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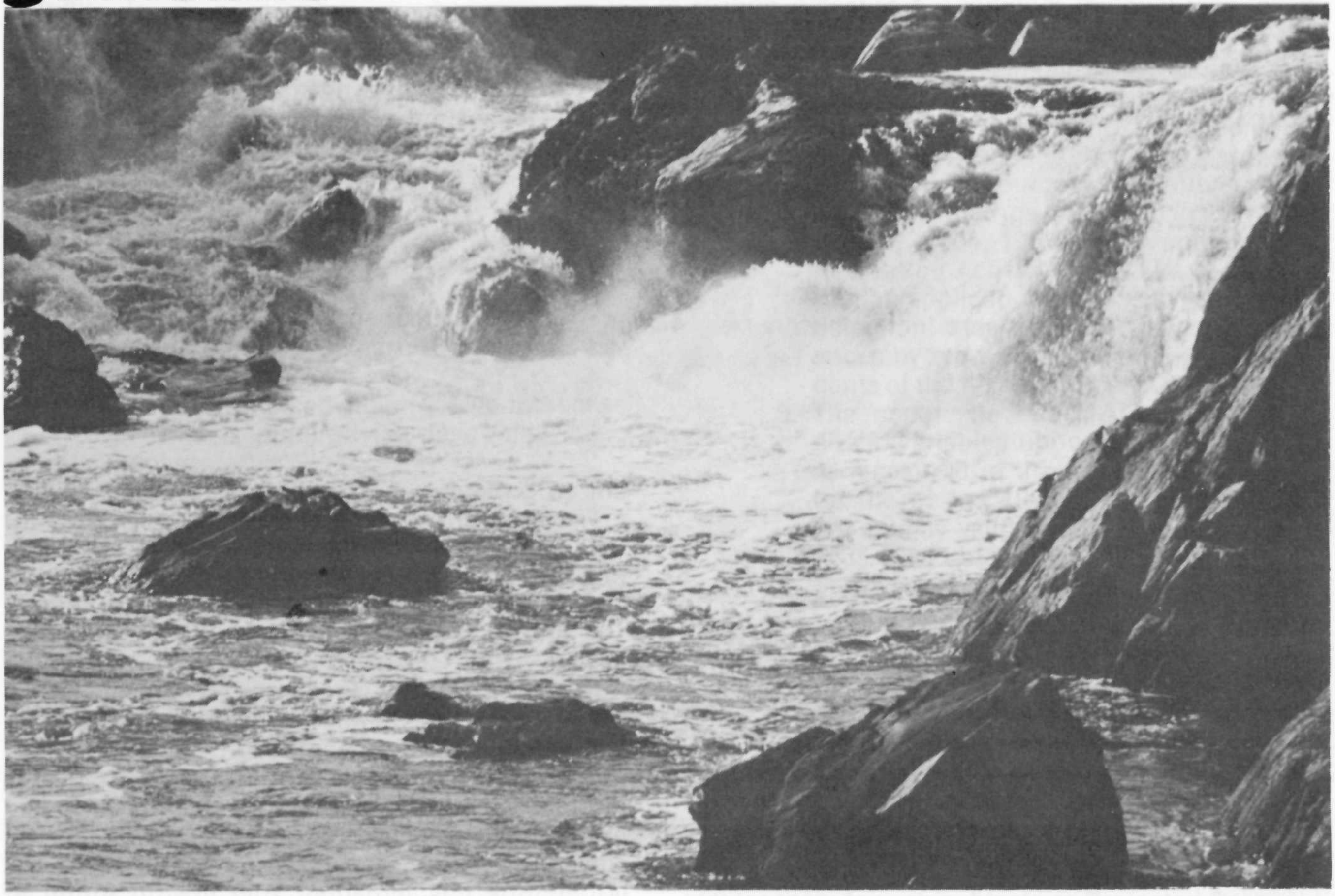

Water resources planning . . .
THE NEXT FIFTY YEARS

INTRODUCTION

The North Atlantic Regional Water Resources Study Coordinating Committee climaxed more than two years of investigation and planning with the release of its extensive Report in July, 1972. The North Atlantic Regional Water Resources (NAR) Study examined a wide variety of water and related land resources, needs and devices in formulating a broad, coordinated program to guide future resource development and management in the North Atlantic Region. The Coordinating Committee, a partnership of resource planners representing some 25 Federal, regional and State agencies led in developing the recommended programs and alternatives.

The NAR Study Report presents the program and the alternatives as a framework for future action based on a planning period running through 2020, with benchmark planning years of 1980 and 2000. The information is contained in a Main Report, 2 Annexes and 22 Appendices. The Appendices contain details of programs in various aspects of the Study.

Three areas of the Study are directly concerned with recreation: Outdoor Recreation, Fish and Wildlife, and Visual and Cultural Environment. VISUAL AND CULTURAL ENVIRONMENT, of particular interest to administrators of recreation areas, was covered in the November/December 1973 issue of GUIDELINE. This article will cover OUTDOOR RECREATION area of the Study. While some information included pertains only to the region studied, many of the programs are applicable in other areas.

The following methodology will give the reader an indication of material available in the Report. The entire Study—or any part—is available for examination or purchase. For further information, write Dept. of the Army, North Atlantic Division, Corps of Engineers, 90 Church Street, New York, N.Y. 10007.

(Continued on page 3)

guideline A PUBLICATION OF THE PARK PRACTICE PROGRAM

NATIONAL RECREATION AND PARK ASSOCIATION

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CONTENTS

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OUTDOOR RECREATION . . . a methodology of the study.

SECTION I: Syllabus

This report concerns itself with Outdoor Recreation activities that are associated with water: swimming, camping, picnicking, boating, water-skiing, sailing, and canoeing. The needs were determined for each of the 21 basins for each target year - 1980, 2000 and 2020. The data indicates that public demand for these activities, already at unprecedented levels, will increase constantly as

the region's population increases
the time required to earn a livelihood becomes less
the amount of disposable income increases over what is required for day-to-day living expense.

