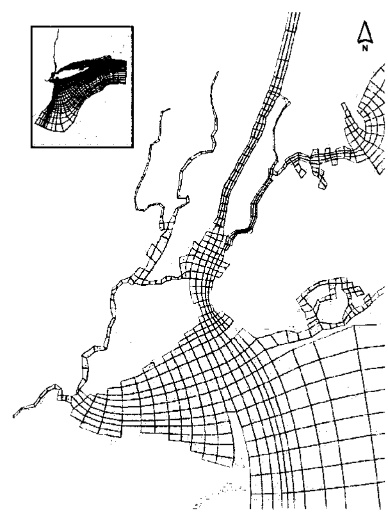
State of New Jersey
Department of Environmental Protection

Calibration Enhancement of the System-Wide Eutrophication Model (SWEM) in the New Jersey Tributaries

Final Technical Report
April 23, 2001 through July 31, 2002



HydroQual, Inc.
under agreement with the
Passaic Valley Sewerage Commissioners

PVSC0020
July 2002

CONTENTS

Section Page

EXECUTIVE SUMMARY ES-1

1 CONCLUSIONS AND RECOMMENDATIONS 1-1

2 INTRODUCTION 2-1

3 TASK 1 - HYDRODYNAMIC SUB-MODEL CALIBRATION/VALIDATION ENHANCEMENT 3-1
3.1 REFINEMENTS IN MODEL GEOMETRY 3-1
3.2 ADJUSTMENTS IN BOTTOM FRICTION 3-1
3.3 SWEM HYDRODYNAMICS CALIBRATION/VALIDATION 3-6

4 TASK 2 - WATER QUALITY SUB-MODEL CALIBRATION/VALIDATION ENHANCEMENTS 4-1
4.1 REVIEW OF CALIBRATION AND VALIDATION LOADINGS 4-1
4.2 TRIBUTARY INPUT LOADING ADJUSTMENTS 4-1
4.3 CSO AND STORMWATER LOADING CORRECTIONS 4-8
4.4 HYDRODYNAMIC TRANSPORT REVISIONS AND ADJUSTMENTS 4-10
4.5 ADJUSTMENTS TO VERTICAL MIXING COEFFICIENTS 4-10
4.6 ADJUSTMENT OF MODEL INPUT PARAMETERS, CONSTANTS, AND COEFFICIENTS 4-11
4.7 SWEM WATER QUALITY SUB-MODEL CALIBRATION/VALIDATION RESULTS AND SENSITIVITIES 4-15
4.8 DISCUSSION OF WATER QUALITY CALIBRATION/VALIDATION ENHANCEMENTS 4-23

5 RECOMMENDED MONITORING PROGRAM 5-1
5.1 ONE YEAR MONITORING PROGRAM FOR SWEM VALIDATION IN THE NEW JERSEY TRIBUTARIES 5-1
5.2 ONE YEAR MONITORING PROGRAM FOR ADDITIONAL INFORMATION FOR SWEM 1994-95 CALIBRATION 5-8
5.3 LONG-TERM MONITORING PROGRAM FOR NUTRIENT AND DISSOLVED OXYGEN MANAGEMENT 5-8

REFERENCES CITED 6-1

APPENDIX I - NEW JERSEY DEP COMMENTS AND HYDROQUAL RESPONSE
APPENDIX II - SCOPE OF WORK FOR SILICA CALIBRATION UPGRADE
APPENDIX III - MEASURED CARBON TO CHLOROPHYLL RATIOS
APPENDIX IV - CALIBRATION/VALIDATION DIAGRAMS (Under Separate Cover)

FIGURES

Figure		Page
2-1	SWEM computational grid for full model domain	2-2
3-1	Orthogonal curvilinear grids of SWEM (a) refined grid	3-2
	and (b) original grid	3-3
3-2	Bathymetric depths (m) of SWEM grid (a) refined grid,	3-4
	(b) original grid	3-5
3-3	Location of field survey data stations in New Jersey tributary area	3-7
3-4	Model computed water levels compared against the observed data at Sandy Hook, Battery Park and Bergen Point	3-9
3-5	Model computed salinity profiles compared against observed data at various stations in New Jersey tributaries (a) Raritan River and Bay	3-10
	(b) Hackensack River	3-11
	(c) Passaic River	3-12
3-6	Model computed temperature profiles compared against observed data at various stations in New Jersey tributaries (a) Raritan River and Bay	3-13
	(b) Hackensack River	3-14
	(c) Passaic River	3-15
3-7	Model computed surface and bottom salinity compared against observed data collected during NJDEP Coastal Monitoring Survey Program in 1988-89 period. Bottom two panels illustrates the river flows and winds used to force the model.	3-17
3-8	Model computed surface and bottom salinity compared against observed data collected during NYCDEP Harbor Survey Program conducted in Kill van Kull and Arthur Kill in 1988-89 period. Bottom two panels illustrates the river flows and winds used to force the model	3-18
4-1	Concentrations assigned for Hackensack River headwater loadings in SWEM	4-3
4-2	Concentrations assigned for Passaic River/Saddle River headwater loadings in SWEM	4-4
4-3	Concentrations assigned for Raritan River/South River headwater loadings in SWEM	4-5
4-4	Dissolved oxygen concentrations assigned for New Jersey tributary headwater loadings in SWEM	4-6
4-5	Algal carbon concentrations assigned for New Jersey tributary headwater loadings in SWEM	4-7
4-6	Loadings assigned in SWEM: comparisons between loading types and loading sources	4-9
4-7	Benthic bivalve biomass as measured in the New Jersey tributaries during 1994-95	4-13
4-8	SWEM sensitivity to vertical moving coefficient adjustments in the Raritan River, August 1995	4-16
4-9	SWEM sensitivity to vertical mixing coefficient adjustments in the Raritan River, September 1995	4-17
4-10	SWEM sensitivity to vertical mixing coefficient adjustments in the Hackensack River, August 1995	4-18
4-11	SWEM sensitivity to vertical mixing coefficient adjustments in the Hackensack River, September 1995	4-19
4-12	SWEM sensitivity to temperature dependence of nitrification rate, Hackensack River and Newark Bay, March 28 to April 8, 1995	4-21

FIGURES (Continued)

Figure | Page

4-13 SWEM sensitivity to temperature dependence of nitrification rate, Raritan River and Raritan Bay, December 10 to 16, 1995 4-22
4-14 SWEM sensitivity to temperature effects on algal growth rate....4-24
4-15 Demonstration of project benefits, Hackensack River and Newark Bay....4-25
4-16 Demonstration of project benefits, Passaic River....4-26
4-17 Demonstration of project benefits, Raritan River and Raritan Bay South....4-27
4-18 DIN Calibration temporal profiles at selected locations....4-29
4-19 POC calibration temporal profiles at selected locations....4-30
4-20 DO calibration temporal profiles at selected locations....4-31
4-21a Hackensack River and Newark Bay Calibration, August 1995....4-34
4-21b Hackensack River and Newark Bay Calibration, August 1995....4-35
4-22a Passaic River and Newark Bay Calibration, August 1995....4-37
4-22b Passaic River and Newark Bay Calibration, August 1995....4-38
4-23a Raritan River and Raritan Bay South Calibration, August 1995....4-41
4-23b Raritan River and Raritan Bay South Calibration, August 1995....4-42
4-24a Arthur Kill and Kill van Kull Calibration, August 1995....4-43
4-24b Arthur Kill and Kill van Kull Calibration, August 1995....4-44
5-1 Recommended station locations for a monitoring program to support further validation of SWEM in the New Jersey tributaries....5-7
5-2 Recommended station locations for monitoring program to support additional calibration of SWEM in the New Jersey tributaries under 1994-95 conditions....5-10

TABLES

Table | Page

Table 3-1 Adjusted bottom friction used in SWEM....3-6
Table 4-1 Revised SWEM Loads....4-8
Table 4-2a SWEM Dissolved Silica Calibration Scorecard.... 4-46
Table 4-2b SWEM Biogenic Silica Calibration Scorecard.... 4-47
Table 5-1 Monitoring Program for the Validation of SWEM in the New Jersey Tributaries....5-2
Table 5-2 Monitoring Program for Additional Information for SWEM 1994-95 New Jersey Tributaries Calibration....5-9

EXECUTIVE SUMMARY

Background

SWEM was developed by HydroQual, Inc., for the City of New York Department of Environmental Protection (NYCDEP) for NYCDEP planning purposes. The NY/NJ Harbor Estuary Program (HEP) maintained a strong interest in and oversight over the development of SWEM. SWEM underwent extensive technical review by representatives of the States of NY, NJ, and CT, and by panels of experts convened by both HEP and the Long Island Sound Study (LISS). The technical review process, with the concurrence of HydroQual, identified that if SWEM is to be used by HEP, LISS, and the States for regional nutrient management, enhancements to the calibration of SWEM in New Jersey waters are warranted. Through its representation on HEP's System-wide Nutrient Workgroup (SWNWG), the State of New Jersey Department of Environmental Protection (NJDEP) agreed to sponsor the necessary enhancements to the calibration of SWEM in New Jersey waters. The necessary enhancements are being performed on behalf of the NJDEP by HydroQual under an agreement with the Passaic Valley Sewerage Commissioners (PVSC).

Summary of Calibration Enhancements - Hydrodynamics

The areas of improvement identified for the enhancement of the SWEM hydrodynamic sub-model include refinements in model geometry (i.e., longitudinal resolution of the model grid segmentation and bathymetry) and adjustments in bottom friction. The Raritan River was re-segmented longitudinally and bathymetry adjustments were made in all three tributaries. Adjustments in bottom friction were made in the Hackensack River. These adjustments improved the calibration of the hydrodynamic sub-model to salinity and temperature as well as the calibration of the water quality sub-model to all of the state variables. A weakness of the calibration which remains is that the SWEM computational grid is restricted to only one lateral element wide in each of the three New Jersey tributaries. Lack of lateral resolution hampers the ability of a model to capture secondary currents and small-scale bathymetric features. Adjustments to bottom friction in SWEM serve as a compensating mechanism for limited lateral resolution.

Summary of Calibration Enhancements - Water Quality

The areas of improvement identified for the enhancement of the SWEM water quality sub-model include loadings, vertical mixing coefficients, benthic filtration rates, nitrification rates, vertical light extinction coefficients, and temperature effects on algal growth. The enhancements both improved the overall level of calibration and/or made SWEM more defensible. In the absence of data, tributary headwater loading concentrations as well as ambient light extinction coefficients were assigned using a more stringent protocol than was followed during the original calibration/validation. Adjustments to benthic filtration rates in the New Jersey tributaries were made in SWEM to make use of data that were not considered in the original SWEM calibration/validation. Adjustments to vertical mixing coefficients, temperature effects on algal growth, and nitrification rates improved the ability of SWEM to better represent measured ambient water quality data. The calibration enhancement effort has led to several conclusions and recommendations regarding the future application of SWEM.

Conclusions and recommendations regarding the future application of SWEM are presented in this report in Sections 1 and 5 and reflect both the professional judgment of HydroQual and feedback and guidance provided by NJDEP during its review of an earlier draft of this report. Section 1 highlights overall conclusions and recommendations. Section 5 presents detailed recommendations for future monitoring. The report appendix provides documentation of the NJDEP review.

SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

- SWEM is a suitable planning tool for addressing nutrient management and regulatory issues in the NY/NJ Harbor Estuary. Further, SWEM is technically defensible and is generally appropriate for TMDL/WLA/LA development in most of the estuary. Collection of additional data in the New Jersey tributaries and, potentially, further SWEM enhancement or additional model development is recommended for TMDL/WLA/LA development within these waters. It is judged, however, that the model is satisfactory at present for preliminary management planning in the New Jersey tributaries.

- As with any model, the application of SWEM for management decisions will require an understanding of model limitations and a judicious interpretation of results.

- Although SWEM is ready to be applied to answer nitrogen and carbon management questions, there still remains room for improvement. In particular, landside loadings (i.e., CSO and stormwater runoff) in SWEM are assigned based on the outputs of a hybrid of Storm Water Management Models (SWMM) and the Rainfall Runoff Modeling Program (RRMP). RRMP was developed and calibrated in the 1970's by HydroQual and has not been updated since. SWMM outputs represent the current best estimates of landside loadings. Unfortunately, SWMM outputs are available to HydroQual only for a limited portion of the SWEM drainage area, basically New York City. To the extent that SWMM outputs are available for New Jersey and other jurisdictions, these should be incorporated in SWEM. To put proper perspective on the significance of this weakness, it is important to remember that for nutrients, CSOs and storm water runoff are only a small percentage (i.e., less than 3% of the total nitrogen loading system wide excluding open ocean inputs) of the total loading. The urgency for inclusion in the model of all available SWMM outputs would apply more in the context of pathogens management rather than nutrient management.

- The synoptic field program conducted in 1994-95 in support of SWEM as well as supplemental monitoring funded by the New Jersey Harbor Dischargers Group (NJHDG) provides a spatially and temporally comprehensive database to fully support calibration and skill assessment of SWEM. The monitoring addressed all SWEM elements: hydrodynamics, loadings, detailed water column biology and chemistry, and sediment fluxes. While the calibration database is unprecedented in terms of its extent, several shortcomings are noted:

- Measurements of light extinction are missing in the New Jersey tributaries. This is due in part to the fact that monitoring was conducted around the clock and sampling events conducted at night do not include light extinction measurements. During other sampling events, there were photometer problems and valid readings were not obtained. Light extinction measurements can be made at a low cost using secchi disks. It is recommended that secchi disk depth be routinely monitored in the New Jersey tributaries as is done in other portions of the Harbor for which extant secchi disk depth measurements from 1994-95 were used to supplement the calibration database. In the New Jersey tributaries in general, there are more nutrients available than the phytoplankton can use and light plays a critical role in controlling or limiting algal growth. It is primarily through algal growth that nutrients are linked to the dissolved oxygen balance. For these reasons, it is important that light penetration be properly accounted for in SWEM.

- The laboratory which conducted the monitoring program in support of SWEM chose to group tributary headwaters with the loading sampling rather than with ambient water sampling. As a result, no direct measurements were made of algal biomass at tributary headwaters and dissolved oxygen was not measured either. As a result, the tributary headwater concentrations for algal carbon and dissolved oxygen assigned in SWEM are estimated as opposed to based on direct measurements.

- The monitoring program in support of SWEM was designed to include twelve ambient sampling events and sampling of loads over twelve months. Due to budgetary problems with the laboratory, the scope of the monitoring program was reduced to nine ambient sampling events and sampling of loads over eight months. The scope reduction of the sampling of loads is the reason why tributary headwater input concentrations are not available for the months October and July through September.

❑ The water year 1988-89 was selected as the SWEM validation year because there is a significant database available (although not as comprehensive as the 1994-95 database) from the Long Island Sound Study for the calibration of the LIS3.0 model, and it is the year upon which the Long Island Sound nitrogen TMDL is based. 1988-89 was also selected because it represents a markedly different condition than 1994-95, providing an opportunity to demonstrate SWEM robustness. Unfortunately, the 1988-89 database is lacking in the New Jersey tributaries. For this reason, it is appropriate to say that SWEM has been validated in Harbor and Sound waters, but not in the New Jersey tributaries. No other year or hybrid of years was identified as having enough data to serve as a validation condition for the New Jersey tributaries. Where possible, 1988-89 SWEM results in the New Jersey tributaries and adjacent waters are compared to data from years between 1988 and 1995, providing a very cursory, gross scale skill assessment.

- The project to enhance the calibration of SWEM in the New Jersey tributaries was a fruitful effort which both improved the level of calibration of SWEM in the three tributary rivers and strengthened the technical basis of assumptions/judgments made in assigning SWEM input values in the absence of data.

- Calibration of SWEM in the Hackensack River was more difficult than originally anticipated at the outset of the project and is limited by a lack of lateral segmentation in the SWEM computational grid and a lack of detailed kinetics for marsh related phenomena.

- In most marine environments, and in the NY/NJ Harbor Estuary complex, nitrogen is the nutrient which is typically managed or controlled. In addition to nitrogen, phosphorus and silica are also important to algal growth and thus the dissolved oxygen balance and have been included in SWEM. In all waters, the SWEM silica calibration is deficient in comparison to nitrogen. This deficiency is being addressed by a study now commencing under funding from the New York City Department of Environmental Protection and could eventually lead to a correction throughout the SWEM domain. As silica may periodically be limiting to algal growth instead of nitrogen in certain Harbor locations, it is advantageous to perfect the silica calibration.

- Modeling now being conducted in the NY/NJ Harbor Estuary under the CARP program will necessitate that SWEM be run for four additional water years, covering 1998 through 2002. The SWEM effort under CARP is a significant opportunity in that it provides the opportunity to have available the necessary SWEM hydrodynamic and carbon inputs to test nutrient management actions in SWEM under a total of six different hydrodynamic, hydrological, and meteorological conditions. Further if nutrient data are available for the four additional years for which SWEM will be run under CARP, it would be possible to perform further skill assessment of SWEM. It is noted that it is unlikely that enough data exist from 1998 through 2002 to support a full SWEM validation in the New Jersey tributaries. At the very least, organic carbon measurements made for CARP can be used for a further skill assessment of SWEM.

SECTION 2

INTRODUCTION

This report presents the technical details of calibration/validation enhancements to the System-wide Eutrophication Model (SWEM) in the Hackensack, Passaic, and Raritan Rivers. The calibration/validation of SWEM for the full model domain, as shown in Figure 2-1, and the initial calibration/validation efforts in the Hackensack, Passaic, and Raritan Rivers have been previously presented by HydroQual in a series of technical reports and have been approved through a peer review process by representatives of the States of NY, NJ, and CT, and by panels of experts convened by both the Harbor Estuary Program (HEP) and the Long Island Sound Study (LISS). This report will not present a review of the initial calibration/validation, but will present enhancements to the calibration/validation of SWEM in New Jersey waters. It is assumed that this report will be used by individuals already familiar with SWEM and the physical features of the estuarine portions of the Hackensack, Passaic, and Raritan Rivers.

Model calibration involves the adjustment of model forcings, constants, coefficients, parameters, and formulations so that the model is able to reproduce the major trends in observed data and explain causality. Model validation involves applying the calibrated model under a different set of environmental conditions. In the validation procedure, the calibrated model is not changed. Enhancements to SWEM conducted under this project were applied to both the calibration and validation. The only allowable differences between calibration and validation are model inputs associated with the specification of the measured or observed conditions specific to calibration or validation conditions (i.e., temperature, precipitation, light extinction, etc., for a given year).

This report is broken down into two major sections or tasks which address the sub-models that comprise SWEM: hydrodynamics and water quality. Within each sub-model section, emphasis is placed on the calibration year 1994-95 since for this period a comprehensive database is available for calibration. An additional year, 1988-89, is also considered as it is the validation year for SWEM. The 1988-89 database is not as extensive as the 1994-95 database and is particularly lacking in the New Jersey tributaries. Although the 1988-89 database was sufficient for validation purposes in the Harbor and in Long Island Sound, it does not provide for a robust model skill assessment in the Hackensack, Passaic, and Raritan Rivers. Where possible, data from other years are included in comparisons to 1988-89 model results to supplement the 1988-89 database. Overall, there is not a sufficient database available to validate the calibration of SWEM in the Hackensack, Passaic, and Raritan Rivers.

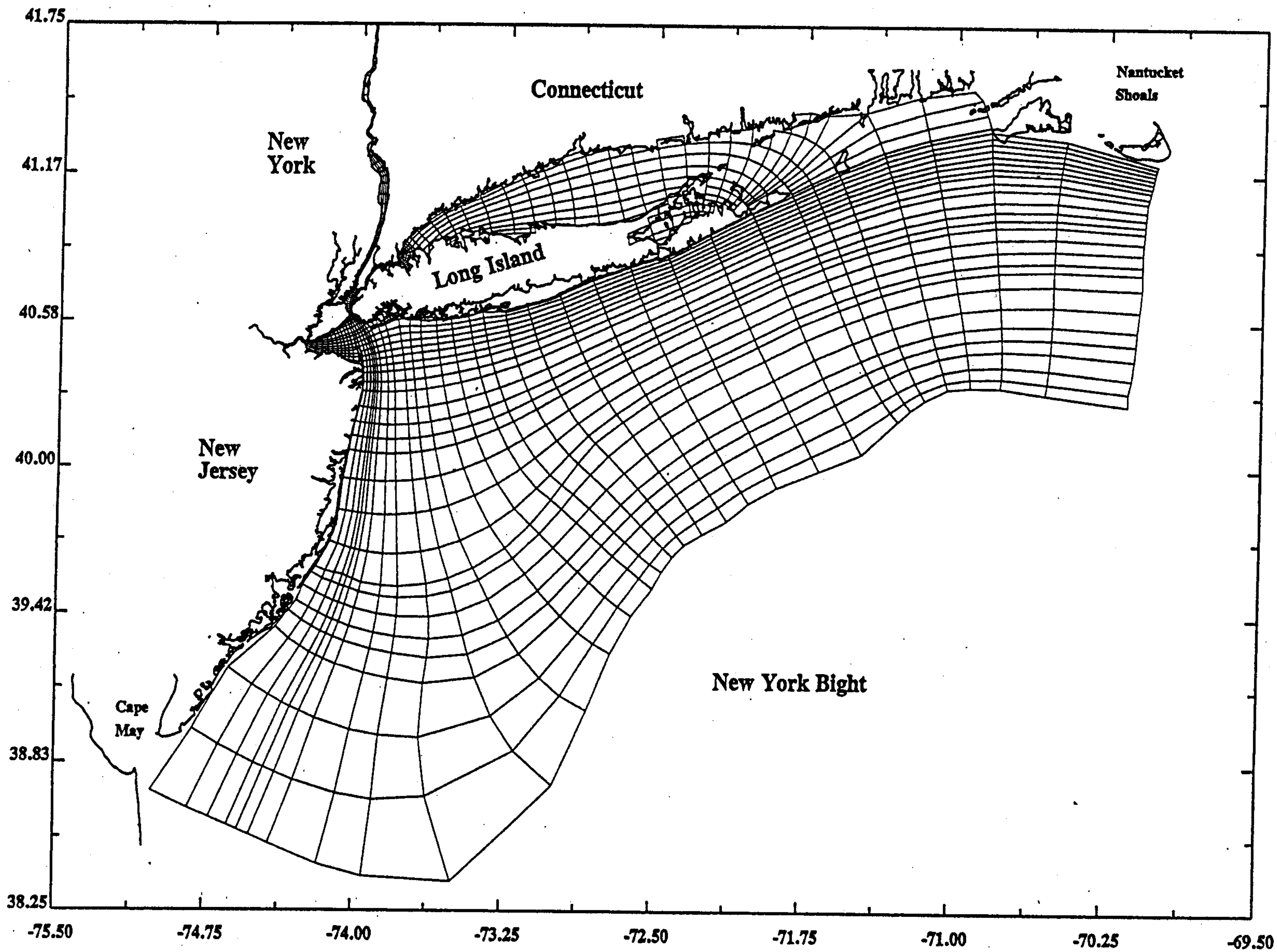


Figure 2-1 **Model Grid for System Wide Eutrophication Model: Complete Model Domain**

Efforts to obtain validation data collected from 1988-89 and other years between 1988-89 and 1994-95 included obtaining several databases:

Academy of Natural Sciences of Philadelphia. 1994. Data Collection Program in Support of the Harbor-Wide Eutrophication Model for the New York - New Jersey Harbor Estuary Program. Report No. 94-29D.

Connell, R., Jr. and L. Messler. 1990. New Jersey Ambient Monitoring Program Report on Coastal and Estuarine Water Quality 1989-1990. NJ Department of Environmental Protection and Energy. Division of Science and Research.

General Testing Corporation. 1990. Bergen County Utilities Authority Impact Analysis of Sewage Treatment Plant Discharges on the Water Quality of the Lower Hackensack River. Appendix B. Part 1: Analytical Data. Submitted to Clinton Bogert Associates.

Hackensack Meadowlands Development Commission and United States Geologic Service. 1994. May - May 93-94 Water Quality Monitoring. Unpublished data available upon request from the Hackensack Meadowlands Development Commission.

Olsen, P.S., and R. Mulcahy. 1991. Red Tides in the Hudson-Raritan Estuary are Associated with Hypoxia and Consequent Fauna Kills. Presentation to Fifth International Conference on Toxic Marine Phytoplankton. Newport, R.I.

These databases, however, are not complete enough for model validation and data comparison purposes for the New Jersey tributaries for a number of reasons. In general, there are no data available for the Passaic and Raritan Rivers or Newark Bay and many of the relevant water quality parameters were not measured. Further, measurements were generally not taken between October 1988 and September 1989. More specifically, the Academy of Natural Sciences database was collected mainly for purposes of defining reactivity rates of different loadings to the SWEM domain and was not intended to provide a validation data set. Reactivity rates derived from Academy of Natural Sciences data collected in the early 1990's are applied in SWEM under both 1994-1995 and 1988-1989 conditions. Data collected by Connell and Messler and Olsen and Mulcahy during the summers of 1989 and 1990 emphasize dissolved oxygen and chlorophyll rather than nutrients and are focused on the waters of Raritan Bay and the New York Bight rather than the New Jersey tributaries. These data are included on the 1988-89 Raritan Bay validation transect plots included in the report appendix. The Bergen County Utilities Authority (BCUA) data, reported by General Testing Corporation are limited to the Hackensack River and were predominantly collected in 1988 before the 1988-89 validation period which begins in October 1988. For reference, BCUA data collected in 1988 are shown in the report appendix model versus data comparisons with model results from the corresponding month in 1989. Although this is admittedly a mismatch of conditions, the 1988 measurements provide some level of guidance for 1989 calculations. Similar to the BCUA data, the Hackensack Meadowlands Development Commission (HMDC) Hackensack River data were not collected during 1988-89 and are shown in the report appendix model and data comparisons for the corresponding month in the validation year for guidance purposes.

The conclusion of obtaining these databases and plotting them against model results along spatial transects is that within the measured data, there are clearly features unique to a given year that a model calculation from a different year will certainly miss. However, the model does reasonably well in some cases at reproducing the features of a different year, suggesting, in some instances, that different years may share common biological and chemical behavior.

The purpose for performing enhancements to SWEM in the Hackensack, Passaic, and Raritan Rivers is to provide the regional managers (i.e., USEPA Region 2 and the States of New Jersey and New York) with a technically defensible management tool that could support nutrient TMDL development for the Harbor.

SECTION 3

TASK 1 - HYDRODYNAMIC SUB-MODEL CALIBRATION/VALIDATION ENHANCEMENT

This report section describes an assessment of the original SWEM hydrodynamic sub-model calibration in the New Jersey tributary system and the areas of necessary improvements which have been identified. The necessary improvements include model geometry and bottom friction. Further, this report section includes a skill assessment, or model and data comparisons, for the enhanced hydrodynamic sub-model calibration/validation.

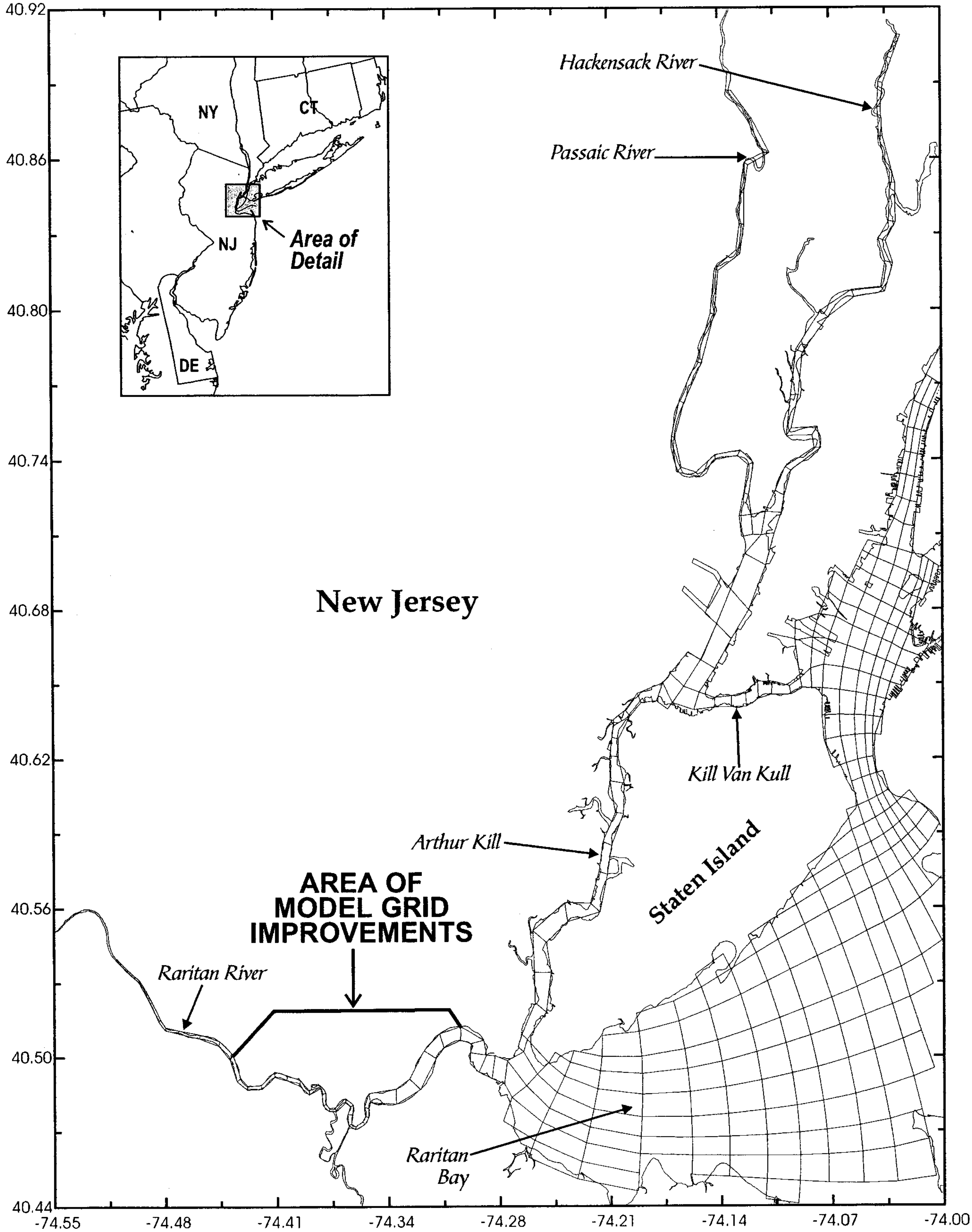
3.1 REFINEMENTS IN MODEL GEOMETRY

Accurate representation of the river geometry is important for modeling the hydrodynamics and water quality of the New Jersey tributary system. Comparison of the existing SWEM model geometry and the actual river bathymetry has been made using recent NOAA Charts (12327, 12332, and 12337). The original SWEM model grid was not fine enough to resolve the coastline features of the Raritan River. The Raritan River grid was redesigned (i.e., more longitudinal segments were added) to better resolve the bathymetric and shoreline features, especially near the meandering and narrow reaches of the river. The Passaic River coastline was resolved adequately and the Hackensack River was resolved fairly well in the previous effort by HydroQual. No changes in the grid resolution were made in Passaic and Hackensack Rivers. Figures 3-1a and 3-1b illustrate the comparison of the redesigned and the original SWEM grids in the New Jersey tributaries area.

Significant improvements in river bathymetry have been made in order to accurately resolve the bathymetric features of all the rivers including the Raritan, the Passaic, and the Hackensack River. The NOAA hydrographic chart was used to gather coastline and bathymetric information for upgrading the river geometry. Accurate resolution in bathymetry is important in order to accurately model the transport physics, and salinity and temperature structure in the Rivers. Figures 3-2a and 3-2b illustrate the bathymetric features of the redesigned and original SWEM computational grids.

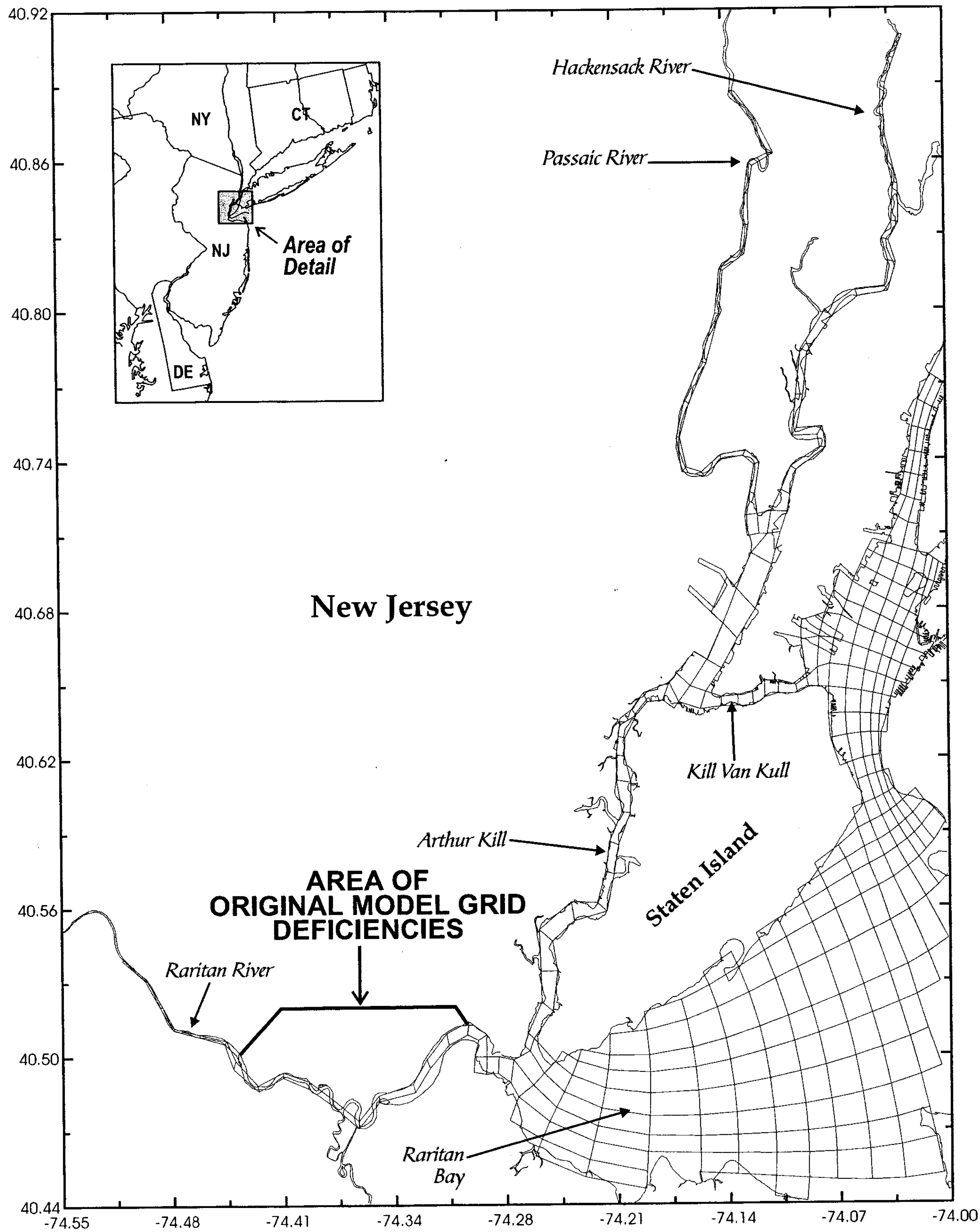
3.2 ADJUSTMENTS IN BOTTOM FRICTION

In addition to the improved coastline and bathymetric representation of the New Jersey tributaries, hydrodynamic calibration parameters have also been readjusted and reconfigured in SWEM. Hydrodynamic calibration parameters were adjusted to better parameterize small scale physics not resolved by the computational grid. For example, the model grid does not provide any



40.92
40.86
40.80
40.74
40.68
40.62
40.56
40.50
40.44
-74.55
-74.48
-74.41
-74.34
-74.28
-74.21
-74.14
-74.07
-74.00
NY
CT
NJ
DE
Area of Detail
Hackensack River
Passaic River
New Jersey
Kill Van Kull
Arthur Kill
Staten Island
AREA OF MODEL GRID IMPROVEMENTS
Raritan River
Raritan Bay

Figure 3-1(a)



Hackensack River
Passaic River
NY
CT
NJ
DE
Area of Detail
New Jersey
Kill Van Kull
Arthur Kill
Staten Island
AREA OF ORIGINAL MODEL GRID DEFICIENCIES
Raritan River
Raritan Bay
40.92
40.86
40.80
40.74
40.68
40.62
40.56
40.50
40.44
-74.55
-74.48
-74.41
-74.34
-74.28
-74.21
-74.14
-74.07
-74.00

Figure 3-1(b)

