclubs featuring big name entertainers. The peerless beauty of the lake, which attracted all these residents and visitors, is now threatened by soil erosion, loss of wildlife and natural vegetation, air pollution, and the aesthetic desecration of tasteless construction.

Can Lake Tahoe be saved from the growing number of people who come to enjoy its charms and from local governments and private entrepreneurs on both the California and Nevada sides of the lake who profit from these hoards of visitors? The struggle to save Tahoe, which has engaged the passionate attention and often conflicting interests of environmentalists, land use planners, and local, State, and Federal policymakers, is an example of what the Council on Environmental Quality calls "The Quiet Revolution in Land Use"[65] —the movement away from the idea that the owner is entitled to make as much money as he can from the use of his land, the attempt to find a policy that reconciles the conservationist's view of land as a resource rather than a commodity and Constitutional guarantees of the right to buy, own, and sell property. This struggle will not only have to be faced at Lake Tahoe but at smaller recreational lakes all across the country.

What You Can Do

Although the field of lake management is reaching new levels of expertise each year, the best approach to lake problems is to be aware of how to prevent them. Owners of waterfront homes interested in maintaining a healthy aquatic balance in their lake can help avoid costly restoration projects by voluntarily reducing use of fertilizers and phosphate detergents, by good landscaping practices and maintenance of septic systems, and by other conservation techniques.

Experiences with severe pollution problems at the Love Canal in New York and the LiPari Landfill in New Jersey dramatically demonstrate how low the cost of prevention would have been compared with restoration expenses If lake restoration is needed, it is the local landowners and the local officials who can bring it about. Over the past two decades considerable incentive and support for lake cleanup programs have come from a long list of citizens' groups, conservation groups, sportsmen's associations, and labor unions.

At new lake-oriented land developments, plans designed to protect the lake specify shoreline buffer zones. Lake protection is also the focus of building and health department regulations covering construction and siting of homes and septic systems. Property owners' associations establish regulations for maintenance of the shoreline and shared open space. Such associations, which are often set up as non-profit corporations with year-round and seasonal residents pooling time, energy, and funds, may enjoy tax advantages while protecting the environment —and owners' investments. Membership may be mandatory as part of the deed of covenant of the lot.

Such associations should be concerned with controlling construction activity and commercial development, controlling aquatic vegetation, and providing lifeguard services. Members should maintain community septic tanks They may also recognize the ecologically destructive, peace-destroying, and physically dangerous results of conflicting lake uses and restrict motor boating, trail-biking along the shore, or other activities.

If the lake offers public access, the development may be eligible for State or Federal financial or technical assistance. The State may, for instance, stock the lake if public fishing is allowed, or provide safety equipment and post public areas with regulations set up by its game, fish, and parks departments.

Besides joining associations, lake area owners may also, in some States, form a sanitary district or a lake management district, special units of government with authority to take on certain responsibilities for lake protection. States vary considerably in the encouragement and funding they offer for lake protection and rehabilitation, but many have special grant programs. State agencies may assist with shoreline protection projects, such as the establishment of lateral parks or greenways along lakes and rivers State agencies may also offer funds for recreational land acquisition, assist construction of wastewater facilities, and work cooperatively with Federal programs, such as EPA's Clean Lakes Program.

On the local level, functions relating to lake conservation may be dealt with by planning and zoning boards, conservation commissions, and public works departments Communities interested in initiating lake cleanup projects should also be aware that many corporations, philanthropic organizations, and public interest groups may be successfully approached for funding or technical or planning advice.

On the Federal level, programs relating to lakes are funded by the Department of the Interior, the Department of Housing and Urban Development, the Department of Agriculture, and the Army Corps of Engineers (see Appendix), as well as by the Environmental Protection Agency. Usually these programs involve cooperation of State and local agencies, and large community investments may be required to match Federal and State funds In 1974, members of the Penn Lake Homeowners Association petitioned the Bloomington (Minnesota) City Council for help when they noticed that ducks were dying and that the lake was in trouble because of low water levels. With State, local, and EPA funding, a well was dug to provide supplemental water in arid periods, sediment-catching basins were constructed, and aeration was instituted to maintain dissolved oxygen levels.

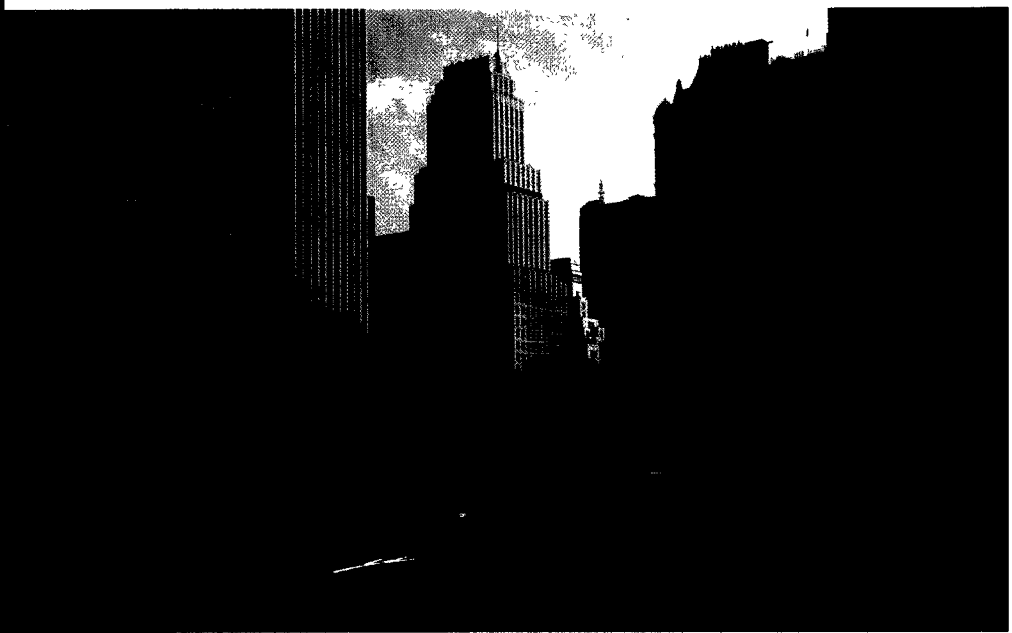
Under its Clean Lakes Program, EPA offers cooperative agreements for restoring publicly-owned freshwater lakes. In evaluating grant proposals, EPA is particularly interested in controlling nonpoint sources (municipal point source control is offered under section 201 of the same law, which relates to wastewater treatment facilities including stormwater management). Section 402 relates to the control of industrial point sources through issuing permits on industrial discharges. In weighing cost-effective solutions to significant clean lake problems the concern is with long-term public benefits through such pollution controls as construction of sediment basins and nutrient traps, leasing or purchasing buffer lands, diverting nutrients, improving agricultural practices, and instituting sound land management practices. In-lake methods such as chemical precipitation, dredging, aeration and drawdown will be considered only as part of more permanent restoration plans.

