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A PROPOSED WORK PLAN FOR CONTINUING 208 STUDIES IN THE HAMPTON ROADS AREA INVOLVING THE LYNNHAVEN RIVER AND NORTHWEST RIVER DRAINAGE BASINS

Prepared for the

HAMPTON ROADS WATER QUALITY AGENCY

by

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Introduction

During the mid-1970's a very extensive and intensive study of water quality was conducted in the Hampton Roads 208 Study Area. Persons interested in the work are referred to the HRWQA Grant Amendment Request dated April 20, 1979, for a brief review of the findings and the gaps in knowledge or data which were noted during those studies. For more detail, the reader is referred to the many volumes of reports submitted to HRWQA by its consultants and the Management Plan which was the final product of these efforts.

In brief, population and land use determinations and projections, plus other planning information, were used to generate estimates of both point source loadings (that is, industrial and municipal waste water discharges) and nonpoint source pollution (eg. agricultural and urban runoff). These waste loadings were then used to estimate the quality of the various water bodies which receive these waste loads. During the project, the consultants noted many areas where either data were lacking or there was an incomplete understanding of the processes at work. In addition, the original estimates of the "problem areas" were not always correct, so that work efforts were not always allocated proportionally to the severity of the water quality problems as they eventually became known. And finally, due to the very large study area involved, and limitations of time and money, certain areas were given relatively little attention.

The HRWQA has proposed to EPA and has received funding to conduct additional studies. These studies will address some of the problems noted in the initial work and will be focused primarily in the Lynnhaven River and Northwest River drainage basins. The Lynnhaven River drainage basin, one of the "Small Coastal Basins" is urban-suburban in nature (49%); 22% of the land is designated as upland forest, 17% as swamp forest, and 12% as agricultural. In terms of drainage capacities, 45% of the soil is classified as well or moderately well drained, and 47% as poorly or very poorly drained.

Previous 208 studies predict that between 1980 and the year 2000, light residential and commercial/institutional usage will increase, and agricultural and vacant land areas will decrease. Population and employment also is predicted to increase by approximately one-third over the same time period. (See Figure 1.)

Comprehensive water quality studies of Lynnhaven Bay have been made by the Virginia Institute of Marine Science in 1976 and 1979. The studies in 1976 were under the original 208 Program for the Hampton Roads area, and consisted of both intensive and slack water surveys. Parameters measured included oxygen demand constituents, nutrients, bacteriological counts, and physical measurements. This work showed that fecal coliform contamination generally exists. Much of the system has been closed to oyster harvesting, and it is cited as being the most severely contaminated area of the small coastal basins. This work also suggested that high nutrient levels may be attributed to runoff from the surrounding land. Although dissolved oxygen levels in the Lynnhaven system are not in violation of state standards, there was concern that the high nutrient levels would produce large diurnal variations in D.O. levels.

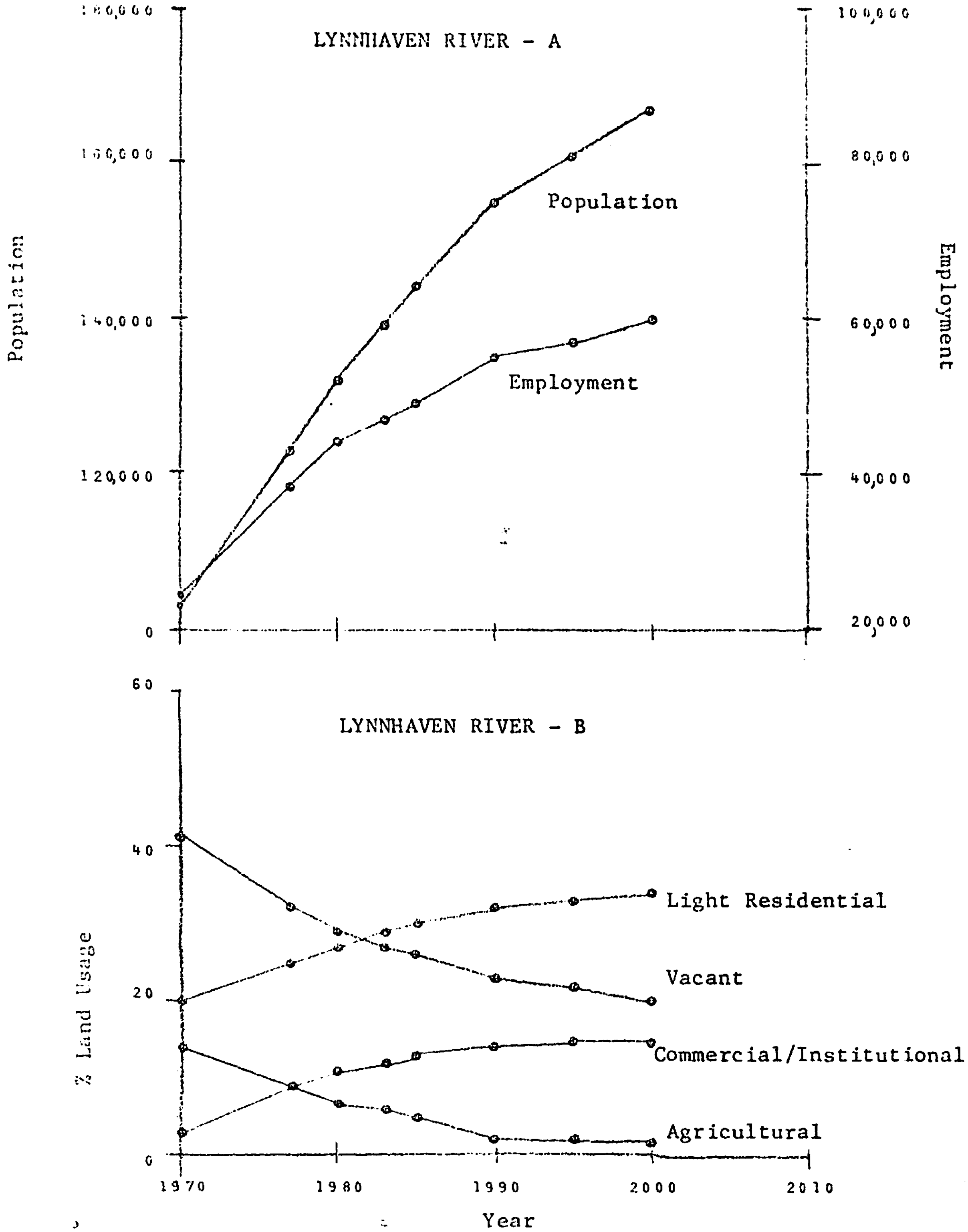


Figure 1. Trends in the Lynnhaven River, Virginia:
A - Population and Employment, B - Land Use

The work completed in 1979 was conducted for the U.S. Army Corps of Engineers, and included high and low slack water surveys on a single day with 4 pairs of surveys conducted during the summer. These, too, showed nutrient enrichment, high BOD's, depressed oxygen levels and high fecal coliform levels in the upper reaches. In general, water quality declined with distance from the inlet and up the tributaries.

With the projected increases in low density residential land usage and population, one can expect increased construction-related activities in the Lynnhaven area. Some research and engineering studies are needed to determine cost-effective strategies for controlling nonpoint source pollution, both for the construction period and for the projected land use shifts.

The Northwest River, which drains to Albermarle Sound, is quite different from Lynnhaven River. The river is fringed by marshes with agricultural and residential lands beyond the swamp.

Most of the land in the Northwest River drainage basin is either poorly or very poorly drained (74%), hence the area is severely limited for the use of septic tanks and subsurface drain fields. The table below characterizes the area with respect to vegetation.

Northwest River Drainage Basin Vegetation Characteristics	
Swamp Forrest	38%
Upland Forrest	35%
Agricultural	25%
Urban-Suburban	1%
Freshwater Marsh	1%

With regard to existing land use, 69% of the land is considered to be open space and undeveloped. Twenty-five per cent of the land is used for agriculture, 2% for low density residential, 2% water, 2% commercial/institutional, and 1% light industry. Projections for the years 1980-2000, calculated in previous 208 studies, show slight decreases in vacant (1%) and agricultural (1%) lands, and slight increases in low density residential (less than 1%) and commercial/institutional (1%) uses. Population and employment trends however, are rising; population is expected to almost double by the year 2000, while employment will more than triple. (See Figure 2.)

There have been water quality problems in the past involving low dissolved oxygen levels (less than 4.0 mg/l), and color. The color of the Northwest River water is dark, probably the result of natural humic acid inputs in the river headwaters. Values of 270 color units (cu) and 325 cu were reported in 1975 and 1970 samples, respectively, greatly exceeding the 75 cu standard set by The State Water Control Board for public water supplies. Previous 208 studies characterized it as being of fair to good quality as a surface water source. The City of Chesapeake is permitted to withdraw 10 million gallons per day at their intake station located just downstream of the Route 168 crossing. Since the river will be used as a drinking water supply, it is important to evaluate how changing land use patterns affect water quality.

