Final Report
Tennessee-Tombigbee Waterway Water Quality Study
Columbus, Mississippi
Project Nos. 05-0521, 05-0522

Prepared by:

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Approval Sheet

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EXECUTIVE SUMMARY

In response to a request from the Alabama Department of Environmental Management (ADEM) and the Mississippi Department of Environmental Quality (MDEQ) through the United States Environmental Protection Agency (EPA), Region 4, Water Management Division (WMD), the Science and Ecosystem Support Division (SESD), Ecological Assessment Branch (EAB) conducted a comprehensive water quality investigation along approximately 35 miles of the Tennessee-Tombigbee Waterway near Columbus, Mississippi. The study was designed to provide a set of water quality and hydraulic data associated with a defined reach of the Tennessee-Tombigbee (Tenn-Tom) Waterway from just above the Columbus/Stennis Pool in Mississippi to just downstream of the Bevill Lock and Dam in Alabama. The data collected during this study was intended to provide insight with respect to: 1) Clean Water Act (CWA) §§ 303 (d)/305 (b) assessments of organic enrichment/dissolved oxygen within the study reach; 2) the water quality and hydraulic characteristics of the system during low flow conditions; and 3) appropriate approaches for representing the system with a water quality model.

General observations about the Tenn-Tom Waterway based on the data gathered during this study follow:

1. The study was conducted during critical conditions of low flow and high temperature. Average flow during the study was 1, 840 cubic feet per second (cfs) and the average water temperature was 31°C.

2. The dissolved oxygen concentrations (DO) measured at the majority of the stations sampled during the study were greater than 5.0 mg/l. However, there were several observed DO concentrations less than 5.0 mg/l measured at the 5 foot depth within the State of Alabama.

3. Mild dissolved oxygen stratification existed throughout the system. The trend was more pronounced down stream of station TT324.4.

4. Data collected during this study is sufficient to enhance the existing QUAL2E model or assist with the construction of a dynamic model.

5. The emerging issue of invasive plant species proliferating within the system should be considered. According to the U.S. Army Corp of Engineers, navigation has been impeded due to their excessive growth (personal communication with Allan Brewer). The U.S. Army Corp of Engineers has utilized aerial and boat spraying of herbicides to control the plant growth. The long term affects of the plant growth and subsequent spraying upon water quality within the system are unknown.

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Distribution List

A copy of this report will be provided to the following individuals:

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1.0 Introduction

The Tenn-Tom Waterway is a 234 mile man-made navigation system which begins at Pickwick Lake on the Tennessee River, flows through northeast Mississippi and western Alabama and finally connects with the Warrior-Tombigbee navigation system at Demopolis, Alabama. Construction began on the Tenn-Tom Waterway in December 1972 and was completed in December 1984. The Waterway was opened for Navigation in January 1985. There are ten locks and dams along the Tenn-Tom Waterway (TENNTOM 2005).

In 1996, the State of Alabama identified the Tenn-Tom Waterway from Bevill Dam upstream to the Alabama/Mississippi state line, which is coincident with the Alabama portion of Aliceville Reservoir, as being impaired by flow alteration(s) and organic enrichment/low dissolved oxygen on their CWA §303(d) list. This segment remains on Alabama's 2006 CWA §303(d) list as impaired by organic enrichment/low dissolved oxygen. The Alabama Department of Environmental Management (ADEM) used the one dimensional steady-state model, QUAL2E to prepare the Draft Total Maximum Daily Load (TMDL) for Aliceville Reservoir. The results of the model described in the Aliceville Reservoir Draft TMDL indicated that the existing waste loads from within the state of Mississippi exceed the assimilative capacity of the Waterway as it exits the State and enters Alabama. The Draft TMDL required a significant reduction in the loads of organic material, most of which are discharged upstream in the State of Mississippi (ADEM 2002).

Following the development of the Draft TMDL, the Mississippi Department of Environmental Quality (MDEQ), ADEM, and representatives of several potentially impacted stakeholders held several meetings to discuss the report. Some of the major concerns expressed during the meetings were the accuracy and validity of the QUAL2E model used to develop the TMDL. It was determined that additional data was needed to improve the model and TMDL. In consideration of the interstate issues associated with the Tenn-Tom Waterway, Alabama requested that the U.S. Environmental Protection Agency (EPA), Region 4 take the lead on the TMDL development, including efforts associated with monitoring and modeling.

The EPA, Region 4, Science and Ecosystem Support Division (SESD), Ecological Assessment Branch (EAB) took the lead in developing and implementing a data collection study in 2005. The results and conclusions from the study are presented in this report.

2.0 Objectives

The objective of this study was to collect a representative set of water quality and hydraulic data associated with the reach of interest during critical conditions of low flow and high temperature. The study was conducted along approximately 35 miles of the Tenn-Tom Waterway beginning at river mile 340 just above the Stennis Lock and Dam and culminating at river mile 304 just below the Tom Bevill Lock and Dam. As stated in the quality assurance project plan for the study, the objectives were to: 1) determine if a dissolved oxygen deficit existed within the study reach and if so, document the extent and severity, 2) determine if the system was stratified and whether a steady-state or dynamic model would be appropriate, and 3) either enhance the results of the existing steady-state model results or to assist in the construction of a dynamic model. It is expected that the EPA, Region 4, Water Management

Division will use the data and information in this report in its evaluation of a TMDL to address the CWA § 303(d)-listed segment of the Tenn-Tom Waterway.

3.0 Discussion of Results

Personnel from the United States EPA, Region 4, SESD, EAB conducted a field study along the Tenn-Tom Waterway near Columbus, Mississippi from August 11 through August 17, 2005. Additional field support was provided by personnel from ADEM and MDEQ. Average water temperature during the study period was 31°C and average daily flows measured by EPA during the study period in the main stem of the Tenn-Tom Waterway were 1,840 cfs. Based on the data enhancement needs of the QUAL2E model and the potential for use of a dynamic model, the following data sets were collected:

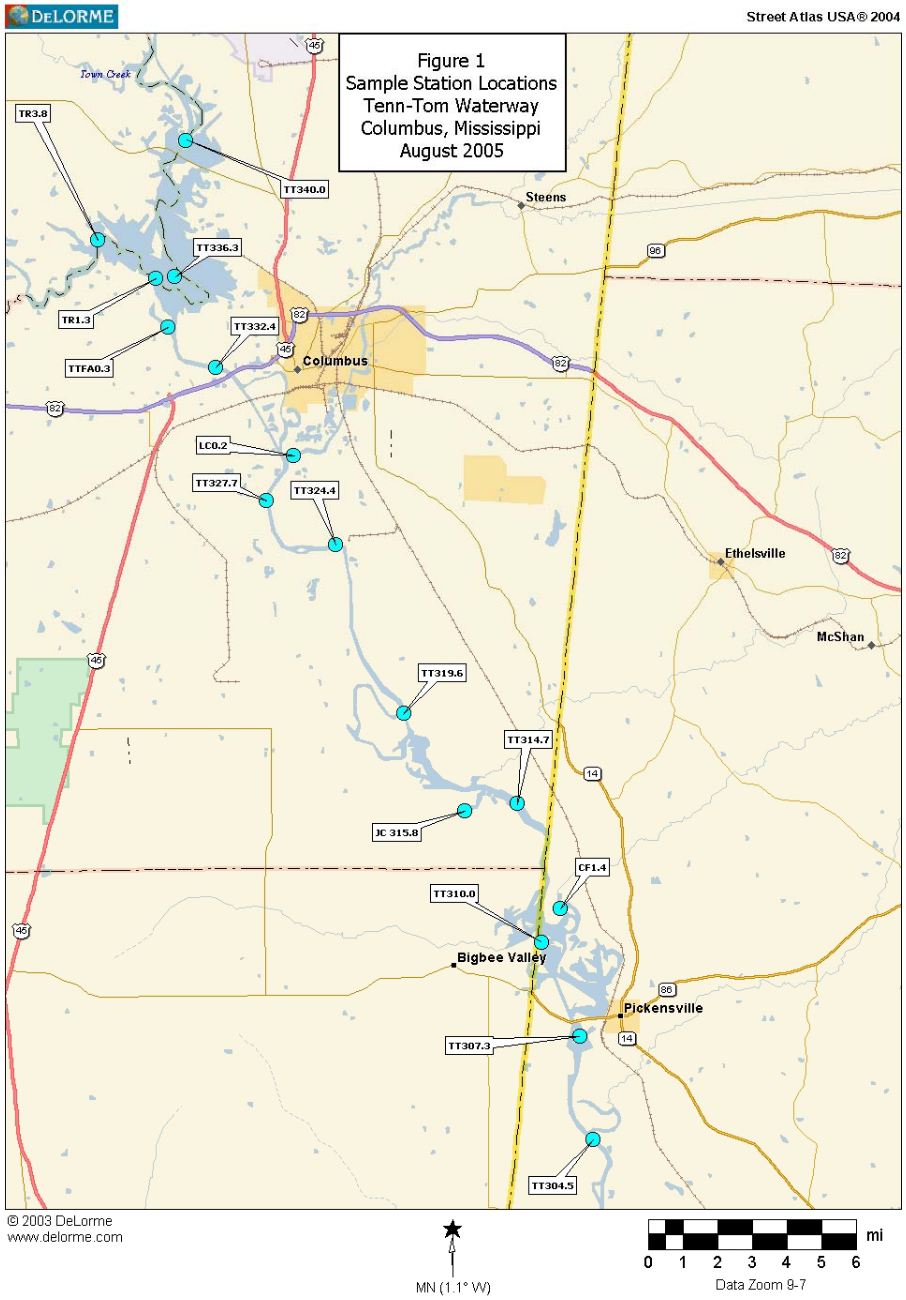
- *in-situ* water quality measurements
- *in-situ* water column profiles
- diffusion/reaeration measurements
- velocity measurements
- flow measurements
- water quality samples; and
- time of travel.

Additionally, meteorological data including air temperature, solar radiation, solar energy, barometric pressure, wind speed and direction, and rainfall were recorded from August 12-16, 2005. A portable weather station was set-up near the Columbus Marina in Columbus, Mississippi. A stage recorder was deployed in the Columbus Pool at the Columbus Marina to record relative changes in stage. An overall change in stage of approximately 0.28 feet occurred during the study. The fluctuation was most likely associated with the dam operations at the Stennis Lock and Dam since a total of 0.26 inches of rainfall was recorded by the weather station during the study period. The complete meteorological and stage data sets are included in Appendix A.

Ten stations were selected for monitoring in the main stem of the Tenn-Tom Waterway. The locations were selected based on the river characteristics, major tributary discharge points, and point source discharges. In addition to the main stem river monitoring stations, five tributaries and the flow augmentation channel at the Stennis Lock and Dam were monitored during the study. Table 1 contains a list of the main stem river and tributary sample stations and a description of their locations and Figure 1 depicts the sample stations along the Tenn-Tom Waterway.

Table 1
Main Stem River and Tributary Station Locations
Tennessee-Tombigbee Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Descriptions	Deg	Min	Deg	Min
TT340.0	Tenn-Tom Waterway near Highway 50 bridge	33	35.418	88	29.020
TT336.3	Columbus Pool near Stennis Lock & Dam	33	32.070	88	29.523
TR3.8	Tibbee River just below Spring Creek	33	32.960	88	31.627
TR1.3	Tibbee River/Columbus Pool	33	31.995	88	29.843
TTRA0.3	Tenn-Tom Waterway Flow Augmentation Channel	33	30.754	88	29.501
TT332.4	Tenn-Tom Waterway near Highway 82 bridge	33	29.779	88	28.114
LC0.2	Luxapallila Creek near mouth	33	27.590	88	25.713
TT327.7	Tenn-Tom Waterway above Weyerhaeuser near marker buoy	33	26.496	88	26.532
TT324.4	Tenn-Tom Waterway below Weyerhaeuser	33	25.287	88	24.464
TT319.6	Tenn-Tom Waterway near Harrison Bend	33	21.143	88	22.382
JC315.8	James Creek at Tenn-Tom Waterway river mile 315.8	33	19.107	88	20.220
TT314.7	Tenn-Tom Waterway near US 49 bridge	33	18.685	88	18.855
CF1.4	Coal Fire Creek at mile 1.6	33	16.911	88	17.498
TT310.0	Tenn-Tom Waterway near MS-AL state line	33	15.198	88	18.230
TT307.3	Tenn-Tom Waterway in Aliceville Pool	33	13.074	88	17.210
TT304.5	Tenn-Tom Waterway downstream of Bevill Lock & Dam	33	10.973	88	17.284



Ten point source dischargers were included in the sampling phase of the study. Seven of the point sources discharge upstream of the upper boundary of the study reach (TT340.0). Two of the ten discharge directly to the Tenn-Tom Waterway along the study reach, and one of the point sources discharges directly to Luxapallila Creek, a tributary to the Tenn-Tom Waterway within the study reach. Table 2 lists the point source dischargers and Figure 2 depicts the point source dischargers within the Tombigbee River Basin.

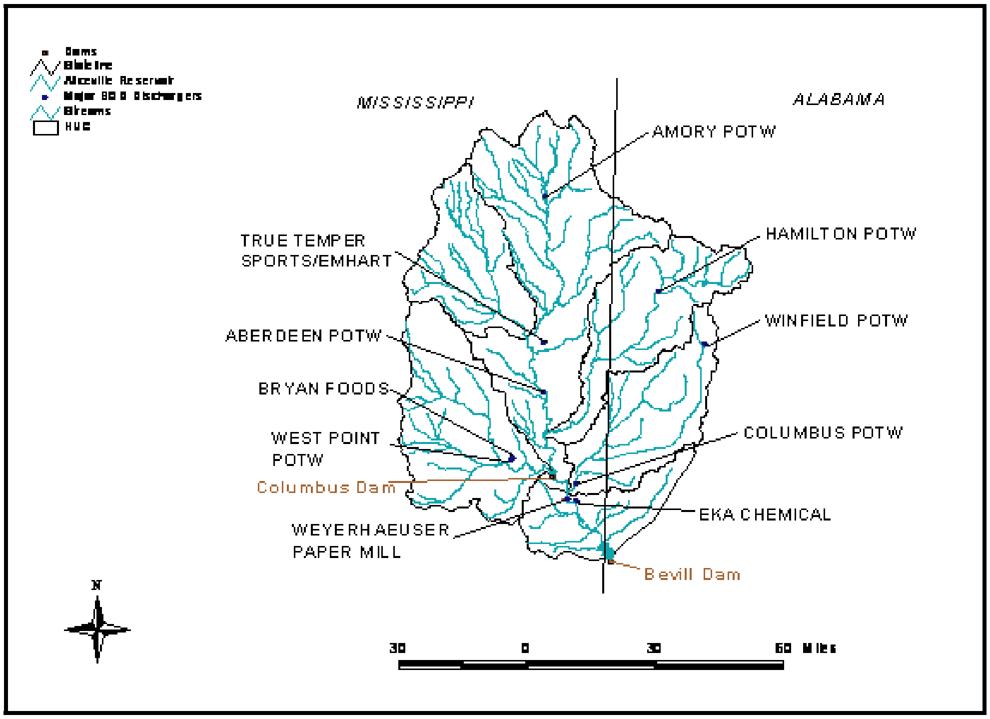
A similar study was initiated in the Tenn-Tom Waterway in July 2003. However, due to excessive rainfall during the study period, which resulted in a drastic change in the water system's conditions, the study had to be abandoned.

A study was again planned for July 2004 but had to be cancelled due to excessive rainfall caused by a hurricane. Sediment oxygen demand (SOD) measurements were conducted in June 2004 as part of the July 2004 study. The SOD rates calculated from the June 2004 measurements are presented in Appendix B. A figure showing the SOD measurement locations is also included in Appendix B.

Table 2
Point Source Sample Stations
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station No.	**Descriptions**
Bryan	Bryan Foods
TT-Sports	True Temper Sports
Aberdeen	Aberdeen POTW
Hamilton	Hamilton POTW
Kerr-McGee	Kerr-McGee Chemical, LLC
WestPoint	West Point POTW
Winfield	Winfield POTW
Columbus	Columbus POTW
W-Paper	Weyerhaeuser CPPC
EKA	EKA Chemical

Figure 2
Point Source Sample Station Locations
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



3.1 *In-situ* Water Quality Measurements

3.1.1 Study Area

YSI 6920 multi-parameter data sondes were deployed at multiple depths, based on the total depth, at each main stem river station along the reach of interest in the Tenn-Tom Waterway. A single sonde was deployed at each tributary station. Typically, the sondes are deployed in the center of the channel or within the main hydraulic conveyance of the water body. Due to barge traffic and other boaters, the sondes were deployed near the edge of the navigation channel in order to protect the equipment.

3.1.2 Methods

The sondes were programmed to collect readings for temperature, dissolved oxygen, pH, and conductivity at 15 minute intervals, for a minimum of 24 hours.

Sondes were deployed at three depths at each main stem river station when total water depths allowed. The sondes were affixed to a weighted line which was held taught by a surface float. The total depth was determined at the deployment location then the sondes were attached to the weighted line at the appropriate depth. After attaching the sondes to the line, the weight, sondes and surface buoy were lowered over the side of the boat. The first sonde was deployed either at one foot below the surface or at the 50% light extinction point, which ever was less. Based on light profiles performed prior to deployment, all sondes were deployed at one foot below the surface. Light profiles are provided in Appendix C. The second sonde was deployed at a depth of 5 feet, which is the applicable depth for the MDEQ and ADEM dissolved oxygen criteria. The third sonde was located midway between the 5 foot depth and the total depth. If the total depth did not exceed 10 feet, only the first two sondes were deployed. This was the case at station TT332.4. A single sonde was deployed at mid-depth at each of the tributary stations, with the exception of Tibbee River. The sondes at the two Tibbee River stations, TR3.8 and TR3.1, were deployed according to the same guidelines used for the main stem river stations because the depth was amenable and the Tibbee River was much larger than the other tributaries and had the potential for greater impact on the Waterway system.

3.1.3 Results

Appendix D contains summary data tables with the maximum, minimum, and average values for each monitoring depth at each location as well as the comprehensive data sets with the 15 minute readings for each station. The deployment depths of the lower layer sondes are provided in Table D-3 in Appendix D and Figures 3 through 6.

Dissolved Oxygen

Figure 3 shows summary graphs of the continuous dissolved oxygen (D.O.) monitoring. The measured DO concentrations at the majority of stations sampled during the study were greater than 5.0 mg/l. However, there were several observed DO concentrations less than 5.0 mg/l measured at a 5 foot depth within the State of Alabama.

Figure 3 reveals a slight decrease in D.O. at TT332.4, downstream of the Columbus Lock and Dam. The decrease in D.O. is most likely a result of the introduction of lower D.O. water from the Tibbee River. The average D.O. measured at TR1.3 in the lower layer (7.5 feet, Table C-4) was 3.17 mg/l. Another downward shift in D.O. occurred at TT314.7 and TT310.0. These stations were in the upper portion of the Aliceville Pool where the retention time increased as the velocity decreased due to the embayment effect from the Aliceville Pool. The slower velocity allowed settling of oxygen demanding material and increased the demand within the water column. Although station TT307.3 is in the Aliceville Pool, the D.O. increased, possibly due to a more robust algal community.

Temperature

Figure 4 contains graphs of the temperature measurements in the main stem of the Waterway. Average temperatures decreased between the upper boundary station and TT324.4. The average temperature increased between TT324.4 and TT3114.7 at five-feet and in the lower layer and stabilized at the higher temperature.

Conductivity

As shown in Figure 5, the average conductivity values ranged from approximately 200 μS/cm to 250 μS/cm from the upper boundary to station TT324.4 at one-foot and five-feet, while the average conductivity at TT340.0 in the lower layer was approximately twice the conductivity at one-foot and five-feet, possibly indicating an upstream tributary or source. The conductivity decreased at TT327.7 due to the introduction of water from Luxapallila Creek, with an average conductivity of approximately 50 μS/cm. There is a noticeable increase in the lower layer conductivity measurements between stations TT324.4 and TT319.6. This may be due to the introduction of the discharges from Weyerhaeuser Paper and EKA Chemical. The cause of the increase in conductivity at station TT307.3 at one-foot is unknown.

pH

Average pH values were approximately 7 standard units (s.u.) and showed little variation at all of the monitoring depths throughout the main stem of the Waterway. Results are shown in the graphs in Figure 6.

