

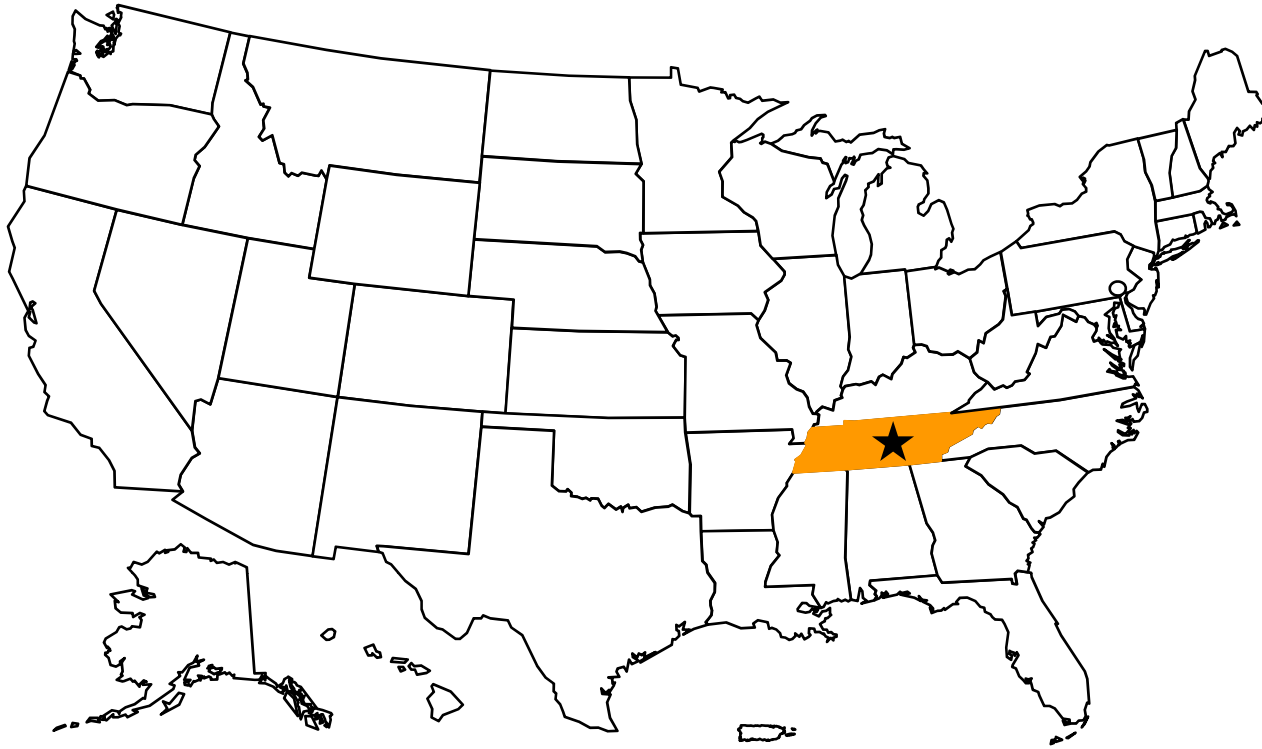
Assimilative Capacity of Rivers, Lakes and Estuaries

Global Water Environment
Water Environment Federation Group
People to People Citizen Ambassador Program

Michael R. Corn, P.E.

