THE POTOMAC ESTUARY

CURRENT ASSESSMENT PAPER NO. 2

December 1977

Orterio Villa, Jr.
Leo J. Clark
Stephen E. Roesch
Susan K. Smith

Annapolis Field Office
Region III
U.S. Environmental Protection Agency

and

Norbert A. Jaworski, Ph.D.
Civil Engineering Department
Oregon State University

TABLE OF CONTENTS

INTRODUCTION

Since the first recorded observation of the water quality of the Potomac Estuary in 1608 by John Smith, considerable effort has been made to understand its numerous physical, chemical, and biological processes. These efforts are typified by studies of the Potomac tidal system conducted by the Annapolis Field Office (formerly the Chesapeake Technical Support Laboratory of the U.S. Public Health Service), beginning in 1964.

One of the major milestones of water quality management for the Potomac Estuary was the agreement resulting from the Potomac enforcement activities of the 1960's. This was the development of a "Memorandum of Understanding" limiting the amount of oxygen demanding materials and nutrients which could be discharged from wastewater facilities in the Washington, D.C., Metropolitan Area. A second result of the enforcement activity was an expanded water quality study of the estuary culminating in the publication of Technical Report 35, "Water Resource-Water Supply Study of the Potomac Estuary," April 1971.

With the passage of the Federal Water Pollution Control Act Amendment of 1972, the implementation of water quality management programs was effected mainly through the "National Pollutant Discharge Elimination System" and planning through Section 208 of the act relating to "areawide waste treatment management." Partially as a result of technical issues such as the ultimate disposal of sludges and the projected high cost of denitrification, considerable interest and debate continues both in the public and private sectors on the various approaches being developed for areawide waste treatment management.

Due to intense interest in the previous and current water quality studies of the Potomac Estuary, the authors of this report thought it would be prudent to put together a document which would attempt to clarify some of the more controversial water quality related issues.

In addition, the Annapolis Field Office of Region III, EPA, conducted water quality surveys in the Potomac Estuary in 1977 for the first time in several years. The data from these surveys are being processed and collated and will be utilized to (1) evaluate the current state of the estuary; (2) update our historical trend information; and (3) refine and update the Potomac Estuary Model. Interpretation of that data has begun and will continue for the next several months with a preliminary report of findings available in early 1978. Tentative findings of these surveys are presented in this report.

Monitoring of the Potomac will continue on a routine basis through at least one annual cycle, and hopefully two, in order to update our baseline data. Additional summer intensives are also envisioned as a part of this effort.

Section I of this paper presents a brief historical overview of some of the technical issues addressed in the past. Section II presents our thoughts on the subject of chlorophyll a and its utilization as an indicator of water quality. Section III is a present status report including major findings and conclusions extracted from the 1977 data. The addenda are included for informational purposes and are meant to serve as aids in unravelling the complex mix of technological terms and principles being used.

In publishing this paper, our hope is to clarify many of the technical issues that have surfaced and, where disagreements exist, at least allow us to talk in common terms concerning the relative importance and impact of these differences.

I. Historical Perspective

Since its inception in 1964, the Annapolis Field Office has been monitoring water quality conditions in the Potomac Estuary. Surveys for the acquisition of this data were conducted in order to determine existing water quality stresses, particularly with regard to standards violations, but more importantly, to better understand how the estuary behaves and why it responds the way it does. It became apparent quite early that the Potomac Estuary was plagued by two separate but interrelated problems which were (1) extremely low DO concentrations and (2) accelerated eutrophication, as evidenced by high nutrient levels and massive algal growth.

In relating DO concentrations* in the estuary to wastewater and other contributions of oxygen demanding material, a real time tidal mathematical model was expanded to include:

(1) carbonaceous BOD

(2) nitrogenous BOD

(3) benthic uptake

(4) algal respiration and oxygen production.

Reaction rates for the various interrelated oxygen demanding systems were obtained primarily from field and laboratory observations. Except for item four, these components of the DO budget have been included in previous modeling studies of other estuarine and river systems.

* DO concentrations have not only been developed as criteria for protecting various aquatic organisms but have been developed as a set of "standards" for regulations.

The hyper-eutrophic condition in the Potomac Estuary presented two problems in developing water quality management needs: (1) There were no standard accepted indicators of eutrophication in tidal systems and (2) the relationships between nutrient concentrations and trophic responses were not well-defined for tidal systems. Historically, most of the efforts in defining the causes and corrective needs of eutrophication were in freshwater lakes. Even the National Academy of Sciences was unable to recommend standardized techniques for quantifying the state of eutrophication in their Water Quality Criteria, 1972 publication.

