DEVELOPMENT OF A DATA BASE FOR WATER-QUALITY MODELING OF THE PATUXENT RIVER BASIN, MARYLAND

By Gary T. Fisher and Robert M. Summers

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DEVELOPMENT OF A DATA BASE FOR WATER QUALITY MODELING OF THE PATUXENT RIVER BASIN, MARYLAND

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SUMMARY:
An extensive data base, data-management system, and geographic information system have been assembled for water-quality modeling. The data have been compiled from readily-available digital data bases, published maps and reports, and data from local files. Cooperation by many organizations and specialized software were required.

KEYWORDS: Hydrologic modeling, Water quality, Data

DEVELOPMENT OF A DATA BASE FOR WATER-QUALITY MODELING OF THE PATUXENT RIVER BASIN, MARYLAND

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INTRODUCTION

This paper describes the procedures and rationale used to develop a data base and data-management system for the Patuxent Watershed Nonpoint Source Water-Quality Monitoring and Modeling Program of the Maryland Department of the Environment[2] and the U.S. Geological Survey. A detailed data base and data-management system has been developed to facilitate modeling of the watershed for water-quality planning purposes; statistical analysis; plotting of meteorologic, hydrologic and water-quality data; and geographic data analysis.

The Patuxent River--an important Chesapeake Bay tributary--is Maryland's prototype for development of a basinwide water-quality-management program. A key step in this program is to build a calibrated and verified water-quality model of the basin using the Hydrological Simulation Program--Fortran (HSPF) hydrologic model (Johanson and others, 1984). HSPF has had extensive use in large-scale basin modeling. This paper describes the compilation of the substantial existing data base for preliminary calibration of the basin model. Included are meteorologic, hydrologic, and water-quality data from Federal and State data bases and a geographic-information system containing digital land-use and soils data. This data-base development is significant in its application of an integrated, uniform approach to data-base management and modeling.

The Patuxent River is a 177-km (kilometers) long channel that drains an area of 2410 km^2 (square kilometers) located in seven Maryland counties (fig.1). It represents about 1.5 percent of the total Chesapeake Bay watershed and about 9.5 percent of the total area of Maryland. The basin is located within the Piedmont and Coastal Plain physiographic provinces, which have maximum relief of about 240 and 140 m (meters), respectively. Most stream channels in the Coastal Plain, which comprises about two-thirds of the basin, drain directly to the Patuxent Estuary, and there is considerable tidal influence in the lower reaches of these streams. Land use in 1985 was about 39 percent forested, 35 percent agricultural, 16 percent urban, and 10 percent other uses. The basin is rapidly urbanizing, particularly in the Piedmont.

1/ U.S. Geological Survey, Towson, Maryland, and Maryland Department of the Environment, Baltimore, Maryland, respectively.

2/ Maryland Office of Environmental Programs, prior to July, 1987.

