NASA Contractor Report 3041

Applications of Remote Sensing to Hydrologic Planning

Harry Loats, Jr., Thomas Fowler,
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I. INTRODUCTION

The development of the LANDSAT earth resources satellite has resulted in the availability of new information which has immediate application and utility to environmental planners and managers. However, in order for this new information to be absorbed into common pratice, efforts must be made to *transfer* it from the research sector to the user sector.

Two important steps are required for this transfer process to occur.

1) The applicability and accuracy of individual remote sensing techniques must be confirmed in the user arena.

2) The economic practicality of remote sensing in augmenting or supplanting conventional data sources must be clearly demonstrated.

ECOsystems, under contract to the NASA Marshall Space Flight Center, has focused upon such technology transfer in the area of hydrology and water quality. The ECHOS hydrologic model and the hydrologically oriented remote sensing analysis procedures developed for NAS8-30539 have formed the basis of the transfer task.

Specifically, the work included four tasks:

Task 1. Demonstrate the hydrologic model developed under the previous phase of this work and its corresponding use of LANDSAT imagery to selected users. Explore with the users the active transfer of remote sensing.

Task 2. Perform demonstrations of the value of the hydrologic model and/or of extracting ground cover information from LANDSAT data as may be requested by the more important users.

Task 3. Publish the material, or present it at selected symposia, and similar meetings as indicated by the users.

Task 4. Document user reactions, specific comments, and positive actions taken. Assess and document the nature and magnitude of potential impediments to technological transfer. Generate a case history of user transfer experience and guidelines as an aid in similar efforts by NASA.

True technology transfer is most beneficially accomplished when the transfer encompasses the overall problem as contrasted to problem support areas. The users are mainly interested in the overall results that accrue from the use of remote sensing and secondarily in the specifics of remote sensing, per se. However, once the utility of the remote sensing application is proven, the diffusion of the remote sensing techniques within the user's organization rapidly occurs. Consequently, this project sought to address end-to-end solutions of important problems where remote sensing would play a key role.

The major project chosen for the technology transfer demonstration was the estimation of non-point source water pollutant loading from storm runoff. The need for such data is national in scope and of immediate importance as a consequence of the federal "208" water quality program, which is described in Section III. LANDSAT derived land cover assessments and the hydrologic parameters therefrom is the key input to non-point source load analysis.

Although "208" is a national program, a local focus exists in the Baltimore Regional Planning Council (RPC). This body is charged with preparation of the water quality plan for the 6,123 square kilometer, six county, central Maryland region surrounding Baltimore. Demonstration of the transfer of LANDSAT analysis techniques and the LANDSAT data oriented ECHOS model at the RPC has both local value and national applicability.

The objective of the project was to determine hydrologic response and consequent pollutant loads from important watersheds using remotely sensed land cover. In joint consultation with the RPC, ECOsystems was asked to apply LANDSAT techniques to the estimation of yearly pollutant loads for one of its three designated prototypical test areas, the Magothy Basin in Anne Arundel County, Maryland.

The progress made during the past year has utilized the research and development previously performed for NAS8-30539. The pertinent results of that contract are presented in the following section.

II. SUMMARY OF PREVIOUS WORK

From February, 1974 through February, 1977, ECOsystems has been performing research directed toward the development and validation of a LANDSAT data oriented hydrologic computer model under MSFC contract NAS8-35039. The effort included the following investigations:

1) Identification of those hydrologic phenomena (infiltration, antecedent soil moisture, etc.) which "drive" peak runoff events, i.e., those parameters to which the watershed's outflow is most sensitive.
2) The incorporation of these factors into a hydrologic computer model compatible to the maximum degree with inputs from remote sensing.
3) The verification of the model for actual watersheds.
4) The documentation of procedures for extracting hydrologic information from LANDSAT imagery.

The ability to estimate streamflow from rainfall events is one of the primary requirements of water resources planners and engineers. It impacts the design and construction of waterworks and the plans for future uses for proximate land areas.

The most useful tool available to water resources managers is the computer model designed to simulate the response of a watershed to a given rainfall input. For acceptable performance, these models require specific physiographic and hydrologic data about the watershed. Typical among model parameters are flow lengths, slope, surface friction, soil moisture, and channel characteristics. Current data is either unavailable or expensive to obtain for many basins; therefore, it is advantageous to exploit the low cost and multi-temporal features of satellite remote sensing to provide more complete information as well as periodic updates. Many of the parameters required are surface or surface-inferred phenomena and, therefore, are potentially measurable from earth resources satellites.

The result of contract NAS8-30539 was a hydrologic computer model oriented to the use of LANDSAT data. The model has been tested on well-instrumented watersheds with good results. A set of procedures was also derived for the extraction of necessary input data from LANDSAT images. These procedures involved the analysis of LANDSAT multispectral and multi-temporal images by means of an optical image analysis. The techniques were applied to land cover classification of typical Maryland watersheds. Average inventory errors were typically five percent or less for the important classes. These accuracies were completely satisfactory for derivation of hydrologic parameters such as Manning's "n" and sub-surface abstractions. The computer model and the analytic techniques employed were described in detail in the final report (CR150235; 150236).

While the utility of the techniques and procedures of rainfall to runoff estimates were of definite interest to the important research users, it was obvious that a more practical technology transfer of remote sensing requires the extension of the techniques to the user community. Examples of these user applications are: simulation of flow peak in a flood prediction application, or the use of the rainfall/runoff to estimate pollutant loads. An important result from this analysis was the realization that LANDSAT data could have an important role in the nationwide EPA sponsored "208" program, discussed in the following section.

III. TECHNOLOGY TRANSFER TO THE BALTIMORE REGIONAL PLANNING COUNCIL

The U.S. Environmental Protection Agency, under Public Law 92-500, Section 208, has adopted regulations mandating regional jurisdictions to develop areawide waste water management plans. The purpose of these programs is to ensure that the areas meet the projected 1983 and future water quality regulations. The plans will be used to guide water quality programs through the year 2000. National federal expenditures for "208" programs are presently set at $380 million over a two year time frame. Legislation is currently pending to project future funding requirements.

Until recently, the major thrust of the EPA has been on point sources, i.e., those pollution sources which are confined to spatially limited areas. The "208" program has expanded the scope to include the non-point sources. In contrast to point sources, non-point sources result primarily from the impact of the hydrologic cycle with the land cover. Land cover and associated environmental conditions determine the type, form, concentration and temporal pattern of pollutants for each watershed.

Quantification of non-point pollutant load requires: 1) current and frequent assessment of land cover over large geographic areas; 2) the determination of the relationships between diverse land cover classes and the pollutants they produce; and 3) the determination of the impact of the hydrologic cycle upon the surface and groundwater transport of pollutants. The rapid classification of stable and transient land cover, therefore, is a necessary and valuable adjunct to the "208" program.

Approximately 9-10% of total federal "208" expenditures can be directly or indirectly related to land cover measurements and land cover/non-point source pollutant load correlation. Regional environmental planners with "208" responsibilities, therefore, are an important potential user class interested in LANDSAT derived hydrologic land cover and pollutant load data. *In many cases, only the LANDSAT type data has the sufficiently good resolution and freshness necessary to accommodate the required loading estimates.*

Because of this potential, it was determined to undertake technology transfer with a Section "208" water resources planning body. In the metropolitan Baltimore area, the "208" program is managed by the Baltimore Regional Planning Council (RPC). The RPC is a multi-jurisdictional organization serving a section of the state of Maryland comprised of the City of Baltimore, and the Maryland counties of Anne Arundel, Baltimore, Carroll, Harford, and Howard. The combined area of the region is approximately 6123 km^2 and is composed of 5841 km^2 of land surface and 282 km^2 of surface water. The total area is equivalent to about one-fifth of a LANDSAT frame. Figure 1 shows the member jurisdictions and their proximity to the major population centers of Baltimore and Washington.

The RPC is currently completing a two year, $2.5 million contract from the EPA. The object of this program is to develop pollution abatement plans. The effort is designed to provide the basis for a continuing planning process within this multi-jurisdictional framework.

The RPC has an in-house staff of some 16 professionals supported by 39 specially hired individuals in the separate city and county jurisdictions. The effort is advised on two levels: by project officers (6) from the jurisdictional public works or health offices and by the political heads (6) of the counties, assisted by the presidents of the county councils (6). Figure 2 indicates the staff and advisory personnel and their affiliation to the RPC-208 project. The total project complement is 118, 60 of which are directly working on the project; the remaining 58 are public, local and federal governmental advisors. *This is an important user audience for LANDSAT generated data products.*

Areawide Waste Treatment Management Planning under Public Law 92-500 for the Baltimore area officially got underway in April, 1976. The Regional Planning Council, as the designated agency, was charged with the responsibility of preparing this areawide plan and for administering the grant funds.

The Regional Planning Council contracted with each of the local jurisdictions to perform various elements of the project control program. The Regional Planning Council also contracted with the State of Maryland Water Resources Administration, to conduct non-point sampling program and to provide liaison between the state "303" Basin Plan work and the Regional Planning Council's "208" program. In addition, a contract was awarded to the U.S. Soil Conservation Service to provide accurate estimates of soil erosion in the region.

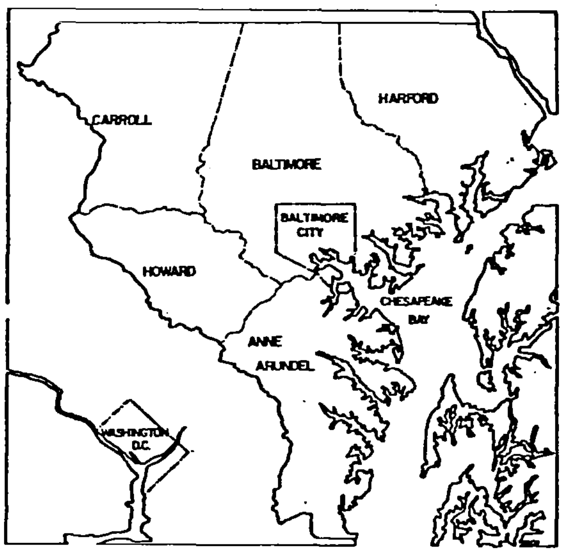


FIGURE 1
AREA COVERED BY BALTIMORE RPC

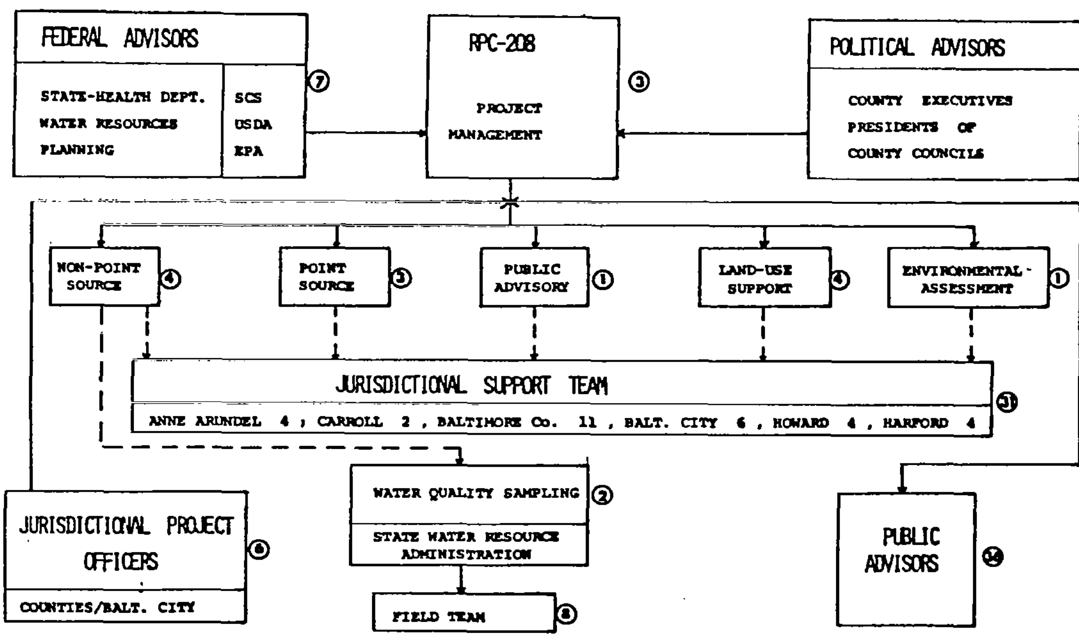


FIGURE 2
STRUCTURE FOR THE RPC-208 PROJECT

The entire work program is being carried out under the direction of the Regional Planning Council's "208" staff. Each of the local jurisdictions participating in the areawide plan also has a "208" staff headed by a project officer. There are a number of subcommittees comprised of members from the RPC "208" staff and the local jurisdiction's "208" staff. Each of these subcommittees meets on a regular basis at least once a month to develop the methodology for carrying out the work and monitoring the progress of the various elements of the respective section.

A Public Advisory Committee (PAC) composed of interested citizens and a Technical Advisory Committee (TAC) composed of technical people provide input to the RPC and local jurisdiction's "208" staff. A coordinating committee composed of elected officials from each jurisdiction sets the general policy and all program outputs are subject to the approval of this committee.

The basic requirements of this initial phase in the "208" planning process were: 1) to assess the present state of pollutant loads and pollution in the region identifying areas of criticality; 2) to develop techniques for quantifying the effect of various land uses on pollutant inputs to the receiving waters; 3) to predict the possible future growth of the region and its effect upon the key population and land use parameters which impact pollutant levels; and 4) to develop alternative structural and non-structural procedures to mitigate and control waterborne pollution to cost-effectively meet the EPA standards and guidelines. The development of an accurate, spatially-distributed data base is a key element to the successful operation of the "208" planning process.

The paucity of accurate data on land cover, water quality, and water quantity has made the technical aspects of the program extremely difficult. Conventional reliance on "black-box" models relating the water quantity and pollutant load outputs to precipitation inputs are neither reliable nor cost-effective. Simple "hand-type" computations made without taking into account the actual and current land cover can produce an unacceptably high error level. However, due to the large areas under consideration and the high cost per drainage area for even the simpler models, greater reliance on an accurate measurement of surface cover and estimation of hydrologic properties therefrom is required.

Under direction of the RPC and with MSFC concurrence, ECOsystems applied LANDSAT data for 1975 and the previously developed hydrologic model to the estimates of pollutant loads in the Magothy Basin. The Magothy is one of the three prototype basins selected by the RPC to develop techniques for region-wide pollutant load assessment. The following report details the application of the LANDSAT techniques to pollutant estimation in the Magothy.

IV. THE USE OF LANDSAT DATA IN THE "208" PLANNING PROCESS

Non-point source pollutant loads are dependent upon the hydrologic response of an area and the pollutants incorporated in and upon the surface of the area. Both the hydrologic response and pollutant accumulation are related to the nature and distribution of the land cover.

Comprehensive data bases do not exist at present for specifying the exact cover of the land surface at a resolution sufficiently small to accommodate existing data on soils and sediment. Conventional land use maps do not have the resolution required to assess pollutant loads from individual small watersheds. The LANDSAT 70m pixel (1.1 acres) is sufficiently small, in most cases, to permit land cover accuracies commensurate with the estimates of pollutant loads.

A basic land use inventory is maintained by the Regional Planning Council updated to 1973. Local zoning boundaries are also available, giving a composite representation of land use and zoning, albeit somewhat dated. This land use inventory does not comprehensively yield land surface cover.

The land use data is currently being updated, reviewed, and validated by "208" staffs and made available for use in "208" planning. This inventory includes areas classified in the following categories: residential, commercial, industrial, institutional, open-space, agricultural, semi-public and military.

In addition to the urban land use inventory, other data sources being utilized in the "208" planning process include current building permits, classified as residential (single family and multi-family) and non-residential, summarized by small planning districts; an inventory of all land subdivisions in the region since 1970; and electric meter connection data, by 1/4 square mile grids, provided semi-annually.

Regional "208" planning requires that the RPC and participating local governments upgrade their land use information data handling capability. Data files are now being created in digitized formats that enable computer mapping and graphic displays which expand land use analytic capability. Data files are being created for inventories of vacant land within planned sewer service areas, zoning restrictions, existing urban land uses, and other data on the region's land.

Initial results of the application of computer classified LANDSAT data at RPC, while encouraging, did not yield accuracies commensurate with the program requirements for the small hydrologic basin levels.

A land cover classification by computer was performed at RPC of the Rhode River Estuary, in Anne Arundel County, Maryland. Ground truth land cover data were supplied by the Smithsonian Institute Chesapeake Bay Center for Environmental Studies (CBCES). The Chesapeake Bay Center's review provided land cover data for nine small sub-watersheds of the Rhode, ranging from 15 to 660 acres in size. The CBCES staff had complied their land cover data in five classes (forest, old fields, cropland, pasture, and residential land). The fifty LANDSAT classes developed were aggregrated into combined classes for comparison. Differences between the CBCES and RPC results varied, depending on the class type, for each watershed. The weighted average difference between the two data sources was 32 percent, not considered sufficiently accurate for the "208" application.

It was noted that the LANDSAT classifications used in the comparison were early April vintage, compiled prior to an exhaustive reclassification of agricultural lands done in cooperation with the Baltimore County Agricultural Extension Service and Soil District Conservationists. The CBCES data was from the late summer and fall of 1975 and represented photointerpretation amended by field checks.

Following additional modification of the LANDSAT signatures, a few locational errors were corrected. The weighted average difference between the two data sources was revised to 20 percent using the revised signatures. The twenty percent difference, however, was still seen as unacceptable in view of the modeling efforts planned and designed around the LANDSAT classifications. The required error limits for individual classes are of order 5-10% for sub-watershed areas of 1,000 hectares. These error bounds are required to maintain final estimates of pollutant loads in the range of 15 to 20% over the entire region. Subsequent adjustment of signature mixes brought the computer classifications within acceptable bounds of approximately 8%.

Figure 3 indicates classification error bounds and the performance of the RPC computer-only classification schemes. In the individual sub-basins the classes considered were: land in crops, pastures, woodland, bare soil, and urban usage.

There are two types of requirements for land cover classification for the RPC's "280" project. Aggregate land cover statistics for water supply, urban storm flow, and estuary pollution are required for the three large watershed prototype areas which comprise 19% of the total area and which typify critical water quality problems in the area.

The statistics derived for each of these relatively large watersheds will be used as inputs to runoff models. The estimation of the direct runoff is crucial to the determination of total pollutant loads and for the estimation of the first flush phenomena. Since the areas of the prototype watersheds are relatively large (>10,000 acres), the requirement for class accuracies of 5% does not impose a severe constraint. Subsequent alteration of the signatures has resulted in acceptable accuracy from computer classification of LANDSAT for the larger hydrologic basins.

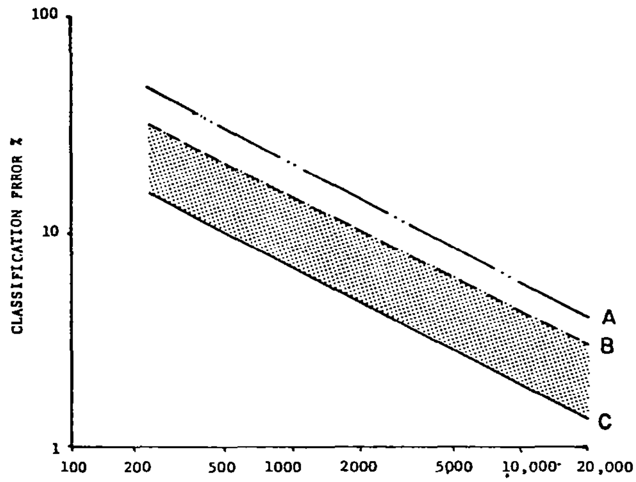
The second requirement is far more stringent and affects a far greater proportion of the area, about 80% of the total. During the early part of June, 1977, it was indicated by RPC that the LANDSAT data could be given a much more extensive role than orginally planned if the accuracies for small areas could approach the requirements indicated in Figure 3.

High accuracies are required for the small areas since the pollutant loads are estimated from correlations with in-situ measurements related to specially selected small, homogeneous areas. The pollutant loads are directly estimated from correlations with the in-situ ground sampling sites illustrated in Figure 4. It is estimated that correlations would exhibit one sigma variance of the order 10-20% given perfect information on land cover. In order to minimize the error contribution from land classification, this requires that small area land classification errors of less than 5-10% be maintained.

Techniques for improving the small area results were required in order to apply LANDSAT data.

FIGURE 3

LAND COVER CLASSIFICATION REQUIREMENTS



LEGEND:

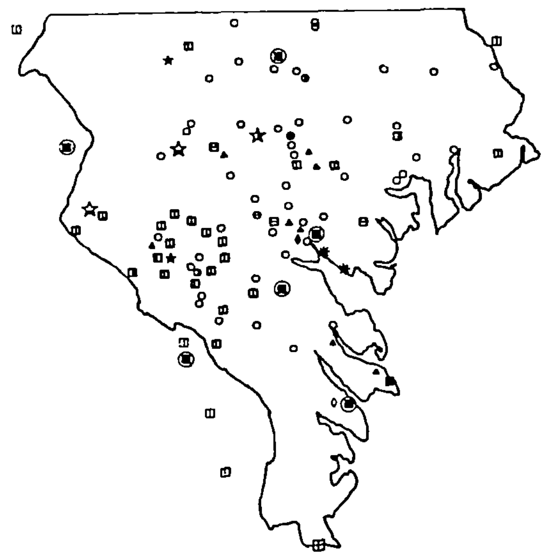
A - Results of Computer Classification at RPC
B - Upper bound of Acceptable Accuracy
C - Desired Accuracy
▩ - Acceptance Range of Classification Error

FIGURE 4

NON-POINT SOURCE — WATER QUALITY SAMPLING LOCATIONS

SOURCE: REGIONAL PLANNING COUNCIL BALTIMORE, MARYLAND

SCALE 1 : 920,000



	NO PRECIPITATION GAGE	NON-RECORDING PRECIPITATION	NON-RECORDING GAGE & PRECIP. QUALITY	RECORDING GAGE	RECORDING GAGE & PRECIP. QUALITY	NON-RECORDING & REC. GAGES
RECEIVING WATER STATIONS	○	⦶	◑	⊖	●	
SMALL WATERSHEDS						
URBAN						
RESIDENTIAL	△	▲	▲	▲	▲	
COMMERCIAL	◇	◆	◆	◆	◆	
INDUSTRIAL	✿	✱	✱	✱	✱	
AGRICULTURAL	☆	☆	☆	☆	★	
PRECIPITATION QUANTITY	□	◫	◨	⊟	■	▣

V. APPLICATIONS OF OPTICAL ANALYSIS TECHNIQUES TO LAND COVER CLASSIFICATIONS FOR NON-POINT SOURCE POLLUTANT LOAD ESTIMATION

During June, 1977, an initial presentation was made by ECOsystems personnel to the responsible planners and engineers at the RPC. The presentation described the utility of LANDSAT data for the determination of hydrologically important land cover classes for single season and seasonally changing features. Demonstrated accuracies for classification of 95% (5% error) for small watershed areas, typical of those of importance to the Baltimore RPC area, were of immediate interest. The correlation of the LANDSAT derived information with important hydrologic parameters governing overland flow was also demonstrated. These included the determination of land use classifications and the derivation of Manning's "n" from satellite imagery as performed in earlier phases of NAS8-30539.

In order to confirm the utility and accuracy of the optical analysis technique for use in non-point sources pollution estimation, it was mutually decided to perform a demonstration test on some small watersheds located throughout the Baltimore region. The Rhode River watershed was selected because of the computer classification data effort and ground truth data available. Two other watersheds, in Carroll and Howard County respectively, were also selected to prove the extendability of results.

5.1 Demonstration of Land Cover Classification using Optical Overlay for Small Test Areas in the Baltimore Region

The optical overlay procedure employed determines land cover classification from LANDSAT using USGS topographic maps as base maps and utilizes aerial photographs for ground truth verification.

Three-band combination color diazos are used in the analysis of land cover. Spectral Band 5 (0.6-0.7 μm) is encoded in magenta, Band 7 (0.8-1.1 μm) is encoded in cyan and Band 4 (0.5-0.6 μm) in yellow. The colors employed are selected to maximize visual discrimination among three bands. The cost of a diazo composite, exclusive of the price of the original imagery, is about one dollar.

Since the diazo film is not color stable when exposed to high intensity projection lights for extended periods, the composites were rephotographed on color slide film. The recent introduction of new colorfast diazo film, however, can obviate this step in the future.

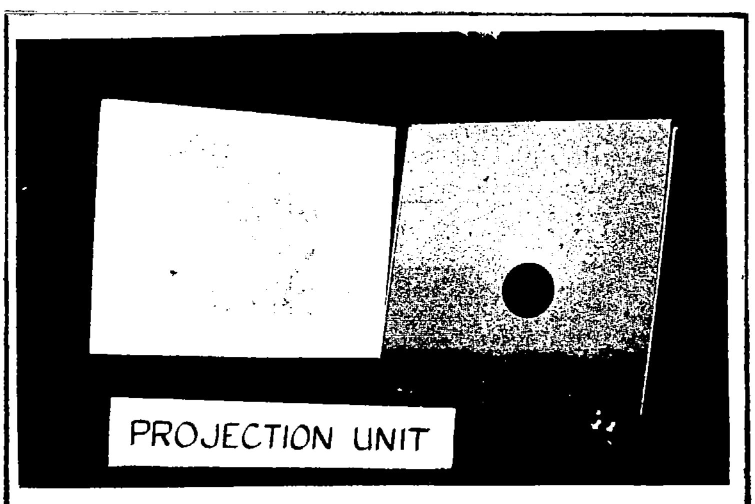
Visual interpretation of LANDSAT imagery is significantly improved by the use of multi-temporal imagery. The accurate identification of such themes as agricultural usage depends upon the observation of their behavior throughout the growing season. LANDSAT land cover analysis was performed using multi-temporal images.

The ECOsystems Universal Image Analyzer, shown in Figure 5, was used. Projected images are reflected onto a work table from an overhead mirror. Electronic controls at the table allow changes in magnification and position of the image. Typically, the projected image is overlayed on a map of known scale, such as the USGS 7 1/2 minute quad sheet (1:24000 scale).

The boundary of the watershed of interest is traced from the USGS map. Land cover is interpreted from the reflectance characteristics of the MSS bands, as determined by the color coding of the composite. Dense vegetation, for example, gives very low reflectance in Band 5. In the projected image, therefore, areas of dense vegetation will appear a dark reddish color; this is due to the magenta

FIGURE 5

ECOSYSTEMS UNIVERSAL IMAGE ANALYZER



coding of Band 5 in the diazo composite. Similarly water will appear black, urban areas will generally be white to light blue, grass and pasture will be a lighter red or orange, bare soil will be light blue to blue, and agricultural areas will vary between blue and light red depending upon the stage of growth of the crops. When the total classification is complete, the areas of each class is planimetered.

5.2 Land Classification of the Rhode River Estuary Test Area

The optical classification procedure was applied to the Rhode River Estuary using LANDSAT imagery from April and October, 1973, and February, 1974. The Rhode is a tributary of the Chesapeake Bay located in Anne Arundel County, Maryland as shown in Figure 6. The test area covers about 3200 hectares and is predominantly rural with some residential development. Other land uses present include forests, grass/pasture and agricultural areas. The 1:24000 USGS topographic map was used to establish the ridge line of the basin.

Color infrared aerial photography at 1:60000 scale provided by the RPC served as the ground truth. These photos were taken in September, 1970, but were deemed accurate for the purposes of this analysis as the area was not subjected to any significant development.

Black and white 1975 LANDSAT originals were combined into diazo color composites with Band 4 in yellow, Band 5 in magenta, and Band 7 in cyan.

Nine small training areas were isolated and an overlay of their location was made. The sequential color of each training area was noted. The image with the highest discriminability for each class was noted and a preliminary classification of the whole basin was made. Successive images were then used to refine the initial classification by the multi-temporal overlay procedure.

The area of each land cover class was then measured by planimeter and compared to a ground truth map derived from the aerial photographs. Table I shows the results of this comparison. The average weighted inventory error was 5.5%.

These results are consistent with earlier findings in that the inventory errors are small except in classes with very small absolute areas, e.g., cropped areas, developed areas and surface water. The accuracies were commensurate with the RPC requirements and represented an improvement over computer-only classifications.

5.3 Land Classification of the Howard County Watershed Test Area

The Howard County site shown in Figure 7 comprises 442 hectares of land; the primary land cover class is grass/pasture. About three percent of the basin has been developed. It drains into the Little Patuxent River, which in turn flows into the Chesapeake Bay.

The procedure applied in the analysis of this watershed was the same as that described for the Rhode River. Because of its small size, no sub-site analysis was attempted. 1:60,000 color infrared aerial photographs were used for ground truth.