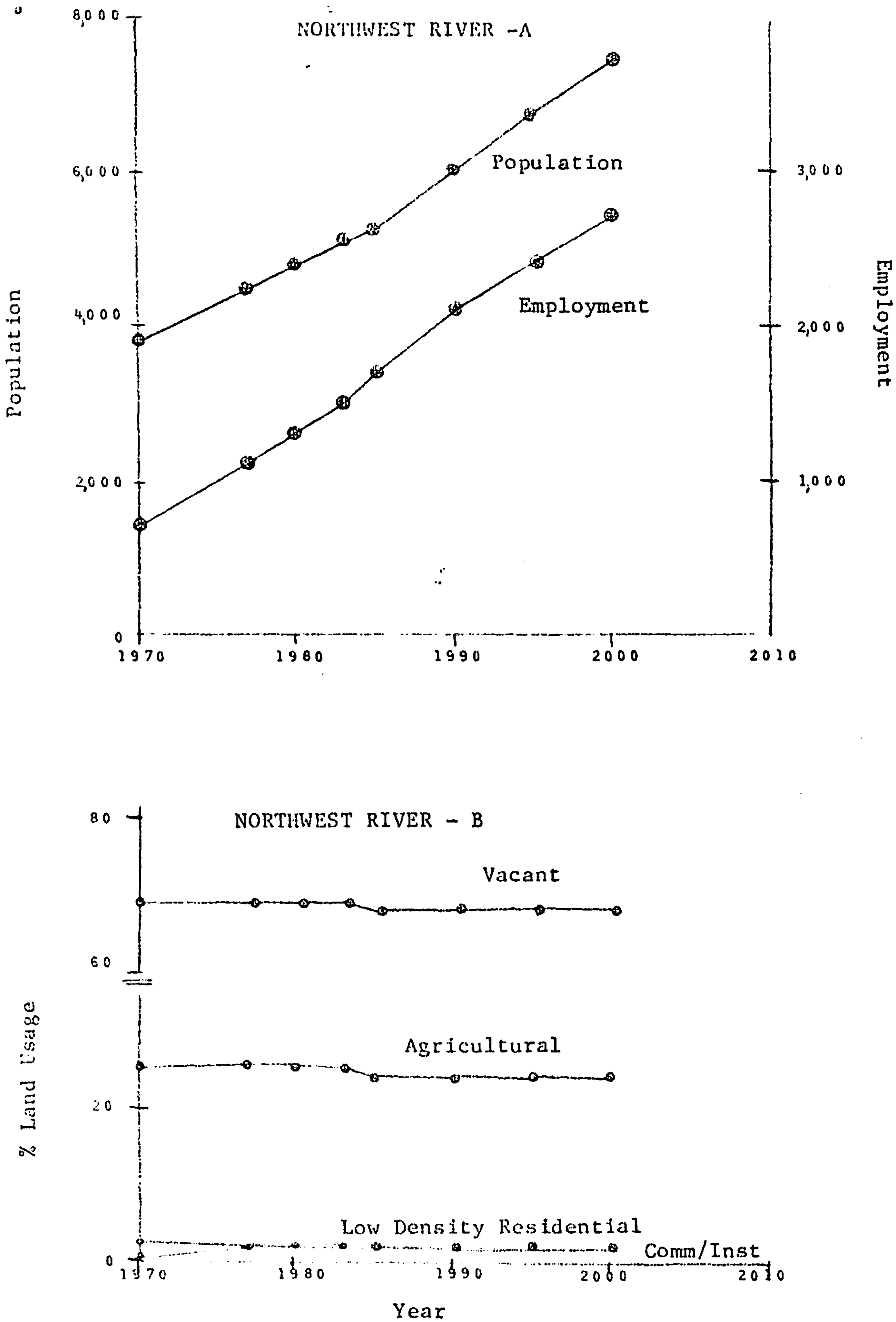


Figure 2. Trends in the Northwest River, Virginia:
A - Population and Employment, B - Land Use

PROGRAM A: BMP EFFECTIVENESS

Prior to the passage of PL92-500, little attention had been given to the topic of nonpoint source pollution. Many studies and much of the work focused on urban areas and the "first flush" concept of capturing the initial, highly polluted runoff and providing it with traditional wastewater treatment. Even now, little information is available to document the costs and the effectiveness of various methods of reducing or controlling nonpoint loads. However, until such information is available, it will not be possible to develop effective management strategies for nonpoint source pollution or to forcefully argue for the implementation of control mechanisms.

TASK A-I: SELECTION OF RUNOFF SAMPLING SITES

The selection of sampling sites involves two steps: first, one must choose the types of land uses and management practices to be monitored and second, specific sites must be selected for sampling. The initial step should include land uses which are prevalent in the drainage basin and/or which produce large amounts of pollutants on a unit area basis. The management practices which are evaluated should have a high potential for both reduction in loadings and acceptance by land owners and developers.

In the Lynnhaven basin, about a quarter of the land is in urban uses (commercial, institutional, streets and industry) and a third is residential. These land uses are projected to increase over the next twenty years, indicating that construction related activities are likely to be important during that period. The remaining major land uses are vacant land and water, both of which produce little pollution on a unit area basis. Therefore, urban uses, residential areas and construction activities appear to be the likely candidates for study. Suggested types of sampling sites for these land uses of or activities are listed in Table 1. Best Management Practices (BMP's) which are either frequently used or required in nonpoint source control in the Lynnhaven area are listed in Table 1 in the appendix.

The Hampton Roads Water Quality Agency and/or its member agencies will select the land use types and the Best Management Practices to be studied. In addition they will have the primary responsibility for identifying potential sites and obtaining permission from landowners to enter the property, establish sampling sites, and collect samples. The Consultant will provide technical advice during the selection process.

Lynnhaven Bay: Percent of drainage basin by land use categories

Land use	1980	2000	Change
Comm/Inst	11%	15%	+4
Industry/streets	12	14	+2
Low. Den. Res.	27	34	+7
High. Den. Res.	3	3	0
Agriculture	7	2	-5
Vacant	29	20	-9
Water	12	12	0

Table 1.

SUGGESTED TYPES OF SAMPLING SITES

I. Urban and Residential Lands

A. Street Sweeping
- mechanical
- high frequency mechanical
- vacuum

B. Drainage Controls

- curbs & gutter, vegetated swales, gravel swales
- porous paving
- tree protection & vegetated buffer strip

C. On-Site Retention

- diversion dikes & perimeter dikes
- settling basins

III. Construction Related Activities

A. Drainage Controls

- mulching, topsoiling, growing grass
- tree protection
- straw bale barrier, storm sewer inlet protection

B. On-Site Retention

- sedimentation basin
- perimeter dike, diversion dikes, gravel outlets

Studies of nonpoint source pollution have utilized both large, mixed-land-use basins and small, single-land-use catchments. For the study of BMP effectiveness, single-land-use catchments are most appropriate. Unfortunately it is impossible to obtain ideal data sets to compare various management practices; there will be either meteorological differences or site differences. In the first instance, a site is monitored when different BMP's are in effect. Thus differences in slope, soils and many other site characteristics will be eliminated. However, this technique requires a relatively long time (such as one year without and one year with a BMP) and there can be variations in meterology, vegetative cover, etc. between years or seasons. Since time is limited for the 208 study, and because many attributes of the Lynnhaven Basin are fairly uniform, it is recommended that the latter approach be used.

Since the purpose of the 208 process is planning, it is not necessary to conduct detailed scientific studies of the mechanisms by which nonpoint pollution is generated. Also it must be understood that the comparisons of BMP's will be quantitative but not especially precise. Variations in site characteristics and weather conditions will produce variations in the system responses. However, these somewhat qualitative evaluations still can be extremely useful for planning purposes. It is suggested that the data generated in the field program be analyzed in terms of loading rate as a function of total rainfall. For the hypothetical example shown in Figure 3, one can note that the data points do not fall precisely on a line, but that distinct trends are apparent.

