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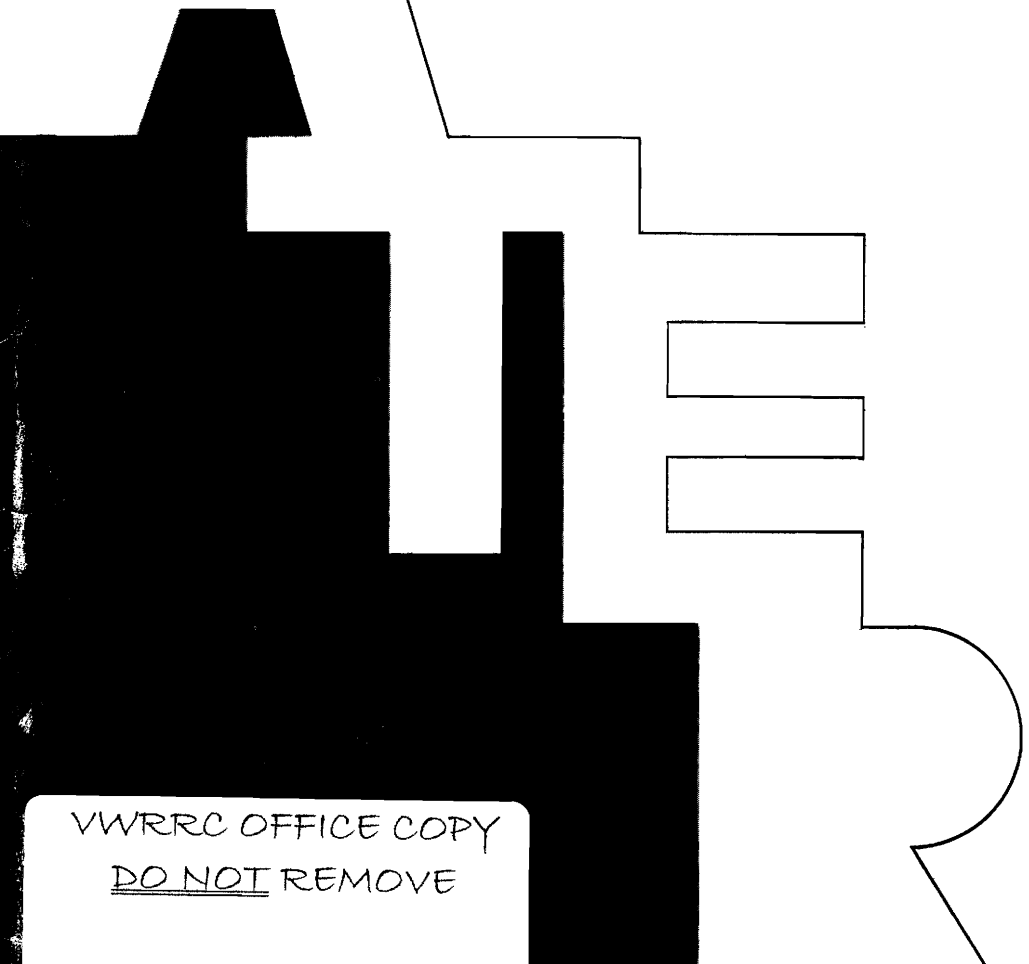
Bulletin 19:
ANNUAL REPORT FISCAL YEAR 1968



ANNUAL REPORT
WATER RESOURCES RESEARCH ACTIVITIES
UNDER PUBLIC LAW 88 - 379
FISCAL YEAR 1968

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

Water Resources Research Center
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PREFACE

The Water Resources Research 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 respcnsibilities 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 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 fourth 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).

William R. Walker, Director

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Significant Technical Accomplishments

Twelve research projects were active under the allotment program during this past year. Several projects commenced during the year represented an expansion into several new disciplines but only one into the social science area. Eight projects were completed on June 30 and the four remaining will be continued into the next fiscal year.

The match fund program was initiated during this year with an award of a project through the Center to the Virginia Institute of Marine Science at Gloucester Point. This research is programed over a three year period.

Three other institutions of higher learning have participated in the allotment and matching fund program. These included the Civil Engineering Department at Virginia Military Institute, the mechanical and chemical departments at the University of Virginia, and the department of Marine Science at the Virginia Institute of Marine Science.

The adequacy of water supply for municipal use may be of increasing importance for some areas of the state. Population growth and marked increases in per capita use of water are the chief factors. Individual daily water uses have grown from 40 gallons in 1900 to approximately 150 gallons in many areas today. The increasing number of water-using dishwashers, swimming pools, not to mention lawn sprinkling and gardening, may well increase the per capita daily consumption to 225 gallons.

Therefore, it becomes obvious that two of the most pressing problems facing a metropolitan area are to find, within the economic restraints, increased amounts of water to satisfy ever increasing needs and then to dispose of the waste water at minimal costs without rendering the water unusable by pollution.

One of the usual methods of increasing the supply of water to a municipality is by using impoundment structures. Of utmost importance in the selection of a site is the amount of water which a watershed will yield. On small watersheds, considerable difficulty is experienced in accurately

determined in relation to rainfall and runoff, it would be easier with the aid of a geologic map and rainfall data to predict more accurately the yield of a given water basin. The Water Center is sponsoring a project, "Evaluation of Geohydrologic Factors in Estimation of Runoff Coefficients on Watersheds Embracing Multiple Geologic Terranes" directed by Dr. Byron N. Cooper, Head of Geological Sciences, to evaluate the significance of this item. Two significant variations in rainfall-runoff relations have already been noted. The Mississippian-Devonian sandstone-shale terranes have shown an amazingly high runoff factor amounting to 53 percent of the total precipitation; while the valley forming limestone-dolomite terranes have a runoff factor of only 27 percent. The results of this project will be an important aid in planning and developing reservoir sites for small watersheds in the Appalachian areas of Virginia where the size of the project could not justify intensive engineering investigations.

The quantity of water available for use in many metropolitan areas is dependent on our technical capabilities to "clean it up" and re-use it. These capabilities to renovate water must always be stretched to the interface of technical knowledge lest we fall behind our ingenious methods to pollute. One of the projects under way at the Water Center is directed toward the removal of trace organics from water by adsorption on coal. Conventional water and waste treatment practices have little or no effect on an increasing number of the highly complex synthetic organic wastes which presently contaminate drinking water supplies. In order to protect these water supplies, new technologies for water and waste treatment must be developed. The use of activated carbon as an adsorbent has been thoroughly evaluated. More recently, a process has been suggested which utilizes the properties of coal as an adsorbent, flocculent, and filter aid for purposes of facilitating the treatment of waste waters. In evaluating this process, there is a real need for quantitative data which describe the extent of adsorption of persistent organics on coal. By comparing these data with published work describing adsorption on activated carbon, the possibility of properly evaluating the coal process will be enhanced.

Those actively engaged in agriculture in Virginia annually face the problem of developing procedures or techniques to increase soil-water storage and plant-use efficiency so the optimum crop yields may be obtained. Although the average annual rainfall would appear to be sufficient for most crops grown, short drought periods of two to three weeks are quite prevalent throughout much of Virginia. These short duration droughts cause considerable loss of revenue due to insufficient water. A research project sponsored by the Water Center has as one of its major objectives to gain a better understanding of the water conservation potential of no-tillage and conventional tillage systems. Hydrologic and climatic data are being collected over a statistically designed experiment so that a complete water budget may be maintained during the growing season. The ultimate objective is to develop a prediction model whereby the moisture conditions under the two systems can be estimated. With these estimates the time of drought may also be evaluated for given conditions.

As a direct result of experimental work on this project, no-tillage is being advocated by the extension personnel as providing multiple benefits for row crop farming. The most efficient use of available moisture provided by the no-tillage method was reflected in increased corn crop yields of 26 bushels per acre, a 43.1 percent increase in dry matter. In addition, surface runoff was found to be only one-seventh as great as that for conventional tillage.

As an extension to the experimental work being conducted, a mathematical model of the crop-soil system was developed to simulate a great variety of climate and soil conditions. Utilizing the computer studies based on the model, it is possible to predict expected yields for a specified set of soil-crop conditions.

Prior to 1945, there was practically no irrigation in Virginia. In the last several years interest in irrigation has increased tremendously with about 70 percent of the tobacco and 50 percent of the potatoe acreage under irrigation. In 1964, water used for irrigation was estimated at

55,000 acre-feet. In 1966, the amount of water had increased by 62,000 acre-feet, and it is anticipated that it will reach 152,000 acre-feet by 1980. Seventy percent of all irrigation water comes from 5,000 ponds located throughout the state. If water is to be available for this anticipated need, it will be necessary to minimize the evaporation loss from these ponds. Evaporation will be highest during the critical growing season. A project at the University of Virginia is currently underway to investigate a chemical substance which will substantially increase the solar reflectance and thus, decrease the evaporation loss from surface impoundments. The national average put the annual evaporation loss from reservoir surfaces at the equivalent of six feet in depth. Virginia might expect to be a little below average, but in any event the amount of water loss can take on staggering proportions.

