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TEMPORAL CHARACTERISTICS OF STORMWATER RUNOFF: AN OVERVIEW

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INTRODUCTION

One of the most noteworthy researches concerning stormwater runoff is that of Rice University for managing the water resources of a 17,000-acre planned community, The Woodlands. The emphasis of the plan is on the use and reuse of urban stormwater runoff and treated wastewater for recreational, aesthetic, and irrigation purposes. As part of the project, the temporal characteristics of about 30 water quality parameters are being monitored at a minimum of seven different locations during storm events. An example of the results forthcoming from the project at Rice University is described in a subsequent portion of this paper, in forthcoming papers (Characklis, *et al.*, 1975), and in an unpublished report (Environmental Science and Engineering Department, Rice University, 1974).

In the development of a stormwater management program for a community, the temporal characteristics and the total load of specific water quality constituents are important design parameters. An example of how the temporal characteristics of stormwater runoff could be incorporated into a water resources management plan for a hypothetical community is shown in figure 1. Possible uses of stormwater runoff are shown as dashed arrows and include recreation, aesthetics, groundwater recharge, low flow augmentation, irrigation, and water supply. Several possible treatment alternatives are depicted in the lower portion of figure 1. Also shown in this illustration is a pollutograph of an unspecified water quality parameter during a storm event for the intermittent stream.

As an example of the importance of temporal data, consider the situation in which manmade lakes are constructed for non-body contact and aesthetic purposes, and inflows to the lakes from base flow and treated wastewater are insufficient to offset evaporation losses. In order to maintain a constant lake elevation, pumping from a nearby intermittent stream during periods when stormwater runoff occurs (figure 1) has been suggested. However, the developer is concerned that the use of untreated runoff may

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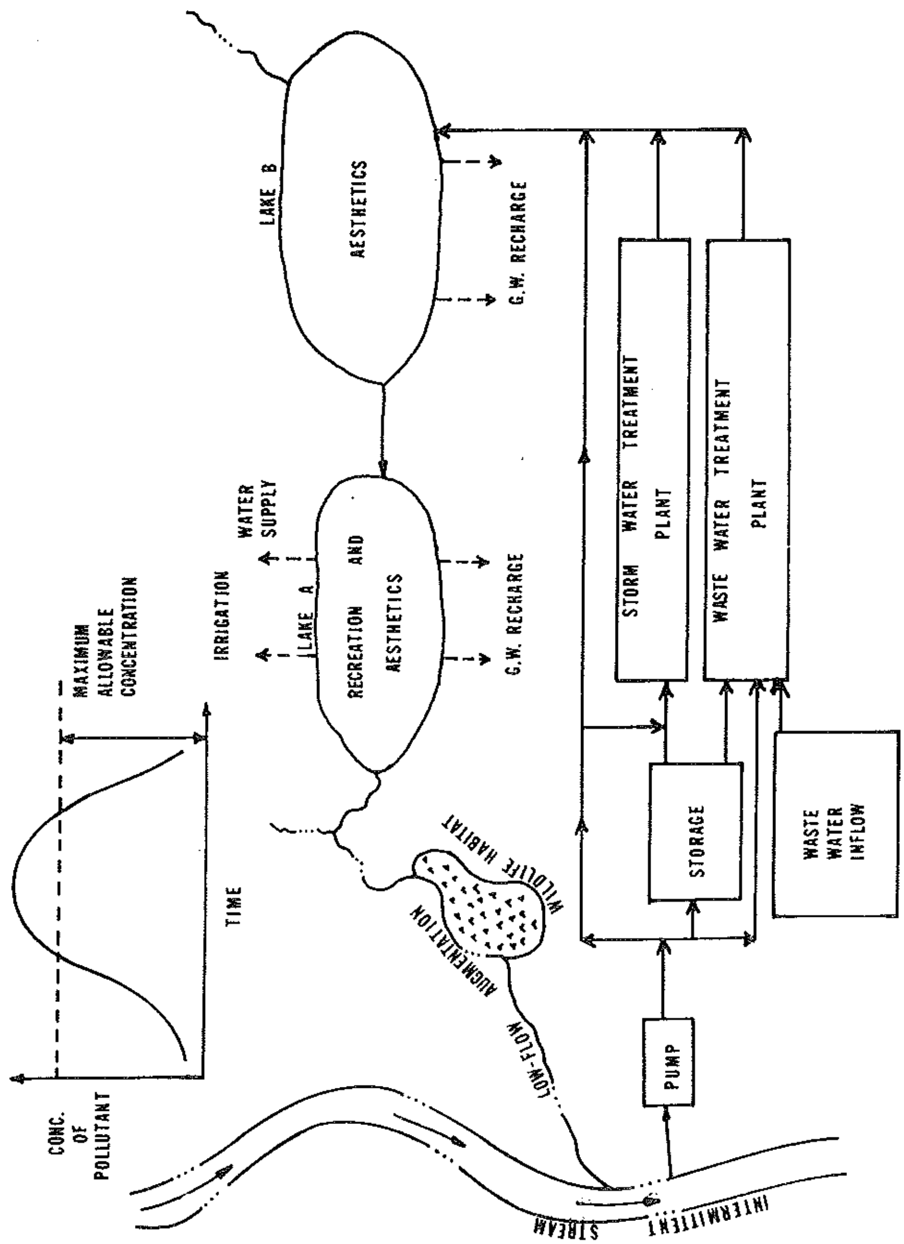