Increasingly, Government agencies cooperate in both urban and rural lake restoration projects through cost-sharing and technical assistance in related water quality problems.

Case Report: Cobbossee Watershed District

In a rural county in Maine, three eutrophic lakes, Annabessacook Lake, Cobbossee Lake, and Pleasant Pond, are currently being restored. Current emphasis is on control of pollution from agricultural runoff. Starting in 1943, lake property owners had complained of nuisance algae, and studies revealed severe oxygen depletion in the hypolimnion. For years, untreated sewage flowed directly into the lakes from municipal and industrial sources. Primary treatment was instituted but this effluent continued to be discharged into the lake. In 1972 interceptor sewers were installed, reducing nutrient loading by 90 percent, and nutrient inactivation was accomplished with aluminum sulfate. Continued nutrient enrichment is from runoff carrying pollutants from barn yards and fields of 38 nearby poultry and dairy farms. Because of poor manure storage facilities, farmers were spreading wastes on

Central Park's 59th Street Pond undergoes a much-needed restoration.



frozen ground in the winter, increasing the likelihood of runoff from fields.

Now State and local agencies, the U.S. Environmental Protection Agency, and two divisions of the U.S Department of Agriculture—the Soil Conservation Service and the Agricultural Stabilization and Conservation Service—are offering financial and technical assistance to correct the problem by entering into cooperative agreements with landowners. Construction of concrete floored manure storage facilities is in progress and other control measures are being instituted. Farmers are asked to contribute 20 to 50 percent of the cost of these improvements and an intensive educational program is demonstrating how investment in manure management systems will improve both lake water quality and farm efficiency. Through private and group discussions, a newsletter, and slide presentations by local soil and water conservation officials, pollution from farm lands is being stopped and farmers are able to store manure over the winter and plow it into the ground in the spring to effectively enrich soil.[66]

Case Report: 59th Street Pond

A charming 4-acre artificial pond located at the southeast corner of Central Park in New York City near the intersection of 59th Street and 5th Avenue is currently in the final stages of restoration. To call the pond "charming" involves a forward look toward its reopening and a backward glance to earlier decades. During recent years the pond has been about as lacking in charm as a handsomely sited well-designed urban lake could possibly be.

The pond adjoins the popular Wollman Skating Rink and was included in the original plan for the park by its designer Frederick Law Olmsted. This masterpiece of urban planning—a vast park in the center of one of the world's biggest cities—is now designated both as a National Landmark and as a New York City Scenic Landmark

A favorite place for strollers and picnickers, for New York City residents and for visitors, the 59th Street Pond has been gathering silt rapidly since 1950, when it was last dredged. Although the lake was originally 1.5 meters (5 feet) deep, at the time restoration began depth ranged from 1 meter (3 feet) to 0.15 meters (6 inches). Even the most optimistic urban nature lover could not describe the waters as refreshing Turbidity and discoloration resulted from high bacterial levels and quantities of organic material. Algal growth made the pond scummy and murky. Coliform counts were off the top of the scale. Although the pond once had fish and ducks as well as other aquatic life, the stagnant conditions led to abandonment for more inviting waters.

The restoration, which involves draining, dredging, and making the bottom impenetrable to avoid future problems, bank repairs, and repair of clogged drainage pipes, is being jointly funded on the Federal level by the Environmental Protection Agency and the Heritage Conservation and Recreation Service (Department of Interior). The responsibility of the latter is a major landscaping project that will anesthetically enhance the surroundings and correct present erosion problems. It will include regrading, and also improving walkways. The project is being managed by the New York City Department of Parks and involves State, regional, and local agencies as well as devoted members of volunteer and community groups—which first agitated for restoration of their historic and valuable 59th Street Pond[67]

Clean Lakes

In Congressional testimony on funding for the Clean Lakes Program, then Senator Walter F. Mondale said,

> **I am always amazed, as I go around my State, by the number of people that come up to me to talk about problems with their community lake. This is a prize jewel in the community. This is where**

Yesterday, Today and Tomorrow

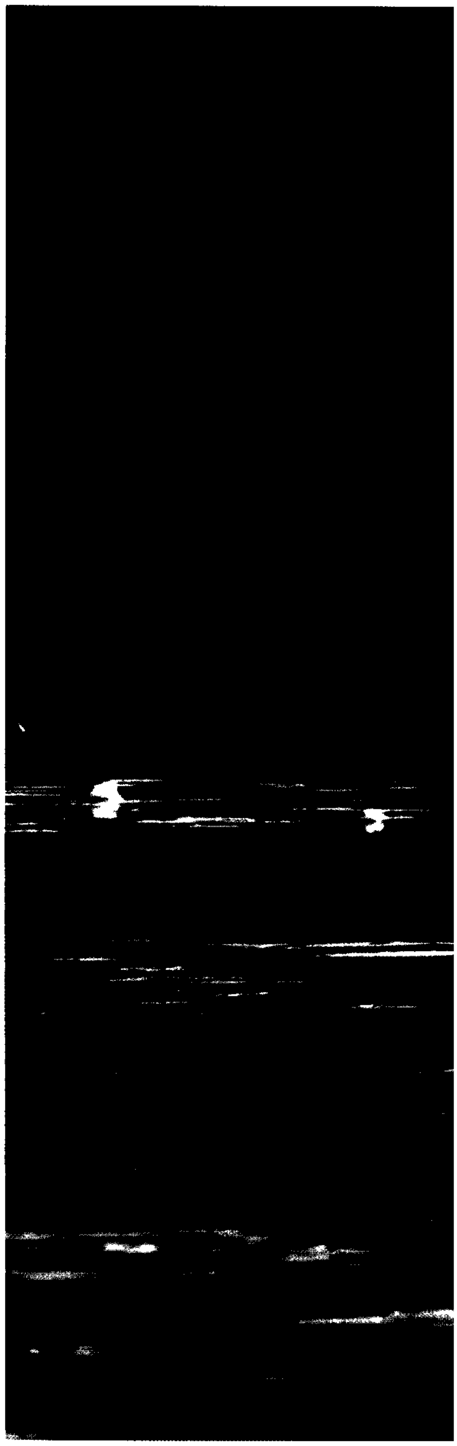
An increasingly strong ethic of conservation has created a mandate against abuse of our nation's lakes, such as the pollution of Alcyon Lake, New Jersey (above, right), and a demand for protection of lakes such as this pond (right) in Chippewa National Forest, Minnesota.