AquAeTer, Inc
Brentwood, TN





Grand Ole Opry
Home of Country Music

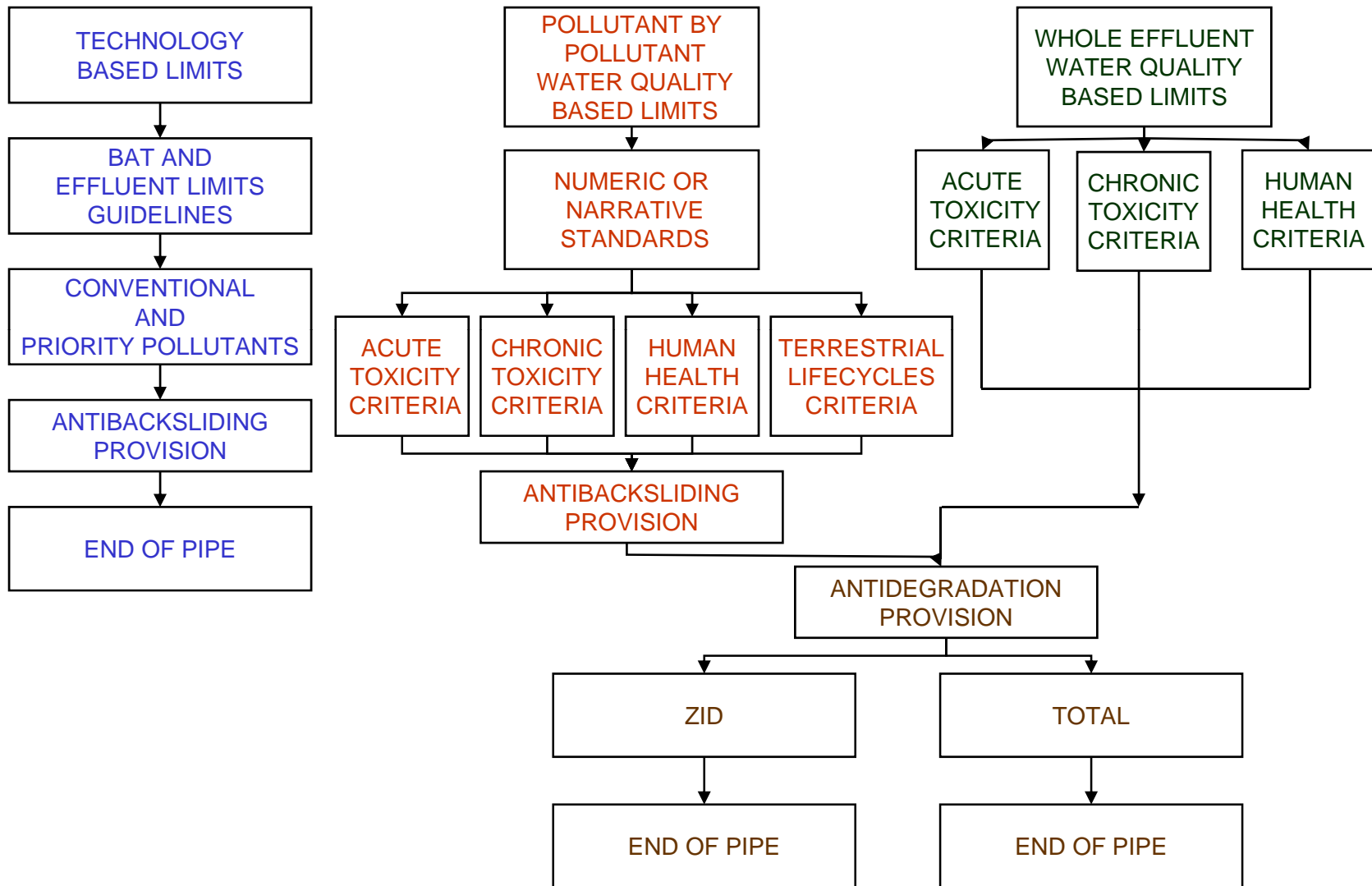


Beech Grove near
Nashville, Tennessee



CLEAN WATER ACT OF 1987

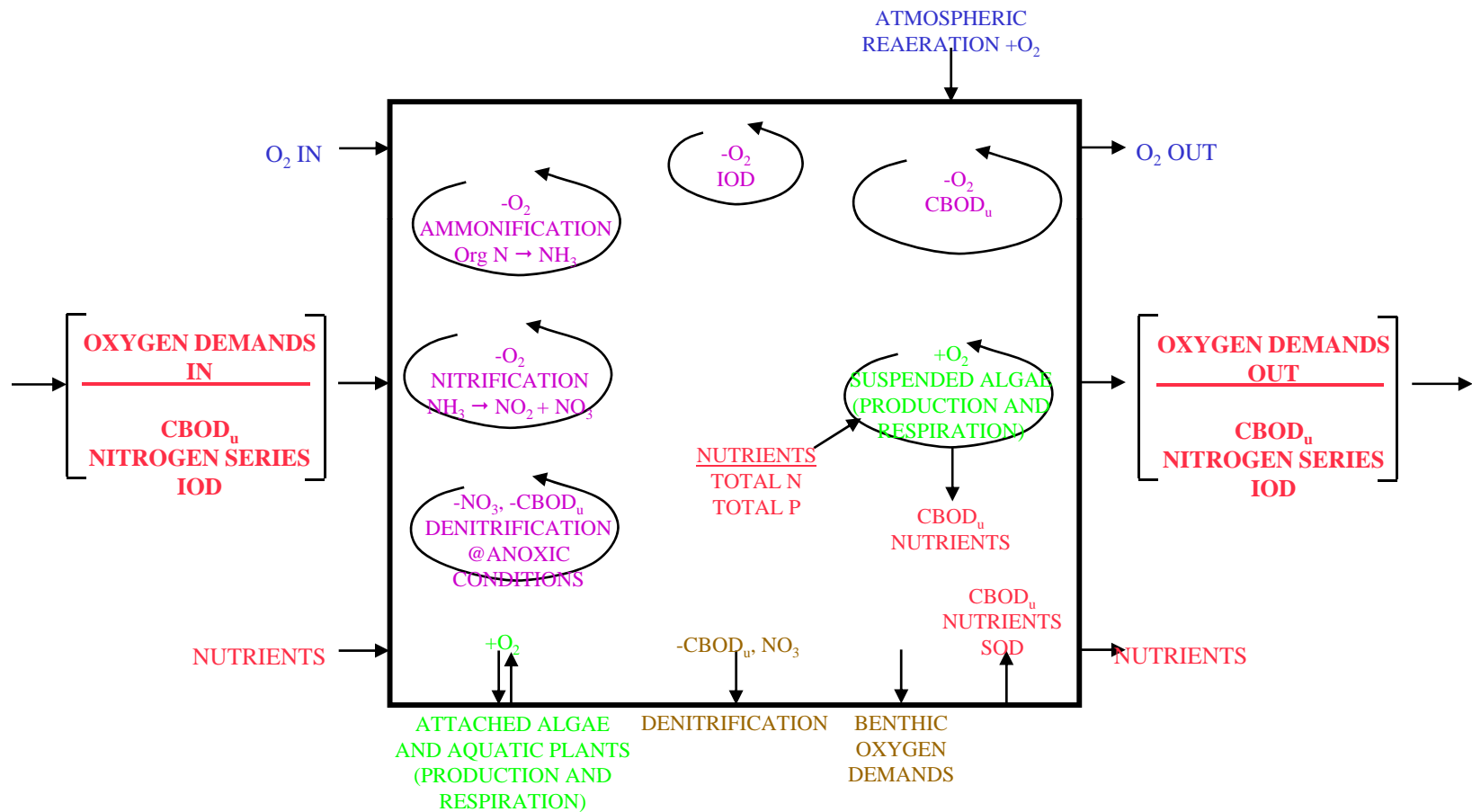
WATER QUALITY-BASED TOXICS CONTROL



Impacts to Receiving Stream Water Quality from Municipal and Industrial Discharges

- **Typical impairments identified downstream from Discharges**
 - DO standard not being met
 - Nutrient enrichment (DO sag or nuisance algal blooms)
 - Metals (typically Hg, Pb, As, Cu)
 - Dioxins
 - Sedimentation (silvicultural activities)
 - Other Toxins – Carcinogens, Non-Carcinogens, Teratogens

Schematic of the Oxygen Balance Calculations In QUAL2E



$$O_2 \text{ BALANCE} = \text{ASSETS} - \text{LIABILITIES} = DO - \text{OXYGEN DEMANDS}$$

Primary Data Requirements for Determining Assimilative Capacity

1. **Statistical Flow and Temperature Scenarios**
2. **River Hydraulics**
3. **Background Water Quality Conditions**
 - a) Time of travel
 - b) bathymetry
4. **Effluent Variability and Characteristics**
 - a) Flows
 - b) Quality
5. **Oxygen Rates (per day)**
 - a) Atmospheric Reaeration Rate
 - b) Algal Productivity and Respiration
6. **River Deoxygenation Rates (per day)**
 - a) Ultimate Carbonaceous Biochemical Oxygen Demand (CBOD_u) decay rate
 - b) Organic nitrogen decay rate
 - c) Ammonia nitrogen decay rate
 - d) Sediment oxygen demand
7. **Calibration/Verification Modeling**
8. **Predictive Modeling to Establish Wasteland Allocations**