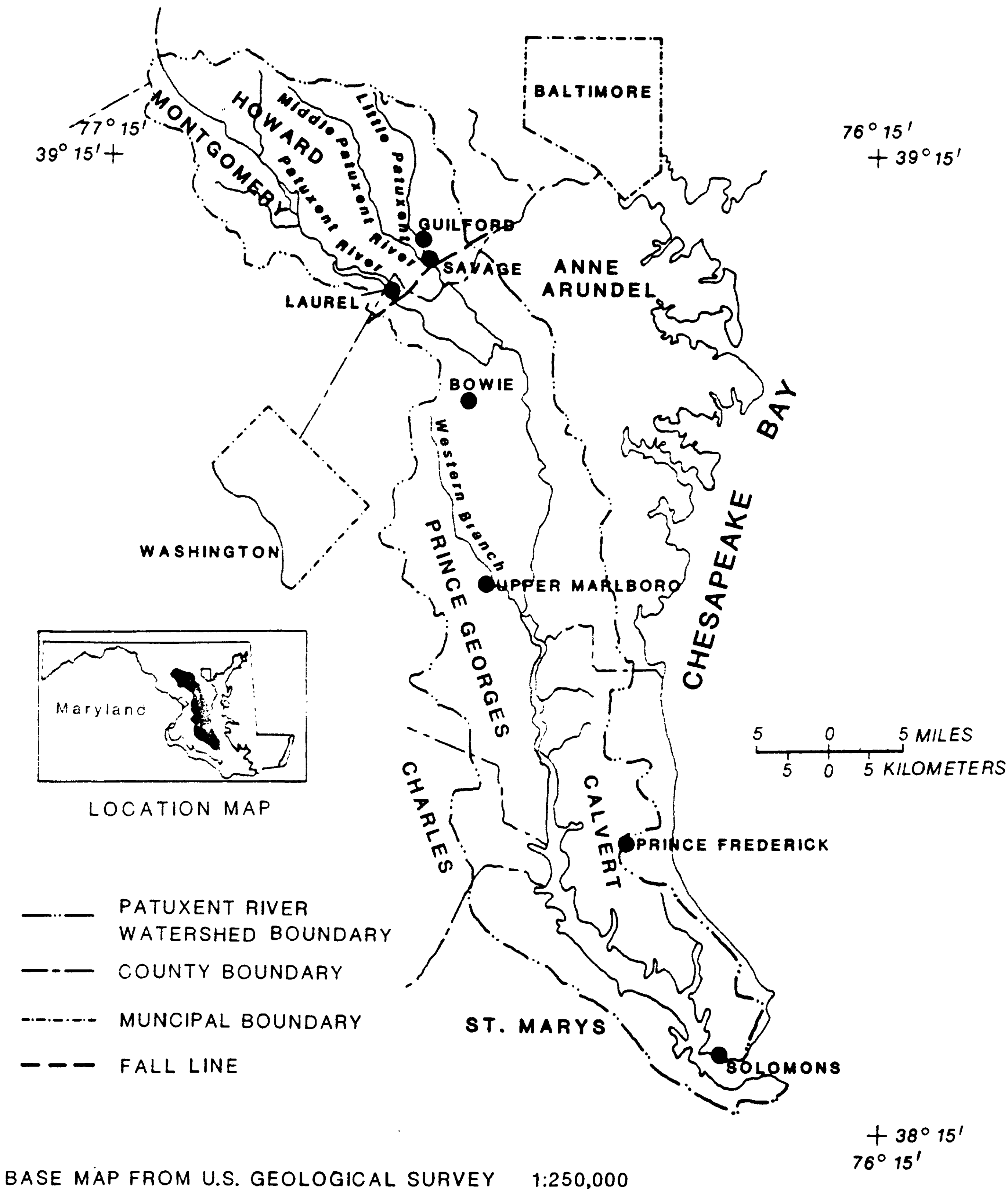


Figure 1.-- Location of the Patuxent River basin, Maryland.

The ongoing Patuxent Watershed Nonpoint Source Water-Quality Monitoring and Modeling Program is a cooperative project of the Maryland Department of the Environment and the U.S. Geological Survey. Funding for data-base development and preparation of a report (Maryland Office of Environmental Programs, 1987) on which this paper is based was provided by the U.S. Environmental Protection Agency.

Development of the data base and report was a team effort. The authors would like to acknowledge the significant contributions of the following individuals: Linda Gustafson, Santha Kurian, Elizabeth Laubach, Sekhoane Rathebe, and Daphne Williams of the Maryland Department of the Environment; Alan Lumb, Kathleen Flynn, Ronald McGregor, Mark Nueslein, and David Perea of the U.S. Geological Survey; and Anthony Donigian, John Kittle, and Doug Beyerlein of Aqua-Terra Consultants.

GENERAL DESCRIPTIONS OF MANAGEMENT AND INFORMATION SYSTEMS

Watershed Data Management System

Watershed models have two categories of input: watershed parameters and time-series data. Watershed parameters include physical dimensions of the watershed and stream channels and parameters for the hydrologic processes, such as interception and infiltration. Time-series data include those used as input, such as precipitation, temperature, evaporation, solar radiation, or flow diversions, and those used for comparison with the simulation results, such as observed streamflow.

ANNIE is a Fortran program designed for minicomputers and microcomputers to help a user interactively create, check, and update input to hydrologic models. For models that require time-series data, ANNIE can be used to reformat, store, list, update, and plot data. The program supports several models, including HSPF. For each supported hydrologic model, there is an information file that is accessed by ANNIE to display questions and check the responses. When all the input has been prepared for a model, the job is submitted for processing. After processing, ANNIE may be used to conduct statistical analysis on the output files from the hydrologic model and to print or plot data from those files.

The Watershed Data Management System (WDMS) is a set of Fortran subroutines and an unformatted direct access file structure which may be used to store nearly all types of hydrologic, hydraulic, meteorologic, and physiographic data for a watershed or drainage basin. The Fortran subroutines have been implemented in the ANNIE system. A number of attributes (table 1) can be associated with the data for identification or to allow searching and sorting. General features of the software are:

1. Transportability - Standard ANSI Fortran 77 is used for all subroutines in the system. Structured programming concepts have been used and no subroutine exceeds 500 lines of code. The software has been tested on four minicomputers and on microcomputers with 512 kilobytes of memory and a 20 megabytes hard disk.

2. Flexibility - The file can be used for small data sets with no attributes except a data set number or with many attributes describing the data. The file can have from 1 to 200,000 data sets. Data sets include a collection of numbers, such as time series, channel cross sections, or drainage networks. Data sets can be located directly by using the unique data set number initially assigned or with search algorithms that use the attributes. Specifications for the attributes are contained in a separate Fortran file that can be updated as new attributes are needed.

3. Time-series data - Data may be stored as a uniform time step or as breakpoint or date-tagged data. Time steps may vary from 1 second to 1 year. Data may be tagged with a quality flag to indicate missing record, estimated data, or other information. Strings of like data values may be compressed at the user's option.

4. File maintenance - Space is allocated as needed and space from deleted files is reused. Data can be added and modified without restructuring the file. Forward and backward pointers exist for each record and each data set for restructuring the data, if necessary.

5. Limitations - Each record is 512 words, so small amounts of data with few attributes will not be stored efficiently. Each record is binary, so system editors cannot be used and the file generally cannot be transferred directly between different computer systems.

Geographic-Information System

A geographic-information system (GIS) contains digitally encoded representations of conventional maps. It contains the same information as any paper map--land cover, roads, technical information and physical features--but in a computer storage device. The advantage of this digital data over the hard copy is that it is not a one-time product; it can be reconstituted in any way that the user requires. A map can be quickly produced with any color scheme, at any scale, and with any combination of physical features.