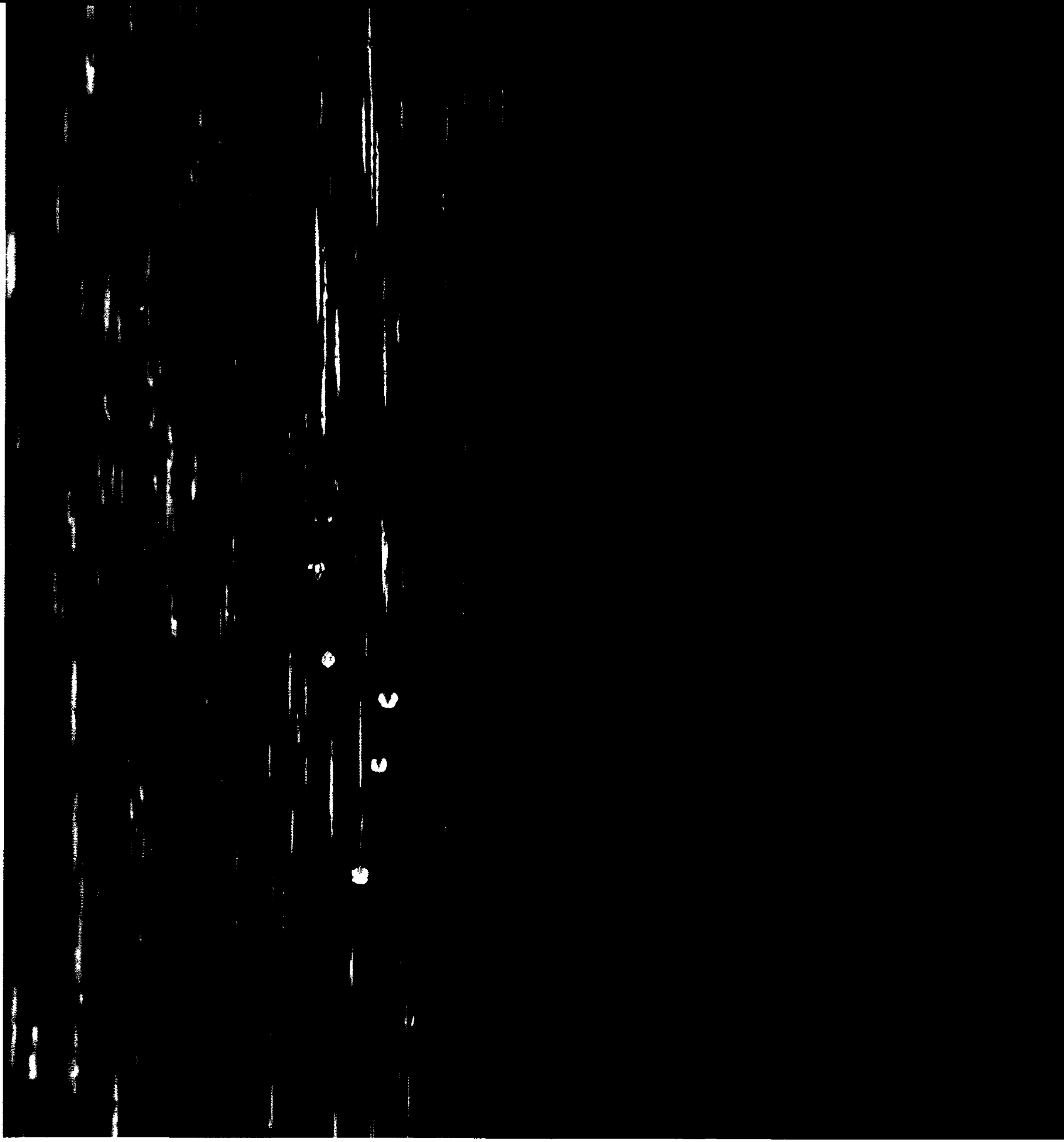
> the kids swim, this is where they fish, this is where they go boating, waterskiing, this is where they get a little breath of fresh air. And most of our communities —many of them—are built around the lake. It is the most prized recreational asset that they have. But those lakes are putrifying, they are suffering from accelerated aging, and unlike rivers and so on that can scour and cleanse themselves, these lakes die, and they die at an accelerated rate unless tactics are used to protect them against that process by cleaning them up and preventing their further pollution.[68]

We do not know how many communities are losing their "prize jewel"—how many lakes nationwide are irretrievably lost because they are now too degraded for restoration measures to be effective. What we do know is that lake protection must become a priority and that abuse of our lake resources must cease. After centuries of indifference and misguided actions, Federal, State, and local governments are now ready to assist in the campaign to clean up our natural environment. Their mandate comes from a populace that, with ever-increasing sensitivity and enthusiasm, has become converted to an ethic of conservation rather than of waste.

We who walk the earth today have viewed, through the eye of the camera mounted on the spacecraft, the fragile planet on which we live. Lake guardianship is only a part, but an essential part, of the effort to save the earth—for ourselves, our children, and distant generations.

It is consonant with the viewpoint presented in this book to adorn both the early and the final sections with quotations from Walden. Although Thoreau had never heard of an ecologist or a photograph from outer space, he took the measure of his own soul on the shores of Walden Pond. The question he asked, well over a century ago, was: "What is the use of a house if you haven't got a tolerable planet to put it on?"





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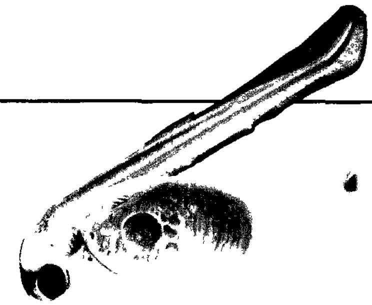

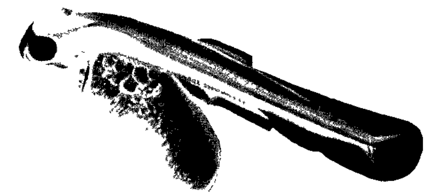

Left: Pickerel frog meets a dragonfly at a pond's edge. Right: a trout egg and trout fry.