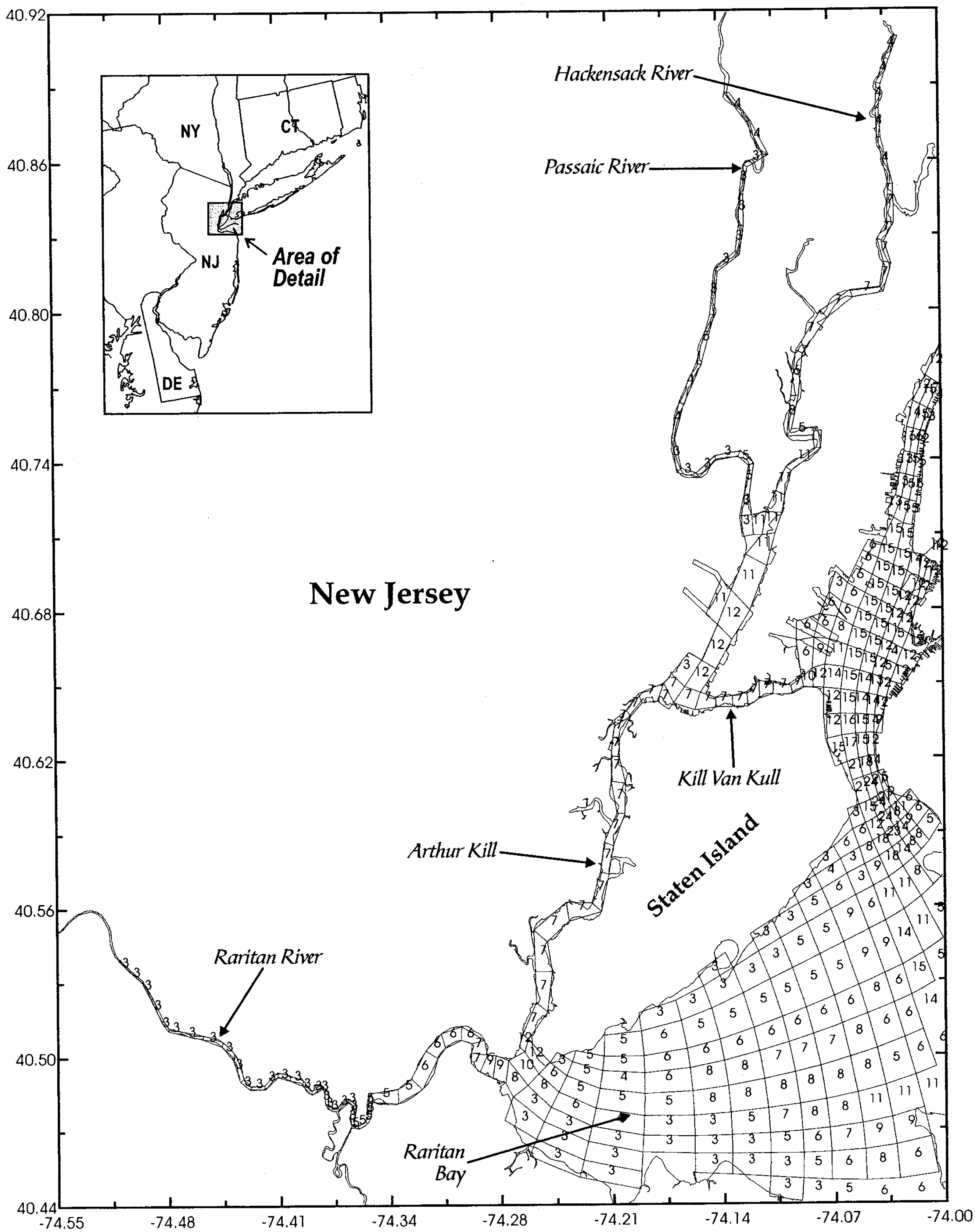
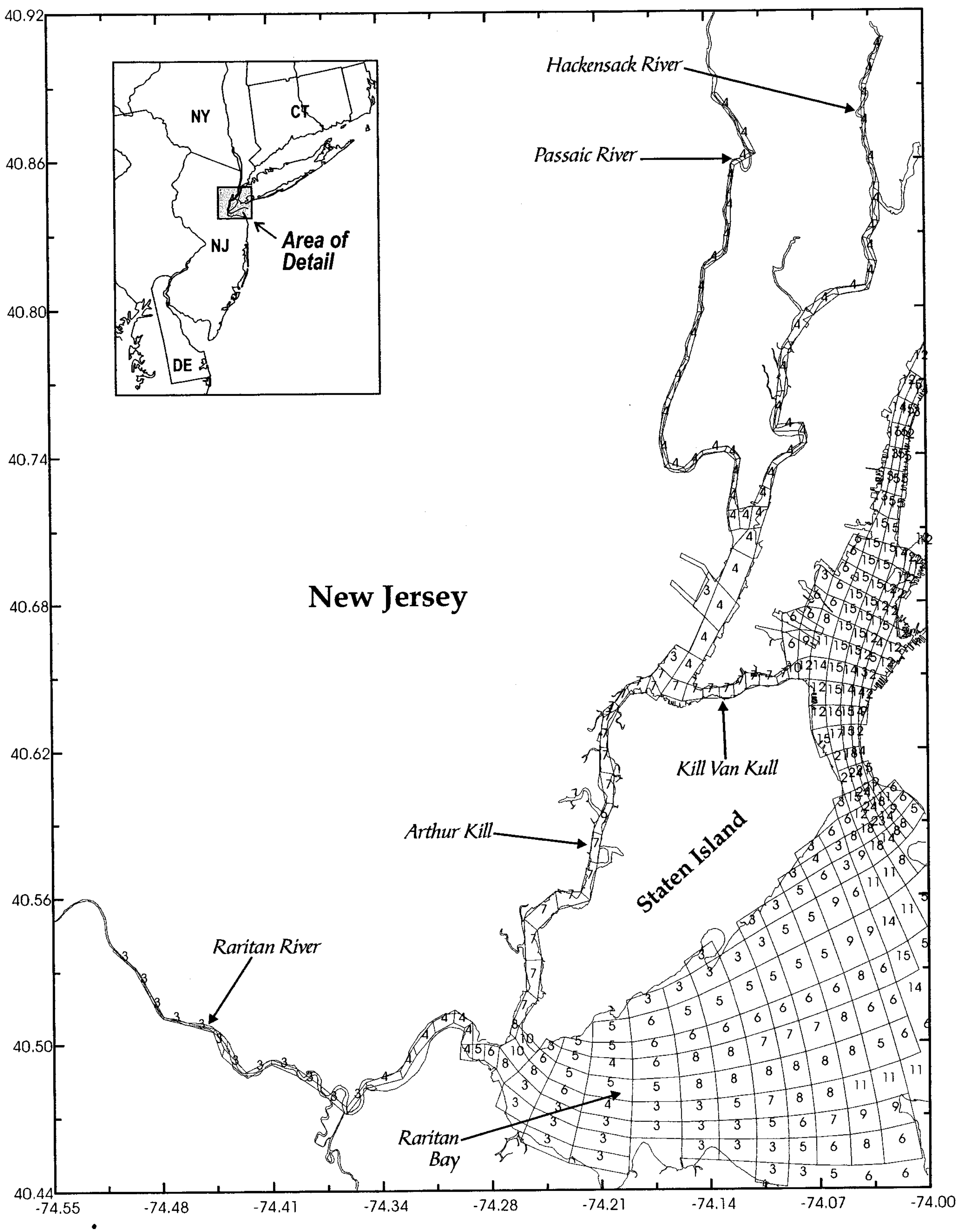

NY
CT
NJ
DE
Area of Detail
Hackensack River
Passaic River
New Jersey
Kill Van Kull
Arthur Kill
Staten Island
Raritan River
Raritan Bay
40.92
40.86
40.80
40.74
40.68
40.62
40.56
40.50
40.44
-74.55
-74.48
-74.41
-74.34
-74.28
-74.21
-74.14
-74.07
-74.00

Figure 3-2(a)



NY
CT
NJ
DE
Area of Detail
Hackensack River
Passaic River
New Jersey
Kill Van Kull
Arthur Kill
Staten Island
Raritan River
Raritan Bay
40.92
40.86
40.80
40.74
40.68
40.62
40.56
40.50
40.44
-74.55
-74.48
-74.41
-74.34
-74.28
-74.21
-74.14
-74.07
-74.00

Figure 3-2(b)

lateral resolution across the Raritan, the Passaic and the Hackensack Rivers. The potential consequence of lack of lateral resolution is that any secondary currents and horizontal velocity shear, that may have resulted from real world meandering geometries and crosswind, would not be resolved by the model grid. Thus, additional mixing resulting from the velocity shear and secondary currents would not necessarily be properly accounted for. Careful investigation of the bathymetry of the Hackensack and the Raritan Rivers suggests that small-scale bathymetric features exist, especially in the Hackensack River, which may not be properly resolved by the SWEM computational grid. Enhanced bottom friction coefficients (i.e., a scale factor is applied) were introduced in SWEM to generate additional mixing in the model to mimic the unresolved mixing likely to have been produced by the secondary currents and small scales bathymetric features in both the Hackensack and Raritan Rivers. Table 1 shows the enhanced bottom friction used in SWEM. The enhanced bottom friction was calibrated against observed salinity and temperature data.

Table 3-1. Adjusted bottom friction used in SWEM

LOCATION	ORIGINAL CALIBRATION SCALE FACTOR	REVISED CALIBRATION SCALE FACTOR
Raritan River	10	50
Passaic River	10	10
Hackensack River	1	50-600

3.3 SWEM HYDRODYNAMICS CALIBRATION/VALIDATION

The SWEM model was originally calibrated and validated against a wide spectrum of hydrographic and water quality data across the model domain. An extensive hydrographic data set was collected in the New Jersey tributary system during a field program conducted in support of SWEM calibration in 1994 and 1995 (HydroQual, 2001). Vertical casts of temperature and salinity were measured during the surveys. Figure 3-3 illustrates the location of these data stations. Additional survey data, conducted during the New York City DEP Harbor survey program, are also available in Kill van Kull and Arthur Kill (Figure 3-3). Field survey data for the 1988 and 1989 validation period are very limited and only surface salinity data are measured near the Raritan Bay area. These data are supplemented by the NJDEP coastal Monitoring Survey data as shown in Figure 3-3. In the present study, the refined and upgraded SWEM model is calibrated and validated against these data.

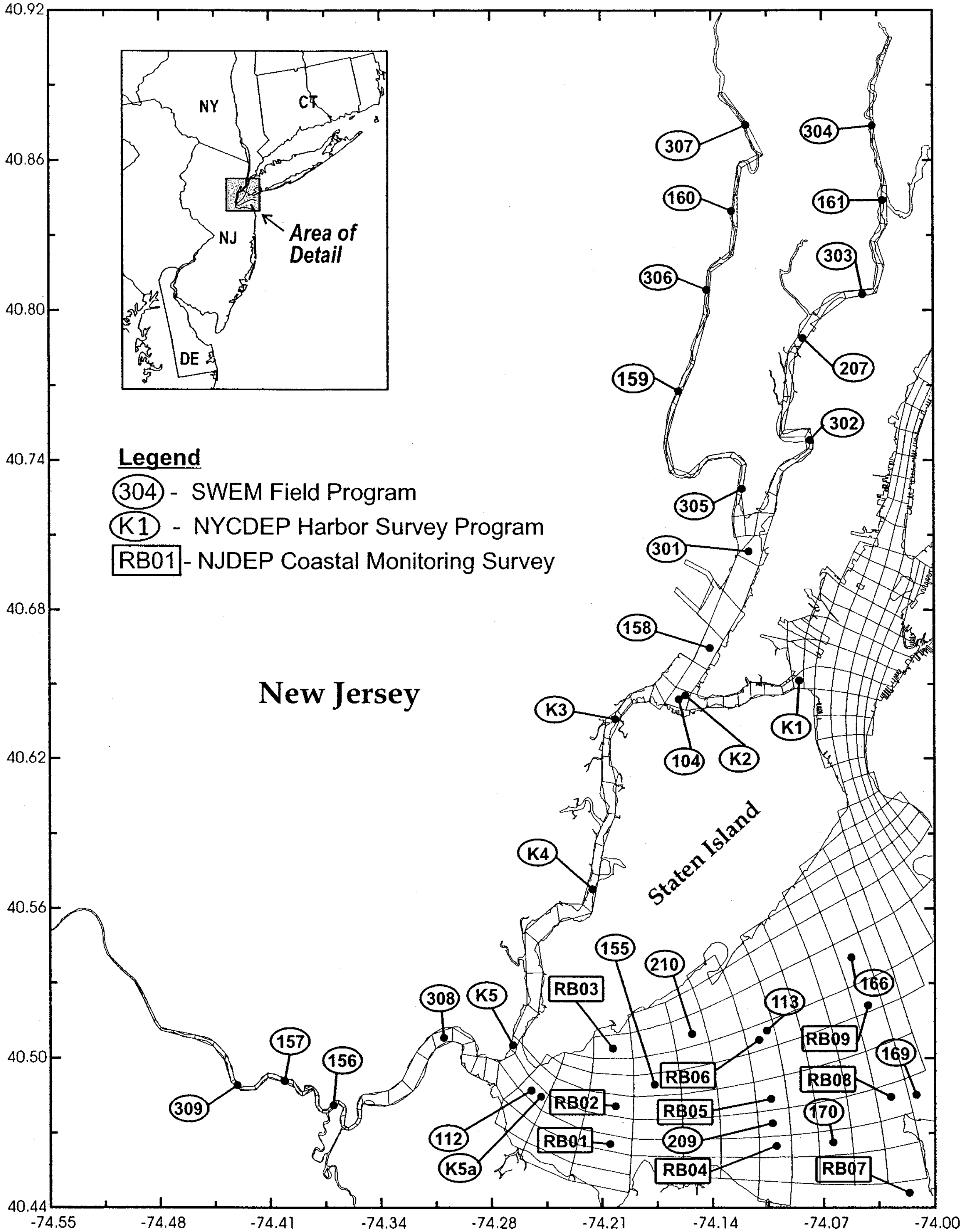
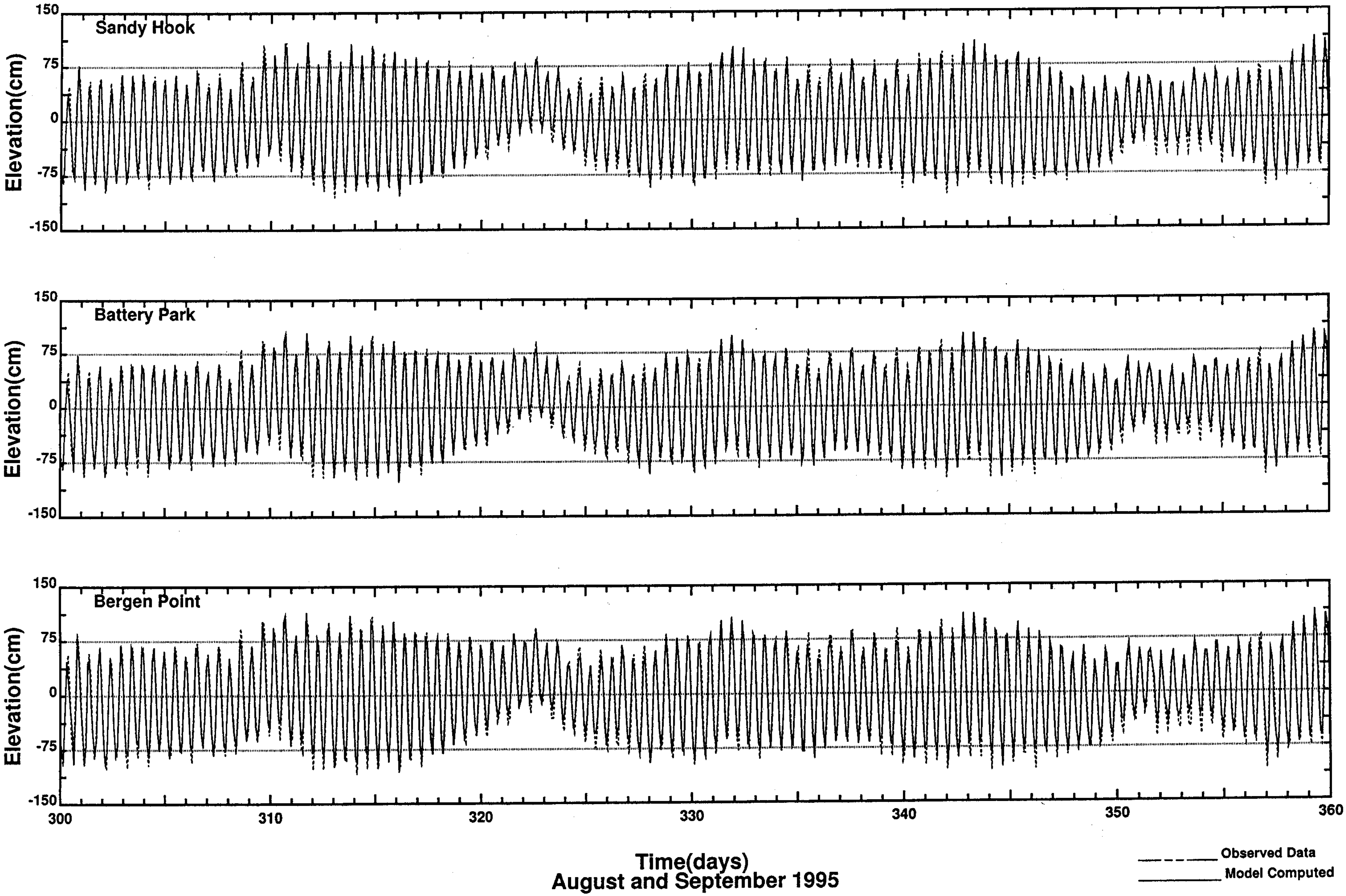

NY
CT
NJ
DE
Area of Detail
Legend
304 - SWEM Field Program
K1 - NYCDEP Harbor Survey Program
RB01 - NJDEP Coastal Monitoring Survey
New Jersey
Staten Island
307
304
160
161
303
306
207
159
302
305
301
158
K3
K1
104
K2
K4
155
210
166
113
RB03
308
K5
RB09
157
156
169
RB06
RB08
309
RB02
RB05
170
112
RB01
209
K5a
RB04
RB07
40.92
40.86
40.80
40.74
40.68
40.62
40.56
40.50
40.44
-74.55
-74.48
-74.41
-74.34
-74.28
-74.21
-74.14
-74.07
-74.00

Figure 3-3

Calibration of the refined SWEM model was performed against 1994 and 1995 field survey data. All the boundary conditions and forcing functions used in the hydrodynamic sub-model are as developed during original calibration. Hence, a detailed description of the forcing functions is not made in this report.

As part of the consistency checking of the refined geometry of the New Jersey tributaries system configured in the enhanced SWEM, comparison of the model computed water level was made against the observed data at Sandy Hook, the Battery and Bergen Point. Figure 3-4 illustrates the comparison for a portion of 1994-1995. It is clearly demonstrated in the figure that SWEM is able to reproduce the water level variation very accurately. Careful visual inspection of this plot suggests that SWEM has accurately reproduced both the tidal signals as well as the low frequency water level signals. This suggests that SWEM responds to high frequency tidal forcing, low frequency winds, and freshwater forcing very well. Results similar to those presented in Figure 3-4 are displayed for the entire 1994-95 simulation period in the Appendix.

Model computed salinity and temperature during the simulation period of October 1994 through September 1995 have been compared to the extensive data set collected in the New Jersey tributary system. Although these measurements were not continuous, these data have considerably large spatial and temporal extent covering the entire tributary system over the full simulation period of 1994-1995. Unfortunately these data do not provide the exact measurement time, rather these data were reported at particular days. The lack of exact measuring time substantially limits the ability to make a point-by-point comparison between model results and the data. Therefore, the model results, with average, and maximum and minimum ranges over the tidal cycle, were compared to the observed data at a particular day of measurement. Figure 3-5 illustrates a comparison between the model-computed salinity for all ten sigma layers and observed salinity across the tributary system. Similar comparisons are also shown for temperature in Figure 3-6. In these figures, the range of model results are presented as bars and the observed data are shown by the open symbols. In general, the stations are presented in upstream to downstream order for each of the three rivers and Newark and Raritan Bays. Exact station locations are identified in Figure 3-3. Figures 3-5a and 3-6a show selected Raritan River and Raritan Bay results. Figures 3-5b and 3-6b show selected Hackensack River results. Figures 3-5c and 3-6c show selected Passaic River results. Results at additional stations are provided in the Appendix. It is clear from these figures that SWEM reproduces both the salinity and temperature structure. SWEM reproduces the salinity temporal gradient observed between high flow spring and low flow summer conditions. Temperature variations in summer and winter months are also reproduced by the model very well. Vertical stratification in both temperature and salinity are captured by SWEM.



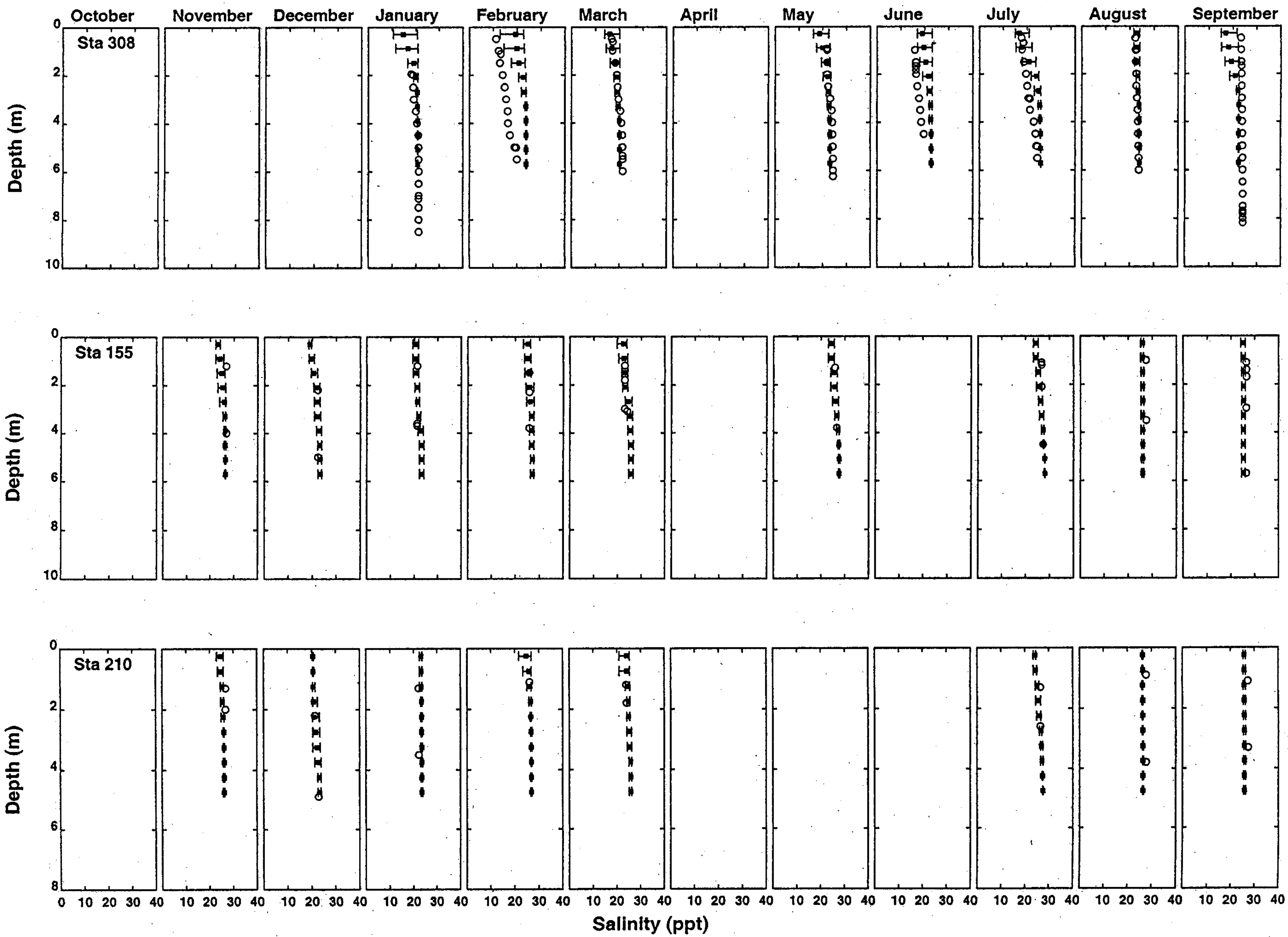
Comparison of Computed Water Surface Elevations with Data

