BULLETIN 46
WATER RESOURCES RESEARCH IN VIRGINIA – ANNUAL REPORT for FISCAL YEAR 1971

WATER RESOURCES RESEARCH IN VIRGINIA
ANNUAL REPORT for FISCAL YEAR 1971

(Public Law 88-379)

Submitted to the Director
Office of Water Resources Research
U.S. Department of the Interior
Washington, D.C. 20240

Water Resources Research Center
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061
September, 1971

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PREFACE

The Water Resources Act of 1964, Public Law 88-379, July 17, 1964, as amended by Public Law 89-404, April 19, 1966, authorized the establishment of State Water Resources Research Institutes or Centers in each of the 50 states plus Puerto Rico. The purpose was to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and of resources which affect water so as to assist in assuring the Nation at all times of a supply of water sufficient in quantity and quality to meet the requirements of its expanding population.

The Act authorizes appropriations every year (continuing indefinitely) to assist each participating state in establishing and carrying out the responsibilities of a competent, qualified Water Resources Research Institute or Center at one university in each state. It also provides for annual matching funds for the centers, and authorizes annual grants, contracts, matching or other arrangements with educational institutions including the Center universities, foundations, private firms, individuals, and local, state, and Federal government agencies to undertake research into any aspect of water problems related to the mission of the Department of the Interior which may be deemed desirable and are not otherwise being studied.

In August 1964, Governor Harrison, by letter to President T. Marshall Hahn, designated the Virginia Polytechnic Institute and State University as the center for Water Resources Research in the Commonwealth of Virginia. The Center was established to plan and conduct competent research, investigations, and experiments of either a basic or practical nature, or both, in relation to water resources and to provide for the training of scientists through such research, investigations, and experiments. It also provides the mechanism for cooperation in water resources research with other institutions of higher learning, private research groups, and action agencies throughout the state.

This is a summary of the seventh Annual Report submitted to the Office of Water Resources Research, Department of the Interior, in compliance with Section 506.1 of the Rules and Regulations Pursuant to the Water Resources Act of 1964 (Federal Register, December 3, 1964).

James E. Hackett
Acting Director

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James E. Hacke[illegible]
Acting Direct[illegible]

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ACTING DIRECTOR'S REPORT

ACTING DIRECTOR'S REPORT

The water resource problems of the Commonwealth of Virginia are inextricably tied to and strongly reflect existing trends of expanding development on the one hand and growing pressures for higher levels of environmental quality control on the other. As a consequence, water resource problems are extremely varied and all areas of the state are affected to one degree or another by these interacting forces.

The need to attain higher levels of water quality control in response to state and Federal water quality standards is a primary concern among communities of the state. Research projects A-032-VA, A-035-VA, and A-030-VA have been concerned with the development of improvements in wastewater treatment techniques and in treatment plant operations. The products of these studies indicate promising opportunities for the use of more economical electrochemical activation techniques in regeneration of activated carbon for tertiary treatment of wastewater and for the use of polyelectrolytes as an economical conditioning agent for alum and lime sludges produced by conventional water treatment plants. Also, the manner of handling waste activated sludge in treatment plant operations has been shown to have considerable effect on dewatering time and proper conditioning for disposal.

In Virginia, as in other areas of the Nation, water quality degradation has resulted when the dilution capacity of waste receiving waters has been exceeded. Effective and practical programs of water resource and wastewater management require a better understanding of the assimilative capacity of stressed environments and of the regenerative capacities of such systems when the stress has been relieved due to the application of appropriate measures of water quality control. Eight of the study projects receiving support through the Center are involved in research on various aspects of these problems.

With respect to the physical characteristics of receiving waters, project B-021-VA has led to the development of a heat and mass transfer coefficient related to air-water systems which allows approximation of the thermal loading capacity for a stream or reservoir. Project A-037-VA has demonstrated that the distribution of chemical and biological substances in freshwater bodies differs significantly between the surface microlayers and the subsurface water.

The role of aquatic plants in improving water quality has been the subject of investigation of project A-033-VA. The results obtained indicate that several aquatic plants are effective removers of pesticide residues.

The ecological impact of heated water and acid mine drainage has been under invesigation in projects B-017-VA and B-034-VA. Laboratory data indicate that long term exposure to heat stresses has a significantly greater impact on control organisms than has short term exposure to rapid heat changes.

Studies in project B-034-VA are attempting to determine biological recovery processes in streams chronically subjected to stress. The recovery process appears to be related to the effectiveness of natural and artificial neutralization of the acidic waters and the existence of recolonizing organisms provided by tributaries containing good quality water.

On the basis of the physical, chemical, and biological information obtained in project A-031-VA, an assessment was made of the probable ecological impact on the North Anna River basin by a proposed nuclear generating facility. In this case the development of the impoundment would, in all probability, enhance the water quality of the basin.

In addition to the problems and concerns of water quality control, the Center has sponsored and administered a number of projects relating to the physical, social, and institutional factors of water resource management within the state. Project A-034-VA, performed in cooperation with the State Division of Water Resources, has established the effectiveness of modern seismic methods as a tool in the definitive study of aquifer containing geologic units throughout the Coastal Plain Province. Project A-036-VA, by development of a computer program for the James River for flood routing and unsteady flow conditions, has provided a means for establishing flow characteristics without a detailed gaging network. Such techniques serve coordinated water resource management for water supply development, water quality control, aquatic life conservation, and flood control by providing basic physical data.

The expanding development in Virginia of large scale impoundment reservoirs as producers of hydroelectric energy has also resulted in extensive use of these major reservoirs for water based recreational activities. The widely fluctuating water levels in such reservoirs have been held to be in conflict with satisfactory recreational use development. The study results of project B-009-VA indicate that operating range restrictions often imposed on reservoir operators to safeguard recreational use potentials have been overly severe and that reservoir operating policy has had little demonstrated impact on recreational usage of the reservoir.

The value of determining public attitude with regard to existing water resource projects or to projected water resource management programs is becoming more widely recognized. Project A-038-VA was designed to explore available techniques for measuring public attitudes on the recreational versus industrial uses of a hydroelectric reservoir in Virginia. The study has shown that meaningful results in public attitudes and perception of water resource use could be obtained through use of appropriate testing techniques. Attitudes toward water resource use according to social characteristics of age, sex, occupation, education, and income could thereby be established as a guide to acceptable water resource management programs.

Investigation into the organization, responsibilities, funding, and methods of operation of administrative agencies concerned with some aspect of water resource use in Virginia has been undertaken by project B-025-VA. Initial results indicate that several water resource agencies in the state are independent of one another without direct central control, and coordination of activities is primarily dependent on cooperative efforts by officials of the agencies involved.

There is a need to organize a program of water resources research within the state, directed not only to the resolution of problems of current interest and concern but to those which are likely to emerge in the future. Comprehensive water resource management that is so clearly indicated for the future will require organized programs of interdisciplinary research of the broadest possible scope. Levels of funding presently available to the Center are, however, inadequate to meet the needs of such efforts.

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ANNUAL ALLOTMENT PROGRAM

ECONOMIC DISPOSAL OF WASTE SLUDGES FROM WATER TREATMENT PLANTS

Project A-030-VA

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September, 1971

ECONOMIC DISPOSAL OF WASTE SLUDGES FROM WATER TREATMENT PLANTS

The primary objective of this research was to study in detail economic methods for concentration, dewatering, and ultimate disposal of water treatment plant sludges resulting from conventional processes. The first year of work emphasized polyelectrolyte conditioning of alum sludges, alum recovery procedures, and the use of natural freezing and thawing as a conditioning process in lagoons. The work during the current year has been concerned with ferric and lime sludges.

A considerable amount of work has been done on conditioning techniques for iron sludges. Tests were run on samples of ferric sulfate sludge collected from the sedimentation basins of a water treatment plant during basin cleaning operations. The purpose of the testing was to determine if cationic, anionic, and nonionic polyelectrolytes could successfully condition the sludge to improve its dewaterability. In addition, the parameters which affected the conditioning mechanism were investigated. Tests that were run during the investigation included specific resistance, COD, total and volatile solids, zeta potential, and pH. Polyelectrolyte conditioned and unconditioned sludge samples were applied to bench scale sand beds to determine the effect of conditioning on the dewatering rate of the sludge.

Results indicated that all types of polyelectrolytes used reduced the specific resistance of the sludge. However, specific resistance was only a qualitative measure of the effect of polyelectrolytes on gravity dewatering of the sludge. Anionic and nonionic polyelectrolytes exhibited chemical bridging as the mechanism of conditioning, while cationic polyelectrolytes conditioned by both chemical bridging and charge neutralization. Both pH and sludge solids content were found to affect the conditioning process. The sand bed studies indicated that sludge conditioned with anionic polyelectrolytes produced a more porous floc structure that dewatered to a cake which was easily removed from the bed. Cost data for polyelectrolytes indicated that conditioning of the sludge by this method was very economical.

The purpose of the most recent phase of the investigation was to determine if polyelectrolytes could be successfully used to improve the dewaterability of lime sludges similar to those produced during water softening. The tests made during the study included specific resistance, COD, total and volatile solids, pH, and zeta potential. These tests helped to determine the factors which affected the conditioning mechanism. Polyelectrolyte conditioned and unconditioned samples were then applied to bench scale sand beds to determine the effect of conditioning on gravity dewatering and air drying of the sludge.

Results indicated that only anionic polyelectrolytes significantly reduced specific resistance. The principal mechanism for improved drainability was shown to be chemical bridging. Solids concentrations were found to affect the conditioning process, while the pH of the sludge was not a factor in anionic conditioning. Sand bed studies indicated that sludges conditioned with anionic polymers produced a porous, open floc structure which facilitated rapid gravity drainage and air drying. Cost estimates for polyelectrolyte conditioning of the sludge indicated that this method would generally be economically feasible.

In addition to the work described above, extensive studies on alum sludge conditioning by polymers and natural freezing and thawing of alum sludges in lagoons were completed. Significant conclusions from this work were:

1. Polyelectrolytes, particularly anionic polymers, are highly effective conditioning agents for alum sludges leading to rapid release of gravity drainage water and improved performance in vacuum filtration.

2. Acidification of alum sludge is an effective means of aluminum recovery, but polymer conditioning of the acidified solution is necessary to achieve effective separation of the recovered aluminum from the remaining solids.

3. The mechanism responsible for the conditioning process is chemical bridging.

4. Alum sludge remains stable during storage in lagoons and dewaterability is not enhanced unless natural freezing and thawing occurs. Freezing and thawing is an effective conditioning process, and thus lagoons should be relatively shallow to take advantage of the benefit of natural freezing in locations where the climate is suitable.

A PRE-IMPOUNDMENT ECOLOGICAL STUDY OF THE BENTHIC FAUNA AND WATER QUALITY IN THE NORTH ANNA RIVER

Project A-031-VA

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September, 1971

A PRE-IMPOUNDMENT ECOLOGICAL STUDY OF THE BENTHIC FAUNA AND WATER QUALITY IN THE NORTH ANNA RIVER

OBJECTIVES

1. To evaluate the composition of the benthic community in the pre-impoundment basin.

2. To evaluate existing water quality in the basin by biological, chemical, radiochemical, and bacteriological analyses.

INTRODUCTION

Location and Hydrology

Virginia Electric and Power Company (VEPCO) is building a 14,500-acre reservoir on the North Anna River which will extend through Louisa, Spotsylvania, and Orange Counties, Virginia (Figures 1 and 2). The purpose of the impoundment is to serve as a coolant for a 4,000,000 kilowatt nuclear powered electrical generating facility being constructed on the impoundment in Louisa County near Mineral, Virginia (Figure 1).

The reservoir will drain approximately 343 square miles or approximately 78% of the total river basin. The North Anna River has very few municipalities or industries in its drainage basin. Most of the area is farmed for agricultural crops, livestock, or timber. Approximately 3,500 acres will consist of cooling lagoons which will hold the thermal effluent from the power plant. The remaining area of the reservoir, 11,000 acres, will be available for recreational use. The normal pool elevation will be at 250 feet mean sea level, and the lake will be 80 feet deep at the dam. The dam is scheduled for completion in 1971. The first reactor is to begin operation March 1, 1974, and approximately 1600 cubic feet per second of water will be needed for cooling. Units 2, 3, and 4 are scheduled to begin operation on March 1, 1975, 1977, and 1978, respectively (VEPCO, personal communication). At maximum operating capacity, 4% of the reservoir volume per day will be needed for cooling. A summary of morphometric data is presented in Table 1, and engineering features of limnological interest and importance are given in Table 2.

The North Anna River is a major tributary of the Chesapeake Bay. The confluence of the North Anna and South Anna Rivers forms the Pamunkey River which in turn unites with the Mattaponi River at West Point, Virginia, and forms the York River. The North Anna River rises in the upper Piedmont province of Orange County and flows southeast for about 60 river miles before joining the South Anna River on the Coastal Plain. In the upper half of its course, the North Anna River forms the boundary between Spotsylvania and Louisa Counties; and in the lower half, it divides Caroline and Hanover Counties. The drainage area of the North Anna is approximately 439 square miles, and the 40 year average discharge is 375 cubic feet per second (Anon., 1970). The maximum recorded flow was 24,300 cubic feet per second on August 21, 1969, and the minimum recorded flow was one cubic foot per second on September 30, 1932. Available records on discharge indicate that the volume flow of the river varies sharply with rainfall. The gradient of the North Anna varies considerably over its course. Figure 3 is a diagram of the gradient from its head water regions through the pre-impoundment area. Station sites as well as the proposed dam are included.

Geology and Mining Activities

The major portion of the drainage basin of the North Anna River is located in the north-central part of the Piedmont physiographic province of Virginia. This province is bordered on the east by the Coastal Plain province and on the west by the Blue Ridge province. The drainage basin consists of gently rolling terrain with broad, flat-topped hills and narrow, eastward sloping valleys. The surface of the Piedmont province exhibits a slight southwestward slope from an altitude of approximately 1000 feet at the western margin to about 200 feet at the eastern margin.

The Piedmont province contains a greater variety of mineral resources than either of the other two provinces. Many of these minerals are of commercial importance. Pyrite, associated with gold, silver, lead, and zinc, is probably more abundant than any of the other minerals and occurs in many places throughout the gold-pyrite belt in the province. The portion of the belt through Louisa and Spotsylvania Counties has been extensively mapped (Cline, et al., 1921).

One of the main tributaries of the North Anna River is Contrary Creek (Figure 2). The land adjacent to the headwaters of this stream was the site of extensive mining operations during the period 1882-1920. Although many minerals were mined, the primary elements sought were iron and sulfur in the form of iron pyrite – FeS_2. During this time (commerical operation:

1885-1920), three different mines were in operation and produced nearly 6,883,000 tons of pyrite which constituted approximately 13.2% of the national output. A comprehensive history of the ownership and mining activities of the properties has been discussed in detail by Katz (1961), Painter (1905a, 1905b), and Watson (1907).

The ore was mined, milled, and washed at the mine sites; and the tailings were deposited along the stream bank (Painter 1905a, 1905b). It has been shown that sulfuric acid is produced when the sulfide is exposed to air and water (Parsons, 1968). As a result, sulfuric acid has been introduced into Contrary Creek, not only from the washings of the mining heyday, but also from subsequent drainage of the tailings along the stream bank. Essentially then, Contrary Creek and the area in the North Anna River below the entrance of Contrary Creek have suffered from acid drainage for nearly 100 years. Figure 4 is an aerial photograph of a portion of the Contrary Creek basin approximately three miles below the mine sites in Louisa County. State Route 652 and the bridge across Contrary Creek are in the foreground. Figures 5, 6, and 7, taken from the bridge seen in Figure 4, show the erosional effects caused by the acid mine drainage.

Relevancy of Pre-impoundment Studies to the Scope of Water Resource Development

President Nixon, in his State of the Union address, stated that the theme of the 1970's will be one in which greater emphasis will be placed on environmental problems. One major facet of the overall environmental picture is that of water pollution. All parties concerned are interested one way or another with waste use or water resource management. As our population continues to grow, it is self-evident that there will be a demand for more convenience. More convenience implies, in part, a greater demand for electrical energy. Mr. George M. Tomlison, Deputy Chief, Bureau of Power, Federal Power Commission, has estimated that the power requirements for 1990 will be at least three times that at present. For the past 30 years, electric power supply and demand has almost doubled in each decade (personal communication, Technical Seminar on Thermal Pollution, Charlottesville, Virginia, February 10-11, 1969). Moreover, in order to meet this demand, it is estimated that 44 nuclear-powered electrical generating facilities are currently being constructed in the United States with an additional 34 being planned (Anon., 1969).

As the electrical industry expands to provide a more leisurely life, the desire for more avocation becomes prevalent. Eventually, the population begins to covet the natural resources that must be lost in order to meet the service demands of the population growth. A pre-impoundment study, if considered before plans are finalized, enables all concerned to view the natural resource before it is modified or changed. The natural resource, in this case a river, should be evaluated not only as a recreational resource, but also as a potential industrial resource (coolant, raw water supply, diluent, etc), public water supply, or agricultural resource (irrigation, water source for livestock, digestion and dilution of feedlot runoff).

Pre-impoundment studies can be used to relate the projected level of thermal effluent from the power plant to the effect on ecological systems in the receiving waters. The resulting aquatic habitat created as a service for power generation can also be affected by heated water discharge from these plants, and the major effects can be summarized as follows (Cairns, 1969):

1. Death through the direct effects of heat. (Precipitation of proteins)
2. Internal functional aberrations. (Changes in respect to rate, growth rate, fecundity, etc.)
3. Death through indirect effects of heat. (Reduced oxygen concentration; disruption and/or cessation of food supply; blue-greens, unavailable as food source for majority of plankton feeders are favored in heated effluents, many species of rotifers, which constitute the major food organisms for young game fish are very sensitive to thermal conditions; decreased resistance to toxic substances)
4. Interference with spawning or other critical activities in the life cycle.
5. Competitive replacement by more tolerant species as a result of the above physiological effects.

Senator Edmund Muskie (U.S. Senate, 1968, hearings before the Subcommittee on Air and Water Pollution) pointed out that (1) waste heated effluent can seriously and adversely affect the ecology of the receiving water, and (2) few utilities have considered the ecological effects of heated water effluent either in site location or operation of thermal generating stations. Moreover, he stressed that little, if any, investigation has been made by most utilities to determine the ecological background of receiving waters. Secretary Udall

(U.S. Senate, Committee on Public Works, 1968) also emphasized the need for preventive action, i.e., evaluating potential water quality hazards and correcting them before they become a water quality problem.

Since the North Anna River will be impounded to serve as a coolant, there will undoubtedly be a significant interest expressed in the recreational and economic assets associated with the reservoir. In order to understand the biotic, physical, and chemical features of impounded waters, it is necessary to have some insight into the history of the river before its waters were impounded. Comprehensive research programs are needed to gain insight into the amount of time required for the community to shift from a lotic to a lentic environment (Gerking, 1963). This, in turn, should assist other state agencies in fish stocking programs and enhance fishery management, i.e., what value is there in stocking a lake in which there is no food? Pre-impoundment studies can also be used to predict potential pollution sources in a new reservoir. Steps can then be taken to correct these sources before they become a problem. Such studies are also beneficial in predicting nuisance vegetational growths which not only detract from the aesthetic, recreational, and economic uses, but also could clog the water intake pipes of industrial plants. Detailed information regarding aquatic studies through pre-impoundment and post-impoundment periods are nonexistent in scientific literature. No doubt such studies have been conducted, but such data has not been formally recorded and probably resides in the files of various state agencies.

There are six pre-impoundment projects currently being supported by Federal funds. Basic procedures involved are similar, but these studies should complement each other rather than duplicate information, as the rivers under study differ in location and physical, chemical, and biological characteristics. The main difference, however, between the project on the North Anna River and other pre-impoundment studies centers around the reason and need for the acquisition of the pre-impoundment information. In addition to the basic and applied knowledge gained from studying changes in the aquatic environment, there are two aspects of using nuclear energy for electrical production which have not been studied in detail and could have significant adverse effects on water quality. These are: (1) the thermal effluent discharged into receiving lake or stream and (2) possible contamination of the receiving waters with radionuclides. None of the pre-impoundment studies currently being funded are directed toward establishing baselines to evaluate the water quality in the future reservoir which will be affected by heated waste discharge and/or possible radioactive contamination from a nuclear powered electrical generating facility. The pre-impoundment study on the

North Anna River proposes to fill an information gap by establishing baselines of radiation background, temperature, oxygen tolerance, etc. on the aquatic flora and fauna of the area, with particular emphasis on those organisms which will "seed" the new reservoir. This information will subsequently be used to evaluate the effects of nuclear powered electrical generation on a reservoir which will be used as a coolant for the nuclear reactors.

With the advent of atomic reactors, greater amounts of electrical energy will be provided by nuclear means in the near future. The demand will increase for information concerning the effect of thermal effluent and possible radioactive contamination in aquatic environments which will be used for recreation purposes. The result of this study will provide a foundation for future observations on water quality and radionuclide levels in the impoundment. A detailed study of the North Anna River Project over a period of several years will also provide a basis through which the effects of nuclear powered electrical generation on the aquatic environment can be predicted. Such a study also forms a baseline for future observations with regard to alterations in community structures as the habitat changes from a lotic to a lentic environment.

INITIATION OF THE PRE-IMPOUNDMENT STUDY

Pre-impoundment studies in the North Anna River basin have been in progress since October, 1968. Acquisition of financial assistance from the Office of Water Resources Research has greatly facilitated and enhanced the research efforts. Collections have been made predominantly at the stations indicated in Figure 2. Samples for bacteriological and routine chemical analyses were collected on a monthly basis while samples for detailed chemical analyses (nutrients, etc.) were collected on a quarterly basis. Biological collections used to evaluate community structure were collected on a quarterly basis corresponding to the yearly seasons (summer, fall, winter, spring). Qualitative biological collections used to supplement the evaluation of the benthic community were also made at irregular intervals.

METHODS

Physical

Temperature data was collected with a calibrated long stem thermometer by immersing the thermometer until equilibration was established.

Flow rate data was obtained on a daily basis from a calibrated discharge station near Doswell, Virginia. The station is approximately 20 miles below the dam site of the impoundment basin and is maintained by the Virginia Department of Conservation and Economic Development, Division of Water Resources. According to John M. Alexander (Commissioner: Testimony before State Corporation Commission, 1969), there is an empirical relationship between flow rate and drainage area within a given river basin. Knowing the drainage area and flow rate at one point and the drainage area at another point, one can then calculate the flow rate at the second point. Accordingly, a factor was obtained from the above office to correct the flow rate at Doswell to approximately the flow rate at the dam site. According to their information, approximately 78% of the flow rate measured at Doswell flows through the proposed dam site.

Water samples collected for analyses of total non-filterable solids were filtered through 0.45 micron Millipore filters that had been previously dried and weighed on a Mettler Balance (type H5). After filtration, filters were again dried and reweighed to determine the dry weight of the suspended non-filterable solids. The filters were subsequently ashed at 500° C for two hours to evaluate the organic and inorganic content of the suspended non-filterable material.

Turbidity values were estimated by means of a Bausch and Lomb Spectronic 20 and expressed in Jackson Units.

Chemical

Oxygen samples were collected with a sewage sampler and analyzed by the Alsterberg (Azide) Modification of the Winkler Method (American Public Health Association, et al., 1960).

Alkalinity samples were also collected with a sewage sampler and analyzed by the potentiometric method after establishing a differential titration curve (American Public Health Association, et al., 1960).