This section of the Study was prepared by the Bureau of Outdoor Recreation (BOR) Department of Interior in cooperation with other Federal agencies and with the States concerned. County and municipal agencies, private organizations and individuals were, also, helpful in formulating this Appendix.

Projected needs were considered at three different levels, using the planning objectives set up for the entire Water Resources Study: Environmental Quality, Regional Development, and National Efficiency. As a frame of reference to determine future demands, supply and need, the Bureau considered the present situation, with reasonable projections of future growth plus industrial and agricultural changes.

SECTION II. Introduction

A. PURPOSE AND SCOPE. The North Atlantic Study Region was divided in accordance with hydrological boundaries into six major subregions and 21 river basins or areas which were adjusted to conform with county lines to facilitate the gathering of data. The Office of Business Economics also divided the study area into 23 water resource planning areas. Each of these boundaries plus that of census regions was plotted in an attempt to identify individual population centers for which projected participation in selected water-oriented outdoor recreation activities could be computed and then distributed among the 21 basins.

This appendix contains estimates of the recreation needs for water and related land resources to the year 2020, and recommends means by which the needs may be met in 1980, 2000, and 2010. It contains evaluations of outdoor recreation resources, recommendations for general measures needed to meet future demand, and identification of specific areas of priority for more detailed studies.

B. ASSUMPTIONS. In approaching this study, a great deal of information was derived from the Outdoor Recreation Resources Review Commission Reports and the "1965 Survey of Outdoor Recreation Activities." Additional material was taken from on-going research. Basic assumptions were:

1. Projected participation in seven activities: boating; canoeing; sailing; swimming; water-skiing; picnicking; and camping provide a reasonable basis for assessing water-oriented outdoor recreation needs.
2. Use of the findings presented in the report entitled "The 1965 Survey of Outdoor Recreation Activities" is valid; in particular, the application of census region participation rates and one-way travel distances by type of trip and activity to residents of the respective census regions.
3. The composite effect of six socio-economic variables upon participation rates as measured in the 1960 ORRRC Survey for the period 1960-1976 and 1960-2000 are equally valid for the time intervals of 1965-1980 and 1965-2000, respectively. These six variables include: Education; Occupation; Age/Sex; Family Income; Residence; and Leisure (available).
4. Persons under 12 years of age will participate at the same rate as those over that age.
5. If provided the opportunity, recreationists will distribute themselves in a random fashion.

In this section of the report, there are numerous tables enumerating data used in the report. These tables include such subjects as Projected Seasonal participation for each of the target years, Activity Day Turnover Rates by Objective, and (see Table M-19) — Water Area Spacial Standards for Selected Activities and Objectives.

Equations used in determining various needs, and the method of formulation for each equation, help to clarify the tables.

C. RELATIONSHIP TO OTHER PARTS OF THE REPORT. The remainder of this Appendix examines in detail the recreation situation as it now exists throughout the Region, together with the projected situation. Once the situation was defined in terms of number of recreationists requiring *x* number of acres for picnicking or camping or *y* number of acres of broad water for boating, sailing, or waterskiing, recommendations followed as to how such needs could best be satisfied.

It must be emphasized that although land and water for recreation are important human needs which are generally conceded to be growing, there are other human needs which are just as important, and many of these are growing too. Water for municipal and industrial use, for rural use, for irrigation, for power cooling and for fish and wildlife are but a few of these other needs. An effort was made to determine what can be done to insure that adequate supplies of water will exist at a given place at a given time to satisfy the various demands - including recreation - which are projected for it.

TABLE M-19

WATER AREA SPACIAL STANDARDS FOR SELECTED ACTIVITIES AND OBJECTIVES

ACTIVITY	OBJECTIVE	STANDARD
Boating	National Efficiency	inboards and 20 hp outboards (3 acres/boat) 20 hp outboards (1 acre/boat) non-powered (1/3 acre/boat)
	Regional Development	inboards and 20 hp outboard (6 acres/boat) 20 hp outboards (1-1/2 acres/boat) non-powered (2/3 acre/boat)
	Environmental Quality	inboards and 20 hp outboards (9 acres/boat) 20 hp outboards (2 acres/boat) non-powered (1 acre/boat)
Sailing	National Efficiency	3 acres/vessel
	Regional Development	6 acres/vessel
	Environmental Quality	9 acres/vessel
Canoeing	National Efficiency	4 canoes/mile of stream or 1/3 acre/canoe
	Regional Development	4 canoes/mile of stream or 2/3 acre/canoe
	Environmental Quality	4 canoes/mile of stream or 1 acre/canoe
*Water-skiing	National Efficiency	plus 1.5 acre/boat
	Regional Development	plus 1 acre/boat
	Environmental Quality	plus 1 acre/boat
**Swimming	National Efficiency	50 sq. ft. of beach/person or 30 sq. ft. of pool/person
	Regional Development	75 sq. ft. of beach/person or 45 sq. ft. of pool/person
	Environmental Quality	100 sq. ft. of beach/person or 60 sq. ft. of pool/person

D. HISTORY. A brief history of land use and conservation describes the efforts made to preserve this country's natural resources after it was discovered that these resources were in danger because Americans believed The Myth of Super-Abundance. These efforts are described in three "waves" of conservation. The first "wave", from 1891 to 1911 in Teddy Roosevelt's time, was essentially one of preservation. The "second wave" in conservation occurred during the Franklin Roosevelt administration and was a resource-oriented effort, involving soil, water, rangeland, reforestation, and electric power. The present "third wave" is more comprehensive, including all the foregoing and much more; the present effort is directed toward improving the total environment of man. These efforts - including extensive legislation - result from the realization that man and his economy are totally and completely dependent upon the planed earth and that how well he manages it will determine how long his species will survive. It is particularly important that the North Atlantic Region should emphasize the urgency for water resources planning in order to identify and preserve the dwindling resources which are rapidly being choked off by urban and industrial development.

