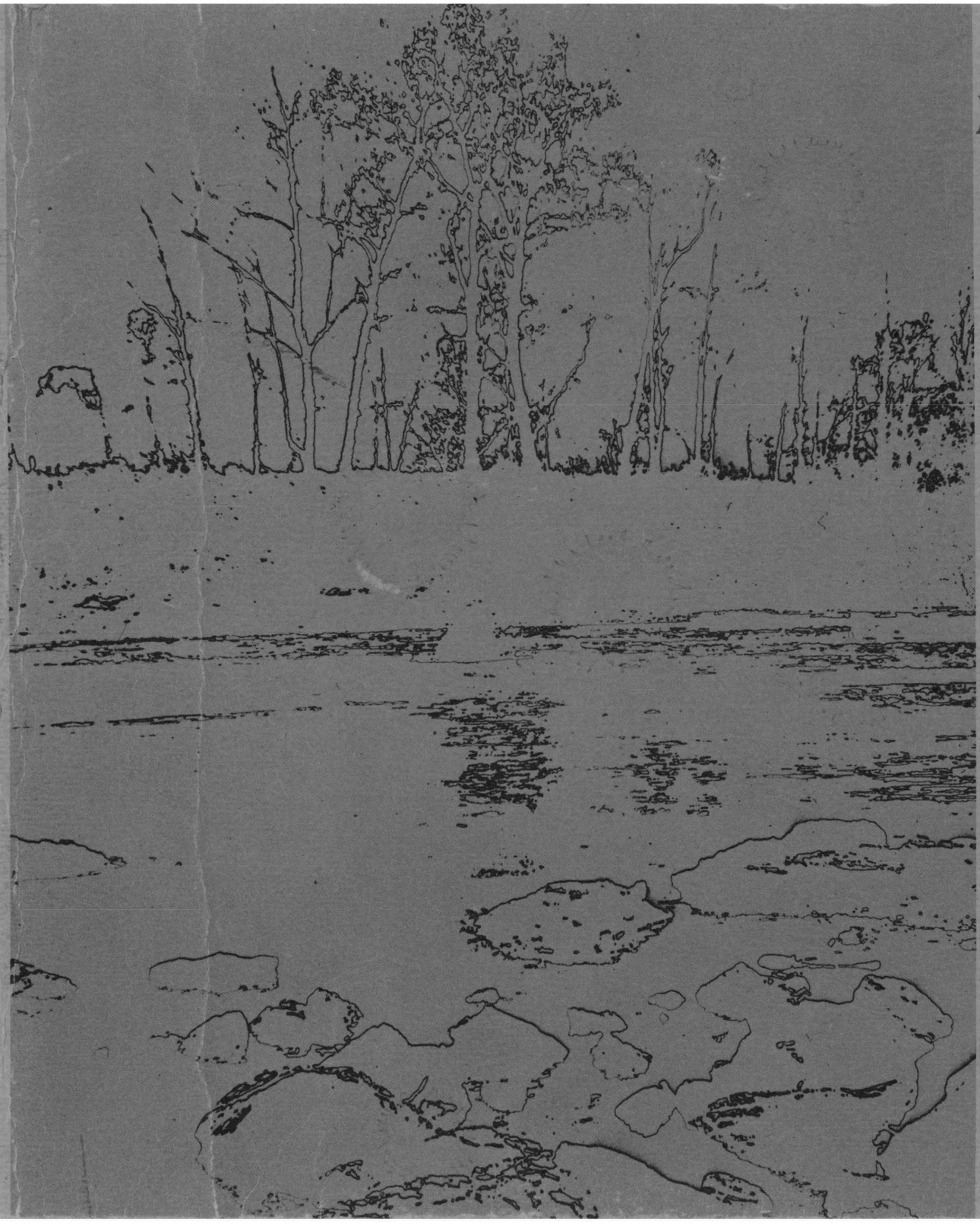

Guarding Our Water Resources

Virginia Water Resources Research Center

Bulletin 83
1974 Annual Report

Virginia Water Resources Research Center
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Blacksburg, Virginia 24061
Telephone (703) 951-5624

Many of the research projects described in this report received funding from the Office of Water Research and Technology, U.S. Department of the Interior, as authorized under the Water Resources Research Act of 1964.

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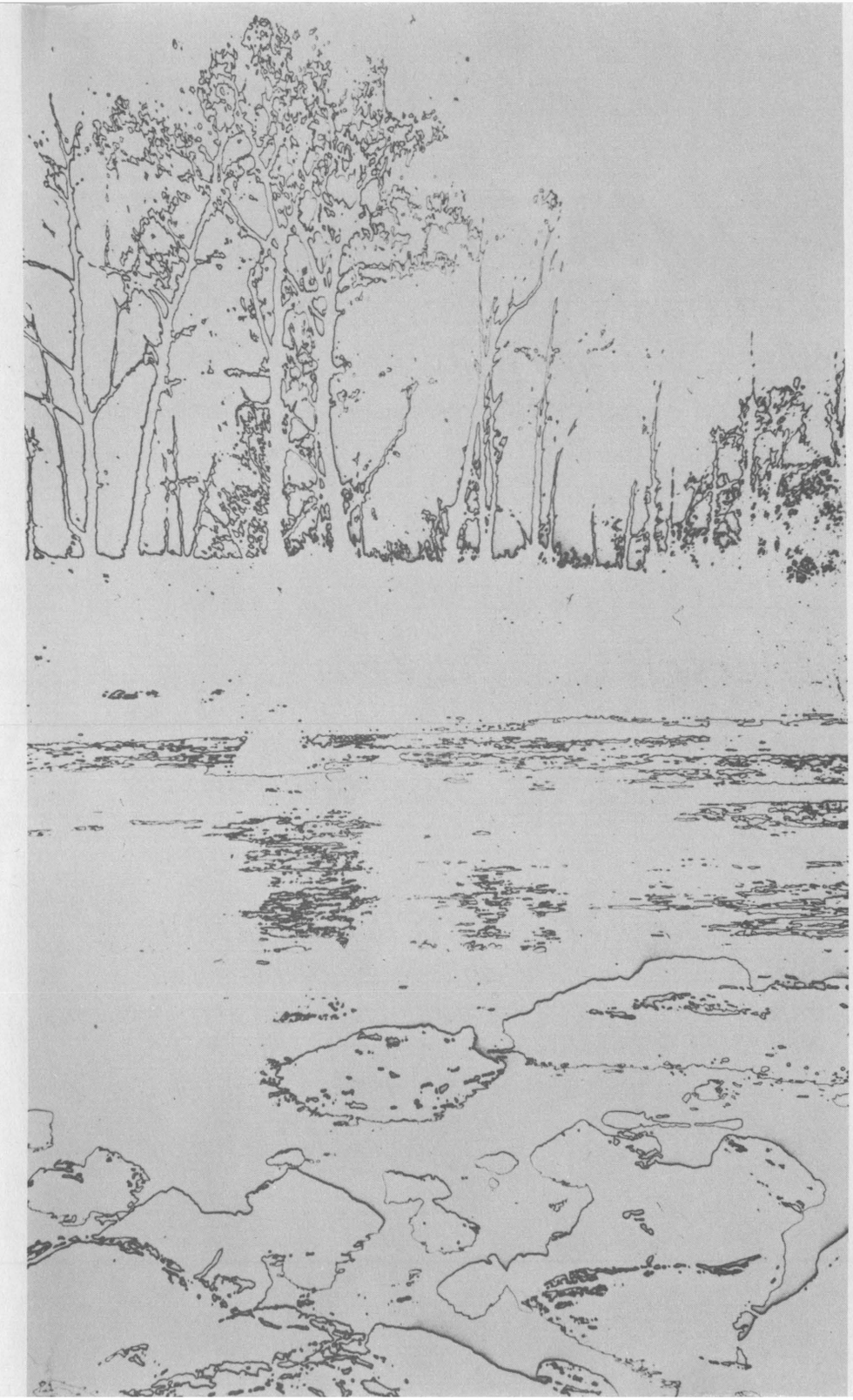
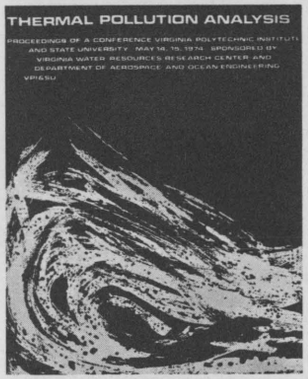
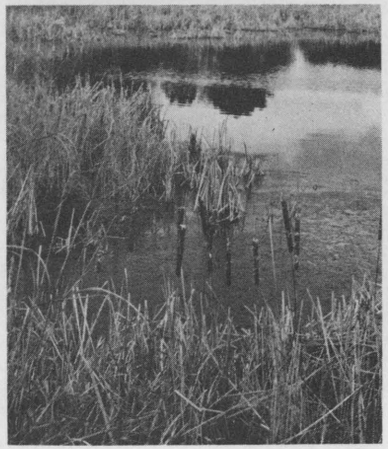


"...It would appear possible to reduce the environmental impact of human activities by developing alternatives to ecologically faulty activities. This can be accomplished, not by abandoning technology and the economic goods which it can yield, but by developing new technologies which incorporate not only the knowledge of the physical sciences... but ecological wisdom as well--a process with very serious economic, social, and political implications."

--Barry Commoner

Contents





Smith Mountain Lake, 40 miles long and covering 20,000 acres, illustrates multiple uses of a water resource. A hydroelectric project, it draws thousands of boaters, swimmers, fishermen, and campers, and also contains a 5,000-acre wildlife development.

Virginia's Water Resources: The Center's Role

With its varied topography, ranging from the Tidewater coastal plain through the central Piedmont plateau and finally to the Blue Ridge and Allegheny highlands in the west, Virginia has an abundant variety of water resources. The state also has a broad spectrum of water problems. Its extensive manufacturing, processing, agricultural, lumber, mining, shipping, commercial fishing, and tourism industries, along with the problems created by burgeoning urbanization and population growth, mean that nearly every potential water resource problem is encountered somewhere within the state's boundaries.

Many of these problems have only lately become matters of public consciousness. A community may have had little concern about stream contamination by a local manufacturing plant—until the plant can't meet new water-quality requirements, and layoffs begin. A small rural town may have ignored its aging sewage-treatment plant—until it learns the facility must be replaced, at monumental expense, to conform to future treatment standards. A homeowner in a new suburb may scoff at the thought of obtaining flood insurance—until the day muddy waters fill his basement family room. A commercial fisherman may have such faith in the self-cleansing ability of shore waters that he thinks pollution is no threat to his livelihood—until suddenly his most productive shellfish beds are condemned because of dangerous contamination. All of these situations have occurred in Virginia in recent years. They, along with a sharply rising national consciousness of deteriorating environmental quality, have helped lead to recognition of the urgency of remedial measures and better resource planning and management—now, before it is too late.

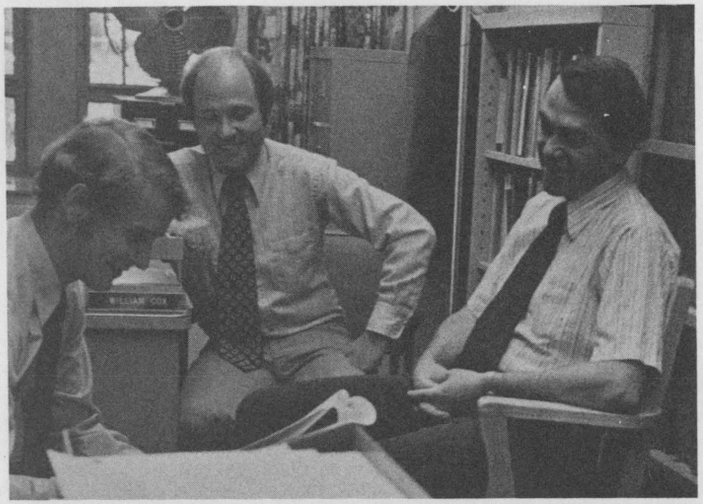
Effective action, however, can stem only from accurate, comprehensive information. Here the crucial need for sound research on water resources problems becomes abundantly clear. Fundamental data must be systematically gathered, compiled, and analyzed to fill gaps remaining from years of relative neglect. And investigations must be made of the new problems discovered almost daily, many of which arise from continuing population and industrial growth and the steady trend toward still more concentrated urbanization.

This is the purpose served by the Virginia Water Resources Research Center. It was established nearly 10 years ago under provisions of the Water Resources Research Act of 1964, an early landmark in what has become an age of acute environmental consciousness. The Act provided for establishment of a federal-state partnership agency in each state which would "stimulate, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and resources which affect water."

In fulfilling this responsibility for Virginia, the Water Center serves three primary functions:

"...In recognition of the vital needs of the citizens of the Commonwealth to live in a healthful and pleasant environment and the necessity of using the natural resources of the Commonwealth to improve the quality of her citizen's lives, it is hereby declared to be the policy of the Commonwealth to promote the wise use of its air, water, land, wildlife, and other natural resources so that they shall be preserved for the use and pleasure of future generations."

—Virginia Environmental Coordination Act of 1973



The Water Center's staff includes (from left): Dr. Peter M. Ashton, Extension specialist; William E. Cox, research associate, and Richard C. Underwood, assistant director.

Office personnel include (from left): Katherine M. Kurtz, editorial assistant; Jean Hagerbaumer, research assistant, and Norene Essary, department secretary.

1. It surveys the state's water resource problems. This function includes providing objective assessments of their nature, extent, and urgency for the information of resource planners, managers, users, and decision-makers. These assessments also guide the center in its assignment of priority research needs.

2. It sponsors and administers water resources research. Through this activity, the Center provides needed data, alternatives, and solutions to water problems. To date, the Center has sponsored 98 projects. Of these, 47 have been completed, 30 are currently under active investigation, and 19 are in the process of being published. Research grants totaling some $1.6 million have been awarded. Funding comes principally from state and federal sources, most importantly the Office of Water Research and Technology (OWRT) in the U.S. Department of the Interior. That office provides a yearly stipend to the Center for the Annual Allotment Program, which has supported 62 research projects. It also provides monies for the Matching Fund Program, a competitive process through which the Center has won backing for another 19 projects. These require non-federal matching funds.

3. It collects and distributes information on water resources. This information is conveyed to interested persons, agencies, institutions, and organizations throughout the state. Activities in this area include publication of a monthly newsletter containing a useful variety of reports on current activities, trends, and developments; the Water Center Bulletin series, containing definitive reports on Center-sponsored research projects and selected other topics, and a variety of special-purpose publications to serve particular needs. Special workshops, seminars, and conferences—more than a dozen over the past year—also augment this information-dissemination function. And the Center maintains a growing library of technical publications and documents in the water resources field—now some 4,000 separate items—available for use by students, researchers, agency personnel, and the public.

Research, however, remains the heartbeat. "Our basic purpose," declares Dr. William R. Walker, Center director, "is to provide opportunities for studying Virginia's water and the resources that affect water. Though research alone rarely can solve water problems, it can provide the insights and data through which planners, managers, and decision-makers can more effectively perform their tasks." Research proposals come from faculty members at public and private colleges and universities throughout the state. After careful review by

technical advisors, those proposals holding the greatest promise of contributing needed knowledge to pressing water problems are selected for funding. Current researchers represent a broad interdisciplinary cross-section—including engineering, economics, geology, biology, agronomy, chemistry, urban planning, environmental studies, statistics, animal science, law, and nutrition. Participating in Center-sponsored research projects have been faculty members at Virginia Military Institute, the University of Richmond, the University of Virginia, Virginia Commonwealth University, Old Dominion University, the Virginia Institute of Marine Science, and Virginia Polytechnic Institute and State University. The ability to select the best researcher for a particular task allows the Center to draw on some of the brightest minds in the state. "The magnitude and complexity of Virginia's water resource problems, plus the urgency of solving them in time, demand that we use the best-trained scientists and the best-equipped facilities available," Dr. Walker says. "This gives us a big advantage in being able to find the best investigators in the state for a project."

In these many ways, the Water Resources Research Center is working to insure that all in Virginia will have access to the needed amount and quality of water at the right place and time. For, unquestionably, water is an essential resource for the future of the Commonwealth.

Dr. William R. Walker (right), Center director, confers with Thomas W. Johnson, assistant to the director.

Highlights of the Year

More Research Focused on Immediate Needs. In its early years, the Water Center's principal efforts tended to be expended in basic research exploring the scientific, institutional, legal, and economic dimensions of Virginia's water resources problems. Building on that base, the Center increasingly sponsors research promising to help solve specific problems confronting the state today, research which will find prompt application. Extensive current investigations in the area of non-point sources of water pollution, for example, are for the purpose of providing information and data needed for better control of this growing problem. The State Water Control Board, which is partially funding one project in this area, expects to derive valuable data for developing needed regulatory guidelines. Research on thermal pollution, too, is expected to produce findings which will quickly be put to use by industries and administrative agencies. The same is true of many other current research projects—those in the areas of more effective water and land-use management, better water-quality monitoring systems, wider public participation in resource-management decisions, safer disposal of farm animal wastes, more equitable cost-sharing arrangements for users of water resources, and more efficient waste-treatment systems, among others. The ways in which Center-sponsored research can be applied to particular and immediate problems are indicated in the descriptions of individual research projects in the "Current Research" and "Research Application" sections of this report.

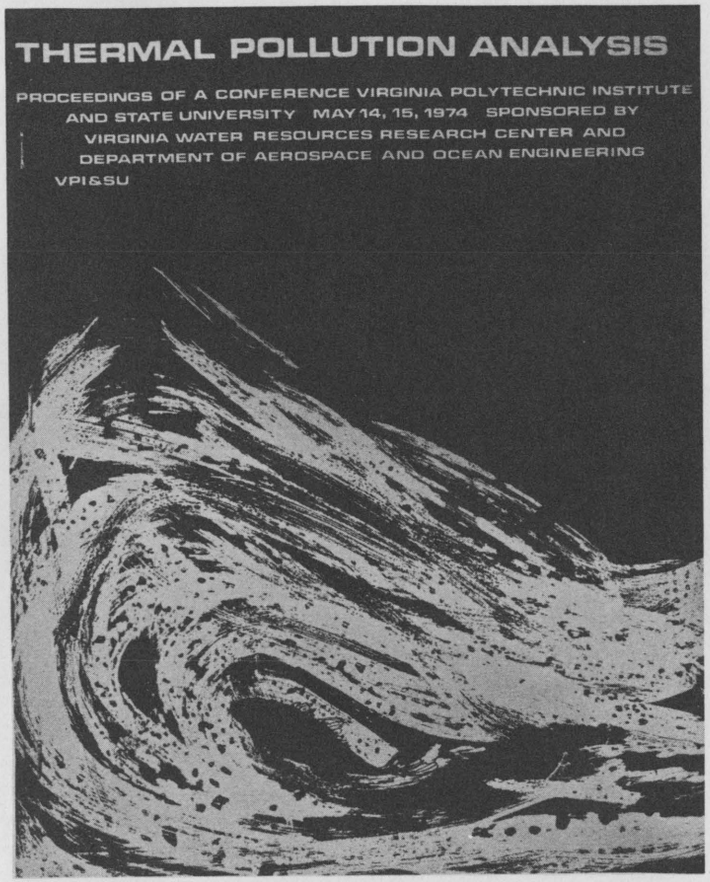
Closer Links with State Agencies. The Water Center has substantially benefited from closer links developed over the past year with state agencies, particularly the Virginia State Water Control Board (SWCB). That agency has contributed direct financial support to two current projects. Center staff members and investigators regularly consult with SWCB personnel about research procedures and objectives for particular projects, in order to produce findings directly applicable to Virginia's water resource problems. On some projects, designated Board officials serve as advisors throughout the research process. Several projects have been initiated in response to the SWCB's special interest in additional research in problem areas—including urban watershed management, non-point sources of pollution, user-charge guidelines, and wider public participation in the National Flood Insurance Program.

Increased Regional Cooperation. While the major portion of the Water Center's research activity is focused on Virginia's problems and needs, it has become clear that closer coordination with water research institutes in other states is not only helpful, but necessary. Six current research projects, all launched during the past year, are part of larger, cooperative regional investigations involving researchers at 13 universities in 11 states, ranging from Massachusetts to Alabama. This indicates a considerable expansion from the rationale that first spurred regional cooperation—a shared physical attribute, such as a river basin, requiring coordinated management efforts. To this stimulus have been added two others: (a) recognition that pooling research expertise often contributes to faster, better problem-solving, and (b) recognition that many of the fundamental resource-management problems facing one state also face others. Additional regional research efforts are in discussion and planning stages.