The use of a GIS in hydrologic modeling is especially beneficial. To model a watershed, data describing the physical characteristics of the basin must be assembled. The traditional approach to assembling these data involves considerable manpower for mechanically overlaying and planimetering maps of the various data types required. Because these efforts are manpower-intensive, variations in the watershed modeling scheme have been extremely limited. However, with a GIS many modeling schemes can be tried.

Table 1.-- List of attributes

[Code numbers 21 and 22 are not used in current attribute list. Code numbers 74 to 79 and 81 relate to flood peak statistics and have not been included to save space.]

Code No.	Code Name	Description	Code No.	Code Name	Description
1	TSTYPE	Type of time-series data	41	STFIPS	State-FIPS code
2	STAID	Station I.D. number (16 char)	42	DSCODE	District code
3	STCODE	State abbreviation code	43	CONTDA	Contributing drainage area
4	HUCODE	Hydrologic-unit code	44	SITECO	Site code
5	SUBHUC	HUCODE extension	45	STANAM	Station name (48 char)
6	COCODE	County or parish code	46	GUCODE	Geologic unit code (7 char)
7	ELEV	Elevation (mean sea level)	47	WELLDP	Well depth
8	LATDEG	Latitude (degrees)	48	AQTYPE	Aquifer type
9	LNGDEG	Longitude (degrees)	49	BASEQ	Base discharge
10	DESCRP	Data description (80 char)	50	DATE	Date
11	DAREA	Drainage area	51	ISTAID	Station I.D. number (8 char)
12	MINVAL	Minimum data value	52	START	Starting date of data
13	MAXVAL	Maximum data value	53	END	Ending date of data
14	MEANVL	Mean data value	54	LATDMS	Latitude (degrees, min, sec)
15	STDDEV	Standard deviation of data	55	LNGDMS	Longitude (degrees, min, sec)
16	SKEWCF	Skew coefficient	56	PARMCD	Parameter code
17	TCODE	Time units code	57	STATCD	Statistics code
18	LCODE	Length units code	58	PRECIP	Mean annual precipitation
19	ACODE	Area units code	59	STORAG	Area of lakes, swamps
20	VCODE	Volume units code	60	TSPTAD	Data aggregation code
23	GCODE	Angle (slope) code	61	FOREST	Forested area
24	SLOPE	Slope	62	SOILIN	Soils infiltration index
25	RMILE	Distance from basin outlet	63	I24-2	2-year, 24-hour rainfall
26	LENGTH	Channel length	64	JANMIN	Minimum January temperature
27	TSBYR	Base year	65	P1-25	1.25-year flood peak
28	TSBMO	Base month	66	P2	2-year flood peak
29	TSBDY	Base day	67	P5	5-year flood peak
30	TSBHR	Base hour	68	P10	10-year flood peak
31	TSPREC	New-group, new-record flag	69	P25	25-year flood peak
32	TSFILL	Time-series filler value	70	P50	50-year flood peak
33	TSSTEP	Primary time step	71	P100	100-year flood peak
34	TGROUP	Unit for group pointers	72	P200	200-year flood peak
35	RWFLAG	Read/write flag	73	P500	500-year flood peak
36	TOLR	Data-compression tolerance	80	YRSPK	Length of peak flow record
40	AGENCY	Agency code			

For this project, a GIS is being assembled that will describe most of the physical and cultural characteristics of the Patuxent River basin. This is being done using ARC-INFO proprietary GIS software (Environmental Systems Research Institute, 1984) on a PRIME minicomputer. A GIS is a system that includes one or more data bases and the software to manipulate, analyze, and display the data. The ARC-INFO software actually includes two separate products: the ARC component handles the geographic information in the GIS (all digitized map data) as well as all graphics operations; the INFO component is a separate data-base management system (HENCO Software, Inc., 1985) and handles all information related to the attributes of the map data.