The hydrogen ion concentration was determined electronically with a Corning pH Meter (Model No. 5).

Nutrient samples were analyzed with a Bausch and Lomb Spectronic 20 and Hach chemical reagents.

Biological

Qualitative samples were collected with a D-frame aquatic dip net.

Quantitative samples were also collected with D-frame dip nets, but collections were made for specified periods of time with an equal amount of effort being expended at each collection site. This procedure was utilized in lieu of other, more quantitative means for several reasons.

The nature of the river bottom substrate did not lend itself to sampling with conventional square foot devices due to the paucity of riffles in the river. The bottom is composed primarily of sand, leaf debris, logs, and pools, rather than the typical rubble-cobblestone bottom where such square foot devices are usually employed. In addition, the water level in the river during the winter months would physically prohibit the use of hand-operated bottom sampling devices.

Moreover, the purpose of the study is to sample and evaluate the entire macrobenthic community in the pre-impoundment basin, rather than a specific habitat. Hence, it seemed more reasonable to utilize a method which would transect all available types of habitat.

Furthermore, by obtaining a relatively large sample of the benthic community, the material utilized for community structure analysis could also be utilized for radiological analysis expressing, however, the background radiation as picocuries/milligram dry weight of tissue. Thus, duplication of effort was eliminated.

Community structure at the various stations was analyzed as a diversity index based on the sequential analysis technique of Cairns, et al. (1968). Samples collected in the field were immediately preserved in formalin and subsequently sorted in the laboratory with the aid of a magnified illuminator.

Bacteriological

Water samples for bacteriological analysis were collected in sterilized bottles and carried through the presumptive test of the Multiple Tube Fermentation Technique (American Public Health Association, et al., 1960). The density of the coliform group was expressed as the Most Probable Number/100 ml of water (MPN/100 ml).

Radiochemical analyses were made on biological samples. These samples were analyzed by the Virginia State Department of Industrial Hygiene and the

Virginia Electric and Power Company and were congruent with the type of radiological analyses which the respective agencies perform. Analysis was made for the following gamma emitters: Barium - 140, Cerium - 144, Cesium - 127, Iodine - 131, Iron - 59, Potassium - 40, Ruthenium - 103, Zinc - 65, Zirconium-Niobium - 95.

CURRENT WATER QUALITY STANDARDS FOR THE NORTH ANNA RIVER

The Virginia State Water Control Board has classified all free-flowing tributaries of the York, Mattaponi, and Pamunkey Rivers as III-A. Since the North Anna River is a free-flowing tributary of the Pamunkey River, it would fall into this category (III-A). A body of water designated III-A is classified as a free-flowing stream somewhere between the crest of the mountains and the coastal zone. The waters are generally satisfactory for use as public or municipal water supply, secondary contact recreation, propagation of fish and aquatic life, and other beneficial uses. The specific water quality standards for such bodies of water are as follows:

Dissolved Oxygen:

Minimum	4.0 mg/l
Daily Average	5.0 mg/l

pH: 6.0 - 8.5

Temperature:

Rise above natural	5°F (15°C)
Maximum	90°F (32°C)

Coliform Organisms:

Monthly average value not more than 5000/100 ml (MPN or MF count). Not more than 5000 MPN in more than 20% of the samples in any month. Not more than 20,000 MPN in more than 5% of such samples. Fecal coliforms (multiple-tube fermentation or MF count) not to exceed a long mean of 1000/100 ml. Not to equal or exceed 2000/100 ml in more than 10% of samples.

Discharge for Proposed Reservoir:

40 c.f.s. – minimum guaranteed flow year round (State Water Control Board Ruling, 1971).

RESULTS AND DISCUSSION

Physical Aspects

Flow Characteristics

The North Anna River meanders slowly through the terrestrial communities of agriculture and timber in Piedmont Virginia. The drainage basin has very few municipalities or industries. Most of the area is farmed for agricultural crops, livestock, or timber. The river suffers from a paucity of rock outcroppings which would lend to the formation of extensive riffle areas. The few riffle areas present within the pre-impoundment basin are mostly the remains of old mill dams which have been broken down and strewn along the immediate river bottom. The river bed within the pre-impoundment basin is characteristic of a depositional area and the major portion of the bottom is characterized by shifting sand. Aside from the few riffles, the only permanent substrates are the large logs, limbs, and accompanying leaf debris which are common constituents on the river bottom. Where sand bars attain some degree of permanence, water willow (Justicia americana) is quick to colonize and in turn affords a suitable habitat for many macrobenthic organisms which would otherwise not be able to survive.

The discharge data shows that the highest flow rates occur in early spring (March-April) which corresponds with run-off from spring rainfall. The maximum mean monthly discharge of 222 cfs in April, 1969, is overshadowed only by the record flood in August, 1969, when the mean monthly value of 2,688 cfs was recorded. The maximum flow during the flood peak was 24,300 cfs. Flow rate in the North Anna River was quite variable and closely related to precipitation in the area (Appendix 2).

Initially it seemed that the fluctuation in the sediment load carried by the river would be demonstrable within the station sites established in the pre-impoundment basin. However, the data to date reinforces Minckley's observation (1963) that the concept of a water column, long used in lentic studies, is not applicable in lotic investigations. There was much variation in the sediment concentration at the station sites and no relationship to river mile. The collection sites were not close enough to measure shifts in sediment loads. As an illustration of this, collections were made at Station I and II on February 26, 1970. On this date a new bridge was being constructed and, because of its headwater nature, the sediment load was abnormally high (88.9 mg/l). However, the river had deposited this load and returned to normal 11.5 miles further downstream. Moreover on two occasions, September 20, 1969, and January 20, 1970, the level of suspended solids rose from 41.3 to 203.4 mg/l and 45.2 to 130.7 mg/l, respectively, between two stations only 1.6 river miles apart. There is no known major source of sediment influx through this distance. Even though there was considerable variation at individual stations, a statistical comparison between the stations (4) upstream and downstream (3) from Contrary Creek showed a significant difference in non-filterable solids at the 10% level (t_{73} = 1.3176).

Contrary Creek usually carries very little suspended material. Parsons (1968) stated that acid polluted streams are usually clear because of oxidation and subsequent precipitation of the metals. Precipitation of the metals pulls the other suspended material from the water. The average of eight total solids samples taken from this tributary, excluding flood or high water conditions, was 15.8 mg/l. Under high water or flood conditions, this value rose to 1623.0 mg/l. Evidently Contrary Creek loads the downstream area with sediment under flood conditions and the sediment is sporadically removed. The tributaries to the North Anna, which will eventually form the cooling lagoons, averaged 8.4 mg/l.

To date no known standards have been imposed regarding total non-filterable solids on Virginia's waters. Cairns (1968) states that arbitrary standards of fixed concentrations cannot be set for all systems; rather the tolerance range for the respective drainage system and region should be established. The recommendation for Settleable Solids of the National Technical Advisory Committee to the Secretary of the Interior (1968) is such that settleable materials should not be added to natural waters in quantities that adversely affect the natural biota. Since no definitive standards are available, it is difficult to determine whether or not the sediment load is excessive or minimal in the North Anna River.

Turbidity measurements were somewhat more definitive. However, even here one could not definitely show a major difference between the area upstream from Contrary Creek and that below. Of the 60 turbidity readings taken in the pre-impoundment basin on the North Anna River itself, 96.6% were over 25 JTU, 60% over 50 JTU, 25% over 75 JTU, and 10% over 100 JTU. The area below Contrary Creek on this date averaged 149 JTU. The lowest turbidities were during the months of February and March. Probably the sudden thunder storms during the summer months created a greater level of turbidity than at other times. During the winter months when the ground is frozen and torrential rains are less frequent, the effects of turbidity are lessened.

As with the total non-filterable solids, the turbidity values for Contrary Creek were low. The values over the period of study averaged 62 JTU with a range between 30 JTU and 109 JTU. The tributaries of the river forming the future lagoons averaged 41 JTU with a range between 26 JTU and 56 JTU.

Temperature

Temperature values in the river were very constant through the pre-impoundment basin on any given collection date. The annual temperature of the main river in the pre-impoundment basin makes an excursion of approximately 31°C. The river is 5.0°C or colder during the months of December through February. Ice formation was quite common in the river during January and February, 1969. In some cases the river was almost frozen completely over except for a small mid-channel. The temperature climbs rapidly through April and plateaus in the middle 20's throughout the summer months. The temperature beings to decline in August and falls rapidly through October. Figure 8 shows the annual temperature cycle of the river in the pre-impoundment basin. Each value is an average for the river on that date.

Chemical Aspects

Oxygen

Figure 8 shows the average oxygen levels in the North Anna River in the pre-impoundment basin. As the graph shows, the concentrations and saturations were highest during the winter months. The lowest oxygen value obtained prior to dam construction 6.4 mg/l, was in August, 1969, and the highest values, greater than 13.0 mg/l, occurred in January, 1969. Even during the summer months, oxygen saturation values were usually in excess of 80%. During the spring of 1970, lower than normal oxygen values were obtained at Station VI, immediately below the dam site. In comparison to the previous year at the same time, the oxygen concentration was depressed approximately 2 mg/l. On any given collection date the oxygen concentration in the river was greatest at Station III. This was due to the collection of water samples at a bridge immediately below a small waterfall at Holladay Mill Pond. The increase was quickly lost however, and saturation values returned to normal.

Alkalinity and pH

Analyses of water samples for alkalinity and pH showed that the river water was neutral-basic with soft-medium hardness. The pH measurements were plagued by the fact that readings were one thing upon placing the electrodes in the water sample, but changed with gentle stirring.

Alkalinity values ranged between 11 and 33.0 mg/l with values at Station V (below Contrary Creek entrance) being lower than Station IV (above Contrary Creek entrance). A statistical comparison of the alkalinities between the upstream and downstream stations from Contrary Creek showed a significant difference at the 10% level ($t_{85} = 4.8524$).

Minerals

The chemical analyses of nutrients also showed a great deal of variation between stations. As would be expected, iron, magnesium, and sulfur (in the form of sulfates) were the most abundant. Iron was usually present at concentrations near 1.0 mg/l. The concentration of magnesium was greater, usually being several mg/l higher below the entrance of Contrary Creek. On February 16, 1969, the concentration of magnesium reached 13.88 mg/l at Station V, 4 miles below Contrary Creek. The value then dropped to 3.07 mg/1 within 8.6 miles. Sulfate concentrations varied considerably and were not always associated with the area immediately below the entrance of Contrary Creek. Concentrations of copper usually ranged between 0.5 to 1.0 ppm and zinc near 1.0 ppm. As with the other nutrients, the concentration of these metals was not always in greatest abundance immediately below Contrary Creek. The State Water Control Board reported two fish kills below Contrary Creek in 1970. Investigators were on the scene at the next high water period and reported 1.91 mg/l zinc, 0.02 mg/l chromium, 0.23 mg/l lead, 8.2 mg/l copper, and 28.0 mg/l of iron at State Route 652 on Contrary Creek.

Analysis of the water and a water-sediment slurry on Contrary Creek at a low flow period showed considerable quantities of iron, silicon, calcium, aluminum, magnesium, barium, titanium, lead, manganese, copper, and zinc. A summary of the analysis is presented in Table 3.

Measurements of phosphorus and nitrogen indicate that the river in the pre-impoundment area did not possess levels indicative of eutrophication. Mackenthun (1968) proposed that the concentration of phosphorus in flowing water should not exceed 0.1 mg/l if biological nuisances are to be avoided. Phosphorus values exceeded this recommended level only once. The extremely high phosphorus values observed in May, 1969, cannot be explained at this time.

Benthic Studies

The greatest contrast in water quality in the pre-impoundment basin centered around the effects of drainage from Contrary Creek upon the macrobenthic communities (Table 5). Figure 9 summarizes the tabulated data and shows the mean seasonal diversity index of macrobenthic communities for one year in the study area. As Figure 9 illustrates, the range of the diversity indices at the control station (Station IV – State Route 208) was very small (S.D. = ±0.02); whereas, the range at the farthest point downstream (Station VII – State Route 658) was considerably greater (S.D. = ±0.08). Contrary Creek showed the greatest range of community diversity (S.D. = ±0.19) and always exhibited the lowest diversity index at any time. A statistical comparison of diversity indices between the control station (State Route 208), and the station immediately below Contrary Creek and Station VII (State Route 601) showed significant differences at the 10% level (t_6 = 3.2986 and t_6 = 1.6409, respectively). Similar comparisons of diversity indices between the control station and the farthest station downstream showed no significant differences at the 10% level (t_6 = 0.9567). This would indicate that the river had recovered at this point. However, a different picture emerges if population sizes, species numbers, and composition of community structure are compared between these two stations.

Figure 10 shows the composition of the macrobenthic communities at the control station above the entrance of Contrary Creek. Although there was some variation of representation of the various orders between seasons, the more sensitive macrobenthic groups (Plecoptera, Ephemeroptera, Trichoptera, and Mollusca) were well represented at all times.

Figure 11 shows an analysis of community structure at Station VII. Note that while the more sensitive insect orders have become re-established, the molluscan species have not. The mollusca at Station IV represented 23 to 44% of the benthic community. Table 6 lists the values for sample size and species numbers for the stations considered in the study. Even though there was no significant difference between the diversity indices at Station IV (control) and Station VII (farthest point downstream) there was a significant difference at the 10% level between the sample sizes (t_6 = 3.0681) and the number of species represented (t_6 = 1.7521). Great care was taken during the first three collecting periods to see that equivalent amounts of time were spent at each station. The sample sizes at Station IV were very consistent;

whereas, the sample size at Station VII varied considerably. The increase in the sample size at Station IV for the summer season, 1970, was due to a longer collection time being spent.

The basin was being cleared, and an effort was made to obtain as many organisms as possible. Since the sample size at Station VII did not show a corresponding increase, it is difficult to assess the significance of an extended collection time on the sample size at Station VII. The inability of the diversity indices to show a significant difference probably originates from the small sample sizes in some of the collections at Station VII. Cairns (1968) in proposing the technique, stated that approximately 200 to 250 organisms are needed to obtain a valid index. As Table 6 shows, this number was not obtained on two occasions.

As stated earlier, the diversity index on Contrary Creek was consistently lower than any of the other stations. Figure 12 shows the seasonal composition of the macrobenthic community on this acid polluted stream. Note that the dominant order was the Diptera and this consisted of one Chironomid species close to Chironomous attenuatus. The majority of other species collected were surface water forms such as Gerris conformis or Dineutus vittatus. Other species of aquatic insects were collected, but nearly all of these consisted of last instar stages. All species of aquatic insects, other than the Chironomid species could be found in the unpolluted upstream tributaries of Contrary Creek. Since only the last instar forms were found, it would appear that the macrobenthic fauna on Contrary Creek, other than the Chironomids, is derived from the drift fauna from upstream tributaries.

After the first summer of collecting, it was established that the sample sizes at Station VII were consistently lower than observed at Station IV, and the molluscan species had not become re-established at Station VII. A study was undertaken during the fall of 1969 to evaluate the community structure in the tributaries of the North Anna River which would form the lagoon system in the new reservoir (Stations L-5, L-6, L-7, L-8). Figures 13 through 16 represent the results of the study. The investigation revealed that five of the seven molluscan species collected at Station IV could be found in one or more of the tributaries. It is a well established fact that benthic invertebrates exhibit drift, and Hynes (1970) has reviewed the subject in detail. Since benthic faunas exhibit drift characteristics, it is reasonable to assume that these species are being introduced into the recovery area, but are failing to become re-established. Although drift studies have indicated that the gastropod species drift very little (Hynes, 1970), it would seem that the pelecypod species would be well adapted to migration into these areas through the glochidia and their obligatory parasitization of fish.

Radioisotopes

Samples were sent to VEPCO and the Department of Industrial Hygiene. VEPCO reported that gamma scans indicated less than five (5) picocuries (pCi) per total sample for the following isotopes: Fe - 59, Co - 60, Zr - 95, Pu - 106, and Cs - 137. The Department of Industrial Hygiene counted beta radiation in the mussel sample and reported the activity shown in Table 7. No particular standards appear to be available regarding whether said counts are high or low. The Department of Industrial Hygiene reported that the counts were slightly higher than observed from clam populations in coastal waters. However, the Department suggested additional samples be taken before making a definitive statement. Additional samples have been collected and are in the process of being prepared.

CONCLUSION

The information gathered thus far on existing water quality conditions in the pre-impoundment area on the North Anna River shows that Contrary Creek has severely altered the macrobenthic communities below the confluence of Contrary Creek and the North Anna River. This alteration is probably due more to the presence of heavy metals and silt draining from Contrary Creek than to a low pH. Results show that the North Anna River has not fully recovered biologically for at least 14 miles downstream below the entrance of Contrary Creek even though additional species are probably being introduced from the tributaries by drift. The point at which the North Anna River recovers to the extent that the macrobenthic fauna is comparable in diversity and members to the the area above Contrary Creek has not been determined.

Since the old spoil banks and mine sites on Contrary Creek will not be covered by the impoundment, precautions should be taken to halt any erosion, siltation, and heavy metal introduction into the new reservoir. Otherwise, the reservoir will probably concentrate these biological deterrents and become a biological desert. Flushing of the impoundment during heavy periods of rainfall would, therefore, further deteriorate the biological communities below the impoundment site.

The results of the study thus far support the observation that the Virginia Electric and Power Company is building their impoundment on the most suitable Piedmont river because, ecologically speaking, the water quality is such that other potential uses in the pre-impoundment area have been eliminated. The presence of the impoundment will in all probability enhance the future water quality of the North Anna River Basin. The recovery zone, when located, is expected to move upstream as the drainage effects of Contrary Creek subside.

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TABLE 1

MORPHOMETRIC DATA OF PROPOSED RESERVOIR ON THE NORTH ANNA RIVER[1]

Type of dam	Compacted earth
Length of dam	3,000 feet
Drainage area	343 square miles
Approximate total area	14,500 acres
Approximate area available for recreational use	11,000 acres
Approximate area used to hold thermal effluent	3,500 acres
Volume - acre feet at 250 ft elevation	360,000 acre feet
Volume - cubic feet at 250 ft elevation	15.7×10^9 cubic feet
Approximate length of reservoir	15 miles
Normal pool elevation	250 MSL
Depth of water at dam	80 feet
Length of shoreline	105 miles
Maximum recorded flow of river	24,300 cfs (August 21, 1969)
Minimum recorded flow of river	1 cfs (September-October, 1932)

[1]Condensed from brochure submitted by VEPCO to the Virginia State Water Control Board for certification of project.

TABLE 2

ENGINEERING FEATURES OF PROPOSED IMPOUNDMENT OF LIMNOLOGICAL INTEREST AND IMPORTANCE[2]

Type of electrical generating facility	Nuclear powered
Potential number of generating units	5
Potential kilowatt capability	4,000,000
Proposed beginning of commercial operation of first unit	1974
Amount of water needed for cooling unit No. 1	1,600 cfs
Amount of water needed for cooling at maximum operating capacity	4% of reservoir volume per day
Minimum flow guaranteed regardless of reservoir level	40 cfs
Maximum temperature of discharge into treatment lagoon at maximum operating capacity	38°C
Projected maximum temperature in lake at maximum operating capacity	32°C

[2] Ibid.

TABLE 3

LOW FLOWS FROM ADOPTED FLOW FREQUENCY CURVES
NORTH ANNA RIVER NEAR DOSWELL, VIRGINIA
DRAINAGE AREA = 439 SQUARE MILES[3]

Duration	Recurrence Interval in Years				Most Probable	Mean
	2	5	10	30		
1 Day	35.0 cfs	10.0 cfs	5.0 cfs	2.0 cfs	49.0 cfs	27.0 cfs
7 Days	45.0 cfs	15.0 cfs	6.5 cfs	3.0 cfs	58.0 cfs	38.0 cfs
30 Days	70.0 cfs	25.0 cfs	12.0 cfs	5.0 cfs	–	–
60 Days	85.0 cfs	35.0 cfs	20.0 cfs	10.0 cfs	–	–
120 Days	150.0 cfs	55.0 cfs	40.0 cfs	28.0 cfs	–	–
274 Days	220.0 cfs	150.0 cfs	140.0 cfs	100.0 cfs	–	–

Average Flow Over 35-Year Period = 380 cfs

[3]Virginia Department of Conservation and Economic Development. Division of Water Resources. Vol. III – Hydrologic Analysis, York River Basin. Planning Bulletin 227.

TABLE 4

ANALYSES OF WATER AND WATER/SEDIMENT
(SIMULATED HIGH DISCHARGE)
DURING LOW FLOW CONDITIONS ON CONTRARY CREEK
AT STATE ROUTE 522, AUGUST 10, 1970

Element (ppm)	Water	Water/Sediment
Iron	78.09	465.04
Silicon	51.05	465.04
Calcium	21.62	36.54
Aluminum	18.62	212.59
Magnesium	28.23	93.01
Barium	nil	2.49
Boron	trace	nil
Titanium	nil	6.31
Lead	0.34	2.16
Manganese	3.84	2.96
Gallium	nil	0.16
Nickel	0.02	0.04
Vanadium	nil	0.08
Copper	0.19	0.73
Sodium	trace	23.58
Zinc	9.61	10.63
Silver	nil	0.02
Cobalt	0.13	0.14
Potassium	trace	trace
Strontium	0.04	0.16
Chromium	0.01	0.24
Other Elements	nil	nil
Total Solids, mg/l	1045.35	3288.83
Sulfate ash, mg/l	600.73	3321.73
% of T. S.	57.47	101.00

TABLE 5

DIVERSITY INDICES OF THE CONTROL, POLLUTED AND RECOVERY STATIONS IN THE PRE-IMPOUNDMENT AREA ON THE NORTH ANNA RIVER

Station No.	IV State Route 208	L-V State Route 652 Contrary Creek	Below Entrance Contrary Cr.	VI State Route 601	VII State Route 658
Diversity Index					
Summer - 1969	0.93	0.20	0.83	0.58	0.99
Fall - 1969	0.92	0.01	0.56	0.72	0.87
Spring - 1970	0.90	0.50	0.80	0.93	0.90
Summer - 1970	0.96	0.06	0.70	0.92	0.77
Mean	0.92	0.19	0.72	0.78	0.88
S. D.	0.0217	0.1907	0.1054	0.1462	0.0785
S. E. Mean	0.0108	0.0954	0.0527	0.0731	0.0393
95% Conf. Limits	0.0212	0.1869	0.1033	0.1433	0.0770

TABLE 6

SAMPLE SIZES AND NUMBER OF SPECIES COLLECTED AT THE CONTROL, POLLUTED AND RECOVERY STATIONS IN THE PRE-IMPOUNDMENT AREA ON THE NORTH ANNA RIVER

Station No.	IV		L-V				VI		VII	
Location	State Route 208		State Route 652 Contrary Creek		Below Entrance of Contrary Creek		State Route 601		State Route 658	
Collection Period	Sample size	No. of species	Sample size	No. of species	Sample size	No. of species	Sample size	No. of species	Sample size	No. of species
Summer - 1969	1152.0	49.0	208.0	9.0	77	24	729	33	495.0	42.0
Fall - 1969	1174.0	46.0	135.0	4.0			838	38	80.0	34.0
Spring - 1970	1128.0	31.0	45.0	3.0	149	15	68	18	51.0	18.0
Summer - 1970	2848.0	48.0	833.0	10.0	140	12	596	35	313.0	34.0
Mean	1575.5	43.0	305.3	6.5	122.0	17	557.8	31	234.8	32.0
S. D.	734.9	7.3	310.1	3.0	32.0	5.1	295.5	7.7	181.4	8.7
S. E. Mean	367.4	3.6	155.1	1.5	18.5	2.9	147.7	3.9	90.7	4.4
95% Conf. Limits	720.2	7.2	303.9	3.0	36.2	5.8	289.6	7.6	177.7	8.5

TABLE 7

BETA COUNT ANALYSES OF MUSSELS

Isotope	Picocuries/gm wet meat
Iodine - 131	0.098 ± 0.021
Ruthenium - Rodium 106	1.22 ± 0.27
Cesium - 137	0.073 ± 0.031
Zircon - 95	0.031 ± 0.006
Zinc - 65	0.0122 ± 0.042
Barium - 140	0.040 ± 0.02
Potassium - 40	0.0012 ±0.0004

FIGURE 1. PROPOSED IMPOUNDMENT ON THE NORTH ANNA RIVER.