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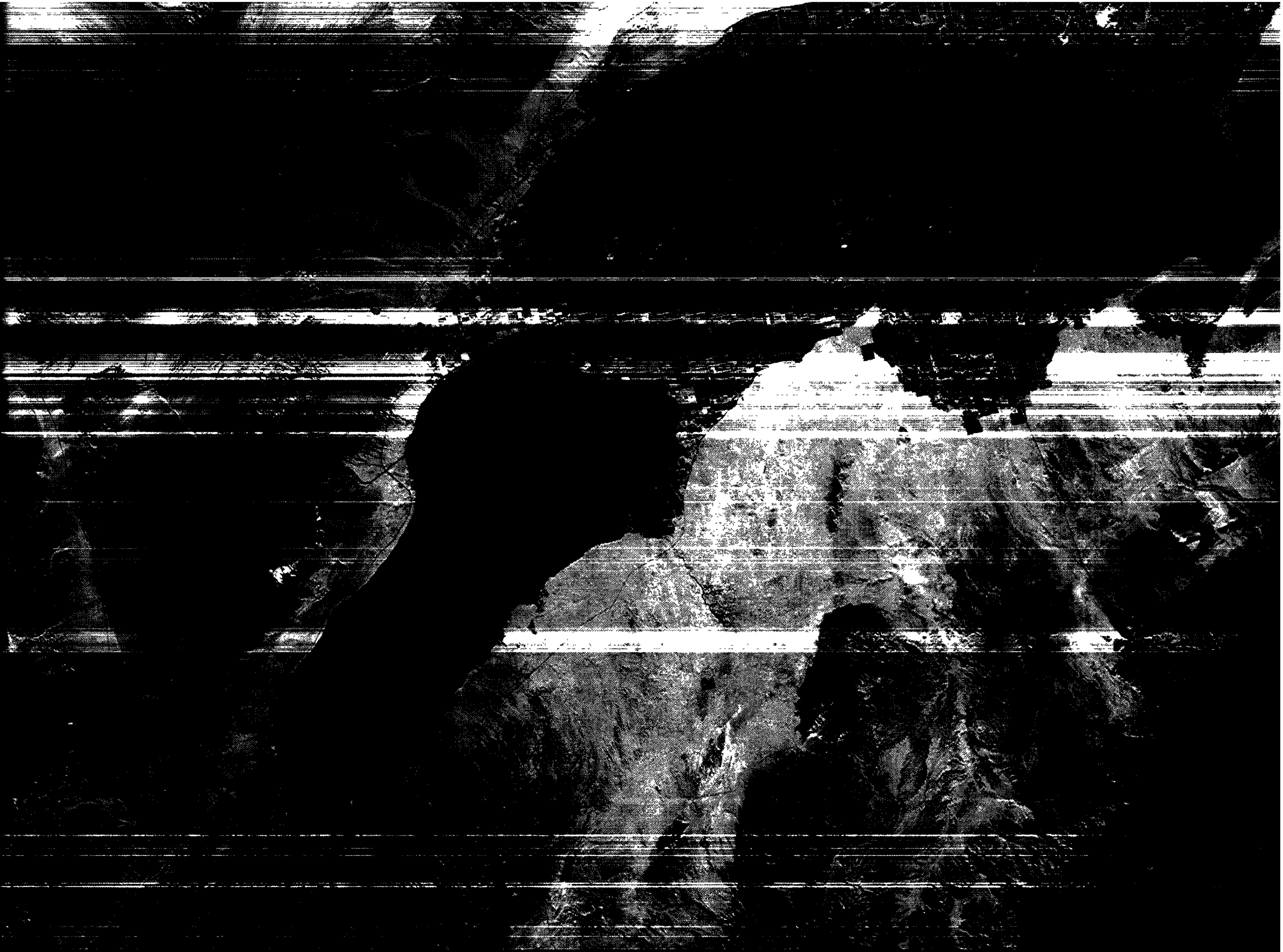
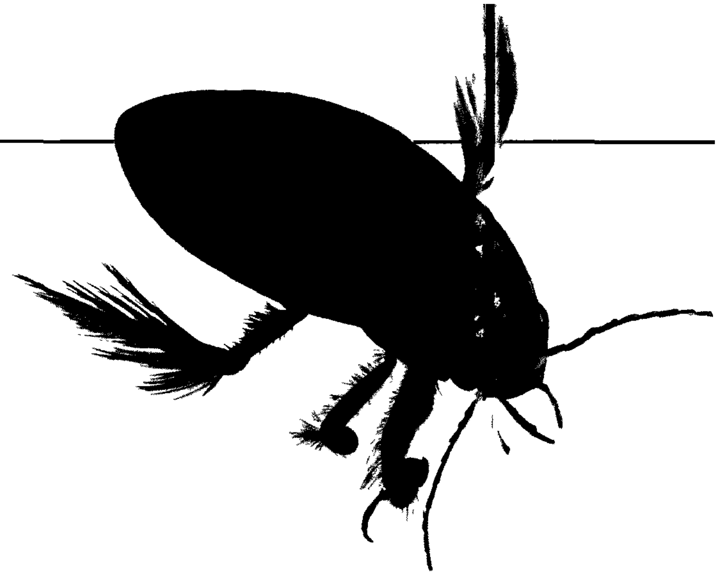


Appendix A Glossary



ADVANCED WASTE TREATMENT. Often abbreviated AWT and also referred to as tertiary treatment. Wastewater treatment usually directed at major plant nutrients: results in a high quality effluent.

AEROBIC. Environment in which oxygen is present. Also refers to processes occurring in presence of oxygen.

ALGAE. Simplest green plants having neither roots, stems, nor leaves; those in fresh water are usually microscopic in size.

ALGAE BLOOM OR ALGAL BLOOM. Very rapid growth of algae with formation of large concentrations which sometimes form floating mats or distinct coloration of the water.

ALGICIDES. Chemical substances that are toxic to algae.

ANAEROBIC. Environment in which oxygen is absent. Also refers to processes occurring in absence of oxygen.

AQUATIC PLANTS. Plants that grow in water. Some aquatic plants are rooted, some are free floating.

BACTERIA. Microscopic single cell organisms that are similar to plants but lacking in chlorophyll

BIOMASS. Total quantity of plants and animals in a specified area.

BIOTA. The plants and animals of an area.

CHLORINATION. Application of the chemical chlorine to water to serve as a disinfectant.

CULTURAL EUTROPHICATION. The acceleration by human activities of the natural aging processes in a lake.

D.O. Dissolved oxygen required for the maintenance of aerobic aquatic organisms. Low D.O. levels approach anaerobic conditions.

ECOLOGY. A branch of science concerned with the interrelationship of organisms to one another and to their environment.

EFFLUENT. Treated or untreated wastewater that flows from sewers, treatment plants, or industrial plants.