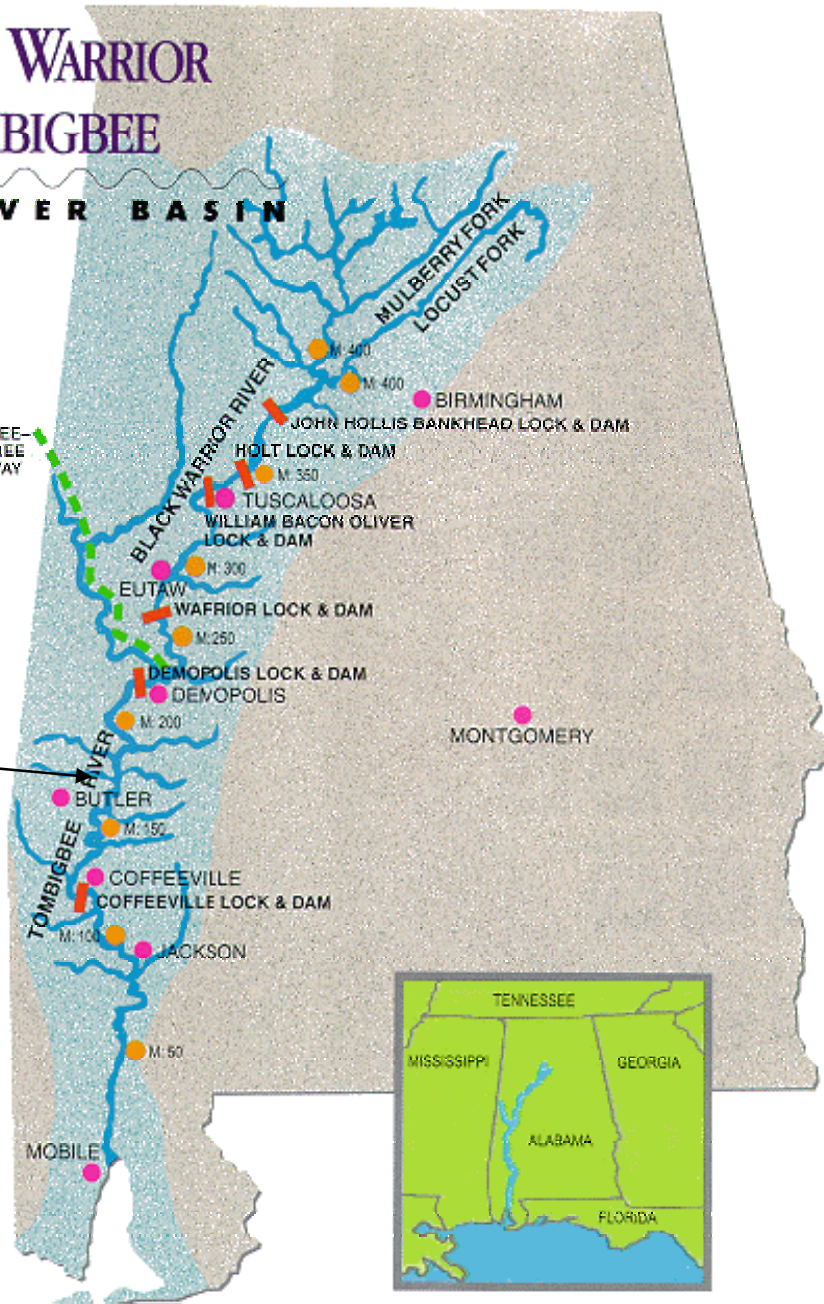


BLACK WARRIOR & TOMBIGBEE

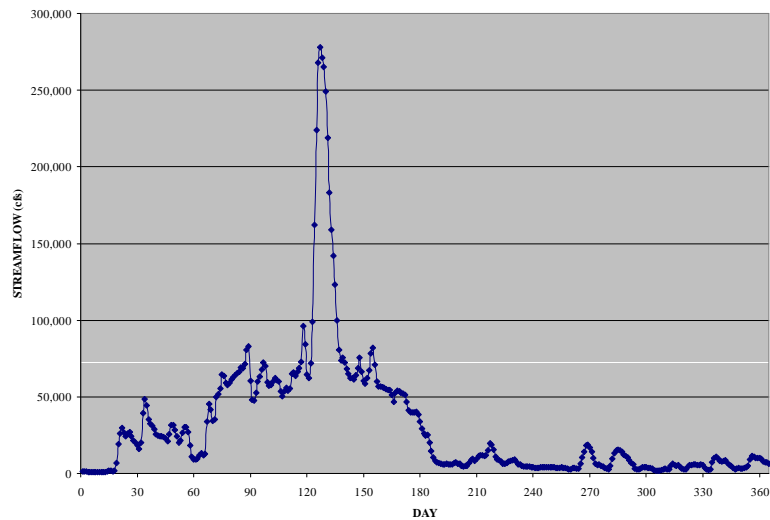
RIVER BASIN

Georgia-Pacific
Naheola Mill
near Pennington, Alabama

- LAKE & RIVER SHORELINE
- LOCK & DAM SITES
- CITIES & TOWNS
- MILEAGE



Mean Daily Stream Flow Red River at Dekalb, Texas



Note: 1 cubic foot per second (cfs) ~
0.028 cubic meters per second (cms)



