

Status Report
Modeling Technical Review Group (MTRG)
Savannah Harbor Expansion Project
August 29, 2000

A meeting was held on Tuesday, August 29, 2000 in Atlanta, GA at the EPA office. The goals of the meeting were as follows:

- Discuss and resolve all comments from MTRG on 1999 Draft Savannah Harbor Data Report.
- Present and discuss Salinity and Hydrodynamic model calibration results.
- Present and discuss Dissolved Oxygen (DO) modeling inputs, including initial Long Term Biochemical Oxygen Demand (LTBOD) curve fit results.

The following persons attended the meeting and participated in the MTRG discussions:

William Bailey	USACE	912-652-5781	william.g.bailey@sas02.army.mil
Jim Greenfield	USEPA IV	404-562-9238	greenfield.jim@epa.gov
Larry Neal	Harbor Committee	770-499-6791	lneal@lawco.com
James Martin	USACE, WES	601-634-3714	martinj@wes.army.mil
Bo Ellis	ATM	843-884-8750	boellis@worldnet.att.net
Chris Ahern	ATM	843-884-8750	cahern@appliedtm.com
Dan Mendelsohn	ASA	401-789-6224	mendo@appsci.com
Eduardo Yassuda	ASATM	843-884-8750	eyassuda@asatm.com.br
Paul Conrads	USGS	803-750-6140	pconrads@usgs.gov
John Sawyer	City of Savannah	912-964-0698	jsawyer@ci.savannah.ga.us
Harvey Seim	UNC		Harvey_seim@unc.edu
Jack Blanton	Skidaway Institute	912-598-2457	jack@skio.peachnet.edu
Larry Keegan	Lockwood Greene	912-352-3000	lkeegan@lg.com
Brittany Robinson	Harbor Committee	912-238-6426	brittany.robinson@ippaper.com
Roy Burke III	GA EPD	404-675-1665	Roy_Burke@mail.dnr.state.ga.us

No other MTRG participants submitted written comments for consideration by the group.

General Discussion

MTRG Comments on 1999 Draft Data Report

A summary of all the MTRG comments on the 1999 Draft Data Report titled, *MTRG Comment Received on the 1999 Savannah Harbor Draft Data Report, Received as of August 17, 2000* was distributed at the meeting. Digital copies of the summary were mailed electronically to the MTRG for review on August 18, 2000, the day after the comment period ended.

All comments were included in the document distributed at the MTRG meeting. The MTRG discussed and resolved each comment and recommended the appropriate revisions to the Draft Data Report. Jack Blanton, Harvey Seim, William Bailey, James Martin and Paul Conrads discussed their comments on the Draft Data Report. Larry Neal discussed the comments submitted by David Sample of Law Engineering. The MTRG recommended that ATM prepare a document with the specific wording of the MTRG responses to each comment received on the Draft Data Report. These responses will be used to edit the Draft Data Report and

are included in Attachment D, *MTRG Responses to Comments on the 1999 Savannah Harbor Draft Data Report, Received as of September 12, 2000*. The *MTRG Responses to Comments on the 1999 Savannah Harbor Draft Data Report, Received as of September 12, 2000* document will be reviewed by the MTRG for acceptance and will then be used to prepare the 1999 Savannah Harbor Data Report.

The MTRG concluded that comments on the Draft Data Report from all participating MTRG agencies should be documented. Roy Burke III and Jim Greenfield submitted comments on the Draft Data Report after the MTRG meeting, their comments are included in the document in Attachment D.

As part of the discussion on the Draft Data Report comments, the MTRG recommended that a sub-section be added to Section 1.0 of the Draft Data Report to specifically address the Results of the 1999 Data Collection. The draft of Section 1.5 to be added to Section 1.0 appears in Appendix E. Response 12 in the Attachment D document, *MTRG Responses to Comments on the 1999 Savannah Harbor Draft Data Report, Received as of September 12, 2000*, describes the MTRG recommendation for this sub-section.

Presentation of the Savannah River Salinity Hydrodynamic Model Calibration Results

The presentation of the Salinity and Hydrodynamic Model Results followed the format of the Model Calibration Report. Slides of the presentation are shown in Attachment A. The MTRG discussed each of the items in the Hydrodynamic Model Calibration Report outline, shown below. Figures to be included in each section were presented to demonstrate the Model Calibration Results. MTRG discussion points and descriptions of the presentation are summarized following the Outline.

Outline for the Hydrodynamic Model Calibration Report:

1.0 Introduction

- 1.1 Introduction
- 1.2 Project Objectives
- 1.3 Project Location
- 1.4 Modeling Study Goals
- 1.5 Report Outline

2.0 Characterization of the Lower Savannah River Estuary

- 2.1 Study Area
- 2.2 Hydrology
- 2.3 Anthropogenic Impacts
- 2.4 Summer 1997 Monitoring Program
- 2.5 Summer 1999 Monitoring Program

3.0 Model Description

- 3.1 Hydrodynamic Model
- 3.2 Thermal Model

4.0 Model Input

- 4.1 Geographic Conditions
 - 4.1.1 Model Grid
 - 4.1.2 Bathymetry
- 4.2 Boundary Conditions

- 4.2.1 Open Tidal Boundary
 - 4.2.1.1 Water Surface Elevation
 - 4.2.1.2 Salinity
 - 4.2.1.3 Temperature
- 4.2.2 River Boundary
- 4.2.3 Meteorological Data
 - 4.2.3.1 Winds
 - 4.2.3.2 Air Temperature
 - 4.2.3.3 Dew Point Temperature
 - 4.2.3.4 Solar Radiation
 - 4.2.3.5 Atmospheric Pressure
 - 4.2.3.6 Relative Humidity

5.0 Convergence and Sigma Transport Tests

5.1 Convergence Test

- 5.1.1 Model Grids
- 5.1.2 Model Input
- 5.1.3 Results

5.2 Sigma Coordinate Transport Test

- 5.2.1 Model Setup
- 5.2.2 Results

6.0 Calibration Methodology

- 6.1 Qualitative Comparisons
- 6.2 Quantitative Comparisons
- 6.3 Mean Error
- 6.4 Absolute Mean Error
- 6.5 Relative Error
- 6.6 Root Mean Square Error
- 6.7 Percentiles

7.0 1997 Model Calibration

- 7.1 Background
- 7.2 Comparison of Model Predictions to Observations
 - 7.2.1 Water Surface Elevation
 - 7.2.2 Velocity Comparison
 - 7.2.3 Cross-Sectional Flows
 - 7.2.4 Salinity
- 7.3 Discussion

8.0 1999 Model Verification

- 8.1 Comparison of Model Predictions to Observations
 - 8.1.1 Water Surface Elevation
 - 8.1.2 Velocity Comparison
 - 8.1.3 Cross-Sectional Flows
 - 8.1.4 Salinity
 - 8.1.5 Temperature

9.0 Summary and Conclusions

MTRG Discussion Points:

- A. A reiteration of the Project Objectives and Modeling Study Goals was presented. They are as follows:
- Convergence test for optimum grid below I-95
 - Implement temperature model
 - Check model calibration to 1997 data set
 - Verify hydrodynamic model to 1999 data set
 - Test vertical mixing scheme
- B. Model input for the 1997 calibration and 1999 verification tests was described.
- Plots of the model grid and bathymetry for the simulations were presented.
 - Plots of the model input were presented for:
 - 1997 River inflow, tidal elevation and salinity boundary conditions.
 - 1999 River inflow, tidal elevation and salinity boundary conditions.
 - 1999 Meteorological conditions, including:
 - Air temperature, dew point temperature, relative humidity, solar radiation, atmospheric pressure and wind speed and direction
- C. A review of the Convergence and Sigma Test results shown at the June 22 MTRG meeting was presented. Topics covered surface elevation, currents and volume flow at 3 representative stations along the river. As requested by the MTRG at the June 22 meeting additional salinity comparisons were also shown.
- a. Comment was made that the salinity results for the convergence tests were somewhat confusing.
 - b. ATM noted that the convergence tests were run using the previous 1st order upwind advection scheme.
 - c. It was suggested that the convergence tests be rerun with the QUICKEST advection scheme now in use.
- D. The hydrodynamic model calibration to the 1997 data set was presented. The presentation consisted of model to observation comparisons and error analyses for surface elevation, currents and salinity for representative stations along the river. 1997 hydrodynamic model calibration presentation included:
- a. Model data comparison plots of 1997 surface elevation:
 - Surface elevation time series at selected stations
 - Mean water level variation time series at selected stations
 - Harmonic constituents for all stations along the river
 - Error analysis statistics for all stations
 - b. Model data comparison plots of 1997 currents:
 - Surface and bottom major axis currents at GPA-04
 - Surface and bottom major axis currents at GPA-08
 - Surface and bottom low frequency currents variations at GPA-04
 - Surface and bottom low frequency currents variations at GPA-08
 - Error analysis statistics for each stations
 - c. Model data comparison plots of 1997 salinity:
 - Surface and bottom salinity time series for each station
 - Surface and bottom low frequency salinity variation
 - Horizontal salinity gradients at surface and bottom along the Front River

- Horizontal salinity gradients at surface and bottom along the Back River
- Vertical salinity gradients at stations along the Front River
- Error analysis statistics for all stations

E. Discussion of the 1997 hydrodynamic model calibration:

- a. A suggestion was made to add the water surface elevation to the salinity gradient plots in a stack plot format.
- b. For the statistics plotted as a function of river mile it was suggested that the plots be broken into two sets, one for the Front River set of stations and one for the Back and Little Back Rivers. For the Front River the stations would include GPA-04,06,08,09,11 and 14. The Back River set would include GPA-04,05,07,15,and 13.

F. The hydrodynamic model calibration to the 1999 data set was presented. The presentation consisted of model to observation comparisons and error analyses for surface elevation, currents, salinity and temperature for representative stations along the river. The 1999 hydrodynamic model calibration presentation included:

- a. Model data comparison plots of 1999 surface elevation:
 - Surface elevation time series at selected stations
 - Mean water level variation time series at selected stations
 - Harmonic constituents for all stations along the river
 - Error analysis statistics for all stations
- b. Model data comparison plots of 1999 currents:
 - Surface and bottom major axis currents at GPA-04
 - Surface and bottom major axis currents at GPA-06
 - Surface and bottom low frequency currents variations at GPA-04
 - Surface and bottom low frequency currents variations at GPA-06
 - Error analysis statistics for each stations
- c. Model data comparison plots of 1999 salinity:
 - Surface and bottom salinity time series for each station
 - Surface and bottom low frequency salinity variation
 - Horizontal salinity gradients at surface and bottom along the Front River
 - Horizontal salinity gradients at surface and bottom along the Back River
 - Vertical salinity gradients at stations along the Front River
 - Error analysis statistics for all stations
- d. Model data comparison plots of 1999 temperature:
 - Surface and bottom temperature time series for each station
 - Surface and bottom low frequency salinity variation

G. Discussion of the 1999 hydrodynamic model calibration:

- a. An observation was made that the measured surface currents at GPA-06 appeared to have no V-component at times. ATM should check the original data.