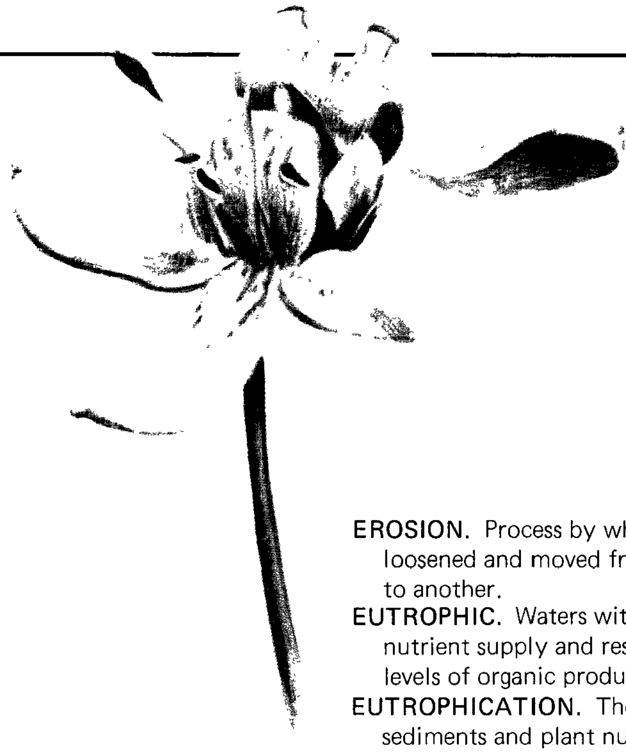
ENVIRONMENT. All the external conditions that surround living things, such as soil, water, and air.

EPILIMNION. Upper warm circulating layer in a stratified lake.

DECOMPOSITION. Breakdown of materials into simpler forms by action of aerobic or anaerobic microorganisms.

DETRITUS. Minute particles of the decaying remains of dead plants and animals.

atellite view of the Salton Sea, a saline ake in south-central California. South of he lake, irrigated land appears as a bright atchwork. A horizontal line bordering he brightest area of farm-land marks the Mexican border. Above, right: diving beetle, a voracious lake predator. At right: a water yacinth, an aquatic plant that chokes many southern waterways.



From near to far right: a common loon, perched at the top of the food web of northern lakes; macrophytes at the edge of a Connecticut pond; sediment exposed to the sun in a western lake-bed; foliage frames a New England pond.

EROSION. Process by which soils are loosened and moved from one place to another.

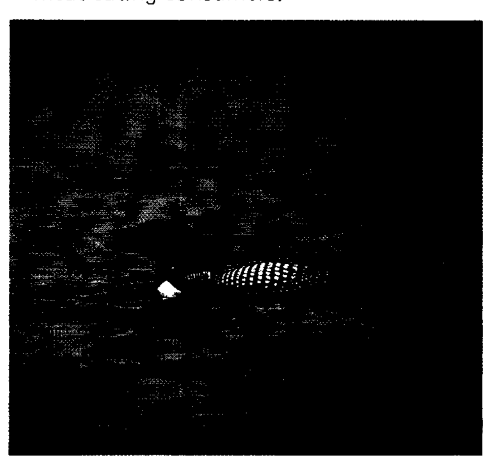
EUTROPHIC. Waters with high rate of nutrient supply and resulting high levels of organic production.

EUTROPHICATION. The addition of sediments and plant nutrients to a lake, leading to decreased volume and increased biological material. This can occur either as a natural stage in lake maturation or in an accelerated fashion due to human activities. (Cultural eutrophication).

FECAL COLIFORM BACTERIA. Bacteria found in feces of warm-blooded animals.

FLUSHING RATE. Time it takes for the total volume of a lake to be replaced. Also known as retention time.

FOOD WEB. A system of interlocking food chains in which energy and materials are first converted to organic matter through photosynthesis and then passed through a series of plant-eating and meat-eating consumers.



GROUNDWATER. Water found below the surface of the soil in the zone of saturation where it fills spaces in soil and rocks. The top level of the groundwater is the water table.

HABITAT. Area which provides the requirements for, and therefore the home for, specific plants or animals.

HYPOLIMNION. The deep, cold, lower level of a stratified lake.

LITTORAL ZONE. Shallow water interfac area between the land of the drainage basin and the open waters of the lake.

LIMNOLOGY. The study of freshwater systems.

MACROPHYTE. Large, rooted aquatic plant.

MESOTROPHIC. Waters with a moderate supply of nutrients and moderate level of organic production.

NUTRIENT. A chemical element or compound which promotes the growth and development of organisms.

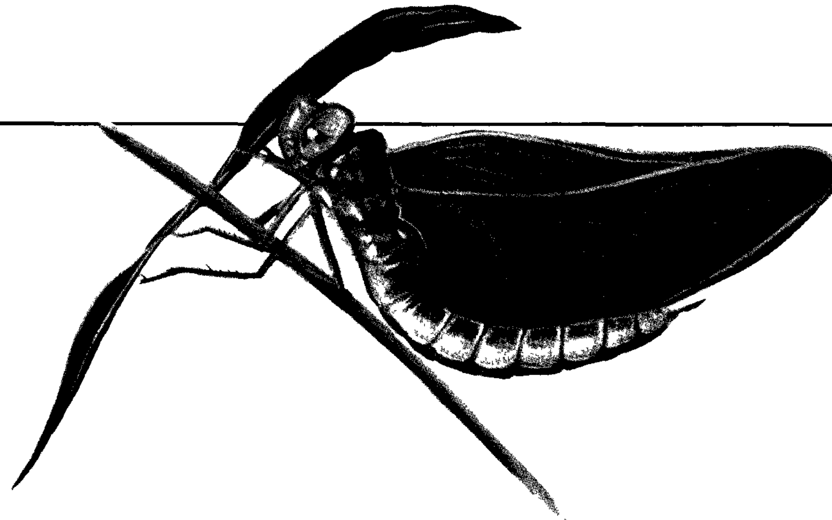
PERCOLATION. Downward movement o water through spaces in soil and rocks.

PALEOLIMNOLOGY. Study of the histor of freshwater lakes.

PELAGIC ZONE. Free open water area of the lake.

PHOTOSYNTHESIS. Synthesis of organic compounds with the aid of light by chlorophyll-containing cells.

PLANKTON. Microscopic free floating plants and animals.



'OLLUTANT. A substance, medium, or agent that causes physical impurity. Official EPA definition in PL 95.217 Sect. 502(6) is: dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.

'ROFUNDAL ZONE Deep central area of a lake.

ƎESIDENCE TIME. Amount of time a substance will remain in a lake before being flushed or settled out.

ƷECCHI DISK. A white disk 20 centimeters (8 inches) in diameter used to measure transparency of water.

ƷEDIMENT. Particles of material transported to a lake or suspended in its water. Also refers to bottom material in lakes that result from its formation, the remains of organisms, erosion from land.