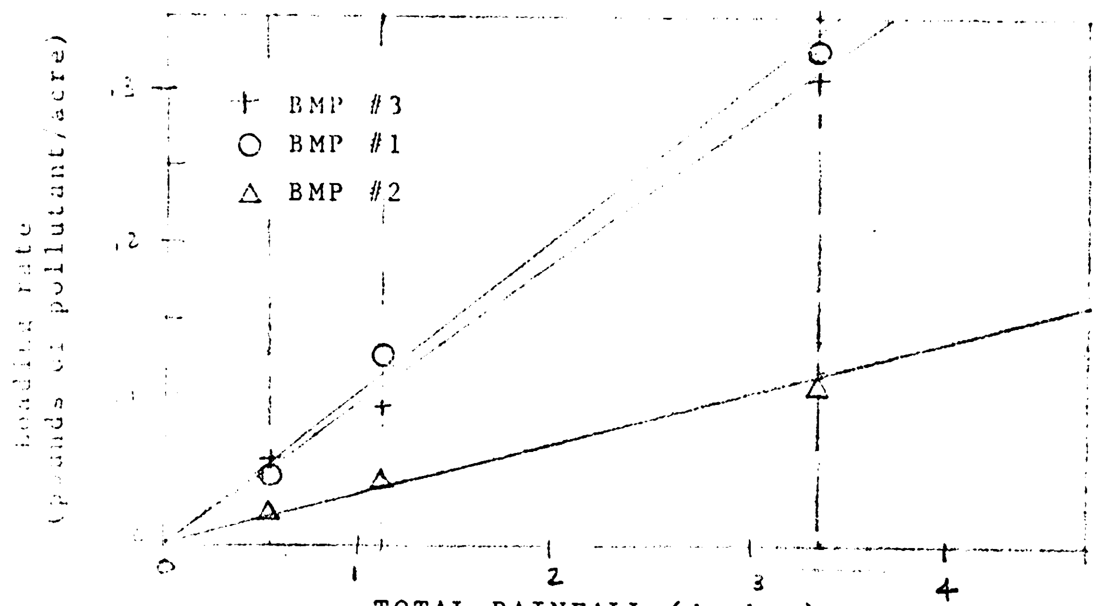


Figure 3. Hypothetical Loading vs. Rainfall Plots

Data from simultaneous measurements during a rain event should be plotted in this form as soon as they become available, so that management decisions can be made regarding the need for additional measurements. For the case shown in the figure, BMP's 1 & 3 have roughly equal loading rates. Thus one would not need to continue to compare these two methods. BMP's 1 and 2, on the other hand, have quite different loading rates. Depending on the potential for implementation and need for definitiveness, measurements could be continued or stopped once the general trends were clear.

For planning purposes, it is desirable to have information on many management practices. Therefore, the Consultant should process field data rapidly and supply the loading rate curves to the Agency for their review. If this protocol is followed, the utility of the field data can be assessed both from planning/management point of view and from the engineering/technical perspective. Unproductive avenues can be dropped as soon as this becomes apparent, and resources allocated to areas that either are proving to be or potentially are more fruitful.

TASK A-II: FIELD MONITORING

Field monitoring of alternative BMP's should provide data which can be used both to evaluate BMP effectiveness and as verification data for the mathematical model STORM. The program should provide for a sufficient number of storm-events at each site to allow an evaluation of the effectiveness of the control practice. On the other hand, the number of times a site is monitored must be kept small to allow for the maximum number of BMP's to be evaluated. Weather conditions for sampling should include at least one heavy and one light storm event, as a practice may be quite effective during light storms, but rendered ineffective by a heavy storm.

If the protocol recommended in Task A-1 is adopted, the Consultant will use the list of selected land uses and management practices to design the field sampling program. Once this is approved by HRWQA, the field operation will be initiated and water samples analyzed for appropriate water quality measures. Data, tabulated and also plotted in terms of loading rate and rainfall, will be submitted to HRWQA for review. The Consultant and the Agency will decide jointly whether a site will be sampled again after two rain events have been monitored. All data will be provided to the modelers for their use.

Several types of information are needed in this program. Basin characteristics can be determined once, but certain aspects, eg. vegetative cover, should be updated periodically. Rainfall should be monitored during site-events, and total rainfall for the rain events during the previous two weeks should be measured as well. The quantity of runoff should be determined for each site-event, and water samples should be collected for analysis of the runoff quality. Samples should be returned to the laboratory as soon as possible and should be analyzed within 72 hours, if at all possible.

A list of the recommended water quality analyses, plus other items to be monitored, are listed in Table 2.

If possible measurements of rainfall and runoff and the taking of samples should be accomplished with automated equipment. For most cases a single composite sample, collected flow proportionally, will be sufficient to characterize the system response. For those instances where runoff quality is expected to vary significantly over the duration of the event, eg runoff from impervious areas, discrete, sequential sampling may be required.

The primary difficulty encountered with manual sampling is that the field personnel must be on-site before the rainfall begins. Especially during the summer when weather patterns are highly localized, it is difficult to achieve this objective without expending considerable time, effort, and money on "dry runs". Automated equipment does not require the presence of personnel before the rain, only following it, so that labor costs are held to a minimum. Equipment costs, though, can be high. It should be noted that it is not necessary to monitor a large number of sites simultaneously. It is preferable to have sites with the same land use but different BMP's sampled simultaneously, to facilitate the data analysis and comparison, especially if only a limited number of storm events will be sampled. With this in mind, the following plan is suggested as a means of securing good data, minimizing both personnel and equipment charges, and allowing for the rapid initiation of the field program once a consultant has been selected.

The proposed plan is to survey land use groups individually and sequentially, with only three or four sets of automatic equipment. For this reason, the land uses/BMP's selected by the Agency should be listed in terms of decreasing priority. The field program would proceed incrementally down the list. The top priority group would be addressed first; that is, sites would

TABLE II - RUNOFF MONITORING

<u>Basin</u>

- size
- soil characteristic
- impervious area
- ground cover
- soil moisture content*

<u>Rainfall</u>

- total rainfall
- duration, (beginning + end time)
- intensity
- air temperature*

<u>Runoff Quantity</u>

- total runoff
- maximum flow* (+time)
- duration of runoff* (beginning + end time)

<u>Runoff Quality</u> ǂ

- Ammonia-Nitrogen
- Nitrate+Nitrite-Nitrogen
- Total Kjeldahl Nitrogen
- Soluble Reactive Phosphorus
- Total Phosphorus
- Dissolved Oxygen°
- Fecal Coliforms (Multiple Tube)°
- Suspended Solids (gravimetric)
- Settleable Solids (gravimetric)
- Water Temperature
- BOD5 (nitrification inhibited)°
- TOC

*Optional, but desirable

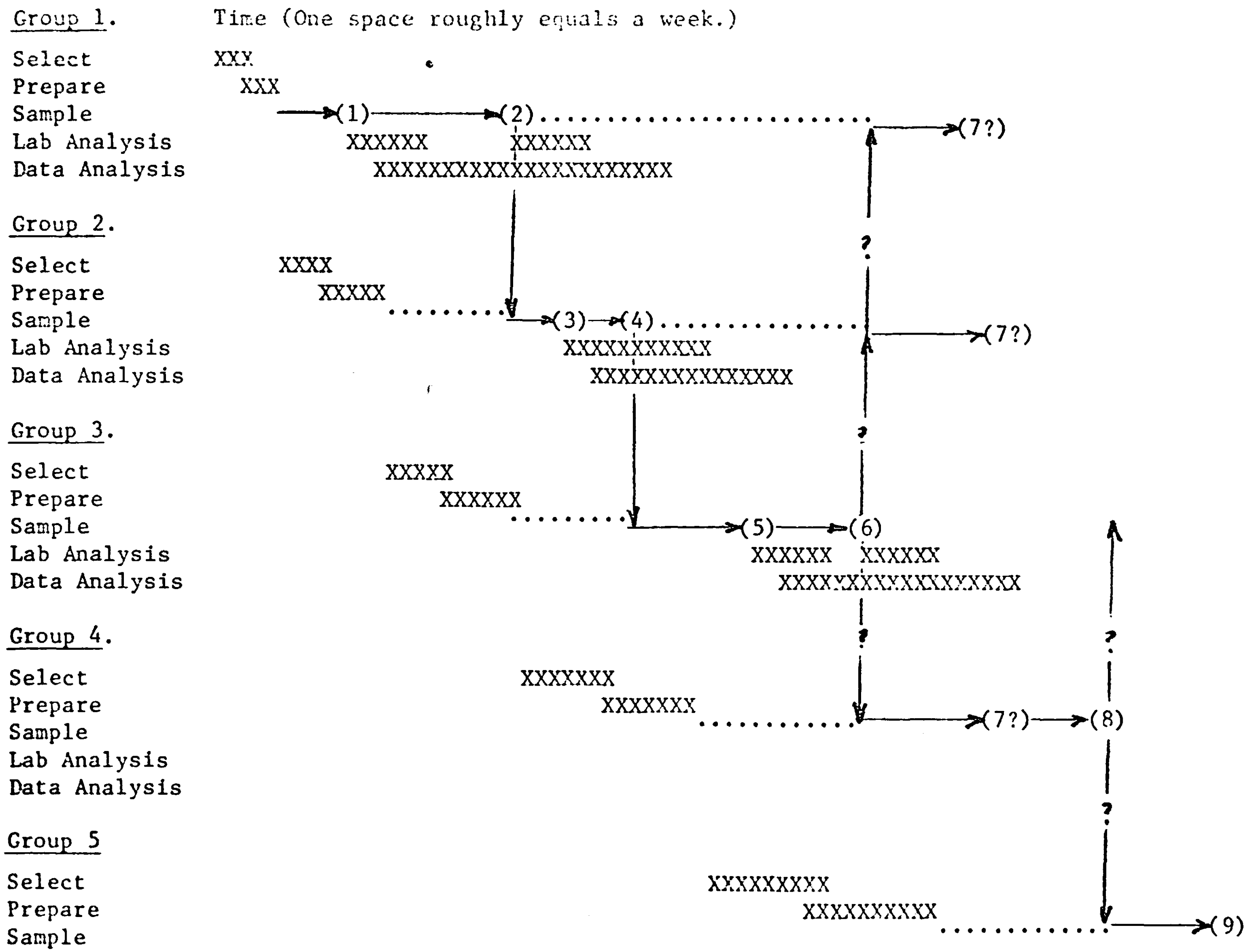
°Grab samples

ǂSynthetic quality control samples should be run periodically and/or samples split with other laboratories. Duplicates and spiked samples also should be a part of the analytical protocol.

be identified, sampling stations determined and prepared, and rain-event sampling initiated. As soon as the first set of sites was ready, during dry periods the personnel could begin selecting and preparing the second set of sites. Once a rain-event or two had been monitored at the first set of sites, the equipment would be moved to the second set of sites, and the work could begin selecting and preparing the third set of sites. This process would continue in this fashion down the list of land uses and BMP's. As laboratory analyses are completed and the data processed, the Consultant and the Agency would jointly determine whether the initial sites warrant further study or new sites should be sampled.