The LANDSAT images used were from April and October, 1973, and February, 1974. By sequential projection of each scene, it was determined that only three cover classes were present: forest, pasture/grass, and residential. Forest was segregated using the February

FIGURE 6

LOCATION OF THE RHODE RIVER TEST SITE

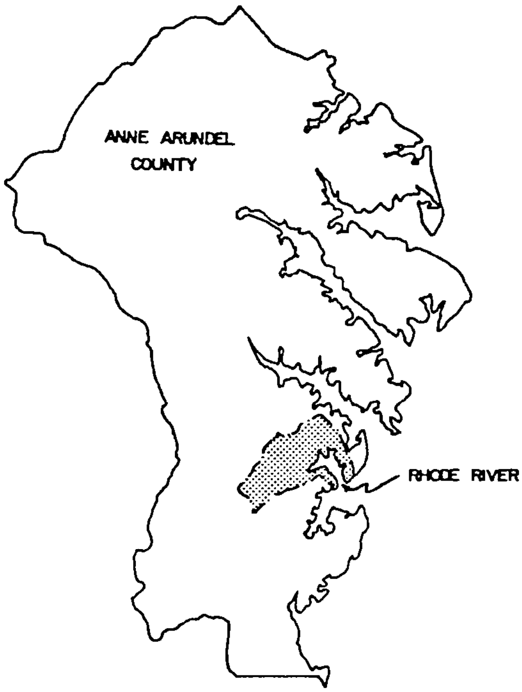


TABLE I

RHODE RIVER WATERSHED
RESULTS OF SATELLITE LAND USE CLASSIFICATION

CLASS	% OF TOTAL AREA (MEASURED FROM AERIAL)	AREA (HECTARES) (AERIAL)	% OF TOTAL AREA (MEASURED FROM LANDSAT)	AREA (HECTARES) (LANDSAT)	% ERROR
Forest	55.1	1,761.5	57.1	1,825.5	3.6
Fields	36.3	1,160.5	38.0	1,214.9	4.7
Cropped Areas	1.0	31.0	0.5	16.0	50.0
Developed	6.6	211.0	4.4	140.7	33.3
Water	4.0	127.9	—	—	—

WEIGHTED AVERAGE ERROR - 5.5%

FIGURE 7

HOWARD COUNTY SITE

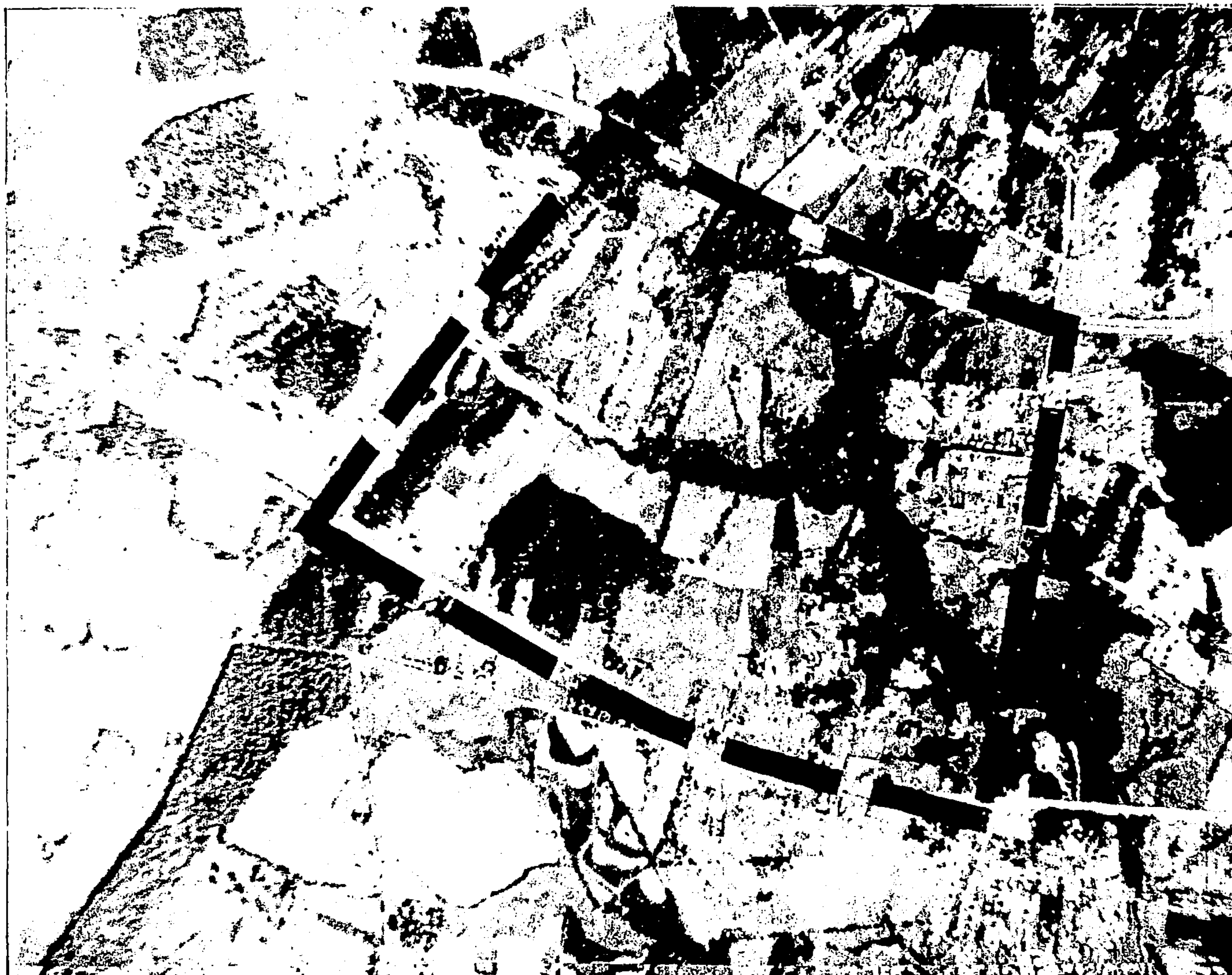


image. Identification of the other land cover classes was accomplished by using the other images in a multi-temporal sequence.

Measurements of the land cover classes were performed and compared with the measurements of comparable classes from the aerial photographs. The results are shown in Figure 8 and Table II. The weighted average error was 2.4% which met the classification criterion established by the RPC.

5.4 Land Classification of the Carroll County Test Area

The Carroll County watershed is located in an agricultural area west of Westminster, Maryland. This site, shown in Figure 9, is predominately agricultural. Of its 650 acres, about 600 are in fields and pastures; the remaining acres are forest. The residential area within the watershed is extremely small. The average size of fields within the site area is about nine acres.

The satellite images were prepared as composites with Band 4 in yellow, Band 5 in magenta, and Band 7 in cyan.

The October image was projected and overlayed on a USGS topographic map to set the scale. The color of each individual field was recorded.

This procedure was subsequently repeated for the February, 1974 image. As noted earlier, no ground truth existed for 1973; therefore, an absolute comparison of the satellite and aerial images was not possible, since fields in the area are rotated from year-to-year. The analysis was continued, however, realizing that changes in the field content from 1973 to 1975 might be the source of error.

FIGURE 8

HOWARD COUNTY TEST SITE

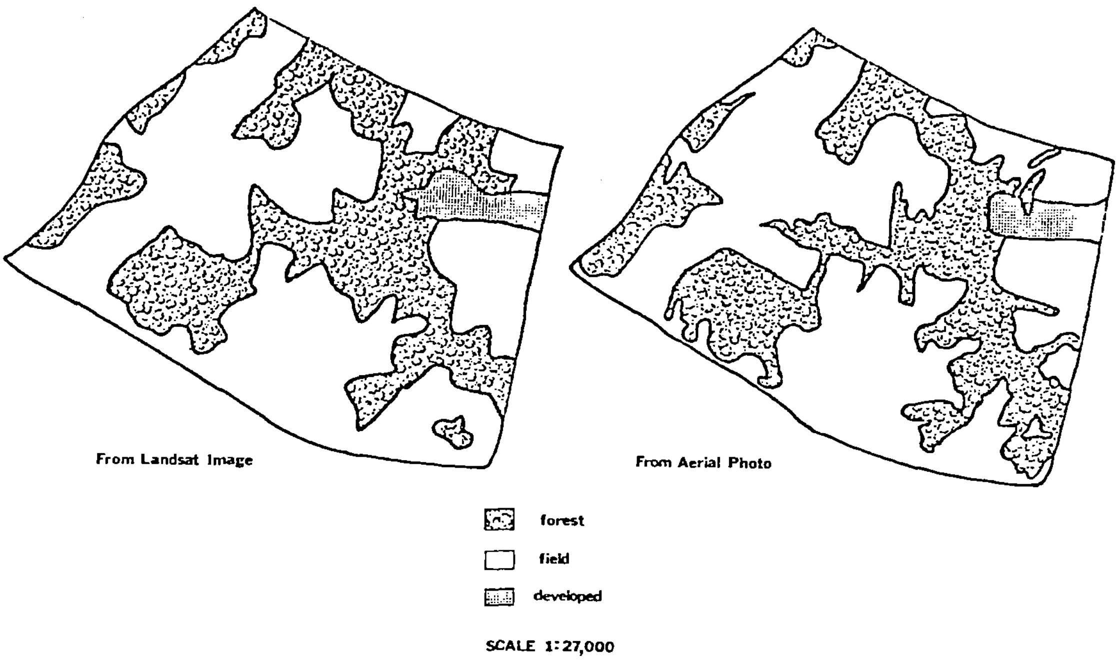


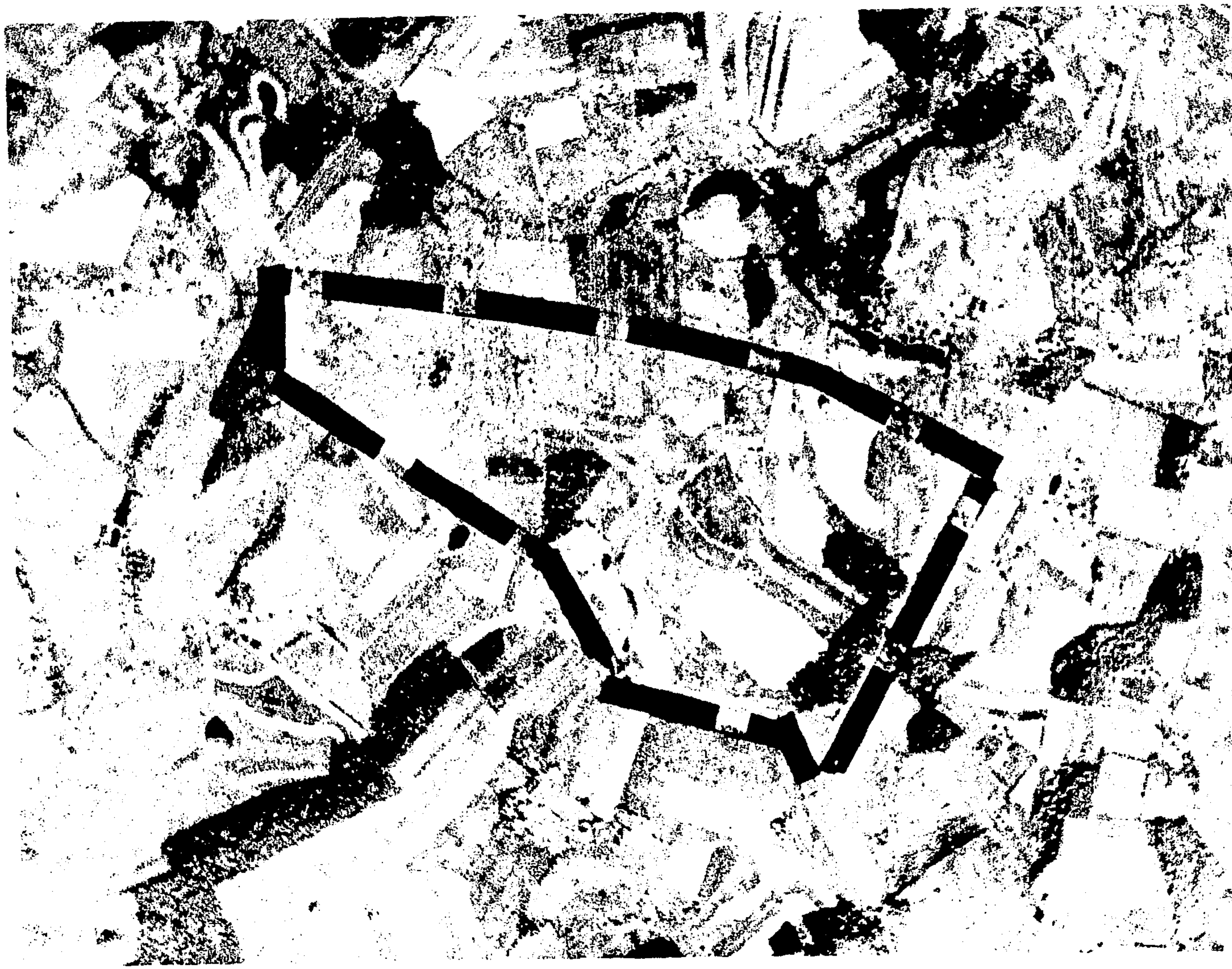
TABLE II
HOWARD COUNTY SITE
RESULTS OF SATELLITE LAND USE CLASSIFICATION

LAND USE CLASS	% OF TOTAL AREA (AERIAL)	AREA-AERIAL (hectares)	% OF TOTAL AREA (LANDSAT)	AREA-LANDSAT (hectares)	% ERROR
FORESTS	35.5	156.9	36.1	159.6	1.7
FIELDS	61.5	271.8	60.3	266.5	1.9
DEVELOPED	3.0	13.3	3.6	15.9	19.5
WATER	-	-	-	-	-

WEIGHTED AVERAGE ERROR = 2.4%

FIGURE 9

CARROLL COUNTY SITE



In examination of the two LANDSAT images, it was noted that two distinct classes of fields were present. Roughly half of the fields underwent a distinct change in color from October to February, i.e., several fields appeared bright orange (indicating dense vegetation) in October and light blue (indicating soil or sparse vegetation) in February. The remainder of the fields remained constant during the season. The former class represented cropped areas while the latter were pastures. The results of the classification are given in Table III and indicated a weighted error of 5% which met the criterion established.

5.5 Conclusions

From the results achieved for the three test basins, it was apparent that overall accuracies from optical analysis are satisfactory for non-point source pollutant assessment. The average inventory error of the three sites was less than five percent. This represents a substantial improvement over the twenty percent errors typical in computer-only analysis. These results permit the computation of surface related hydrologic parameters at desired accuracies.

The three hydrologic parameters of importance to the pollutant load estimates are: surface friction of the overland flow areas of the watershed (Manning's "n"), estimation of the seasonal values of the ratio of direct-to-delayed runoff due to a given storm event, and the impervious/pervious fractions of the watershed. All three of these parameters play key roles in the determination of non-point source pollution estimates for the non-prototype areas and are amenable to direct estimation from satellite imagery.

TABLE III

CARROLL COUNTY SITE

RESULTS OF SATELLITE LAND USE CLASSIFICATION

LAND COVER CLASS	% OF TOTAL AREA (aerial)	AREA (hectares) AERIAL	% OF TOTAL AREA (LANDSAT)	AREA (hectares) LANDSAT	% ERROR
CROPPED AREA	44.6	116.0	42.1	109.5	5.6
PASTURES	55.4	144.0	57.9	150.5	4.5

WEIGHTED AVERAGE ERROR = 5%

Optical LANDSAT image analysis was also cost effective. Direct comparison of the cost per unit area was not possible since detailed records of the alternatives were not available from the RPC. The projected costs from the ECOsystems experience of $\$0.50/km^2$ would yield a total cost of $2500 for the RPC area, a figure which was well received by the RPC personnel.

There is an inherent interest at RPC to use LANDSAT type information in a simple and direct way. So far the problems of limited accuracy, cost of acquisition of ground truth, and difficulty in signature extension using conventional LANDSAT computer classification techniques have limited the utility of the LANDSAT data. The application of the simple optical techniques appears to have potential for upgrading the utility of LANDSAT. An explanation of how to interpret LANDSAT images using these procedures was made to the RPC personnel. The optical technique permitted direct interpretation by the multi-disciplinary RPC team with enhanced information return. The low cost of the images permits expanded analysis of seasonal land cover which closely matches the requirement for incorporation into the modeling of pollutant loads associated with critical runoff events.

Based on the results achieved for the test sites and this positive reception by the RPC, the complete land cover analysis and pollutant load assessment of the Magothy River was undertaken. The procedure applied and the conclusions reached are reported in the next section.

VI. ESTIMATION OF NON-POINT POLLUTANT LOADS FOR THE MAGOTHY BASIN USING LANDSAT DERIVED DATA

The estimation of non-point source pollutant loads from representative watersheds is a key element in RPC's approach to areawide wastewater management for the Baltimore Region. The anticipated high cost of modeling each of the more than 100 water quality districts comprising the region required that the RPC select a limited number of "prototype" basins which were adjudged to be representative of the region and from which the total non-point source loads of the non-prototype areas could be estimated.

One of the three prototype regions selected by the RPC was the Magothy River basin located in close proximity to the ECOsystems facility at Gambrills, Maryland. The Magothy is a 8600 hectare watershed which drains into the tidally dominated Magothy River as shown in Figure 10.

The ECOsystems model ECHOS* was used to calculate annual pollutant loads for the Magothy. The model computes overland flow from individual rain events and stores the output as flow versus time. The process is repeated for each sub-basin. Subsequently, the model routes the output of the appropriate sub-basin or sub-basins through successive channels until the basin outlet has been reached. Tabular results are prepared giving the time since the start of rainfall, rain and discharge rates, and cumulative rain and discharge. Total discharge for the month is computed and converted to pollutant loads using loading factors determined for the existing land use categories.

*See Appendix A for a description of the model.

FIGURE 10

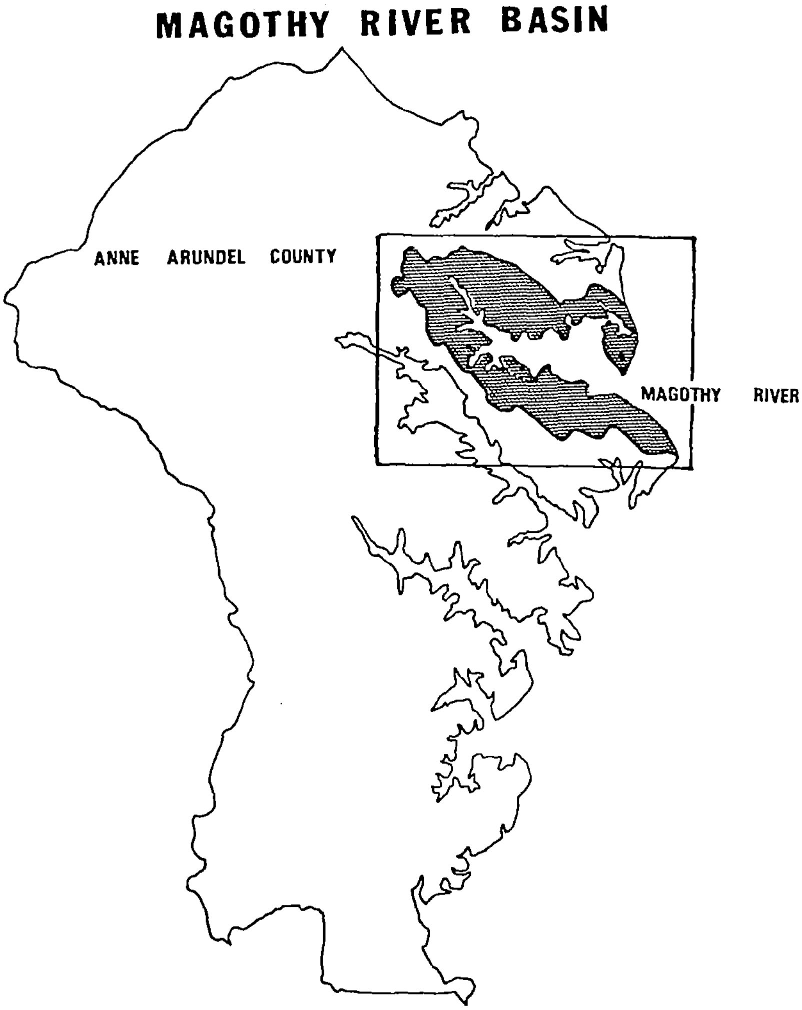


TABLE IV

COLOR COMPOSITE ANALYSIS: MAGOTHY RIVER BASIN

SCENE \ SAMPLE	Forest 1	Forest 2	Pasture/Grass 3	Agriculture 4	Agriculture 5	Extractive 6	Extractive 7	Residential 8	Residential 9	Commercial/ Industrial 10	Commercial/ Industrial 11	Water 12
April 9, 1973	Gray	Gray	Lt. Pink	Dk. Pink	Dk. Pink	White	White	Lt. Pink	Lt. Pink	Lt. Blue	Lt. Blue	Blue
Oct. 6, 1973	Red	Red	Lt. Blue	Lt. Blue	Lt. Blue	[White]	[White]	Lt. Blue	Lt. Red	[Blue]	[Blue]	Black
Oct. 6, 1973	Blue	Blue	Red	Red	Red	Red	Red	Red	Red	Red	Red	White
Feb. 27, 1974	[Brown]	[Brown]	Lt. Blue	Lt. Blue; Orange	Lt. Blue: Orange	White	White	Lt. Blue	Lt. Brown	Lt. Blue	Lt. Blue	Black
May 14, 1975	Dk. Orange	Dk. Orange	Blue-Orange	Blue-Orange	Blue-Orange	Lt. Blue	Lt. Blue	Orange	Lt. Orange	Blue	Blue	Black
Aug. 8, 1975	Dk. Orange	Dk. Orange	Orange	Orange	White-Orange	White	White	Orange-Blue	Orange-Blue	Blue	Blue	Black
Oct. 14, 1975	Purple	Purple	Purple	Lt. Blue-Orange	Lt. Blue-Pink	White	White	Purple	Purple	Lt. Blue	Lt. Blue	Black

[ ] - INDICATES PREFERRED IMAGE

Table IV indicates that no single image shows agricultural areas in marked contrast with the other classes. It was determined by examination of all the available scences that agricultural areas followed a unique progression of colors: dark pink in April, light blue to white in October, and orange/light blue in February. All areas exhibiting this behavior were then classified as agricultural.

Residential areas were not strongly separable from pasture/grass in any scene. This is due to the low density (2-4 units per acre) of most residential development present. Some of the more densely developed residential areas could be consistently identified; most appeared to be the same as the pasture/grass areas in all scences. The residential class was determined from aerial photography. The use of a hybrid satellite/aerial remote sensing system to derive pollution loads represents a necessary compromise.

On the basis of this technique, the land classification map shown in Figure 12 was prepared. The entire Magothy River watershed was also mapped and classified from the aerial photo. Because of the age of the aerials (September, 1970), imagery from 1975 was acquired from the Baltimore RPC and the ground truth map updated. Alterations were required in ten areas reflecting the post 1970 residential and/or commercial development.

The areas of each land cover class were computed from the aerial and hybrid maps for each of the seventeen subbasins. The results are reported in Table V. The overall classification accuracy of 2.3% is consistent with the other watersheds analyzed and well within the requirement of the RPC. The land use classifications was also used to develop

FIGURE 12

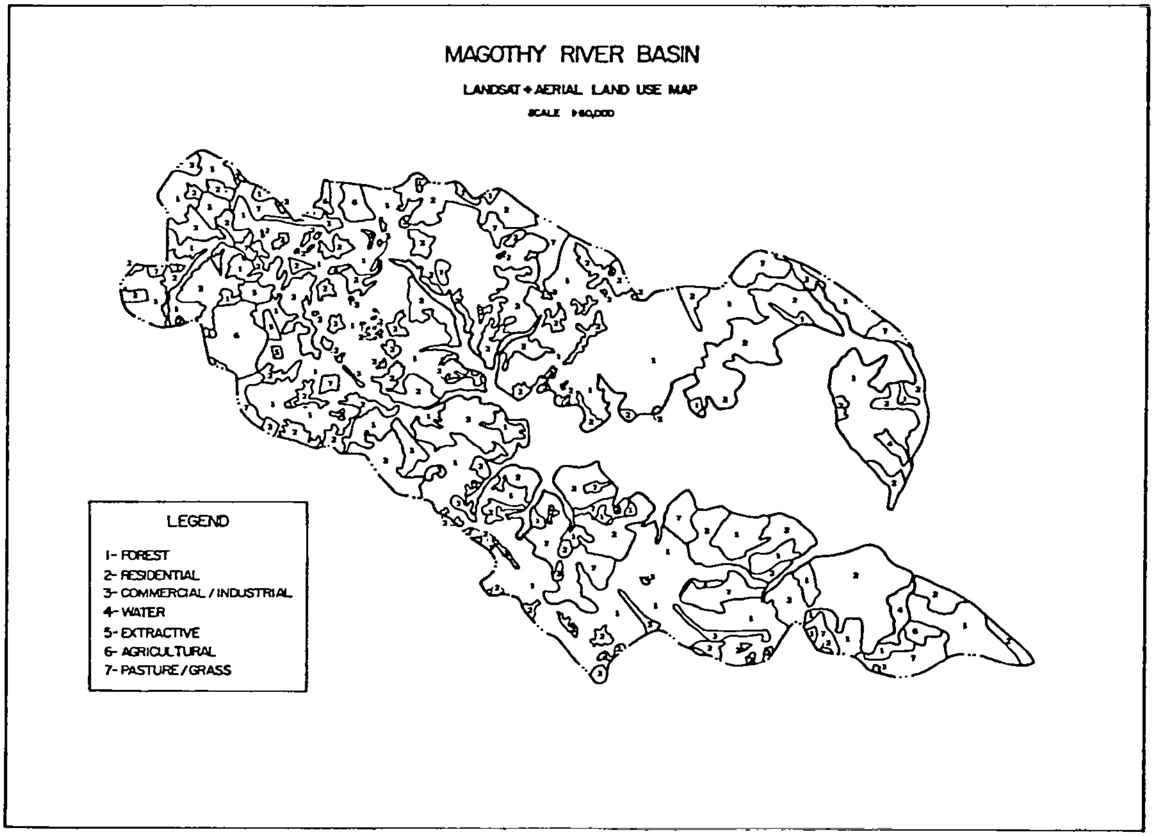

MAGOTHY RIVER BASIN
LANDSAT + AERIAL LAND USE MAP
SCALE
LEGEND
1- FOREST
2- RESIDENTIAL
3- COMMERCIAL / INDUSTRIAL
4- WATER
5- EXTRACTIVE
6- AGRICULTURAL
7- PASTURE / GRASS

TABLE V

LANDSAT & AERIAL CLASSIFICATION OF THE MAGOTHY RIVER

AREA, HECTARES

SUBBASIN	FOREST	RESIDENTIAL	COMMERCIAL, INDUSTRIAL	WATER	EXTRACTIVE	AGRICULTURE	PASTURE, GRASS	TOTAL
1	72.0	25.6	-	18.6	-	-	-	116.2
2	339.2	255.6	-	-	-	-	74.4	669.2
3	281.1	204.5	-	-	-	-	-	485.6
4	237.0	25.6	-	-	-	-	-	262.6
5	474.0	227.7	-	-	-	-	55.7	757.4
6	1279.2	697.1	69.7	5.8	41.8	190.5	86.0	2370.1
7	181.2	51.1	-	-	-	-	-	232.3
8	434.5	209.1	13.9	-	-	-	39.5	697.0
9	106.8	160.3	34.9	-	-	-	-	302.0
10	97.6	41.8	11.6	-	-	-	-	151.0
11	260.1	48.9	20.9	-	-	-	65.1	395.0
12	188.2	165.0	16.3	-	-	-	95.3	464.8
13	300.8	178.9	10.5	-	-	-	67.4	557.6
14	260.3	264.8	25.6	-	-	-	53.4	604.1
15	241.7	162.6	2.3	-	-	23.2	104.6	534.4
TOTAL	4753.7	2718.6	205.7	24.4	41.8	213.7	641.4	8599.3
ERROR	-1.5%	-	-1.9%	-9.6%	-5.2%	-8.9%	+18.9%	

WEIGHTED AVERAGE ERROR = 2.3%

the required hydrologic inputs to the ECHOS model and to assess the pollutant load conversion coefficients for the 17 sub-watersheds.

6.2 Determination of the Rainfall and Runoff Inputs to the Model

Storm generated, non-point source load estimation utilizes the correlation between land cover generated pollutant loads and the volume of runoff. Sediments and sediment-entrained pollutants are carried overland by storm water runoff and deposited into the stream channels. After deposition in the channels, they are transported and altered by channel flow processes to the stream outlet. The process of pollutant delivery to the channel outlet can be simulated by computer models with routines for overland and channel flow, such as the ECHOS model developed under NAS8-30539.

The ECHOS model requires calibration with a small number of actual rainfall and runoff records. Though the Magothy River is not permanently gaged, a limited amount of on-site data was collected by the RPC. Historical and current rainfall records were also available for nearby weather stations.

On-site data were taken for various months during 1977 at three sites: Bay Hills, Severna Park, and Cape St. Clair. Measurements were taken for a total of 80 rainfall events. However, sufficient runoff records existed for only four events at Cape St. Clair: 24 February, 18 March, 2 April, and 25 July, 1977 from which to construct an accurate hydrograph. Rainfall hyetographs and runoff hydrographs for these dates are graphed in Figures 13a, b, c, and d. These graphs show the actual runoff response of Magothy sub-watersheds to actual rain events.