The current demand for outdoor recreation opportunities is great and the projected demand for the three target years, i.e., 1980, 2000, and 2020 indicates a steadily growing demand for such facilities. The history section presents background information on what has been accomplished in the past. The remainder of Appendix M looks to the future, listing anticipated needs and proposals for meeting these needs.

SECTION III. Regional Summary

A. PRESENT STATUS. The Outdoor Recreation situation is not an encouraging one. Federal, State, and local agencies have performed admirably well in providing recreation opportunity, but they have been limited, through fiscal constraints, in the recreation facilities they have been able to provide. It appears that there are sufficient quantities of both land and water; the problem, essentially, is one of uneven distribution of people over the land and the overall degradation of the environment in general and of the recreation base in particular. Unfortunately, there appears to be no solution to the problem of uneven distribution of people; indeed, it will intensify if urbanization trends continue as they have in the past.

The second problem is not insoluble but needs immediate attention. In geographical areas of high density the present recreation situation is critical, not only because so little remains in the way of unspoiled land and pure water which could be added to the existing recreation base, but also because such land, when it does exist, is usually developed for maximum monetary return (such as shopping centers or housing sub-divisions.) In areas of less intense population concentrations, the existing recreation situation while perhaps not critical is certainly cause for concern. Zoning laws, industrial waste, and financial considerations are but a few of the factors involved in strengthening recreation resources.

B. FUTURE DEMANDS. In looking to the future, one is struck with the enormity of the projected demand on the recreation base. First, the number of persons will increase. (Population in the NAR Study Area in the year 2020 is expected to increase by nearly 93 percent over the 1960 population figure.)

Second, the work force will have greater amounts of time available for leisure and, in most cases, sufficient means to do it. (The 35-hour week and three-week vacation period will be commonplace by the year 2000.) Another factor, and one perhaps which will assume added significance in the future, is the human need to seek a respite of a few hours, or a few days, totally removed from the turmoil and tensions which characterize an urbanizing, highly-industrialized society.

In summarizing future needs for recreation, one cannot but be impressed by their sheer magnitude, together with the tremendous costs involved in providing for them. Estimates of these costs, including land acquisition and development and stream acquisition, have been computed for each basin and appear in three tables according to Objective.

C. MEANS OF SATISFYING DEMAND. Eight suggestions are included in this section to help meet the demand for water-based recreation. First, water quality of existing rivers must be upgraded and industrial pollution of streams must be sharply curtailed. Because water pollution is so widespread and because it is so detrimental to recreation, every effort should be made to achieve approved water quality standards on or before target date. In this regard greatly increased Federal spending is an absolute necessity.

It is very apparent that recreation needs and the struggle for environmental quality are intertwined. The land and water best suited for recreation is located at considerable distance from population centers and the recreation base closest to the consumer has been befouled as a result of his other activities. It is hoped that the current interest in ecology will continue and that sufficient amounts of money will be made available to improve the water quality of the rivers of the Region's two largest cities - New York and Philadelphia. If the rivers were upgraded to a "B" category, swimming could be enjoyed by the city residents, but this would be extremely expensive. A less costly approach would be to improve these streams to a "C" category - acceptable for boating, sailing and fishing, and to construct large "natural" lakes adjacent to the stream for swimming. Additionally, many commercial waterfront properties have fallen into disuse and offer excellent access for mass recreation.

The above plan could be used also for medium and small cities, especially when the waterfront area has progressed from a state of disuse to one of decay, but the principle in all cases is identical; to bring to the city dweller, particularly the ghetto resident, the opportunity for water-based recreation which he heretofore has not had or could not afford.

A second major way in which water-based recreation needs may be satisfied is to incorporate recreation from the very beginning in multiple-purpose reservoir planning.

A third way, and one which has been emphasized in the sub-regional analysis, is the development of entirely new recreation facilities, either day-use or extended use, and the expansion and improvement of existing facilities where such is physically possible.

A fourth method of enhancing outdoor recreation and environmental quality is to be found in the Wild and Scenic Rivers Act. Three rivers of the North Atlantic Region have been listed as potential additions to the National Wild and Scenic Rivers System. Seven additional streams have been suggested for evaluation in planning reports by Federal agencies as potential alternative uses of the water and related land resources involved. These seven are:

Hudson, New York: Segment from source to Luzerne, including tributaries.

Beaverkill, New York: The entire river.

Mullica, New Jersey: The entire river including tributaries, Wading River and Bass River.

Pocomoke, Maryland: The entire river.

Rappahannock, Virginia: Segment from Tidewater to Remington, including the tributary Rapidan River to the community of Rapidan.

Shenandoah, West Virginia: The entire river.

Cacapon, West Virginia: The entire river.

There exists still another way in which outdoor recreation opportunity can be increased, and that is to more fully utilize water supply reservoirs. Many such water bodies are located relatively close to centers of population, yet they are closed to public recreation under the theory that recreation would conflict with their primary purpose. This is not necessarily true, and an effort should be made to prove that water supply and recreation are not incompatible.

In addition to the large-scale methods suggested, the following thoughts have possible merit and should be considered further:

1. The majority of recreation facilities receive comparatively little use during the week, but on weekends they are saturated. Efforts should be made to spread the demand more evenly over seven days by staggering workdays. For example, some employers have extended working hours for four days and allow their employees a three-day weekend.

2. If NAR recreation areas suffer from congestion resulting from vehicular traffic, thought should be given to ways whereby vehicles can be kept outside of the areas, and the manner in which people would be transported within the park proper.

3. If salt water beaches become saturated in the future, large rafts could be anchored a mile or so off-shore and used for swimming, picnicking and as a moorage for boats. Such a platform might serve as a base for scuba-equipped recreationists to depart for underwater tours to examine indigenous plant and animal life.