Figure 1. Hypothetical Stormwater Management System.

stimulate the growth of undesirable algae and macrophytes and thereby diminish the value of the lakes. Before a suitable management plan can be formulated, several very important questions must be answered. What is the limiting nutrient for the growth of algae and macrophytes in stormwater runoff? What is the maximum allowable concentration of the limiting nutrient? Is the maximum allowable concentration exceeded in the stream during periods of stormwater runoff? If so, during what portion of the hydrograph is the maximum allowable concentration exceeded? Also, what treatment alternatives are available to reduce the concentration of the limiting nutrients to an acceptable concentration?

The nature of the limiting nutrient can be evaluated via laboratory bioassay experiments using stormwater runoff from the site, while pilot scale studies could be completed to identify treatment alternatives. The answers to the third and fourth questions require field studies directed toward defining the temporal characteristics of stormwater runoff. Once the field and laboratory studies are completed, the time periods when stormwater runoff can be pumped directly to the lake system without degrading their aesthetics and recreation value can be identified. When treatment is necessary to reduce the concentration of the limiting nutrient to an acceptable level, the degree and type of treatment required can easily be established from the pollutographs, the pilot scale studies, and the bioassay results. The above example, although simplified in many respects, illustrates why information on the temporal characteristics of stormwater runoff is imperative when water resource management strategies are being formulated.

STORMWATER RUNOFF CHARACTERISTICS OF THE WOODLANDS

The characteristics of stormwater runoff have been evaluated for five storm events to date at a maximum of four sampling sites. Water quality parameters monitored include orthophosphate, total phosphorus, ammonia, nitrate, nitrite, Kjeldahl nitrogen, total chemical oxygen demand, soluble chemical oxygen demand, total organic carbon, soluble organic carbon, pH, dissolved oxygen, temperature, specific conductance, biochemical oxygen demand, suspended solids, dissolved solids, total solids, turbidity, total bacteria, total coliform bacteria, fecal coliform bacteria, fecal streptococcus bacteria, *Salmonella-Shigella* sp., *Pseudomonas* sp., *Staphylococcus* sp., chlorinated hydrocarbons, and algal bioassay studies.

A summary of the characteristics of suspended solids, total COD, total phosphorus, and Kjeldahl nitrogen for five storm events monitored to date is shown in table 1. Listed for each storm event are the peak flow rate, peak pollutant concentration, average pollutant concentration, and pollutant loading. The sampling site is Panther Branch at the Sawdust Road gaging station, which has a drainage area of 34.5 sq mi. Approximately 90 percent of the drainage basin consists of undeveloped forest land, while the remaining ten percent is forestial land under development. Panther Branch is characterized by alluvial sediments, small riffles, and slow-moving pools during base flow conditions.

The variation in the loading of the four parameters with the size of the storm event is shown graphically in figure 2. The load of each pollutant is expressed in pounds, and the size of the storm event is represented by the product of the peak discharge divided by the drainage area. Although the data available to date are admittedly limited, it appears that a definable relationship exists between the total load and the size of the storm event.

TABLE 1. Summary of Suspended Solids, Total COD, Total Phosphorus, and Kjeldahl Nitrogen Characteristics of Stormwater Runoff for The Woodlands.