/huron2/PVSC*/SWEM9495/PLOTS/elev_plot2.gdp

DATE: Thu Feb 21 TIME: 15:25:25

Figure 3-4

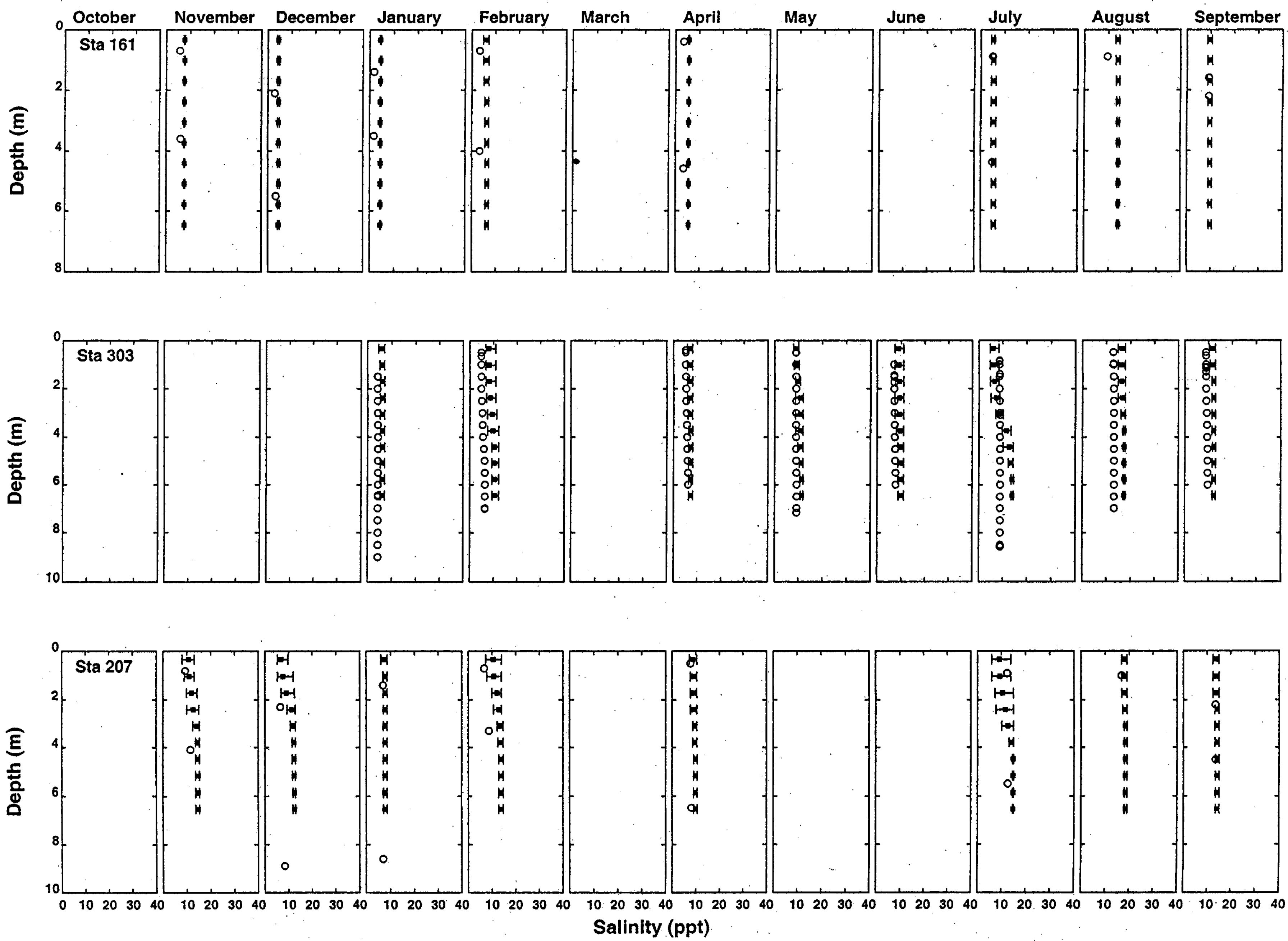
Raritan River and Bay



/daffy2/PVSC*/REV_RARR_PLOTS1/GCMTSR/sal_vert2.gdp
HIFRIC_FINALWQ

Figure 3-5a

Hackensack River



/daffy2/PVSC*/REV_RARR_PLOTS1/GCMTSR/sal_vert5.gdp
HIFRIC_FINALWQ

Figure 3-5b

Passaic River

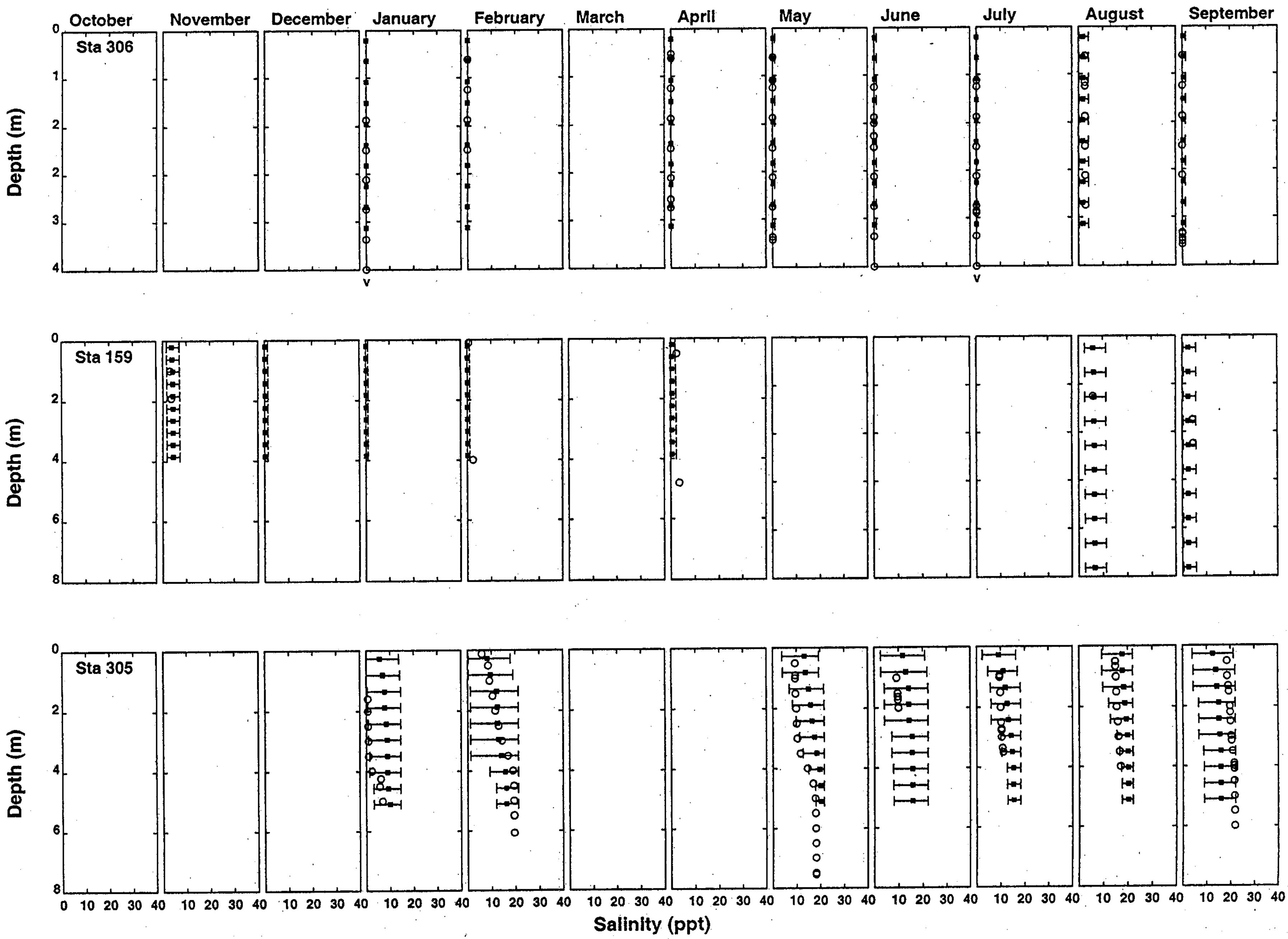


Figure 3-5c

Raritan River and Bay

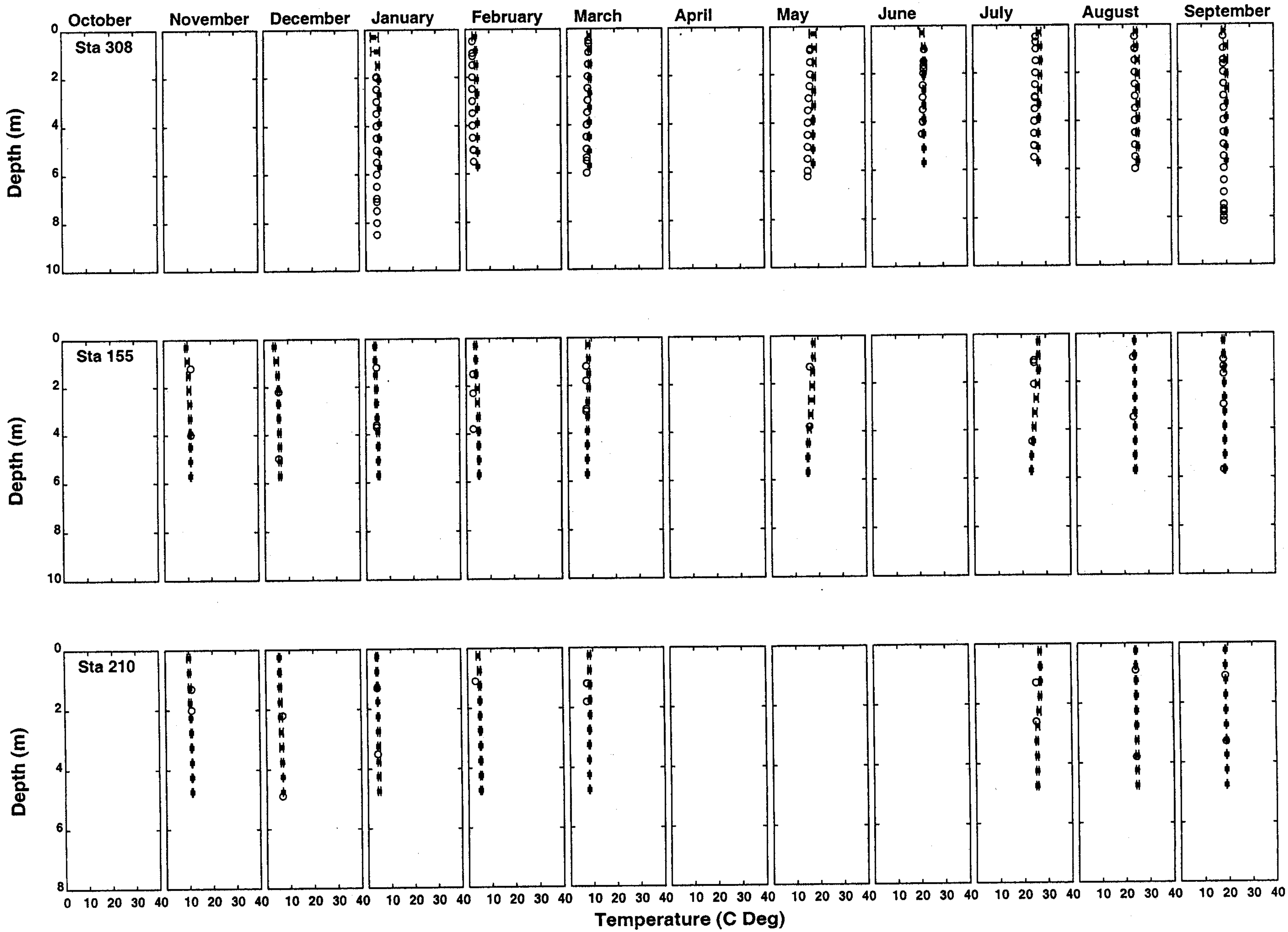


Figure 3-6a

/daffy2/PVSC*/REV_RARR_PLOTS1/GCMTSR/sal_vert2.gdp
HIFRIC FINAL WO

Hackensack River

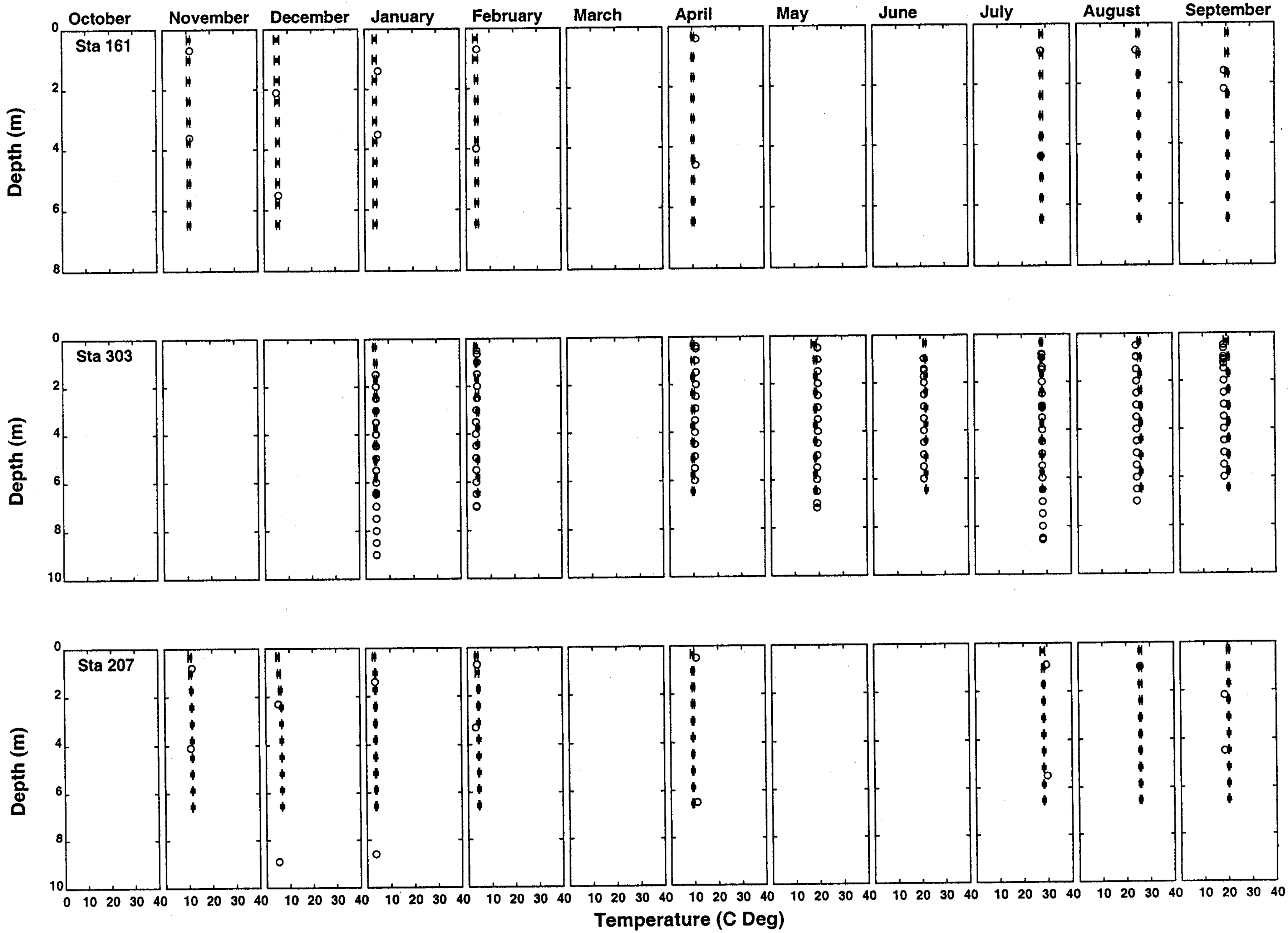


Figure 3-6b

/daffy2/PVSC*/REV_RARR_PLOTS1/GCMTSR/sal_vert5.gdp
HIERIC_FINALWQ

Passaic River

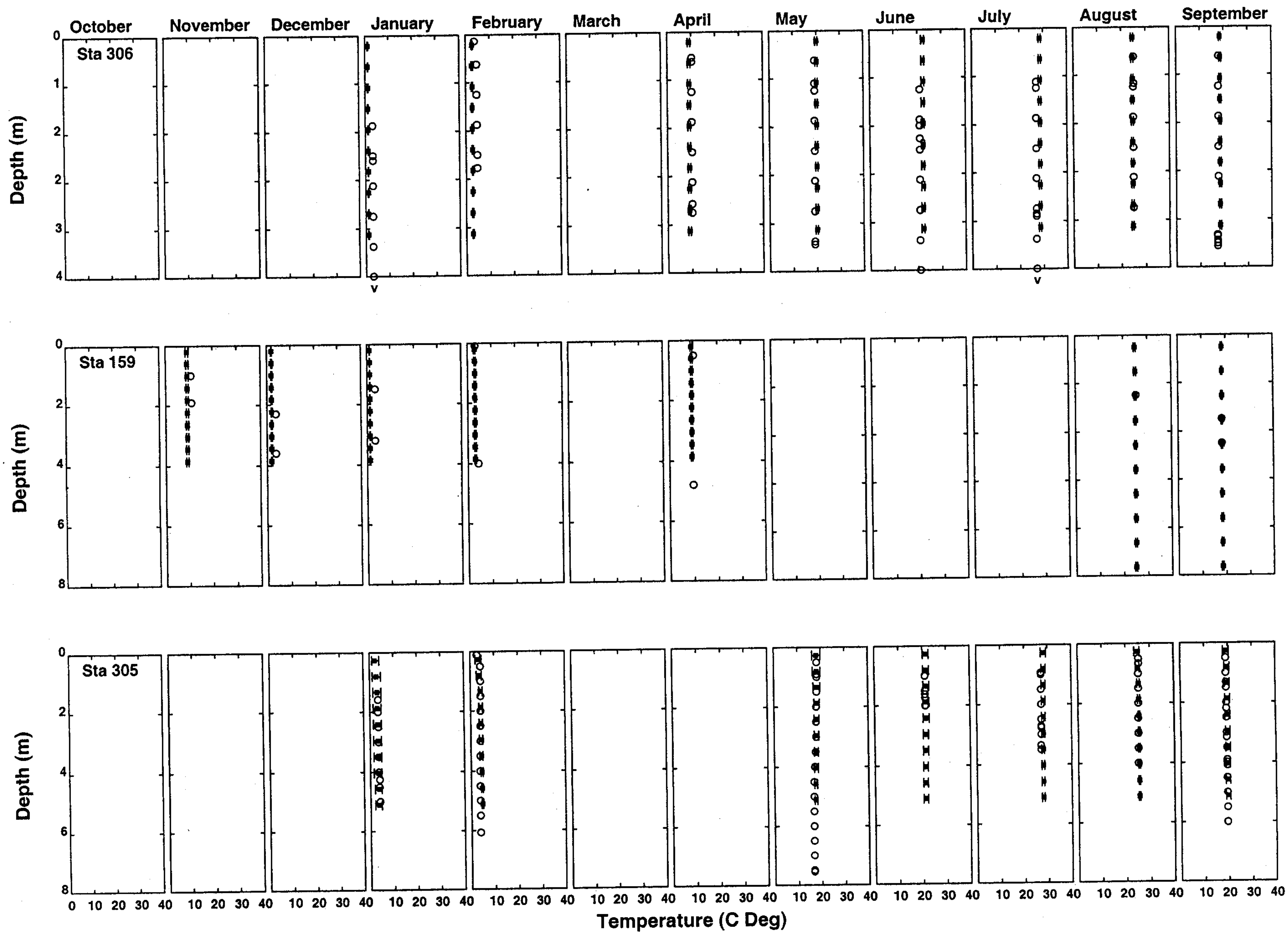
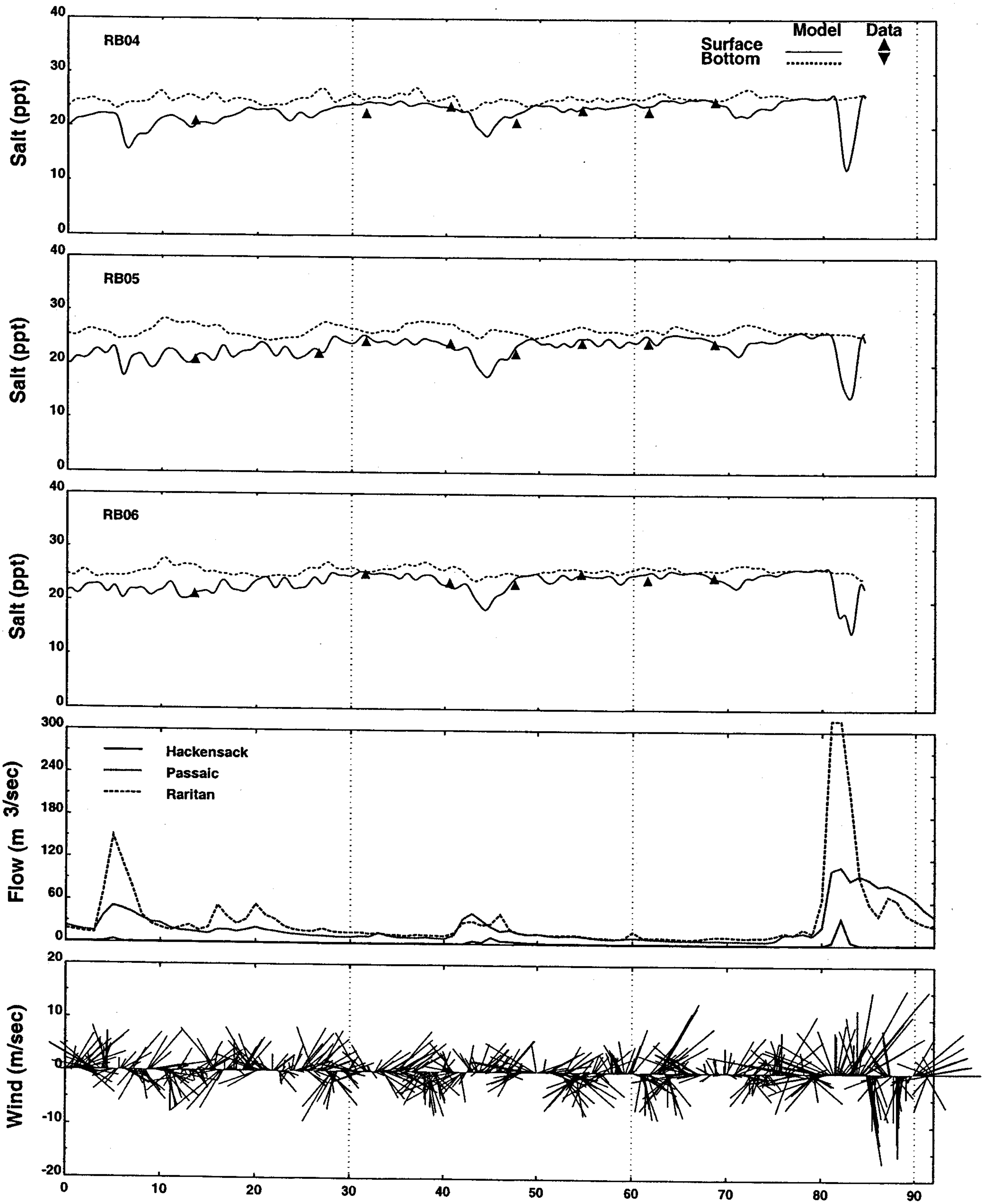


Figure 3-6c

As discussed in the report introduction, 1988-89 monitoring efforts provide very limited data in the New Jersey tributaries. Observations of temperature and salinity were made only at the surface and are limited to the Raritan Bay area. Nevertheless, these limited data provide an opportunity to cursorily validate SWEM. The simulation period, from October 1988 through September 1989, is characterized by a marked difference in freshwater flows from the 1994-95 simulation period. In general, 1988-89 is very wet in comparison to 1994-95. Validation of the SWEM 1994-95 calibration for 1988-89 conditions represents a challenge because of the marked differences between 1994-95 and 1988-89 conditions. Based on the very limited data, SWEM appears to reproduce both the salinity and temperature structure for 1988-89 in New Jersey waters. Figure 3-7, illustrates the comparison of the model computed surface and bottom salinity against the observed data at selected locations in Raritan Bay. Figure 3-8 shows a similar comparison at stations in the Kill Van Kull and Arthur Kill. Figures 3-7 and 3-8 show results for July-September only. Results for the full 1988-89 period and for additional locations are presented in the Appendix.



July 1 - September 30, 1989

Figure 3-7

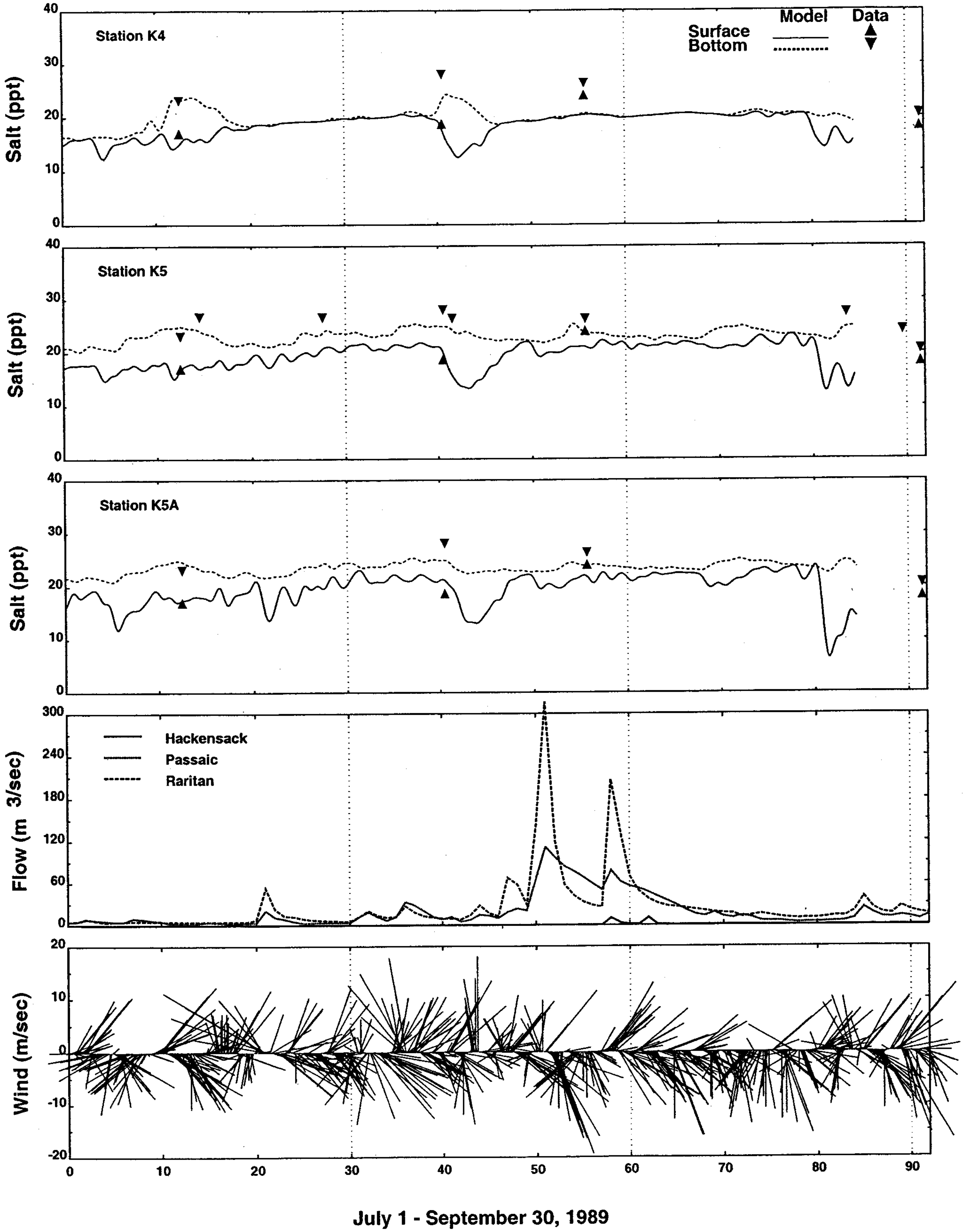


Figure 3-8

DATE: Thu Feb 21 TIME: 15:43:13

SECTION 4

TASK 2 - WATER QUALITY SUB-MODEL CALIBRATION/VALIDATION ENHANCEMENTS

The calibration enhancements to the water quality sub-model of SWEM include the following:

- review of calibration and validation loadings
- hydrodynamic transport revisions and adjustments
- adjustment of model input parameters, constants, and coefficients

Each of the calibration enhancements to the water quality sub-model of SWEM is described below. Also presented are model results.

4.1 REVIEW OF CALIBRATION AND VALIDATION LOADINGS

The review undertaken on this project of the loadings previously developed for the calibration and validation years showed, that for both calibration and validation years, adjustments to the concentrations assigned in the absence of measurements to tributary headwater inputs for several model variables were appropriate. The review of loadings also showed that the flows used in calculating a portion of the CSO and stormwater loadings were incorrect. These changes to loadings are described in greater detail below.

4.2 TRIBUTARY INPUT LOADING ADJUSTMENTS

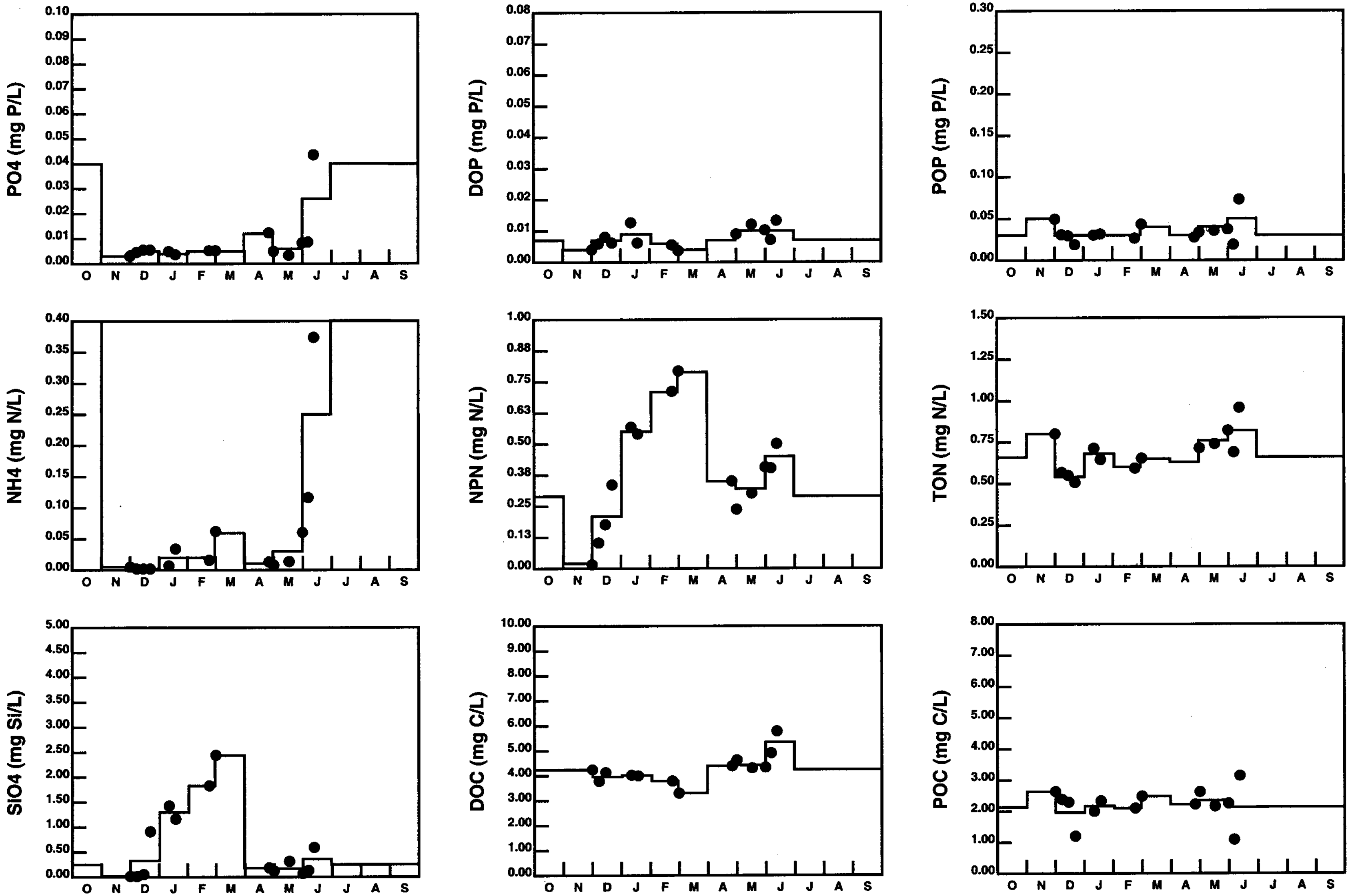
Tributary input loads to SWEM are assigned as both quality and flow. Daily flows for the New Jersey tributaries obtained from the USGS are specified in SWEM. As part of the recalibration effort, tributary concentrations, and therefore loads, were adjusted for the Hackensack, Passaic, Saddle, Raritan, and South Rivers to better represent available data. There are no monitoring data available for the Saddle River at its confluence with the Passaic River or for the South Rivers at the Duhernal Dam. Saddle River concentrations were assumed to mimic the Passaic River concentrations at the Dundee Dam and South River concentrations were assumed to mimic Raritan River concentrations at the Fieldville Dam. For the Hackensack, Passaic, and Raritan Rivers, concentration measurements are available for most of the state (modeled) variables for a portion of the 1994-95 calibration period. In cases where there are data collected at the fall line during the SWEM monitoring program, these concentration values are assigned. When no data are available for a given month or parameter, the nearest in-stream data point is used to adjust boundary conditions.

Tributary boundary condition concentrations were either increased or decreased or left the same as the original calibration in the months where there were no data available at the fall line. This was done in order to better match observed concentrations at the first available data point in stream. The fall line concentrations that were adjusted were kept within the range of the available concentration data for each individual fall line location. Once the fall line concentrations were adjusted for the calibration year, they were also applied to the validation year where there was no data available on which to base the boundary conditions. The final values for the adjusted fall line nitrogen, phosphorus, and carbon concentrations are shown in Figures 4-1, 4-2, and 4-3 for the Hackensack River, Passaic River/Saddle River, and Raritan River/South River, respectively.

There were no monitoring data for dissolved oxygen or phytoplankton chlorophyll at the fall line locations. Dissolved oxygen boundary conditions were set based on the first in stream data point. The dissolved oxygen concentrations were assumed to be no less than the first in stream data point. In some cases, concentrations were adjusted upward to create a more temporally consistent forcing function. Dissolved oxygen boundary conditions are shown in Figure 4-4.

Phytoplankton is modeled in SWEM as carbon. Therefore, phytoplankton carbon concentrations at the fall line locations had to be estimated. Measurements of POC at the fall line when available include not only algal carbon but carbon from other sources as well. Measured particulate organic carbon (POC), particulate organic nitrogen (PON), and particulate organic phosphorus (POP) concentrations at the boundary were used for the estimation of algal carbon. The particulate organic nutrient concentrations were converted to POC concentrations using algal cell stoichiometric relationships. The smallest of the estimates of POC from the three methods (i.e., from fall line POC concentrations, from POC determined from PON, and from POC determined from POP) was used to assign the algal carbon concentration at each tributary boundary. The algal carbon concentrations used for each of the tributary boundary conditions is shown in Figure 4-5.

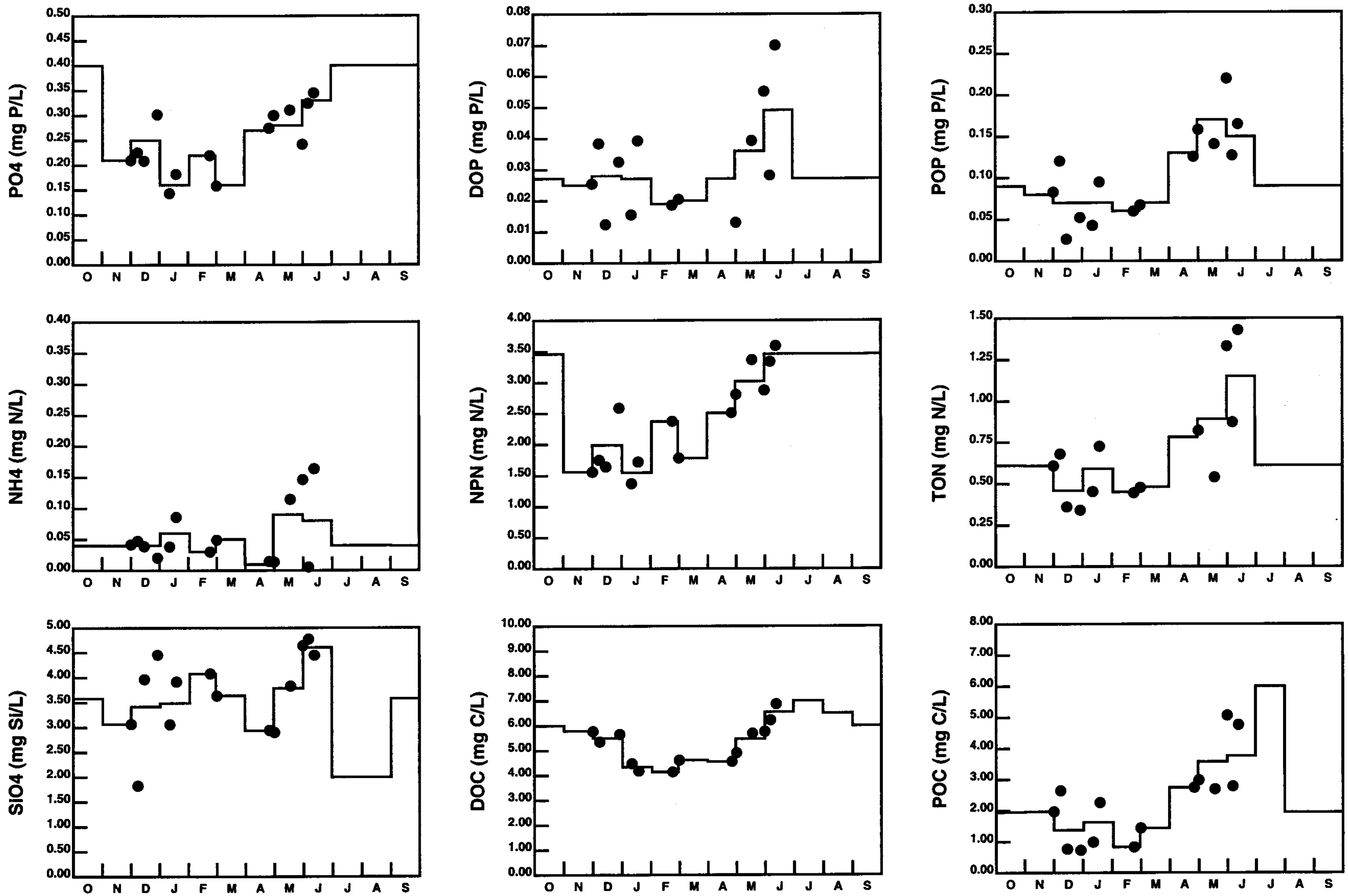
The total algal carbon in SWEM is split into two assemblages, a summer group and a winter group, which have different carbon to chlorophyll ratios. The total algal carbon concentrations were split based upon the monthly average temperatures of the water at each individual fall line consistent with the algal growth kinetics in SWEM which are temperature dependent and specific to each assemblage.



SWEM - HACKENSACK RIVER

Boundary Condition

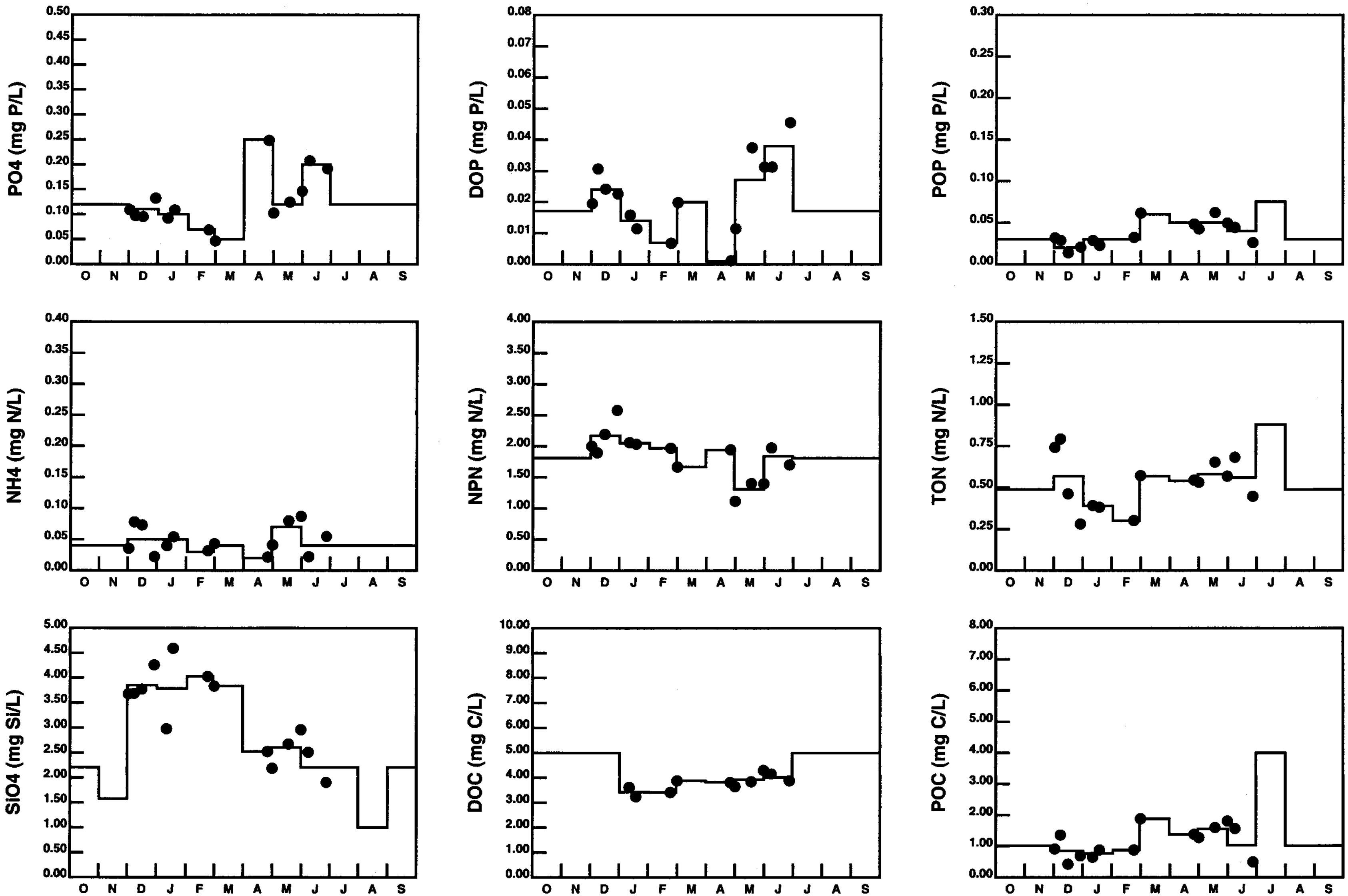
Figure 4-1



SWEM - PASSAIC RIVER/SADDLE RIVER (Passaic River Data)

Boundary Condition

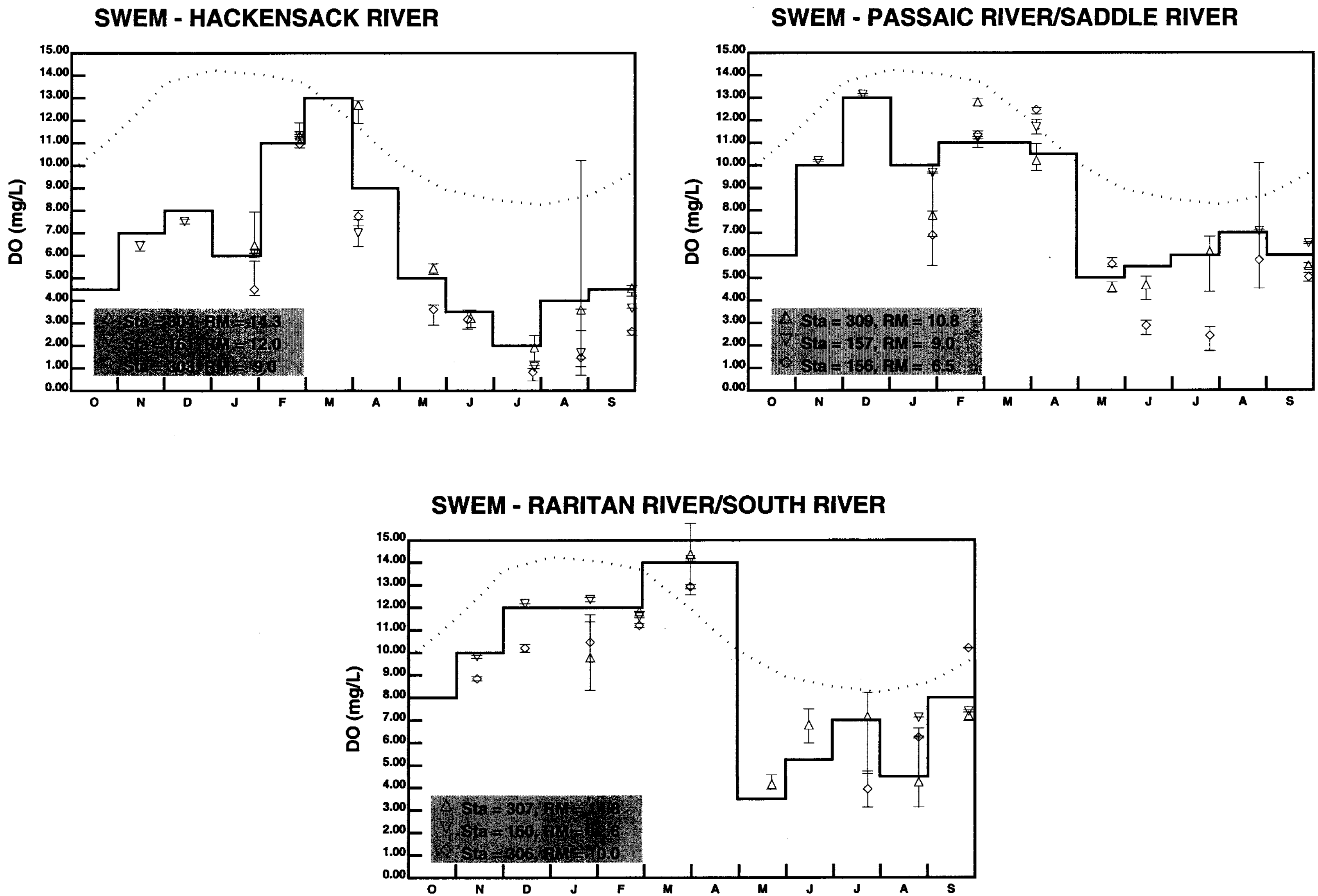
Figure 4-2



SWEM - RARITAN RIVER/SOUTH RIVER (Raritan River Data)

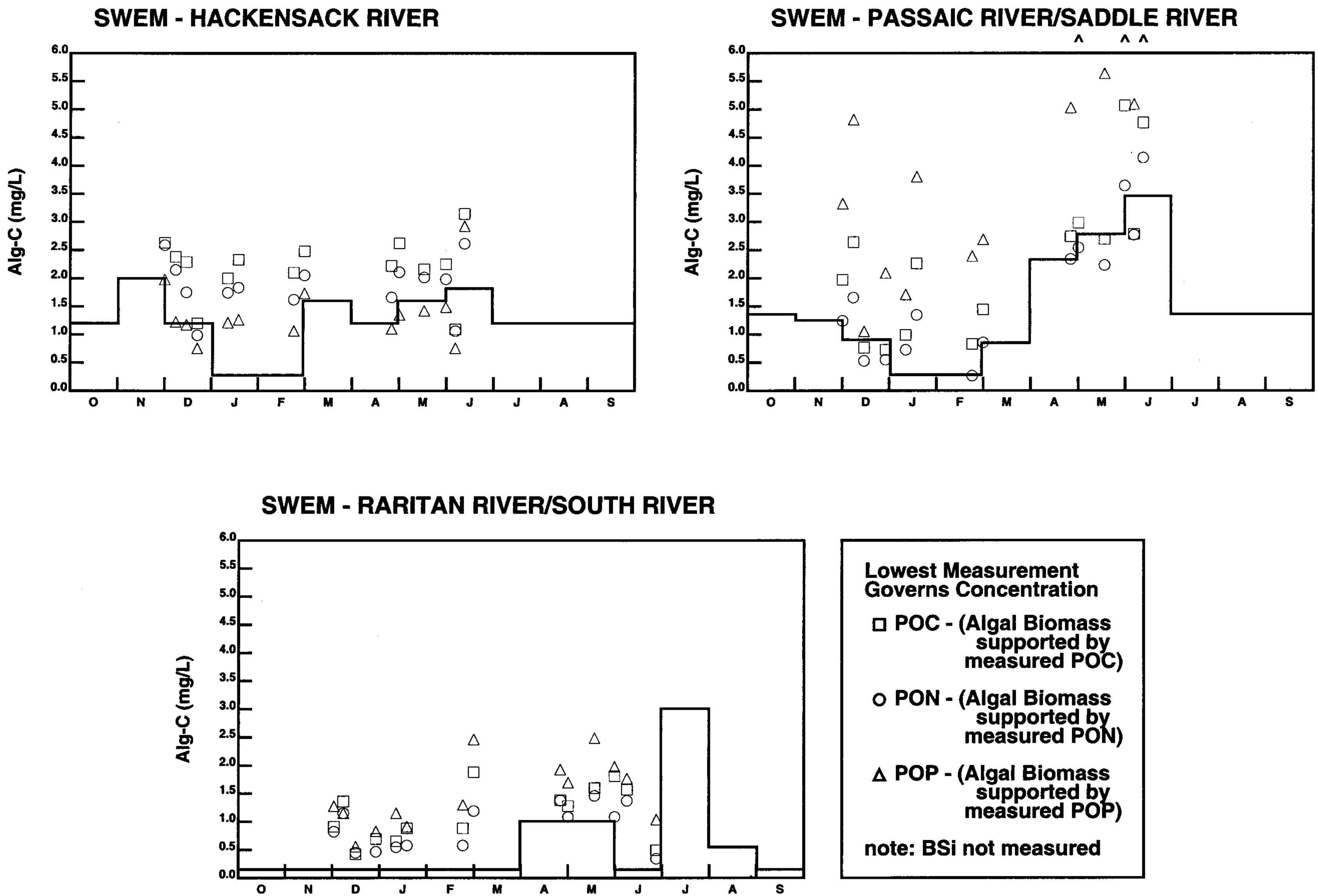
Boundary Condition

Figure 4-3



Dissolved Oxygen Boundary Condition with Downstream Data Guidance

Figure 4-4



Algal Carbon Boundary Condition

Figure 4-5

4.3 CSO AND STORMWATER LOADING CORRECTIONS

CSO and stormwater (SW) loads were adjusted to correct a previous error in flow. The flows from a number of CSO and SW locations were incorrect in the previous 1994-1995 SWEM hydrodynamic sub-model calibration. These flows were corrected in the calibration enhancement. The corrected CSO and SW flows were multiplied by appropriate concentrations to obtain revised CSO and SW loads. CSO and SW loadings are a relatively small component of the total loading to the model. Figure 4-6 represents the relative contribution of the various loading sources (excluding the impact of the open ocean boundary) and includes the revised CSO, SW, and Tributary loads developed during the recalibration project. The loads are also shown in Table 4-1.