Since algae impact DO through their diurnal photosynthesis-respiration cycle, as well as through their death and decomposition, and furthermore, since they can also create nuisance or aesthetically undesirable conditions, it was imperative that some measure of their levels or standing crop in the water column be made on a continuing basis. Chlorophyll *a*, a major pigment required for the conversion of solar energy into organic cellular material (photosynthesis) in both aquatic and terrestrial plants, was selected as an appropriate indicator of algal standing crop. Chlorophyll *a* had two features which were especially appealing: (1) It is relatively easy to analyze for in a laboratory and (2) the scientific literature is rich in the use, interpretation, acceptability, and limitations of this parameter based upon numerous studies.

The intent of measuring chlorophyll was not only to ascertain algal standing crop conditions but to: (1) provide an interpretative tool that would assist in the analysis of nutrient and DO data, (2) develop formulations expressing in-stream reactions and (3) establish interrelationships among these constituents for use in mathematical models. This latter purpose of chlorophyll data can best be exemplified by the course taken in Technical Report 35 to develop a water quality management program, including a nutrient control policy for the Potomac Estuary based on nutrient-phytoplankton-DO relationships.

It should be noted that chlorophyll a was not the only indicator of the hyper-eutrophic state of the upper Potomac Estuary. Others included the following:

1. A reconstruction of the ecological succession and nutrient loadings of the estuary from 1910 to the present

2. Transparency, primarily measured by Secchi Disk (this parameter is widely used by limnologists in lake studies)

3. Dominant algal species

4. Diurnal cycles of DO

5. The dissolved oxygen level in the lower estuary (this is equivalent to the measurement of DO in the hypolimnion in lakes).

Based upon the various adverse impacts caused by algae, which threaten compliance with current water quality standards, a subjective analysis was performed in order to establish an acceptable eutrophic state using chlorophyll a. It was termed a subjective analysis because a very limited amount of "hard" data existed and, consequently, judgement played an important role. Of these impacts, the one pertaining to aesthetics or nuisance conditions governed the selection of a 25 μg/l of chlorophyll a as an indication of an acceptable eutrophic state.

The next step entailed estimating the maximum nitrogen and phosphorus concentrations that could be present in the water in order to meet the 25 μg/l of chlorophyll and other objectives. Six independent methods were used to estimate maximum acceptable concentrations of phosphorus and nitrogen which would maintain a predetermined eutrophic level. They were:

(1) Algal composition analysis

(2) Analysis of data on an annual cycle and longitudinal profile basis

(3) Bioassay studies

(4) Nutrient and algal modeling

(5) Comparison with a less-stressed estuary

(6) Review of historical nutrient and ecological trends in the Potomac Estuary.

Carbon was not considered as a possible limiting nutrient because it could not be removed to the degree necessary to control algal growth. The nutrient criteria decided upon for Zones I, II, and III, which were expressed as ranges because of differences in growth potential among the various zones of the estuary, were:

Inorg N - 0.3 - 0.5 mg/l

Total P - 0.03 - 0.1 mg/l

In that the upper reach of the Potomac Estuary is usually light limited, the use of a linear acceptable concentration by zones is a practicable approach. Inherent in this approach is the possibility (mainly under low-flow and high temperature conditions) that for a short period of time undesired algal growth could occur in this upper reach because of exceptionally good water clarity. This means that the 25 μg/l of chlorophyll a could be exceeded. The main emphasis was placed on those reaches of the upper estuary which were suspected or proven to be conducive to algal growth.

The final step in the operation was to translate the above nutrient criteria, as well as oxygen demanding characteristics for DO enhancement, into allowable zonal loadings or maximum daily loads. This should not be confused with individual wasteload discharge allocations, which actually specify the source and location of individual waste inputs on a mass emission rate basis. Allowable zonal loadings strictly reflect the assimilative capacity of the particular zone commensurate with pre-selected water quality objectives.