The current expansion in all sorts of water recreation is likely to continue in the future. With greater numbers of people, increasing per capita income, greater leisure time, increased mobility, and continued urbanization, outdoor recreation is taking on greater significance among our wants and preferences.

While it is quite clear that we have a large demand for outdoor recreation facilities and areas of nearly all types, there is little information on the demand combination among types. Some notion of price-use relationships for various types and locations of recreation facilities could certainly have economic utility.

There is some question regarding the validity of the usual type demand statements and projections. They are not really projections of demand, but rather projections of consumption. The data used in support of them are invariably use data. They may be attendance figures for existing facilities or the number of activity-days engaged in by the population concerned. The resulting use that is made of facilities is then not an estimate of the demand, but again, an estimate of the consumption which has consequently occurred.

Much of the increased use of recreation facilities in a given area certainly can be attributed to changes in facilities available. Care should be taken, for example, that increased fishing in a given area resulting from improved facilities not be interpreted as an increase in demand for such, and thus suggest that even more investment should be allocated to that region.

Recreation and tourism can be a significant economic support for many areas of Virginia. The problems of operating recreational facilities are not less than those of other businesses, and there are several other factors which make the economic and commercial aspects of the recreation industry somewhat more hazardous or more difficult than others. These include the extreme seasonal patterns of demand, the susceptibility of this kind of expenditure to fluctuations in the business cycle, and the hazards of weather.

The recreational use of a region generated local business and these businesses and their employees pay local taxes, but services of local government are also demanded. These may cost fully as much as the increased taxes. A person may seek such business even when costs exceed taxes as the best means of employing local people, but there should not be an easy persumption that increased recreation or tourist business will necessarily improve local revenue.

Much research is needed concerning the amount of the expenditure staying in the local area; who in the area benefits financially from recreational expenditures; the relationship to the local tax burden; and the employment and wages generated by these expenditures.

The Outdoor Recreation Commission for Virginia is charged with the selection, acquisition and development of recreational areas in the Commonwealth. Of utmost importance to the Commission is determination of demand, where and for what. A miscalculation of the demand for different types of outdoor recreation can result in large wastes of the taxpayer's money, disgruntled citizenry, and possible irreversible decisions. To assist in providing some insight into the question of outdoor recreation demand, the

Water Center sponsored a study on "Demand for Water Recreation" which was directed by Dr. Norman L. Brown and Dr. Donald C. Darnton of the Economics Department. Since outdoor recreation boasts one of the most rapid rates of growth among the many competing uses of consumer income, it would seem that water-based recreation would be of key significance in this trend. We know the influence of many factors which are responsible for this rise in aggregate use, but much less is known about the relationship between use and cost to the user. The lack of understanding of the forces underlying the demand for water recreation stems in part from the heterogeneous nature of the product.

The research seeks to measure recreational value to an individual user since recreational services are not provided and sold through the market mechanism. This investigation was designed as a pilot project to develop a method for estimating the value placed upon certain types of water recreation activities by those who participate, to antecede a much broader study designed to establish demand curves to relate cost to the rate of use for the various types of water activity.

Businessmen need such information in deciding whether or not to provide recreational facilities and offer them for sale, and this same basic information should be of assistance to the Outdoor Recreation Commission as it seeks to discharge its responsibility with economic relevancy.

With a growing interest on the part of the public in clean streams and increasing pressure on the part of both state and federal government to keep deleterious substances out of the public waters, an urgent need has arisen for the textile industry in Virginia and the southeastern United States to find economical, effective means of treating dye bath wastes. The increased demand for synthetic fibers (dacron, nylon, and orlon) has accentuated the problem since dispersed dyeing techniques are used in their manufacture. Synthetic fibers are relatively unreactive and not easily dyed by conventional techniques. These fibers have a hydrophobic characteristic necessitating the adding of a swelling agent "carrier" such as o-phenylphenol

to improve the dyeability of polyesters and retarders or dispersants to regulate the dyeing rate. The result of these sophisticated dyeing techniques is improved color characteristics and waste streams that are difficult to treat. Conventional techniques such as aeration, settling, and flocculation are not entirely satisfactory in treating black and blue-black waste streams. The Water Center has a project on color removal which will continue for another year. Definite results are not available at this time.

The number of good hydro-electric power sites is limited but the need to meet the peak power demand, and to economically use the increased capacity of off-peak power from nuclear plants makes pumped-storage facilities increasingly attractive. However, very little is known regarding the effect of pumped-storage reservoirs operations of biological productivity and water quality. Under the direction of Dr. Stuart E. Neff an investigation of this type was initiated on Smith Mountain Lake, Virginia, the eighth pumped-storage hydrogeneration system in the United States.

Specifically, it was determined that the turbulence and mixing caused by recycling water during pumpbacks affected the gorge area near the dam and extended up the impoundment for a distance of four miles above the dam. This pumped-storage operation can enhance primary productivity where the effect of the recycled water can be felt. However, the overall characteristics are effected to a large extent by river effluent feed of the lake, particularly in the upper reaches. These effluents will have an increasingly greater influence on oxygen concentration and distribution within the reservoir as this enrichment continues. River effluents feeding the lower impoundment are also significant since the water quality near the dam reflects the quality of water that is recycled. In this study, it was seen that the degree of quality betterment by the operation is dependent upon the quality of water available for recycling.

Despite the measured benefits, the lake has rapidly undergone the development of limnological conditions which characterize older main stream reservoirs; this development has occurred in spite of the recycling of large

quantities of water during the pumped-storage operation. The anticipated beneficial effects of the recycling process appear to be limited.

Various agencies, state and federal, have an increasing need for this type of limnological data in order to suggest possible changes in new reservoir construction to accommodate the findings observed.

A plentiful supply of water which is low in organic and inorganic pollutants is an obligate requirement for any industry in which microbial processes are involved. In the pharmaceutical, chemical, and food industries water of high quality is a prerequisite natural resource. In large areas of western Virginia, North Carolina, and Maryland, considerable difficulty has been experienced in various microbial fermentations, and the problem has been most pronounced in the cheese industry. It was a major objective of Dr. Robert E. Benoit in his study, "Evaluation of the Effect of Trace Elements on the Activity of Microorganisms with Special Emphasis on the Lactic Streptococci" to determine the cause of the various abnormal fermentations in relation to water quality. It has been demonstrated that when water used in microbial media is passed through a mixed bed (amino/cation) ion exchange column, the problem of abnormal fermentations can be eliminated, but if the water is not treated some bacteria permanently lose the ability to metabolize certain substances after continued growth on these media.

The lactic streptococci were used in this study to illustrate trace element response because they are sensitive to the factor causing the change and they are one of the most important groups of bacteria in cheese starter cultures. A very high percent of abnormal lactic streptococci were isolated from local milk sources and the metabolism of these bacteria was studied. The isolation data in conjunction with laboratory tests indicate that an unknown trace metal was responsible for this problem. Apparently, the plants used to feed the dairy cattle accumulate this factor in a much higher level than is found in the local water supply, therefore, milk contained more of the trace element than the local water supply. The trace element may

influence biological systems which are not microbial, therefore, the public health aspects of this problem will be enlarged as the quantitative techniques developed in this work are perfected. Difficulties have been encountered in determining what trace element is producing this effect, but this study is being continued in cooperation with trace element chemists.

In this investigation, it was demonstrated that the abnormal fermentation problem can be eliminated by:

1. Using an ion exchange treatment of the water used in the preparation of microbial media, or
2. Frequent rotation of starter cultures used in the fermentations with cultures which originate from different geographical areas.

One of the most interesting results of this work was the demonstration that the lactic streptococci have a metabolic system which is expressed under the influence of the trace element, but it is not expressed without it. Under specified conditions, this new metabolic pathway could be used to improve the quality of some fermented food products.

Accurate prediction of streamflow is a primary need in development of many water resource projects. The time span of the prediction can range from several hours or days for floods and outlet works to months or years in water-supply determination. The research undertaken by Dr. James M. Wiggert, "Instantaneous Unit Hydrograph Response by Harmonic Analysis," was designed to test the efficacy of a particular method of short-term analysis and prediction.

The method studied was suggested by O'Donnell, who proposed the use of harmonic analysis to describe the Instantaneous Unit Hydrograph. The Instantaneous Unit Hydrograph can be described as the curve that results when the discharge past a given point in the stream, is plotted against time as a unit quantity of rainfall excess is released instantaneously over the watershed. Harmonic analysis is a mathematical technique which expresses the form of the hydrograph function in a finite series.

Some of the basic problems developed in the course of the research showed that further definition work is necessary, because study results indicate inadequacies in the present details of the method. The results of the prediction calculations are highly dependent on the number of data presented to the computation; the watersheds do not always exhibit consistency in the predictor forms.

