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SPRUCE CREEK WATERSHED NON-POINT SOURCE LOADING MODEL

BY

JAMES L. SMOOT B.S.E., Florida Technological University, 1975

RESEARCH REPORT

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Graduate Studies Program of the College of Engineering of Florida Technological University

> Orlando, Florida 1977

SPRUCE CREEK WATERSHED NON-POINT SOURCE LOADING MODEL

BY

JAMES L. SMOOT

ABSTRACT

The pollutant transport from watershed to receiving waters is modeled for Spruce Creek basin. The data requirements for such a model are: daily rainfall; monthly lake evaporation; soil and land use breakdown; water quality history for the main indicators, total nitrogen, total phosphorus, suspended solids, and total organic carbon; surface flow and interflow delay coefficients; channel flow time; daily flow gage records; and channel flow characteristics.

The model uses the SCS runoff curve number method to generate rainfall excess where the antecedent conditions are varied daily by a water budget analysis. The direct runoff is delayed and routed by the CDET and Muskingum method respectively. Daily pollutant loadings are generated by the use of pollutant loading functions which relate pollutant mass loading to average daily flow for the pollutants desired. These are totaled for each year of simulation ' to predict average pollutant loading from the water shed in pounds per acre per year for use in water quality planning.

Martin P. Wanielista, PhD, P.E. Director of Research Report

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CHAPTER I

INTRODUCTION

The deterioration in surface water quality due to agricultural and urban development as well as the drainage of mosquito breeding wetlands has been shown in many watersheds throughout the U.S.A. (Wanielista 1976). Many computer models have been developed in recent years to simulate urban runoff and its quality (S.W.M.M., Qual-Illudas, Colston-Illudas, etc.) or agricultural runoff and its quality. The majority of these models are very thorough and therefore require substantial input data and are expensive to use.

There is a need for a planning level of detail model for use on predominately agricultural watersheds. A similar model, "STORM", is for use on urban watersheds (Wanielista 1976). The model developed in this study fills this niche by quantifying pollutant loads washing off the watershed during multi-event simulations. The computer program used was a modification of a model entitled "Water Yield" (Williams, et al 1976). Modification resulted in minimal computer costs. For instance, the computer costs for eleven years of daily simulation by the Modified Record Extender model for flow and four pollutants would be less than \$10.00 on an IBM 370 system. It should be noted that the recommended operation of the above model includes a previous modeling using the Water Yield Calibration Model to generate a long-term runoff curve number and a soil moisture depletion coefficient for the desired simulation period. If the requirements for this model are not available (monthly runoff gaged data) they can be estimated from similar watersheds. This additional model operation would increase the cost of the previously mentioned modeling by about \$2.00 for the eleven year simulation.

In using the above modeling procedure the data requirements include some hydrologic factors such as daily rainfall, average monthly lake evaporation, which can usually be obtained from the National Oceanic and Atmospheric Administration, and a land use and soil breakdown which can usually be obtained from the local county planning agency and the Soil Conservation Service, respectively. Flow records are also desirable and for many watersheds can be obtained from the U.S. Geological Survey. Water quality data is desirable and can be obtained for many watersheds from the local, county, or state environmental or health department or the U.S. Geological Survey. If quality data is not available for a particular watershed, the pollutant loading functions from a similar watershed may be substituted, or a limited field program for collection of data could be conducted.

CHAPTER II

OBJECTIVES AND SCOPE

The main objectives of this research project were to investigate fully the background information, pertaining to the hydrologic and water quality conditions, available on the Spruce Creek watershed, use of a mathematical computer model to simulate flow and pollutant loadings to the receiving waters, and to summarize the pollutant impact on the receiving water for both present and future land use conditions (the year 2000) based on the above modeling. The investigation of the background information is primarily limited to the work of the U.S. Geological Survey, the Volusia Council of Governments, and the Soil Conservation Service.

It is not within the scope of this report to assess the effect and cost effectiveness of Best Management Practices to reduce pollutant generation. A discussion of some management alternatives is contained within this report but this listing is abridged and none of these management alternatives have been recommended for implementation. It was also not part of the scope of this research project to model the water quality relationships in the receiving waters but rather to provide the necessary inputs for such modeling for future estuary modeling to be performed by personnel in the Volusia County 208 Wastewater Management Study.

CHAPTER III

PHYSICAL DESCRIPTION OF THE WATERSHED

General

Spruce Creek drainage basin lies entirely in Volusia County which is in the East-central coastal region of the Florida peninsula. The creek with its system of canals and swales drains about 60,000 acres (Volusia Council of Governments 1974). The main channel flows North and East and is about 18 miles long. The outfall of this drainage system is Strickland Bay which is connected to the Halifax River. The Halifax River empties into the Atlantic Ocean via Ponce de Leon Inlet.

The headwaters of Spruce Creek are located about three miles due East of Lake Ashby in what is called the Samsula Canal. The Samsula Canal is a man-made drainage channel with an average width of about 40 feet and an average depth of about 12 feet. At these headwaters the water flows due north toward the town of Samsula. The Samsula Canal is fed by other man-made channels which drain the surrounding farm and pasture land. The Samsula Canal is connected to the natural headwaters of Spruce Creek just south of State Route 40A. At this point the creek continues to flow north via the natural vegetated, meandering stream. The creek turns east just north of the Spruce Creek Airport and then continues eastward to Strickland Bay. This section of Spruce Creek has also been desig-

SPRUCE CREEK VICINITY MAP

FIGURE I



nated as a Florida Canoe Trail.

Topography

The topography of the Spruce Creek drainage basin in general is extremely flat with a slightly higher sand ridge to the west which separates the coastal basin from the St. Johns River basin. Elevations on this western ridge are about 50 feet above mean sea level (msl) near State Route 44. The elevations in the eastern part of the basin where Spruce Creek discharges to Strickland Bay are about mean sea level. The headwaters of Spruce Creek (Samsula Canal) are at about 27 feet above msl (U.S. Geological Survey 1956).

According to Wyrick (1960), the Spruce Creek watershed lies on well defined lowland marine terraces. During Pleistocene time the sea fluctuated between levels both above and below its present level, submerging greater or lesser land areas according to its height. Whenever the height of the sea remained relatively stationary for a long period, waves and currents eroded the sea floor and formed an essentially level surface called a marine terrace. When the sea dropped to a lower level, each marine terrace emerged as a level plain. The landward edge of such a terrace became an abandoned shoreline, an abrupt scarp separating it from the next higher terrace, and the seaward edge became the new shoreline. Generally, sand dumes were built up along the new shorelines.

The three marine terraces that underlie Spruce Creek watershed are the Talbot terrace, Pamlico terrace and the Silver Bluff terrace. The Talbot terrace was formed toward the end of the Sangamon interglacial stage, when the sea dropped to a height of about 45 feet above the present sea level. This terrace forms the western part of the drainage basin. The Pamlico terrace, which comprises much of Spruce Creek basin, was formed during a recession of the ice during the Wisconsin glacial stage. During this recession sea level was 25 to 30 feet above its present level. The lowlands in Spruce Creek basin lie on the Silver Bluff terrace which was also formed during the Wisconsin glacial stage. During this time the ocean was five to six feet above present sea level (Wyrick 1960, Knochenmus 1971).

Geology

Sediments of Pleistocene and Recent age blanket Volusia County in the area of the Spruce Creek basin. These sediments are generally beds of unconsolidated sand and shell which overlie beds of clay and shell of Miocene or Pliocene age. Limestone of Eocene age underlies the deposits of Miocene and Pliocene age. In the region of Spruce Creek this limestone is about 40-80 feet below the mean sea level (Wyrick 1960).

According to Knochenmus (1971), in the Spruce Creek basin, the Pleistocene and Recent sediments are the reservoir for the nonartesian groundwater, and the Miocene or Pliocene clays tend to confine groundwater under artesian pressure in the underlying limestone of Eocene age. The Pleistocene and Recent sediments' contact with underlying deposits is marked by a bed of coarse sand grains, waterworn shells, clay, and, at a few places, a combination of these materials cemented together by calcium carbonate. These deposits are chiefly fine to medium grained quartz sand, locally mixed with shells. In many parts of the basin the sediments are stained yellow or orange by iron oxide. Locally, the sand has been cemented into "hardpan" by deposition of iron oxide at the water table. These deposits yield small quantities of water to shallow wells in the The unconsolidated beds of fine sand, shells, and calcareous area. silty clay which overlie the artesian aquifer were calssified as Caloosahatchee marl of Pliocene and late Miocene age. These deposits consist of a basal shell bed overlain by calcareous clay, fine sand, and silty shell beds. The permeability of the clay beds in these deposits is relatively low, such that they serve to confine water under pressure in the artesian aquifer. The basal shell bed yields a small amount of water and hence some will exist in it.

In the Spruce Creek region the limestone deposits closest to the surface are the Ocala Group. The Upper Eocene unit referred to as the Ocala limestone consists of three formations. They are, in ascending order, the Inglis, the Williston, and the Crystal River formations. All three are fragmental marine limestones which are differentiated on the basis of fossil content and lithology.

Immediately below the Ocala limestone is the Avon Park limestone formation. This formation in the Spruce Creek basin area is about 280 feet thick. The color of the Avon Park limestone

ranges from chalky white to light brown or ashen gray but most of it is tan. Some beds, especially near the top of the formation, are composed of a loose coquina of marine organisms. The Avon Park limestone is almost invariably dolomitized. The process of dolomitization (replacement of some of the calcium of limestone by magnesium) often changes the permeability of the limestone bed. This change generally reduces the permeability.

Lake City limestone underlies the Avon Park formation. This limestone is of early middle Eocene Age and is quite variable in thickness. These deposits consist of layers of dark brown dolomite separated by layers of chalky limestone. The dolomite is very crystalline and contains few fossils. The unconformity separating the Lake City limestone from the Avon Park limestone above it is marked by a thin layer of well rounded phosphatic pebbles and a 6 foot layer of brown clay and peat.

The above limestone formations of Eocene Age and thin, permeable shell beds at the base of the Miocene and Pliocene deposits make up the artesian aquifer in the Spruce Creek basin region. This water is confined by overlying beds of clay in the Miocene or Pliocene deposits.