Enlarged Staff Capabilities. Creation of two new staff positions has enhanced the Water Center's ability to serve the state's water resources research and information needs more effectively. Close working arrangements with Virginia Tech's Extension Division have been developed by Dr. Peter M. Ashton, who joined the Water Center staff during the late spring of 1973. An economist specializing in the field of natural resources, he has worked closely with Extension personnel to convey research findings to users and to make the Center more responsive to research needs as expressed by potential users. In addition, he is a principal investigator on four current research projects and has conducted a number of workshops, seminars, and conferences designed to accomplish quicker, more effective transmittal of research findings. The second new position, filled in July of 1974, provides a staff person charged with organizing a more comprehensive program for collecting, analyzing, and disseminating information bearing on the solution of water resource problems. Richard C. Underwood, an experienced writer and editor, will attempt to identify more precisely those user groups who should be kept informed of Center activities and to develop more effective means of technology transfer—that is, conveying the results of research promptly to those who need it.

"Once we could make mistakes in using our environment that made entire regions uninhabitable. Today we are capable of making the entire world uninhabitable."

—Raymond F. Dasmann

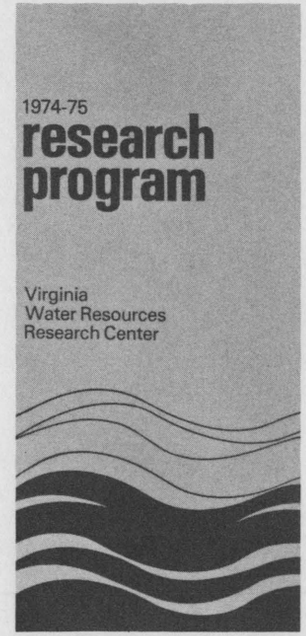


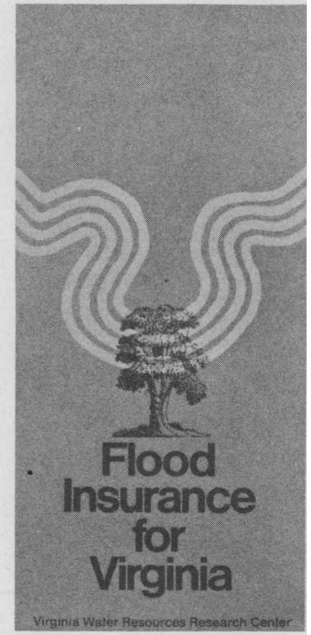
More Conferences and Seminars. The Water Center sponsored a greater number and variety of conferences and seminars, attended by a greater number of participants, than in any previous year. One was a Conference on Land Use Issues, held in May of 1974 and co-sponsored by the Center and Virginia Tech's Extension Division. It drew over 100 registrants—representatives of federal, state, and local governmental units, members of the academic and research communities, those representing special interests such as conservation, interested private citizens, and others. Conference proceedings are being published as a Cooperative Extension Service publication co-edited by Dr. Peter M. Ashton of the Center staff and Dr. J. Paxton Marshall, Extension specialist in public policy and professor in Virginia Tech's Department of Agricultural Economics. A second conference in May was a state-of-the-art assessment of thermal pollution analysis. It was co-sponsored by Virginia Tech's Department of Aerospace and Ocean Engineering, whose chairman, Dr. Joseph A. Schetz, currently is co-investigator in a Water Center research project (B-054) exploring thermal discharge effects in a receiving stream. A 268-page report of conference proceedings was published by the Water Center, and conference papers also are scheduled for publication by the American Institute of Aeronautics and Astronautics in its hardcover "Program" series. Dr. Schetz also conducted conferences at Washington and Lee University, the University of Kentucky, and The Pennsylvania State University, reporting on results of his investigations. A third subject was examined in a series of five seminars, held at five different locations in the state during the spring of 1974 and attended by town, county, and state officials. These seminars demonstrated application of a computer-based mathematical allocation scheme (developed in Research Project A-050) to land-use planning. A final activity of this type was a seven-part Water Center Seminar Series, offered throughout the academic year on the Virginia Tech campus. At each session, a nationally prominent authority discussed a key issue raised by the final report of the National Water Commission. The seven major papers have since been published as Water Center Bulletin 75, edited by Dr. Peter M. Ashton.

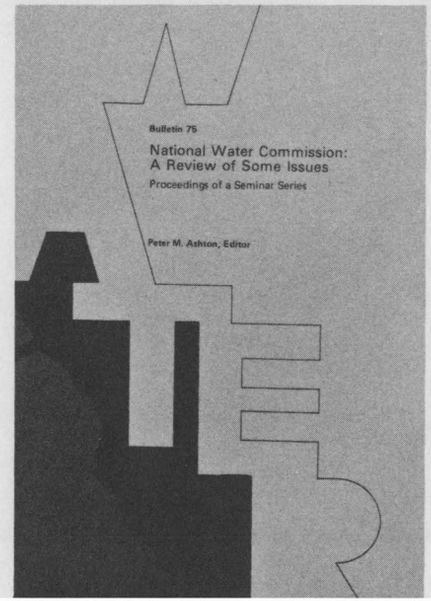
Wider Professional Exposure. Center staff members and principal investigators prepared some 40 papers presented at meetings or published in professional journals, not including four theses or dissertations based at least in part on Center research projects. A high percentage of these papers stemmed directly from Center-sponsored research. More than a third were prepared by Center staff members directly engaged in research projects.

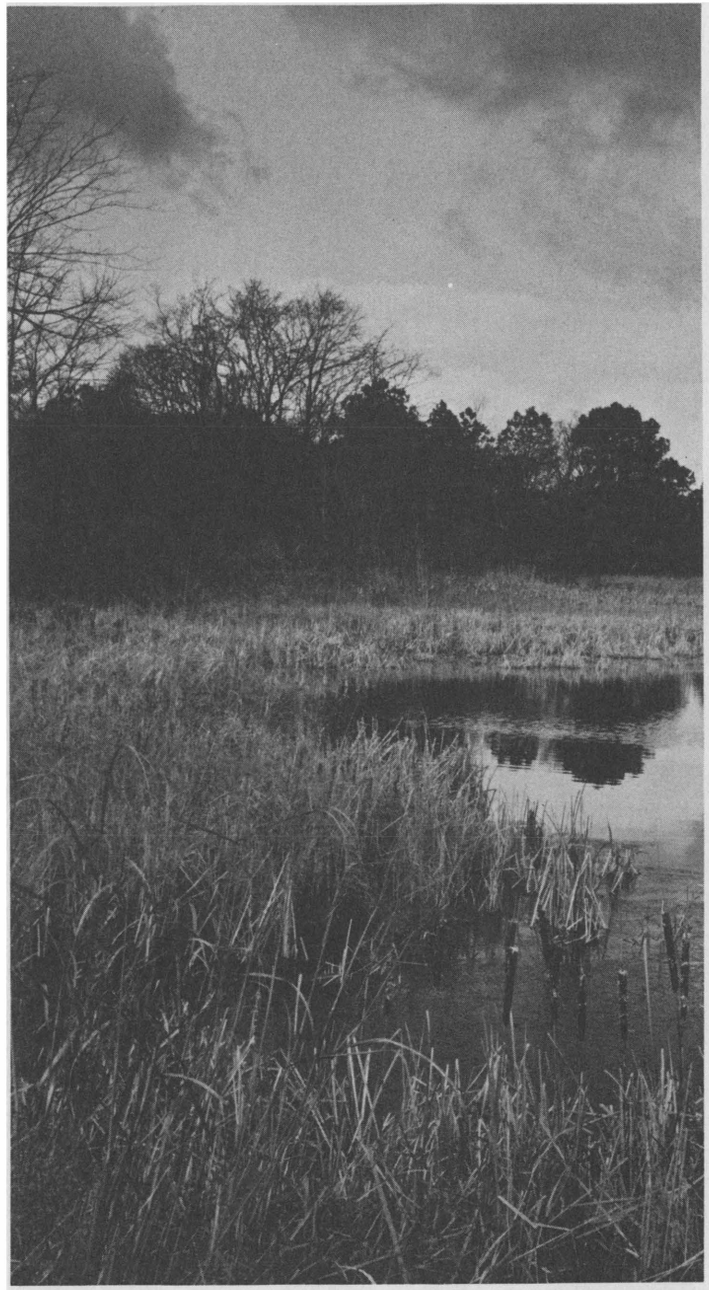
Papers were presented to such gatherings as the International Symposium on the Development of Ground Water Resources, the Second International Symposium on Underground Waste-Management and Artificial Recharge, the Fifth International Heat Transfer Conference, the National Conference on the Control of Hazardous Materials Spills, the National Symposium on the State of America's Drinking Water, and national conferences of the American Society of Civil Engineers, the Entomological Society of America, and the Weed Science Society of America. Periodicals in which various papers were published included *Groundwater, Water Spectrum, Water Resources Bulletin, Water Research, Journal of the Water Pollution Control Federation, Virginia Agricultural Economics, Virginia Professional Engineer*, and the William and Mary *Law Review*. In addition to making the Center's activities more widely known, these activities have hastened the process of technology transfer and have fostered useful feedback concerning future research needs. The Center also was a first-time exhibitor at the 1974 annual convention of the Virginia Farm Bureau, reaping similar benefits.

A Growing Publications Program. More materials serving a wider variety of purposes than ever before were produced during the past year in the Water Center's publications program. Ten new titles were issued in the *Bulletin* series; another 19, currently in preparation, will bring the total number of bulletins to 90. A typical bulletin contains a full report by the investigators in a Center-sponsored research project, though the series also includes Water Center annual reports and occasional special presentations on topics of interest in the water resources field. (A complete list of Bulletin titles, published or now in preparation, is available on request.) Virginia Water Center *News*, a monthly newsletter, added new topics to its already broad range of reporting on state and national developments in the water resources field, and circulation climbed to nearly 3,000. Again this year, the Center published a *Research Program* booklet with summary descriptions of all 1974-75 research projects. An informational brochure on recent revisions to the National Flood Insurance Program also was produced and made available to state agencies and the public. It supplements *Flood Insurance for Virginia*, a booklet produced in 1973 as a needed service to the state. Papers presented at a Thermal Pollution Analysis Conference, co-sponsored by the Center in May of 1974, were published in a 268-page volume. And the Center prepared a popularly written, well-illustrated annual report in the fall of 1973 which was the first designed not only for those in the water resources field, but also for the general public.









None of man's corruptions are yet visible at this salt marsh, still preserved in its natural state near Jamestown.

Five Year Research Program

The Virginia Water Resources Research Center's fundamental purpose is to provide research findings needed for effective planning and management of Virginia's water resources. Objective, timely, reliable, and relevant data are essential for informed decision-making. Research targeting problem areas, both current and projected, can provide a constant flow of needed information to the state's decision-makers.

To insure that its research program most effectively serves this function, the Water Center conducted an intensive study to identify the principal water resource problems confronting the Commonwealth. It was coordinated by Dr. Leonard A. Shabman of Virginia Tech's Department of Agricultural Economics. A large group of water resource decision-makers throughout the state—including state agency officials, industrial managers, planning district personnel, and local and county government officials—were asked to name and rank the most important water problems facing Virginia over the next five years, and to describe what information was needed to solve them. This process, which included both a written questionnaire and follow-up personal interviews, produced a preliminary list of 13 problem areas. These then were presented for discussion to university researchers in a series of workshops held throughout the state. They were asked for critical comments and for suggestions on where research could most effectively be brought to bear.

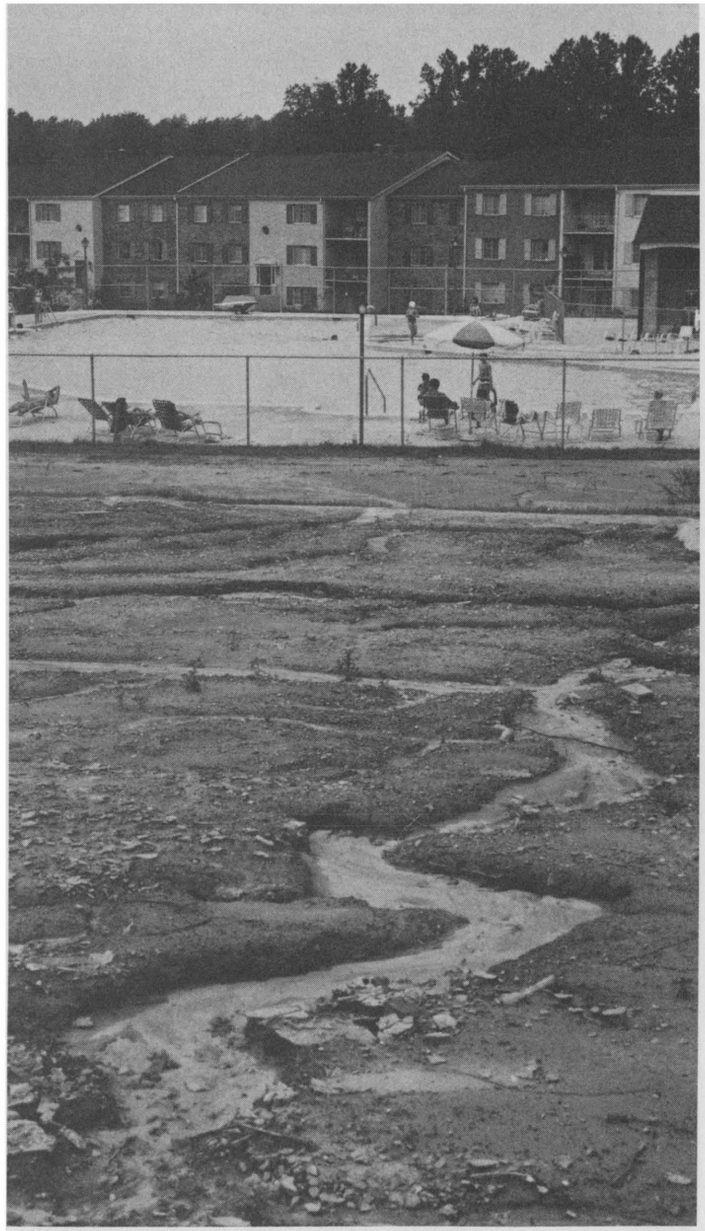
From this involved procedure, which coalesced the thinking of decision-makers with that of researchers, was derived a final list of eight major water-resource problem areas warranting priority research attention over the next few years. These were adopted as the Water Center's Five-Year Research Program, and now are receiving priority research attention. They are:

1. **Municipal and Industrial Water Supply.** With proper management, the state's available water supplies are expected to be sufficient to meet demands in the immediate future. By the year 2000, however, public water requirements are expected to more than triple, and industrial requirements to more than double. Additionally, water supplies are unevenly distributed in relation to areas of greatest need. By 1980, for instance, a supply deficit of over 10 million gallons a day is projected for the Norfolk-Portsmouth area. And by the year 2000, Newport News, Hampton, Lynchburg, and Richmond also are expected to have supply deficits. Using existing water supplies to meet consumptive needs may lead to another serious problem: direct conflicts with other uses of water and land. Hence research is suggested in these areas, among others: (a) the legal aspects of interbasin water transfers; (b) virus and bacteria treatment problems associated with reusing water of depreciating quality; (c) public attitudes concerning reuse of water; (d) legal, economic, and organizational arrangements for best management of ground-water supplies; (e) factors inhibiting fuller co-operation among governmental units in providing water supply, and (f) more effective, less costly methods of water treatment.

2. **Preventing Flood Damages through Non-Structural Alternatives.** Despite the expenditure of over $8 billion in federal monies since the 1930's on flood-prevention measures, flood losses nationally continue to average more than $1 billion a year, and are expected to triple by the year 2000. In Virginia, Hurricanes Camille, in 1969, and Agnes, in 1972, took a total of 136 lives and inflicted property damages estimated at nearly $450 million. It is clear that structural measures cannot reduce this toll, and that non-structural alternatives—notably land-use controls—must be vigorously pursued. But these often are difficult to implement because of fears of economic loss or depreciation of the tax base. Research in this category might include: (a) identification of typical obstacles and attitudes toward flood-plain management programs; (b) compilation of information helpful to local officials in developing resource-management programs, perhaps including a model flood-plain ordinance, and (c) objective assessment of the costs and benefits of flood-plain management.

"If there is any theory that guides this nation's problem-solving techniques, the element of 'action through crisis' must be given a high rating. If experience yields wisdom, surely crisis-induced action, which is expensive in money and in social costs, must give way to preventative action..."

—National Water Research Opportunities



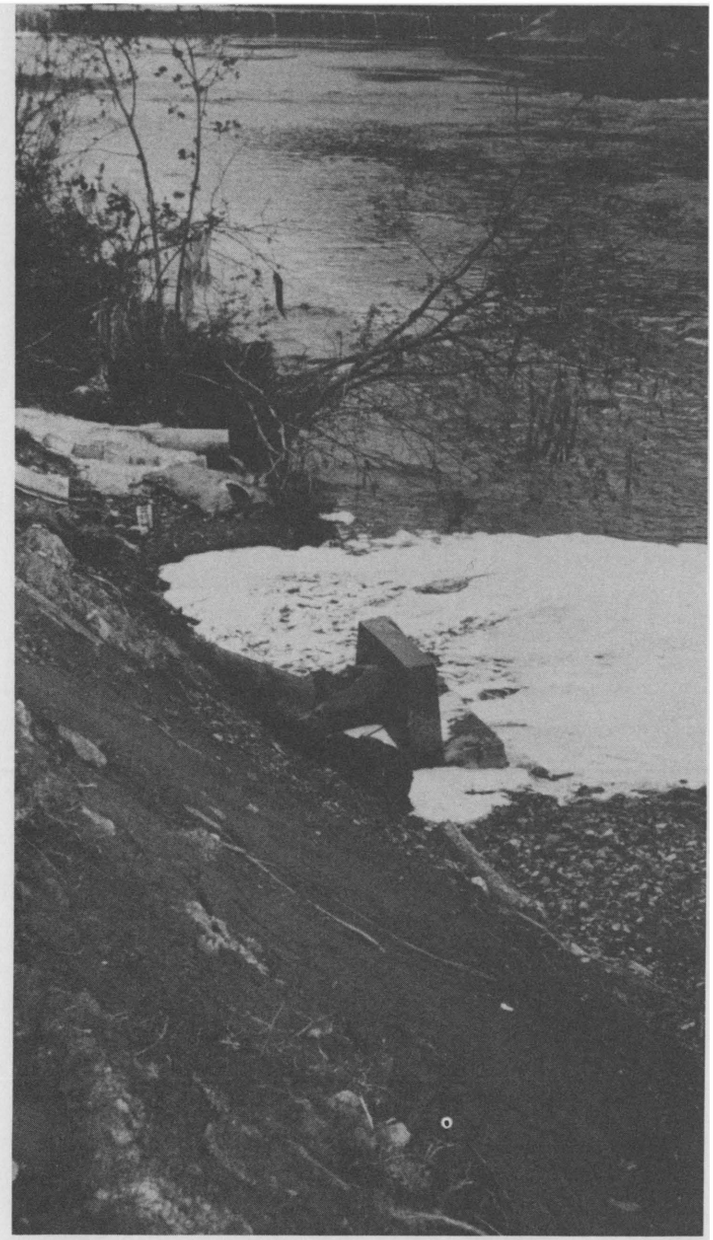
Scalping land for urban development often creates conditions such as this, with remaining topsoil being washed away to clog nearby streams. Heavy rainfall here would deposit sediment in the swimming pool.

3. Water and Land-Use Management. Virginia's population, which through the 1960's grew at a rate of 30 percent faster than the national average, is expected to exceed 9 million persons by the year 2000. This, coupled with a continuing trend toward urban concentration, demands careful planning and management to reduce the stresses and conflicts certain to result. Research needs in this category include: (a) determination of the influence, by state region, of future population and economic growth on the demand for existing water and land resources; (b) investigation of how water and land resources might be used to improve the economic viability of rural areas; (c) study of the potential of demand management by means of economic incentives, educational programs, and development of water-saving technology for homes and industries; (d) inventorying the waste-assimilative capacity of Virginia streams; (e) exploring use of water-quality standards and water-supply availability as land-management tools, and (f) evaluation of the costs and social benefits of current and future water-quality standards, including recent federal legislation prohibiting any discharges of pollutants into streams or lakes beginning in 1985.