Despite the problems, the method offers promise in operational streamflow prediction. The method is particularily adaptable to the digital computer, and it lends itself to continuous, real-time hydrograph computation if given data from remote sensing devices such as rain gages, weirs and ground-water monitors.

Urban drainage systems represent the investment of very large sums of money by the responsible agencies. It is usually desirable to provide systems that will give an optimal return on this investment. The return for money spent can be measured in terms of damage prevented and enhancement of the utility of the land and other facilities. The purpose of the study by Dr. John Knapp, "Prediction Models for Investment in Urban Drainage Systems," was to develop a method using charts and equations for predicting investment costs and design patterns of urban drainage systems as aids in planning and designing networks.

Two forms of equations were used with reasonable success. One represents the effect of physical and design considerations to be used as a planning aid, and the second can be used to estimate cost after preliminary design layout. The development of such prediction models will enable agencies such as the Federal Housing Administration, municipal and regional planning commissions, and consulting engineers, to judge alternatives after a rapid and reasonably accurate prediction of cost.

In cooperation with the North Carolina Water Resources Institute, a preliminary ecological study of the water resources and land-use patterns of the Dismal Swamp was undertaken.

The Dismal Swamp of Virginia is adjacent to a center of rapid growth, the Norfolk-Portsmouth area. It is a unique wetland which offers many problems for development. Little is known of what effect alteration of this area (such as filling, clearing, changing of drainage patterns, etc,) might have on the surrounding region. Yet, pressures are developing for the alteration of the Dismal Swamp, requiring wholesale drainage and clearing. It is obvious that previous drainage changes have affected water levels in the swamp, but the possible effects of large-scale projects are not yet established, and the presumed usefulness of the land afterwards is at best, debatable.

The Dismal Swamp does have a long history of one activity--lumbering. Strong pressures are now developing, and some modifications actually proceeding, for going beyond mere harvesting of trees to alteration for productive agriculture. On the other hand, there are interests in both state and national groups who feel that a large portion of the Dismal Swamp should be preserved in its natural condition. The Virginia Outdoor Recreation Commission has a plan calling for the establishment of a multiple-use park, including timber, game, recreation and wilderness.

Proponents of the various views do not have sufficient scientific information to present formidable arguments for their position. The results of the current research should provide some insights into the multiple aspects of the problem, and hopefully provide data for intelligent planning and development.

Most of the data gathered is still under analysis, the results of which will be forthcoming in several bulletins to be published by the Center.

Center's Involvement in Public Affairs

Liaison between the Water Resources Research Center and the state and federal agencies concerned primarily with some aspect of water resources is maintained by the Director through personal contacts. Additional emphasis on the water research needs of these agencies needs to be reflected in

the Center's total research program, but will have to be deferred until state financial assistance is made available.

The James River Basin Association, which was instrumental in securing the authorization of Gathright Dam on the Jackson River, and the Roanoke River Association are two citizens' groups with which the Center cooperated. In addition, the Division of Water Resources is establishing Basin Advisory Committees as planning studies are completed for each of the major river basins of the state. The Director has met with the first of these groups, the New River Advisory Committee, and discussed areas of mutual interest and the part that research might play in developing the information on which intelligent policy decisions can be made.

The Director has been appointed to the Subcommittee of the Virginia Advisory Legislative Council to study and make legislative recommendation to the January, 1970, meeting of the General Assembly on the Disposal of Solid Wastes which Affect Waters and Streams and the Licensing of Water and Sewage Plant Operators.

The Director has appeared before Virginia citizen groups when some aspect of water resources development has been a major concern. In addition, the Director addressed the Mississippi Water Resources Conference in Jackson, Mississippi.

In June, the Center sponsored a five-day seminar on Water Quality Management for state and federal agency personnel, industrial representatives, and consulting engineers. In addition to the sanitary engineers and statistics staff of Virginia Polytechnic Institute, the program featured nationally-known experts--W. W. Eckenfelder, University of Texas, Austin; Peter Krenkel, Vanderbilt University, Nashville, and John Jeris, Manhattan College, New York. The specific objective of the seminar was to present an intensive course of instruction on the latest developments in water quality management with emphasis upon water pollution control. Financial support for the program was provided by Title I of the Higher Education Act and a participants' fee.

In order that the activities and research of the Center should become more generally known throughout the state, a sixteen-page brochure, "Water Resources Research in Virginia," was prepared. In addition to general information on the creation and operation of the Center, it described in non-technical terms the type of research being done, the impact, both future and immediate, which it might have on water problems nationally and particularly in the Commonwealth of Virginia.

Center Involvement in Academic Affairs

The Director has been active throughout the year as guest lecturer in courses with a strong water orientation. In addition, he has spoken to local student groups regarding career opportunities in this resource area.

The Director served on a committee appointed by the administration to make a comprehensive review of agricultural engineering because of their program in soil and water. Recommendations were made regarding structure, curriculum, and the emphasis to be placed on its academic, research, and extension activities in the future.

The Center, in an effort to engender additional interest of the social scientists in the opportunities for research related to water, sent a sociologist to the Workshop for Sociological Aspects of Water Resources Research in Logan, Utah. It is hoped that the interest generated will instigate a research project from the sociology department in either the Allotment or Matching Fund Program.

Regional Cooperation

The North Carolina Water Resources Research Institute and the Water Center at Virginia Polytechnic Institute pooled some of the research talent at each institution to make a preliminary ecological study of the land and water-use pattern of an area known as the Dismal Swamp. The Swamp is located near the coastal area of southeastern Virginia and northeastern North Carolina. An attempt was made to divide the investigation along the lines of major interest as evidenced by the faculty at each school, rather

than on geographic lines. Aerial photographs were taken of the Swamp area in both states. Complete interpretation of the photographs has not been completed at this time. On-site investigative work was undertaken by two biologists, a fisheries expert, and a forester with expertise in photogrammetry. The budget expenditures for the project were primarily for the aerial photographs, support of two graduate students, and some travel expenses. The time of the four faculty members from Virginia Polytechnic Institute was contributed by the school.

THE EFFECT OF WATER QUALITY ON THE METABOLISM OF THE LACTIC STREPTOCOCCI

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September 1968

THE EFFECT OF WATER QUALITY ON THE METABOLISM OF THE LACTIC STREPTOCOCCI

Since there is considerable diversity in the fermentation rate of different strains of Streptococcus lactis, research work has been conducted in an attempt to elucidate these differences. Specifically, in southwestern Virginia, a predominance of Streptococcus lactis variety tardus in cow milk was observed. The predominance of variety tardus indigenous to the area produced economical as well as public health problems. Starter cultures of variety tardus failed to coagulate milk organisms, and as a result of this slow fermentation, a variety of dairy products spoiled or had an off flavor. The metabolism of Streptococcus lactis can be permanently altered by the water quality of the bacterial environment. In the presence of a factor in the water of southwestern Virginia, mutant cells of Streptococcus lactis selectively become the dominant lactic streptococci. These cells have been designated Streptococcus lactis variety tardus because they have an impaired ability to ferment lactose and the end products are quantitatively and qualitatively different. This investigation was a continuation of work initiated at V.P.I. with the long term objective being an investigation of the ecology and physiology of Streptococcus lactis variety tardus.

To study the nature of this process, the project developed the following objectives:

1. To isolate the "tardus" factor from various water sources in southwestern Virginia which is responsible for the conversion of rapid fermenting strains of Streptococcus lactis to slow fermenting strains of Streptococcus lactis variety tardus. A bioassay was developed and correlated with trace element analyses.
2. To determine the extent of the geographic area in which the slow fermenting Streptococcus lactis variety tardus is more predominant in natural populations than S. lactis.
3. To illucidate the previously unknown metabolic pathway which S. lactis may use to ferment carbohydrates.

Typical microbial techniques were used throughout the investigation. Metabolic end products were determined by silicic acid column chromatography and gas chromatography. Some preliminary work was preformed with C^{14} labelled substrates. Trace element analyses were performed by emission spectroscopy.

The following results were considered significant:

1. A chromatographic procedure was developed which permits the rapid identification of S. lactis var. tardus.
2. It is possible to prevent a rapid fermenting strain of S. lactis from losing this potential if the water used in the media to cultivate this bacterium is first passed through an anion/cation mixed bed ion exchange column.
3. It was demonstrated that the tardus factor which is responsible for the conversion of fast fermenting strains of S. lactis into var. tardus strains is present in several watershed systems in southwestern Virginia. The data indicate that the "tardus" factor is a trace element, but it has not been established which element produces this change.
4. It was demonstrated that S. lactis has the genetic potential to produce a number of endproducts in major quantity which were not previously believed possible with this bacterium. These include: acetic acid, formic acid, ethanol, several neutral products and carbon dioxide. In rapid fermenting strains of S. lactis, the metabolic pathway which permits the production of these products is repressed. However, the "tardus" factor permits the selection of mutant bacterial which are able to grow and become the dominant bacterium in natural systems.