Date of Storm Event	Peak Discharge, cfs	Pollutant Concentration, mg/l		Pollutant Loading	
		Peak	Average	Lbs	Lbs/sq mi-in.
		SUSPENDED SOLIDS			
1-18-74	1,260	2,090	250	1,500,000	36,000
4-22-74	9.6	1,600	980	15,000	140,000
10-28-74	111	984	740	87,000	110,000
10-28-74	195	1,260	840	330,000	120,000
12- 5-74	305	719	86	290,000	13,000
4- 7-75	1,100	672	170	1,200,000	25,000
		TOTAL COD			
4-22-74	9.6	124	93	1,400	13,000
12- 5-74	305	73	57	190,000	8,300
4- 7-75	1,100	75	48	340,000	7,000
		TOTAL PHOSPHORUS (P)			
4-22-74	9.6	1.14	.5	7.1	68
10-28-74	111	.36	.3	34	42
10-28-74	195	.27	.2	70	26
12- 5-74	305	.53	.1	340	15
4- 7-75	1,100	.48	.1	620	13
		KJELDAHL NITROGEN (N)			
4-22-74	9.6	2.1	1.4	22	210
12- 5-74	305	2.2	.9	3,100	130
4- 7-75	1,100	4.1	1.4	9,900	210

Relationships such as those shown in figure 2 can be used to estimate the pollutant load for any size storm event at the sampling site. Using these predicted loadings, the relative significance of dry weather flow versus stormwater runoff can be calculated on a weekly, monthly, seasonal, or yearly basis.

STORMWATER RUNOFF CHARACTERISTICS FOR SEVERAL WATERSHEDS

An effort was made to compile information on the temporal characteristics of stormwater runoff for different watersheds throughout the United States. Unfortunately, few published reports are available at present in which a sufficient number of samples was collected throughout the storm event to accurately define the temporal variation in the characteristics of runoff. Some data were available, however, on four water quality parameters at several different watersheds. The parameters evaluated included suspended solids, total chemical oxygen demand, Kjeldahl nitrogen, and total phosphorus. For each storm event the peak concentration, average concentration, and pollutant load were

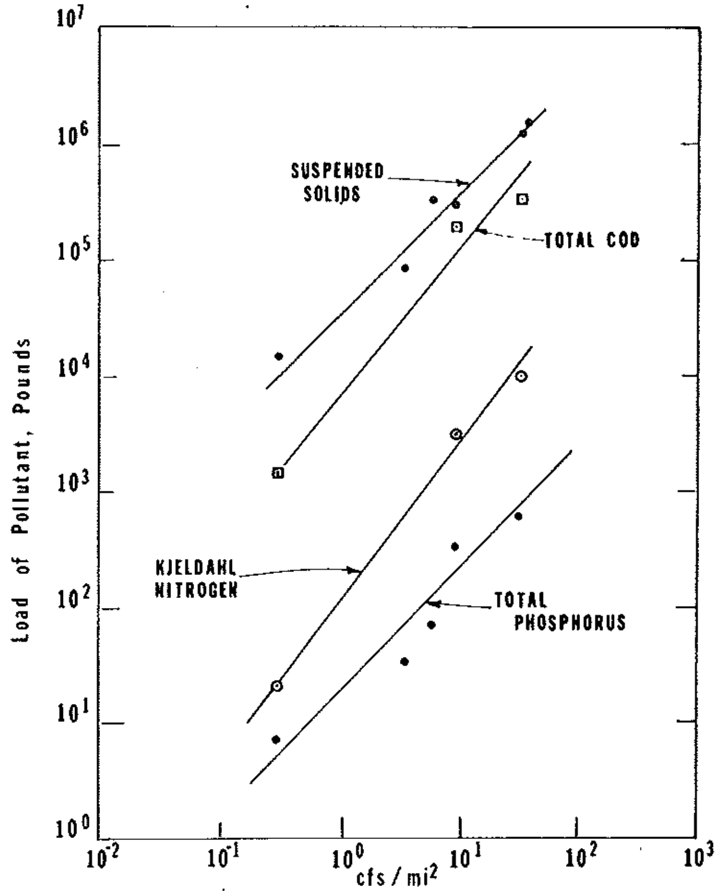

Figure 2. Summary of Pollutant Loadings in Stormwater Runoff for Panther Branch at Woodlands, Texas (Drainage Area = 34.5 mi^2).

determined for each parameter. The results for each parameter at each location were then compiled and the minimum, mean, and maximum values were determined. Figures 3 through 6 present the results. Average values are shown by a dashed line, while the range of each characteristic is denoted by a solid line.