Soils

The soils making up the Spruce Creek watershed are quite varied. They range from an excessively drained sand to a poorly drained soil. The breakdown of the basin in terms of generalized soil groups is shown in Table 1. It can be seen from this table that nearly 80 percent of the basin consists of D type soils since none of the basin can be considered in the drained condition since drainage density is low. The soil types that exist in the basin are mostly Paola, Pomello Variant, Pomello, Satellite, Immokalee, Myakka, Wauchula, Placid, Myakka Depressional, and Freshwater Swamp (Hydraquents) (U.S. Department of Agriculture 1976).

Paola and Pomello Variant soils make up 8.18% of the basin and occur in sand ridges in the portion of the basin immediately around the creek itself in the area of the Spruce Creek Airport. These soils also exist in a ridge forming the northeastern basin boundary in the area near Port Orange. The Paola series consists of excessively drained deep sandy soils that occur on nearly level to moderately steep uplands. In a representative profile the surface layer is dark gray sand 3 inches thick. The subsurface layer is light gray sand 22 inches thick. It is underlain by yellowish brown and light yellowish brown sand to 80 inches or more deep. They formed in thick deposits of marine sand. The Pomello Variant series consist of well drained very rapidly permeable sandy soils on dune like hills of the low coastal plain. They formed in sandy sediments of marine or Eoline origin. A typical profile has a thin dark gray surface layer over thick brownish subsurface layers that extend to 60 inches or more. Below are black to dark reddish brown weakly cemented sand.

TABLE 1

SPRUCE CREEK BASIN SOIL TYPE BREAKDOWN BY GENERALIZED SOIL GROUP

Generalized S Soil Type	SCS Hydrologic Soil Class	Percent of Basin
Paola-Pomello Variant	A	8.18
Pomello-Satellite- Immokalee	C	13.61
Myakka-Wauchula	A/D	54.23
Placid-Myakka Depressional	A/D	7.71
Freshwater Swamp	D	16.27
		100.00%

SOURCE: U.S. Department of Agriculture. Soil Conservation Service. <u>Urban Hydrology for Small Watersheds</u>. Technical Release No. 55. Washington, DC: U.S. Government Printing Office, January 1975. Also: U.S. Department of Agriculture. Soil Conservation Service. <u>Volusia County, Florida - Soils</u>. Special Advanced Report. Gainesville, Florida: University of Florida Agricultural Experiment Station: 1976.

Pomello, Satellite, and Immokalee series occur, in a ridge, in the western portion of the basin defining the western drainage divide and in the southeastern portion near New Smyrna defining that drainage divide. This soil group makes up 13.61% of the Spruce Creek watershed. The Pomello series consist of moderately well drained sandy soils that occur in low ridges on the lower coastal plain. A representative profile has a gray fine sand surface layer about 4 inches thick and a white subsurface layer about 38 inches thick. Between a depth of 42 and 54 inches is a dark reddish brown nearly cemented fine sand. Below 54 inches is brown to light gray fine sand. These soils are formed in marine sands. The Satellite series consists of nearly level somewhat poorly drained soils. In a representative profile the surface layer is dark gray sand about 6 inches thick. Below this to depths of 80 inches is gray, light brownish gray, grayish brown, and dark grayish brown sand. These soils occur on nearly level low ridges on higher elevations in the flatwoods. They also are formed in thick beds of marine sands. The Immokalee series consists of poorly drained sandy soils with a weakly cemented BH horizon below a depth of 30 inches. They occur on coastal flatwoods and are formed in sandy marine sediments. In a representative profile the surface layer is very dark gray fine sand 6 inches thick. Next is 6 inches of light gray fine sand and the 23 inches of white fine sand. Between 35 and 54 inches is weakly cemented black and dark reddish brown fine sand. Brown fine sands extend to below 80 inches.

The Myakka and Wauchula soils make up most of the basin. This 54.23 percent is distributed throughout the middle of the basin generally in a north-south alignment. The Myakka series consists of poorly drained sandy soils that have a weakly cemented BH horizon within 30 inches of the surface. They too occur in coastal flatwoods and are formed in sandy marine deposits. The representative profile for this soil consists of a surface layer that is black and about 6 inches thick. Below this is 14 inches of white sand. Between 20 and 56 inches is black weakly cemented sand that becomes reddish brown and dark brown and friable with depth. Below 56 inches is dark grayish brown sand to a depth of more than 80 inches. The Wauchula series consists of nearly level poorly drained soils that occur on low ridges and in depressions in flatwoods. A representative profile has black and very gray fine sand surface layers about 7 inches thick that overlie gray fine sand subsurface layers. Black and dark reddish-brown weakly cemented fine sand layers are next and are within depths of 30 inches. Gray fine sandy loam and sandy clay loam layers are within depths of 40 inches.

The depressed region in the western portion of the basin consists of Placid and Myakka Depressional soils which account for 7.71 percent of the entire basin. This soil deposit lies nearly north-south about 3 miles west of Spruce Creek Airport. The Placid series consists of very poorly drained nearly level soils. In a typical profile, the surface layer is fine sand about 20 inches thick. It is black in the upper 10 inches and very dark gray in the lower 10 inches. Between depths of 20 to 30 inches is gray fine sand. The next layer is grayish brown fine sand to about 18 inches thick. Below this to depths of 80 inches or more is dark grayish brown fine sand. The Myakka Depressional series consists of poorly drained sandy soils that have a weakly cemented BH horizon within 30 inches of the surface. They are on lower coastal flatwoods and were formed in sandy marine deposits. In a typical cross section the surface layer is black sand about 6 inches thick. Below this is 14 inches of white sand. Between 20 and 56 inches is black weakly cemented sand that becomes reddish brown and dark brown and friable with depth. Below 56 inches is dark grayish brown sand to a depth of more than 80 inches.

The Freshwater Swamp association which consists of Hydraquents, Terra Ceia, Typic Fluvaquents, and other similar soils make up 16.27 percent of the Spruce Creek basin. This fraction is located adjacent to the creek near the mouth at Strickland Bay and extends upstream to about the Spruce Creek Airport. Most of this generalized group is made up of Hydraquent soil series. Hydraquents consist of nearly level, poorly drained, fine textured calcareous accumulations from washing limestone aggregates. They occur in holding basins and natural depressions near limestone mines. A representative profile consists of a mixture of white calcium carbonate and silica clay mottled with yellowish brown to depths of 80 inches or more. The other soils that make up the Freshwater Swamp association are primarily mucky soils which are nearly impervious (U.S.

Department of Agriculture 1976).

Vegetation

The vegetation in the Spruce Creek watershed varies greatly from the high sand ridge on the west, to the flatwoods in the center, to the wetlands in the southern portion. The basin is heavily vegetated which can account for a tremendous nutrient assimilation capability. The individual ecosystems are very diversified especially in the wetlands region comprising a very stable natural environment (U.S. Department of Agriculture 1974).

Farming practice in the basin has changed the natural vegetation in two ways. First, the water table has been lowered in some locales such that grasses and crops suited to dry soils could prosper. This increases ecosystem stress in immediately adjacent areas. Secondly, much of the natural vegetation has been stripped so that the land may be used for grazing.

The farming practices of using pesticides, fertilizers, and herbicides on crops has had a water quality effect on aquatic vegetation in the Spruce Creek itself as well as in the receiving waters. This effect has been magnified by the practice of channelizing thereby increasing the flow rate and reducing natural assimilation capabilities.

The sand ridges in the basin carry a good strand of Turkey Oak and Sank Live Oak. The lower vegetation here consists of Saw Palmetto and various perennial shrubs, forbs, and grasses. TABLE 2

SPRUCE CREEK BASIN SOIL DESCRIPTIONS

Soil Type	Depth (inches)	Permeability (inches/hr.)	Available Water Capacity (in./in.)	Soil Reaction (pH)	High Water Table (ft. below sur- face)	SCS Hydrologic Soil Class	
Paola	0-25 25-80	20 20	.0205 .0205	4.5-5.5 4.5-5.5	6.0	A	
Pome11o Variant	0-72 72-100	20 20	.0205 .1015	4.5-5.5 4.5-5.5	6.0	A	
Pomello	0-42 42-64 64-80	20 2.0-6.0 6.0-20	.0205 .1015 .0205	4.5-6.0 4.5-6.0 4.5-6.0	3.5-6.0	U	
Satellite	0-80	20	.0205	4.5-7.8	1.0-3.5	C	
Imokalee	0-6 6-35 35-54 54-72	6.0-20 6.0-20 0.6-6.0 6.0-20	.0508 .0205 .1015 .0205	4.5-6 4.5-6 4.5-6 4.5-6	0-1.0	B/D	
Myakka	0-20 20-36 36-80	6.0-20 0.6-6.0 6.0-20	.0205 .1015 .0205	4.5-5.5 4.5-5.5 4.5-5.5	0-1.0	A/D	

Soil Type	Depth (inches)	Permeability (inches/hr.)	Available Water Capacity (in./in.)	Soil Reaction (pH)	High Water Table (ft. below sur- face)	SCS Hydrologic Soil Class
Wauchula	0-7 7-21 21-28 28-37 37-80	6.0-20 6.0-20 0.6-6.0 6.0-20 0.6-6.0	.0815 .0205 .1525 .0810	4.5-5.5 4.5-5.5 4.5-5.5 4.5-5.5 4.5-5.5	-1.0-1.0	B/D
Placid	0-20 20-75	6.0-20 6.0-20	.15-20 .0508	3.6-5.5 3.6-5.5	-1.0-1.0	A/D
Myakka	0-20 20-36 36-80	6.0-20 0.6-6.0 6.0-20	.0205 .1015 .0205	4.5-5.5 4.5-5.5 4.5-5.5	-1.0-1.0	A/D
Hydraquents	0-80	90°	.1520	7.9-8.4	-2.0-1.0	D
SOURCE	U.S. Depa	irtment of Agricu	dture. Soil (Conservation	Service. Urbar	1 Hydrology for

January 1975. Also: U.S. Department of Agriculture. Soil Conservation Service. Volusia County, Florida - Soils. Special Advanced Report. Gainesville, Florida: University of Florida Agricul-tural Experiment Station: 1976. Small Watersheds. Technical Release No. 55. Washington, DC: U.S. Government Printing Office,

TABLE 2-Continued

The highland in the central portion of the basin contains mostly low vegetation which consists of five varieties of Bluestem, Lopsided Indiangrass, Pineland Threeawn, Hairy Panicum, Smooth Cordgrass, Maidencane, Switchgrass, Paspalums, Inkberry, Saw Palmetto, and other half shrubs, annual and perennial grasses and forbs. There are a few Sand Live Oaks in these locations.