The evidence presented in this work supports the hypothesis that S. lactis is transformed into var. tardus in this area, and under certain conditions it is dominant over S. lactis. The trace element aspects of this work are still under investigation. Preliminary data indicate that several trace elements are present in the water of southwestern Virginia in abnormal

concentrations. To completely describe the condition it is necessary to determine which of several trace elements are responsible for the "tardus" effect, and what concentration of these elements is necessary to produce the "tardus" effect.

The findings of this work will be of use to any industry which uses microbial fermentations. The dairy industry will be able to make immediate use of these results in the fermentation of such products as cheese, buttermilk, etc. The geographical area was limited to southwestern Virginia, but it is very likely that other regions of the country have a similar problem. It is suggested that some strains of S. lactis var. tardus could be employed to produce useful industrial chemicals from some carbohydrate waste products, such as vegetable processing plant waste.

REMOVAL OF TRACE ORGANICS FROM WATER BY ADSORPTION ON COAL

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September 1968

REMOVAL OF TRACE ORGANICS FROM WATER BY ADSORPTION ON COAL

Conventional water and waste treatment practices have little or no effect on an increasing number of the highly complex, synthetic organic wastes which presently contaminate drinking water supplies. In order to protect these water supplies, new technologies for water and waste treatment must be developed. The use of activated carbon as an adsorbent has been thoroughly evaluated. More recently a process has been suggested which utilizes the properties of coal as an adsorbent, flocculent, and filter aid for purposes of facilitating the treatment of waste waters. However, little attention has been given to the extent of adsorption of trace quantities of persistent, biologically-resistent organic contaminants, especially pesticides. Assay of microquantities of this type of material requires an analytical sensitivity which cannot be obtained by use of a normal procedure measuring chemical oxygen demand. In evaluating this process there is a real need for quantitative data which describe the extent of adsorption of persistent organics on coal. By comparing these data with published work describing adsorption on activated carbon, the possibility of properly evaluating the coal process will be enhanced. This research is designed to evaluate and extend the work currently being done in coal filtration by determining how effective coal is as an adsorbent for the removal of the persistent organics and the economic feasibility of substituting coal for activated carbon as an adsorbent.

In conducting this study to obtain the quantitative data required, three project objectives were stated:

1. The evaluation of the extent of adsorption on coal of biochemically resistant organic materials in an aqueous solution.
2. The determination of the kinetics of such adsorption processes.
3. The evaluation of the extent to which adsorption on coal may be substituted for adsorption on activated carbon as an advanced waste treatment process.

To develop these objectives, the planned research includes batch and fluidized column-type studies aimed at determining the extent and kinetics of adsorption on coal of biochemically resistant organic materials. The selected solutes represent as wide a range of physical and chemical properties as feasible and include straight-chain and highly branched sulfonated alkylbenzenes, phenols, quinine sulfate, triethanolamine, and several common pesticides including 2, 4-dichlorophenoxyacetic acid, parathion, lindane and either aldrin or dieldrin. Several ranks of coal from varying locations and with varying pre-treatments are used.

Analytical procedures employed depend on the nature of the adsorbate. Some of the substances can be readily determined by light pesticides liquid-liquid extraction of the organic into hexane and subsequent analysis by electron capture gas chromatography is appropriate.

Data obtained from these experiments are analyzed to show the kinetics of the adsorption process by plotting the rate of adsorption for the batch tests as well as typical breakthrough curves for the column studies. Data representing equilibrium conditions are tested for fitting an appropriate adsorption isotherm, perhaps of the Langmuir type. The experimental results are compared with published data for adsorption on activated carbon in order to evaluate the suitability of use of coal for removal of trace organics in water.

To date, significant data has been obtained on the uptake of two types of contaminants in a coal contact process. A representative chlorinated hydrocarbon insecticide, lindane, has been studied in considerable detail in a batch-type process utilizing high volatile C bituminous grade coal. Extensive work has also been completed on the removal of phosphate containing compounds utilizing a variety of coal types. A batch type process was also used in this work, and kinetic and equilibria data describing the distribution of the contaminants have been obtained. In the lindane studies eighty to ninety percent removal of this insecticide was achieved within one hour utilizing a coal dose of one gram per 100 milliliters and an

initial lindane concentration of 100 parts per billion. Removal varied significantly with pH and increased with decreasing lindane concentrations. The equilibria data for lindane adsorption were reasonably well described by the Freundlich isotherm equation.

The phosphate studies included consideration of orthophosphate, metaphosphate, and pyrophosphate compounds. The uptake by the finely ground coal was in each case achieved in one hour. Equilibrium was reached, on the average, after an uptake of about one milligram of phosphate per gram of coal assuming an initial phosphate concentration of 20 mg/l. Uptake varied significantly with system pH as well as with the type of coal utilized. Equilibrium data was shown to fit a Freundlich isotherm at low phosphate concentrations and a Langmuir isotherm at higher concentrations. A sixty to eighty per cent increase in pyrophosphate over orthosphosphate removal was noted while the removal of metaphosphate was similar to that of orthophosphate.

Consideration has been given to the mechanism of phosphate removal. Batch studies have indicated that optimum removal occurs when the system pH is in the range of 4.0 to 5.0. This pH corresponds to the point where ferric phosphate is least soluble and a surface reaction involving the formation of this compound has been postulated as an important mechanism in achieving the observed removals. Further support for this theory is gained from the studies utilizing various coals. Enhanced phosphate uptake was noted with lower grade coals and a definite correlation was observed between phosphate uptake and iron content of the coal.

In future studies, attention will be given to other persistent organic compounds. Representative pesticides to be studied include parathion and perhaps dieldrin and 2, 4-D. It is also proposed to extend the work to include upflow (fluidized) column studies as a means of determining the potential of the coal-contact process for an application of this type. The column study results will be compared with the batch system and, to the extent possible, the results of two types of operation will be correlated so that,

hopefully, batch tests may be useful in predicting the results that can be achieved with continuous flow columns.

In addition, the extent of parathion uptake by various types of coal will be determined. The work contemplated will largely utilize a batch system, and the effect of varying pH, coal type, and size of coal particle will be noted.

Column studies will be initiated to determine the nature and extent of phosphate removal in a counter-current system. Normalized break-through curves will be obtained and the potential of this type of system will be evaluated in terms of technical capability and economic feasibility.

The significant results obtained to date from this research investigation can find direct application to water and waste treatment processes. The fact that lower grade coals are more promising as contact media in terms of contaminant removal greatly increases the potential of the process for economically feasible applications in the wastewater treatment field.

SOLAR REFLECTANCE OF MONOLAYER-COVERED WATER SURFACES AS RELATED TO EVAPORATION SUPPRESSION

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September 1968

SOLAR REFLECTANCE OF MONOLAYER-COVERED WATER SURFACES AS RELATED TO EVAPORATION SUPPRESSION

Water reservoirs in the United States experience an average evaporation loss of six feet of water depth annually. With increased population and industrialization, the demands for water increase. Consequently, it is very important that new methods of water conservation be investigated.

During the past fifteen years, there has been a considerable effort at evaporation suppression through the use of monolayer chemical films. Materials such as cetyl alcohol and stearyl alcohol have been found to be effective as barriers to the diffusion of water into the atmosphere. Studies have indicated that the evaporation of small lakes may be reduced by as much as 35%.

An alternate approach to the evaporation suppression problem would be to attempt to reduce the amount of incident energy absorbed by the water surface. An analysis of the literature shows that the major factors in the "energy budget equation" are the energy absorbed from the sun and sky, the energy emitted by the water surface, and the energy lost as a result of evaporation. If the absorbed energy could be reduced, it would logically follow that the energy loss terms would also be reduced. This would be accompanied by a decrease in the water temperature and the rate of evaporation. Therefore, the investigation of ways to increase the reflection of incident solar energy is important. It is the purpose of this study to determine the chemical substances which will substantially increase the solar reflectance of lake surfaces.

There are two basic categories of substances studied:

Dyes: By their very nature, dyes have a high coefficient of absorption in the visible energy wavelengths where most solar energy is found. It has been shown that a yellow dye pigment in the bulk form may reflect as much as 68.5% of the solar energy when incident normal to the surface.

Polymers: An increase in film thickness tends to increase the reflectance for films having certain optical properties. Because of their physical nature, polymers should produce thicker films. Thus it should be possible to enhance reflectance with certain polymeric materials.

One major emphasis of the work related to both dyes and polymers is the search for products which, when applied to a water surface, will:

(a) form stable monolayers themselves,

(b) form a stable monolayer in solution with other monolayer forming substances, or

(c) form a stable thin film.

The reflectance studies are experimental and require a solar reflectometer. This requires an energy source which closely approximates the spectral distribution of solar energy. A detector system is required which is capable of determining the ratio of the reflectance of a film-covered water surface relative to the reflectance of a pure water surface.

An analytical study of the heat and mass transfer problem is made with the aid of a digital computer in order to determine the changes in evaporation losses which accompany changes in solar reflectance. This work requires the application of established techniques to the general conservation of heat and mass transfer.