4. Marine Environment. Virginia's 120 miles of Atlantic coastline, Chesapeake Bay's 1.9 million surface acres of water, and extensive estuarine and wetlands areas are major state economic and recreational resources. But problems are apparent, and most can be resolved only with needed research data. Statutory responsibility for both basic and applied research in this area has been assigned by the state to the Virginia Institute of Marine Science at Gloucester Point, which also serves important educational and advisory functions. The Institute already is at work on some topics suggested by the Five Year Program study as worthy of special attention. They include: (a) how best to coordinate the future resource management of Chesapeake Bay; (b) establishing economic and other values to various uses of marine areas, as management and planning aids, and (c) studying the effects of tidal action, sediment deposit, and other conditions on estuarine areas.

5. Resource Inventory and Monitoring. The state's burgeoning population and economic growth places an increasing demand on the waste-assimilative capacity of streams. Expenditures for waste-treatment facilities—currently averaging $140 million annually in governmental spending—will continue to climb in the future to meet increasing waste-processing demands. With cost-efficient use of such funds a primary concern, research assistance is needed in the following areas, among others: (a) developing technologies and financing arrangements to help smaller communities lacking the economic base to upgrade waste-processing systems, and (b) identifying factors which impede greater acceptance of joint waste-treatment systems serving a number of smaller communities, by which substantial savings might be achieved.

6. Municipal and Industrial Waste Treatment. The state's burgeoning population and economic growth places an increasing demand on the waste-assimilative capacity of streams. Of immediate concern are requirements for more effective waste treatment under the Federal Water Pollution Control Act Amendments of 1972, which look toward achieving no discharges of pollutants by 1985. They specify, for municipal treatment facilities, that at least secondary treatment must be used by 1977, and that the best practicable water treatment technology be employed by 1983. Expenditures for municipal treatment facilities, currently averaging $140 million annually in governmental spending, will continue to climb to meet waste-processing demands and the stringent federal regulations. Manufacturing industries, an important foundation of the state's economic base, also face special problems. The federal regulations specify that all of their wastewater discharges are expected to employ, by 1977, the best practicable control technology currently available, and are required to apply, by 1983, the best available technology economically feasible. With better, more cost-efficient treatment methods such a pressing need, research assistance is suggested in the following areas, among others: (a) developing more effective, least-cost waste-treatment technologies for both industries and municipalities; (b) developing financing arrangements to help smaller communities lacking the economic base to upgrade waste-processing systems, and (c) identifying factors which impede greater acceptance of joint waste-treatment systems serving a number of smaller communities, by which substantial savings might be achieved.

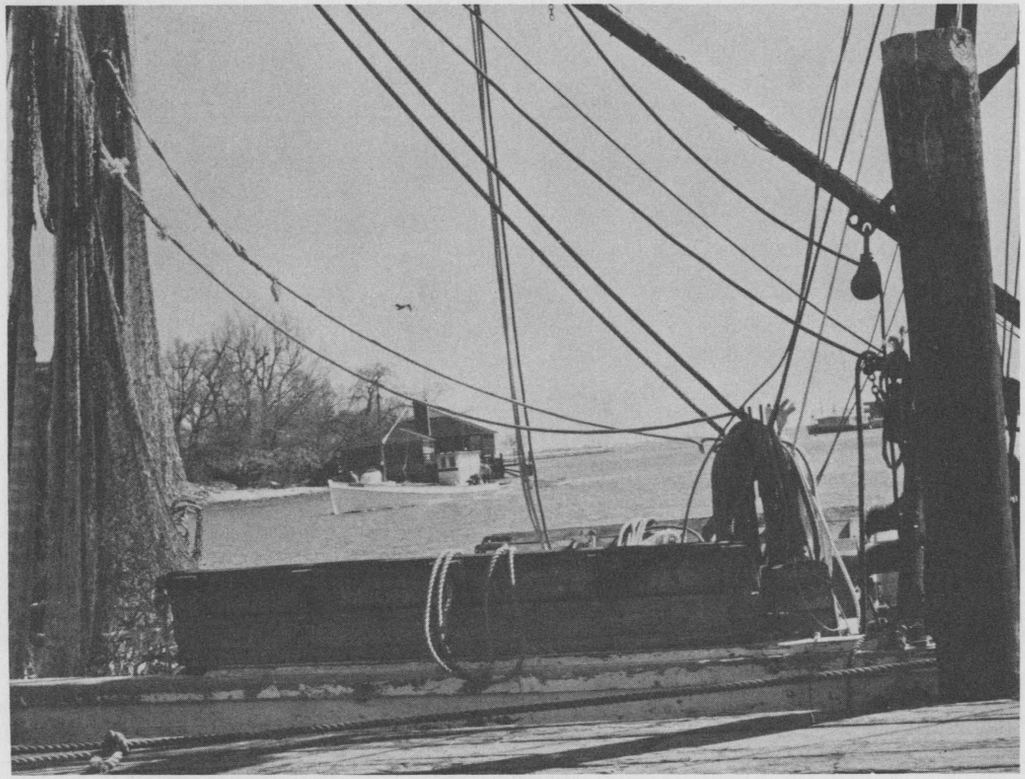


Telltale white froth signals that undesirable effluents are being piped into the James River near Lynchburg.

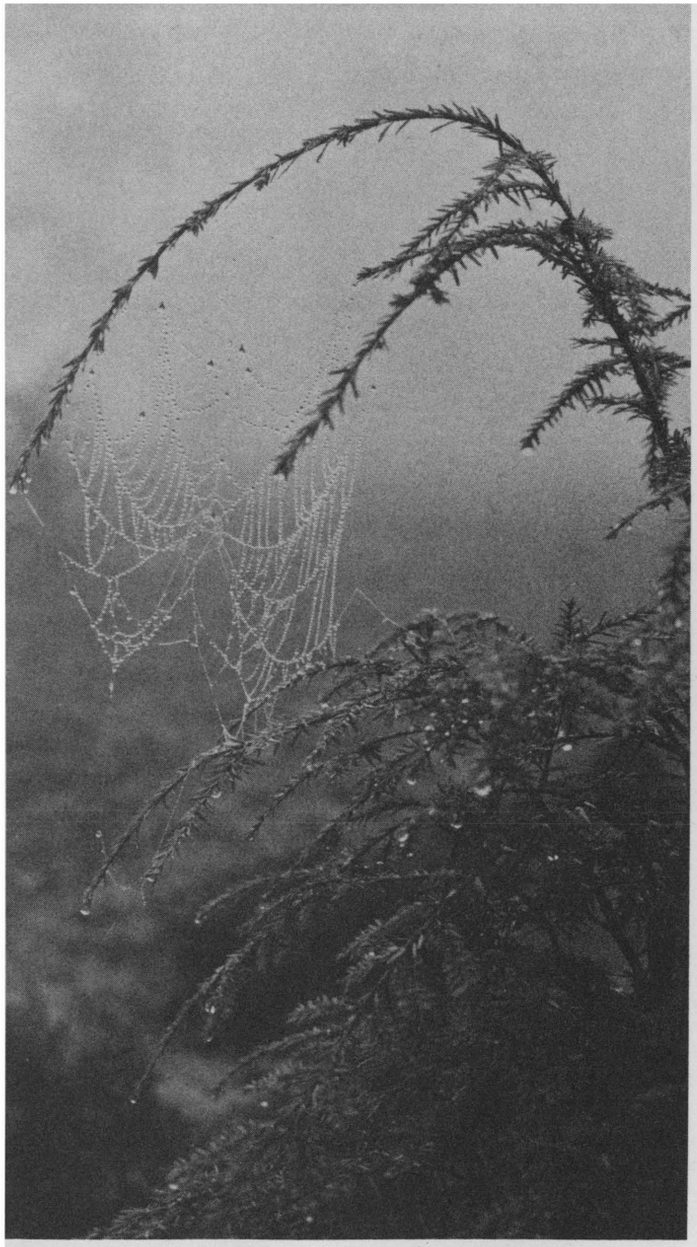
7. Undisclosed Sources of Pollution. Despite massive expenditures for reducing water pollution due to point-source waste discharges, such as those from municipal treatment facilities and industrial plants, many streams continue to have high contamination rates due to non-point sources. These pollutants, conveyed by land runoff and underground seepage, include sedimentation, agricultural fertilizers and pesticides, and drainage from mining operations and septic systems. Some studies have shown that the contribution of non-point sources to water pollution far exceeds that from point sources. Research topics worthy of investigation include: (a) identification of types, quantities, and sources of non-point pollutants; (b) investigation of appropriate control measures; (c) exploration of legal and economic incentives encouraging application of more effective controls; (d) analysis of the impact of specific non-point source pollutants on the environment, including aquatic plant and animal life, and (e) assessment of the economic and environmental importance of damages to such non-point sources as sedimentation, seepage, and urban and agricultural runoff.

8. Outdoor Recreation. Virginia's population increase over the next few decades will mean exceptional increases in the demand for public recreational areas offering water-based activities such as boating, swimming, and fishing. Planning how best to meet these needs, however, has been hampered by lack of clear objectives and effective strategies. Research helpful in this regard would include: (a) developing new waste-treatment technology for parks, especially in remote areas where operating simplicity, low cost, and adaptability to seasonal-use variations are of central importance; (b) assessing viable methods of funding state purchase of additional recreational areas before further price escalations, and (c) investigation of means by which the private sector might be encouraged to provide additional outdoor recreational facilities.

The Water Center now is focusing its research activities on these eight categories, with the objective of offering needed data, alternatives, and solutions based on careful scientific investigation. The Five-Year Research Program illustrates the Center's conviction that solving Virginia's water problems requires action on a broad front as part of a long-range program, with priority areas and research needs clearly delineated.



Virginia's 120 miles of Atlantic coastline and Chesapeake Bay are major state economic and recreational resources which, with burgeoning population, must be zealously safeguarded.



Current Research

On the following pages are summary descriptions of the Virginia Water Center's current investigations as well as several projects in the final publication phase. Objectives and procedures typically described are those outlined in approved research proposals, and may not reflect changes and refinements often made during the course of an investigation.

Each project is listed under one of the eight principal categories of the Five-Year Research Program (see preceeding section).

Under the first category, Water and Land-Use Management, are 17 projects, far more than are found in any other category. This represents, in part, the Center's conviction that very substantial problems confront the state in this area, and that a varied quantity of research data is urgently needed. For Fiscal 1975-76, proposals are being invited in all eight classifications. This should spur increased activity in many of the other areas.

It should be underscored that project classification is arbitrary and singular. In only one instance is a project double-listed. Most, however, will produce findings applicable in two or more water-problem categories. Project A-045, for instance, which seeks to predict algal growth in proposed reservoirs and is listed under Outdoor Recreation, also bears on the categories of Water and Land-Use Management, Resource Inventory and Monitoring, Municipal and Industrial Water Supply, Municipal and Industrial Waste Treatment, and Undisclosed Sources of Pollution. The same multiple application could be cited in most other cases as well.

Each project is identified by a letter-number code. The "A" projects, such as A-048, are funded entirely through the Annual Allotment Program of the Office of Water Research and Technology (OWRT), U.S. Department of the Interior. The "B" projects are sponsored through the Matching Fund Program of the same agency, following a competitive process. They require non-federal matching funds on at least a dollar-for-dollar basis.

The "D" projects are funded from a variety of sources. Support for "B" and "D" projects has come from the Virginia State Water Control Board, the National Science Foundation, the Water Center, the Virginia Institute of Marine Science, Virginia Tech's Research Division, the North Carolina Office of Water and Air Resources, and other sources.

More complete information on any of these research projects, including their scheduled completion and publication dates, may be obtained from the Water Center.

A Mathematical Water-Quality Scout

"Today's water is the only water that will be available for the future. There will be no more of it tomorrow than there is at present."

—Rep. John P. Saylor

One function of water-quality management is insuring that no pollutants enter any body of water in harmful quantities. To do this most effectively, a manager should be able to forecast what effects additional amounts of various pollutants would have, as a guide to what restraints should be exercised. This, however, is a complex and difficult task.

Research Project A-048 has produced a valuable tool for this purpose. It is a mathematical model of a 60-mile stretch of the James River Estuary—from Richmond to Hog Island—which allows prediction of how water quality would be affected under a variety of changed conditions, including higher nutrient and contaminant levels. Dr. Richard G. Krutchkoff, professor of statistics at Virginia Tech, directed the project. To a mathematical framework of his design, he applied basic inputs on the estuary's geometrical, hydrological, meteorological, and water-quality characteristics. Then, by a complex computer program, he studied the water-quality effects of changes in flow rates, sewage inputs, temperature, and other factors. In this way the investigation was able to specify which of the variables, if changed, would degrade water quality, and to what degree.

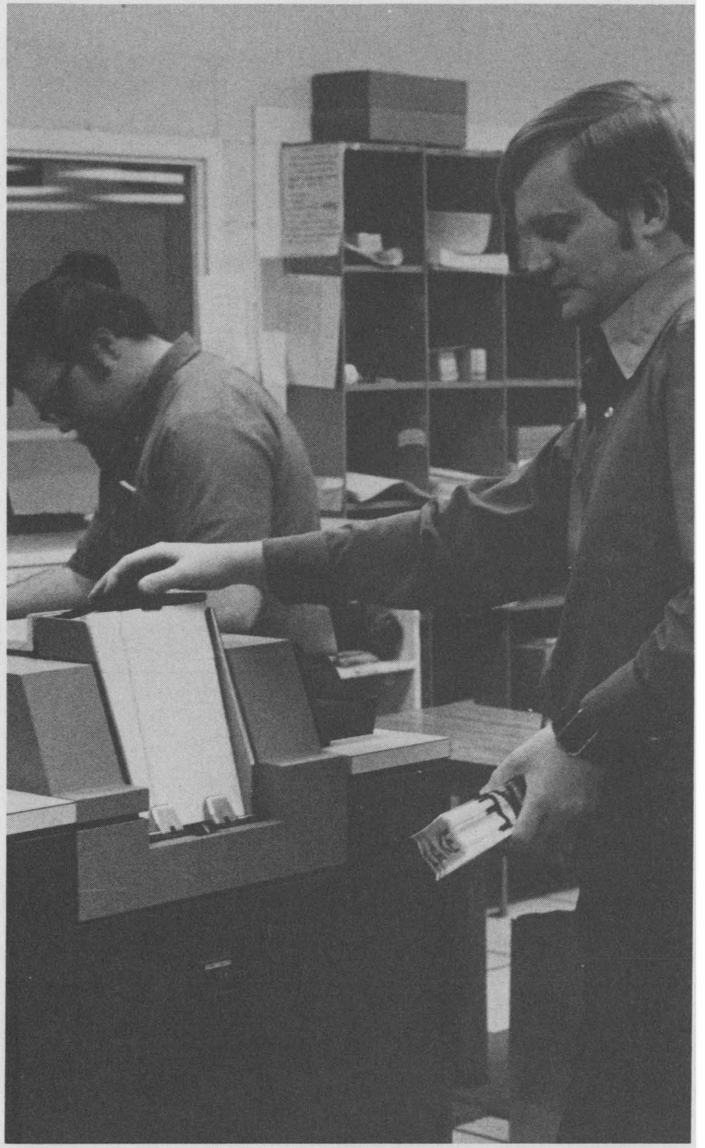
The research identifies which variables are most useful as indicators of water quality, and which must be watched most closely to insure maintenance of existing quality levels. Beyond this, however, the model can be used to predict the effect of increased industrial discharges of organic wastes, of greater sewage discharges, and of changes in sewage treatment methods, among other possibilities. In sum, it is a valuable tool for water management personnel concerned with the James River Estuary.

As environmental considerations grow in importance and complexity, the need for well-trained managers of natural resources becomes increasingly apparent. Research Project A-049 has developed a training exercise—a computer-based game called "DAM"—which already has proved valuable in simulating multi-disciplinary considerations and conflicts always involved in resource management.

The principal investigator, Dr. Robert T. Lackey of Virginia Tech's Department of Fisheries and Wildlife Sciences, based the game on an actual resource-management situation: Smith Mountain Lake, a large, multiple-purpose pump-storage facility near Roanoke. Information about the lake and its varied uses was translated into some 1,300 basic computer cards which provide the game's data base.

Players are divided into five management units representing the regional planning commissioner, a fisheries manager, a power company executive, a recreation specialist, and a city mayor. Each team receives a sheet containing decision alternatives. As each decision is selected and fed into the computer, the machine reports back on how that decision affects the goals of the other teams. Players quickly see the interrelationship of the interests involved, and come to appreciate the fact that several viewpoints—among them biological, chemical, physical, political, economic, and sociological—must be taken into consideration before workable resource-management decisions can be made.

The game currently is used as an instructional device for Virginia Tech students. It also has been adapted, through separate Research Project D-009, for simpler operation using a terminal resemblinga portable typewriter. This version was used in several environmentally oriented courses and in a series of workshops held for U.S. Forest Service personnel and other natural resource managers. In all uses, it has proved a helpful exercise in enhancing decision-making skills.



Computers are extensively employed in research analysis of many of today's complex water resource problems.

Urban Watersheds: A Problem Analysis

Research Project D-006, now nearing publication, targets the problems arising from uncontrolled or poorly controlled development in urban watershed areas. It is developing guidelines for systematic analysis of these situations, out of which can come appropriate remedial actions.

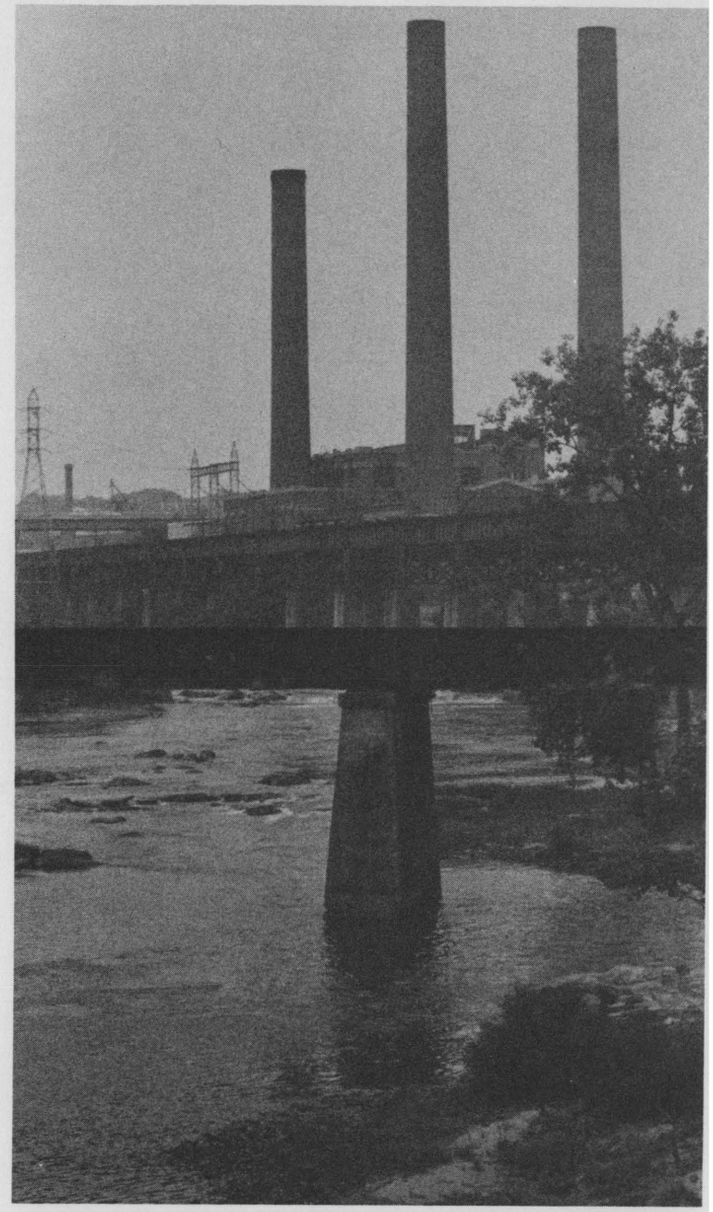
These problems are conspicuous in many urban areas. Urbanization modifies, and sometimes totally disrupts, the drainage patterns and other natural functions of a watershed, just as these natural processes often disrupt or endanger man-built facilities. Far too often, urban development occurs without proper prior consideration of these natural factors. Dr. James E. Hackett of Virginia Tech's Division of Environmental and Urban Systems, the principal investigator, has selected the Peters Creek Watershed in the Roanoke-Salem metropolitan area as a case-study area. It illustrates many prototype urban watershed problems—lack of comprehensive planning, of environmentally responsive zoning, of effective implementation even of existing subdivision control ordinances; substantial development on the flood plain, with extensive and poorly rationalized land filling and channel modification; serious degradation of water quality from construction sedimentation, septic tank seepage, and other conditions; uneven application of varied land-use control measures by overlapping political jurisdictions.