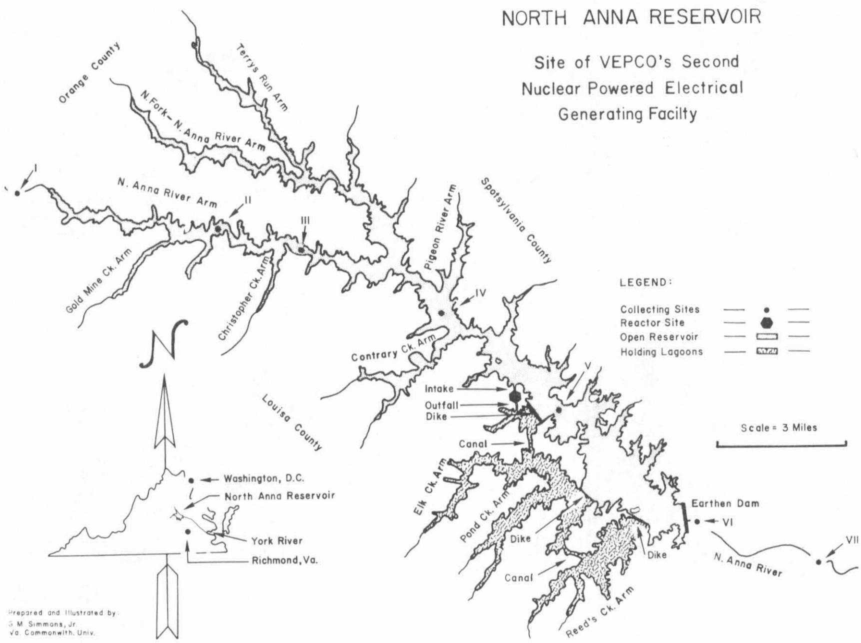


FIGURE 2. DRAINAGE BASIN OF PROPOSED IMPOUNDMENT SHOWING COLLECTION SITES.

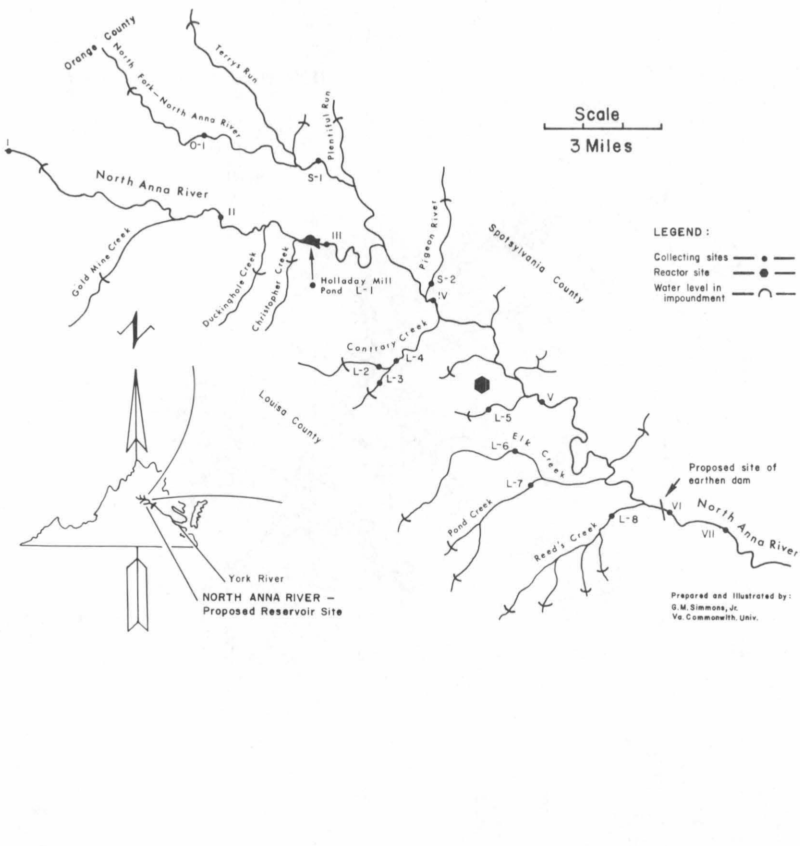


FIGURE 3. LONGITUDINAL PROFILE OF NORTH ANNA RIVER THROUGH THE PRE-IMPOUNDMENT BASIN.

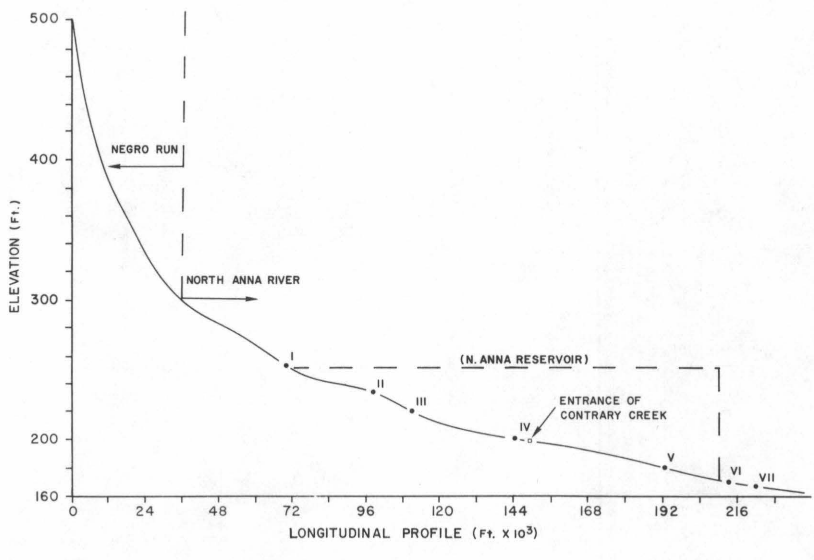


FIGURE 4. AERIAL PHOTOGRAPH OF A PORTION OF THE CONTRARY CREEK BASIN. STATE ROUTE 652 - STATION L-4 AND BRIDGE ACROSS CONTRARY CREEK ARE IN FOREGROUND.

FIGURE 5. EROSIONAL EFFECTS OBSERVED FROM BRIDGE ON STATE ROUTE 652 ACROSS CONTRARY CREEK. LEFT OF CENTER UPSTREAM VIEW.

FIGURE 6. EROSIONAL EFFECTS CAUSED BY ACID MINE DRAINAGE AS OBSERVED FROM BRIDGE ON STATE ROUTE 652 ACROSS CONTRARY CREEK. CENTER UPSTREAM VIEW.

FIGURE 7. EROSIONAL EFFECTS CAUSED BY ACID MINE DRAINAGE AS OBSERVED FROM BRIDGE ON STATE ROUTE 652 ACROSS CONTRARY CREEK. RIGHT OF CENTER UPSTREAM VIEW.

FIGURE 8. SUMMARY OF TEMPERATURE, OXYGEN, AND PER CENT SATURATION OF OXYGEN FOR THE STUDY PERIOD IN THE PRE-IMPOUNDMENT BASIN.

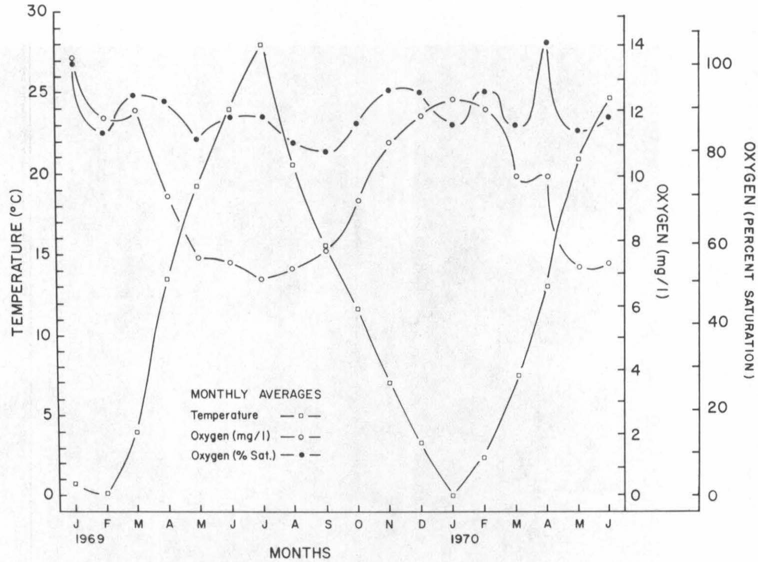


FIGURE 9. SUMMARY OF DIVERSITY INDICES IN THE NORTH ANNA RIVER FOR THE PERIOD OF STUDY.

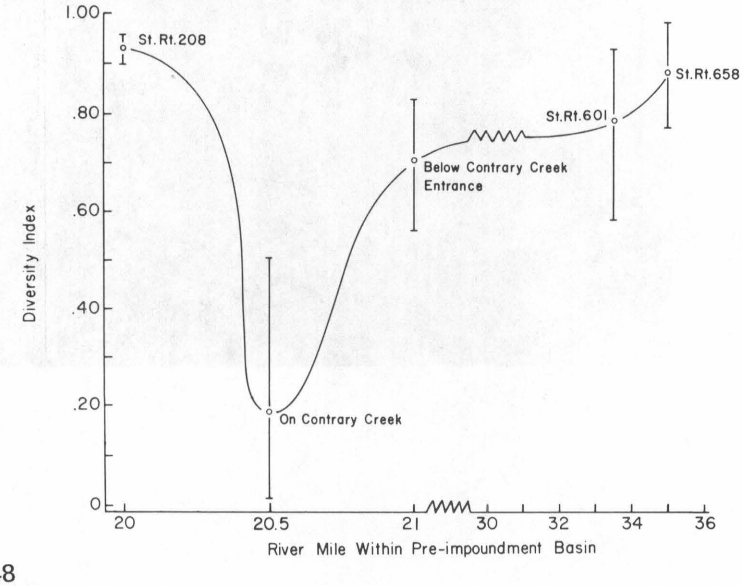


FIGURE 10. COMMUNITY STRUCTURE OF MACROBENTHOS AT STATE ROUTE 208 FOR THE PERIOD OF STUDY.

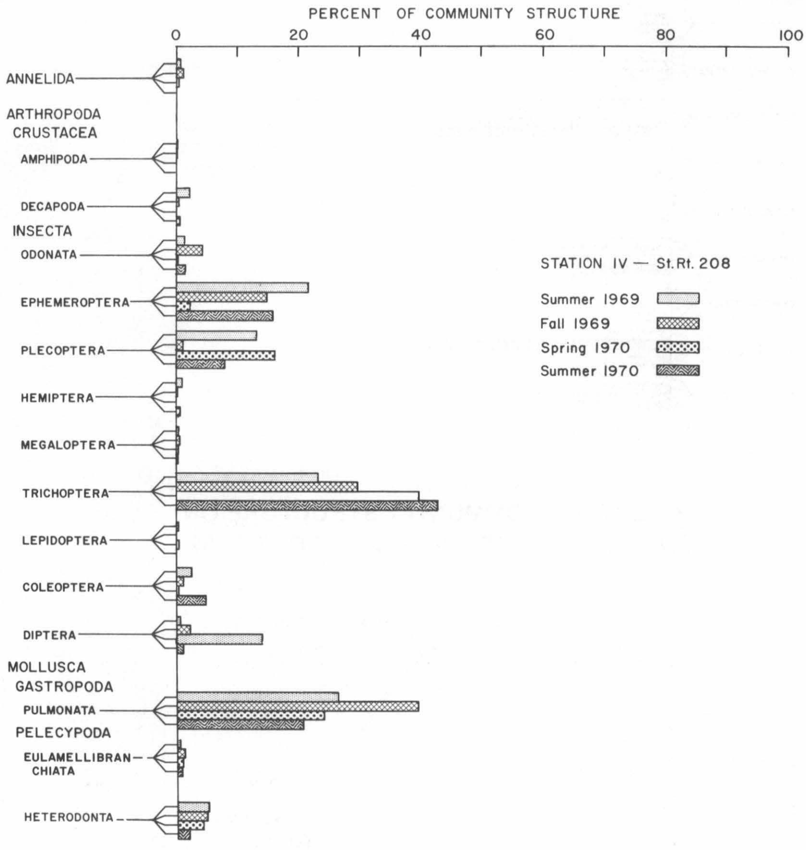


FIGURE 11. COMMUNITY STRUCTURE OF MACROBENTHOS AT STATE ROUTE 658 FOR THE PERIOD OF STUDY.

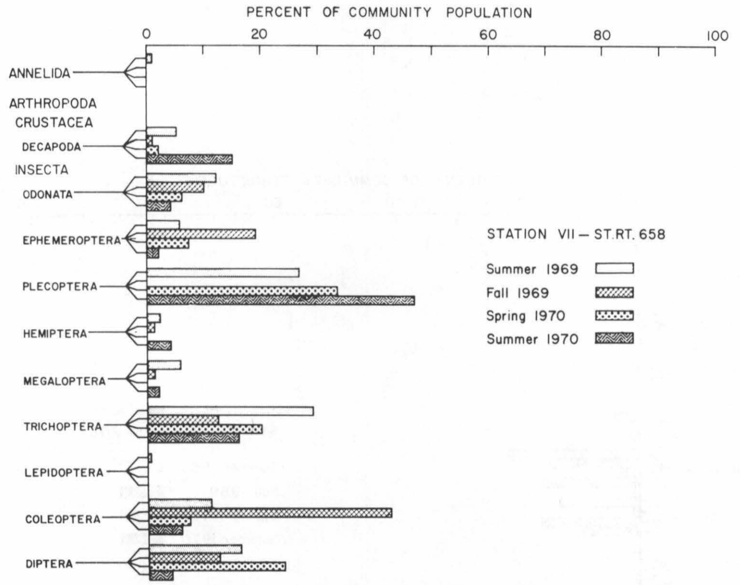


FIGURE 12. COMMUNITY STRUCTURE ON CONTRARY CREEK AT STATE ROUTE 652.

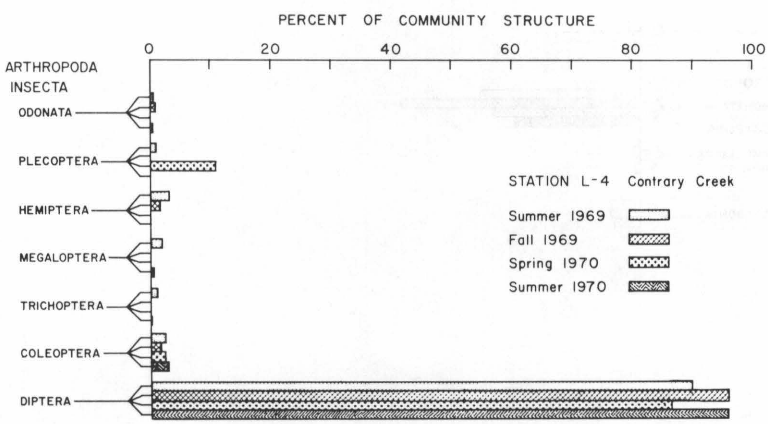


FIGURE 13. COMMUNITY STRUCTURE IN MEL'S CREEK AT STATION L-5 DURING EARLY FALL, 1969.

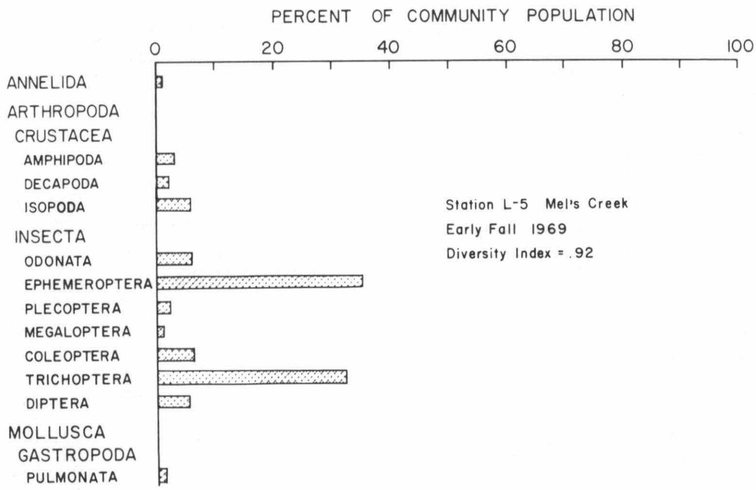


FIGURE 14. COMMUNITY STRUCTURE IN ELK CREEK AT STATION L-6 DURING EARLY FALL, 1969.

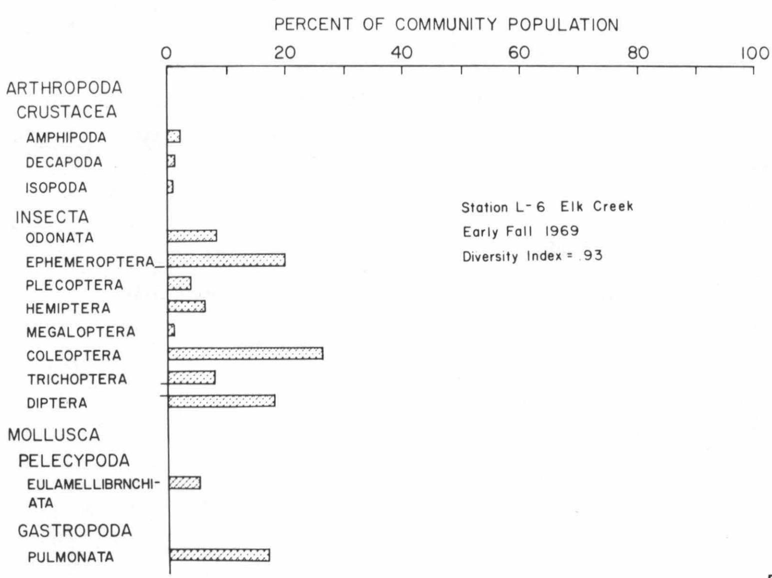


FIGURE 15. COMMUNITY STRUCTURE IN POND CREEK AT STATION L-7 DURING EARLY FALL, 1969.

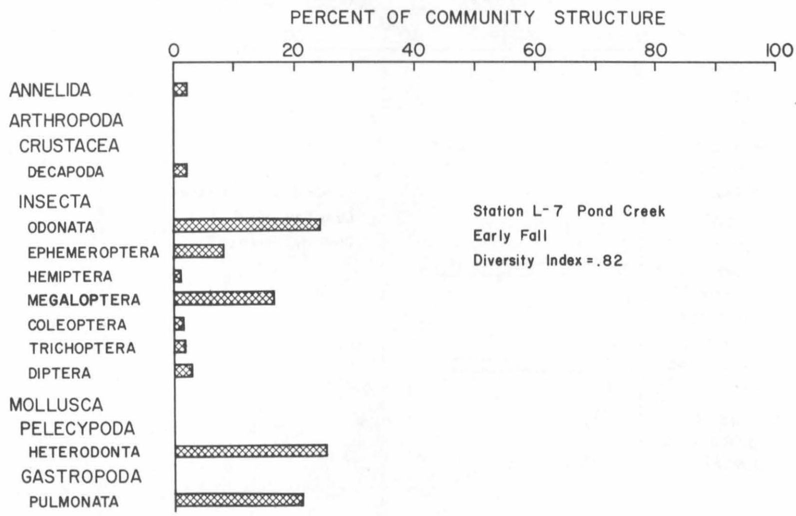
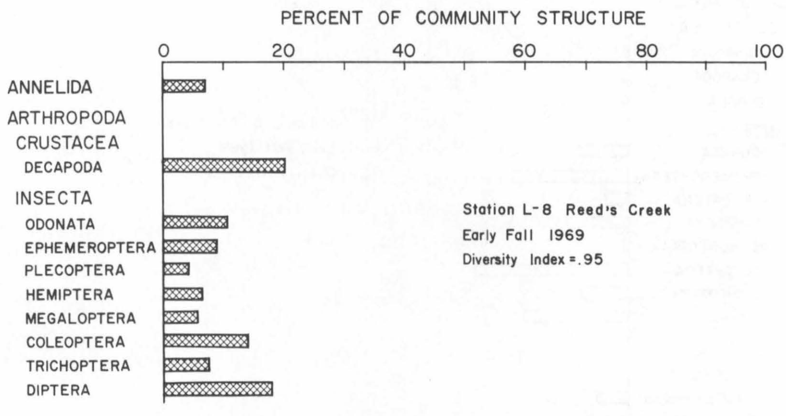


FIGURE 16. COMMUNITY STRUCTURE IN REED'S CREEK AT STATION L-8 DURING EARLY FALL, 1969.



ELECTROCHEMICAL ACTIVATION AND REGENERATION OF CARBON SURFACES FOR TERTIARY WATER TREATMENT

Project A-032-VA

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ELECTROCHEMICAL ACTIVATION AND REGENERATION OF CARBON SURFACES FOR TERTIARY WATER TREATMENT

Description of Research Performed

The objective of this project was to study the feasibility of electrochemically activating and regenerating carbon surfaces for use in tertiary water treatment to remove persistent pesticides. Work performed during the fiscal year 1969-70 was concerned with development of activation procedures. Work during fiscal year 1970-71 was directed toward study of the absorption process for a selected pesticide and toward the development of a small scale absorption cell for use in pesticide removal from otherwise potable water.

Summary of Experimental Work

(a) Selection of a pesticide for study and development of analytical methods. The pesticide Dieldrin was chosen for study and an analytical scheme was devised for its detection. Analysis for Dieldrin was based on extracting the aqueous Dieldrin with chloroform, evaporating the chloroform extract, and then dissolving the Dieldrin residue in hexane. The hexane solution was analyzed in a gas chromatograph with an electron capture detector. Standard solutions of 99.5^{+}% Dieldrin in hexane were used as standards in calibrating the chromatograph. Average recovery factors for Dieldrin in the extraction procedure were found to be about 91%, and the average reproducibility of the analysis was ±13%.

(b) Study of Dieldrin degradation. Because some of the experiments were of several weeks duration, a study was made of the stability of aqueous Dieldrin solutions. A solution of 0.30 ppm Dieldrin in distilled water at room temperature was placed in a glass beaker and stirred with a Teflon covered stirring bar. Samples were removed and analyzed every 24 hours for seven days. The results of this indicated a Dieldrin decomposition that was first order in Dieldrin with a reaction rate constant of 0.00865 hr^{-1}.