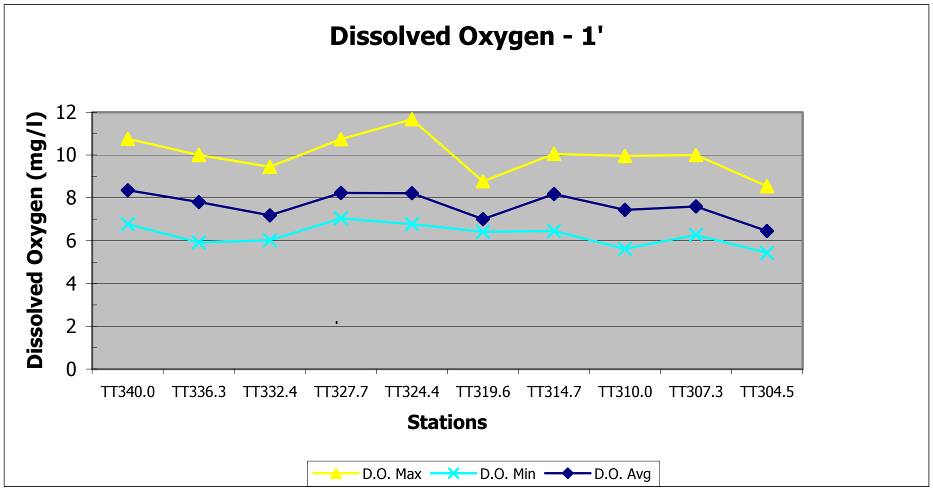
3.1.4 Quality Assurance/Quality Control

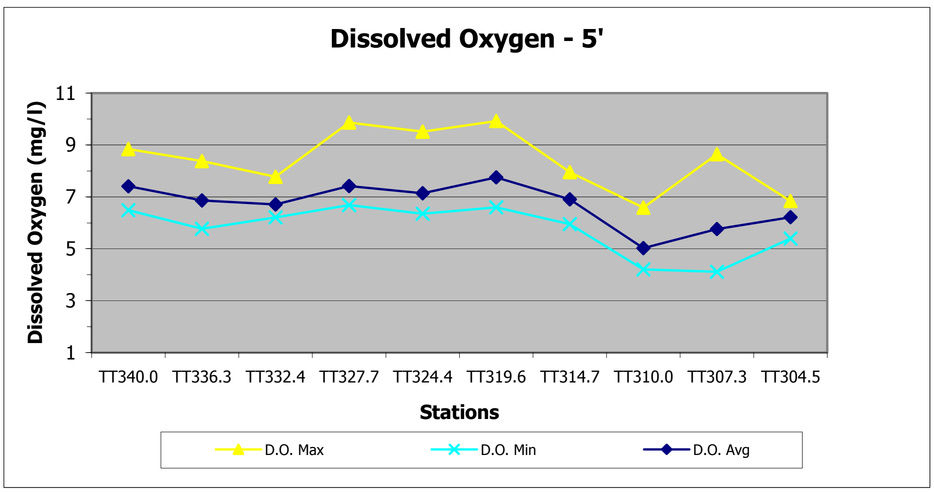
All sondes were calibrated according to Section 18.2 of the Ecological Assessment Standard Operating Procedures and Quality Assurance Manual, January 2002 (EASOPQAM). Prior to deployment, each sonde was calibrated using known standards and the results were recorded on calibration data sheets. Upon retrieval, the sonde calibrations were checked using known standards and the results were recorded on calibration data sheets. Measurement tolerances for each parameter measured by the sonde are provided in Table 3. The calibration data sheets will be maintained with the official project file in the SESD records room.

Table 3
In-Situ Water Quality Parameter Measurement Tolerances
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

In-Situ and Field Parameters	Units	Analytical Method	Sensitivity of Primary Equipment
Dissolved Oxygen	mg/l	Membrane-electrode type meter (Instrument manufacturer's specifications)	$\pm$ 0.2 mg/l
pH	SU	Electrode probe	$\pm$ 0.2 su
Conductivity	usiemens/cm	Conductivity probe (Instrument manufacturer's specifications)	$\pm$ 1% of reading
Temperature	^{o}C	Thermistor	$\pm$ 0.15 ^{o}C

Figure 3
In-Situ Dissolved Oxygen Measurements
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005





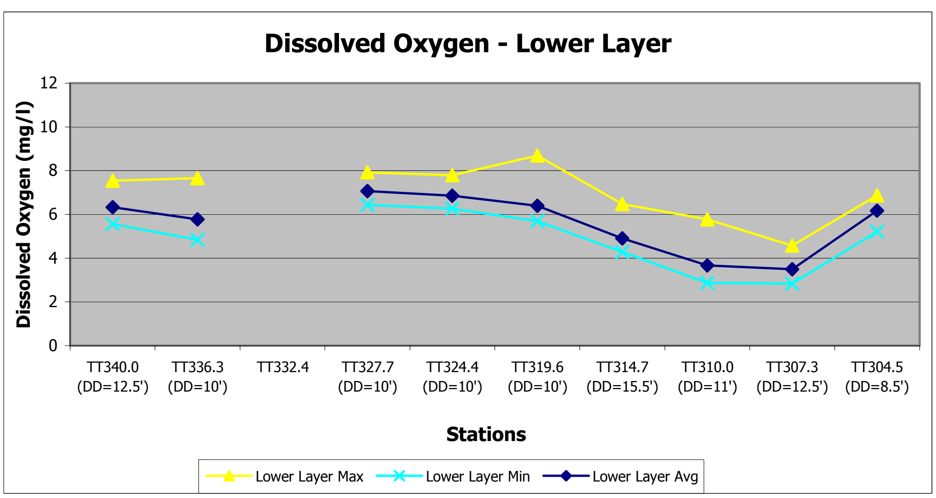
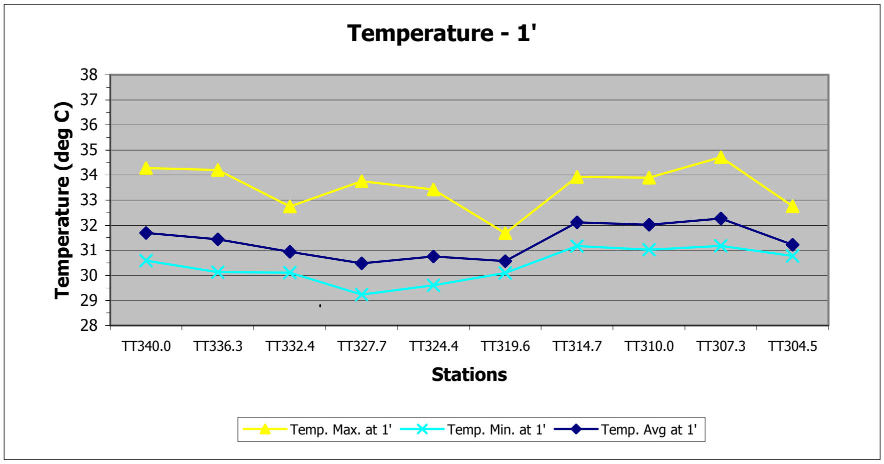
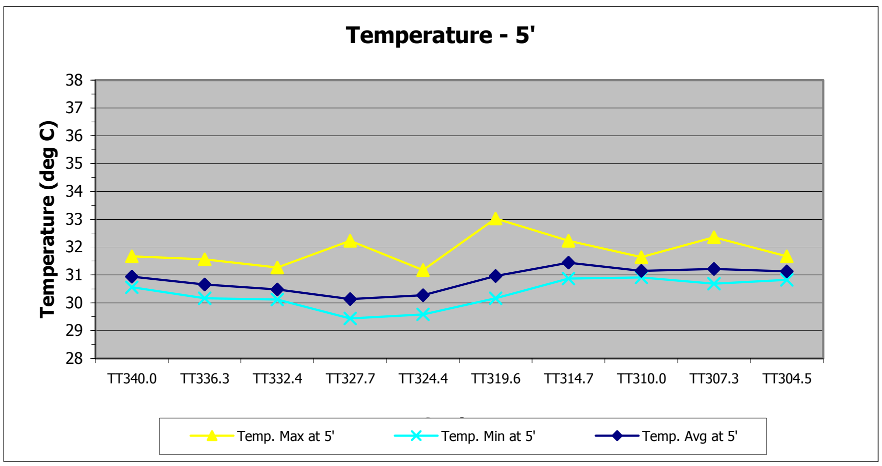


Figure 4
In-Situ Temperature Measurements
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005





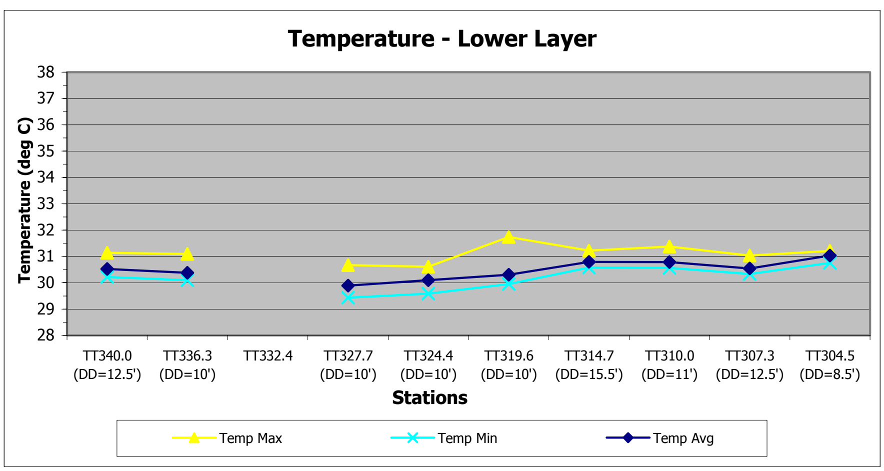
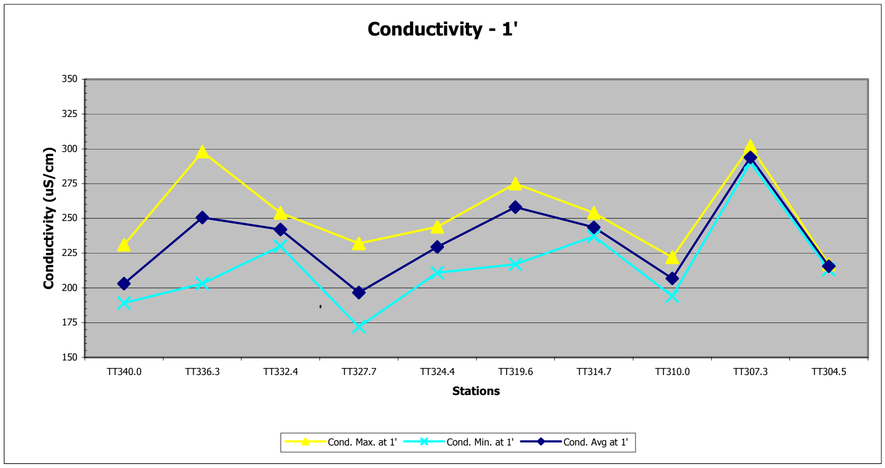
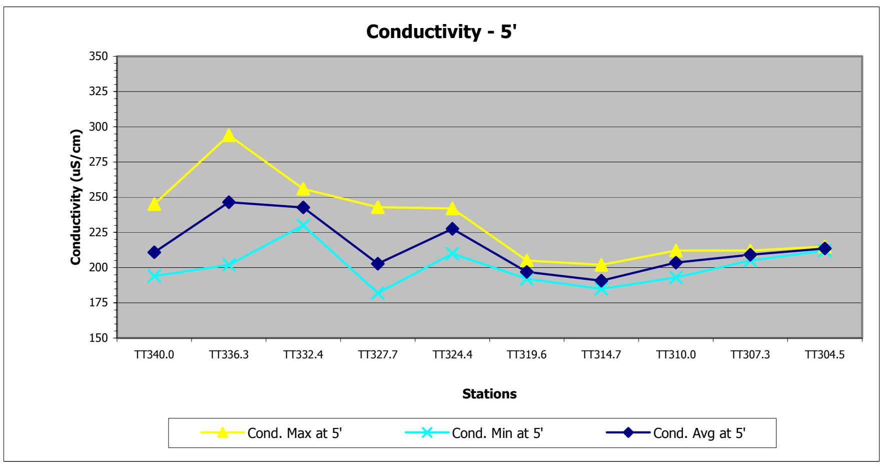


Figure 5
In-Situ Conductivity Measurements
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005





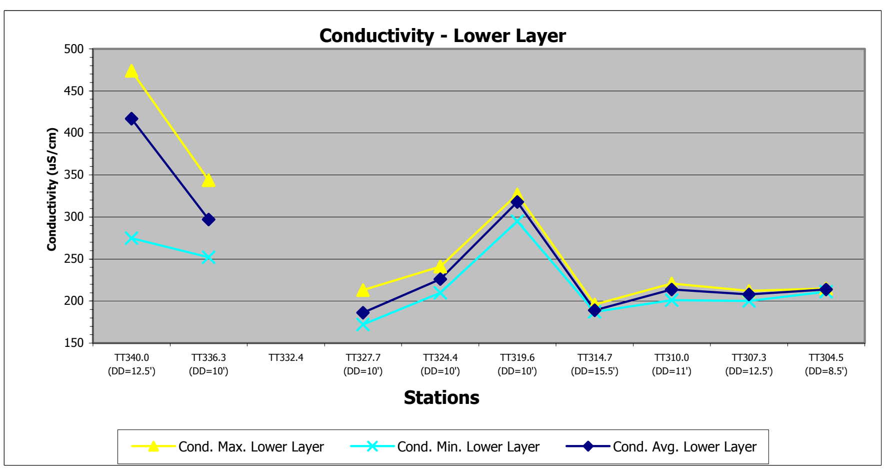
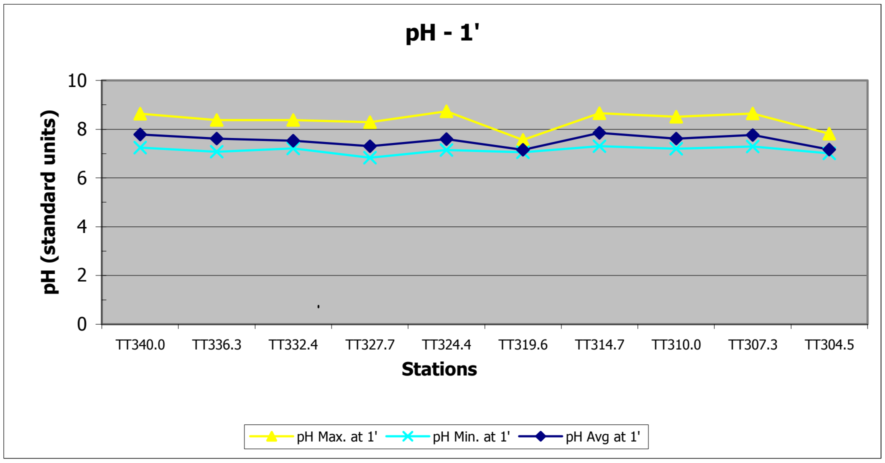
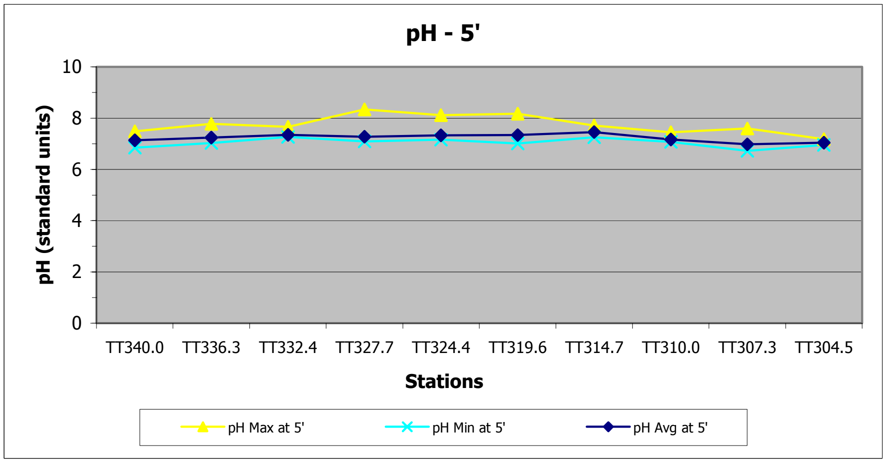
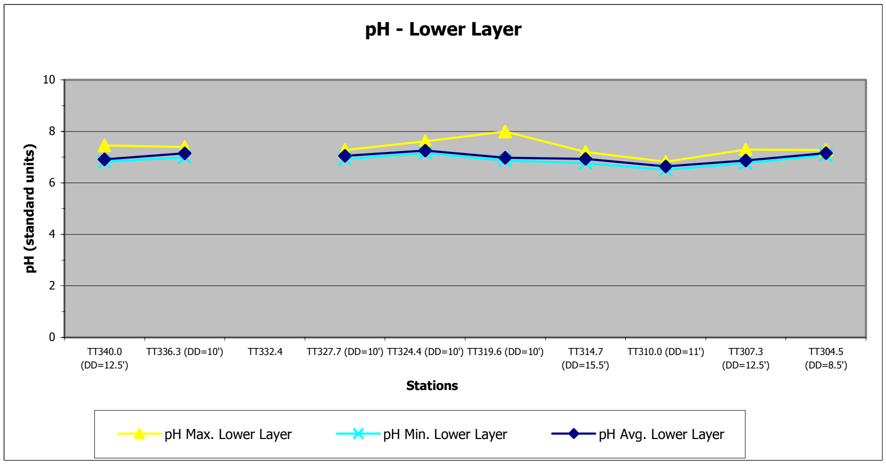


Figure 6
In-Situ pH Measurements
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005







3.1.5 Data Validation/Verification

Readings from the calibration checks performed after each deployment were compared to pre-deployment calibration values to ensure the readings were within the tolerance limits of the instrument.

All instrumentation end checks were within the tolerance limits specified by the manufacturer with the exception of three. The same sonde was deployed at station TT327.7 in the lower layer and at TT304.5 at 1 foot. The end check showed that the sonde was slightly out of range for conductivity. The manufacturer specifies that the probe should read within ± 1% of the standard. The sonde was within 1.2% following the deployment at TT327.7 and 1.6% following the deployment at TT304.5. The conductivity data collected at both stations is useable based on the objectives of the study. The end check of conductivity for the sonde used in the lower layer at TT310.0 showed that the instrument was reading 3.8% higher than the standard. Based on the objectives of the study, the data collected at TT310.0 is acceptable. The end check of dissolved oxygen for the sonde deployed at 1 foot at TT314.7 was beyond the tolerance limit of the instrument. The sonde is capable of reading the dissolved oxygen within 0.2 mg/l. The sonde read 0.87 mg/l less than the standard. The values for dissolved oxygen at TT14.7 may have been underestimated during the deployment period. This should be taken into consideration when utilizing the data. The data for this sonde is flagged in Appendix D. Calculations based on this data were conducted for the community oxygen metabolism assessment. This data is also flagged.

3.2 Water Column Profiling

3.2.1 Study Area

A profile of the water column was conducted at each main stem and tributary station along the Tenn-Tom Waterway study area with the exception of stations TT340.0 and TT336.3. These stations were inadvertently omitted. The profiles consisted of measuring dissolved oxygen, pH, conductivity, and depth at discrete intervals throughout the water column.

3.2.2 Methods

A Quanta multi-parameter sonde was used to conduct the water column profiles in the center of the channel. Measurements were conducted at the surface and then one foot intervals if the total depth was less than 10 feet. If the total depth was greater than 10 feet, measurements were conducted at the surface and then at intervals of two feet. All measurements were recorded in a bound field log book, which will be maintained with the official project file in the SESD records room.

3.2.3 Results

Table 4 contains the results of the water column profiles. Generally, measurements for temperature and dissolved oxygen decreased from the surface to the bottom at all stations.

Mild stratification was noted within the dissolved oxygen measurements at several stations as shown in Figure 7. This is most likely due to production occurring within the photic zone. The stratification is more pronounced from station TT324.4 to the lower boundary station TT304.5. Another factor potentially affecting the dissolved oxygen was the operation of the Locks and Dams. In order to assess that effect, successive dissolved oxygen profiles were conducted downstream, within (pre and post filling), and upstream of Stennis Lock and Dam during early morning operations. The results of the profile measurements are shown in Figure 8. The highest dissolved oxygen concentration was observed downstream of the lock and the lowest dissolved oxygen levels were noted inside the lock prior to filling. All dissolved oxygen concentrations inside the lock prior to filling were below 4 mg/l. The low dissolved oxygen concentrations in the lock may be attributed to the water drawn in when the lock is filled. The lock draws water from the western shore of the Columbus Pool, which emanates from the Tibbee River. Data generated during the *in-situ* water quality monitoring showed low dissolved oxygen concentrations (avg. DO 3.17 mg/l) in the lower layer of the Tibbee River at station TR1.3, which was the closest station to Stennis Lock and Dam. The water that flowed into the lock was turbulent and this turbulence may have created sufficient reaeration to raise the dissolved oxygen concentration inside the lock above 4 mg/l at full pool.

There was no change in conductivity with depth from station to station. There was an overall change from upstream to downstream. Beginning at TT336.4, the conductivity was approximately 225 µS/cm. Luxapallila Creek flowed into the Waterway downstream of TT332.4 with a conductivity of 47 µS/cm. Following the inflow of Luxapallila Creek, the conductivity downstream at TT327.7 was less than the conductivity at TT332.4. Overall, the conductivity increased somewhat at TT324.4, TT319.6, TT314.7 and TT310.0. The conductivity decreased slightly at TT307.3 and TT304.5.

The pH generally decreased from the surface to the bottom in the main stem of the river. This is most likely due to photosynthetic activity in the upper portion of the water column. The trend was reversed at the lower boundary station, TT304.5. The pH increased from surface to bottom. This was not the case in the data generated during the period that sondes were deployed at TT304.5. The reason for the reverse in trend during the profile could not be determined.