FIGURE 13a

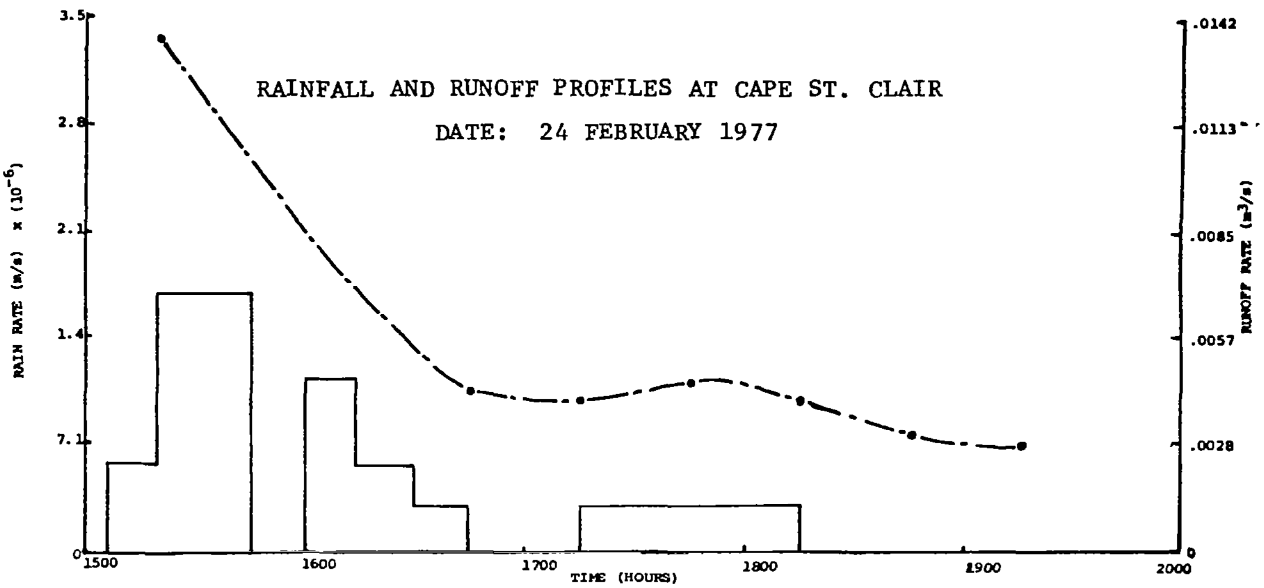


FIGURE 13b

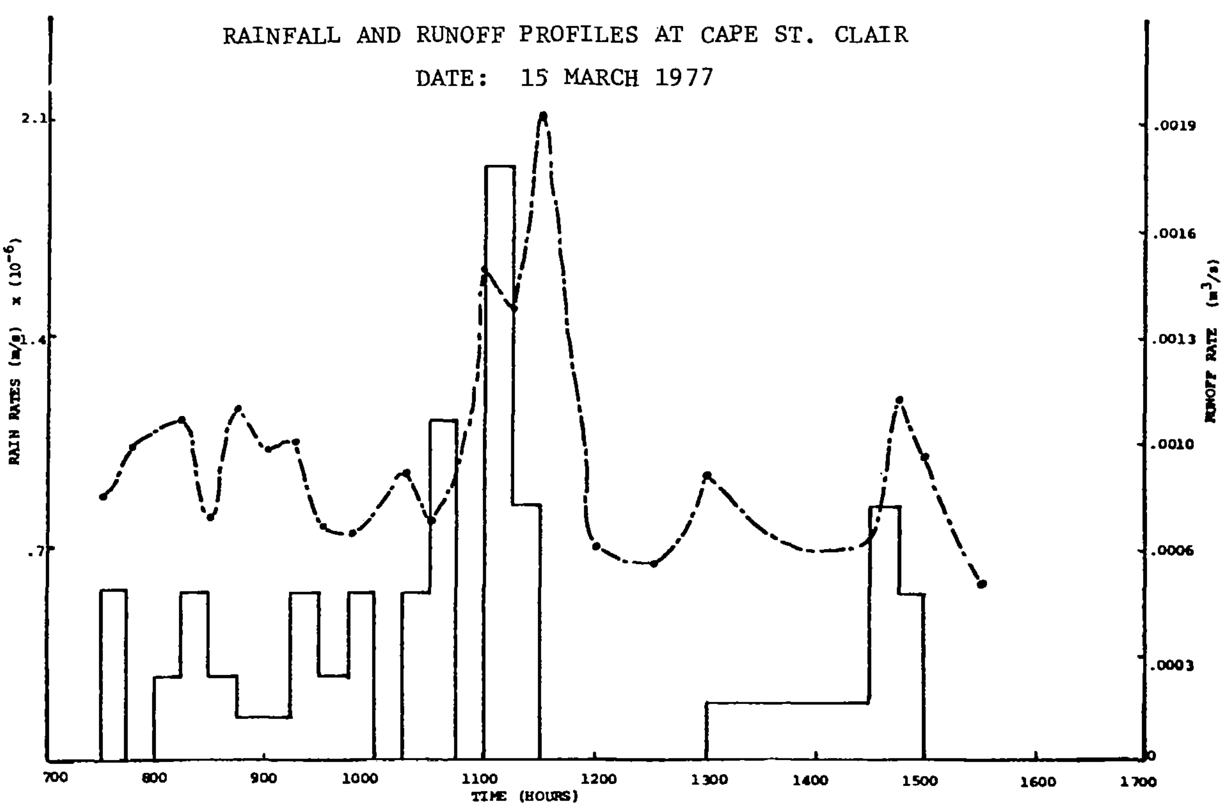


FIGURE 13c

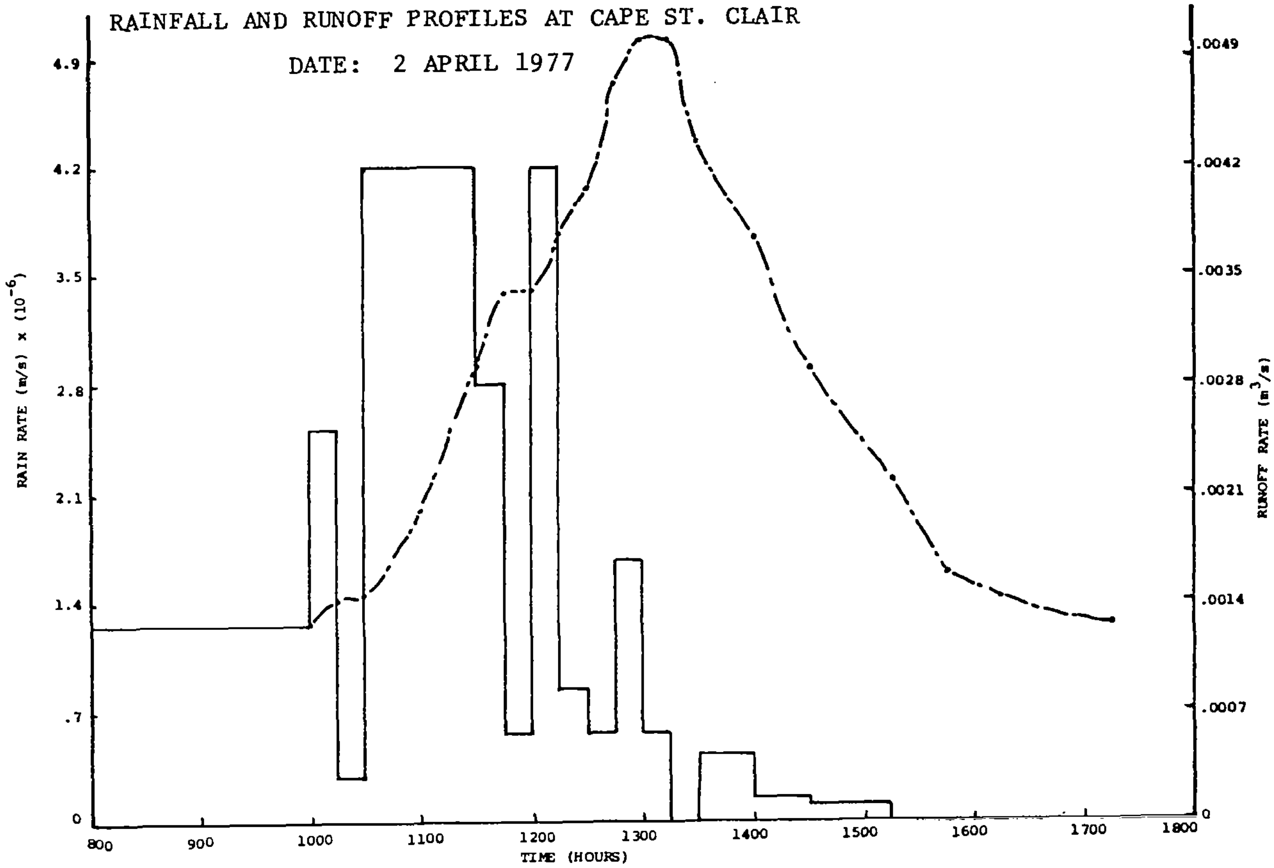
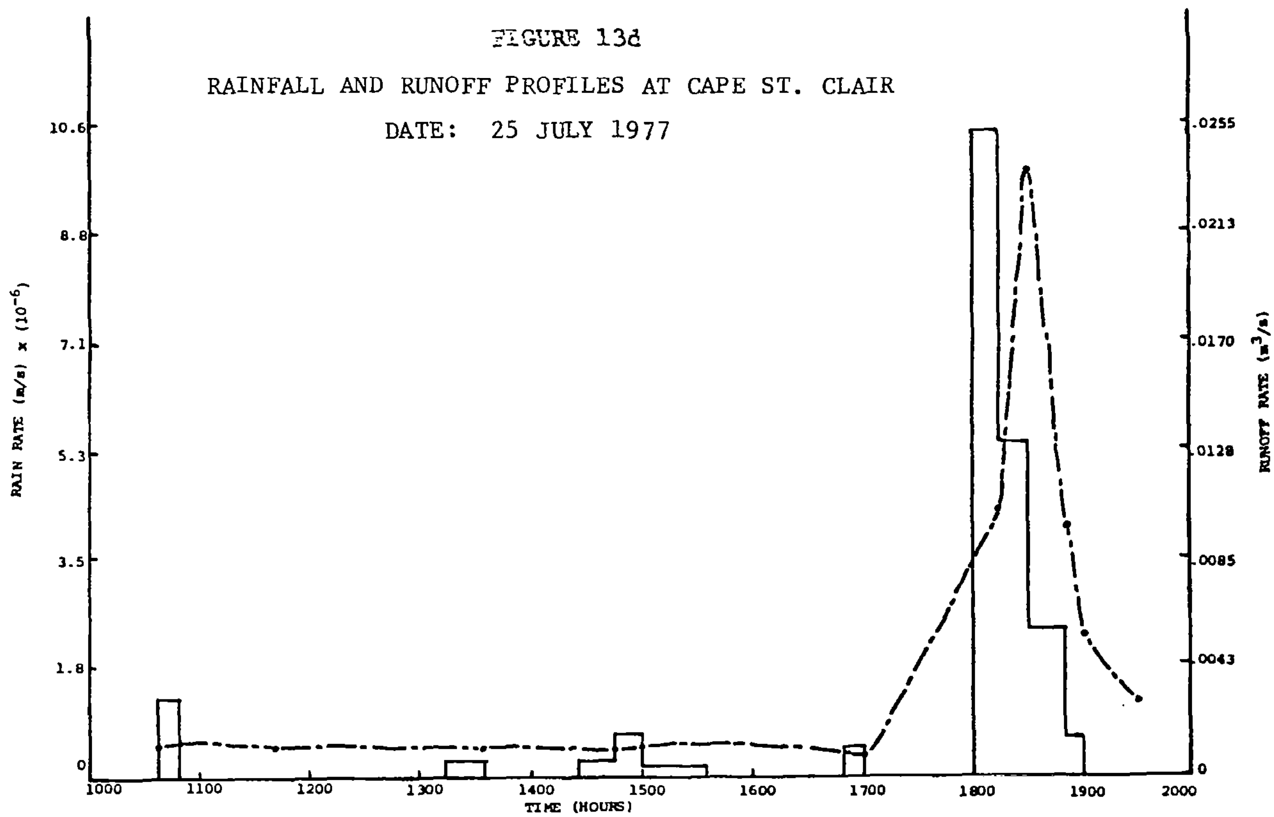


FIGURE 13d



Monthly averages of number of storm events, volume, duration, intensity and time between storms were computed from an analysis of twenty-five years of hourly rainfall records from the nearby NOAA weather station at Baltimore Friendship Airport. Typical rainfall data available from NOAA is shown in Table VI. The raw data were processed by computer to produce a statistical summary. The monthly summary presented in Table VII gives the intensity, volume, duration and time between storms and includes the average, minimum, maximum, standard deviation, variance and C.V. for each parameter. Table VIII summarizes the data from the Table VII and lists the selected parameters of the monthly average rain events to be used in the simulation.

Direct runoff from a storm of a given volume, magnitude and average intensity depends directly upon the distribution of the rain rates over time. Discharge rates and volumes vary with the "shape" of the rain input. Average peak rain rate and average time to peak rate were derived for each month using a large, fifty percent sample of the storms from 1948-1975 and recording the peak rate and time to peak rate. The sample comprised from 100 to 150 storms, depending on the month for the period of record, and were representative of the actual rainfall behavior.

The temporal rainfall profiles were approximated by a series of discrete intervals with total volume, intensity, peak rate, and time to peak equal to the average values adjusted to match the durations and volumes specified in Table VII. The June 1975 profile is shown in Figure 14 along with its discrete approximation as an example of this procedure. The average number of storms expected during each month was computed from the average time between storms and is also given in Table VIII.

TABLE VI

HOURLY RAINFALL DATA: BALTIMORE AIRPORT GAGE FOR THE PERIOD JANUARY - JUNE 1975

		HOURLY PRECIPITATION-HUNDREDTHS OF AN INCH																							
STATION	DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
180470	1/ 1/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	1/ 4/75	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	1/ 6/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	10	10	6	11	3	0
180470	1/ 8/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	9
180470	1/ 9/75	12	20	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	1/11/75	0	8	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	1/13/75	0	0	0	1	2	3	6	3	8	15	4	5	2	4	3	2	0	0	0	0	0	0	0	0
180470	1/18/75	0	0	0	0	0	0	0	0	0	0	5	3	9	21	12	4	1	0	0	0	0	0	0	0
180470	1/19/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	9	10	1	1	4	2
180470	1/20/75	1	1	0	1	1	3	0	3	2	1	1	1	3	1	1	0	0	0	0	0	0	0	0	0
180470	1/24/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
180470	1/25/75	1	1	1	1	1	0	0	0	2	3	5	0	0	11	4	3	0	0	9	0	0	0	0	0
180470	1/31/75	0	1	2	2	4	5	3	2	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	2/ 1/75	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	2/ 4/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	6	6	5	5
180470	2/ 5/75	5	5	5	5	3	2	3	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	.0
180470	2/ 6/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
180470	2/12/75	0	0	0	0	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	0
180470	2/17/75	0	0	0	0	0	10	5	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	2/18/75	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	2/23/75	0	0	0	0	0	0	0	2	27	27	10	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	2/24/75	2	1	1	0	0	0	0	10	3	3	0	0	1	3	3	2	1	1	1	3	0	0	0	0
180470	3/ 1/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	3/ 7/75	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0
180470	3/10/75	0	0	0	0	0	0	0	0	0	0	0	0	2	2	6	0	0	0	0	0	0	0	0	0
180470	3/12/75	0	0	0	0	0	0	0	0	2	8	2	10	8	7	14	1	0	0	0	0	0	0	0	0
180470	3/13/75	0	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
180470	3/14/75	8	14	5	4	0	4	1	0	0	1	24	22	5	12	3	0	0	0	0	0	0	3	3	0
180470	3/19/75	0	0	0	0	3	13	10	7	24	5	17	69	35	46	4	0	0	0	0	0	0	0	0	0
180470	3/24/75	0	0	0	0	6	9	4	33	7	0	0	0	0	0	5	15	12	0	0	0	0	0	0	0
180470	3/29/75	1	0	0	0	0	3	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	3/30/75	11	2	10	16	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	4/ 1/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	4/ 3/75	0	0	0	0	1	2	1	2	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	4/15/75	0	4	8	5	3	8	1	1	1	4	0	0	0	5	2	0	0	0	0	0	0	0	0	0
180470	4/18/75	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
180470	4/19/75	0	0	0	0	0	0	0	0	0	0	0	15	2	0	0	0	0	0	0	0	0	0	0	0
180470	4/23/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
180470	4/24/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	12	11	1	0	0
180470	4/25/75	6	2	0	0	0	0	0	0	0	0	0	0	0	4	17	10	0	45	24	13	13	4	0	0
180470	4/28/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
180470	4/29/75	0	0	0	12	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	5/ 1/75	1	1	0	14	17	19	6	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	5/ 3/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	15
180470	5/ 4/75	16	18	23	12	16	33	11	7	5	0	0	0	0	0	0	22	1	0	0	5	27	0	0	0
180470	5/ 5/75	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	5/ 6/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	47	0	0	0	0	0	0	0
180470	5/12/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	1	0	0	0	11	16	2
180470	5/13/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0
180470	5/15/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	0
180470	5/16/75	11	3	1	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180470	5/22/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	21	0	0	0	0	0
180470	5/24/75	0	0	0	0	0	0	0	0	0	0	0	112	63	0	0	0	0	0	0	0	0	0	0	0
180470	5/30/75	0	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0	0	0	0	0	0	0	0	0
180470	5/31/75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	36	19	27
180470	6/ 1/75	1	0	0	0	1	0	10	5	0	0	0	0	0	0	22	2	0	0	0	0	0	0	0	0

TABLE VII

MONTHLY STATISTICAL SUMMARY, 1948-1975 FOR THE BALTIMORE AIRPORT RAIN GAGE.

RAINFALL STATISTICS BY MONTH(FOR RIOD OF RECORD)

MONTH		NUMBER	TOTAL	MINIMUM	MAXIMUM	AVERAGE	STD DEV	VARIANCE	COEF-VAR
1									
	DURATION	242.	0.185100E+04	0.100000E+01	0.460000E+02	0.764876E+01	0.696439E+01	0.485027E+02	0.910525E+00
	INTENSITY	242.	0.821559E+01	0.428600E-02	0.175001E+00	0.339487E-01	0.281867E-01	0.794493E-03	0.830274E+00
	VOLUME	242.	0.748486E+02	0.100000E-01	0.257000E+01	0.309292E+00	0.411560E+00	0.169382E+00	0.133065E+01
	DELTA	242.	0.202645E+05	0.450000E+01	0.740000E+03	0.837376E+02	0.909082E+02	0.826430E+04	0.108563E+01
2									
	DURATION	228.	0.181100E+04	0.100000E+01	0.440000E+02	0.794298E+01	0.646381E+01	0.417809E+02	0.813777E+00
	INTENSITY	228.	0.978554E+01	0.500100E-02	0.580005E+00	0.429190E-01	0.497011E-01	0.247020E-02	0.115802E+01
	VOLUME	228.	0.876787E+02	0.100000E-01	0.198000E+01	0.384556E+00	0.454940E+00	0.206970E+00	0.118303E+01
	DELTA	228.	0.180290E+05	0.500000E+01	0.653000E+03	0.793746E+02	0.770031E+02	0.592947E+04	0.973803E+00
3									
	DURATION	269.	0.194400E+04	0.100000E+01	0.350000E+02	0.722677E+01	0.665828E+01	0.443327E+02	0.921336E+00
	INTENSITY	269.	0.133354E+02	0.600100E-02	0.110000E+01	0.495740E-01	0.790442E-01	0.624799E-02	0.159447E+01
	VOLUME	269.	0.104648E+03	0.100000E-01	0.426300E+01	0.389027E+00	0.537747E+00	0.289172E+00	0.138229E+01
	DELTA	269.	0.206770E+05	0.400000E+01	0.413500E+03	0.768662E+02	0.731712E+02	0.535402E+04	0.951930E+00
4									
	DURATION	302.	0.171400E+04	0.100000E+01	0.110000E+03	0.567550E+01	0.788164E+01	0.621203E+02	0.138871E+01
	INTENSITY	302.	0.145816E+02	0.571500E-02	0.320005E+00	0.482833E-01	0.429516E-01	0.184484E-02	0.889574E+00
	VOLUME	302.	0.932482E+02	0.100000E-01	0.596000E+01	0.308769E+00	0.501735E+00	0.251708E+00	0.162486E+01
	DELTA	302.	0.193120E+05	0.400000E+01	0.305300E+03	0.639470E+02	0.640831E+02	0.410665E+04	0.100213E+01
5									
	DURATION	312.	0.161200E+04	0.100000E+01	0.370000E+02	0.516667E+01	0.556670E+01	0.309882E+02	0.107743E+01
	INTENSITY	312.	0.217916E+02	0.500100E-02	0.875002E+00	0.698450E-01	0.908359E-01	0.825115E-02	0.130054E+01
	VOLUME	312.	0.107508E+03	0.100000E-01	0.391000E+01	0.344577E+00	0.493959E+00	0.243995E+00	0.143352E+01
	DELTA	312.	0.205310E+05	0.0	0.356000E+03	0.658045E+02	0.626475E+02	0.392470E+04	0.952024E+00
6									
	DURATION	291.	0.116300E+04	0.100000E+01	0.240000E+02	0.399656E+01	0.403647E+01	0.162931E+02	0.100998E+01
	INTENSITY	291.	0.311471E+02	0.500100E-02	0.220000E+01	0.107035E+00	0.186797E+00	0.348932E-01	0.174520E+01
	VOLUME	291.	0.109418E+03	0.100000E-01	0.440300E+01	0.376008E+00	0.557014E+00	0.310264E+00	0.148139E+01
	DELTA	291.	0.206775E+05	0.400000E+01	0.577500E+03	0.710567E+02	0.837154E+02	0.700827E+04	0.117815E+01
7									
	DURATION	254.	0.887000E+03	0.100000E+01	0.343000E+02	0.349213E+01	0.375930E+01	0.141324E+02	0.107651E+01
	INTENSITY	254.	0.324048E+02	0.500100E-02	0.199000E+01	0.127578E+00	0.200213E+00	0.400853E-01	0.156934E+01
	VOLUME	254.	0.107448E+03	0.100000E-01	0.541300E+01	0.423025E+00	0.712471E+00	0.507615E+00	0.168423E+01
	DELTA	254.	0.199020E+05	0.450000E+01	0.384000E+03	0.783543E+02	0.762868E+02	0.581967E+04	0.973613E+00
8									
	DURATION	266.	0.109500E+04	0.100000E+01	0.310000E+02	0.411654E+01	0.431294E+01	0.186015E+02	0.104771E+01
	INTENSITY	266.	0.308834E+02	0.500100E-02	0.101000E+01	0.115092E+00	0.156359E+00	0.244482E-01	0.134686E+01
	VOLUME	266.	0.129188E+03	0.100000E-01	0.795000E+01	0.485671E+00	0.853624E+00	0.728674E+00	0.175762E+01
	DELTA	266.	0.198005E+05	0.400000E+01	0.410500E+03	0.744380E+02	0.748290E+02	0.559938E+04	0.100525E+01
9									
	DURATION	229.	0.114700E+04	0.100000E+01	0.430000E+02	0.500873E+01	0.592052E+01	0.350526E+02	0.118204E+01
	INTENSITY	229.	0.178645E+02	0.800100E-02	0.607143E+00	0.780109E-01	0.101132E+00	0.102276E-01	0.129638E+01
	VOLUME	229.	0.964286E+02	0.100000E-01	0.425300E+01	0.421086E+00	0.728936E+00	0.531203E+00	0.173085E+01
	DELTA	229.	0.213905E+05	0.400000E+01	0.636000E+03	0.934083E+02	0.110398E+03	0.121878E+05	0.118189E+01
10									
	DURATION	189.	0.116500E+04	0.100000E+01	0.240300E+02	0.616402E+01	0.564458E+01	0.318612E+02	0.915730E+00
	INTENSITY	189.	0.108285E+02	0.666800E-02	0.306668E+00	0.572934E-01	0.565640E-01	0.319949E-02	0.987269E+00
	VOLUME	189.	0.824889E+02	0.100000E-01	0.458000E+01	0.436449E+00	0.653503E+00	0.427066E+00	0.149732E+01
	DELTA	189.	0.198630E+05	0.450000E+01	0.504000E+03	0.105095E+03	0.108193E+03	0.117057E+05	0.102948E+01
11									
	DURATION	214.	0.147600E+04	0.100000E+01	0.590000E+02	0.689720E+01	0.674336E+01	0.454730E+02	0.977696E+00
	INTENSITY	214.	0.107131E+02	0.500109E-02	0.255000E+00	0.500474E-01	0.482061E-01	0.232382E-02	0.963208E+00
	VOLUME	214.	0.919387E+02	0.100000E-01	0.516000E+01	0.429620E+00	0.667285E+00	0.445269E+00	0.155320E+01
	DELTA	214.	0.208980E+05	0.450000E+01	0.699000E+03	0.976542E+02	0.100437E+03	0.100876E+05	0.102850E+01
12									
	DURATION	218.	0.193500E+04	0.100000E+01	0.333000E+02	0.887615E+01	0.662687E+01	0.439155E+02	0.746594E+00
	INTENSITY	218.	0.965064E+01	0.500100E-02	0.186667E+00	0.442690E-01	0.358855E-01	0.128777E-02	0.810623E+00
	VOLUME	218.	0.105199E+03	0.100000E-01	0.395000E+01	0.482563E+00	0.562239E+00	0.316113E+00	0.116511E+01

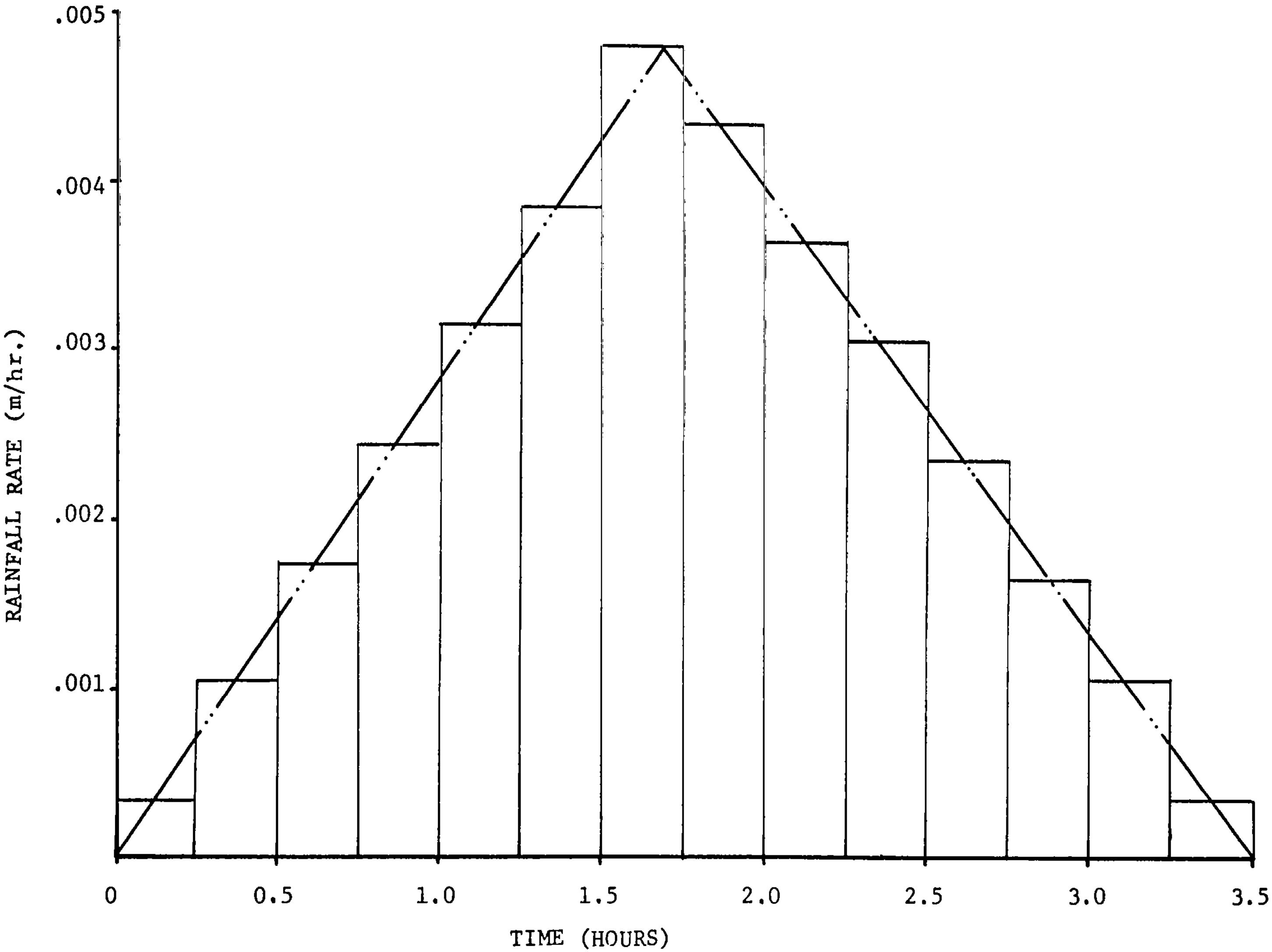
TABLE VIII

SUMMARY OF THE PARAMETERS OF THE AVERAGE MONTHLY RAINFALL FOR BALTIMORE AIRPORT GAGE 1948-1975

	DURATION hr.	VOLUME cm	INTENSITY cm/hr.	P_c cm/hr.	T_p hr.	AVERAGE NUMBER STORMS
January	9.12	7.9	9	1.7	3.37	8.14
February	8.96	9.8	1.1	2.4	3.89	7.63
March	7.55	9.9	1.3	2.3	3.31	8.78
April	6.40	7.8	1.3	2.6	2.97	10.24
May	4.93	8.8	1.8	3.6	2.74	10.52
June	3.52	9.5	2.7	4.8	1.71	9.65
July	3.32	0.8	3.2	6.1	1.79	9.11
August	4.18	2.3	2.9	5.8	1.98	9.48
September	5.39	10.7	2.0	3.6	2.63	7.29
October	7.62	11.1	1.5	3.2	3.20	6.60
November	8.58	10.9	1.3	3.1	3.60	6.78
December	11.12	12.3	1.1	3.8	3.85	7.46

FIGURE 14
AVERAGE RAINFALL PROFILE

JUNE 1948-1975



For each month, the model computes the runoff for the average storm for that month. The pollutant load is computed for that storm. Total monthly pollutant loads are computed by multiplying the load for the average storm by the average number of storms for the month.

While the ECOsystem ECHOS model was designed to utilize the time history of runoff, the anticipated RPC data relating pollutant load to time history of discharge was not available. The RPC indicated that the relationships it had derived for pollutant load to total runoff would provide the information desired on total annual pollutant loads. Subsequent improvements with the time history of runoff should improve upon the results. Appendix A gives a detailed listing of the ECHOS model with examples of the data input required.

6.3 Calibration of the Runoff Portion of the ECHOS Model

Calibration of the ECHOS model requires the measurement, derivation, or estimation of the hydrologic parameters which permit it to most accurately reflect the actual behavior of the basin. Most of the parameters required are relatively easy to determine. Average slope, area, flow lengths, and channel dimensions are readily available from sources such as USGS topographic maps. Other parameters, however, are not so well understood or documented. It is particularly difficult, for example, to have accurate knowledge of movement of sub-surface water or soil moisture content just prior to a rainfall event.

These parameters were estimated for the Magothy River Watershed using the rainfall and runoff records described in the previous section. The calibration was made for the Cape St. Clair sub-basin and the results extrapolated to the remainder of the watershed. A map of Cape St. Clair is shown in Figure 15.

Manning's "n" was estimated directly from this LANDSAT classification by using the relationships given in Table IX. Preliminary estimates of soil moisture parameters were made from the SCS soil survey for Anne Arundel County, Maryland and used the SCS land cover relationships. These included final (saturated) infiltration rate, soil moisture capacity and percolation rate. Antecedent soil moisture was estimated using the following relationship adapted from the US Weather Bureau:

$$ASM_{(n)} = P_{(n)} + .9ASM_{(n-1)}$$

where:

ASM_n = Antecedent moisture on day (n)

P_n = Precipitation on day (n)

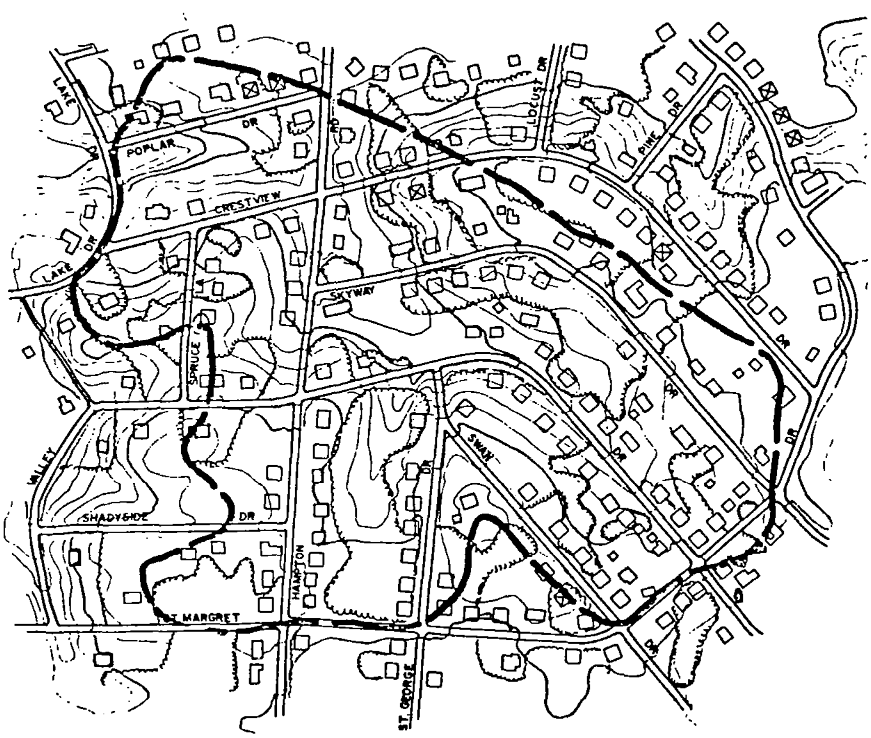
$ASM_{(n-1)}$ = Antecedent moisture on day (n-1)

The initial value of the antecedent soil moisture (ASM) was assumed to be zero immediately after the longest dry period occurring from ten to twenty days prior to the day of the test event. Values of ASM were then computed for each day, up to the day of the test event. The final value was used as an initial estimator for the ASM for each event.