(c) Studies of the dynamics of Dieldrin absorption on carbon surfaces. Initially it was assumed that pesticides would simply absorb on exposed carbon surfaces and that an equilibrium between absorbed and dissolved pesticide would be rapidly established. Study of the resulting absorption equilibrium was carried out by immersing carbon coupons in beakers containing a measured volume of aqueous Dieldrin and determining the loss of Dieldrin from the solution phase. In the course of these studies, it was found that there is indeed a surface equilibrium that is established within minutes, but it was also found that a slow absorption process continues that requires about 24 hours for substantial completion. Furthermore, not all of the absorbed Dieldrin can be recovered by elution with distilled water, and this suggested that there may be another even slower absorption process.

A model for the absorption process was developed, and an analytical solution was obtained for the expected time variation of the solution phase Dieldrin concentration following immersion of the carbon coupon. However, data analysis is imcomplete at present.

Tentatively, it is assumed that rapid absorption of Dieldrin by the carbon surface is simply absorption on wetted carbon surfaces and that the continuing slow absorption is either due to surface diffusion of Dieldrin into macropores not wetted by the solution or else is due to diffusion of Dieldrin into the carbon structure along grain boundaries.

(d) Equilibrium studies. Because of the two types of absorption phenomena observed, a fast surface absorption completed in minutes and a slower absorption step requiring about 24 hours for completion, two types of equilibrium measurements were made. A pseudo-equilibrium was determined by measuring the Dieldrin absorption taking place after a contact time of 10 minutes and a second equilibrium was taken to be that absorbed after 24 hours of contact. Data necessary for constructing a curve of equilibrium solution concentration versus surface uptake in the range of 0 to 0.30 ppm aqueous Dieldrin were obtained at 25°C. Typical results are shown in Table 1 for Graphitar 39, a commercial carbon manufactured by the U.S. Graphite Co.

TABLE 1

DIELDRIN ABSORPTION EQUILIBRIUM

10 min equilibrium		24 hr equilibrium	
soln. conc. ppm	Dieldrin absorbed Mg/cm^2	soln. conc. ppm	Dieldrin absorbed Mg/cm^2
0.164	0.83	0.012	6.3
0.200	2.06	0.014	10.3
0.230	3.17	0.018	13.1
0.270	6.97	0.054	17.6

As can be seen from Table 1, the 24 hr equilibrium is responsible for most of the ultimate absorptive capacity of the carbon.

(e) Design, construction, and operation of a pilot scale absorption cell. A small scale absorption cell was constructed. This consisted of a plexiglas enclosure designed to hold two parallel rows of carbon coupons with a spacing of .035 in. between the parallel carbon surfaces to allow passage of an aqueous solution of Dieldrin. The spacing between the surfaces was that calculated to give 90% removal of Dieldrin with fresh carbon surfaces at the desired rates of water treatment. The cell contained two rows of coupons (Graphitar 39) with 8 coupons of dimensions 2 1/4 x 2 1/4 x 1/2 in. in each row. A solution of 0.20 ppm Dieldrin in distilled water at room temperature was fed to the absorption cell at a rate of about 2.9 liters/day for a 20 day period. During this period the effluent was analyzed for Dieldrin. Following this absorption cycle, the cell was eluted with distilled water at a flow rate of about 3.0 liters/day for seven days and the effluent was analyzed for Dieldrin. The carbon was then removed from the cell and electrochemically activated by the procedures previously determined. The activated carbon was remounted in the absorption cell and 0.20 ppm Dieldrin was again passed through the cell for a 20 day period at a rate of 2.9 liters/day.

Results from the pilot scale absorber showed an initial Dieldrin removal of 85% and this slowly dropped during the 20 day absorption cycle to give 53% removal at the 20th day. Elution with distilled water recovered only about 15% of the Dieldrin absorbed. Following electrochemical activation, an initial Dieldrin removal of 95% was observed. The percent removal slowly decreased during the 20 day cycle, and on the 20th day a removal of about 60% was observed.

IMPROVING WATER QUALITY BY REMOVAL OF PESTICIDE POLLUTANTS WITH AQUATIC PLANTS

Project A-033-VA

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IMPROVING WATER QUALITY BY REMOVAL OF PESTICIDE POLLUTANTS WITH AQUATIC PLANTS

Research during the first year has included 2,4-D, diphenamid, atrazine, dicamba, and dichlobenil herbicides. Several aquatic plants were used including algae, submersed species, and emersed species. The research involving each pesticide is reported separately. All studies except algae were conducted under controlled environmental conditions with 12 hour days of 1300 lux at 21°C and 12 hour dark periods at 20°C. Algae studies were under 1500 ft-c continuous light at 23°C.

1. Atrazine: Parrotfeather (Myriophyllum brasilienses L.) shoot cuttings rooted in Vermiculite for 10 days were transplanted to 473 ml jars (5 plants per jar) containing 1/2 strength Hoagland's solution 8 days before initiating removal studies. Atrazine was used at 0, 1×10^{-7}, 1×10^{-6}, and 1×10^{-5} molar concentrations in 400 ml of water per jar. Samples of the solutions were taken to determine the amount of chemical remaining at various intervals. After 20 days, the amount of ^{14}C-labeled material contained in the plant was determined. The effect of atrazine on growth and transpiration was also recorded.

The data reported have been summarized in Figure 1. The growth of parrotfeather was quite rapid even in the presence of 10^{-6} and 10^{-7} M atrazine-^{14}C. These plants gained over 50% in length of shoot during a 3 week period. Atrazine-^{14}C became inhibitory at 10^{-5} M reducing growth to 1/3 the normal rate.

Transpiration rate continued to increase as plants became larger indicating normal flow of water through the plant. The high concentration of atrazine may be influencing this process as a leveling off occurred.

Atrazine-^{14}C removal was gradual from the solution over the 20 days. About 28% of the atrazine in the cultures was removed during a 20-day period by parrotfeather. The remainder was accounted for in the culture (66%), sampling and volatility (4%), and unaccounted loss through plants (2%).

2. Dicamba: A similar study with parrotfeather and dicamba-^{14}C is presented in Figure 2. The growth of these plants was quite good during this study increasing shoot length about 10 cm in 20 days. The rate of transpiration was not affected by the dicamba in solution. The rate of removal of dicamba was about 28 to 40% in 20 days or slightly better than

for atrazine. This may be directly related to transpiration rate as the plants used in the dicamba study also removed more water from the culture.

Water hyacinth (Eichhornia crassipes L.) transpired at 6 times the rate of parrotfeather. The amount of dicamba-^{14}C removed from solution was considerably more for water hyacinth, but this was not in proportion to the increased water flow through the plant (Figure 3). Dicamba has been shown to translocate in both apoplast and symplast. It is likely that some dicamba is moved up in the plant and then retranslocated back to the roots for release back to the culture solution.

3. Diphenamid: Effects of diphenamid on parrotfeather transpiration and growth were studied. Growth and transpiration was similar in 1×10^{-6} and 1×10^{-5} M diphenamid solutions while a 1×10^{-4} M concentration caused an immediate reduction in transpiration. Parrotfeather plants died within one week at the higher treatment level.

Diphenamid was removed gradually from solution as shown in Figure 4. This herbicide has been found to inhibit root growth primarily in crop plants. In the case of parrotfeather, the shoot tip showed the first visual effects of diphenamid in the form of dieback.

4. 2,4-D: The studies with 2,4-D have been with unicellular algae. Uptake studies of 2,4-D-2-^{14}C were conducted with the unicellular alga, Chlamydomonas reinhardtii. Under bacteria free conditions, the algal suspension was agitated on a reciprocal shaker at 80 excursions per minute in a growth chamber maintained at 23°C and 1500 ft-c at the flask surface using both fluorescent and incandescent light. The herbicide was added to the suspension at 1×10^{-5} M and subcultures prepared to have five sampling times from 0 to 72 hours after initiating the pesticide into the culture. Initially, the alga rapidly removed 2,4-D from the culture. However, the rate of uptake was slower but steady after a short period. As a result the rate of increase in cell mass was greater than pesticide uptake. After 72 hours the algal tissue had a concentration of herbicide and/or metabolite 90 times that in the initial culture fluid.

An uptake and metabolism study was conducted with Scenedesmus (a green alga) over a three day period. 2,4-D concentration was 1.1 ppmw. The experimental procedure was the same as described previously. The amount of radiolabel in solution was monitored over the three day period as was the amount in the cells. The algal culture was fairly dense at the beginning of the experiment (0.077 mg dry wt/ml) but did increase to 0.11 mg dry wt/ml by the end of the experiment.

The data indicate that over 50% of the uptake during the entire experiment occurred during the first few minutes, and 100% of the uptake observed occurred within 24 hours. The total uptake was about 10% of the original material applied.

Since algae are notorious for producing extracellular storage products, it was thought that the radiolabel being detected in solution was not all 2,4-D but also a metabolite of 2,4-D. The culture fluid from samplings throughout the experiment was spotted on TLC plates and developed. Autoradiographs from these plates showed no metabolites present over the three day period. It seems apparent that the uptake demonstrated here on Scenedesmus is due to simple adsorption and it reaches equilibrium quite rapidly.

5. Dichlobenil: The influence of four species of aquatic plants on dichlobenil (2,6-dichlorobenzonitrile) residues in water was investigated during 1970-71. Two emersed species, parrotfeather and water hyacinth and two submersed species, Eurasian water milfoil (Myriophyllum spictatum) and elodea (Elodea canadensis) were utilized.

At various time intervals after treatment, plant and water samples were taken, extracted with benzene, and the amount of dichlobenil remaining in the water and the amount of dichlobenil and 2,6-DCBA (2,6-dichlorobenzoic acid) accumulated in the plants were determined by gas-liquid chromatography. A gas chromatograph with a ^{63}Ni electron-capture detector and equipped with a "u" shaped 6 ft by 1/4 in. glass column packed by 1.5% QF-1 and 1.95% OV-17 was utilized. The operating conditions were as follows: column temperature 150°C, injector temperature 225°C, detector temperature 280°C. The carrier gas was pre-purified nitrogen with a flow rate of 30 ml per minute. Under these conditions, the retention time of dichlobenil was 1.5 minutes and 2.6-DCBA methyl ester was 2.0 minutes. The lower limit of detection for dichlobenil was 10 picograms and 100 picograms for the methyl ester of 2,6-DCBA. Recovery of dichlobenil from water was 90% and from plant material ranged from 64% to 80% depending upon species. The recovery of 2,6-DCBA from plant material ranged from 42% to 73% with an average recovery of 68%.

Prior to the initiation of removal studies, the toxicity of dichlobenil to three plant species; emersed parrotfeather, Eurasian milfoil, and elodea was determined. Five rates were used, 17.00, 1.70, 0.17, 0.017, and 0.00 μg/ml. Toxicity was measured by effect on plant growth as measured by shoot growth and fresh weight for 14 days.

The lower rates, 0.17 and 0.017 μg/ml had a negligible effect on growth as compared to the control. While at the highest rate, 17 μg/ml, plant growth was severely affected within three days. The submersed plants became chloritic and disintegrated on contact while the toxicity symptoms on parrotfeather were manifested by leaf burn and severe tip dieback which increased with time. At the intermediate rate, 1.7 μg/ml, plant growth was reduced slightly, but toxicity symptoms were not noticeable until the 12th to 14th day after treatment. With these results two rates, 1.7 and 0.17 μg/ml, were selected for further studies.

The submersed species, Eurasian milfoil and elodea, exhibited a very low rate of removal during the 16 day sampling period. Eurasian milfoil and elodea at the low rate (0.17 μg/ml) removed approximately 30% of the dichlobenil during the first six hours after treatement. After this time period, no additional removal was exhibited by either species. After four days, the amount of dichlobenil in the water with plants was higher than in the control chambers without plants indicating the release of the herbicide from the plants back into the water. At the end of the 16th day the amount of dichlobenil in elodea was 2.48 μg while in Eurasian milfoil, 4.15 μg was present.

At the higher rate, 1.7 μg/ml, the submersed species exhibited similar removal rates. As at the lower rate, removal was greatest during the initial six hours and at 24 hours the amount of dichlobenil in the water with plants was as high as in containers without plants indicating again a release from the plant. At the end of 16 days, both plant species contained approximately the same amount of dichlobenil, i.e. 25 μg.

Removal of dichlobenil from water by parrotfeather was highest during the first 24 hours after treatment. During this period, approximately 15% of the dichlobenil was removed. After this period, there was very little removal by the plants at either treatment level and volatilization accounted for the greatest portion of the additional loss of the material.

During the treatment period, in addition to the removal of the herbicide, growth and transpiration were also measured. There was no difference in the growth of the plants at either treatment level when compared to untreated control plants. Transpiration rate, however, was affected by the herbicide treatment. At the end of 16 days the transpiration rate of the plants receiving the high treatment was reduced by 30% while transpiration rate of the plants at the lower treatment rate was reduced by less than 10%.

The amount of dichlobenil in the plant tissue remained relatively constant after 24 hours at both treatment rates. The roots contained the greatest amount of dichlobenil. There was, however, some translocation into the aerial parts of the plant but at a very reduced rate. There was an approximate ten fold difference in the amount of herbicide detected in the plants at the high and low rate indicating that dichlobenil may be taken up passively in the transpiration stream.

The results obtained with the other species indicated that there was no significant difference in uptake between the two rates. Therefore, the uptake of dichlobenil by water hyacinth was investigated using only one concentration, 1.7 μg/ml. Again, the greatest amount of removal occurred during the first 24 hours with no significant uptake during the remainder of the treatment period. The amount of dichlobenil in the plant was highest in the root with approximately 30% as much in the aerial parts as in the root. The amount in the plant decreased with time indicating that the herbicide was metabolized by the plant. Transpiration was reduced by approximately 30% when compared to plants receiving no treatment.

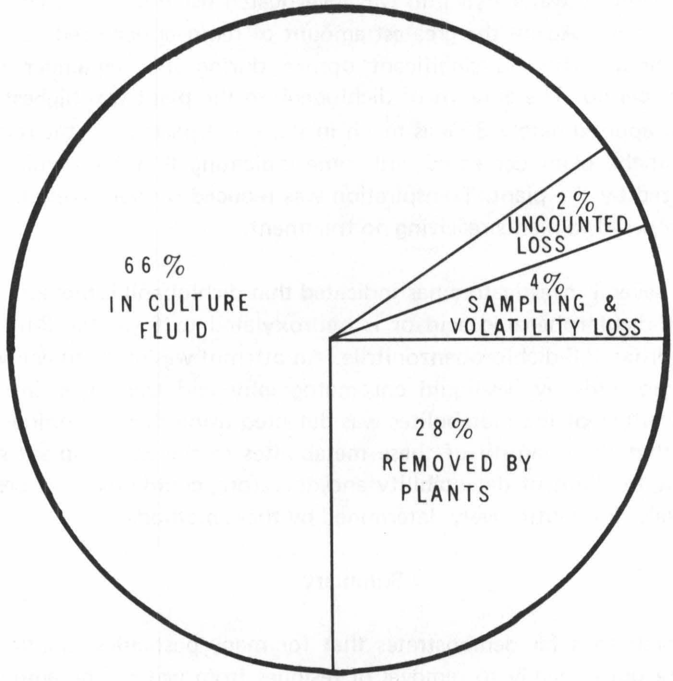
Work by several investigators has indicated that dichlobenil is metabolized to either 2,6-dichlorobenzoic acid or is hydroxylated to form the 3-hydroxy- and 4-hydroxy-2,6-dichlorobenzonitrile. An attempt was made to analyze for these compounds by gas-liquid chromatography and thin layer chromatography. Neither of the metabolites was detected using these techniques. It is possible that the quantity of these metabolites in the various plant species was below the limit of detectability and, therefore, could not be successfully qualitatively or quantitatively determined by these methods.

Summary

The research thus far demonstrates that for many pesticides aquatic plants contribute quite readily to removal of residues from water. The amounts of residue expected in the water under normal use would be far below the levels used in these studies.

FIGURE 1

The amount of ^{14}C from atrazine in various locations at the termination of the study with parrotfeather. Unaccounted loss (2%) was removed by plants and possibly $^{14}CO_2$ given to the atmosphere.

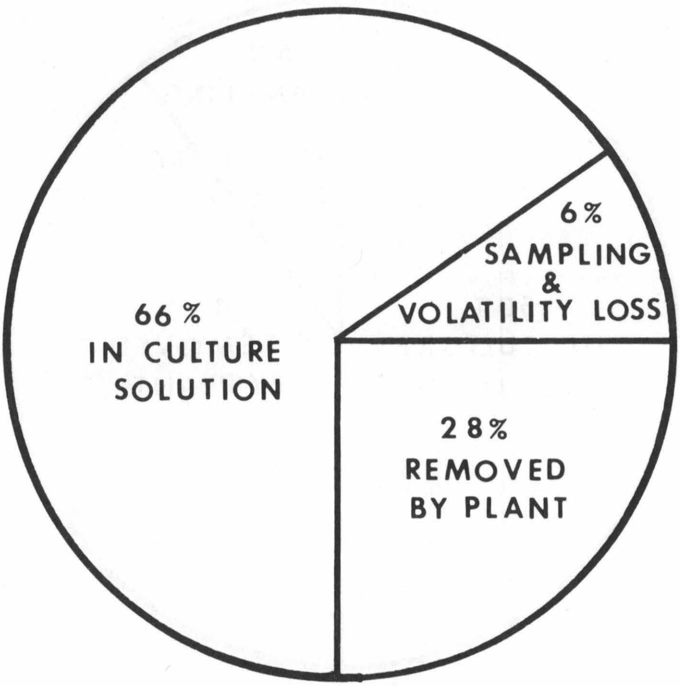


LOCATION OF ^{14}C ACTIVITY

AFTER 20 DAYS ($10^{-6}M$)

FIGURE 2

The amount of ^{14}C from dicamba-^{14}C in various locations at the termination of the study with parrotfeather.



LOCATION OF ^{14}C ACTIVITY AFTER 20 DAYS

FIGURE 3

The amount of ^{14}C from dicamba-^{14}C in various locations at the termination of the study with water hyacinth.

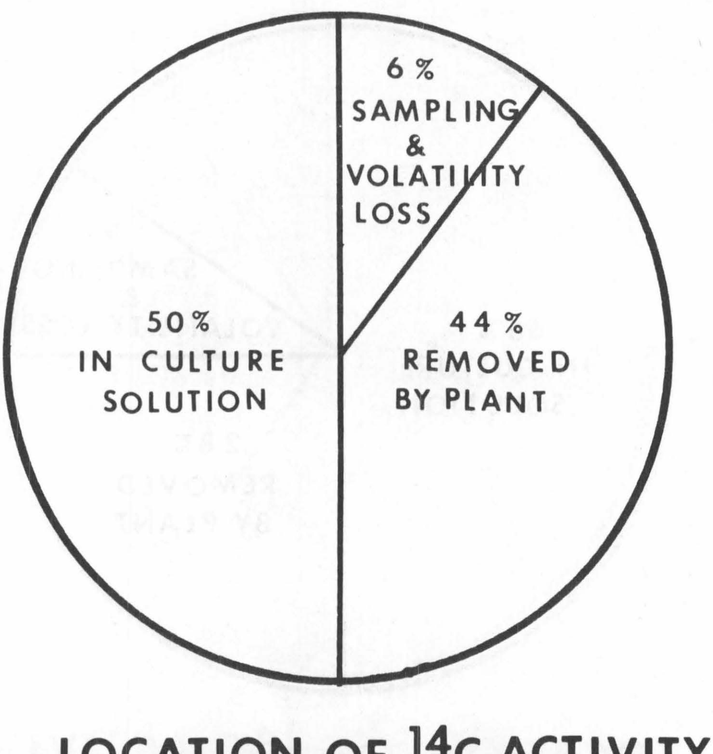
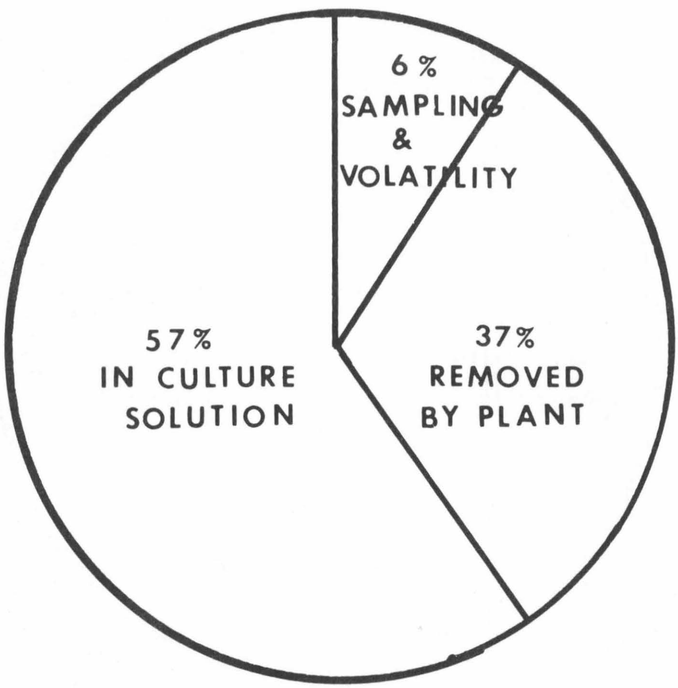


FIGURE 4

The amount of ^{14}C from diphenamid-^{14}C in various locations at the termination of the study with parrotfeather.



LOCATION OF ^{14}C ACTIVITY AFTER 20 DAYS

SEISMIC INVESTIGATION OF GROUND WATER RESERVOIRS IN THE VIRGINIA COASTAL PLAIN SEDIMENTS

Project A-034-VA

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SEISMIC INVESTIGATION OF GROUND WATER RESERVOIRS IN THE VIRGINIA COASTAL PLAIN SEDIMENTS

Seismic reflection and refraction surveys were made at two sites on the Virginia coastal plain during August, 1970. Site No. 1 was approximately 5 miles NNE of Franklin, Virginia, and Site No. 2 was approximately 3 miles north of Boykins, Virginia. The locations are shown in Figure 1. These seismic measurements were made in an effort to evaluate the effectiveness of modern explosion seismic methods in determining the thickness of the unconsolidated coastal plain sediments and stratigraphic subdivisions within this sedimentary section. The project was also intended to provide information for planning field operations and costs of future seismic surveys on the Virginia coastal plain.

The seismic surveys were planned specifically to obtain information about the unconsolidated coastal plain sediments. The thickness of this sedimentary section is approximately 1000 feet at Site No. 1 and approximately 500 feet at Site No. 2. This choice of sites, therefore, provides a test of conventional explosion seismic methods in two substantially different situations as regards total thickness. The composition of the unconsolidated sedimentary section, however, is similar at these sites, consisting of interbedded sand and clay units. Electrical logs from wells located within one mile of the seismic survey sites provide some independent information about the subsurface lithology.

It was found at both sites that reflections were clearly recorded from the base of the unconsolidated sediments. These reflections were evident on the field records and were confirmed by computer velocity analysis based upon correlation of time shifted seismic data. In addition to the reflection from the base of the section, at least three additional reflections from horizons within the unconsolidated sediments were identified after computer velocity analysis. They indicate the presence of low velocity zones representative of alternating sand and clay sequences. These intermediate reflections were not clearly evident on the field records, but they can be correlated with lithologic changes noted on electric logs. Several lithologic changes evident on the well logs were not revealed by the seismic reflection records.