- b. A discussion arose regarding a high salinity event that occurred during the third week of August. The event was particularly apparent in the data at stations GPA-04 and GPA-06. The model predictions did not appear to predict the magnitude of the bottom salinities at either GPA-04 or GPA-06.
 - c. Salinity gradients that included station GPA-08 appeared incorrect. ATM will look at the original data for that station. Should also use the same stations for the 1999 gradient plots as used in the 1997 gradient plots for easier intercomparison.
 - d. In order to better understand the salinity intrusion extent it was suggested that a plot of the slack water high tide salinity data for each station versus river be made. ATM should consider plotting min, mean, max or 10th, 50th and 90th percentiles. Several participants would also like to see the salinity 'stack plots' of all of the stations on one page again as shown at earlier MTRG meetings.
 - e. For the salinity profile plots a suggestion was made to plot the data in the "waterfall" plot format. This would show a series of vertical profiles of salinity (salinity vs. depth) on a single plot with the origin moving slightly for each new data set. ATM should consider using this format for the current profiles as well.
 - f. Other salinity model prediction comments included: the model appeared to underpredict salinity at GPA-05; the tidal excursion at GPA-04 appeared to be too large.
 - g. A question was raised whether the model time series locations chosen, although having the correct geographic reference, best represented the discretized geometry and bathymetry location. ATM should consider looking at predictions in nearby cells for comparison.
 - h. For the temperature model, the observed temperatures could be used for the boundary conditions. For the upstream boundary one of the stations above I-95 could be used (e.g. GPA-17); for the open boundary, GPA-02 and/or GPA-26 could be used.
 - i. A temperature increase in the harbor area was noted. The temperatures in the harbor area appear to be higher than either those upstream or those nearer to the ocean. It was postulated that the increases could be due in part to the two power stations in the vicinity; Savannah Electric and Georgia Power. ATM will investigate the power generation history of the plants in order to estimate their temperature contribution.
 - j. The MTRG observed and discussed problems with the prediction of the high salinity event during the third week of August. A potential cause identified was the possibility that the model output shown was for a simulation that used a constant open boundary salinity condition. This will be reviewed by ATM.
- H. A review of some of the changes in the model since the previous application in 1997, and objectives and a summary of the status of the present study was made. Topics included:
- a. Two data sets used for calibration/verification are now available, the 1997 data set for calibration and the 1999 data set for validation.
 - b. A temperature model prediction has been added for comparison to the 1999 data set. Insufficient temperature data was collected to adequately compare 1997 predictions.

- c. The QUICKEST advection scheme was implemented in the salinity and temperature models. This transport scheme is 2nd order accurate versus the 1st order accurate upwind scheme previously used.
- d. Variable open boundary parameters were implemented for the salinity and temperature predictions.
- e. Many new statistical comparisons have been added since the previous application. New model-data comparison statistics should allow us to focus in on where the predictions might need improvement and to determine which is the all around better of the final calibration/verification scenarios.
- f. Many improvements have been made over previous application. Surface elevation response along the river has been improved, capturing much of the observed surface setup in the upper portion of the study area. Salinity predictions for 1997 overall have been improved and 1999 has been added.
- g. The goal for the model predictions is to capture the fundamental physical processes in the system for both the 1997 and 1999 data sets, although they represent quite different environmental conditions. Predictions cover very large range of data and length of the river. Surface elevation, currents, salinity and temperature capture most of the major trends in observations. The notable exception to this is the neap tide, high salinity event observed during the third week of August 1999.

I. Discussion points on the summary presentation.

- a. For the present hydrodynamic model calibration scope of work, the 1997 data set is to be used for calibration and the 1999 data set for verification. It was suggested that because the follow on dissolved oxygen (DO) modeling effort will focus on the 1999 data set, for which water quality data was collected, perhaps the 1999 data set should also be used for the hydrodynamic model calibration and the 1997 data set be used for verification. This would require a change in focus for the hydrodynamic model calibration effort. It was recommended by the MTRG that ATM redirect the hydrodynamic model calibration effort focus to the 1999 data set and use the 1997 data set for verification. ATM will redirect the focus of the calibration effort to the 1999 data set and use the 1997 for verification.
- b. Notes on the 1999 focus included: variable upstream and open boundary conditions for temperature and salinity should be checked and implemented; assure that the latest 1999 bathymetric channel survey data should be included in the grid.

Update on Dissolved Oxygen Modeling Inputs and Presentation of LTBOD Curve Fitting Results

Eduardo Yassuda presented an update on the Dissolved Oxygen Modeling Task SEGDO1. A revised table of model coefficients and constant rates was distributed at the meeting. The revised table appears in Attachment C. The MTRG concluded that the first results to be presented using the Water Quality Model will be salinity simulations. The rationale for this test is to demonstrate that the transport schemes of the water quality model are compatible with the hydrodynamic model.

ATM presented their preliminary LTBOD curve fitting results obtained from application of the LTBOD.exe program. Slides of the LTBOD presentation are shown in Attachment B. Results from three sampling dates at the sampling locations were compared and general trends in the data were discussed. Results were also

compared longitudinally and general trends discussed. LTBOD curve fitting results will ultimately determine the kinetic values to be used in the Dissolved Oxygen Model. Therefore, the MTRG will recommend the most appropriate curve fit results and thus the finalized kinetic values before they are input into the dissolved oxygen model.

The MTRG recommended that a discussion group be formed to develop proposed model input values for the dissolved oxygen model in the most efficient manner. All MTRG members are invited to participate and, if interested, will be supplied with the LTBOD laboratory analysis data from Law Engineering. The LTBOD.exe program will be distributed with the laboratory data. The LTBOD discussion group participants will meet October 3rd, the day before the next MTRG meeting to discuss their individual curve fitting results. The goal of the October 3rd meeting will be to determine kinetic values to be used in the Water Quality Model. MTRG participants in the LTBOD Discussion Group will then present proposed finalized kinetic values to the MTRG the following day.

Future Activity

Comments and questions related to any particular issue should be directed to Chris Ahern of ATM (cahern@atm-s2li.com).

The MTRG agreed that the next meeting will be held in Atlanta at the EPA office building on October 4th or 5th from 9:00 AM until 3:30 PM. The LTBOD discussion group participants will meet October 3rd, before the next MTRG meeting to discuss their individual curve fitting results.

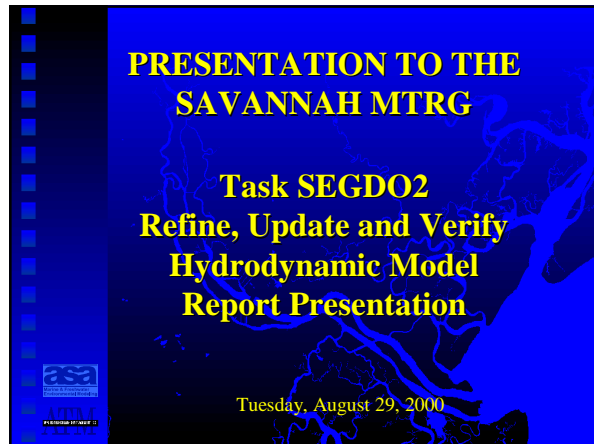
August 29, 2000 Presentation
to the MTRG: *Task SEGDO2,*
Refine, Update and Verify,
Hydrodynamic Model Report
Presentation

ATTACHMENT A

**PRESENTATION TO THE
SAVANNAH MTRG**

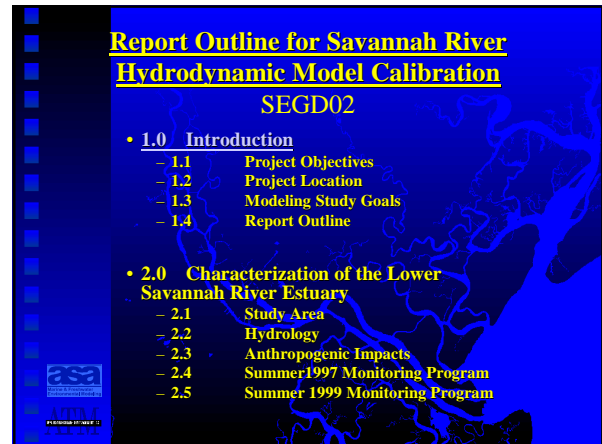
Task SEGDO2
Refine, Update and Verify
Hydrodynamic Model
Report Presentation

Tuesday, August 29, 2000



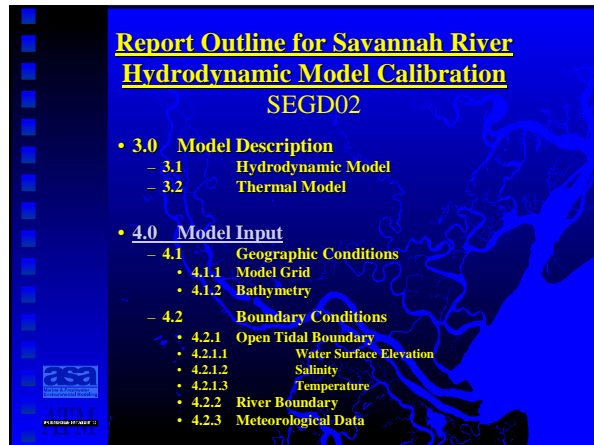
**Report Outline for Savannah River
Hydrodynamic Model Calibration**
SEGDO2

- **1.0 Introduction**
 - 1.1 Project Objectives
 - 1.2 Project Location
 - 1.3 Modeling Study Goals
 - 1.4 Report Outline
- **2.0 Characterization of the Lower Savannah River Estuary**
 - 2.1 Study Area
 - 2.2 Hydrology
 - 2.3 Anthropogenic Impacts
 - 2.4 Summer 1997 Monitoring Program
 - 2.5 Summer 1999 Monitoring Program



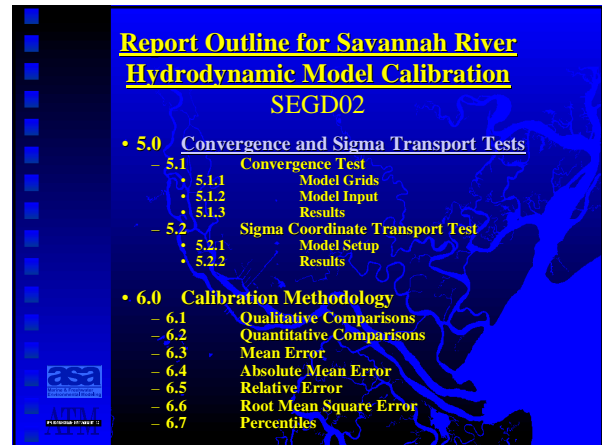
**Report Outline for Savannah River
Hydrodynamic Model Calibration**
SEGDO2