Perhaps most significantly, Dr. Hackett has found that even basic data required for systematic analysis and decision-making usually is not available. One important contribution of his study, then, will be recommendations concerning what information must be collected and compiled so managers of urban watersheds have the data needed for problem analysis and effective action.

Research Project B-062 shares some of the general objectives of the preceeding project. However, it is part of a cooperative regional program exploring better means of achieving coordinated management of water and land resources in urban areas. The Virginia Water Center's assignment is to identify what basic information and data are required for effective land use and water resources planning and management, to test these conclusions by studying two urbanized Virginia regions having different characteristics, and finally to describe how this information and data can be computer-adapted for uniform resource planning and management. Again, the principal investigator is Dr. James E. Hackett, of Virginia Tech's Division of Environmental and Urban Systems.

The need for research assistance in this area becomes increasingly apparent with each passing year. As more once-rural areas are developed and urbanized, officials charged with water and land-use management confront tough questions. How much development, and of what types, should be permitted? What environmental considerations must be made to insure, for instance, that adequate water supplies are available for consumption and waste disposal, and that further development does not increase flood hazards? Unfortunately, existing data in a developing community often is inadequate to provide a sound base for planning and decision-making.

This research should provide a more consistent procedure for gathering essential resource-management information and data. The project is one of four in the regional investigation to which researchers at the University of Georgia, Georgia Tech, and the University of North Carolina also are contributing.



The James River at Richmond, which regularly overflows its heavily developed banks, illustrates the need for closely integrating land use plans with water resource management.

Cost-Efficient Growth Patterns

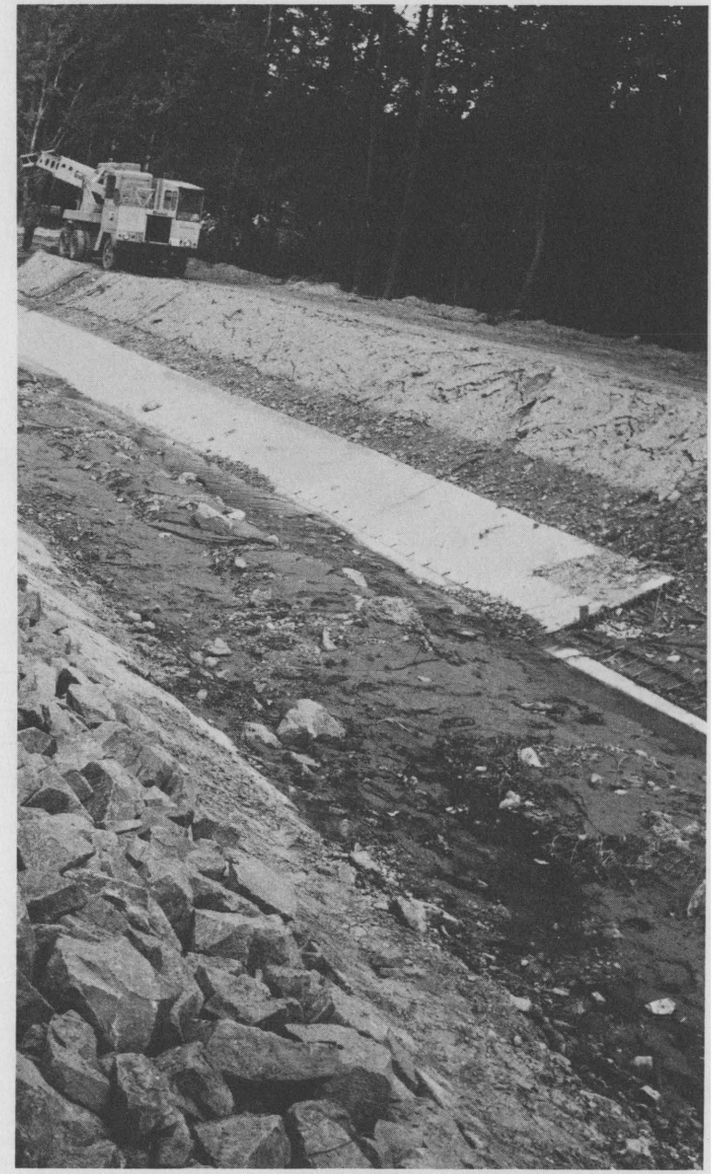
One of the largest questions facing developing communities is how to provide water-supply and sewage facilities at least cost. This problem has become more acute in recent years because of skyrocketing construction costs and the need to comply with stiffer federal and state water-quality regulations. It is complicated still further by the fact that local land-use controls—such as zoning regulations—have a direct bearing on what economies can be effected.

Research Project A-050 provides a systematic method of analyzing these variables through application of a mathematical technique known as TOPAZ—which stands for "Technique for the Optimal Placement of Activities in Zones." First developed for land-use planning in Melbourne, Australia, the technique provided a means of determining how future land uses in the area should be arranged in order to hold to a minimum costs for such municipal services. Dr. John W. Dickey, of Virginia Tech's Center for Urban and Regional Studies, applied the TOPAZ technique directly to planning needs of the town of Blacksburg, demonstrating its practical application. Among their findings: (1) decision-making using least cost as the chief criterion appears most appropriate; (2) very accurate cost estimates are required; (3) greater economies in providing municipal services are possible when development is progressive and contiguous than when it "leapfrogs," and (4) present land-use planning and control measures usually are too fragmented or weak to support least-cost addition of water and sewage facilities.

These findings already have proved of special interest to professional planners, who were introduced to the TOPAZ technique in a series of workshops at five Virginia locations led by Dr. Dickey and Dr. Peter M. Ashton of the Water Center staff. By rapidly superimposing various alternative land-use schemes on basic data about a community, TOPAZ can spell out cost figures and other consequences—and in this way enhance selection of best choices.

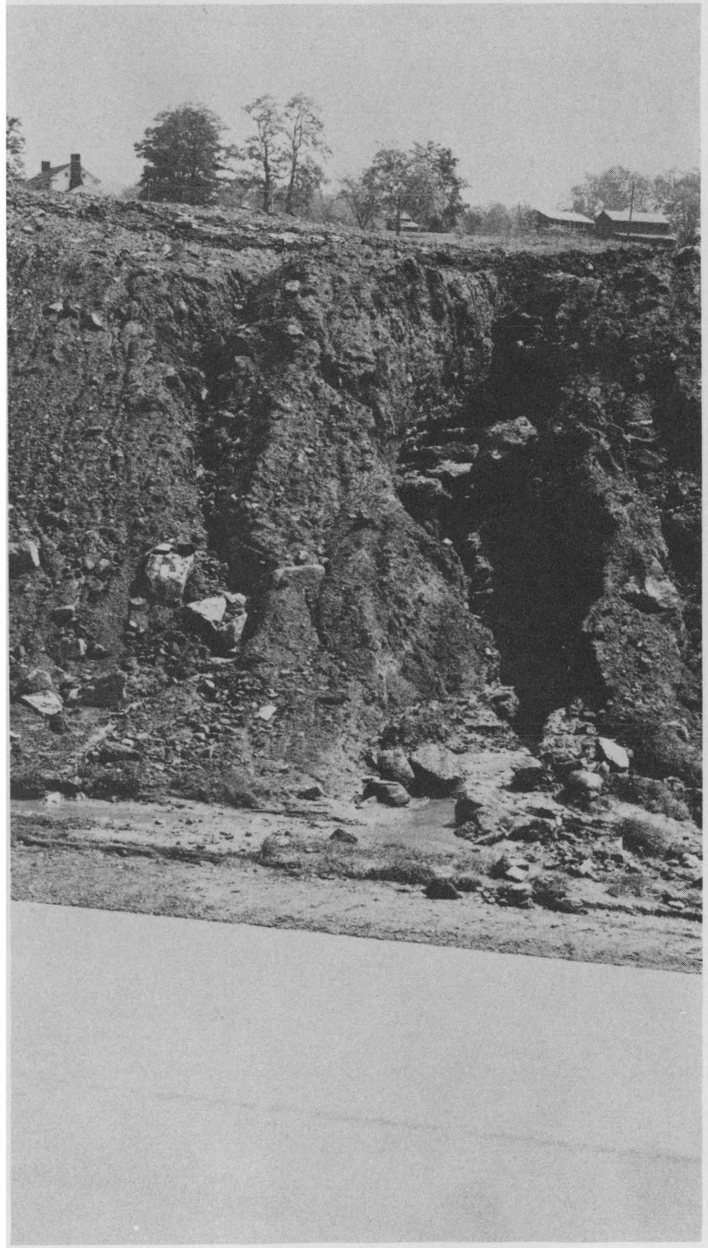
Urban living costs and congestion, a willingness to commute longer distances, and the appeal of "country" living have led to booming residential developments in many far-fringe areas, including once sparsely settled sections of Virginia's coastal plain. This trend has potentially explosive consequences. For example, many parts of coastal Virginia are characterized by high water tables and clay-rich soils unable to receive and naturally purify the greater volumes and increased concentrations of wastewaters resulting from heavy development. But in addition to creating potentially severe health and flooding hazards, urbanization in these areas raises larger questions. Should lack of the ability to handle wastewater be a constraint on further development? At what point might undesirable social, economic, legal, and jurisdictional consequences of continued development be called into play as limiting factors?

Questions such as these are the focus of Research Project A-060, led by Dr. Peter M. Ashton of the Water Center staff and Dr. Harry J. Pence, a staff engineer with Virginia State Technical Services. They are studying coastal-plain Virginia counties where accelerating development has made these issues acute. Their goal is to develop a procedure for relating environmental characteristics to the social, economic, political, and public-health implications of urbanization. Part of the process will include an assessment of what interest groups are involved in development and how their often-conflicting interests might be reconciled for the greater public good. Procedures they develop should provide a framework for analysis and decision-making in other areas faced with similar problems.



Storm drains such as this are a familiar sight in heavily developed sections such as northern Virginia, where they are required to carry off rainfall once absorbed by land in its natural state. Often, however, new problems arise.

Predicting Environmental Consequences



Any disturbance of natural lands has environmental consequences. Highway construction, for instance, is a leading contributor to soil erosion, which results in extensive deposits of sediment in nearby streams.

Land-use planning officials face the chronic problem of how to forecast the environmental consequences of a variety of hypothetical development directions. If, for instance, a large portion of the natural terrain is paved or covered with structures, will the resulting loss of natural absorption create flood conditions following heavy rains? Questions such as these are critical in many developing areas of Virginia. One is the South River Watershed near Waynesboro, struck by disastrous floods in 1969 and 1972. This area, recently designated a pilot flood-plain project area by the Virginia General Assembly, is the focus of a number of studies by federal, state, and local agencies aimed at inventorying the watershed's natural resources and identifying primary flood-hazard areas.

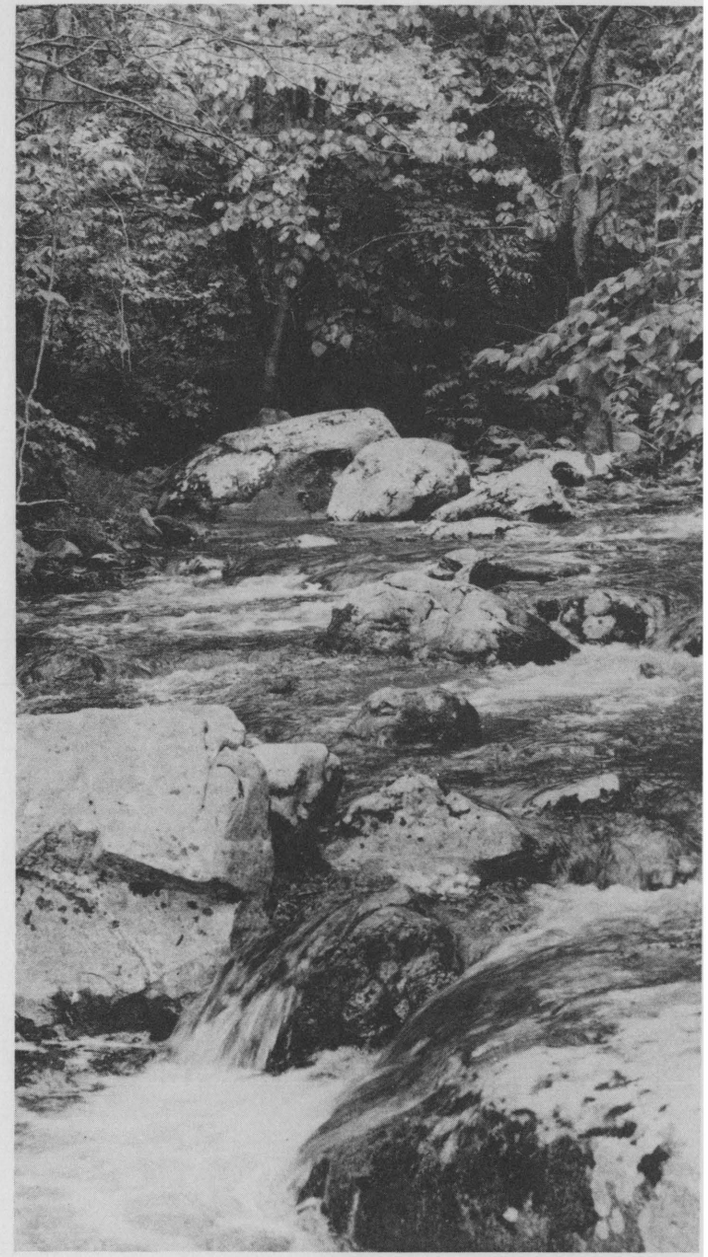
Research Project A-062 is a key study in this effort. It teams researchers at Virginia Tech and Virginia Military Institute in an effort to develop a computer-based hydrologic model of the South River Basin. If successful, such a model will allow prediction of the effect of specific land-use changes on the watershed's flooding problems. This would be a valuable management and planning tool for the Central Shenandoah Planning District Commission, which has jurisdictional responsibility for the area and which assisted in formulation of the research proposal.

The VMI investigators, Dr. John W. Knapp and Dr. Donald K. Jamison of the civil engineering faculty, will combine hydrologic data on the South River and its tributaries to develop an over-all model of the watershed. The Virginia Tech team, Dr. Dinshaw N. Contractor of civil engineering and Dr. Vernon O. Shanholtz of agricultural engineering, will determine the minimum information required to predict the impact of land-use changes and then merge these computations with the hydrologic model to produce a final predictive watershed model. This will be field-tested and refined so it can have application in any watershed area where essential data on soil characteristics and hydrologic variables are available.

Sharply heightened awareness of the need to protect the environment has led, over the past few years, to a proliferation of legislation and of state and national agencies having administrative and regulatory responsibilities in the field of natural resources. This has created, in some areas, a bureaucratic maze characterized by fragmented or overlapping responsibilities, weak coordination among agencies addressing the same natural-resource problems, lack of clear delineation of responsibility, confusion about the interrelationships among state and federal agencies in the same fields of responsibility, and sometimes an incredible red-tape syndrome which has seemed only to impede, rather than advance, proper resource management.

This situation is addressed by Research Project B-025, a study of Virginia state agencies and interstate agencies concerned with water-resources management. Its purpose is to assess the relative efficiency of their programs in terms of economy, technical proficiency, political viability, effectiveness, and relationship to other programs. The investigators are Dr. William R. Walker, director of the Water Resources Research Center, and William E. Cox, Center research associate. Their experience, during the nearly five-year duration of the study, illustrates the need for such an examination. Many agencies under study at the project's inception have since been disbanded, combined or replaced by new units; as a result, the list of agencies under study has undergone constant revision. Even so, preliminary findings and recommendations of this project already have been provided on request to Virginia state officials and have helped suggest better organizational patterns for state water-resource agencies.

The final report, now in preparation, should be a very helpful document as the state continues its efforts to implement a more coherent, better coordinated, more effective water resources management program, and to insure that the state's programs are adequately interrelated with interstate and federal programs with the same general goals.



Proper resource management in Virginia should include preservation of streams such as this in their natural state.

As any citizen knows, bureaucratic attitudes and mechanisms sometimes quash an individual's efforts to be heard on legislative or administrative matters of public concern. In some cases, the wheels of government seem to roll on in directions counter to the will of the citizenry. Only greater public participation in planning and decision-making can insure that public interests are best served.

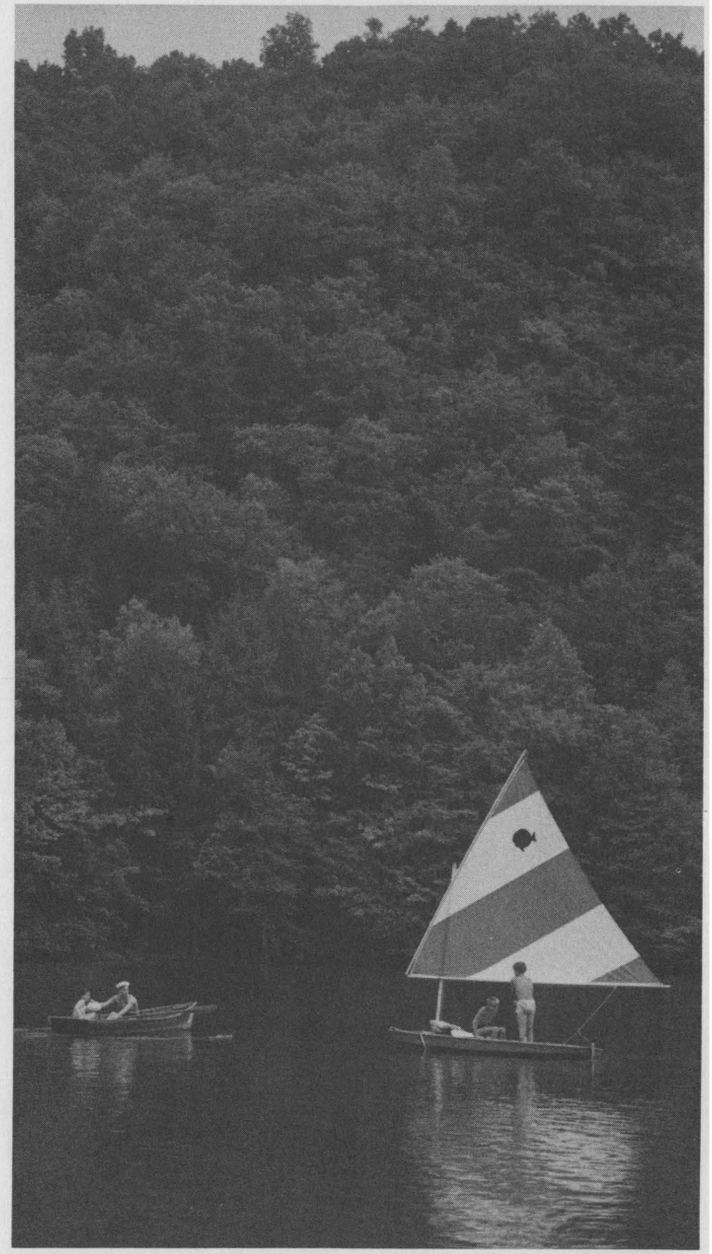
One area in which increased public participation is not only desirable, but necessary, is in water resources planning and management. In this context, Dr. Peter M. Ashton, of the Water Center staff, and Dr. William R. Walker, Center director, are exploring legal options available to the public for holding governmental units accountable for their actions, and what means of recourse are open to those who take issue with specific governmental decisions and actions. Research Project B-064 is examining the procedures through which interaction with agency officials is possible, as well as statutes which guarantee public involvement in agency decision-making. The final phase of the research will produce suggestions for policy or legislative changes which would better safeguard the public interest.

This project is one portion of a regional study program on public participation in water resource planning and management. North Carolina State University, Clemson University, Mississippi State University, and Georgia Tech are the other institutions taking part in the over-all program. In this subject area, as in several others, the regional approach is especially useful because the problem is shared and because a pooling of expertise usually leads to faster, better problem-solving having broader application than studies confined to one state.

How can the general public have an effective voice in decisions concerning use of natural resources? This is one of today's toughest questions in the environmental area, despite general agreement that citizen preferences must be incorporated into decision-making and policy-formulation processes.