The seismic reflection method offers a relatively quick and accurate means of measuring the total thickness of the unconsolidated coastal plain sediments. Good results could be obtained after 3 to 4 hours of effort at one site. If more detail is desired about intermediate reflecting horizons, more time would be required to obtain confirming records from several different shot locations at a particular site. It would be reasonable to spend one day at a site to thoroughly apply the various techniques likely to be productive in this region.

Seismic refraction data indicating the presence of consolidated rock beneath the coastal plain sediments were obtained at both sites. Compressional wave velocities of between 5000 feet/sec and 6500 feet/sec are characteristic of the unconsolidated sediments in contrast to velocities in excess of 16,000 feet/sec measured for the underlying consolidated rock commonly referred to as "basement." Because of this large velocity contrast, refraction recording lines need only extend to distances of 3 times the thickness of the unconsolidated section to obtain satisfactory refraction data.

Two factors render the refraction method somewhat imprecise for determining total thickness of the unconsolidated coastal plain sediments. First is the existence of low velocity zones within the section. These cannot be detected by conventional methods of refraction seismology, but are known to exist from reflection data. The second source of uncertainty lies with variations in depth to the water table. If the thickness of the unsaturated zone varies three feet from place to place along the refraction line, the resulting shifts in seismic wave arrival times would obscure evidence of deeper velocity changes indicative of stratigraphic horizons.

Study of refraction data from both sites revealed, at best, two velocity subdivisions within the unconsolidated sedimentary section, and these were quite imprecisely defined. Comparison of refraction and reflection results indicates an uncertainty of as much as 12% in values of total thickness of unconsolidated sediment calculated from refraction data.

It is concluded from these studies that seismic reflection methods offer a means of determining total coastal plain unconsolidated sediment thickness to an accuracy of better than 5%. Refraction methods, in contrast, are probably only accurate within approximately 10%. The reflection method provides some information about stratigraphic units within the unconsolidated sedimentary section. This information would be useful in stratigraphic correlation if some independent borehole logs are available. It is recommended that sonic logs be obtained in an area where seismic reflection work is planned. Such data would greatly enhance the interpretation of reflection records.

The seismic investigations of the Virginia coastal plain sediments involved field operations and data processing and interpretation. The logistical aspects of the field program will be considered first followed by discussion of data analysis.

To investigate fully the potential of modern conventional seismic methods, thirty boreholes, each being 25 feet deep, were drilled and cased at each site. Following the drilling program, a five man seismic crew equipped with a 24 channel analog magnetic tape and photographic recording seismic system spent 5 days at Site No. 1 and 3 days at Site No. 2. After considerable experimentation, a satisfactory operating technique was developed for study of the unconsolidated sedimentary section.

In general, a seismic crew consisting of one trained seismologist and two field assistants would be sufficient to carry out a successful field program. The crew should be equipped with seismic recording apparatus, an earth auger capable of drilling 10 feet into unconsolidated material, explosives and blasting caps, and seismic photographic and magnetic tape recording supplies.

The necessary seismic recording equipment depends upon the information desired. If simple refraction measurements of total sediment thickness alone are planned, then portable photographic recording seismic apparatus should suffice. Such equipment can be operated with nominal training. Cost of such apparatus begins at approximately $6000. To carry out a seismic reflection survey with intentions of accurately mapping total sediment thickness and tracing some stratigraphic horizons would require a magnetic tape recording seismic system. The lowest cost of such apparatus would probably exceed $30,000, however, such equipment can sometimes be obtained on loan from university or other research groups.

The explosives needed for both reflection and refraction work are minimal. As very effective energy coupling is achieved on the coastal plain, it is possible to obtain a variety of seismograms with less than 5 lbs of ammonium nitrate explosive, approximately 30 feet of prima cord, and 10 blasting caps for an individual site. The total cost of explosives needed at a site should not exceed $10.

The cost of expendable recording supplies, including magnetic tapes and photographic chemicals and paper, should not exceed $10 for a particular site. Other expendable supplies incident to the operation of recording and drilling vehicles would be estimated at less than $15 for a particular site if no major repairs are required.

The field costs of a seismic survey of the Atlantic coastal plain sediments, therefore, include salaries and field expenses of a three man crew and approximately $35 for expendable supplies for each site. If a large number of sites are to be occupied it is reasonable to estimate 3 to 6 hours working time at each site. Thus, one or two sites could be occupied during a normal work day.

The costs of data analysis again depend upon the objectives of the survey. A simple refraction survey would include four to six photographically recorded seismograms. Data preparation and calculations would require approximately 2 to 4 hours for each site. Nominal computer analysis costs, drafting of illustrations and incidental processing costs would be approximately $10 for a site. A seismic reflection survey would require computer velocity analysis of generally three seismograms for a site at a cost of approximately $40. In addition, refraction data from the site should be processed which would add $10 to the cost.

The data analysis should be undertaken by a trained seismologist. It would take an estimated 4 to 6 hours to analyze data from a reflection site. The estimated costs of a seismic survey including field work and data analysis are summarized in Table 1. It is assumed that the necessary equipment is available for the study. Salaries are not included in Table 1. It is estimated that field work would require an average of 1.5 man days of effort for a refraction site and 2.0 man days for a reflection site. Data analysis would require approximately 0.3 man days for refraction studies and 0.5 man days for reflection analysis.

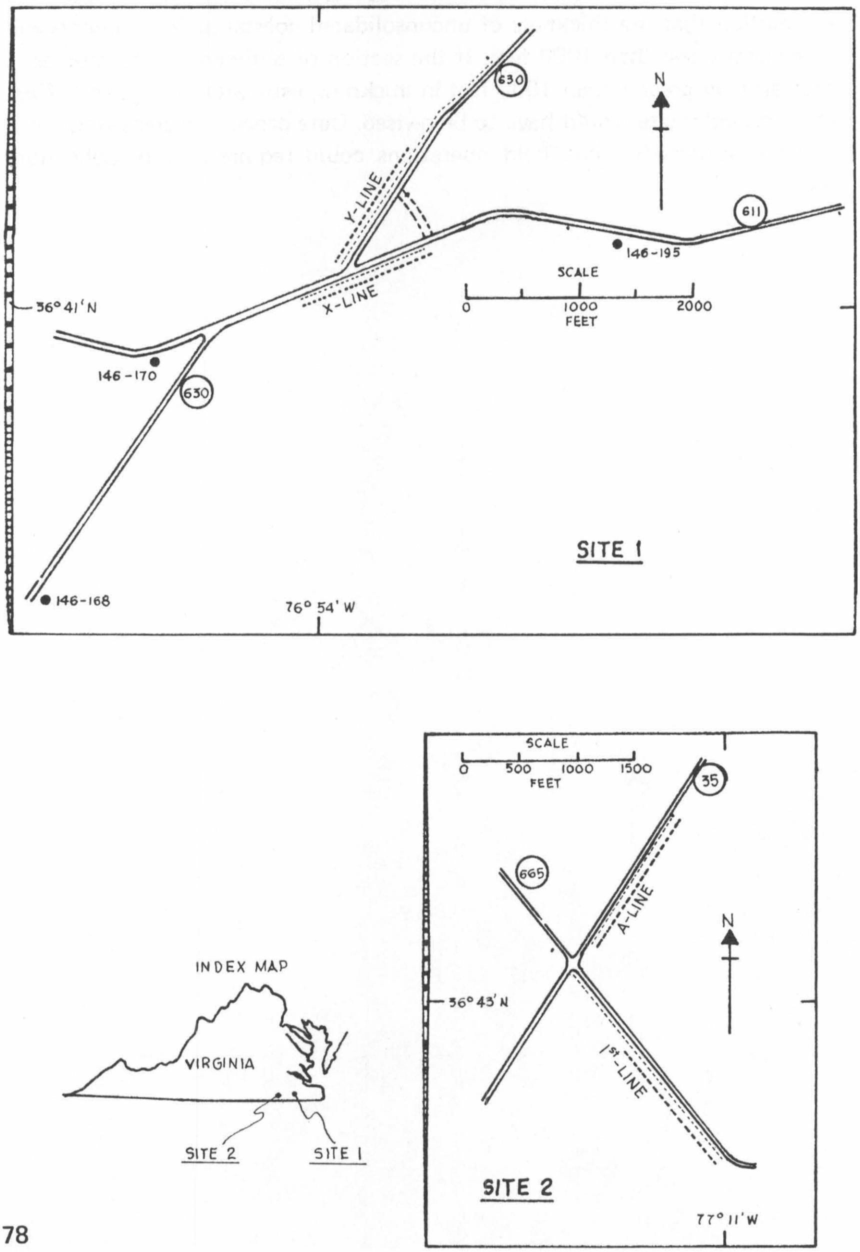
TABLE 1

COST ESTIMATES FOR SEISMIC SURVEYS PER SITE

Item	Refraction Survey	Reflection Survey
Recording supplies	$ 5.00	$10.00
Explosives	7.00	10.00
Other supplies	15.00	15.00
Computer analysis	3.00	30.00
Data preparation	7.00	10.00
Totals	$37.00	$75.00

These cost estimates pertain to actual field operations and data processing. They do not include the costs of preliminary planning for land access permits, renovation of field equipment, and preparation of final reports. These costs would depend upon the extent of effort planned for a particular project. It should also be emphasized that the cost estimates are based upon the assumption that the thickness of unconsolidated coastal plain sediments will be generally less than 1000 feet. If the section of sediments to be studied is substantially greater than 1000 feet in thickness, estimates of time and effort at a particular site would have to be revised. Data processing costs would not increase appreciably but field operations could require considerably more time.

FIGURE 1. LOCATION AND ARRANGEMENT OF SEISMIC STUDIES ON THE VIRGINIA COASTAL PLAIN.



OPTIMAL CONDITIONING PROCEDURES FOR WASTE ACTIVATED SLUDGE DISPOSAL

Project A-035-VA

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OPTIMAL CONDITIONING PROCEDURES FOR WASTE ACTIVATED SLUDGE DISPOSAL

Description of Research

During the first year of this research project, a series of laboratory studies were conducted to evaluate the effect of typical waste treatment plant handling procedures on the subsequent filterability of waste activated sludge. Areas of investigation were aerobic digestion, anaerobiosis, dissolved oxygen levels, mixing effects, temperature effect, bacteriostatic condition, sludge chlorination, suspended solids concentration effects, pH effects, and batch aerobic digestion versus continuous aerobic digestion. A further aim of the research was to determine the chemical and biological properties of sludge that affect filterability, and the experiments were designed to yield such information.

Laboratory-scale procedures were used throughout the study; however, the waste activated sludge used for all experiments was obtained directly from a 600 gpd extended aeration sewage treatment plant prior to each test. Buchner funnel techniques were used to measure changes in filterability. In addition, sludge and filtrate changes were detected by measuring pH, DO, BOD, TOC, oxygen uptake, dehydrogenase enzyme activity, zeta potential, specific conductance, extracellular carbohydrates, cellular protein, and suspended solids.

At many activated sludge plants, the waste sludge is thickened and then subjected to anaerobic digestion prior to sludge dewatering. Data accumulated during this study show that anaerobic conditions rapidly cause extreme degradation of sludge filterability accompanied by a sharp increase in soluble organic carbon indicating considerable cell destruction. By contrast, aerobic digestion produced an initial improvement in filtration rate and a decrease in soluble organic carbon. Further, filtration characteristics degraded by anaerobic conditions could be recovered by subsequent aeration, and the period of aeration required for recovery was the same as that needed to reach maximum filtration improvement before anaerobiosis. Interestingly, the filtration rate of both aerobically and anaerobically conditioned sludge correlated linearly with the soluble organic carbon concentration.

While aerobic digestion always produced an initial improvement in sludge filterability, with maximum improvement occurring in 4 to 6 days, greater periods of aeration caused a worsening of filtration rates (Figure 1). Further evaluation showed that the mechanism of filtration improvement was biological in nature. When biological environmental conditions were suitable for activity and the sludge was in the initial stages of endogenous metabolism, sludge filterability either improved or remained good. When biological activity was disrupted by chlorination, quick changes in pH or temperature, or by the absence of oxygen, the sludge filterability rapidly degenerated. Filterability also failed to improve or became worse when biological activity was slowed down by cooling to 6°C or by extended aerobic digestion.

Biological flocculation was concluded to be the primary mechanism of filterability improvement. Analysis showed that extracellular polymeric substances were produced by the viable organisms during endogenous metabolism. When the biological energy in the system was sufficiently low, these polymers caused coagulation and bridging between sludge particles, thus improving the filtering properties of the sludge. Zeta potential had no effect on the flocculation process. Since bridging by biologically produced polymers was the principal mechanism, bioflocculation could be accomplished only if most of the biological cells were intact and active. Extracellular polymers were produced only when oxygen was present in the system. However, the organisms responsible for production survived up to 4 days in the absence of oxygen.

Dissolved oxygen concentrations above 2 mg/l did not further enhance sludge filterability. The mixing rate during conditioning was criticial, however, whether the system was aerobic or anaerobic. Vigorous mixing degraded the filtration rate.

Sludge filtration was found to be a linear function of suspended solids concentration. An increase in solids caused an increase in filtration resistance. The solids concentration did not affect the degree of filtration improvement produced by aerobic digestion. Controlling the pH during digestion had no effect on the filtering properties.

The temperature of aerobic digestion did affect the filtration characteristics of the sludge. Digestion temperatures of 25 and 30°C were superior to 20 and 35°C for conditioning purposes. Although the temperature of 30°C produced maximum filterability more rapidly, because of rapid worsening beyond the optimum point, the 25°C temperature proved to be better for control purposes. A striking aspect of the temperature studies was the difference in temperature effect on sludge filtration rate before and after digestion (Figure 2).

Sand bed drying studies showed that aerobic digestion improved the gravity drainage of waste activated sludge even more than it improved the filtration rate. The order of improvement was 70% and 46%, respectively.

The results show that the way waste activated sludge is handled can have a drastic effect on the rate of dewatering. To achieve optimum conditioning, the biological organisms must be aerobically maintained in the endogenous phase and must be active and intact when subjected to dewatering procedures. While stressing the sludge by temperature, pH, chlorine, or anaerobic conditions will cause a large reduction in filtering rate, good filtration properties can be restored by subsequent aeration.

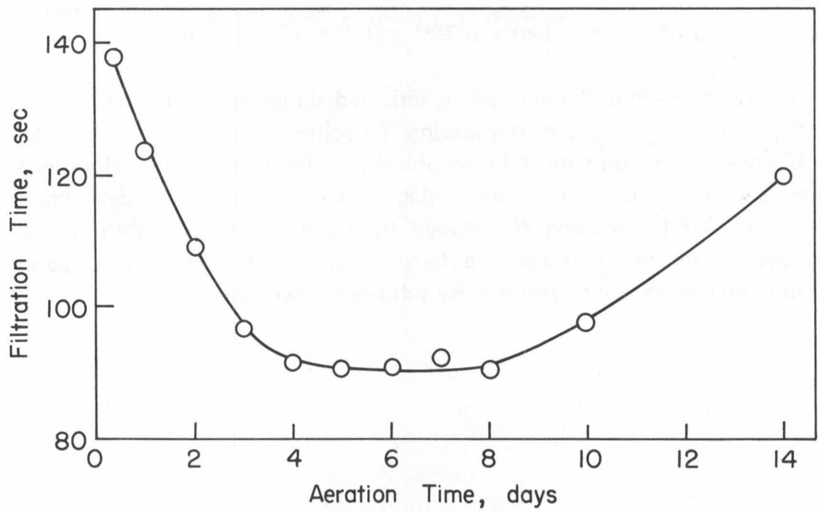

Figure I. VARIATION IN FILTERABILITY WITH AEROBIC DIGESTION

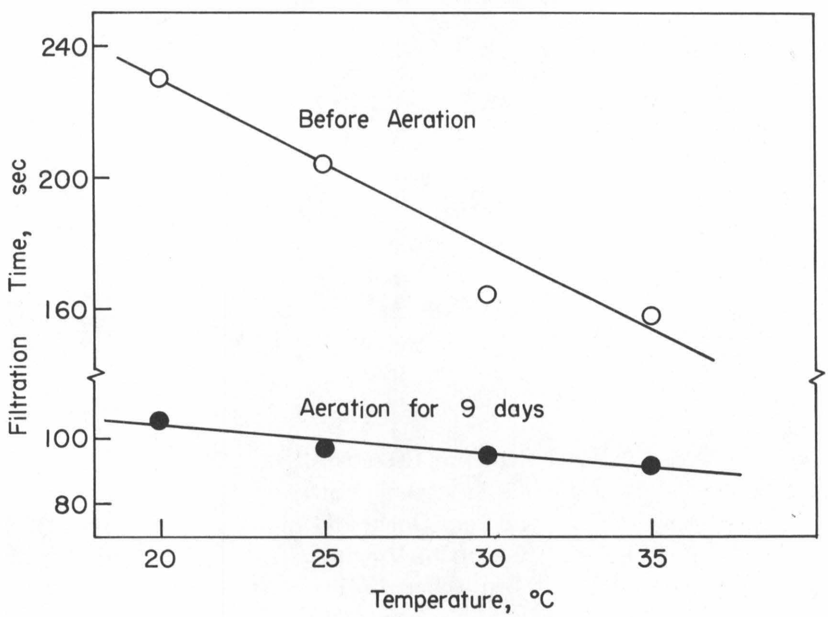

Figure 2. VARIATION IN FILTERABILITY WITH TEMPERATURE

BIOLOGY AND CHEMISTRY OF SURFACE FRESHWATER MICROLAYERS

Project A-037-VA

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September, 1971

BIOLOGY AND CHEMISTRY
OF SURFACE FRESHWATER MICROLAYERS

Objectives

This report covers the design and construction of three microlayer samplers based on different principles of operation. These included:

1. A surface screen sampler (SSS), first described by Garrett (1965) and prior to this study employed only in studies of sea slicks; it collects primarily by capillary action.

2. A modification of the "aquatic guillotine" first described by McBain and so far only used in laboratory research; it collects by physically separating a microlayer from the water surface – like a microtome.

3. A rotating surface drum sampler (SSD) first described by Harvey (1966) and so far only used in the ocean; it collects by cohesive force effects.

Early analyses of these potential samplers revealed many weaknesses and problems with the "Aquatic Guillotine" but gave rise to another plan for a Surface Sampling Tray (SST). This device consists of a 1.0 m^2 stainless steel tray subtended by an aluminum frame and four cylindrical ballasts at the corners. By adjusting the volume of water in the ballasts, the tray balances horizontally, and also achieves a level in water of any density resulting in a precise depth of surface water remaining in the tray. One operates the SST by pushing it at an acute angle beneath the water surface. The tray rises horizontally cutting 1.0 m^2 of surface. During the next 15 to 20 min, the water in the tray gradually leaves via small holes. The rate and manner of emptying has been designed to minimize turbulence effects which would draw off the surface water prior to removing the subsurface water.

Three screens were first obtained and have been under test since the summer of 1970. The first Surface Sampling Tray was completed in the fall of 1970, modified by the spring of 1971, and currently is being redesigned to eliminate weight and bulkiness and insure better stabilization in water. The Surface Sampling Drum is now under construction after long delays and problems concerning the cost of applying smooth ceramic coating to the steel drum.

Results and Discussion

The Surface Sampling Screen (SSS) and Surface Sampling Tray (SST) reveal striking differences of certain substances between the microlayer and subsurface (10 cm) water (Tables 1 through 6). These include ammonium, nitrate, ortho-phosphate, total phosphate, surfactants of the ABS and LAS types, and iron. These data vary with aquatic environment and climatic conditions. Biological differences are also evident. For example, the surface microlayer contained many times more fungi and a significantly higher most-probable-number of fecal coliform bacteria than did the subsurface water (Tables 11 and 12). Direct microscopic observations of algae in microlayer samples, taken with the SSA and SST, revealed different species diversity and population sizes from those of the subsurface water (Tables 7 through 10).

Methods for bioassay of thiamin, biotin, and niacin have been developed and tested. Several assays have been run on water collected during winter months, but no detectable vitamins have been found. One exception was April 1, 1971, when the Farm Pond revealed: 0.05 (SSS), 0.025 (SST), and 0.02 (SS) mμg Biotin/ml.

A tendency has been noted for a reduction in the differences between the different sampling procedures from the fall of 1970 into the winter and spring of 1971. It is believed that higher winds and increased turbulence and mixing during the colder weather has reduced the chances for both chemical and biological conditions to develop differences in the surface microlayers. Thus, it is anticipated that the best data showing differences will come during summer and early fall sampling.

The surface sampling drum (SSD) is still under construction, so no comparisons can be made. [The delay in the construction of the SSD is due to the necessity to utilize several industrial sources for various parts, notably the drum which needs a special ceramic coating to obtain the required surface smoothness.] However it appears that the SSS samples are more different both chemically and microbiologically than are the SST samples, from those of control subsurface (SS). Figure 1 shows a redesign of the SST Prototype No. 1, called No. 2. This design should be free of some of the earlier weaknesses and so give better sampling results.

Table 1

Select comparisons of surface microlayer chemistry with subsurface waters, screen sampler, 1970. *May be significant.

Date	Source[1]	Sample	Chemical Concentration (mg/l) NH_4^+-N	NO_3^--N	Total $PO_4^{\equiv}$-P
7/16	Ox. Pond	S	1.00	6.0*	8.6
		Sub	0.95	3.0	7.8
7/13	Duck Pond	S	0.29*	1.1*	0.05
		Sub	0.01	0.1	0.03
7/18	Mtn. Lake	S	0.13*	0.33*	0.65*
		Sub	0.06	0.22	0.25

[1]Ox. Pond = Sult's Trailer Court, sewage oxidation pond, Merrimac, Va.
Duck Pond = V.P.I. & S.U. campus, Blacksburg, Virginia.
Mtn. Lake = Virginia Mountain Lake

Table 2

Surfactant concentrations in surface microlayers and subsurface waters, screen sampler, 1970. *May be significant.

Date	Source	Sample	Concentration ABS and/or LAS (mg/l)
6/24	Ox. Pond	S	0.12*
		Sub	0.02
7/8	Ox. Pond	S	0.10*
		Sub	0.04
6/22	Duck Pond	S	0.05*
		Sub	nil
6/13	Duck Pond	S	0.04
		Sub	nil
7/9	Mtn. Lake	S	nil
		Sub	nil
7/15	Mtn. Lake	S	nil
		Sub	nil

Table 3

Chemical data from microlayer samples, Farm Pond, March 16, 1971 (all values in mg/l). *May be of significance.

Chemical	Sampling Method		
	SSS	SST	SS
Ammonium (as N)	0.13*	0.21	0.22
Nitrite (as N)	0.017	0.016	0.017
Nitrate (as N)	0.16	0.18	0.18
Ortho-phosphate	0.02	0.04	0.02
Meta & polyphosphate	0.08*	0.12*	0.23*
Iron (ferrous)	0	0.02	0
Silica	2.2	2.12	1.68*
Sulfate	18	19	18
Surfactants	0	0	0
Total Dissolved Solids:	260.0	232.0	326.0*
Total Nitrogen	Spurious values obtained for all samples		

SSS = surface sampling screen
SST = surface sampling tray
SS = subsurface sampling

Table 4

Supplementary chemical data from microlayer samples, Farm Pond, April 1, 1971 (all values in mg/l). *May be significant.