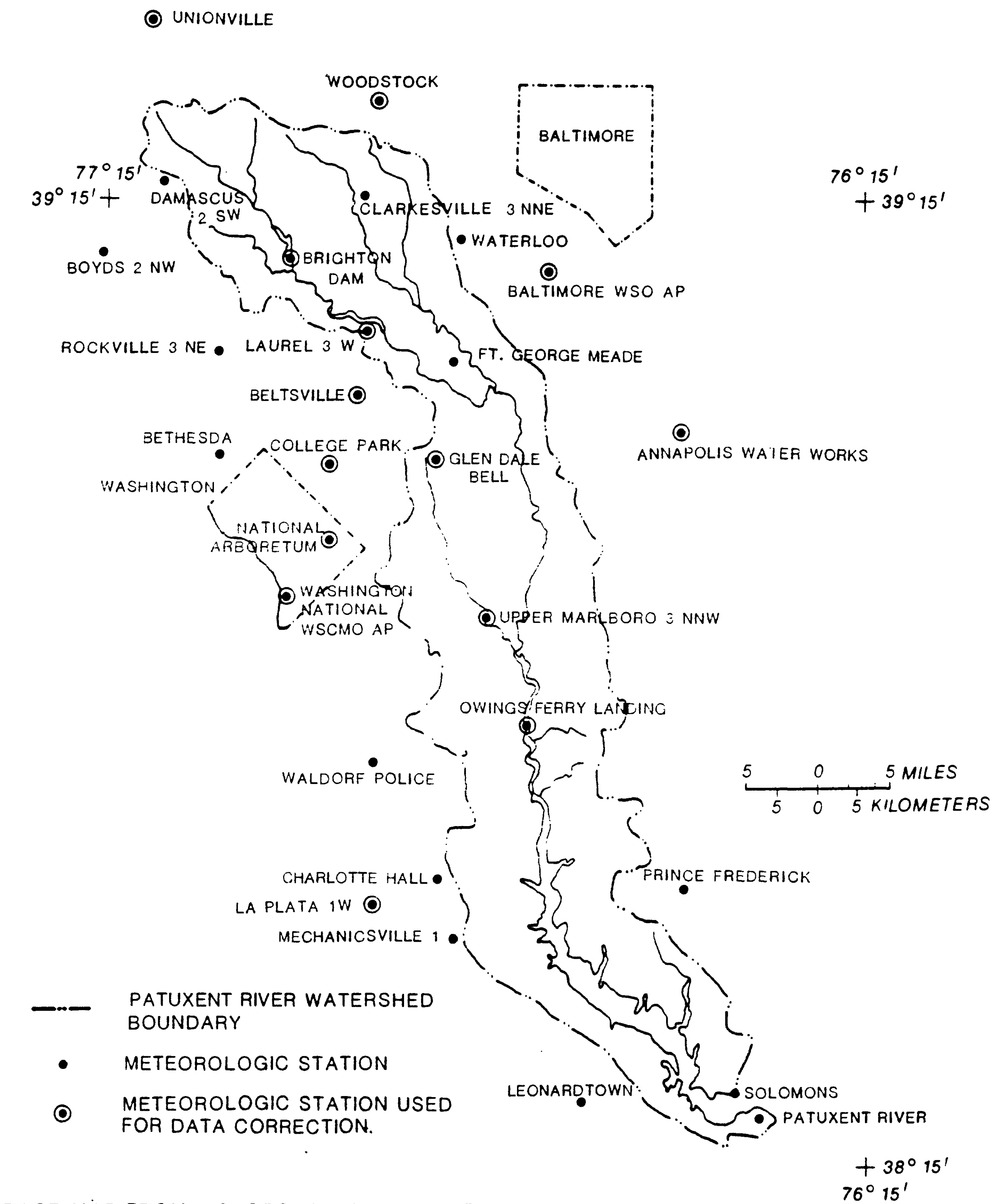
DATA-BASE DEVELOPMENT

An initial decision was made to use 1950 as the beginning year for the data base. This decision was made because the time period of greater interest for simulation is more recent, when significant land development and population growth have occurred. An ending year of 1985 was used for data-base compilation because newer data have not all been published.

Meteorologic Data

Long-term meteorologic data records for Maryland are available only from the National Weather Service, although much of the data are actually collected by cooperating agencies. These records, on magnetic tape, were obtained from the National Climatic Data Center at Asheville, North Carolina. Data from the tapes were converted to WDMS files using ANNIE utilities. A total of 28 precipitation stations are in or near the Patuxent watershed (fig.2). Some of these stations are no longer active and some collected data for only short periods of time. All of the stations have daily data, but only four (Baltimore WSO AP, Beltsville, College Park, and Unionville) have hourly data available.

The period of record for each meteorologic station was checked to see if there were any periods of missing data or periods for which only an accumulated total value was known; these were identified using the WDMS Fortran subroutines of ANNIE (designated hereafter as ANNIE/WDMS), and nearby stations were selected for use in estimating or correcting data for these missing/accumulated periods. Hourly station data were corrected using hourly records; daily stations used daily records. To avoid introducing a bias into the data-correction process, only stations that had at least 25 years of record were selected to use as a basis for making corrections. This criterion reduced the number of usable stations from 28 to 14 (fig.2). The result of the correction process was the filling-in of all missing and accumulated data periods for all 28 stations.



BASE MAP FROM U.S. GEOLOGICAL SURVEY 1:250,000

Figure 2.-- Meteorologic-data stations in or near the Patuxent River basin, Maryland.

The ANNIE/WDMS data-estimation procedures automatically revise data based on criteria supplied by the user. In addition to telling the program what stations to use to perform the data correction, the user also specifies how to weight data from one or more source. Several weighting options are available in the program. For the Patuxent River basin stations, weighting factors equal to the relative inverse of the distance from the target station to the source stations were used. Source stations were those closest to the target station. For example, if the data for station A (the target station) were corrected using station B (10 km distant) and station C (20 km distant), then the relative weighting factors were 0.67 for station B data and 0.33 for station C data. If only one source station were used, then its weighting factor was 1.00.