A previously calibrated and verified mathematical model was used to establish the maximum allowable ultimate oxygen demand (UOD), nitrogen (N), and phosphorus (P) loadings under low-flow conditions. Attention is focused toward these particular parameters (UOD, N, and P) because of their direct or indirect influence on DO and the eutrophic state of the upper estuary. It can be implied from the foregoing discussion that chlorophyll served as a valuable indicator in the process of establishing a wastewater treatment policy, but that the ultimate aim was to comply with both specific water quality standards (DO) and general aesthetic (absence of nuisance conditions) water quality conditions which are legally enforceable.

It should be noted that Technical Report 35, while refining the loading allocations of the "Memorandum of Understanding," firmly established the following:

1. The upper Potomac Estuary has a limited capacity to receive oxygen demanding waste (finite limits were developed per zone in the report).

2. The upper estuary was experiencing serious eutrophication problems caused mainly by the discharge of nutrients from the wastewater facilities in the Washington Metropolitan Area.

3. Similar to the limits on oxygen demanding materials, there is a limit to the nutrient loadings that can be converted to biomass in the upper Potomac Estuary if a healthy ecosystem is to be maintained.

While refinements will continue to be made to the loading allocations and criteria values as more data are obtained, the basic conclusions, as stated above, are still valid today.

Another important point which should be made is that Technical Report 35 documented a scientific study that attempted to set forth technical information on water quality requirements for developing an achievable and sound wastewater management policy for the Potomac Estuary. It utilized the best available data base at that time (1970-71) but, like any scientific study, a strenuous effort must continually be made to fill data gaps, learn more about the natural system, re-evaluate certain assumptions, refine certain inputs that are known or suspected to be sensitive to the final results, and maintain the ability to temper previous results and conclusions accordingly. If current technology (advanced waste treatment) cannot deliver the effluent quality concentrations as predicted at the time Technical Report 35 was prepared and published, the feasibility of the wastewater management alternatives proposed in Technical Report 35 must be re-evaluated. An example of this re-evaluation was made in 1976 by EPA during the testimony of Dr. Jaworski at the Blue Plains Adjudicatory Hearing. The major conclusion of the re-evaluation was to delay the denitrification requirement for two years until the effect of phosphorus removal alone was evaluated.

It is the role of the scientists and engineers to objectively describe the water quality implication of various proposed treatment scenarios. It is the role of the policy maker to balance the predicted water quality implication against the costs for the various treatment scenarios and choose that best mix of management techniques that both meets the imposed regulatory responsibilities and is in the overall best interest of the public. It is important to incorporate into both roles the flexibility to take advantage of new data as it is developed.

More recent data and modeling efforts have reaffirmed that the upper estuary has limited ability to assimilate nutrients and yet maintain a healthy trophic state. In addition, the need for the control of nutrients (initially phosphorus and, if needed, nitrogen) to sustain a more desirable trophic state has been reinforced.

The definition of that desired trophic state and indicators used to describe it remain elusive to this day. An approach currently being endorsed by certain groups appears to be the adoption of a fixed chlorophyll concentration of 25 $\mu g/l$ throughout the entire estuary rather than setting nutrient concentrations by zones. Some of the shortcomings of this approach are presented in the next section.

II. Chlorophyll *a* as an Indicator of the Trophic State of the Upper Potomac Estuary

A great deal of discussion has recently taken place concerning the chlorophyll *a* concentration desirable in the Potomac Estuary. It is vitally important to realize that a specific chlorophyll *a* concentration or any other trophic state indicator* by itself has to be used with caution in defining the overall ecological health of a body of water for several reasons. First, it is difficult to obtain a representative water sample for chlorophyll *a* or any biomass indicator which is statistically valid since distribution in the water column is subject to the whims of wind, wave action, and currents. As a result, algal growths are not uniformly distributed and tend to concentrate in certain areas. Second, the identification of the specific algal species present is important since different species of algae have:

(1) Varying amounts of chlorophyll *a*

(2) Different sizes and behavior patterns

(3) Different grazing potentials

(4) Different growth and nutritional requirements

(5) Various impacts on the food chain.

Chlorophyll *a* is found in all algae but a chlorophyll *a* concentration alone does not discriminate between desirable and nuisance species. Ideally, a given level of chlorophyll *a* should be used in conjunction with the identity of the species of algae present at that time so that

* These include: (1) other measures of biomass such as dry weight, ATP or species counts, (2) diversity indices, (3) productivity, (4) transparency, and (5) DO levels in hypolimnion.

a grazing value can be approximated and the effects on the food chain inferred. A balanced community consisting of algal species which are utilized in the food chain would be a healthy link in the Potomac's biological regime.