The schematic, Table 3, which follows illustrates how this system would work. This approach has several advantages. First, the field work could be initiated rapidly without waiting for all sites to be selected. Second, equipment purchases would be kept small since only a small set of sites would be monitored on any given rain event. Also, a small cadre of field technicians could effectively and efficiently prepare and maintain the sites, minimizing travel time, false-starts, and other non-productive factors. Finally, this approach would provide numerous opportunities during the study for The Agency and The Consultant to alter or redirect the field efforts as called for by the results of the initial samplings. To some, this "open ended" quality could be viewed as a disadvantage, since it would not be possible to specify precisely beforehand the number of sites and/or site-events which will be monitored during the study. However, experience in the previous 208 studies indicates that it is impossible to anticipate the results of field studies and that attempts to chart progress and products on precise time tables only leads to repeated revisions of these charts as time goes by. A suggested field program is given in Table 4.

Table 3. Schematic Work Plan for Nonpoint Source Test Sites



The symbol (7) indicates the seventh rain event. The horizontal arrows indicate preparedness for rain event sampling, and the vertical arrows represent the transfer of the automated equipment.

TABLE IV SUGGESTED FIELD PROGRAM FOR BMP TESTING

Priority	BMP GROUP	TYPE OF SAMPLE	Samples/ Event	NUMBER OF: Sites	Storms	Site-Events	Samples
1	Street Sweeping	Discrete	4	3	3	9	36
5	Porous Paving	Composite	1	2	3	6	6
3	Drainage Control	Composite	1	4	3	12	12
	Swales Curbs & Gutters Dike w/ Gravel outlet Mulching						
2	Settling Basins	Discrete	4	2	3	6	24
4	Vegetated Buffer Strips	Composite	1	3	3	9	9
	TOTAL			14		42	87

Sampling criteria, eg. time since last antecedant rainfall and minimum rainfall, will be land-use dependent and should be determined jointly by The Agency and The Consultant once the land use/BMP list is prepared.

TASK A-III: PREPARE DETAILED MANUALS

The data generated by the field sampling program will be used to provide comparisons of alternative management practices. The information should be compiled and presented in a manual for use by planners, land owners and others. The material should be presented in a clear, straight-forward fashion avoiding technical jargon and other aspects which would reduce the effectiveness of the manual. Although the matter is technical in nature, it should be presented in a non-technical fashion insofar as possible.

These manuals will be prepared by the Agency, one of the member agencies, or by one of the localities. The responsibility of the Consultant is to provide data from the field program, to assist in the interpretation of the data, and to review the manuals with regard to technical aspects.

PROGRAM B - LYNNHAVEN BAY

The previous 208 studies indicated that the Lynnhaven Bay system is relatively urbanized at present and that urbanization will become more complete by the turn of the century. There are signs that present nutrient loadings to the bay are sufficiently high to warrant attention now and that increased loadings could result in deteriorated water quality.

The mathematical model utilized in these studies was calibrated and validated with dry weather water quality conditions. Budgetary constraints did not allow measurement of stormwater impact in the receiving waters and the model validation with respect to the stormwater impact has not been conducted. The proposed study plan provides for the fine-tuned calibration of the mathematical model, field measurement and model simulation of stormwater impacts on receiving waters, and testing of control strategies utilizing information gathered in Program A - BMP Effectiveness.

TASK B-I FINE-TUNED CALIBRATION AND VALIDATION OF THE MATHEMATICAL WATER QUALITY MODEL OF THE RECEIVING WATERS

The water quality model of the Lynnhaven Bay developed for the 208 program is a tidal prism model. The physical transport of pollutants was effected by simulating the flushing of freshwater runoff and tidal flow. The model is capable of predicting instream distributions of dissolved oxygen, fecal coliform bacteria and salinity. The model also includes the simulation of the nitrogen cycle, phosphorus cycle, and phytoplankton growth. Therefore, the model requires a substantial amount of hydrographic data as well as water quality data for model calibration and validation.

A. Data Requirements

1. Estuary geometry

Geometric data in the forms of segment volume and mean segment depth are required as input data to the water quality model. These data are usually derived from the bathymetric data of cross-section profiles measured at a selected grid pattern. Bathymetric data of the Lynnhaven Bay have been measured by VIMS in the original 208 program. These data were used for the construction of the model.

2. Water surface elevation

Water surface elevation changes in response to tidal effect are needed for the calculation of the flow field. Several self-recording tide gauges were installed in the Lynnhaven Bay for the original 208 program. The data from these tide gauges were used for the construction of the water quality model. Additional sets of measurements covering periods of stormwater runoff should be made for the purpose of studying stormwater impact. Self-recording tide gauges should be installed simultaneously at locations shown in figure 4.

3. Current velocity

Current velocity data are not normally required for the model. They are calculated based on time varying water surface elevations and estuary geometry. However, current velocity data may serve to cross check the calculation. No current data were collected in the original 208 study. For this continuing study, current measurements should be made during the period tide gauges are installed. The measuring locations ~~and depths~~

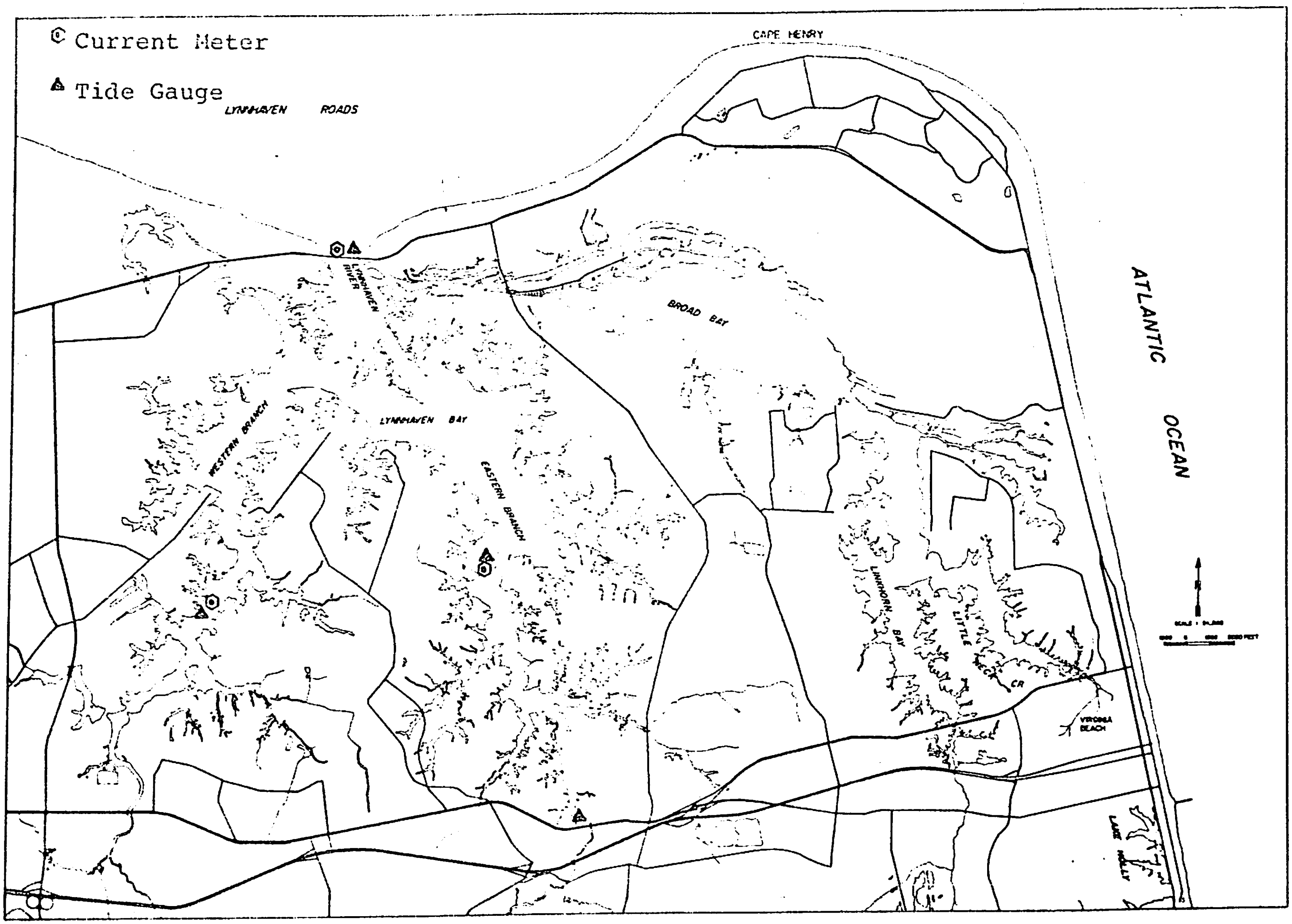


Figure 4 Tide gauge and current meter stations

are indicated in Figure 4.