Table 4
In-Situ Water Column Profile Data
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

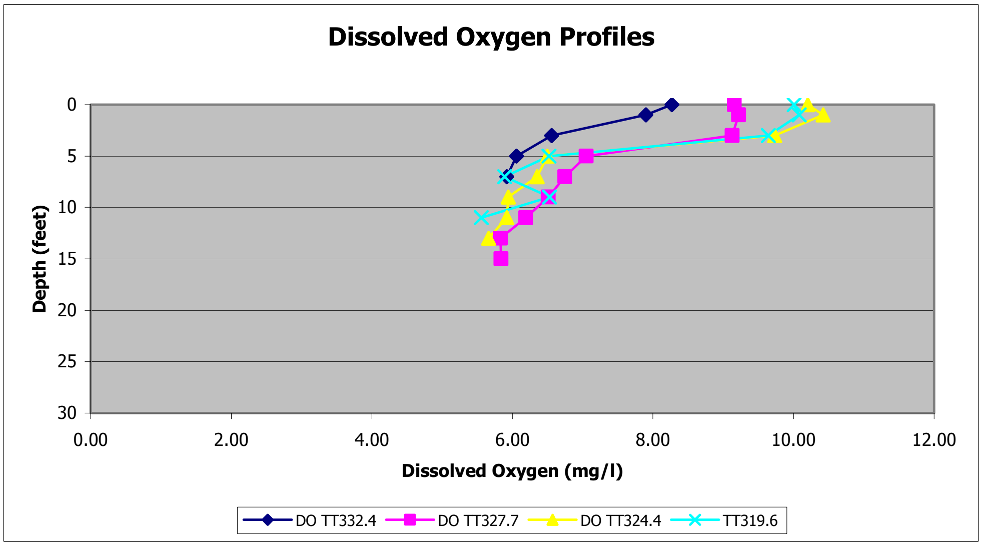
Station	Date/Time	Depth (ft)	Temp (°C)	Cond (µs/cm)	D.O. (mg/l)	pH (s.u.)
TR3.8	8/11/2005	Surface	31.53	244	7.60	8.24
	1005	1	31.51	243	6.81	8.26
		2	31.13	243	7.26	8.21
		3	30.89	245	6.01	7.99
		4	30.85	246	5.82	7.87
		5	30.74	252	5.06	7.69
		6	30.27	271	3.22	7.34
		6.5 (Bottom)	30.08	279	2.35	7.21

Station	Date/Time	Depth (ft)	Temp (°C)	Cond (µs/cm)	D.O. (mg/l)	pH (s.u.)
TR1.3	8/11/2005	Surface	30.24	216	4.27	7.20
	840	1	30.11	216	4.90	7.16
		2	30.14	216	4.40	7.20
		3	30.08	215	4.37	7.17
		4	30.03	215	4.47	7.19
		4.5 (Bottom)	29.95	215	4.35	7.13
TTFA0.3	8/11/2005	Surface	32.25	260	8.04	7.48
	1200	1	31.88	260	7.44	7.38
		2	30.50	259	6.92	7.21
		3	30.41	259	7.19	7.11
		4	29.88	260	5.92	6.94
		5	29.86	259	5.88	6.89
		5.5 (Bottom)	29.84	259	5.77	6.85
TT332.4	8/11/2005	Surface	32.68	226	8.27	7.57
	1250	1	31.37	226	7.90	7.36
		2	30.92	226	7.46	7.17
		3	30.45	226	6.56	6.95
		4	30.36	225	6.26	6.89
		5	30.33	224	6.06	6.85
		6	30.30	224	5.98	6.83
		6.5 (Bottom)	30.31	224	5.92	6.82
LC0.2	8/11/2005	Surface	28.93	47	6.93	6.45
	1325	1	28.52	47	6.96	6.33
		2	28.30	47	6.78	6.30
		3	27.76	47	6.70	6.24
		4	27.52	47	6.76	6.22
		5	27.44	47	6.73	6.20
		5.5 (Bottom)	27.41	47	6.72	6.15
TT327.7	8/11/2005	Surface	33.25	180	9.16	7.97
	1400	1	32.57	177	9.22	7.92
		2	31.19	170	9.19	7.78
		3	30.77	172	9.13	7.82
		4	30.34	168	8.32	7.40
		5	29.78	151	7.05	7.04
		6	29.66	141	6.80	6.85
		7	29.55	134	6.75	6.79
		8	29.45	132	6.56	6.70
		9	29.44	132	6.51	6.67
		10	29.36	128	6.49	6.66
		11	29.17	118	6.19	6.61
		12	28.97	107	6.04	6.52
		13	28.90	106	5.83	6.49
		14	28.90	106	5.82	6.47
		15 (Bottom)	28.88	106	5.84	6.46
TT324.4	8/11/2005	Surface	33.19	170	10.20	8.24
	1445	1	32.57	170	10.42	8.24

Station	Date/Time	Depth (ft)	Temp (°C)	Cond (µs/cm)	D.O. (mg/l)	pH (s.u.)
		2	31.95	169	10.56	8.23
		3	30.79	174	9.73	7.99
		4	29.94	173	6.92	7.24
		5	29.83	176	6.50	6.90
		6	29.81	176	6.23	6.88
		7	29.78	175	6.35	6.81
		8	29.71	175	6.22	6.75
		9	29.66	175	5.94	6.73
		10	29.64	175	5.88	6.71
		11	29.62	175	5.92	6.67
		12	29.62	175	5.65	6.66
		12.25 (Bottom)	29.61	174	5.66	6.66
TT319.6	8/11/2005	Surface	33.37	193	10.01	8.23
	1530	1	33.54	194	10.08	8.25
		2	31.57	191	10.47	8.19
		3	30.73	190	9.64	7.87
		4	30.35	191	8.04	7.38
		5	29.96	195	6.52	7.02
		6	29.83	198	6.04	6.86
		7	29.78	198	5.89	6.79
		8	29.76	197	5.80	6.74
		9	29.76	197	6.53	6.73
		10	29.75	197	5.56	6.72
		10.5 (Bottom)	29.75	197	5.56	6.71
JC315.8	8/11/2005	Surface	34.05	234	10.23	8.29
	1700	1	33.16	235	10.46	8.41
		2	31.50	238	10.19	8.21
		3	30.39	260	7.79	7.43
		4	29.95	281	5.28	7.01
		5	29.63	297	4.15	6.88
		5.5 (Bottom)	29.41	303	2.72	6.76
TT314.7	8/11/2005	Surface	34.83	229	9.65	8.26
	1615	1	33.87	226	10.64	8.34
		2	32.18	225	10.65	8.31
		3	30.79	222	8.21	7.50
		4	30.36	222	6.15	6.96
		5	30.16	223	5.27	6.76
		6	30.06	224	5.85	6.73
		7	30.01	224	5.20	6.72
		8	30.02	224	5.19	6.70
		9	30.02	224	4.91	6.69
		10	30.00	225	5.04	6.69
		11	29.93	228	4.75	6.66
		11.5 (Bottom)	29.91	228	4.58	6.66
CF1.4	8/12/2005	Surface	25.75	36	6.76	5.49
	1246	1	25.73	36	6.70	5.51

Station	Date/Time	Depth (ft)	Temp (°C)	Cond (µs/cm)	D.O. (mg/l)	pH (s.u.)
		2	25.73	36	6.67	5.53
		3	25.65	36	6.62	5.55
		4	25.68	35	6.58	5.57
		5	25.64	36	6.55	5.58
		6	25.64	36	6.47	5.58
		6.5 (Bottom)	25.65	36	6.51	5.58
TT310.0	8/12/2005	Surface	31.98	231	7.35	6.94
	1355	2	30.66	233	6.01	6.79
		4	30.43	234	5.42	6.68
		6	30.27	234	4.77	6.62
		8	30.19	235	4.67	6.60
		10	30.15	235	4.51	6.58
		12	30.13	235	4.22	6.56
		14	30.13	235	4.15	6.56
		16	30.12	235	4.14	6.56
		16.5 (Bottom)	30.12	235	4.12	6.54
TT307.3	8/12/2005	Surface	33.60	205	8.21	7.94
	1430	2	32.14	202	8.19	7.68
		4	30.89	221	6.67	7.26
		6	30.60	213	5.37	6.86
		8	60.51	208	4.90	6.76
		10	30.22	221	4.47	6.67
		12	29.91	204	3.57	6.55
		14	29.76	193	2.77	6.46
		16	29.70	189	2.69	6.42
		18	29.68	189	2.78	6.40
		20	29.63	186	2.50	6.38
		22	29.59	183	2.35	6.36
		24	29.53	181	2.12	6.33
		26	29.48	178	1.90	6.32
		27.7 (Bottom)	29.37	178	1.48	6.30
TT304.5	8/12/2005	Surface	30.33	197	7.25	6.26
	1040	2	30.29	198	7.12	6.42
		4	30.30	197	7.02	6.47
		6	30.30	198	7.19	6.53
		8	30.29	198	7.19	6.56
		10	30.27	197	7.08	6.57
		12	30.26	197	6.82	6.59
		14	30.30	197	6.88	6.61
		16	30.27	197	7.14	6.60
		18	30.26	196	7.03	6.61
		20	30.26	196	7.08	6.61
		22	30.27	196	6.93	6.62
		24	30.25	196	6.82	6.63
		26 (Bottom)	30.26	196	6.80	6.64

Figure 7
Dissolved Oxygen Graphs from Water Column Profiles
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



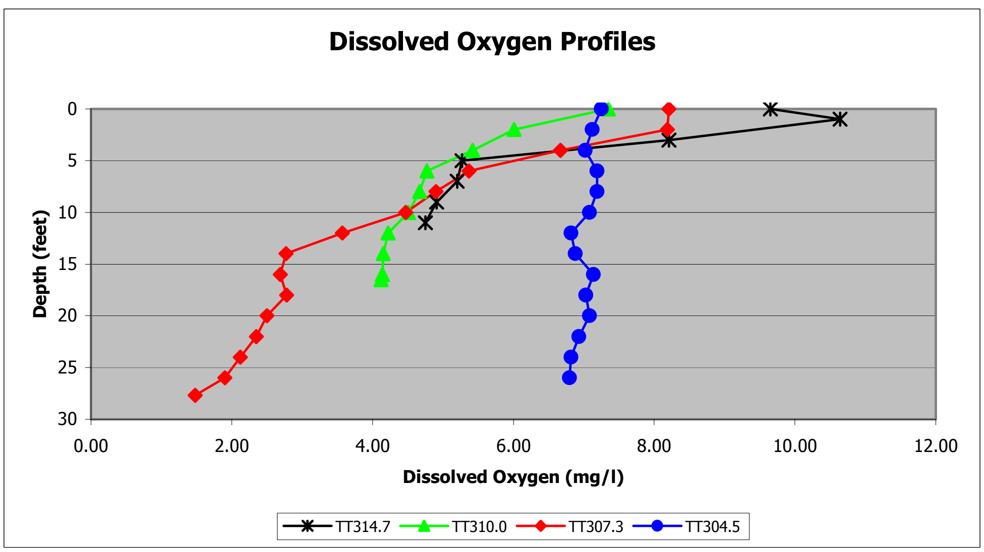
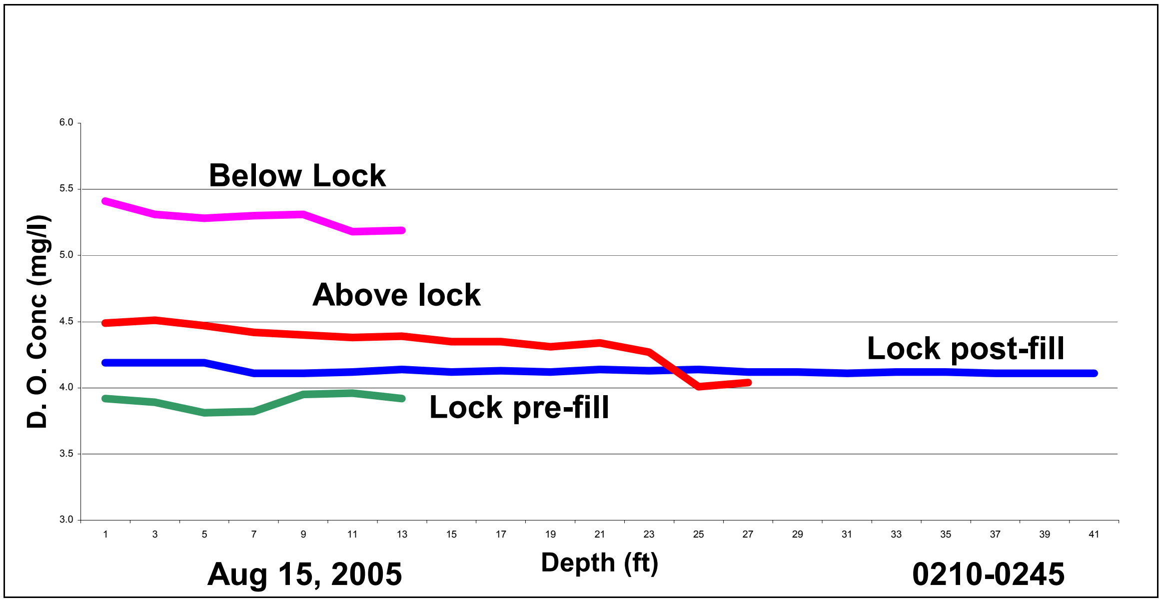


Figure 8
Dissolved Oxygen Profiles at Stennis Lock and Dam
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



3.2.4 Quality Assurance/Quality Control

The sonde used for the water column profiles was indicated in the logbook. The sonde was calibrated according to the procedures outlined in Section 18.2 of the EASOPQAM using known standards prior to conducting the profiles and the calibration results were recorded in a logbook associated with the instrument. Upon completion of the water column profiles, the calibration of the sonde was checked using known standards and the results were entered into the instrument's logbook. The sonde was within the instrument's tolerance levels based on the end calibration check. A copy of the calibration record will be maintained with the official project file in the SESD records room.

3.2.5 Data Validation/Verification

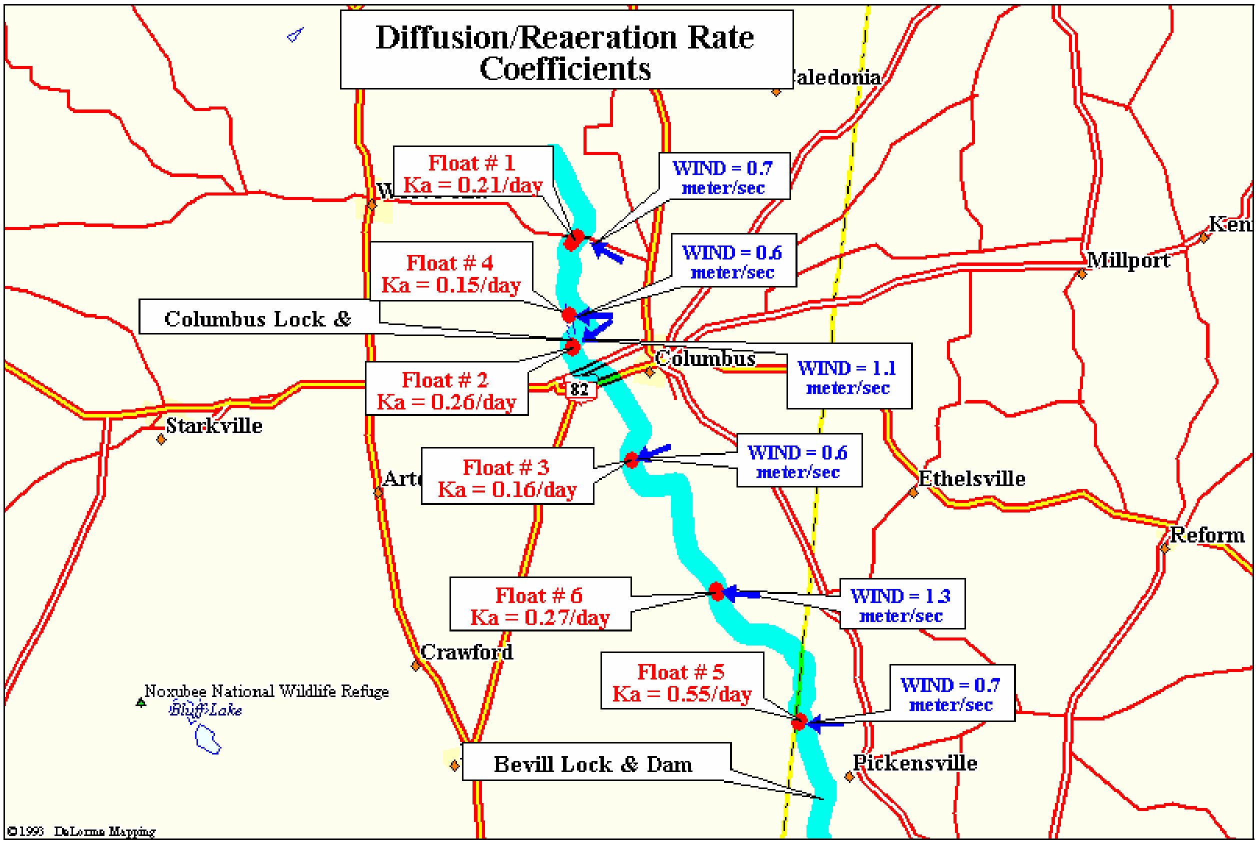
Data validation was performed by the project leader. Readings from the calibration checks performed after each day of use were compared to pre-use calibration values to ensure the readings were within the tolerance limits of the instrument

3.3 Reaeration

3.3.1 Study Area

Measurements to determine reaeration rate coefficients (K_a) were conducted over a five day period between river mile 340 and river mile 304 on the Tenn-Tom Waterway. The measurement locations and associated reaeration rate coefficients are shown in Figure 9.

Figure 9
Reaeration Rate Measurement Locations
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



3.3.2 Methods

Reaeration throughout the Tenn-Tom Waterway was measured using a modified floating dome technique developed within the Ecological Assessment Branch (EPA 2002). This technique measures the flux of dissolved oxygen across the air-water interface within a closed metal dome. Dissolved oxygen and temperature measurements were recorded over time from within the dome atmosphere and just below the water surface. The data was processed in a spreadsheet for the purpose of determining diffusion rates. When divided by the water column dissolved oxygen deficit, these rates result in reaeration rate coefficients.

3.3.3 Results

Diffusion measurements were conducted at night to control system variables, particularly dome temperature and photosynthetic dissolved oxygen increases. Measurements were conducted during six floats over five nights. Table 5 summarizes the data collected during each float and the calculations used to determine the reaeration rate coefficients. Appendix E contains the detailed field measurements recorded during each float as well as wind speed and direction data. Five of the six K_a values from these measurements ranged from 0.15 to 0.27 per day at 20°C. K_a rates in this range are considered low for this type of system. Low reaeration rate coefficients were a function of the deep, slow moving waters of the waterway. Lack of vertical velocity vectors limited the opportunity for any given piece of water to turn over and take on dissolved oxygen.

Low flows that occurred during the study resulted in slow moving waters. Waterway flows averaged 1,840 cfs as measured by EPA for the six day study. This is slightly above the daily average flow of 1,540 cfs recorded at the Stennis Lock and Dam by the United States Geological Survey during 88 years of record (USGS 2005). The maximum allowable flow for the study was 2000 cfs. The average flow measured in the Waterway during the study was slightly below the allowable maximum flow. Mean velocities were less than 0.2 fps at all main stem stations above the Bevill Lock and Dam (Section 3.5, Table 8).

Wind can affect the reaeration rate. Most winds measured during the study traveled East to West while the Waterway flows from North to South thus offering little fetch or mixing (Figure 10). High channel banks further limited wind fetch and therefore reaeration.

The sixth K_a value was 0.55 per day at 20°C, which is somewhat greater than the other five coefficients. This value is slightly elevated for the slow moving water of the system. However, the area where these measurements were conducted is the upper boundary of the Aliceville Reservoir and the Waterway becomes more pool-like which offers greater surface area for wind fetch.