Most of the foregoing suggestions are, by the nature of this study, oriented in one way or another toward water. However, outdoor recreation includes a great many more activities than the seven concentrated upon here, and it is obvious that the land base throughout the NAR - especially that portion which is privately owned - is being underutilized for outdoor recreation. Great strides have been made by a number of private paper and lumber companies in making their lands available for public use, but there is still much that can be done. The cooperative program whereby public hunting and fishing opportunities are made available on privately-owned farms and woodlands has been a successful one, and it seems possible that the program could be expanded to include hiking, camping, nature study, photography, and similar activities. Future water resource studies should examine this opportunity in greater depth.

SECTION IV. Subregional Summaries

An effort was made in each subregional analysis to relate recreation needs to other social and human needs, and suggestions for meeting recreation needs took into account the devices and tools which conceivably might be employed to satisfy or to provide for these other needs. These other needs include an adequate supply of water for industrial and municipal use, flood control, and a reserve sufficient for low-flow augmentation. Reservoirs of various kinds, and flood plain management are two of the more important devices utilized for meeting these needs. In both cases increased recreation opportunity can often be a valuable by-product, and this fact is stressed throughout the subregional analyses.

Finally, considerable thought was given to the recreationists themselves: their interests, desires, and needs, and whether in the years to come significant differences may occur in what people seek in the way of outdoor recreation.

Complete summaries are given for each of the six sub-regions of the NAR. As an example of the material included, an outline of details will be presented here for Subregion F. Comparable information is available in the Appendix for all subregions of the North Atlantic Region.

AN EXAMPLE

SUBREGION F

I. *Introduction* Subregion F is the most southern of the six main subregions in the North Atlantic Region Water Resource Study Area. The subregion encompasses southern Pennsylvania, eastern West Virginia, Maryland (excluding the Baltimore area and eastern shore) and northern and eastern Virginia. Three main basins are included, which are described briefly below:

Basin 19. The Potomac River.

Basin 20. The Rappahannock and York Rivers.

Basin 21. The James River.

II. *Tables* - with accompanying interpretive notes.

A. MAP of Subregion F

B. Recreation Land and Water Needs for Basin 19

C. Projected Annual Participation in Water-Oriented Outdoor Recreation in Subregion F by Basin and Target Years

D. Recreation Land & Water Needs for Basin 20

E. Recreation Land Needs in Subregion F by Basin and Target Year

F. Recreation Land and Water Needs for Basin 21

G. Recreation Beach Needs in Subregion F by Basin and Target Year

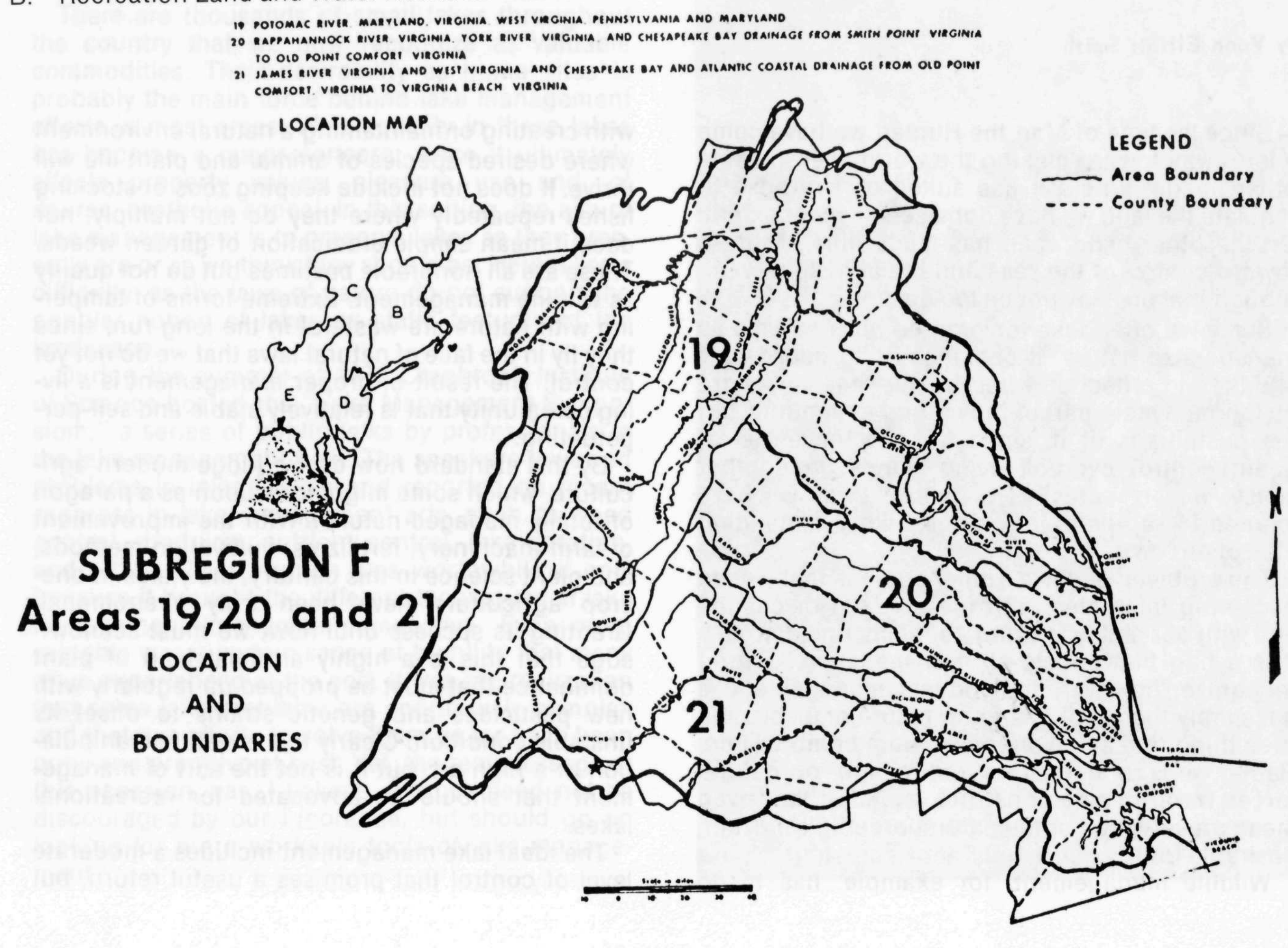
H. Swimming Pool Needs in Subregion F by Basin and Target Year