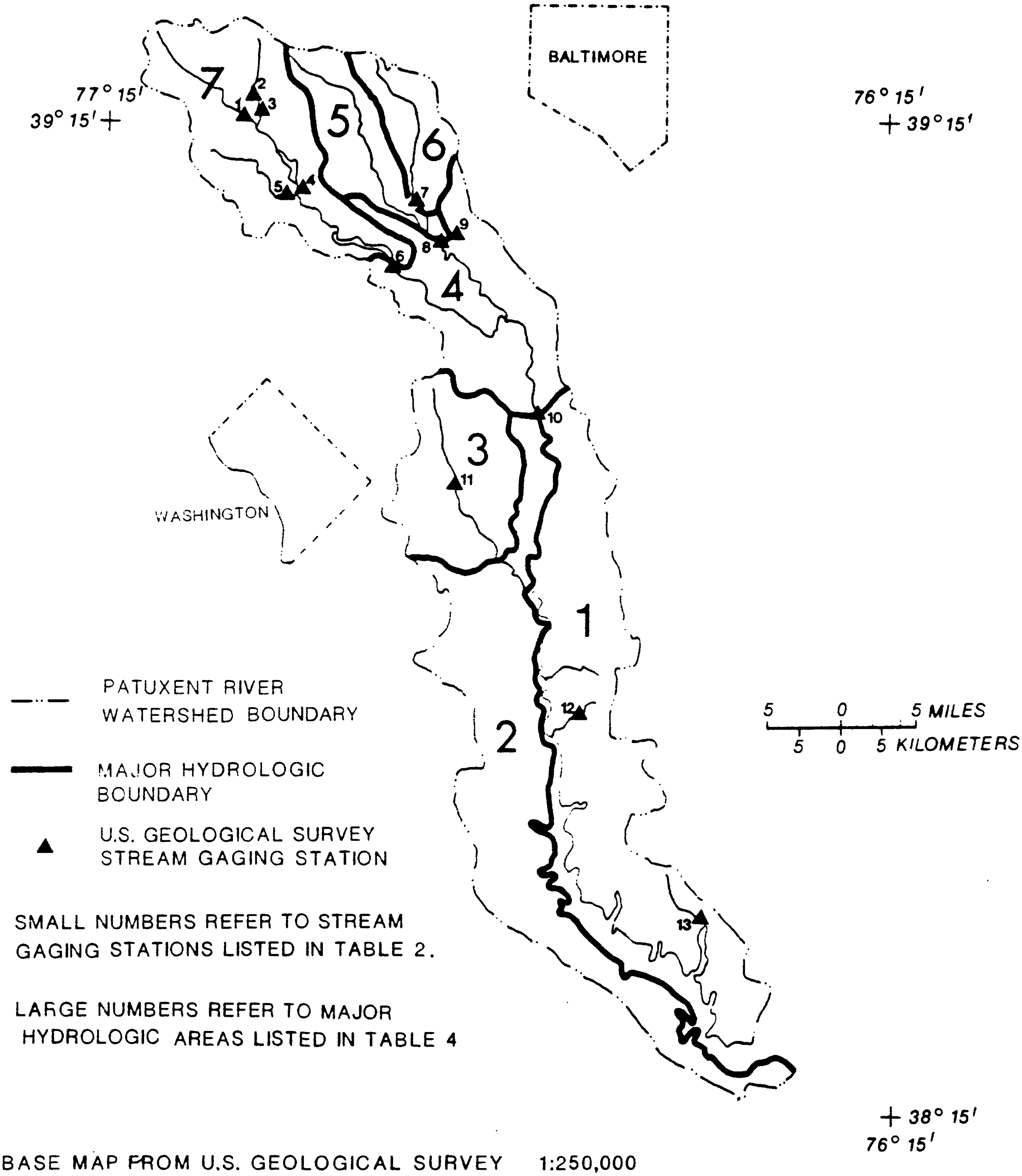
Hydrologic Data

Hydrologic data records for the Patuxent River basin were available from the U.S. Geological Survey. These data were retrieved directly from the WATSTORE (Water Storage and Retrieval) data base maintained by the Survey and converted to WDMS files using ANNIE utilities. Thirteen continuous gaging stations were operated from 1950 through 1985. Table 2 lists, and figure 3 shows, the streamflow stations for which data were added to the data base. Few stations have been located in the lower Patuxent River basin, because there are few drainage areas larger than several square kilometers.

Table 2.-- Streamflow data-collection stations in the Patuxent River basin

[Drainage area is in square kilometers.]

No.	Station identifier	Station description	County	Drainage area	Year began	Year ended
1	01591000	Patuxent River near Unity	Montgomery	90.1	1944	Active
2	01591400	Cattail Creek at Roxbury Mills Rd.	Howard	59.3	1978	Active
3	01591500	Cattail Creek at Roxbury Mills	Howard	71.7	1944	1956
4	01591610	Patuxent River below Brighton Dam	Howard	204	1980	Active
5	01591700	Hawlings River near Sandy Spring	Montgomery	70.4	1978	Active
6	01592500	Patuxent River near Laurel	Prince Georges	342	1944	Active
7	01593500	Little Patuxent River at Guilford	Howard	98.4	1932	Active
8	01594000	Little Patuxent River at Savage	Howard	255	1939	1980
9	01594400	Dorsey Run near Jessup	Anne Arundel	30.0	1948	1958
10	01594440	Patuxent River near Bowie	Anne Arundel	901	1955	Active
11	01594500	Western Branch near Largo	Prince Georges	78.2	1949	1975
12	01594600	Cocktown Creek near Huntingtown	Calvert	9.97	1956	1976
13	01594800	St. Leonard Creek near St. Leonard	Calvert	17.4	1956	1968



BASE MAP FROM U.S. GEOLOGICAL SURVEY 1:250,000

Figure 3.-- Hydrologic-data stations and major hydrologic areas in the Patuxent River basin, Maryland

Water-Quality Data

Data Sources

Water-quality data necessary for nutrient, sediment, and oxygen-system studies have been collected throughout the Patuxent River basin since the early 1950's. For this project, a major effort has been undertaken to obtain all of the relevant nontidal water-quality data and put them into a readily accessible form suitable for use with computer models. The U.S. Environmental Protection Agency's (USEPA) STORET (Storage and Retrieval) and Chesapeake Bay Program data bases, the Survey's WATSTORE data base, and the Department of the Environment's water-quality data base have been inventoried and appropriate data has been obtained. The parent agencies can provide information on these data bases.