Once the initial value of all parameters required by the model was determined, a series of calibration runs were made for the March, April, and July events. Discrepancies in the runoff rate recorded for the February event precluded its use for calibration.

FIGURE 15

CAPE ST. CLAIR - SUBBASIN



SOURCE: BALTIMORE REGIONAL PLANNING COUNCIL

TABLE IX

MANNING'S ROUGHNESS COEFFICIENT FOR OVERLAND FLOW FOR VARIOUS SURFACE TYPES

WATERSHED SURFACE	MANNING'S "N"
Smooth Asphalt	0.013
Concrete (Trowel Finish)	0.013
Rough Asphalt	0.016
Concrete (Unfinished)	0.017
Smooth Earth (Bare)	0.018
Firm Gravel	0.020
Cemented Rubble Masonry	0.025
Pasture (Short Grass)	0.030
Pasture (High Grass)	0.035
Cultivated Area (Row Crops)	0.035
Cultivated Area (Field Crops)	0.040
Scattered Brush, Heavy Weeds	0.045
Light Brush and Trees (Winter)	0.050
Light Brush and Trees (Summer)	0.060
Dense Brush (Winter)	0.070
Dense Brush (Summer)	0.100
Heavy Timber	0.100
Idle Land	0.030
Grass Land	0.032

Results of the first runs showed that the initial percolation rates chosen were too large, causing the upper soil layer to drain too quickly. This parameter was adjusted and subsequent runs made until a satisfactory fit was realized. An example of the goodness-of-fit of the technique is shown in Figure 16 for the 25 July 1977 event.

At this stage in the calibration, all but one of the parameters were fixed. Final calibrations were made by adjustment of antecedent soil moisture. It was anticipated that some refinement might be necessary to compensate for the fact that average, rather than peak rainfall data were to be used as inputs to the model. The average rain intensity derived from the statistics of the Airport gage were generally lower than the three test events at Cape St. Clair.

In order to correctly adjust the antecedent soil moisture, it was necessary to compute the fraction of runoff expected from rainfall for each month. Values for the months of the test events could be calculated directly as shown in Table X. Alternately and for the general case of limited data, the SCS curve numbers procedure using LANDSAT derived land cover was used to test the validity for ungaged basins. For the remaining months, the average value of 1.78 was used. This fraction was applied to the average rainfall volumes by month to compute expected monthly runoff. Figure 17 shows the computed monthly runoff volume as a % of the rainfall for a typical sub-basin, Dividing Creek.

The final calibration runs were made by adjusting antecedent moisture. Dividing Creek was used due to its homogeneous composition, relatively large size, and monostream configuration.

FIGURE 16

RESULTS OF THE CALIBRATION RUN FOR CAPE ST. CLAIR WATERSHED FOR THE

25 JULY 77 EVENT

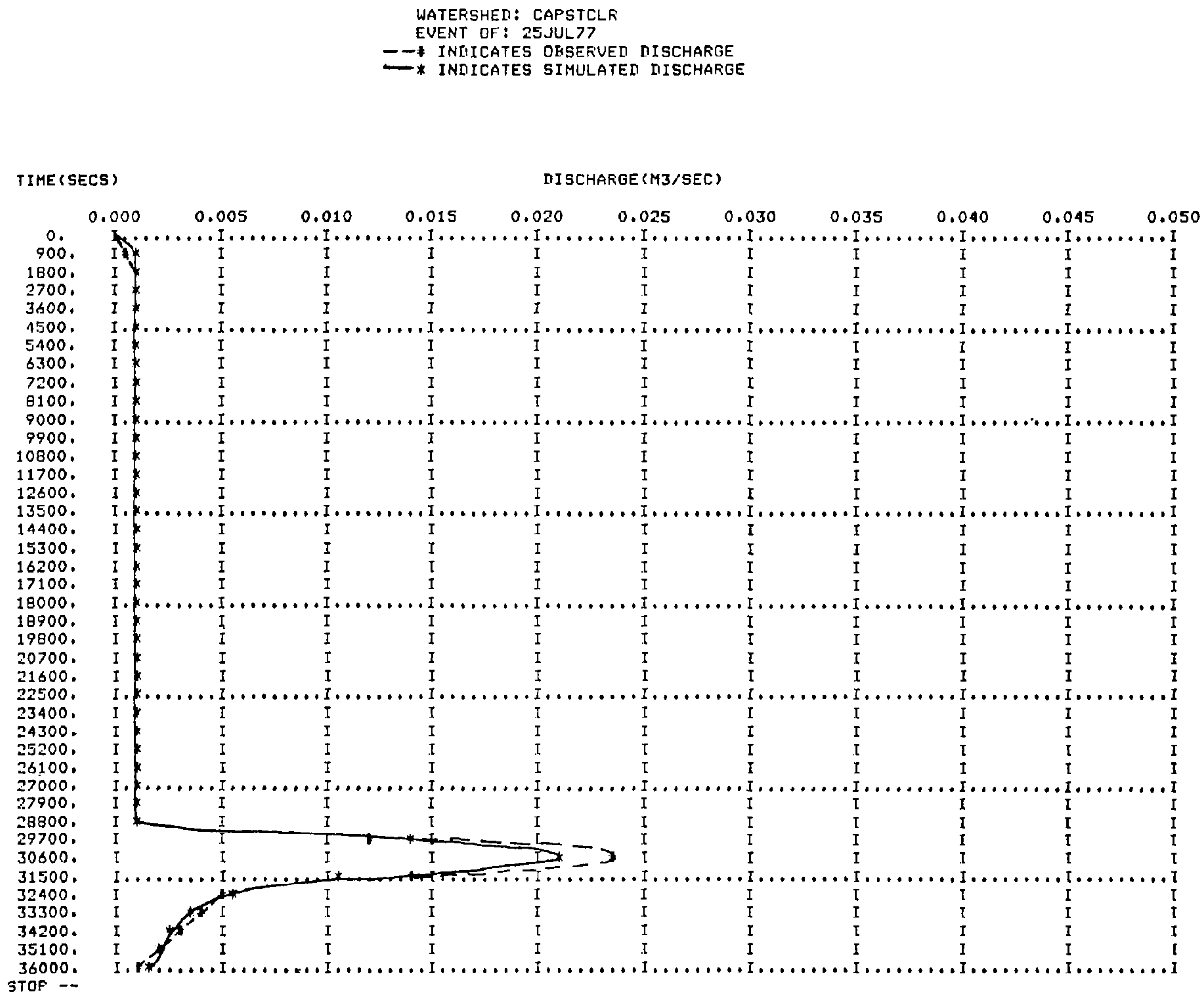


TABLE X

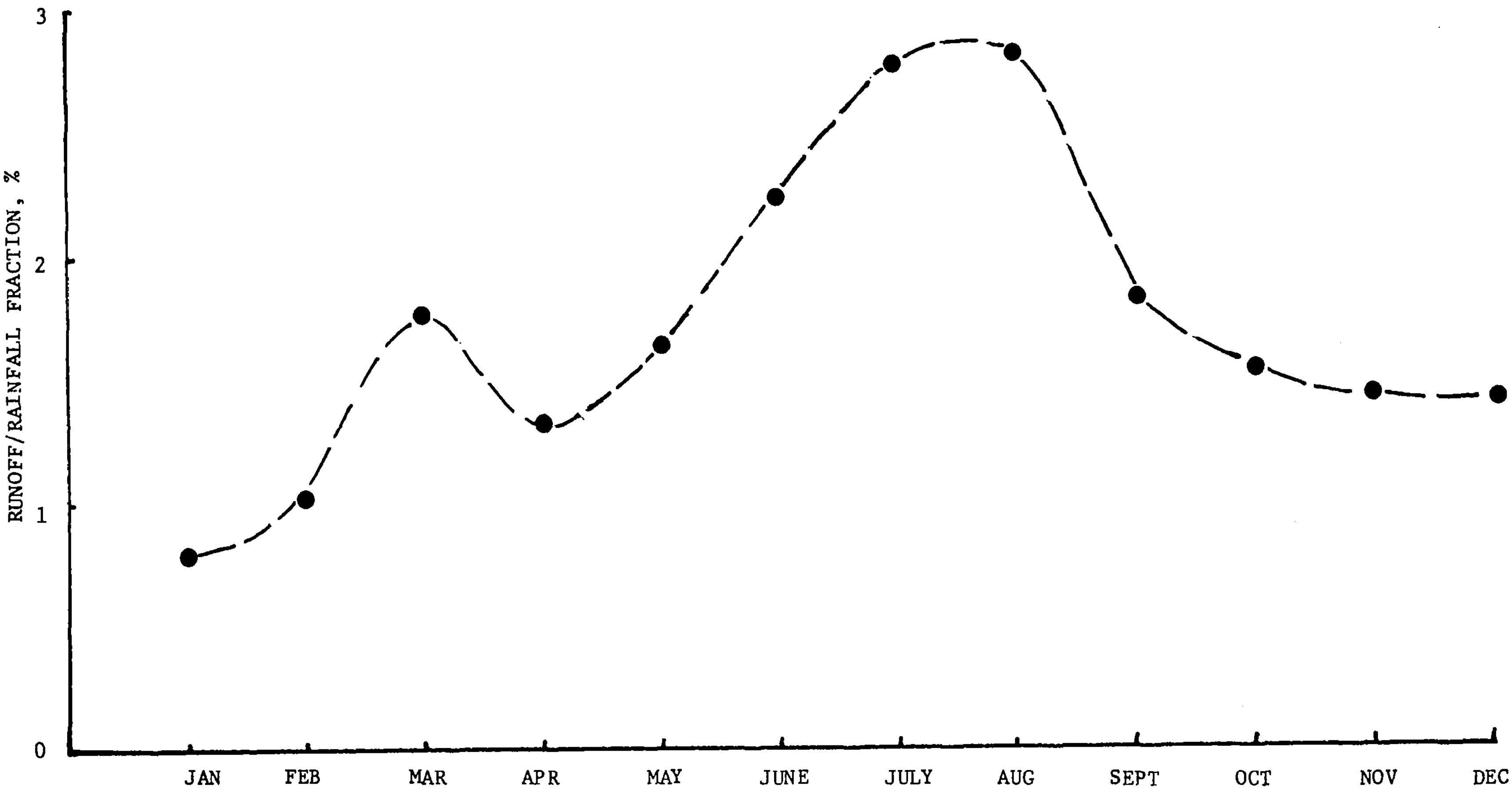
RUNOFF AS A % OF RAINFALL FOR THE CAPE ST. CLAIR SUBBASIN CALIBRATION EVENTS

	RAINFALL VOLUME (cubic meters)	DISCHARGE VOLUME (cubic meters)	RUNOFF AS A % OF RAINFALL
FEB	1982	20.0	1.0%
MAR	1353.8	32.65	2.0%
APR	5560	72.3	1.3%
JULY	3771.2	87.3	2.8%

AVERAGE PERCENT DISCHARGE = 1.78%

FIGURE 17

DIVIDING CREEK SUB-BASIN PERCENT OF RAINFALL BECOMING DIRECT RUNOFF



Three runs were made for each month at different values of antecedent moisture. The volume of runoff was recorded and plotted on a graph of discharge versus antecedent moisture. Interpolated values of ASM at zero error were then read directly from the graph. The results of repeating this process for each month are given in Figure 18. This curve is indicative of rational hydrologic behavior. Lower values of soil moisture are evidenced in months with higher evapotranspiration and solar radiation and vice-versa. The antecedent moisture figures derived for Dividing Creek were assumed to hold for all other sub-basins.

6.4 Derivation of Pollution Loading Factors for Magothy River Basin

Non-point source pollutant estimation from land cover classification involves the use of empirical loading factors which relate pollutant loads to the land use classes, generally:

$$PL_j = \sum_{j=1}^{m} \sum_{i=1}^{n} (LU_i \times LF_{ij})$$

where:

PL_j = Pollutant load, volume/time

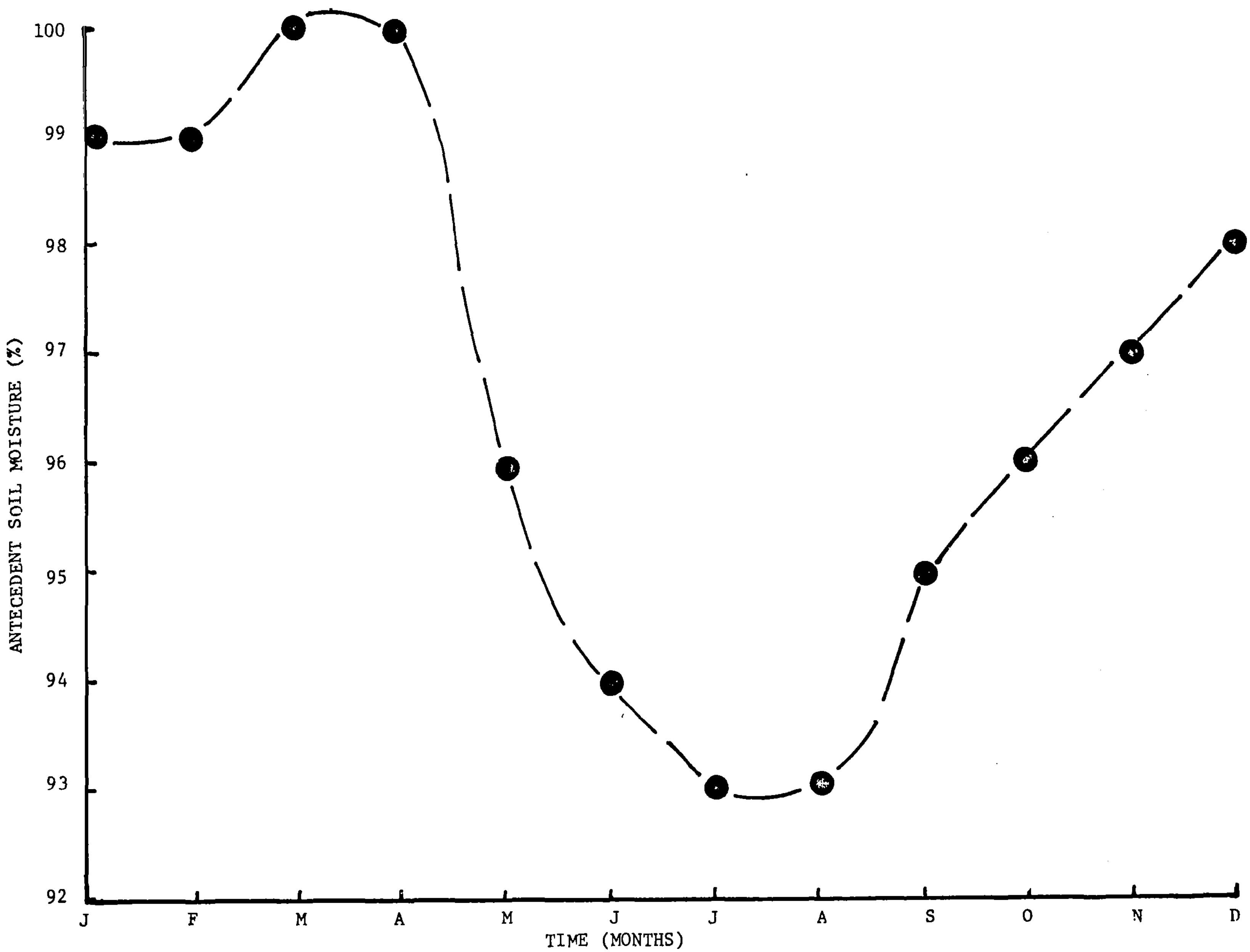
LU_i = Area of land use type i, area

LF_{ij} = Loading factor for land use type i and pollutant type j, volume/unit area/time

The available data supplied by the RPC, indicated that the estimation of pollutant load from land cover measured by LANDSAT was the preferable technique. Pollution assessment from streamflow, precipitation,

FIGURE 18

MONTHLY VALUES OF ANTECEDENT SOIL MOISTURE SELECTED FOR THE MAGOTHY SIMULATION



and sediment load are generally more applicable to very large areas and do not adequately reflect the response characteristics of small basins. The general form of the sediment-pollutant coefficients would not account for loading differences among the smaller Magothy sub-basins. The use of land class - pollutant loading factors directly uses the surficial and temporal characteristic of the watershed and is therefore directly amenable to remote sensing analysis.

The applicability of loading factors derived for one geographic area to another locale is not certain. It is far preferrable to use loading factors developed in the region under study. The availability of extensive water quality sampling at the RPC provided ECOsystems with the necessary data.

With the assistance and at the direction of the RPC, two such sets of loading coefficients were investigated. One was developed for watersheds in North Carolina and the other by the Washington Council of Governments for Maryland and Virginia basins. The data for the pollutants of interest the RPC are shown in Tables XI and XII. These data sets were judged suitable for the Magothy by the RPC because of their geographic proximity and because they showed a reasonable numerical consistency for the individual pollutants.

The loading factors were stored on computer disk files to be read into the ECHOS model. After the cumulative monthly discharge was computed for a sub-basin, the program calculates a weighted average pollutant concentration based upon the fraction of the sub-basin in each land use class. These factors are then multiplied by the discharge to yield total pollutant loading. This procedure is repeated for each

TABLE A1

POLLUTANT LOADING FACTORS - WASH/COG

LAND USE	SUSPENDED SOLIDS (mg/l)	BOD (mg/l)	COD (mg/l)	TOTAL KJELDAHL NITROGEN (mg/l)	TOTAL NITROGEN (mg/l)	TOTAL PHOSPHOROUS (mg/l)
Shopping Ctr.	74	No Data	54.66	1.81	2.43	0.20
Strip Commercial	98		111.53	1.33	1.76	0.27
High Rise Residential	34		96.28	0.87	1.20	0.22
Townhouse/ Garden Apts.	115		73.46	1.12	1.49	0.29
Med. Density Residential	42		95.88	1.94	2.42	0.38
Large Lot Residential	142		115.15	2.76	3.64	0.35
Construction	763		89.35	1.61	1.76	0.26
Forest	No Data		72.40	1.28	1.30	0.12
Conventional Till Agri.	1681		853.4	8.90	13.42	3.18
Minimum Till Agri.	133		86.24	1.93	3.52	1.14
Pasture	544		549.00	4.97	5.16	1.06

TABLE XII

POLLUTANT LOADING FACTORS - RPC - TRIANGLE 5

LAND USE	% IMPERVIOUS AREA	SUSPENDED SOLIDS CONCENTRATION (mg/l)	BOD CONCENTRATION (mg/l)	COD CONCENTRATION (mg/l)	TOTAL KJELDAHL NITROGEN CONCENTRATION (mg/l)	TOTAL PHOSPHOROUS CONCENTRATION (mg/l)
Rural	4	167	7.0	38.2	0.71	0.41
LAC	12	239	7.6	61.1	1.03	0.47
LAR	16	293	7.7	76.1	2.32	0.49
HAR	32	751	12.2	140.6	2.34	0.68
HAC	35	633	13.2	172.8	2.22	0.60
CBD	80	179	15.3	178.2	2.97	0.46

LAC = Low Activity Commercial

LAR = Low Activity Residential

HAR = High Activity Residential

HAC = High Activity Commercial

CBD = Central Business District

month. At the end of the year's simulation, an annual total is calculated.

6.5 Simulation of Magothy River with ECHOS Model

The ECHOS model approximates the natural basins of irregular shape as areally equivalent rectilinear areas having areally averaged hydrologic parameters derived from existing data. These segments are tributary to channel segments with assumed rectangular cross sections and uniform geometric and hydrologic characteristics all along its length. The numbers of blocks and stream segments required for simulation is dictated by the size and geometry of the actual basin.

Figure 19 shows the Dividing Creek sub-basin. The sub-basin is composed of one main stream separating two half basins. Both half basins generally flow into Dividing Creek rather than into the Magothy River. The sub-basin was approximated by two blocks and a single stream segment. Figure 20 shows the computer approximation for the Little Magothy River sub-basin. Because a significant fraction off this sub-basin drains directly into the main channel of the Magothy River, it was approximated by three blocks as shown in the figure.

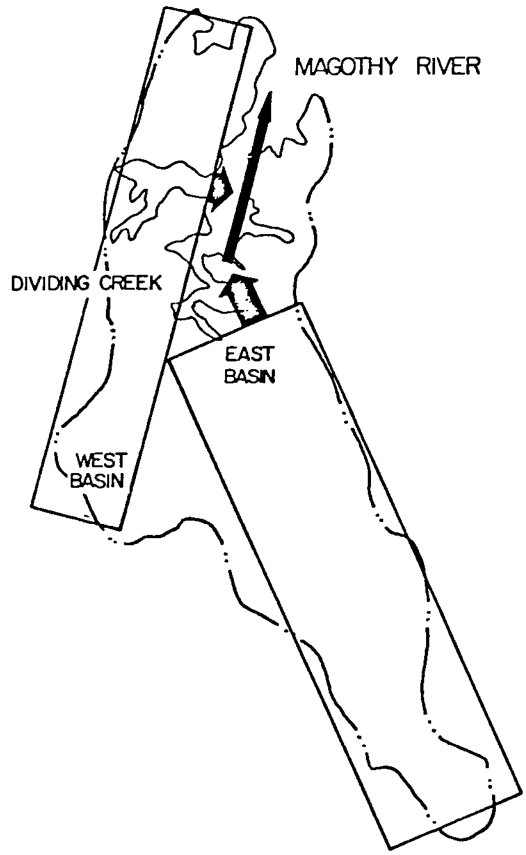
Average hydrologic, soils and physiographic properties were assigned to each sub-basin as shown in Table XIII. The computer program reads in the parameters for a single sub-basin, the basin structure, monthly rainfall profiles, and the loading factors and then performs overland flow and channel routing calculations.

A series of twelve monthly simulations were made for each of the sub-basins. The results from each run were converted to pollutant

FIGURE 19

COMPUTER REPRESENTATION OF THE DIVIDING CREEK WATERSHED

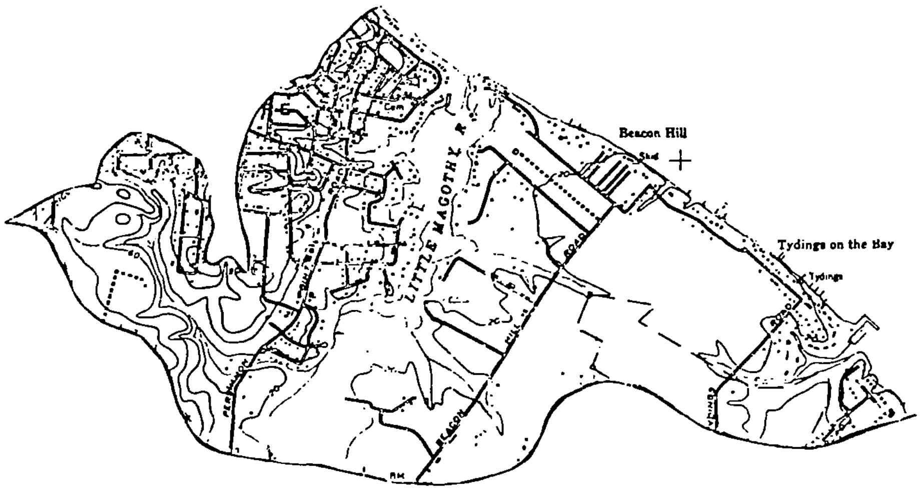
ACTUAL



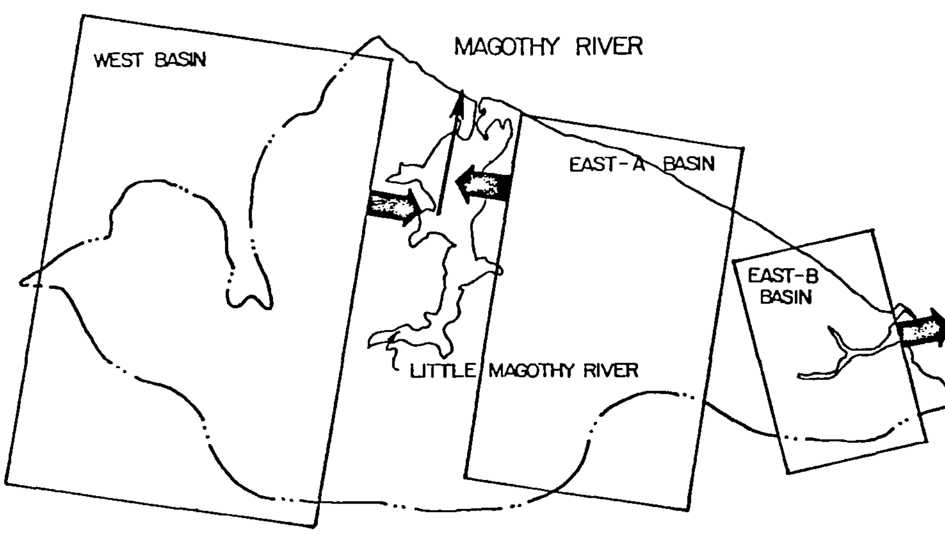
SIMULATED

FIGURE 20

COMPUTER REPRESENTATION OF THE LITTLE MAGOTHY RIVER WATERSHED



ACTUAL



SIMULATED

TABLE XIII

MAGOTHY RIVER BASIN - MODEL ECHOS MODEL DATA INPUT

SUBBASIN #		AREA (m^2)	SLOPE (%)	OVERLAND FLOW AVERAGE LENGTH (m)	CHANNEL LENGTH (m)	WIDTH (m)	MANNINGS "N"	SOIL CAPACITY (m)	INFILTRATION I_f m/hr	PERCOLATION m/hr
1	W	494423.79	.074	328.08		1507	.072	.023	.039	.001
	E	483271.37	.037	272.07	*	1776	.065	.064	.037	.001
2		6744909.78	.017	540.14	*	12487	.066	.038	.065	.001
3	W	2628252.78	.038	486.12	2743.90	5407	.076	.039	.054	.001
	E	2226765.79	.017	606.15		3674	.064	.055	.069	.001
4	W	825278.81	.015	544.14	2743.90	1517	.083	.034	.059	.001
	E	1799256.50	.039	640.16		2811	.098	.031	.049	.001
5	W	3936802.95	.021	720.18	3963.41	5466	.071	.038	.121	.001
	E	3935687.71	.008	558.14		7051	.078	.043	.113	.001
6	W	11192803.06	.025	1104.28	7621.95	10136	.070	.043	.140	.001
	E	12695419.07	.021	849.81		14939	.064	.044	.130	.001
7	W	1286245.35	.027	449.75	3048.78	2860	.078	.048	.116	.001
	E	1037174.72	.028	426.83		2430	.093	.053	.138	.001
8	W	4078066.89	.025	942.24	6097.56	4328	.077	.043	.121	.001
	E	2888475.82	.033	576.14		5014	.068	.047	.082	.001
9	W	2200743.48	.017	800.20	2743.90	2750	.052	.041	.123	.001
	E	817843.86	.034	360.09		2271	.054	.052	.082	.002
10	W	1148698.88	.029	576.15	2134.15	1994	.084	.033	.040	.001
	E	360594.79	.055	304.08		1186	.042	.038	.068	.001
11	W	2713754.63	.037	594.15	3963.41	4568	.085	.044	.050	.001
	E	1237918.21	.033	504.13		2456	.056	.050	.045	.001
12	W	1858736.05	.036	117.30	4115.85	15846	.057	.029	.047	.001
	E	2788104.08	.049	534.13		5220	.061	.046	.061	.001
13	W	2174721.18	.042	600.15	2743.90	3624	.073	.055	.122	.001
	E_A	2068439.00	.069	416.10		4971	.081	.040	.056	.001
	E_B	1360223.47	.032	640.16	*	2108	.039	.030	.046	.001
14	W	3572490.69	.034	792.20	3048.78	4510	.073	.051	.057	.001
	E	2468401.47	.051	492.12		5016	.042	.039	.077	.001
15	W	2068439.00	.026	368.09	3963.41	5619	.067	.043	.076	.001
	E_A	2117152.24	.013	688.17		3077	.047	.059	.109	.001
	E_B	1199095.07	.006	496.12	*	2417	.082	.061	.090	.001

*Sub-basin drains directly into Magothy River loads using the two transfer tables supplied by the RPC. Monthly totals were computed for each sub-basin by multiplying the simulation values by the average number of storms for that month and an aggregate yearly total was determined. The simulation of the Magothy was performed for each of the 17 sub-basins shown delineated in Figure 21.

6.6 Non-Point Source Pollutant Loads for the Magothy for 1977

Average monthly runoff was simulated for the 1977 calendar year for the Magothy Basin in Anne Arundel County, Maryland.

Pollutant concentration coefficients derived from empirical data and LANDSAT derived surface cover were used to convert monthly runoff to monthly pollutant load for the 17 sub-basins comprising the Magothy Basin.

Monthly and annual pollutant loads were estimated including total suspended solids, BOD, COD, total Kjedahl nitrogen, total nitrogen and total phosphorous using average loading coefficients supplied by the RPC.