Table 4-1. Revised SWEM Loads

Total Nitrogen (Metric Tons Per Year)

Jurisdiction	STP	CSO	Stormwater	Tributary	Atmospheric	TOTAL
All	0	0	0	0	69470	69470.0
Connecticut	2621	226.8	1400	14410	0	18657.8
New Jersey	11250	318.9	730.8	13190	0	25489.7
New York City	38870	1424	119.7	0	0	40413.7
New York (non NYC)	25680	315.6	632	4870	0	31497.6
Total	78421	2285.3	2882.5	32470	69470	185528.8

Total Phosphorus (Metric Tons Per Year)

Jurisdiction	STP	CSO	Stormwater	Tributary	Atmospheric	TOTAL
All	0	0	0	0	853.6	853.6
Connecticut	485.1	33.71	152	952.6	0	1623.4
New Jersey	1283	88.32	91.53	887.9	0	2350.8
New York City	3808	211.6	13	0	0	4032.6
New York (non NYC)	3330	87.42	79.13	490.2	0	3986.8
Total	8906.1	421.05	335.66	2330.7	853.6	12847.1

Total Organic Carbon (Metric Tons Per Year)

Jurisdiction	STP	CSO	Stormwater	Tributary	Atmospheric	TOTAL
All	0	0	0	0	96060	96060.0
Connecticut	4470	1314	11660	61080	0	78524.0
New Jersey	9910	3733	7646	54330	0	75619.0
New York City	45540	8946	1086	0	0	55572.0
New York (non NYC)	31830	3695	6610	11280	0	53415.0
Total	91750	17688	27002	126690	96060	359190.0

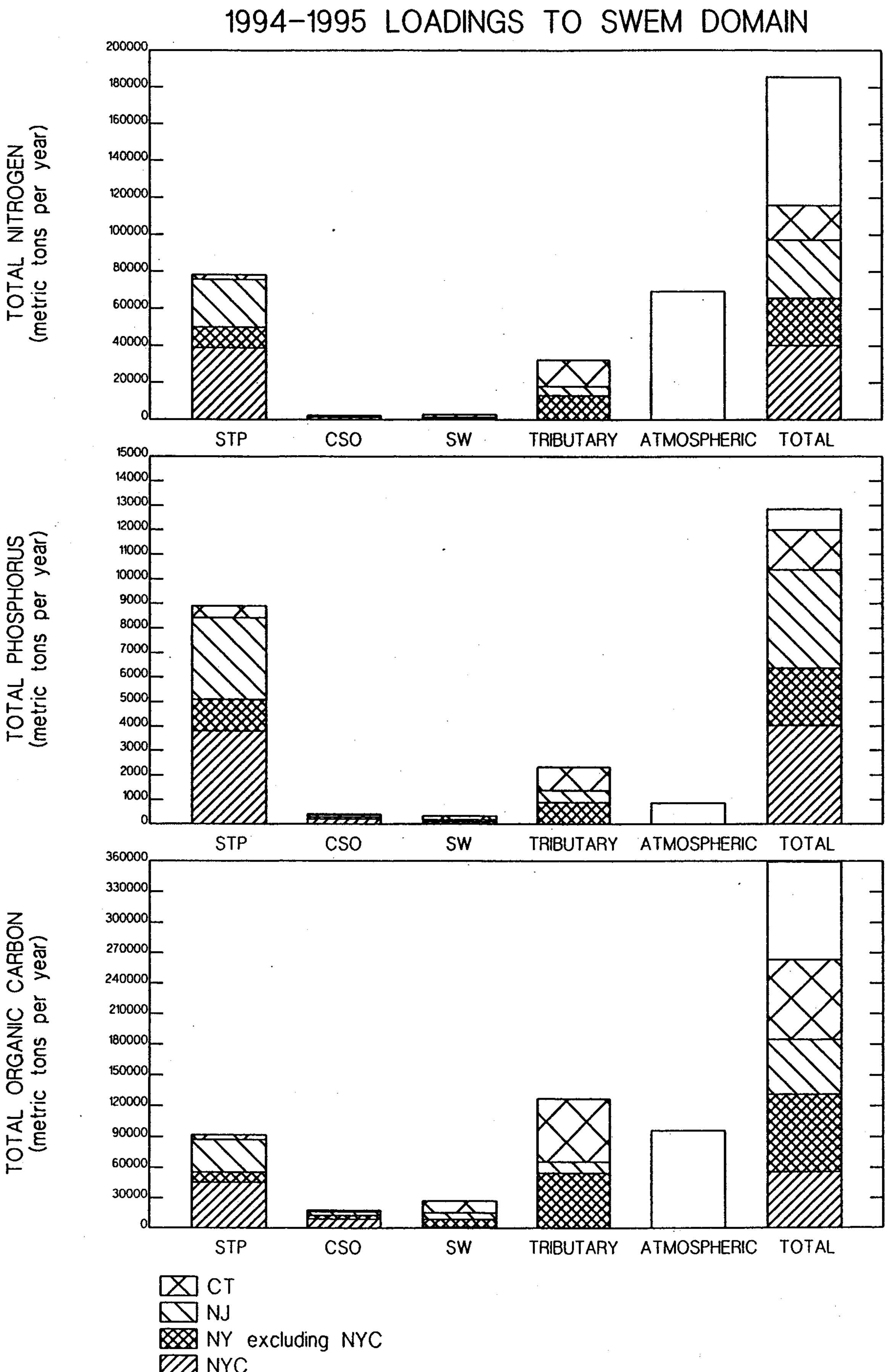

1994-1995 LOADINGS TO SWEM DOMAIN
TOTAL NITROGEN (metric tons per year)
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000
STP
CSO
SW
TRIBUTARY
ATMOSPHERIC
TOTAL
TOTAL PHOSPHORUS (metric tons per year)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
STP
CSO
SW
TRIBUTARY
ATMOSPHERIC
TOTAL
TOTAL ORGANIC CARBON (metric tons per year)
0
30000
60000
90000
120000
150000
180000
210000
240000
270000
300000
330000
360000
STP
CSO
SW
TRIBUTARY
ATMOSPHERIC
TOTAL
CT
NJ
NY excluding NYC
NYC

Figure 4-6

4.4 HYDRODYNAMIC TRANSPORT REVISIONS AND ADJUSTMENTS

As described in the preceding report section for Task 1, adjustments to the hydrodynamic sub-model were performed and include modifications of the SWEM computational grid. These changes to the computational grid necessitated changes to many of the inputs to the SWEM water quality sub-model. While these changes were time and resource consuming, the changes were basically an accommodation for the new segments added to the computational grid and do not require further discussion. While Task 1 efforts resulted in an improved hydrodynamic calibration/validation and a new transport regime for driving water quality sub-model calculations, there were several instances where the transport calculated by the hydrodynamic sub-model did not reproduce the stratification observed in salinity and other variables. Within the water quality sub-model, adjustments to vertical mixing coefficients calculated from the hydrodynamic sub-model were made to improve the calibration/ validation and are detailed below.

4.5 ADJUSTMENTS TO VERTICAL MIXING COEFFICIENTS

Vertical diffusivities, or vertical mixing coefficients, computed by 3-D hydrodynamic models do not always adequately represent vertical distributions of water quality parameters. The adjustment of vertical mixing coefficients in 3-D numerical modeling of estuarine systems has become a common practice (Pritchard, 1998), and is not unique to the calibration/validation effort in the Hackensack, Passaic, and Raritan Rivers. In the original SWEM calibration, vertical mixing coefficient adjustments in several areas of the model domain were necessary to achieve the observed stratification in key water quality variables, particularly dissolved oxygen. During the original SWEM calibration, vertical mixing coefficient adjustments in the New Jersey tributaries were not considered, but were considered as part of the re-calibration effort and are described below.

The inclusion of vertical mixing coefficient adjustments in the SWEM New Jersey tributaries brings the tributaries on par with the rest of the SWEM domain. The adjustment of vertical mixing coefficients in SWEM has held up to the scrutiny of an in-depth peer review process by two different independently convened Modeling Evaluation Groups (MEG). The adjustment of vertical mixing coefficients are to be viewed as a part of the model calibration and as such are appropriately carried forward as the model is used for projection purposes. Vertical mixing coefficient adjustments have been uniformly applied under both 1994-95 and 1988-89 conditions and should continue to be applied as the model is used for projection purposes. To put into perspective the issue of vertical mixing coefficient adjustment, consider that prior to the advent of the coupling of water quality models with hydrodynamic models, mixing coefficients were completely a user defined calibration parameter.

Vertical diffusivities were adjusted in the Hackensack River and Newark Bay main stem in June through September to better represent the level of stratification observed in the dissolved oxygen data. A minimum vertical diffusivity value, or floor, of 5×10^{-4} m^2/s was used for this time period in order to provide better mixing without increasing the larger vertical diffusivities beyond the accepted range. All vertical diffusivity values less than 5×10^{-4} m^2/s were increased to 5×10^{-4} m^2/s. This resulted in a better calibration of the stratification observed in the dissolved oxygen data. It is recognized that the strategy of using a minimum or floor value is just one approach to compensating for a shortcoming in the state-of-the-science in three dimensional hydrodynamic modeling. Other approaches were not tried since the end result would be to increase low mixing produced by the hydrodynamic sub-model regardless of approach.

Vertical diffusivities were also adjusted for the same period of time in the Raritan River for River miles 2.5 to 7.5 in order to better represent the stratification observed in the dissolved oxygen data. A minimum vertical diffusivity value of 2.5×10^{-4} m^2/s was used for the model segments from river mile 2.5 to 7.5 during the period of June through September in order to provide a better calibration of the model stratification to observed dissolved oxygen data. For the purpose of correcting a calculation by the model of dissolved oxygen standards violations which were not supported by data this minimum vertical diffusivity change was also applied in October and November.

4.6 ADJUSTMENT OF MODEL INPUT PARAMETERS, CONSTANTS, AND COEFFICIENTS

Several adjustments were made to parameters, constants and coefficients in the SWEM water quality sub-model. These adjustments include changes in benthic filtration, the effect of temperature on nitrification, vertical light extinction coefficients, and temperature effects on algal growth. These adjustments were made to better represent natural processes and the available data. Additionally, as discussed in Section 4.8, adjustments were also made to selected model inputs for the purpose of diagnosing the behavior of the model.

There were several changes to improve benthic filtration. Two segments of the SWEM computational grid on the west side of Newark Bay previously had no benthic filtration. The benthic filtration rate in these segments was set equal to the rate in the rest of Newark Bay. Benthic filtration in the New Jersey tributaries was adjusted based on an analysis of data collected by the New Jersey Harbor Dischargers Group (NJHDG). These data were not available in time for the original SWEM calibration.

A benthic filtration rate was calculated for the New Jersey tributaries in the same manner as the rest of the model domain. Data for all three New Jersey tributaries were used to determine one rate due to a limited amount of available data. The suspension feeding bivalve data were plotted on log probability axis and the mean concentration in gm dry wt./m2 was determined (Figure 4-7). From the mean of the suspension feeding bivalve data and a relationship between bivalve concentration and bivalve filtration rates, a clearance rate of 0.046 m/d was determined. This rate was then assigned to the Hackensack, Passaic, and Raritan River segments.

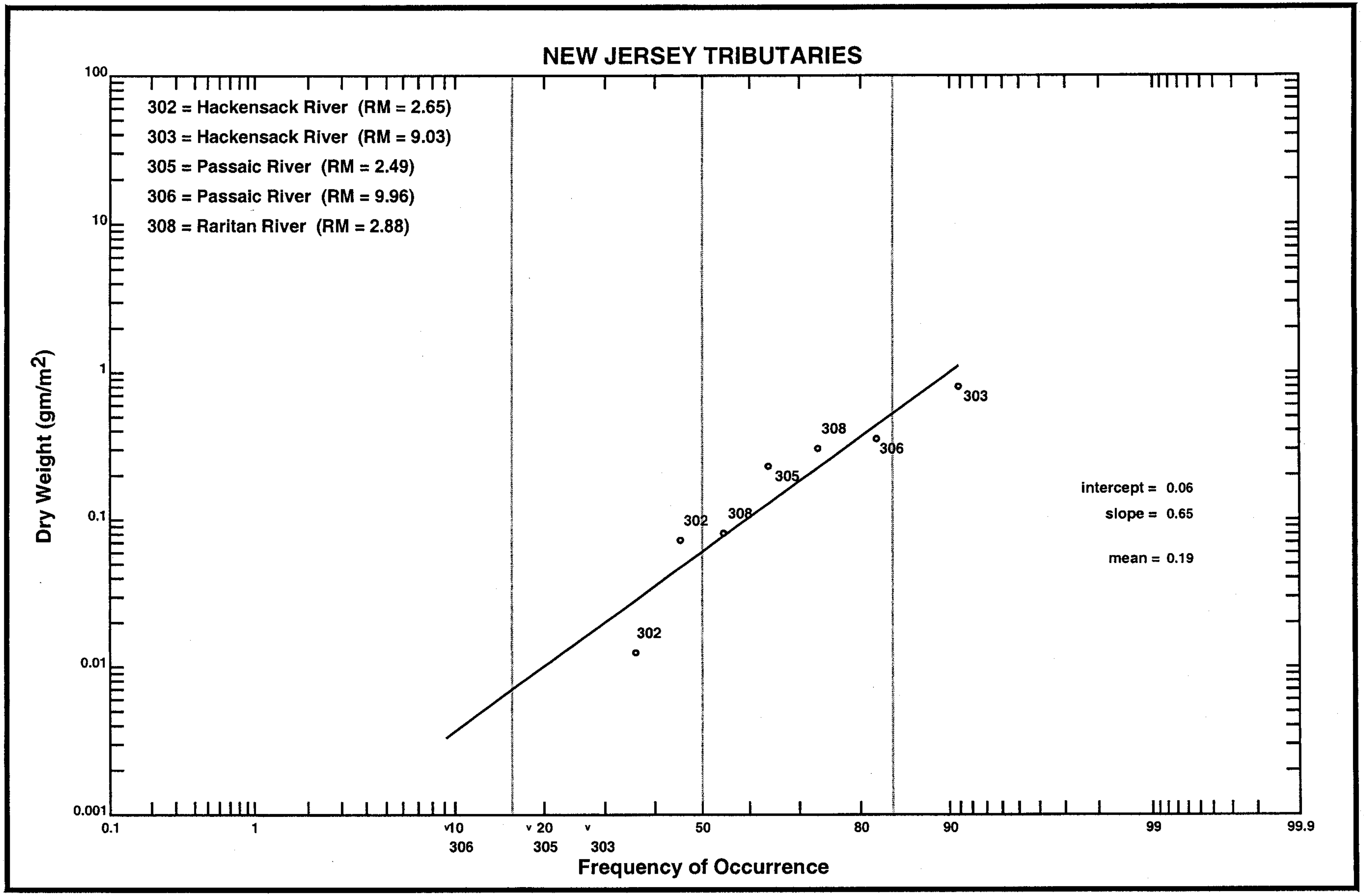
At low temperatures, nitrification rate is known to drop off faster than is described by the relationship included in the original SWEM calibration/validation and can go to zero. To include this behavior in SWEM, an increased temperature limitation to the nitrification rate was added for the entire model domain and better represents nitrification rates likely to occur during winter months.

Water column transparency and, therefore, light extinction coefficient plays an important role in primary production. Phytoplankton primary productivity is greater in areas of high light penetration than in light-limited areas, given the same nutrient availability.

Light extinction in SWEM and other eutrophication models is parameterized as the sum of two components: a base extinction coefficient and the effect of algal self-shading. The base extinction coefficient component is a model input. The algal self-shading component is calculated by the model and is not an input. The base extinction coefficient represents the extinction of light in the water column due to suspended solids and other non-living algal cell particulates. The base extinction coefficient varies in both space (settling of solids as one moves downstream) and time (as a function of freshwater flow induced resuspension or stormwater runoff) and is largely user-defined absent detailed information. The algal self-shading term accounts for the effect algal cells themselves have on attenuation (absorption and scattering) of light through the water column and is expressed as a product of the algal biomass produced in the model and a self-shading parameter (which acts as a multiplier). The multiplier used has somewhat universal application and has been relatively constant across other modeling projects.

In an ideal case, light extinction is either measured directly or as secchi depth and serves as a target for the sum total of the two modeled light extinction components. The calibration to measured light extinction data is an iterative process since the modeled components of light extinction are dependent on each other. For example, decreasing the base light extinction coefficient assigned in the model could allow for more algal growth which would automatically increase the modeled algal self-shading component of the overall light extinction coefficient.

Since the multiplier controlling the algal self-shading component of the light extinction coefficient is more or less well known, this input was not adjusted during either the SWEM original calibration or calibration enhancement efforts. Adjustments to light extinction in SWEM were limited to the base extinction component only.



NJHDG BIVALVE SUSPENSION FEEDER DRY WEIGHTS (gm/sq. meter)

Figure 4-7

DATE: Wed Feb 27 TIME: 15:21:01

The challenge of calibration to measured light extinction is that only the total light extinction is typically measured, not the two components. Consider a measured light extinction coefficient of 2 per meter. This could be assigned in the model in a number of ways. For example, this could be assigned in the model as a base extinction coefficient of 2 per meter with some algal growth occurring or alternatively it could hypothetically be assigned as a base extinction coefficient of 1.5 per meter with potentially 30 μg/l of additional chlorophyll occurring as growth and a resultant self-shading component of 0.5 per meter. Both examples would match the measured extinction of 2.0 per meter. For this reason, the calibration of light extinction and the assignment of base extinction coefficients often involve the consideration of productivity, dissolved oxygen, and other related data in addition to measured extinction data.

Due to a lack of extinction data in the tributaries and in order to maintain a consistent set of extinction coefficients, the transects of the New Jersey tributaries were broken up into sections and an annual value for the base extinction coefficient (total extinction minus extinction due to algal self shading) for each section was used. In some cases this value was then adjusted for several months of the year to better represent an annual cycle in the value of the base extinction coefficient as suggested by the limited available data.

The base extinction coefficients for the Hackensack River were set equal to 1 per m year round. The Passaic River was broken into two sections. Upstream of Passaic River mile 10, the base extinction coefficients were set equal to 5 per m. From Passaic River mile 10 downstream to the confluence with Newark Bay, the extinction coefficients were set as 6 per m. These values were further revised to 3 per m in the upstream section and 4 per m in the downstream section in May and 2 per m in the upstream section and 3 per m in the downstream section in June through September based upon algal productivity. To address dissolved oxygen standards violations calculated by the model which were not supported by data, base extinction coefficients in the Passaic River were further adjusted to 2 per m over the entire river length for July thru September. The base extinction coefficients for the Raritan River segments were set at 2.5 per m year round. For the purpose of addressing dissolved oxygen standards violations calculated by the model which were not supported by the data, further adjustments were made to the base extinction coefficients near the mouth of the Raritan River to effect a smooth transition between higher base extinction coefficients assigned upstream in the Raritan River and lower base extinction coefficients assigned in Raritan Bay. Newark Bay and Raritan Bay both had more extensive sets of extinction data available. Values of the extinction coefficients in these waters were adjusted based upon extinction data

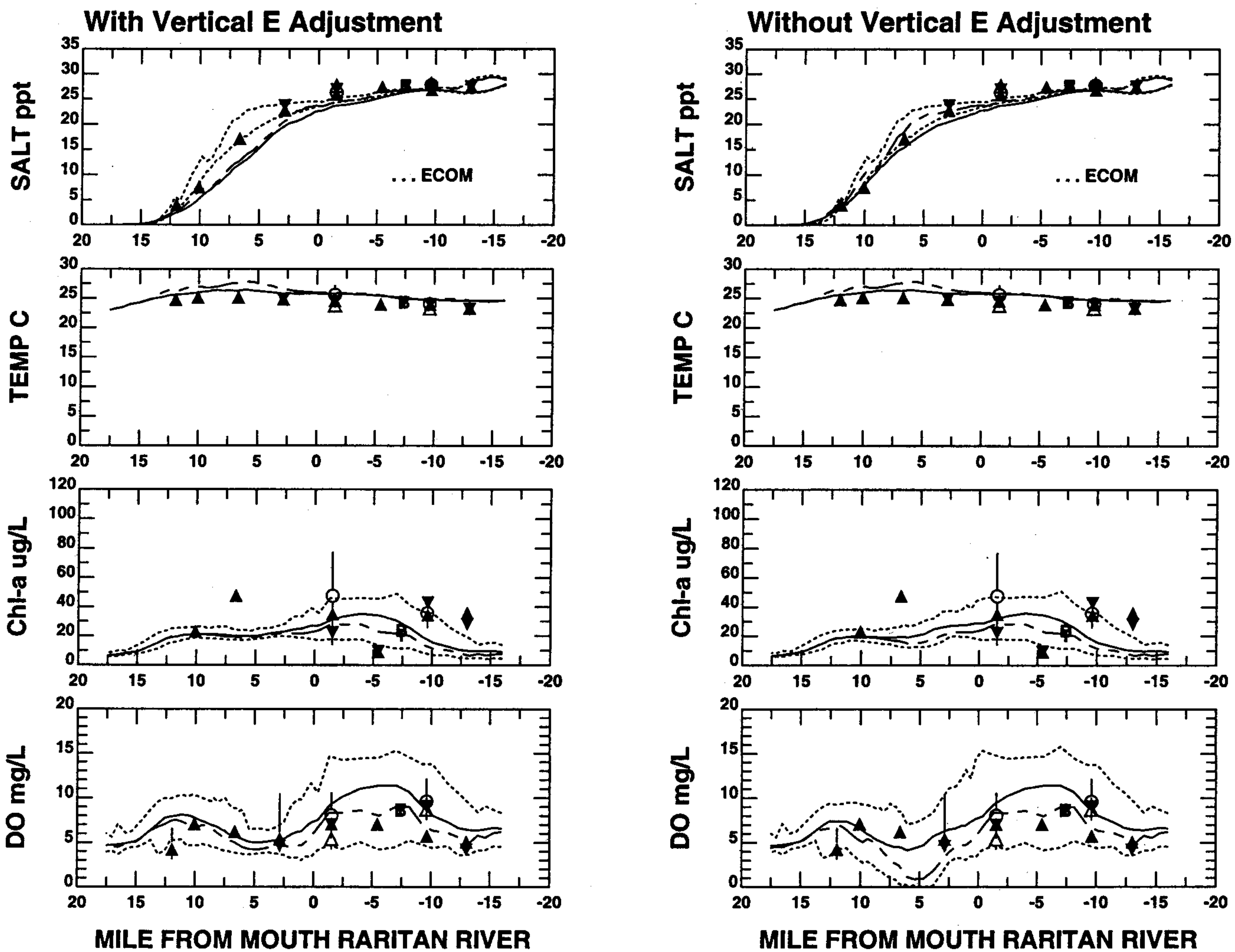
Algal growth in SWEM is parameterized through the use of coefficients for each assemblage which specify the optimum temperature at which maximum growth will occur. The parameterization also includes coefficients which account for the decline in optimal growth rate as the temperature changes either above or below the optimal temperature for growth. Observed chlorophyll-a data show a smoother transition from lower to higher temperatures than SWEM was calculating. In order to represent this transition better, the coefficient, an exponent, which controls the decline in algal growth rate at temperatures above the optimum temperature was adjusted from 0.006 to 0.004, and the optimum temperature was changed from 6 °C to 8 °C for the winter algal group. This change was applied model wide, producing a better calibration of the chlorophyll-a data during the times of transition from one algal assemblage to the other due to a change in temperature.

Also targeted at improving the calibration during the times of transition from one algal assemblage to the other, an adjustment to the zooplankton grazing rate coefficient was made during June. The zooplankton grazing rate coefficient in June was increased from 0.03 to 0.06. Measurements of zooplankton biomass were not made during the month of June. The change to the zooplankton grazing rate coefficient is based on the assumption that zooplankton biomass estimates based on July measurements apply to June also. The effect of adjusting the June zooplankton grazing coefficient was to delay somewhat the onset of the summer phytoplankton bloom. Further adjustments to the zooplankton grazing rate were not made as part of the calibration enhancement project as no new data or information were available concerning zooplankton biomass and grazing rates.

4.7 SWEM WATER QUALITY SUB-MODEL CALIBRATION/VALIDATION RESULTS AND SENSITIVITIES

The improved SWEM calibration was used to perform sensitivity analyses for the key modifications made on this project. The sensitivities presented below illustrate the efficacy or benefits of revisions to vertical mixing coefficients, temperature effects on nitrification, and temperature effects on algal growth rate. Each sensitivity simulation performed represents the response of the calibrated model to a singular change in an input parameter.

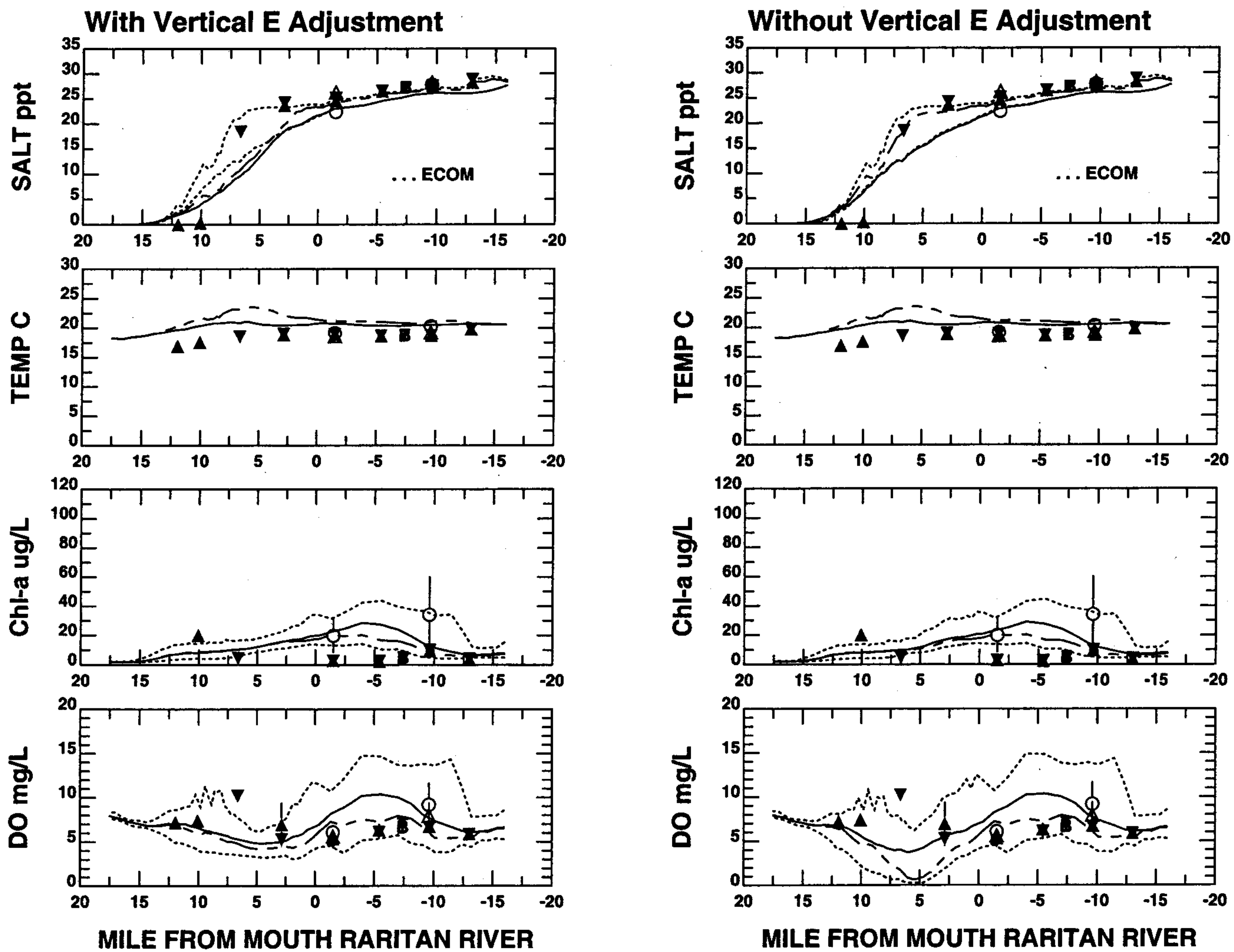
Figures 4-8 through 4-11 illustrate the effect of adjustments to vertical mixing coefficients in the Raritan and Hackensack Rivers on SWEM results as described above. For purposes of this illustration, SWEM results for the August and September 1995 surveys for four selected parameters are shown. Each figure presents model and data comparisons along spatial transects both with and without adjustment to vertical mixing coefficients. The observed data which are collocated with model results, are shown by filled upward pointing (near surface) and downward pointing (near bottom) triangles. When more than one data point is available due to collection at multiple depths, means and ranges are shown. It is noted that data from near bottom waters are often missing because samples at depth were not taken. In some cases, proximal, but not collocated, data points are shown using the letters T (near surface) and B (near bottom). Additionally, data collected by other programs during the same month as the SWEM monitoring program surveys are shown with non-filled symbols. 10-day mean model results in near surface and near bottom waters are shown by



Aug 20-29,1995
RARITAN RIVER AND NORTH SHORE OF RARITAN BAY

Figure 4-8

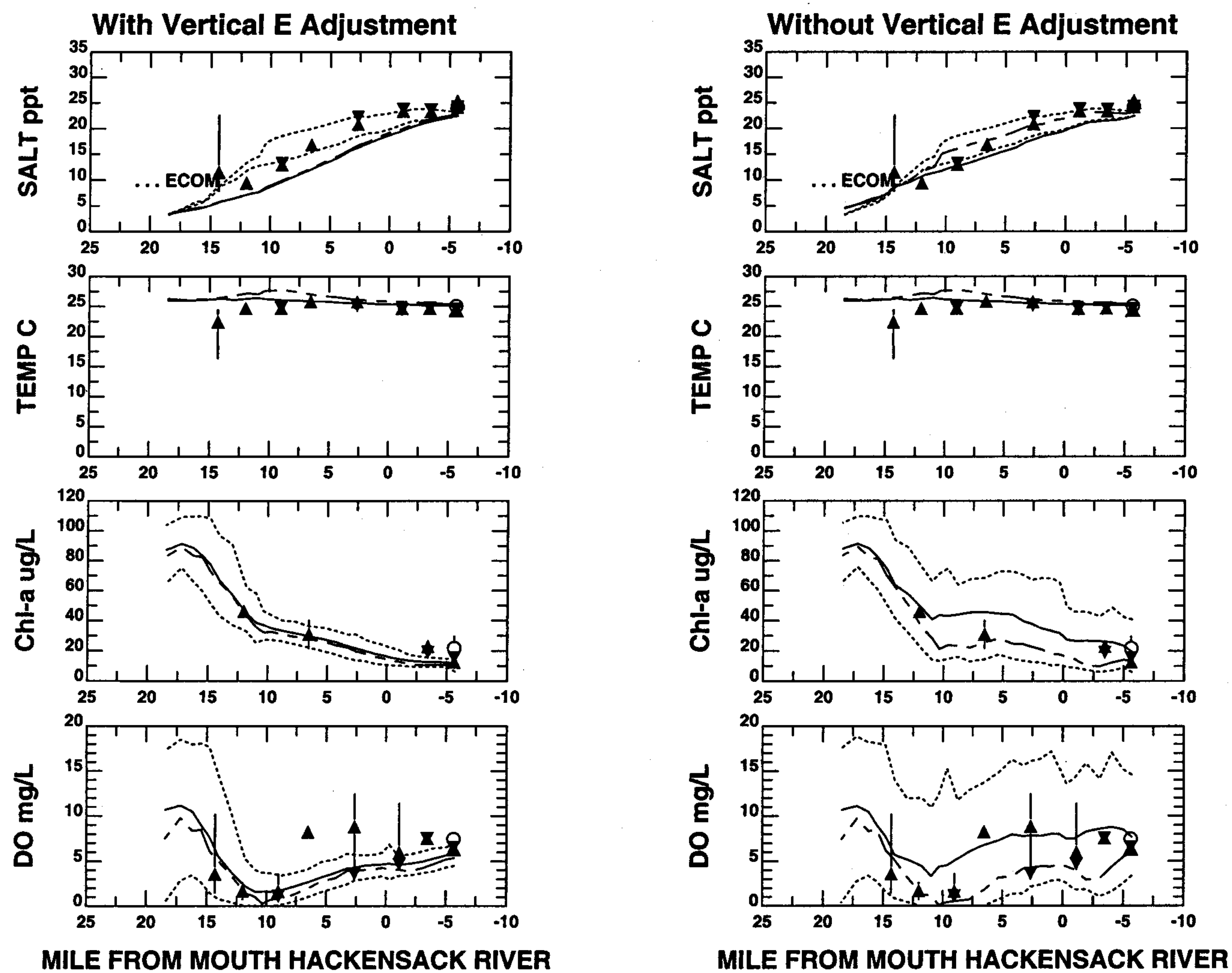
DATE: Fri Jul 19 TIME: 10:45:37



Sep 23-Oct 2,1995
RARITAN RIVER AND NORTH SHORE OF RARITAN BAY

Figure 4-9

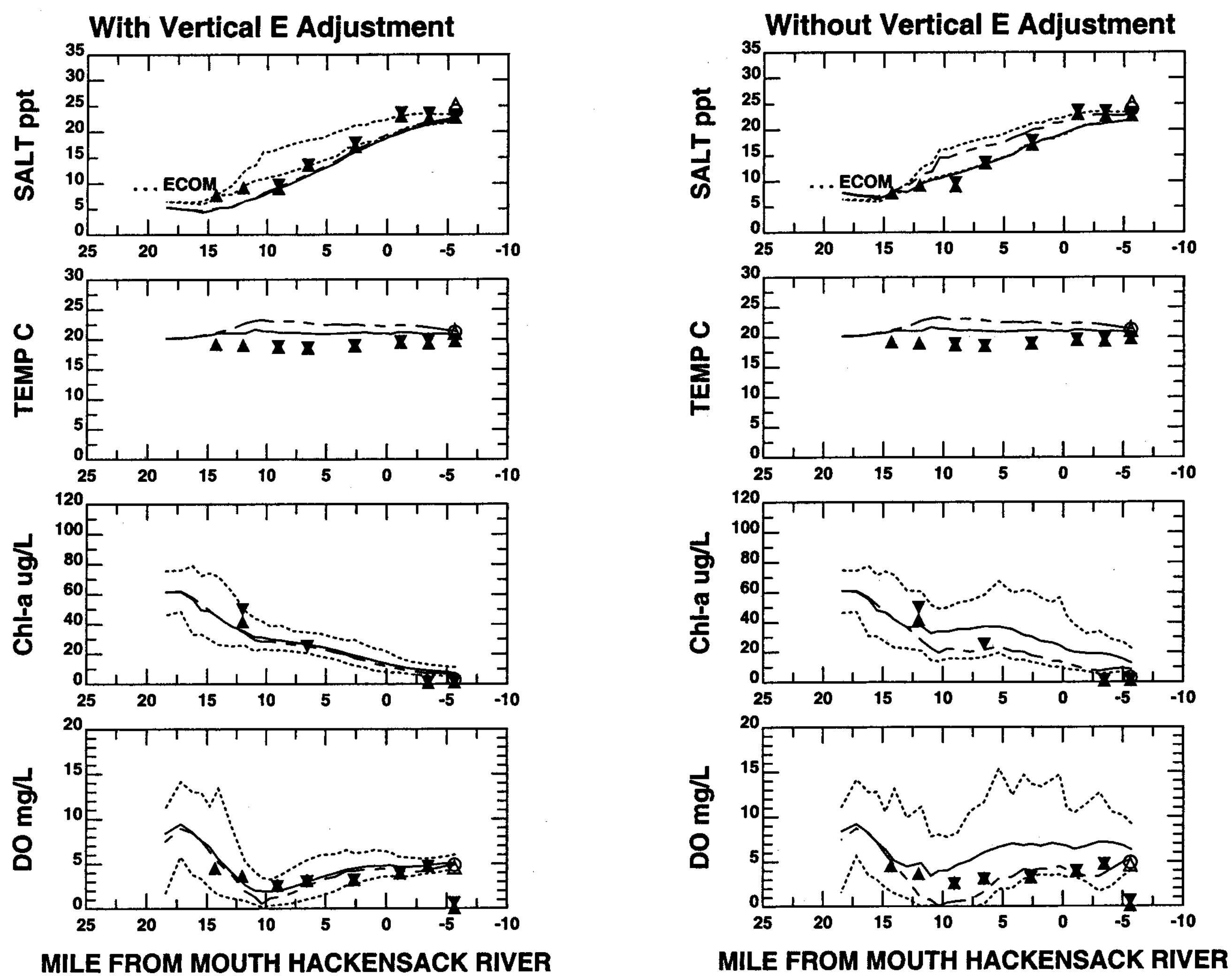
DATE: Fri Jul 19 TIME: 10:45:40



Aug 20-29,1995
HACKENSACK RIVER AND NEWARK BAY

Figure 4-10

DATE: Fri Jul 19 TIME: 10:47:11



Sep 23-Oct 2,1995
HACKENSACK RIVER AND NEWARK BAY

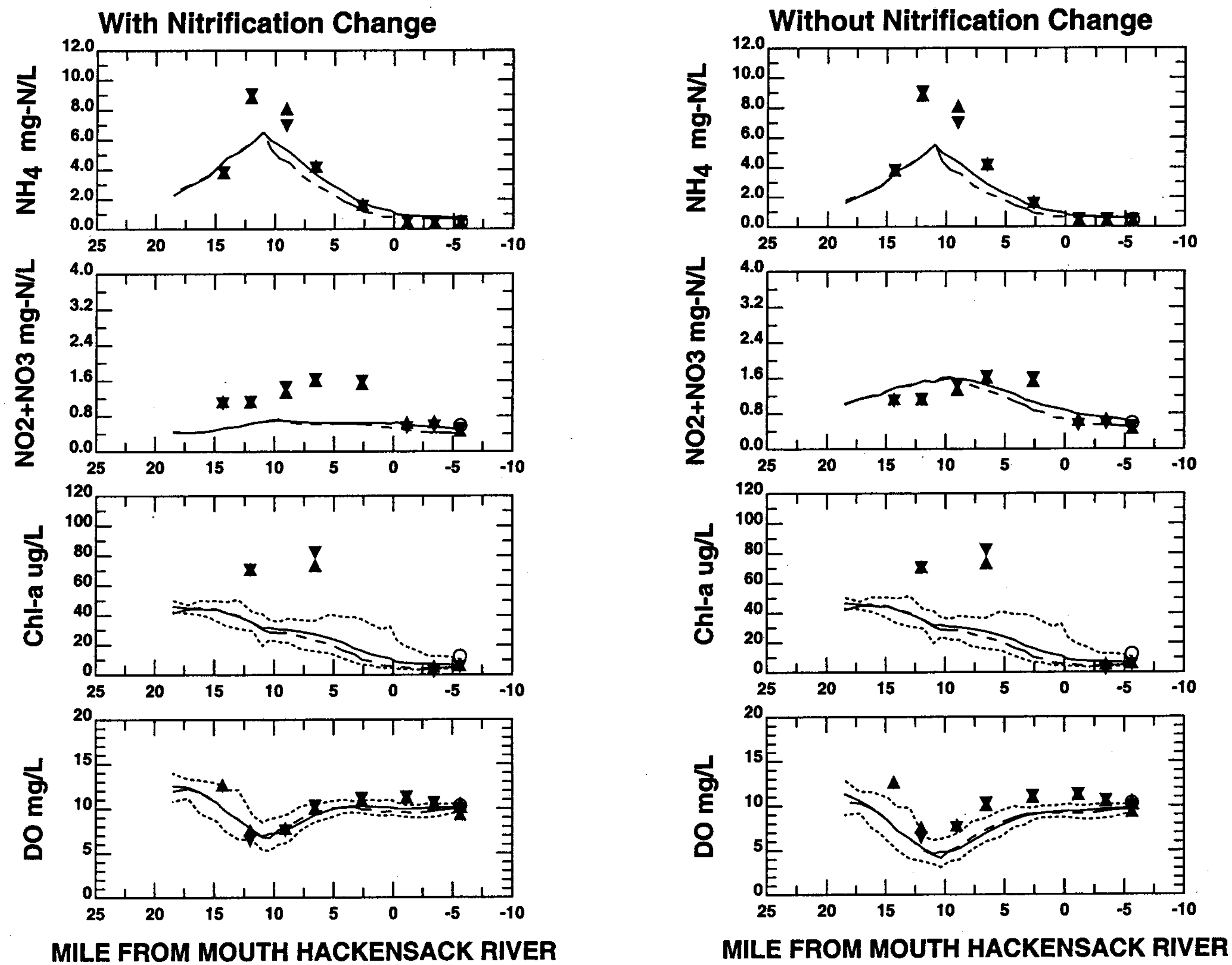
Figure 4-11

DATE: Fri Jul 19 TIME: 10:47:15

the solid and coarsely dashed lines, respectively. For dissolved oxygen and chlorophyll, the 10-day maxima and minima calculated by SWEM are shown by the finely dashed lines. For salinity, the finely dashed lines show the salinity as computed by the hydrodynamic sub-model ECOM which truly represents the hydrodynamic calibration. Due to the fact that hydrodynamic transport patterns which are calculated every 50 seconds in the hydrodynamic sub-model are passed to the water quality model on an hourly basis, there is a significant difference between the salinity calculated by each sub-model even before vertical mixing coefficient adjustments are applied.