With this in mind, two researchers, Dr. Leonard A. Shabman of Virginia Tech's Agricultural Economics Department and Dr. Peter M. Ashton, Extension specialist and economist on the Water Center's staff, are at work on a case study of citizen attitudes and participation in the natural-resource planning of Chesapeake Bay. They are gathering data from the U.S. Census Bureau, an Army Corps of Engineers study of the bay, and a comprehensive survey of public preferences and beliefs being conducted by the Citizens' Program for Chesapeake Bay. This information, they believe, will allow determination of whether a representative cross-section of the area's population is participating in the public planning process for resource management. From this analysis, they plan to identify what procedures might best encourage broader public participation, and what alternative methods might more effectively sample public opinion before public policy decisions are made.

This Research Project, A-059, is believed to be one of the first in the nation to analyze public participation on the basis of an in-depth survey of local residents' attitudes and characteristics. It should provide information of special value in countless other areas where maximum public participation is not only desirable, but essential.



Public participation in resource management decisions is needed to insure that adequate water-based recreational opportunities are provided for a growing population.

Resolving Water Law Conflicts

State water-rights laws, as they have evolved over the years, now must be applied to a wide variety of competing interests and uses—including recreational, water supply, navigation, and irrigation. Because of these often conflicting claims, a growing need has arisen for studying the implications of water laws. Project B-040 is one such attempt to identify those interests which compete for preferential treatment under water laws. Additionally, it will recommend better ways of resolving the conflicts which inevitably arise.

The project's principal investigator is Dr. William R. Walker, director of the Water Center, who is both a lawyer and a civil engineer. He is examining state water-rights laws to identify situations where state law may frustrate development of water resources, or where existing laws may encourage practices which prevent water from being used most efficiently or for the benefit of the few rather than the many. From the study are expected recommendations for corrective action.

This is one of several Center-sponsored research projects in recent years concerning water laws, and follows a basic study by Dr. Walker and Center Research Associate William E. Cox of "Water Resources Laws in Virginia," published as Water Center Bulletin 9.

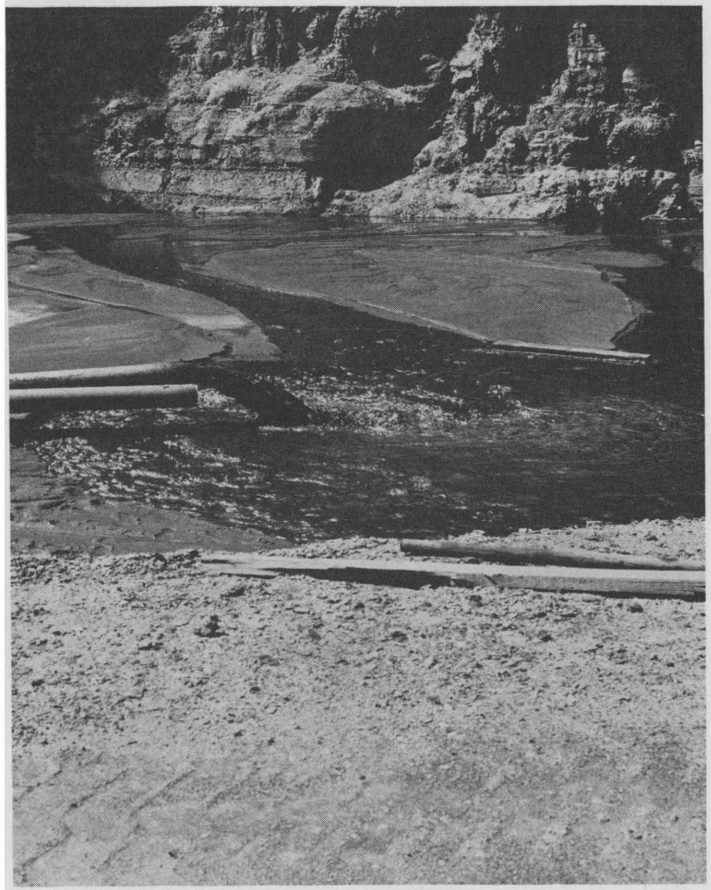
Rare is the person who does not applaud and benefit from road improvements that make highway travel more pleasurable. Unfortunately, some road-construction techniques add substantially to siltation deposits in nearby streams, and this can wreak havoc among fish and other aquatic organisms. Virginia's General Assembly recognized this problem in 1973 when it passed erosion-control legislation. Even so, an urgent need exists for determining the effectiveness of various erosion-control measures—as a guide for management and regulation of future road construction.

Providing such data is the purpose of Research Project A-056, led by Dr. James R. Reed, Jr., a biologist at Virginia Commonwealth University. Using fish and certain aquatic organisms as indicators, he is studying the effects of siltation from eight sites where road construction is in progress. Careful placement of collection sites will allow differentiation between construction-based sedimentation and that stemming from other non-point sources of water pollution.

His findings are expected to be useful in selecting the most effective erosion-control methods for highway construction—and, in some cases, indicating that environmental costs of construction at a first-choice site simply are too great.

Besides being ugly, erosion from highway construction deposits sediment in nearby streams that may kill aquatic plant and animal life, destroying ecological balance.

Acid Mine Drainage: How Bad Is It?



Enlightened mining procedures can dramatically reduce stream damage. This settling pool for coal sludge removes most solids and allows reuse of the remaining liquid.

Southwestern Virginia's numerous mines and quarries now are recognized as important contributors to stream pollution caused by acid drainage from operational sites. At least 13 streams are known to suffer from this kind of pollution, which may destroy their usefulness for recreational and other socially beneficial activities. Because the importance of this kind of pollution only recently has been recognized, objective data is scarce for selecting appropriate control methods.

Research Project B-034, soon to be published as Water Center Bulletin 66, provides valuable case-study data which should be of special value to mine and quarry operators as well as officials of state and federal regulatory agencies. Led by Dr. John Cairns, Jr., director of Virginia Tech's Center for Environmental Studies, the project documents the toxic effect of mine-acid drainage on a stream's aquatic communities, and describes the conditions under which a stream receiving mine-acid drainage is able to purify itself. The researchers discovered, for instance, that one of the streams studied recovered from the effects of acid mine discharges in as few as 19 days, as measured by its ability to sustain normal populations of aquatic creatures, and that artificial means of restoring water quality could hasten this process. One of the study's conclusions was that a stream's ability to recover from acid mine drainage depends on maintenance of good water quality, and that this is closely related to the volume of acid discharge it receives as compared to streamflow volume.

This research adds understanding to the various factors influencing the natural recovery of a stream receiving acid drainage, and thus contributes important data useful in developing management techniques which hasten stream recovery rates.

Conventional power-generating plants have been a source not only of air pollution, but also of another more subtle but equally hazardous pollutant: heated water. Most power plants are located at waterside for a good reason—they require large quantities of water for cooling purposes, and it is easy simply to discharge the heated water back into the waterway from which it was drawn. But there are environmental consequences, often serious. Heat increases the sensitivity of aquatic life to toxic substances, may cause premature egg hatches or early migrations among fish, reduces water's ability to retain dissolved oxygen which sustains stream life, and curtails the ability of the receiving body of water to assimilate wastes. Other effects, too, are being discovered as researchers explore this long-neglected area.

Two authorities on flow and heat-transfer processes, Dr. Joseph A. Schetz and Dr. Clark H. Lewis of Virginia Tech's Aerospace and Ocean Engineering Department, are investigating the effects of heat on water bodies in Research Project B-054. Using advanced computer techniques, they are attempting to design a mathematical model which will allow prediction of temperature-pattern changes in a receiving body of water over a variety of conditions. This would permit planners to determine the environmental consequences of an infinite number of schemes, in advance, before selecting the site of a new power plant. The technique could eliminate the need of investing large amounts of time and money in site selection, and would be a valuable tool for power companies and regulatory agencies alike.

The project is particularly timely in view of current pressures to develop additional nuclear-powered generating plants. Considerably less efficient than fossil-fuel plants in energy conversion, they invariably produce far larger thermal discharges from cooling processes.

Stopping Algae: A Team Approach

Research Project B-074 is a good example of the merits of regional teamwork to find the solution to a specific, immediate environmental problem. It addresses a severe problem of algal growth in North Carolina's Albemarle Sound, known to be caused by a large increase in the amount of nutrients being carried to the small aquatic plants. The problem is not North Carolina's alone, however, for the Chowan River, a major stream discharging into the Sound, is itself fed by three main tributaries—the Blackwater, Nottoway, and Meherrin Rivers—all of which lie largely in Virginia to the north. It quickly became apparent to a task force of federal and state officials, called together to plan effective remedial action, that the two states would have to work together to solve the problem.

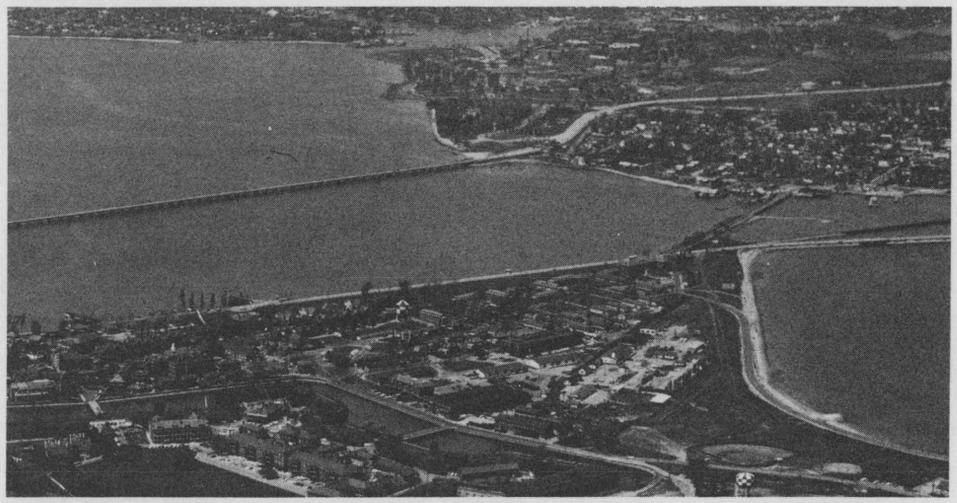
The Virginia Water Center's assignment is to develop a mathematical predictive model of the upper reaches of the Chowan, including its three Virginia tributaries, which will allow simulation of the various conditions—including the presence of nutrients—which encourage the algal growth. Dr. Dinshaw N. Contractor and Dr. Paul H. King, both civil engineering faculty members at Virginia Tech, are the investigators. Their model, when produced, will provide the starting point for an equivalent model of the Chowan's lower reaches, sponsored by the North Carolina Water Resources Research Institute. The two models, plus additional research from two other studies, should allow determination of the most effective algae-restricting measures for the Sound, and also should enable prediction of water-quality consequences to be expected from any change in conditions.

In addition to the two water centers, other agencies participating in this over-all effort are the North Carolina Office of Water and Air Resources, the Virginia State Water Control Board, the U.S. Geological Survey, and the U.S. Environmental Protection Agency.

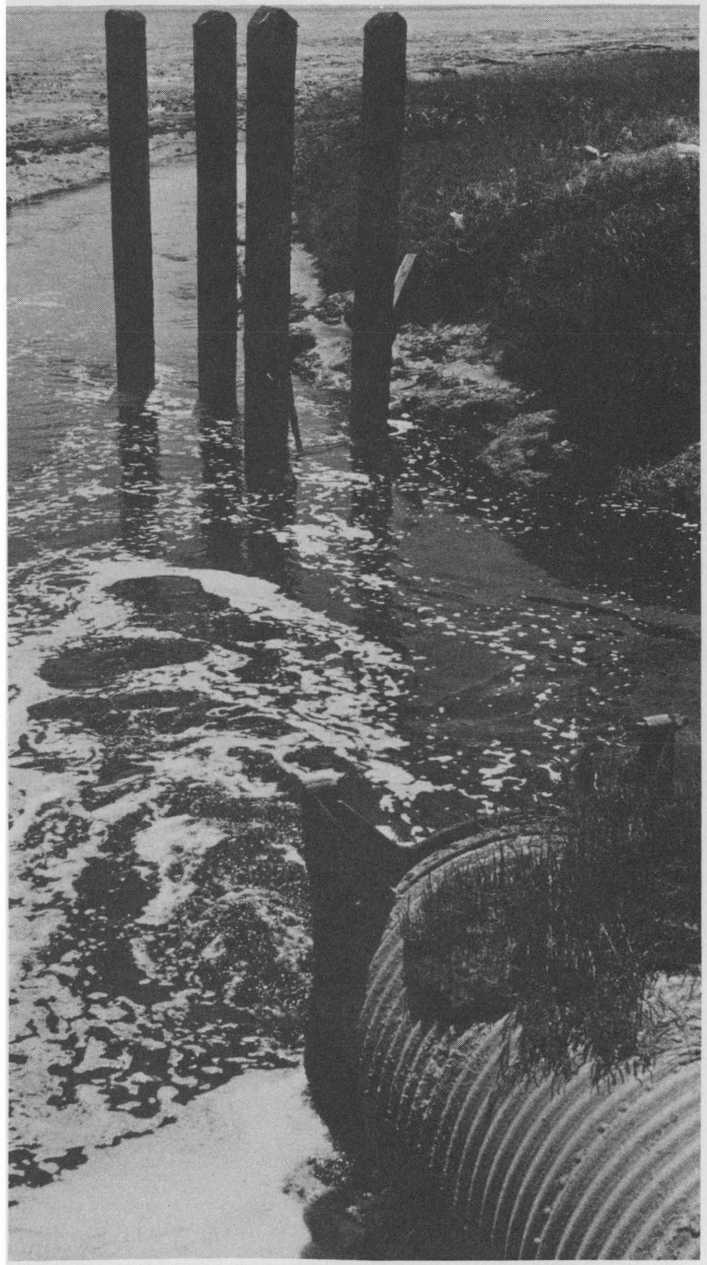
Large federal expenditures for improving port and navigational facilities, long unquestioned, have come under increasing scrutiny, particularly regarding inland waterways. The implicit subsidization of inland waterways users is harder to justify in the face of greater demands for federal support of other water resources projects serving larger public interests. Why, many ask, should commercial shipping and barge concerns enjoy the benefits of channel maintenance and lock and port facilities when, in fact, they contribute nothing to their costs?

Research Project B-061 is part of a regional effort to assess issues and alternatives involved in achieving more equitable cost-sharing by users of water resources. Dr. Leonard A. Shabman, a Virginia Tech agricultural economist, is conducting the investigation. It includes a review of the competitive position of inland waterway transportation in relation to other transportation modes in the southeastern U.S., assessment of the distribution of benefits in relation to present cost allocations, and an evaluation of the potential impact of such prospective cost-sharing arrangements as user charges, taxes, permits, and other regulations.

Their findings will be joined with those of related investigations on water resources cost-sharing at Clemson University and the University of Georgia. The three-pronged regional research effort is being directed by the Virginia Water Center.



Commercial shipping and barge operators using inland waterways such as the James River, seen here at Hampton Roads, may one day be required to share costs of maintaining port and navigational facilities they now use at no charge.



Industries discharging wastes into streams, thus adding to the cost of processing water for consumption, now are required in many communities to help pay for treatment facilities.

Another type of user charges is explored by Dr. Peter M. Ashton of the Water Center staff in Research Project D-005, sponsored by the Virginia State Water Control Board. It assesses the implications of the Federal Water Pollution Control Act Amendments of 1972, which made available federal grants to those communities having adopted some system of user charges. One stipulation is that significant industrial users must share in repaying the grant. The study is designed to assist localities which apply for the grants by providing better understanding of the criteria involved in defining user-charge rate structures, and in developing proportional capital cost-recovery systems.

The new federal requirements were designed to alleviate the increasing problems many communities are having in financing waste-treatment facilities. For years, industries have used waterways as cost-free depositories for industrial waste discharges—leaving to the nearby municipalities the problems and costs of treating waters thus contaminated. User-charge systems would help allocate treatment costs among users of treatment facilities and help promote financial self-sufficiency for municipal treatment works.

Though Dr. Ashton's full report is not yet published, the Environmental Protection Agency already has asked permission to use parts of this report in its national guidelines on industrial cost-recovery systems.

Mosquito Larvae as Water Detectives

The use of insects as water-quality monitors—detectors of harmful pollutants—is not a new concept, but is generating much attention today. Such procedures in the past typically have not been developed to a point of final simplicity and precision, whereby their findings would be universally accepted as valid even if obtained by relatively unskilled personnel. Yet a great current need exists for such water-quality monitoring tests. As state and federal agencies seek to enforce more rigid water-quality standards, the usefulness of simple, standard monitoring tests becomes more and more apparent.

Research Project A-042, now in the final stages of completion, holds promise of having developed such a test. Led by Dr. E. C. Turner, Jr., a Virginia Tech entomologist, the project has developed an "idiot-proof" water-quality monitoring kit which can be used to test for the presence of heavy metals, such as copper and zinc. The kit's basic component is a pair of graduated water troughs, small enough to be easily carried. A sample of the water to be tested is placed in one trough, and a control sample of known purity is placed in the other. Then, at one end where a standard fluorescent lighting tube is mounted, a designated quantity of mosquito larvae are deposited. When the light is turned on, the larvae migrate away from the light source. The distance they migrate during a designated period of time tells how much metal pollutant is present in the test sample—according to charts developed and verified by the researchers.

This project was focused on detection of toxic metals, a problem in Virginia streams. Modification and refinement of the procedure, however, could produce simple detection tests for other contaminants as well. As a supplement to or replacement of more expensive chemical methods, the monitoring kit developed by Dr. Turner holds great promise.

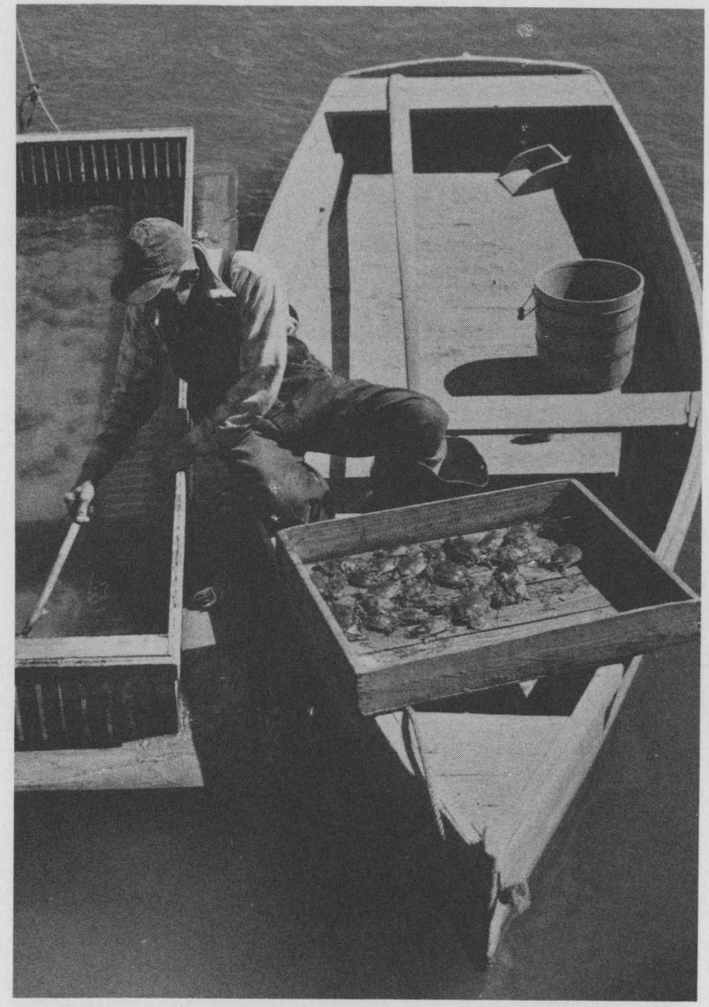
Another Biological Monitor: The Rotifer

Dr. Arthur L. Buikema, Jr., and Dr. John Cairns, Jr., both of Virginia Tech's Biology Department, also investigated biological water-quality monitoring in Research Project A-047. As in Project A-042 mentioned above, they focused efforts on detecting the presence of heavy metals. However, the test organism chosen was a common species of bdelloid rotifer, an invertebrate aquatic organism. Inexpensive to obtain and easy to breed and feed, they also proved to be reliable indicators of metal pollutants. Use of the rotifers as test organisms is especially advantageous because they serve as a food for fish. In some cases, a stream's water quality may not be lethal to fish but, at the same time, may be toxic to organisms such as rotifers. Hence a health rotifer population is one indication that sufficient food sources are available to sustain normal fish populations.