Table 5
Reaeration Rate Coefficient Measurements and Calculations
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

TEST CONDITIONS

TEST	SYSTEM TYPE	LOCATION	DATE	TEST DURATION MINUTES	DOME VOLUME LITERS	DOME CANTACT AREA SQUARE METERS	DEPTH OF WATER METERS	SALINITY OF WATER PPT	ALTITUDE ABOVE SEALEVEL FEET
Float # 1	Tn-Tom	TT 340.0	8/11-12/2005	180	7	0.089	4.5	0	163
Float # 2	Tn-Tom	TT 334.2	8/13-14/2005	150	7	0.089	3.88	0	136
Float # 3	Tn-Tom	TT327.3	8/14-15/2005	165	7	0.089	4.57	0	136
Float # 4	Tn-Tom	TT335.8	08/15/2005	95	7	0.089	4.49	0	136
Float # 5	Tn-Tom	TT310.4	08/15/2005	90	7	0.089	6.21	0	136
Float # 6	Tn-Tom	TT319.4	08/16/2005	75	7	0.089	4.54	0	136

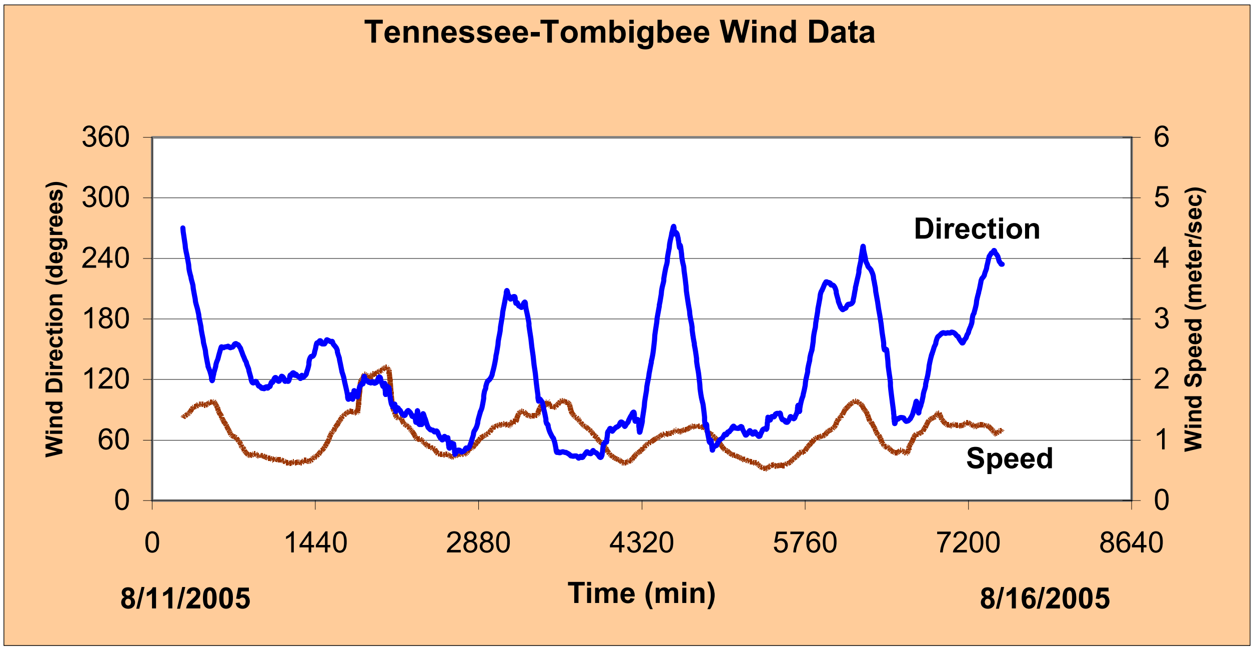
FIELD DATA

TEST	DOME DO INITIAL MG/L	DOME DO FINAL MG/L	DOME TEMP INITIAL DEG C	DOME TEMP FINAL DEG C	DOME DO SATURATION INITIAL MG/L	DOME DO SATURATION FINAL MG/L	AMBIENT DO AVERAGE MG/L	AMBIENT TEMP AVERAGE DEG C	AMBIENT DO SATURATION MG/L
Float # 1	6.91	6.99	30.7	30.3	7.42	7.47	7.7	30.6	7.44
Float # 2	3.98	4.11	27.61	27.39	7.84	7.87	5.8	29.9	7.53
Float # 3	5.99	6.06	28.3	28.1	7.75	7.77	7.3	30.6	7.44
Float # 4	4.18	4.225	28.18	28.12	7.76	7.77	5.6	30.5	7.46
Float # 5	6.6	6.76	32.9	32.65	7.16	7.19	8.2	32.8	7.17
Float # 6	5.885	5.96	31.66	31.42	7.31	7.34	7.9	31.5	7.33

CALCULATIONS

TEST	"V" VOLUME OF OXYGEN ACCRUED IN DOME LITERS	"D" DIFFUSION RATE GM/M3/HR	"K" REAERATION CONSTANT GM/M3/HR	"K2" REAERATION RATE DOME METHOD '/DAY (Base e)
Float # 1	0.0070	0.0083	0.09	**0.28**
Float # 2	0.0190	0.0315	0.10	**0.33**
Float # 3	0.0086	0.0110	0.06	**0.20**
Float # 4	0.0068	0.0153	0.06	**0.20**
Float # 5	0.0239	0.0411	0.22	**0.74**
Float # 6	0.0095	0.0269	0.11	**0.35**

Figure 10
Wind Speed and Direction Measurements at Columbus Marina
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



During the study period, the algal community in the Tenn-Tom Waterway caused the DO in the water column to become supersaturated during the day. Dissolved oxygen moves in the direction of the gradient that exists in the water column. When the water column is supersaturated, it releases oxygen to the atmosphere. When the dissolved oxygen is below saturation levels, the water column receives oxygen from the atmosphere. The oxygen travels across the air-water interface at the same rate, regardless of the direction it is moving. Therefore, reaeration can either add oxygen to the system or remove it. Based on the results of the diffusion measurements, the net effect of reaeration for the Tenn-Tom Waterway was a loss in oxygen from the water column to the atmosphere.

Additionally, the tugs and barges that traveled along the Waterway appeared to impact the oxygen dynamics of the system. Increases and decreases in dissolved oxygen were noted in the oxygen concentrations measured by the sondes located in the water column. These changes could be somewhat correlated to the passage of tugs and barges. The increases may have been caused by the jet-like prop wash generated by the tugs. The decreases may have been due to disruption of the algal community from the prop wash, which caused vertical mixing that resulted in a transfer of the algae to a depth beyond the photic zone.

3.3.4 Quality Assurance/Quality Control

The primary instrumentation used for collecting data to calculate the reaeration rate coefficients was a dissolved oxygen meter and a diffusion dome. The dissolved oxygen meters were calibrated prior to each measurement period using water with a known oxygen content. The oxygen content was determined using the azide-modified Winkler Titration method. The meters were checked at the end of each measurement period against water with a known oxygen content to ensure the accuracy was within 0.2 mg/l. During the end checks, all meters read within 0.2 mg/l of the oxygen content of the water as measured with the Winkler Titration. Therefore, all measurements were valid. All calibrations and end checks were recorded in the field log book. The field logbook will be maintained with the official project file in the SESD records room.

3.3.5 Data Validation/Verification

Reaeration rate coefficient calculations were performed by the Module Leader. All calculations used to determine the reaeration rate coefficients contained within this report were verified by peer review. A peer review was performed by another scientist within EAB familiar with reaeration measurement and reaeration rate coefficient calculations. All measurements and calculations were acceptable.

3.4 Community Oxygen Metabolism Analysis

3.4.1 Study Area

Community oxygen metabolism analysis was conducted on each main stem river station based on dissolved oxygen measurements obtained from the deployment of the YSI 6920 data sondes (Section 3.1).

3.4.2 Methods

The community oxygen metabolism analysis is a method for determining oxygen production and respiration rates of a water body based on graphical analysis of diurnal dissolved oxygen curves (Odum 1958). The Tenn-Tom Waterway Water Quality Study Plan stated that oxygen production and respiration would be measured using the Light and Dark Bottle (Oxygen) Method outlined in Standard Methods, 20th Ed. However, suspected increases in final light bottle dissolved oxygen concentrations limited confidence in associated dissolved oxygen measurements. While incubation times were reduced throughout the study in an attempt to address this issue, a community metabolism approach based on the diurnal dissolved oxygen data provided production and respiration rates of greater confidence. The data generated from light/dark bottle deployment could not be used.

In order to conduct a community analysis of the study reach of the Tenn-Tom Waterway, measurements for diurnal DO, reaeration rate coefficient, depth and water temperature were required. The diurnal DO and water temperature measurements were obtained from the sonde deployments discussed previously in Section 3.1. The reaeration rate coefficients were determined from the dome diffusion measurements and the depths were obtained from the bathymetric survey conducted by the U.S. Army Corps of Engineers (ACOE) (Appendix G). Calculations were conducted for each depth where sondes were deployed and then averaged to provide a gross primary production (GPP) and respiration (R) value at each main stem monitoring station.

An example of the graphical community analysis for station TT340.0 is presented in Figures 11 through 13. Community analysis required determination of the oxygen rate of change over a diurnal period of twenty-four hours. This rate of change of oxygen was then corrected for the diffusion of oxygen from the atmosphere to the water column. Diffusion was computed as the reaeration rate coefficient times the water column dissolved oxygen deficit. Water column dissolved oxygen deficit was determined as the arithmetic difference between saturation and ambient dissolved oxygen concentrations. Once the rate of change curve was corrected for diffusion, it was then plotted (blue-green line). The dissolved oxygen curve (blue, dashed line) for the diurnal monitoring period was also plotted on the 2^{nd} Y-axis (right side of graph). During review of the diurnal DO curves, a pattern of anomalies was noted. During daylight hours when production was most prominent, a noted decrease in production occurred at many stations. Some stations experienced cessation in production and respiration was most prominent. The changes in production could not be attributed to a lack of solar radiation due to cloud cover. One plausible explanation for the anomalies may be the disturbance caused by the passage of tugs and barges. The anomalies were of sufficient significance to warrant inclusion in the community oxygen metabolism calculations. Close reconciliation of the final oxygen budget lends credence to the inclusion of the anomalies in the calculations. The estimated passages of the barges were superimposed on the graphs. Times of barge passage were estimated from U.S. ACOE lock records.

Analysis of the graphs required establishment of a constant respiration line. The location of the line that best represented night time respiration conditions on the DO rate of change curve was determined using professional judgment. Establishment of the constant respiration line was necessary due to the transient increase in dissolved oxygen as a result of barge passages and lockage flow pulses. The area between the dissolved oxygen rate of change curve and the respiration line is attributed to GPP. This area was tinted green on the graphs to represent plant production of oxygen. A second area, tinted blue on the graphs (Figures 12 and 13), represents the possible effect of oxygen accrual due to barge and lock operation. The brown areas on the graphs below the respiration line represent excess respiration (R) in the system beyond the constant respiration rate. Unit areas for the community analysis are gm O_2/m^3/hr.

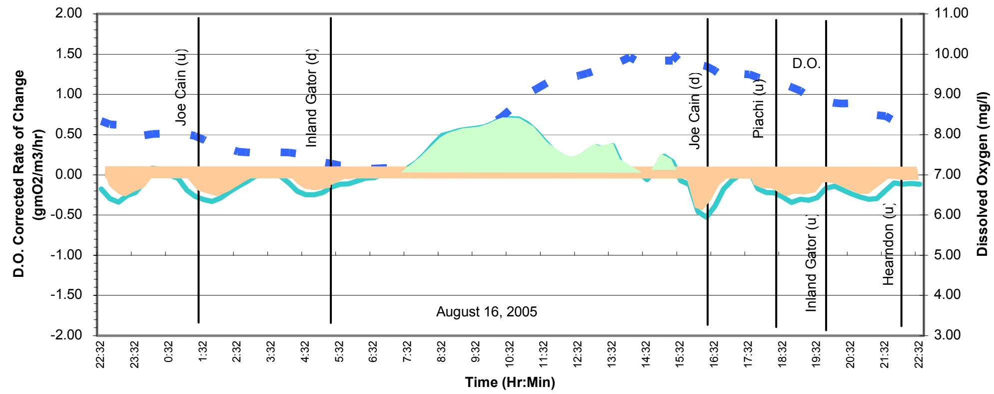


Figure 11 , Community Metabolic Curve - TT340.0 @ 1 ft

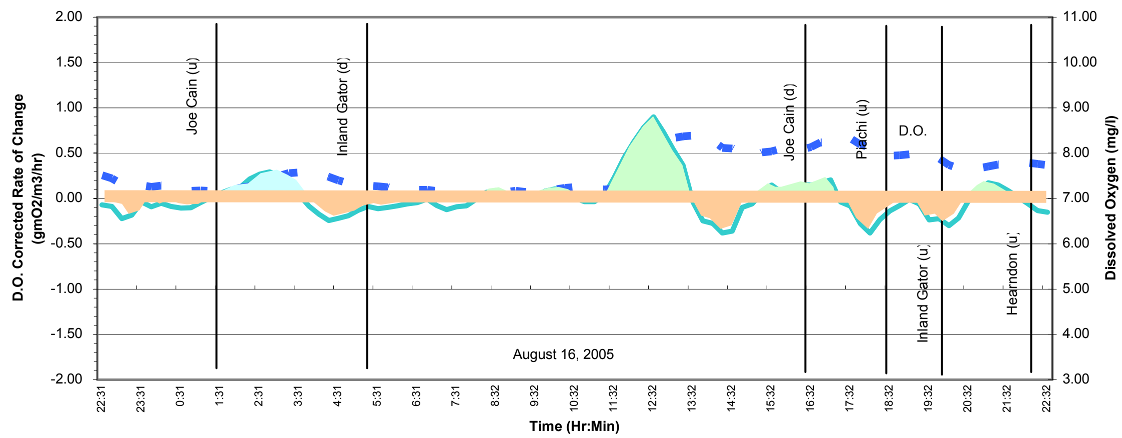


Figure 12, Community Metabolic Curve - TT340.0 @ 5 ft

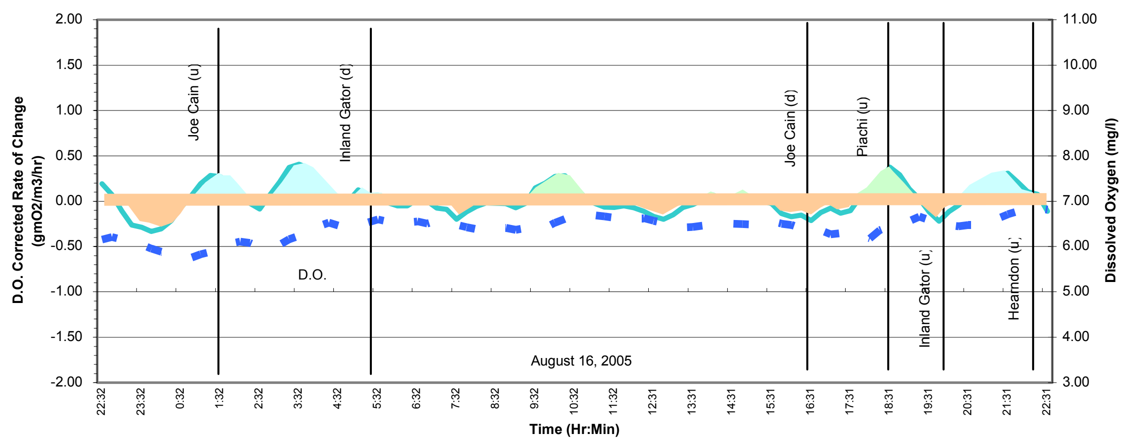


Figure 13, Community Metabolic Curve - TT340.0 @ 12 ft

The community production and respiration graphs presented in Figures 11-13 are an example for the upper boundary station, TT340.0, which is 5.3 miles upstream of the Stennis Lock and Dam. The evaluation of the curves from station TT340.0 revealed an active algal community as evidenced by the appreciable gross primary production (GPP) rate at the one foot depth. The GPP rate at five feet showed a decrease in production. At 12 feet, adequate light was not available for oxygen production. Oxygen produced within the photic zone was possibly transported to the lower layer through mechanisms such as passage of tugs and barges and the operation of the locks. In contrast, the artificial oxygen production rates potentially caused by the tugs and barges and locks (blue areas on the graphs) were lowest at the surface and highest at the bottom. Prop location and tilt may have created the greatest aeration near the bottom. Finally, the largest excess respiration occurred near the surface as shown in the one foot graph. The top, active algal community may have responded to the passage of the tugs and barges. The algae appeared to be affected by the action of the props, which likely caused vertical mixing and may have transferred the algae to a depth beyond the photic zone. The depth which was most impacted was the upper five feet, which had the most active algal community. All of the Tenn -Tom Waterway stations were evaluated using this procedure, as presented in Appendix F, and resulted in similar findings.

The analysis of the dissolved oxygen rate of change curves allowed an evaluation of the oxygen balance. This required that the GPP, barge aeration, and respiration rates be plotted against depth. The resulting rates are presented in units of gm O_2/m^2/day. The areas under each layer are summed and presented in Table 6 (Area under the Curve box).

Table 6
Community Metabolic Analysis for Station TT340.0
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 15-16, 2005

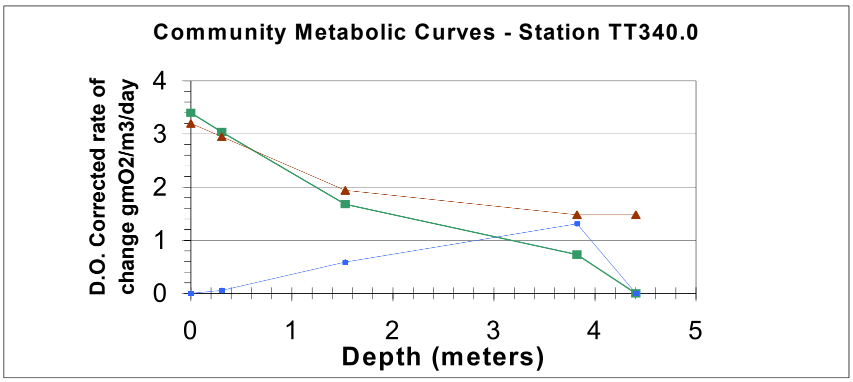
Station	Depth (feet)	Avg D.O. (mg/l)	Avg Temp (° C)	GPP (gmO2/m3/day)	Respiration (gmO2/m3/day)	Tug (gmO2/m3/day)	Depth (meters)
	0			3.4	3.2	0	0
TT340.0	1	8.46	31.7	3.04	2.95	0.056	0.31
	5	7.58	30.9	1.68	1.94	0.59	1.53
	12.5	6.40	30.5	0.73	1.48	1.31	3.82
	14.4			0	1.48	0	4.40
	avg	7.48	31.0				

	Area under the curve		
Segment	GPP gO2/m2/day	R gO2/m2/day	Tug gO2/m2/day
0 m to 0.30	0.98	0.94	0.01
0.30 m to 1.53 m	2.89	2.99	0.40
1.53 m to 3.82 m	2.76	3.92	2.18
3.82 to 4.40	0.21	0.86	0.38
	6.85	8.71	2.96

GPP & R estimated from curve for the top 0.30 meters and bottom 0.6 meters

corrected for depth		
GPP gO2/m3/day (mg/l/day)	R gO2/m3/day (mg/l/day)	Tug gO2/m3/day (mg/l/day)
1.55	1.98	0.67

D.O. @ saturation	7.43
Community GPP	1.55
Community R	-1.98
Atmospheric Ka	-0.22
Tug Aeration	0.67
D.O. @ balance	7.46
D.O. avg in H2O	7.48
Community GPP:R	0.79



The summed results were corrected for depth and an oxygen balance was computed as shown in the gray box in Table 6. The balance involved computing the dissolved oxygen concentration at saturation. This number was determined by averaging the temperature readings collected at fifteen minute intervals over a twenty four hour period for each sonde. A mean temperature was computed from the three average temperatures (sondes at 1′, 5′ and lower layer depths). At station TT340.0, this temperature was 31.0 °C. This resulted in a saturation dissolved oxygen of 7.43 mg/l for the day. Community respiration consumed 1.98 mg/l. Community GPP and barge/lock operations contributed 1.55 mg/l and 0.67 mg/l, respectively, to the system. Reaeration removed 0.22 mg/l of oxygen as off-gassed supersaturated dissolved oxygen. The final dissolved oxygen concentration was 7.46 mg/l. This was very close to the twenty-four hour dissolved oxygen concentration average of the three sondes in the water column of 7.48 mg/l.

The aeration attributed to the tugs/barges was assumed to contribute oxygen to the system. Examination of the dissolved oxygen curves revealed a loss of oxygen during the photosynthetically active period possibly due to the disturbance of the algal community from the tugs and barges. This loss or consumption of oxygen was attributed to respiration of the algal community, although it was most likely the result of the vertical mixing that resulted from the tug props which caused the transfer of the algae to a lower depth beyond the photic zone.

3.4.3 Results

All of the main stem river stations were analyzed using the community oxygen metabolism approach. While slight differences in the data occurred between stations, every effort was made to consistently apply the procedures used to analyze the data. The results of the community analysis are summarized in Table 7. The "Calculated D.O. Budget" column and "Daily Avg. D.O." column under the major heading of "Community Metabolic Analysis" in Table 7 compare the calculated community based dissolved oxygen budget results with the daily average of the sonde dissolved oxygen readings. The close agreement in the two columns provided defensibility in the use of the community based technique.

Table 7
Summary Community Metabolic Data
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Integrated Time-of-Travel Depth (meters)	Water Column Avg Temp (° C)	Water Column D.O. Sat (mg/l)	Community Metabolic Analysis Community GPP (mg/l/day)	Net Diffusion (mg/l/day)	Community Total Respiration (mg/lday)	Tug Aeration (mg/l/day)	P:R	Calculated D.O.Budget (mg/l)	Daily Average D.O.(sondes) (mg/l)	SOD (gmO2/m2/day)	Water Column Analysis Daily GPP Water Column (mg/l)	Water Column Respiration (mg/l)
TT340.0	4.40	31.00	7.43	1.55	-0.22	-1.98	0.67	0.78	7.45	7.48	-1.26	1.55	-1.69
TT336.3	6.33	31.00	7.43	1.61	-0.12	-2.46	0.44	0.65	6.90	7.02	-1.26	1.61	-2.26
TT332.4	3.55	30.70	7.47	1.62	0.04	-2.51	0.17	0.65	6.79	6.95	-0.77	1.62	-2.29
TT327.7	3.64	30.40	7.51	2.24	-0.18	-2.82	0.52	0.79	7.27	6.98	-0.46	2.24	-2.69
TT324.4	4.16	30.20	7.53	2.11	-0.20	-2.77	0.61	0.76	7.28	7.52	-0.53	2.11	-2.64
TT319.6	3.94	30.60	7.48	2.65	0.10	-3.74	0.68	0.71	7.17	7.09	-1.44	2.65	-3.37
TT314.7	6.12	31.40	7.38	2.20	-0.21	-4.03	1.43	0.55	6.77	6.77	-0.90	2.20	-3.88
TT310.2	6.30	31.20	7.41	2.39	-0.04	-6.24	2.23	0.38	5.75	5.27	-1.05	1.52	-6.07
TT307.3	6.51	31.30	7.39	3.67	-0.10	-6.52	1.87	0.56	6.31	5.60	-1.05	2.39	-6.36
TT304.5	3.88	31.10	7.42	2.17	0.19	-3.65	0.51	0.59	6.64	6.13	-1.05	2.17	-3.38
AVERAGES				**2.22**	**0.07**	**3.67**	**0.91**						

Note: Dissolved Oxygen results from the sonde at station TT314.7 at the 1.0 foot mark were used in the community calculations even though the end check was outside the acceptable calibration range.