The water-quality data base for this project is maintained in Statistical Analysis System (SAS) format on the Cheasapeake Bay Program computer in Annapolis, Maryland. The SAS system provides a high degree of flexibility for manipulating data, including advanced statistical and graphical techniques (Barr and others, 1979). To simplify comparisons of data, data sets are designed with standardized variable names and documentation. The conventions used are consistent with those used in Maryland's Chesapeake Bay water-quality data base.

Sources of available data were determined by searching the data files of both the Department of the Environment and the Survey. These agencies or others with which they cooperate have collected most, if not all, of the data useful to this project. The data search included a NAWDEX (National Water Data Exchange retrieval. NAWDEX is an interagency inventory of water-resources data that is maintained by the Survey.

Stream Data

A number of water-quality monitoring efforts have been conducted over the years to determine concentrations of nutrients in stream and river water at various points in the Patuxent River basin. An attempt has been made to document and obtain all nontidal data of value to the present study.

The earliest reports documenting water quality focus on flow, and on dissolved oxygen and bacterial concentrations in the river (Allison, 1966; Wolman and others, 1967). Some of the earliest documentation of nutrient concentrations are a series of data reports in the files of the USEPA Region III Annapolis Field Office. These reports summarize water-quality monitoring activities conducted during 1967-70.

In the late 1960's, Maryland began to collect and store water-quality data in a computerized data base. These data are available from the Maryland Annapolis Data Center. Those data applicable to the Patuxent basin have been transferred to the Chesapeake Bay Program computer and are contained in SAS data sets for use by the present study.

The Survey has operated a sampling station on the Patuxent River near Bowie since 1977 as part of its National Stream Quality Accounting Network (NASQAN). These data have been retrieved directly from WATSTORE and transferred to SAS data sets.

Nonpoint Source Data

The University of Maryland has operated studies of agricultural runoff at its Forage Research Farm in Howard County since 1977. Ayars and others (1981) reported results from the first two years of data collection.

The Maryland Department of Natural Resources conducted a study of five small watersheds in the Patuxent basin during 1980-82 (Bostater and others, 1982). One forested (Coastal Plain) and four mixed agricultural watersheds (two each in the Coastal Plain and the Piedmont) were studied. Runoff from 6 to 31 storms was sampled at each site. Unfortunately, although some statistical analyses of the data are available in the report, efforts to obtain the raw data have not yet been successful. The two mixed agricultural watersheds in the Coastal Plain were studied previously by the Smithsonian Institution's Environmental Research Center. Most of those data have been published (Correll and others, 1977).

Another monitoring effort was conducted in association with the Columbia Clean Lakes Program. According to the Patuxent Water-Quality Management Plan (Office of Environmental Programs, 1983), suburban storm-water-runoff monitoring was conducted in the early 1980's on a number of small tributaries draining to the Columbia lakes.

Point Source Data

Ten sewage-treatment plants are the major (more than 379 cubic meters per day each) point-source contributors of nutrients to the Patuxent River system. Eight plants discharge between the Fall Line (fig.1) and the mainstem stream-gaging station on the Patuxent River near Bowie. The other two discharge to Western Branch (fig.1).

The water quality of point sources is of critical concern in this study. Efforts to use the considerable body of existing data have been hampered because there is no single data source that can be used to characterize the bulk of the data. Two principal sources of data are the self-monitoring data collected by plant operators and reported to the State and the compliance-check monitoring done by Department of the Environment field crews.

Self-monitoring data generally are regarded as the best source of information for water-quality characteristics that are stipulated in discharge permits. Samples are collected at variable frequencies, but temporal coverage is satisfactory for statistical analyses. Constituents monitored include flow; concentrations of total Kjeldahl nitrogen and ortho and total phosphorus; and biological oxygen demand. Total-nitrogen data usually are not provided. Most of the self-monitoring data are stored as paper files at the Department of the Environment. Mean monthly data are provided to and stored on the USEPA's Permit Compliance System data base.

The State compliance-check monitoring is the only source of data available for water-quality information not required for discharge permits. Grab samples are collected once per month, at the most. Usually, a full suite of nutrient species is measured. The data are stored in the Maryland water-quality data base.

Geographic Data

Attributes of the GIS for the Patuxent River basin include cultural and hydrologic features, land use, soils, and slopes. Table 3 lists the attributes and the sources of information. Using ARC-INFO, parameters describing the basin will be developed from these data for various approaches to modeling the watershed.