The experiments, using a standard bioassay procedure, developed mortality-rate data for the rotifers as they were placed in water samples containing known concentrations of metals and metal salts. Similar experiments also were conducted with refinery effluent mixtures, and again the rotifers were found to be useful indicators of the presence of certain common components. Other test results discuss the effect of water hardness and alkalinity on the toxicity of certain pollutants.

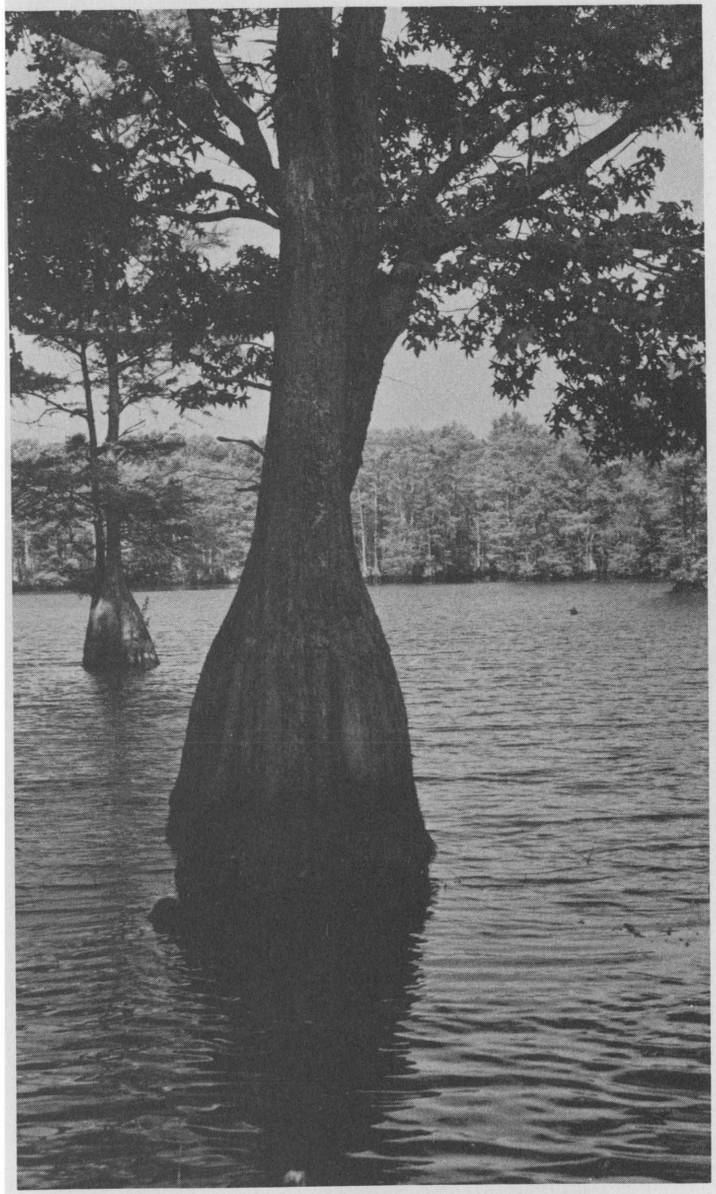
Like the two investigations above, Research Project A-057 seeks more precise methods of providing early warning of deteriorating water quality—but by chemical and physical procedures rather than biological monitors. Just begun, its objectives are to develop and refine detection procedures for a variety of toxic substances often found in agricultural pesticides and industrial wastes—including carbamates, chlorophacinone, and polychlorinated biphenyls. Existing methods of detecting these substances are not adequate for present needs. They lack the sensitivity for specific identification of many pesticides, allow some residues to go undetected, and frequently require large samples and large additional quantities of water which made field use difficult or impossible.

Roderick W. Young, of Virginia Tech's Department of Biochemistry and Nutrition, is the principal investigator. His research is expected to have particular application in detecting pollution from non-point sources, conveyed principally by surface-water or groundwater runoff along natural drainage routes. Already, the State Water Control Board has expressed special interest in reviewing the results of his investigations.



Virginia's shellfish industry, an important segment of the state's economy, has been hit often in recent years by contamination of productive beds. Better pollution monitoring methods often would allow earlier preventive measures.

Positive Contributions of Wetlands



Dismal Swamp, stretching from southeastern Virginia into North Carolina, is a unique ecological treasure which is under the constant threat of urban incursion from developers.

Virginia's many salt marshes, particularly those in coastal areas now undergoing extensive urban development, are under attack. With each passing year, pressures increase to give them over to residential and industrial expansion—uses which would produce positive economic benefits. Once destroyed, of course, a marsh area cannot be reestablished. But environmentalists and others who resist such proposed encroachments can be effective only if they base their arguments on scientific fact, not on theories, desires, or aesthetic considerations.

Research Project B-027, led by Dr. Michael E. Bender of the Virginia Institute of Marine Science at Gloucester, has gathered a large amount of data on the natural functions served by salt marshes—specifically the Ware and Carter Creek marshes, both of which feed the York River Estuary. The study focuses on ways in which the salt marsh ecosystem affects plant life in the estuary by interacting with such plant nutrients as phosphorous and nitrogen, and also by exporting organic carbon to the estuary in both dissolved and particulate form.

Now being readied for publication, the report should be of special interest and value to those who must balance the ecological, aesthetic, and recreational values of marshlands against the economic benefits that may be derived from allowing their destruction for development. Since any such change is irreversible, it is a decision that must be weighed with extreme care.

A Test for Algal Growth Potential

The presence of excessive clusters of algae on the surface of a pond, lake, or reservoir is a sure sign of trouble. Proliferation of these small, rootless aquatic plants can lead to fish kills, water discoloration, and foul decomposition odors. Scientists know that certain chemicals—notably phosphorous, a common component in sewage-treatment discharges—encourage algal growth. But testing for the presence of phosphorous is not a sure indication of algal growth enhancement; other factors also come into play. One of the impediments to more effective control of algae populations has been lack of any simple test for determining the algae-nourishing potential of a body of water. A test of this kind also could serve as a basic indicator of water quality, which decreases as the ability of the water to nourish algae increases.

Development of such a test is the objective of Research Project B-063, directed by Dr. Joseph H. Sherrard of Virginia Tech's civil engineering faculty. Using a standard algal assay bottle-test procedure, he hopes to develop improved sampling and analytical techniques which can give early warning of increased algal growth potential. His study area is the Roanoke River basin above Smith Mountain Lake, where excessive algal growth is a major problem. Since the river receives discharges from a Roanoke sewage treatment plant being upgraded during the period of the study, it will be possible to observe how more efficient phosphorous removal affects algal growth.

This is one of four projects in a cooperative regional program which seeks to develop improved water-pollution sampling techniques. Researchers at the University of Florida, the University of North Carolina, and the University of Tennessee also are at work on related investigations.

Excessive masses of algae, a small aquatic plant, are found in many streams, lakes, and reservoirs. Nurtured by phosphorous and other components in sewage and agricultural runoff, they are a warning that eutrophication—premature aging of the body of water—already has begun.

Guarding a Reservoir's Benefits

One justification for the construction of a reservoir, along with such primary reasons as power generation or water supply, is provision of recreational opportunities. But feasibility studies, required before construction is authorized, typically have given little consideration to changes in water quality which may result from the impoundment. In particular, many reservoirs have collected and trapped nutrients from streams and overland runoff, and these nutrients have fostered excessive growth of algae. This, in turn, depletes the dissolved oxygen content of the waters, may kill off fish and plant life, and is likely to result in noxious accumulations of decaying algae along the shore. In short, excessive algal growth can destroy the recreational potential of a reservoir, which often is a principal reason for its creation.

Research Project A-045 set out to create a basis for understanding and, in fact, for predicting the quantity and expected distribution of algae in a proposed reservoir. Conducted by Dr. George M. Hornberger and Dr. Mahlon G. Kelly, Jr., of the University of Virginia's Department of Environmental Sciences, the project developed a computer-based mathematical model which can determine what ecological changes—such as algal growth—will result from changes in the physical environment. The model was developed specifically for application to Sugar Hollow Reservoir, a Charlottesville water-supply facility. The process by which it was developed, however, can be followed in developing models for other particular locations.

Now in the process of being published as a Water Center bulletin, "A Predictive Model for Lake Eutrophication," the study provides a new, scientific procedure for insuring that the recreational benefits of newly constructed reservoirs are not eroded with the passage of years.

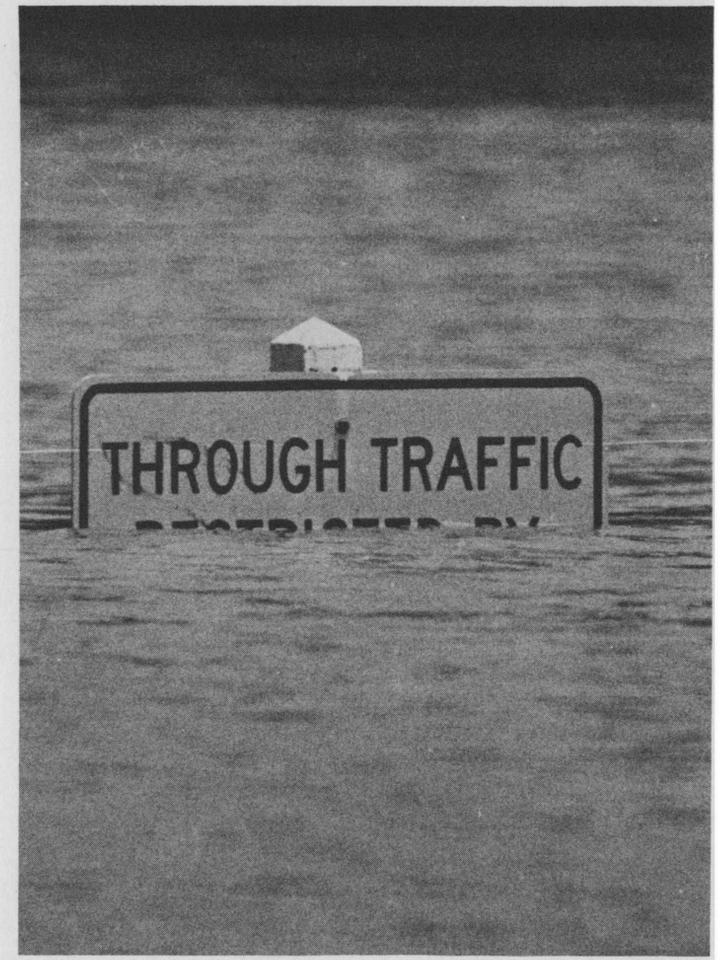
Non-Structural Prevention of Flood Damages

Obstacles to Non-Structural Alternatives

Despite all the dams, channels, floodwalls, levees, and other structural devices man has erected to control the waters, floods continue to take an ever-higher toll of human lives and property. In Virginia, the damages wrought by Hurricane Agnes in 1972 were three times those caused by Hurricane Camille three years earlier, though the two storms were of almost equal intensity. Nationally, flood damages are expected to triple by the year 2000 unless present conditions and land-use practices are substantially changed.

As a result, interest in non-structural measures for preventing flood damage has grown rapidly. These lie chiefly in the area of better control and management of flood-plain areas most vulnerable to rising waters. Among the methods available are stricter land-use regulations, taxation discouraging unwise land use in flood-hazard zones, and public acquistion of flood-plain lands to prevent their development. But such measures have been slow to find acceptance in the state.

Research Project A-054 is attempting to find out why. Led by Dr. Leonard A. Shabman, a Virginia Tech agricultural economist, it is studying public attitudes, the political decision-making process, and economic considerations as they may bear on adoption of non-structural alternatives. From this research are expected suggestions for ways to encourage wider adoption of non-structural measures. These should find useful application in scores of flood-prone communities throughout the state.



Flood Recovery at Least Cost

Flood scenes, unhappily, are familiar to thousands of Virginians. The problem is not that the waters rise, for they always have and always will. Rather it is that men persist in erecting structures where high waters are sure to flow.

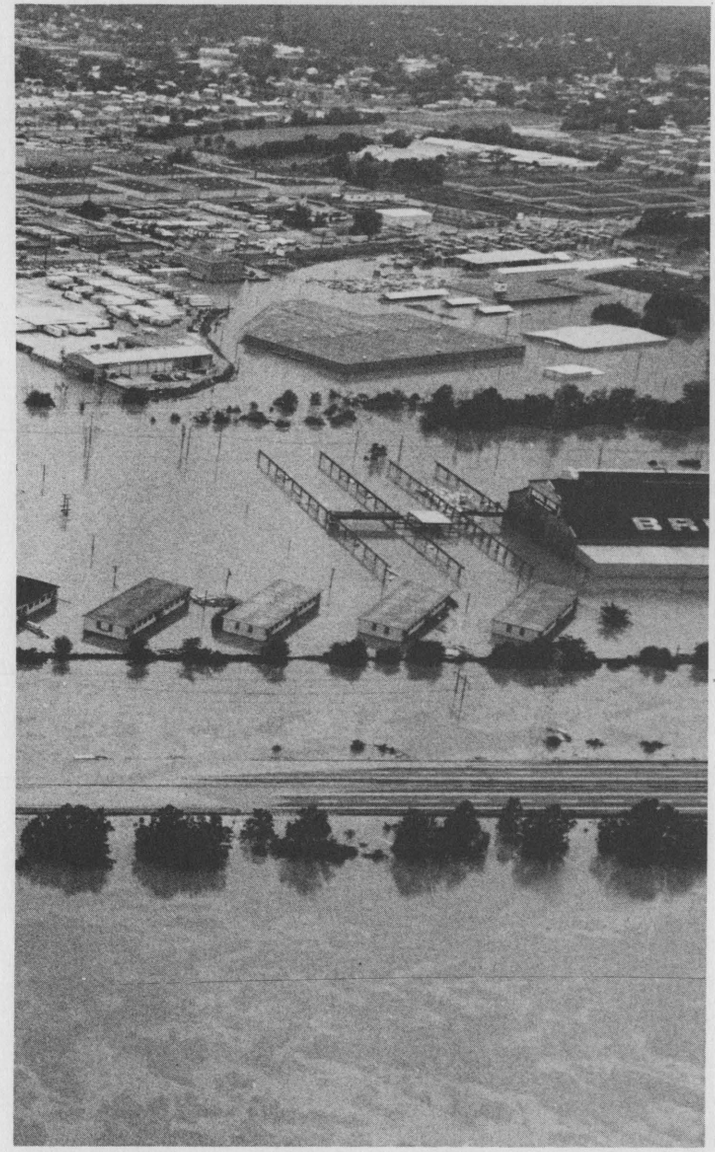
Thousands of Virginia families know the anguish, upheaval, and economic loss that can be caused by flooding. Many, sadly, were not covered by flood insurance, and had to rely on public relief programs and on the Red Cross, churches, and other private efforts for recovery assistance. Relatively few flood victims in recent years have had coverage available under the National Flood Insurance Program, which offers a 90 percent federal subsidy of premium costs to residents of communities which have qualified under the program's provisions. For those victims who were insured, of course, the anguish was diminished and recovery was rapid.

But in the larger economic sense, and for the taxpayers as a whole, which is less expensive—the National Flood Insurance Program, or the combination of governmental and private relief efforts? Dr. William R. Walker, director of the Water Resources Research Center, is directing Research Project B-030 to find answers to this question. Using a case-study approach of flood-struck Virginia communities, he is comparing the over-all costs of recovery under the National Flood Insurance Program with the costs of recovery through conventional relief schemes.

The results of this investigation should suggest whether a voluntary or a compulsory insurance program for a flood-prone area is necessary for insurance to be practical, and whether modification may be suggested in the existing program to make it more attractive. With flood recovery a major expense for many communities throughout the state, the study is timely indeed.

As of August, 1974, some 130 Virginia communities had qualified for participation at least under the emergency provisions of the National Flood Insurance Program. The emergency provisions, a first and simpler step toward qualification in the regular or permanent program, are due to expire at the end of 1975. A terminal date for entry into the regular program also has been set for mid-1977. These circumstances suggest the need for an intensive effort to inform Virginia property owners of the program's availability, and to encourage them to see that their communities begin now to meet required qualifications. For unless a community provides specified information and institutes certain land-use control measures, thus qualifying for program membership, the heavily subsidized flood insurance is not available to local homeowners and businessmen.

Research Project D-008, funded by the State Water Control Board, is producing two public-service television announcements about the National Flood Insurance Program. One 30 and the other 60 seconds in length, they outline the value of the program for Virginia communities and outline the necessary qualification steps. The two announcements, produced by Virginia Tech's TV-Radio-Film Services unit, will be distributed to all television stations in the state. In this way, it is hoped, more citizens will become aware that time is running out for qualification under the program.



Saving Money by Recovering Chemicals

If the nation's streams and lakes are to be free of pollutant discharges by 1985, the date set by federal legislation, better and more economically feasible means of advanced waste treatment must be found. In some cases, the required technology is known but costs still are prohibitive. For example, coagulant chemicals used in many treatment processes are increasing in cost and scarcity, factors which have hampered their wider use. And use of these coagulants, often necessary for thorough removal of pollutants, often results in still larger volumes of sludge—and still higher treatment costs.

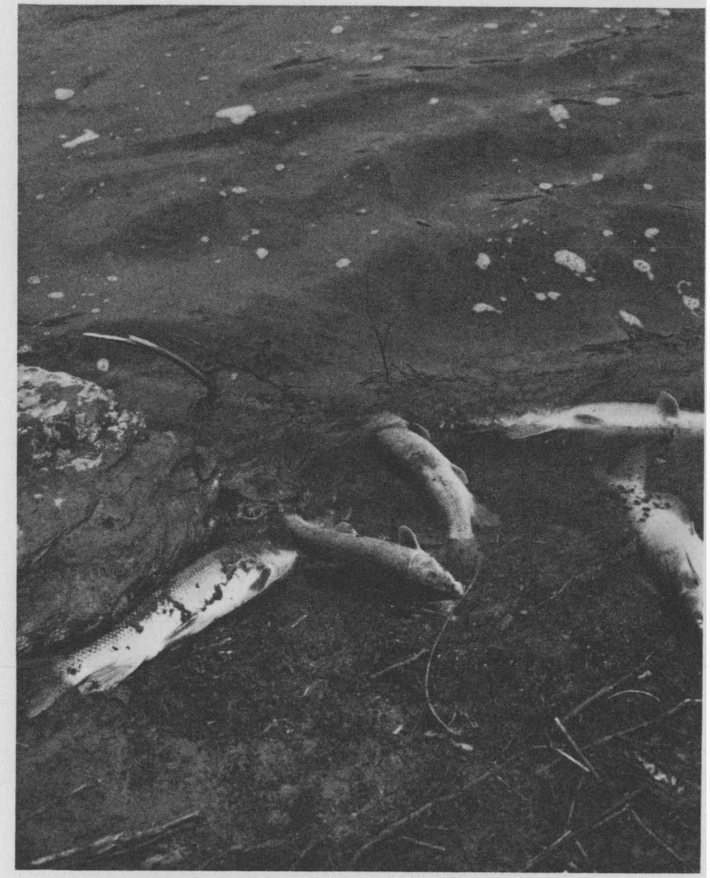
This dilemma was the subject of an investigation led by Dr. Paul H. King of Virginia Tech's civil engineering faculty. Now being readied for publication, the study suggests several techniques which together hold the promise of solving the problem. First, it describes a process by which alum and iron salts—the commonly used coagulating chemicals—can be recovered and reused through treatment of sludge by sulfuric acid. An accompanying economic study suggests that installation and operation of such a process is economically feasible for any plant handling approximately 25 million gallons a day. Second, the investigation discovered that use of the acidic process for recovering coagulant chemicals also dramatically reduced sludge volume and improved the settling characteristics and filterability of the remaining sludge.

These findings—which are the research equivalent of having your cake and eating it, too—should be of immediate interest to municipal officials throughout the state. They offer great hope that the unusual combination of greater efficiency at no greater cost may be possible in treating municipal wastes.

The "mercury scare" of the latter 1960's, caused by the revelation that considerable amounts of the metal were being discharged into the nation's waterways, did serve the purpose of quickly raising public consciousness about the hazards of water pollution. Vigorous action by federal and state agencies and by industries has considerably reduced this threat. Even so, new discharge requirements require the removal of still more mercury in waste treatment. This presents problems, for existing mercury-removal processes are costly. In Virginia, mercury pollution caused the banning of fishing on the North Fork of the Holston River in 1970, and the Olin Corporation closed its Saltville plant, located on that stream, saying that the expense of more thorough mercury removal wiped out its profits.