4. Freshwater and point source discharges

Freshwater and point source discharges are the required input data of the water quality model. Because of its small topographic relief, the entire Lynnhaven system is under tidal influence and no stream gauges are installed in the system. The quantity as well as the quality of the freshwater runoff have to be calculated with the STORM model. Birchwood Gardens STP is the only point source discharge in the system. It discharges treated municipal waste water into Buchanan Creek of the Western Branch. The quantity and quality of this discharge should be monitored by the discharger, the State Water Control Board, or the Consultant.

5. Benthic oxygen demand

The oxygen demand of the benthic layer is often a significant sink of dissolved oxygen. Accurate measurements of benthic oxygen demand should greatly enhance the model calibration process. The oxygen demand should be measured in-situ to insure maximum accuarcy. Some benthic oxygen demand data were collected by VIMS in October, 1975. In the summer of 1979, VIMS collected more data in the Eastern Branch of the Bay. Additional measurements hould be made at stations indicated in Table 5. The stations in the Western Branch should be measured twice and the stations in the Eastern Branch should be measured once.

6. Meterological data

Solar radiation data are required as input to the water quality model. Wind speed and direction data may be needed to identify abnormal hydrographical and water quality conditions. These data can be obtained from National Weather Service or local weather stations.

7. Instream water quality data

Water quality data in the receiving water are required for model calibration and validation. To collect these data, two types of field surveys should be conducted. One is the slack water survey and the other is intensive survey. The slack water surveys consist of monthly trend monitoring to identify long-term (i.e. seasonal) water quality variations. The intensive survey consists of hourly intensive sampling to identify short-term (i.e. intra-tidal) water quality variation as the result of stormwater impact.

a. Slack water surveys

The trend monitoring of water quality should be conducted on a monthly basis. At least one survey should be conducted each month from April, 1980 to October 1980. Suggested sampling stations are shown in Figure 5. Table 5 shows the sampling depths at each of the stations.

b. Intensive stormwater impact survey

One intensive survey should be conducted in the months from June

Table 5 Water Quality Sampling Stations

Station	Sampling Depths*	$CBOD_u$	Benthic Demand
1	T,B		
2	M	X	X
3	M		
4	M		X
5	M	X	X
6	M		X
P1	M		X
S1	M		X
W1	M		
W2	M	X	
W3	M		
W4	M		X
W5	M		X
B1	M	X	X

* T = top or 2 ft below surface
B = bottom or 2 ft above bottom
M = mid-depth

The following water quality parameters should be measured or sampled at each station:

TKN
Ammonia nitrogen
Nitrite nitrogen
Nitrate nitrogen
Total phosphorus
Ortho-phosphorus
Chlorophyll "a"
BOD_5 (nitrogen inhibited)
Dissolved oxygen
Fecal Coliform
Salinity
Temperature
Secchi disk depth

In addition, samples for the ultimate BOD (nitrogen inhibited) should be collected at the selected stations as indicated above.

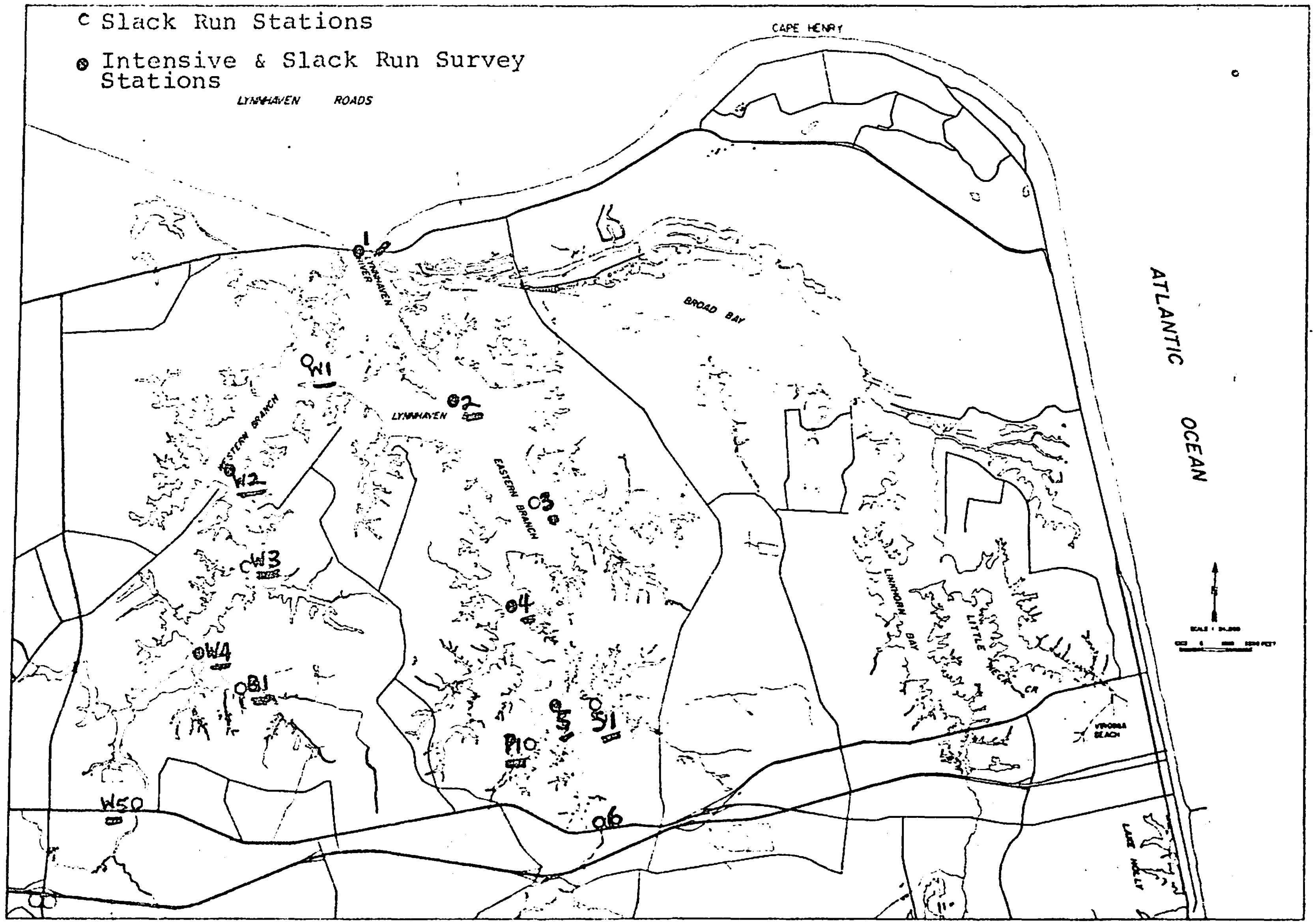


Figure 5 Water Quality Sampling Stations

to July 1980. The survey should start within one day after the storm event for which the nonpoint pollutant loadings are monitored. The sampling stations are shown in Figure 5. Table 6 shows the sampling frequency for each of the parameters. The survey should be conducted continuously for at least 25 hours.

B. Model Calibration

Most of the biochemical reaction constants in the simulated systems of water quality have been calibrated during the development of the model for the orignial 208 program. These calibrated values should be used as guides for the fine-tuned calibration of the model. The intensive survey data of this program should be used for model calibration.

C. Model Validation

One important usage of the model will be the evaluation of stormwater impact on water quality in the receiving waters. To demonstrate the model capability in this respect, the model should be validated with the intensive survey data collected after a storm event.

D. Model Documentation

The mathematical model should be documented in a report to the HRWQA. This report should include a description of the model and the refinement made over the original version, appropriate figures and tables demonstrating that the model has been calibrated, appropriate figures and tables demonstrating that the model has been validated for stormwater impacts, and the results of a sensitivity analysis of the model. The Consultant should either supply a tape or punched cards to the HRWQA or maintain a copy of the model in its files for use by others.