The research performed up to the present data has been divided into two categories:

(1) finding a monolayer which will reflect more solar energy, and

(2) determining the amount of energy reflected from such monolayer-covered surfaces.

(1) Finding a Monolayer

Since yellow reflects more of the solar energy than does any other color, substances are being investigated which are yellow in bulk form and which will form monolayers. However, reflectance alone does not determine the amount of evaporation suppression. The monolayer also reduces the evaporation of water due to the fact that it also presents a barrier which the water must diffuse through.

It has been postulated that the diffusion rate is related to the surface pressure of the film. Accordingly, a film balance has been constructed to measure surface pressures of the monolayers, and equipment to measure diffusion rates of water through monolayers is presently being made. With this apparatus, it may be possible to relate the diffusion rates to the

film pressures, and thus obtain an equation to predict the effectiveness of the monolayer in reducing evaporation. The measurement of the film pressure will also indicate the reproducibility of the spreading of the monolayer.

(2) Solar Reflectance Measurements

This work has been divided into two parts. One part has dealt with the theoretical calculations of evaporation suppression due to increased solar reflectance. The various coefficients and relationships required in order to evaluate the transient, one-dimensional heat conduction equation have been justified. Solutions of this equation for simulated reservoir conditions (both with and without a monolayer present) are being obtained at the present time. Thus, calculations of evaporation suppression due to the presence of a monolayer will soon be routine.

The other section of this work is aimed at experimental measurements of the change in reflectance due to the presence of the monolayer. The experimental apparatus necessary for this work has now been constructed, and measurements are being made with it at the present time. A carbon-arc source is being used to simulate the spectrum of solar energy, and our optical set-up will allow the angle of this incident energy to be varied.

In the work remaining, the resulting correlations should not only indicate the effectiveness of the monolayers as far as reflecting more solar energy, but general guidelines should be obtained which will aid in selecting the best monolayer to use in connection with diffusion reduction also.

DEMAND FOR WATER RECREATION

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September 1968

Outdoor recreation boasts one of the most rapid rates of growth among the many competing uses of consumer income. The Outdoor Recreational Resources Review Commission estimates that users of the out-of-doors spent approximately $20 billion in 1962 to enjoy the pleasures of this type of activity. Estimates of future expansion in population, available leisure time, and incomes, suggest an increasing need for facilities to accommodate this expanded recreational activity. The influence of many factors which are responsible for this rise in aggregate use is known, but much less is known about the relationship between use and cost to the user. Determining the value of any recreational benefit is difficult. Frequently, recreation services are not provided and sold through the market mechanism, and so we have no sure measure of the value of a visitor-day of water skiing, swimming, or some other water activity. In the absence of a market price it would be desirable to find a way to measure what consumers would be willing to pay if they had to purchase the service in the market.

To limit the scope of the project, only those activities suitable for lakes were considered; water activity at streams and at the seashore was omitted. The three types of facilities providing water recreation which are included are (1) swimming pools which provide very limited water recreation, (2) small lakes which usually provide swimming and some other activities such as fishing and boating (usually restricted to no motors or to low horsepower motors), and (3) large lakes which offer virtually all types of water activity: swimming, fishing, boating (unlimited power), water skiing, etc. These facilities are referred to as type I, II, and III, respectively.

This project was designed as a pilot project aimed at developing a method for estimating the value placed upon certain types of water recreation activities by those who participate.

The objective of the total project was to derive demand curves for the various types of water activity and of water facilities. Furthermore, the

verification of four hypotheses about those demand curves was sought:

(1) The demand schedule rises as the type of facility rises from I, to II, to III,

(2) The coefficient of elasticity of demand falls as the type of facility rises,

(3) The demand schedule for lesser water activities (swimming, for example) rises as the type of water facility increases,

(4) The coefficient of elasticity of demand for lesser water activities falls as the type of water facility increases.

The pilot phase of the project also has four objectives:

(1) to develop the questionnaire for collecting information,

(2) to determine the best way to distribute and collect the questionnaire,

(3) to determine specific recreation sites to be included in the major study,

(4) to obtain the cooperation of the owners of the selected study sites.

In order to estimate the demand curves and to test them against standard economic theory, several pieces of information were needed:

(1) costs associated with the visit to the site

(2) number of people in the party

(3) number of days spent at the site

(4) types of water activities (and others) engaged in by the party

(5) income of the family group

(6) home of the party

Data was gathered by questionnaires distributed at selected recreation areas. Information obtained consisted of three types: Socio-economic characteristics of the visitor, costs incurred in using the facility, and types of activities in which respondents participated. Costs are defined as those recognized by the user in getting to and from the area plus those on the site. This approach has a tendency to obtain only the variable, or

out-of-pocket costs; except in those probably rare instances in which the user explicitly allocates overhead expenses to the visit.

The cost data was related to the users' places of residence (county) to find the rate of use per thousand population associated with different costs. Use of the socio-economic data allows investigation of the influence of non-cost factors upon the demand for water recreation.

This pilot phase of the project was not intended to develop accurate estimates of the demand curves for various types of water activities at different recreational sites. The limited amount of data which are available allow the construction of very crude demand curves and to compare these with patterns hypothesized by the theory of demand. However, the amount of information available at this time is insufficient to derive demand curves for each of the separate activities and possible combinations of activities.

The basic premise of the theory of demand is that as expenditure per visitor-day declines, participation in any given water recreation activity should rise. While the results do not show a continuous verification of this theory, they do suggest a tendency in that direction. A greater number of observations would be desirable.

A second hypothesis is that the demand for three combined activities should be greater than the demand for two, which, in turn, should be greater than the demand for a single water activity. Graphically, this would appear as three demand curves each one farther to the right as the number of activities increases. For any given expenditure, the number of visitor-days should be greater the larger the number of activities. Here again, the results showed support for the hypothesis, although there was deviation.

Claytor Lake and Douthat State Park were two test sites included in the pilot study. Differences in the two test sites lead to a third hypothesis. The demand for water recreation should be greater at Claytor Lake than at Douthat State Park, because the former offers users a wider range of water activities. Boats may carry unlimited sized motors at Claytor Lake and water skiing is allowed, but not at Douthat. The evidence available strongly supports this expectation.

The successful economic analysis of water based recreation constitutes a valuable contribution to designing and planning for the development of the natural water resources. Federal, state, and local agencies are concerned with the economic growth of recreation as a source of employment and income. Recreation is one of the benefits against which costs of private and public water impoundments are compared. Continuing inability to gauge recreational demand presents a serious deficiency in present day planning.

TREATMENT OF DYEING BATH WASTE STREAMS BY FOAMING AND FLOTATION TECHNIQUES

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September 1968

TREATMENT OF DYEING BATH WASTE STREAMS BY FOAMING AND FLOTATION TECHNIQUES

With a growing interest on the part of the public in clean streams and ever increasing pressure on the part of both state and Federal government to keep deleterious substances out of the public waters, an urgent need has arisen for the textile industry in Virginia and the southeastern United States to find an economical, effective means of treating dye bath wastes. The increased demand for synthetic fibers (dacron, nylon, and orlon) has accentuated the problem since dispersed dyeing techniques are used in their manufacture. Synthetic fibers are relatively unreactive and not easily dyed by conventional techniques. These fibers have a hydrophobic characteristic, necessitating the adding of a swelling agent "carrier" such as o-phenylphenol to improve the dyeability of polyesters and retarders or dispersants to regulate the dyeing rate. The results of these sophisticated dyeing techniques is improved color characteristics and waste streams that are difficult to treat. Conventional techniques such as aeration, settling, and flocculation are not entirely satisfactory in treating black and blue-black waste streams.

This investigation is to study waste treatment and color removal of dispersed dye bath waste using foaming techniques. The work includes a study of dispersant surfactant using foam fractionation, adsorptive bubble fractionation, and homogeneous ion flotation (complexing). The project objectives include:

(1) A better understanding of the mechanisms involved

(2) An estimate of the costs using developed techniques in conjunction with traditional means of separation (flocculation).

(3) Foaming techniques that will be helpful in the removal of phenol and phenol derivatives.

The initial stream to be studied is a synthetic black or blue-black dispersed dye formulation including carrier approximating waste stream conditions from the dyeing of polyesters (Dacron) and triacetate rayon.

Depending on the outcome, the treatment of waste streams from other types of dying procedures may be tested using foaming techniques.

Laboratory studies are conducted on the removal of the carrier and color from synthetically mixed waste which is typical of a waste stream from a dispersed black dye bath. The techniques utilized are:

(1) Foam fractionation continuous column.

(2) Adsorptive Bubble fractionation.

(3) Complex formation of homogeneous ion flotation.

The separations are studied as a function of pH, bubble gas rate, ion concentration, and additive concentration, i.e. extra surfactant.

A preliminary appraisal is made on the use of foaming techniques for treating typical waste streams from other dyeing processes. The treatment of waste water from chrome dyeing operation (acid dye used mainly on wool) would be one possible example.