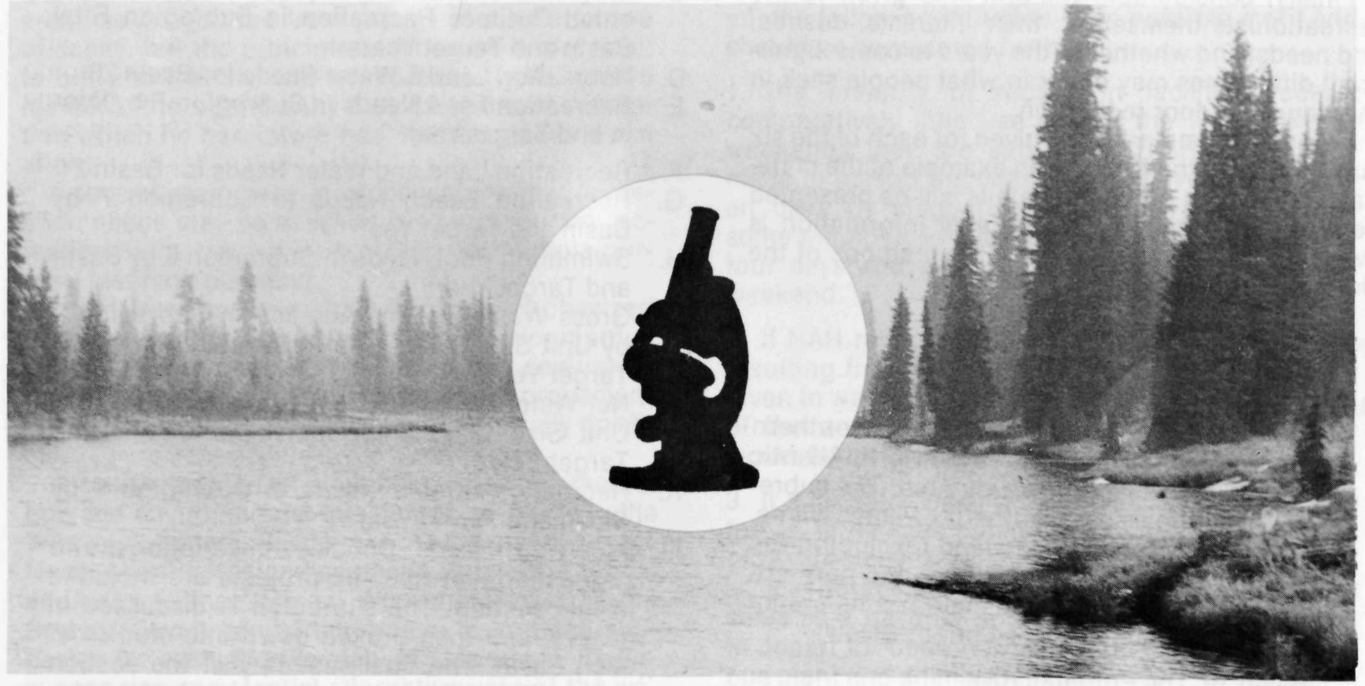
I. Gross Water Surface Acreage in Subregion F by Unit Size Classes for Individual Basins and Target Years

J. Net Water Surface Acreage in Subregion F by Unit Size Classes for Individual Basins and Target Years

K. Recreation Stream Needs in Subregion F by Basin and Target Year

III. *Satisfying Needs* Detailed descriptions and suggestions for specific projects are included in this section. The subregion is discussed in general and then broken down into studies of each Basin. The final summary of the section states that "the resource base required for quality recreation does exist in Subregion F. With proper care and coordinated development, these resources are capable of providing a broad selection of outstanding recreation opportunities."





LAKE MANAGEMENT
Science or dream?

By Vann Elliott Smith

Since the time of Man the Hunter, we have come a long way toward making the world over in some other image. Where it has suited our purpose to regulate the land we have done so to a great extent. On the other hand, man has made little progress toward control of the seas and the atmosphere, although that era may not be too distant.

Since we often take for granted our new role as managers of nature, it becomes us to pause now and then to reflect on what the title means. We are no longer a mere part of the natural community but the custodians of it, since we now have life-or-death control over all living things. In another sense, we are parasites of nature since we have learned to sap its great energies while expending little of our own.

The problem, as Alvin Toffler put it, is that we are becoming infatuated with the concept of change and with our ability to bring about change. Perhaps it is a bug that infects all new managers. We do recognize, however, that honest management is not simply the act of changing nature or displacing it—a thing that any typhoon or atom bomb will do. Rather it is a deliberate redirection of natural forces toward some constructive end. It may even mean preservation of the natural order in a current, desirable form.

Wildlife management, for example, has to do with creating or maintaining a natural environment where desired species of animal and plant life will thrive. It does not include keeping zoos or stocking fishes repeatedly where they do not multiply, nor does it mean simple eradication of garden weeds. These are all honorable pastimes but do not qualify as wildlife management. Extreme forms of tampering with nature are wasteful in the long run, since they fly in the face of natural laws that we do not yet control. The result of proper management is a living community that is relatively stable and self-perpetuating.