- **3.0 Model Description**
 - 3.1 Hydrodynamic Model
 - 3.2 Thermal Model
- **4.0 Model Input**
 - 4.1 Geographic Conditions
 - 4.1.1 Model Grid
 - 4.1.2 Bathymetry
 - 4.2 Boundary Conditions
 - 4.2.1 Open Tidal Boundary
 - 4.2.1.1 Water Surface Elevation
 - 4.2.1.2 Salinity
 - 4.2.1.3 Temperature
 - 4.2.2 River Boundary
 - 4.2.3 Meteorological Data



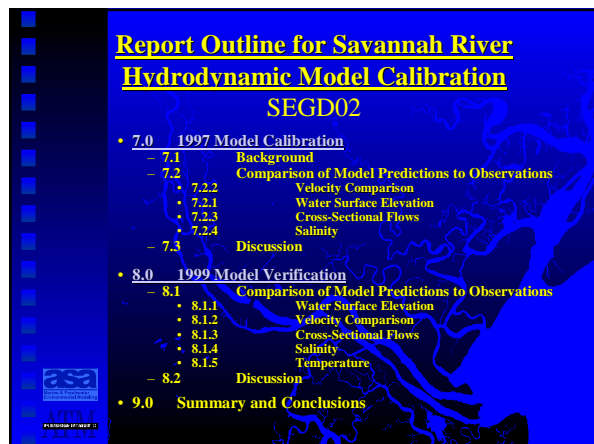
**Report Outline for Savannah River
Hydrodynamic Model Calibration**
SEGDO2

- **5.0 Convergence and Sigma Transport Tests**
 - 5.1 Convergence Test
 - 5.1.1 Model Grids
 - 5.1.2 Model Input
 - 5.1.3 Results
 - 5.2 Sigma Coordinate Transport Test
 - 5.2.1 Model Setup
 - 5.2.2 Results
- **6.0 Calibration Methodology**
 - 6.1 Qualitative Comparisons
 - 6.2 Quantitative Comparisons
 - 6.3 Mean Error
 - 6.4 Absolute Mean Error
 - 6.5 Relative Error
 - 6.6 Root Mean Square Error
 - 6.7 Percentiles



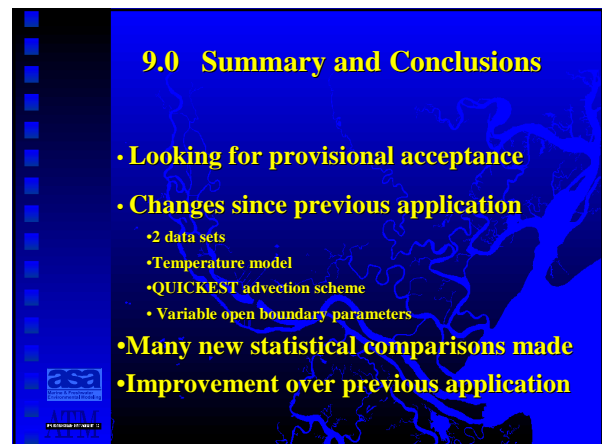
**Report Outline for Savannah River
Hydrodynamic Model Calibration**
SEGDO2

- **7.0 1997 Model Calibration**
 - 7.1 Background
 - 7.2 Comparison of Model Predictions to Observations
 - 7.2.2 Velocity Comparison
 - 7.2.1 Water Surface Elevation
 - 7.2.3 Cross-Sectional Flows
 - 7.2.4 Salinity
 - 7.3 Discussion
- **8.0 1999 Model Verification**
 - 8.1 Comparison of Model Predictions to Observations
 - 8.1.1 Water Surface Elevation
 - 8.1.2 Velocity Comparison
 - 8.1.3 Cross-Sectional Flows
 - 8.1.4 Salinity
 - 8.1.5 Temperature
 - 8.2 Discussion
- **9.0 Summary and Conclusions**



9.0 Summary and Conclusions

- **Looking for provisional acceptance**
- **Changes since previous application**
 - 2 data sets
 - Temperature model
 - QUICKEST advection scheme
 - Variable open boundary parameters
- **Many new statistical comparisons made**
- **Improvement over previous application**



9.0 Summary and Conclusions

- Addressed MTRG earlier concerns
- Model predictions adequately represent complex physics in the system
 - Surface elevation, currents, salinity and temperature capture major trends in observations
 - Predictions cover large range of data and length of the river
 - 1997, 1999 predictions provided test of vertical mixing scheme

ATMOS
HYDRO
OCEANO

August 29, 2000 Presentation
to the MTRG: *Presentation of
Preliminary Long Term
Biochemical Oxygen Demand
(LTBOD) Curve Fitting Results*

ATTACHMENT B


Presentation to the

Modeling Technical Review Group

Presentation of Preliminary Long Term Biochemical Oxygen Demand (LTBOD) Curve Fitting Results


August 29, 2000

Applied Technology and Management, Inc.




Information Packets:

- Summary of ATM's preliminary LTBOD curve fitting results
- "CLYO" Curve fitting summary pages missing
- Raw Data will be made available for individual curve fitting analysis




Overview of Presentation:

- I. Background of on LTBOD
- II. Review of LTBOD Data from Section 10 of the 1999 Draft Data Report
- III. Presentation of Curve Fitting Results
- IV. Creation of Curve Fitting Discussion Group to Present Finalized Results




Background on LTBOD
Use of LTBOD curve fitting results

- Curve fitting analysis is separate analysis related to the calibration of the dissolved oxygen model
- Model kinetic values based on curve fitting results
- Finalized values will be presented to the MTRG for approval before they are incorporated into the Dissolved Oxygen Model




Background on LTBOD
LTBOD.exe

- Developed by GA EPD, Water Quality Management Program (Roy Burke III)
- Non-linear analysis program
- DOS executable
- Version 2.20, released December 29, 1993
- Provides curve fits: first order and logistics
- Calculates UBOD, rate of oxidation (k) and f-ratio (UBOD/BOD-5)



Background on LTBOD
LTBOD Laboratory Analysis

- Performed by Law Engineering and Environmental Services, Bio Tox Laboratory at Kennesaw, GA
- Laboratory analysis developed with GA EPD, Water Quality Management Program
- 120 days for sample analysis



Review of LTBDOD Data
General Information

- 49 LTBDOD samples collected
- Sampling Locations: LTBDOD stations (1 through 6), CLYO, and Marsh Exchange
- 4 LTBDOD sampling efforts:
 - Week 2 (August 11, 1999)
 - Week 4 (August 25, 1999)
 - Week 6 (September 8, 1999)
 - Marsh Exchange Transects (September 22, 1999)
- 4 reports received from Law Engineering (last report delivered May 17, 2000)

Review of LTBDOD Data
1999 Draft Data Report

- 1999 Draft Data Report Section 10, "LTBDOD Data", completed in June 19, 2000 CD distribution

Brief Review of Figures

Presentation of Curve Fitting Results
UNBOD and UCBOD assumptions

First order curve fit is assumed to be UCBOD, no UNBOD constituent.

Presentation of Curve Fitting Results
UCBOD Comparison

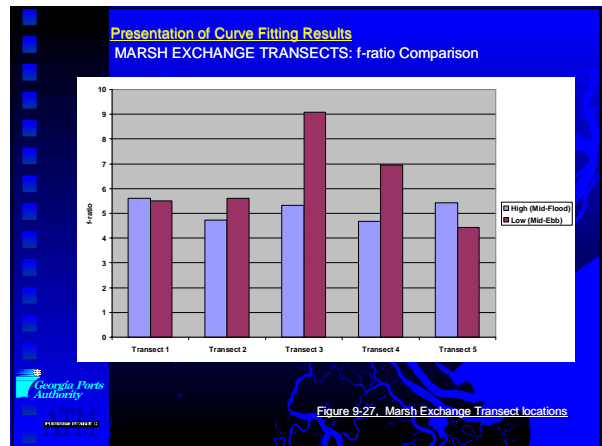
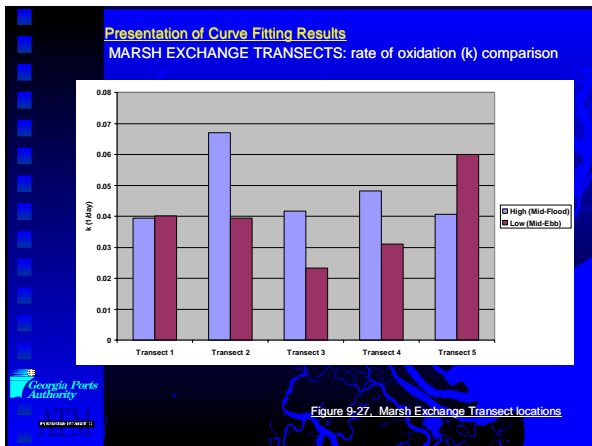
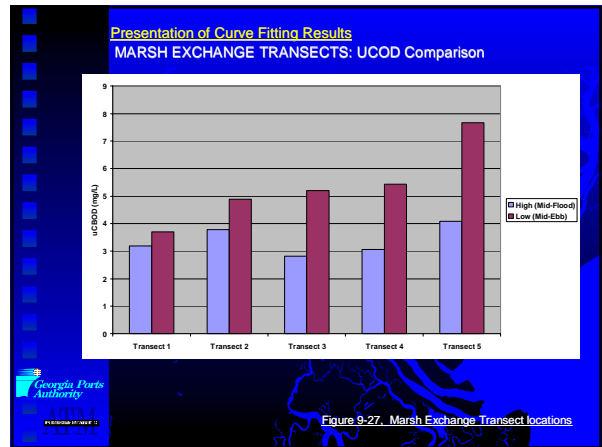
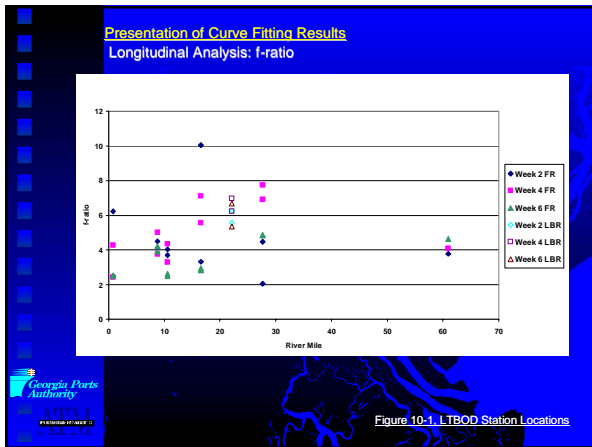
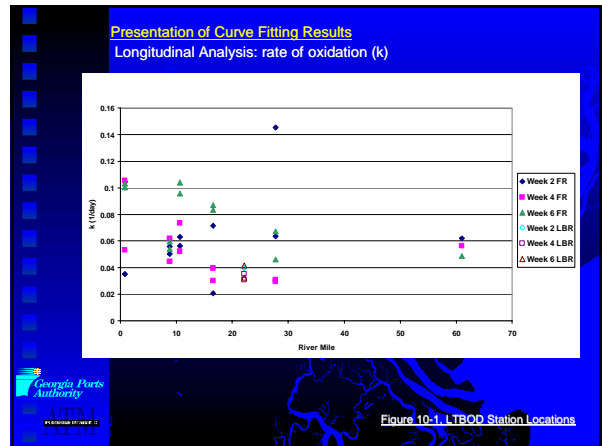
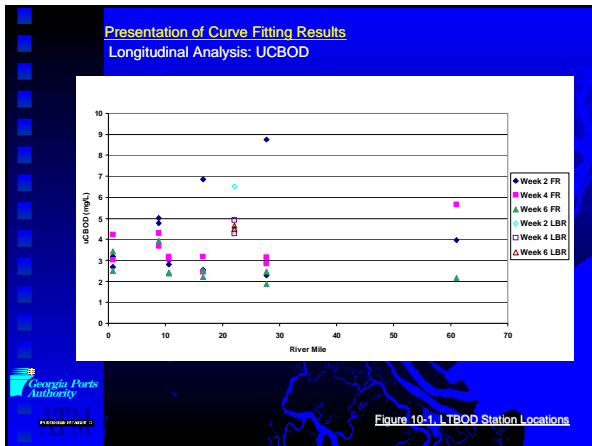
Figure 10-1. LTBDOD Station Locations