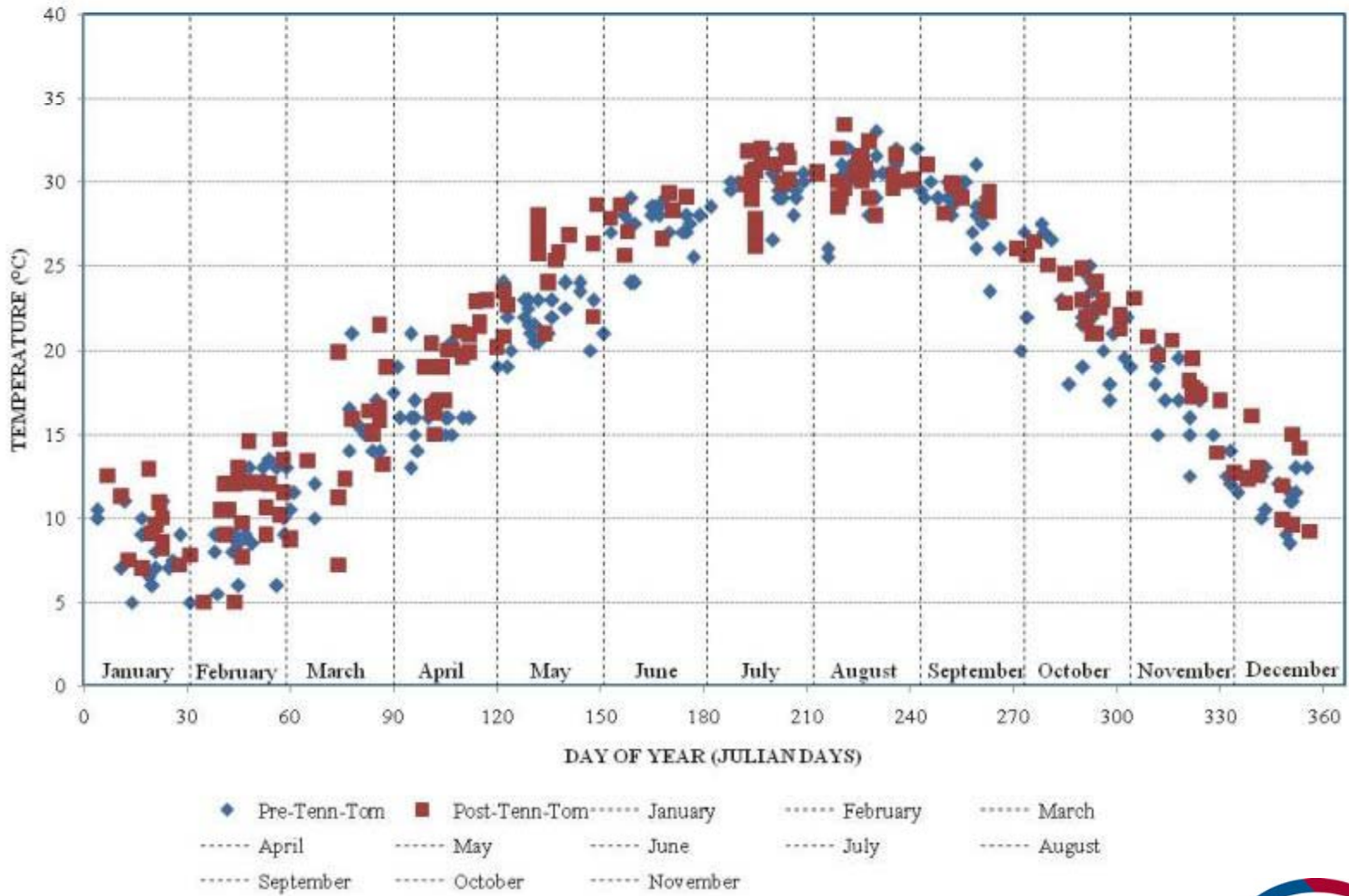
Calculation of 7Q10 for September

DEMOPOLIS			COFFEEVILLE		
RECURRENCE	YEAR OF OCCURRENCE	MINIMUM 7-DAY AVERAGE FLOW	RECURRENCE	YEAR OF OCCURRENCE	MINIMUM 7-DAY AVERAGE FLOW
(yrs)		(cfs)	(yrs)		(cfs)
24.0	2007	1,336	24.0	1999	1,450
12.0	2000	1,391	12.0	2007	1,736
10.0		1,531	10.0		1,774
8.0	1987	1,670	8.0	1995	1,813
6.0	2006	1,767	6.0	2000	1,846
4.8	1999	1,804	4.8	2006	2,007
4.0	1995	1,830	4.0	1987	2,057
3.4	2002	2,153	3.4	1998	2,339
3.0	1990	2,157	3.0	1990	2,386
2.7	1998	2,264	2.7	2002	2,749
2.4	1986	2,987	2.4	1986	3,443