By this standard how do we judge modern agriculture, which some might look upon as a paragon of totally managed nature? With the improvement of farm machinery, fertilizers, cultivation methods, and plant science in this century, the yields in one-crop agriculture have been truly phenomenal. Granting its success until now, we must acknowledge that this is a highly artificial kind of plant dominance that must be propped up regularly with new pesticides and genetic strains to offset its unstable condition. Clearly this is nature manipulation of a high art, but it is not the sort of management that should be advocated for recreational lakes.

The ideal lake management includes a moderate level of control that promises a useful return, but does not forever need new and ingenious devices to keep it going. Next to this ideal, there are some questions which arise about lake management—a fairly new field of endeavor that now lies somewhere between science and imagination.

Benign Control

First, is it reasonable to think of managing natural communities, such as lakes, in the spirit of modern agriculture? Lakes, in contrast to the Iowa cornfield, are societies of hundreds of species whose lives are intertwined in the most intricate way. It is naive to hope that we can simply draw a line between desirable and undesirable species, saving the former and weeding out the latter at will. A lake, forest, or estuary is a super-organism that we may set about to manage for a variety of practical and aesthetic reasons. Ideally, however, preserving some sort of natural balance will be an important part of this design, since a living community can become unrecognizable when its natural order collapses for any reason. This is not the place to expound on food webs, competition, symbiosis, and the like, but these relationships are the fabric of all living communities in balance. The business of managing lakes requires that we know a good deal about lakes and their biology. That goal is still far away, even though progress is being made on many fronts.

There are thousands of small lakes throughout the country that we now recognize as valuable commodities. Their desirability as home sites is probably the main force behind lake management efforts in most areas. Water quality in these lakes has become a major concern, since it ultimately affects property values, pleasure use and, of course, aesthetic appeal. In this setting, the aim of lake management is to preserve lakes as they presently are or as we think they should be. Herein lies a difficulty, as the laws of nature do not support the popular notion of lakes as static features of the landscape.

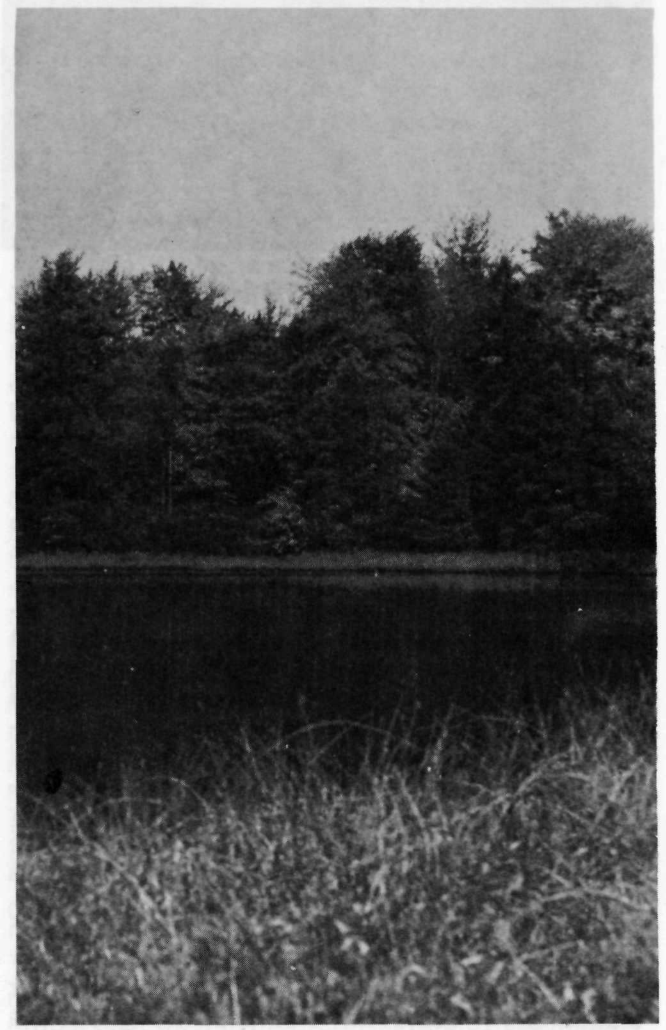
During the summer of 1972 Cranbrook Institute of Science hosted the "Lake Management Symposium," a series of public talks by professionals in the lake management field. The speakers reviewed problems in inland lakes and reported on recent progress in lake management arts, such as weed control, dredging, nutrient control, lake aeration, and others. The program was worthwhile if only because it brought the different techniques of lake management into some perspective. Even more valuable was a certain sense of humility that many of us experienced at the end. It was the realization that some lake problems are enormously complex and that our efforts to solve them so far have been puny and primitive at best. Yet, the real message of this occasion was, I believe, that we need not be discouraged by our ignorance, but should go on looking for more workable tools of lake management.

Aging Lakes

As many authorities have pointed out, the biggest problem of inland lakes is related to aging since their creation in glacial times. The majority were formed about ten thousand years ago by melting blocks of ice left by the retreating glaciers. Called *kettles*, many of these lakes are bowl-shaped depressions without a discrete inlet or outlet. Over the centuries they have functioned as catch basins, trapping all materials that were washed off the surrounding land. The accumulation of organic matter and minerals in these lakes created a rich broth of nutrients where aquatic plants and animals now flourish. In most lakes of southern Michigan and many other regions, the enrichment process—eutrophication—and their domination by plants are both well along. Other lakes already have developed into swamps and bogs.

While the rate of natural enrichment has been slow by human standards, certain habits of civilized man have accelerated the process manyfold. One is our love of living close beside lakes and thereby increasing the flow of runoff and nutrients

Lake surrounded by natural vegetation



Lush vegetation in eutrophic lake shallows

to the water. There is no longer any doubt that "cultural" eutrophication causes lakes to grow themselves to death much faster than is normal. In result, the aging process is telescoped in time, throwing natural cycles out of balance and creating obnoxious conditions in the lake.