To date work has been on a synthetic water waste stream containing 400 ppm, Foron Black "K" Powder and 200 ppm Dispersing Agent #8 having a pH of 6.5. This solution approximates the concentration of the waste dye and dispersion agent leaving the dye bath assuming a 90% utilization of dye and 90% hold up of surfactant on the polyester-cotton mix.

A few batch tests have been conducted. At the start of a run, foam is abundant but as the bubbling continues the amount of foam decreases. In these tests the air rates were high and too much foamate was taken overhead (~ 5% of feed) because of liquid entrainment in the foam. The results were inconclusive although differences were observed and a separation is taking place.

In this foaming project, interest centers on the selective removal of impurities and stream quality as a function of time using foam fraction. Variables such as air rate, pH, and effect of salts are of particular interest.

Finally, it is hoped some progress can be made on defining the problem involved in removing phenol from water using foaming techniques. The unique

approach to be used here is the complexing tendency of the phenol for various ions. Concentration and pH appear to be important variables.

The necessity for finding a solution to this problem in a relatively short time is imperative because of the new stream standard being proposed for interstate streams by recent federal legislation. This project will assist in providing some of the information necessary to develop new waste treatment techniques.

SIMULATION OF THE HYDROLOGIC CYCLE ON SMALL AGRICULTURAL WATERSHEDS BY DIGITAL TECHNIQUES

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September 1968

SIMULATION OF THE HYDROLOGIC CYCLE ON SMALL AGRICULTURAL WATERSHEDS BY DIGITAL TECHNIQUES

Design engineers have long sought quantitative answers about various hydrologic and hydraulic components of a given watershed area which would enable them to design with more certainty within the parameters and restraints of the problem. Digital equipment has provided part of the tools necessary to make quantitative studies of various segments of the hydrologic cycle. Stanford University has developed a watershed model which shows considerable promise for combining the climatic, hydrologic and meteorologic data for large river systems to produce information long needed by the design engineer. With this preliminary work, a good foundation has been established for developing a model for small agricultural watersheds.

From the data obtained from small watershed studies in Virginia during the past ten years, it is feasible to develop a small watershed model building on the experience and results of the Stanford model. Past research at this institution indicates that information developed with respect to large watersheds is not readily applicable to small watersheds and therefore the need for the additional work is very badly needed. It thus appears that if the information obtained in the past is to be used to its best advantage, then the development of a model for small watersheds is imperative. The results of this study should be applicable not only to Virginia, but to most other areas.

The project objectives are (1) test the Stanford Watershed Model on small agricultural watersheds in Virginia, and (2) modify the model as required to fit the flow regimes of these small agricultural watersheds.

The concept of excess precipitation followed by routing through a partial linear storage system to obtain lag time is used in lieu of the Stanford technique. Storage routing without coefficients is used in lieu of the semi-graphical technique for reservoir routing.

After the Stanford Model was concerted for this study, the functional program was tested using hydrologic data collected from experimental

watersheds to determine the applicability of this algorithm for studying flow regimes.

A major problem in simulating the flow on these watershed areas is to obtain correct spatial and time distribution. Not only must the flow be initiated correctly in time, but the response at some downstream point must also be correctly positioned. Time distributions also by necessity become closely related to spatial distributions of flow.

In the Stanford Model time delay histogram(s) are used to position flow in time in order to obtain the correct lag time response for specific input conditions. It is felt that for small agricultural watersheds the concept of excess precipitation followed by routing through partial linear storage to obtain lag time would be more efficient and more nearly represent the true physical conditions.

Excess precipitation is estimated from the relation:

$$f = a(S-F)^n = f_c$$

where

- f = Rate of infiltration in inches per hour
- S = Storage potential of a soil above some impending layer (total porosity minus antecedent soil moisture) in inches
- F = Accumulated infiltration in inches
- f_c = Constant rate of infiltration after prolonged wetting in inches per hour

a and n are constants which depend on soil characteristics

Solution of the above formulation for the accumulative infiltration curve is obtained by a series of iterations to find ΔF such that $(\Delta F/\Delta t) \leq f_1 + f_2/2$. The difference between infiltration volume and precipitation for a given time increment becomes rainfall excess. Delayed infiltration is accounted for from rainfall excess with the remainder being routed through a partial linear storage system to obtain lag time for overland flow.

Unlike most of the classical procedures for obtaining infiltration estimates, the above formulation allows for infiltration recovery during periods of no rainfall or periods of very light rainfall. The processes of

evapotranspiration and percolation to ground water storage are accounted for by this procedure.

Precipitation excess is positioned in time by successive applications of linear systems of storage routing. Basically, this procedure consists of routing n times using one nth of the indicated storage for each successive routing. Experimental evidence indicate that proper lag is obtained when $n = 2$. Verification of these values for the watershed areas in question is planned.

The continuity equation, which states that inflow minus outflow equals change in storage, is used to route through the linear storage system. By substituting $m/2(q)$ for S, the continuity equations for two linear systems become:

$$(1)\quad q_2' = (\Delta t/m + \Delta t)(PE_1 + PE_2) + (M - \Delta t/M + \Delta t)\, q_1'$$

and

$$(2)\quad q_2 = (\Delta t/M + \Delta t)(q_1' + q_2') + (M - \Delta t/M + \Delta t)\, q_1$$

where

- q = theoretical discharge from the first partial reservoir
- M = storage coefficient in cfs-hr.
- t = time interval in hours
- PE = precipitation excess
- q = final discharge rate

subscripts 1 and 2 refer to the beginning and end of Δt.

The discharge hydrograph resulting from the above routing becomes the input hydrograph to the stream channel. The response of this input at some downstream point is determined by channel routing. Channel routing may be accomplished by a number of ways. Most of these procedures have been developed by assuming idealized stream hydraulic conditions and then applying the results to natural streams or reservoirs.

The method to be tested here is storage routing without coefficients. The method is formulated from the continuity equation:

$$\partial Q/\partial X + \partial A/\partial f = q$$

and some rating function

$$Q = f(a)$$

Unlike classical storage routing techniques, this procedure requires no estimate of coefficients, e.g., in the Muskingham method two coefficients X and K are introduced to partially account for wedge storage. The partial derivatives are estimated by the technique of finite differences.

The rates of flow and depths of flow at selected sections along the channel system define a section rating function. This function may be determined from the Manning and Chezy formulations for turbulent flow conditions or in natural channels water surface profiles may be developed.

Crab Creek and Brush Creek watersheds have been selected for the initial evaluation phase. The Crab Creek Watershed, with an area of 786 acres and mixed land use, has a relatively low annual water yield. The Brush Creek Watershed has the same land use and approximately the same area (893 acres) but has a high annual water yield.

Ten years of records are available for these two stations. The necessary model input parameters for these two watersheds, which includes 6-hour precipitation, 6-hour daily discharge, evapotranspiration, watershed physical characteristics (including sub-watershed areas and channel geometry) and soils data have been prepared. Surface and subsurface drainage characteristics have been determined from historical records. Estimates of potential evapotranspiration have been made using max-min temperature data and pan evaporation.

The results of this study will provide procedures and techniques to determine the hydrologic implications of a given area's response when subjected to specific climatic, land use, and meteorologic experiences, with emphasis on small agricultural watersheds. The relevance of the work is accentuated by the ever increasing demands that society places on the conservation use and distribution of inland waters. The design engineer must be able to determine how much water will be available for rural and urban use. The method utilized in this investigation appears to be the most logical approach for dealing with this problem.

A PRELIMINARY ECOLOGICAL STUDY OF WATER RESOURCES AND LAND USE PATTERNS OF THE DISMAL SWAMP AREA OF VIRGINIA

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A PRELIMINARY ECOLOGICAL SURVEY OF THE WATER RESOURCES AND LAND USE PATTERNS OF THE DISMAL SWAMP AREA OF VIRGINIA

Natural and undeveloped areas of the United States have often been the subject of controversy. They are usually subjected to pressures for alteration and development by conflicting interests. The greatest pressures, and sometimes the most acrimonious conflicts, occur when they are adjacent to centers of rapid population growth. The problems are compounded when the physical characteristics of the undeveloped area make any kind of development difficult when the methods are not in contention.

The Dismal Swamp of Virginia is a natural area adjacent to a center of rapid growth, the Norfolk-Portsmouth area. It is a unique wetland which offers many problems for development. Little is known of what effects alteration of this area (such as filling, clearing, changing of drainage patterns, etc.) might have on the surrounding region. Yet, pressures are developing for the alteration of Dismal Swamp, especially so that it can be used for productive agriculture. Such use would require wholesale drainage and clearing. It is obvious that previous drainage changes have affected water levels in the swamp, but the possible effects of large-scale projects are not yet established, and the presumed usefulness of the land afterwards is, at best, debatable.

Dismal Swamp does have a long history of one activity, lumbering. Strong pressures are now developing, and some modifications actually proceeding, for going beyond mere harvesting of trees to alteration for productive agriculture. On the other hand, there are interests in both state and national groups who feel that a large portion of Dismal Swamp should be preserved in its natural condition. Virginia Outdoor Recreation Commission has a plan calling for the establishment of a multiple-use park, including timber, game, recreation, and wilderness. Proponents of neither of these views, nor any other, have sufficient scientific information to present formidable arguments for their position.