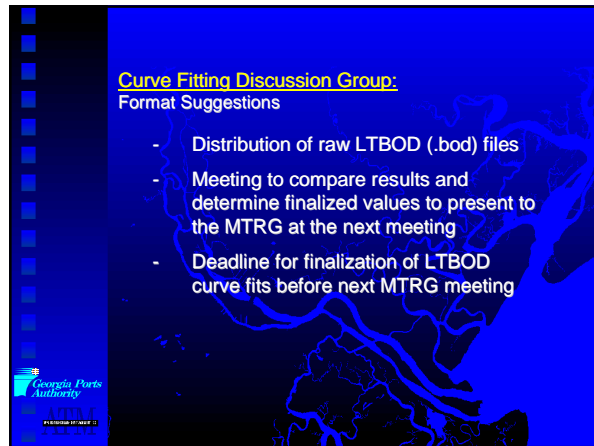
Presentation of Curve Fitting Results
Rate of oxidation (k) Comparison

Figure 10-1. LTBDOD Station Locations

Presentation of Curve Fitting Results
f-ratio Comparison

Figure 10-1. LTBDOD Station Locations

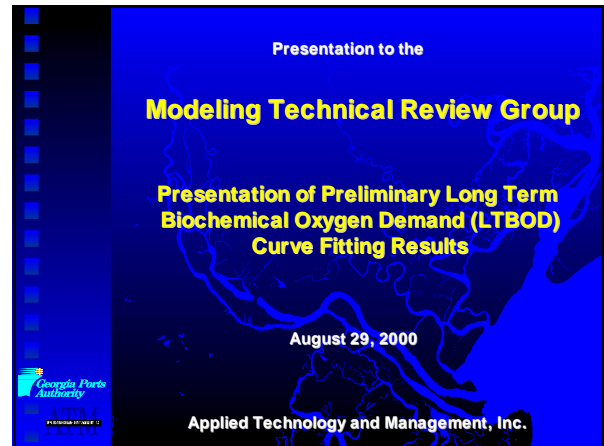




Curve Fitting Discussion Group:
Format Suggestions

- Distribution of raw LTBOB (.bod) files
- Meeting to compare results and determine finalized values to present to the MTRG at the next meeting
- Deadline for finalization of LTBOB curve fits before next MTRG meeting

Georgia Ports Authority
APPLIED TECHNOLOGY AND MANAGEMENT, INC.



Presentation to the

Modeling Technical Review Group

Presentation of Preliminary Long Term Biochemical Oxygen Demand (LTBOB) Curve Fitting Results

August 29, 2000

Applied Technology and Management, Inc.

Georgia Ports Authority
APPLIED TECHNOLOGY AND MANAGEMENT, INC.

August 29, 2000 Presentation
to the MTRG: SEGDO1
Dissolved Oxygen Model
Handout

ATTACHMENT C

TASK SEGDO1 – DISSOLVED OXYGEN MODEL

The goal of this task is to develop a calibrated dissolved oxygen model to evaluate the impacts of the proposed deepening upon the resources within the Lower Savannah River. The dynamic conditions in the estuarine portion of the system result in a wide range of dissolved oxygen concentrations, and a dynamic model will be used to evaluate the spatial and temporal distribution of dissolved oxygen within the primary study area under pre-defined critical conditions.

Although the dissolved oxygen model extends from Clyo down, for the purposes of this task the primary study area covers the Lower Savannah River from I-95 to the mouth of river below Fort Pulaski, and includes the Middle River, the Back River, the Little Back River, and the South Channel. Overlap exists between the model developed under this Task and a model being developed by EPA for the upper Savannah River.

Under this task, the basic processes that will be considered within the water quality component (BFWASP) of the WQMAP system were identified and reviewed by the MTRG. The processes were determined from a literature search and the analysis of historic data as they relate to the characteristics of the dissolved oxygen processes within the Lower Savannah River.

The approach determined by the MTRG is to consider the balance between the reaeration, oxidation (CBOD and NBOD) and sediment oxygen demand processes, which are already included in the present kinetics implemented in the BFWASP component of the WQMAP system. However, during the calibration process, where BFWASP existing kinetics are insufficient to meet the needs identified under this task, an implementation plan with appropriate kinetic modifications will be prepared and submitted to the Technical Review Group for approval.

MODEL FORMULATION

The water quality model component of WQMAP is based on the same boundary-fitted grid as the hydrodynamic model. It uses the hydrodynamic model output plus additional parameters to estimate the dynamic distribution of 8 state variables in the water column and underlying benthos. The EPA WASP5 eutrophication model (Ambrose et al., 1994) forms the basis of the water quality model kinetics. The WASP5 kinetic rate equations have been incorporated into WQMAP to form a fully non-linear eutrophication, 3-dimensional, time-dependent, advection-diffusion model system in boundary-fitted, general curvilinear coordinates. For the Lower Savannah River, the dissolved oxygen balance will be represented by:

$$\frac{\partial C_6}{\partial t} = k_2 \Theta_2^{T-20} (C_S - C_6) - K_d \Theta_d^{T-20} \left(\frac{C_6}{K_{BOD} + C_6} \right) C_5 - \frac{64}{14} K_{12} \Theta_{12}^{(T-20)} \left(\frac{C_{i6}}{K_{NIT} + C_{i6}} \right) C_1 - \frac{SOD}{D_j} \Theta_S^{T-20}$$

$$\textit{In-stream DO} = \textit{reaeration} - \textit{oxidation} \\ - \textit{nitrification} - \textit{SOD}$$

where,

Coefficient	Symbol	Units	Literature Range	BFWASP
Reaeration rate @ 20 °C	K_2	1/day	0 ~100	Formula
Temperature coefficient	Θ_2	-	1.008~1.047	1.047
DO saturation	C_s	mg O ₂ /L	Formula	Formula
Deoxygenation rate @ 20 °C	K_d	1/day	0.02~4.24	0.06
Temperature coefficient	Θ_d	-	1.02~1.06	1.03
Half saturation constant for oxygen limitation	K_{BOD}	mg O ₂ /L	0.5	0.5
Nitrification constant rate @ 20 °C	K_{12}	1/day	0.001~0.6	0.30
Temperature coefficient	Θ_{12}	-	1.02~1.08	1.04
Half-saturation constant for oxygen limitation	K_{NIT}	-	0.1~2.0	2.0
Sediment Oxygen Demand	SOD	g/m ² -day	0.05~10	1.5
Temperature coefficient	Θ_s	-	1.02~1.08	1.047
Diffusive exchange coefficient	E_{DIF}	m ² /day	(1~4) x 10 ⁻⁴	1.0 x 10 ⁻⁴
Benthic layer depth	D_j	m	0.0-0.7	0.10

The DO fluxes on the air-water interface are determined as a product of a reaeration coefficient multiplied by the difference between DO saturation and the DO concentration at the surface layer. The reaeration coefficient can be assumed to be proportional to the water velocity, depth, and wind speed (Thomann and Fitzpatrick, 1982). In WQMAP, there are three user-defined options for the reaeration coefficient:

- Constant reaeration (defined in the interface).
- Time variable (function defined in the interface).
- Calculated internally as a function of average water velocity, depth, wind, and temperature.

For this study a site-specific reaeration coefficients will be used. Until the determination of the site-specific coefficient by EPA, preliminary simulations will be conducted using constant reaeration coefficient. The constant reaeration will be calculated using an average tidal velocity magnitude (from data) and the thickness of the upper surface layer. The reaeration occurs within the upper layer of the three-dimensional model and then is advected and diffused downward based upon the vertical turbulence parameters.

The use of ultimate oxygen demand (UBOD) as a measure of the oxygen-demanding processes simplifies modeling efforts by aggregating their potential effects. Oxidation of organic matter, nitrification, non-predatory mortality and respiration by zoo and phytoplankton are nitrogenous-carbonaceous-oxygen-demand, collectively combined into the state variable UBOD. The kinetic pathway of UBOD (C_5) is represented in the BFWASP model by:

$$\frac{\partial C_5}{\partial t} = -k_D \Theta_D^{T-20} \left(\frac{C_6}{K_{BOD} + C_6} \right) C_5 - \frac{v_{s3} (1-f_{D5})}{D_i} C_5 - \frac{5}{4} \frac{32}{14} K_{2D} \Theta_{2D}^{(T-20)} \left(\frac{K_{NO3}}{K_{NO3} + C_6} \right) C_2$$

where,

Coefficient	Symbol	Units	Literature Range	BFWASP
Organic matter settling velocity	v_{s3}	m/day	0.5~2.0	0.0
Fraction dissolved UBOD	f_{D5}	-	0.0~1.0	1.0
Denitrification rate @ 20 °C	k_{2D}	day ⁻¹	0.02~1.0	0.15
Temperature coefficient	T_{2D}	-	1.02~1.08	1.04

Additional Model Coefficients

Organic nitrogen mineralization @ 20 °C	K_{71}	1/day	0.01 ~ 0.4	0.04
Temperature coefficient	Θ_{71}	-	1.02 ~ 1.08	1.08

INITIAL AND BOUNDARY CONDITIONS

The initial concentration for DO will be determined from saturation, while the initial spatial distribution of UBOD will be determined from the 1999 monitoring data. Similar to the salinity boundary condition applied to the hydrodynamic simulations, the DO and UBOD concentrations at the offshore and riverine boundaries will be calculated in the outflow, and set to prescribed values during inflow. The rationale is that model boundaries are placed away from the area of interest, so the effects of their specification are minimized. Likewise, the boundary condition for the storage cells representing the marshes will be calculated on the outflow (flood tide), and assumed a prescribed value during inflow (ebb tide).

As to the point source loading into the system, the results of the study “Characterization of the Point Source Discharges” conducted by Law Engineering will be utilized. The results of this study will be summarized to provide at each discharge location: flows, concentrations, and multipliers to define UBOD.