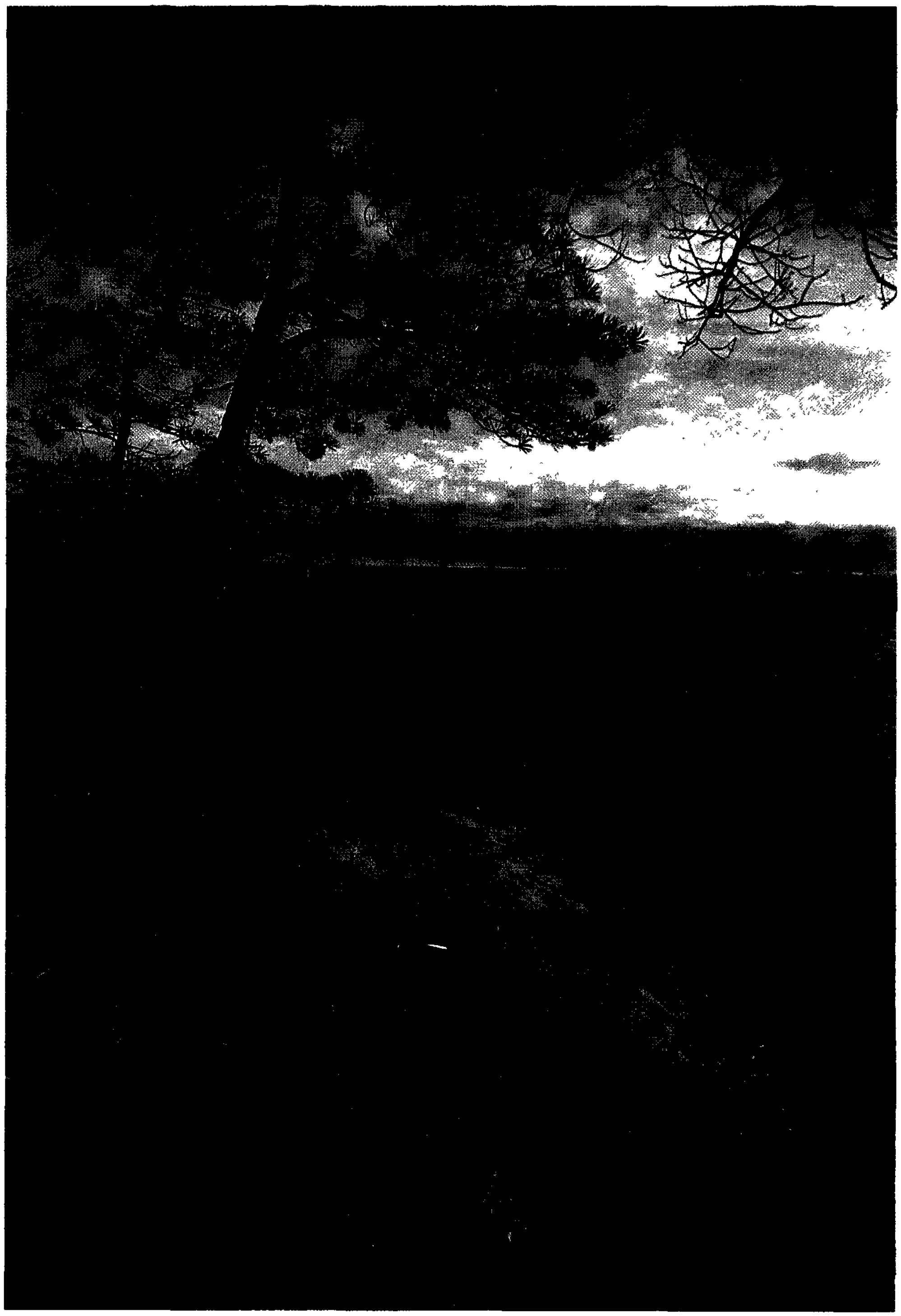
STRATIFICATION. Thermal layering of a lake in which the water column is divided by density into a cold lower region and a warm upper region with a relatively thin boundary area between.

THERMOCLINE. Region of rapid temperature transition in a stratified lake that separates the epilimnion.

TRIBUTARY. Stream or river that flows into a lake.

TURBIDITY. Condition of opacity or muddiness in water resulting from particles in suspension

WATERSHED. Land area that is drained by a stream or river system.



Appendix B Federal Agency Functions Relating to Lakes

Large enough to look and act like an ocean, Lake Superior assaults shoreline at Eagle Harbor on Michigan's Keewenaw Peninsula.

Included are directly related financial and technical assistance programs that can be used to match Clean Lakes Program funds (Clean Water Act, section 314) and also indirectly related opportunities for funding and advice that can be coordinated with a Clean Lakes project.

Department of Agriculture

Agricultural Stabilization and Conservation Service. Project grants and advisory services are offered under 10-year agreements to owners of wetland areas who agree not to destroy these areas or use them for agriculture. Other programs offer individuals and groups cost-share grants for testing administrative, engineering, and management systems designed to improve water quality in rural areas and for establishing approved conservation practices on agricultural land. Aims are to help solve water, woodland, and pollution abatement problems on farms and ranches.

Farmers Home Administration. Guaranteed/insured loans are available through this branch of the USDA through a variety of programs designed to improve the economic and environmental aspects of farm and rural community life. Funds are available for such projects as land conservation measures, pollution abatement measures, irrigation, drainage, treatment of sanitary, storm, and solid wastes, improvement of sedimentation control, fish and wildlife development, and public water-based recreation.

Forest Service. Grants for research and financial assistance are offered in the fields of watershed management, wildlife habitat management, reforestation, and other forest-related areas.

Science and Education Administration. This branch of USDA disseminates technical information and makes funds available in agricultural research. Many previous research projects have been directly related to lake protection.

Soil Conservation Service. Cost-share grants are available for soil and water conservation measures designed to prevent erosion in the Great Plaines area. Other programs offer similar assistance in resource conservation in other parts of the country. Grants, advisory services, and counseling are offered in projects involving flood prevention, irrigation, and water-based fish and wildlife recreation programs. Over 140 varieties of grasses, legumes, and shrubs are available for conservation purposes such as erosion control, streambank protection, wildlife food and cover, and beautification. Direct payments and advisory services are offered for reclamation of land and water areas affected by coal mining activities.

Department of Commerce

Economic Development Administration. Project grants and direct loans are available to encourage long-term economic growth in areas lagging behind the rest of the Nation. Included as qualified public facilities are water and sewer systems.