The use of chlorophyll a is valuable as a relative indication of the algal standing crop, i.e., biomass. It aids in the evaluation of nutrient data, the assessment of nutrient impacts, and the interpretation of anomalies in the oxygen balance of receiving waters. It is a parameter that is useful in the interpretation of analytical data, but has not been developed to a point where it can be used as the sole indicator of a trophic state even in lakes.*

More important to the ecosystem, and more indicative of water quality than a specific chlorophyll level, is the overall health and balance of the biological community, including phytoplankton, zooplankton, and higher trophic levels. It is this entire biological system which we seek to improve. While various indicators have been and are being used to assess the trophic state of the upper estuary, the major emphases of Technical Report 35 and current activities are directed toward defining the maximum allowable nutrient concentration which will produce the desirable trophic state. This approach allows the use of multiple trophic state indicators and is consistent with the current state of knowledge for lakes, as summarized in the reference cited below.*

For the reasons outlined above, chlorophyll a as a sole indicator of the trophic state of the estuary cannot be defensibly supported at

* In a recent review of Trophic Status Indices, the readers are referred to "Summary Analysis of the U.S. Portion of the North American OECD Eutrophication Study Results Emphasizing Nutrient Loadings-Lake Responses Relationships and Trophic Status Indices," by Walter Rest and G. Fred Lee currently being published by EPA.

at this time. Thus it follows, in the opinion of the authors, that to consider chlorophyll a as a water quality criteria lacks scientific basis and, moreover, the data and the consequences of having chlorophyll a as a standard with enforcement implications have not yet been developed.

III. Present Status

There is a vital need for a continuing water quality monitoring program in the Potomac Estuary. This need is underscored in two separate but highly important ways: first, a very unique opportunity exists for establishing the impact of varying levels of advanced wastewater treatment in an estuarine environment, on a scale never before attempted; and second, data gaps are present that limit the degree in which cause and effect relationships in water quality behavior can be assessed. The second has particular importance in dictating the degree of confidence one can place in mathematical models and the manner in which they are calibrated and verified.

The Annapolis Field Office initiated an intensive monitoring program this past summer, which is expected to be continued and refined in subsequent summers, for the purpose of updating and expanding the Potomac Estuary's data base and attempt to provide answers relative to the denitrification issue. Some of the specific objectives of this monitoring effort are presented below:

1. To identify the major species of algae inhabiting the Potomac, their relative concentrations or counts, and to determine whether or not a relationship exists between dominant algal species and chlorophyll a magnitude.

2. To better define or quantitate some of the adverse impacts of algae such as diurnal DO variability and DO depletion attributable to algal death and decomposition.

3. To acquire data relative to the composition of algae cells and the nutritional status of these cells, with special emphasis on possible limiting nutrients, and to generally develop better nutrient-phytoplankton relationships.

4. To quantitate both point source waste discharges and upper basin loads entering the estuary at Chain Bridge with respect to nutrients, BOD, and other pertinent parameters.

5. To attempt to determine the impact of a storm event on the water quality of the estuary.

6. To refine some of the pertinent model rates and to provide a recent data set that could be used to upgrade and reverify the present Dynamic Estuary Model (DEM).

As can be seen from the above, a major thrust of the Potomac monitoring program is to more reliably establish current eutrophication levels and the implications of such levels in terms of nutrient concentrations. A considerable amount of chlorophyll a data was collected as part of this effort. These data are now being analyzed and information will be made available as soon as the interpretive phase is completed.

Some of the more important findings from the preliminary interpretation of the data are given below.

1. Minimum DO concentrations measured during the 12 slack water runs varied between 2 - 3 mg/l. With one exception (September 8), these levels occurred in the immediate vicinity of the Blue Plains Sewage Treatment Plant.

2. Chlorophyll levels were highly variable both over time and space. Maximum concentrations of about 300 μg/l were recorded during one week in August between Gunston Cove and Indian Head. Concentrations during the study period averaged between 100 to 150 micrograms per liter of chlorophyll *a*.

3. Phytoplankton counts and species identification were performed. During the early phase of the survey when chlorophyll levels were about 100 μg/l or less, there appeared to be some diversity in algal populations as both green and blue green varieties were observed. However, as the study progressed and chlorophyll levels attained their peak values, the blue green algae, *Oscillatoria*, became the dominant form, almost to the complete exclusion of the other forms observed earlier. *Anacystis cyanea*, the dominant form of algae inhabiting the Potomac Estuary during the 1960's, was not present to any noticeable degree.