DO MODEL CALIBRATION

Using the 3-dimensional water quality model described in the previous Section, it is possible to synthesize the available literature and field data collected from various parts of the estuary during the summer of 1997 and 1999. Although model simulations will be performed to predict instantaneous and absolute values of DO concentration, the main focus is to predict the system’s response to the proposed deepening under different river-discharge and critical scenarios.

Calibration Methodology

In the Lower Savannah River Estuary, it is most likely that the temporal and spatial distribution of DO is a function of (1) background conditions, (2) marsh exchange, (3) point and non-point sources, (4) temperature and salinity, and (5) river discharge and tide range.

Using the 3-dimensional water quality model described in the previous section, the biogeochemical balance is established between the UBOD (including the carbonaceous and the nitrogenous portions), boundary exchange, including marsh storage and reaeration at the air-water interface, and advective transport. Consequently, model coefficients to be determined during calibration are as follows:

- Reaeration rate (K_2) and related parameters
- Sediment oxygen demand (SOD)
- UBOD decay rate (K_D)
- Nitrification constant rate (K_{12})
- Denitrification constant rate (K_{2D})
- Mineralization of Organic Nitrogen (K_{71})
- Temperature coefficients based on the field monitoring programs (1997 and 1999)

The model calibration will be conducted using the water quality data collected during the summer of 1997 and 1999. A detailed description of the data sets is presented in the report, entitled "*Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, July-September 1997*" and "*Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, August 2 through October 9, 1999*"

During calibration, model coefficients will be adjusted until the computed solution produced the best match to the measured data. The criteria for the desired level of accuracy will include but not be limited to the following:

- Graphical
- RMS errors
- Percentile frequency of occurrence
- Least Squares Regression

MODEL SENSITIVITY

Model sensitivity tests will be performed by adjusting the various model kinetic rates and constants within the range of literature values. The results will be presented relative to the impacts of the coefficient variations upon the dissolved oxygen concentrations within the system. The model sensitivity testing will follow the presentation of the initial model calibration to the SEG Technical Review Group and be under their guidance. Under this task the model will be refined and where necessary recalibrated based upon the SEG Technical Review Group input. Upon completion of this sub-task the model will be fully calibrated and tested and ready for use in impact evaluations.

MTRG Responses to
Comments on the 1999
*Savannah Harbor Draft Data
Report* Received as of
September 12, 2000

ATTACHMENT D

RESPONSES TO COMMENTS ON THE 1999 SAVANNAH HARBOR DRAFT DATA
REPORT RECEIVED AS OF SEPTEMBER 12, 2000

Comments provided by the following MTRG members:

- 1) Wade Seyle, USACE
- 2) Jack Blanton, SKIO
- 3) William Bailey, USACE
- 4) James Martin, WES
- 5) Paul Conrads, USGS
- 6) David Sample, Law Engineering
- 7) Roy Burke III, GA EPD
- 8) Jim Greenfield, EPA

Please note that all comments shown in this document appear as they were received by Chris Ahern (cahern@atm-s2li.com) of ATM. Comments are presented in the order in which they were received.

Please also note: All responses were discussed at the August 29, 2000 MTRG meeting in Atlanta GA. Each response is numbered and appears in a text box (such as the one around this note) beneath the comment.

COMMENT 1:

>>> "Seyle, Wade F SAS" <Wade.F.Seyle@sas02.usace.army.mil> 05/03/00 11:01AM
>>>

Chris - I reviewed the subject report and have the following comments. I also added a few since we talked.

Section 1 - Only 19.5 miles of the lower Savannah River are being considered for deepening as part of the expansion project, not 21.5.

Response 1: Agree, "21.5 miles" will be edited to "19.5 miles".

Section 3 - The first paragraph in Section 3.5 indicates that the data is plotted relative to the elevation of the pressure transducer. Consider including a table that lists the elevation of the transducers.

Response 2: The first paragraph of Section 3.5 will be replaced with the following paragraph:

"Depth data were collected by water quality instruments at Continuous Water Quality Stations. Continuous Water Quality Stations are described in Section 2.1.1. Stations where depth data was collected are referred to as tide stations and are shown in Figure 3-1a and 3-2b. The depth data for each tide stations are shown in Figures 3-3 through 3-33. Depth data for each tide station are relative to the water quality instrument pressure transducer. In general, the pressure transducers are less than 5 cm vertically from the water quality probes. Therefore, the pressure transducers were elevated at the same level as the water quality probes. The water quality probes were elevated at predetermined height of 1 meter from the river bottom."

Section 4 - Consider adding a statement in the write-up that velocities with negative values indicate a flood tide (or upstream flow) and velocities with positive values indicate an ebb tide (or downstream flow).

Response 3: The following sentence will be added to the first paragraph after the first sentence:
“Figures 4-3 through 4-58 and Appendix G show positive values (red) indicating velocity in the ebb direction and negative (blue) values indicating velocity in the flood direction.”

Section 10 - Should be proof-read, there are several missing/extra words in sentences throughout the section. In Table 10-1, suggest indicate that the marsh exchange transects were taken at the mid-point of high and low tides.

Response 4: Agree, Section 10 was redistributed June 16, 2000 when the LTBOD data was available and was edited to address this comment.

Section 11 - The last sentence of Section 11.2 is confusing and difficult to understand how the adjustment was made to reference the GPA water surface elevation to NGVD using USGS water surface elevations. Perhaps a more detail could be provided to make the explanation clearer.

Response 5: Agree, Section 11 was redistributed June 16, 2000 when the Water Surface Elevation Data Comparison was complete. Section 11 was edited to address this comment.

Appendix L - Some of the depths appear to be actual depths and some (Sattion 26 and Houlihan Bridge) appear to be "cells". If this is the case, consider indicating all depths as a distance, if possible. Also, consider indicating that the depth unit is in meters (if that is the unit of measure). Houlihan is misspelled in this appendix.

Response 6: Depths listed in Appendix L are actual depths. Field crews positioned (raised and lowered) the instrument to get the approximate whole meter depth for 24-hour Station 01 and 03. The rationale for profiling to the whole meter is the place is the profile is easier to track through the profile.

Following are some general comments:

It may be appropriate to include the statement concerning the flow direction (see section 4 comment above) in the Introductory section since some of the

appendices have the same plots and figures that show positive and negative flow values.

See Response 3

Consider stating that cross-section plots are oriented "looking upstream (or downstream)" instead of "south to north", etc. If some one reviewing the data is not familiar with the orientation of the river, they may not be able to tell which direction they are looking.

Response 7: The South to North orientation was chosen to make the format universal for all transects that might not have a easily distinguishable upstream or downstream direction.

Are all of the depths listed in the appendices in meters?

Response 8: All ATM generated figures in the Appendices are in meters. The figures will be edited to label the units more clearly.

Thanks, Wade

COMMENT 2:

>>> Jack Blanton <jack@skio.peachnet.edu> 05/25/00 12:01PM >>>
Chris, Seems like I forgot to forward you a list of recommendations for the Draft Data report on the Savannah River. This list represents requests for Harvey and me. We recommend that the next report provide:

1. time-series contour plots of the moored ADCP station data

Response 9: Time-series contour plots of the ADCP data will be included in the Modeling Report and compared to the modeling output time series. Contours will be velocities through the water column vs. time.

2. vertical profiles of salinity and temperature of the longitudinal station data

Response 10: Waterfall plots of the EPD profile data presented in Figures 9-10 to 9-17 will be also be presented in the form of Waterfall plots. The MTRG recommended the Waterfall plots of the EPD Data be included in the Final Data Report to better present and compare the data.

3. ASCII files of the plotted data

Response 11: The schedule of data availability to the MTRG is yet to be determined. ATM is presently analyzing the data and acknowledges MTRG members would like ASCII files of the data to perform their own analyses.

Enjoyed meeting you at the last meeting.

Regards, Jack

Jack Blanton (jack@skio.peachnet.edu)
Skidaway Institute of Oceanography
10 Ocean Science Circle
Savannah, GA 31411
Voice: 912-598-2457
FAX: 912-598-2310

COMMENT 3:

>>> "Bailey, William G SAS" <William.G.Bailey@sas02.usace.army.mil> 07/06/00
03:44PM >>>

I am writing to concur with a discussion held during last month's MTRG meeting and present additional views on this issue. Please consider this an official comment on the Draft Data Report.

A discussion I started at the June MTRG meeting concerned the report's minimal discussion about the instream DO samples that were lost when the lab prematurely diluted them. The issue is mentioned in Appendix R, Section 3.2. However, I believe that discussion needs to be substantially expanded. Since we lost such a large percentage (44 %) of the instream BOD/CBOD samples collected that week, the report should identify what samples were lost.

The general issue expands to one of notifying the reader/reviewer that not all the data discussed in the SOW was actually obtained. The MTRG agreed to a sampling plan -- a scope of work. That plan was the result of thoughtful discussions between representatives of various organizations that led to decisions on the information that would be needed to fully determine and describe the intricacies of the water quality conditions in the harbor. As a result of various factors, ATM was not able to produce data for all the samples identified in the SOW. There were variances from the approved sampling plan. At this point, ATM, GPA, the MTRG and subsequent reviewers will need to be confident that the data that was collected is sufficient to (1)adequately represent the variable water quality conditions in the harbor, and (2)allow adequate calibration of a hydrodynamic model that represents those variable conditions, thereby sufficiently fulfilling the intentions of the original SOW.

At the MTRG meeting I requested that the locations of the lost BOD/CBOD samples be identified. This would allow a determination of whether sufficient instream data exists in all portions of the harbor, especially

critical ones, to fulfill the two needs expressed above. I continue to believe such a map would be helpful and I again request you include it in the Data Report.

One MTRG member suggested you prepare a table comparing the samples specified in the SOW with the data that is useable. I concur with that suggestion. I believe such a table would allow ready identification of any large discrepancies from the SOW which may indicate potential problems in fulfilling the original intent of the data collection effort.

Another MTRG member suggested you handle this issue in a separate chapter or appendix to the Data Report. That would certainly make it easy to determine exactly what data was obtained from your substantial effort. If you feel that the information can be included in an existing chapter, that would be fine, but it would appear that the issue of variances from the SOW would extend beyond the individual Appendices J through R where data are presented.

The data collection effort was a LARGE and complicated task. From my understanding, ATM did well in performing that task. Most of the reasons that not all the data was obtained were not controllable by your firm. I believe the comments above will assist you in closing the loop in a professional manner on this extensive data collection effort.

William Bailey
Corps Of Engineers

Response 12: The MTRG decided that a sub-section should be added to Section 1 describing the data collection effort. Section 1.5 was added to the Draft Data in response to this decision. Section 1.5 is titled, Results of the Summer 1999 Data Collection Effort. Table 1.1 describes the specific incidents where the Data Collection Effort Scope did not comply with the Scope of Work (SOW).