Consider Figures 4-8 and 4-9 which show SWEM results along the Raritan River and in Raritan Bay for the August and September 1995 survey periods. Before vertical mixing coefficient adjustment, there is an under prediction of dissolved oxygen in the Raritan River in both near surface and near bottom waters in the vicinity of River miles 5 to 0 during August and September. Before vertical mixing coefficient adjustments, calculated mean and minima dissolved oxygen values approach 0 absent the support of measured data. Notice the improvement in both cases in dissolved oxygen after vertical mixing coefficient adjustment. Calculated dissolved oxygen is now 2 mg/L or better. Notice also that the chlorophyll concentrations are barely changed by the adjustment to vertical mixing, evidencing that dissolved oxygen more than any other parameter, is sensitive to vertical mixing coefficient adjustment. Similar observations are made upon inspection of representative SWEM results in the Hackensack River and Newark Bay for the same period as shown on Figures 4-10 and 4-11. The vertical mixing coefficient adjustments improve the dissolved oxygen calibration, and to a lesser extent the chlorophyll calibration as Figure 4-11 illustrates. On Figure 4-10, the dissolved oxygen data are suspect and were not considered as they show stratification which doesn't appear for either July or September and are not consistent with other August data measurements.

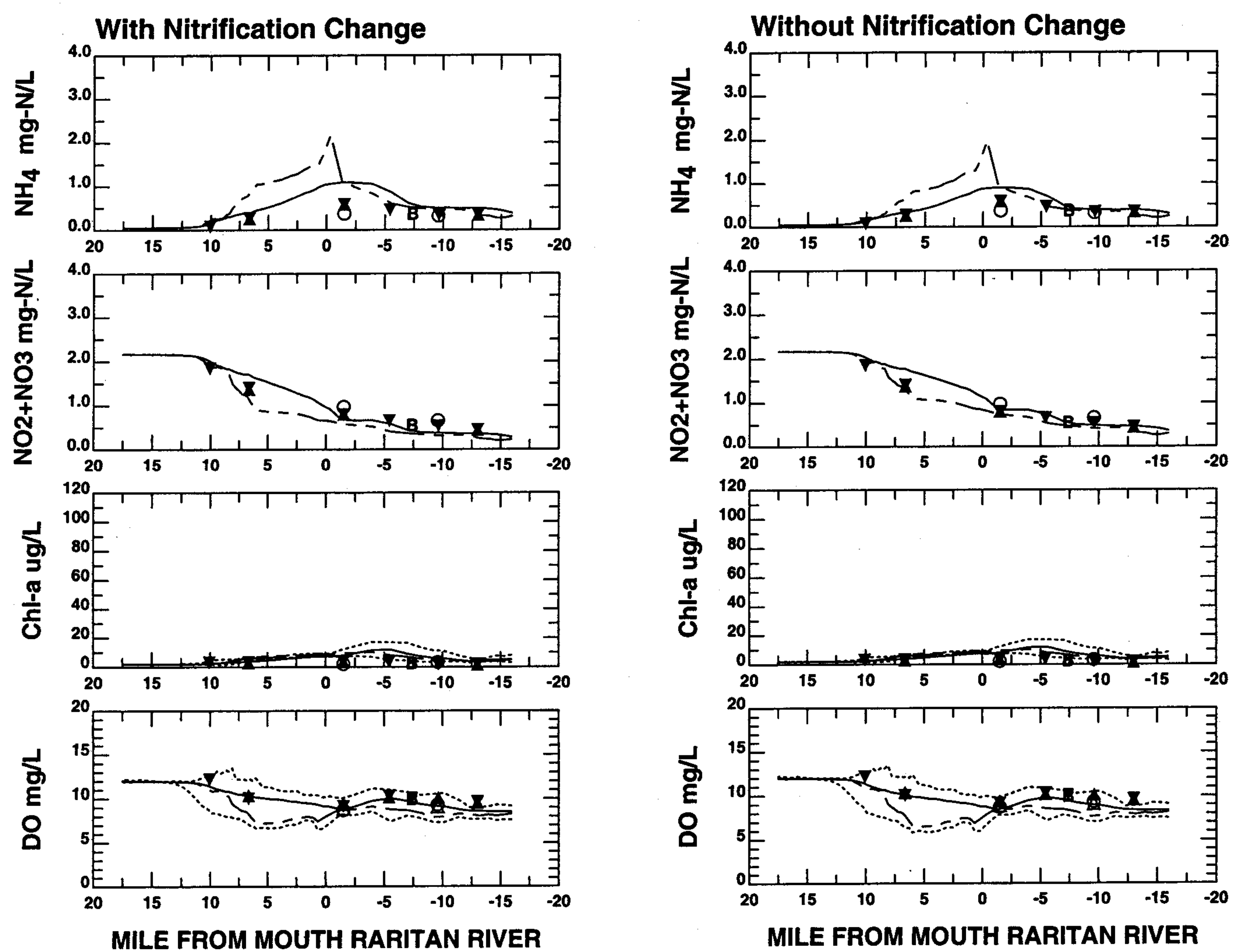
Figure 4-12 and 4-13 show examples of the sensitivity of SWEM to adjustment of nitrification rate at low temperatures. Nitrification is modeled in SWEM with dependencies on dissolved oxygen (i.e., a Michaelis expression with half saturation constant is used) and temperature. For this reason, the adjustment in SWEM to nitrification rate at low temperatures will not behave uniformly across locations and time for the same temperature. In general, reducing the nitrification rate causes an increase in ammonia nitrogen concentration, a decrease in nitrate and nitrite concentration, and an increase in dissolved oxygen concentration as illustrated on Figures 4-12 and 4-13. Figure 4-12 shows the Hackensack River and Newark Bay transect for the March 28 to April 8, 1995 sampling period. The change to SWEM kinetics to reduce the nitrification rate at low temperatures affects the model results as expected and identified above. In this specific example, the resultant increases in ammonia nitrogen and dissolved oxygen model results are consistent with the observed data; however, the resultant decrease in nitrate plus nitrite nitrogen calculation is inconsistent with observed data. It is a "trade-off" to weigh the benefits to the ammonia nitrogen and oxygen calibrations over the negative impact to the nitrate plus nitrite nitrogen calibration.



Mar 28-Apr 8,1995
HACKENSACK RIVER AND NEWARK BAY

Figure 4-12

DATE: Fri Jul 19 TIME: 10:33:43



Dec 10-16,1994
RARITAN RIVER AND NORTH SHORE OF RARITAN BAY

Figure 4-13

DATE: Fri Jul 19 TIME: 10:31:55

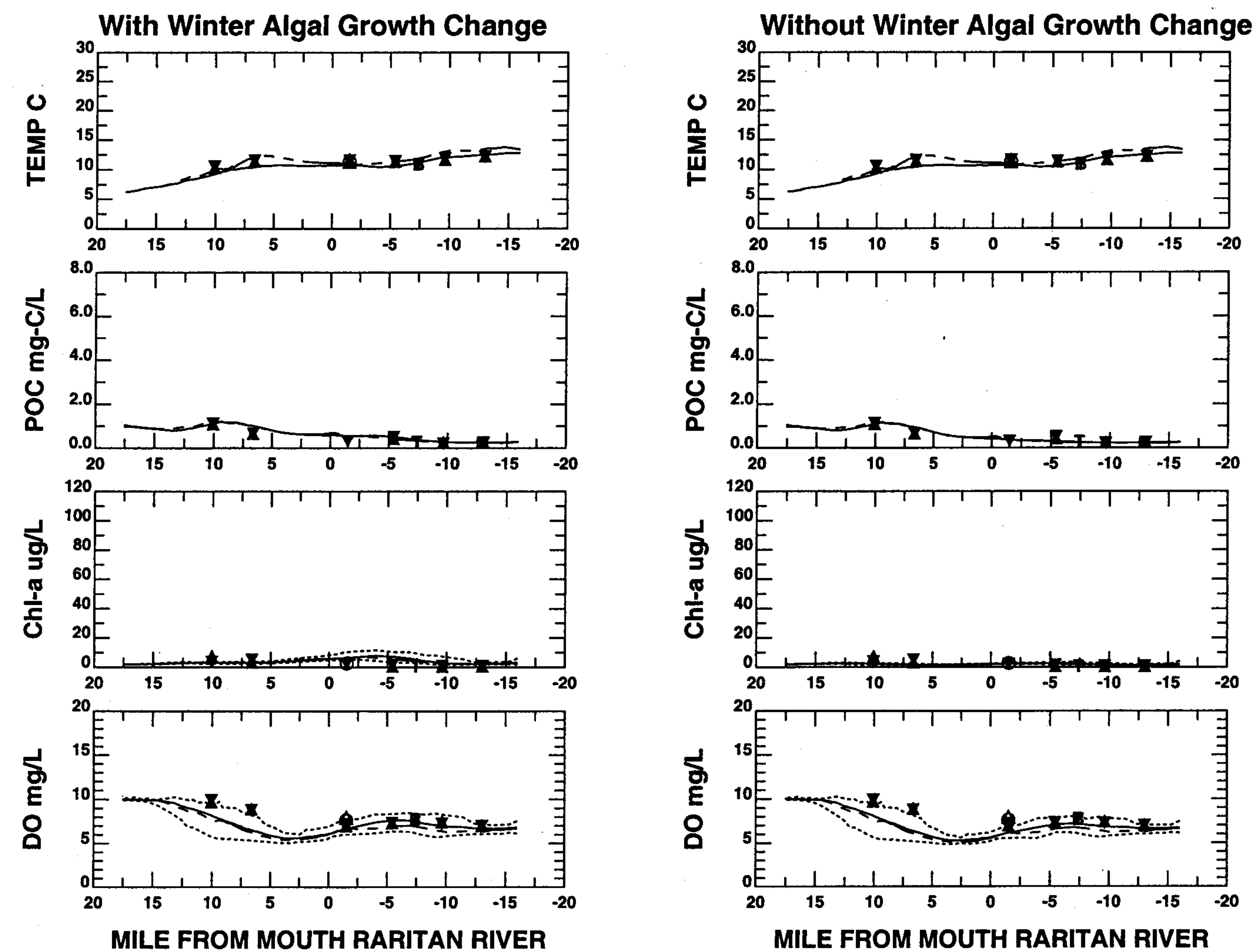
Further, as the change to nitrification rate was applied model wide, it is appropriate to factor into the trade-off" other locations and other periods. Figure 4-13 shows the sensitivity of SWEM to the nitrification rate change in the Raritan River and a portion of Raritan Bay for the December 10 to 16, 1995 sampling period. The Raritan example results show less sensitivity to the nitrification rate change than do the example results in the Hackensack River.

Figure 4-14 shows an example of the SWEM sensitivity to changes in algal growth kinetics for the winter group. There are two components to the change in algal growth kinetics. The optimum temperature for the growth of the winter assemblage of algae, predominantly diatoms, was adjusted from 6°C to 8°C. The impact of this change is to increase algal biomass (i.e., chlorophyll and particulate organic carbon concentrations are raised) during the winter months November through February. Algal growth is increased because the onset of the diatom bloom occurs earlier with the increased optimum temperature. The rate of decline in growth at temperatures above the optimum temperature of growth was also decreased, causing the diatom bloom to persist longer in the spring (i.e., into May). Although these changes appear fairly significant at face value, they did not have a major effect on model results as shown in Figure 4-14. The increases in chlorophyll, particularly organic carbon, and dissolved oxygen associated with this kinetic change are modest. The rationale for these changes was to smooth the transition between winter and summer algal assemblages.

Overall, the level of calibration of SWEM in the New Jersey tributaries is now commensurate with the level of calibration of the model for all waters system wide. There are location and time specific instances however where the calibration of SWEM in the New Jersey tributaries is still inadequate for regulatory purposes. Calibration and validation diagrams are included in the appendix of this report for plotting transects covering the entire domain and all monitoring periods. A brief discussion of the calibration in the New Jersey tributaries is presented here with representative demonstrations of the model calibration.

4.8 DISCUSSION OF WATER QUALITY CALIBRATION/VALIDATION ENHANCEMENTS

Some examples have been selected to demonstrate the level of improvement of the enhanced calibration over the original SWEM calibration. Figures 4-15 through 4-17 show representative comparisons of SWEM results before and after the enhancement project. Figure 4-15 shows the comparison for the Hackensack River and Newark Bay transect for December 1994 conditions. It is clear that the level of calibration is much improved for chlorophyll and dissolved oxygen because of the enhancement project. It is not clear which calibration is better for ammonia. It is not appropriate to judge the salinity calibrations because one would not expect salinity data for grab samples to compare favorably against 10-day average model results. Figure 4-16 shows a similar comparison for the Passaic River in the early spring. In this example, the level of calibration after the enhancement project is excellent, and significantly better than the original calibration.



Nov 12-17,1994
RARITAN RIVER AND NORTH SHORE OF RARITAN BAY

Figure 4-14

DATE: Fri Jul 19 TIME: 10:29:11

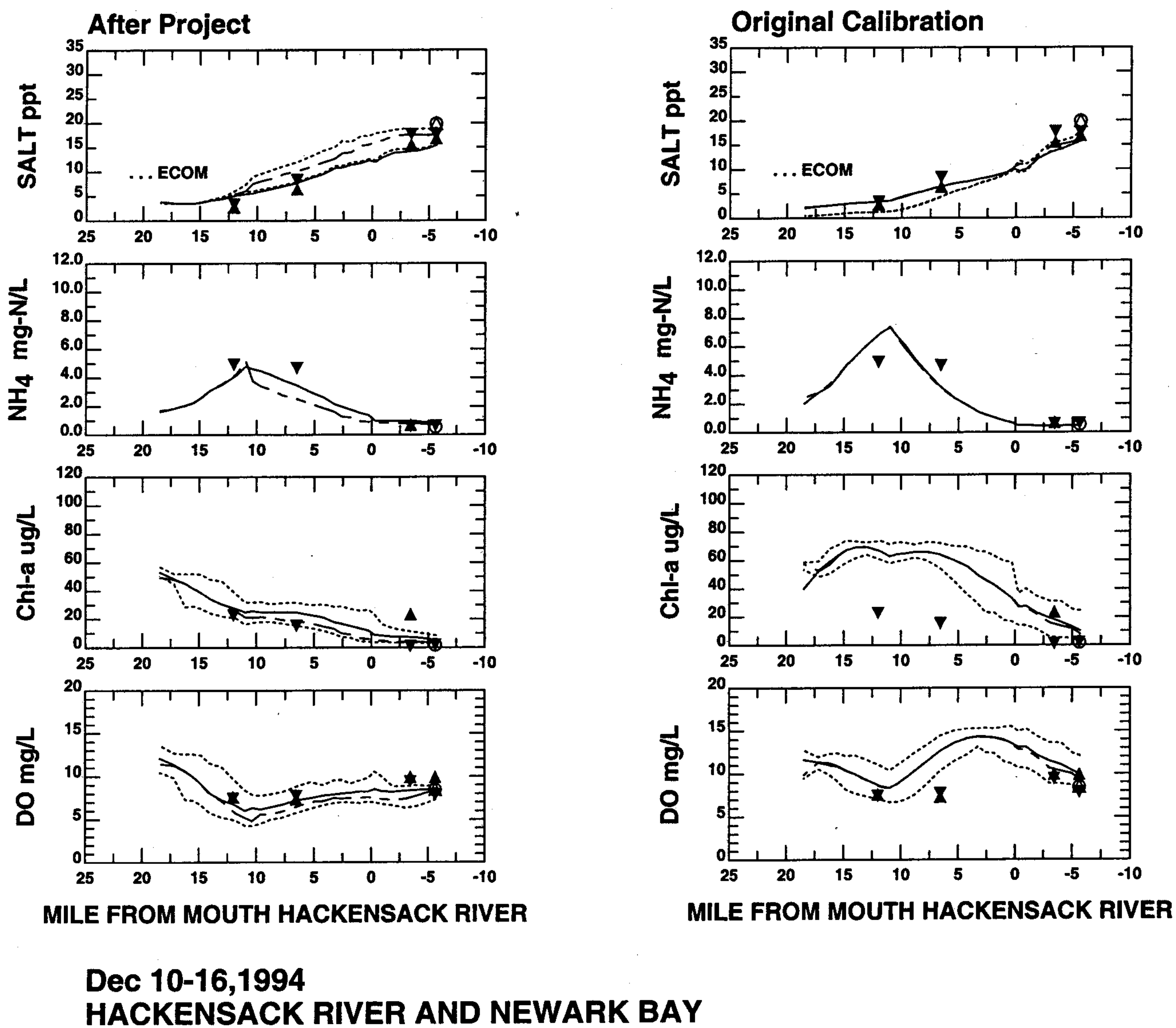


Figure 4-15

DATE: Fri Jul 19 TIME: 11:38:12

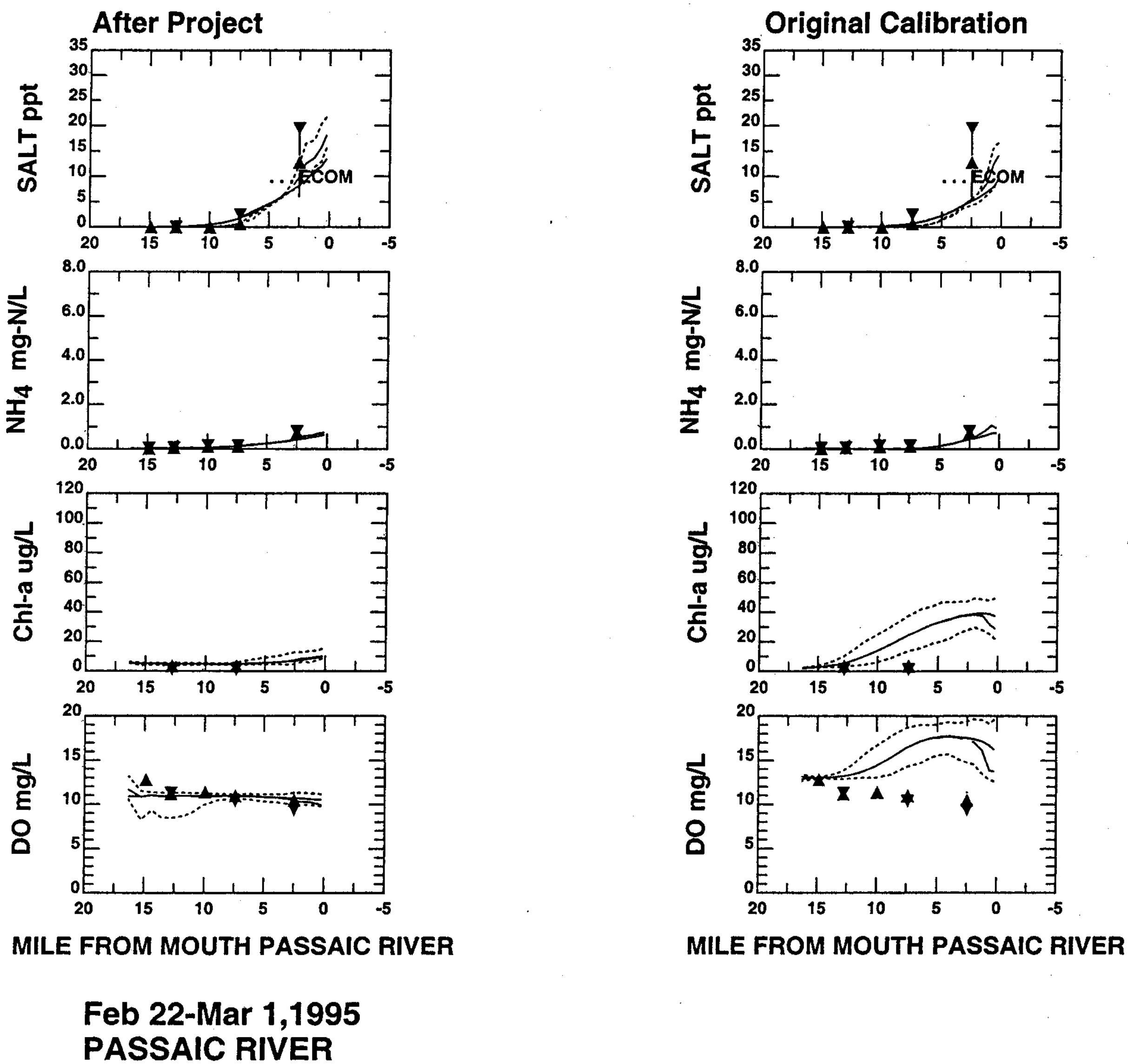
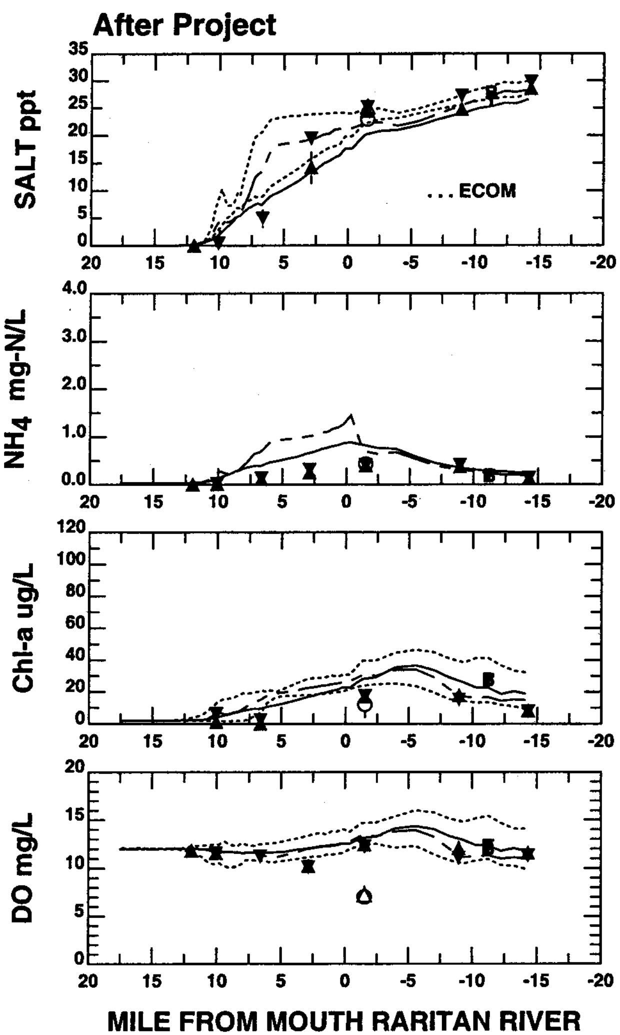
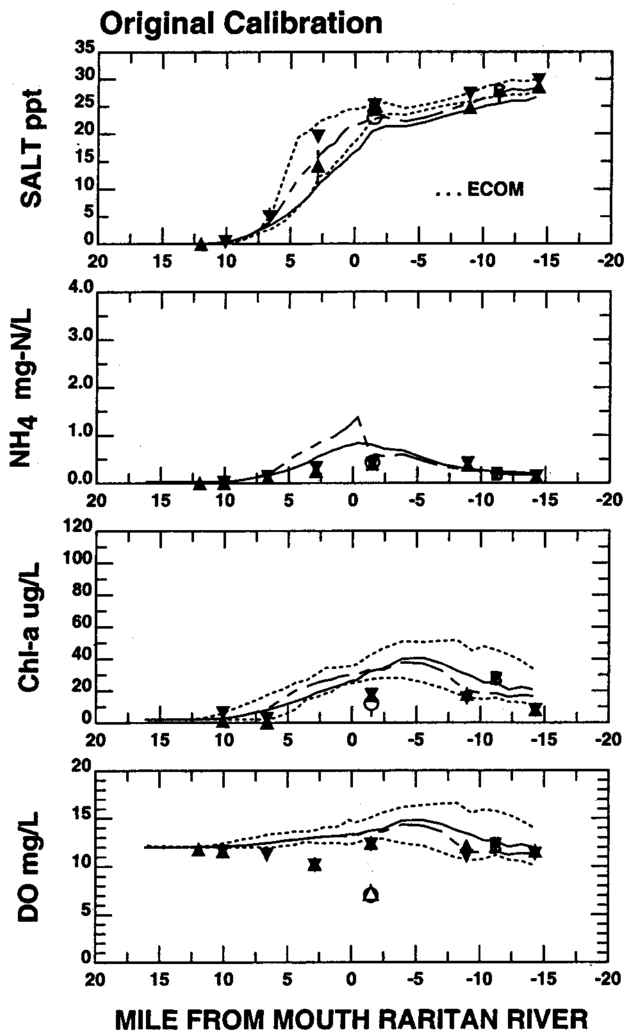


Figure 4-16

DATE: Fri Jul 19 TIME: 11:38:47





Feb 22-Mar 1,1995
RARITAN RIVER AND SOUTH SHORE RARITAN BAY

Figure 4-17

DATE: Fri Jul 19 TIME: 11:37:16

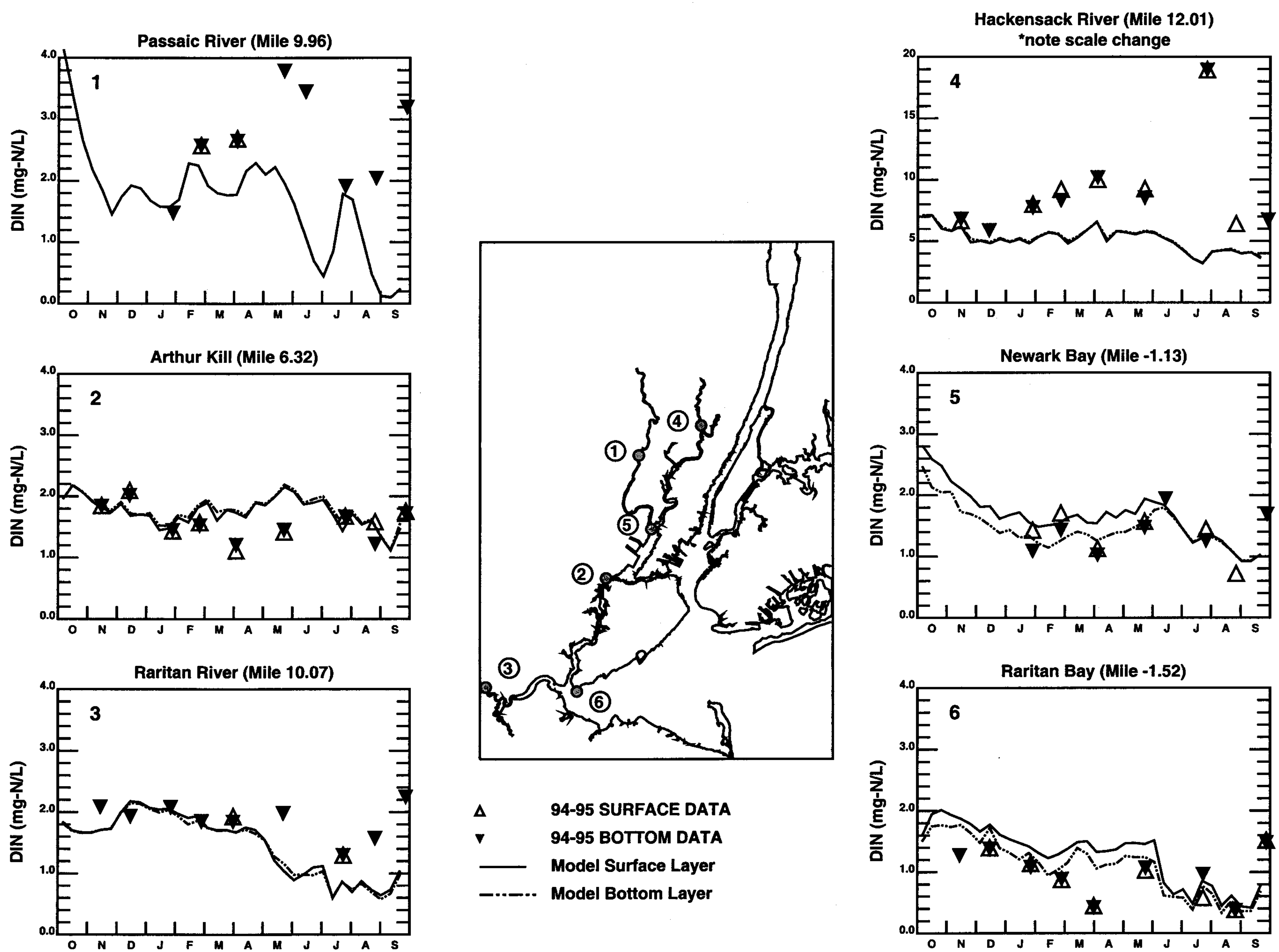
Figure 4-17 demonstrates the benefits of the project in the Raritan River and southern portion of Raritan Bay. The improvements in dissolved oxygen and chlorophyll are apparent and changes in ammonia nitrogen are more ambiguous. Based upon all of the differences in calibration after the project on an overall basis, the project resulted in an improved calibration.

While it is appropriate to compare the enhanced calibration to the original calibration, the enhanced calibration must be independently acceptable. Two metrics of acceptability of the enhanced calibration include: the ability of SWEM to calculate gradients and trends over an annual cycle at multiple locations and the ability of SWEM to simultaneously capture all of the components of the dissolved oxygen balance reasonably well.

The ability of SWEM to capture gradients and trends over an annual cycle is shown in Figures 4-18 to 4-20. These figures show temporal profiles of model and data comparisons at representative locations in each tributary and in Raritan Bay. Across each of the distinctly different tributaries and Raritan Bay the model picks up the major seasonal trends in the data.

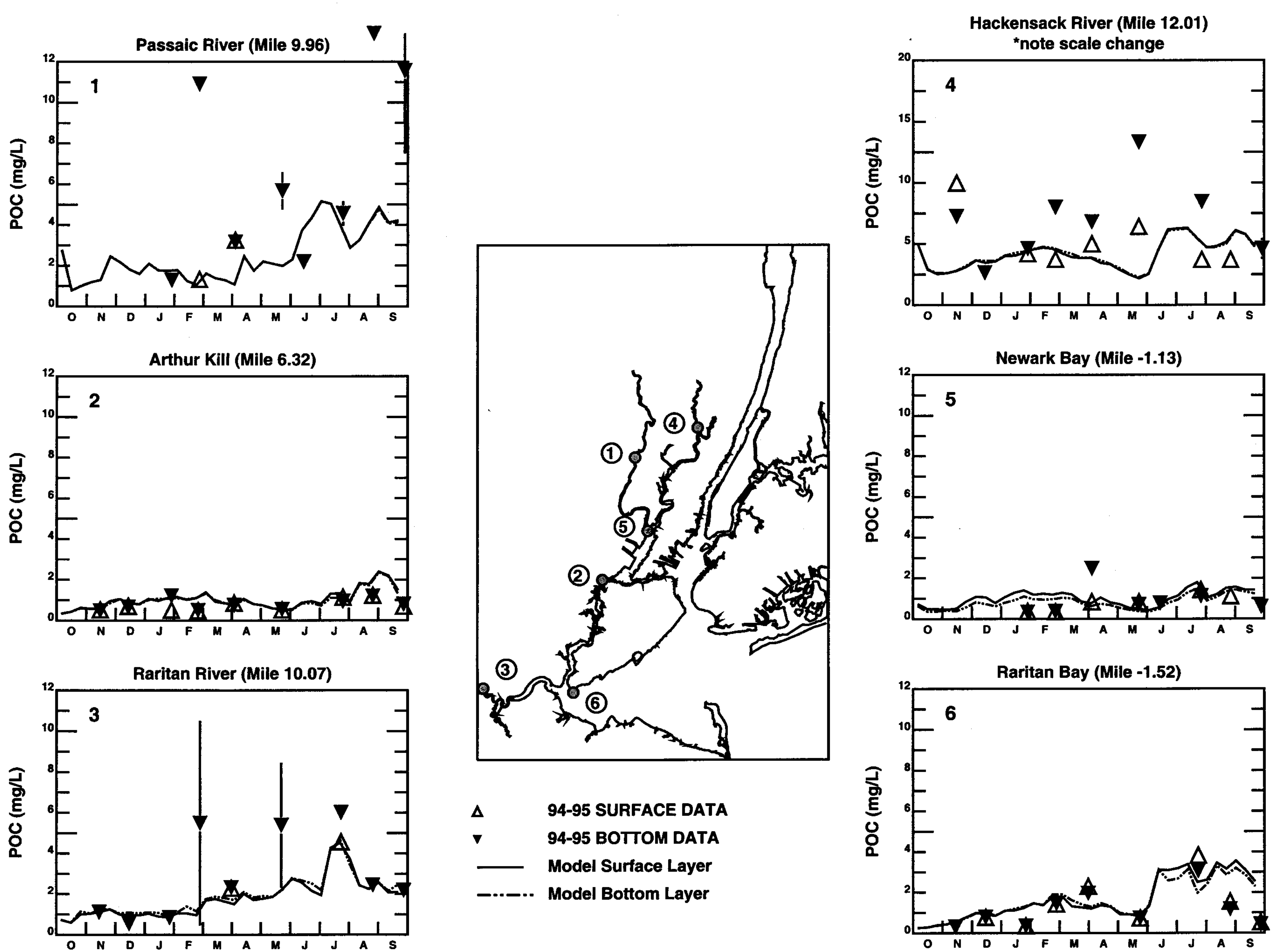
Figure 4-18 shows temporal model and data comparisons for selected locations for dissolved inorganic nitrogen (i.e., ammonia nitrogen plus nitrate and nitrite nitrogen). Since inorganic nitrogen is the form of nitrogen used by phytoplankton for growth, ambient concentrations of dissolved organic nitrogen can be viewed as a reservoir or surplus (i.e., what the phytoplankton have not used up). Ambient levels of dissolved inorganic nitrogen are extremely high in the Hackensack River (5 to 20 mg/L as nitrogen) and considerably lower in other New Jersey waters such as Raritan Bay (less than 2 mg/L as nitrogen). Measured ambient levels of dissolved inorganic nitrogen do not appear to reach levels where they could limit algal (less than tenths of a mg/L). This has important implications for modeling calculations and management decisions in that small changes to sources of nitrogen are unlikely to produce dissolved oxygen improvements. SWEM is able to capture the significant range in ambient dissolved inorganic nitrogen concentration across stations. SWEM does not capture smaller scale variations over time at an individual stations and is poorly calibrated at the location shown in Figure 4-18 for the Passaic River during summer months when observed dissolved inorganic nitrogen concentrations exceed 2 mg/L. SWEM also appears to be over-stratified in Newark Bay relative to the measured dissolved inorganic nitrogen in near surface and near bottom waters; however, as Figures 4-19 and 4-20 will show, this is not the case for particulate organic carbon and dissolved oxygen.