A number of water quality problems are typical of aging lakes and are the targets of lake management efforts. Perhaps the most obvious ones are associated with algal blooms, which may appear dramatically as floating scums, mats, or smelly, discolored water. These are clear signs that nutrient levels are high but they only confirm what should have been evident sooner. A more general clue to enrichment is the total concentration of organic matter in a lake. This includes all of the living plants and animals, their dead remains and all dissolved organics. Although a scientist could estimate this by measuring the total carbon in a water sample, anyone might infer it generally from the murky water or large beds of aquatic plants in a eutrophic lake.

When organic matter rots, it depletes oxygen in the surrounding water. This happens in the deeper waters of eutrophic lakes during summer or winter stagnation. If depletion is severe throughout the lake, fishes and other animals die in mass. As a side effect, organic debris decomposes less efficiently in this anoxic state, and sediments form at a higher rate. Usually, a black, sticky ooze lies at the bottom of such lakes.

As a lake becomes steadily more enriched, its population of plants and animals shifts from a variety of "clean water" forms toward a smaller group of species that tolerate eutrophic or even foul waters. The most successful of these soon dominate the lake and may become nuisances from man's viewpoint.

In short, a complex of changes follows the eutrophication process in lakes. They range over a wide spectrum of biological, physical, and chemical effects that will be studied intensely for many years to come. Yet, the underlying problem of so much concern to man can be stated simply: already rich lakes have been fertilized to excess by man, with unwholesome results. The challenge facing lake managers is to (1) find ways of halting the flow of nutrients to lakes; (2) remove nutrients and organic materials that are there now; (3) learn to guide biological production in lakes toward wholesome ends, without causing imbalances. The last prospect is at once the most difficult and intriguing one, but the first two demand our attention more at the moment.

Nutrients Versus Organisms

One simple truth should be a guiding light for all those who would rehabilitate aging lakes: the principle that mass is conserved. A nutrient, a plant, an animal, or a bacterium are only different forms of the same chemical elements, which are in constant motion between the living and the non-living states. For practical purposes the kettle lake can be thought of as a chamber with a one-way door: nutrients and organic materials that enter the lake stay there, in one form or another, either in the water or on the bottom. If our aim is to remove a certain amount of phosphorus, it matters little in principle whether we remove it as inorganic phosphate, as fish flesh, or as algae, since all contain phosphorus. Yet, from an efficiency standpoint it may matter a great deal. The point is, that in whatever form phosphorus is removed, its occurrence in other forms is reduced accordingly.

Controlling Nutrients

Undoubtedly, the best and cheapest way to limit the rate of aging is to keep nutrients out of lakes. Enrichment is mainly a function of the amount and type of drainage from neighboring land. Removal of forest cover around the lake increases stormwater runoff and erosion of soils. Cultivated grass, which usually replaces natural vegetation around an urban lake, does not absorb nutrients or impede runoff as well. Furthermore, runoff from developed land contains additional nutrients that are by-products of our civilized ways. Septic tank drainage,

street runoff, waterfowl wastes, and lawn fertilizers are major sources of salts, phosphates, and nitrates that enter lakes. While phosphorus is only one of many elements that plants require, it is unique among the main nutrients in being relatively scarce in nature, but abundant in waste waters. Thus, there are logical efforts being made to prevent weed problems by limiting the input of phosphorus alone.

On residential lakes nutrient control is a discipline that involves a number of human activities and the cooperation of every homeowner. Where septic tanks are in use, their proper functioning and placement well back from the lake are critical. Now being used in Sweden is a modified septic system which treats waste water chemically to remove most of the phosphorus. In one way this approach may even be superior to centralized collection and treatment of sewage, since it helps to replenish the local water table. Residents are well advised to cut back on their use of detergents and fertilizers, both rich in phosphorus. They are also wise to take stock of their lake during any cloudburst and note the sources of surface runoff. Paved streets and parking lots are notoriously rich in petroleum residues, salts, and even animal bacteria. An efficient collection system for stormwater runoff is the best answer, but many lakeside communities have none.

The preservation of "green belts" or zones of natural shrubbery around lakes to trap nutrients is a sound principle, but there is little agreement yet on how wide the zones should be or what vegetation is best. The fact remains that runoff from pavement or bare soil is many times richer in nutrients than it is from well-vegetated lands.

Once nutrients enter a lake their removal becomes a much greater problem. There, the dilution factor of one part nutrient per million of water, more or less, makes any lake-filtering scheme an expensive proposition. More encouraging, however, are some recent experiments in Wisconsin, where lake water was pumped onto wooded land and allowed to return through the soil as groundwater. Certain types of soils have a high affinity for phosphorus, as many studies on land disposal have shown. Also promising is the newer technique of treating lake water in place with aluminum salts, which bind with reactive phosphate and organic particles, carrying them to the bottom. This method, long used in sewage treatment, is fairly economical and should prove to be effective in the richer lakes. In moderate doses the salts appear to have little effect on wildlife.

Aquatic plant management embraces two schools of thought: in one approach weeds are eradicated in the lake with chemicals or by animal predators; in the other approach, weeds are removed from the lake by harvesting. Chemical treatment with herbicides is by far the most convenient and widely used method of weed or algal control. Although a wide spectrum of copper, arsenic, and organic compounds have been used, the continuing need is to find more selective poisons that do not kill beneficial plants or animal life. To this date no one has thoroughly assessed the long-term effects of any herbicide on aquatic life. It seems fair to say only that some herbicides do kill plants without overt damage to other wildlife. While some people take comfort from this, others view our incomplete knowledge with alarm. The search for natural enemies of plant pests is in part an effort to avoid the threat of latent toxicity from herbicides. Since many of our problem weeds originally were imports from Europe or Asia, the further importation of alien fishes, insects, or waterfowl that eat these weeds is under study as a means of control. However, it is always likely that the predator species also will prove to be more a nuisance than an asset.