COMMENT 4:

>>> "Martin, James L WES" <martinj@wes.army.mil> 07/17/00 01:29PM >>>
Review of Draft Report: Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, August 2 through October 9, 1999 (Sections on CD's dated April 27 and June 19, 2000)

James L. Martin
ERDC WES

General comments:

I found this to be a very well prepared and presented summary of the data

collection effort and data results. The only comment of significance I have is with regards the discussion at the past MTRG meeting and the recommendations by William Bailey, CESAS regarding lost samples and deviations from the accepted sample plan. I concur that additional text (and/or tables) is required identifying deviations from the original sample plan. While much of this material is in the text, the deviations should be summarized in a single section so that impact of these deviations can be addressed point by point in the subsequent data analysis report. Otherwise, I offer only the following minor specific comments.

See Response 12

Specific Comments

1. Does everyone concur that it will be necessary to have a color printer? Otherwise a number of the figures will not be readable in hard-copy.

Response 13: ATM distributed the Draft Data Report in pdf format on Compact Disk so every MTRG member could view the color images on the computer screen instead of printing the hardcopies of the color images.

2. It would help if the date of preparation were given on all documents prior to final to aid in identifying revisions (as was done on some tables; and if there are to be any further revisions).

Response 14: The next distribution of the Data Report will be the final and therefore will not be added to page. However in future reports to the MTRG, revision dates will be added to the documents. Revision dates will allow the MTRG to better keep track of what version they are commenting on.

3. References to updates (such as "data have been updated" or "will be updated" should be removed from the final report.

Response 15: Agree, the references described will be removed.

4. Section 3.6, 3rd paragraph" change "on after Hurricane" to "after Hurricane"

Response 16: Agree, the edit will be completed for the Final Data Report.

5. Section 3.6.2, 1st paragraph change "measurement and deploy the" to "measurement and deployment of"

Response 17: Agree, the edit will be completed for the Final Data Report.

6. Insert figure for 3-30

Response 18: Figure 3-30 will be inserted for the Final Data Report.

7. Change Figure numbering from "3-01" and "4-01" to "3-1" and "4-1" for consistency with other sections

Response 19: Figure numbers will be made consistent in future reports.

8. Figure 4-2 is missing

Response 20: Figure 4-2 will be inserted for the Final Data Report.

9. Section 5.4, 1st paragraph: change "equilibrium of dissolve oxygen" to "equilibrium of dissolved oxygen"

Response 21: Agree, the edit will be completed for the Final Data Report.

10. Section 5.5 to 5.7: complete section

Response 22: Section 5.5 to 5.7 will be completed for the Final Data Report. It is important to note that the reference "Compare to 1997 Data" does not mean a detailed comparison. A general reference will be made to the 1997 Data in each of these sections. A comparison of the 1997 data and 1999 will be performed in future analyses.

11. Section 7.4: Could the City's data be included in plots for these Stations? How about a comparison with the salinity signal?

Response 23: Comparison of the City of Savannah's chloride data to the summer 1999 Continuous Chloride Data Collection will be addressed in the Chloride Modeling Report. The reference to a comparison of the Chloride Data to the summer 1999 Continuous Chloride Data will be edited to refer to the Chloride Modeling Report.

12. Section 8.3.2: Reference to request for raw dissolved oxygen data no longer in revised section 8.3.1.

Response 24: Reference to request for raw dissolved oxygen data removed because the requested data was received and presented in the June 16th distribution of the Draft Data Report. A historical account of the MTRG requests to the laboratories was provided in section 8.3.1.

13. Section 9.5: complete section

Response 25: Example Cross-Sectional Distribution plots will be presented in Section 9 for the Final Data Report. Raw Cross-Sectional Profiling Data is presented in Appendix O.

14. Change legend on profile plots for DO so that lower numbers are in red

Response 26: Legend for Figures 9-8, 9-10, 9-12, 9-14 and 9-16 will be edited such that lower values of DO are in red.

15. Page 10.3, second paragraph , 1st sentence (revised chapter): change "10-gallon" to "10-gallon bucket"

Response 27: The edit described will be completed for the Final Data Report.

16. Section 11.3: complete salinity comparisons once USGS data become available

Response 28: USGS Conductivity Data for the requested Savannah River Stations were still not available as of September 15, 2000. Suzie Grams of USGS in Atlanta promised to contact ATM when the data became available.

17. Appendix B: Station GPA-15 and others following, correct alignment at end of paragraph

Response 29: Alignment of paragraph bottom on pg B-12, in Appendix B will be corrected for the Final Data Report.

18. Appendix J: The revised (6/19) version only contained only the week 1 water chemistry samples (with the revised CBOD-5 data).

Response 30: Weeks 1 through 7 were inadvertently left out of Appendix J.pdf distributed on June 19, 2000. Appendix J will include all weeks in the Final Data Report.

19. Appendix J: Explain/correct highlights on week 7 water chemistry data

Response 31: Highlights on Week 7 water chemistry columns labeled TKN-N, Total P, and Orthophosphate will be removed.

20. Appendix J: It would help if the station order in the sample description were the same for each table. Missing data could be indicated in this way.

Response 32: Order of Appendix J water chemistry sample data is based on sample number to allow for easier tracking of data. Where samples were not collected due to extenuating circumstances, missing station numbers will be referred to. Where samples were collected and improperly diluted by the laboratory (see Section 8 or Appendix R or Section 1.5) sample number will be referred to.

21. Appendix P: Missing from original and revised CD

Response 33: Appendix P will be included for the Final Data Report Distribution.

James L. Martin, Ph.D., P.E.
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COMMENT 5:

>>> <pconrads@usgs.gov> 07/19/00 11:19AM >>>

Chris,

Sorry for the delay getting review comments to you on the Savannah Harbor Data Report. Better late than never. I grouped all my comments together by sections and did not break out the editorial and technical comments. I believe the editorial comments will be fairly obvious. Give me a call if you have any questions or comments.

Paul

(See attached file: Savannah Harbor Data Report Review.doc)

Paul Conrads

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Stephenson Center Suite 129
720 Gracern Road
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ATTACHED FILE: Savannah Harbor Data Report Review.doc

Section 1

Show ALL geographical references mentioned in the text in Figure 1-1. Include Fort Pulaski, South Channel, Fort Jackson, Front River, Back River, Savannah National Wildlife Refuge, Abercorn Creek, and Raccoon Creek.

Response 34: Features mentioned are included on other Section Figures where referenced. The purpose of this figure is to orientate readers to the Savannah area. Therefore Figure 1-1 will not be relabeled.

Delete the last two sentences on page 1-1. This information is repeat in Section 1-4, which is the more appropriate place for it.

Response 35: Agree, the last two sentences will be edited as to not repeat the sentences in Section 1-4.

The list on page 1-3 can be improved to help the reader get a better understanding of the monitoring program and the structure of the report. Consider breaking the list into two groups of bullets—continuous monitoring and field sampling. Add a reference to the appropriate Section and figure in the report at the end of each bullet.

Response 36: Agree, the list on page 1-3 will be edited to better distinguish between continuous monitoring and water sampling. References to sections will also be added for the Final Data Report.

Section 2

Section 2.1.1 states “a total of 24 locations”. On page 1-3 states “21 stations”. Make sure the number of stations is consistent.

Response 37: The reference in Section 2.1.1 refers to the total number of Continuous In-stream Water Quality Data Collection Stations in the summer 1999 Data Collection Effort. The reference on page 1-3 refers to the total number Water Quality Data Collection Stations at which YSI instruments were deployed. Stations where bottom and surface instruments were deployed are counted as one Stations. The list on page 1-3 will be edited in response to a separate comment, see Response 36, the text will be further edited to further distinguish between the “21 Station locations” and “24 Station locations” references.

Fourth paragraph of Section 2.1.4, last sentence is incomplete.

Response 38: The fourth paragraph in Section 2.1.4 will be edited to the following:
“The 24-hour stations were distributed throughout the Lower Savannah River System to capture longitudinal characteristics over a 24-hour period. The 24-hour sampling locations were selected to be on the Front River downstream of Fort Jackson, on the Front River near the City of Savannah, upstream of the Navigation Project and on the Little Back River at the Fish and Wildlife Dock. The 24-hour sampling event is described in detail in Section 9.2.”

Page 2-6, last set of bullets includes “24-hour Dynamic Event”. Should “Event” be plural?

Response 39: The reference “24-hour Dynamic Event” is correct because only one 24-hour event was performed. The “24-hour Dynamic Event was described in Task Statement SEGP312, which is located in Appendix A.

Figures 2-3 through 2-8 not listed under “List of Figures” on page v.

Response 40: Figures 2-3 through 2-8 were inadvertently not included in the List of Figures and will be added for the Final Data Report.

Table 2-2, No.22—space in MacroCTD

Response 41: The description for the Water Quality Meter listed on Lines 21 and 23 in Table 2-2 will be edited to “Macro CTD”, as it appears in Line 22.

Section 3

Figures 3-23b and 3-25 need an explanation of measured points and best-fit line. Need update to Figure 3-30.

Response 42: A description of the best-fit lines in Figures 3-23b and 3-24b will be added to Section 3.6. Figure 3-30 will be added for the Final Data Report.

Section 4

I counted 30 ADCP transect locations on Figures 4-1a and 4-1b and 29 locations are listed in Section 1, page 1-3.

Response 43: The reference to “29 ADCP Transect locations” in Section 1, page 1-3 will be edited to “30 ADCP Transect locations”.

The ADCP, due to the limitations of the instrument, does not measure all the water in the cross section. The depth of the instrument and the blanking distance is discussed in Section 4-4. Are estimates made of the amount of flow in the top 1.5 meters of the cross section? The ADCP is also limited by the depth of water that it can profile, usually 1 to 2 meters. Were estimates made at the edge of water to account for the flow where it is too shallow for the ADCP to measure? Moving bed can be a problem making transects. What were the field procedures used to check for moving bed? Appendix F has a good summary of QA/QC field procedures but discussion of these issues would be appropriate in the text of Section 4.

Response 44: Reported discharge data was determined by the RD Instrument’s TRANSECT program. The program and the flow calculating algorithms are discussed in Appendix F. References to Appendix F and the how the discharge values were calculated by the RD Instruments TRANSECT program will be added to Section 4.3.

Section 5

Update the historical references in the section.

See Response 22

Page 5-4, third paragraph, second sentence – *dissolved* instead of dissolve.

Response 45: The second sentence in third paragraph on Page 5-4 will be edited as follows:
“By allowing the tap water to sit in the container overnight and/or throughout the day for at least 4 hours, the dissolved oxygen in the container would reach an equilibrium of dissolved oxygen concentration.”

I was unclear of how the QA/QC data was used in finalizing the data. For example, if field measurements by a monitor showed the dissolved-oxygen concentration to be 4.8 mg/L and the monitor was recording 5.0 mg/L, was a 0.2 mg/L correction (or shift) applied to the data to compensate for the drift? A description of the post-deployment procedure in the text would be helpful. Appendix H gives a YSI example but it is difficult to tell if the same procedure was used.

Response 46: A discussion of the QA/QC procedures used to determine what data to ultimately present will be detailed in Section 1.5 of the Final Data Report. Examples of each parameter will be given and general QA/QC guidelines described.

Were the dissolved-oxygen data corrected for specific conductance internally in the instrument or as a post-processing routine?