Chemical	Sampling Method		
	SS	SST	SSS
Ammonium (as N)	0.37	0.33	0.39
Nitrite (as N)	0.012	0.017	0.015
Nitrate (as N)	1.45	1.60	1.60
Ortho-phosphate	0.03	0.03	0.06*
Meta & polyphosphate	0.08	0.09	0.06*
Silica	0.83	0.73	0.74
Total Dissolved Solids	282	273	264
Total Nitrogen (as % solids)	1.31	1.57	2.07*

Table 5

Supplementary chemical data from microlayer samples, Mountain Lake, Giles County, Virginia, April 13, 1971 (all values as mg/l). *May be significant.

Significant Chemical	Sampling Method		
	SSS	SST	SS
Ammonium (as N)	0.08	0.08	0.09
Nitrite (as N)	0.004	0.002	0.008*
Nitrate (as N)	0.08*	0.04	0.02
Ortho-phosphate	0.03	0	0.02
Meta & polyphosphate	0.03	0.02	0.03
Iron (as ferrous)	0	0.02	0.02
Silica	0.55	0.58	0.57
Sulfate	1	0	2
Total Dissolved Solids	19.2	19.8	20.6
Total Nitrogen (as % of solids)	6.2	5.8	7.0

Table 6

Chemical data from microlayer samples, Sult's Trailer Court Sewage Oxidation Pond, Merrimac, Virginia, June 30, 1971 (all values as mg/l). *May be Significant.

Chemical	Sampling Methods		
	SSS	SST	SS
Ammonium (as N)	0.55*	0.40	0.45
Nitrite (as N)	0.00	0.00	0.00
Nitrate (as N)	0.02	0.03	0.04
Ortho-phosphate	9.00	12.00	7.00
Meta & polyphosphate	14.00	14.00	15.00
Ferrous Iron	0.05*	0.05*	0.01
Total Dissolved Solids	226.5	247.0	220.0
Total Nitrogen (as % solids)	7.5		15.0*

Table 7

Population sizes of algal genera in surface microlayers and subsurface waters, screen sampler, 1970 (cells/cc).

Date	Source	Sample	Total	Algal Genera[1]					
				1	2	3	4	5	6
7/16	Ox. Pond	S	1389	43		713		370	
		Sub	1240	66		598		297	
7/17	Duck Pond	S	90	27					13
		Sub	26	3					0
7/18	Mtn. Lake	S	Algae very sparse, statistical						
		Sub	accuracy questionable						

(Continued)

Date	Source	Sample	Total	7	8	9	10	11	12
7/16	Ox. Pond	S		10	23	30		200	
		Sub		23	17	13		226	
7/17	Duck Pond	S					50		0
		Sub					13		10
7/18	Mtn. Lake	S	Algae very sparse, statistical						
		Sub	accuracy questionable						

[1]Algal genera: (1) Ankistrodesmus, (2) Ceratium, (3) Chlorella, (4) Cosmarium, (5) Euglena, (6) Fragillaria, (7) Micratinium, (8) Oocystis, (9) Oscillatoria, (10) Peridinium, (11) Scenedesmus, (12) Staurastrum.

Table 8

Population sizes of algal genera in surface microlayers and subsurface (SS) waters, surface sampling screen (SSS), and surface sampling tray (SST), 1971 (cells/cc). *May be significant.

Date	Source	Sample	Total	Algal Genera[1] 1	2	3	4	5	6
7/16	Farm Pond	SSS	1270	120*	2	2	1	1	1
		SST	912	68	1.8	0.5	2	<1	0.5
		SS	1097	94.4	4	2.8	5	1.1	<1
4/1	Farm Pond	SSS	465	43.3*	1.7	2.8	5.3	1.7	
		SST	480	66.9	3.6	4.2	2.2	<1	
		SS	4464	69.4		1.7	1.1	1.4	

(Continued)

Date	Source	Sample	Total	7	8	9	10	11	12
3/16	Farm Pond	SSS							
		SST		<1	1	<1	<1		
		SS				<1	<1	<1	
4/1	Farm Pond	SSS				1.9	1.7		2.8
		SST							
		SS				<1	<1		

[1]Algal genera, all numbers X 10^{-3}: (1) Synedra, (2) Fragillaria, (3) Chlorella, (4) Navicula, (5) Cymbella, (6) Gomphonema, (7) Diatoma, (8) Scenedesmus, (9) Nitzschia, (10) Dinobryon, (11) Amphora, (12) Anabaena.

Table 9

Population sizes of algae in surface microlayers and subsurface (SS) waters, surface sampling screen (SSS) and surface sampling tray (SST), April 13, 1971, in Mountain Lake, Virginia (cells/cc). *May be significant.

Algae	Count X 10^{-3}		
	SSS	SST	SS
Cyclotella	10.3	9.4	10
Dinoflagellates	<1	–	–
Dinobryon	1.7*	–	–
Microalgae	<1	–	–
Sphaerocystis	–	2.8*	6.7*
Oocystis	–	–	<1
Others	–	<1	–
Total algal cells	64	51	86

Table 10

Population sizes of algae in surface microlayers and subsurface (SS) water, surface sampling screen (SSS), and surface sampling tray (SST), June 30, 1971, in Sult's Trailer Court Sewage Oxidation Pond, Merrimac, Virginia. *May be significant.

Algae	Counts of Cells/cc/10^{-3}		
	SSS	SST	SS
Dictyosphaerium	104	120	232*
Scenedesmus	1.7	1.4	5.6*
Euglena	<1.0*	1.7	15
Chlamydomonas	<1.0	<1.0	
*Uroglenopsis	2.5*	2.5*	1.4
Total algal cells	110.8	126.1	253.6

Table 11

Counts of bacteria and fungi in a surface microlayer and subsurface water of a farm pond, fall, 1970.

1. Most probable number of coliform bacteria per 100 ml of water

Screen	760
Subsurface	348

2. Number of bacteria per ml of water as determined by spread plate technique on:

   a. Plate-Count Agar[1]

Screen	6,400
Subsurface	6,500

   b. Pond-Water Agar[2]

Screen	22,800
Subsurface	20,000

3. Number of fungi per ml of water as determined by spread plate technique on Potato-Dextrose Agar[3]

Screen	180
Subsurface	3

1 Tryptone 5.0 g
Yeast Extract 2.5 g
Dextrose 1.0 g
Agar 15.0 g
Distilled Water 1000 ml

2 Peptone 1.0 g
Yeast Extract 1.0 g
Agar 150 g
Pond Water 500 ml
Distilled Water 500 ml

3 Potatoes, Infusion from 200.0 g
Dextrose 20.0 g
Agar 15.0 g
Distilled Water 1000 ml

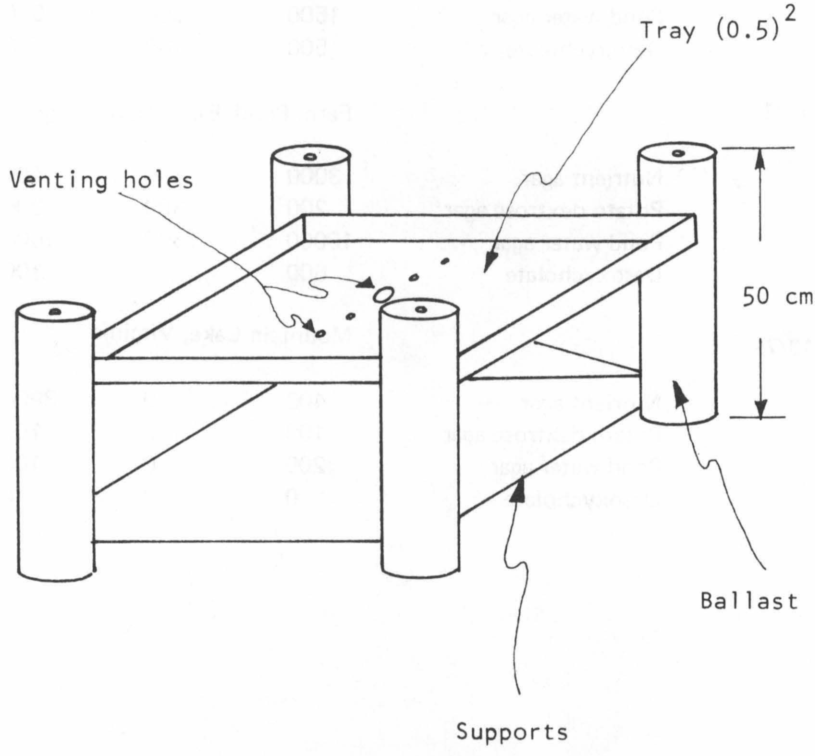
Table 12

Counts of bacteria in surface microlayers and subsurface water in 1971.

Date	Medium	Sampling Method SSS	SST	SS
3/16/71		Farm Pond, Blacksburg, Virginia		
	Nutrient agar	1100	2200	4200
	Potato dextrose agar	500	300	0
	Pond water agar	1500	5900	7500
	Desoxycholate	500	100	0
4/1/71		Farm Pond, Blacksburg, Virginia		
	Nutrient agar	3000	300	400
	Potato dextrose agar	200	300	200
	Pond water agar	10000	1600	1600
	Desoxycholate	600	0	100
4/13/71		Mountain Lake, Virginia		
	Nutrient agar	400	0	3900
	Potato dextrose agar	100	100	100
	Pond water agar	200	0	100
	Desoxycholate	0	0	0

FIGURE 1

SURFACE SAMPLING TRAY (SST)
PROTOTYPE 2



TECHNIQUES FOR MEASURING PUBLIC EVALUATION OF RECREATIONAL AND HYDROELECTRIC WATER USE

Project A-038-VA

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September, 1971

TECHNIQUES FOR MEASURING PUBLIC EVALUATION OF RECREATIONAL AND HYDROELECTRIC WATER USE

Description of the Project and Findings

Design

The project was designed to explore techniques for measuring public attitudes on uses of water resources. The specific focus was on two uses: recreational and industrial.

A Likert technique and a Semantic Differential technique were employed as approaches to the exploration of public attitudes. The Likert technique consists of summated ratings for responses by a number of subjects on a series of water related statements. A sixteen item Likert scale was developed containing four subscales of four items each designed to measure the dimensions of relevance, powerlessness, involvement, and deference. For each of the sixteen statements, the interviewee selects one of five responses, ranging from "strongly agree" to "strongly disagree," that most closely represents his feeling about the statement.

The Semantic Differential technique is designed to serve as a method for measuring "meaning." It is a multi-dimensional rating scale based upon the assumption that words represent things. In design, the Semantic Differential combines scaling procedures with controlled association of word meanings. A respondent is asked to select a number from one to seven that most closely describes his interpretation of the association between the concept and a pair of adjectives. For the present study, a scale consisting of eight adjective pairs was constructed. Interviewees were asked to associate the adjective pairs with two statements, one of which dealt with water use for recreation and the other involved industrial use of water.

A random sample of respondents was selected in the City of Roanoke, Virginia, using a cluster sampling technique and 1970 census tract data. Interviews were conducted in the respondent's home by graduate students of the Department of Sociology at Virginia Tech who received training in advance of interview assignments. The research instrument was a pretested interview schedule containing the Likert scale, the Semantic Differential scale, a series of questions to assess knowledge and use of water resources, and classification questions related to personal and social characteristics of respondents. A facimile of the interview schedule containing specific water related questions is included with this report.

The subject under consideration was Smith Mountain Lake, a body of water near the City of Roanoke that is called upon to serve both recreational needs and to generate hydroelectric power. The facility is a man-made lake constructed by the Appalachian Power Company to produce electric power. Water impounded in the lake produces 500 miles of shoreline as well as a body of water suitable for recreational activities.

Likert Technique

Responses to items on the Likert Scale produced a reliability coefficient of 0.538. While this was not as high as had been hoped, it did suggest some degree of scale unidimensionality. The four subscales failed to demonstrate a degree of reliability that would warrant further examination. It had been expected that respondents who preceived a great deal of relevance on water questions would consider either a pattern of involvement or deference in attempts to seek solutions. Had such a pattern been forthcoming, it would have been possible to conduct a path analysis to ascertain patterns associated with the choice to initiate individual action or to defer to someone else for such action. A similar pattern could have been expected for those respondents who were overrepresented on the "powerlessness" subscale. It was expected that a person who described an issue as relevant, but felt powerless to initiate alternative action, would necessarily defer to others rather than initiate individual action.

An examination of the Likert scale in relation to demographic characteristics of respondents suggested that persons with higher occupational positions and educational attainment were more negative toward water related questions than persons at the opposite end of the occupational and educational continuum. A similar finding was noted for family income: as income increased, so did the proportion of negative responses. It was also found that younger respondents were more negative than older respondents. No noteworthy difference was detected in the response patterns for men compared with women.

Semantic Differential Scale

While the scale reliability for the Likert items was only moderately high, a substantial correlation coefficient was found for the scales associated with the two semantic differential statements. Specifically, a reliability of 0.84 was found for the adjective pairs with the statement regarding Smith Mountain Lake as a recreational area. For the statement concerning the lake as a source for hydroelectric power, a reliability coefficient of 0.87 was found.

Further exploration into the utility of the power versus the recreation scales involved the utilization of factor analysis. The matrix of correlations of the sixteen responses to the two semantic differential items was factored using squared multiple correlations as estimates of the communality and Kaiser's criterion as an index of the completeness of the solution. The solution was then rotated to "meaningfulness," according to the varimax criterion. Examination of the resulting rotated factor matrix revealed that the most appropriate solution consisted of two factors which accounted for 81% of the variance of the communalities. The first factor consisted of the eight responses to the statement, "Consider Smith Mountain Lake as a recreational area." The second factor contained responses to the statement, "Consider Smith Mountain Lake as a source for the production of electric power." This indicated that the respondents evaluated the recreational and industrial uses of Smith Mountain Lake independently.

The finding of scale unidimensionality and reliability of the scale items appears to provide a useful tool for measuring attitudes toward use of water resources. In measuring attitudes, it is generally considered that a multi-item scale provides a more valid technique than a single-item scale. Several benefits are evident: First, a multi-item scale affords the opportunity to measure intensity of the attitude as well as direction. Second, since the multi-item scale is less direct than a single question, it is not as likely to elicit responses that are biased by culturally defined expectations of the respondent. Finally, a scale can be checked for item reliability, as has been described in the previous paragraph. It appears that the semantic differential technique employed with the present study has utility as a multi-dimensional approach to the study of attitudes as they relate to multiple use of water resources.

With the funding of a substantial reliability coefficient for semantic differential scales, respondents were subdivided into four categories according to their specific response pattern. A response mean was determined on choices for each of the two semantic differential statements.* Persons who were below the sample mean for both the statement on power and on recreation were described as having a "positive orientation"; those above the mean for both statements were characterized as having a "negative orientation." When a respondent was found to be above the sample mean on the

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*In order to minimize respondent bias, the negative and positive adjectives were alternated, as they appear on the interview schedule. For purposes of analysis, all positive adjectives were associated with low numbers and negative adjectives with high numbers.

power statement and below the mean for the statement dealing with recreation, a person was described as having a "recreation orientation." If the response mean for the power statement was below the mean for all respondents and above the mean for recreation, the respondent was characterized as having a "power orientation."

On the basis of orientation, it was found that 171 sample subjects could be classified as having a "positive orientation" while 46 were associated with a "negative orientation." There were 45 respondents in each of the "recreation oriented" and "power oriented" categories. In order to assess the differences in response patterns, interviewees were further subdivided according to social characteristics of age, sex, occupation, education, and income in relation to their orientation to recreation and power.

It was found that younger persons were more recreation oriented than older persons, and that the older respondents tended to be more power oriented. It was also found that women were more negatively oriented to both power and recreation, while men were more power oriented and generally held a more positive orientation than women.

An examination of the occupational distribution of respondents disclosed that housewives were the most negatively oriented group. Retired persons were more power oriented. Blue-collar workers were overrepresented in the power and positive oriented categories; white-collar respondents were also overrepresented in the positive orientation category.

Respondents with low educational attainment (grade school) were far more power oriented than persons at other educational levels. High school graduates were characterized as more recreation oriented than other respondents.

When family income was over $15,000 per year, respondents tended to be more recreation oriented. For respondents whose family income was below $5,000 per year, a power orientation was more characteristic.

Findings in this study suggest that the semantic differential technique can serve as a useful tool in measuring attitudes toward dual uses of water resources for recreation and industry. Selected demographic variables presented some evidence to suggest the categories of persons whose attitudes most closely reflect either a positive or negative view toward dual uses of water resources. While the findings are not as absolute as might be desired, they do present minimal guidelines for further study in the area.

Knowledge, Use, and Voting Behavior

In addition to demographic characteristics, the research instrument contained a series of questions designed to explore three areas: (1) knowledge about the lake by respondents, (2) the extent to which sample subjects engaged in recreational activities associated with water, and (3) voting behavior.

Using the four orientations – positive, negative, recreation, and power – respondents were categorized according to their knowledge about design and uses of Smith Mountain Lake. Findings indicated that persons with a positive orientation were more accurate in their knowledge about the lake than persons with a negative orientation. Similarly, power oriented persons were more accurate in their responses than recreation oriented persons.

An exploration into water based recreational activities of respondents disclosed that power oriented persons participated less in recreational activities. Since older persons were generally more power oriented, these persons were also likely to engage in water based recreational activities.

When voting behavior of respondents was examined, it was noted that negatively oriented persons were less likely to vote than respondents in the three other categories.

Utility to the Profession

For the professional charged with the responsibility of decisions regarding the allocation of water resources, this study makes available at least a minimal view of public attitudes on the subject and presents two techniques that have received an initial test of utility. If public support is sought for a particular use of a water resource, the professional has a set of emperically tested guidelines to suggest which segments of the public are most likely and least likely to support that use. Thus, the focus of attention in attempts to gain public support can be directed to that segment of the population where resistance is most likely to develop.

ROANOKE SURVEY: NOVEMBER 1970

conducted by:

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Tract ___ Area No. ___ Field No.___

Address: ______________________________

Status: Complete ___

Incomplete ___ Reason: ______________________

Refused ___

Callback Report: Residence Type:

Date	Status	Residence Type	
		House, single detached	________
____________		House, duplex	________
____________		House, multiple unit	________
____________		Apartment	________

Respondent: Trailer ________

Sex: ______________ Other (specify) ________

Date of Interview: __________ Time: began ______ ended ________

Interviewer: ______________________ No. ________

Coder: ______________________ No. ________

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DO NOT WRITE IN THIS SPACE

RESEARCH INSTRUMENT FOR ROANOKE STUDY 1970

INTRODUCTION: I am ____________________ with Virginia Tech. We are conducting interviews in this area and want to ask you a few questions.

1. How long have you lived in the Roanoke Valley?

   __________ years
   __________ all my life (Skip to 3)
   __________ refused

2. Where did you live before coming to Roanoke?

   __________ does not apply (respondent lived all life in area)
   ______________________________ Name of community
   Did you live in a rural _____ area?
   urban _____ area?
   suburban _____ area?

3. Have you ever heard of a body of water in this area called *SMITH MOUNTAIN LAKE*?

   _____ No (Skip to 11)
   _____ Yes

4. Do you remember how you first heard about *SMITH MOUNTAIN LAKE*?

   _____ No
   _____ radio/TV
   _____ newspapers
   _____ friend/neighbor
   _____ found by accident
   _____ other (specify)

5. Have you ever visited the *lake*?

   _____ No
   _____ Yes How often? _____ once
   _____ occasionally
   _____ frequently

6. Do you know whether *SMITH MOUNTAIN LAKE* is a "man made" or a "natural" lake?

______ man made
______ natural
______ don't know

7. There is a dam at *SMITH MOUNTAIN LAKE*. Do you know who built the dam?

______ No
______ government
______ power company
______ other

8. Do you know if the water at *SMITH MOUNTAIN LAKE* is used for generating electric power?

______ No
______ Yes
______ don't know

9. Do you know if there are boating, fishing or recreational facilities at the *lake*?

______ No
______ Yes
______ don't know

10. Do you know if *SMITH MOUNTAIN LAKE* water is used for irrigation?

______ No
______ Yes
______ don't know

11. Now, I would like to get your opinion on some statements concerning water resources in America. The card I handed you lists five choices from STRONGLY AGREE, to AGREE, to NEUTRAL, to DISAGREE, to STRONGLY DISAGREE. A number appears with each choice. When I read a statement, please select the number that most closely reflects <u>your</u> feeling about the statement. What I want is the way <u>you</u> feel, not what you think other people feel. Do you understand?

	1 SA	2 A	3 N	4 D	5 SD
(1) Experts should make the decisions on the way water resources are used.					
(2) Government should control policy on uses of water resources.					
(3) Generating electric power is more important than using a lake for recreational purposes.					
(4) I believe the public should get involved in doing something about water problems.					
(5) The most important use for a man made lake is to provide electric power for the surrounding area.					
(6) Industrial development of a community depends upon an adequate supply of water.					
(7) The news media present accurate information about water resource problems.					
(8) If I wanted to do something about changing priorities of water use, I wouldn't know where to start.					

	1 SA	2 A	3 N	4 D	5 SD
(9) Who controls water resources doesn't concern me.					
(10) The one who builds a dam has first rights to the use of the water.					
(11) Persons like me don't have much to say about the way water resources are used.					
(12) I should provide more information to my friends about water problems.					
(13) I don't spend much time thinking about water resources problems.					
(14) My knowledge about water resources is so limited that a meaningful comment is difficult.					
(15) What power companies want, power companies get in the use of water resources.					
(16) Changes in water use policy depend upon public support.					

Now, if you will turn the card over, you will see eight sets of words with the numbers 1 through 7 between them. Let me give you an example of what I want. Suppose I asked you to describe the size of *SMITH MOUNTAIN LAKE* using the terms LARGE - SMALL. You could say "1" if you thought it was very large, "4" if you considered it medium size, etc. Do you understand?

12. With the sets of words on your card, please consider *SMITH MOUNTAIN LAKE* as a recreational area:

VALUABLE	1	2	3	4	5	6	7	WORTHLESS
UNFAIR	1	2	3	4	5	6	7	FAIR
USEFUL	1	2	3	4	5	6	7	USELESS
UNPLEASANT	1	2	3	4	5	6	7	PLEASANT
HAPPY	1	2	3	4	5	6	7	SAD
UNIMPORTANT	1	2	3	4	5	6	7	IMPORTANT
GOOD	1	2	3	4	5	6	7	BAD
UGLY	1	2	3	4	5	6	7	BEAUTIFUL

13. Now, use the same words to describe *SMITH MOUNTAIN LAKE* as a source for the production of electric power.

VALUABLE	1	2	3	4	5	6	7	WORTHLESS
UNFAIR	1	2	3	4	5	6	7	FAIR
USEFUL	1	2	3	4	5	6	7	USELESS
UNPLEASANT	1	2	3	4	5	6	7	PLEASANT
HAPPY	1	2	3	4	5	6	7	SAD
UNIMPORTANT	1	2	3	4	5	6	7	IMPORTANT
GOOD	1	2	3	4	5	6	7	BAD
UGLY	1	2	3	4	5	6	7	BEAUTIFUL

14. In the past year, has anyone in your home engaged in the following activities:

(a)	Fishing	D/K _____	No _____	Yes _____
(b)	Boating	D/K _____	No _____	Yes _____
(c)	Water Skiing	D/K _____	No _____	Yes _____
(d)	Camping	D/K _____	No _____	Yes _____
(e)	Picnicking	D/K _____	No _____	Yes _____
(f)	Hiking	D/K _____	No _____	Yes _____

15. Does your family own a boat? No _____ Yes _____

16. Does your family have camping equipment? No _____ Yes _____

17. In the past year, have you attended a meeting of any club or organization where water problems were discussed?

____ No
____ Yes Do you remember the problem discussed? _________
____

18. Did you vote in the election earlier this month?

____ No . . . Did you vote in the presidential election two years ago?
____ Yes ____ No
____ Refused ____ Yes

19. NOTE TO INTERVIEWER: If respondent voluntarily indicates reason for not voting, write it below. Do not probe.

[Questions 20 through 35 consisted of a Semantic Differential Scale and a Likert Scale designed to measure public attitudes on the role of an educational institution.]