The farming, primarily in the Samsula area, is located on lowlands which were, before the land was drained, predominantly wet. The natural vegetation here consists mostly of low vegetation. Some of the varieties are: Creeping Bluestem, Chalky Bluestem, Hairy Panicum, Paspalum, Smooth Cordgrass, Maidencane, Saw Palmetto, Inkberry, Southern Bayberry, Fetterbush Lyonia, St. Johnswort, Sand Cordgrass, Cut Grass, and other shrubs, forbs and grasses.

These wetlands are very productive with potential yields of 5500 pounds per acre dry weight of vegetation per year.

The freshwater swamp areas of the basin contain mostly Blue Maidencane, Giant Cutgrass, and Maidencane as well as other wetland plants (U.S. Department of Agriculture 1976).

Land Use

The urban portion of Spruce Creek basin, under existing conditions, comprises only 4.32 percent. Of this, only 2.41 percent is utilized for residential. Most of the watershed remains in its natural state which is composed of grasslands, forested uplands, and wetlands. This unutilized portion makes up over 80 percent, as can

be seen in Table 3. The remaining land is devoted to agriculture with most of it in crop and pasture. This relatively small portion is located mostly in the Samsula area just adjacent to Spruce Creek.

The existing residential property is predominately large estate type development, where lot sizes exceed one acre. The existing commercial and industrial properties make up less than one percent of the basin and should be classified as light commercial and light industrial. The only such property which releases potentially harmful waterborne wastes is a nursery on SR 44 at the Samsula Canal. The wastewater released here most likely contains pesticides, herbicides, and fertilizers. The recreation portion of the basin contains the Fly-In golf course which also generates fertilizer and pesticide wastes which flow into Spruce Creek near the Spruce Creek Airport.

The existing agricultural interests in the basin are mostly in row crops, chicken farming, cattle raising, and commercial fern growing. There are a few feed lots in the area comprising 0.27 percent or about 162 acres. The concentrated wastes from these lots is washed into drainage ditches which flow unrestricted into Spruce Creek.

The future land use predictions for Spruce Creek basin, in the year 2000, shows it as essentially remaining the same. The only significant change is for the urban (residential) portion to double or to comprise about 5 percent of the total basin. Much of this new residential development will consist of housing developments in the north-central or northeast sections of the basin, with average lot

TABLE 3

SPRUCE CREEK BASIN EXISTING LAND USE BREAKDOWN

Land Use	Percentage of Basin
Urban (Residential)	2.41
Urban (Commercial)	0.23
Urban (Industrial)	0.70
Urban (Transportation)	0.59
Urban (Recreation)	0.39
Agriculture (Crop/Pasture)	14.29
Agriculture (Confined Feeding)	0.27
Range Land (Grasslands)	12.22
Forested Uplands	25.70
Wetlands (Mixed Forest)	35.87
Wetlands (Vegetated Non-forest)	7.33
	_100.00%

SOURCE: Volusia Council of Governments. <u>Aerial Photographs</u> of Volusia County, Florida. Daytona Beach, Florida: 1975. sizes of 0.5-1.0 acre. The agricultural interests are anticipated to remain unchanged.

CHAPTER IV

HYDROLOGIC CONSIDERATIONS

Stream Gaging

The only permanent gaging station on Spruce Creek is located just north of SR 40A. This station has an F-type stage recording gage which is used to record daily water elevations. Using an elevation-flow rating curve, these elevations can be converted into flow in cubic feet per second. The rating curve was developed by obtaining various flow rates under different flow regimes. The flow is calculated by a measurement of the cross-sectional area and development of a velocity profile using Price velocity meters. The stream gage is located as far upstream as it is because it needs to be out of tidal range. Tidal effects can be seen as far upstream as northwest of the Spruce Creek Airport. The present gage location is the only accessible site in this area.

The gaging station is owned and operated by the U.S. Geological Survey since its installation in May 1951. The station number is 02248000. The contributing watershed area at this gage is thought to be about 20,000 acres. The exact size is difficult to assess because it varies with different hydrologic conditions. The 20,000 acres is probably true only under very wet conditions. Under drier conditions some of this area does not contribute flow and should not be considered (U.S. Geological Survey 1965-1975). Over the period from 1965-1975 the area has been calibrated with the computer program and found to be about 17,500 acres.

Stream Flow Characteristics

The flow in Spruce Creek varies greatly, but generally it can be classified as a small stream. The flows range from about 1.0 cfs base flow to flood peaks of over 500 cfs. The velocities also have quite a range. They range from about 0.1 foot per second to about 3 feet per second. The stream gradient is about 1.4 feet per mile which is common for streams in the marine terraces of Florida (U.S. Geological Survey 1956).

The main stream naturally meanders quite a bit in the flat land near the Spruce Creek Airport. The gradient in this area is about 0.25 foot per mile. The natural meanders of the main stream and tributaries, coupled with heavy vegetation, increase the resistance to flow. This allows floodwaters to stand for long periods of time and gives mosquitoes a place to breed. The Volusia County Mosquito Control office maintains an ongoing program to clean up vegetation in the stream channels as well as dig new canals to drain mosquito breeding wetlands.

Groundwater

The groundwater in the Spruce Creek watershed consists of two sources, the nonartesian (water table) aquifer and the artesian aquifer. The nonartesian aquifer is located mostly in Pleistocene and Recent sediments although the upper part of Miocene or Pliocene sediments may constitute a part in some localized regions of the watershed. This aquifer ranges from about 25 feet thick in the eastern portion of the basin. The water table aquifer is recharged chiefly by local rainfall. It also receives a small amount of recharge by upward seepage of artesian water in the area of artesian flow immediately adjacent to the Spruce Creek itself near the outfall between the Spruce Creek Airport and Strickland Bay. Within the gaged basin above SR 40A the recharge is essentially due to local rainfall and irrigation seepage where the water is derived from artesian aquifer supplies. Water is lost from the water table seepage into the artesian aquifer, in those areas in which the water table stands higher than the artesian pressure head (piezometric head); and by evapotranspiration. In addition some of the irrigation for agriculture comes from this source (Wyrick 1960).

The artesian aquifer in the basin consists mainly of Eocene Age limestone. The water in the artesian aquifer moves generally to the east or from a high piezometric head to a lower one. The piezometric head ranges from 35 feet above msl in the eastern portion near Strickland Bay. Since the ground elevations near Strickland Bay are less than 10 feet, the aquifer discharges to Spruce Creek at a rate depending on soil permeabilities and proportional to the piezometric surface and ground surface differential. This artesian aquifer is recharged principally by rainfall on a recharge area to the northwest of the basin on the Penholoway terrace near Deland. Karst topography in this tenace have caused sinkholes that break through the confining beds overlying the artesian aquifer. Thus, water may move easily downward from the water table aquifer to the artesian aquifer where the water table is higher than the piezometric surface. Near DeLand the water table is as much as 30 feet higher than the piezometric surface. The artesian aquifer is also recharged by seepage from the water table aquifer through the confining aquitard above the artesian aquifer where the water table is at a higher head than the piezometric surface. The artesian aquifer characteristics of the coefficients of transmissibility and storage were calculated using the Theis graphical method. The results showed that the coefficients of transmissibility (T) and storage (S) were 300,000 gpd/ft and 7.2×10^{-4} , respectively (Wyrick 1960).

Rainfall

The annual rainfall on the Spruce Creek watershed is approximately 52 inches (Knochenmus 1971). According to Wanielista (1976), 55 percent falls within a 4 month period from June through September. This data has been obtained over a long period of record at the Daytona Beach Regional Airport.

In addition to the Daytona Beach Regional Airport (National Oceanic and Atmospheric Administration Station) just North of the basin, other rainfall recording stations are located in and near Spruce Creek watershed. The East Volusia Mosquito Control District maintains six rain gages near the basin during the rainy season (April-September). Another rain gage near the basin is the Lake Ashby fire tower maintained by the U.S. Forest Service. Upon further analysis of the data, the above gages, with the exception of the Daytona Beach Regional Airport gage are not read constantly every day at the same time. Therefore because of this and other data discrepancies, the Daytona Beach Regional Airport gage data was not adjusted according to the Theissen weighting method.

The summer rainfall generally consists of convective (nonfrontal) storm patterns. Therefore the precipitation is very localized or spotty in its aerial distribution. The storm intensity is also extremely variable which increases the need for adequate rainfall gage density over the basin. The winter or fall storms in this region are generally due to cyclonic or frontal influence. These storms are more spatially distributed and have more uniform intensity from one place to another (Linsley, et al 1975).

The spatial distribution of rainfall is so varied in some storms rain gages 20 feet apart could vary by as much as 20 percent (Viessman 1977).

Evapotranspiration

Evaporation varies greatly from one point to another in the basin and from day to day, month to month, and year to year. Evaporation from ponded water surfaces and from soil is a complex thermo-chemical process depending on many interconnected variables. Evaportion from ponded water reserves (lake evaporation) is a function of solar radiation, air temperature, vapor pressure, wind, atmospheric temperature, water temperature, and to a lesser degree other meteorological and thermo-chemical variables. Evaporation from the soil moisture is even more complex than lake evaporation, depending on soil related factors such as: capillary moisture, depth to the groundwater table, amount of entrained air, and soil temperature, in addition to the factors affecting the lake evaporation rates (Chow 1964; Linsley, et al 1975).

In addition to evaporation, transpiration also depletes water stored in the basin. Transpiration is the process by which plants release water to the air through the stomata in the leaves while the plant takes in air for photosynthesis. A small amount of water is used in the photosynthetic process, but this amount is less than 0.125 percent of that transpired. The rate of transpiration is then very dependent on environmental conditions in the same way evaporation is. On the average over 95 percent of daily transpiration occurs during daylight hous, compared to 75-90 percent for soil evaporation.