Response 47: Dissolved Oxygen readings were collected by YSI instruments. These instruments correct DO for salinity internally, a parameter recorded simultaneously during the 1999 Data Collection Event. References to the internal salinity correction for DO will be added to section 5.0 text for the Final Data Report.

Was salinity computed internally in the monitor or as a post-processing routine? What algorithm was used for the computation?

Response 48: Salinity is reported by the instrument. Salinity is calculated from conductivity and temperature readings using the algorithms found in *Standard Methods for the Examination of Water and Wastewater* (1989 ed.).

Section 6

In Section 6.1, change “USGS No. 02198500” to “USGS Gaging Station No. 02198500”.

Section 6.3, second sentence—station should be plural.

Page 6-2, first complete sentence—give the units of measure for “approximately 45 above MHW”.

Response 49: Section 6.1 will be edited as suggested. In Section 6.3, “station” will be edited to “stations”. On page 6-2, “approximately 45 above MHW” will be edited to “approximately 45 ft above MHW”.

Section 7 – No comments

Section 8

Make sure oxygen uptake values are computed from the raw data are included in the report. (Section 8.3.2, page 8 -6, paragraph 2)

Response 50: Raw laboratory analysis results are presented in figures 8-3 and 8-4 for BOD-5 and CBOD-5 respectively.

Reference *Standard Methods* and the version number in Tables 2 and 3.

Response 51: As mentioned in Response 48, references to *Standard Methods for the Examination of Water and Wastewater* (1989 ed.) will be added to the report text.

In the Figures 8-3 through 8-9, where reporting limits of the labs are given, identify on the plots the lab that was responsible for the analysis.

Response 52: The laboratories that performed the analysis presented in Figures 8-3 through 8-9 are listed in Table 8-1. As suggested, references to Savannah Laboratories and Analytical Environmental Services will be added to Figures 8-3 through 8-9. References to the laboratories and the weeks of the analysis will be made in the figure title block.

When comparing the historical STORET data, indicate in the text (and perhaps in a footnote to the tables) that it is a comparison of all the historical data and not just the August and September or summer data from the database.

Response 53: Tables 8-4 through 8-9 list the dates of historical data compared to the 1999 In-Stream Water Chemistry Data. As suggested by the above comment, a statement will be added to Section 8.3 describing both the time of record for the historical STORET data and the 1999 In-Stream Water Chemistry Data.

Section 9

Section 9.2.3, second paragraph—Dissolved Oxygen should be lowercase.

Response 54: The phrase “Dissolved Oxygen” will be edited to “dissolved oxygen”.

Make sure to include Section 9.5.

See comment 25

Section 10

Page 10-3—first paragraph states that the travel time from the USACE depot is approximately 20 minutes. Unclear as to the destination and the significance of the statement.

Response 55: The last sentence in the first paragraph on page 10-3 will be edited to the following:
“Travel time from the USACE Engineers Depot to LTBO-01, for example, is 20 minutes. Therefore the field crew had to depart from the Engineers Depot more than 20-minutes before the predicted high slack event at LTBO-01.”

There is a lot of description of the messenger sampler (Van Doren Sampler). Most of the other monitoring equipment is shown in the appendix. May want to consider including a picture/drawing of the messenger sampler.

Response 56: A sketch of a messenger sampler (Van Doren Sampler will be included in Appendix C. The sketch will be referenced in Section 10.

The last Law Engineering Report did not have a date, only a month. Probably should be "September 22, 1999 through January __, 2000."

Response 57: The title of the report is *Long Term Biochemical Oxygen Demand Test, Marsh Exchange Samples, Savannah Georgia, September 1999 through January 2000. May 2000*. As stated in Table 10-1, the Marsh Exchange Transects were collected September 22, 1999.

Section 11

1. Grid lines and legends did not come through in the second version.

Response 58: Gridlines appear lightly on printed versions of the pdf format. The MTRG determined including a copy of the most recent *Adobe Acrobat Reader* program with the Final Report on compact disk would be helpful.

COMMENT 6

>>> "Sample,David" <DSample@kennesaw.Lawco.com> 08/04/00 04:16PM >>>
Chris, I apologize for the lateness of these comments. Here they are:

1. Distribution of BOD and COD: The frequency component (lower half) of figures 8-3 and figures 8-4 might be made more meaningful if a reference continuous fitted distribution was included for comparison. For figure 8-3, the normal, or log normal distribution may be appropriate, for figure 8-4, an exponential distribution may be appropriate.

Response 59: The requested analyses of the BOD and CBOD data will be addressed in the Dissolved Oxygen Modeling Report. The purpose of the Data Report is to present the data collected during the Summer 1999 Data Collection Event.

2. Appearance of negative salinity: Figures 9-2 and 9-3 exhibit a graphic anomaly in which salinity appears to dip below zero due to the "smoothing" function, both from river mile 20 to river mile 22. Since the values actually are zero, or close to it, is it possible to turn off the "smoothing" function between river mile 20 and river mile 22 on these figures?

Response 60: The purpose of the best-fit line is to demonstrate general trends in the data. The MTRG concluded that the best-fit line for Figures 9-2 and 9-3 should be "less smoothed" for the Final Data Report.

3. Supersaturated dissolved oxygen: In figures 9-28 (transect 1) and 9-32 (transect 3) oxygen values obviously well above saturation values (correcting for salinity) are shown. Both of these are transects are along a slough near the Middle River. For interpretation of these values, water temperature and/or oxygen saturation and/or deficit values would also be necessary. In general, dissolved oxygen is a very important parameter of concern in the Savannah River system, and needs to be monitored and/or reported in this context to enhance the effectiveness of the dataset being collected.

Response 61: The raw data for the Marsh Exchange Transects, including temperature and percent saturation, is shown in Appendix M. Data from Transects 1 and 3 were collected the same day, September 9, 1999. Primary productivity could account for the super-saturated dissolved oxygen and the values for other marsh transects just below saturation. Since the high dissolved oxygen concentration cannot be explained, the dissolved oxygen data in Figures 9-28 and 9-32 will not be presented in the Final Data Report. A reference to the removed dissolved oxygen data will be added to Section 9.3.3.

4. Large difference between high slack and low slack LTBOD values: The values for LTBOD for weeks 2 exhibit a marked difference between the high slack and the low slack values for stations LTBOD-01, LTBOD-03, and LTBOD-04 that is not exhibited in LTBOD-02, LTBOD-05, and LTBOD-06 (figure 10-9). Looking ahead to week 4, this trend is not repeated for LTBOD-04 and is markedly dampened for LTBOD-03 (figure 10-10). Looking further to week 6, only LTBOD-01 exhibits a marked difference between the high and low slack LTBOD values. Since the trend seems to be independent of the river distance, I suggest a review of the sampling logs in particular for week 2 and LTBOD-04. Possibly some resuspended "fluff" from bottom sediments may have entered the sample erroneously.

Response 62: The MTRG concluded that a separate discussion would be formed to discuss the LTBOD Data. The LTBOD discussion group is open to all MTRG members all of received the LTBOD Data and the analysis program to obtain their own results. The goal for forming the LTBOD discussion group is to discuss observed trends and finalize kinetic values for each LTBOD station. The LTBOD discussion group will meet October 4, 2000 in Atlanta, the day before the MTRG meeting.

5. River Mileage: It would be helpful to record the river mile on the figures 10-4 through 10-16 so that comparisons could be made to other historical information.

Response 63: Table 10-3 will be added to Section 10 to list river miles for each LTBOD Station and Marsh Exchange Transect Location.

6. LTBOD graphs mislabeled: Figures 10-2 through 10-7 state in their title block that they are for LTBOD01. This appears to be mislabeled, as it states elsewhere on the figure that the figure is for LTBOD-01 through LTBOD-06.

Response 64: Figures 10-3 through 10-7 are mislabeled. All figures titles are shown as follows: "Figure 10-X, LTBOD Test Results: BOD and NBOD at LTBOD01 for Weeks 2, 4 and 6". "LTBOD01" will be edited to correspond with the LTBOD station listed on the plots in Figures 10-3 through 10-7.

COMMENT 7

>>> "Roy Burke" <Roy_Burke@mail.dnr.state.ga.us> 08/31/00 11:25AM >>>
Good Morning Chris,

I have examined your Savannah Harbor Draft Data Report and concur with comments made by others on the MTGR committee with respect to additions and corrections. As a representative of the Georgia Environmental Protection Division my response appears below:

"The 1999 field data gathered by ATM, and yourself, comprise the largest and most comprehensive model calibration data set that I have ever seen. The quality assurance and quality control measures employed were rigorous and consistent throughout, even during difficult times. I am therefore confident that the available 1999 data are appropriate for subsequent model development to support the difficult decisions that lie ahead.

Given the enormous and unwieldy volume of field data on hand, the Draft Data Report does an excellent job of describing and presenting this information in a friendly and easy to use format. I therefore congratulate you and ATM for doing a fine job with this difficult effort. There are no deficiencies in the Draft Report, detectable to me, that would detract from a most commendable effort."

COMMENT 8

>>> <Greenfield.Jim@epamail.epa.gov> 09/12/00 06:55AM >>>

The data collected on the Savannah Harbor during 1997 and 1999 is an excellent data set , along with the existing historic data, for model development and are appropriate for subsequent model development to support the difficult decisions that lie ahead.

The data report, when accompanied by the data text files will be a good compilation of the data ATM collected and great historic record.

Good job.

James M Greenfield
61 Forsyth Street 15th Floor
Water Mngt Division - EPA Region 4
Atlanta, Georgia 30303
Email: greenfield.jim@epa.gov
Phone: 404.562.9238
Fax: 404.562.9224

Section 1.5: “Results of the
1999 Data Collection”
that will be added to
Section 1.0 of the *Final
Savannah Harbor Data Report*

ATTACHMENT E

1.5 RESULTS OF THE 1999 DATA COLLECTION

Applied Technology and Management performed the summer 1999 data collection in accordance with the task statements approved by the MTRG, accepted by the SEG and recommended to Georgia Port Authority.

The task statements were drafted as a collaborative effort between the MTRG, SEG, GPA and ATM. As stated in Section 1.3, task statements SEG311, SEG312, and SEG313 are found in Appendix A. The MTRG agreed that the finalized task statements outlined a complete data set that would be more than sufficient for the purposes of calibrating the water quality models described in each task statements.

The MTRG met during the data collection event and immediately after to review the data collected to date and provide further consultation to the data collection effort. The MTRG was briefed on the progress of the Data Collection Effort. ATM presented unexpected developments in the Data Collection Event for discussion in the MTRG. The decisions of the MTRG were then applied to the Data Collection Effort. Through collaboration with the MTRG, the 1999 Data Collection effort succeeded in meeting all objectives outlined in the task statements.

1.5.1 Preparation for the 1999 Data Collection Effort

Preparation for the summer 1999 Data Collection Effort started soon after the final approval of the task statements were obtained from the MTRG on May 4, 1999. Instrumentation, personnel, and equipment were mobilized to Savannah from July 5 through 16, 1999.