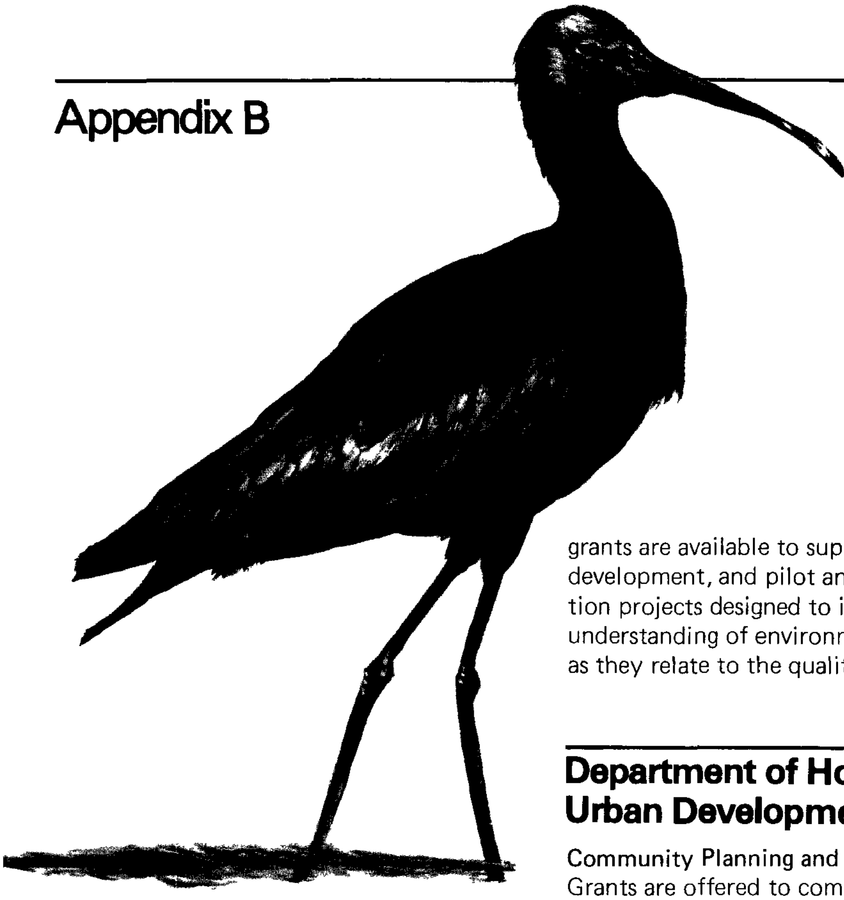
Department of Defense

Department of the Army, Office of the Chief of Engineers. Specialized programs attack problems of control and eradication of undesirable aquatic plants and beach and shore erosion. Corps of Engineers flood control projects may also relate in various ways to lake protection.

Office of Education

Environmental Education. Project

Appendix B



Glossy ibis (above) and wood duck (right) make lakes their feeding grounds.

grants are available to support research, development, and pilot and demonstration projects designed to improve public understanding of environmental issues as they relate to the quality of life.

Department of Housing and Urban Development

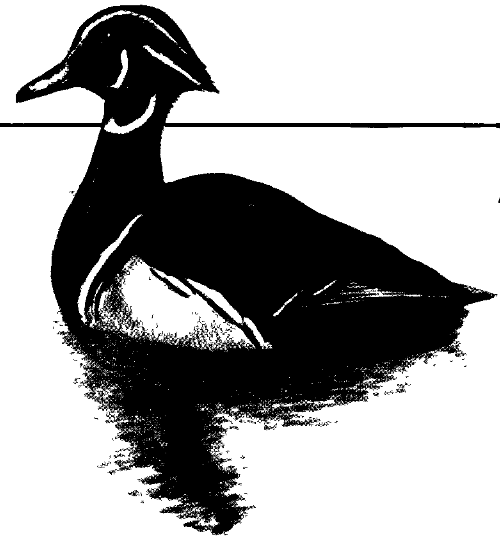
Community Planning and Development. Grants are offered to communities to undertake activities for improvement to community facilities that affect public health and safety including water and sewer projects.

Department of the Interior

Office of Surface Mining Reclamation and Enforcement. Grants and direct payments and technical assistance are available for projects to protect society and the environment from adverse effects of coal mining operations.
Heritage Conservation and Recreation Service. Project grants are available for the preparation of comprehensive statewide outdoor recreation plans and acquisition and development of outdoor recreation areas and facilities for the general public. Project grants are also offered to economically hard-pressed communities for rehabilitation of existing recreational facilities and for demonstration of innovative ways to enhance park and recreation opportunities and develop recreation plans. Advice and demonstration on recreation-related matters are offered to States, localities, and private interests.
Water and Power Resources Service (formerly the Bureau of Reclamation). Project grants and direct loans are offered for such rehabilitation and improvement projects as irrigation and drainage and for multi-purpose plans involving flood control, fish and wildlife, recreational development, municipal and industrial water supplies.
U.S. Fish and Wildlife Service. Formula grants are available to support projects designed to restore and manage sport fish populations and for restoring or managing wildlife populations. Information and technical assistance are available on protection and enhancement of freshwater fishery resources, the effects of pesticides on fish and wildlife ecology, and management of waters for sport fishing.
Office of Water Research and Technology. Grants provide Federal funds through State water resource institutes for research and development of water resources management techniques which are, in most instances, applicable to lakes.
Geological Survey. Assistance is offered in cooperative projects to prepare geologic maps. Technical information and maps provide information for development and management of natural resources and efficient operation of interrelated projects at the Federal, State and local level.

Environmental Protection Agency

Office of Water and Waste Management. Project grants are offered for construction of wastewater treatment works including privately owned individual treatment systems. The project may include but may not be limited to treatment of industrial wastes. Formula grants are available for the establishment and maintenance of adequate measures for prevention and control of water pollution. Broad support is available for permit programs, pollution control studies, planning, surveillance, and enforcement. Project grants are provided to areawide and State planning



Appendix C Clean Lakes Water Act (33 U.S.C. 1251 et seq.)

agencies to develop a water quality management plan for areas approved by the appropriate regional EPA administrator. Solid and hazardous waste management program support grants assist in the development and implementation of State and local programs and support rural and special communities in programs and projects for solving solid waste management problems. Project grants are available to promote the demonstration and application of solid waste management and resource recovery technology and assistance to preserve and enhance the quality of the environment and conserve resources.

Office of Research and Development. Project grants are available to support research and to determine the environmental effects and control requirements associated with energy, to identify, develop and demonstrate necessary pollution control techniques; and to evaluate the economic and social consequences of alternative strategies for pollution control of energy systems. Other project grants may be used for research, development, and demonstration projects relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution.

Office of Planning and Management. Guaranteed/insured loans are available to assist and serve as an incentive in construction of municipal sewage treatment works that are required to meet State and Federal water quality standards.