The term used to refer to the collective losses from evaporation and transpiration is evapotranspiration. For the purposes of this study and the subsequent hydrologic modeling, lake evaporation will be used as an indicator of total evapotranspiration. It has been found by the Texas Water Development Board (1976) that lake evaporation could be correlated better with soil moisture than other indicators. The nearest weather station which records evaporation rates is the NOAA station at Lisbon, Florida which is 42 miles due west from the watershed (National Oceanic and Atmospheric Adminis-

tration 1965-1975). The data collected at this station is in terms of pan evaporation. Florida Department of Environmental Regulation (1976) indicates that in Volusia County the annual lake evaporation is approximately 45.5 inches per year or about 0.77 times pan evaporation. These rates expressed in terms of monthly averages for the period of hydrologic simulation (1965-1975) are shown in Table 4.
1965-1975 AVERAGE PAN AND LAKE EVAPORATION RATES-LISBON, FLORIDA

Evaporation Rate	(Inches/Month)	
Pan	Lake*	
2.98	2.30	
3.30	2.54	
4.88	3.76	
6.52	5.02	
7.17	5.52	
6.48	4.99	
6.35	4.89	
5.85	4.51	
5.10	3.93	
4.45	3.43	
3.25	2.50	
2.75	2.12	
59.08	45.51	
	Evaporation Rate Pan 2.98 3.30 4.88 6.52 7.17 6.48 6.35 5.85 5.85 5.10 4.45 3.25 2.75 59.08	

SOURCE: National Oceanic and Atmospheric Administration. Local Climatological Data. Environmental Data Service, U.S. Department of Commerce. Washington, DC: U.S. Government Printing Office, 1964-1975.

*Lake evaporation = 0.77 x Pan Evaporation.

CHAPTER V

WATER QUALITY CONSIDERATIONS

General

The water quality condition in Spruce Creek and its receiving water, Strickland Bay, is dictated primarily by the nonpoint pollutants generated within the watershed. There are no typical point sources discharging into Spruce Creek or its tributaries. These point sources would consist of sewage treatment plant outfalls or industrial waste outfalls. The definition of nonpoint sources then is a source from which pollutants are dispersed and are released at an unmanaged rate (Wanielista 1976). The nonpoint source pollutants generally are released from agricultural land uses in the basin. These sources are termed rural nonpoint sources as compared to urban nonpoint sources. In many watersheds in Florida the nonpoint source effects account for as much as 90 percent of water quality degradation.

Nonpoint sources are many and varied as shown in Fig. 2. Some of the urban sources are stormwater, sanitary landfill lechate, and septic tank effluent. These pollutants find their way to receiving waters in numerous ways. Some of the other man-generated nonpoint sources are agricultural activities, construction, recreation, and mining. In addition to these sources directly or indirectly related to man other nonpoint sources sometimes referred to



as background or natural sources can cause water quality degradation. Some of these sources are precipitation containing atmospheric washout, wildlife wastes, salt water intrusion, and organics from decay in woodlands and wetlands.

Pollutant Source Description

The source of pollutants in Spruce Creek is entirely from nonpoint generators. These generators consist mostly of degradation of organic material in forest and wetlands, uncontrolled fertilizer and pesticide washoff from agricultural land, animal waste from wildlife as well as agricultural interests, rainfall contained pollutants, and a smaller amount of septic tank effluent and urban stormwater runoff. The transport of these pollutants to the Spruce Creek itself is by waterborne means. This transport consists of overland as well as underground routes. In both routes some fraction of the pollutant is removed from the water by sorption due to soil particles, filtration of soils, uptake by biological organisms, or chemical degradation. Some common nonpoint sources are shown in Fig. 2.

Pollutant Source Loading Rates

The rate at which pollutants are generated, removed and transported varies greatly depending on the nature of the pollutant as well as the nature of the location and transport mechanisms. It has become common to estimate nonpoint source pollutant transport in terms of pounds per year per acre for most land uses; pounds per year per animal for animal-growing operations; and pounds per year per curb-mile for streets and highways. Many of these loading rates are long-term averages and account for varying antecedent conditions, varying rainfall intensities and various removal mechanisms. This approach to quantifying and qualifying nonpoint sources is very gross and should only be utilized over long periods of time such that errors are minimized. This approach is also only good for comparison purposes or for gross estimates of receiving water pollutant budgets. These budgets are useful to assess long-term effects of pollutant transport on water quality.

The pollutants chosen to be indicators of water quality in Spruce Creek are total nitrogen, suspended solids, total organic carbon, and total phosphorus. The total nitrogen and total phosphorus were chosen because they represent the major nutrients and are an indicator of the potential for eutrophication. Total organic carbon was chosen so as to represent a level of organic strength of the water. In a specific water this has been shown to correlate well with biological oxygen demand (five day) and chemical oxygen demand (Wanielista 1976). The suspended solids was chosen because many pollutants are tied up in sediment and this could be correlated with them if needed at a later date.

The water quality data utilized for developing pollutant loading rates for Spruce Creek came from three sources. They were: STORET data from the Florida Department of Environmental Regulation, U.S. Geological Survey monthly and quarterly sampling, and one set of data from the Volusia Council of Governments 208 Staff field sampling program.

Linear regression was utilized to produce a "best fit" with the data. The four principal water quality indicators are shown in terms of mass loading (pounds per day) versus flows (cfs) in Figs. 3, 4, 5, and 6. The regression correlation coefficient, r, which is a measure of the fit of the line to the data, was very high for all regressed relationships. They range from 0.9608 to 0.996. It should be noted that a 1.0 would denote a perfect correlation. This correlation is thought to be very good since the data base consisted of 17 data points with range in flow from about 1.1 cfs to 111 cfs.

Receiving Water Quality

The receiving water for Spruce Creek is Strickland Bay and in turn the Halifax River (inland waterway). The only influent to Strickland Bay is the Spruce Creek although tidal flushing disperses pollutants into the bay from the Halifax River and Turnbull Bay. The water quality in the Halifax River is dictated largely by the influent, both point and nonpoint sources, north of Strickland Bay in the Daytona Beach general area.

The dissolved oxygen levels as a whole are much lower in the Spruce Creek than in the Halifax River. Because the BOD values are lower on the average, this D.O. drop is assumed to exist because of less reoxygenation, in the Spruce Creek itself due to the much smaller surface area to depth ratio, lack of algal respiration due



CORRELATION BETWEEN MASS LOADING-TOTAL NITROGEN AND AVERAGE FLOW



CORRELATION BETWEEN MASS LOADING-SUSPENDED SOLIDS AND AVERAGE FLOW



CORRELATION BETWEEN MASS LOADING -TOTAL ORGANIC CARBON AND AVERAGE FLOW



CORRELATION BETWEEN MASS LOADING-TOTAL PHOSPHORUS AND AVERAGE FLOW

to high color, and lack of wind on the water surface due to overhanging trees and other vegetation. The coliform count and nutrient concentrations in the Spruce Creek effluent are much higher than that of the Halifax River as shown in the Volusia Council of Government 208 Field Sampling Program results. The average pollutant concentrations for Spruce Creek and the Halifax River in that vicinity for the two samplings taken are shown in Table 5.

An algal assay was performed in samples taken during the above sampling program. The results of this assay showed that the algal growth in the Halifax River is nitrogen limited. That is if nitrogen levels are allowed to increase then algal productivity will increase as well. A 122 percent increase in algal production was stimulated with just a 0.2 mg/l addition to total nitrogen. This is a good indicator of the sensitivity of the receiving water to nitrogen (U.S. Environmental Protection Agency, 1977).

Pollutant Abatement Methods

Pollutant abatement methods for nonpoint source pollutants are collectively termed Best Management Practices (BMP). The use of BMP's implies the enumeration of all possible control or abatement methods to arrive at the "best". This "best" practice usually refers to the most cost effective method or the best pollutant removal efficienty per cost involved. These costs can be measured in terms of capital costs; operation, repair, and maintenance costs; and aesthetic or other measures of cost or benefit.

TABLE 5

COMPARISON OF SPRUCE CREEK AND THE HALIFAX RIVER WATER QUALITY (VCOG 1976)

	Pollutants Concentration*(ppm)				
Location	D.O.	BOD5	TN	OP	TC**
Halifax River at Strickland Bay	6.5	1.3	1.25	.060	3.062
Spruce Creek at Strickland Bay	3.7	1.2	1.65	.103	40,262

SOURCE: Volusia Council of Governments. 208 Field Sampling Program. Ormond Beach, Florida: October 1976.

*Values shown are the average for the August 1976 and October 1976 samplings.

**Total Coliform in count/100 ml

where:

D.O. = Dissolved Oxygen BOD5 = 5 day Biological Oxygen Demand TN = Total Nitrogen = TKN + NO₂ + NO₃ OP = Orthophosphate TC = Total Coliform Generally, management practices are broken down into the categories of prevention, control, and treatment. Prevention, as a technique, must be applied before a problem surfaces. Prevention is considered to include conversion of a nonpoint source problem to a point source, which then is subject to applicable regulation. Treatment, where needed, could include runoff physical, chemical and/or biological processing, in whole or in part before release. This treatment could consist of natural as well as man made treatment alternatives. Control involves the reduction of sources or control of sources to minimize effects.

The cost of pollutant abatement varies greatly. For runoffstorage capital costs range from \$0.21 to \$2.12 per gallon depending on geographical area and many site specific variables (Wanielista 1976). The costs of other abatement methods including swales are very site specific and average costs are not useful.