TASK B-II: FIELD DATA COLLECTION AND ANALYSIS

A. Tidal water surface elevation

Self-recording tide gauges should be installed simultaneously at the locations indicated in Figure 4 for a period of 19 days encompassing the days that stormwater impact are monitored.

B. Current measurements

Current measurements, velocity speed and direction, should be made at the sites stations and depths indicated in Figure 5 following the storm and concurrently with stormwater impact studies. These measurements should be made at least hourly, more frequently if possible, over 6 tidal cycles.

Table 6. Water Quality Sampling

	INTENSIVE SURVEY Sampling Period: 25 hrs Sampling Points: 7		SLACK SURVEY Sampling Period: 7 months Sampling Points: 15		
Analysis	Frequency	# Samples	Frequency*	# Samples	Total # Samples
Temperature	Hourly	175	M	135	310
Salinity	"	175	M	135	310
D.O.	"	175	M	135	310
TKN	Every 2 hr	91	M	135	226
Ammonia-N	"	91	M	135	226
Nitrite-N	"	91	M	135	226
Nitrate-N	"	91	M	135	226
Total-P	"	91	M	135	226
Ortho-P	"	91	M	135	226
Chlorophyll "a"	"	91	M	135	226
$CBOD_5$	Every 3 hr	63	M	135	226
Fecal Coliform	"	63	M	135	226
Secchi disk	Every 2 hr	91	M	135	226
$CBOD_u$			M	36	36

* Slack survey sampling will take place once per month, with an additional two in conjunction with the intensive survey.

C. Point source discharges

The Birchwood Gardens STP should be monitored. Data submitted to the State Water Control Board should be obtained and evaluated to assure that they are sufficient to provide long term background information. During the period of the stormwater impact study, the discharge should be monitored on at least three days, with samples collected throughout the day, if possible. The samples should be analyzed for the same parameters as water quality samples, listed in Table 5.

D. Benthic oxygen demand

Benthic oxygen demand measurements should be made at the nine stations listed in Table 5. Those stations in the Western Branch should be measured only once. The Consultant should submit the method for this measurement to the HRWQA for their approval.

E. Slack water surveys

Six same slack surveys should be made during the months of April through October 1980 at rougly monthly intervals. The stations and sampling depths are those given in Table 5 and samples should be analyzed for those parameters listed in the slack survey section of Task B-1. Two boats should be used for each survey to allow for simultaneous collection of samples in the Eastern and Western Branches.

F. Intensive stormwater impact survey

An intensive survey should be conducted during the months June through July 1980 to document stormwater impacts. Sampling stations are those shown in Figure 5, and the water quality analyses and frequency of sample collection are those shown in Table 5. Also two additional slack water surveys should be made roughly two and five days following the intensive survey.

G. Laboratory analyses

Water samples collected during any of the above field projects should be returned to the laboratory and analyzed quickly and within those time limits recommended by EPA, as often as this is possible. A quality assurance program should be developed and submitted to the HRWQA for their approval. This should include quality control, duplicate and spike samples, comparative analyses with EPA or other certified laboratories and so on.

H. Data report

The data resulting from the various field programs should be tabulated and included in a brief data report along with any additional information that is necessary to interpret the tabulated data.

TASK B-III: GENERATE NONPOINT SOURCE LOADINGS

The mathematical model STORM was used during the initial 208 studies to generate nonpoint source pollutant loadings. The Consultant will need to acquire this model (it is in the public domain) and be able to reproduce the loadings generated earlier. In addition, the model must be recalibrated to reproduce the runoff loads for the BMP's tested in Program A.

A. Operate the STORM model

The Consultant must acquire the model STORM and make it operational. Land use statistics, values of coefficients and other input data for the model should be obtained from the Malcolm Pirnie reports to HRWQA and used to generate nonpoint loadings. These loads should be compared with those generated by Malcom Pirnie, and any discrepancies between them must be accounted for.

B. Modify the STORM model

The field data collected from small catchments during storm events will be used to calibrate the storm runoff model. Through successive trials, and adjustment of parameters, the model will be adjusted until it reproduces total runoff volume, runoff duration, time rate of runoff, total pollutant runoff and, as closely as possible the curve of pollutant runoff versus time.

C. Interfacing STORM and Lynnhaven water quality model

The STORM runoff predictions should be written in such a way as to generate the nonpoint source loading inputs required by the water quality model. The data reformatting should be accomplished either by a subroutine or by a separate data handling step. In either case, disk file storage should be used throughout, thus eliminating hand calculation and key-punching.

TASK B-IV: ASSESS EFFECT OF BMP IMPLEMENTATION

The strength of mathematical models as planning tools is that alternative management strategies can be tested with minimal cost. For this particular instance, it is necessary to determine the water quality response of the receiving waters to implementation of BMP's. Although the Consultant will have prime responsibility for this task, close coordination with the HRWQA and its member agencies is a necessity.

A. Develop test plans

The data on BMP effectiveness generated in Program A should be used to develop various control strategies for reducing nonpoint source pollutant loadings to Lynnhaven Bay. These strategies could be developed according to various criteria such as minimum cost or maximum pollutant reduction, immediate change versus phased implementation, all land owners change versus BMP implementation with change in land use or modification of facilities. If data are available from the National Urban Runoff Program or other such projects, these too should be utilized in developing alternative management strategies.

B. Determine water quality effects of each test plan

STORM should be used to generate nonpoint source pollutant loads for each test plan, and the water quality model of Lynnhaven Bay utilized to determine what changes in water quality result with the implementation of each test plan.

C. Report on model testing

A brief report on the results of the model tests should be submitted to the HRWQA along with computer printouts of selected model runs. The format of this report should be that which provides the information easily and readily to the planning agencies.

PROGRAM C - NORTHWEST RIVER

During the previous 208 studies, the Northwest River was investigated with respect to population and land use trends, and nonpoint source pollutant loads. However, there was no study of the water quality of the river.

Over the last decade or so, there has been considerable study of the Northwest River with respect to its potential as a source of drinking water and the changes which might occur with varying water withdrawal rates. Recently, the City of Chesapeake began withdrawing water from the river just downstream of the Route 168 bridge. As part of the permitting process, the city has been monitoring and continues to monitor water quality at the intake site and at several locations downriver, the furthest point being near the mouth in Tull's Bay.

Since both population and employment are expected to increase significantly in the future, there is concern that these changes could lead to increased nonpoint source pollution and impair the quality of the river water. Although the data collected by the City of Chesapeake are interesting and useful for many purposes, they are not suitable for assessing nonpoint source impacts. Therefore it is necessary to provide a receiving water model of the Northwest River so that water quality changes which occur with land use shifts can be assessed.

TASK C-I DEVELOP A WATER QUALITY OF THE NORTHWEST RIVER

The Northwest River has the unique characteristic that it borders extensive swamp areas on both sides. During periods of dry weather, ground water from the Dismal Swamp feeds the river and sustains the river flow. In the event of rainfall, the surface runoff filters through the swamp to reach the river body. The common approach of directly linking the nonpoint source model model and receiving water model can not be applied here. The nonpoint source model, e.g. STORM, would provide the quantity and quality of stormwater runoff which discharges into the swamp. However, the water quality model of the receiving waters requires as input data the quantity and quality of water entering the river body. Therefore, there would be a data gap between the two. The lack of knowledge and understanding of the role of swamps, plus time and budget constraints preclude the closing of this data gap in this program. An alternate approach needs to be devised.

A. Model Description

On account of the data gap mentioned above it is recommended that a "black box" type of model be developed. That is, instead of simulating the physical and biochemical processes, an empirical or statistical relationship will be established between the instream water quality condition and the nonpoint source runoff.

1. Time Scale

The model should consist of two modes, one for the dry weather condition and the other for the stormwater runoff event. For the dry weather condition, the model should predict the steady, equilbrium water quality condition in response to given hydrological and meteorological conditions. For the stormwater runoff event, the model should predict the time varying water quality condition in response to the quantity and quality of nonpoint source runoff.

2. Spatial Scale

The major water quality concern of the Northwest River is the public water supply of the City of Chesapeake. Therefore, a model capable of predicting water quality conditions at the intake location would be sufficient. It is not necessary for the model to predict water quality condition throughout the length of the river. However, the model should be able to accept the input of nonpoint source runoff from each branch of the river.

3. Hydrodynamic Transport

Since the model would be a "black box" type, the simulation of hydrodynamic transport will not be affected by advection and diffusion processes. Some type of phase-lag response should be formulated empirically or statistically.

4. Water Quality Parameters

Because the river is a source of public water supply, the water quality parameters of the model should include at least fecal coliforms and the nitrogen series--organic-nitrogen, ammonia-nitrogen, nitrite and nitrate-nitrogen. The water in the Northwest River is characteristically acid swamp water. The organic rich bottom sediment exerts a high oxygen demand and the dissolved oxygen level is frequently less than 50% saturation. Since the dark water which restricts light penetration as well as acid pH minimizes algal growth, the study of the impact of alternate BMP's on eutrophication is not of high priority.