Mechanical harvesting of aquatic plants is an alternative that roughly compares in cost to herbicide treatments. It is effective in lakes where weeds are plentiful and easy to reach. Without question, plant destruction is more complete with herbicides, but so is the disruption of natural cycles within the lake. A major problem avoided by weed harvesting is the drastic depletion of oxygen caused by mass decay of dead plants in the water. The amount of nutrients removed by a single weed harvest is not very dramatic: something more than 1,000 pounds of wet plants represent less than a pound of phosphorus. Clearly, though, plant removal of some kind is progress in the right direction. If uses can be found for harvested plants, the cost of harvesting will be reduced.

Controlling Anoxia

Organic decay, as noted above, depletes the oxygen in lakes, particularly in deep waters where stagnation occurs. Although some anoxia is normal at times in all eutrophic lakes, it can become extreme, causing fish kills and obvious putrefaction throughout the lake. Artificial aeration is the remedy for oxygen-starved waters, and a variety of aeration systems have been effective. Theoreticians still argue about whether small bubbles or large pulses of air work best, and whether it is better to mix lakes constantly by bubbling, or to preserve the natural stratification by aerating only the deeper water without bubbling. In either case, aeration is definitely of temporary benefit to lake animals and possibly has some long-term effects. Namely, sediments that form under oxygen-rich conditions are more stable and compact than the soft muds of anoxic lakes. As a natural form of treatment, aeration has much to recommend it, but its total impact on aquatic communities is still poorly understood.

Controlling Sediments

Sedimentation is the natural process that ultimately converts all lakes into swamps. Recent progress in suction dredging methods have made it possible to "remake" lakes at a realistic cost. By removing layers of accumulated muck, dredging restores a lake to its former shape and depth, if not to its original quality. In fact, dredging may cause more or less severe changes in water quality depending on the nature of lake sediments that are stirred up. It may prove useful to combine dredging with a settling treatment (i.e., with alum) to carry down suspended silt. One of the main benefits of dredging is to remove some of the shallow, sunlit zones where weeds thrive under high nutrient conditions.

Controlling Health Hazards

Lake waters may be dangerous to health at times due to human pathogens that enter via sewage. The well-known coliform test is used to gauge the likelihood of contamination at a given time and place, because direct measurement of pathogens is difficult. Fortunately, since most human bacteria do not survive long in lake waters, they cease to threaten human health soon after sewage pollution is controlled. A few pathogens may persist for a long time. Other forms of chemical contamination in suburban lakes may consist of some pesticide or herbicide residues. So far, pesticides in fish have been more a problem in the Great Lakes than in inland lakes; evidently the higher organic content of the latter has the effect of dissipating these toxins more rapidly.

Controlling Water Levels

In a kettle lake the seasonal water level is usually governed by the surrounding ground water levels. Water management is largely a matter of conserving lake water during dry periods by limiting its use or discharge from the watershed. Large-scale pumping from wells has been known to depress the water table over the adjacent area, and could lower lake levels. Significant water may be lost by evaporation when lawns are irrigated heavily from lakes. It is possible that dredging the dense sediments from some lakes might change water levels by opening up new springs or unplugging natural drains.

Controlling Animals

Fish management on small lakes has consisted mainly of eradication and restocking programs designed to maintain populations of desirable fishes. To some extent trout and other fisheries have been supported artificially by repeated stocking in waters where the species normally do not reproduce. Use of selective breeding to generate more versatile strains of gamefishes is an exciting prospect, but is still largely in the future.

Some farm ponds and barren lakes have been fertilized to increase fish yields, but excess fertility, if anything, has been the main problem in suburban lakes. By cultivation of wild and domestic waterfowl around lakes, residents have unwittingly added to their nutrient problems. Three domestic ducks, for instance, contribute about the same amount of waste nutrients per year as a man. Certain waterfowl have been introduced to lakes as a weed control device, but this clearly does not help in nutrient removal.

Future Prospects

The management tools mentioned above seem to fall into three categories according to their aims and results. Some, like aeration and herbicide treatments, are in the *cosmetic* category, since they treat symptoms of eutrophication and may have no lasting benefit. Next are the *prophylactic* measures, like stormwater control, that are aimed toward preventing enrichment. Finally, the *therapeutic* methods, like nutrient or sediment removal, are designed to "reverse" eutrophication for a time. Some methods, like weed harvesting, are both cosmetic and therapeutic in nature. Generally, those approaches to lake management that stress either prevention or therapy are most valuable in the long-range view.

Among the small lakes considered here most of the human problems stem directly from excessive nutrients. In our future management schemes, we should be impressed by one very prominent feature of eutrophic lakes: their awesome productivity. An average 40-acre lake, during the summer, for instance, may contain about 50 tons of organic material, most of it manufactured by aquatic plants from nutrients. Rather than attempt to suppress this organic production with chemicals or machinery, we might learn to direct the life processes toward useful ends. The means to do so will develop naturally with increasing knowledge of aquatic ecology, food chains, and so on. For example, very selective inhibitors might be discovered that would suppress growth of the particular blue green algae that cause nuisance conditions in lakes. Indications are that some natural agents of chemical antagonism may function now between aquatic plants. Other agents might prove useful to encourage growth of desirable algae that are the preferred food of zooplankton and small fishes. By ensuring the dominance of certain plant forms in a lake, we would improve its aesthetic qualities and increase fish yields, without disrupting natural cycles. However, past experience advises us to use caution in all such tampering with nature. We already may expect far too much obedience from natural systems.

Human nature may prove to be the most important factor of all in the future success or failure of lake management programs. So far our main response to lake enrichment problems has been to apply "treatment" after the fact. A less dramatic but more rewarding course than treating symptoms is correcting causes.