Management practices for the abatement of nonpoint pollutants can be summarized as follows:

1. Conversion to a point source subject to regulation

2. Prevention

- a) Recharge, detention, and retention
- b) Impervious storage areas
- c) Infiltration techniques
 - (1) French drains
 - (2) Seepage pits
 - (3) Swales

- d) Control of erosion
 - (1) Slope stabilization
 - (2) Mulching
 - (3) Check dams
- e) Salt water intrusion
 - (1) Limited pumping
 - (2) Recharge
 - (3) Monitoring wells
- f) Other
- 3. Treatment
 - a) Ponds before discharge
 - b) Swales
 - c) Unorthodox catch basins
 - d) Stormwater processing in treatment plants
 - e) Recycling to the land from outfall points
 - f) Other

4. Controls

- a) Stormwater routing
- b) Street sweeping
- c) Catch basin cleaning
- d) Soil conservation techniques
- e) Monitoring wells and limited pumping
- f) Other
- 5. Governmental regulation and enforcement

Abatement methods may also be categorized by application such as for specifically urban, construction, and agriculture/non-urban. The abatement methods for such a breakdown include the following:

1. Urban

- a) Gravel barriers on flat roofs or findams on pitched roofs
- b) Dutch drains (gravel-filled ditches with optional drainage pipe in base)
- c) Swales
- d) Porous paving-asphalt
- e) Terraces, runoff spreaders, etc.
- f) Seepage or recharge basins
- g) Seepage pits or dry wells (pits usually filled with gravel or rubble - sometimes cased)
- h) Pits, gravity shafts, trenches, tile fields
- i) Detention basin
- j) Recharge of excess runoff via pressure injection wells
- k) Prevention of runoff pollution by street cleaning and other "at source" techniques
- 1) Trash catches of various screen sizes
- m) French drains
- 2. Construction
 - a) Temporary mulching and seeding of all stripped areas
 - b) Traffic control on construction sites, berms and crushed stone on construction roads
 - c) Temporary checkdams on all waterways draining more than onehalf acre of land under construction
 - d) Roadside swales

- e) Stabilization of critical areas with sod
- f) Seeded area protected with organic mulch
- g) Streambank protection using mattresses, blankets, gabions
- 3. Agriculture/Non-urban
 - a) No-till plant in prior crop residues
 - b) Conservation tillage
 - c) Sod-based rotations
 - d) Meadowless rotations
 - e) Winter cover crop
 - f) Timing of field operations
 - g) Plow-plant systems
 - h) Contouring and graded rows
 - i) Contour strip cropping
 - j) Terraces

The efficiencies of best management practices are measured by quantity reductions (hydrograph modifications) and improvement of water quality. Much information exists on the hydrograph modifications but little is available for understanding the quality modifications resulting from various management practices. However, an assessment of efficiencies does appear in mathematical models such as "STORM", "SWMM", "Best Management Practices", and others. As an example, Table 6 illustrates the results of various treatment levels but efficiencies for control practices in agricultural or woodland areas are lacking due to their site specific nature and variability (Wanielista 1976).

TABLE 6

Туре	Remo BOD5	val Effici S.S.	encies (%) T.P.	T.N.
Sedimentation	30	60	13	11
Filtration and chlorination	40	65		
Screening/dissolved air with chemicals	57	77	69	17
Microscreening	50	70	70	70
Bio-discs	54	70	/	
2 stage lime, filtration, carbon adsorption, ammonia stripping, and lime recalcination	94	93	96	71

AVERAGE TREATMENT EFFICIENCIES

SOURCE: Wanielista, M. P. <u>Nonpoint Source Effects</u>. Environmental Systems Engineering Institute, Florida Technological University. Orlando, Florida: Florida Technological University, January 1976.

CHAPTER VI

MODEL DESCRIPTION

SCS Soil-Cover Complex Method

The hydrologic cycle established the basic framework for water budget modeling. The time variability as shown in Fig. 7 is important to develop a functional rainfall/runoff model. From the figure proportional relationships can be established as:

$$\frac{S}{S'} = \frac{Q}{P}$$
(1)

where: S = infiltration occuring after runoff begins in inches

S'= potential abstraction in inches

Q = actual direct runoff in inches

P = precipitation in inches

Also, S = P-Q, so substituting P-Q for S yield:

$$\frac{P-Q}{S^{\dagger}} = \frac{Q}{P}$$
(2)

or:

$$Q = \frac{P^2}{P+S'}$$
(3)

Additional work done by the Soil Conservation Service (SCS) and reported in the U.S. Department of Agriculture (1974) identified an empirical relationship between the initial abstraction and storage and thus developed a similar equation where the initial abstraction, Ia, is assumed equal to 0.25'. Using more than 3000 soil types



FIG. 7. Time variability of hydrologic events

divided into 4 hydrologic groups, the SCS developed runoff curve numbers (CN) to estimate S'. Essentially the maximum storage of water is calculated using:

$$S' = \frac{1000}{CN} -10$$
 (4)

and rainfall excess using:

$$Q = \frac{(P - 0.2S')^2}{(P + 0.8S')}$$
(5)

A description of the SCS Hydrologic soil groups is given in Table 7 as abstracted from the National Engineering Handbook (Wanielista 1976). It should be noted that some soils as shown in Tables 1 and 2 have dual classifications such as A/D and B/D. The first letter applies to the drained condition with the second letter applying to the undrained natural condition. In the Spruce Creek basin all dual classified soils can be assumed to be the undrained natural condition since drainage ditches are not at sufficient density to draw the water table down over a wide area.

Runoff curve numbers can be estimated if the soil classification and the cover crop (land use) are known. In Table 8, runoff curve numbers (CN) are shown. The antecedent moisture condition is designated as number two. The SCS established three antecedent moisture conditions for use with CN's. These are:

CONDITION 1: A condition of drainage basin soils where the soils are dry but not to the wilting point.

CONDITION 2: The average case.

TABLE 7

SCS HYDROLOGIC SOIL GROUPS

Soil Group	Description
A	LOWEST RUNOFF POTENTIAL. Includes deep sands with very little silt and clay; also deep, rapidly permeable gravel.
В	MODERATELY LOW RUNOFF POTENTIAL. Mostly sandy soils less deep than A, and less aggregated than A, but the group as a whole has above- average infiltration after thorough wetting.
C	MODERATELY HIGH RUNOFF POTENTIAL. Comprises shallow soils and soils containing consid- erable clay and colloids, though less than those of group D. The group has below average infiltration after presaturation.
D	HIGHEST RUNOFF POTENTIAL. Includes mostly clays of high swelling percentage, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.

SOURCE: U.S. Department of Agriculture. Soil Conservation Service. <u>Urban Hydrology for Small Watersheds</u>. Technical Release No. 55. Washington, DC: U.S. Government Printing Office, January 1975.

NOTE: A mixed designation, i.e., B/D refers to drained/ undrained natural situation.

TABLE 8

RUNOFF CURVE NUMBERS FOR SELECTED LAND USES

LAND HER DECENTORION		HYDROLOGIC SOIL GI			
LAND USE DESCRIPTION	A	B	C	D	
Cultivated land- : without conservation tree	atment 72	81	88	91	
: with conservation treatme	ent 62	71	78	81	
Pasture or range land: poor condition	68	79	86	89	
good condition	39	61	74	80	
Meadow: good condition	. 30	58	71	78	
Wood or Forest land: thin stand, poor cover	, no mulch 45	66	77	83	
good cover-	25	55	70	77	
Open Spaces, lawns, parks, golf courses, cer	meteries, etc.				
good condition: grass cover on 75% or m	more of the area 39	61	74	80	
fair condition: grass cover on 50% to '	75% of the area 49	69	79	84	
Commercial and business areas (85% imperviou	15) 89	92	94	95	
Industrial districts (72% impervious).	81	88	91	93	
Residential:-					
Average lot size Average % Imp	pervious-				
1/8 acre or less 65	77	85	90	92	
1/4 acre 38	61	75	83	87	
1/3 acre 30	57	72	81	86	
1/2 acre 25	54	70	80	85	
l acre 20	. 51	68	79	84	
Paved parking lots, roofs, driveways, etc	98	98	98	98	
Streets and roads:					
paved with curbs and storm sewers-	98	98	98	98	
gravel	76	85	89	91	
dirt	72	82	87	89	
			1		

SOURCE: U.S. Department of Agriculture. Soil Conservation Service. <u>Urban Hydrology for Small Watersheds</u>. Technical Release No. 55. Washington, DC: U.S. Government Printing Office, 1975. CONDITION 3: When heavy rainfall or light rainfall with low temperatures has occurred producing high runoff potential. To adjust the curve numbers (CN) for the above conditions, Table 9 can be used.

SCS Water Yield Theory

The Water Yield model uses the SCS curve number procedure as previously described (Williams, et al 1976). The Water Yield model consists of three separate models: the Calibration model, Record Extending model, and Ungaged Watershed model. The Calibration model utilizes daily rainfall, monthly flow data, and lake evaporation (LE) and predicts the long term CN, soil moisture depletion coefficient (B), and an expression for the accuracy of the fit between the gaged and predicted flows. The Record Extender model and the Ungaged Watershed model both take daily rainfall, starting CN, long term CN, B, and lake evaporation to predict daily runoff from the watershed.

In reality the CN varies continuously with soil moisture rather than the three indexes discussed earlier. Runoff prediction accuracy can be improved considerably by using a soil moisture accounting procedure to estimate the curve number for each storm. The soil moisture index, SM, is related to the potential abstraction (S') by:

$$SM = V - S' \tag{6}$$

in which V = the maximum value of moisture storage in the soil in inches. A value of 20 inches is assigned to V because it provides

TABLE 9

CURVE	NUMBER	ADJUSTMENTS
	and the state was as a	

CN	Corresponding CN's			
Condition 2	Condition 1	Condition 3		
100 95 90 85 80 75 70 65 60 55 50 45 60 55 50 45 40 35 30 25 20 15 10	$ \begin{array}{r} 100 \\ 87 \\ 78 \\ 70 \\ 63 \\ 57 \\ 51 \\ 45 \\ 40 \\ 35 \\ 31 \\ 26 \\ 22 \\ 18 \\ 15 \\ 12 \\ 9 \\ 6 \\ 4 \\ 2 \end{array} $	100 98 96 94 91 88 85 82 78 74 70 65 60 55 50 43 37 30 22		

SOURCE: U.S. Department of Agriculture. Soil Conservation Service. <u>Urban Hydrology for Samll Watersheds</u>. Technical Release No. 55. Washington, DC: U.S. Government Printing Office, January 1975. ample storage to allow a wide range of curve numbers and yet is small enough to allow daily rainfall to influence SM properly. Therefore SM becomes:

$$SM = 20 - S' = 20 - \frac{1000}{CN} + 10$$
 (7)

Soil moisture is depleted continuously between storms by evapotranspiration and deep seepage. Depletion is greater when soil moisture and lake evaporation are high, and most rapid immediately after a storm (high SM). This relationship is expressed by:

$$\frac{d(SM)}{dt} = -B \times SM^2 \times LE$$
(8)

where t = time; B = depletion coefficient; and LE = lake evaporation. Integrating the above equation yields:

$$SM_{t} = \frac{SM}{1.0 + B \times SM \sum_{t=1}^{T} LE_{t}}$$
(9)

in which SM = soil moisture index at the beginning of the first storm; $SM_t = soil$ moisture index at time t; $LE_t = average$ monthly lake evaporation for day, t; and T = number of days between beginning of storms.