Several general trends in the data presented are evident. First, the suspended solids and total phosphorus characteristics of stormwater runoff are higher in the watershed under construction at Woodlands, Texas, in comparison to the forestial site at the same location. In contrast, the characteristics of total chemical oxygen demand and total Kjeldahl nitrogen are independent of construction activity. The increased values of peak concentration, average concentration, and pollutant load for suspended solids are expected with construction work because of the increased erosivity of unstabilized soils.

A second observation is that the suspended solids and total chemical oxygen demand data for the Durham, North Carolina, watershed (Colston, 1974) are considerably higher

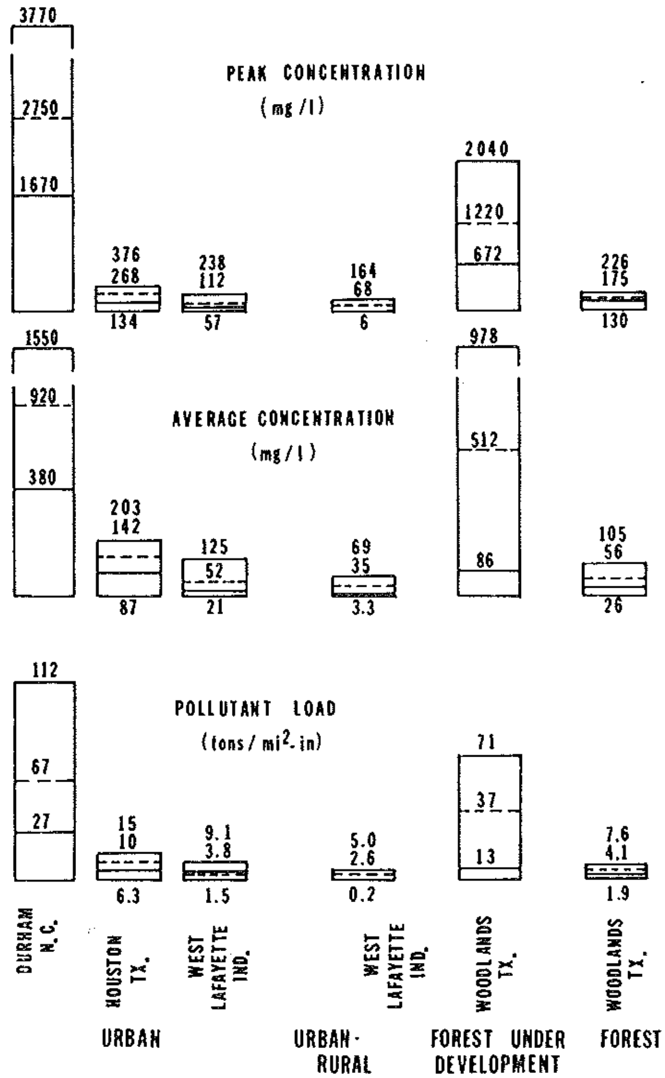

Figure 3. Characterization of Suspended Solids in Stormwater Runoff.

than the results for urbanized watersheds in Houston, Texas (Charaklis, *et al.*, 1975), and West Lafayette, Indiana (McElroy and Bell, 1974). The higher values recorded at Durham, North Carolina, may be attributable to the location of the intake of the sampling device used, which was located on the bottom of the stream bed. Consequently, during runoff events the samples were taken from the extreme lower portion of the stream and are most probably not directly comparable with the results of the other watersheds.