Table 3.-- List of Geographic Information System attributes and data sources

Attribute	Source	Date	Publishing Agency
Boundaries	1:100,000 maps	1979	U.S. Geological Survey
Transportation	1:100,000 maps	1979	U.S. Geological Survey
Streams and Water Bodies	1:24,000 maps	1979	U.S. Geological Survey
Soil	Natural Soils Maps 1:62,500	1972	Maryland Department of State Planning
Slope	Natural Soils Maps 1:62,500	1972	Maryland Department of State Planning
Land Use	1:62,500 maps	1985	Maryland Department of State Planning

Cultural and hydrologic features are being identified and digitized from Survey 7.5-minute quadrangles and include all features in a class that appear on the maps. Cultural features in the data base include political boundaries, railroads, and major roads. Hydrologic features include streams, water bodies, and watershed boundaries.

Hydrography

Watershed boundaries have been identified on the maps for all points at which modeling might occur. These points include stream gaging stations, river confluences, and road crossings. Table 4 explains the numbering system used to identify the watersheds and Figure 3 shows the locations of major watersheds.

Table 4.-- Numbering system used to identify watersheds in the Patuxent River basin

Major hydrologic area	Range of numbers used	Location in the basin
1	1000-1999	Eastern shore of estuary from mouth to Patuxent River watershed above gaging station near Bowie
2	2000-2999	Western shore of estuary from mouth to Western Branch watershed
3	3000-3999	Western Branch watershed
4	4000-4999	Patuxent River watershed above gaging station near Bowie and below gaging stations at Laurel and Little Patuxent River at Savage
5	5000-5999	Little Patuxent River watershed between gaging stations at Savage and Guilford
6	6000-6999	Little Patuxent River watershed above gaging station at Guilford
7	7000-7999	Patuxent River watershed above gaging station at Laurel

Land Use

Land-use data have been obtained from the Maryland Department of State Planning. These data are available as county maps at a scale of 1:62,500 and have been updated in 1973, 1978, 1981, and 1985. The land-use classification is done by interpretation of high-altitude aerial photography. Table 5 lists the land-use categories used by Maryland and also compares them to the corresponding land-use categories in the U.S. Geological Survey System (Anderson and others, 1976). The comparison is made because the Survey system is widely used.

Table 5. -- Comparison of land-use classification systems

Maryland System		U.S. Geological Survey System	
No.	Description	No.	Description
10	Residential	11	Residential
11	Low-density residential	111	Single-family units
12	Medium-density residential	111	Single-family units
13	High-density residential	112	Multi-family units
14	Commercial	12	Commercial and services
15	Industrial	13	Industrial
16	Institutional	17	Other urban or built-up land
17	Extractive	75	Strip mines, quarries, and gravel pits
18	Open urban land	17	Other urban or built-up land
20	Agricultural	2	Agricultural
21	Cropland	211	Cropland
22	Pasture	212	Pasture
23	Orchards/vineyards	22	Orchards, groves, vineyards, nurseries, and ornamental horticultural areas
24	Feeding operations	23	Confined feeding operations
25	Row and garden crops	211	Cropland
40	Forest	4	Forest
41	Deciduous forest	41	Deciduous forest
42	Evergreen forest	42	Evergreen forest
43	Mixed forest	43	Mixed forest
44	Brush	32	Shrub and brush rangeland
50	Water	5	Water
60	Wetlands	6	Wetland
70	Barren land	7	Barren land
71	Beaches	72	Beaches
72	Bare exposed rock	74	Bare exposed rock
73	Bare ground	76	Transitional areas

Two land-use data sets have been entered into the data base for the Patuxent River basin. Land use for 1973 is included as a base year, after which much of the basin has been extensively developed. Land-use data for 1985 are included because it is the most recent and will indicate the greatest changes since the base year. Additional data for 1978, 1981, and subsequent updates may be included later to provide information on land-use transitions and related hydrologic effects.

Soils

Soils data have been obtained from the Maryland Department of State Planning. These data are available as county maps at a scale of 1:62,500 or 1:63,360. The maps have been developed by reclassifying the detailed soil mapping of the U.S. Soil Conservation Service (SCS) into Natural Soils Groups (Maryland Department of State Planning, 1973).

SCS has classified the major soils found in Maryland into about 225 soil series and 750 soil types on various slopes, resulting in over 1000 mapping symbols on the detailed soils maps. Soil series refers to a group of soils developed by the same genetic combination of processes, whereas soil type refers to both the soil series and texture of the surface horizon. The detailed soils maps have been developed for site-specific planning and design, but, because of their complexity, they are cumbersome for large areal applications.

The Natural Soils Groups were developed by Maryland to simplify the application of soils data for large areal applications. They are simply an aggregation of the detailed soils classification, wherein all soil types with similar properties have been grouped together. A table is available in the cited report that lists some of the physical and chemical properties associated with the various soil groups.

In addition to providing estimates of the soil properties, the Natural Soils Group mapping provides a range of land-surface slopes for each mapping unit. Slope is an important factor in determining hydrologic response of the land surface.

Agricultural Practices

Agricultural practices are an important part of the geographic data base that cannot be easily obtained using remote-sensing techniques. Cropland can be identified readily from aerial photography, but identification of crop type and tillage practice is not possible without several overflights a year. As a result, it is necessary to obtain data on crop type and agricultural practices from other sources.