During a storm the amount that infiltrates, P-Q, must be added to the soil moisture. When runoff is subtracted from rainfall, it is eliminated from the watershed and can no longer be depleted. Thus the soil moisture index depletion equation becomes:

$$SM_{t} = \frac{SM + P}{1.0 + B \times (SM + P) \sum_{t=1}^{T} LE_{t}} - Q$$
(10)

The soil moisture depletion coefficient is found by an iteration technique using Newton's method for solving nonlinear equations. To estimate B initially, the average daily depletion is calculated by subtracting average annual runoff from average annual rainfall and dividing by the number of days in a year. So:

$$DP = \frac{AVP - AVQ}{365}$$
(11)

in which DP = average daily depletion; AVP = average annual rainfall; and AVQ = average annual runoff. So for 1 day:

$$SM_{t} = \frac{SM_{a}}{1.0 + B \times SM_{a} \times LE_{t}}$$
(12)

where SM_a is computed from the condition 2 curve number. If rainfall and runoff are zero for one day:

$$DP = SM_{a} - SM_{t}$$
(13)

or substituting and rearranging in the previous equation yields:

$$B = \frac{-DP}{LE_{t} \times SM_{a} (DP - SM_{a})}$$
(14)

The above model is self calibrating such that if the initial SM is too low, predicted runoff is low and SM builds up rapidly; if initial SM is too high, predicted runoff is high and SM decreases. The initial estimate of SM is SM.

After B has been computed the soil moisture depletion equation (10) is solved to yield Q every time there is a value of P.

Direct Runoff Delay

Direct runoff from the basin is delayed and attenuated using a procedure developed by Huber, et al (1976) in which a fraction, CDET coefficient, of the available surplus water will remain on the land per day. Thus, the lower the value of detention constant, CDET, the faster the rate of runoff from a given soil type--land use complex.

Since direct runoff includes interflow, there is some delay in the actual conversion of rainfall to runoff. That is, if 50 percent of a daily rainfall amount will appear as direct runoff, it does not necessarily mean that the direct runoff all occurs on the same day. In general, however, the greater the volume/depth of available surplus water, the faster it will run off. Huber, et al (1976) assumes that all of the surplus water will appear as runoff; the values of CDET merely delay it. Values of CDET, the fraction of direct runoff remaining on the land per day, are taken from Huber, et al (1976) and are shown in Table 10.

In the absence of "hard" data, the estimate of CDET made by Huber et al (1976), were based upon analogy with SCS curve numbers (CN) previously discussed. The higher the CN, the greater the percentage of rainfall the appears as direct runoff and the faster it is presumed to runoff. Values of CDET, shown in Table 10, are based on the assumption that soils that are well drained under natural conditions (SCS Hydrologic Soil Group A) would have about 10 percent of available surplus water appear as direct runoff per day, while soils

TABLE 10

DETENTION CONSTANTS, CDET, USED FOR DELAY OF DIRECT RUNOFF^a, AND EQUIVALENT DETENTION TIMES

Land Use		Hydrologic Soil Group			
		A	В	C	D
1.	Urban	0.0 ^b 0.0 ^c	0.0 0.0	0.0	0.0 0.0
2.	Crops	0.9 9.49	0.7 2.80	0.6 1.96	0.6 1.96
3.	Improved Pasture	0.9 9.49	0.7 2.80	0.6 1.96	0.6 1.96
4.	Unimproved Pasture	0.9 9.49	0.7 2.80	0.9 9.49	0.8 4.48
5.	Citrus	0.9 9.49	0.7 2.80	0.6 1.96	0.6 1.96
6.	Forest	0.9 9.49	0.7 2.80	0.9 9.49	0.8 4.48
7.	Marsh	0.9 9.49	0.7 2.80	0.9 9.49	0.8 4.48

SOURCE: Huber, W. C.; Heaney, J. P.; Bedient, P. B. and Bowden, J. P. <u>Environmental Resources Management Studies in the Kissimmee</u> <u>River Basin</u>. Gainesville, Florida: University of Florida, 1976.

^aDirect runoff is overland flow, interflow and channel runoff.

^bValue of CDET = fraction of direct runoff remaining on land, day. See text for source of values.

^CEquivalent detention time, T, (days).

that are poorly drained under natural conditions or drained by channels under developed conditions have as much as 40 percent per day. Thus, in general, land use-hydrologic soil group combinations with SCS curve numbers less than 70 have CDET values of 0.9 while curve numbers near 90 have CDET values of 0.6. Variance from this generalization is the result of an attempt to distinguish between radically different curve numbers for the same land use.

The CDET values increase (CN decreases) when moving into hydrologic soil groups C and D (see Table 10). This is because they are assumed to retain their natural characteristics of low runoff (volume and rate) when they are developed, whereas land uses crops, improved pasture, and citrus evince the reverse. In other words, the latter three land uses exhibit faster runoff rates because of the channelization required for drainage. Urban land use produces very rapid direct runoff rates even in Florida where a larger portion may appear as interflow while en route to drainage channels. Therefore, it is reasonable to assume that all direct runoff from urban areas occurs within one day (i.e., CDET = 0.0).

An equivalent exponential decay coefficient was derived by Huber, et al (1976) for a CDET value by noting that:

$$CDET^{n} = exp(-kn\Delta t)$$
 (15)

hence:

$$k = \frac{1}{\Delta t} \ln \text{ CDET}$$
(16)

where $k = equivalent decay coefficient, day ^-1$

 $\Delta t = time step (1 day for values of CDET used)$

n = number of time steps

Average detention time in days is then:

$$T = 1/k \tag{17}$$

These values are also shown in Table 10.

Flood Routing

The previously described CDET relation delays and attenuates direct runoff from the watershed to the main drainage channel. There is also delay and flow attenuation in the main drainage channel which must be calculated. The method chosen to "route" the flows through the channel storage in the Spruce Creek is the Muskingum Method.

The Muskingum method was developed by E.T. McCarthy in connection with studies of the Muskingum Conservancy District Flood Control Project of the U.S. Army Corps of Engineers in 1934 (Chow 1964). This method of flood routing involves the concept of wedge and prism storages.

Storage volume can be correctly related to outflow with a simple linear function only when inflow and outflow are equal (steady state). During the advance of a flood wave, however, inflow, always exceeds outflow, thus producing a wedge of storage. Conversely, during the recession, outflow exceeds inflow, resulting in a negative wedge storage. The wedge can be related to the difference between the instantaneous values of inflow and outflow. In addition there is a prism of storage below the wedge. Generally the wedge storage can be thought of as that storage resulting from a sloping water surface in the channel. This storage as a function of inflow and outflow then takes the form:

$$S = K(xI + (1.0 - x)0)$$
 (18)

where:

S = storage in the channel reach, length³
K = slope of discharge (storage constant), time
x = constant which weights the inflow and outflow
I = inflow to channel, length³/time

0 = outflow from channel, length³/time

K has the dimension of time and represents the time required for the center g mass of the flood wave to traverse the reach (travel time through the channel reach). This K is actually not constant but varies as a function of the flow in the reach. It will be assumed constant for this work and will be set equal to the average flow regime travel time.

The storage-continuity equation for a reach of channel may be expressed as:

$$S_2 - S_1 = \frac{(I_1 + I_2)t - (0_1 + 0_2)t}{2}$$
 (19)

where:

$$S_1 = \text{storage at time} = 1, \text{length}^3$$

 $S_2 = \text{storage at time} = 2, \text{length}^3$
 $I_1 = \text{inflow at time} = 1, \text{length}^3/\text{time}$
 $I_2 = \text{inflow at time} = 2, \text{length}^3/\text{time}$

Combining the previous two equations yields the Muskingum routing equation:

$$O_2 = C_0 I_2 + C_1 I_1 + C_2 O_1$$
 (20)

where:

$$C_0 = \frac{-Kx - 0.5t}{K - Kx + 0.5t}$$
(21)

$$C_{1} = \frac{K_{X} + 0.5t}{K - K_{X} + 0.5t}$$
(22)

$$C_2 = \frac{K - K_X - 0.5t}{K - K_X + 0.5t}$$
(23)

and where $C_0 + C_1 + C_2 = 1.0$

Application of the Muskingum routing equation is a simple process since C_0 , C_1 and C_2 are constants. The average travel time for the Spruce Creek watershed was considered to be 1.0 days to the USGS gaging station and 2.0 days to Strickland Bay. The constant x in the Muskingum flood routing procedure ranges from 0.0 to 0.5 with x = 0.0 being a reservoir condition and x = 0.5 being pure translation (wave motion) in an idealized unifrom channel--no change in the shape of the inflow hydrograph. Most natural channels have values of x in the range of 0.2 to 0.3. In the case of the Spruce Creek, an x = 0.2 was used (Linsley, et al 1975).

The routing interval, t, must be short enough to adequately define the hydrograph shape which means that it must be shorter than the travel time through the reach (K). It is generally recommended that t be at least 0.25 - 0.5 times K. A longer or major change in flow could traverse the reach within the routing period. Also, t must be greater than 2Kx to avoid negative values of C_0 .

Water Quality Functions

The runoff quantity from the watershed is predicted, as described above, on a daily basis. This is assumed to be a constant flow rate for the entire day.

Water quality data is also desirable on a daily basis such that pollutographs and loadographs can be developed. A relationship between mass loading in pounds per day for each pollutant and flow in cubic feet per second was developed and presented in an earlier section. The equations for the "best fit" line relationships are input to the model. Then on a daily basis the mass loading for each pollutant can be estimated. The model at present generates the mass loads per day per pollutant and outputs these in table form. The model is also capable of predicting daily concentrations of pollutants in parts per million (ppm). The mass loadings for each pollutant are totaled for each year of simulation and summarized. This makes long term water quality assessment an easier task.