2.2	1985	3,019	2.2	1985	3,753
2.0	1988	3,120	2.0	1997	3,991
1.8	1991	3,337	1.8	1991	4,170
1.7	1997	3,351	1.7	1993	4,457
1.6	1993	3,667	1.6	1989	4,507
1.5	2003	3,759	1.5	1994	4,549
1.41	1989	4,067	1.41	2004	5,333
1.33	1996	4,370	1.33	1992	5,619
1.26	2004	4,383	1.26	1996	5,996
1.20	2005	4,579	1.20	2001	6,096
1.14	1994	4,686	1.14	2005	6,217
1.09	2001	4,797	1.09	1988	6,289
1.04	1992	5,571	1.04	2003	9,334



Monthly Temperatures

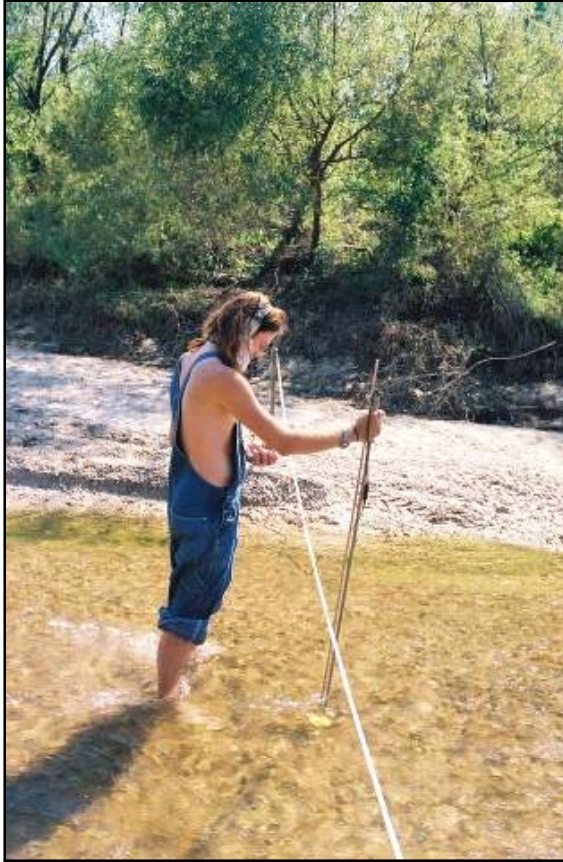
TOMBIGBEE RIVER TEMPERATURE DATA
Data Collected by USGS between Demopolis and Coffeeville