The SCS, the Soil Conservation Districts, and the U.S. Agricultural Stabilization and Conservation Service compile crop acreage and conservation practice data annually for each county in Maryland. The information is provided to the agencies by farmers on a voluntary basis. Not all of the farmers participate, so only a part of the cropland in a county is represented. The data have been compiled manually into a SAS data set. The contents of the data set are summarized in table 6.

To permit the data to be aggregated on a watershed basis, it was necessary to locate each farm on a map of the watershed and assign it a subbasin code. The same subbasins were used as described under hydrography above.

Information on the acreage of each crop and the tillage practice used was obtained from the 1984 annual acreage report in each county's files. Only crops and practices that were widely used were included in the data base. Crops included corn, small grains, soybeans, and tobacco. In many cases, land was double cropped (small grains grown in the winter in conjunction with another crop in the growing season).

Table 6.-- Contents of agricultural practices data set

[Variables 4 to 20 are area in acres.]

Variable Number	Variable Name	Description
1	BASIN	Sub-basin code
2	COUNTY	County farm is located in
3	FARM	Farm tract number
4	CCT	Conventional-till corn
5	CMT	Minimum-till corn
6	CNT	No-till corn
7	BCT	Conventional-till soybeans
8	BMT	Minimum-till soybeans
9	BNT	No-till soybeans
10	GCT	Conventional-till small grains
11	GMT	Minimum-till small grains
12	GNT	No-till small grains
13	GCT_TCT	Conventional-till small grains/conventional-till tobacco
14	GCT_CCT	Conventional-till small grains/conventional-till corn
15	GCT_CMT	Conventional-till small grains/minimum-till corn
16	GCT_CNT	Conventional-till small grains/no-till corn
17	GCT_BCT	Conventional-till small grains/conventional-till soybeans
18	GCT_BMT	Conventional-till small grains/minimum-till soybeans
19	GCT_BNT	Conventional-till small grains/no-till soybeans
20	GMT_CCT	Minimum-till small grains/conventional-till corn
21	TOTAL	Total acreage
22	STATUS	Code for status and source of data

SUMMARY

An extensive data base, data-management system, and geographic information system have been assembled for water-quality modeling of the Patuxent River basin--an important tributary to the Chesapeake Bay. The data have been compiled from readily available meteorologic, hydrologic, and water-quality digital data bases. Published maps and reports and data from local files were the source of information for the geographic information system. Development of a working, comprehensive data base required three elements: a cooperative team approach involving several organizations with access to the data and expertise to retrieve selected data, a cooperative working relationship with organizations outside the primary team for obtaining additional data and feedback on data-base development, and computer software to manipulate the data and bind the overall system into a uniform framework.

REFERENCES

Allison, J. T., 1966, The Patuxent River, physical, chemical, and bacteriological water quality - summer surveys 1964, 1965, 1966: State of Maryland, Department of Water Resources, Division of Water-Quality Investigations, Report No.4.

Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E., 1976, A land use and land cover classification system for use with remote sensor data: U.S.Geological Survey Professional Paper 964, 28 p.

Ayars, J. E., Inman, J. C., McClung, Gwendolyn, 1981, Nonpoint contributions from agricultural activities in the Maryland Piedmont: Interstate Commission on the Potomac River Basin, Nonpoint Pollution Control - Tools and Techniques for the Future, Proceedings, Gettysburg, Penn., p. 74-81.

Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T., 1979, A user's guide to SAS: SAS Institute, Inc., P.O. Box 10066, Raleigh, N.C., 329 p.

Bostater, C., McGraney, D., Berlett, S., and Pushkar, D., 1982, Intensive watershed study, the Patuxent River basin: U.S.Environmental Protection Agency, Chesapeake Bay Program, Annapolis, Md.

Correll, D. L., Faust, M. A., and Pierce, J. W., 1977, Nonpoint source studies on Chesapeake Bay: VII. Preliminary tests of the application of Rhode River statistical models to Patuxent River subwatersheds: Chesapeake Research Consortium, Publication No. 61.

Environmental Systems Research Institute, 1984, ARCINFO Users Manual: Environmental Systems Research Institute, Redlands, Calif., Version 3, July 1985.

HENCO Software, Inc., 1985, INFO Prime Reference Manual: HENCO Software, Inc., Waltham, Mass., Revision 9.3, February 1985.

Johanson, R. C., Imhoff, J. C., Kittle, J. L., Jr., and Donigian, A. S., Jr., 1984, Hydrological Simulation Program - Fortran, User's manual for release 8.0: U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Ga., 767 p.

Maryland Department of State Planning, 1973, Natural soil groups technical report: Maryland Department of State Planning, Publication No. 199, 153 p.

Office of Environmental Programs, 1983, 208 Water quality management plan for the Patuxent River basin: Maryland Department of Health and Mental Hygiene, Office of Environmental Programs.

_____ 1987, Description of the Patuxent watershed nonpoint source water quality monitoring and modeling program data base and data base management system: Maryland Department of Health and Mental Hygiene, Office of Environmental Programs, Technical Report No.56, 106 p., 3 appendixes.

Wolman, M. G., and Schick, A. P., 1967, Effects of construction on fluvial sediments in urban and suburban areas of Maryland: Water Resources Research, v.3, p. 451-464.