The miss of the measured dissolved inorganic nitrogen near River mile 10 during May and June and to a lesser extent in April in the Passaic River is related to an undercalculation of the nitrate plus nitrite concentrations. The model at this time and location is in excellent agreement with measured ammonia concentrations as evidenced by the Passaic River model and data comparison transect plot provided in the appendix for the May 20-26, 1995 survey. For the February and July



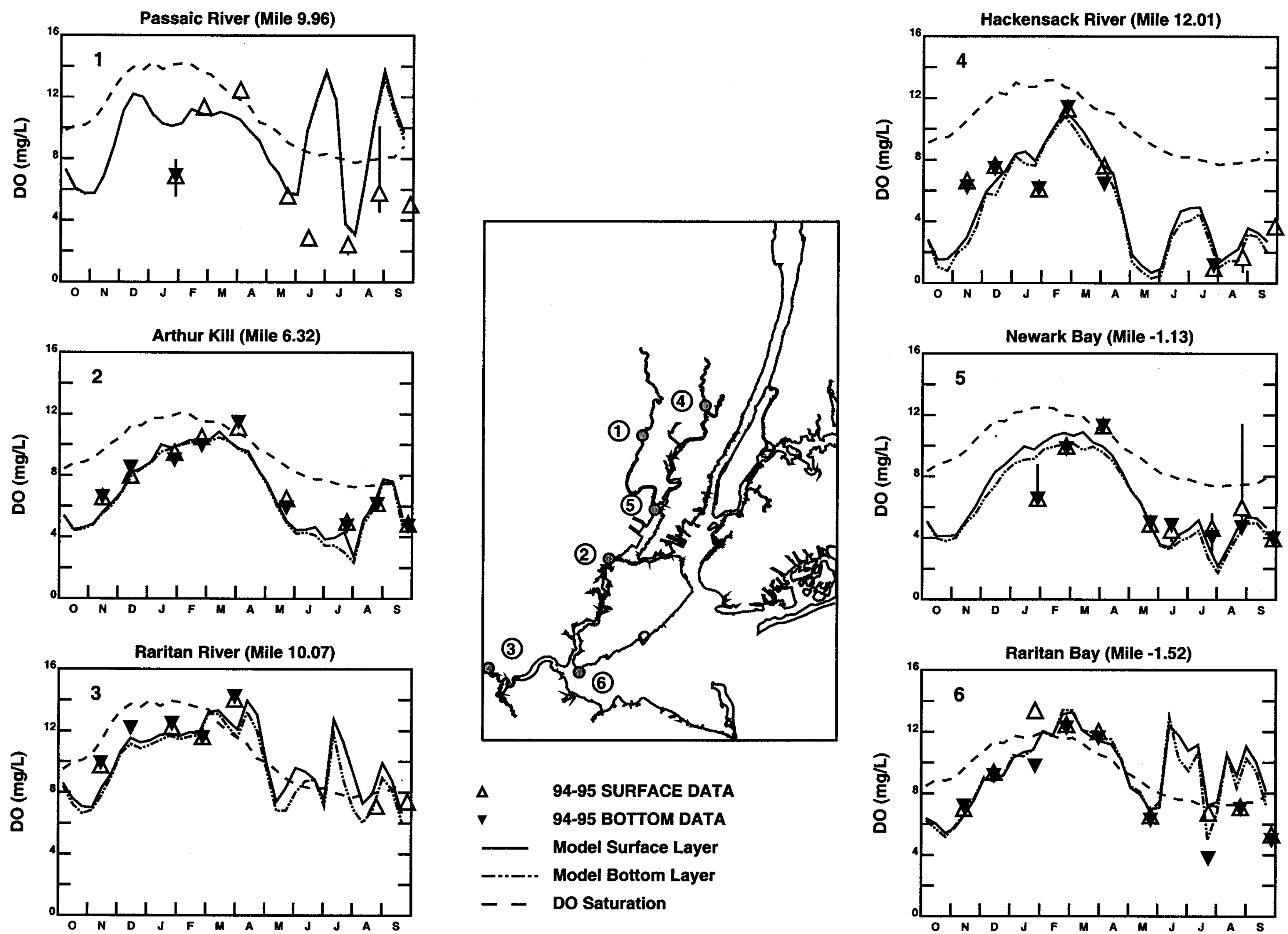
Passaic River (Mile 9.96)
Arthur Kill (Mile 6.32)
Raritan River (Mile 10.07)
Hackensack River (Mile 12.01)
*note scale change
Newark Bay (Mile -1.13)
Raritan Bay (Mile -1.52)
DIN (mg-N/L)
O N D J F M A M J J A S
1
2
3
4
5
6
94-95 SURFACE DATA
94-95 BOTTOM DATA
Model Surface Layer
Model Bottom Layer

Figure 4-18



Passaic River (Mile 9.96)
1
Arthur Kill (Mile 6.32)
2
Raritan River (Mile 10.07)
3
Hackensack River (Mile 12.01)
*note scale change
4
Newark Bay (Mile -1.13)
5
Raritan Bay (Mile -1.52)
6
POC (mg/L)
O N D J F M A M J J A S
94-95 SURFACE DATA
94-95 BOTTOM DATA
Model Surface Layer
Model Bottom Layer

Figure 4-19



Passaic River (Mile 9.96)
Arthur Kill (Mile 6.32)
Raritan River (Mile 10.07)
Hackensack River (Mile 12.01)
Newark Bay (Mile -1.13)
Raritan Bay (Mile -1.52)
DO (mg/L)
O N D J F M A M J J A S
94-95 SURFACE DATA
94-95 BOTTOM DATA
Model Surface Layer
Model Bottom Layer
DO Saturation

Figure 4-20

periods, the model calibration for both ammonia nitrogen and nitrate plus nitrite nitrogen is also excellent. The problem with under calculation of nitrate plus nitrite nitrogen in the late spring months does not appear to be related to a problem with too much algal uptake as the model somewhat underpredicts algal biomass at this time/location. A source of nitrate plus nitrite appears to be missing. The precipitous decrease in nitrate plus nitrite nitrogen is coincident with an unexplained elevation in dissolved oxygen concentration as Figures 4-18 and 4-20 show. Several steps were taken to adjust SWEM to explore the causality including:

- delaying the decline of the winter algal bloom through adjustments to parameters controlling the temperature dependence of the growth rate of the winter algal bloom as described in Section 4.6

- delaying the decline of the winter algal bloom with decreased zooplankton grazing

- delaying the onset of the summer algal bloom by raising the zooplankton grazing rate in June

- altering the timing of the winter bloom by increasing the saturating light intensity specified for the winter bloom

None of the above changes revealed an explanation or a remedy for the precipitous behavior of the model.

Also shown on Figure 4-18 is an elevation in dissolved inorganic nitrogen concentration in the Hackensack River in the vicinity of mile 12 during July which is not captured by the model. The elevation in dissolved inorganic nitrogen is simultaneous with elevations in ammonia nitrogen and dissolved inorganic phosphorus and depressions in nitrate plus nitrite nitrogen and dissolved oxygen. This coincidence suggests that the low dissolved oxygen may be triggering a release of ammonia nitrogen and dissolved inorganic phosphorus from the sediment bed to the water column which isn't occurring in the SWEM sediment flux model because the model may somewhat over-estimate the dissolved oxygen at this point in space and time. Calculated dissolved oxygen minima are less than 1 mg/l during July near mile 12, in agreement with data. Calculated dissolved oxygen means however for the July survey period are as high as 4 mg/l near mile 12.

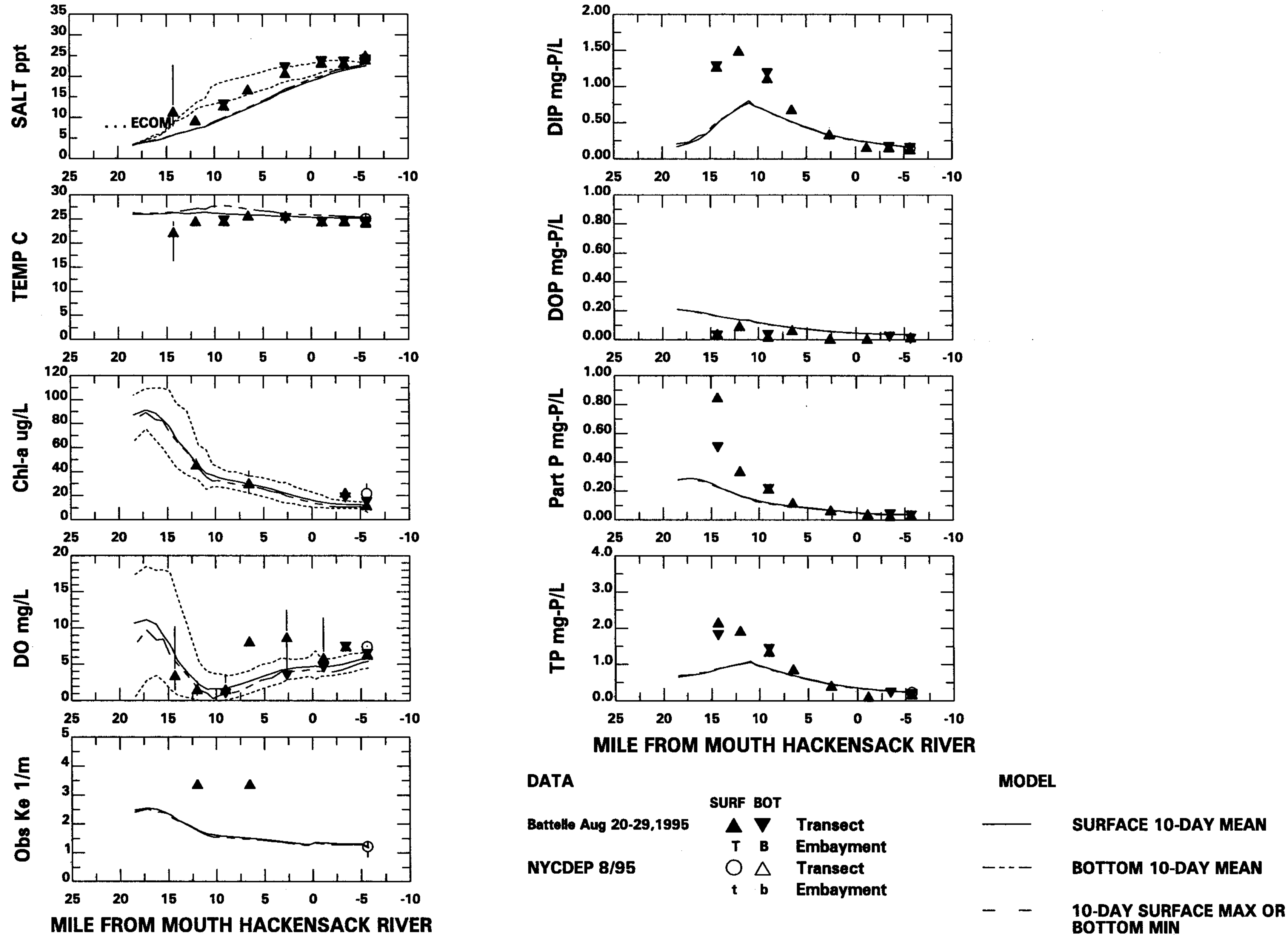
Figure 4-19 shows temporal model and data comparisons for the same selected locations for particulate organic carbon. Calculated and observed particulate organic carbon concentrations are higher in the Hackensack and Passaic Rivers than in the other New Jersey waters shown such as the Arthur Kill and Raritan Bay. The concentration gradient across stations is captured by SWEM. SWEM also captures smaller scale temporal gradients at individual locations. At the Raritan River location, for example, the model tracks an observed spike in particulate organic carbon in July which is likely a summer algal bloom. A similar spike is calculated one month early in Raritan Bay. In the Hackensack River, the particulate organic carbon data show several instances of stratification and de-stratification which are not observed in either the measured dissolved inorganic nitrogen or dissolved oxygen data and are not calculated by the model.

Figure 4-20 shows the analogous model and data results for dissolved oxygen. SWEM does an excellent job of capturing the observed temporal changes in dissolved oxygen at individual locations as well as observed differences across locations. The ability of SWEM to calculate dissolved oxygen well is significant. Dissolved oxygen is the ultimate endpoint for judging model and data comparisons because it represents an integrated response to many different physical and biological processes.

The ability of SWEM to simultaneously capture all of the components of the dissolved oxygen balance is shown by spatial transects which include model and data comparisons for 18 state variables for 9 data surveys. Spatial transects are presented for each tributary and Newark Bay and Raritan Bay during the month of August, a critical summer month when ambient levels of dissolved oxygen are particularly important in terms of compliance with water quality standards for dissolved oxygen and more importantly, for the protection of marine organisms. Also shown is a spatial transect of the Arthur Kill and Kill van Kull.

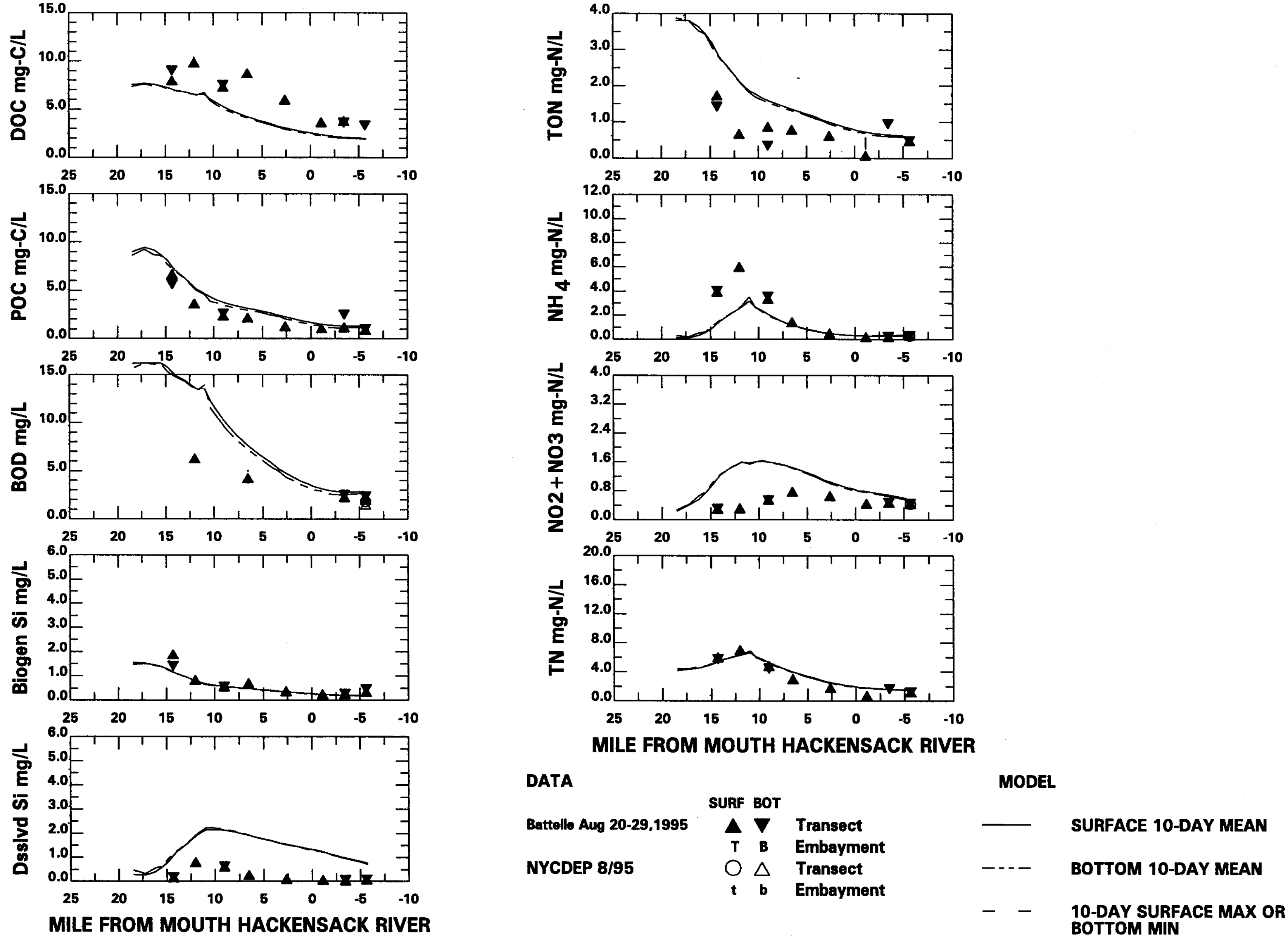
Figures 4-21a and 4-21b show model and data comparisons for 18 state variables under August 1995 conditions in the Hackensack River and Newark Bay main stem. For this particular month, the Hackensack River and Newark Bay complex model and data agree well for both chlorophyll a and particulate organic carbon (POC) suggesting that algal dynamics are well represented in SWEM, despite limited information on light extinction. The dissolved oxygen model and data comparison is also favorable, although the data show stratification in the last few miles of the Hackensack River above the confluence with Newark Bay (i.e., mile 0) that the model does not capture. It is questionable, however, as to whether or not the stratification in the data is real as it does not appear in any of the other measured data at the same location and time. Further, the dissolved oxygen model and data comparisons in the Hackensack River are excellent for every other calibration sampling date, including April, May, and July of 1995.

Total nitrogen and total phosphorus are relatively conservative constituents or tracers and can be used to assess the ability of the model to capture the overall transport pattern. The agreement between model and data for total nitrogen is excellent, evidencing that transport is accurately modeled. SWEM does not capture the total phosphorus data just downstream of the Oradell Dam (i.e., above mile 10). Given that the flow coming over the Oradell Dam is very small, headwater inputs to the Hackensack River have virtually no influence on concentrations downstream of the Dam in the Hackensack River. This has been demonstrated with model runs in



HACKENSACK RIVER AND NEWARK BAY

Figure 4-21a



HACKENSACK RIVER AND NEWARK BAY

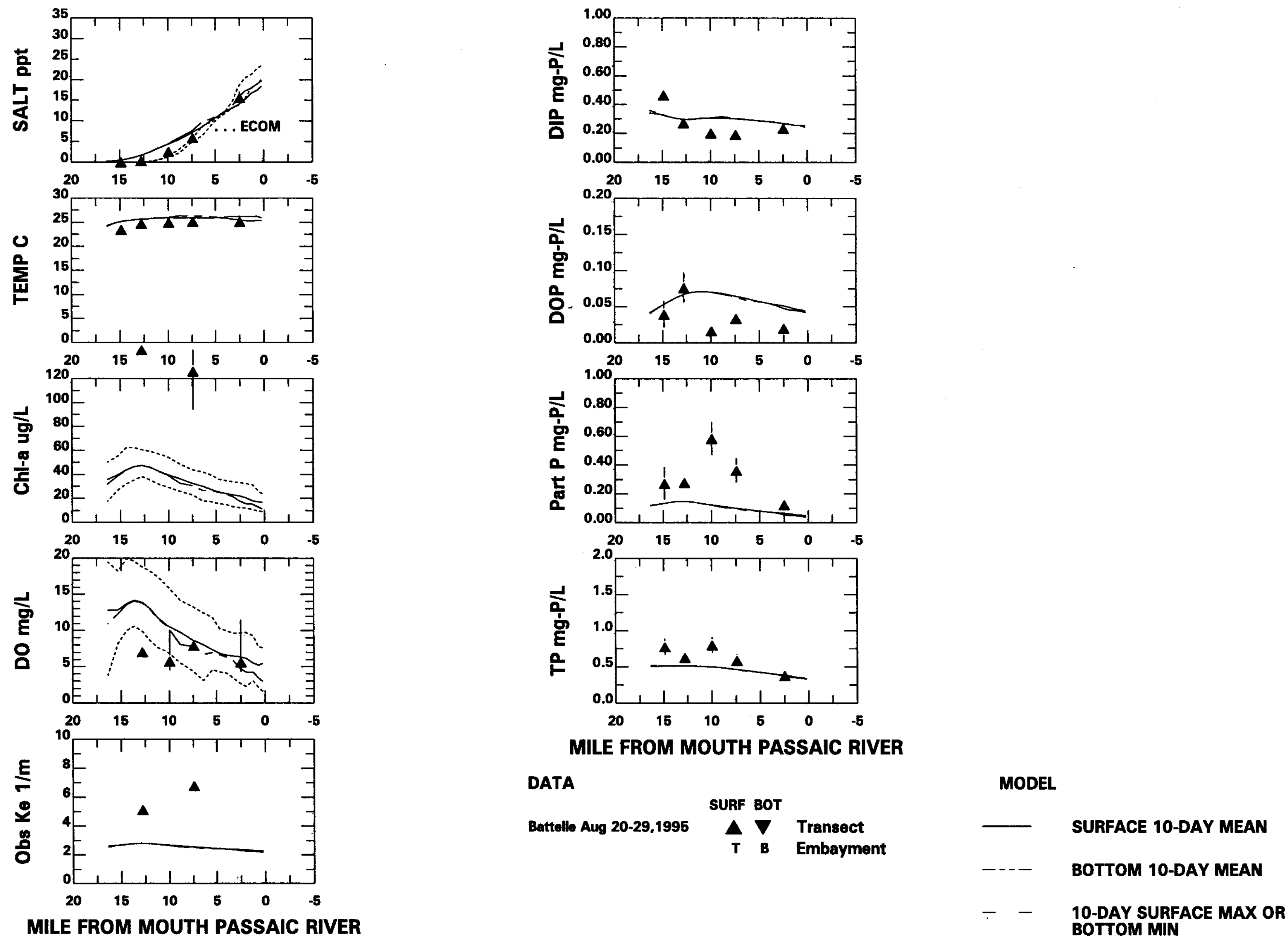
Figure 4-21b

which large changes to concentrations assigned to the flow coming over the Dam had virtually no effect on calculations downstream of the Dam. The miss of the total phosphorus data therefore may be due to an inaccurate specification or omission of a particulate and dissolved inorganic phosphorus loading coming into the River downstream of the Dam. While such a miss is bothersome, dissolved inorganic phosphorus concentrations in that portion of the River are in surplus of what is required to support the phytoplankton and is therefore inconsequential to the dissolved oxygen balance. The model and data comparisons of total phosphorus at the head of the Hackensack River are very good for other data collection periods during the 1994-95 water year. The miscalibration appears in July and August.

The missing source of phosphorus could potentially be explained as a missing phosphorus flux from the sediment bed. Phosphorus sorption in sediments is iron driven. In SWEM, phosphorus sorption is parameterized with a single partition coefficient, independent of iron concentration. If iron concentrations are high in Hackensack River sediments as is the case in Chesapeake Bay sediments, the phosphorus sorption partition coefficient should be set to a higher value in SWEM for the Hackensack River, effectively storing more phosphorus in the sediment bed. The mechanism for eventually releasing phosphorus stored in the sediment bed to the water column is parameterized in SWEM as a reduction in the phosphorus sorption partition coefficient when the water column dissolved oxygen is less than 2 mg/l. Dissolved oxygen levels in the head end of the Hackensack River suggest that a phosphorus release from the sediment is possible. The ability to specify phosphorus sorption partition coefficients in SWEM as a function of sediment iron concentrations would require both a long term data record of sediment iron concentrations and significant changes to the SWEM model code structure.

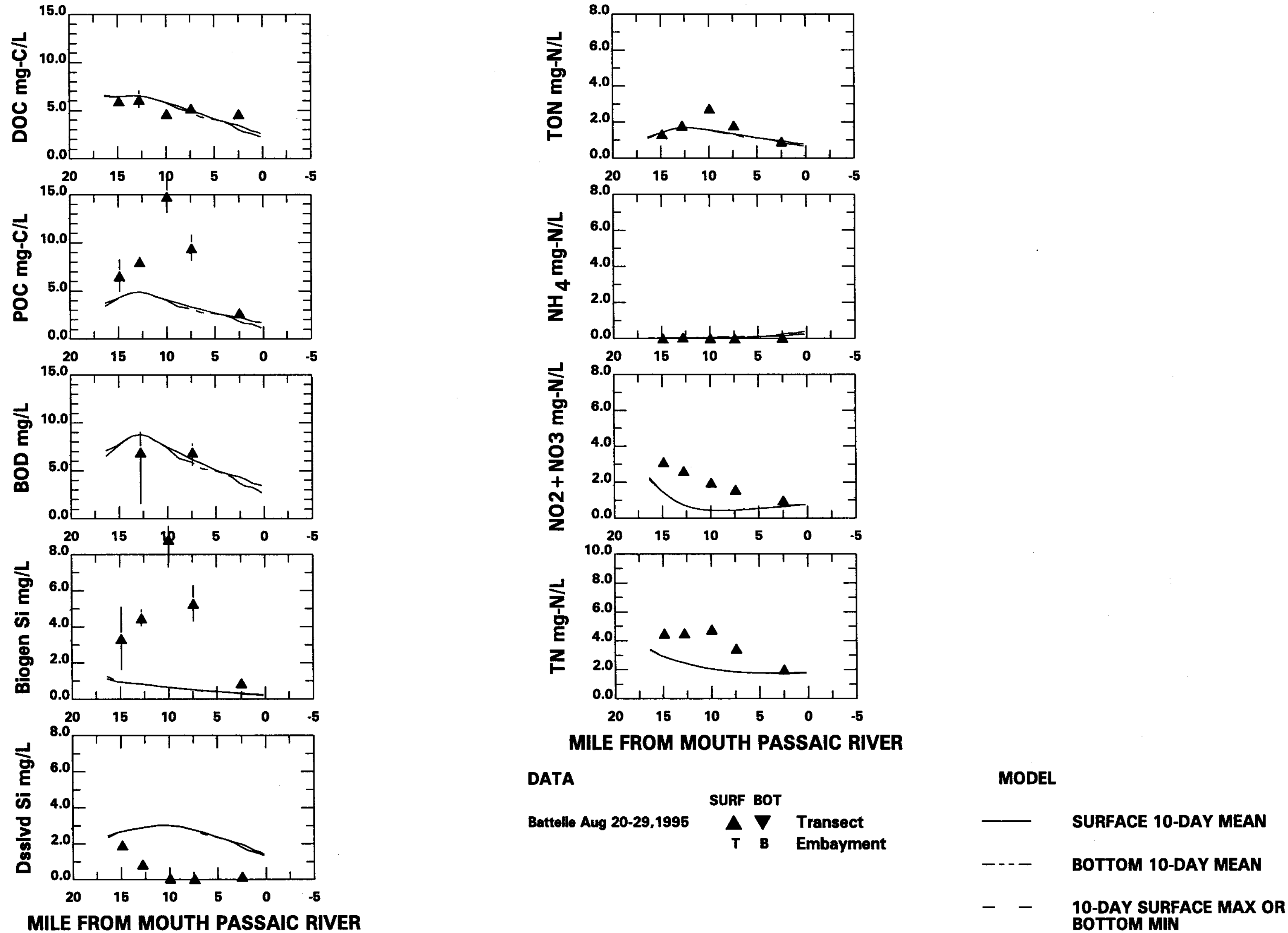
There also appears to be a discrepancy between calculated and observed nitrogen speciation in the upstream portion of the Hackensack River. Again this is likely associated with a loading problem downstream of the Dam which can't be resolved with existing information and is not problematic in terms of the dissolved oxygen balance and nutrient limitation because in the downstream area of the Hackensack River and in Newark Bay where reserves of dissolved inorganic nitrogen are small, there is excellent agreement between model calculations and measured data. The nitrogen speciation discrepancy between model and data does not persist year round but appears under summer conditions.

Figures 4-22a and 4-22b show model and data comparisons for 18 state variables under August 1995 conditions in the Passaic River. August 1995 conditions in the Passaic River are dramatically different from conditions in July, 1995. Several of the measured variables, i.e. chlorophyll, particulate phosphorus, biogenic silica, and particulate organic carbon suggest a concentration "spike" in the vicinity of mile 10 which the model does not capture. The origins of this "spike" in the data are uncertain and could not be definitively determined. While the



PASSAIC RIVER

Figure 4-22a



PASSAIC RIVER

Figure 4-22b

simultaneous elevation in measured chlorophyll and POC suggest elevated algal biomass which could be a diatom bloom or floating algal mat, the model and data comparisons for dissolved inorganic nitrogen (i.e., ammonia and nitrate plus nitrite) and dissolved oxygen suggest that additional algal growth could not be supported. The model underpredicts the measured dissolved inorganic nitrogen concentrations while underestimating the algal biomass on both a POC and chlorophyll basis. For this particular month and location, inconsistencies in the data make it difficult to assess model calibration. Further, it is not known whether or not the apparent algal bloom is an abnormal condition specific to 1995 or whether such a bloom typically occurs in the Passaic River every summer. Long-term monitoring recommendations presented in Section 5 would help answer this question.

Phytoplankton species counts conducted in August 1995 as part of the SWEM monitoring program show diatom species to comprise at least 30% of the phytoplankton count in Newark Bay, providing some evidence that a diatom bloom in the Passaic River in August 1995 might have occurred. Unfortunately, phytoplankton species counts were not performed in the Passaic River in August when the diatom bloom is believed to have occurred. Phytoplankton counts conducted in the Passaic River as part of the supplemental monitoring funded by NJHDG show diatoms to be 10% or less of the total phytoplankton count during July, the month before the apparent bloom, and September, the month after the apparent bloom.

If a diatom bloom did occur in August 1995 in the Passaic River, it was of very short duration. The bloom is a feature that SWEM can't reproduce as configured. To model such would require extensive revisions to the kinetic structure of SWEM to include a third algal functional group with a much higher growth rate than currently used for either of the two algal functional groups in SWEM now. Further, it might be appropriate to include a salinity dependence on the development of such a bloom in the model as it may be limited to salinity levels found in tributary areas.

An analysis of the observed particulate organic nitrogen and phosphorus data and biogenic silica data at mile 10 illustrates some of the calibration difficulty associated with the August 1995 Passaic River data. The observed total organic nitrogen, particulate phosphorus, and biogenic silica concentrations of 3, 0.45, and 7.5 mg/l respectively when combined with Redfield non-diatom algal cell carbon to nutrient ratios of 5.67, 40, and 10 for N,P, and Si, respectively, yield algal carbon estimates of 17, 18, and 75 mg/l. While the algal carbon implied by the measured N and P concentrations are consistent, the algal carbon implied by the measured Si concentration is significantly higher. Further, the measured POC is in agreement with the algal carbon implied by the N and P concentrations. For the silica calibration to work, a carbon to silica ratio of around 2 would be required. Such a low carbon to silica ratio is inconsistent with the parameterization of the silica content of the summer algae in SWEM. The minimum carbon to silica ratio specified for the summer algae in SWEM is 10. For winter diatoms, the minimum specified carbon to silica ratio is

2.5. The carbon to silica ratio of around 2 shown by the observed data at mile 10 are consistent with a "pure" diatom bloom. SWEM is not configured to calculate a "pure" diatom bloom.

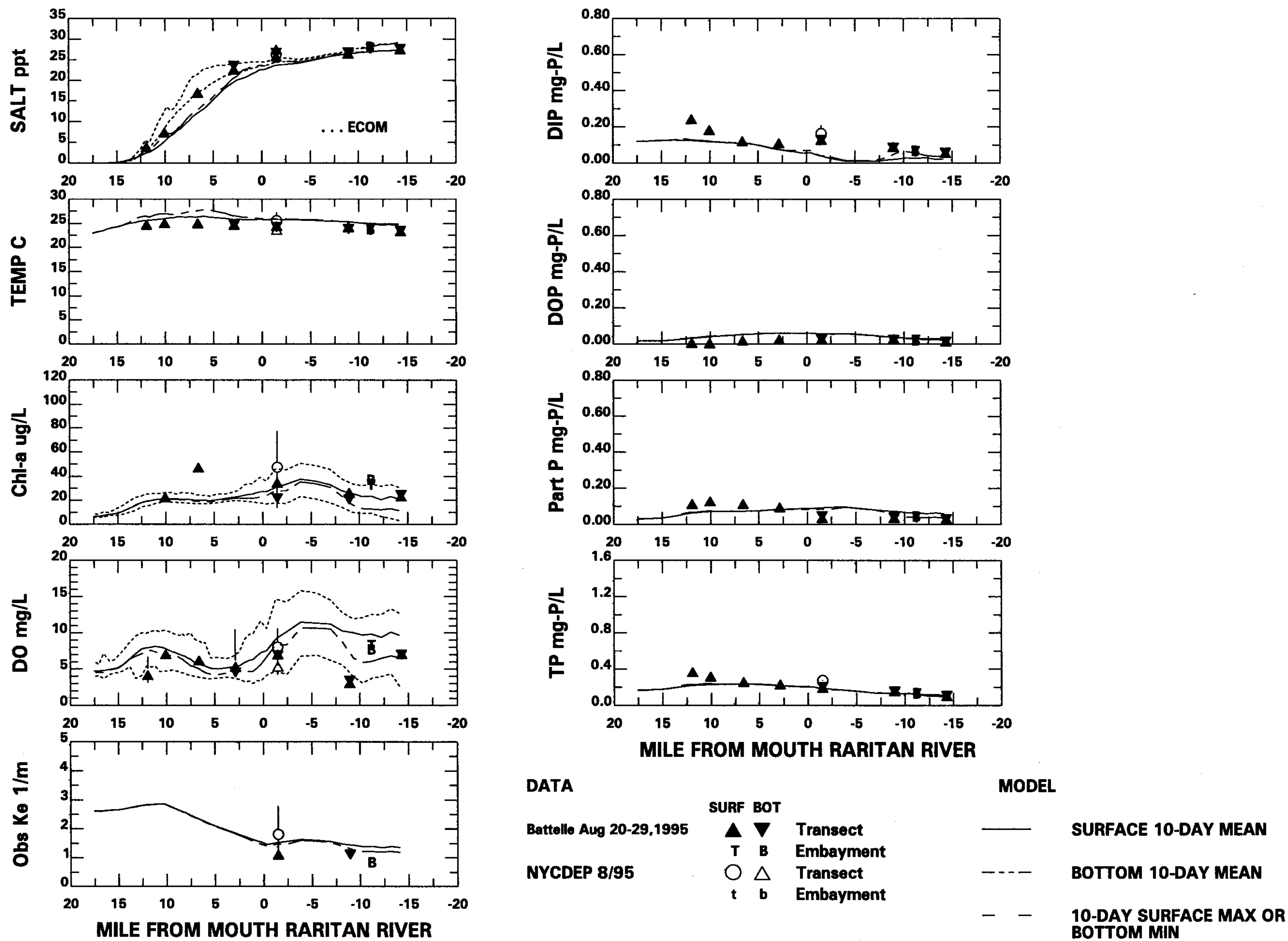
Several diagnostic simulations were performed with SWEM in which the carbon to silica ratio for the summer group was lowered as suggested by the August 1995 Passaic River data near mile 10. This model input change did not result in the model reproducing the bloom suggested by the data. A greater uptake of silica by the same algal biomass as calculated previously resulted since the algal biomass achieved is controlled by factors in addition to available silica including the availability of other dissolved inorganic nutrients, light, and residence time in the photic zone. The results of changing the carbon to silica ratio for the summer algal group were also inspected for other periods in the Passaic River as well as in other areas of the study domain. In general, the change while helpful in certain locations under August conditions, worsens the calibration in all locations under July and September conditions.

Figures 4-23a and 4-23b show model and data comparisons for 18 state variables under August 1995 conditions in the Raritan River and in the southern portion of Raritan Bay. Model and data comparisons for this transect/time are very good. In particular, the speciation of total nitrogen and total phosphorus are well represented by model calculations as is dissolved oxygen (i.e., both DO and BOD).

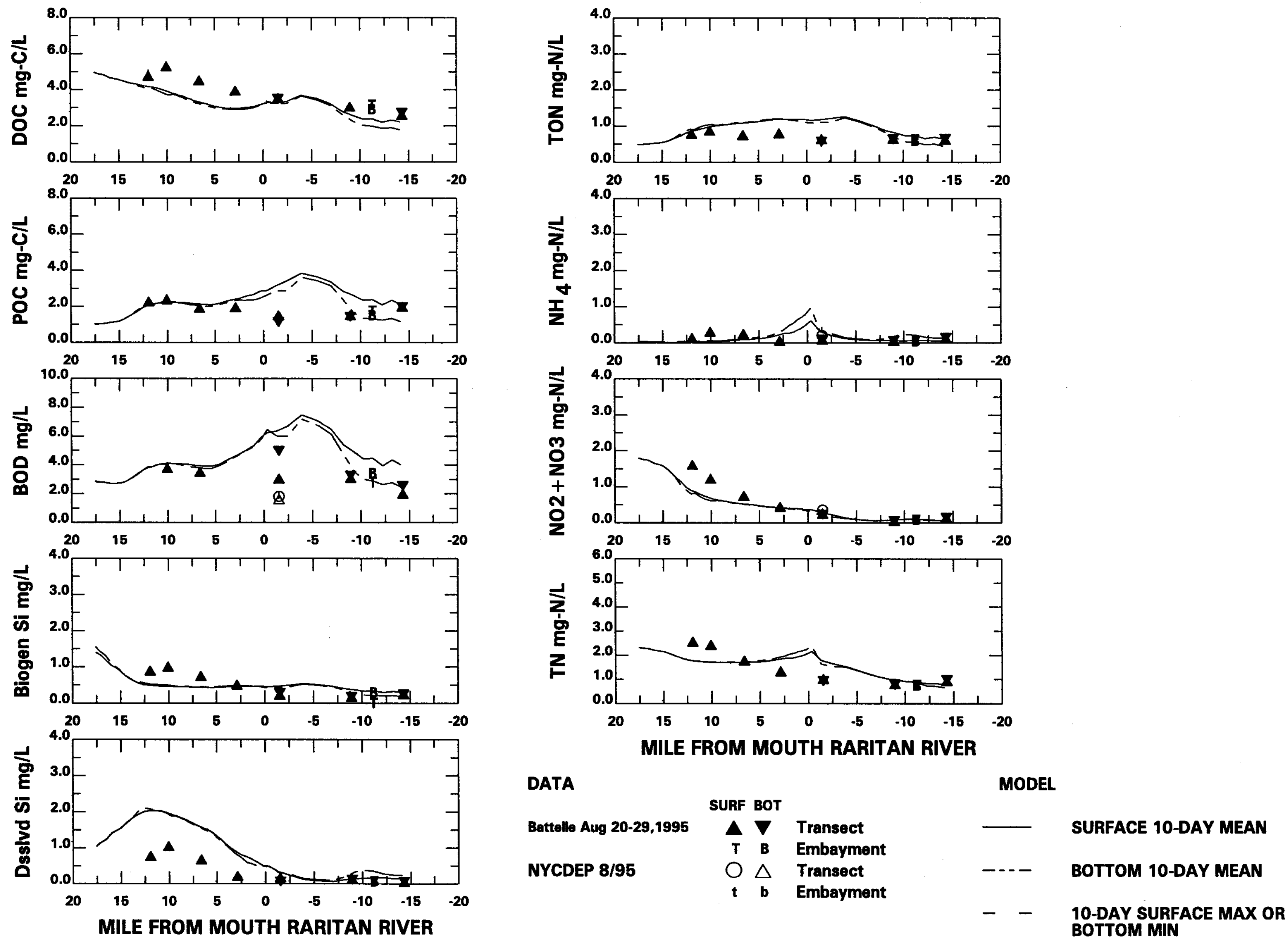
Figures 4-24a and 4-24b show model and data comparisons for 18 state variables under August 1995 conditions in the Arthur Kill and Kill van Kull. Model and data comparisons for this transect/time are very good. The calibration in the Kills is of critical importance as it serves as a connection between the Hackensack, Passaic, and Newark Bay complex and the Raritan River and Bay system.

In a general sense, the SWEM silica calibration is deficient in comparison to the nitrogen calibration. HydroQual has a contract in place with NYCDEP to upgrade SWEM with respect to the silica calibration. The contract period of performance is somewhat open ended pending availability of appropriate HydroQual staff. As with any calibration effort, the level of success of the re-calibration is uncertain. The appendix contains a copy of HydroQual's scope of work for SWEM silica calibration upgrade. Table 4-2 presents a scorecard for the SWEM silica calibration. For specific data survey periods and study area transect locations, a check mark in Table 4-2 indicates a favorable model and data comparison.

The silica calibration becomes important for dissolved oxygen regulatory purposes if there is an occasion where silica concentrations are low enough to limit or impede algal growth. The 1994-95 database used for SWEM calibration shows that dissolved silica concentrations reach limiting levels during August in the lower Hackensack and Passaic Rivers and Newark Bay and to a lesser extent in the lower Raritan River. SWEM does not pick up the silica limitation indicated by the data.