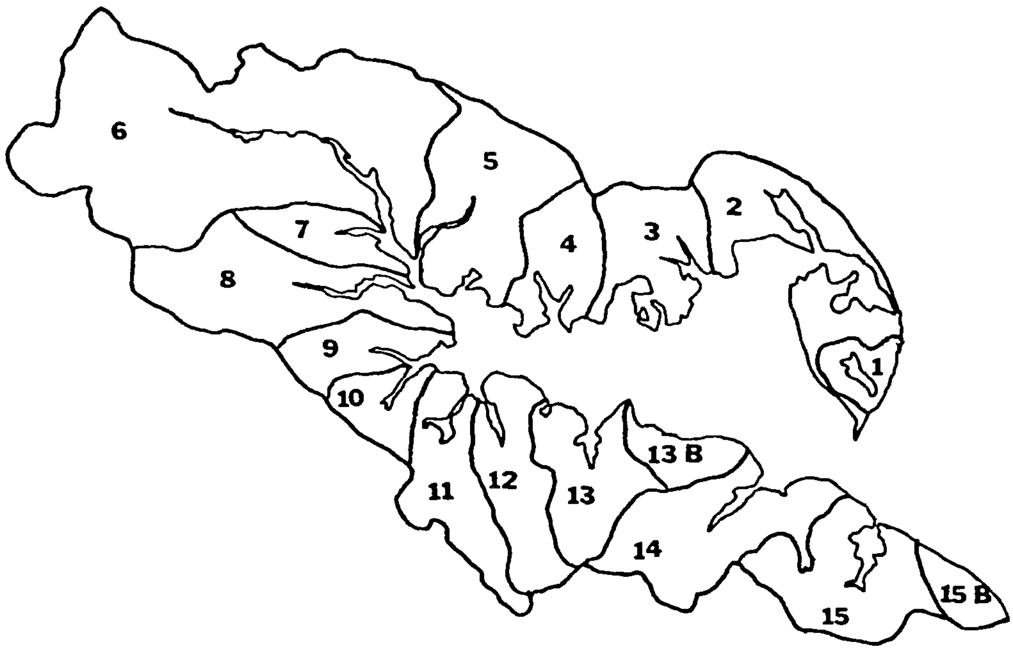
Individual storm load estimates compared very closely to the limited stream sampling data supplied by the RPC.

Table XIV summarizes the % of annual pollutant loads estimated by the ECHOS model for the Magothy Basin by sub-basin. The results of the simulation indicates that the storm load contribution for the pollutants in metric tons/year are given in Table XV.

Table XVI presents the annual average unit pollutant loads for the sub-basins and represents the pollutant loads adjusted to compensate for the area variation between the sub-basins. When the unit pollutant loads for each pollutant component is compared to the unit volume of

FIGURE 21

MAGOTHY RIVER SUB-BASINS



SUBBASIN #1	SUBBASIN NAME	AREA (hectares)	% AREA	SUBBASIN #II	SUBBASIN NAME	AREA (hectares)	% AREA
1	Otter Pond	116.2	1.4	10	Cypress Ck.	151.0	18
2	Cornfield Ck.	669.2	7.8	11	Dividing Ck.	395.0	4.6
3	Grays Ck.	485.6	5.6	12	Mill Ck.	464.8	5.4
4	Blackhole Ck.	262.6	3.1	13	Forked Ck.	435.0	5.1
5	Cockey Ck.	757.4	8.8	13B	Bayberry	122.6	1.4
6	Lake Waterford	2370.1	27.6	14	Deep Ck.	604.1	6.9
7	Old Man Ck.	232.3	2.7	15	Little Magothy River	426.3	4.9
8	Cattail Ck.	497.0	8.1	15B	Tydings	108.1	1.3
9	Cape Arthur	302.0	3.5				

TABLE XIV

RPC - TRIANGLE J DATA

AREAS	TSS	% OF TOTAL POLLUTANT LOAD					
		BOD	COD	TKN	TN	TP	AREA
Otter Pond	4.1	4.4	4.1	3.9	-	4.3	1.3
Cornfield	5.7	5.7	5.8	6.0	-	5.6	7.8
Grays Creek	5.0	4.9	5.0	5.4	-	5.0	5.7
Blackhole Creek	0.9	1.1	0.9	0.6	-	1.2	3.0
Cockeys Creek	4.5	4.6	4.4	4.3	-	4.3	8.8
Lake Waterford	23.1	23.0	22.7	21.9	-	23.0	27.6
Old Man Creek	1.3	1.4	1.2	1.1	-	1.2	2.7
Cattail Creek	1.2	1.2	1.2	1.1	-	1.2	8.1
Cape Arthur	2.2	2.0	2.3	2.4	-	1.9	3.5
Cypress Creek	3.8	4.0	3.8	3.6	-	3.7	1.8
Dividing Creek	1.7	2.0	1.6	1.3	-	1.9	4.6
Mill Creek	7.3	7.3	7.3	7.5	-	7.5	5.4
Forked Creek	8.5	9.2	8.3	7.5	-	9.3	5.1
Bayberry	6.6	5.6	6.9	8.2	-	5.6	7.0
Deep Creek	19.0	18.3	19.4	20.4	-	18.6	5.0
Little Magothy River	2.5	2.5	2.4	2.4	-	2.5	1.4
Tydings	2.7	2.9	2.7	2.6	-	3.1	1.2
MT/yr.	91	3.1	22.1	0.54	-	0.19	
Kg/ha.	782.8	26.5	190.5	4.67	-	1.61	

TABLE XIV (cont'd)

WASHINGTON - COG DATA

AREAS	% OF TOTAL POLLUTANT LOAD						
	TSS	BOD	COD	TKN	TN	TP	AREA
Otter Pond	1.3	-	2.7	3.4	3.3	2.3	1.3
Cornfield	5.3	-	5.9	5.9	5.8	5.5	7.8
Grays Creek	2.4	-	3.2	4.2	4.2	3.1	5.7
Blackhole Creek	.3	-	.6	.75	.63	.78	3.0
Cockey Creek	3.2	-	4.1	4.2	4.1	3.1	8.8
Lake Waterford	34.2	-	25.4	24.3	25.6	27.3	27.6
Old Man Creek	.36	-	.8	1.0	1.0	.8	2.7
Cattail Creek	.75	-	1.0	1.1	1.05	.8	8.1
Cape Arthur	1.37	-	1.4	1.9	1.9	1.6	3.5
Cypress Creek	1.49	-	2.5	3.0	3.05	2.3	1.8
Dividing Creek	1.05	-	1.8	1.6	1.5	1.6	4.6
Mill Creek	9.8	-	10.0	8.5	8.2	8.1	5.4
Forked Creek	6.9	-	9.2	8.5	7.9	7.0	5.1
Bayberry	8.2	-	7.0	7.2	7.5	7.0	7.0
Deep Creek	16.9	-	17.9	18.6	18.7	16.0	5.0
Little Magothy River	5.7	-	4.6	3.6	3.6	4.7	1.4
Tydings	.9	-	1.8	2.2	2.1	1.6	1.2
MT/yr	447.7	-	498.8	8.02	9.50	1.28	
Kg/ha.	52.1	-	58.0	0.93	1.11	0.15	

TABLE XV

ANNUAL POLLUTANT LOADS FOR THE MAGOTHY

(Metric Tons/year)

POLLUTANT	DATA SOURCE		
	RPC (TJ)	WASH-COG	AVERAGE
TSS	782.8	447.7	615.3
BOD	26.5	-	26.5*
COD	190.5	498.8	344.7
TKN	4.67	8.02	6.3
TN	-	9.5	9.5*
TP	1.61	1.28	1.4

*Not averaged.

TABLE XVI

AVERAGE ANNUAL POLLUTION LOADING (Kg/Ha) MAGOTHY RIVER BASIN

SUB-BASIN	TSS	BOD	COD	TKN	TN	TP	VOLUME DISCHARGE (m^3)	UNIT VOLUME (m^3/hec)
1. Otter Pond	164.82	9.88	91.51	1.95	2.66	0.43	19429.06	167.20
2. Cornfield	51.39	2.28	30.32	0.56	.82	0.12	23600.95	35.27
3. Grays Creek	50.97	1.68	26.34	0.60	.84	0.12	21236.03	43.73
4. Black Hole Creek	14.28	1.04	8.76	0.17	.22	0.04	4267.46	16.27
5. Cockey Creek	32.40	3.24	11.20	0.72	1.02	0.08	20444.90	26.99
6. Lake Waterford	70.54	2.58	35.83	0.63	1.02	0.15	105387.43	44.47
7. Old Man Creek	24.88	1.58	14.14	0.29	.40	0.07	6065.37	26.11
8. Cattail Creek	8.99	.92	5.20	0.10	.28	0.02	5088.14	7.30
9. Cape Arthur	38.54	1.74	18.82	0.43	.60	0.08	8563.79	28.36
10. Cypress Creek	121.31	6.96	65.89	1.37	1.90	0.30	17322.87	114.72
11. Dividing Creek	22.38	1.64	15.24	0.24	.68	0.06	8444.76	21.39
12. Mill Creek	108.81	4.16	68.52	1.11	1.68	0.24	31231.09	67.19
13. Forked Creek	76.09	5.64	71.09	1.18	1.72	0.28	41534.26	95.48
13B Bayberry	360.30	12.16	195.38	3.89	5.82	0.73	2375.25	193.78
14. Deep Creek	186.21	8.04	104.55	2.02	2.94	0.42	80810.68	133.77
15. Little Magothy River	52.21	1.56	32.33	0.47	.80	0.11	10953.92	25.70
15B Tydings	116.83	7.12	65.03	1.38	1.88	0.30	13371.38	123.70

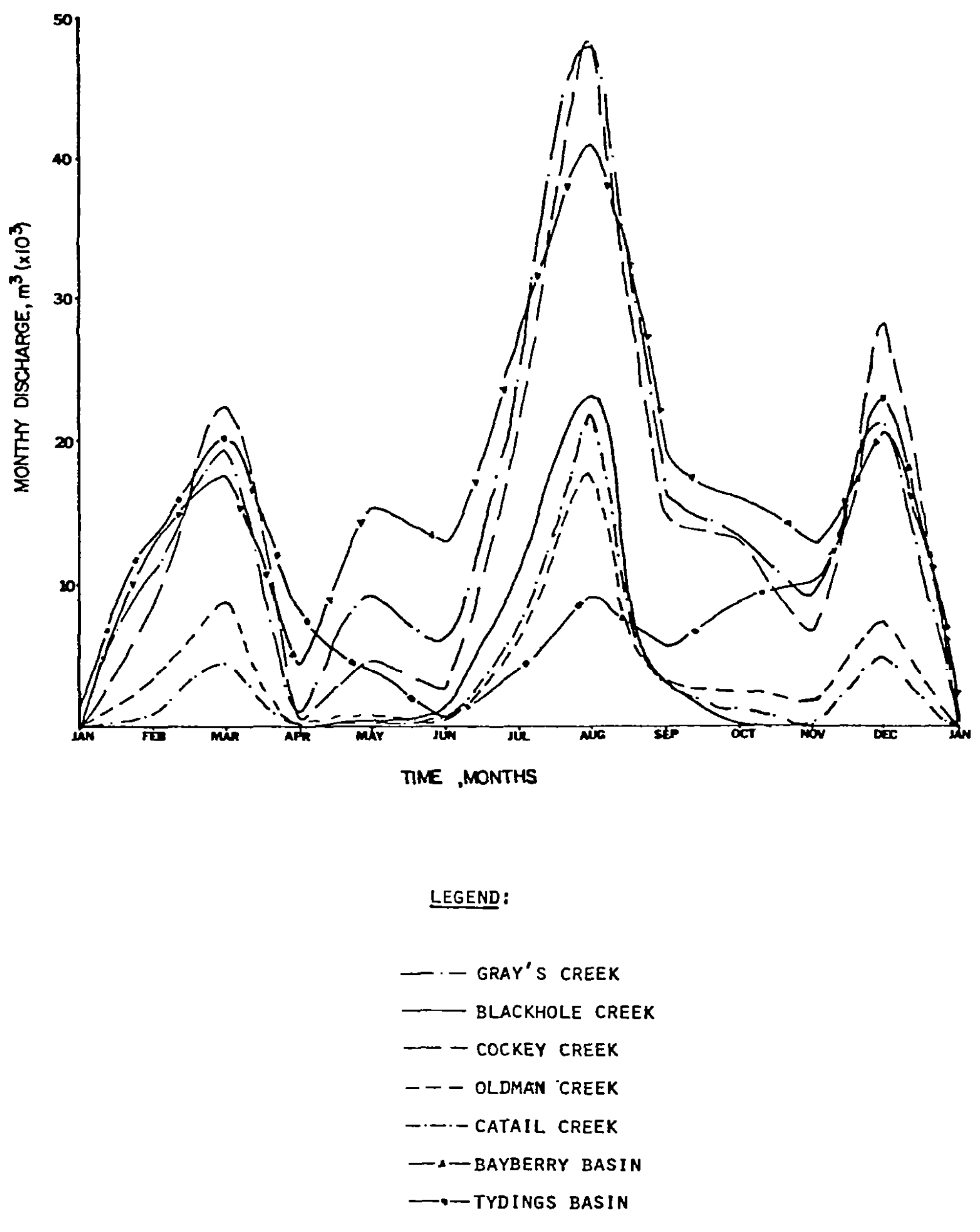
runoff, it is evident that the primary generator of high unit pollutant load response is the hydrologic response of the basin, i.e., the quantity of runoff per unit area. In each case, except Mill Creek, there is a direct correspondence between high unit pollutant load and high unit runoff.

The relatively high pollutant loads from Mill Creek can possibly be explained by the high fraction of pasture and commercial land use in Mill Creek which contribute high total suspended solids. Contrast the pollutant loads from Mill Creek with a unit volume of runoff of 67.2 m^3/ha. with that of the Tydings sub-basin which has equivalent pollutant loads but has almost double the (123.7 m^3/ha) unit volume of runoff.

Figure 22 displays the simulated monthly runoff for selected sub-basins of the Magothy. The relative magnitude of the curves are a direct result of the area variation since the rain was considered to be uniform over the total area. These curves all have a similar shape which is dictated by the assumption of uniform rainfall rate throughout the Magothy Basin. Minor differences, particularly for low values of runoff are a result of the variation of soils and infiltration between the sub-basins. For example, Blackhole Creek, which has approximately 3% of the total area, has significantly less runoff for the period January through June. Blackhole Creek is comprised of soils with higher percolation rates. Cockey Creek, which is approximately 9% of the total area, exhibits relatively high runoff for the whole year.

FIGURE 22

COMPUTED MONTHLY RUNOFF
FOR MAGOTHY RIVER SUB-BASINS WITH FLOW-DOMINATED POLLUTANT LOADING



Since the pollutant load conversions are sensitive to the volume of runoff, the monthly runoff curves are a good indicator of the timing of the major pollutant contributions.

Figure 23 shows the relative monthly contribution of pollutants for the Dividing Creek sub-basin and is characteristic of all of the sub-basins. The large contribution for the period centered upon August is a direct consequence of the rain profiles characteristic of the post summer period. Table XVII presents the summary of the average monthly rainfall event profiles. The table shows that the March-May period is characterized by low intensity rains of relatively long duration and which have relative low unit volumes. This combination tends to produce low runoff and hence low pollutant loading contributions. The July-September period, in contrast, is characterized by relatively short, high intensity rain events which produce higher runoff and thereby contribute high pollutant loads. The shift of the peak period toward the winter months is probably due to the seasonal effect of evapotranspiration which peaks in July and rapidly decays toward December as shown in Figure 24.

Figures 25a through f show the annual unit pollutant load (kg/hectare) for the Magothy Basins for the pollutants considered. These figures are compared with similar ones for land use and runoff in Figures 26 to 29. It is noted that the values for pollutant loads are rationally explained for the most part by the values of unit runoff. High values of unit runoff yield high across-the-board pollutant loadings, and the reverse is true for low unit runoff values. In certain cases, however, pollutant loading is "driven" by land use rather

FIGURE 23

TIME PHASING OF POLLUTANT LOAD

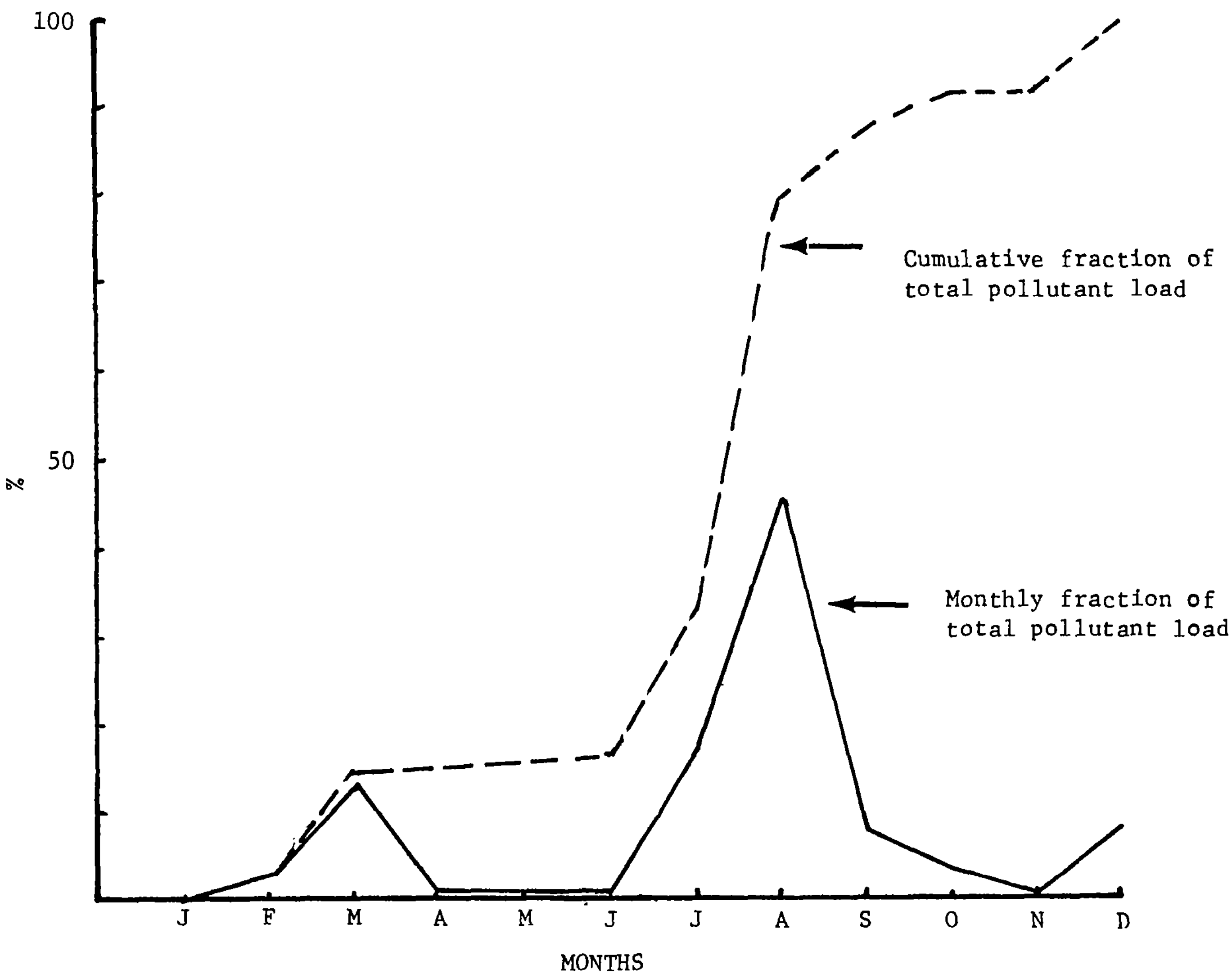


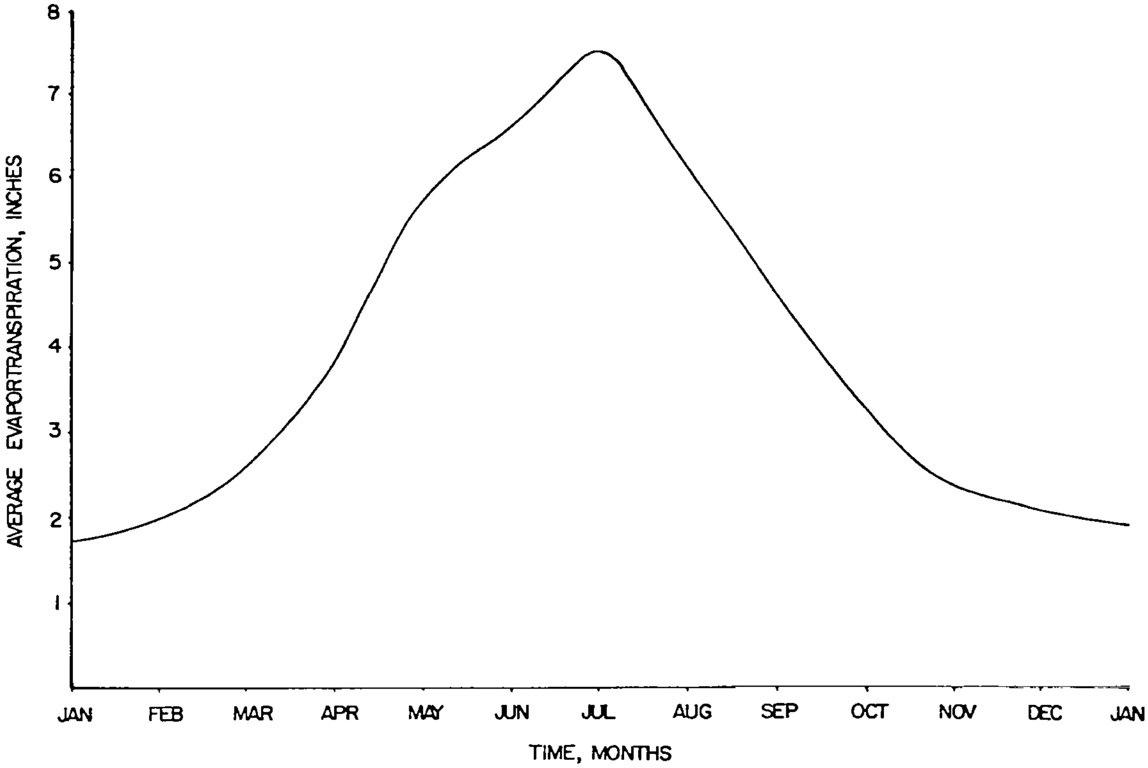
TABLE XVII

CHARACTERISTICS OF THE AVERAGE RAINFALL EVENT

	DURATION	UNIT VOLUME	INTENSITY mm/hr.
January	9.12	7.9	.9
February	8.96	9.8	1.1
March	7.55	9.9	1.3
April	6.40	7.8	1.3
May	4.93	8.8	1.8
June	3.52	9.5	2.7
July	3.32	10.8	3.2
August	4.18	12.3	2.9
September	5.39	10.7	2.0
October	7.62	11.1	1.5
November	8.38	10.9	1.3
December	10.91	12.3	1.1

FIGURE 24

20-YEAR AVERAGE MONTHLY EVAPORTRANSPIRATION AT BELTSVILLE, MD



SOURCE: NATIONAL CLIMATIC CENTER, ASHVILLE, TENN.

UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

FIGURE 25a

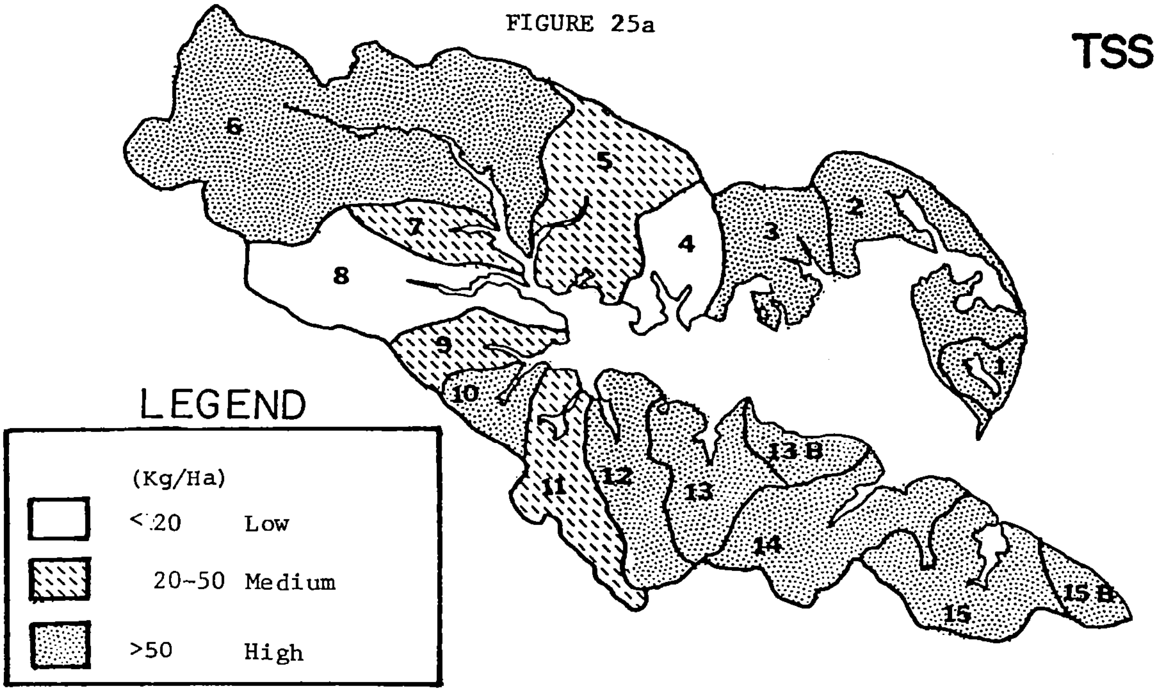
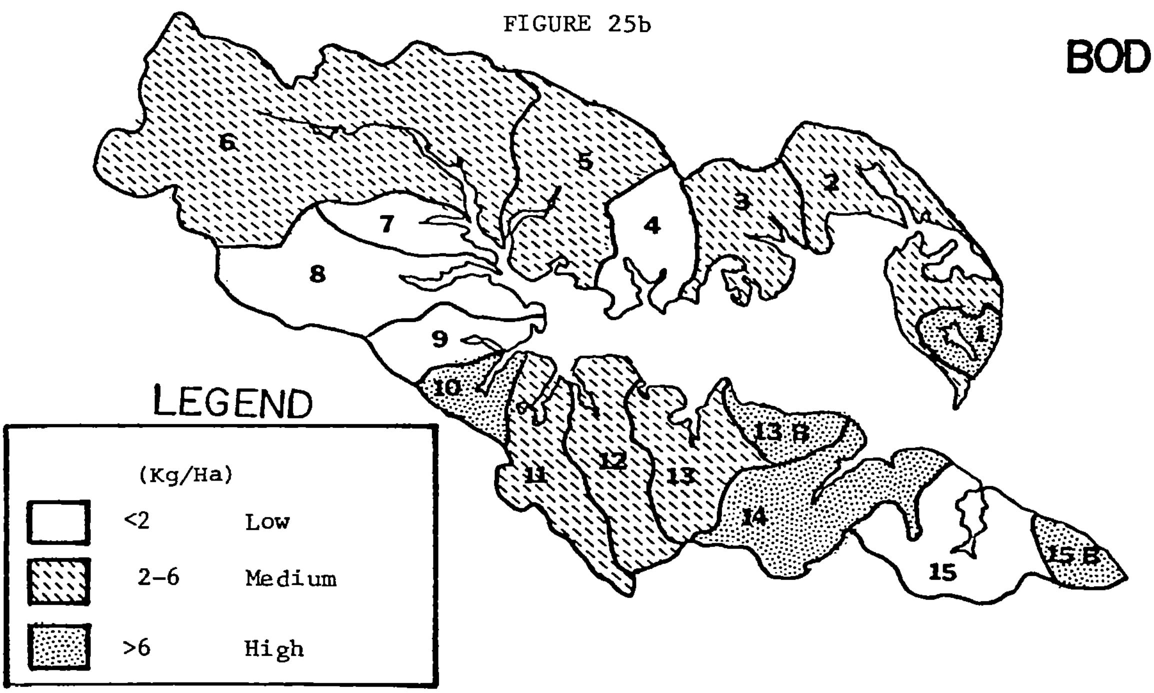


FIGURE 25b



UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

FIGURE 25c

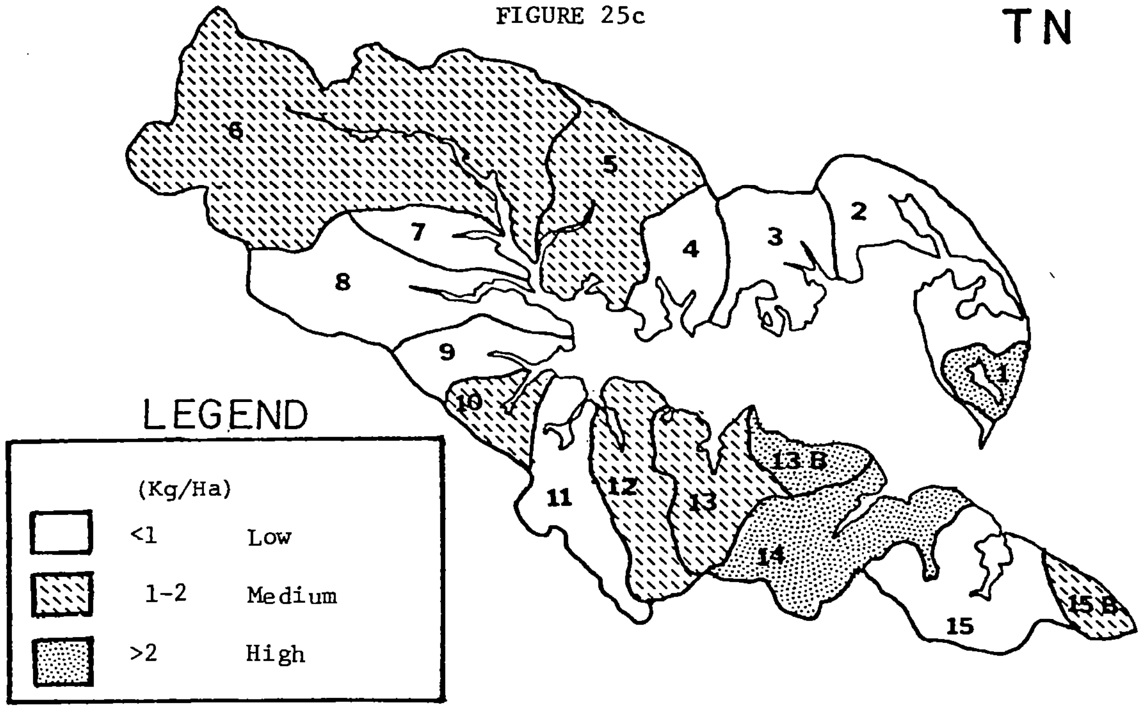
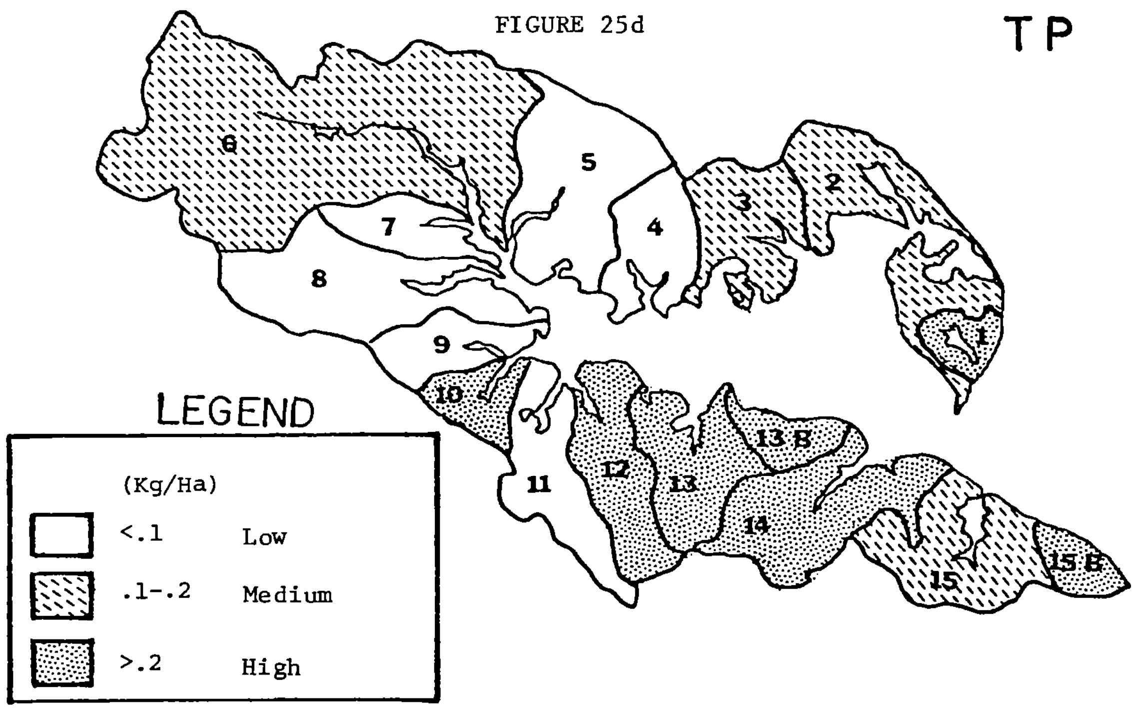