4. Algal mats floating on the surface of the Potomac Estuary were never observed during the course of this study, as they were during the late 1960's, but the greenish tint was present in the high bloom areas extending from about the Woodrow Wilson Bridge to Sandy Point. The indigenous forms of freshwater algae this past summer appeared to be almost microscopic in size and well dispersed in the water column.

5. Water clarity of the Potomac Estuary was quite low, as usual, particularly in the middle reach which supports the major blooms. Typical Secchi Disk readings were about 20 - 24 inches. Minimum values during large algal blooms ranged between 7 - 12 inches, whereas the

maximum readings in the extreme upper reach (above Hains Point) ranged between 30 - 35 inches.

6. Blue Plains is by far the largest single point source discharger of oxygen demanding material and nutrients in the Potomac Estuary. During the study period it contributed an average flow of 276 mgd and the following average loadings:

BOD_5	-	81,000 lbs/day*
TKN	-	36,500 lbs/day
NH_3	-	32,500 lbs/day
NO_2+NO_3	-	250 lbs/day
TPO_4	-	12,000 lbs/day

In terms of BOD_5, TKN, and TPO_4, these loadings represent approximately 85, 75, and 55 percent, respectively, of the total point source wastewater load generated by the Washington Metropolitan Area.

7. Based upon a statistical analysis of intensive type data collected in the Potomac Estuary during 1965, 1968, 1969, and 1970, as well as the 1977 data, it can be concluded that DO concentrations in the critical reach have, in fact, improved with time. All of this data was collected at surface stations during high temperature-low flow periods having somewhat similar algal bloom intensities.

* On September 8, 1977, a mechanical breakdown occurred at the Blue Plains treatment plant causing a BOD_5 loading of 345,000 pounds. If this loading is eliminated from the data, the average BOD_5 loading becomes 58,000 lbs/day, representing 78 percent of the total point source BOD_5 load generated by the Washington Metropolitan Area.

8. Phosphorus concentrations in the upper Potomac Estuary showed a substantial decrease in 1977 over previous years. Inorganic nitrogen, on the other hand, did not exhibit a well defined trend in either direction.

9. An analysis of the spatial distribution of nutrients and chlorophyll (i.e., phytoplankton densities) in the Potomac Estuary indicates that the nitrogen may be limiting algal growth in the area of maximum production (downstream of Hallowing Point) since concentrations of inorganic nitrogen reach nondetectable levels during peak bloom periods. It is suspected that light may be the limiting factor in the upper zone (i.e., upstream of Piscataway Creek), where considerably lower chlorophyll levels are normally found.

10. Two attempts were made to track and monitor a discrete parcel of water in the upper Potomac Estuary between Rosier Bluff and Piscataway Creek over a semi-diurnal period extending from 0600 hours to about 1700 hours. A drogue was used for this purpose. During both occasions (August 16 and 30) tidal conditions, weather conditions, flows and water temperatures were very similar.

On August 16 the DO concentration (surface) was 1.5 mg/l at 0600 hours and increased to about 5.5 mg/l by 1700 hours. The ambient chlorophyll concentration was 80 μg/l. Computed rates of oxygen production were 0.0020 mg O_2/μg chloro/hr between 0600 and 1200 hours, and 0.0075 mg O_2/μg chloro/hr between 1200 and 1700 hours.

On August 30 the DO concentration (surface) varied from 2.5 mg/l at 0600 hours to 11 mg/l at 1700 hours. This variation translated to an oxygen production rate of 0.0049 mg O_2/μg chloro/hr. The ambient chlorophyll concentration was 135 μg/l and the weather was again mostly sunny and very hot.

ADDENDUM I

Zone I Loadings

	Chesapeake Technical Support Lab (1969)*	Annapolis Field Office (TR 35 1971)**
BOD_5	16,500[1]	---
UOD	---	75,000[2]
Total Inorganic N	---	3,400[2]
Total Unoxidized	8,000[1]	---
Phosphorus (as P)	740	900

1969 Conditions:

(1) flow = 705 cfs
(2) temp = 29°C
(3) DO objective = 5.0 mg/l

1971 Conditions:

(1) flow = 300 cfs
(2) temp = 29°C
(3) DO objective = 5.0 mg/l

Both 1969 and 1971 results are based on the following assumptions:

(1) all effluents are discharged into the main channel of the Potomac

(2) all effluents receive equivalent degrees of treatment.