Programs Providing Labor. A number of programs provide labor for conservation work. They are administered by the Forest Service of USDA (Youth Conservation Corps and Young Adult Conservation Corps), the Department of Labor's Employment and Training Administration (CETA and other employment and training programs), and Action (Retired Senior Volunteer program and others.

Section 314.

(a) Each State shall prepare or establish, and submit to the Administrator for his approval—

(1) an identification and classification according to eutrophic condition of all publicly owned freshwater lakes in such State,

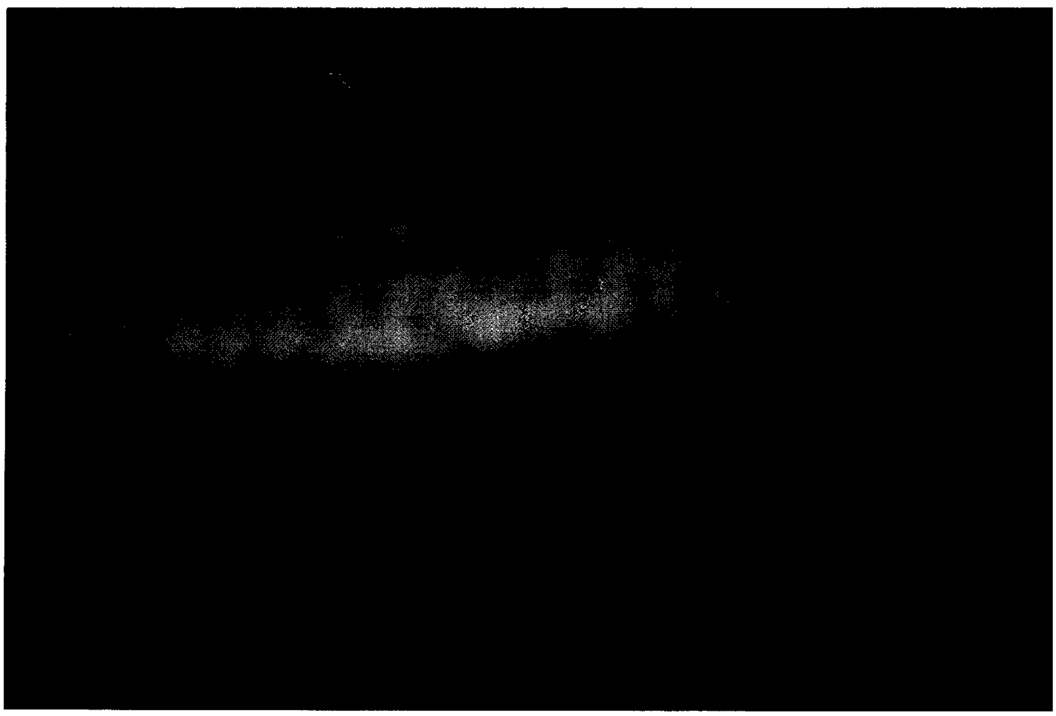
(2) procedures, processes, and methods (including land use requirements), to control sources of pollution of such lakes; and

(3) methods and procedures, in conjunction with appropriate Federal agencies, to restore the quality of such lakes

(b) The Administrator shall provide financial assistance to States in order to carry out methods and procedures approved by him under this section. The Administrator shall provide financial assistance to States to prepare the identification and classification surveys required in subsection (a) (1) of this section.

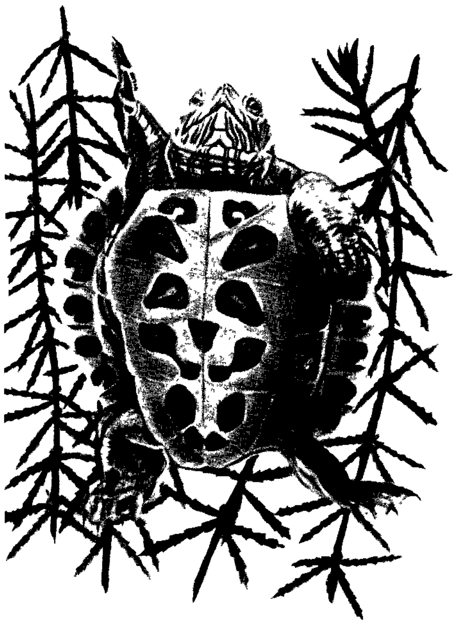
(c) (1) The amount granted to any State for any fiscal year under this section shall not exceed 70 per centum of the funds expended by such State in such year for carrying out approved methods and procedures under this section.

(2) There is authorized to be appropriated $50,000,000 for the fiscal year ending June 30,1973, $100,000,000 for the fiscal year 1974; $150,000,000 for the fiscal year 1975; $50,000,000 for the fiscal year 1977; $60,000,000 for fiscal year 1978; $60,000,000 for fiscal year 1979; and $60,000,000 for fiscal year 1980 for grants to States under this section which such sums shall remain available until expended. The Administrator shall provide for an equitable distribution of such sums to the States with approved methods and procedures under this section.



A water strider on a woodland pond

Appendix D List of Reviewers



ıt left, a snapping turtle, whose shell and ıowerful jaws place it at the top of its ood chain. Above, a red-eared turtle, esident of the south central U.S.

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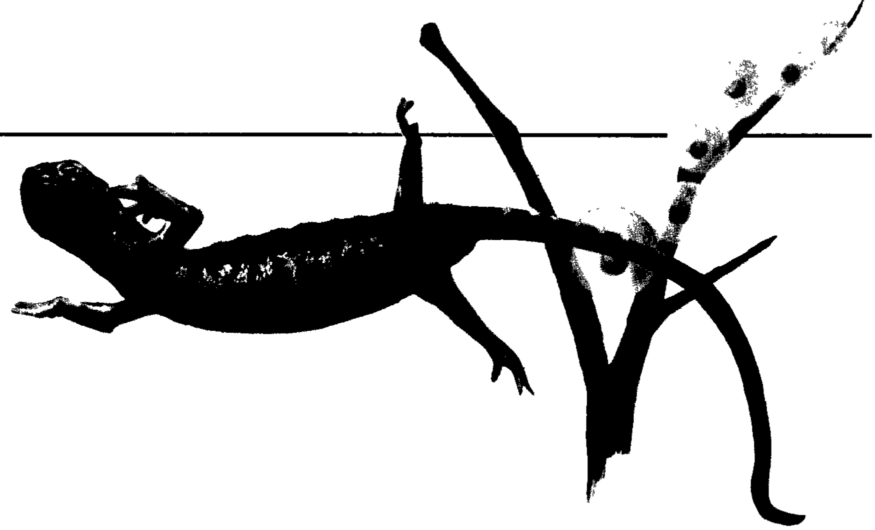

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