Continuous water quality monitoring station mounts were being deployed by July 19, 1999. All In-stream water quality instruments were deployed by August 10, 1999. The instrument servicing schedule was begun August 3, 1999. Week 1 of the Water Chemistry Sampling Effort started on August 2, 1999. Table 5.1 shows the schedule of water quality and hydrodynamic instrument deployment and servicing.

Innovative practices were used to deploy the continuously monitoring water quality instruments. Where no structures for mounting instruments were available, mounting systems were designed and fabricated. Section 2 of this report describes the designs and variety of deployments used for the summer of 1999 data collection.

1.5.2 Performing the Data Collection Tasks

ATM deployed as many as 10 engineers staff members to perform the tasks described in the task statements. During most days of the Data Collection Effort, three boats were on the Savannah River performing separate data collection tasks. Some data collection events required all boats to perform the same data collection tasks at different points on the river. Figure 8-2 shows images of the different boats performing data collection tasks.

Even with all the careful consideration, planning and preparation for the data collection events there were interruptions in the data collection. Weather events and equipment breakdowns interrupted data collection during several occasions. Most weather event interruptions were recoverable with extra effort on good weather days. With additional effort on good weather days or combining tasks for a day of data collection, the interruptions were recovered.

Inclement weather was the most common data collection interruption during the summer of 1999. Lighting and heavy rain events are considered inclement weather ATM policy does not allow field crews to work when these conditions arise. Although considered extremely hot and dry during August and most of September, afternoon thunderstorm and frontal systems were a regular occurrence. In order to deal with the frequent afternoon storm, data collection efforts were organized so they were nearly completed before 3 PM.

Interruptions were unavoidable in the 14 weeks of the data collection. Overall the interruptions that did occur during the data collection were not detrimental to the overall data collection. In most cases recovery from inclement weather and equipment failure was possible.

Inevitably some equipment will fail during a water quality monitoring study. Given the size and scope of the 1999 Hydrodynamic and Water Quality Monitoring of the Lower Savannah River, few equipment failures were experienced. Equipment failures did result in lost in-stream continuous water quality data but the failures were discovered after the short deployment period, less than two weeks. Therefore the failures did not result in total loss of the water quality data and were usually short lived. Continuous In-stream Water Chemistry data are plotted for each station in Figures 5-3 to 5-31.

1.5.3 Hurricane Floyd

The evacuation of Savannah for the Hurricane Floyd was an interruption in the data collection effort that was unrecoverable. Table 1-1 describes the data not collected due to the interruption in the data collection caused by Hurricane Floyd.

Event 1 in Table 1-1 summarizes the interruption of the Water Chemistry Sample Collection Effort. The required evacuation of Savannah and the surrounding areas due the approaching Hurricane Floyd was announced at 2:00 PM on Monday September 13, 1999. The evacuation was required by 8:00 AM September 14, 1999. Table 1-3 summarizes the Continuous In-Stream Monitoring Stations where water chemistry data were not collected from September 14 through 17, 1999.

Event 2 in Table 1-1 summarizes the interruption in the Continuous In-stream Water Quality Data Collection Effort. ATM personnel accomplished the removal of five continuously monitoring water quality stations on Monday September 13, 1999 before evacuating that evening. Section 5.2 describes why the specific Continuous In-stream Water Quality Monitoring Stations were removed due to the approaching hurricane. The Continuous In-stream Water Quality Stations that were removed Monday September 13, 1999 and then redeployed September 20, 1999 are listed below.

- GPA-26B
- GPA-26S
- GPA-04B
- GPA-04S
- GPA-03B

Event 3 in Table 1-1 summarizes the interruption in the Continuous In-stream Hydrodynamic Data Collection Effort. The bottom mounted Acoustic Doppler Current Profiler (ADCP) at GPA-04 was removed on Monday September 13, 1999 when the water quality instruments were removed. As discussed in Section 5.2, the instrument location was thought to be the most vulnerable due to their proximity to the ocean and the potential loss of the instruments. Anchors for the navigation channel markers served as tether points for the instrument mounting structures on the bottom of the River. If the markers had dragged their anchors due to the storm surge, the instruments tethered to the navigation channel markers could be lost.

Mounting systems are described in Section 2 of this report. Further detail in the mounting system for each station is available in Appendix B, the formatted “as-built” notes. The locations of the Continuous In-stream Water Quality Stations are described in Section 5 of this report. Locations of the Continuous In-stream Hydrodynamic Stations, including the two bottom mounted ADCP locations, are described in Section 3.

1.5.4 Water Chemistry Data Invalidated by Laboratory Error

Results from 57 of 130 week 7 BOD water chemistry samples submitted to Analytical Environmental Services (AES) are unusable due to laboratory error. Table 1-2 summarizes the loss of BOD data as a result the laboratory diluting or performing the analysis with too little sample volume. The week 7 Continuous In-stream Water Quality Stations where the Water Chemistry Data was lost are listed in Table 1-3.

Section 8.0 describes the Water Chemistry Sampling Event and presents the valid results from the laboratory analyses. Tables summarizing weekly laboratory results are located in Appendix J. Issues related to the laboratory error and split samples analysis are presented in the January 17, 2000 report titled: *Findings of In-Stream Water Chemistry Data, Savannah Harbor Expansion Project – Field Data Collection, August 2 through October 9, 1999*. The January 17, 2000 Report can be found in Appendix R.

1.5.5 QAQC of the Data Presented in the Data Report

The data presented in the Final Data Report have undergone an extensive Quality Analysis and Quality Check (QAQC) process. Data that are not shown in the data presentation and are not described in Sections 1.5.3 or 1.5.4 were not accepted after the QAQC process.

Examples of how the QAQC process was applied to the different types of instrument deployments and water sampling efforts, listed in Section 1.3, are found in the corresponding Sections of the Final Data Report Text. The corresponding Section numbers for each type of data listed are referenced in Section 1.3.

1.5.6 MTRG Conclusions

With the exception of the specific examples described in Section 1.5.3 and 1.5.4, ATM successfully completed the objectives outlined in the task statements. At the August 29, 2000 MTRG meeting in Atlanta, the MTRG concluded that the 1999 Data Collection Effort results presented in this Data Report are acceptable for the next phase outlined in the task statements, model calibration. Calibration of the Hydrodynamic, Salinity, Dissolved Oxygen and Chloride models will therefore be calibrated to the data presented in this report.

Comments from the MTRG on the April 27, 1999 and June 16, 1999 distributions of Draft Data Report are located in Appendix S. After reviewing the Draft Data Report and discussing all comments submitted by individual members, the MTRG developed responses to each of the comments, which are listed below each of the comments. MTRG comments on the Draft Data Report were applied to the April 27, 1999 and June 16 distributions of the Draft Data Report to produce the Final Data Report.

The April 27, 1999 distribution of the Draft Data Report to the MTRG contained the following components:

- Table of Contents
- List of Figures
- Sections 1.0 to 11.0
- Appendix A to Q

The June 16, 1999 distribution of the Draft Data Report to the MTRG contained the following components:

- Updated Table of Contents
- Updated List of Figures
- Additional Appendix G Figures, Contours of all ADCP Transects
- Updated Section 8.0, Savannah Labs J-values replaced
- Completed Section 10, LTBOD Data added
- Completed Section 11, Added USGS and Continuous Instrument Water Surface Elevation Plots
- Added Appendix R, January 17, 1999 Report titled: *Findings of In-Stream Chemistry Data, Savannah Harbor Expansion Project – Field Data Collection, August 2 through October 9, 1999*

Table 1-1: Summary of the Data Collection Interruption Due to Hurricane Floyd (September 15 to 17, 1999)

Event #	Type of Data	Dates	Description of Data Not Collected
1	Continuous In-Stream Water Chemistry Data	September 14 through 17, 1999	59 of 65 Week 7 (September 13 to 17, 1999) Water Chemistry Samples at the Continuous In-Stream Water Quality Stations. The water quality samples that were not collected for Week 7 are listed in Table 1-3.
2	Continuous In-Stream Water Quality Data	September 14 through 20, 1999	Continuous Instrument Data at GPA-03B, GPA-04B, GPA-04S, GPA-26B and GPA-26S. Instruments were removed to avoid loss from Hurricane. See Section 5.2 for specific discussion of instrument removal and replacement September 20, 1999.
3	Continuous In-Stream Hydrodynamic Data	September 14 through 20, 1999	ADCP removed from GPA04 to avoid loss from Hurricane Floyd. See Section 3.6 for discussion on instrument removal and replacement September 20, 1999.

Table 1-2: Summary of Week 7 (October 5 to 9, 1999) Water Chemistry Samples Results Invalidated by Laboratory Error

Type of Data	Dates	Description of Water Chemistry Data lost
Continuous In-Stream Water Chemistry Data	October 5 through 9, 1999.	57 of 130 BOD and CBOD samples provided to AES Laboratories were either diluted or analyzed with reduced volumes. The results of the analysis for those 57 samples are therefore invalid. The sampling locations that were invalid are listed in Table 1-4.

Table 1-3: Continuous In-Stream Water Quality Stations Where Week 7 (September 13 to 17, 1999) Water Chemistry Samples Were Not Collected Due to Hurricane Floyd Evacuation (September 14 to 17, 1999),

See Event #1 in Table 1-1.

(X = Water Chemistry Sample Not Collected)

Sampling Station	High Slack Sample	Low Slack Sample
GPA-02B	X	X
GPA-02S	X	X
GPA-03B	X	X
GPA-04B	X	X
GPA-04S	X	X
GPA-05B	X	X
GPA-06B		X
GPA-06S		X
GPA-07S	X	X
GPA-08B		X
GPA-08S		X
GPA-09B	X	X
GPA-09S	X	X
GPA-10S	X	X
GPA-11RB	X	X
GPA-12RS	X	X
GPA-14B	X	X
GPA-15S	X	X
GPA-16M	X	X
GPA-17M	X	X
GPA-18B	X	X
GPA-19B	X	X
GPA-20B	X	X
GPA-21B	X	X
GPA-21S	X	X
GPA-22B		X
GPA-22S		X
GPA-23M	X	X
GPA-24M	X	X
GPA-25M	X	X
GPA-26B	X	X
GPA-26S	X	X

Table 1-4: Continuous In-Stream Water Quality Stations Where
 Week 7 (October 5 to 9, 1999) BOD and CBOD Sample Results
 Were Invalidated Due to Laboratory Error
 (X = Both BOD and CBOD Analysis Results Invalid)

Sampling Station	High Slack Sample	Low Slack Sample
GPA-02B	X	X
GPA-02S	X	X
GPA-03B	X	X
GPA-04B	X	X
GPA-04S	X	
GPA-05B	X	
GPA-06B	X	
GPA-06S		X
GPA-09S	X	
GPA-11RB	X	
GPA-21B	X	X
GPA-22B	X	X
GPA-23M	X	X
GPA-24M	X	X
GPA-25M	X	X
GPA-26B	X (CBOD only)	X
GPA-26S	X	X