Research Project A-044, now being prepared for publication, explored new, more economical methods for removing mercury from industrial discharges. A research team led by Dr. Donald L. Michelsen, a Virginia Tech chemical engineer, investigated three different processes for mercury removal. An integral part of the study was preparation of economic analyses, showing real costs of installing and operating each of the processes. They found that three commonly available types of substances, all of them inexpensive, could be used for the purpose, serving the same function as commercial ion-exchange resins which are effective but far more costly. Tannery hair, they indicate, is perhaps the most effective and most versatile of the substances, but mercury also can be removed with modified scrap tire-tread rubber, with milk proteins such as are found in whey, with keratin (a substance found in human hair), and with xanthates, which are sodium salts of xanthic acid widely used as flotation reagents for heavy metal sulfides.

The full report of their findings, to be issued as Water Center Bulletin 74, is expected to be an important contribution in advancing the current state of the art in removal of mercury from wastes.



More thorough removal of chemicals from municipal and industrial wastewater discharges would contribute directly to reducing the occurrence of fish kills such as this.

Better Sludge Disposal by Freezing

Disposing of sludge, a semi-solid residue, is perhaps the most difficult problem in sewage treatment. The problem grows year by year as populations increase, and as more thorough treatment processes often result in the production of still greater amounts. In addition, sludge disposal is an economic liability, accounting for up to half the costs of building and operating a municipal waste-treatment facility.

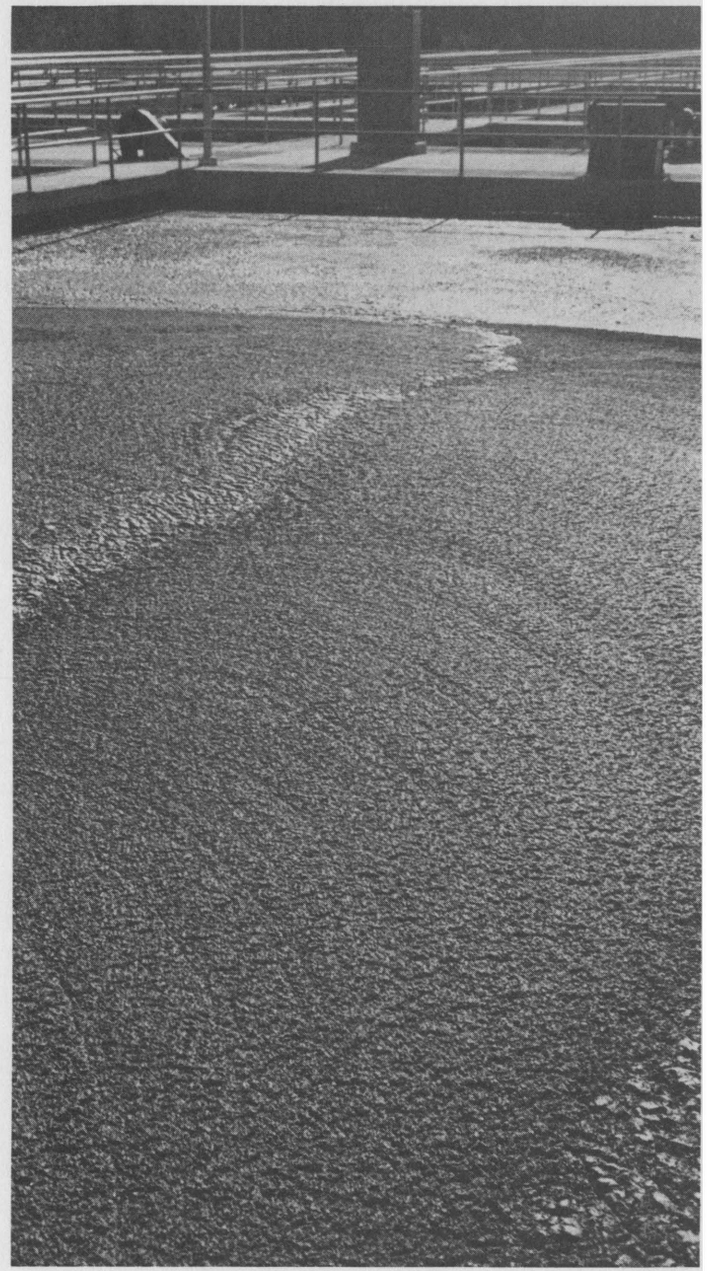
Dr. Clifford W. Randall and Dr. N. Thomas Stephens of Virginia Tech's civil engineering faculty headed a two-year investigation to explore a relatively simple but new sludge handling process: indirect freezing of the sludge with bubbled butane. Research Project A-051, now being readied for publication, indicates that the new technique has great promise for simplifying the ultimate sludge-disposal process and, thus, for reducing handling costs. The butane is bubbled through the sludge at slightly less than atmospheric pressure, converting the water to ice and leaving a mixture of ice and solid material. As the ice melts, the solid settles, permitting the liquid component to be siphoned off the top. This liquid is almost totally free of pollutants. The remaining solid material is highly concentrated and may be disposed of by burning or in landfills. The technique is so promising that a patent already has been applied for.

The process has many possible applications elsewhere where disposal of biological sludge is a chronic problem. The paper industry is one, and already a Western Michigan University paper technologist is investigating application of the technique to processing sludge produced by paper mills. The investigators also have been contacted by several other industrial firms and governmental agencies anxious to receive full details on the process.

For many small towns and rural communities in Virginia, waste disposal is an econonic life or death issue. Already operation of waste-treatment works is a major budgetary item, and mandatory federal standards effective in 1985 will require major new expenditures. Few of these smaller communities, however, have the resident technical expertise to determine what treatment system will meet the new standards at least cost.

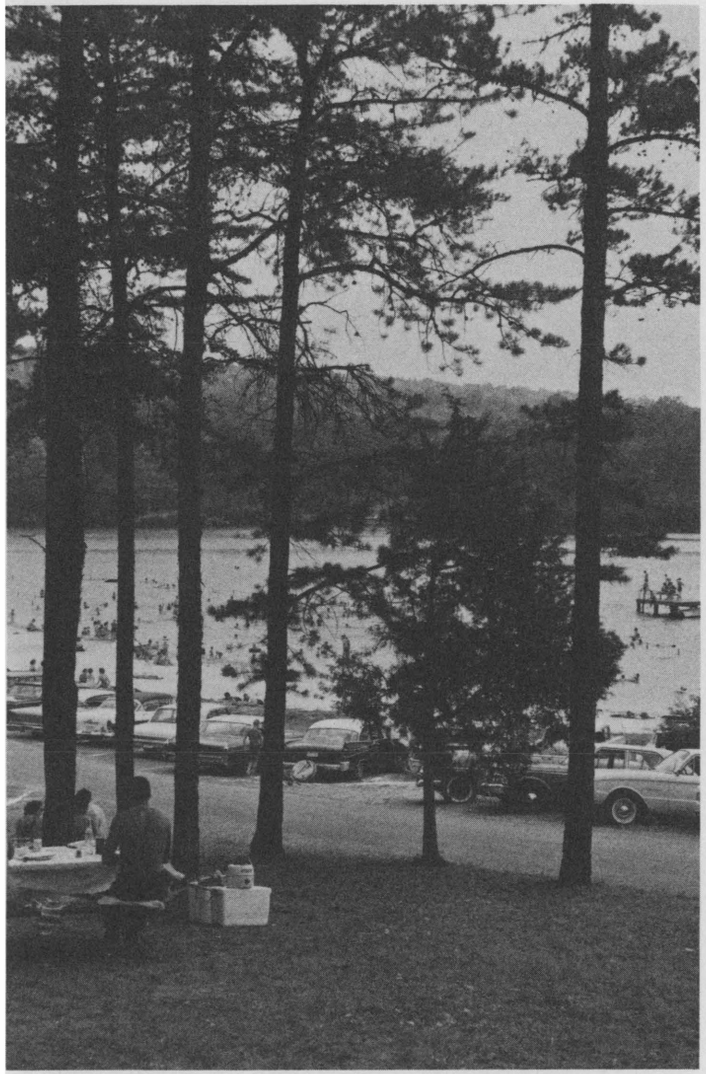
To answer this need, Research Project A-052 has evaluated treatment systems and cost factors common to communities having populations of up to about 5,000. Led by Dr. Clinton E. Parker of the University of Virginia's civil engineering faculty, an investigating team sought to suggest a waste-treatment system that would provide required performance at least cost, could be operated by personnel with a minimum of technical training, and would not encourage algal growth in the treatment lagoons commonly used.

Their report, now being readied for publication, has encouraging data for small communities. For those with populations under 500, use of lagoons followed by chemical-physical treatment are described as economically comparable to extended aeration treatments. For communities serving populations of up to 5,000, the research indicates that use of a system of lagoon-chemical-physical treatment could cut initial costs by as much as 50 percent as compared to extended aeration followed by chemical-physical treatment. They conclude that, where phosphorous and nitrogen reductions are sought, a system of lagoon-chemical-physical treatment offers considerable economic advantages to a smaller community.



Finding better methods of handling ever-increasing quantities of sludge, such as this at the Richmond Treatment Plant, is one aim of research in the waste treatment area.

How Algae Can be Starved Out



Even state parks such as this, far from urban sprawl, are not free of water quality problems, often due to such non-point sources of pollution as farm animal wastes, agricultural runoff, sedimentation, and drainage from septic tanks and mines.

Discharges from waste-treatment plants often are given major responsibility for contributing to problems stemming from excessive algal growth in streams and lakes. Algae not only are conspicuous in quantity—floating greenish or green-blue masses of the tiny plants cover large surface areas of some bodies of water—but also contribute to early aging (eutrophication) of a stream or lake. If unimpeded, excessive algal growth eventually can deplete waters of dissolved oxygen necessary to sustain fish and other aquatic organisms, can discolor the water, and can pile up on banks and beaches in smelly, decaying masses.

Scientists know that nitrogen, phosphorous, and carbon components stimulate algal growth. The catch is that research has not yet been able to pinpoint what amounts of each, or what combination amounts from among the three, most effectively enhance the proliferation of algae. Obtaining such data is the objective of Research Project B-039, led by four Virginia Tech faculty members—Dr. John Cairns, Jr., and Dr. Kenneth L. Dickson of biology, and Dr. Clifford W. Randall and Dr. Paul H. King of civil engineering. They are investigating different methods for removing these elements at least cost, and hope to indicate what amounts of each must be removed in waste treatment to preserve stream purity.

On occasion, the Virginia State Water Control Board has banned additional residential and industrial sewer connections until advanced treatment processes are installed at waste-treatment facilities for removal of additional phosphorous, nitrogen, and carbon. But such advanced treatments are costly, and experts disagree on what removal standards should be enforced for the three elements so they do not add to algal growth problems. This research should provide helpful data for these determinations.

With the continuing increase in confined animal production, animal wastes have come to be recognized as a significant non-point source of water pollution. Consider hog raising, a thriving enterprise in many sections of Virginia. Large amounts of wastes are deposited by many animals confined to a small area. The problem of economical, ecologically acceptable waste disposal is compounded by common use of quick-growth feed rations containing trace elements, pharmaceuticals, and salts—all potentially dangerous pollutants. They are concentrated in manure, often further concentrated in lagoon fluids, and may accumulate in soils on which manure is deposited to levels approaching toxicity for some plants and animals. Of immediate concern to Virginia's hog farmers is a recent Environmental Protection Agency ruling that all farm wastes must be recycled by 1977. Clearly, the question of how to handle swine wastes economically and acceptably is a high-priority question.

Research-based answers now are being sought in Research Project A-063. It is directed by a team of Virginia Tech faculty members representing three different disciplines: Dr. Eldridge R. Collins, Jr., agricultural engineering; Dr. David C. Martens, agronomy, and Dr. Ervin T. Kornegay, animal science. Their objective is to develop a practical, ecologically acceptable method for disposing of swine wastes on fields after lagoon-system treatment. The investigation is expected to produce a recommended collection-treatment-land application system for swine wastes. It may shed light, too, on which plant covers and soil types work best for land disposal of wastewaters.

A Cattle Waste Disposal System

Virginia's thriving dairy industry, second only to the state's beef industry in gross animal-product value, also is confronted by the Environmental Protection Agency's requirement that all farm animal wastes must be treated and recycled by 1977. A high percentage of the state's dairy farmers have herds of under 100 head, and relatively few have any system for treating milking-center wastes. Moreover, commercial systems generally are too costly for small operators and also have proved highly unreliable.

Research Project D-014 targets this dilemma. It seeks to design, install, and demonstrate for the state's cattle farmers a simple, low-cost, environmentally acceptable disposal system for milking center wastes, using readily available components. The investigators are Virginia Tech faculty members Dr. Eldridge R. Collins, Jr., of agricultural engineering, and Dr. W. Ray Murley, of dairy science. After assessing the efficiency and applicability of various techniques, they will install and test a recommended system at the Virginia Tech Dairy Cattle Center and also, with supplementary funding from the Virginia Dairy Council, at a working dairy farm elsewhere in the state. Liquid wastes will be sprayed on soil-plant test areas, which will be monitored for their ability to assimilate or screen pollutants and for long-range effects on soil and plants due to wastewater irrigation.

Faculty members, researchers, and extension personnel attached to the departments involved will help make the system known throughout the state, so operators of small dairy herds can consider the system's applicability to their needs.

Increasing waste-disposal costs have focused increased attention on the possibility of injecting liquid waste materials into deep strata of the earth, well below the level of any water-supply sources. Many industries already use the so-called "deep well" method, partly because treatment processes can be simpler and thereby less expensive. So deep-well waste injection has been proved technically and economically feasible.

But nagging questions increasingly are asked about the environmental, legal, economic, and institutional implications of deep well waste injection. Will it increase subsurface pressures to dangerous levels? Will the fluids, after injection, be contained in the designated area, or will they move to where they could contaminate ground waters used for water supply? Who is liable in the event of an accident? What controls should be imposed on the process, and who should enforce them?

Water Center Director William R. Walker directed a team of investigators in a thorough assessment of the advantages and disadvantages of deep-well waste injection. It included examination of economic, geological, legal, and regulatory questions, and suggests types of restraints which seem proper to insure adequate environmental protection. The final stage of this National Science Foundation project, now nearing completion, involves a series of workshops at which experts from physical, economic, and legal-institutional disciplines review the draft of the final report. Their comments will be reflected in the published completion report, insuring its accuracy, comprehensiveness, and direct applicability.

A research investigation of deep well waste injection, funded by the National Science Foundation, now is nearing completion with a series of workshops at which experts critically assess preliminary findings and conclusions.

Locating Underground Water Electrically

Viewed generally, Virginia appears to have ample water-supply sources for the years immediately ahead. But appearances can be deceiving. Water supply requirements are expected to triple by the year 2000, and another major problem is how the supply sources are distributed in relation to demands. A supply deficit of over 10 million gallons a day is projected for the Norfolk-Portsmouth area by 1980, and Newport News, Hampton, Lynchburg, and Richmond are expected to experience supply deficits by the year 2000. Where can needed additional water be found?

Subsurface ground waters are one promising source. Locating such supplies, however, can be difficult and expensive. It is for this reason that Dr. Mohamed Sabet, of Old Dominion University's Department of Geophysical Sciences, set out in Research Project D-002 to map the location of ground waters on Virginia's coastal plain. His findings are now being prepared for publication as Water Center Bulletin 73.

Dr. Sabet's procedure was based on the electrical resistance of rock. This property is a function of the amount of water present in the pore spaces, the salinity of the water, the distribution of the pores, and the presence or absence of conductive minerals such as clay. Clean, dry sands, for instance, have higher electrical resistance than water-saturated sands containing clay materials. And the higher the salinity of the groundwater, the lower the electrical resistance it offers. Applying these principles by calculating resistivities and then taking electrical soundings, the investigation mapped the location, depth, and width of groundwater aquifers in a wide section of the coastal plain, where water-supply problems are more acute than anywhere else in the state.

Undisclosed Sources of Pollution

Mapping a Weed Killer's Travels

Ask the average person to identify the chief sources of water pollution, and chances are he'll quickly mention such things as the discharge of municipal sewage or of chemicals and other industrial wastes from factories and businesses. Such specific point sources do contribute very substantially to water pollution. But water quality also is degraded by so-called "non-point" sources—including sedimentation (urban and rural) and toxic agricultural chemicals washed into water bodies by rainfall runoff, and seepage from septic systems and mining or quarry operations. Research on non-point sources of water pollution traditionally has run a distant second to that on point sources, which are more easily identified and studied.

Research Project A-046, directed by Dr. Chester L. Foy, a Virginia Tech plant pathologist, is investigating one major source of non-point pollution—agricultural herbicides. Specifically, Dr. Foy is tracing how water moves these herbicides away from their sites of application, and what effects concentrated levels of these chemicals have on non-target plants and organisms. On the basis of these observations, the study will suggest methods of reducing the amount of herbicide residues that may find their way into surface or ground waters, with the detrimental effects on water quality that invariably result.

Much of Virginia's agricultural enterprise, and some industries, rely heavily on the use of herbicides because of their labor-saving benefits. This research should contribute needed knowledge to how herbicides can continue to be used—but in ways which do not add to environmental problems.

At field plots such as this, researchers are studying how residual agricultural herbicides are carried away from their original sites of application by water, and how the chemicals affect non-target plants and organisms.

A longer-range project with somewhat similar objectives is gathering data on the precise impact of various agricultural chemicals on water quality in the Southern Piedmont region of Virginia. Led by Dr. Vernon O. Shanholtz, a Virginia Tech agricultural engineer, the study is monitoring three small watersheds at the Southern Piedmont Research and Continuing Education Center near Blackstone, Virginia, to determine what agricultural chemicals and what amounts of each are carried away from field sites after application.

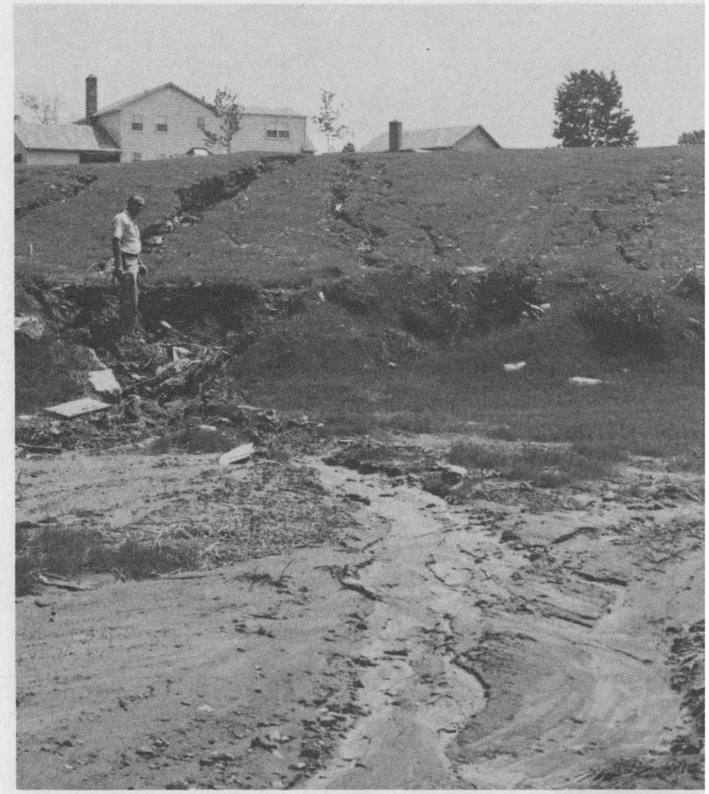
Greater knowledge of the pollution contributions of agricultural pesticides and fertilizers is required before intelligent decisions can be made concerning control measures. It would be foolish, for instance, to impose regulations on the use of one type of fertilizer or spray when, in fact, its contribution to the over-all pollution load of a stream is negligible. Selective controls do seem appropriate, however, for some of the ingredients in insect sprays are toxic to aquatic life, and some of the nutrients in fertilizers which encourage better crop growth also nourish algae populations which can choke a pond, lake, or reservoir.

Information garnered from this project, contributed to a broader study, should allow more precise estimation of the impact of agricultural chemicals on water quality in Southern Piedmont Virginia. Findings also should be applicable to other soil types and topography, and of great value in developing sensible and effective guidelines for the use of agricultural chemicals in a manner insuring continued high crop yields without adding to water pollution.