FIGURE 25d



UNIT POLLUTANT LOADING - MAGOTHY RIVER SUBBASINS

FIGURE 25e

COD

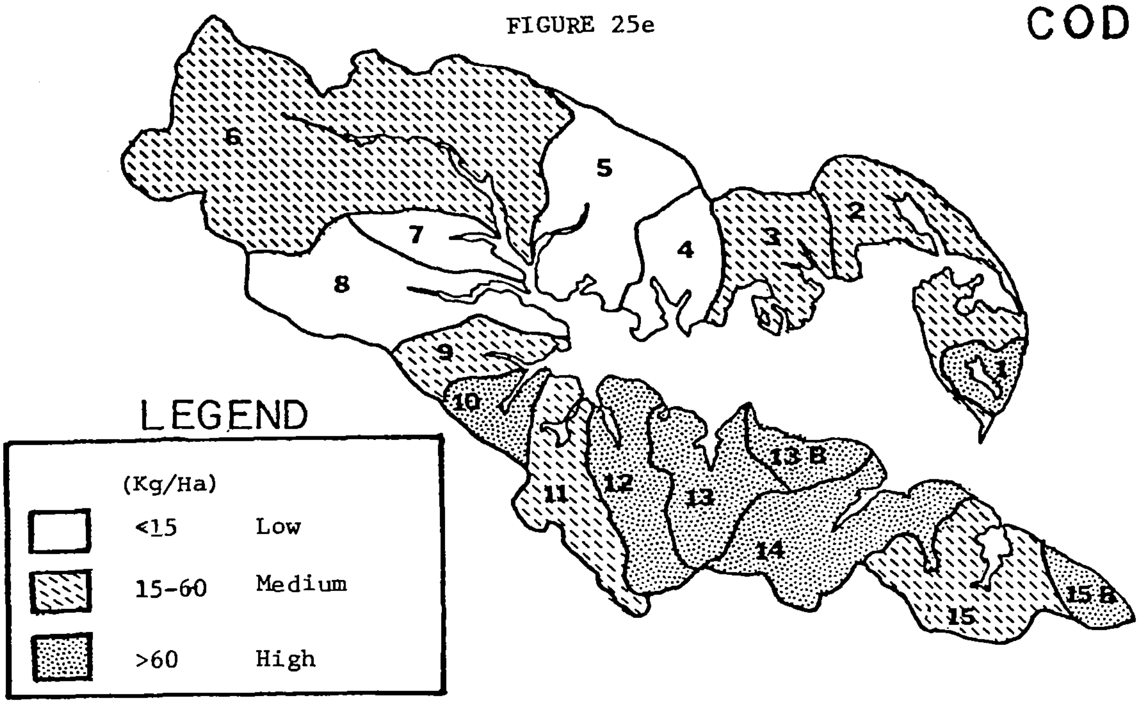


FIGURE 25f

TKN

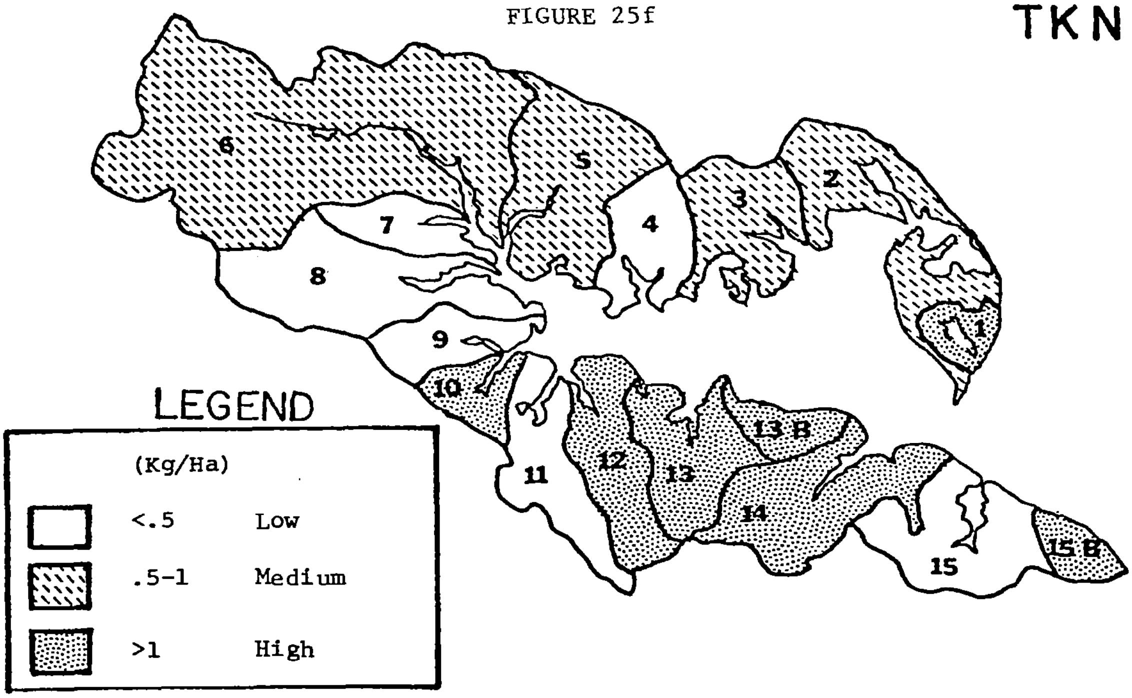


FIGURE 26

PERCENT FOREST AREA - MAGOTHY RIVER SUBBASINS

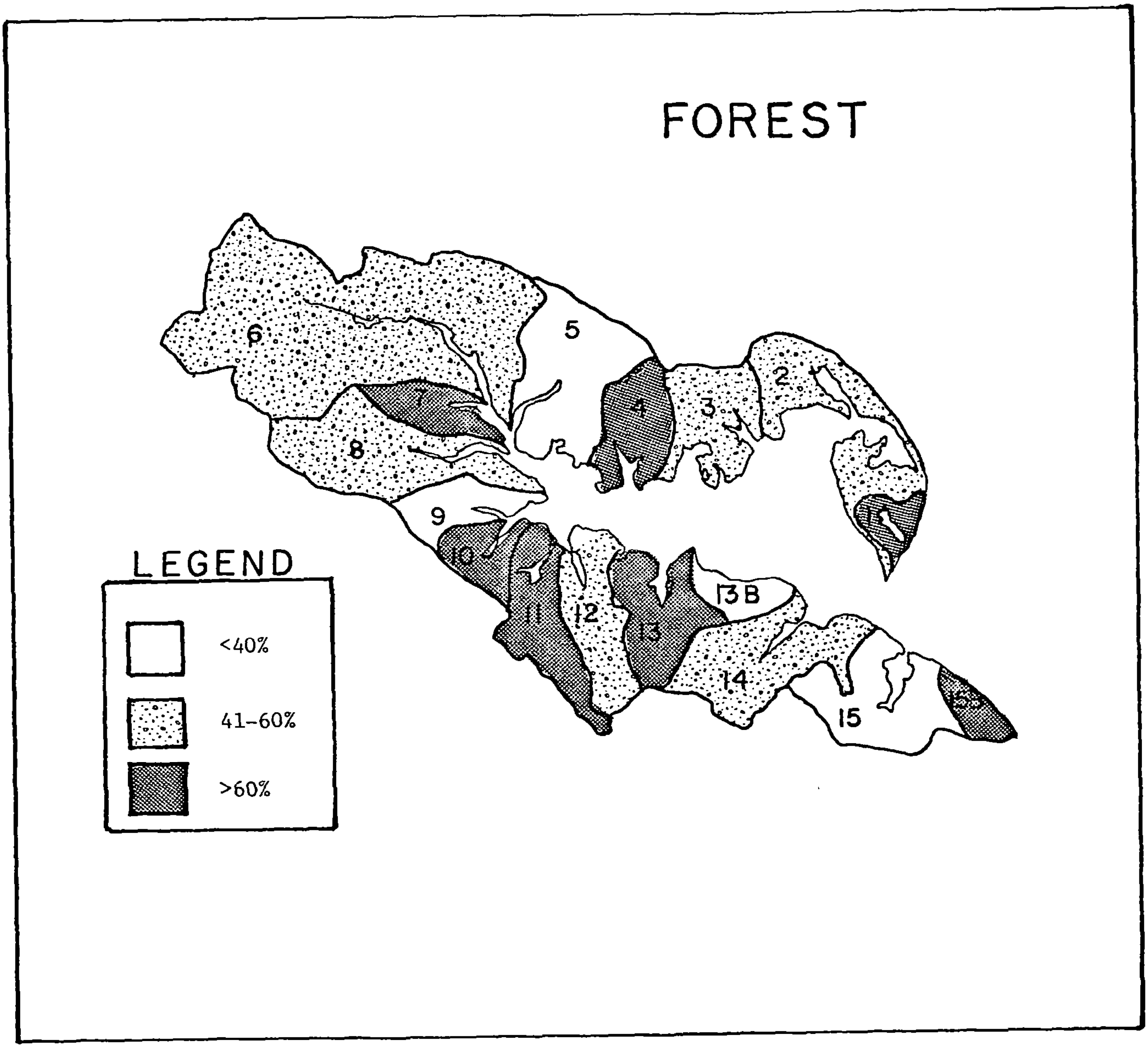


FIGURE 27

PERCENT URBAN/RESIDENTIAL AREA - MAGOTHY RIVER SUB-BASIN

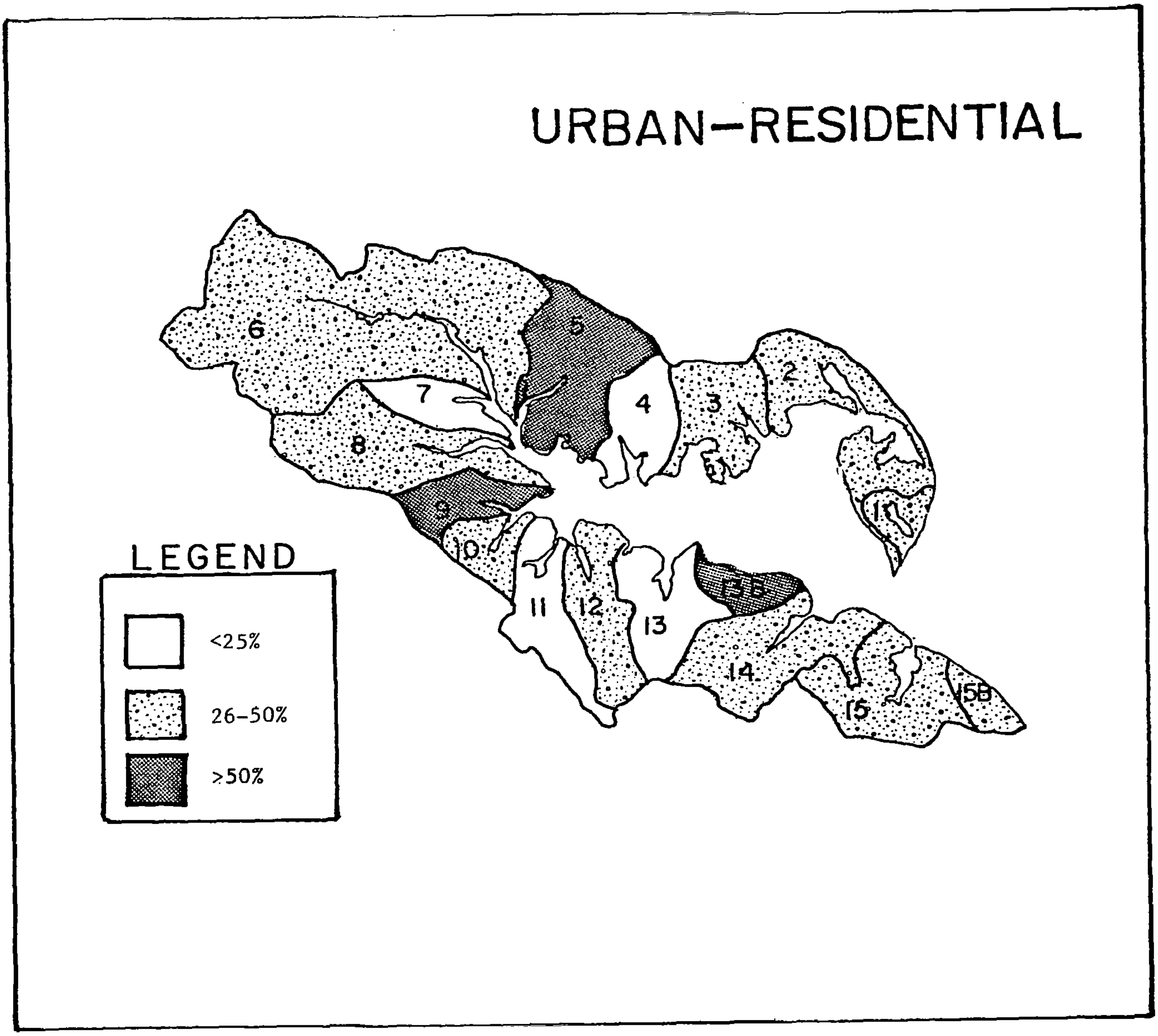


FIGURE 28

PERCENT AGRICULTURE - PASTURE AREA - MAGOTHY RIVER SUBBASINS

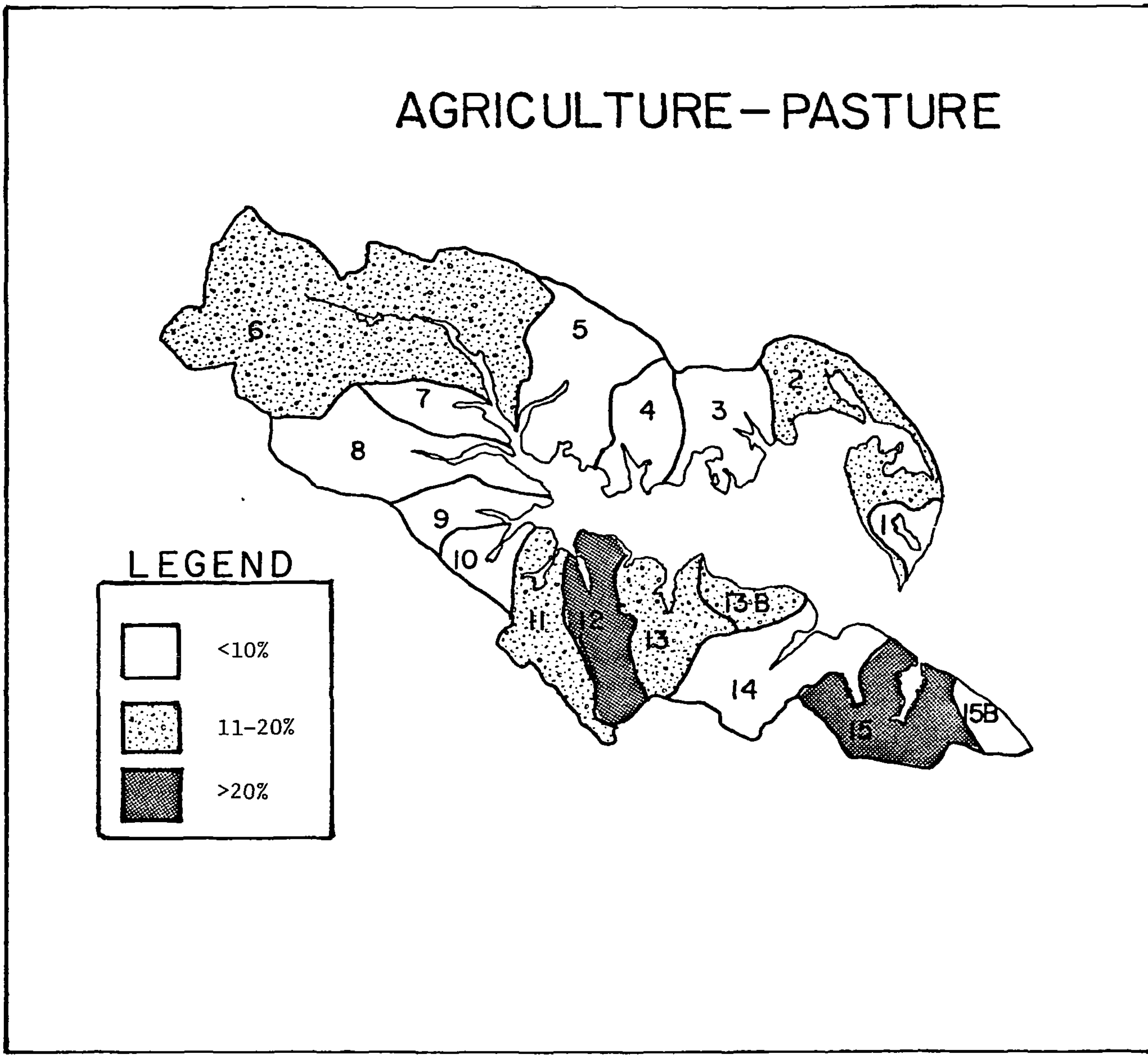
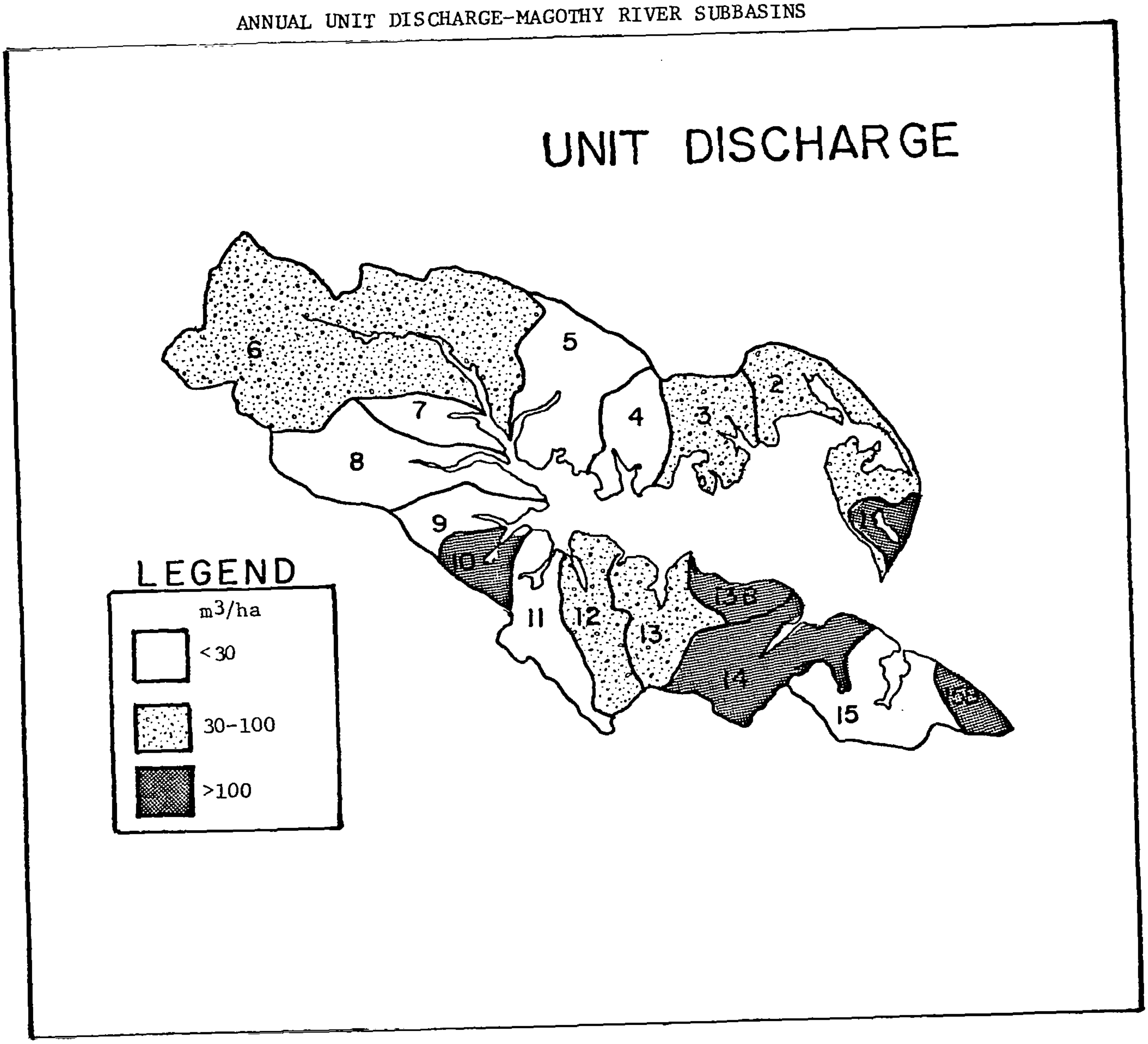


FIGURE 29

ANNUAL UNIT DISCHARGE-MAGOTHY RIVER SUBBASINS



than flow. As shown in Table XVIII, seven of the Magothy River sub-basins produced pollutant loads which could not fully be explained by unit discharge. Mill Creek, for example, did not behave like the flow dominant Blackhole sub-basin. The unexpectedly high values of suspended solids, COD, TKN, and phosphorous result from the high proportion of pasture present rather than unit discharge. This exemplifies the importance of adequate land use data to non-point source pollutant modelling.

TABLE XVIII

MAGOTHY RIVER SUB-BASINS - DRIVERS OF POLLUTANT LOADING

SUBBASIN	TSS	BOD	COD	TKN	TN	TP	UNIT DISCHARGE	POLLUTANT LOAD DRIVER
1. Otter Pond	H	H	H	H	H	H	H	Runoff
2. Cornfield	H-M	M	M	M	L-M	M	M	Runoff
3. Gray's Creek	H-M	M	M	M	L-M	M	M	Runoff
4. Black Hole Creek	L	L	L	L	L	L	L	Runoff
5. Cockey Creek	M	M	L	M	M	L	L	Medium Values due to 7% Pasture
6. Lake Waterford	H	M	M	M	M	M	M	High TSS due to 6% agriculture
7. Old Man Creek	L-M	L	L	L	L	L	L	Runoff
8. Cattail Creek	L	L	L	L	L	L	L	Runoff
9. Cape Arthur	M	L	M	L	L	L	L	Medium values due to 12% strip commercial
10. Cypress Creek	H	H	H	H	H-M	H	H	Runoff
11. Dividing Creek	L-M	L-M	L-M	L	L	L	L	Low-Medium values due to 1% strip commercial
12. Mill Creek	H	M	H	H	M	H	M	High values due to 20% pasture
13. Forked Creek	H	M	H	H	M	H	M	High values due to 11% pasture, 3% strip commercial
13B. Bayberry	H	H	H	H	H	H	H	Runoff
14. Deep Creek	H	H	H	H	H	H	H	Runoff
15. L. Magothy River	H	L	M	L	L	M	L	Medium, High values due to 6% agriculture; 25% pasture
15B. Tydings	H	H	H	H	M-H	H	H	Runoff

VII. THE USE OF THE LANDSAT DERIVED POLLUTANT LOAD AT RPC

The resolution of region-wide land cover measurement and concommitant non-point source pollutant load assessment has had a beneficial impact upon "208" planning work. Prior to demonstration of optical classification techniques using LANDSAT data, a major concern over project implementation had existed. The RPC now feels it has at its disposal techniques which greatly reduce the analytic effort while maintaining satisfactory precision.

Using a hybrid procedure of LANDSAT and aerial remote sensing, land use analysis can be accomplished to the required level of detail (Level 1) in very short time for small areas. Basins of size comparable to the Magothy could be analyzed by one person in approximately three days after the imagery has been received and prepared. An opportunity for resource savings exists. Using computer classification of LANDSAT CCT, accurate land use data for the total region and larger areas within the region have been generated.

Response to these procedures by the RPC personnel has been favorable. The work performed on the Magothy has been included in the RPC's draft "208" plan as indicated in the following section.

7.1 Excerpt from the RPC "208" Plan

Magothy River Pollutant Load Analysis (Note figures not included)

The analysis of water quality samples during wet weather conditions is important for an accurate understanding of non-point sources of pollution. The cost of wet weather quality sampling, however, is extremely high.

An alternative to the actual collection of wet weather water quality data is the development and calibration of a computer model which simulates natural stream conditions. This approach is being demonstrated through a special analysis of the Magothy River Watershed.

The computer model developed for the Magothy River Watershed uses land cover data from LANDSAT satellite imagery and aerial photography, pollutant load data, and rainfall and runoff records. The model calculates wet weather pollutant loadings, using these data.

The steps followed in developing and applying the computer model for the Magothy River are listed below:

1. Land Use Analysis from LANDSAT and Aerial Imagery:

   The remote sensing analysis of the Magothy River watershed was completed during the January reporting period.

   The procedure first required the preparation of satellite and aerial imagery into color slide form, as described in the December report. Subsequently, a preliminary examination of the aerial scene containing the Magothy River was made. It was determined that seven general land use classes were present: residential, commercial/industrial, extractive, agriculture, water, forests, and pasture/grass areas.

   The entire Magothy River Watershed was mapped and classified from the aerial photo. Because of the age of the aerials (September, 1970), imagery from 1975 was acquired from the Baltimore RPC, and the ground truth map updated. Changes had to be made in about ten areas reflecting new residential or commercial development.

   Test sites were then selected for each class. This area constituted about two to three percent of the total watershed. A map was prepared locating the sites and the watershed boundary.

This map was used as the basis for LANDSAT classifications of land use. Each satellite scene was projected over the map of test sites and the colors of each class were recorded. The images of May, August, and October, 1975, February, 1974, and April and October, 1973 were used. This information was then used to determine which scenes were preferable for identifying different land use classes. For example, forest appeared dark in the February, 1974, scene while potential confusers were lighter. This image was therefore used to segregate forest. Similar logic was applied to separation of the other land use classes.

High color contrast in the October 6, 1973 scene allowed the relatively easy separation of the extractive and commercial/ industrial classes. The negative image of October 6 showed water as bright white; it was therefore readily separated. Three classes - residential, pasture/grass, and agricultural - then remained to be segregated. No single image shows agricultural areas in marked contrast with the other classes. Therefore, the temporal characteristics of cropped fields had to be relied upon. By examination of all the available scenes, it was determined that agricultural areas followed a unique progression of colors: dark pink in April, light blue to white in October, and orange/light blue in February. All areas exhibiting this behavior were then classified as agricultural. No scene indicates residential areas strongly separable from pasture/grass. This is due to the low density (2-4 units per acre) of most residential development present. Some of the more densely developed residential areas could be consistently identified, but most behaved like pasture/grass areas all through the year. The total residential fraction could not be segregated to the accuracies required by the Regional Planning Council. It was decided, therefore, to extract the residential class from the aerial photography. While the use of computer compatible tapes or additional images might permit the total classification from LANDSAT, the use of a hybrid satellite - aerial remote sensing system to derive pollution loads represents a tool useful to the Regional Planning Council.

On the basis of this technique, the land use map shown in Figure 3-B-23 was prepared. Overall classification error was 2.3%.

2. Pollution Loading Factors

Two sets of pollution loading figures received from the RPC and the Washington COG were used in the modeling. These sets of numbers were reasonably consistent; they were used as multipliers to convert flow to kilograms of pollutants.

3. Rainfall/Runoff Records

Runoff records were received from the RPC for three separate sites: Cape St. Clair, Bay Hills, and Severna Park. Sufficient data points to plot outflow hydrographs, which matched available rainfall data, existed only for four events at Cape St. Clair.

These events were for February 24, March 18, April 2, and July 25, 1977.

In addition to on-site rainfall data, records were obtained for the Baltimore gage, giving hourly rainfall values for 1948-1974. From these data, average monthly rainfall profits were developed.

4. Model Calibration

The ECOsystems Hydrologic Simulator (ECHOS) was calibrated using the data from Cape St. Clair. The physical parameters of area, slope, flow length, and stream characteristics were taken from USGS 1:24000 topographic maps. Land cover (surface friction) came directly from the map prepared from the satellite and aerial analysis.

The four rainfall events were run and matched to actual hydrographs. Runs were made until a satisfactory fit was achieved. An example is shown in Table 3-B-15. These runs were used primarily to set the values of subsurface soil moisture depletion.