Clearly, a full-scale study of the ecology of Dismal Swamp and of the possible effects of different land-use practices is needed. This two-year project, in cooperation with North Carolina, should indicate the feasibility of a full-scale investigation of the Dismal Swamp problem. Attention is to be focused on past and present land use patterns.

The principal objectives can be outlined as follows:

1. To assemble and present the available information on the geology, ecology, and history of land use of the Dismal Swamp of Virginia.
2. To compare the limnological features of Lake Drummond and surrounding water to other natural aquatic habitats, and to relate these features to populations of aquatic organisms.
3. To determine the present land-use pattern, the nature of the interests of those concerned with the land-use pattern, and possible future alternative proposals for land use of the Dismal Swamp of Virginia.
4. To determine the feasibility of a full-scale evaluation, in cooperation with North Carolina, of alternative land-use proposals for the Dismal Swamp and their possible effects on the general area; and, if such an evaluation is considered feasible, to present an appropriate proposal to a granting agency.

The final evaluation is to be based upon the following studies:

1. A "history" of Dismal Swamp will be prepared. This will emphasize the geology, ecology, and history of land use for the area.
2. A physical description of the area will be written. This will be based on field work, aerial photography, available geological information, including hydrography, and edaphic data.
3. Analyses for water quality will be made regularly during the study. Data from collection and identification of aquatic organisms will be used to correlate water quality with population composition and distribution.

4. A description of recent and present land use practices will be made. This description will rely on historical records, past and present aerial photography, and field work. Proposals for future land use, as made by interested parties, will also be studied.
5. Procedures 2, 3, and 4 will provide the basis for an evaluation of past, present and proposed land-use practices for the Dismal Swamp area. This evaluation will be made.
6. If the data and evaluations of procedures 1 through 5 generate a sufficient number of unanswered questions, a proposal for a full-scale study of the Dismal Swamp, in both Virginia and North Carolina, will be prepared for submission to an appropriate granting agency.

Data were collected on an irregular time schedule from established "stations" and some other locations. Standard field equipment was used in this collection of data. Aerial photography was used for vegetation analysis. Information was acquired on temperature, oxygen levels, acidity, salinity, and primary productivity in Lake Drummond. A detailed analysis of fish populations was made and some suggestions made concerning fish management. Aerial photography of a selected portion of Dismal Swamp was flown using several film and filter techniques. (Analysis of this has not been completed). It was concluded that the most important single need for an understanding of the environment of Dismal Swamp is a one- or two-year detailed limnological study. There is an indication from this study that the basic physical and chemical conditions of the water are not conducive to a high, balanced, biological productivity; but this aspect required much more detailed study.

The planned study of this project is urgently needed to establish factual information necessary to the satisfactory development of the Dismal Swamp area of Virginia for all groups concerned. In addition, the methods and principles developed in this study will be applicable to similar problems in Virginia and other states.

BIOLOGICAL AND CHEMICAL STUDY OF VIRGINIA'S ESTUARIES

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BIOLOGICAL AND CHEMICAL STUDY OF VIRGINIA'S ESTUARIES

Virginia's three major estuarine systems are the James, the York, and the Rappahannock. These three estuaries are at the present time utilized for all intended purposes. All are major seafood-producing areas. They are heavily utilized by sport fishermen and for water contact sports. Their aesthetic value is of immeasurable importance to the millions of tourists who visit the historical Tidewater Virginia area.

In addition, several industries utilize the saline water for cooling purposes. They are utilized for commerce and military activities. The systems also serve to assimilate the domestic and industrial wastes from the human activities along the shores.

One system receives very heavy nutrient enrichment from municipal and industrial wastes (the James), and two receive agricultural run-off which is the major source of nitrogen and phosphorus.

Most materials introduced into the inland drainage systems undergo oxidation and stabilization before entering the tidal basins. The inorganic ions eventually enter the estuaries as dissolved solids in the freshwater inflow. The ionic composition includes nitrates and phosphates from land run-off and from waste treatment plants.

The tidal portions of our nation's streams have the natural characteristics which tend to concentrate human populations and industrial activities. The waste products of these activities may be piped through sub-aqueous outfall lines directly into continental shelf waters but more often they are discharged into the adjacent estuary.

Waste treatment technology has developed methods for rendering most industrial wastes and domestic wastes quite innocuous; however, the final inorganic products may degrade the receiving waters by producing atypical algal blooms and aquatic nuisance conditions. This has occurred in the bays of Long Island, the upper tidal Potomac River, and in the upper tidal James River.

Secondly treated domestic wastes from a population of 1 million people contain approximately 3.2 mg-at of nitrogen and 0.5 mg-at of phosphorus per liter in various organic and inorganic forms. The daily effluents from a city of 1 million population enrich the receiving stream with approximately 16.3 metric tons of nitrogen and 5.4 metric tons of phosphorus each day. This level of enrichment is capable of producing algal blooms which may in themselves degrade the environment, or the composition of the flora may change to forms which are not utilized by estuarine filter-feeding animals.

All of the uses of these estuarine systems are consistent with the intended use of our water resources; however, in order to obtain maximum utilization from these systems, they must be developed, they must be managed so that man can obtain a sustained yield, and they must not be abused in such a way that only a few may benefit. The greatest threat to our estuarine resources is from the latter.

This study is designed to determine the environmental factors which result in the major ecological differences which exist between the James, York, and Rappahannock estuaries in Virginia. Our existing data suggest that these differences may be due to nutrient levels as influenced by enrichment from the freshwater zone and by the turnover rates within the systems. This study evaluates the four forms of phosphorus and the five forms of nitrogen in the water column and the phytoplankton response to the various levels found. The phytoplankton response to the nutrient levels in the water column results in a better understanding of the nutrient assimilation capacity of estuarine systems. In addition, hydrographic data is collected to describe the physical characteristics of the estuaries, and isohaline zones within and between the three estuaries are compared.

Monthly cruises are conducted on each of the three systems. The James and York river stations will be occupied at low slack water on one day and the two vessels will occupy the stations on the Rappahannock on the following day. Stations are established in the field on the day of the cruise at the 25, 20, 15, 10, 5, and <0.5‰ zones. Fixed stations based on miles from

the mouth cannot be used in this study because salinity zones may move upstream as much as 20 miles from the time of spring run-off to low freshwater discharge periods in the late fall. The stations are occupied at slack before flood tide. Physical hydrographic profiles of the water column are made by sampling at 2-meter intervals from the surface to the bottom. Water samples are collected using a submersible pump. Temperature and pH are determined and samples are prepared for dissolved oxygen analysis in the field. Additional samples are collected and iced for laboratory analyses.

The laboratory procedures include separation of samples to determine total phosphorus (TP), soluble reactive phosphorus (SRP), particulate reactive phosphorus (PRP), soluble unreactive phosphorus (SUP), and particulate unreactive phosphorus (PUP). In addition, the total nitrogen analysis was separated into the nitrate, nitrite, ammonic, soluble organic, and particulate organic components. Chlorophyll "a", salinity, alkalinity, and the routine parameters are also determined.

Since only the soluble reactive phosphorus is immediately available to phytoplankton, the isolation of the forms permits an evaluation of the role of phosphorus as a limiting factor in phytoplankton production.

The data derived from this experimental design permit the isolation of the dependent and independent variables within each system and make possible a comparison of the chemical and biological factors which are responsible for the observed differences between the systems.

Some significant results in the study may be listed:

1. Hydrographic data for the period indicate that the freshwater discharges into Chesapeake Bay were generally above the median values for the past 17 years of record.
2. Nutrient data for the period indicate that significant differences exist between the three systems.
3. All systems show a decrease in mean total nitrogen values from the head of the estuary to the mouth which is probably the result of dilution with water of marine origin. With the exception of the

upper estuarine James, the nitrogen values and the component levels were within the expected range.

4. The detectable increase in phosphorus near the mouth of the James does not reflect the enrichment levels at the heads of the tidal systems since this nutrient form is removed from solution and suspension before the water mass enters the estuarine section. This result may have been due to either local enrichment or to phosphate-phosphorus entering the estuary with marine water.
5. Phytoplankton levels in the three estuaries were determined from the chlorophyll "a" values. A high mean value for the transition zone of the Rappahannock River resulted from summer populations of freshwater forms being flushed into the head of the estuary.
6. Phytoplankton populations as indicated by chlorophyll "a" levels and by species composition indicated that "normal" conditions existed during this phase. Aquatic nuisance conditions or environmental degradation resulting from blooms were not observed during the study period.

There are many people and economic establishments affected by the three Virginia estuaries under study through various user relationships. This project should serve as a means of determining which of the estuarine environmental factors are dominant, and suggest means by which they might be modified or controlled so that the maximum benefits can be realized from the three systems. In addition, Regulatory and Planning Agencies concerned with coastal waters require information on the nutrient assimilation capacity of estuarine systems.