Recently promulgated federal regulations require, over the next several years, the installation of advanced waste-treatment facilities in many communities. The new requirements are intended to help safeguard the quality of the nation's waters. But according to Dr. Leland L. Harms of Virginia Tech's civil engineering faculty, "there is a definite possibility that millions of dollars will be spent on advanced water-treatment facilities without realizing the expected water-quality improvements." The reason: degradation of water quality by non-point sources of pollution.

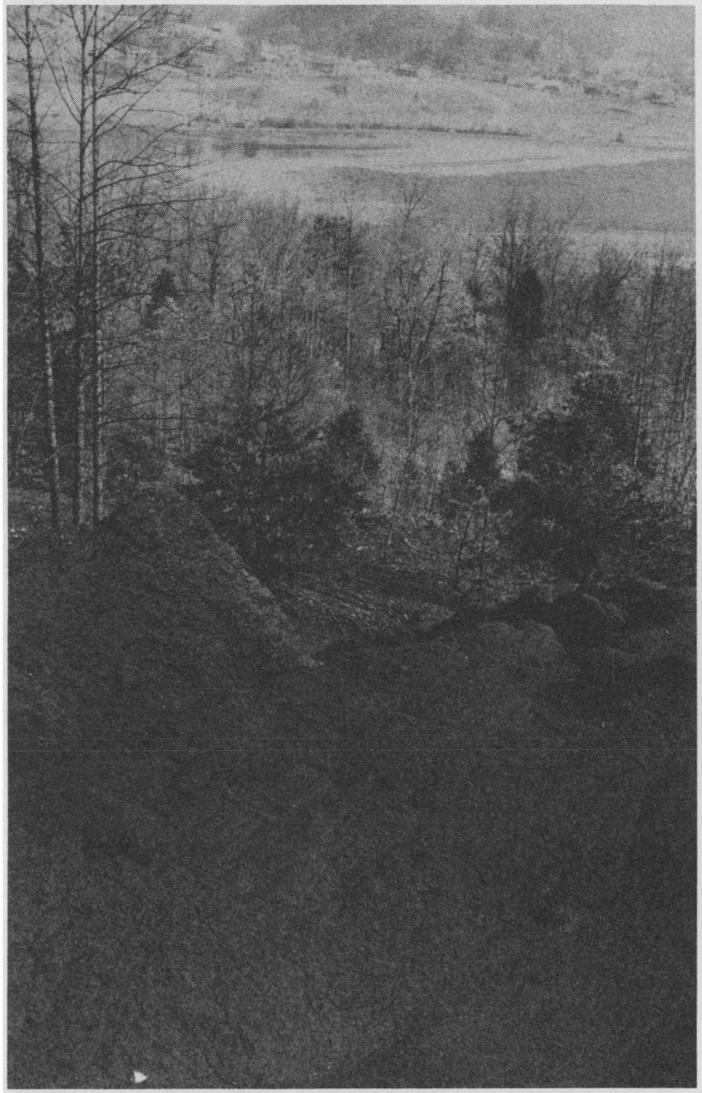
Research Project A-053, directed by Dr. Harms, seeks to produce valuable new information on non-point sources of pollution through a pilot investigation in the upper South River Watershed near Waynesboro. His principal objectives are three: (1) to assess, by comparison with point sources, the importance of non-point sources of pollution in the watershed area; (2) to suggest what basic data is needed for other investigations of this kind, and (3) to recommend possible measures for alleviating water pollution from non-point sources.

The project is expected to produce procedures and data having wide possible application elsewhere. It is especially timely because the President's Council on Environmental Quality recently cited the need to "greatly expand our knowledge of the causes, sources, and trends in water pollution"—including a "much greater emphasis on non-point sources." The project is sponsored, in part, by the State Water Control Board, which hopes eventually to develop procedures for reducing the contribution of non-point sources to contamination of Virginia's streams and lakes.



Urban development, extensive here in northern Virginia, often means vastly increased deposits of sediment in nearby streams—and with it, water degradation due to the presence of residual agricultural fertilizers and herbicides.

Predicting Strip-Mine Pollution



In addition to being unsightly, this spoil pile at a Clinch River Valley mine leaves sulfur-bearing materials exposed to rainfall and the elements, producing acids which are washed downhill into receiving streams.

In some sections of the nation, including Southwest Virginia, mining operations always have been a principal non-point source of water pollution. The current energy crunch may increase this contribution, for achieving energy self-sufficiency probably will require tapping the nation's large coal reserves—many of which are available only by strip-mining techniques. These circumstances have sparked an urgent call for research on the environmental consequences of strip-mining operations. How much acid, for example, is produced at a typical strip-mining site where sulfur-bearing materials are left exposed to the elements? And what is the correlation between annual rainfall and runoff from mining sites, on the one hand, and the production and deposit of acids in nearby streams?

Two researchers at Virginia Tech, Dr. Vernon O. Shanholtz of agricultural engineering and Dr. Dinshaw N. Contractor of civil engineering, are addressing questions such as these in Research Project A-055. They are studying oxidation rates and removal mechanisms for sulfur-bearing materials at several strip-mining sites. From this data, they plan to produce mathematical models of these processes. The models would provide the basis for development of a more comprehensive and general model which, if given certain basic information about strip-mining operations and conditions at a given site, could predict the effect on a nearby receiving stream of acid drainage from the mine.

A complete model with this potential, toward which this research is contributing, would be invaluable in determining the most economical and least polluting mining techniques for a particular site.

Research Project B-068 addresses one especially troublesome aspect of swine-waste disposal—seepage from the waste-treatment lagoons commonly employed. These lagoons typically have been located for convenience, with little or no consideration of soil characteristics and drainage patterns. Yet seepage from such lagoons can be a human health hazard, particularly when contamination finds its way into a water table used as a source of drinking water. This is particularly likely in the Tidewater region of Virginia, where most water tables are close to the surface and where hog production has increased rapidly in recent years.

These circumstances now are under study by two Virginia Tech agronomists—Dr. Daniel L. Hallock of the Tidewater Research and Continuing Education Center, and Dr. David C. Martens—in association with extension personnel and faculty members from four academic departments. By closely monitoring three swine-waste lagoons in areas having different soil and drainage characteristics, they are determining the amount and movement of biological and chemical pollutants from the lagoons into ground water, and how this varies according to soil composition and drainage patterns. The study includes measurement of chemical oxygen demand, fecal coliform bacteria, and heavy-metal concentrations known to be high in swine waste.

Data from this investigation should be useful in determining the appropriate use, location, and construction of swine-waste lagoons to avoid excessive seepage and human health hazards. The study also should be of special interest to the State Water Control Board as it seeks to establish regulatory guidelines for waste disposal from confined animal facilities.

Landscaping usually comes last in building projects such as this high school, guaranteeing that high costs will be paid in erosion, sedimentation, and stream contamination. Here some 60 acres of soil had been left exposed for nearly a year.

Research Project D-007 is the Virginia Water Center's contribution to a five-state regional research effort to identify the contributions of non-point sources of pollution to the quality of surface waters in heavily urbanized areas of the Northeast. In some segments of this region, limits on available water supplies already are in sight, and water quality already approaches danger levels. Better control of non-point sources of pollution is seen as a necessity. But before this can be accomplished, more comprehensive information is required.

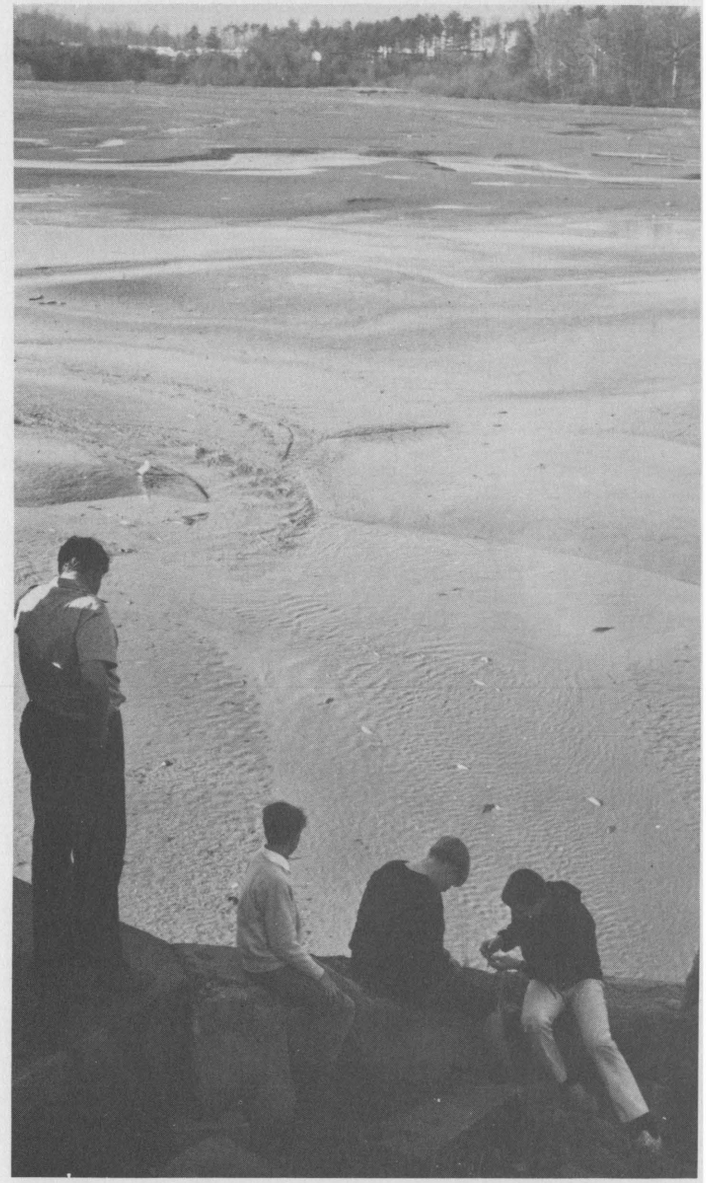
Dr. Clifford W. Randall, of Virginia Tech's civil engineering faculty, heads the Virginia contribution to the effort. Using the Occoquan Creek Watershed in northern Virginia as a case study, his project seeks to estimate what kinds and amounts of non-point source pollutants enter the waterways, and to establish criteria for similar studies elsewhere. As part of this process, Dr. Randall expects to develop better methods of analyzing the presence of heavy metals—dangerous pollutants—in urban streams and of relating their presence to sedimentation from nearby land clearance and construction activities. He also hopes to present an improved statistical basis for estimating stream pollution from non-point sources on an annual, seasonal, and unusual-event basis.

Other university researchers involved in the regional study are at Rutgers, Cornell, Maryland, and Massachusetts. All will use standardized techniques to minimize variables due to investigative style and to insure data comparability.

Urban sedimentation, one of the largest, most destructive components of non-point pollution in areas of heavy new construction, is undergoing intensive examination and analysis in Research Project D-009. Rapid residential, industrial, and commercial development often scalps vegetation and topsoil from construction sites and produces much higher erosion rates. The increased sedimentation thus deposited in nearby streams and lakes often contains residual agricultural chemicals, which, coupled with the sheer volume of soil particles, reduce the water's dissolved oxygen content, harm plant and animal life, encourage algal growth, increase the cost and difficulty of processing water for domestic or industrial uses, and magnify the risk of flood damages.

These consequences of urban sedimentation are clearly seen at Lake Pembroke in Virginia Beach, site of massive fish kills in 1973. Proposals for remedial measures, such as sediment basins, storm drainage treatment, and dredging have bogged down because insufficient data exists for making reasoned decisions. To fill this void, Dr. Chin Y. Kuo of Old Dominion University's Civil Engineering Department is gathering data on soil types, drainage patterns, sediment composition, and runoff rates in the Lake Pembroke area, and will attempt to correlate this data with the types and stages of construction nearby.

His findings should be helpful in determining appropriate erosion-control methods for the area. They also should have application in other situations where rapid, intensive urban development has created similar water-quality problems.



Lake Accotink, once a water-supply reservoir in urbanizing Fairfax County, illustrates the ravages of sedimentation. It was receiving some 700 tons of sediment per square mile per year from its drainage area, and soon filled to uselessness.

Marine Enviroment

Natural Functions of a Marsh

In this final category of concentration under the Five-Year Research Program, one project previously described ("Positive Contributions of Wetlands") warrants citation. It gathered a large amount of information on the natural functions served by two salt marshes adjoining the York River Estuary. Now being readied for publication, the research report describes ways in which the salt marsh ecosystem affects plant life in the estuary by interacting with such plant nutrients as phosphorous and nitrogen, and by exporting organic carbon. The research was conducted by staff members of the Virginia Institute of Marine Science at Gloucester Point, an institution which is conducting a wide variety of other studies aimed at better understanding and protection of the state's marine resources.

Other Research: Information Dissemination

Speeding Research Findings to Users

One current research project which does not fall naturally under any of the eight categories above, yet bears directly on all, is B-059, funded by the U.S. Office of Water Research and Technology. It arose from recognition of the fact that, while scientists are producing an increasing body of helpful research on water-resource problems, many decision-makers in government offices, on regulatory bodies, and in industry are unaware of these resea;ch findings and how they can be applied to the solution of current problems. How best to get research results to such persons rapidly, and in a form facilitating convenient application and use, has become a crucial problem.

In response to this need, Dr. William R. Walker, director of the Virginia Water Center, is directing a study to determine what information dissemination methods are most effective in getting the results of scientific research into the hands of potential users. The investigation seeks to determine whether information gaps as seen by decision-makers actually exist, or whether completed research has filled them. It then will attempt to identify which method or combination of methods appears most effective, considering costs, for adequate dissemination of research information.

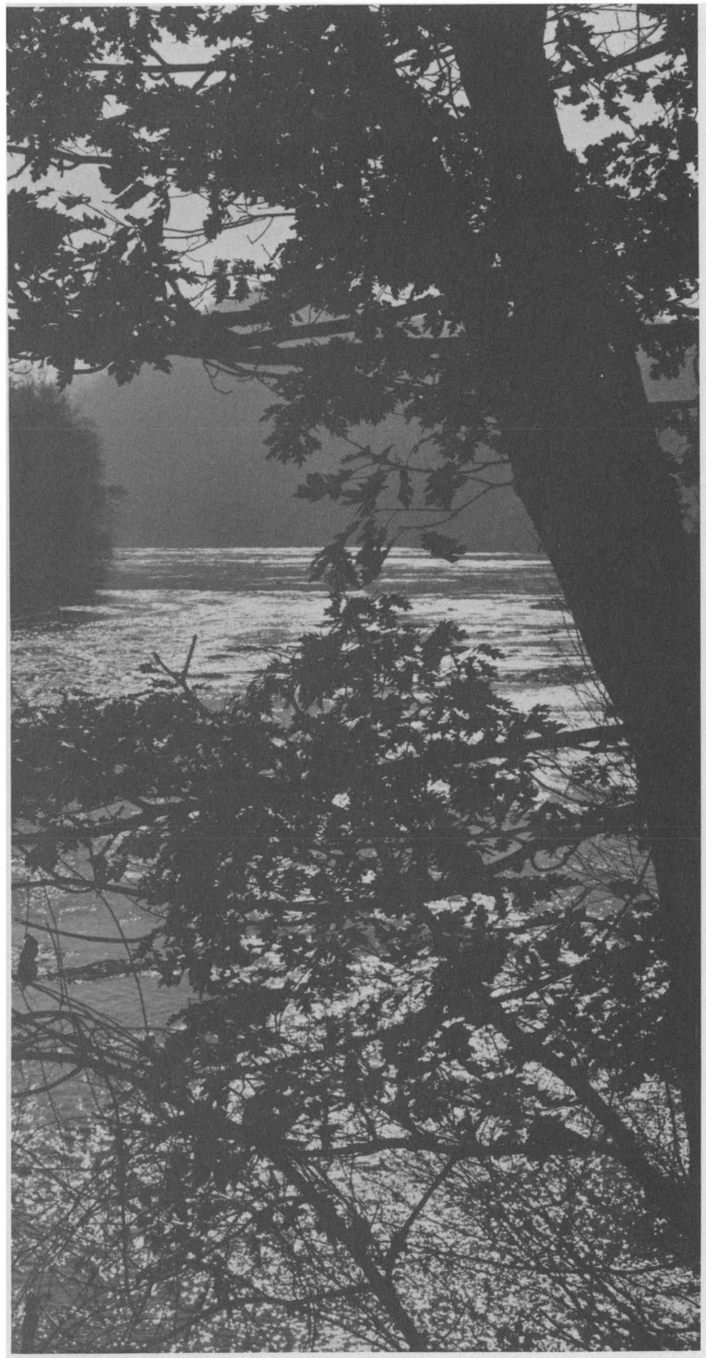
From this study are expected guidelines which will help suggest more effective communication techniques on a state and regional basis. Without proper technology transfer—from researcher to user—research serves little purpose.

Research Application: Five Examples

From its inception, the Water Center has been application-oriented. That is, it has sought to sponsor research projects promising to yield information of direct value in addressing important water resource problems. The effectiveness of this approach is documented by numerous examples of Center-sponsored research findings which have quickly and directly been applied to water problems—within the state, and beyond. Five examples are cited here.

Project A-035 explored more efficient, more economical means of disposing of sludge from waste-treatment processing. Sludge handling typically has accounted for at least 40 percent of waste-treatment costs. New requirements for more thorough treatment are expected to increase sludge volume and, as a direct consequence, processing costs. This research project analyzed all principal sludge-handling procedures and concluded that aerobic digestion, under stated conditions, was most effective in reducing sludge volume through improved dewatering characteristics, and therefore was most cost-efficient. On the strength of these findings, the City of Atlanta set up a new treatment plant to use aerobic digestion and vacuum filters, a combination process recommended by the research. Though insufficient time has elapsed for long-term cost comparisons, city officials already have labeled the process a success and estimate annual savings of as much as $80,000.

Project A-051 developed and tested a new sludge-treatment process—freezing the semi-solid waste material with bubbled butane at slightly less than atmospheric pressure. This uncomplicated technique accomplishes more effective separation of liquid and solid components, thus simplifying the ultimate disposal process and reducing handling costs. The process has many possible applications, since disposal of biological sludge remains a costly and difficult problem in many industries, not alone municipal waste treatment. Patent application has been made on the process. Already, however, a paper technology professor at Western Michigan University is conducting experiments to determine whether the process can be adapted to processing sludge produced by paper mills. He expects to have production equipment manufactured and installed at a paper mill for field testing. Several industrial firms and governmental agencies also are anxious to receive full details soon to be published as a Water Center Bulletin. One Japanese corporation has announced its intention to implement the new method as soon as possible.



One of Virginia's loveliest and most interesting water resources is the New River, which ranks second only to the Nile among the world's rivers in its geological age.

Project B-041 provided a computer-based mathematical model allowing accurate prediction of changes in a stream's temperature pattern caused by a given heated discharge. Its applicability to practical needs was underscored when the Environmental Protection Agency issued more stringent requirements, effective January 1, 1974, for industries discharging wastes into streams and lakes. Utility companies, for example, now must provide comprehensive data on the thermal component of proposed discharges to document that they will operate within environmentally acceptable limits. Duke Power Company in Raleigh, N.C., learned of the predictive model and engaged one of the project investigators to adapt it for supplying required data on three new power plants. The adaptations enabled the company to meet present EPA standards for obtaining waste-discharge permits.

Project B-025 expiores the responsibilities, linkages, and relative efficiencies of Virginia's state water resources programs and agencies. While the final project report is still in preparation, the investigation earlier produced a series of recommendations for governmental structure which were considered by the Governor's Council on the Environment in preparing comprehensive legislation for submission to the Virginia Legislature. These guidelines and "Virginia's Water Policy: The Imprecise Mandate," a publication resulting from the project, have contributed support and direction for reorganization efforts which continue at the state level.

Projects A-009 and A-018 studied a no-tillage system of crop production. The research found that the system reduced topsoil losses due to erosion runoff by 90 percent while at the same time making 25 percent more soil moisture available to the crop and raising crop yields by at least 21 percent. Already it is estimated that the method is used to produce a third or more of the commercially grown corn in the state, and that within a few years the percentage will exceed 75 percent for both corn and soybean crops. When that happens, the larger crop yields will be produced at annual production-cost reductions estimated at $6 million annually for corn and $2.9 million annually for soybeans. In this instance, research pointed the way to a technique which not only cuts topsoil losses and reduces stream pollution from agricultural runoff, but also produces larger crops at less cost.

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