The summary P:R ratios ranged from 0.38 to 0.79, which defined the Waterway as a heterotrophic system, where oxygen consumption exceeded oxygen production. An average of 2.22 mg/l of oxygen was produced (avg. Community GPP) in the Tenn-Tom Waterway. This was offset by a daily average respiration of oxygen of 3.67 mg/l. Induced aeration from the locks and barge traffic entrained approximately 0.91 mg/l of oxygen daily. Lastly, reaeration contributed an average of 0.07 mg/l/day of oxygen.

3.4.4 Quality Assurance/Quality Control

All data used for the Community Oxygen Metabolism calculations was obtained from the *in-situ* water quality monitoring presented in Section 3.1. See Section 3.1.5 for a discussion of quality assurance and quality control. The sonde used to collect the dissolved oxygen measurements at one-foot at TT314.7 was outside of the tolerance limits for the DO probe.

The measurements may have been underestimated by approximately 1 mg/l based on the end check of the sonde.

3.4.5 Data Validation/Verification

Data validation for the sondes was performed by the project leader. Readings from the calibration checks performed after each deployment were compared to the tolerance limits of the instrument to ensure they were within the limits.

Community oxygen metabolism analyses were performed by personnel experienced in performing the calculations and interpreting the data. All calculations were verified by peer review. A peer review was performed by another scientist within EAB familiar with community oxygen metabolism analysis. All calculations were acceptable.

3.5 Flow Measurements

3.5.1 Study Area

Flow measurements were conducted at several Tenn-Tom main stem and tributary stations during the study period including TT340, TT332, TT327, TT324, TT319, TT314, Luxapallila Creek (LC02), Coal Fire Creek (CF1.4) and the north and south ends of the oxbow just upstream of Luxapallila Creek. The oxbow measurements were intended to provide a measure of the amount of flow diverted through the oxbow (see Figure 1).

Additionally, the Weyerhaeuser Paper Company maintains a STORK Ultrasonics Acoustic Velocity Monitoring (AVM) system near their discharge, which is located between stations TT327.7 and TT324.4. Data from this meter is available upon request from Weyerhaeuser.

3.5.2 Methods

With the exception of Coal Fire Creek, flow measurements were made using a boat-mounted RD Instruments Acoustic Doppler Current Profiler (ADCP). Once a suitable transect was identified at each station, four cross-section flow measurements were made. Data collected by the ADCP, including measured water velocity, direction, and distance, were fed in real-time to a laptop computer. Software developed by the manufacturer provided calculation of the resulting flow at the end of each transect. A brief data review was conducted in the field following the initial four measurements to assess the variability of the resulting flows and determine, based on best professional judgment and time available, if additional measurements would improve the flow estimate. Generally, one to three additional measurements were made at stations where more data was deemed warranted.

The lower portion of Coal Fire Creek at the confluence of the Tenn-Tom Waterway is a braided, wide system with very shallow depths. Due to the depth and poorly defined channel, the boat-mounted ADCP was not an option for flow measurement in Coal Fire Creek. Instead, an EPA crew, using an 18′ aluminum boat, traveled upstream in Coal Fire Creek from the Tenn-Tom Waterway to access a fairly defined section of the creek. A Sontek Acoustic Doppler Velocimeter (ADV) was then used to measure flow in Coal Fire Creek.

Flow measurement was also attempted in James Creek near Mile 315 of the Tenn-Tom Waterway using the boat-mounted ADCP. Similar to Coal Fire Creek, James Creek near its mouth, featured a poorly-defined channel with no measurable flow at the time of measurement.

3.5.3 Results

Table 8 shows the average flow resulting from at least 4 individual measurements at each station. A coefficient of variation (sample standard deviation/average) is provided to give an indication of the variability in the individual measurements. As shown in Table 8, flows were below 3000 cfs throughout the Tenn-Tom Waterway, except at Station TT314 on August 12, 2005. Also, flow was generally higher on August 12, 2005 than on August 16, 2005.

Flow measurements demonstrated the potential variability in Tenn-Tom currents both on a short-term basis (minutes) and a longer-term basis (days). In the short term, for example, measured flows at station TT340 on August 16, 2005 showed a successive drop with each measurement during the 23 minute measurement period likely as a result of Stennis Lock operations. August 12, 2005 measurements at TT340 showed a large, progressive change from nearly 700 cfs in an upstream direction to over 300 cfs in a downstream direction in a 20 minute period possibly due to wave reflection off the Stennis Lock and Dam and/or wind. Flow changes associated with impounding above the locks over a period of days was exhibited at station TT314 where flow was nearly four times higher on August 12, 2005 than on August 16, 2005 while at TT319 similar flows were measured on both dates.

Flow measurements suggest approximately a quarter of the Waterway flow (as measured at TT332) entered the oxbow system during August 16, 2005 measurements. Both upstream and downstream velocities were measured in the north end of the oxbow making these results less certain; however, measurements in the south oxbow were in a consistent downstream (into the Tenn-Tom Waterway) direction and were less variable.

A single measurement made in Coal Fire Creek on August 14, 2005 yielded a flow of 49.5 cfs. At the time of flow measurement, a staff gage was installed on the right creek bank to provide a measure of stage change. The staff gage was initially set to an arbitrary stage of 1.95′ equating to the 49.5 cfs flow. There was no change in stage in Coal Fire Creek between August 14, 2005 and August 16, 2005. The flow was assumed to be constant and no additional measurements were conducted.

A cross-section with width and depth desirable for ADCP flow measurement could not be found in James Creek. Nevertheless, flow measurements were attempted in the deepest accessible location on August 12, 2005 and August 16, 2005 revealing weak currents in both upstream and downstream directions. The data suggest generally weak currents (often less than 0.1 fps) throughout the cross-section with sporadic higher velocities (0.3 – 0.8 fps) in varying directions in the deeper portion of the cross-section possibly resulting from wave action emanating from the Tenn-Tom Waterway. As a result, a consistent series of net flow measurements could not be completed.

Table 8
Flow Measurements
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Date	Time	# Meas	Avg Q (cfs)	COV (%)	Avg V (Q/A) range (fps)	Comments
TT340	8/12	18:02-18:22	4	Q: -679 to 317 cfs		0.01–0.13	Rapid change in flow/direction.
TT340	8/16	09:08-09:31	5	934	18	0.08-0.12	Successive flow decrease over measurement period.
TT332	8/16	17:48-18:04	4	1472	17	0.20-0.31	Avg velocity for 3 of 4 measurements: 0.29-0.31
TT327	8/16	15:46-15:58	4	2133	6	0.26-0.31	None.
TT324	8/12	14:35-15:13	6	2256	18	0.19-0.31	Avg:2320 cfs, COV: 10% excluding high & low.
TT324	8/16	15:15-15:29	4	2123	4	0.23-0.25	None.
TT319	8/12	12:35-12:49	4	2438	8	0.27-0.32	None.
TT319	8/16	14:35-14:52	4	2138	11	0.23-0.28	None.
TT314	8/12	11:35-11:57	4	3147	8	0.22-0.27	None.
TT314	8/16	13:46-14:14	6	882	15	0.06-0.09	Avg: 873 cfs, COV: 15% excluding high & low.
LC02	8/12	15:33-15:59	7	531	32	0.17-0.52	Avg: 539 cfs, COV: 20% excluding high & low.
LC02	8/16	16:15-16:24	4	469	10	0.27-0.34	None.
North Oxbow	8/16	17:21-17:35	4	330	60	0.06-0.17	Bi-directional currents
South Oxbow	8/16	16:48-17:00	4	385	21	0.07-0.12	None.
Coal Fire	8/14	12:00	1	49.5	-	-	Measurement by ADV.

Upon request from the U.S. EPA, SESD, EAB, the U.S. Army Corp of Engineers conducted a bathymetric survey along the study reach in the Tenn-Tom Waterway. Channel cross-sections were surveyed at 1,000-foot intervals between waterway mile 341 and 304. The complete data set is included in Appendix G.

3.5.4 Quality Assurance/Quality Control

Flows were measured using a boat-mounted ADCP with the exception of Coal Fire Creek. Resulting flows are an average based on a minimum of four individual measurements at each station. Due to low velocities, the ADCP was not able to provide velocity profiles to the river bottom; however, more than sufficient data was collected to provide acceptable flow calculations.

Navigational limitations in Coal Fire Creek precluded flow measurement by ADCP. Instead, a single flow measurement was obtained using an ADV to determine velocities at the two-tenths and eight-tenths depths.

3.5.5 Data Validation/Verification

Flow calculations were performed using ADCP manufacturer's software. Resulting flows were reviewed by the module leader and the project leader.

3.6 Current Measurements

3.6.1 Study Area

Endeco 174 recording current meters were deployed at several locations in the Tenn-Tom Waterway and in selected tributaries as described in the QAPP and shown in Table 9.

3.6.2 Methods

In order to accommodate equipment inventories, current meter deployments/retrievals were conducted in three phases coincident with deployment of recording *in-situ* water quality meters. The first deployment occurred on August 11, 2005 at stations TT340, TT336, TR3.8, TR1.3, and TTFA03. Prior to the study, these meters were programmed to record current speed and direction at 15 minute intervals in concert with *in-situ* monitors; however, during the initialization process in the field, each meter returned to its factory default recording interval of 2 minutes. A recording interval of 2 minutes was more frequent than needed and an interval of 15 minutes was specified in the Quality Assurance Project Plan (QAPP). Therefore, to avoid this problem on later deployments, Endeco meters were subsequently reset and initialized by laptop computer and successfully recorded at 15 minutes intervals as intended. The meters were set at six-tenths of the total depth measured at the time of deployment. To protect instrumentation and prevent impeding boat traffic, current meters were deployed just outside of the navigation channel. Retrieval of the meters for this first deployment occurred on the morning of August 13, 2005.

Following field downloading of the recorded data, these 5 meters were redeployed at the following stations on the afternoon of August 13, 2005: LC02, TT327, TT324, TT319, and JC315. Current speed and direction were recorded at 15 minute intervals until retrieval on the morning of August 15,2005. Again following data downloading, meters were redeployed on the afternoon of August 15, 2005 for a final deployment at stations TT314, TT310, TT307, TT304, and TT340. This second current meter deployment at TT340 (denoted TT340a) was in concert with a redeployment of the *in-situ* water quality meters which were displaced during the first deployment.

Also, from August 13 – 16, 2005, an Interocean S4 current meter was deployed at station TT332 in order to evaluate potential changes in current speed associated with lock operation and barge traffic. For this reason, the S4 was set to record current speed and direction at two minute intervals.

3.6.3 Results

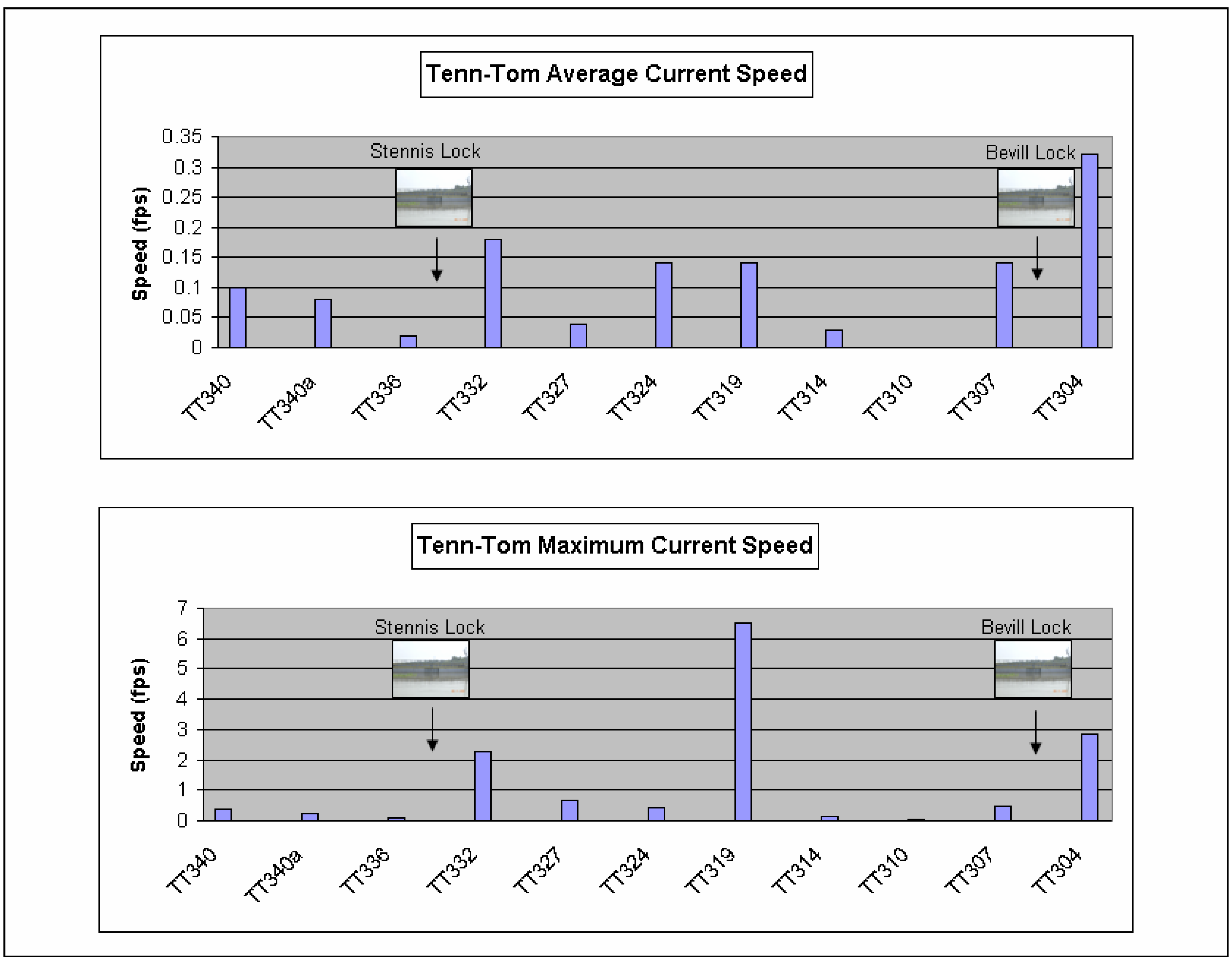
Table 9 summarizes the results of current monitoring in the Tenn-Tom Waterway study area during the August 2005 water quality survey. Figure 14 shows a comparison of average and maximum current speeds on the main stem of the Tenn-Tom Waterway, while Figure 15 depicts the affects of barge/lock operations at station 332.4 of the Tenn-Tom Waterway. Figure 16 shows the monitoring results obtained from the Endeco Current meter at stationTT340 and a histogram of current direction obtained from the current meter at TT340.0. Appendix H contains similar figures depicting the results for the remainder of the stations. These figures represent corrected data for Stations LC02, TT304, and TTFA03. Specifically, current direction was determined to be 180 degrees in error at these stations resulting in predominantly upstream measured current directions at TTFA03 and exclusively upstream measured current directions at LC02 and TT304. A review of velocities collected using an Acoustic Doppler Current Profiler (ADCP) during flow measurements the day before and after current meter deployment shows downstream currents at LC02. TT304 is located below the Bevill lock and would be expected to show some downstream currents associated with lock releases. The meter deployed at TTFA03 (in the flow augmentation channel) was found at retrieval in the main stem of the Tenn-Tom approximately 1.5 miles downstream of its deployment location. While upstream currents are experienced in the flow augmentation channel, predominantly downstream currents would be required to move a weighted current meter in a downstream direction. It was further determined that the same current meter (Endeco #182) was deployed at each of these stations (LC02, TT304, and TTFA03) further suggesting a meter malfunction thus resulting in a correction of 180° to the directional data at Stations LC0.2, TT304.5, and TTFA0.3.

Table 9
Current Meter Data Summary
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Endeco Meter #	Deployment Start	Deployment End	Depl. Depth (ft)	Max. Speed (fps)	Ave. Speed (fps)	Min. Speed (fps)
TT340 TT340a	115 115	8/11 12:40 8/15 17:30	8/13 08:52 8/17 13:36	12 12	.39 .24	.10 0.08	≤0.016 ≤0.016
TT336	116	8/11 10:47	8/13 09:02	9	0.12	0.02	≤0.016
TT332	(S4)	8/13 14:41	8/16 11:03	6	2.29	0.18	≤0.016
TT327	116	8/13 16:42	8/15 09:50	9	0.68	0.04	≤0.016
TT324	115	8/13 16:34	8/15 09:50	9	0.44	0.14	≤0.016
TT319	202	8/13 17:05	8/15 10:10	9	6.51	0.14	≤0.016
TT314	202	8/15 16:30	8/17 09:28	15.5	0.15	0.03	≤0.016
TT310	116	8/15 17:19	8/17 09:41	10	0.03	0	≤0.016
TT307	181	8/15 19:22	8/17 10:39	12	0.47	0.14	≤0.016

Station	Endeco Meter #	Deployment Start	Deployment End	Depl. Depth (ft)	Max. Speed (fps)	Ave. Speed (fps)	Min. Speed (fps)
TT304	182	8/15 18:40	8/17 10:14	7	2.85	0.32	≤0.016
TR3.8	202	8/11 11:45	8/13 09:32	18	0.15	0	≤0.016
TR1.3	181	8/11 12:16	8/13 09:13	6	5.74	0.03	≤0.016
TTFA03	182	8/11 13:52	8/13 11:10	3	7.97	0.56	≤0.016
LC02	182	8/13 15:05	8/15 09:43	3.5	1.37	.32	≤0.016
JC315	181	8/13 17:35	8/15 10:23	5	0.79	0.06	≤0.016

Figure 14
Main Stem Station Avg/Max Currents
Tenn-Tom Waterway
Columbus, Mississippi
August 2005



As shown in Table 9, average current speeds were generally low with each station recording velocities below the instrument minimum threshold (<0.016 fps) during periods of monitoring. Generally, lower velocities are observed approaching each lock from upstream with highest velocities observed at the station just below each lock (TT332/TT304 – Figure 14). The apparent exception on Figure 14 is station TT319 where the maximum recorded speed was over 6 fps; however, as shown in Figure H-6 (Appendix H), high velocities were only observed during the last two hours of the monitoring period and may be associated with barge operation. Excepting these last two hours, the average current speed at TT319 was 0.04 fps with only one observation exceeding 0.20 fps. Also, Figure H-6 (Appendix H) shows some current measurements in an upstream direction at TT319 further suggesting affects from barge or lock operation. Similarly, barge or lock operation may have caused the bi-directional currents observed at Stations TT310 and TT307 (Figures H-8 and H-9 (Appendix H)). Only four current speeds at Station TT310 were above the minimum instrument threshold while direction measurements were quite varied suggesting very slow moving water possibly mildly affected by barges or lock operation. The variations in current speeds at stations potentially affected by barges may be related to the proximity of each meter to the ship channel.

During the monitoring period, there were virtually no current speeds above the instrument threshold at mile 3.8 of the Tibbee River (TR3.8) with the exception of a twenty minute period on afternoon of August 12, 2005 when speeds reached 0.15 fps. The direction histogram does suggest some very weak current movement in both an upstream and downstream direction. At mile 1.3 (TR1.3), more frequent current speeds above instrument threshold were observed, generally up to about 0.5 fps moving primarily into the Columbus Pool (i.e., downstream). Current speeds in Luxapallila Creek were generally in the 0.2 to 0.6 fps range with a few measurements above 1 fps. As discussed previously, measured currents were virtually all in an upstream direction; however, this is believed to be due to an instrument error. Also, as previously discussed, the current meter deployed in the flow augmentation channel (TTFA03) drifted into the Tenn-Tom Waterway during the monitoring period. The flow measurement crew passed this station at approximately 6:00 p.m. on the afternoon of August 12 and did not observe any movement of the meter; therefore, it is believed the drift occurred after this time. A closer review of the data shows current speeds exceeding 7 fps on the afternoon of August 12 immediately followed by 0 fps current speed suggesting that the meter may have drifted a short distance. A similar pattern is again observed a short time later. Finally, following another current in excess of 7 fps around 7:00 p.m., the meter appears to drift from 7:15 to 8:15 p.m. probably reaching its final retrieval location. This data further suggest an instrument directional malfunction as each of these high current measurements was recorded in an upstream direction, yet the current meter drifted downstream. Only the TTFA03 current data prior to 6:00 p.m. on August 12, 2005 should be used for modeling purposes. Finally, current speeds were very low in James Creek. Following intermittent currents up to 0.7 fps through noon on August 14, 2005, the remainder of the monitoring showed no currents above instrument threshold. Data suggest generally downstream flow with occasion upstream currents which is consistent with ADCP data collected during flow measurements in James Creek.

An Interocean S4 current meter was deployed at station TT332.4 to provide an indication of the affects of barge/lock operation on current speeds in the Tenn-Tom Waterway downstream of Stennis Lock. The meter recorded current speed and direction at two minute intervals. Figure 15 shows the resulting current speed/direction data for August 14 and 15,

2005. Also depicted in Figure 15 are the lock operations with a green triangle representing the "Start of Lockage" (SOL) and a red diamond representing the "End of Lockage (EOL). It should be noted that each series of Start and End Lockages could represent filling of the lock or emptying of the lock depending on which direction an approaching vessel was heading and the status of the lock (full or empty) at the time the vessel requiring lockage arrived. Records supplied by the Mobile District Corps of Engineers provided this information. Using this information, it was possible to separate current surges resulting from emptying of the lock, a "pit dump" in Corps terminology, from those resulting from barge prop wash. The current surges associated with pit dumps are denoted on Figure 15 by the white numerals. Vessel induced currents are indicated by the current direction markers with downstream currents representing a vessel moving upstream and upstream currents resulting from a vessel moving downstream.