5. Data Requirements and Field Surveys

a. River Geometry

Since the water quality model will be a "black box" type model, detailed geometric data of the river is not necessary. A cross-sectional profile at the intake location will be sufficient. The cross-sectional profile is to be used to calculate the river discharge.

b. Water Surface Elevation

The water surface elevation at intake location should be measured at the same time current velocity is measured.

c. Current Velocity

The velocity distribution in the cross-section at the intake is required to calculate river discharges. The current may be measured with a hand held current meter. The cross-section should be partitioned into a minimum of three compartments, and at each compartment the current should be measured at least at two depths. The measurement should be made when the water quality samples are collected.

d. Freshwater and Point Source Discharges

Freshwater discharge and pollutant loading from stormwater runoff will be provided by the nonpoint source model STORM. The only point source upstream of the water intake is from a naval facility, which has a high degree of treatment. It is believed that the pollutant loading from this point source is insignificant. However, at least one set discharge data should be obtained.

e. Instream Water Quality Data

Two types of instream water quality surveys should be conducted, dry weather survey and stormwater impact survey.

1. Dry Weather Survey

Once a month from May to September, water quality samples should be collected at intake location to analyzed for the water quality parameters listed in A-4. The samples should be collected when there is no wind tide set-up. The current velocities (B-3) should be measured when water samples are collected.

2. Stormwater Impact Survey

Immediately after a storm for which the nonpoint runoff is monitored water sample collection and velocity measurements should be conducted at intake location every two hours until stormwater runoff recedes.

B. Modelling Studies

The Consultant will analyze data, develop necessary relationships, calibrate, and if data and budget constraints permit, verify the model. A report describing and documenting the model calibration and sensitivity analyses will also be provided.

TASK C-II - FIELD PROGRAM

A field program must be conducted to supply the data to calibrate the water quality model. These surveys should be conducted as specified in Task C-I, Section A - Data requirements and field surveys. All water samples collected should be returned to a qualified laboratory promptly and analyzed for the parameters noted within time limits specified by EPA. Standard methods should be employed and a quality assurance program should be established to insure the validity of the data.

The data from the field program should be tabulated and provided to the HRWQA along with a brief explaining sampling techniques, analytical methods and other information necessary for interpretation of the data.

The Consultant will meet with the agency or firm conducting the field surveys at least once to coordinate field and modelling efforts. Additionally the Consultant will advise and provide limited technical and field assistance as requested by the Agency.

A detailed description of the field program is given in the appendix.

TASK C-III GENERATION OF NONPOINT SOURCE LOADS

The Consultant should acquire the model STORM and make it operational using statistics and coefficients determined by Malcolm Pirnie Engineers in previous 208 studies. The model should be run and predictions compared with earlier values. Discrepancies between the two sets of predictions should be accounted for.

Using local climatological data and data generated by the BMP effectiveness studies and/or other nonpoint source programs, the Consultant should operate the STORM model to provide nonpoint source loadings for that portion of the Northwest River drainage basin above the Route 168 crossing of the river. Nonpoint loads should be estimated for the summer of 1980 and for the same set of water quality measures as used in the Lynnhaven studies.

TASK C-IV: ASSESS EFFECT OF CHANGING LAND USE

The Consultant should conduct a series of model runs using the STORM and river water quality models in order to assess the effects of projected land use changes. Land use statistics should be those generated in previous 208 studies, with any modification suggested by the HRWQA or its member agencies. At a minimum the models should simulate 1980 conditions, plus those projected for 1983 and 1995.

Should the predictions indicate degraded water quality conditions, the consultant should develop several strategies for reducing or eliminating these problems, and test these strategies with the STORM and the river water quality models.

A report should be prepared which presents the projected water quality trends and alternative control strategies for ameliorating any anticipated water quality problems.

SUGGESTED SCHEDULE AND ESTIMATED COSTS

The schedule for accomplishing the tasks is presented in the following table in terms of the beginning date and completion date for each task. It should be noted that the completion dates for the BMP field testing and the model studies are same as those in the Grant Amendment Request. However, to maintain this schedule the Consultant must be selected and a contract negotiated rapdily. In addition, The Agency and other interested parties must move quickly to identify those land uses which are of interest and importance, and to select those management practices which appear to have the greatest potential for implementation and amelioration of nonpoint pollution problems.

Costs for the several tasks have been estimated. These costs reflect wages and salaries, unit charges, indirect charges rates etc. which are in effect at VIMS. The estimates should be modified accordingly to determine the costs at other institutions or firms. The estimates by program are:

Program A:	BMP Effectiveness	$ 119,000
Program B:	Lynnhaven Bay	$ 95,000
Program C:	Northwest River	$ 23,000
	Total	$ 237,000

PROPOSED TIMETABLE

Tasks	Begin	End
Program A: BMP Effectiveness		
Select BMP's	April 1, 1980	April 30, 1980
Select Sites	May 1, 1980	July 31, 1980
Landowner Approval	May 10, 1980	August 10, 1980
Site Preparations	May 20, 1980	August 20, 1980
Sampling	June 1, 1980	October 31, 1980
Lab Analyses	Jnne 1, 1980	November 30, 1980
Data Analysis	June 1, 1980	December 31, 1980
Summary Report	January 1, 1981	March 31, 1981
Program B: Lynnhaven Bay		
Model Preparation	April 1, 1980	March 31, 1981
Calibrate/Modify	April 1, 1980	August 31, 1980
Validate (Stormwater Impact)	September 1, 1980	December 31, 1980
Documentation Report	January 1, 1981	March 31, 1981
Field Studies	April 1, 1980	December 31, 1989
Slackwater Surveys	April 1, 1980	October 31, 1980
Stormwater Survey	June 15, 1980	July 31, 1980
Data Report	November 1, 1980	December 31, 1980
STORM Model Preparation	April 1, 1980	December 31, 1980
Operate/Modify	April 1, 1980	June 30, 1980
Calibrate (1980 Conditions)	July 1, 1980	December 31, 1980
BMP Effectiveness Tests -	January 1, 1981	April 30, 1981
Program C: Northwest River		
Water Quality Model	April 1, 1980	February 28, 1980
Develop	April 1, 1980	September 30, 1980
Calibrate	October 1, 1980	December 31, 1980
Documentation Report	January 1, 1981	February 28, 1981
Field Studies	May 1, 1980	September 30, 1980
STORM Model Preparation	April, 1980	December 31, 1980
Operate/Modify	April 1, 1980	June 30, 1980
1980 Simulation	July 1, 1980	December 31, 1980
Land Use Changes Tests	January 1, 1981	April 31, 1981

PROGRAM A: BMP EFFECTIVENESS

Project Management, Data Analysis & Report Preparation					$35,000
	Hours	Rate	Amount		
Scientist/Eng'r	1400	$10	$14,000		
Technician	400	5	2,000		
Secretary	375	4	1,500		
	Subtotal			$17,500	
Fringe Benefits & Indrect Charges				17,500	
Major Equipment Purchases					$19,000
Flowmeter	4	$2250	$9,000		
Composite Samplers	4	950	3,800		
Accessories	4	200	800		
Fibreglas Sheds	4	750	3,000		
H-Flumes	8	200	1,600		
Recording Raingage	1	800	800		
Site Preparation - 14 Sites					$35,000
Labor:	Hours	Rate	Amount		
Scientist	8	$10	$ 80		
Field Eng'r	16	8	128		
Technician	64	7.25	464		
Technician	60	5.50	330		
	Subtotal			$1,002	
Fringe Benefits & Indirect Charges				$1,000	
Plywood flume				200	
Foundation for shed				100	
Travel 5 trips				100	
Supplies				100	
Total cost per site				$2,500	
Site Event Preparedness and Sampling (60 Site-events)					$30,000
Labor:	Hours	Rate	Amount		
Scientist	2	$10	$20		
Field Eng'r	4	8	32		
Technician	8	7.25	58		
Technician	12	5.50	66		
	Subtotal			$176	
Fringe Benefits & Indirect Charges				174	
Water Quality Analyses				100	
Travel				50	
	Cost per site-event			$500	
	TOTAL FOR PROGRAM A				$119,000

PROGRAM B: LYNNHAVEN BAY

Labor:	Rate	Hours B1	B2	B3	B4	Total	Amount
Scientist	$15	80	80	40	120	320	$ 4,800
Scientist	$13	–	60	440	140	640	8,320
Scientist	$10	400	120	–	60	580	5,800
Technician	$ 8	–	160	–	–	160	1,280
Technician	$ 6	400	400	–	–	800	4,800
Technician	$ 5	–	600	640	80	1320	6,600
Technician	$ 4	–	160	–	–	160	640
				Subtotal			$32,240
Water Quality Analyses		–	14,000	–	–		$14,000
Computer		$2,400	900	900	1,500		5,700
Travel		40	800	100	280		1,220
Boat Rental		–	4,000	–	–		4,000
Supplies		–	1,200	–	–		1,200
Equip Rental		–	2,000	–	–		2,000
Drafting, Printing		800	–	800	800		2,400
Fringe Benefits & Indirect Charges							32,240
		Total for Program B					$95,000