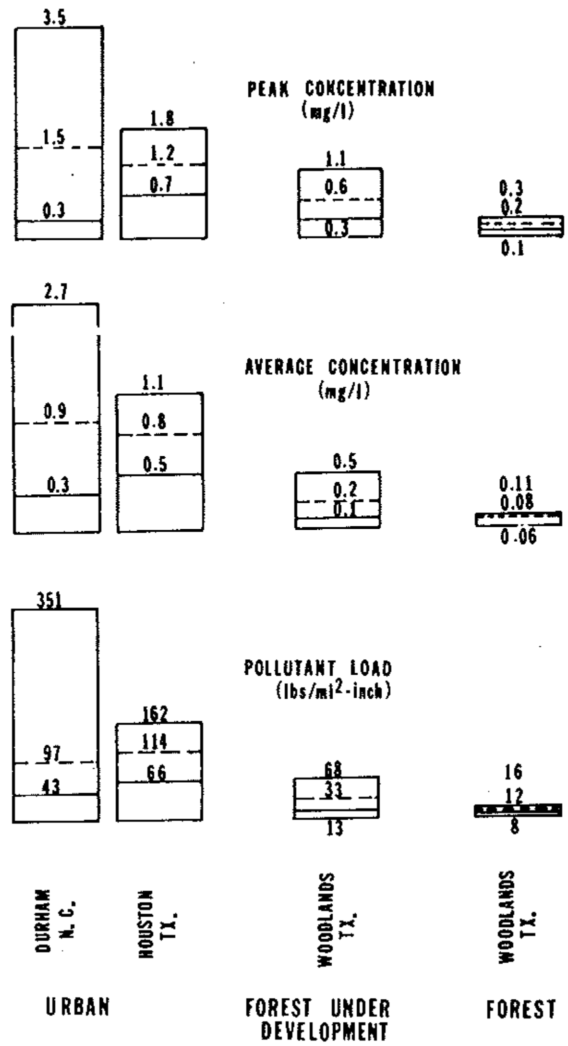

Figure 4. Characterization of Total Phosphorus in Stormwater Runoff.

Finally, the characteristics of total phosphorus, total chemical oxygen demand, and suspended solids are generally higher in the urbanized watersheds in comparison to the values monitored in the forestial watershed at Woodlands, Texas. For example, the average pollutant load of total phosphorus for the forestial watershed was 12 lbs/sq mi-in., whereas values of 97 and 114 lbs/sq mi-in. were recorded for the two urbanized watersheds.

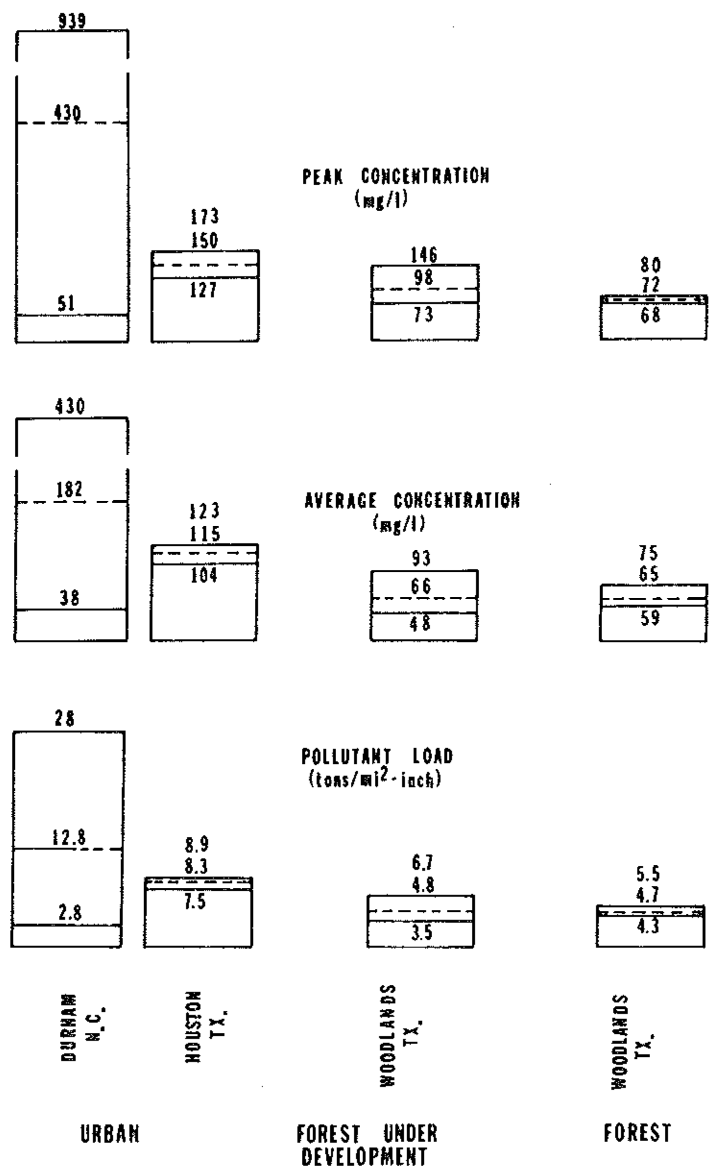

Figure 5. Characterization of Total Chemical Oxygen Demand in Stormwater Runoff.