This examination shows that during periods of inactivity, prevailing currents were generally 0.1 – 0.2 fps. Following pit dumps from the Stennis Lock, downstream currents consistently increased to a speed of 0.7 to 0.8 fps with few exceptions. Depending on the size and draft of the locking barge, resulting current speeds ranged from 0.4 to > 1 fps. However, the affects on current from barge passage appears much shorter-lived than the affects of pit dumps.

A confirmatory dye tracer study was conducted above and in the Columbus Pool. Approximately eight liters of Rhodamine WT dye was released instantaneously in the Tenn-Tom Waterway north of the Highway 50 bridge on 08/10/05 at 1800 hours. The dye tracer study revealed a mean reach velocity of 0.19 fps. This is within the range of velocities measured by the current meters. Table 10 contains a summary of the dye tracer data and Figure 17 shows the dye path and centroid of the dye cloud. Figure 18 is a graphical display of the time of travel data. Three peaks are noted on the graph. This is most likely due to the backwash affects from the lockages at the Stennis Lock and Dam.

3.6.4 Quality Assurance/Quality Control

Currents were measured using impeller type Endeco current meters and an S4 electromagnetic current meter. Meters were deployed and data retrieved according to the EASOPQAM and manufacturer's instructions. Dye tracing utilized Rhodamine WT tracer with monitoring by boat-mounted fluorometer and submersible pump. The fluorometer was calibrated and end checked with known tracer standards. End checks were within EAB tolerances. Therefore, the data is valid.

3.6.5 Data Validation/Verification

A thorough examination of the current data resulted in a determination of a directional error in Endeco meter #182 as described in Section 3.6.3. Reported directional data for this meter was corrected by 180°. Current measurement results were compiled by the Module Leader and reviewed by another senior scientist familiar with current measurement.

Figure 15
Lock/Barge Affects on Currents
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

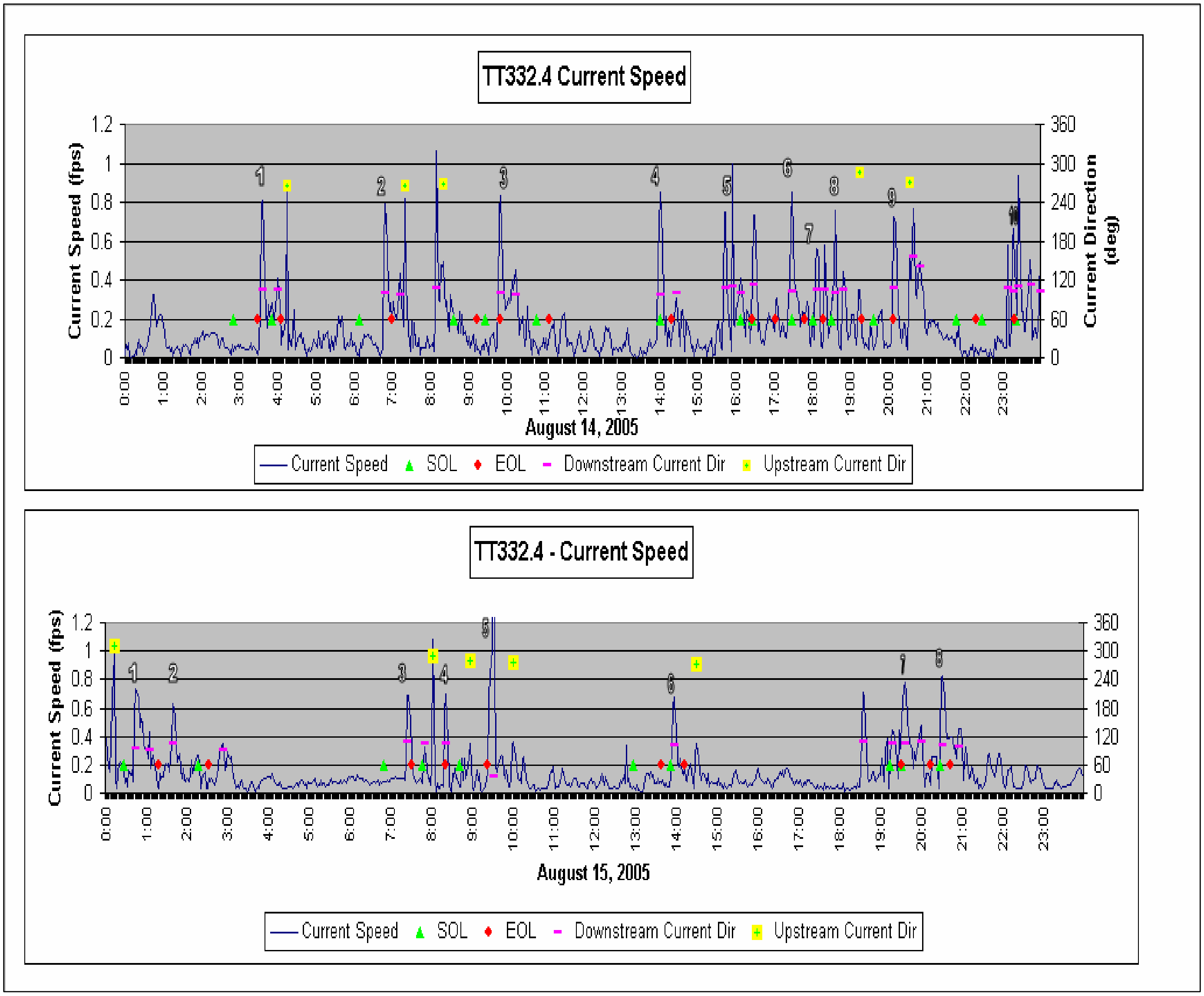
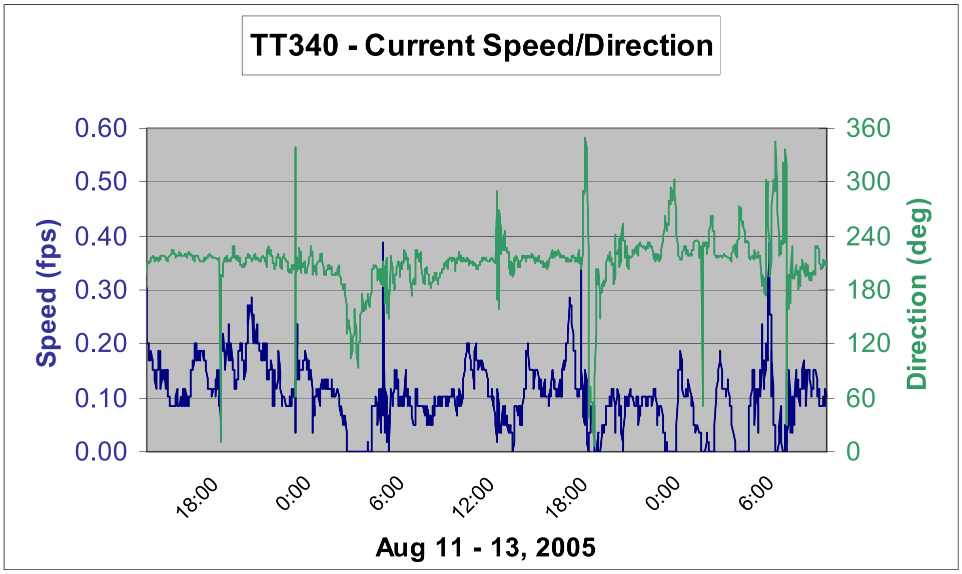


Figure 16
TT340 Current Speed/Direction
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



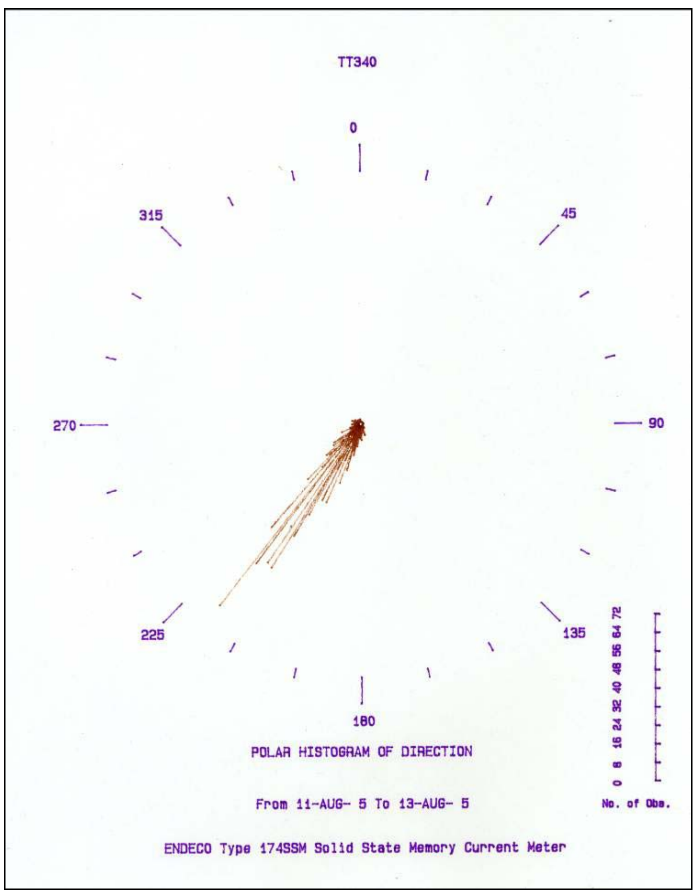


Figure 17
Time of Travel Dye Release Path
Tenn-Tom Water Way Water Quality Study
Comumbus, Mississippi
August 2005

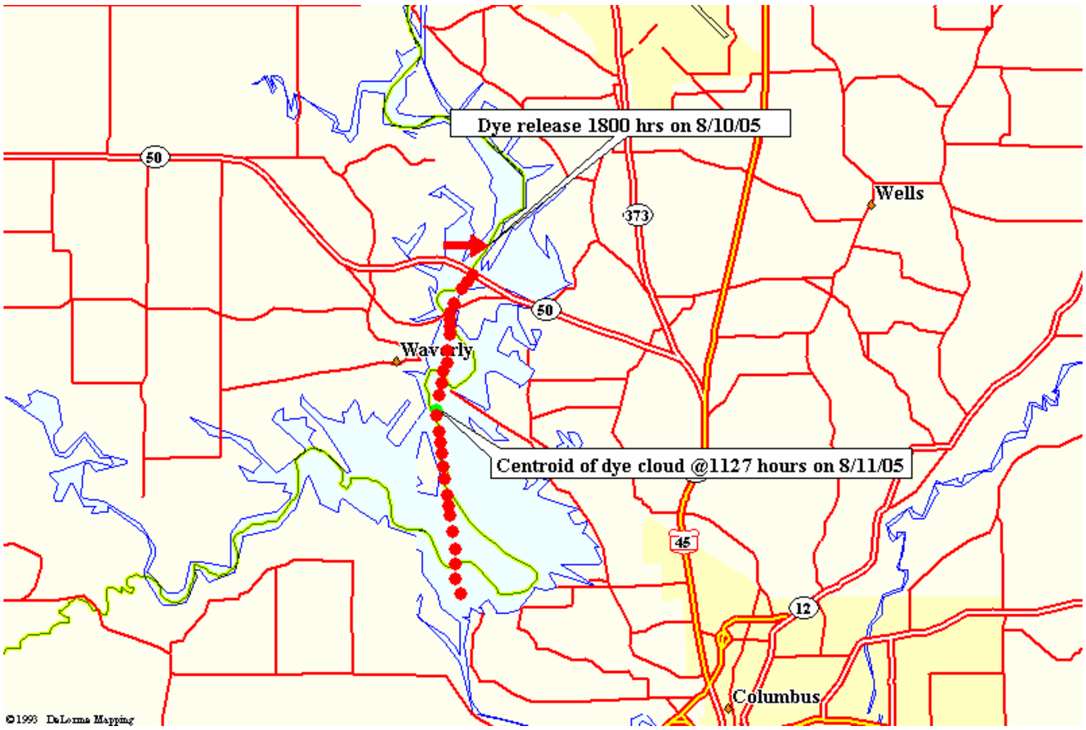


Figure 18
Time-of-Travel Graph
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

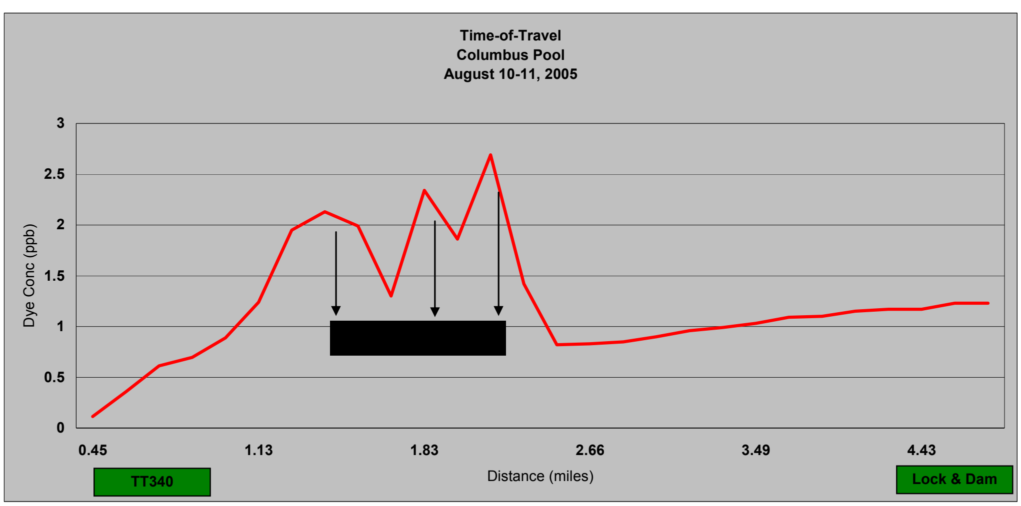


Table 10
Dye Tracer Data
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

						Longitudinal X-Section				
DATE	TIME (HH:MM)	CUM TIME (Hours)	LATITUDE (Deg.Min)	LONGITUDE (Deg.Min)	DISTANCE (miles)	RAW DYE CONC (PPB)	TEMP °C	ADJ DYE CONC (PPB)	INC AREA	CUM AREA
8/11/05	1045	16.75	35.081	29.216	0.45	0.114	30.6	0.00	0.0	0.0
	1050	16.83	35.002	29.287	0.56	0.357	30.9	0.32	0.0	0.0
	1052	16.87	34.931	29.360	0.66	0.614	31.1	0.67	0.0	0.0
	1056	16.93	34.754	29.480	0.89	0.697	31.3	0.79	0.0	0.1
	1059	16.98	34.636	29.515	1.02	0.888	31.3	1.04	0.0	0.1
	1101	17.02	34.567	29.526	1.13	1.240	31.2	1.51	0.0	0.2
	1103	17.05	34.487	29.529	1.22	1.950	31.2	2.47	0.1	0.2
	1105	17.08	34.395	29.537	1.33	2.130	31.2	2.71	0.1	0.3
	1110	17.17	34.206	29.567	1.54	1.990	31.3	2.53	0.2	0.5
	1114	17.23	34.062	29.578	1.71	1.300	31.3	1.60	0.1	0.7
	1115	17.25	33.966	29.605	1.83	2.340	31.1	2.98	0.0	0.7
	1119	17.32	33.829	29.646	1.99	1.860	31.3	2.35	0.2	0.9
	1122	17.37	33.696	29.694	2.16	2.690	31.4	3.48	0.1	1.0
	1127	17.45	33.526	29.732	2.35	1.420	31.5	1.77	0.2	1.3
	1129	17.48	33.450	29.726	2.44	0.820	31.7	0.96	0.0	1.3
	1133	17.55	33.257	29.683	2.66	0.830	31.5	0.97	0.1	1.4
	1137	17.61	33.145	29.667	2.8	0.850	31.4	1.00	0.1	1.4
9/19/02	1140	17.67	33.002	29.648	2.94	0.900	31.6	1.07	0.1	1.5
	1143	17.72	32.866	29.632	3.11	0.960	31.7	1.15	0.1	1.5
	1147	17.78	32.727	29.605	3.28	0.990	31.7	1.19	0.1	1.6
	1152	17.87	32.540	29.569	3.49	1.030	31.5	1.24	0.1	1.7
	1155	17.92	32.414	29.555	3.64	1.090	31.4	1.32	0.1	1.8
	1158	17.97	32.295	29.542	3.78	1.100	31.7	1.34	0.1	1.9
	1202	18.03	32.100	29.500	4.01	1.150	31.4	1.40	0.1	1.9
	1207	18.12	31.904	29.465	4.24	1.170	31.4	1.43	0.1	2.1
	1211	18.18	31.732	29.463	4.43	1.170	31.3	1.42	0.1	2.2
	1215	18.25	31.570	29.451	4.63	1.230	31.5	1.51	0.1	2.3
	1220	18.33	31.388	29.391	4.85	1.230	31.4	1.51	0.1	2.4

3.7 Water Quality Sampling

3.7.1 Study Area

Water quality samples were collected from the main stem river stations, tributary stations and several point source dischargers during the study. Table 11 contains a list of the sample stations and their locations.

Table 11
Sample Stations and Locations
Tenn-Tom Waterway
Columbus, Mississippi
August 2005

Station No.	Location
	Tenn-Tom Main Stem And Tributary Sampling Stations
TT 340.0	Tenn-Tom Waterway near Highway 50 bridge
TT 336.3	Columbus Pool near Lock & Dam
TR 3.8	Tibbee River just below Spring Creek
TR 1.3	Tibbee River/ Columbus Pool
TTFA 0.3	Tenn-Tom Waterway Flow Augmentation Channel
TT 332.4	Tenn-Tom Waterway near Highway 82 bridge
LC 0.2	Luxapallila Creek near mouth
TT 327.7	Tenn-Tom Waterway above Weyerhaeuser discharge
TT 324.4	Tenn-Tom Waterway below Weyerhaeuser discharge
TT 319.6	Tenn-Tom Waterway near Harrison Bend
JC 315.8	James Creek @ mile 315.8
TT 314.7	Tenn-Tom Waterway near US 49 bridge
CF 1.4	Coal Fire Creek @ mile 1.6
TT 310.0	Tenn-Tom Waterway @ MS-AL state line
TT 307.3	Tenn-Tom Waterway in Aliceville Pool
TT 304.5	Tenn-Tom Waterway downstream of Bevill Lock & Dam
	Point Source Sampling Stations
Bryan	Bryan Foods
TT-Sports	True Temper Sports
Aberdeen	Aberdeen POTW
Hamilton	Hamilton POTW
Kerr-McGee	Kerr-McGee Chemical, LLC
WestPoint	West Point POTW
Winfield	Winfield POTW
Columbus	Columbus POTW
W-Paper	Weyerhaeuser CPPC
EKA	EKA Chemical

3.7.2 Methods

In order to address temporal variability, two rounds of sampling were conducted at all of the stations listed in Table 11. During the first round of sample collection, samples were analyzed for long-term biochemical oxygen demand (BOD_{LT}), ammonia, nitrate-nitrite, total and dissolved phosphorous (TP & TDP), total kjeldahl nitrogen (TKN), and total organic carbon

(TOC). Due to laboratory space limitations, five day BODs were performed during the second round of sampling rather than long-term BODs. All of the remaining parameters were analyzed during the second round of sampling. Non-linear analysis was conducted for the long-term BOD results using the Long Term BOD Analysis Program (V3.0) developed by the Georgia Environmental Protection Division (GAEPD2004). The analysis resulted in estimates of ultimate BODs, decay rates, f-ratios, and other factors required by water quality models. Estimates of ultimate carbonaceous BODs were determined using first order curve fits. The results from the non-linear analysis are presented in Appendix I.

Samples for chlorophyll a analysis and algal growth potential testing (AGPT) were collected from the stations listed in Table 12.

Table 12
Chlorophyll a and AGPT Sample Locations
Tenn-Tom Waterway
Columbus, Mississippi
August 2005

Station	Chlorophyll a	AGPT
TT340.0	X	X
TT336.3	X	X
TT332.4	X	X
TT327.7	X	
TT324.4	X	X
TT319.6	X	
TT314.7	X	X
TT310.0	X	
TT307.3	X	
TT304.5	X	X

Samples collected from the main stem river and tributary stations were collected using submersible pumps. The samples were collected from a single point in the main hydraulic conveyance of the water bodies and vertically composited within the photic zone. The photic zone was determined prior to sample collection using a photometer. The photometer profiles are presented in Appendix C. Samples from the point source dischargers were collected using automatic samplers. The point source samples were composited over a 24 hour period.

Chlorophyll a and AGPT samples were collected using a submersible pump. Chlorophyll a samples were collected from each depth corresponding to light and dark bottle deployment during data collection of photosynthesis and respiration in the water column. Additionally, vertically composited chlorophyll a samples were collected within the photic zone so that ADEM could compare the values with data collected in association with their Basin Monitoring Program. AGPT samples were collected from mid-depth within the water column.