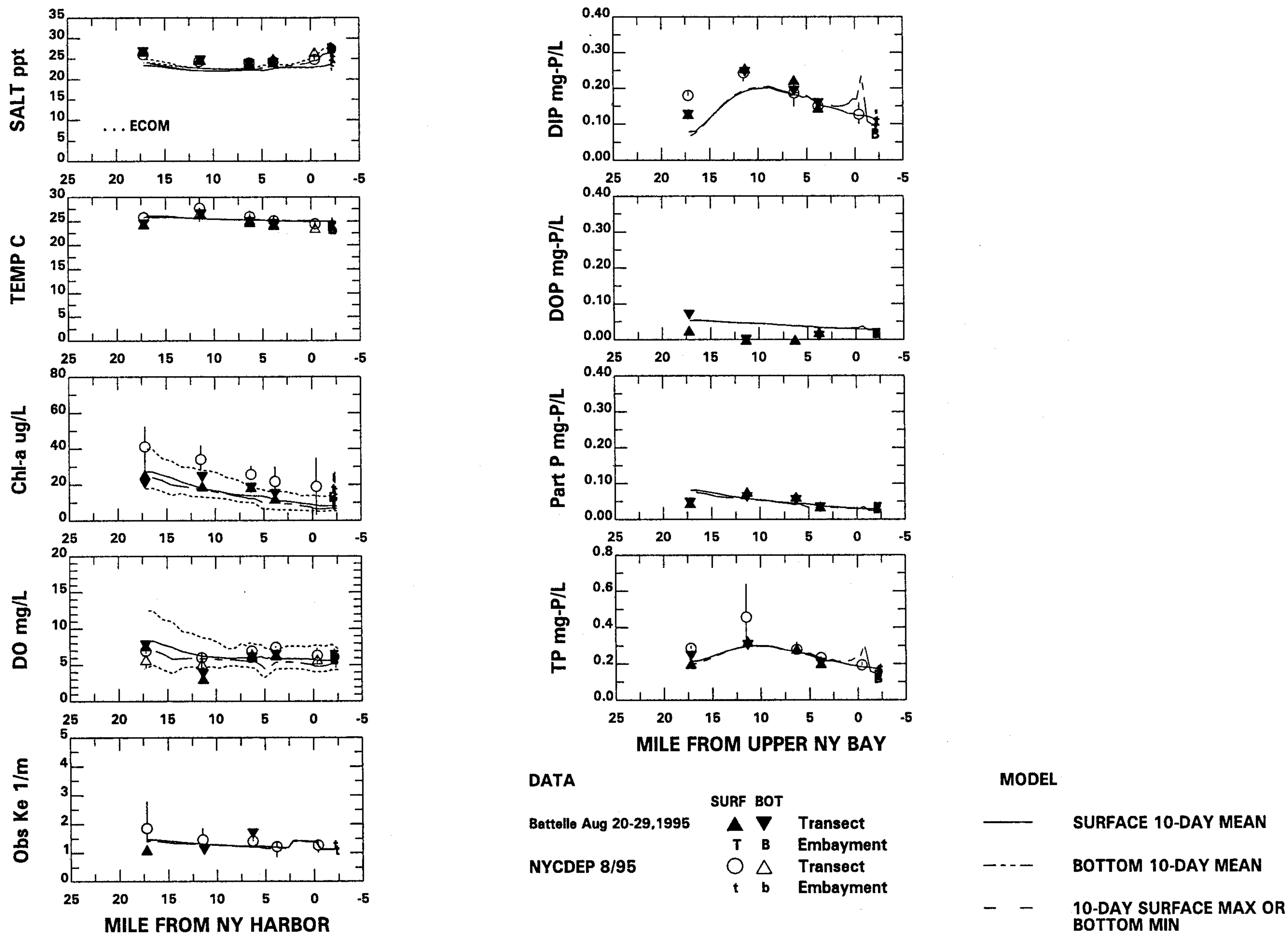


RARITAN RIVER AND SOUTH SHORE RARITAN BAY
Figure 4-23a



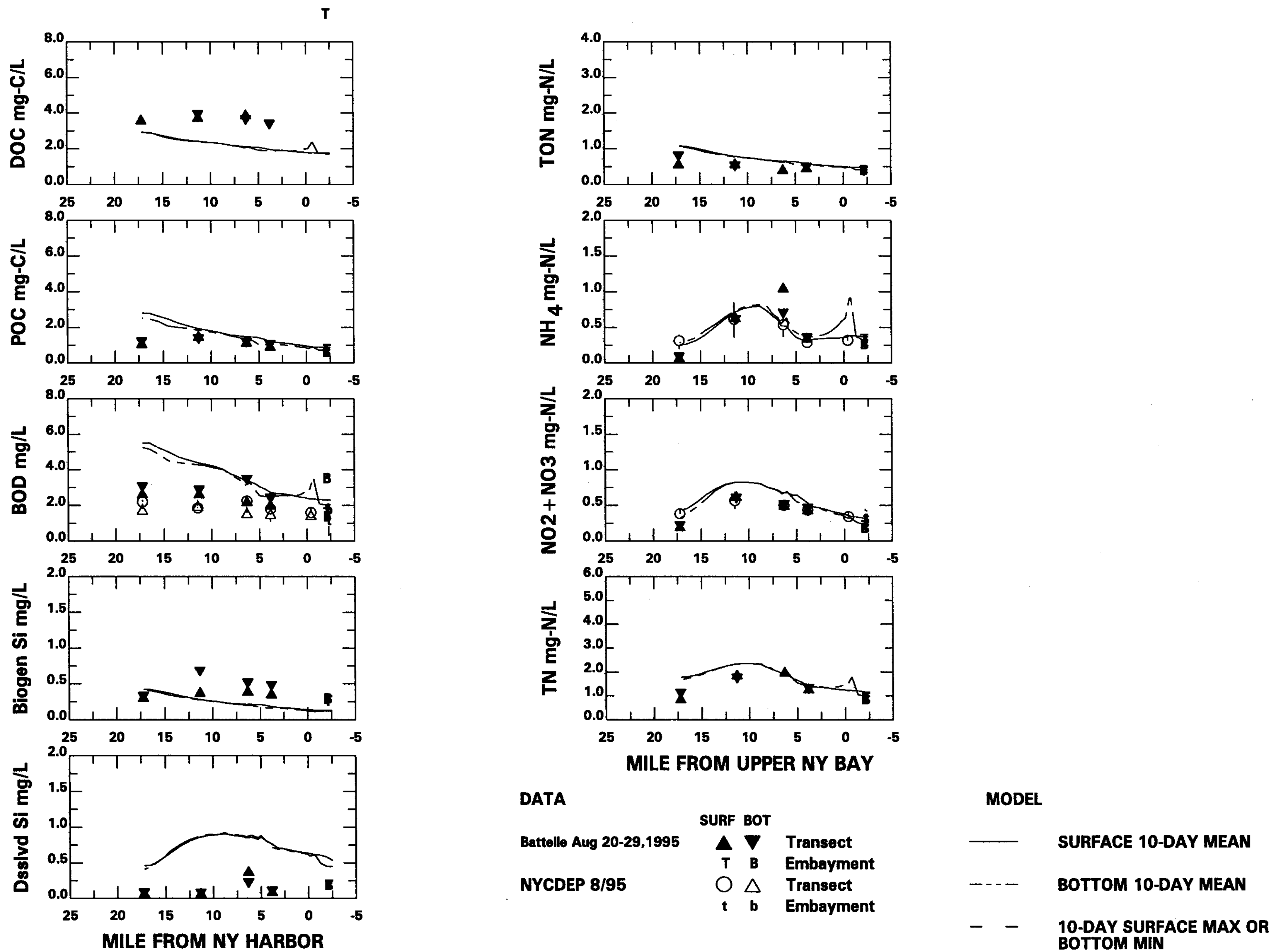
RARITAN RIVER AND SOUTH SHORE RARITAN BAY

Figure 4-23b



ARTHUR KILL AND KILL VAN KULL

Figure 4-24a



ARTHUR KILL AND KILL VAN KULL

Figure 4-24b

This miss of the silica limitation by SWEM appears to be related to a diatom bloom suggested by the data which SWEM is not configured to pick up. The silica limitation in the data underscores the importance for determining through monitoring how representative the August 1995 diatom bloom is of typical conditions in the New Jersey tributaries before proceeding with regulatory measures within the tributaries. It may be necessary to reconfigure SWEM for the calculation of diatom blooms in the summer if indeed such blooms are typical. On other occasions, such as April at the head of the Hackensack, SWEM does an excellent job of capturing measured low dissolved silica concentrations. There are also instances such as January and February where SWEM somewhat underpredicts the measured dissolved silica concentrations in the Hackensack River.

A complete set of model and data transect plots for all data collection periods which cover the 1994-95 annual cycle are presented in the appendix. Also presented in the appendix is a complete set of model and data transect plots for 1988-89 validation conditions. The validation data set is lacking in the New Jersey tributaries as described in Section 2.

Table 4-2a. SWEM Dissolved Silica Calibration Scorecard

MODEL REGION	DATA SURVEY PERIOD								
	11/94	12/94	1/95	2/95	4/95	5/95	7/95	8/95	9/95
Hackensack River	√	√				√	√		√
Newark Bay	√	√	√	√	√	√	√		
Passaic River			√	√		√			√
Raritan River	√	√	√	√		√			√
Raritan Bay	√	√	√	√	√	√	√		√
Arthur Kill and Kill van Kull	√	√	√			√	√		√
Hudson River	√			√					
Upper and Lower Bay	√	√	√	√	√	√	√		√
New York Bight	√	√	√	√	√	√	√	√	√
East River	√	√				√	√		
Long Island Sound	√	√	√	√	√	√	√		
Harlem River		√		√		√	√		

√ = Favorable model and data comparison

Table 4-2b. SWEM Biogenic Silica Calibration Scorecard

MODEL REGION	DATA SURVEY PERIOD								
	11/94	12/94	1/95	2/95	4/95	5/95	7/95	8/95	9/95
Hackensack River	√	√	√	√			√	√	√
Newark Bay	√	√	√	√	√	√	√	√	√
Passaic River		√	√	√	√				
Raritan River	√	√	√	√			√		√
Raritan Bay	√	√	√	√	√	√	√	√	√
Arthur Kill and Kill van Kull	√	√	√	√	√				
Hudson River									
Upper and Lower Bay			√	√	√		√		
New York Bight	√	√	√	√	√	√	√	√	√
East River				√	√				
Long Island Sound					√				
Harlem River				√					

√ = Favorable model and data comparison

SECTION 5

RECOMMENDED MONITORING PROGRAM

NJDEP requested that as a part of the Calibration Enhancement of SWEM recommendations be made for future monitoring efforts. The monitoring recommendations for the Department's consideration include three aspects: a year-long monitoring program that would support a full validation of SWEM in the New Jersey tributaries, an abbreviated year-long program which, while not sufficient to support a model validation, could be applied to augment the 1994-95 calibration data set, and finally a long-term monitoring program that would serve the Department in future modeling and management.

5.1 ONE YEAR MONITORING PROGRAM FOR SWEM VALIDATION IN THE NEW JERSEY TRIBUTARIES

A monitoring program suitable for supporting the validation of SWEM in the New Jersey tributaries would have to be at least on par with or better than the 1994-95 calibration monitoring program in terms of frequency and completeness of synoptic measurements. The monitoring program would require five major components: physical oceanography ; ambient water quality; ambient sediment quality and fluxes; loading water quality; and biomass. A difference between a monitoring program conducted strictly for the validation of SWEM in the New Jersey tributaries and the 1994-95 system-wide calibration monitoring program is that spatial coverage of monitoring stations in contiguous waterways to the New Jersey tributaries can be significantly reduced. A recommended monitoring program is presented in Table 5-1. Figure 5-1 shows recommended station locations for ambient monitoring components of the recommended monitoring program.

The recommended monitoring program presented in Table 5-1 is based on the assumption that many ongoing monitoring programs will continue to be in place in the future. More specifically, it is assumed that NOAA will continue to maintain tidal stage gauging stations at Sandy Hook, Bergen Point, the Battery, Willets Point, Bridgeport, Montauk, Atlantic City, and Cape May. The continuous water elevation records collected at these gauges are necessary for model forcing and model skill assessment. It is also assumed that NOAA will continue to maintain meteorological stations at the regions airports and at a buoy at the apex of New York Bight, ALSN6A8. These meteorological stations provide wind speed and direction, rainfall, and cloud cover data necessary for forcing the hydrodynamic and water quality sub-models of SWEM. A further assumption is that the USGS will continue to monitor freshwater flows at the heads of tide of tributary rivers contained in the SWEM domain. It is also assumed that effluent flow reported on Discharge Monitor Reports (DMRs) will be available for all STPs within the SWEM domain.

Table 5-1. Monitoring Program for the Validation of SWEM in the New Jersey Tributaries

TYPE	MEASUREMENT	RECOMMENDED		COST SAVERS
		LOCATIONS	FREQUENCY AND DEPTHS	
physical oceanography ambient	temperature salinity	Hackensack River - 5 Passaic River - 5 Newark Bay - 2 Kills - 2 Raritan River - 4 Raritan Bay - 8 Hudson River - 2 Upper Bay - 1 East River - 2 Harlem River - 1 Long Island Sound - 1 Bight Apex - 1	monthly x 12; vertical casts	bi-monthly x 6 half the stations in NJ Tributaries supplement/verify with ongoing monitoring (HMDC, PVSC, NYCDEP, CTDEP)
physical oceanography boundary	temperature salinity	New York Bight Long Island Sound	continuous for one year; near surface and near bottom	continuous for 1 month per quarter for 1 year
physical oceanography	current velocity	Newark Bay	continuous for one year; near surface and near bottom	continuous for 1 month per quarter for 1 year
water quality key NJ tributary headwaters	temperature dissolved oxygen chlorophyll-a dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N	Hackensack - Oradell Dam Passaic-Dundee Dam Saddle-Dundee Dam Raritan - Fieldville Dam South - Duhernal Dam	monthly x 12; near surface and near bottom	

	particulate organic N dissolved Si biogenic Si dissolved organic carbon particulate organic carbon BOD5			
water quality other tributary headwaters	temperature dissolved oxygen chlorophyll-a dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si biogenic Si dissolved organic carbon particulate organic carbon BOD5	NY - Hudson; Croton: Sawmill NJ - Elizabeth; Rahway; Navesink; Shrewsbury; Manasquan; Metedeconk; Toms River; Mullica River; Westecunk; Tuckahoe; Great Egg CT - Norwalk; Housatonic; Naugatuck; Quinnipiac; Connecticut; Thames	monthly x 12; near surface and near bottom	apply 1994-95 concentrations use concentration/flow regressions developed by LISS for rivers in CT
water quality STPs	temperature dissolved oxygen dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si dissolved organic carbon	all within model domain	monthly x 12	apply 1994-95 concentrations monitor largest facilities only eliminate constituents reported on DMRs

	particulate organic carbon BOD5			
water quality CSO/SW	temperature dissolved oxygen dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si dissolved organic carbon particulate organic carbon BOD5	4 NJ 1 NYC 1 NY 1 CT	4 wet events	use 1994-95 concentrations
water quality atmospheric deposition	dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si dissolved organic carbon particulate organic carbon BOD5	4 in NJ Tributaries 3 elsewhere	4 wet events and 4 dry events	use 1994-95 concentrations coordinate with NJADN or other programs

water quality boundary	temperature dissolved oxygen chlorophyll-a dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si biogenic Si dissolved organic carbon particulate organic carbon BOD5	New York Bight Long Island Sound	quarterly for one year; near surface and near bottom	use 1994-95 concentrations
water quality ambient	temperature dissolved oxygen chlorophyll-a secchi depth dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si biogenic Si dissolved organic carbon particulate organic carbon BOD5	Hackensack River - 5 Passaic River - 5 Newark Bay - 2 Kills - 2 Raritan River - 4 Raritan Bay - 8 Hudson River - 2 Upper Bay - 1 East River - 2 Harlem River - 1 Long Island Sound - 1 Bight Apex - 1	monthly x 12 near surface and near bottom	bi-monthly x 6 half the stations in NJ Tributaries supplement/verify with ongoing monitoring (HMDC, PVSC, NYCDEP, CTDEP)

sediment quality and fluxes	chromate reactive particulate sulfide acid volatile particulate sulfide porewater hydrogen sulfide sulfide flux particulate organic C dissolved organic C SOD dissolved inorganic P flux porewater dissolved inorganic P particulate organic P particulate inorganic P porewater Si particulate Si nitrate N flux ammonia N flux particulate organic N porewater ammonia N porewater nitrate N	Hackensack River - 1 Passaic River - 1 Raritan River - 1 Newark Bay - 1 Raritan Bay - 1	bimonthly x 6	
biological	algal speciation zooplankton biomass as C benthic filter-feeder biomass as C	Hackensack River - 1 Passaic River - 1 Raritan River - 1 Newark Bay - 1 Raritan Bay - 1	bimonthly x 6; algal and zooplankton near surface, benthic organisms on bed	
Note: The monitoring program proposed above assumes that data currently available from NOAA, USGS, and EPA's Permit Compliance System will continue to be available in the future.				

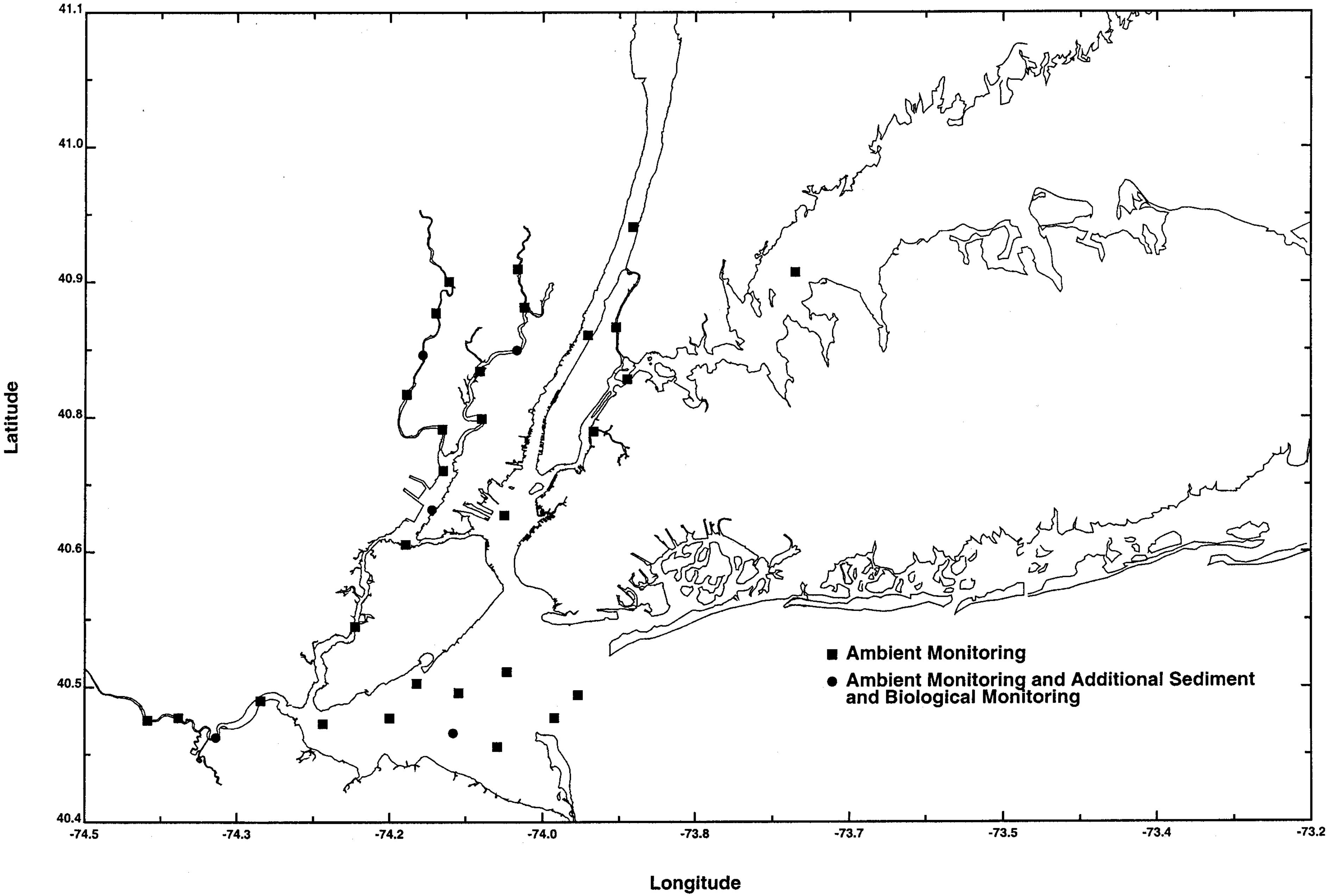


Figure 5-1. Recommended station locations for a monitoring program to support further validation of SWEM in the New Jersey tributaries.

In the event that any of these ongoing monitoring programs are discontinued, they would necessarily have to be added to the monitoring program presented in Table 5-1 and undertaken by the Department.

5.2 ONE YEAR MONITORING PROGRAM FOR ADDITIONAL INFORMATION FOR SWEM 1994-95 CALIBRATION

It is noted that there is a risk involved with undertaking a data collection program to augment the 1994-95 SWEM calibration data set. Collecting future data to augment data from a prior year is risky because it is not possible to determine how much of the data collected from the new year is specific to the ambient conditions of the new year which are not necessarily the same as the conditions of the prior year. For example, August 1995 was a near drought condition. Data collected during a future August with relatively high rainfall, for example, may not be directly applicable to August 1995 conditions. At best, the new data set could be used only for guidance and to document variability between years. A recommendation for a monitoring program to provide additional information for SWEM 1994-95 calibration is presented in Table 5-2. Figure 5-2 shows the location of recommended stations for the ambient monitoring components.

5.3 LONG-TERM MONITORING PROGRAM FOR NUTRIENT AND DISSOLVED OXYGEN MANAGEMENT

A long-term monitoring program will enable the Department to have a documented record of changes from year to year that will enable evaluation of future management efforts as well as naturally occurring phenomena. Recently, two long-term monitoring programs have been instituted in the New Jersey tributaries: PVSC began monitoring at 16 stations in 2000 and HMDC began monitoring at 14 stations in 1993 on a quarterly basis. It is recommended that the Department support and build upon these two programs . Specific recommendations for supplementing these programs are offered below. The recommendations are based on the objectives of nutrient and dissolved oxygen management considerations.

HMDC stations cover the Hackensack River as well as the tributaries which drain to the Hackensack. HMDC has 5 of its 14 stations in the Hackensack River main stem downstream of the Oradell Dam which provide adequate spatial coverage of the River. It is recommended that a station be added upstream of the Oradell Dam. The siting of this station should be somewhere between the USGS station at Rivervale, New Jersey (mile 27.2) and the Oradell Dam (mile 22.6). In terms of temporal coverage, it is recommended that the quarterly monitoring be upgraded to bi-monthly or monthly. Further, the HMDC seasonal monitoring program includes BOD, ammonia nitrogen, temperature, salinity, dissolved oxygen, and nitrate nitrogen. It is recommended that chlorophyll-a, secchi depth, dissolved inorganic phosphorus, total phosphorus, total nitrogen, dissolved silica, biogenic silica, dissolved organic carbon and particulate organic carbon be added. It

Table 5-2. Monitoring Program for Additional Information for SWEM 1994-95 New Jersey Tributaries Calibration

TYPE	MEASUREMENT	RECOMMENDED		COST SAVERS
		LOCATIONS	FREQUENCY AND DEPTHS	
water quality	secchi depth	Hackensack River - 5 Passaic River - 5 Newark Bay - 2 Raritan River - 4	monthly x 12	bi-monthly x 6 half the stations in NJ Tributaries
water quality key NJ tributary headwaters	temperature dissolved oxygen chlorophyll-a dissolved inorganic P dissolved organic P particulate organic P ammonia N nitrate plus nitrite N dissolved organic N particulate organic N dissolved Si biogenic Si dissolved organic carbon particulate organic carbon BOD5	Hackensack - Oradell Dam Passaic-Dundee Dam Saddle-Dundee Dam Raritan - Fieldville Dam South - Duhernal Dam	monthly x 12; near surface and near bottom	months July through September only
biological	zooplankton biomass as C	Hackensack River - 1 Passaic River - 1 Raritan River - 1 Newark Bay - 1 Raritan Bay - 1	monthly x 12; near surface	bimonthly x 6`
sediment	Iron concentration P flux N flux	Hackensack River - 1 Passaic River - 1 Raritan River - 1 Newark Bay – 1 Raritan Bay - 1	monthly x 12	bimonthly x 6
Note: There are no guarantees that the above data will be fully applicable to 1994-95 conditions.				

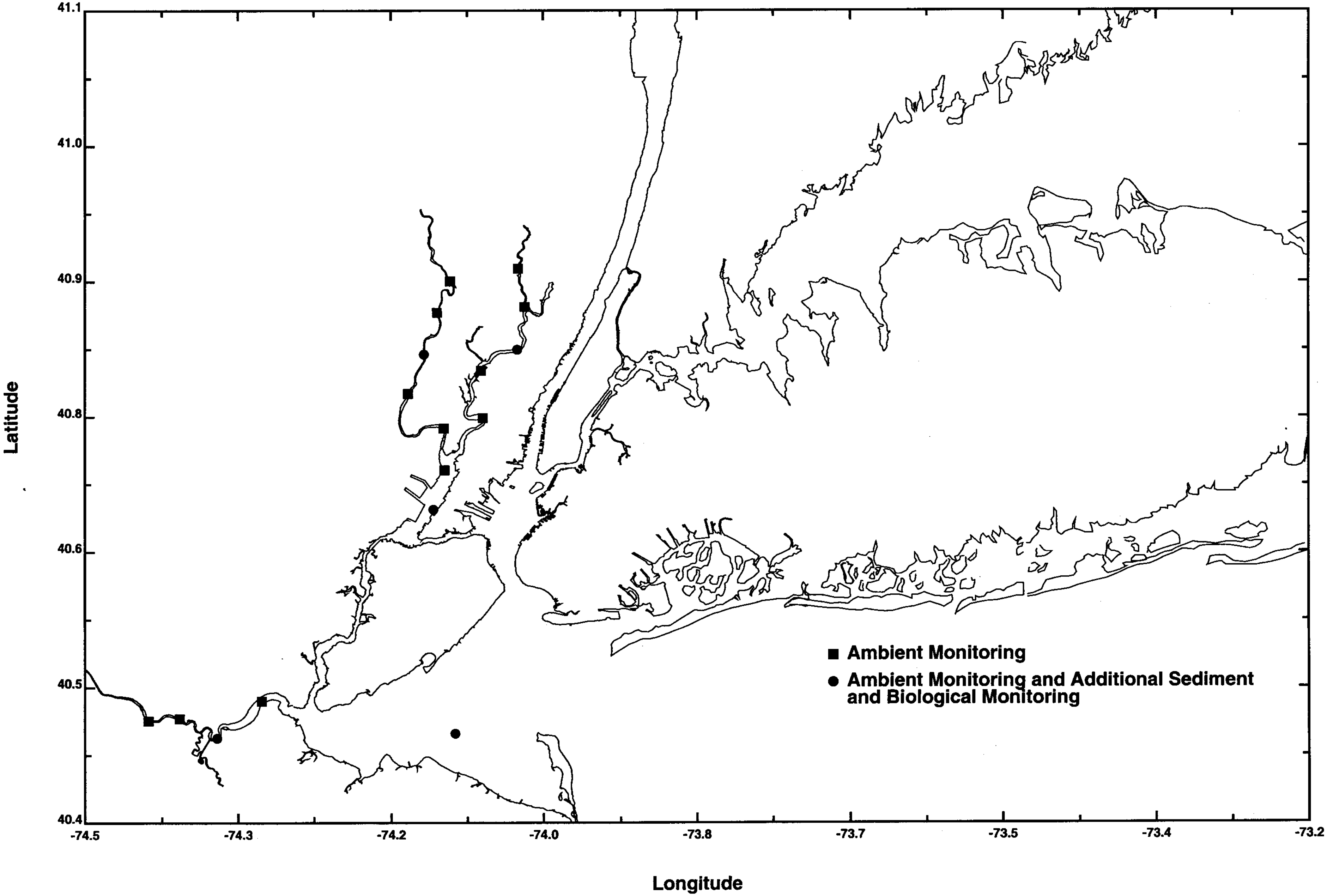


Figure 5-2. Recommended station locations for a monitoring program to support additional calibration of SWEM in the New Jersey tributaries under 1994-95 conditions.

is further recommended that some over the tidal cycle work be added to assess over the tidal cycle variability as the current program includes monitoring at low tide only.

PVSC maintains 16 stations which provide excellent spatial coverage in the Passaic River both upstream and downstream of the Dundee Dam as well as in Newark Bay and the mouth of the Hackensack River. There are also stations which monitor contributions to the Passaic River from the Saddle and Third Rivers. PVSC monitors irregularly several times over the course of the year and provides in some instances up to twice monthly temporal coverage. It is recommended that a more regular schedule be maintained to provide at least bi-monthly coverage for all stations. PVSC sampling includes temperature, dissolved oxygen, salinity, carbonaceous BOD5, ammonia, total Kjeldahl nitrogen, nitrate, nitrite, total and ortho phosphorus, and chlorophyll a. It is recommended that secchi depth, dissolved silica, biogenic silica, dissolved organic carbon, particulate organic carbon, and total BOD5 be added. There is also some indication that PVSC will maintain future stations in the Kill van Kull and Arthur Kill.

Similar programs need to be developed for the Raritan River and Raritan Bay. At least 3 stations along the River and 4 stations in Raritan Bay are recommended. It is also recommended that stations be occupied at the Duhernal and Fieldville Dams to provide for headwater inputs to the Raritan and South Rivers. These stations should have analyte lists on par with the recommendations for the Hackensack, Passaic, and Newark Bay and temporal coverage of at least bi-monthly. It is acknowledged that these recommendations assume that the NYCDEP will continue to maintain Harbor Survey coverage of the Kill van Kull, Arthur Kill, and on a limited basis in Raritan Bay.

The long-term monitoring program as recommended above provides for an assessment of ambient conditions as well as headwater inputs. It does not provide for monitoring of loadings to the New Jersey Tributaries from CSOs, STPs, and stormwater runoff. It is not intended that the long-term monitoring program would necessarily be fully supportive of a model, but rather that the long-term monitoring program would provide a metric for assessing future management actions and would be a strong foundation to support future modeling work.

SECTION 6

REFERENCES CITED

HydroQual, Inc. 2001. Newtown Creek Water Pollution Control Project East River Water Quality Plan Task 10.0 System-Wide Eutrophication Model (SWEM) Sub-Task 10.6 Validate SWEM Hydrodynamics, prepared for City of New York Department of Environmental Protection under subcontract to Greeley and Hansen.

National Oceanic and Atmospheric Administration National Ocean Service Coast Survey. 1995-1997. Chart Nos. 12327, 12332, and 12337.

Pritchard, D. W. 1998. The Odum Award Acceptance Speech: Donald Pritchard Challenges Federation Members to Correct Current Problems with Hydrodynamic Models and to be Advocates for Improved Observational Tools. Estuarine Research Federation Newsletter, 24(1): 1 and 15.

APPENDICES

APPENDIX I

NEW JERSEY DEP COMMENTS AND HYDROQUAL RESPONSE

This report section documents a review of an earlier draft of this report conducted by NJDEP and HydroQual's response to comments made as a result of NJDEP's review. The NJDEP review is summarized in the attached letter dated May 20, 2002. HydroQual's response to this letter is described below following the order of the letter.

State of New Jersey

James E. McGreevey
Governor

Department of Environmental Protection

Bradley M. Campbell
Commissioner

Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418
Telephone: (609) 984-0058
Fax: (609) 777-0942
www.state.nj.us/dep/watershedmgt

Monday, May 20, 2002

Robin Landeck Miller
Project Manager
HydroQual, Inc.
One Lethbridge Plaza
Mahwah, NJ 07430

Re: Calibration Enhancement of the System-Wide Eutrophication Model (SWEM) in the New Jersey Tributaries

We received the draft Final Technical Report for the above-mentioned project on March 4, 2002. Since the Department funded this project through a Memorandum of Agreement (MOA) with Passaic Valley Sewerage Commission (PVSC), we reviewed the report to ensure that it satisfies the specific requirements in the Scope of Work (SOW) for the MOA. The Department recognizes the substantial amount of high quality work performed by HydroQual in performance of this contract, nevertheless we must review the product against the specific requirements in the SOW. The following comments, which also reflect the discussions during our project meeting on May 13th, 2002, must be addressed in the Final Technical Report before we can make the determination that the specific requirements in the Scope of Work have been fully performed.

1. The Department entered into this MOA based on the good faith presumption that the data were sufficient to perform the work. Indeed, this presumption was written by HydroQual into the SOW, where both hydrodynamic and water quality data were described as follows:
   - 1994/95 calibration year - "a comprehensive and synoptic database of [hydrodynamic and water quality] measurements exists."
   - 1988/89 validation year - "a limited database of [hydrodynamic and water quality] exists in the vicinity of the New Jersey tributaries."

   As the report indicates, the description of data availability was overly optimistic. Insufficient light extinction data as well as headwater tributary data compromised calibration in the New Jersey tributaries. In addition, the report found that "the 1988-89 database is lacking in the New Jersey tributaries." As a result, it was not possible to validate SWEM in the New Jersey tributaries, as required in the SOW.

Early discussions between the Department and HydroQual had identified data issues, in particular the paucity of validation data from 1988-89 in the New Jersey tributaries. Furthermore, HydroQual expended considerable effort to locate and make use of alternative data sets whenever feasible. These efforts should be detailed in the Final Report. In any case, it is not possible to obligate a contractor to perform a task when the required historical data do not exist, nor is it possible to obtain additional historical data. However, as an alternative means of fulfilling the specific requirements of the SOW, HydroQual agreed at our meeting to develop specific monitoring recommendations for the Department to consider that would provide data to address the calibration and validations shortcomings in the New Jersey tributaries. The Department is aware, of course, that additional data from the calibration year cannot be obtained. However, additional new data could be used to supplement the calibration database. For instance, the report recommends collecting additional secchi disk depth measurements. The monitoring recommendations should specify locations as well as a general sampling regime. Additionally, monitoring recommendations should outline a validation sampling program that would provide enough data to perform adequate skill assessments in the New Jersey tributaries.

2. In order to improve the accuracy of the SWEM calculations of various parameters, including dissolved oxygen, the SOW requires the contractor to adjust various calibration coefficients, as necessary. Included among the coefficients specifically mentioned in the SOW that may be adjusted were: benthic filtration and zooplankton grazing coefficients based upon data collected in New Jersey tributaries; and improvements to silica kinetics over the entire domain. It was noted during our meeting that the zooplankton grazing coefficients were not modified because only data regarding benthic filtration were available. The Final Technical Report should explain this. As noted in the Technical Report and also suggested by the model and data comparisons, it may be very important to improve the silica calibration. While it is noted that a current study funded by New York City Department of Environmental Protection may lead to a correction of the silica kinetics throughout the SWEM domain, the silica improvements fall directly within the SOW for this project. More detail should be provided in the Final Technical Report as to what improvements to the silica kinetics are expected. Also, the Final Technical Report should recommend additional data needed to address silica kinetics and zooplankton grazing specific to the New Jersey tributaries.

3. Given the following calibration shortcomings and lack of validation in the tributaries, it does not appear that the SWEM is currently capable of making regulatory predictions of water quality end points in the tributaries. The Recommendations in the Final Technical Report should address the improvements that would be necessary to better calibrate and validate SWEM in the New Jersey tributaries, and specific monitoring recommendations to obtain the required data.

    - The Technical Report concludes that SWEM calculates dissolved oxygen violations in the Passaic and Raritan Rivers that are not supported by data, and that "this issue is in the process of being addressed." At our project meeting, HydroQual described enhancements that were made subsequent to the draft Final Technical Report to address the apparent oxygen under-predictions. It is not clear whether the seasonal changes to light extinction and vertical mixing coefficients represent real calibration enhancements or just a means of conforming the model output to a particular data set. This issue should be discussed in the Final Technical Report along with professional recommendations.

- The dissolved inorganic nitrogen (DIN) calibration, described on page 4-26 and Figure 4-18, should be discussed in greater detail. While it is true that concentrations of DIN are essentially surplus, the lack of fit may reflect a model inadequacy that has not been sufficiently explored. Also, the model output should be examined to determine what is causing the model prediction of DIN to plunge from May to June, especially in the Passaic River. The concentrations are too high to be limiting algal growth, and the data do not appear to substantiate the decrease. As discussed at our project meeting, the model may be making too quick a transition to summer algal assemblage.
- Model and data comparisons for the Hackensack River, described on pages 4-30 and 4-33, reveal discrepancies in the upstream portion of the river, namely under-prediction of total phosphorus and incorrect speciation of nitrogen. The Report points out that the impact in the downstream area and in Newark Bay is negligible due to the comparatively small flow over the Oradell Dam. This emphasis on the impact of the tributaries on downstream locations belies the purpose of this project, which was to improve calibration and validation in the tributaries. The confidence of the model to calculate end points in the open waters is important, but one of the purposes of this project was to increase the confidence of model predictions within the tributaries themselves. Some effort to resolve the calibration problems in the upper portion of the Hackensack should be made.
- While the trend is exaggerated in the August 1995 transect in the Passaic River, there is a trend among all the summer transects in the Passaic River and Raritan River / Raritan Bay: the model under-predicts chlorophyll-a and at the same time over-predicts dissolved silica. Dissolved silica data suggest that silica might be limiting algal growth, which would suggest that the model is over-limiting algal growth by some other factor. If this is the case, the dissolved oxygen fit in the summer may be caused by off-setting model miscalculations. The database may not be sufficient to resolve this issue, but it should nonetheless be explored in the discussion, along with the potential impact of adjusting silica kinetics as planned.
- The Department agrees that inconsistencies in the data make it difficult to assess the lack of fit for chlorophyll-a in the Passaic River during the August 1995 transect and, to a lesser extent, the July 1995 transect. However, the chlorophyll-a data should be compared with calculations of chlorophyll-a based on organic nutrient concentrations and algal cell stoichiometric relationships to assess the consistency of the data. Also, the relationship between the lack of fit and the needed improvements in the silica kinetics should be assessed, since the silica compartments also miss the data substantially.

4. The Department also notes that several improvements were made to SWEM that were domain-wide and not required in the SOW for this MOA. These include corrections to the combined sewer overflows and stormwater loadings, improved temperature limitation term for nitrification, and improved parameterization of coefficients that describe temperature effects on algal growth. The Department recognizes that these corrections and modifications

have improved the performance and credibility of the SWEM, and is supportive of these efforts. However, the work required by the SOW should be performed as agreed.