PROGRAM C: NORTHWEST RIVER

Task C-1: Water Quality Model — $18,680

Labor:	Hours	Rate	Amount	
Scientist	40	15	$ 600	
Grad Student	1 year		6,000	
Technician	138	7.25	1,000	
	Subtotal			$7,600
Fringe Benefits & Indirect Charges				7,600
Computer	9 hrs	$300		2,700
Travel				780

Task C-3: STORM Model Projections — $ 3,200

Labor	Hours	Rate	Amount	
Scientist	100	$13	$1,300	$1,300
Fringe Benefits & Indirect Charges				$1,300
Computer	2 hrs	$300		600

Task C-4: Water Quality Projections — $ 1,120

Labor	Hours	Rate	Amount	
Scientist	20	$15	300	
Scientist	20	13	260	
	Subtotal			$560
Fringe Benefits & Indirect Charges				560

TOTAL FOR PROGRAM C — $23,000

TABLE I. COMMON BMP'S FOR THE LYNNHAVEN AREA

Management Practice	HRWQA #	Category	Brief Description/Function
(1) Storm Sewer Inlet Protection	30.0520	Operation/Maintenance/management	1) Reduce availability construction-related pollutants 2) retain pollutants & polluted water on-site a map.
(2) Perimeter Dike	20.0123	Drainage System Composition	1) Direct sediment-laden storm runoff to on-site trapping facilities located at the perimeter of the site or disturbed area until area is stablized.
(3) Access Road	20.0160	Drainage System Composition	1) To provide routes 2) Minimize soil loss from erosion retards gully development, affords access & functions as turn-around area
(4) Gravel outlet	20.0131	Drainage System Composition	Drains storm runoff collected behind a sediment-retaining structure. TEMPORARY
(5) Swales and Waterways	20.0137	Drainage System	Provides disposal of excess surface water, reduces flow velocity w/out damage by erosion or flooding
(6) Temporary Seeding	10.0211	Vegetative/Runoff Absorption	Control erosion & sedimentation in areas where soil has been distribed
(7) Mulching	10.0221	Vegetative/Runoff Absorption	Conserves moisture; prevent surface compaction or crusting; reduces runoff & erosion controls weeds; helps establish plant cover on farm construction sites. Establishes vegetative cover for erosion reduction.

Management Practice	HRWQA #	Category	Brief Description/Function
(8) Topsoiling	10.0222	Vegetative/Run-off Absorption	Establishes vegetative cover for erosion reduction
(9) Permanent Seeding	10.0212	V-R/A	Protects soil surface
(10) Straw bale barrier	20.0124	Drainage System Composition	Traps sediment at on-site construction areas to prevent clogging of drainage control structures & reduce sediment runoff.
(11) Tree Protection	10.0260	V-R/A	Establishes stand of trees for erosion & sediment control, landscape beautification watershed protection, dust control & dune stabilization
(12) Erosion Control	30.2130	Operation/maintenance/management	prevents rills & gullies by permitting subsurface water migration w/out removal of soil particles.
(13) Diversion Dike or Ditch	20.0125	Drainage System Composition	Intercepts & diverts surface runoff

PROPOSED WATER QUALITY MEASUREMENTS OF THE NORTHWEST RIVER

Table 2 presents an outline of the information necessary to establish a data base with respect to seasonal water quality trends in the Northwest River, in the area of the City of Chesapeake water intake. Sampling sites include the area of the water intake facility, with alternate samples being taken from lines within base operations, containing untreated water. The parameters listed in the table are suggested due to their usefulness in the modeling efforts, and their pertinence in the evaluation of river water quality.

In cases where applicable, the use of meters and recorcers for the measurement of such parameters as dissolved oxygen or temperature is advised. Sampling frequency is minimally once permonth, although additional samples will greatly aid in the formation of a more complete data base. Sampling period is from May through September. Sampling efforts should be made during dry periods, a minimum of three days following a rain event.

An additional consideration, resources permitting, is an intensive study conducted for 26 hours, with hourly sampling for the following parameters; temperature, dissolved oxygen, turbidity, total nitrogen, total phosphorus and total organic carbon.

Table 3 summarizes research needs for the stormwater, "wet period" survey of the Northwest River. This survey should be made after a major storm event, and should continue until stormwaters have receded (this to be a joint decision between the Agency, the Consultant and the City of Chesapeake).

Table 4 outlines sampling and analytical protocol for determining point source inputs into the Northwest River, while Table 5 presents information necessary to satisfy hydrographic requirements of the model.

TABLE 2. DETERMINATION OF DRY WEATHER CONDITIONS & ESTABLISHMENT OF DATA BASE FOR NORTHWEST RIVER, VIRGINIA

SEASONAL TRENDS (Minimum Effort)	SEASONAL TRENDS (Optional Effort)
<u>Station</u>: Intake area, although additional stations are desirable.	<u>Station</u>: Intake area water available in treatment facilities, but untreated.
<u>Frequency</u>: Monthly, although greater frequency is advised.	<u>Frequency</u>: Daily, if possible, and unless otherwise noted.
<u>Measurements</u>:	<u>Measurements</u>:
Elevation*	Turbidity
Current Velocity**	Suspended Solids
Temperature (Min-Max if possible)	Organic Nitrogen (weekly)
Turbidity	Ammonia-Nitrogen (")
Suspended Solids	Nitrate-Nitrite (")
Secchi Depth	Nitrite-Nitrogen (")
Organic Nitrogen	Orthophosphate (")
Ammonia-Nitrogen	Total Phosphorus (")
Nitrate-Nitrogen	pH (")
Nitrite-Nitrogen	Sulfate (Optional)
Orthophosphate	Total Organic Carbon (weekly)***
Total Phosphorus	Biochemical Oxygen Demand (weekly)
pH	Fecal Coliforms (weekly)
Chloride	
Dissolved Oxygen (Min-Max if possible)	
Sulfate (Optional)	
Total Organic Carbon ***	
Biochemical Oxygen Demand (5 days)	
Biochemical Oxygen Demand (30 days)	
Chlorophyll <u>a</u> ***	
Fecal Coliforms	

Notes: Samples should be taken during dry weather conditions, a minimum of three days past a preceding rain event.

* For these samples, the Consultant will install a gauge or other device; the City of Chesapeake should be responsible for maintaining the device, and assisting in its installation.

** Current velocity measurements should be made at a minimum of six sites on a transect across the Northwest River, perpendicular to the intake site.

*** Chesapeake will collect these samples and perform pretreatment (filtering, preserving or freezing); the Consultant will perform analyses.

TABLE 3. DETERMINATION OF STORM EFFECTS ON NORTHWEST RIVER: SAMPLING PROTOCOL

STATION(S): A sample from the intake area is the minimum, however more samples are recommended.

FREQUENCY: Every two hours following the storm until stormwater has receded (There will be one storm survey).

MEASUREMENTS:
Elevation*
Velocity**
Temperature
Turbidity
Suspended Solids
Secchi Depth
Color (Optional)
Organic Nitrogen
Ammonia-Nitrogen
Nitrate-Nitrogen
Nitrite-Nitrogen
Orthophosphate
Total Phosphorus
pH
Chloride
Dissolved Oxygen
Sulfate (Optional)
Total Organic Carbon***
Biochemical Oxygen Demand (5 days)
Biochemical Oxygen Demand (30 days), daily
Chlorophyll a ***
Fecal Coliforms

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* For these measurements, the Consultant will install a guage or other device; the City of Chesapeake will be responsible for assisting in its installation, and maintenance.

** Current velocity measurements should be made at a minimum of 2 depths at 3 stations on a transect across the Northwest River, perpendicular to the intake site.

*** Chesapeake will collect these samples and perform pre-treatment (filtering, preserving or freezing); the Consultant will perform the analyses.

TABLE 4. QUANTIFICATION OF POINT SOURCES ON THE NORTHWEST RIVER, VIRGINIA; RECOMMENDED ANALYSES

STATIONS: All significant point sources.

FREQUENCY: At least once, preferably twice or three times.

MEASUREMENTS: Velocity/Flow
Suspended Solids
Turbidity
Organic Nitrogen
Nitrate-Nitrogen
Nitrite-Nitrogen
Ammonia-Nitrogen
Orthophosphate
Total Phosphorus
pH
Chloride
Dissolved Oxygen
Sulfate (Optional)
Total Organic Carbon*
BOD5
BOD30
Fecal Coliforms

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* Chesapeake will collect and perform pretreatment; the Consultant will perform analyses.

TABLE 5. ANALYSES NECESSARY TO DETERMINE HYDROGRAPHY OF CITY OF CHESAPEAKE INTAKE AREA ON THE NORTHWEST RIVER

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1. Cross-Sectional Profile

2. Water Surface Elevation (Joint effort between the Consultant and City of Chesapeake)

3. Current Velocity (Minimum of 2 depths at 3 sites across transect)