Flow measurements were conducted at key locations in the main stem river and at each tributary station in order to estimate loadings of the chemical constituents detected in the samples. Flow rate measurements of the discharge during the 24 hour composite period at each point source sampling location were obtained from the facilities to estimate loadings of the chemical constituents detected in the point source samples.

3.7.3 Results

The analytical results of the water samples collected during this study along with the estimates of ultimate BOD and f-ratios are presented in Tables 13 and 14. In general, nutrient concentrations were consistent within the main stem of the river from the upper boundary of the study reach to the lower boundary. BOD_{LT} and BOD_5 concentrations were within the range of typical levels measured in riverine systems. Many of the BOD_5 concentrations reported in Tables 13 and 14 were qualified with a "J", which indicated that the reported data value is an estimate. This is because the minimum quantitation limit (MQL) for BOD_5 is 2 mg/l. At the request of the project leader, the laboratory reported the BOD_5 as low as possible. Any concentrations reported below the MQL were qualified. The majority of the point source dischargers were located above the upper boundary of the study area. The effects of their discharges were accounted for at boundary station TT340.0. Weyerhaeuser Paper and EKA Chemicals were the only point source dischargers located within the boundaries of the study reach. Both companies discharge between stations TT327.7 and TT324.4.

Loading calculations were conducted using the concentrations in Tables 13 and 14. Loadings for constituents reported with a "U" qualifier, which indicates the constituent was not detected above the MQL, were calculated using the MQL. The MQL is the number reported before the "U" in Tables 13 and 14. Loadings for constituents reported with any other qualifiers were calculated using the number immediately before the qualifier.

Because the samples were collected as composites of the photic zone, separate loading calculations were performed for the photic zone and the portion of the water column below the photic zone to account for the potential difference in flow and constituent concentration. Collecting the samples within the photic zone potentially resulted in a positive bias of the nutrient concentrations because of increased levels of production that would be anticipated in the photic zone in comparison to the total water column. Tables 15 and 16 show the results of the loading calculations. The loadings for the photic zone were calculated first. Flow for the photic zone was calculated from the measurements conducted using the ADCP. This flow was applied to the concentrations detected in the samples to estimate loadings in the photic zone. Cumulative loads were then calculated, beginning at station TT340.0, to conduct a mass balance within the study reach. To calculate the initial loads at TT340.0, the concentrations were applied to the entire water column because there was not adequate data to partition the concentrations between the photic zone and the lower portion of the water column. To increase the accuracy of the mass balance, loadings from several minor tributaries, which were not included in the water quality study, were estimated and included in the calculations.

Table 13
Main Stem River and Tributary Sampling Analytical Results
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Date/Time	Ammonia (mg/l)	Nitrate-Nitrite (mg/l)	TKN (mg/l)	TDP (mg/l)	TP (mg/l)	TOC (mg/l)	BOD_{LT} (mg/l)	BOD_5 (mg/l)	$CBOD_u$* (mg/l)	f Ratio
TT340.0	08/12/05 1800	0.050U	0.050U	0.43	0.010U	0.041	3.4	5.86	1.84J	5.1	2.97
TT340.0	08/16/05 1002	0.050U	0.050U	0.35J	0.012	0.038	3.2	NA	1.57J	**4.8**	
TT336.3	08/12/05 1100	0.050U	0.050U	0.45	0.016	0.052	3.4	6.34	1.9J	5.39	3.03
TT336.3	08/16/05 1058	0.050U	0.050U	0.39	0.021	0.041	3.4	NA	1.03J	**5.39**	
TT332.4	08/12/05 1635	0.050U	0.050U	0.45	0.014	0.061	3.9	6.81	1.64J	6	3.86
TT332.4	08/16/05 1058	0.050U	0.050U	0.45	0.014	0.052	4.0	NA	1.55J	**6.15**	
TT327.7	08/12/05 1435	0.050U	0.050U	0.43	0.014	0.053	4.1	7.26	2.06	6.32	3.06
TT327.7	08/16/05 1137	0.050U	0.050U	0.41	0.012	0.039	3.9	NA	2.45	**6.01**	
TT324.4	08/12/05 1425	0.050U	0.050U	0.57	0.021	0.077	4.8	9.07	2.91	7.86	3.03
TT324.4	08/16/05 1151	0.050U	0.050U	0.46	0.020	0.051	15.0	NA	1.97J	**7.86**	
TT319.6	08/12/05 1220	0.050U	0.050U	0.53	0.032	0.080	4.9	8.13	2.43	6.99	3.13
TT319.6	08/16/05 1209	0.050U	0.050U	0.51	0.019	0.061	4.9	NA	2.4	**6.99**	
TT314.7	08/12/05 1120	0.050U	0.050U	0.47	0.016	0.065	5.0	6.83	1.41J	6.11	4.69
TT314.7	08/16/05 1255	0.050U	0.050U	0.54	0.016	0.065	5.0	NA	2.75	**6.11**	
TT310.0	08/12/05 1355	0.050U	0.050U	0.49	0.018	0.064	4.8	6.26	1.38J	5.45	4.60
TT310.0	08/16/05 1205	0.050U	0.050U	0.43	0.015	0.051	4.8	NA	1.53J	**5.45**	
TT307.3	08/12/05 1430	0.050U	0.050U	0.55	0.015	0.059	5.0	8.56	2.31	7.64	3.43
TT307.3	08/16/05 1045	0.050U	0.050U	0.55	0.011	0.053	4.7	NA	1.97J	**7.18**	
TT304.5	08/12/05 1110	0.054	0.050U	0.52	0.025	0.061	4.8	5.93	1.27J	5.18	5.17
TT304.5	08/16/05 1120	0.050U	0.050U	0.44	0.015	0.048	4.7	NA	1.55J	**5.07**	
TR3.8	08/12/05 1050	0.050U	0.050U	0.79	0.045	0.110	6.2	11.3	4.34	9.47	3.20
TR3.8	08/16/05 1134	0.050U	0.050U	0.73	0.033	0.090	11.0	NA	3.13	**9.47**	
TR1.3	08/12/05 1030	0.050U	0.050U	0.68	0.029	0.10	4.9	10.05	2.77	8.78	3.65
TR1.3	08/16/05 1054	0.050U	0.050U	0.54	0.020	0.079	4.4	NA	1.42J	**7.88**	
TTFA0.3	08/12/05 1405	0.050U	0.050U	0.50	0.012	0.073	3.8	7.33	2	6.45	3.60
TTFA0.3	08/16/05 1043	0.050U	0.050U	0.49J	0.013	0.072	3.7	NA	1.77J	**6.28**	
LC0.2	08/15/05 1520	0.050U	0.20	0.22	0.025	0.039	2.7	3.14	0.53J	2.77	5.92
LC0.2	08/16/05 1123	0.050U	0.23	0.23	0.033	0.053	2.8	NA	0.43J	**2.87**	
JC315.8	08/12/05 1355	0.050U	0.050U	0.74	0.016	0.14	5.5	10.9	3.24	9.4	3.39
JC315.8	08/16/05 1234	0.050U	0.050U	0.98	0.018	0.13	5.5	NA	3.11	**9.4**	
CF1.4	08/12/05 1305	0.050U	0.11	0.31	0.010U	0.038	3.7	3.45	0.49J	3.24	10.03
CF1.4	08/16/05 1000	0.050U	0.13	0.20J	0.010U	0.035	3.3	NA	0.46J	**2.89**	

U-Analyte not detected at or above reporting limit. The number is the minimum quantitation limit.
J-Identification of analyte is acceptable; reported value is an estimate.
NA - Not analyzed

* - CBODu values calculated using non-linear curve analysis.
$CBOD_u$ - values calculated based on $CBOD_u$/TOC ratios from first round of sampling.

Table 14
Point Source Sampling Analytical Results
Tenn-Tom Waterway Study
Columbus, Mississippi
August 2005

Station	Date/Time	Ammonia (mg/l)	Nitrate-Nitrite (mg/l)	TKN (mg/l)	TDP (mg/l)	TP (mg/l)	TOC (mg/l)	BOD_u (mg/l)	BOD_5 (mg/l)	$CBOD_u$* (mg/l)	f Ratio
Aberdeen	08/11/2005 0955	0.092	0.76	2	0.82	0.95	14	31.3	6.93	25.40	4.23
Aberdeen	08/14/2005 0955	0.11	0.52	2	0.78	0.95	15	NA	6.66	**27.21**	
Bryan	08/11/2005 1000	0.068	110	2.5	27	27	24	19.9	1.13J	24.00	13.84
Bryan	08/14/2005 1030	0.068	110	2.4	27	27	25	NA	1.43J	**25.00**	
Columbus	08/11/2005 0946	0.10	6.2	1.1	0.68	0.77	14	23.7	4.42	21.10	3.65
Columbus	08/14/2005 0945	0.34	7.9	1.5	1.4	1.5	14	NA	4.57	**21.10**	
EKA	08/11/2005 1036	1.4	0.21	1.6	1.4	1.9	16	26.6	4.14	21.40	3.86
EKA	08/14/2005 1027	0.55	0.096	0.72	0.39	0.67	11	NA	4.71	**14.71**	
Hamilton	08/11/2005 0930	0.072	3.5	1.1	2.9	3	6.1	7.36	1.18J	5.63	6.40
Hamilton	08/14/2005 0930	0.13	1.5	1.1	2.8	2.8	12	NA	2.42	**11.08**	
KerrMcGee	08/11/2005 1105	0.050U	0.067	0.46	0.010U	0.021	13	32.1	4.37	33.00	8.51
KerrMcGee	08/14/2005 1045	0.050U	0.061	0.68AJ	0.010	0.022	12	NA	3.25	**30.46**	
TTSports	08/11/2005 1000	3.1	36	5.2	8.0	8.0	30	106	29.3	7.65	3.06
TTSports	08/14/2005 1000	1.2	81	2.5	1.8	2.3	20	NA	23.1	**5.10**	
Wpaper	08/11/2005 1130	2.1	NAI	4.2	1.0	1.2	150	95.5	7.77L	92.50	8.84
Wpaper	08/14/2005 1100	2.2	NAI	4.6	1.0	1.2	160	NA	5.75L	**98.67**	
Westpoint	08/11/2005 0915	0.13	5.0	2.0	1.1	1.1	22	30.6	4.17	27.30	7.18
Westpoint	08/14/2005 0940	0.078	3.8	1.8	1.3	1.3	20	NA	3.1	**24.82**	
Winfield	08/11/2005 1035	2.1	0.050U	14	1.4	1.8	23	102	7.47L	44.50	3.60
Winfield	08/14/2005 1030	11	0.050U	14	1.3	1.7	22	NA	7.34L	**42.57**	

L- Identification of analyte is acceptable; reported value may be biased low. Actual value is expected to be greater than reported value.
U-Analyte not detected at or above reporting limit. The number is the minimum quantitation limit.
J-Identification of analyte is acceptable; reported value is an estimate.
A-Analyte analyzed in replicate. Reported value is 'average' of replicates.
NAI-Not Analyzed due to Interferences.
[shaded] = Data should not be utilized due to QC/QA concerns. See discussion in Section 3.7.4.
* - $CBOD_u$ calculated using non-linear curve analysis.
$CBOD_u$ - values calculated based on $CBOD_u$/TOC ratios from first round of sampling.

Table 15
Loading Calculations – First Round
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

12-Aug-05

							PHOTIC ZONE				TOTAL WATER COLUMN				RIVER - LOWER HALF			
	Total	Photic Zone	Water Column Concentration				Load				Cumulative Load*				Load			
Station	Flow (cfs)	Flow (cfs)	TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)	TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)	TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
TT340.0	317	158.5	0.48	0.041	3.4	5.10	410	35	2903	4355	820	70	5807	8710	410	35	2903	4355
TT336.3	317	158.5	0.5	0.052	3.4	5.39	427	44	2903	4603	820	70	5807	8710	393	26	2903	4107
TT332.4	811	405.5	0.5	0.061	3.9	6.00	1092	133	8520	13108	2936	360	20010	34159	1843	227	11489	21051
TT327.7	1342	671	0.48	0.053	4.1	6.32	1735	192	14822	22847	4137	471	27734	42084	2402	280	12912	19237
TT324.4	2256	1128	0.62	0.077	4.8	7.86	3768	468	29171	47767	4631	618	45187	52893	864	150	16016	5126
TT319.6	2438	1219	0.58	0.08	4.9	6.99	3809	525	32181	45907	4631	618	45187	52893	822	93	13006	6986
TT314.7	3147	1258.8	0.52	0.065	5.0	6.11	3527	441	33910	41438	7354	922	67646	78166	1457	228	13772	15183
TT310.0	3147	1258.8	0.54	0.064	4.8	5.45	3662	434	32553	36962	7517	939	68995	79551	1484	251	16477	21045
TT307.3	3147	1258.8	0.6	0.059	5.0	7.64	4069	400	33910	51814	7517	939	68995	79551	1077	285	15121	6192
TT304.5	2375	950	0.57	0.061	4.8	5.18	2917	312	24568	26513	7309	783	61532	66444	2021	217	17000	18387

POINT SOURCE & TRIBUTARY LOADINGS									
	Total	Concentration				Load			
Station	Flow (cfs)	TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
TTFA0.3	225	0.55	0.073	3.8	6.45	667	88	4606	7819
TR3.8	538	0.84	0.110	6.2	9.47	2435	319	17971	27449
TR1.3	538	0.73	0.10	4.9	8.78	2116	290	14203	25449
LC0.2	531	0.42	0.039	2.7	2.77	1202	112	7724	7925
JC315.8	17	0.79	0.14	5.5	9.40	72	13	504	861
CF1.4	49.5	0.42	0.038	3.7	3.24	112	10	987	864
EKA	0.74	1.81	1.900	16.0	21.40	7	8	64	86
Wpaper	21.52	4.2	1.200	150.0	92.50	487	139	17389	10723

Photic Zone Load = (Photic Zone Flow)*(Water Column Concentration)*(Constant)

Cumulative Load = (Total Flow)*(Water Sample Concentration)*(Constant) + Tributary Load (if applicable)

Lower Half Load = (Cumulative Load) - (Photic Zone Load)

TRIBUTARY LOADING ESTIMATES									
	Total	Concentration				Load			
Station	Flow (cfs)	TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
Gilmer	54	0.59	0.08	4.2	6.0475	172	23	1222	1759
Cedar	8	0.59	0.07925	4.2	6.0475	25	3	181	261
Brken Pump	16	0.59	0.07925	4.2	6.0475	51	7	362	521
Cypress	5	0.59	0.07925	4.2	6.0475	16	2	113	163
Nash	26	0.59	0.07925	4.2	6.0475	83	11	588	847
Stored load	NA					2371	254	19964	21545

Table 16
Loading Calculations – Second Round
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

16-Aug-05

Station	Total Flow (cfs)	Photic Zone Flow (cfs)	Water Column Concentration TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	PHOTIC ZONE Load TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)	TOTAL WATER COLUMN Cumulative Load* TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)	RIVER - LOWER HALF Load TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
TT340.0	934	467	0.4	0.038	3.2	4.80	1006	96	8051	12077	2013	191	16103	24154	1006	96	8051	12077
TT336.3	934	467	0.44	0.041	3.4	5.39	1107	103	8554	13561	2013	191	16103	24154	906	88	7548	10592
TT332.4	1472	736	0.5	0.052	4.0	6.15	1983	206	15861	24402	3723	420	28856	46994	1740	214	12995	22593
TT327.7	2133	1066.5	0.46	0.039	3.9	6.01	2643	224	22409	34543	5039	572	36867	55212	2396	348	14457	20670
TT324.4	2123	1061.5	0.51	0.051	**4.8**	**7.86**	2917	292	**27451**	**44951**	5257	631	**44384**	**59879**	2340	339	**16932**	**14928**
TT319.6	2138	1069	0.56	0.061	4.9	6.99	3225	351	28221	40258	5257	631	44384	59879	2032	279	16163	19621
TT314.7	882	352.8	0.59	0.065	5.0	6.11	1121	124	9504	11614	5738	687	47739	64464	4513	554	37248	51784
TT310.0	882	352.8	0.48	0.051	4.8	5.45	912	97	9124	10359	5877	703	48949	65697	4861	596	38838	54272
TT307.3	882	352.8	0.6	0.053	4.7	7.18	1140	101	8934	13650	5877	703	48949	65697	4633	592	39028	50980
TT304.5	843	337.2	0.49	0.048	4.7	5.07	890	87	8539	9215	2241	220	21449	23181	1248	123	11923	12900

POINT SOURCE & TRIBUTARY LOADINGS

Station	Total Flow (cfs)	Concentration TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	Load TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
TTFA0.3	225	0.54	0.072	3.7	6.28	655	87	4485	7613
TR3.8	538	0.78	0.090	6.2	9.47	2261	261	17971	27449
TR1.3	538	0.59	0.079	**4.4**	**7.88**	1710	229	**12754**	**22841**
LC0.2	531	0.46	0.053	2.8	2.87	1316	152	8010	8218
JC315.8	17	1.03	0.13	5.5	9.40	94	12	504	861
CF1.4	49.5	0.33	0.035	3.3	2.89	88	9	880	771
EKA	0.73	0.82	0.670	11.0	14.71	3	3	43	58
Wpaper	8.67	4.6	1.200	160.0	98.67	215	56	7474	4609

Photic Zone Load = (Photic Zone Flow)*(Water Column Concentration)*(Constant)

Cumulative Load = (Total Flow)*(Water Sample Concentration)*(Constant) + Tributary Load (if applicable)

Lower Half Load = (Cumulative Load) - (Photic Zone Load)

BOLD - Numbers in bold are based on constituent concentrations from first round of sampling.

TRIBUTARY LOADING ESTIMATES

Station	Total Flow (cfs)	Concentration TN (mg/l)	TP (mg/l)	TOC (mg/l)	CBODult (mg/l)	Load TN (lb/day)	TP (lb/day)	TOC (lb/day)	CBODult (lb/day)
Gilmer	54	0.59	0.07	3.8	5.4	172	21	1113	1560
Cedar	8	0.59	0.07	3.83	5.36	25	3	165	231
Brken Pump	16	0.59	0.07	3.83	5.36	51	6	330	462
Cypress	5	0.59	0.07	3.83	5.36	16	2	103	144
Nash	26	0.59	0.07	3.83	5.36	83	10	536	751
Stored load	NA	NA	NA	NA	NA	103	10	988	1066

The tributaries were not included in the study due to personnel and equipment limitations. The loads were estimated using the following procedure:

- the area of the watersheds of the sampled and un-sampled tributaries were determined using geographical information system (GIS) coverages;

- a proportional flow was calculated for each un-sampled tributary based on the watershed areas and flow of each tributary that was sampled during the study. These flow values were then averaged for each un-sampled tributary. For example, the average flow for Spring Creek was derived by multiplying the flow from TR1.3 by the ratio of the area of the String Creek Watershed to the area of the Tibbee River Watershed. This calculation was performed for Spring Creek and each of the sampled tributaries. The values were then averaged. The average flow value for each un-sampled tributary was used in the loading calculations.

- estimates of constituent concentrations were calculated by averaging the concentrations of the results from the sampled tributaries.

Loading estimates were conducted using this method for Spring Creek, Catalpa Creek, Gilmer Creek, Cedar Creek, Broken Pumpkin Creek, Cypress Creek and Nash Creek.

Between stations TT314.7 and TT310.0, the Tenn-Tom Waterway begins to widen and form the Aliceville Pool. Velocity decreases significantly in this area. To compensate for the storage of water in the Aliceville Pool, a load was calculated and included in the cumulative load at station TT314.7. Once beyond the Bevill Lock and Dam, the Tenn-Tom Waterway hydrology again resembles the hydrology at stations TT327.7 and TT319.6.

Load determinations for the lower portion of the water column below the photic zone were calculated by subtracting the photic zone loads from the cumulative loads.

Since long-term BOD samples were not collected during the second round of sampling, values for the $CBOD_u$ were estimated based on a ratio of $CBOD_u$:TOC from the first round of sampling. This ratio was then multiplied by the TOC concentrations from the second round of sampling to calculate the $CBOD_u$ concentrations that were used in the loading calculations for the second round of sampling. An evaluation of the TOC data in Table 13 shows that the TOC concentrations for the main stem river stations are consistently in the range of 3.4 mg/l to 5.0 mg/l. The concentration of TOC detected in the sample from TT324.4 (15 mg/l) is a great deal higher than the other stations and the concentration of TOC in the sample collected from TT324.4 during the first round of sampling. Upon request from the project leader, the laboratory reviewed the data from that analysis. The laboratory confirmed that the concentration reported for that analysis is valid. However, it is considered an anomaly based on comparison to the other data. Because of this the concentration detected in the sample from TT324.4 during the first round of sampling was used for loading calculations for both rounds of sampling. A similar difference in TOC concentration was noted at TR3.8. The TOC concentration (6.2 mg/l) from the first round of sampling was used for loading calculations for both rounds of sampling.