5. The Department offers the following specific comments in their approximate order of appearance.

   - Figures 4-4 and 4-5 should also plot the points on which the boundary conditions were developed, even though they are not measured values from the tributary headwaters. The values from the first in-stream point (Figure 4-4) and the calculated values based on particulate organic nutrients (Figure 4-5) should be plotted, otherwise there is no basis to gauge the appropriateness of the boundary condition.
   - Section 4.5 describes the adjustments made to vertical diffusivities. The application of a minimum vertical diffusivity, or floor, is only one of several options for increasing the lower vertical diffusivities without increasing the larger vertical diffusivities beyond the accepted range. Another way to achieve the same goal while still preserving the relative vertical diffusivities from one location to another might be to change each value a certain percentage toward the mean vertical diffusivity, effectively tightening up the range but retaining the distribution. The Technical Report should discuss whether other options were explored, and whether there is a physical basis to prefer one to the other. As discussed at our project meeting, changing a physical property for only three months represents an artificial means of causing the model to achieve stratification. Therefore the model could not be used for predictions for future conditions that might lead to a change in the stratification period. This limitation should be discussed in the Technical Report, as well as the fact that the limitation is common to many 3-D water quality models and brings the tributaries on par with the rest of the SWEM domain.
   - Section 4.6 describes adjustments made to light extinction coefficients. The base extinction coefficients were adjusted in the New Jersey tributaries to better reflect the annual cycle suggested by the available data. Further seasonal adjustments were made in the Passaic River "based upon algal productivity." (p.4-13) It is unclear how algal productivity would suggest changes to the base extinction coefficient, which by definition does not include algal self-shading effects. The Final Technical Report should explain why the coefficient describing algal impact on light extinction was not treated as a calibration parameter, but rather only the base extinction coefficient was adjusted.
   - It appears that Figures 4-8 through 4-11 have switched the "With Vertical E Adjustment" and "Without Vertical E Adjustment" headings, based on the description of the changes on page 4-18.
   - In the first sentence of the first complete paragraph on page 4-26, "original" should be changed to "enhanced" to read: "the enhanced calibration must be independently acceptable."
   - On page 4-30 and Figure 4-21a, the model and data comparison for dissolved oxygen in the Hackensack River states that "the data show stratification in the last few miles of the Hackensack River ... that the model does not capture." It should be noted that dissolved

oxygen model and data comparisons in the Hackensack River are excellent for every other calibration sampling date, including April, May and July of 1995.

- References are cited throughout the report, but not provided in detail.

It is the Department's understanding that HydroQual agreed at our project meeting to address these comments in the Final Technical Report. According to the terms of our MOA, the Final Technical Report must be completed within 90 days of the revised expiration date 3/31/02, or June 30, 2002. Please contact me (thomas.amidon@dep.state.nj.us ; 609-292-0984) if you have any questions. Thank you.

Sincerely,

Thomas Amidon
Research Scientist
Watershed Modeling Team, Northeast Bureau

cc Deb Hammond, NJDEP
Bruce Goldberg, NJDEP
Marzooq Al-Ebus, NJDEP
Sheldon Lipke, PVSC
Bridget M. McKenna, PVSC
Robin Landeck Miller, HydroQual
John St. John, HydroQual

HydroQual Response

1. In response to the Department's request that the Final Report detail the considerable efforts undertaken by HydroQual to locate and make use of available data sets for SWEM validation in the New Jersey tributaries under 1988-89 conditions, text was added to Section 2.0 to describe the efforts. In response to the Department's request that recommendations for additional monitoring in the New Jersey tributaries be prepared by HydroQual as part of fulfilling project requirements for model validation, Section 5.0 starting on page 5-1 was added to the Final Report.

2. As requested by the Department, the Final Report has been revised to explain why modifications to zooplankton grazing were not focused on as part of the calibration enhancement effort even though zooplankton grazing was identified in the Scope of Work as a potential area for adjustment. Further, additional SWEM simulations and a modification to zooplankton grazing on a model wide basis have been completed by HydroQual since issuing the Draft Report which benefits the calibration in New Jersey waters and which the Final Report explains. Revisions to the Final Report documenting this work may be found in Section 4.6 on page 4-15. In response to the Department's request for additional information on the silica calibration, revisions to the Final Report text have been made in Section 4.8 on page 4-40 and Appendix 2 has been added. Further, monitoring recommendations for collection of additional data are presented in Section 5.0. Additional data collection and model calibration to these data may potentially bolster the ability to better calibrate SWEM for both grazing and silica beyond the current level of understanding.

3. In accordance with the Department's request, both the Draft Report and Final Report prepared by HydroQual provide a very frank assessment of SWEM strengths and weaknesses. HydroQual is in concurrence with the Department that although the SWEM calibration in the New Jersey tributaries has been improved to the extent supported by the overall model framework and available information, it is not yet ready to fully support TMDL/WLA/LA development in the New Jersey tributaries if and when necessary, particularly in the Hackensack and Passaic Rivers. It is HydroQual's opinion though that SWEM being the best available tool at this time can be used appropriately to answer fundamental management questions that are necessary for guiding the direction TMDL/WLA/LA development might take. SWEM is also an appropriate tool to assist water quality managers for determining WLA for the tributaries as they impact water quality in the open waters of NY/NJ Harbor. The application of SWEM or any other model requires a judicious interpretation of results. The Final Report Conclusions and Recommendations Section includes model limitations. Additionally, at the request of the Department, both Section 5.0 and the Conclusions and Recommendations Section of the Final

Report point out limitations in the available data and suggest additional monitoring which could potentially lead to either further improvement of SWEM in the New Jersey tributaries or a better understanding of how representative 1994-95 conditions are of a suitable regulatory baseline. Additional monitoring, however, is not necessarily a guarantee for an improved model calibration.

With regard to adjustments made to assigned light extinction coefficients and vertical mixing coefficients in SWEM during both the original SWEM calibration and the SWEM calibration enhancement in the New Jersey tributaries, these adjustments like any other part of model calibration are appropriately carried forward to projection work unless there is knowledge that the projection condition would change physical conditions, in this case either the stratification of the water column or the clarity of the water column. In response to the Department's request, this issue is discussed in the Final Report on page 4-10 in Section 4.5. Additional changes made to assigned light extinction coefficients and vertical mixing coefficients since issuing a draft report to the Department are described on pages 4-11 and 4-14. These changes were made to correct model calculation of dissolved oxygen standards violations not supported by data.

In response to the Department's request, a more detailed discussion of the dissolved inorganic nitrogen calibration presented on Figure 4-18 has been incorporated into the Final Report in Section 4.8 on page 4-28. Further, additional SWEM simulations have been performed to further explore DIN calibration issues as well as the model parameterization of the transitioning between winter and summer algal assemblages. These work efforts are described in Section 4.8 on page 4-32, and in Section 4.6 on page 4-14 .

In response to the Department's comments, text has been added to the Final Report on page 4-33 to further and more clearly explain calibration difficulties occurring during certain months at the head of the Hackensack River for total phosphorus and for nitrogen speciation.

In response to the Department's request, additional attention has been given to the status of the silica calibration in the Final Report on page 4-40 and in Appendix 2. With regard to the calibration of the model to chlorophyll data, it is inappropriate to comment on the chlorophyll calibration without a simultaneous consideration of the calibration to particulate organic carbon data. SWEM by design allows for a single user-specified algal cell carbon to chlorophyll ratio for each of the two seasonal phytoplankton assemblages considered in the model. Further, monitoring data do not provide a direct measure of the algal cell carbon to chlorophyll ratio as the measured ambient particulate organic carbon also includes detritus and non-algal particulate organic carbon. The measured ambient carbon to chlorophyll ratios therefore provide an upper limit or "certainly lower than" numbers for carbon to chlorophyll ratios assigned in the model.

The high spatial and temporal variability in measured carbon to chlorophyll ratios for selected New Jersey waters is shown in the figures presented in Appendix 3. For reference, the carbon to chlorophyll ratios assigned in the model, 50 for the winter assemblage and 100 for the summer assemblage, are also shown with the measured data.

In accordance with the Department's requests, specific issues and difficulties with the calibration to data collected in the Passaic River during August 1995 are more fully discussed in the Final Report on page 4-36.

4. It was correctly noted by the Department that HydroQual performed corrections in some instances on a domain-wide basis to universal constants, coefficients, and multipliers. These changes were performed in a manner fully consistent with the scope of work. In each case, a single change was made for purposes of improving the calibration in New Jersey waters. Necessarily, the change also affected water outside New Jersey and the change was either tolerated or had minimal effects outside of the New Jersey tributaries. Restricting the changes to New Jersey waters only would have required major and costly modifications to the configuration of SWEM to accommodate site specific constants and coefficients. The approach taken was to achieve benefit to the calibration of SWEM in the New Jersey tributaries in the most cost effective manner possible. In no case were changes made that did not relate directly to the calibration in the New Jersey tributaries.

5. At the request of the Department, Figures 4-4 and 4-5 have been revised to include more detailed information. Section 4.5 on page 4-10 has been expanded in recognition of specific comments from the Department regarding adjustments to vertical mixing coefficients. Section 4.6 on page 4-12 now includes a more detailed discussion of the parameterization of light extinction in SWEM in response to comments from the Department. It is noted that Figures 4-8 thru 4-11 were not mislabeled and the discussion of these figures on page 4-15 has been clarified. The first complete paragraph on page 4-26 of the Draft Report, now on page 4-28 of the Final Report, has been edited as directed by the Department. Discussion of Figure 4-21a on page 4-33 has been modified as suggested by the Department. HydroQual appreciates the spirit of the Department's comment which highlights positive performance of the model. Section 6, References Cited, was added to the Final Report in response to a Department Comment.

HydroQual

Environmental
Engineers & Scientists

May 23, 2002

Mr. Thomas Amidon
Research Scientist, Watershed Modeling Team, Northeast Bureau
State of New Jersey Department of Environmental Protection
Division of Watershed Management
P.O. Box 418
Trenton, New Jersey 08625-0418

PVSC0020

Subject: Calibration Enhancement of the System-Wide Eutrophication Model (SWEM) in the New Jersey Tributaries - HydroQual Response to DEP Letter of May 20, 2002

Dear Mr. Amidon:

HydroQual has received the Department's letter of May 20, 2002 outlining the Department's review of HydroQual's technical report and the meeting which took place on May 13, 2002 in the Department's office. As indicated in the Department's letter, HydroQual has agreed to address the Departments's review and comments in a final technical report. Accordingly, it is necessary for HydroQual to perform additional SWEM simulations as well as other efforts as will be described below. Given the level of effort required to produce a final technical report consistent with the Department's review and comments, HydroQual anticipates having a final technical report for the State in approximately 8 to 10 weeks. The technical approach to produce a final technical report consistent with the Department's comments as detailed below will not meet the June 30, 2002 deadline. The technical approach is anticipated to include on order of 200 man hours and up to seven additional SWEM simulations.

Technical Approach for Addressing DEP Comments and Production of Final Technical Report

1. HydroQual will amend the technical report to include:

- discussion of efforts made to utilize additional data for 1988-89
- expanded discussion of monitoring recommendations for consideration by the Department including supplementation of the 1994-95 database and collection of an additional validation database

2. HydroQual will amend the technical report to include:

- clarification of why changes were not made to zooplankton grazing kinetics
- recommendations for additional data needed to address silica kinetics and grazing specific to the New Jersey tributaries
- an appendix with a copy of the scope of work for the New York City Department of Environmental Protection Silica Calibration Upgrade Project

3. HydroQual will perform at least two (but as many as seven) additional SWEM simulations to potentially address:

- softening the timing of the transition from winter to summer algal assemblages
- better capturing uptake of silica by the summer algal assemblage
- improving the calibration at the head of the Hackensack (if a loading adjustment is identified)

4. HydroQual will perform:

- an assessment of the consistency of the July and August data in the Passaic River based on algal cell stoichiometric relationships
- potential (i.e., if any are identified) loading adjustments to improve the calibration in the head of the Hackensack River for total phosphorus and nitrogen speciation.

5. HydroQual will amend the technical report to include:

- discussion and summary presentation of additional SWEM simulations
- discussion of potential silica limitations as suggested by data
- discussion of assessment of data consistency in the Passaic River for July and August
- discussion and summary presentation of model enhancements and results developed since the draft report which improve model and data comparisons of dissolved oxygen and dissolved oxygen standards compliance in the Passaic and Raritan Rivers. The discussion will identify a recommendation for incorporating these modifications into projection work

6. HydroQual will amend the technical report to include:

- improved versions of Figures 4-4 and 4-5
- increased discussion of vertical mixing adjustments
- clarification of protocol for adjustments to light extinction coefficients
- check on consistency between Figure 4-8 and 4-11 labels and text discussion on page 4-18
- suggested wording changes
- more complete citation of references

HydroQual appreciates the Department's assessment and looks forward to completing the Memorandum of Agreement (MOA) Scope of Work (SOW) with the submission of a final technical report as described above. Kindly advise us of the Department's willingness to extend the June 30, 2002 deadline.

Very truly yours,

HydroQual, Inc.

Robin Landeck Miller

Robin Landeck Miller
Senior Project Manager

RLM/lkj
PVSC0000\0020\AMIDON052302LTR

cc: NJDEP
Deb Hammond
Marzooq Al-Ebus
Bruce Goldberg
PVSC
Bridget McKenna
Sheldon Lipke

APPENDIX II

HYDROQUAL SCOPE OF WORK FOR SWEM SILICA CALIBRATION UPGRADE CONTRACT WITH NEW YORK CITY DEP

This report appendix reproduces a portion of a sub-contract agreement between HydroQual and Greeley and Hansen, LLP under contract with NYCDEP which includes among other efforts scope for upgrade of the SWEM calibration for silica. In recognition of the regional interest in the continued development of SWEM, the relevant portion of the contract scope of work is provided here for informational purposes only.

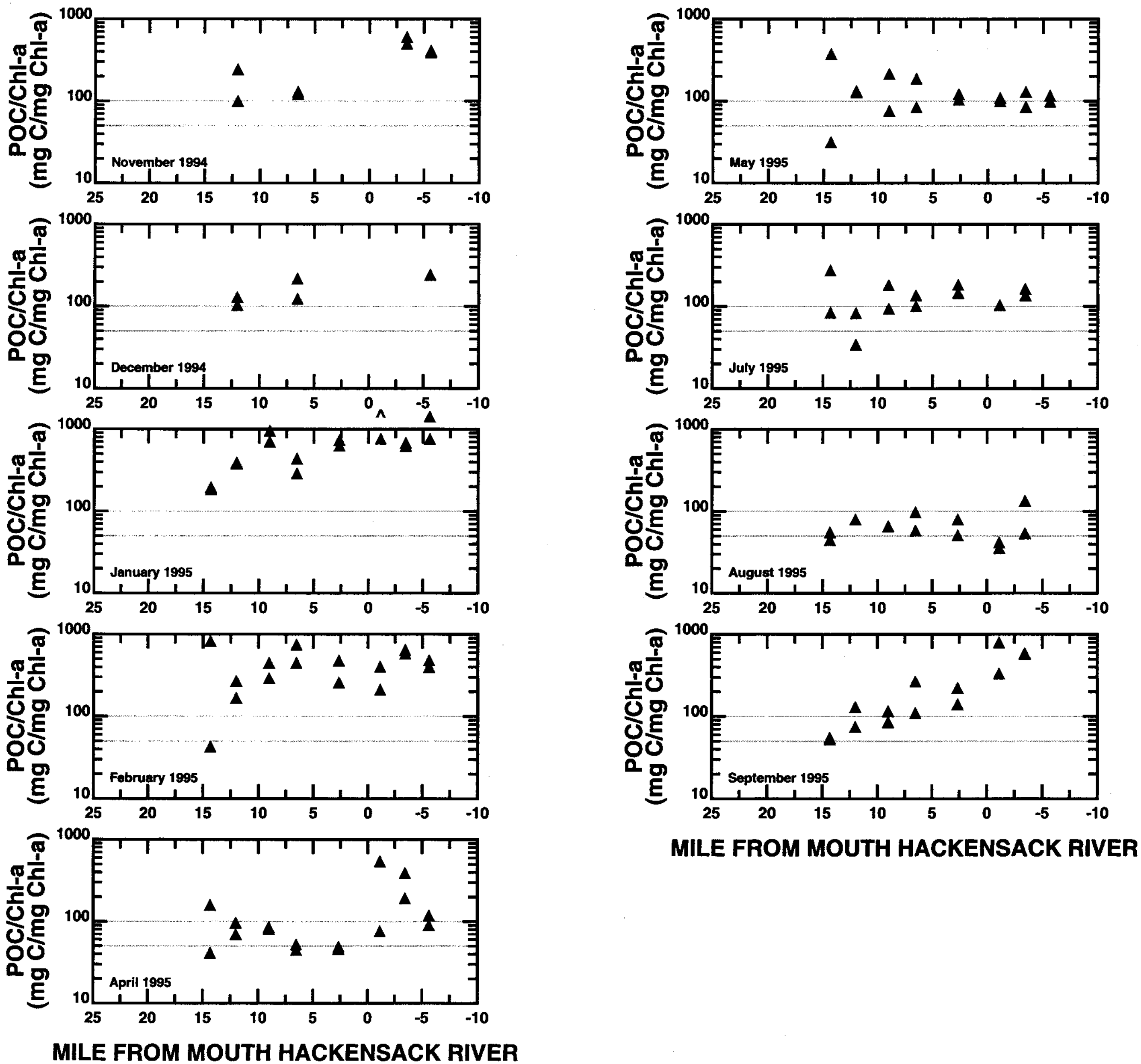
> Sub-task 10.15 - Upgrade SWEM Calibration for Silica
>
> The Engineer shall conduct a survey of the scientific literature to compile detailed information on the properties of silica in marine and estuarine environments including:
>
> - rates of mineralization of biogenic silica to dissolved silica
> - rates of uptake of dissolved silica by phytoplankton and zooplankton
> - silica content of the algal species indigenous to the NY/NJ Harbor complex
> - silica levels in WPCP effluent, CSO, and stormwater
> - silica levels in ocean water
> - silica levels in tributary headwater
>
> As appropriate, the Engineer shall incorporate findings of the literature survey into the SWEM framework by adjusting kinetic formulations and values assigned to kinetic constants and coefficient source/sink terms. The Engineer shall prepare a report for the NYCDEP summarizing findings of the literature survey and upgrades made to SWEM for consideration for future SWEM runs.

Work on this sub-task is expected to fully commence in the Fall.

APPENDIX III

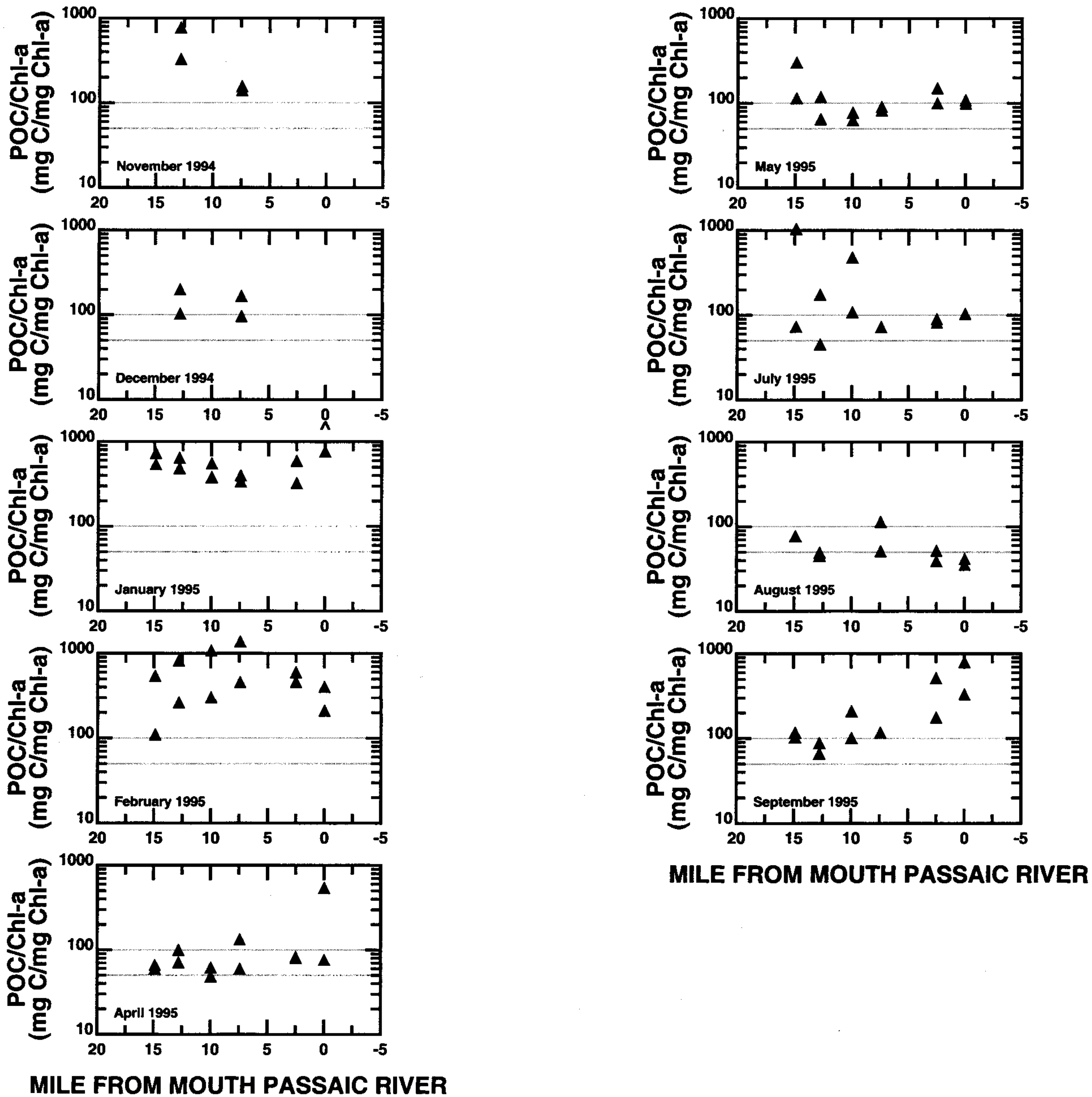
CARBON: CHLOROPHYLL DIAGRAMS

This report section presents measured ambient carbon to chlorophyll ratios along selected spatial transects in New Jersey waters of the SWEM domain. The high level of spatial and temporal variability in these data demonstrate why the simultaneous consideration of the calibration to particulate organic carbon and carbon to chlorophyll data is necessary. SWEM by design allows for a single user-specified algal cell carbon to chlorophyll ratio for each of the two seasonal phytoplankton assemblages considered in the model. Although the ambient monitoring data presented on the spatial transects do not provide a direct measure of algal cell carbon to chlorophyll ratio since the measured ambient particulate organic carbon also includes non-algal particulate organic carbon, the measured carbon to chlorophyll ratios do provide an upper limit or "certainly lower than" number for algal cell carbon to chlorophyll ratios assigned in the model. For reference, the algal cell carbon to chlorophyll ratios assigned in the model, 50 for the winter assemblage and 100 for the summer assemblage, are also shown with the measured data.



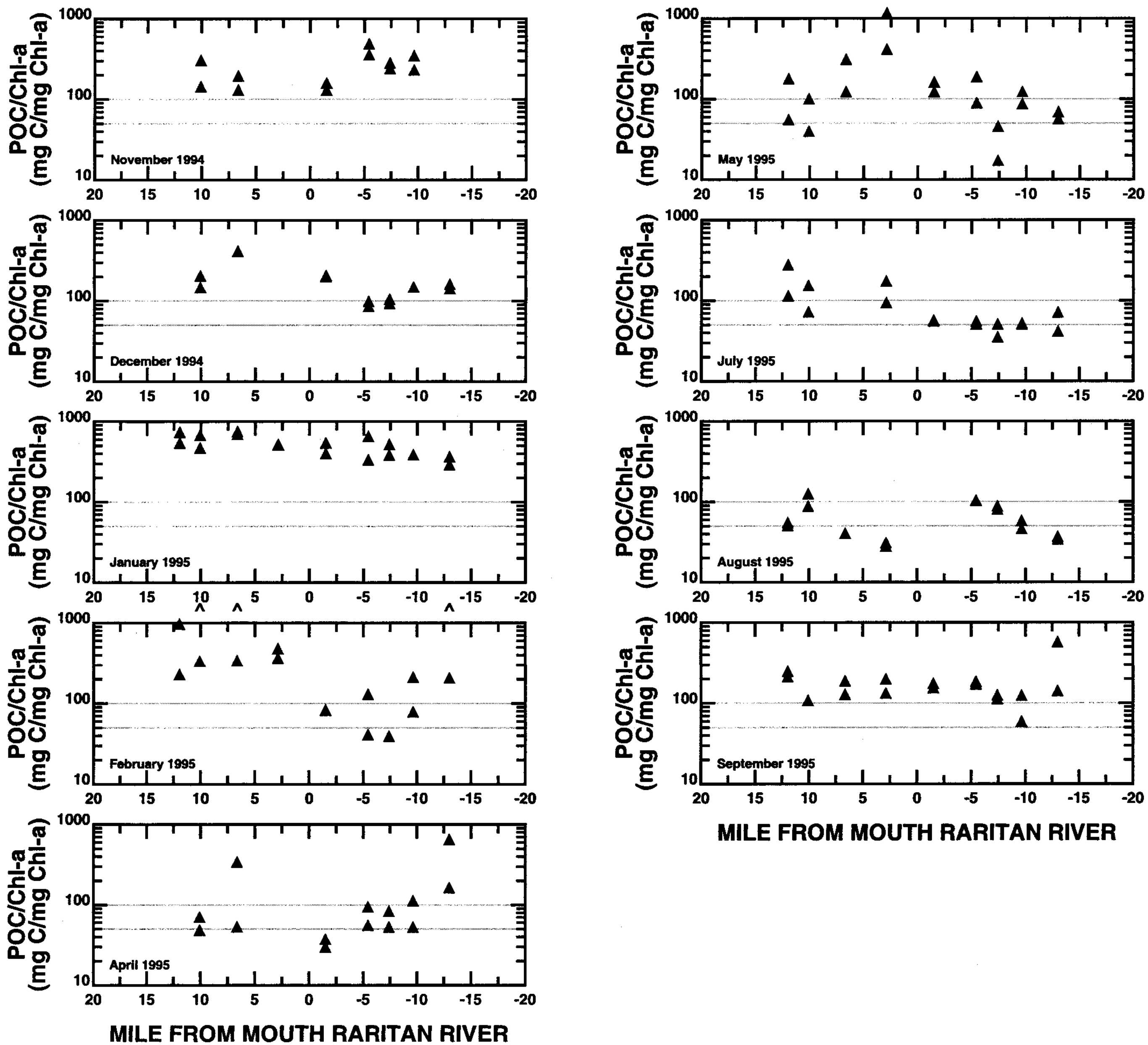
HACKENSACK RIVER AND NEWARK BAY

DATE: Tue Jul 16 TIME: 11:44:07



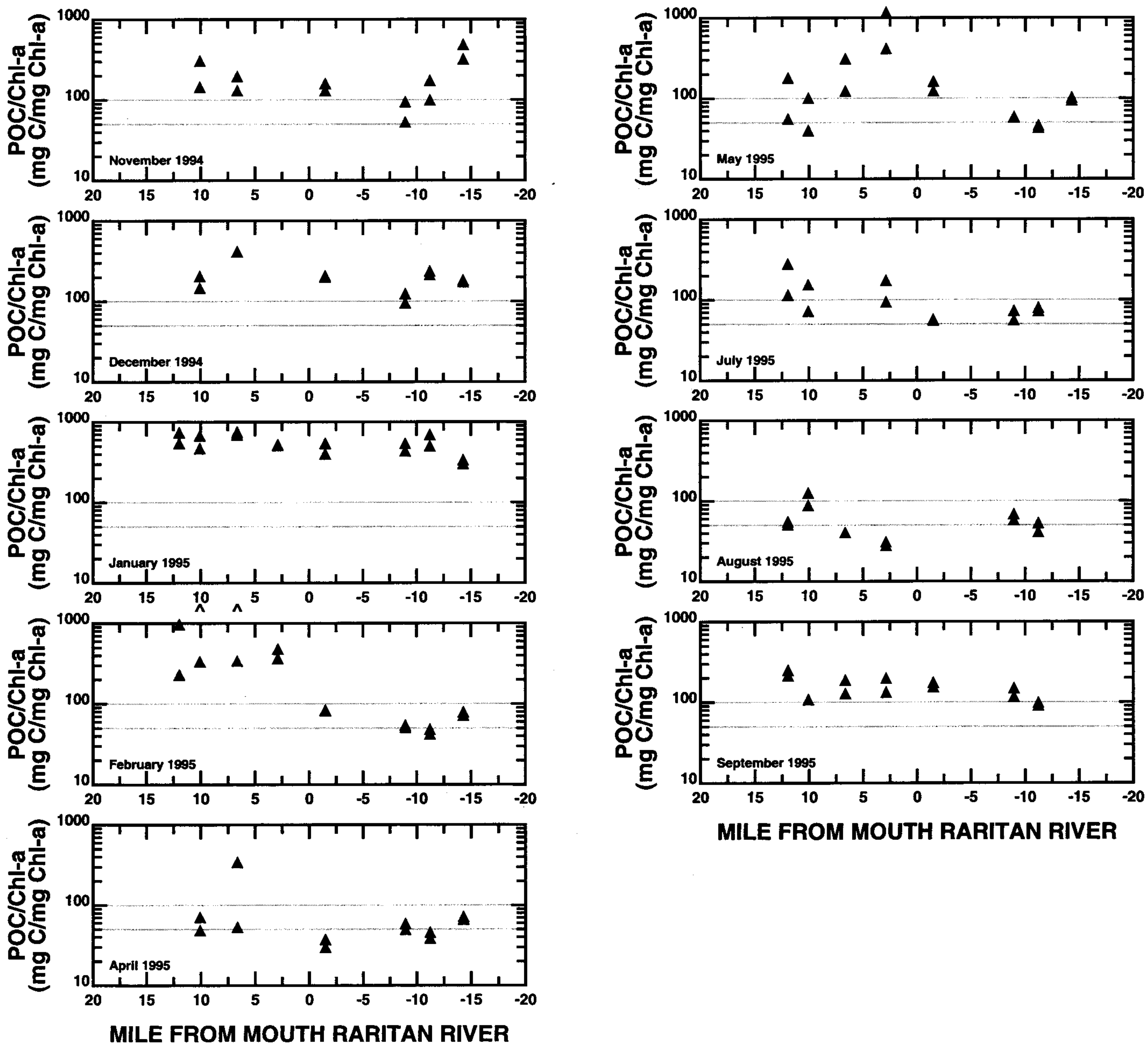
PASSAIC RIVER

DATE: Tue Jul 16 TIME: 11:44:08



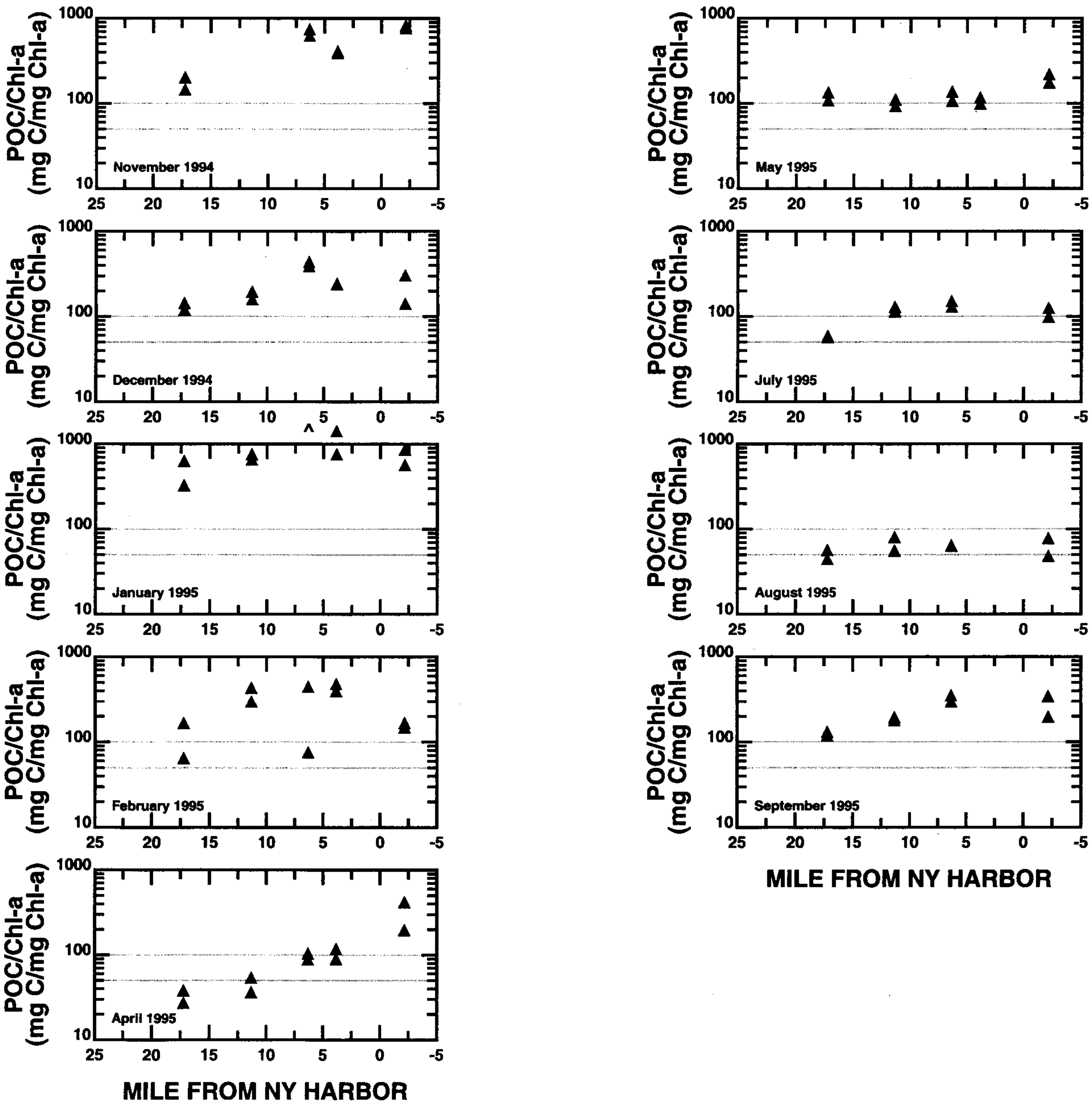
RARITAN RIVER AND NORTH SHORE OF RARITAN BAY

DATE: Tue Jul 16 TIME: 11:44:06



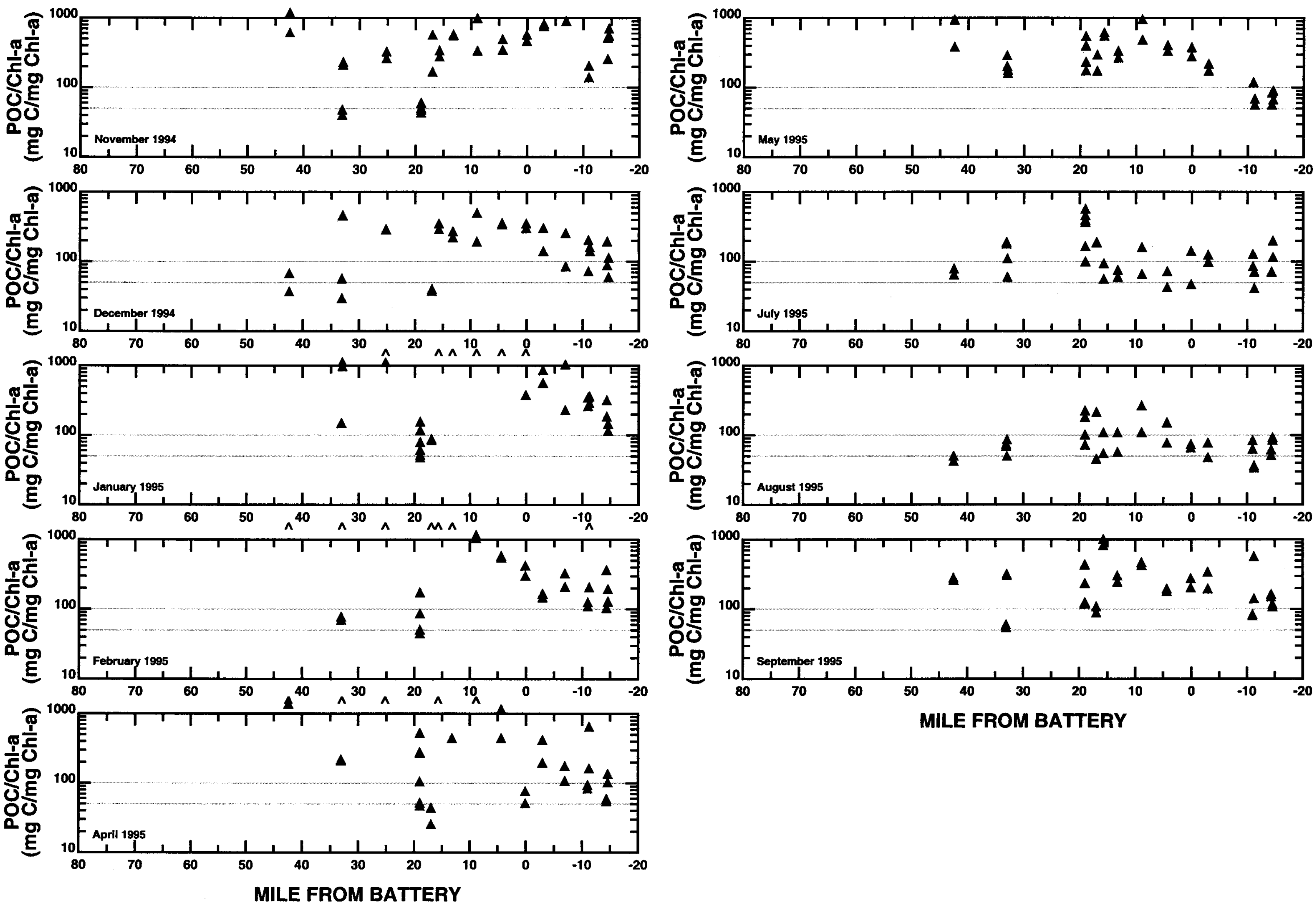
RARITAN RIVER AND SOUTH SHORE OF RARITAN BAY

DATE: Tue Jul 16 TIME: 11:44:06



ARTHUR KILL AND KILL VAN KULL

DATE: Tue Jul 16 TIME: 11:44:07



HUDSON RIVER, UPPER AND LOWER BAY, OCEAN

DATE: Tue Jul 16 TIME: 11:44:08