Ultimate Oxygen Demand is calculated as follows:

$$UOD = 1.45\ BOD_5 + 4.57\ TKN$$

[1]In the 1969 zonal loadings BOD_5 and Total Kjeldahl Nitrogen (i.e., total unoxidized nitrogen) were considered in relation to their impact on the oxygen balance. No nitrogen criteria were proposed for nutrient control purposes.

[2]Technical Report 35 incorporated the BOD_5 and TKN into an Ultimate Oxygen Demand loading for dissolved oxygen control and also recommended an inorganic nitrogen guideline which would provide a degree of control of eutrophication related problems.

* Adopted by conferees in the "Memorandum of Understanding"

** Presented in Technical Report 35

ADDENDUM II

The Dynamic Nature of Technical Reports and Mathematical Models

Technical Report 35 was one of a series of reports presenting technical findings and was not meant to be the absolute "final" work on chlorophyll a guidelines or any other recommendations. Technical reports are periodically published and updated as new information becomes available. Unfortunately, due to higher priority commitments, we have not had the staff resources which would allow us to update Technical Report 35 as should have been accomplished by now.

Mathematical models are evolving tools which can and should be improved with time. One must recognize the limits of a math model or any other model where one tries to duplicate and eventually anticipate responses of natural ecosystems. It is presumptuous to try to differentiate between the impacts of 30 and 40 micrograms per liter of chlorophyll a with finality. Such differences are beyond the sensitivities of most models. The biological reaction rates which are contained in the model mechanisms are not that well known to provide such a degree of resolution. Other uncertainties exist which leads one to make somewhat subjective decisions concerning the inputs to a model. The output of any model run is only as good as the assumptions, rates, and data that have gone into it.

Mathematical models are predictive tools that operate within definable limits. Recognizing the sensitivity and accuracy with which a given model can predict future conditions based on known inputs and estimated reaction rates is a difficult and delicate process. As greater understanding of mechanisms and reaction rates is realized, models are modified and even recalibrated and reverified to incorporate this better information. This is a dynamic process. For these reasons we see no great shift of policy regarding either the recommended chlorophyll a levels or our general attitude towards the eutrophic condition of the Potomac. We recognize the need to decrease the magnitude of bloom events and we are convinced that we are proceeding towards that end in a reasonable and scientifically valid manner.

It is a known fact that algae need nitrogen and phosphorus, as well as other nutrients and favorable physical conditions, in order to grow. We know that at the present time we have an excess of both nitrogen and phosphorus. By removing a high percentage of the phosphorus at point sources we should inhibit algal growth under certain conditions, inducing a phosphorus-limited system. Until advanced waste treatment with a high degree of phosphorus removal goes on line, we will not know with certainty the estuarine response to this type of treatment. In that a healthy ecosystem also contains significant algal growth, the species are usually grazed by other organisms in the next level of the food chain, thus are considered to be beneficial to the ecosystem as a whole. What we want to achieve is a sufficient reduction in phosphorus loads to decrease bloom intensity and possibly induce a shift back to a utilizable species. Current model predictions indicate that phosphorus effluent concentrations as contained in area sewage treatment plant permits should result in a substantial decrease in algal bloom intensities, although not necessarily to a level of 25 μg/l of chlorophyll a on a continuous basis. There will be times when the levels will be less and under certain conditions the levels will be greater. More important than the 25 µg/l level is the enforcement of nutrient limits in the upper estuary in order to promote biological diversity without producing nuisance conditions.

No one knows with certainty what level of chlorophyll a will result in a healthy, ecologically balanced Potomac Estuary. Certainly it is different for different aquatic systems. The diversity of the algal species involved in the bloom, as well as the chlorophyll a level, are required to evaluate the biological health and stability of the estuary. Predictive tools such as methematical models, like other tools, must be used with care and restraint. Their predictions are not end products but merely guides that can be consulted in making managerial decisions.

Technical Report 35 did not consider the possibility of inducing a phosphorus limited system because of predicted low cost nitrogen control. Current planning makes this alternative more feasible because of the projected $100 million or more cost for a denitrification facility. If future studies show the desirability of additional controls, appropriate recommendations toward that goal will be made. However, they will not be made without adequate, verified, scientific information at hand.