TRAINING AND EDUCATION ASPECTS OF THE WATER RESOURCES RESEARCH PROGRAM

TRAINING AND EDUCATION ASPECTS OF THE WATER PROGRAM UNDER P.L. 88-379

A. New Courses Developed

CAPITAL FACILITIES PLANNING (Interdisciplinary)
Allocation of fiscal resources of government to carry out public programs; timing and staging of public improvement projects; methods of evaluation and priority establishment; an examination of the instruments for the effectuation and implementation of long-range public policy objectives and plans through fiscal management.

ECONOMIC GEOLOGY (Not Interdisciplinary)
The study of nonmetallic mineral deposits exclusive of mineral fuels; the occurrence classification, and genesis of metalliferous mineral deposits; and the occurrence, classification, and origin of oil and gas.

ENVIRONMENTAL GEOLOGY (Interdisciplinary)
The applications of geologic knowledge to problems and activities associated with urban and regional development; water resources, mineral resources, waste disposal, subsurface storage, construction, and physical planning.

FUNDAMENTALS OF GEOPHYSICAL SCIENCES (Not Interdisciplinary)
The major theories, measurements, and results of solid-earth geophysics; seismology, geodesy, geomagnetism, and terrestrial heat flow are the four principal areas of concentration.

LAND USE POLICIES (Interdisciplinary)
Analysis of statutes, ordinances, and court decisions in light of planning goals and policies; emphasis upon philosophies, approaches and critical concerns in such areas as subdivision regulation, zoning, urban renewal, and tax policy.

NATURAL RESOURCE ECONOMICS (Not Interdisciplinary)
Natural resource utilization, development, and public policy are analyzed in an economic and political framework. Models and analytical techniques used in resource management and evaluation of resource development projects are studied.

REAL PROPERTY APPRAISAL (Not Interdisciplinary)
Theory, methods, and procedures of real estate valuation; factors determining the value of real property; history of land prices; and critical evaluation of appraisal methods in relation to types of property and proprietory interests in property.

URBAN SOCIOLOGY (Interdisciplinary)
Advanced study of the growth, ecological makeup, organization, disorganization, and change of urban society.

New Staff Members Added

Arnold, Jesse C. - Ph.D. - Statistics

Cairns, John - Ph.D. - Protozoology and Pollution Ecology

Case, Leland S. - M.A. - Economics

Ehrenthal, Frank - Dott. di Arch. - Urban Design

Lambert, William - Ph.D. - Statistics

Ray, Clayton E. - Ph.D. - Vertebrate Paleontology

Steiss, Alan W. - M.U.R.P. - Planning

Yearwood, Richard M. - Ph.D. - Government

Staff Members Employed to Replace Those Who Retired, Died, or Moved

Amos, D. F. - M.S. - Agronomy

New Research and Training Facilities Other Than Research Equipment Items

Derring Hall - new building for Geology, Biology and Education.
New laboratory facilities include:
1. Seismic modeling laboratory
2. Heat flow laboratory
3. Earth tide measurements laboratory

Cowgill Hall - new building for the center of Urban and Regional Studies.

Interdepartmental, Interuniversity, or Regional Agreements Consumated with Respect to Improved Research and Training Capabilities

Center for Urban and Regional Studies has joint appointments with other departments (Geology, Sociology, Economics, etc.), which permits active participation in organized training programs beyond simple liaison. As an example, there is an interdepartmental agreement between the Department of Geological Sciences and the Center for Urban and Regional Studies to share a faculty member at the professional rank.

Also, there is an established cooperative training program between the Center for Urban and Regional Studies and the Department of Government and Business Administration at George Washington University, Washington, D. C., which includes exchange of faculty.

The Water Resources Research Center in cooperation with the North Carolina Water Resources Institute initiated a project concerned with the ecological study of the water resources and land-use patterns of the Dismal Swamp. The Swamp is located in southwestern Virginia and northeastern North Carolina. The study is divided primarily according to areas of interest and specialities at each of the schools rather than on geographic lines. The cost for this study is borne by each Center according to the personnel participating in the project.

In an effort to utilize the research capabilities at the other institutions of higher learning in the state, the Center is sponsoring projects at the Virginia Military Institute and the University of Virginia under the allotment program and a matching fund project at the Virginia Institute of Marine Science. In each case the participating institutions keep auditable accounts on the disbursements of funds according to approved budgets. A recap of expenditures are provided by the Center on a quarterly basis. The research program is reviewed by the Director with the principal investigators at regular intervals.

B. Student Enrollment

	No. Enrolled	No. Graduating
Juniors	89	0
Seniors (Bachelor's degree candidates)	77	73
Master's degree students	41	29
Doctoral degree students	57	12
Postdoctoral degree students	1	0

C. Number of Students Using Equipment and Supplies Purchased Wholly or in Part with P.L. 88-379 Funds

Category of Students	No. Using Equipment, Supplies, etc.
Undergraduates	5
Master's students	22
Doctoral students	16
Postdoctorate students	0

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

Category of Students	Scientific Discipline	Number
Undergraduates	---	0
Master	Microbiology	2
	Zoology	3
	Geophysics	2
	Civil Engineering	2
	Fishery Biology	1
	Chemical Engineering	1
Doctoral	Microbiology	2
	Zoology	3
	Civil & Agricultural Engineering	1
	Chemical Engineering	1
Postdoctoral	---	0

E. Employment Status of 1967-68 Graduates in Water-Related Fields

Category of 1967-68 graduate by degree obtained	No. Employed in Water-Related Positions in:				No. ret. for adv. degree	No. enter Military service	No. unemploy or unknown
	Federal Agencies	State Agencies	Col. and Univ.	Other such as private			
Bachelor	1	1	0	0	7	5	59
Master	3	1	4	1	10	4	6
Doctoral	1	1	3	1	0	1	5
TOTAL	5	3	7	2	17	10	70

F. Type of Employment of 1967-68 Graduates in Water-Related Fields

Category of grad by degree Obtained	No. of Graduates engaged in water-related work in:						
	University or College			Agency or pvt water resources research	Operating and mgmt	Planning	Other wtr resources work
	teach prim	resrch prim	resrch and teach				
Bachelor	0	1	0	0	0	1	0
Master	1	1	2	2	3	0	0
Doctoral	1	1	3	0	0	0	1
TOTAL	2	3	5	2	3	1	1

PUBLICATIONS AND THESES

PUBLICATIONS AND THESES

Publications

Benoit, Robert E.
1968. The effect of water quality on the metabolism of the lactic streptococci. Bulletin 13. Water Resources Research Center. Pages 1-69.
Based on project A-005-VA.

Blanton, S. J. and R. E. Benoit
1965. Metabolism of Streptococcus lactis variety tardus derived from Streptococcus lactis. Bacteriological Proceedings. Page 10.
Based on project A-005-VA.

Chiang, T. T. and J. M. Wiggert
1968. Analysis of hydrologic systems. Bulletin 12. Water Resources Research Center. Pages 1-94.
Based on project A-013-VA.

Phillippe, J. T. and J. M. Wiggert
1968. Instantaneous unit hydrograph response by harmonic analysis. Bulletin 15. Water Resources Research Center. (in press).
Based on project A-014-VA.

Shanholtz, V. O.
1968. Computer system for the reduction and analysis of soil moisture data. Bulletin 16. Water Resources Research Center. (in press).
Based on project A-009-VA.

Shanholtz, V. O. and J. H. Lillard
1968. Hydrologic aspects of no-tillage versus conventional tillage systems for corn production. Bulletin 14. Water Resources Research Center. Pages 1-38. (in press).
Based on project A-009-VA.

Simmons, G. M., Jr. and S. E. Neff
1968. Primary production and water quality in Smith Mountain Lake, Virginia. Proceedings 17th Southern Water Resources and Pollution Control Conference. (in press).
Based on project A-012-VA.

Theses

Rawls, W. J.
1968. Prediction models for investment in urban drainage system. M.S. Thesis. Virginia Polytechnic Institute. 60 pages.
Based on project A-011-VA.

Scott, M. W.
1967. Isolation and lactose metabolism of Streptococcus lactis variety tardus from southwestern Virginia. Ph.D. Thesis. Virginia Polytechnic Institute. 106 pages.
Based on project A-005-VA.

Simmons, G. M., Jr.
1968. Investigations of limnetic inorganic carbon assimilation in a mainstream and pumped storage impoundment. Ph.D. Thesis. Virginia Polytechnic Institute. 234 pages.
Based on project. A-012-VA.

Slagle, B. S.
1967. Adsorption of lindane on coal. M.S. Thesis. Virginia Polytechnic Institute. 42 pages.
Based on project A-015-VA.

Stanton, I. W.
1967. The effect of coal on the removal of phosphate from solution. M.S. Thesis. Virginia Polytechnic Institute. 63 pages.
Based on project A-015-VA.

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