Model Operation

The SCS Water Yield "Calibration Model" is the first to be used. As previously described, it requires the input of daily rainfall, average monthly lake evaporation rates in inches per month, condition 2 SCS runoff curve number (CN), starting CN, and monthly gaged flows for the basin in inches per month. The model then back calculates the soil moisture depletion coefficient and the long-term CN such that the best correlation exists between gaged and predicted flows.

The long-term curve number and soil moisture depletion coefficient are input into the next model; the Modified Extender Model. In addition the other data input consists of: the number of years of simulation, the starting year of simulation, the area of the watershed in acres, the CDET coefficient, Muskingum routing values (MK, X, TIME), monthly lake evaporation, daily rainfall in inches, and the slope and y-intercept of all four pollutant loading functions.

A refinement to the above procedure is to remove the base flow from the gaged monthly runoff values. This is needed since the SCS Water Yield models do not include any boundary inputs such as base flow.

CHAPTER VII

MODEL RESULTS

Flow Predictions

The daily flows predicted by the Modified Record Extender Model are quite close to gaged values considering the gross assumptions of the model such as uniform rainfall intensity and aerial coverage, average monthly lake evaporation rated used to predict actual daily total evapotranspiration rate, uniform weighted CN over the entire basin, no boundary transfers of water (ground water basin area the same as surface water basin area), and constant delay coefficient and channel routing times regardless of flow conditions. A comparison of these daily flows is shown in Figs. 8, 9, 10, 11 and 12 for selected storms within the period of simulation. The total volume of runoff for gaged versus simulated flows for the eleven year period of simulation from January 1965 thru December 1975, shows a perfect correlation since the soil moisture depletion coefficient, long term curve number, and later the basin area were calculated to yield such a correlation. For the entire period of record the average base flow was assumed to be 4.0 cfs for the above calibration.

The CDET coefficient of delay was calibrated and found to range from 0.65 for high flow conditions to 0.90 for low flow conditions. Since a long-term simulation is desirable an average value of 0.80 was found to work well for the gaged basin.


















The channel travel time, MK, ranged from 0.2 days for high flow conditions to about 8 days for low flow conditions. A value of 1.0 days was chosen to best represent the avarage condition to the gaging station.

The above modeling was then extrapolated to predict runoff for the entire basin, not just the gaged basin. The assumption made was that the long term curve number and the soil moisture depletion coefficient would remain constant. The fact that the soil type and land use breakdown remained essentially constant supported the above assumption. Another assumption was that the flow travel time, MK, would be increased from one day to two days. The final assumption was that the CDET delay coefficient would also remain constant. Since the topography, soils and the land use remain essentially unchanged this is also a supportable assumption.

The anticipated land use in the watershed is expected to remain almost unchanged in the year 2000 (Volusia Council of Governments 1976). Therefore, the curve number and the soil moisture depletion coefficient would also remain essentially constant. For these reasons the above model could be used to predict future runoff conditions for any desirable storm or simulation. If with future development the runoff characteristics of the basin do change (i.e. storm sewers, retention/detention basins, etc.) these changes could be included in the model by a CDET or flow travel time adjustment.

Quality Predictions

The water quality predictions for the Spruce Creek watershed are based on the previously described mass loading functions for the four pollutants: total nitrogen, suspended solids, total organic carbon, and total phosphorus. For the period of simulation these pollutants have been modeled and reported on the basis of annual loading and average annual loading. See Tables 12, 13, 14, and 15. These average annual loadings for the four pollutants have been listed in terms of pounds per acre per year to make easier the task of comparison with other watersheds. The values shown in Tables 12, 13, 14, and 15 are for the present conditions existing over the entire basin.

The above pollutant loadings should not be confused to indicate future conditions. The pollutant loadings of future conditions cannot be estimated without the knowledge of hydrologic modifications and other changes effecting the rate of pollutant generation and transport. The values shown in Tables 12, 13, 14, and 15 would only be a true estimate of future conditions if no hydrologic modifications occur and if no Best Management Practices are utilized on either existing or new development.

An estimate of pollutants concentrations on a daily basis for the period of simulation was not included in this report since there are so many variables affecting such a prediction. It was thought that the correlation between an average concentration of a pollutant with an instantaneous grab sample concentration would be

Parameter	Value
Curve Number	83.81
B (Soil Moisture Coefficient)	0.0000773
Average Annual Rainfall	46.314 inches
Average Annual Runoff	12.726 inches
Annual r ²	0.3014
Monthly r ²	0.1977
Standard Deviation Annual Monthly	6.854 1.708

CALIBRATION MODEL RESULTS

Year		Load (1bs.)
1965		60,711
1966		435,551
1967		93,269
1968		451,354
1969		298,866
1970		98,158
1971		218,337
1972		315,359
1973		194,501
1974		297,533
1975		188,422
	TOTAL	2,652,061 lbs.

NOTE: Average Annual Loading = 241,096 lbs./year or 4.51 lbs./acre/year.

SUSPENDED SOLIDS MASS LOADING

Year		Load	(1bs	.)
1965		115	,985	
1966		757	,383	
1967		166	,900	
1968		779	,112	
1969		521	,795	
1970		175	,022	
1971		383	,484	
1972		552	,397	
1973		345	,293	
1974		515	,500	
1975		331	,896	
	TOTAL	4,644	,767	lbs.

NOTE: Average Annual Loading = 422,252 lbs./year or 7.91 lbs./acre/year.

TOTAL ORGANIC CARBON MASS LOADING

Year		Load (1bs.)
1965		1,598,736
1966		11,658,670
1967		2,484,780
1968		12,095,680
1969		7,995,187
1970		2,616,849
1971		5,835,621
1972		8,431,179
1973		5,188,481
1974		7,969,328
1975		5,031,990
	TOTAL	70,906,501 lbs.

NOTE: Average Annual Loading = 6,446,046 lbs./year or 120.71 lbs./acre/year.

TOTAL PHOSPHORUS MASS LOADING

Year		Load	(1bs.)
1965		2,	618
1966		17,	,701
1967		3,	859
1968		18,	260
1969		12,	176
1970		4,	,052
1971		8,	928
1972		12,	874
1973		8,	007
1974		12,	064
1975		7,	719
	TOTAL	108,	258

NOTE: Average Annual Loading = 9,842 lbs./year or 0.18 lbs./acre/year.

poor and would not be a useful indication of long-term water quality.

For purposes of comparison the pollutant mass loadings from selected Florida watersheds at a flow rate of 100 cfs and shown in Table 16. Mass loading rates for Spruce Creek have been developed and are presented in Table 17 with those for selected Florida watersheds (Wanielista 1976).

COMPARISON OF MASS LOADING IN LBS/DAY AT A CONSTANT FLOW RATE OF 100 C.F.S. FOR SELECTED WATERSHEDS IN FLORIDA

	Mass	Loading	@ 100	C.F.S.(1bs	./day)
Watershed	TP	TKN	TN	TOC	SS
Ten Mile	63	597			
Shingle Creek	782	2 30		8,995	2,644
Spruce Creek	39		941	25,126	1,671
Tomoka River	36	499			
Bonneville Basin	63	455	534	16,530	7,344
Big Econlockhatchee River	152	294	334	23,000	517

SOURCE: Wanielista, M. P. <u>Nonpoint Source Effects</u>. Environmental Systems Engineering Institute, Florida Technological University. Orlando, Florida: Florida Technological University, January 1976.



COMPARISON OF MASS LOADING RATES IN POUNDS PER ACRE PER YEAR OF SELECTED FLORIDA WATERSHEDS

Watershed	Туре	TOC	SS	IN	TP
Spruce Creek	Agricultural	120.71	7.91	4.51	0.18
Shingle Creek SCl SC3	Urban Agricultural	22.63 32.85	10.11 9.27	0.97 1.05	1.57 2.30
Big Econlockhatchee	Agricultural	61.71	15.45	1.16	0.19
Lake Eola	Urban	119.67	211	5.07	2.32

SOURCE: Wanielista, M. P. <u>Nonpoint Source Effects</u>. Environmental Systems Engineering Institute, Florida Technological University. Orlando, Florida: Florida Technological University, January 1976.

CHAPTER VIII

MODELING SUMMARY

The overall accuracy of the above modeling is considered to be good. The generation of a long-term loading rate for each pollutant is thought to be reasonably accurate while the generation of daily flow rates or even annual flows and daily pollutant concentrations or loading would have to be considered poor in the customary sense.

A measure of the accuracy of the flow predictions is shown by the multiple regression coefficient generated by the Calibration Model. This measure of accuracy, r, equals 0.5490 or r^2 equals 0.3014 for flow prediction on an annual basis or an r^2 equal to 0.1977 on a monthly basis. The correlation of flow on a daily basis was not calculated but it would be less than those values shown above.

The accuracy of the quality predictions can only be as good as the flow predictions they are based on. An additional error in these predictions due to development of the mass loading functions is small as shown by the r values in Figs. 3, 4, 5, and 6.

The reason the model accuracy is not better is because of the simplistic nature of the model as compared to the infinitely complex natural system to be modeled. A more accurate model could have been developed but such an undertaking would, in my opinion, bring diminishing returns for such a project as this one.

Based on the algal assay performed on the Halifax River, discussed in Chapter IV, the discharge from the Spruce Creek watershed is significantly higher in pollutant concentrations than the background level in the Halifax River. This holds true for all pollutants modeled as well as total coliform which was not modeled. The total coliform counts were based on two sampling runs and because of. this they are not felt to be a significant long-term indication of water quality.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

The majority of inaccuracies in the modeling were concluded to be due to variables in the natural system being modeled as con-Some of the variables are: rainfall intensity and duration, stant. CDET, channel flow travel time, lake evaporation rates, and soil moisture depletion coefficient. It can be concluded that the results of the modeling and its inherit level of accuracy is sufficient to indicate that the Spruce Creek watershed under present conditions generates a substantial quantity of pollutants as indicated by the four pollutant parameters modeled. It can be further concluded that the Spruce Creek with its system of natural as well as man-made tributaries transport the above pollutants to their outfall in the Strickland Bay. The fate of these pollutants after delivery is not known. This modeling effort did not try to assess the source/sink nature of the Strickland Bay or the Halifax River nor did it model tidal mixing, tidal flushing, or tidal transport of pollutants. Another shortcoming of the model is that is assumed complete transport of pollutants in that all pollutants were conservative and that no pollutant sink/source relationship existed within the Spruce Creek itself. This shortcoming existed when extrapolating the data for the gaged basin to incorporate the entire basin.