FINALLY, A FEW QUESTIONS FOR CLASSIFICATION PURPOSES:

36. Are you married?

____ single
____ divorced
____ separated
____ married How many years? ________

37. Are there any children in your family?

____ No
____ Yes Number ____ How many live at home? ______

38. Are there any other adults that live in your home?

____ No
____ Yes Number ______

39. What is your occupation? ____________________

firm name ____________________

40. What is the occupation of your spouse? ____________________

firm name ____________________

41. What is the highest grade in school you completed?

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

42. What is the highest grade in school your spouse completed?

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

43. What is your age? ______

44. What is the age of your spouse? ______

45. Was your total family income last year over or under $10,000?

(a)____ over 10,000 Was it over or under 15,000

____ over

____ under

(b)____ under 10,000 Was it over or under 5,000

____ over

____ under

THANK YOU FOR YOUR COOPERATION.

****

INTERVIEWER'S COMMENTS

MATCHING GRANT PROGRAM

EFFECTS OF RESERVOIR OPERATING POLICY ON RECREATION BENEFITS

Project B-009-VA

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September, 1971

EFFECTS OF RESERVOIR OPERATING POLICY ON RECREATION BENEFITS

The early stages of this study indicated that in many cases the operating policies advocated by regulatory agencies imposed unnecessary constraints on the operation of reservoirs. Some twenty-seven multi-purpose reservoirs operated by the U.S. Army Corps of Engineers were studied in detail, and in no case could it be shown that recreational usage of the projects was reduced because of operating policy for the nine year period of record. However, in most of these cases, drawdowns rarely exceeded 10 feet. Nonetheless, in two cases average drawdowns during the recreation season exceeded 20 feet without noticeably adverse effects upon attendance. Simple and multiple linear regression techniques were used, and both correlation coefficients and F tests for significance were employed.

Since that time, several additional reservoirs have been studied using similar techniques and comparable results have been obtained. Taken together, these reservoir sites are widely distributed geographically and may well indicate conditions existing generally throughout the United States. It should be noted, however, that over the last several years the demand for outdoor recreation has grown much more rapidly than the population. Therefore, it is only reasonable that there will come a time when the supply of outdoor recreation facilities will exceed the demand and then it is quite possible that operating policy may have a much greater effect on attendance.

Information concerning the relationship of reservoir operating policy to recreation benefits is without practical use until it is incorporated with data relating to other purposes into a model that seeks to optimize the operation of a water resource system. The nature of the operation of a water resource system lends itself very well to analysis by any of a number of the more common techniques of systems analysis. Several very good linear and dynamic programming models for the optimization of the operation of a single reservoir have appeared in the literature. Some attempts have been made to analyze complete, or semi-complete, water resource systems by these methods, and although most have utilized oversimplified approaches, the results have been very encouraging.

As a part of the current study, one such dynamic programming model has been modified and improved so that the relation of recreation to other project purposes and to pool surface elevation may be studied more completely than it has in the past. The system studied included three reservoirs operated in conjunction with a localized system of downstream wastewater treatment plants for the combined purposes of water quality maintenance, hydro-power generation, and water based recreation. The pollutional characteriatics of the study basin have been varied from very heavily industrialized to very lightly industrialized at the same time that the value of recreation and the relationship between recreation benefits and pool surface elevation were varied. The analysis of the results of the simulated operation of the system is proceeding, and several tentative conclusions have been reached. Among these are that even though the effect of reservoir drawdown on the realization of recreation benefits is not nearly so severe as many had assumed, recreation requirements may still have an important impact on the optimum allocation of water resources for a given basin. Obviously, the effect of recreation on the operating schedules selected by the dynamic programming technique as being the optimal set of such schedules increases as the value of recreation itself is increased. Previous investigations in an earlier portion of the study indicated that perhaps recreation is currently severely undervalued by many planning agencies. However, the overall effect of this policy has been offset considerably by the severe operating range restrictions often placed on reservoir operators.

THE EFFECTS OF HEATED WASTE WATERS UPON MICROBIAL COMMUNITIES

Project B-017-VA

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[illegible] OF HEATED WATER [illegible]

UPON [illegible]

Project B-0[illegible]

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THE EFFECTS OF HEATED WASTE WATERS UPON MICROBIAL COMMUNITIES

Diatom Studies

Autecological studies of diatoms exposed to thermal stress commenced following the development and testing of suitable laboratory procedures. Intact diatom populations (Navicula seminulum) were examined with reference to the effects of defined abrupt temperature increases within the non-lethal temperature range of the species. Laboratory procedures utilized permitted three basic categories of abrupt temperature increases defined as follows: (1) Stress 1, increases of approximately 10-12°C above ambient in < 20 seconds followed by a return to approximately ambient in <60 seconds; (2) Stress 2, increases of approximately 7°C above ambient in <1 hour with maintenance at this increase for the duration of the growth period, i.e. approximately 96 hours; and (3) a combination of Stress 1 and 2 above. Stress 1 and 2 were designed to generally simulate certain possible types of temperature increases resulting from the presence of electric power generating facilities on aquatic ecosystems. Simulation of passage through a steam condensor (Stress 1) and overall downstream temperature increases resulting from the addition of thermal effluents to water masses (Stress 2) were, thus, attained in the laboratory. Advantages of the test procedure lie in its simplicity, reasonable reproducibility, and use of standardized diatom populations (age, density, nutrients, photoperiod, etc.) isolated from other forms of stress.

Separate diatom populations at three ambient temperatures, 18, 23, and 29°C, were established by preadaption through at least five successive weekly transfers in culture. These actively dividing cell lines were then used as test inocula for repeated experiments.

All experiments were run for 7 days (with stress application within this period) to provide estimations of the effects on replicate diatom populations actively dividing in the exponential growth phase. From the third to the seventh day is the time when the growth rate can be most accurately correlated with the effects of the test medium. All experiments at each ambient temperature examined were repeated later for confirmation. Both the immediate effects (directly after Stress 1 only) and the delayed effects (approximately four days after Stress 1 only, Stress 2 only, and both Stress 1 and 2 combined) were ascertained using the following criteria:

(1) General Survey – carried out under the light microscope; the general

morphological condition of diatoms following stress. Emphasis here was upon major changes in organic content, pigmentation, and vacuoles in the majority of cells.

(2) Induced Fluorescence Survey – carried out under the ultraviolet fluorescence microscope; the physiological condition of diatoms as pertains to readily noticeable major alterations in cellular lipids stained with 3,4 Benzpyrene-caffeine lipid fluorochrome. The number of cells with alterations in total visible lipid were recorded as a percent.

(3) Autofluorescence Survey – carried out under the ultraviolet fluorescence microscope; the physiological condition of diatoms as pertains to readily noticeable changes in the cell metalloporphyrin content (chlorophyll a + c) and fluorescence.

In addition to the immediate and delayed physio-morphological effects just described, the ability of diatom populations to survive and reproduce under the same stress regimen was investigated. These experiments would provide data with reference to the ability of diatoms to continue "normal" division rates downstream in the presence of, or following stress. This was accomplished through the use of standard cell counts following the A.S.T.M. (1968) technique. Calculations provided an estimate of the total number of divisions observed during a given 7 day growth period of unstressed and stressed diatom populations. Reproduction experiments were conducted at each ambient temperature, i.e. 18, 23, and 29°C and repeated later for conformation.

Samples from diatom populations grown at 18°C and exposed to various stress categories did not demonstrate any significant difference in the number of cells with major alterations in lipid patterns when compared to controls. Autofluorescence surveys under the ultraviolet microscope did not demonstrate any significant differences between control and experimental populations while general surveys under the light microscope did not reveal any consistent morphological changes. No consistent major differences in reproduction resulting from Stresses 1 or 2 alone or in combination were noted in these experiments; however, the possibility that some irregular growth stimulation resulted from exposure to Stress 2 is seen in the data.

Examination of diatom populations grown at 23°C, utilizing the induced fluorescence of 3,4 Benzpyrene-caffeine lipid fluorochrome as well as surveys of metalloporphyrin autofluorescence following the described stress patterns, indicated no significant difference between experimentals and controls.

General surveys under the light microscope also indicated a lack of consistent morphological differences between experimental and control populations. No significant effect of the defined temperature increases on population reproduction was seen as indicated by the total number of divisions which occurred during the seven day period.

Exposure of populations grown at 29°C to Stress 1 alone produced no significant differences (immediate or delayed) in the total percent of altered cells as surveyed under the ultraviolet microscope using the induced fluorescence of 3,4 Benzyprene-caffeine fluorochrome. Exposure to Stress 2 and combinations of Stresses 1 and 2, however, produced a marked effect on all 29°C diatom populations tested; the vast majority of cells viewed demonstrated major alterations in total cellular lipid patterns under the ultraviolet microscope.

Autofluorescence surveys of cellular chlorophyll in 29°C populations also failed to exhibit any noticeable consistent differences (immediate or delayed) between control and experimental populations following exposure to Stress 1 alone. Stress 2 and combinations of Stresses 1 and 2, however, produced a marked reduction in the characteristic visible red autofluorescence of chlorophylls a + c; the vast majority of diatoms seen displaying little or no autofluorescence. Light microscopic surveys demonstrated generally normal pigmentation in diatoms following exposure to Stress 1. However, populations receiving Stress 2 alone or combinations of Stresses 1 and 2 demonstrated a general decrease in total visible pigmentation accompanied by a major change in all pigmentation color (from the characteristic brown-yellow to green).

Generally, all categories of defined abrupt temperature stress applied to actively dividing 29°C populations produced a decrease in reproduction. Exposure to Stress 1 alone produced a partial suppression of cellular division over the seven day population growth period. Stress 2 alone or in combination with Stress 1 produced an even more marked decrease in the number of divisions occurring over the population growth period.

Algal-Chytridiaceous Fungal Relationship

A biological model was selected for the study of defined temperature increases on algal-chytridiaceous fungal relationships under controlled conditions in the laboratory. This was accomplished by numerous collections from several natural habitats in Montgomery and Giles County in search for diatoms and/or other algae infested with chytridiaceous fungi. One such

Chytridium hemicysta was isolated into unifungal culture for use as a laboratory inoculum source. Unialgal cultures of the Chlorophyta, Netrium digitus, were also obtained and subcultured in the laboratory on standard media until an actively growing cell line was preadapted to an ambient temperature of 23°C.

Experiments were conducted by preparing replicate cultures of Netrium digitus of fixed volume and known cell density and exposing them to infestation by viable zoospores of Chytridium hemicysta. These combined populations of algae and chytrids were then subjected to the standard temperature stress regimen described above in the diatom studies. The algal test inoculum was adjusted so as to provide both live and expired Netrium sp. cells on the test commencement day. The purpose of expired cells was to provide suitable host material for infestation by viable zoospores in order to estimate the effects of temperature shocks on the chytrid alone. Live cells of Netrium sp. were added to provide an estimate of the effects of the various temperature shocks on the algae alone (i.e. morphology and survival of live cells). Cells were considered live if they appeared visually normal, i.e. intact membrane structure, chloroplast, etc. All counts were done utilizing a hanging drop depression slide under low power. Temperature stress was applied shortly after the inoculation of all culture populations of algae and chytrids on day 1. On day 3, all cultures in each experiment were sampled and counts were made of the number of Netrium sp. cells clearly demonstrating infestation by Chytridium sp. These were then recorded as a percent of the total cells observed. On day 5, terminal counts of the live Netrium sp. cells were carried out on all culture populations and recorded as the average number of cells per milliliter.

No significant difference in the ability of Chytridium hemicysta to infest expired Netrium sp. cells were seen in these data when populations exposed to Stress 1 alone were evaluated. Exposure to Stress 2, alone or in combination with Stress 1, demonstrated decreased infestation of Netrium sp. cells by Chytridium hemicysta in all observed populations. Live cell counts of Netrium digitus at the termination of each experiment provided data with reference to the effect of each stress category on cell condition and survival. Exposure of populations to Stress 1 alone, Stress 2 alone, and a combination of Stress 1 and 2 produced various degrees of cellular damage and a general decrease in the number of live Netrium sp. seen at termination time (suppression of division).

CONVECTION HEAT TRANSFER FROM WATER SURFACES

Project B-021-VA

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CONVECTION HEAT TRANSFER FROM WATER SURFACES

A study of convective heat, mass, and momentum transfer between laminar parallel flow of air and water was undertaken. Analytical solutions of the laminar boundary layer equations for both the gaseous and the liquid phases were obtained by an analog computer. Profiles of velocity, temperature, and concentration as well as their gradients were obtained from these solutions. A range of air and water velocities and temperatures normally encountered by natural water bodies was considered.

The experimental verification of these results was carried out in an air-water facility of rectangular cross-section with a high aspect ratio to simulate two-dimensional flow. Temperatures were measured by means of thermocouples. Concentration of water vapor in air was obtained through the use of a Mach-Zehnder interferometer and the thermocouple-measured temperatures. A Helium-Neon gas laser was used as a light source for the interferometer. The velocity measurements were made with a low velocity anemometer.

Analytical and experimental results which are in good agreement indicate a marked influence of the interfacial motion on heat and mass transfer rates as exhibited by changes in the temperature and concentration gradients. In co-current flow the increase in the interfacial velocity increased the heat and mass transfer rates. This is due to increased convective heat and mass removal resulting from the finite velocity of the interface itself and the increased velocities in the boundary layer close to the interface.

For higher velocity ratios, the velocity in the lower fluid may be assumed uniform, and the energy convection in the lower fluid may be neglected. This will result in a linear temperature profile in the liquid.

[illegible] flow [illegible] and water was undertaken. Analytical [illegible] for both the gas [illegible] liquid [illegible] computer. Profiles of velocity, [illegible] depth were [illegible] velocities and temperatures [illegible] were considered.

[illegible] these results [illegible] with a high [illegible] temperatures were measured [illegible] of water vapor in air was [illegible] and the thermocouple [illegible] was used as a light source [illegible] were made with a [illegible]

[illegible] results which are in good [illegible] interfacial motion on heat and mass transfer rates [illegible] in the temperature and concentration gradients [illegible] in the interfacial velocity [illegible] increased [illegible] of the interface [illegible] layer close to the interface.

[illegible] the velocity in the lower [illegible] energy convection in the lower liquid may be [illegible] temperature profile in the liquid.

ANALYSIS OF WATER RESOURCE ADMINISTRATIVE AGENCIES

Project B-025-VA

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September, 1971

ANALYSIS OF WATER RESOURCE ADMINISTRATIVE AGENCIES

Research performed during the fiscal year has consisted of a continuing investigation into the organization, responsibilities, funding, and methods of operation of each of the several administrative agencies concerned with some aspect of water resource use in Virginia. Most of the research has involved state agencies, but some consideration of Federal agencies has been necessary because of the effect on state agency operation. Research activities have fallen into the following categories: (1) study of pertinent legislation; (2) review of existing studies of water resource management and water law; and (3) interviews with personnel of the various agencies involved.

The study of legislation has included both current and prior statutes in an attempt to trace the development and growth of each agency and its authority. Applicable court interpretations have also been considered.

Reports resulting from studies of problems relative to water resource use and water resource law have been analyzed to determine previously ascertained deficiencies in the law and in the institutional arrangements for its administration. Of special interest have been official studies authorized by the state legislature such as those conducted by the Virginia Advisory Legislative Council and other groups. An attempt has been made to determine if the recommendations arising from these studies have been adopted and put into practice.

Interviews have been utilized to determine the organizational structures and operating procedures developed within the agencies for performing their assigned functions.

This research into agency activities essentially has been completed and a preliminary draft utilizing the information has been prepared. The basic initial conclusion that can be drawn from the study at this point is that the several water resource agencies in the state possess considerable independence of one another and are not under direct central control. Coordination of activities appears to be primarily dependent on cooperative efforts by the officials of the agencies involved.

FUNCTION OF THE MARSHES IN REDUCING EUTROPHICATION OF ESTUARIES OF THE MIDDLE ATLANTIC REGION

Project B-027-VA

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FUNCTION OF THE MARSHES IN REDUCING EUTROPHICATION OF ESTUARIES OF THE MIDDLE ATLANTIC REGION

The objective of this study, which was initiated January 1, 1971, is to define the nutrient budgets of several eastern coastal plain marshes. In the original grant application two marshes were to be studied, one in an area unperturbed by man, the other in an area of enrichment due to domestic wastes. The intention of contrasting these two systems is still the aim of the present study, but we have decided to first develop nutrient budgets in two marshes unperturbed by man. Two marshes were selected because of differences in their dominant vegetation. The primary factor affecting the distribution of marsh plants in estuarine areas is salinity, and we believe that the natural differences or similarities between two systems of various salinities must be established before perturbed systems can be fully evaluated.

Figure 1 shows the general location of the two marshes presently under study. To date only the Ware Creek Marsh has been intensively sampled. Sampling will begin on the Carter Creek Marsh during July of 1971 and will be continued until at least July of 1972. Nutrient flux studies are presently being conducted at monthly intervals (weather conditions permitting) during periods of spring tides. During these studies, the following parameters are being measured hourly over a complete tidal cycle:

- Temperature
- Salinity
- Dissolved oxygen
- Chlorophyll a
- Phosphorus: ortho; total dissolved; and total
- Nitrogen: NO_2; NO_3; Kjeldahl (both dissolved and total)
- Carbon: dissolved organic and inorganic
- Alkalinity
- Carbon uptake by phytoplankton
- Volume of flow
- Detritus ($\geqslant 234\mu$; $< 234\mu$ and $\geqslant 64\mu$; and $< 64\mu$ and $\geqslant 0.8\mu$ With each of these fractions we determine % organic and inorganic and qualitative examination for composition.
- Estimates of marsh grass production via successive vegetation clips.

Examples of the type of data we are collecting are shown in Figures 2 and 3. Mass balance calculations will be made for each parameter to which they are applicable and correlations, via regression analysis will be made between the various factors.

We plan to begin study of a nutrient enriched marsh during the summer of 1971 and continue the study through the summer of 1973.

FIGURE 1. GENERAL LOCATION OF STUDY AREAS.

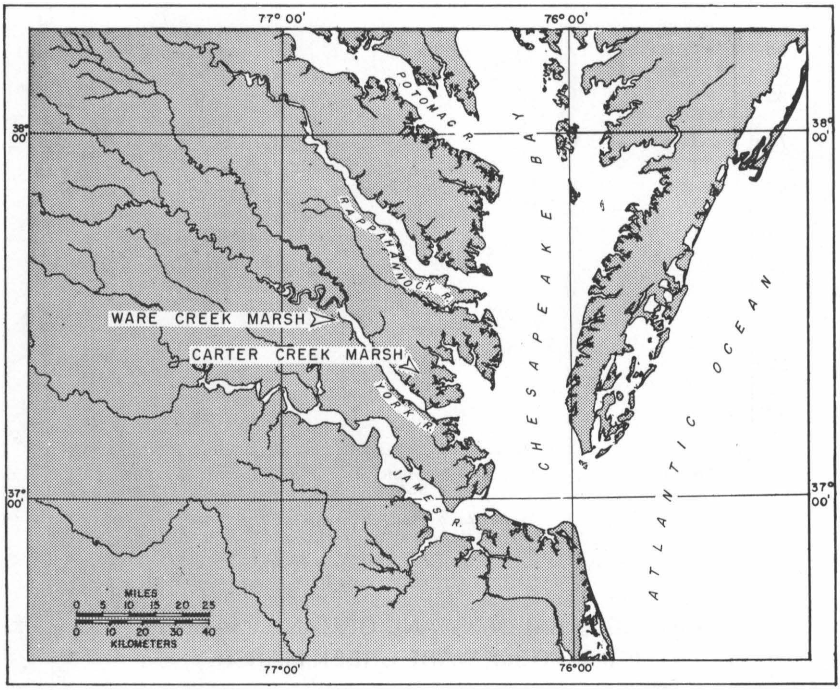


FIGURE 2. PO_4 AND WATER COLOR, WARE CREEK MARSH.

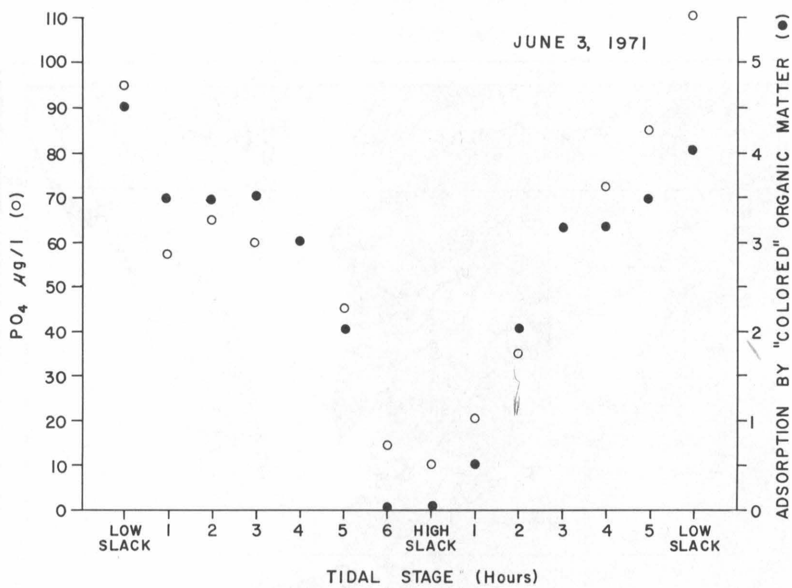
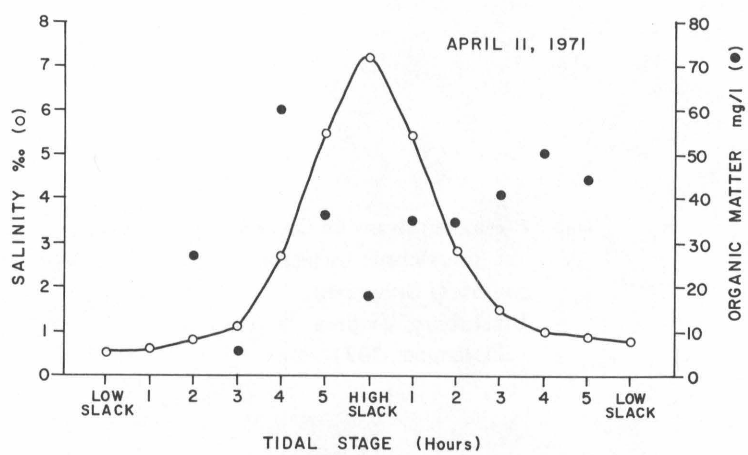


FIGURE 3. SALINITY AND ORGANIC MATTER ($<63\mu \geqslant 0.8\mu$), WARE CREEK MARSH.