The four events, combined with the Baltimore rainfall data, were also used to set appropriate antecedent soil moisture. From the discharge record, the percentage of rainfall which became runoff was computed. The fractions derived are shown below:

February	1.0%
March	2.0%
April	1.3%
July	2.8%

From these four points, curves were extrapolated based upon comparison of rainfall columns and peak rates as derived from the 25 year Baltimore records.

It was now known, for example, that in August about 2.8 percent of rainfall would become direct runoff on the average. A second set of calibrations was then performed to set antecedent soil moisture (API) to a value that would produce the correct percentage of runoff. This was done by trial and error, setting an estimated value of API and recording the resultant runoff. The optimal set of antecedent soil moisture percent are given below:

Month	Optimal % API
January	99%
February	99
March	100
April	100
May	96
June	94
July	93
August	93

September	95
October	96
November	97
December	98

The values derived are very well balanced when considered from a hydrologic point of view. High values of soil moisture were obtained for months with lower solar radiation and ET and vice-versa.

These values were input to the ECHOS data files. The simulation of pollutant loads could now be run.

5. Model Runs

The Magothy Basin was broken down into major sub-basins. The initial run was made for sub-basin 11, Dividing Creek. ECHOS reads the rainfall profile month by month, calculates overland flow, routes the runoff through the stream channel and computes the hydrograph at the outlet. Streamflow is cumulated and converted to pollutant loads using the COG and RPC factors described earlier. Monthly loads and an average annual summary are produced.

Total loads are given by multiplying the load from the average storm by the average number of storms per month as calculated from the Baltimore data. An example of the output from the computer analysis runoff summary and pollutant loadings for the Dividing Basin during July is shown on Table 3-B-16.

7.2 The RPC's Direct Response

The favorable reaction to the Magothy River analysis stems directly from the fact that the technique was demonstrated for an area where the results would be immediately useful.

The written comments given in Appendix B were received from the RPC on the use of LANDSAT data to derive non-point source pollutant loads.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The application of LANDSAT derived data to non-point source pollutant load estimation of the Magothy Basin was successfully accomplished for the Baltimore Regional Planning Council. The pollutant loads and the LANDSAT-oriented techniques which were used to derive them have been incorporated into the current RPC "208" plan and have been selected for future broader applications at RPC. The cost-effectiveness and the applicability of the techniques for present and future use in regional NPS investigations have been judged to be excellent by the RPC personnel.

A. Significant Findings as Regards LANDSAT Derived Land Cover:

1. The relatively high cost of aerial photography and the limited frequency of total regional coverage gave rise to the need for LANDSAT-oriented land cover classification techniques. The need for accurate sub-basin land use data requires an improvement over conventional land use estimates with large cell size. LANDSAT computer classifications are adequate for large area estimates, but exhibit relatively high errors for small areas. The development of a hybrid, LANDSAT-optical technique with minimum aerial coverage input for residential areas proved a successful, cost-effective solution to the problems in the Baltimore RPC area.

2. Average errors of less than 5% were obtained for the four small areas investigated in these studies. The area evaluated ranged from 108 hectares to 8,600 hectares.

3. Accuracies obtained by this hybrid analysis technique were commensurate with the error budget adopted for non-point source pollutant load estimation by the RPC.

B. Significant Findings as Regards Pollutant Loads for the Magothy Protypical Area Include:

1. Annual pollutant loads from storms resulting from the average rainfall were computed to be: 615.3 metric tons per year of total suspended solids, 26.5 metric tons per year of BOD, 344.7 metric tons per year of

COD, 6.3 metric tons per year of TKN, 9.5 metric tons per year of total nitrogen and 1.4 metric tons per year of total phosphorous.

2. The major period of storm load contribution was the period of July through September. The characteristic occurrence of high intensity storms in this period accounted for 70% of the total storm load.

3. High unit pollutant loads were computed for the following sub-basins of the Magothy: Otter Pond, Cypress Creek, Mill Creek, Bayberry, Deep Creek and Tydings. These sub-basins total 31% of the total area of the Magothy.

C. Significant Findings as Regards the Application of Hydrologic Models Based Upon Satellite Data for Non-Point Source Load Estimation

1. A simple, useful, and cost-effective modeling procedure has been developed to estimate annual and event-oriented pollutant loads from storms, using specific or generalized pollutant load coefficients.

2. The procedure is based upon land cover data derived from satellite images.

3. The accuracy levels of the procedure is commensurate with the accuracy level of the input pollutant data.

4. The procedure provides environmental and land use planners with practical, easily adopted techniques from which to estimate the sensitivity of specific watersheds to current and future land use distributions and patterns.

5. The model developed has been made extremely flexible to accommodate the maximum user-derived inputs.

6. Techniques for estimating the input parameters for areas with limited data have also been developed and demonstrated.

The experience gained during this technology transfer project supports the expectation which surround the availability of frequent accurate land cover data from satellites such as LANDSAT. The user population is large and widespread. Certain problems like those engendered by the EPA "208" program are immediately amenable to solutions using LANDSAT data.

Technology transfer requires that not only the user be made familiar with the LANDSAT products but that he also be aided in developing the models, techniques and algorithms necessary for its successful employment. Most users are not engaged in pure research pursuits and hence require "proof" before committing these resources to the use of a new and not as yet proven sources of data. Once these problems are overcome, however, the users are quick to grasp and improve the use of the data.

1. It is recommended that the procedures developed herein be made available to a broad spectrum of "208"-type users.

2. It is further recommended that the utility of pollutant load estimation techniques be tested for the so-called non-designated areas throughout the U.S. where data is much less available than in designated regional areas such as the Baltimore RPC.

3. The correlative parameter in this pollutant load model was chosen to be total runoff from an event due to the unavailability of flow to load correlations. It is recommended that further simulations be carried on as these data become available and that a concomitant expansion of the rainfall recurrence case be considered to include expected non-linearities in the flow-to-load relationships.

4. Following the suggestions given by the Baltimore RPC, it is recommended that a procedural handbook be prepared illustrating the application of LANDSAT data to non-point pollution estimation for subsequent transmittal to the large user audience throughout the U.S.

APPENDIX A: ECHOS MODEL DESCRIPTION

- o DESCRIPTION OF THE MODEL
- o SAMPLE OUTPUT
- o FORTRAN LISTING

Description of the Model

The ECOsystems Hydrologic Simulator (ECHOS) requires that the following data about each sub-basin be known or estimated:

1. Average slope, m/m
2. Area, m^2
3. Average Overland Flow Length, m
4. Width (equal to area ÷ flow length), m
5. Average Mannings "n"
6. Soil Moisture Capacity, m
7. Antecedent Moisture Content, m
8. Final (saturated) Infiltration Rate, m/sec.
9. Percolation Rate, m/m
10. Detention Storage, m

Additionally, these data are required for each stream segement:

1. Length, m
2. Average slope, m
3. Channel width, m
4. Channel Manning's "n"

As adapted for the Baltimore RPC, (Version 1P) data are also required giving pollutant loading factors for two sets of land use classification, one supplied by RPC and one received from the Washington Council of Government (COG):

<u>RPC Classes</u>

Rural (∿ 4% impervious)

Low Activity Commercial (∿ 12% impervious)

Low Activity Residential (∿ 16% impervious)

High Activity Commercial (∿ 35% impervious)

High Activity Residential (∿ 32% impervious)

Central Business District (∿ 80% impervious)

<u>COG Classes</u>

Shopping Centers

Strip Commercial

High Rise Residential

Town House/ Garden Apartments

Med. Density Single Family Residential

Construction

Forest

Conventional Tillage Agriculture

Minimum Tillage Agriculture

Pasture

The program is written in language. It is presently configured for a PDP 11-34, 32K computer but has also run on IBM and Honeywell machines of comparable size.

The program reads the data it requires out of separate files prepared in advance of a run on disk or tape. Four files are involved; for the Magothy River they have been called DATA.DAT, RAIN.DAT, LINK.DAT, and CON.DAT. Examples of each are given in Table AI a,b,c, and d.

DATA.DAT contains values for all the physiographic parameters of each sub-basin and stream. It also includes the initial conditions of the simulation and time-keeping information. RAIN.DAT contains a set of intensities and corresponding durations for each month. LINK.DAT gives the program the connection between sub-basins and channels, i.e., it identifies which basins flow into which streams. CON.DAT contains the pollutant loading factors and land use fractions for the RPC and COG data.

A simplified flow chart for ECHOS is shown in Figure 1A. Briefly, the model reads the first rainfall profile and the parameters for the first sub-basin. It computes overland flow and stores it as elements of a flow-versus-time matrix. The process is repeated for each sub-basin. Subsequently, the model rates the output of the appropriate sub-basin or sub-basins through the channel or channels as specified by LINK.DAT. Flow is routed until the basin outlet has been reached. A table is then printed out giving time since the start of rainfall, rain and discharge rate, and cumulative rain and discharge. Finally, total discharges for the month are computed and converted to pollutant loads using the loading factors

TABLE A1

DATA FILES

```
REENTER
*ERDX1:CON.DAT$EWDX1:CON.DAT$R$B$/L$$
04191006.500000000.002553903.300000000.000000000.000000000.0
0167.000007.000038.200000.710000.41
0239.000007.600061.100001.030000.47
0293.000007.700076.100002.320000.49
0751.000012.200140.600002.340000.68
0633.000013.200172.800002.220000.60
0179.000015.300178.200002.970000.46
00000000.000000000.000000000.000000000.000000000.002553903.3
00000000.003443794.600000000.000000000.000747211.9
0074.000054.660001.810002.430000.20
0098.000111.530001.330001.760000.27
0034.000096.280000.870001.200000.22
0115.000073.460001.120001.490000.29
0042.000095.880001.940002.420000.38
0142.000115.150002.760003.640000.35
0763.000089.350001.610001.760000.26
0000.000072.400001.280001.300000.12
1681.000853.380008.900013.420003.18
0133.000086.240001.930003.520001.14
0544.000549.000004.970005.160001.06
```

```
.R EDIT
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00540.140.0170.066012478..002500000.0380000000.0000002420.000018056
CORNFLD 06744909.8
01
01000.000.0040.0382.00
*EX$$
```

```
R EDIT
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EAST
0001DUMMY
01
*EX$$
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A

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.0000017901800.
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.0000047201800.
.0000045101800.
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.0000037201800.
.0000032901800.
.0000028601800.
.0000023601800.
.0000019301800.
.0000015001800.
.0000010701800.
.0000006401800.
.0000002101800.
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.0000004201800.
.0000012501800.
.0000022201800.
.0000030601800.
.0000033401800.
.0000047201800.
.0000055601800.
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.0000052801800.
.0000044401800.
.0000036101800.
.0000027801800.
.0000019401800.
.0000011101800.
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.0000063901800.
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.0000016601800.
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.0000005101800.
```

B

```
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.0000083101800.
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.0000071001800.
.0000049601800.
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.0000009401800.
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.0000095600900.
.0000073700900.
.0000051700900.
.0000032900900.
.0000011000900.
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```

C

```
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.0000065301800.
.0000046001800.
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.0000040801800.
.0000032201800.
.0000023501800.
.0000013601800.
.0000005001800.
00.9706.78NOVEMBER17030600
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.0000014301800.
.0000023101800.
.0000033001800.
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.0000051701800.
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.0000085301800.
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.0000051701800.
.0000045101800.
.0000038501800.
.0000031901800.
.0000024201800.
.0000017601800.
.0000009901800.
.0000003301800.
00.9807.46DECEMBER22039600
.0000003801800.
.0000011401800.
.0000018201800.
.0000025201800.
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.0000030301800.
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.0000018201800.
.0000014401800.
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.0000006101800.
.0000002301800.
```
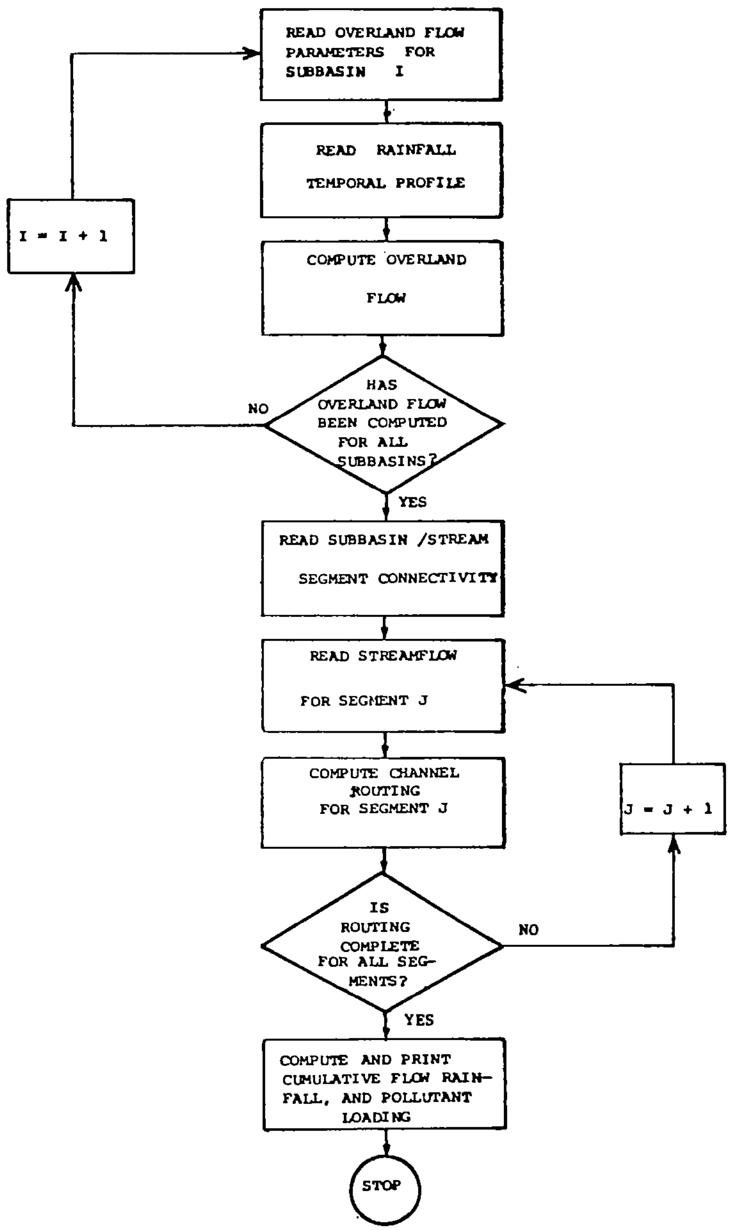

FIGURE 1A

ECHOS MODEL: SIMPLIFIED FLOW CHART



of CON.DAT. Tables showing the monthly loads for organic pollutant are then output. (A detailed description of the d derivation of ECHOS is given in the final report of NAS8-30539, 24 February, 1977).

Table AII is a sample output of the model for the Dividing Creek sub-basin of the Magothy River. The output derived from the file data is shown in Table Al a through d.

Table AIII gives a listing of ECHOS, Version 1P.

TABLE AII: SAMPLE OUTPUT; ECHOS MODEL

```
                         ECOSYSTEMS HYDROLOGIC SIMULATOR (ECHOS)
                                       VERSION 1F


**************************************************************************************************
* SUBBASIN: EAST                                                                                 *
* LENGTH=   504.13 METERS  SLOPE= 0.033  N= 0.056  WIDTH=   2456.METERS  DETENTION=0.00250 METERS  *
* SOIL  MOISTURE CAPACITY = 0.050000001 METERS     ANTECEDENT SOIL MOISTURE= 0.049500000 METERS    *
* PERCOLATION RATE= 0.000000220 M/SEC              FINAL INFILTRATION RATE= 0.000012500 M/SEC      *
**************************************************************************************************

**************************************************************************************************
* SUBBASIN: WEST                                                                                 *
* LENGTH=   594.15 METERS  SLOPE= 0.037  N= 0.085  WIDTH=   4568.METERS  DETENTION=0.00250 METERS  *
* SOIL  MOISTURE CAPACITY = 0.044000000 METERS     ANTECEDENT SOIL MOISTURE= 0.043560002 METERS    *
* PERCOLATION RATE= 0.000000238 M/SEC              FINAL INFILTRATION RATE= 0.000013900 M/SEC      *
**************************************************************************************************

**************************************************************************************************
* STREAM SEGMENT: DIVID CK                                                                       *
* LENGTH=  3963.41METERS         SLOPE= 0.010         N= 0.038         WIDTH= 2.00METERS           *
**************************************************************************************************
```

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: JANUARY
AVG. NO. OF STORMS: 8.14

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000360	0.0000	128.0342
1800.	0.00000000	0.0000000360	0.0000	256.0684
2700.	0.00000000	0.0000001070	0.0000	636.6145
3600.	0.00000000	0.0000001070	0.0000	1017.1606
4500.	0.00000000	0.0000001790	0.0000	1653.7751
5400.	0.00000000	0.0000001790	0.0000	2290.3896
6300.	0.00000000	0.0000002500	0.0000	3179.5161
7200.	0.00000000	0.0000002500	0.0000	4068.6426
8100.	0.00000000	0.0000003220	0.0000	5213.8374
9000.	0.00000000	0.0000003220	0.0000	6359.0322
9900.	0.00000000	0.0000003930	0.0000	7756.7388
10800.	0.00000000	0.0000003930	0.0000	9154.4453
11700.	0.00000000	0.0000004720	0.0000	10833.1162
12600.	0.00000000	0.0000004720	0.0000	12511.7871
13500.	0.00000000	0.0000004510	0.0000	14115.7715
14400.	0.00000000	0.0000004510	0.0000	15719.7549
15300.	0.00000000	0.0000004150	0.0000	17195.7051
16200.	0.00000000	0.0000004150	0.0000	18671.6543
17100.	0.00000000	0.0000003720	0.0000	19994.6738
18000.	0.00000000	0.0000003720	0.0000	21317.6953
18900.	0.00000000	0.0000003290	0.0000	22487.7852
19800.	0.00000000	0.0000003290	0.0000	23657.8770
20700.	0.00000000	0.0000002860	0.0000	24675.0371
21600.	0.00000000	0.0000002860	0.0000	25692.1973
22500.	0.00000000	0.0000002360	0.0000	26531.5332
23400.	0.00000000	0.0000002360	0.0000	27370.8672
24300.	0.00000000	0.0000001930	0.0000	28057.2734
25200.	0.00000000	0.0000001930	0.0000	28743.6777
26100.	0.00000000	0.0000001500	0.0000	29277.1543
27000.	0.00000000	0.0000001500	0.0000	29810.6289
27900.	0.00000000	0.0000001070	0.0000	30191.1758
28800.	0.00000000	0.0000001070	0.0000	30571.7207
29700.	0.00000000	0.0000000640	0.0000	30799.3379
30600.	0.00000000	0.0000000640	0.0000	31026.9531
31500.	0.00000000	0.0000000210	0.0000	31101.6406
32400.	0.00000000	0.0000000210	0.0000	31176.3262

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: JANUARY
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	0.000	0.000	0.000	0.000	0.000

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	0.000	0.00	0.000	0.000	0.000

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: FEBRUARY
AVG. NO. OF STORMS: 7.63

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000420	0.0000	149.3732
1800.	0.00000000	0.0000000420	0.0000	298.7465
2700.	0.00000000	0.0000001250	0.0000	743.3097
3600.	0.00000000	0.0000001250	0.0000	1187.8729
4500.	0.00000000	0.0000002220	0.0000	1977.4172
5400.	0.00000000	0.0000002220	0.0000	2766.9614
6300.	0.00000000	0.0000003060	0.0000	3855.2522
7200.	0.00000000	0.0000003060	0.0000	4943.5430
8100.	0.00000000	0.0000003340	0.0000	6131.4160
9000.	0.00000000	0.0000003340	0.0000	7319.2886
9900.	0.00000000	0.0000004720	0.0000	8997.9590
10800.	0.00000000	0.0000004720	0.0000	10676.6299
11700.	0.00000000	0.0000005560	0.0000	12654.0469
12600.	0.00000000	0.0000005560	0.0000	14631.4639
13500.	0.00000000	0.0000006670	0.0000	17003.6523
14400.	0.00000000	0.0000006670	0.0000	19375.8418
15300.	0.00000000	0.0000006110	0.0000	21548.8672
16200.	0.00000000	0.0000006110	0.0000	23721.8926
17100.	0.00000000	0.0000005280	0.0000	25599.7285
18000.	0.00000000	0.0000005280	0.0000	27477.5625
18900.	0.00001425	0.0000004440	0.0128	29056.6504
19800.	0.00033558	0.0000004440	0.3148	30635.7402
20700.	0.00169698	0.0000003610	1.8421	31919.6387
21600.	0.00542458	0.0000003610	6.7242	33203.5391
22500.	0.01116251	0.0000002780	16.7705	34192.2461
23400.	0.01898889	0.0000002780	33.8605	35180.9570
24300.	0.02618044	0.0000001940	57.4229	35870.9180
25200.	0.03221604	0.0000001940	86.4173	36560.8828
26100.	0.03465437	0.0000001110	117.6063	36955.6562
27000.	0.03447625	0.0000001110	148.6349	37350.4258
27900.	0.03222093	0.0000000420	177.6337	37499.8008
28800.	0.02927647	0.0000000420	203.9825	37649.1719

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: FEBRUARY
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	274.036	10.978	63.728	1.272	0.647

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	99.254	190.49	2.704	2.855	0.356

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: MARCH
AVG. NO. OF STORMS: 8.78

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000520	0.0000	184.9383
1800.	0.00000000	0.0000000520	0.0000	369.8766
2700.	0.00000000	0.0000001570	0.0000	928.2480
3600.	0.00000000	0.0000001570	0.0000	1486.6194
4500.	0.00000000	0.0000002620	0.0000	2418.4238
5400.	0.00000000	0.0000002620	0.0000	3350.2283
6300.	0.00000000	0.0000003670	0.0000	4655.4658
7200.	0.00000000	0.0000003670	0.0000	5960.7036
8100.	0.00000000	0.0000004710	0.0000	7635.8179
9000.	0.00000000	0.0000004710	0.0000	9310.9316
9900.	0.00000000	0.0000005760	0.0000	11359.4785
10800.	0.00000000	0.0000005760	0.0000	13408.0264
11700.	0.00000000	0.0000006390	0.0000	15680.6338
12600.	0.00000000	0.0000006390	0.0000	17953.2402
13500.	0.00000000	0.0000006210	0.0000	20161.8301
14400.	0.00000000	0.0000006210	0.0000	22370.4199
15300.	0.00000000	0.0000005460	0.0000	24312.2715
16200.	0.00000701	0.0000005460	0.0063	26254.1250
17100.	0.00030524	0.0000004710	0.2810	27929.2383
18000.	0.00271932	0.0000004710	2.7284	29604.3535
18900.	0.01004917	0.0000004040	11.7727	31041.1816
19800.	0.02589324	0.0000004040	35.0766	32478.0098
20700.	0.04984923	0.0000003370	79.9409	33676.5508
21600.	0.08218576	0.0000003370	153.9081	34875.0937
22500.	0.11506171	0.0000002620	257.4636	35806.8984
23400.	0.14304954	0.0000002620	386.2082	36738.7031
24300.	0.15575710	0.0000001870	526.3896	37403.7695
25200.	0.15440488	0.0000001870	665.3541	38068.8359
26100.	0.13917698	0.0000001120	790.6133	38467.1641
27000.	0.11739077	0.0000001120	896.2650	38865.4922
27900.	0.09321304	0.0000000370	980.1567	38997.0820
28800.	0.07302280	0.0000000370	1045.8773	39128.6719

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: MARCH
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	1616.834	64.768	376.001	7.507	3.820

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	585.606	1123.89	15.951	16.846	2.102

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: APRIL
AVG. NO. OF STORMS: 10.24

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000510	0.0000	181.3818
1800.	0.00000000	0.0000000510	0.0000	362.7636
2700.	0.00000000	0.0000001660	0.0000	953.1436
3600.	0.00000000	0.0000001660	0.0000	1543.5234
4500.	0.00000000	0.0000002750	0.0000	2521.5625
5400.	0.00000000	0.0000002750	0.0000	3499.6016
6300.	0.00000000	0.0000003900	0.0000	4886.6387
7200.	0.00000000	0.0000003900	0.0000	6273.6763
8100.	0.00000000	0.0000004980	0.0000	8044.8164
9000.	0.00000000	0.0000004980	0.0000	9815.9561
9900.	0.00000000	0.0000006070	0.0000	11974.7549
10800.	0.00000000	0.0000006070	0.0000	14133.5537
11700.	0.00000000	0.0000007220	0.0000	16701.3516
12600.	0.00000000	0.0000007220	0.0000	19269.1484
13500.	0.00000000	0.0000005240	0.0000	21132.7578
14400.	0.00000000	0.0000005240	0.0000	22996.3672
15300.	0.00000000	0.0000004280	0.0000	24518.5508
16200.	0.00000000	0.0000004280	0.0000	26040.7363
17100.	0.00000000	0.0000003320	0.0000	27221.4961
18000.	0.00000000	0.0000003320	0.0000	28402.2559
18900.	0.00000005	0.0000002360	0.0000	29241.5918
19800.	0.00000057	0.0000002360	0.0006	30080.9258
20700.	0.00000057	0.0000001470	0.0011	30603.7324
21600.	0.00000057	0.0000001470	0.0016	31126.5391
22500.	0.00000057	0.0000000510	0.0021	31307.9199
23400.	0.00000057	0.0000000510	0.0026	31489.3027

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: APRIL
RFC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	0.005	0.000	0.001	0.000	0.000

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	0.002	0.00	0.000	0.000	0.000

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: MAY
AVG. NO. OF STORMS: 10.52

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000940	0.0000	334.3115
1800.	0.00000000	0.0000000940	0.0000	668.6230
2700.	0.00000000	0.0000002810	0.0000	1668.0012
3600.	0.00000000	0.0000002810	0.0000	2667.3794
4500.	0.00000000	0.0000004690	0.0000	4335.3809
5400.	0.00000000	0.0000004690	0.0000	6003.3818
6300.	0.00000000	0.0000006570	0.0000	8340.0059
7200.	0.00000000	0.0000006570	0.0000	10676.6299
8100.	0.00000000	0.0000008310	0.0000	13632.0859
9000.	0.00000000	0.0000008310	0.0000	16587.5430
9900.	0.00000000	0.0000010000	0.0000	20144.0488
10800.	0.00000000	0.0000010000	0.0000	23700.5547
11700.	0.00000000	0.0000007100	0.0000	26225.6738
12600.	0.00000000	0.0000007100	0.0000	28750.7930
13500.	0.00019675	0.0000004960	0.1771	30514.8203
14400.	0.00307646	0.0000004960	2.9459	32278.8457
15300.	0.00918785	0.0000002950	11.2150	33328.0156
16200.	0.01883091	0.0000002950	28.1628	34377.1836
17100.	0.02505752	0.0000000940	50.7145	34711.4961
18000.	0.02774033	0.0000000940	75.6808	35045.8086

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: MAY
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	140.182	5.615	32.600	0.651	0.331

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	50.773	97.44	1.383	1.461	0.182

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: JUNE
AVG. NO. OF STORMS: 9.65

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000001100	0.0000	391.2156
1800.	0.00000000	0.0000003290	0.0000	1561.3060
2700.	0.00000000	0.0000005490	0.0000	3513.8276
3600.	0.00000000	0.0000007680	0.0000	6245.2241
4500.	0.00000000	0.0000009880	0.0000	9759.0518
5400.	0.00000000	0.0000012070	0.0000	14051.7539
6300.	0.00000000	0.0000013200	0.0000	18746.3418
7200.	0.00000000	0.0000013200	0.0000	23440.9297
8100.	0.00000000	0.0000011440	0.0000	27509.5723
9000.	0.00000000	0.0000009560	0.0000	30909.5918
9900.	0.00089749	0.0000007370	0.8077	33530.7383
10800.	0.00787075	0.0000005170	7.8914	35369.4531
11700.	0.02187117	0.0000003290	27.5755	36539.5430
12600.	0.03327187	0.0000001100	57.5201	36930.7578

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: JUNE
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	97.732	3.915	22.728	0.454	0.231

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	35.398	67.94	0.964	1.018	0.127

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: JULY
AVG. NO. OF STORMS: 9.11

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000001230	0.0000	437.4502
1800.	0.00000000	0.0000003540	0.0000	1696.4532
2700.	0.00000000	0.0000005850	0.0000	3777.0093
3600.	0.00000000	0.0000008160	0.0000	6679.1182
4500.	0.00000000	0.0000010480	0.0000	10406.3359
5400.	0.00000000	0.0000012790	0.0000	14955.1064
6300.	0.00000000	0.0000015100	0.0000	20325.4297
7200.	0.00000000	0.0000016940	0.0000	26350.1504
8100.	0.00036758	0.0000013250	0.3308	31062.5195
9000.	0.02616293	0.0000011050	23.8775	34992.4570
9900.	0.13193822	0.0000008430	142.6219	37990.5898
10800.	0.31343022	0.0000005980	424.7090	40117.3789
11700.	0.49779883	0.0000003670	872.7280	41422.6172
12600.	0.57992494	0.0000001230	1394.6605	41860.0664

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: JULY
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	2237.058	89.613	520.236	10.387	5.285

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	810.246	1555.02	22.070	23.308	2.909

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: AUGUST
AVG. NO. OF STORMS: 9.46

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000001080	0.0000	384.1026
1800.	0.00000000	0.0000003230	0.0000	1532.8540
2700.	0.00000000	0.0000005390	0.0000	3449.8105
3600.	0.00000000	0.0000007700	0.0000	6188.3198
4500.	0.00000000	0.0000010010	0.0000	9748.3818
5400.	0.00000000	0.0000012170	0.0000	14076.6494
6300.	0.00000000	0.0000014320	0.0000	19169.5664
7200.	0.00000000	0.0000015950	0.0000	24842.1934
8100.	0.00000000	0.0000015950	0.0000	30514.8203
9000.	0.00278445	0.0000014630	2.5060	35717.9883
9900.	0.06634991	0.0000012320	62.2209	40099.6055
10800.	0.27713221	0.0000010010	311.6399	43659.6680
11700.	0.61399269	0.0000007850	864.2334	46451.5234
12600.	0.92908120	0.0000005540	1700.4065	48421.8281
13500.	1.06917965	0.0000003390	2662.6682	49627.4844
14400.	1.00847340	0.0000001080	3570.2942	50011.5859

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: AUGUST
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	5946.829	238.222	1382.957	27.612	14.049

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; HT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	2153.898	4133.74	58.668	61.960	7.732

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: SEPTEMBR
AVG. NO. OF STORMS: 7.29

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000001040	0.0000	369.8766
1800.	0.00000000	0.0000001040	0.0000	739.7532
2700.	0.00000000	0.0000003120	0.0000	1849.3829
3600.	0.00000000	0.0000003120	0.0000	2959.0127
4500.	0.00000000	0.0000005050	0.0000	4755.0479
5400.	0.00000000	0.0000005050	0.0000	6551.0835
6300.	0.00000000	0.0000007130	0.0000	9086.8721
7200.	0.00000000	0.0000007130	0.0000	11622.6611
8100.	0.00000000	0.0000009210	0.0000	14898.2031
9000.	0.00000000	0.0000009210	0.0000	18173.7441
9900.	0.00000000	0.0000009900	0.0000	21694.6855
10800.	0.00000000	0.0000009900	0.0000	25215.6250
11700.	0.00000000	0.0000008320	0.0000	28174.6387
12600.	0.00000000	0.0000008320	0.0000	31133.6504
13500.	0.00067487	0.0000006530	0.6074	33456.0469
14400.	0.01051014	0.0000006530	10.0665	35778.4453
15300.	0.03753251	0.0000004600	43.8458	37414.4375
16200.	0.08861833	0.0000004600	123.6023	39050.4297
17100.	0.14782076	0.0000002820	256.6410	40053.3633
18000.	0.20524813	0.0000002820	441.3643	41056.3008
18900.	0.22742464	0.0000000890	646.0464	41372.8281
19800.	0.21599340	0.0000000890	840.4405	41689.3594

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: SEPTEMBR
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	1078.760	43.214	250.870	5.009	2.549

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	390.719	749.86	10.643	11.240	1.403

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: OCTOBER
AVG. NO. OF STORMS: 6.60

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000620	0.0000	220.5033
1800.	0.00000000	0.0000000620	0.0000	441.0067
2700.	0.00000000	0.0000001860	0.0000	1102.5167
3600.	0.00000000	0.0000001860	0.0000	1764.0267
4500.	0.00000000	0.0000003090	0.0000	2862.9871
5400.	0.00000000	0.0000003090	0.0000	3961.9473
6300.	0.00000000	0.0000004330	0.0000	5501.9141
7200.	0.00000000	0.0000004330	0.0000	7041.8813
8100.	0.00000000	0.0000005570	0.0000	9022.8555
9000.	0.00000000	0.0000005570	0.0000	11003.8291
9900.	0.00000000	0.0000006810	0.0000	13425.8096
10800.	0.00000000	0.0000006810	0.0000	15847.7900
11700.	0.00000000	0.0000008800	0.0000	18977.5156
12600.	0.00000000	0.0000008800	0.0000	22107.2402
13500.	0.00000000	0.0000007300	0.0000	24703.4902
14400.	0.00000000	0.0000007300	0.0000	27299.7383
15300.	0.00000000	0.0000005940	0.0000	29412.3027
16200.	0.00000000	0.0000005940	0.0000	31524.8672
17100.	0.00000000	0.0000005070	0.0000	33328.0156
18000.	0.00014296	0.0000005070	0.1287	35131.1641
18900.	0.00156652	0.0000004080	1.5385	36582.2187
19800.	0.00692867	0.0000004080	7.7743	38033.2734
20700.	0.01691719	0.0000003220	22.9998	39178.4687
21600.	0.03244998	0.0000003220	52.2048	40323.6641
22500.	0.04948571	0.0000002350	96.7419	41159.4414
23400.	0.06656066	0.0000002350	156.6465	41995.2227
24300.	0.07638235	0.0000001360	225.3906	42478.9062
25200.	0.07803639	0.0000001360	295.6234	42962.5937
26100.	0.07063751	0.0000000500	359.1971	43140.4180
27000.	0.06032138	0.0000000500	413.4864	43318.2461

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: OCTOBER
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	480.502	19.248	111.743	2.231	1.135

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	174.034	334.01	4.740	5.006	0.625

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: NOVEMBER
AVG. NO. OF STORMS: 6.78

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000550	0.0000	195.6078
1800.	0.00000000	0.0000000550	0.0000	391.2156
2700.	0.00000000	0.0000001430	0.0000	899.7960
3600.	0.00000000	0.0000001430	0.0000	1408.3762
4500.	0.00000000	0.0000002310	0.0000	2229.9290
5400.	0.00000000	0.0000002310	0.0000	3051.4819
6300.	0.00000000	0.0000003300	0.0000	4225.1289
7200.	0.00000000	0.0000003300	0.0000	5398.7759
8100.	0.00000000	0.0000004290	0.0000	6924.5171
9000.	0.00000000	0.0000004290	0.0000	8450.2578
9900.	0.00000000	0.0000005170	0.0000	10288.9717
10800.	0.00000000	0.0000005170	0.0000	12127.6846
11700.	0.00000000	0.0000006160	0.0000	14318.4922
12600.	0.00000000	0.0000006160	0.0000	16509.3008
13500.	0.00000000	0.0000008530	0.0000	19543.0000
14400.	0.00000000	0.0000008530	0.0000	22576.6992
15300.	0.00000000	0.0000005940	0.0000	24689.2637
16200.	0.00000000	0.0000005940	0.0000	26801.8281
17100.	0.00000000	0.0000005170	0.0000	28640.5410
18000.	0.00000000	0.0000005170	0.0000	30479.2559
18900.	0.00000000	0.0000004510	0.0000	32083.2402
19800.	0.00000000	0.0000004510	0.0000	33687.2227
20700.	0.00000009	0.0000003850	0.0001	35056.4766
21600.	0.00004824	0.0000003850	0.0435	36425.7305
22500.	0.00029889	0.0000003190	0.3125	37560.2539
23400.	0.00110513	0.0000003190	1.3071	38694.7812
24300.	0.00229098	0.0000002420	3.3690	39555.4570
25200.	0.00381064	0.0000002420	6.7986	40416.1289
26100.	0.00495621	0.0000001760	11.2592	41042.0742
27000.	0.00576055	0.0000001760	16.4437	41668.0195
27900.	0.00598982	0.0000000990	21.8345	42020.1133
28800.	0.00598133	0.0000000990	27.2177	42372.2070
29700.	0.00595877	0.0000000330	32.5806	42489.5703
30600.	0.00591150	0.0000000330	37.9009	42606.9375

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: NOVEMBER
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	45.245	1.812	10.522	0.210	0.107

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	16.387	31.45	0.446	0.471	0.059

RUNOFF SUMMARY FOR DIVIDECK BASIN
AVG. EVENT FOR: DECEMBER
AVG. NO. OF STORMS: 7.46

TIME (SECS)	DISCHARGE (M3/S)	RAIN RATE (M/S)	CUMULATIVE DISCHARGE(M3)	CUMULATIVE RAINFALL(M3)
900.	0.00000000	0.0000000380	0.0000	135.1472
1800.	0.00000000	0.0000000380	0.0000	270.2944
2700.	0.00000000	0.0000001140	0.0000	675.7361
3600.	0.00000000	0.0000001140	0.0000	1081.1777
4500.	0.00000000	0.0000001820	0.0000	1728.4618
5400.	0.00000000	0.0000001820	0.0000	2375.7458
6300.	0.00000000	0.0000002520	0.0000	3271.9854
7200.	0.00000000	0.0000002520	0.0000	4168.2246
8100.	0.00000000	0.0000003250	0.0000	5324.0889
9000.	0.00000000	0.0000003250	0.0000	6479.9536
9900.	0.00000000	0.0000004010	0.0000	7906.1123
10800.	0.00000000	0.0000004010	0.0000	9332.2715
11700.	0.00000000	0.0000004770	0.0000	11028.7246
12600.	0.00000000	0.0000004770	0.0000	12725.1777
13500.	0.00000000	0.0000010450	0.0000	16441.7266
14400.	0.00000000	0.0000010450	0.0000	20158.2754
15300.	0.00000000	0.0000005450	0.0000	22096.5703
16200.	0.00000000	0.0000005450	0.0000	24034.8672
17100.	0.00000000	0.0000005070	0.0000	25838.0156
18000.	0.00000000	0.0000005070	0.0000	27641.1641
18900.	0.00000000	0.0000004610	0.0000	29280.7129
19800.	0.00000000	0.0000004610	0.0000	30920.2617
20700.	0.00000000	0.0000004240	0.0000	32428.2207
21600.	0.00002987	0.0000004240	0.0269	33936.1797
22500.	0.00032761	0.0000003860	0.3217	35308.9922
23400.	0.00174515	0.0000003860	1.8924	36681.8008
24300.	0.00527335	0.0000003400	6.6384	37891.0117
25200.	0.01220103	0.0000003400	17.6193	39100.2266
26100.	0.02257541	0.0000003030	37.9372	40177.8477
27000.	0.03679891	0.0000003030	71.0562	41255.4687
27900.	0.05299573	0.0000002650	118.7523	42197.9414
28800.	0.06991061	0.0000002650	181.6719	43140.4180
29700.	0.08294231	0.0000002190	256.3200	43919.2930
30600.	0.09053081	0.0000002190	337.7977	44698.1680
31500.	0.09084085	0.0000001820	419.5545	45345.4531
32400.	0.08571155	0.0000001820	496.6949	45992.7344
33300.	0.07610982	0.0000001440	565.1938	46504.8711
34200.	0.06476632	0.0000001440	623.4835	47017.0078
35100.	0.05345680	0.0000000980	671.5946	47365.5469
36000.	0.04372070	0.0000000980	710.9432	47714.0820
36900.	0.03581090	0.0000000610	743.1730	47931.0273
37800.	0.02945849	0.0000000610	769.6857	48147.9766
38700.	0.02438080	0.0000000230	791.6284	48229.7773
39600.	0.02032214	0.0000000230	809.9183	48311.5742

POLLUTANT LOADING: DIVIDECK BASIN
EVENTS OF: DECEMBER
RPC CONCENTRATION DATA

LAND USE: RURAL= 0.92; LAC= 0.01; LAR= 0.06; HAC= 0.00; HAR= 0.00; CBD= 0.00

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSFOROUS
	1063.825	42.615	247.397	4.939	2.513

COG CONCENTRATION DATA

LAND USE: SHOP CTR= 0.00; STRP COM= 0.01; HR RES= 0.00; TH/GA= 0.00; MDSFR= 0.00
LLSFR= 0.06; CON= 0.00; FOR= 0.82; CT AG= 0.00; MT AG= 0.00; PAST= 0.10

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	385.310	739.48	10.495	11.084	1.383

ANNUAL LOADING - RPC DATA

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	BOD	COD	TOTAL KJELDAHL NITROGEN	TOTAL PHOSPOROUS
	12981.008	520.001	3018.782	60.272	30.667

ANNUAL LOADING - COG DATA

POLLUTANT: LOAD-KGS.	SUSPENDED SOLIDS	COD	TOTAL KJELDAHL NITROGEN	TOTAL NITROGEN	TOTAL PHOSPOROUS
	4701.627	9023.32	128.064	135.248	16.879

STOP --