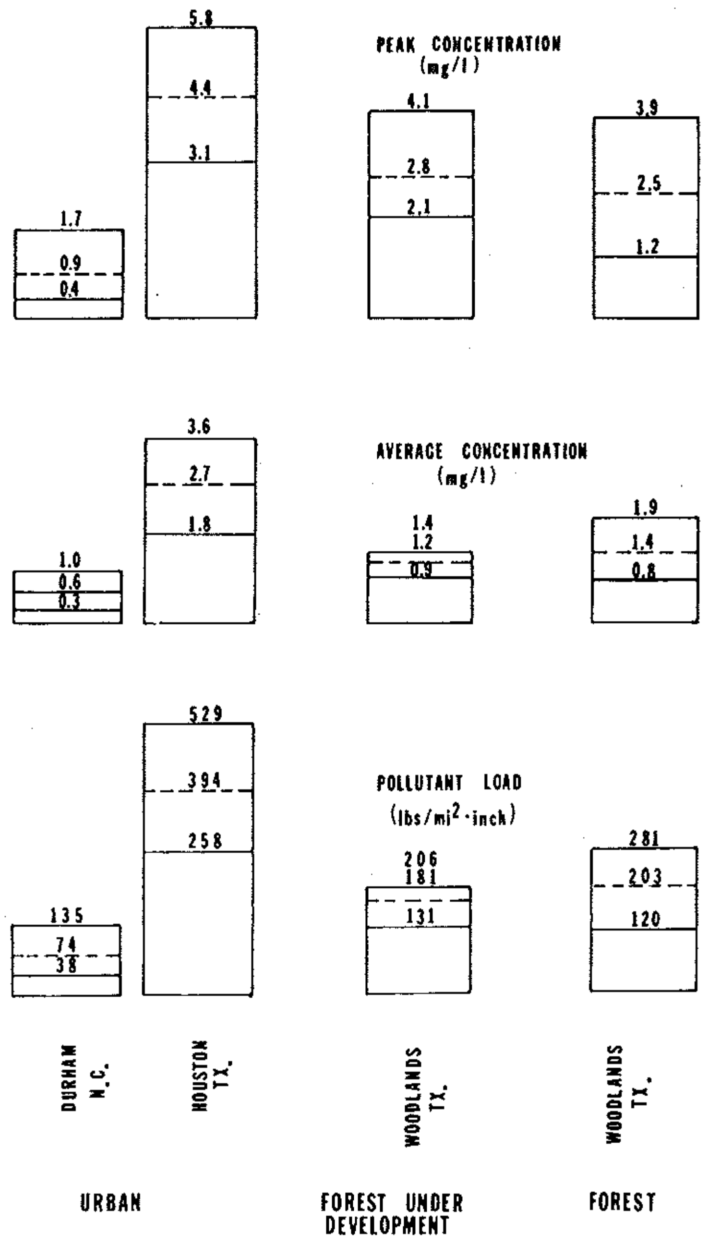

Figure 6. Characterization of Total Kjeldahl Nitrogen in Stormwater Runoff.

SUMMARY AND DISCUSSION

Very little information is currently available on the temporal characteristics of water quality parameters in stormwater runoff. A majority of the projects which have been completed were conducted in urbanized areas. These studies were for the most part fragmentary because the scope of these projects was directed toward evaluating a specific water quality problem rather than toward a comprehensive evaluation. One exception is the investigation recently reported for a small urbanized watershed in Durham, North Carolina (Colston, 1974), in which the temporal characteristics of indicator bacteria, metals, nutrients, solids, and organics were studied. Little or nothing is currently known concerning the temporal characteristics of oils, pesticides, other refractory organics, viruses, and pathogenic bacteria in stormwater runoff. Current investigations, such as that being conducted at Woodlands, Texas, will provide additional information in the immediate future. Additional comprehensive studies of the temporal characteristics of surface runoff should be initiated at other locations in the United States.

With a clear understanding of the characteristics of stormwater runoff, water management officials will be better able to formulate comprehensive policies and plans for managing surface runoff.

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