A refinement of the above modeling could be to develop a

pollutant budget for the receiving waters, including benthic nutrient and carbonaceous material transfer to and from the water. This refinement would be useful to assess the long-term condition of the receiving waters.

In addition to the above refinement it is recommended that a feasibility study be performed to assess what level of pollutant removal is needed, if any. This assessment would incorporate many factors including point source as well as other nonpoint source pollutant generators. The feasibility would be based on the economic considerations of additional point source treatment versus the optimum combination of Best Management Practices for all nonpoint generators. This analysis would be performed only on the receiving water as a whole unless the in-stream water quality in Spruce Creek is shown to be undesirable.

Another recommendation is that an on-going sampling program be started to supplement the U.S.G.S. program now underway. the U.S.G.S. monthly and quarterly sampling program only assesses the quality at the gaging station. It is suggested that sampling at other locations in the basin as well as in the receiving water be started such that the major pollutant generators can be identified and the possible management alternatives identified. Within this sampling program, it is suggested that colliform counts be made such that the long-term effect on the receiving water in the way of a shell fishing classification could be made. It is also suggested that in the way of management alternatives a regulatory policy be inacted to restrict new development from increasing nonpoint source contributions.

APPENDIX A

LISTING OF THE MODIFIED RECORD EXTENDER COMPUTER MODEL

\$JOB CCCCCCC THIS PROGRAM IS USED TO EXTEND SHORT RUNDEF RECORDS BY SIMULATING DAILY RUNDEF WITH THE SCS CURVE NUMBER METHOD. IT WAS MODIFIED TO PREDICT RUNDEF IN CES AND POLLUTANT CONCENTRAT TOM PER DAY AND LOADINGS PER YEAR MODIFIED BY J. SMOOT AND M. WANIELISTA A high control of the second control of 1 S 34 •EXTENSION 39 121 ç, 10 COCC 121341561789 c C 0000000 3333344 4444444455 С

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212 213 214	1V = '. F7.4.' IN'/T10.'NO DAYS WITH RUNOFF = '.IIO) 113
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2445	108 FOPMAT(T50, DAILY RUNOFF ', 14, ' IN CUBIC FEET PER SECOND', /) WR(1,1)=SAVWR DAVM=0. TOT=0. CO=(.5*TIME-MK*X)/(MK-MK*X*.5*TIMF)
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MODIFIED EXTENDER PROGRAM--SPRUCF CREEK WATERSHED TO STRICKLAND RAY

					ME	ASURFD RA	VINFALL /	PHED RIJNO	IFF (INCH	(S)			
YEAR	JAN	FER	MAR	APR	HAY	NUL	JUL	AUG	SEP	007	NON	DEC	TOTAL
1965	2.270	3.000	3.050	1.000	0.0000	9.700 0.844	3.720	2.970	4.330	3.450	0.970	2.140	36.130
1966	6.800 0.103	5.580 2.822	0.360	2.550	6.770 0.332	15.190	7.090	7.930	4.490	4.600 2.30R	1.190	1.600	60.249 22.951
1967	1.2560	3.980	0.310	0.000	0.730	7.510	9.040 2.66A	3.020	5.560	0.190	0.000	2.989	34.590
1948	0.420	1.730	1.790	0.0000	4.790	14.380	6.250	11.090 5.284	6.070	7.440	2.\$30 0.583	0:051	58.149
1969	1.530	5.030 E15.0	2.740	0.120	6.470	2.470	2.610	9.400 PEE.5	R.890 4.961	5.970	1.940	5.030	50.219 15.846
1970	3.940	3.799	3.590	7.040	1.690	0.001	0.010	3.617	3.540	3.H70 0.145	0.310	0.720	33.400
1971	0.690	5.490	2.000	2.570 0.678	3.120	4.730	3.200	3.970	7.200	9.530	1.330	2.490	44.219
1972	2.370	3.970	5.722	1.410	4.020 0.199	7.040	3.220	8.290 2.862	0.420	3.080	10.960	2.480	53.939
1973	2.223	2.020	2.630	3.090	2.410	4.320	4.690	2.113	5.140	4.400	0.750	2.549	44.229
1974	6.00.0	1.100	3,190	0.440	2.660	R.650 0.790	6.310	198.9	10.500	1.410	0.000	2.200	47.200
1975	1.540	2.270	1.520	2.940	0.000	9.000	5.910	3.169	6.610 1.981	5.440 2.458	1.460	0.030	45.209
AVE P	1.986	3.177	2.531	1.512	3.247	7.721	5.154	6.453	5.705	4.635	1.985	2.217	415.74
AVE O	0.445	0.874	0.405	0.235	0.103	1.925	1.318	2.214	2.121	2.041	0.655	0.463	12.700

MODIFIED EXTENDER PROGRAM -- SPRUCE CREEK WATERSHED TO STRICKLAND RAY

NO DAYS WITH RAIN = 1241. AVERAGE ANNUAL RAINFALL = 44.31 AVERAGE MONTHLY CLIMATIC INDEX = 3.792 DEPLETION CONSTANT H = 0.7770000E-04STAPTING CUVE NUMBER = 84.00 NUMBER OF YEARS = 11 MAXIMUM OFFENTION PARAMETER S = 20.0

AVERAGE CURVE NUMBER = 83.90

STANDARD DEV-PRED RUNDEF MONTHLY = 0.171442E 01 ANNUAL = 0.687221E 01 MODIFIED EXTFNDER PROGRAM--SPRUCE CREEK WATERSHED TO STRICKLAND RAY

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DAILY LOADINGS IN POUNDS FOR TN

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- Chow, Ven Te. <u>Handbook of Applied Hydrology</u>. New York: McGraw-Hill Book Company, 1964.
- Chow, Ven Te. Open-Channel Hydraulics. New York: McGraw-Hill Book Company, 1959.
- Huber, W. C.; Heaney, J. P.; Bedient, P. B.; and Bowden, J. P. <u>Environmental Resources Management Studies in the Kissimmee</u> <u>River Basin</u>. Gainesville, Florida: University of Florida, 1976.
- Knochenmus, Darwin, D. and Beard, Michael E. <u>Evaluation of the Quan-</u> <u>tity and Quality of the Water Resources of Volusia County,</u> <u>Florida</u>. Report of Investigations No. 57. Tallahassee, Florida: United States Geological Survey, 1971.
- Linsley, R. K.; Kohler, M. A.; and Paulhus, J. L. H. <u>Hydrology for</u> Engineers. 2nd ed. New York: McGraw-Hill Book Company, 1975.
- National Oceanic and Atmospheric Administration. Local Climatoligical Data. Environmental Data Service, U.S. Department of Commerce. Washington, DC: U.S. Government Printing Office, 1964-1975.
- Snell, L. J.: Anderson, Warren. Water Resources of Northeast Florida. Report of Investigations No. 54. Tallahassee, Florida: United States Geological Survey, 1970.
- Texas Water Development Board. Estimated Monthly Runoff System -User Reference Manual. Austin, Texas: June 1976.
- U.S. Department of Agriculture. Soil Conservation Service. Agricultural Waste Management Field Manual. Washington, DC: U.S. Government Printing Office, August 1975.
- U.S. Department of Agriculture. Soil Conservation Service. Environmental Planning Handbook. Gainesville, Florida: University of Florida Agricultural Experiment Station, 1974.
- U.S. Department of Agriculture. Soil Conservation Service. Urban Hydrology for Small Watersheds. Technical Release No. 55. Washington, DC: U.S. Government Printing Office, January 1975.

- U.S. Department of Agriculture. Soil Conservation Service. <u>Volusia</u> <u>County, Florida - Soils</u>. Special Advanced Report. Gainesville, Florida: University of Florida Agricultural Experiment Station, 1976.
- U.S. Environmental Protection Agency. Ecology Branch, Region IV. Halifax River Algal Assay. Athens, Georgia: May 1977.
- U.S. Geological Survey. <u>Quadrangle Maps: Samsula, Lake Ashby, New</u> <u>Smyrna Beach, Daytona Beach, Daytona Beach N.W., Daytona, S.W.</u> Washington, DC: Department of the Interior, 1956.
- U.S. Geological Survey. <u>Water Resources Data for Florida</u>. Part 1. Surface Water Records. Tallahassee, Florida: U.S. Geological Survey, 1965-1975.
- Viessman, et al. <u>Introduction to Hydrology</u>. 2nd ed. New York: Dun-Donnelley, 1977.
- Volusia Council of Governments. <u>Aerial Photographs of Volusia County</u>, Florida. Daytona Beach, Florida: 1975.
- Volusia Council of Governments. <u>Open Space and Recreation for Volu</u>sia County, Florida. Daytona Beach, Florida: October 1973.
- Volusia Council of Governments. <u>Stormwater Management Plan for</u> <u>Volusia County - Phase I</u>. Daytona Beach, Florida: April 1974.
- Volusia Council of Governments. 208 Field Sampling Program. Ormond Beach, Florida: October 1976.
- Wanielista, M. P. "Design Storms and the Computation of Direct Runoff (Rainfall Excess)". Paper presented at the Urban Hydrology Workshop of the Florida ASCE and Florida Technological University, Orlando, Florida, September 23, 1976.
- Wanielista, M. P. <u>Nonpoint Source Effects</u>. Environmental Systems Engineering Institute, Florida Technological University. Orlando, Florida: Florida Technological University, January 1976.
- Williams, J. R. and LaSeur, W. V. "Water Yield Model Using SCS Curve Numbers". Journal of the Hydraulics Divisions - ASCE HY9 (September 1976): 1241-1253.

Wyrick, Granville G. <u>The Ground-water Resources of Volusia County</u>, <u>Florida</u>. Report of Investigations No. 22. Tallahassee, Florida: United States Geological Survey, 1960.