```
      DIMENSION RAIN(25),DURN(25),OUTQ(3,100),OVL(2,100),UPS(4,100),
     1QC(15),O(100),P(100),HC(10),X(100),CTR(15),IXLN(100),OUTQC(3,100)
     2,XLOAD(12,12),FRAC(12),TOTLOD(10),AVG(12),ARCOG(12),ARRPC(6)
     3,CYRLOD(10),RYRLOD(10)
      DATA ISTAR,IPLUS/'*','+'/
      DOUBLE PRECISION BASIN,STREAM,BASNAM,DATE
      WRITE (7,411)
C
C   READ HYDROLOGIC PARAMETERS FOR OVERLAND FLOW FROM MASTER FILE
C
      CALL ASSIGN (1,'DX1:LINK.DAT',12)
      CALL ASSIGN (2,'DX1:DATA.DAT',12)
      CALL ASSIGN (3,'DX1:RAIN.DAT',12)
      CALL ASSIGN (5,'DX1:CON.DAT',11)
      PX=0.
      DO 15 IJ=1,10
      CYRLOD(IJ)=0.
   15 RYRLOD(IJ)=0.
   20 PX=PX+1.
      READ (2,412) NS,D1,J,T1,H1
      DO 199 I=1,NS
      READ (1,417) BASIN
      READ (2,413) XL,SL,EN,W,DETEN,CAP,PERC,FI
      READ (3,415) PCT,STORMS,DATE,J1,TOT
      READ (3,414) (RAIN(I1),DURN(I1),I1=1,J1)
      JXX=J1+1
      IF (I .EQ. NS) GO TO 30
      DO 25 MN=1,JXX
   25 BACKSPACE 3
   30 API=CAP*PCT
      IF (PX .NE. 1.0) GO TO 100
      DO 50 I10=1,100
   50 IXLN(I10)=ISTAR
      WRITE (7,418) IXLN
      WRITE (7,436) BASIN,XL,SL,EN,W,DETEN,CAP,API,PERC,FI
      WRITE (7,435) IXLN
C
C  STATEMENTS 100 TO 199 COMPUTE OVERLAND FLOW
C
```

```
      S=S-SDELT
      IF (S .LT. 0.) S=0.
      IF (S .GT. CAP) S=CAP
      IF (K .LT. J) GO TO 199
      IF (Q .EQ. 0.) GO TO 195
  195 OUTQ(I,K1)=Q*W
      K=0
      K1=K1+1
  199 CONTINUE
C
C    LINES 200 TO 299 PERFORM CHANNEL ROUTING
C
      READ (2,438) BASNAM,AREA
      TIME=0.
      QCUM=0.
      J1C=(TOT/(J*D1))
      READ (2,419) NODES
      DO 299 M=1,NODES
      READ (2,420) XLC,SLC,ENC,WC
      READ (1,421) KUPS,KOVL,STREAM
      IF (PX .NE. 1.) GO TO 288
      WRITE (7,418) IXLN
      WRITE (7,422) STREAM,XLC,SLC,ENC,WC
      WRITE (7,435) IXLN
  288 DO 293 IJK=1,100
  293 IXLN(IJK)=IPLUS
      WRITE (7,418) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,440) BASNAM,DATE,STORMS
      WRITE (7,443)
      WRITE (7,441)
      WRITE (7,443)
      IF (KUPS .EQ. 0) GO TO 203
      DO 202 J2=1,KUPS
      READ (1,419) K7
      DO 202 I3=1,J1C
      UPS(J2,I3) = OUTQC(K7,I3)
  202 CONTINUE
```

```
  203 IF (KOVL .EQ. 0) GO TO 205
      DO 204 J2=1,KOVL
      READ (1,419) K7
      DO 204 I4=1,J1C
      OVL(J2,I4) = OUTQ(K7,I4)
  204 CONTINUE
  205 ALFAC = (SLC**.5/ENC)
      TEMPC = D1*J
      T=0.
      DO 210 I5 = 1,10
      HC(I5) = 0.
  210 QC(I5) = 0.
```



```
      K=0
      SEGLEN = XLC/10.
      L3=0
      K2 = 1
      DO 299 I6 = 1,N
      K=K+1
      T=T+D1
      IF (T .GT. TEMPC) GO TO 219
      GO TO 225
  219 K2=K2+1
      TEMPC = TEMPC+(D1*J)
  225 DO 228 L=1,10
      TOTFLO=0.
      IF (L .NE. 1) GO TO 213
      IF (KUPS .EQ. 0) GO TO 252
      DO 206 J6=1,KUPS
  206 TOTFLO=TOTFLO+(UPS(J6,K2)/WC)
      GO TO 252
  213 TOTFLO=QC(L-1)
  252 IF (KOVL .EQ. 0) GO TO 229
  242 DO 207 I7=1,KOVL
```

```
  207 TOTFLO=TOTFLO+(OVL(I7,K2))/(10.*WC)
  229 IF (HC(L) .LE. 0.) GO TO 251
      IF ((TOTFLO-QC(L)) .EQ. 0.) GO TO 231
      HC(L) = HC(L)+(D1*((TOTFLO-QC(L))/SEGLEN))
  231 IF (HC(L) .LE. 0.) GO TO 281
  241 QC(L) = (ALFAC*(HC(L)**1.67))/((2.*HC(L)+1.)**.67)
      GO TO 228
  251 IF (TOTFLO .LE. 0.) GO TO 281
      HC(L) = D1*(TOTFLO/SEGLEN)
  253 IF (HC(L) .LE. 0.) GO TO 281
      GO TO 241
  281 HC(L)=0.
      QC(L)=0.
  228 CONTINUE
  291 IF (K .LT. J) GO TO 299
      L3=L3+1
      OUTQC(M,L3)=(QC(10)*WC)
      IF (M .NE. NODES) GO TO 299
      DURTOT=0.
      ICOUNT=0
      RNCUM=0.
      TIME=TIME+(D1*J)
      IJK=0
  294 IJK=IJK+1
      IF (IJK .GT. J1) GO TO 295
      DURTOT=DURTOT+DURN(IJK)
      IF (TIME .LE. DURTOT) GO TO 295
      ICOUNT=ICOUNT+1
      GO TO 294
  295 DURTOT=DURTOT-DURN(IJK)
      IF (ICOUNT .EQ. 0) GO TO 297
      DO 296 IJL=1,ICOUNT
  296 RNCUM=RNCUM+(AREA*DURN(IJL)*RAIN(IJL))
```

```
  297 DIFF=TIME-DURTOT
      IF (DIFF .LT. 0.) DIFF=0.
      ICOUNT=ICOUNT+1
      RNCUM=RNCUM+(AREA*DIFF*RAIN(ICOUNT))
      QCUM=QCUM+(D1*J*OUTQC(M,L3))
      WRITE (7,442) TIME,OUTQC(M,L3),RAIN(ICOUNT),QCUM,RNCUM
  511 K=0
      IF (I6 .NE. N) GO TO 299
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
      READ (5,434) (ARRPC(IL),IL=1,6)
      JK=0
  512 JK=JK+1
      IF (JK .EQ. 7) GO TO 515
      READ (5,444) (XLOAD(JK,JL),JL=1,5)
      GO TO 512
  515 DO 518 IL6=1,6
  518 FRAC(IL6)=ARRPC(IL6)/AREA
      DO 520 JP=1,5
      TEMP=0.
      DO 520 JUL=1,6
      TEMP=TEMP+FRAC(JUL)* XLOAD(JUL,JP)
  520 AVG(JP)=TEMP
      DO 530 IJ=1,5
      TOTLOD(IJ)=0.001*STORMS*QCUM*AVG(IJ)
  530 RYRLOD(IJ)=RYRLOD(IJ)+TOTLOD(IJ)
      WRITE (7,418) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,445) BASNAM,DATE
      WRITE (7,443)
      WRITE (7,447) (FRAC(IJ3),IJ3=1,6)
      WRITE (7,443)
      WRITE (7,448)
      WRITE (7,443)
      WRITE (7,449) (TOTLOD(IJ4),IJ4=1,5)
```

```
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,450)
      WRITE (7,443)
      READ (5,434) (ARCOG(IL),IL=1,11)
      DO 540 IL1=1,11
  540 FRAC(IL1)=ARCOG(IL1)/AREA
      JK=0
  545 JK=JK+1
      IF (JK .EQ. 12) GO TO 550
      READ (5,444) (XLOAD(JK,JL),JL=1,5)
      GO TO 545
  550 DO 560 JP=1,5
      TEMP=0.
      DO 560 JUL=1,11
```



```
      TEMP=TEMP+FRAC(JUL) * XLOAD(JUL,JP)
  560 AVG(JP)=TEMP
      DO 570 IJ=1,5
      TOTLOD(IJ) =0.001*STORMS*QCUM*AVG(IJ)
  570 CYRLOD(IJ)=CYRLOD(IJ)+TOTLOD(IJ)
      WRITE (7,452) (FRAC(IJ1),IJ1=1,11)
      WRITE (7,443)
      WRITE (7,453)
      WRITE (7,443)
      WRITE (7,454) (TOTLOD(IJ2),IJ2=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
  299 CONTINUE
      IF (PX .EQ. 12.) GO TO 300
      REWIND 1
      REWIND 2
```

```
      REWIND 5
      GO TO 20
  300 WRITE (7,418) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,439)
      WRITE (7,443)
      WRITE (7,448)
      WRITE (7,443)
      WRITE (7,449) (RYRLOD(IJ4),IJ4=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
      WRITE (7,443)
      WRITE (7,416)
      WRITE (7,443)
      WRITE (7,453)
      WRITE (7,443)
      WRITE (7,454) (CYRLOD(IJ2),IJ2=1,5)
      WRITE (7,443)
      WRITE (7,435) IXLN
      WRITE (7,435) IXLN
  411 FORMAT (/////,41X,'ECOSYSTEMS HYDROLOGIC SIMULATOR (ECHOS)',/,57X,
     1'VERSION 1P',//)
  412 FORMAT (I2,F4.0,I3,F8.0,F7.5)
  413 FORMAT (F8.2,2F5.3,F7.0,F9.8,,3F11.9)
  414 FORMAT (F10.9,F6.0)
  415 FORMAT (2F5.2,A8,I2,F7.0)
  416 FORMAT (10X,'+',36X,'ANNUAL LOADING - COG DATA',37X,'+')
  417 FORMAT (A8)
  418 FORMAT (//,10X,100A1)
  419 FORMAT (I2)
  420 FORMAT (F8.2,2F5.3,F4.2)
  421 FORMAT (2I2,A8)
  422 FORMAT (10X,'*',1X,'STREAM SEGMENT: ',A8,73X,'*',/,10X,'*',
     1X,'LENGTH= ',F8.2,'METERS',10X,'SLOPE= ',F5.3,10X,'N= ',
     2F5.3,10X,'WIDTH= ',F4.2,'METERS',8X,'*')
```

```
0345      434 FORMAT (6F10.1)
0346      435 FORMAT (10X,100A1)
0347      436 FORMAT (10X,'*',1X,'SUBBASIN: ',A8,79X,'*',/,10X,'*',1X,'LENGTH= '
             1,F8.2,' METERS',2X,'SLOPE= ',F5.3,2X,'N= ',F5.3,2X,'WIDTH= ',F7.0,
             2'METERS',2X,'DETENTION=',F7.5,' METERS',2X,'*',/,10X,'*',1X,'SOIL
             3 MOISTURE CAPACITY = ',F11.9,' METERS',5X,'ANTECEDENT SOIL MOISTUR
             4E= ',F11.9,' METERS',4X,'*',/,10X,'*',1X,'PERCOLATION RATE= ',F11.
             59,' M/SEC',14X,'FINAL INFILTRATION RATE= ',F11.9,' M/SEC',6X,'*')
0348      438 FORMAT (A8,F10.1)
0349      439 FORMAT (10X,'+',36X,'ANNUAL LOADING - RPC DATA',37X,'+')
0350      440 FORMAT (10X,'+',33X,'RUNOFF SUMMARY FOR ',A8,' BASIN',
             132X,'+',/,10X,'+',37X,'AVG. EVENT FOR: ',A8,37X,'+',/,
             210X,'+',36X,'AVG. NO. OF STORMS: ',F5.2,37X,'+')
0351      441 FORMAT (10X,'+',9X,'TIME',10X,'DISCHARGE',9X,'RAIN RATE',10
             1X,'CUMULATIVE',9X,'CUMULATIVE',9X,'+',/,10X,'+',8X,'(SECS)
             2',11X,'(M3/S)',12X,'(M/S)',12X,'DISCHARGE(M3)',6X,'RAINFALL
             3(M3)',7X,'+')
0352      442 FORMAT (10X,'+',7X,F7.0,6X,F12.8,8X,F12.10,4X,F13.4,7X,F12.4,
             110X,'+')
0353      443 FORMAT (10X,'+',98X,'+',/,10X,'+',98X,'+')
0354      444 FORMAT (5F7.2)
0355      445 FORMAT (10X,'+',33X,'POLLUTANT LOADING: ',A8,' BASIN',
             132X,'+',/,10X,'+',40X,'EVENTS OF: ',A8,39X,'+',/,10X,
             2'+',38X,'RPC CONCENTRATION DATA',38X,'+')
0356      446 FORMAT (A4)
0357      447 FORMAT (10X,'+',11X,'LAND USE: RURAL= ',F5.2,'; LAC= ',F5.2,';
             1 LAR= ',F5.2,'; HAC= ',F5.2,'; HAR= ',F5.2,'; CBD= ',F5.2,5X,'+')
0358      448 FORMAT (10X,'+',9X,'POLLUTANT:',7X,'SUSPENDED',7X,'BOD',
             27X,'COD',7X,'TOTAL KJELDAHL',7X,'TOTAL',10X,'+',/,10X,
             3'+',9X,'LOAD-KGS.',8X,'SOLIDS',30X,'NITROGEN',13X,'
             4PHOSPOROUS',5X,'+')
0359      449 FORMAT (10X,'+',24X,F10.3,4X,F8.2,3X,F8.2,5X,F12.3,9X,
             2F12.3,3X,'+')
0360      450 FORMAT (10X,'+',38X,'COG CONCENTRATION DATA',38X,'+')
0361      451 FORMAT (F10.2)
0362      452 FORMAT (10X,'+',9X,'LAND USE: SHOP CTR= ',F5.2,'; STRP COM= ',
```

```
              1F5.2,'; HR RES= ',F5.2,'; TH/GA= ',F5.2,'; MSFR= ',F5.2,
              24X,'+',/,10X,'+',19X,'LLSFR= ',F5.2,'; CON= ',F5.2,'; FOR= ',
              3F5.2,'; CT AG= ',F5.2,'; MT AG= ',F5.2,'; PAST= ',F5.2,2X,'+')
0363      453 FORMAT (10X,'+',9X,'POLLUTANT:',7X,'SUSPENDED',7X,'COD',7X,
              1'TOTAL KJELDAHL',7X,'TOTAL',7X,'TOTAL',8X,'+',/,10X,'+',
              29X,'LOAD-KGS.',8X,'SOLIDS',20X,'NITROGEN',13X,'NITROGEN',4X,
              3'PHOSPOROUS',3X,'+')
0364      454 FORMAT (10X,'+',24X,F10.3,4X,F8.2,2(9X,F8.2),3X,F10.3,3X,'+')
0365      999 STOP
0366          END
^C
```

APPENDIX B: RPC RESPONSE TO MAGOTHY RIVER ANALYSIS

Regional Planning Council

Milton H. Miller, Chairman
C. Bowie Rose, Sr., Vice Chairman
Frederick L. Dewberry,
Executive Director

701 St. Paul Street
Baltimore, Maryland 21202
(301) 383-5838

April 20, 1978

Mr. Harry Loats
Technical Director
ECO Systems International, Inc.
P. O. Box 225
Gambrills, Maryland 21054

Re: Performance and Application of the Magothy (Anne Arundel County, Maryland) Hydrologic Planning Analysis

Dear Harry:

The Baltimore Regional Planning Council's (BRPC) Section 208 Water Quality Management Planning Program would like to sincerely thank ECO Systems International for its technical support in hydrologic planning of the Magothy River Basin (Anne Arundel County, Maryland). Chosen by BRPC as one of three areas of intensive study, the Magothy Basin represents one of numerous tidal watersheds along the Chesapeake Bay's Western shore. ECO Systems has provided land cover classification and hydrologic planning tools -

(1) defining spatial location and extent of seven land cover types by watershed,

(2) simulating storm-related runoff, and

(3) quantifying non-point or diffuse sources of water entrained pollution flux. -

through practical application.

As the primary goal of Public Law 92-500 is to provide "fishable and swimmable waters" in the nation's waters by 1983, the BRPC is presently engaged in the water quality planning process for seven major river basins. Briefly, the process includes: (1) identification and quantification of pollutant sources for both existing and projected future conditions, (2) design of problem abatement alternatives, (3) testing and evaluation of alternatives for selection of the most cost-effective and feasible one by elected decision-makers.

The ECO Systems analysis and resulting methodology allows BRPC to evaluate non-point source pollutant flux temporarily and spatially under both existing and projected land cover conditions. Sub-basins will be evaluated and ranked according to established selection criteria from highest to lowest flux generation. This focuses the reduction of pollutants in sub-basins with the most critical problems.

To follow the initial problem analysis for existing conditions, the water quality planning process will be composed of the following steps:

(1) Project land cover changes and compute the resulting pollutant load generation and delivery for a selected number of alternatives

(2) Establish the impact on the estuarine receiving water quality from land generated pollutant flux by application of steady state modeling

  (a) existing conditions
  (b) projected future conditions

(3) Apply broad NPS pollutant control strategies by existing and projected pollutant source loads

(4) Select the most cost-effective control strategy and critical areas of primary application.

In the proposed continuing planning process, ECO Systems hydrologic planning methodologies - as applied in the Magothy River - should be used throughout the BRPC region for non-point source pollutant quantification. The present planning program allows only portions of three river basins to be studied with sufficient resources to propose detailed control strategies. ECO Systems methodologies require low resource expenditures with most hydrologic data available from existing documentation. Therefore, water quality planning staff should be able to apply the methodologies with minimal training.

Sincerely,

Samuel R. Martin

Samuel R. Martin
Non-Point Source Engineer/
Planner
Baltimore Water Quality
Planning Program

Regional Planning Council

701 St. Paul Street
Baltimore, Maryland 21202
(301) 383-5838

May 1, 1978

Mr. Harry Loats
Technical Director
ECO Systems International, Inc.
Box 225
Gambrills, Maryland 21054

Dear Harry:

I wish to express my appreciation for the work which you did on the Magothy River for the Baltimore Region 208 planning effort. We received two major benefits from your effort. First, the Magothy work significantly advanced the use of satellite data as a principal methodology for use by the Regional Planning Council in future planning projects and also, the water quality and pollutant loading analysis was of material benefit in helping us to understand the mechanics of non-point source and estuarine water quality problems.

Thank you for the special effort which you undertook to help us.

Sincerely yours,

H. Clayton Ervine
Technical Coordinator

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16. ABSTRACT

The transfer of LANDSAT remote sensing technology from the research sector to "user operational" applications requires demonstration of the utility and accuracy of LANDSAT data in solving real problems. This report describes such a demonstration project in the area of water resources, specifically the estimation of non-point source pollutant loads. The work was performed by ECOsystems for the Baltimore Regional Planning Council (RPC) as an integral part of their Section 208 water resources planning responsibility.

Non-point source pollutants were estimated from land cover data from LANDSAT images. Land cover was classified by simple optical analysis of multi-band, multi-temporal images. Classification accuracies for three small test watersheds were above 95 percent. Land cover was converted to pollutant loads for a fourth watershed, the Magothy River, through the use of coefficients relating significant pollutants to land use and storm runoff volume. These data were subsequently input to the ECOsystems Hydrologic Simulator (ECHOS) model which simulated runoff from average expected rainfall. The result was the estimation of monthly expected pollutant loads for the 17 sub-basins comprising the Magothy watershed. The results of this effort were used by RPC for its 208 area-wide wastewater plan. The RPC has indicated that the techniques used are preferred for extension to other watersheds in the region. The key to the successful transfer is that the new technology was applied to problems pertinent to the user with results that were immediately useful.

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