EVALUATION OF FLOOD INSURANCE IN A DISASTER AREA

Project B-030-VA

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September, 1971

EVALUATION OF FLOOD INSURANCE IN A DISASTER AREA

The study area for this research project is the town of Buena Vista, Virginia, which experienced a severe flooding condition late in 1969. Initial work on the project involved the collection of damage estimates from all the relief agencies (Federal, state, and private) working in the disaster area. In addition, the expenditures for the recovery operation were identified. Inspection and personal interviews were conducted in an effort to elicit more detailed information regarding damages and cost of rehabilitation. An initial effort was made to develop flood damage stage curves to facilitate analysis of the cost and rate of recovery with and without flood insurance.

Work was suspended on the project after only two months had elapsed because the graduate student conducting the investigation returned to Utah. W. R. Walker, director of the project, was on leave from the university and could not satisfactorily indoctrinate a new researcher, working only on weekends.

RECOVERY OF STREAMS AFFECTED BY ACID MINE DRAINAGE

Project B-034-VA

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RECOVERY OF STREAMS AFFECTED BY ACID MINE DRAINAGE

The project involved two main areas of exploration. The first was an experimental shock treatment of a healthy stream to note the effects of a short term stress and the recovery processes involved in restoration of the aquatic community to its previous complexity after the stress. The second approach was the study of rivers and streams which are already affected by acid mine discharges. These streams and rivers were selected with acid discharges in the upstream regions and downstream portions with improved water quality and improved biological diversity.

The work on a short term shock of low pH was carried out on a small, very productive stream near Blacksburg, Virginia, Mill Creek. To provide two areas of similar habitat to allow the use of one as an experimental area and the other as a reference area, a one hundred foot long riffle section was divided in half along 60 feet of its length. This divider separated the stream into two portions of nearly comparable habitat. The experimental shock acidification was carried out using concentrated sulfuric acid. The stream was nearly blocked and flow was reduced alternately by 70 to 80% on both sides. The alternate reduction in flow was provided to expose both experimental and reference sections to the same low flow condition. As the flow was reduced on the experimental side, the acid was poured along the length of the section. As the water left the experimental site, it was neutralized with sodium hydroxide. The pH in the section was reduced to well below 4.0 and maintained at that level for 15 minutes. Sampling consisted of the collection of five Surber square foot samples along both the experimental and reference sections before and after the experimental shock. The values for diversity and density are contained in Figures 1 and 2.

The effects of the experimental shock were a reduction in diversity and a moderate reduction in density in the experimental area. The experimental section appeared to recover within 28 days to the values obtained before the experimental shock was performed. A secondary stress effect may be noted in both the experimental and reference sections, with the greatest effect occurring in the reference section. High sediment loadings occurred in sections of the stream during high rainfall. Runoff from an adjacent dirt road entered near the upstream edge of the experimental site and was channeled along the reference section. The depression in diversity and density values on days 49 and 64 shows the effect of this high sediment loading.

The second approach to the study of recovery involved the study of several rivers or streams which receive acid mine drainage. Since acid drainage is a constant stress to the stream and the stream organisms, the study of recovery in streams which are receiving acid discharges involves observation through distance rather than time. Three river and stream systems were selected for study. Two of these are naturally neutralized by alkaline tributaries, and the third is artificially neutralized by a lime neutralization plant. All of the experimental streams are located in Pennsylvania.

A complete river system was selected which would possibly show recovery in the downstream portions. The Casselman River in Somerset County, Pennsylvania, is approximately 40 miles long and flows in an approximate horseshoe from its headwaters in Garrett County, Maryland, to its confluence with the Youghigheny River in Pennslyvania. The Casselman receives several acid discharges in the upstream region and has several alkaline tributaries in the downstream portion. The acid loading has severe effects on the stream. The pH is depressed to below 3.0 in some portions of the stream, and recovery occurs to a pH of 5.5 to 6.5 in the lower portions of the river. Biological sampling of this river was at best inconclusive. The downstream portions of the stream are highly variable in water quality, and biological sampling has produced very little information concerning recovery processes. Initially, 17 stations were established on the Casselman, but this number has been reduced to five because of the instability of the downstream areas.

A second stream in the same area was also selected for study. Indian Creek (Figure 3) which flows through Westmoreland and Fayette Counties, Pennsylvania, receives a series of discharges, the largest being Champion Run in the mid portion of the stream. The acid discharges depress the pH from a range of 7.0 - 7.5 to a range of 6.0 - 6.5. The neutralizing capacity of the stream improves water quality within 2.5 miles, but biological recovery is not evidenced for approximately 8 miles below the acid discharges (Figure 4). Recovery in this stream is striking, and it provides information which should help identify the recovery processes. The mid portion of the stream shows good water quality, but biologically the area is very unproductive. This region has no tributaries, thus there are no sources for recolonizing organisms to enter the stream. The downstream portions show slight recovery after the entrance of several small tributaries, and the far downstream portions of the stream show good recovery and high productivity after the entrance of one or two good tributaries. Five stations were initially sampled on Indian Creek, but because of the evident recovery, this number was expanded to 11 and further studies are taking place on the stream. Because one of the mechanisms for recolonization is the downstream drift of invertebrate organisms, studies to note this drift and its effects are now underway.

The third stream is artificially neutralized by an automatic lime neutralization plant. The stream is Little Scrubgrass Creek in Venango County, Pennsylvania (Figure 5). The total length of the stream is approximately five miles, and the extreme headwaters region of the stream is in an abandoned mine. The lime neutralization plant is located approximately 1.5 miles from this headwaters region. The water quality of the stream is improved from a pH range of 3.5 - 4.5 to a range of 7.5 - 8.5 by the liming operation. The water quality is maintained in the downstream portions by the excess buffering capacity produced by the liming operation. Samples were obtained from 8 stations including several tributaries (Figure 6). The results show some recovery in the mid section of the stream where a good tributary provides recolonizing organisms, but the downstream portion of the stream is evidently affected by isolated acid discharges; the greatest effect may be noted in the effect of the North and South Forks on diversity and density values (Figure 6). Sampling carried out this spring (1971) showed the almost complete destruction of aquatic life in the stream. A combination of low flow and a floc produced by the liming operation has effectively destroyed all suitable habitats for aquatic invertebrates in the stream. The floc is settled in a pond constructed on the plant site, but the pond is full and floc is draining into the stream with the effluent waters.

Late last winter the experimental divider on Mill Creek was washed away by a high flow on the stream. A new divider was constructed on the same site, the the length was extended to approximately 100 feet. To note the recovery of an area which is totally destroyed, the experimental stream section will be heat treated to produce a 100% kill. The experimental acidification produced at best a 25% kill, and the rapid improvement of the section was probably due to the light kill and the availability of food organisms to make the site attractive for recolonizers. An attempt will be made this year to produce a complete kill of all organisms in the section and study the recovery of that section. Heat was selected because it can be localized at the experimental section, and a heat rise in a naturally cold stream should effectively kill all of the organisms in the section.

To further investigate the recovery processes involved in streams which are chronically stressed, several techniques will be used other than sampling procedures already outlined. Extensive drift studies are planned for Indian Creek. Along with drift information, artificial substrates will be placed in the stream to note the recolonization rate in certain sections. Additional samples will be made on all other river systems, and if recovery is evidenced from the floc loading on Little Scrubgrass Creek, further studies will be continued there. At present, another site where artificial neutralization of acid mine drainage exists is being sought. Two possibilities exist at present, one a neutralization plant which is already operating on Mingo Creek for the Consolidation Coal Company, and the other is another Consolidation Coal Company plant which is due to go on line sometime later this year. Plans are still tentative for this work.

FIGURE 1. DENSITY AND DIVERSITY VALUES OBTAINED FOR THE EXPERIMENTAL SECTION OF MILL CREEK.

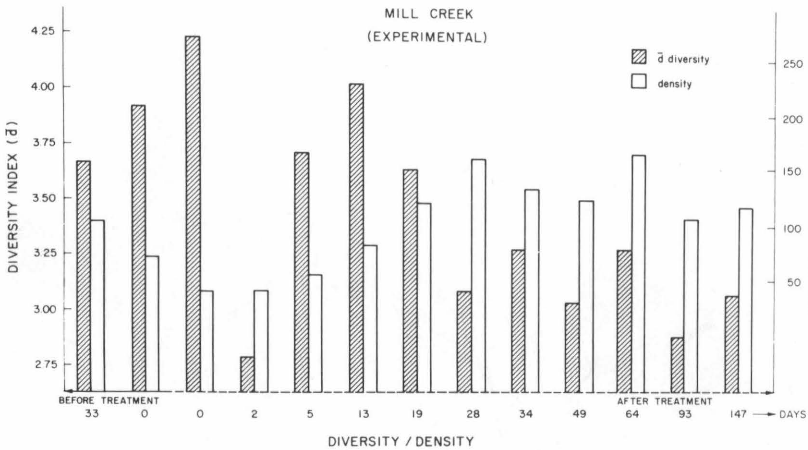


FIGURE 2. DENSITY AND DIVERSITY VALUES OBTAINED FOR THE REFERENCE SECTION OF MILL CREEK.

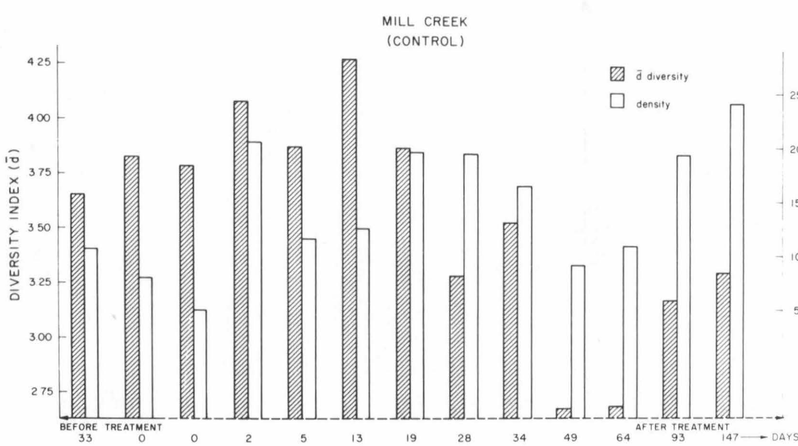


FIGURE 3. INDIAN CREEK, FAYETTE COUNTY, PENNSYLVANIA.

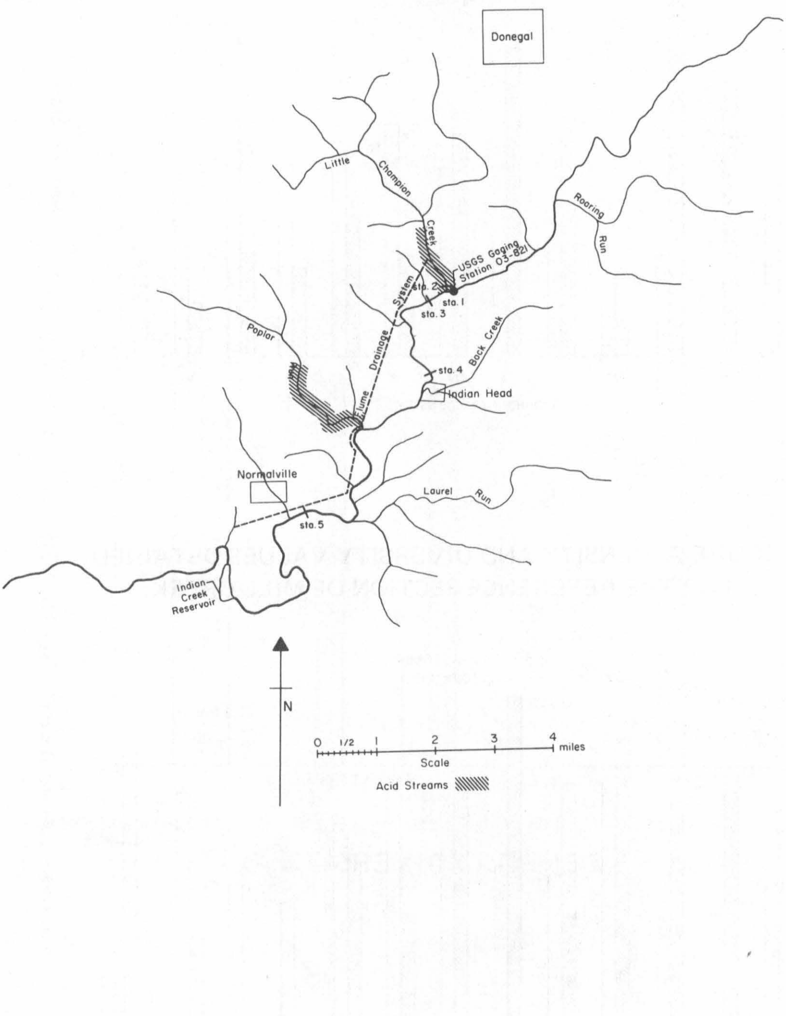


FIGURE 4. DENSITY AND DIVERSITY VALUES OBTAINED FOR STATIONS ON INDIAN CREEK.

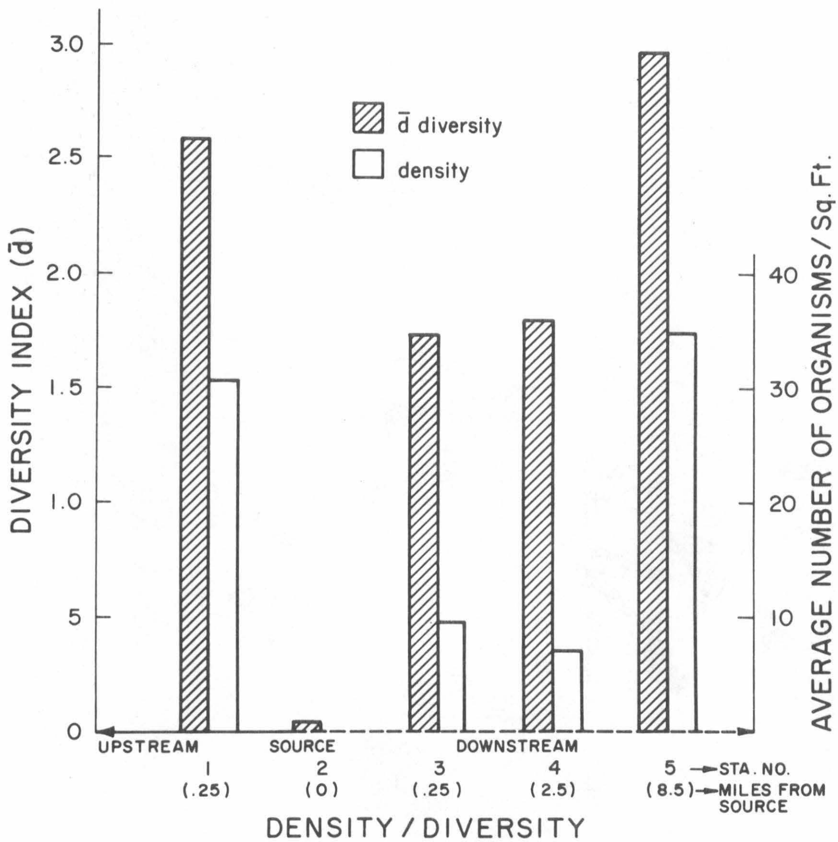


FIGURE 5. LITTLE SCRUBGRASS CREEK, VENANGO COUNTY, PENNSYLVANIA.

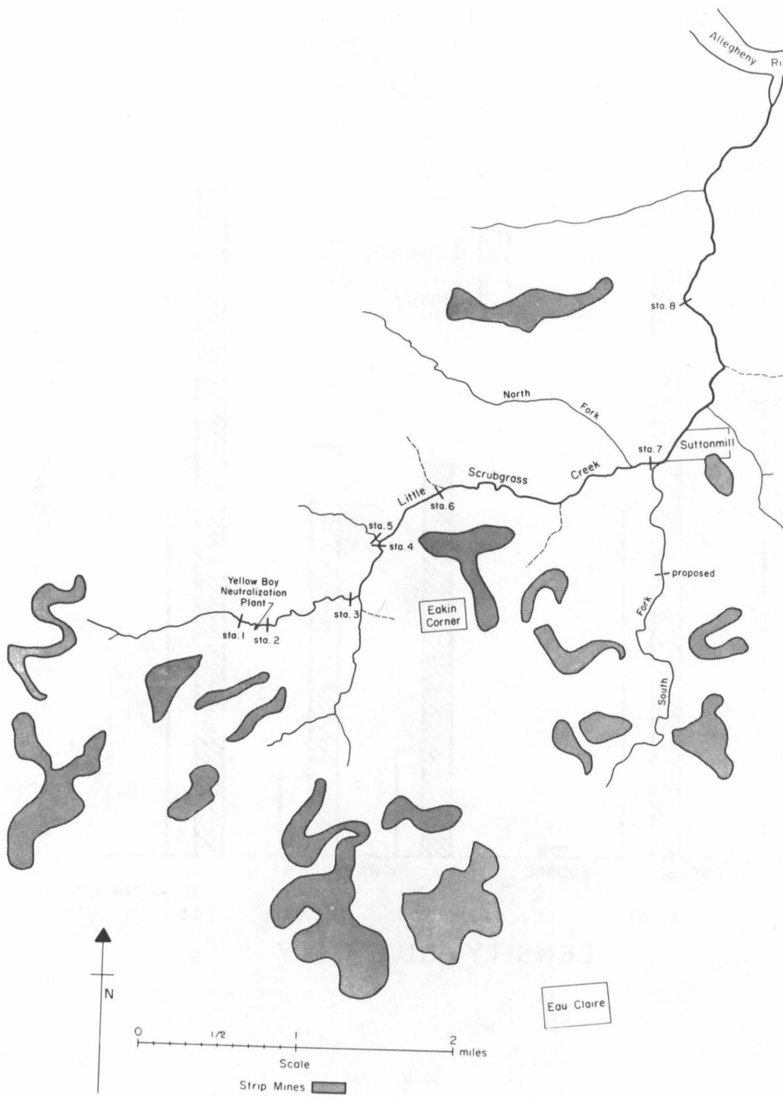
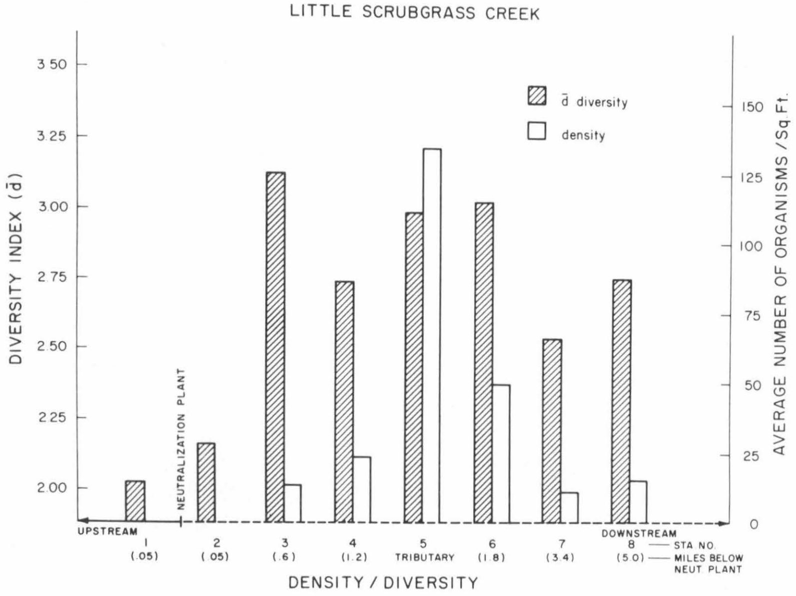


FIGURE 6. DENSITY AND DIVERSITY VALUES OBTAINED FOR STATIONS ON LITTLE SCRUBGRASS CREEK.



TRAINING AND EDUCATIONAL ASPECTS OF THE WATER RESOURCES RESEARCH PROGRAM UNDER P.L. 88-379

TRAINING AND EDUCATIONAL ASPECTS OF THE WATER RESOURCES RESEARCH PROGRAM UNDER P.L. 88-379

A. New Courses Developed

University of Richmond

Methods in Microbiology

University of Virginia

Water Use and Quality Control
Water Resource Planning

Virginia Polytechnic Institute and State University

Fishery Ecology
Environmental Quality Engineering
Algal Ecology
Sprinkler Irrigation Technology
Aquatic Entomology
Soil Interpretation for Multi-Purpose Utilization
Advanced Separations Processes

B. New Staff Members Added

University of Richmond

James Conyers - B.S. - Biology
Michael Dahlberg - Ph.D. - Biology

University of Virginia and College of William and Mary
(Virginia Institute of Marine Science)

Michael Bender - Ph.D. - Biological Oceanography
Robert Byrne - Ph.D. - Geological Oceanography
Mark Chittenden - Ph.D. - Biological Oceanography
Frank Fang - Ph.D. - Physical Oceanography
Paul Haefner - Ph.D. - Biological Oceanography

Paul Hyer - Ph.D. - Physical Oceanography
Robert A. Jordan - Ph.D. - Biological Oceanography
Fred Kazama - Ph.D. - Biological Oceanography
Albert Kuo - Ph.D. - Physical Oceanography
Joseph Loesch - Ph.D. - Biological Oceanography
Kenneth L. Marcellus - M.S. - Biological Oceanography
John Merriner - M.S. - Biological Oceanography
J. C. Munday - Ph.D. - Geological Oceanography
John Musick - Ph.D. - Biological Oceanography
C. L. Smith - Ph.D. - Chemical Oceanography

Virginia Polytechnic Institute and State University

E. F. Benfield - Ph.D. - Extension Specialist, Water Pollution
S. W. Bingham - Ph.D. - Plant Physiology
Kenneth L. Dickson - Ph.D. - Water Pollution Ecologist
Albert C. Hendricks - Ph.D. - Limnologist
Burl F. Long - Ph.D. - Agricultural Economics

C. New Water Resources Research and Training Facilities

University of Richmond
(Virginia Institute of Scientific Research)

New laboratory

Virginia Polytechnic Institute and State University

2 new bioassay laboratories
1 new water chemistry laboratory
1 primary productivity research laboratory

D. Number of Students Receiving Employment or Other Financial Support through the P.L. 88-379 Program

Category of Students	Scientific Discipline	Number
Undergraduate	Biology	9
	Chemical Engineering	1
	Geophysics	1
Master	Biology	1
	Biological Oceanography	1
	Chemical Engineering	1
	Engineering	2
	Sociology	2
Doctoral	Biology	2
	Biophysics	1
	Engineering	3
	Marine Environmental Chemistry	1
Postdoctoral		0

E. Type of Employment of 1970-71 Graduates in Water-Related Fields

Category of grad. by degree obtained	University or College: Tchg. prim.	Res. prim.	Res. and tchg.	Agency or Pvt. water resources research	Oper-ating and mgmt.	Plan-ning	Other wtr. re-sources work
	No. of Graduates Engaged in Water-Related Work in:						
Bachelor	0	0	0	0	0	0	3
Master	1	0	0	1	1	0	1
Doctoral	0	0	1	1	0	0	0
TOTAL	1	0	1	2	1	0	4

F. Employment Status of 1970-71 Graduates in Water-Related Fields

Category of grad. by degree obtained	No. Employed in Water-Related Positions in: Federal agen-cies	State agen-cies	Col. and univ.	Other such as private	No. ret. for adv. degree	No. entering military service	No. unemploy. or unknown
Bachelor	0	2	0	0	0	2	1
Master	0	0	1	2	0	0	1
Doctoral	0	0	1	1	0	0	0
TOTAL	0	2	2	3	0	2	2