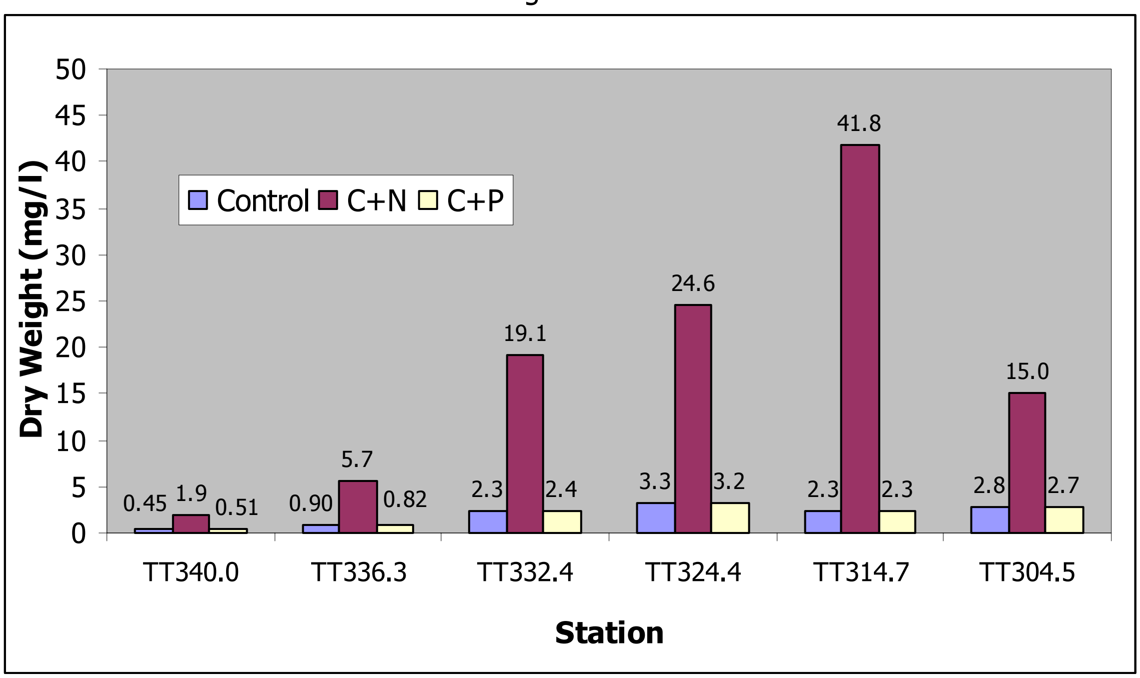
The results from the AGPT samples are presented in Table 17 and Figure 19. The AGPT results show that the study reach of the Tenn-Tom Waterway is nitrogen limited. Figure 19 shows that when nitrate was added to the sample, the maximum standing crop of the test algae increased more than when equal portions of phosphate were added to the sample.

Table 17
AGPT - Maximum Standing Crop Results
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Station	Control	C+N	C+P
TT340.0	0.45	1.9	0.51
TT336.3	0.90	5.7	0.82
TT332.4	2.3	19.1	2.4
TT324.4	3.3	24.6	3.2
TT314.7	2.3	41.8	2.3
TT304.5	2.8	15.0	2.7

AGPT - Algal Growth Potential Test
C+N - Control + 1.0 mg/l Nitrate-N
C+P - Control + 0.05 mg/L Phosphate-P
Freshwater AGPT using Selenastrum as test alga

Figure 19
AGPT Results
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005



The chlorophyll a data is presented in Table 18. The values for the individual depths as well as the composite samples are shown for each location. The determination of the depths for the individual samples was based on light transmission measurements conducted during deployment of the light and dark bottles for photosynthesis and respiration quantification. Chlorophyll a concentrations at stations TT340.0 and TT336.3 remained somewhat consistent throughout the water column. Typically, the concentrations are higher in the upper portion of the water column where the greatest amount of light transmission occurs and decrease in the lower, darker portion of the water column. Figure 20 shows that the results at TT332.4 are more typical. The chlorophyll a concentration was approximately 13 µg/l in the surface waters and decreased to 5.5 µg/l near the bottom. The concentration decreased again at TT327.7 and was consistent throughout the water column. This is most likely due to mixing with the water from Luxapallila Creek. Figure 20 shows a drastic increase in the chlorophyll a concentration at stations TT324.4 and TT319.6. The concentrations increase again in the Aliceville Pool probably due to the slow moving waters in the embayed area. The chlorophyll a concentrations decrease at TT304.5 as the Waterway once again becomes river-like. Similar trends are noted on the graph of the results from the photic zone composite samples in Figure 20.

Table 18
Chlorophyll a Results (Fluorometer Corrected)
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

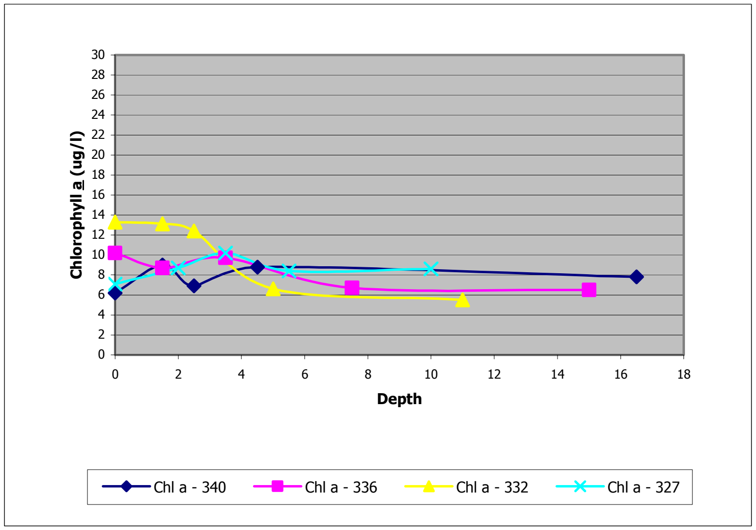
Station	Date	Time	Depth (ft)	Chlorophyll a* (µg/l)
TT340.0A	8/11/2005	1006	0	6.2
TT340.0B	8/11/2005	1005	1.5	9
TT340.0C	8/11/2005	1004	2.5	6.9
TT340.0D	8/11/2005	1003	4.5	8.8
TT340.0E	8/11/2005	1002	16.5	7.8
TT340.0PZ	8/11/2005	959	Photic Zone Composite	9.3
TT336.3A	8/11/2005	1143	0	10.2
TT336.3B	8/11/2005	1142	1.5	8.7
TT336.3C	8/11/2005	1141	3.5	9.7
TT336.3D	8/11/2005	1140	7.5	6.7A
TT336.3E	8/11/2005	1139	15	6.5
TT336.3PZ	8/11/2005	1138	Photic Zone Composite	6.7
TT332.4A	8/12/2005	954	0	13.3
TT332.4B	8/12/2005	955	1.5	13.1
TT332.4C	8/12/2005	956	2.5	12.4

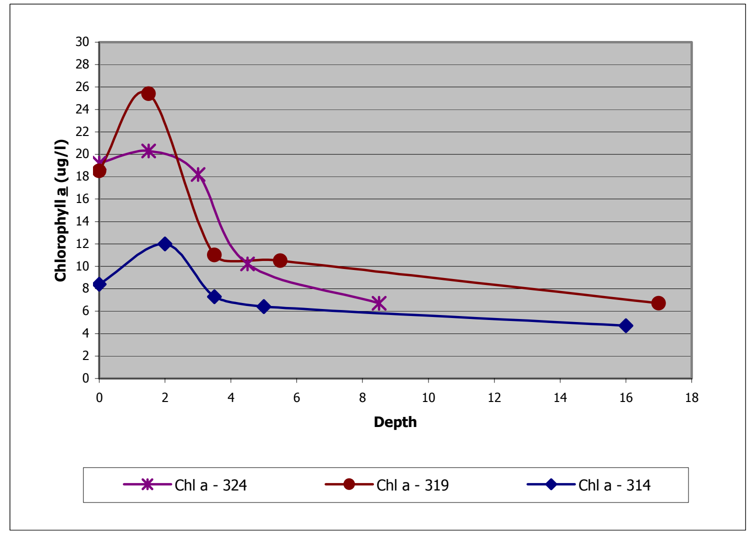
Station	Date	Time	Depth (ft)	Chlorophyll a* (µg/l)
TT332.4D	8/12/2005	957	5	6.6
TT332.4E	8/12/2005	958	11	5.5
TT332.4PZ	8/12/2005	953	Photic Zone Composite	7A
TT327.7A	8/13/2005	934	0	7.1
TT327.7B	8/13/2005	933	2	8.7
TT327.7C	8/13/2005	932	3.5	10.2A
TT327.7D	8/13/2005	931	5.5	8.4
TT327.7E	8/13/2005	930	10	8.6
TT327.7PZ	8/13/2005	935	Photic Zone Composite	5.5
TT324.4A	8/12/2005	1104	0	19.2
TT324.4B	8/12/2005	1103	1.5	20.3
TT324.4C	8/12/2005	1102	3	18.2
TT324.4D	8/12/2005	1101	4.5	10.2
TT324.4E	8/12/2005	1100	8.5	6.7
TT324.4PZ	8/12/2005	1059	Photic Zone Composite	11
TT319.6A	8/13/2005	1109	0	18.5
TT319.6B	8/13/2005	1108	1.5	25.4
TT319.6C	8/13/2005	1107	3.5	11
TT319.6D	8/13/2005	1106	5.5	10.5
TT319.6E	8/13/2005	1105	17	6.7
TT319.6PZ	8/13/2005	1110	Photic Zone Composite	9.8A
TT314.7A	8/14/2005	1007	0	8.4
TT314.7B	8/14/2005	1008	2	12A
TT314.7C	8/14/2005	1009	3.5	7.3
TT314.7D	8/14/2005	1010	5	6.4
TT314.7E	8/14/2005	1011	16	4.7
TT314.7PZ	8/14/2005	1012	Photic Zone Composite	6.2
TT310.0A	8/14/2005	915	0	11.5
TT310.0B	8/14/2005	916	2.5	13.5
TT310.0C	8/14/2005	917	3.5	8.2
TT310.0D	8/14/2005	918	5	7.1
TT310.0E	8/14/2005	919	22	4.6
TT310.0PZ	8/14/2005	920	Photic Zone Composite	7.6
TT307.3A	8/15/2005	923	0	11.2
TT307.3B	8/15/2005	924	2	16.9
TT307.3C	8/15/2005	925	3.5	15.8
TT307.3D	8/15/2005	926	5	13.4

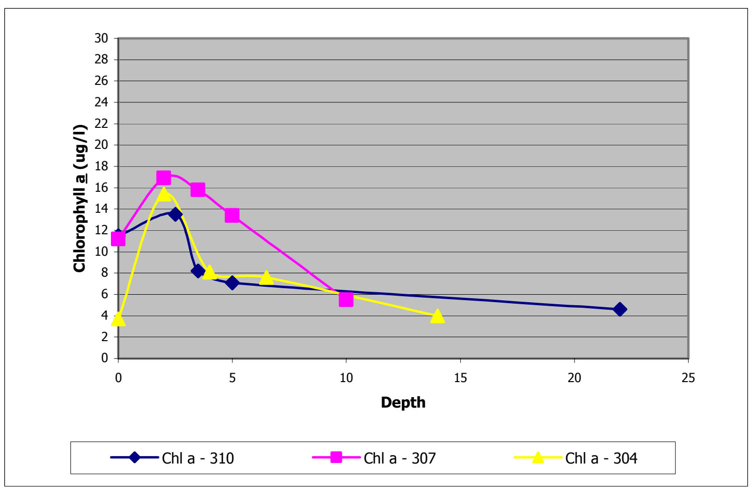
Station	Date	Time	Depth (ft)	Chlorophyll a* (µg/l)
TT307.3E	8/15/2005	927	10	5.5A
TT307.3PZ	8/15/2005	928	Photic Zone Composite	12.2
TT304.5A	8/15/2005	1045	0	3.7
TT304.5B	8/15/2005	1046	2	15.4
TT304.5C	8/15/2005	1047	4	8.1
TT304.5D	8/15/2005	1048	6.5	7.6
TT304.5E	8/15/2005	1049	14	4
TT304.5PZ	8/15/2005	1050	Photic Zone Composite	9.3A

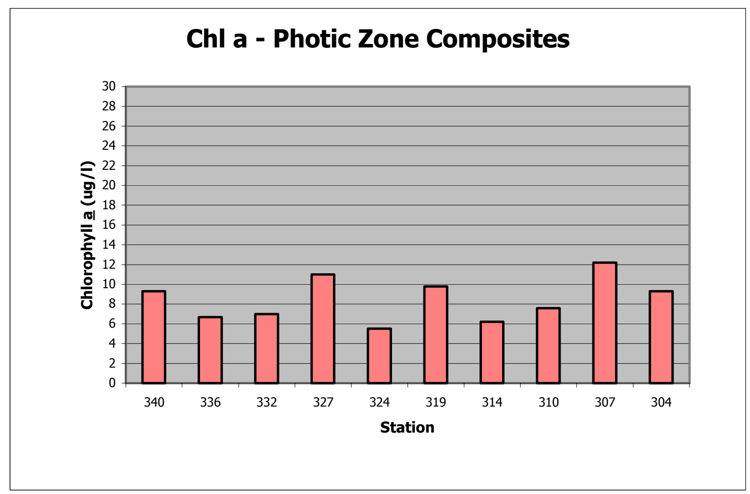
A - Analyte analyzed in replicate. Reported value is average of replicates.
* - Chlorophyll a fluorometer corrected.

Figure 20
Chlorophyll a Data
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005









3.7.4 Quality Assurance/Quality Control

The quality of the sampling methods used to collect the samples was assessed through the use of split, duplicate and blank samples. Table 19 contains a list the quality control samples collected during the study and the analytical results.

Table 19
Quality Control Sample Results
Tenn-Tom Waterway Water Quality Study
Columbus, Mississippi
August 2005

Sample ID	Desc.	Date/Time	Collected By	Ammonia (mg/l)	NO_3-NO_2 (mg/l)	TKN (mg/l)	TP (mg/l)	TDP (mg/l)	TOC (mg/l)
QCPB01	Preservative Blank	08/12/2005 1740	EPA	0.050U	0.050U	0.050U	0.010U	0.011	1.0U
QCPB02	Preservative Blank	08/16/2005 1500	EPA	0.050U	0.050U	0.050U	0.010U	0.010U	1.0U
QCEB01	Rinse Blank	08/13/2005 1030	MDEQ	0.050U	0.050U	0.050U	0.014	0.012	1.0U
QCEB02	Rinse Blank	08/14/2005 1035	ADEM	0.050U	0.050U	0.050U	0.011	0.010U	1.0U
QADIBK	Deinonized Water System Blank	08/16/2005 1556	EPA	0.050U	0.050U	0.050U	0.010U	0.010U	1.0U
QARBCC	Composite Container	08/16/2005 1158	EPA	0.050U	0.050U	0.050U	0.010U	0.010U	1.0U
QCBF01	Filter Blank	08/12/2005 0930	EPA	NA	NA	NA	NA	0.016	NA
Hamilton	Split Sample	08/14/2005 0930	ADEM	0.13	1.5	1.1	2.8	2.8	12
HamiltonS	Split Sample	08/14/2005 0930	ADEM	0.12	1.4	1.1	2.8	2.7	12
WPaper	Duplicate	08/11/2005 1130	MDEQ	2.1	NAI	4.2	1.2	1.0	150
WPaperD	Duplicate	08/11/2005 1130	MDEQ	2.0	NAI	4.0A	1.2	1.0	160
TT314.7	Split	08/16/2005 1255	EPA	0.050U	0.050U	0.54	0.065	0.016	5.0
TT314.7S	Split	08/16/2005 1255	EPA	0.050U	0.050U	0.51	0.063	0.014	5.0
TR3.8	Duplicate	08/12/2005 1050	EPA	0.050U	0.050U	0.79	0.11	0.045	6.2
TR3.8D	Duplicate	08/12/2005 1050	EPA	0.050U	0.050U	0.90	0.11	0.042	12

U – Analyte not detected at or above reporting limit.
A – Analyte analyzed in replicate. Reported value is average of replicates.
NA – Not analyzed.
NAI – Not Analyzed due to Interferences.

In general, the quality of the data generated was acceptable based on the data quality objectives for the study. Some detections were noted in the following blank samples:

- Four of the quality control samples collected to assess the equipment used to collect and process the samples contained low levels of TDP and TP. Sample QCBF01 was a filter blank and contained 0.016 mg/l of TDP, which is slightly above the MQL of 0.010 mg/l for TDP. The sample was collected by passing deionized water through a filter, which came from the same lot as those used to filter the samples collected during the study. This result indicates that there were potentially low levels of phosphorus present on the filters.

- Sample QCPB01 was a preservative blank. It was collected to assess whether the chemicals used to preserve the samples were a source of contamination. QCPB01 contained 0.011 mg/l of TDP, however, TP was not detected in the sample. TP and TDP have the same MQL. Since TDP is a component of TP and there was no TP greater than the MQL, the most likely source of the TDP is the filters. A second preservative blank, QAPB02 was collected in the same manner and no constituents were detected above the analytical reporting limits.

- Samples, QCEB01 and QCEB02, were collected by MDEQ and ADEM, respectively, as rinse blanks from automatic samplers that were used to collect the point source samples. Sample QCEB01 contained 0.014 mg/l of TP and 0.012 mg/l of TDP. QCEB02 contained 0.011 mg/l of TP. The source of the TP in the samples cannot be isolated. However, the concentrations of TP in the quality control samples are much lower than the concentrations detected in the samples collected from the point sources and should not adversely impact the results. The exception was KerrMcGee. Total phosphorus was detected at a concentration of 0.021 mg/l and 0.022 mg/l at KerrMcGee during the two rounds of sampling. The concentrations of TP reported for the KerrMcGee samples should not be utilized due to the uncertainty surrounding the source of the TP in the equipment rinse blanks. The concentration of TDP detected in QCEB01 could again be attributed to the filter used to process the sample.

In summary, though low levels of TP were detected in the two equipment blanks, the TP data from the study should not be adversely impacted with the exception of KerrMcGee. The TP results from KerrMcGee may have been impacted by the sampling equipment.

Split and duplicate samples were collected from the main stem of the river and one tributary and from two point source dischargers. Duplicate samples were collected to address variability within the sampling media.

- Samples TR3.8 and TR3.8D were collected from the Tibbee River. The samples were collected using two separate submersible pumps side by side. The samples were collected into separate compositing containers and then divided among their respective sample bottles. The difference in the results was within acceptable ranges with the exception of TOC. One sample contained 6.2 mg/l and the other contained 12 mg/l. This is a difference of 48%. This is similar to the difference in TOC concentration measured at station TT324.4 during sampling rounds one and two. The source of the differences cannot be established for either set of samples. However, when comparing the differences in concentrations of the other constituents in the duplicate samples collected from TR3.8, there is little variation. Based on the similarity of the concentrations of the other constituents, the sampling method that was used resulted in the collection of representative samples.

- The second duplicate sample was collected from the discharge at the Weyerhaeuser Paper Company. The sample was collected using two automatic samplers. The largest variance within the results of the two samples was 6%. This demonstrates that the sampling method utilized resulted in a representative sample.

- Table 19 shows the variation of the results for the split samples collected from station TT314.7 and the Hamilton POTW were nominal. This indicates that the sample handling procedures resulted in representative samples.

No constituents which were analyzed for were detected in samples QADIBK and QARBCC. Sample QADIBK was a water sample collected from the portable deionized water generating system used by EPA for decontaminating equipment while in the field. The analytical results show that no contamination was introduced into the samples collected during the study from the deionized water used for equipment cleaning. Sample QARBCC was a rinse blank conducted on one of the composite containers that was used for collection of the samples in the river and tributaries. The samples were pumped into the container, homogenized by swirling the container, and then divided into the sample bottles. The composite container was rinsed with deionized water between sample stations. The analytical results from sample QARBCC show that no contamination was introduced into the samples by the compositing container.

3.7.5 Data Validation/Verification

Samples were analyzed and the results verified by the U.S. EPA, Region 4, SESD, Analytical Support Branch in accordance with the policies and procedures outlined in the Analytical Support Branch Laboratory Operations and Quality Assurance Manual, October 2005.

4.0 Conclusions

The primary objective of this study was to collect a representative set of water quality and hydraulic data associated with the reach of interest during critical conditions of low flow and high temperature. The study was conducted within the critical condition criterion. Average flow measured by EPA during the study was approximately 1,840 cfs. The average daily flow for the study period measured by the USGS during 88 years of record is 1,540 cfs. The average monthly flow for August as measured by the USGS since 1985 when the Tenn-Tom Waterway opened for navigation is approximately 1,836 cfs. The average yearly flow based on data obtained from the USGS is approximately 6,860 cfs. When compared to the USGS records of flow, the flow measured during the study period was very similar to that recorded since navigation began on the Tenn-Tom Waterway and was a great deal less than the yearly average flow of 6, 860 cfs.

As stated in the quality assurance project plan for the study, the data was collected to: 1) determine if a dissolved oxygen deficit existed within the study reach and if so, document the extent and severity, 2) determine if the system was stratified and whether a steady-state or dynamic model would be appropriate, and 3) either enhance the results of the existing steady-state model results or to assist in the construction of a dynamic model. It is expected that the EPA, Region 4, Water Management Division will use the data and information in this report in its evaluation of a TMDL to address the CWA § 303 (d)-listed segment of the Tenn-Tom Waterway.

Mild dissolved oxygen stratification existed throughout the system. The trend was more pronounced downstream of station TT324.4. Temporal variations in river currents and vertical variations in water quality on the scale of this synoptic survey should be considered in the determination of an appropriate modeling framework. The data collected during this study is sufficient to enhance the existing QUAL2E model or assist with the construction of a dynamic model.

Another factor that should be considered within the system is the emerging issue of invasive plant species. Water hyacinth and bulrush are becoming increasingly problematic. Navigation has been impeded due to their proliferation. The U.S. Army Corp of Engineers has utilized aerial and boat spraying of herbicides to control the plant growth. The affects of the plant growth and subsequent spraying upon water quality within the system are unknown.

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