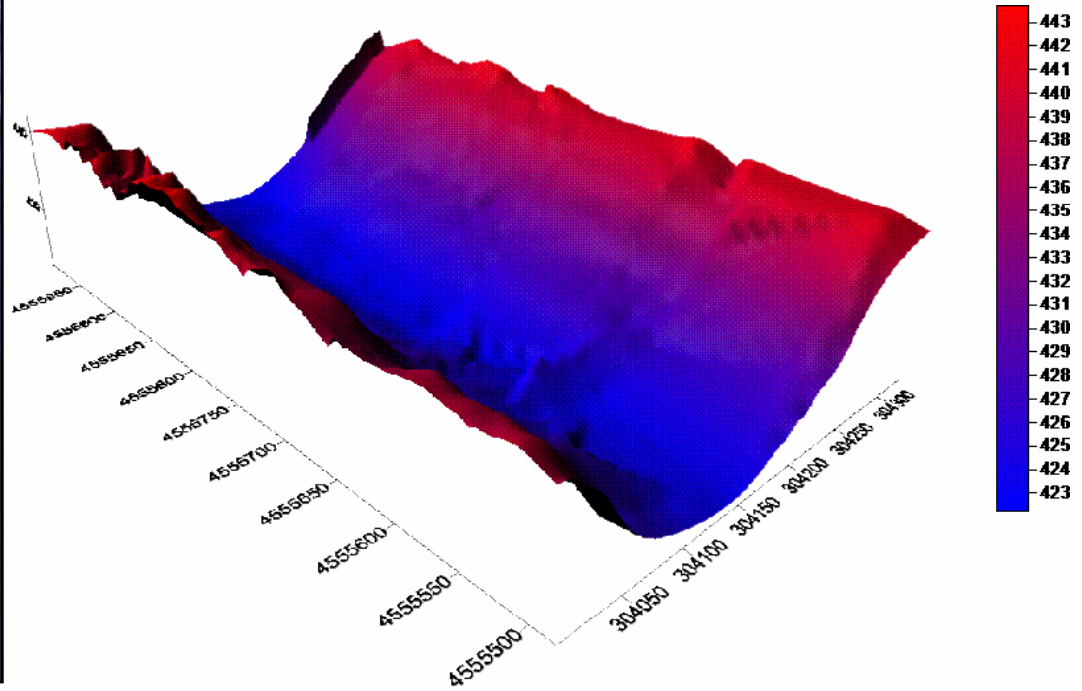
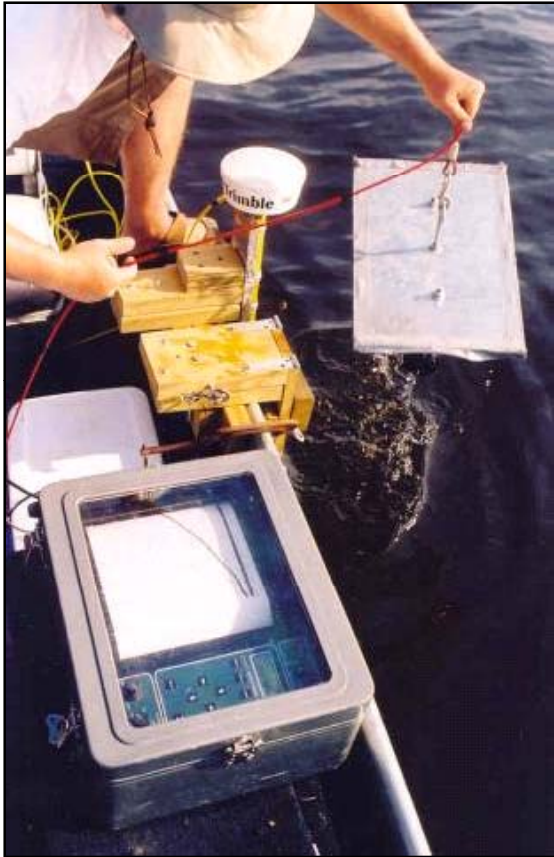
Flow and Temperature

MONTH	DEMOPOLIS LOCK & DAM (cfs)	COFFEEVILLE LOCK & DAM (cfs)	90TH PERCENTILE TEMPERATURE (°C)
JAN	7,192	9,037	11.0
FEB	12,183	14,314	13.5
MAR	7,456	8,121	16.5
APR	5,199	6,220	21.5
MAY	2,291	2,572	26.7
JUN	2,198	2,802	28.6
JUL	2,460	2,885	32.0
AUG	1,627	1,681	31.5
SEP	1,531	1,774	30.0
OCT	907	1,257	26.3
NOV	1,267	1,736	19.9
DEC	2,857	3,791	13.0

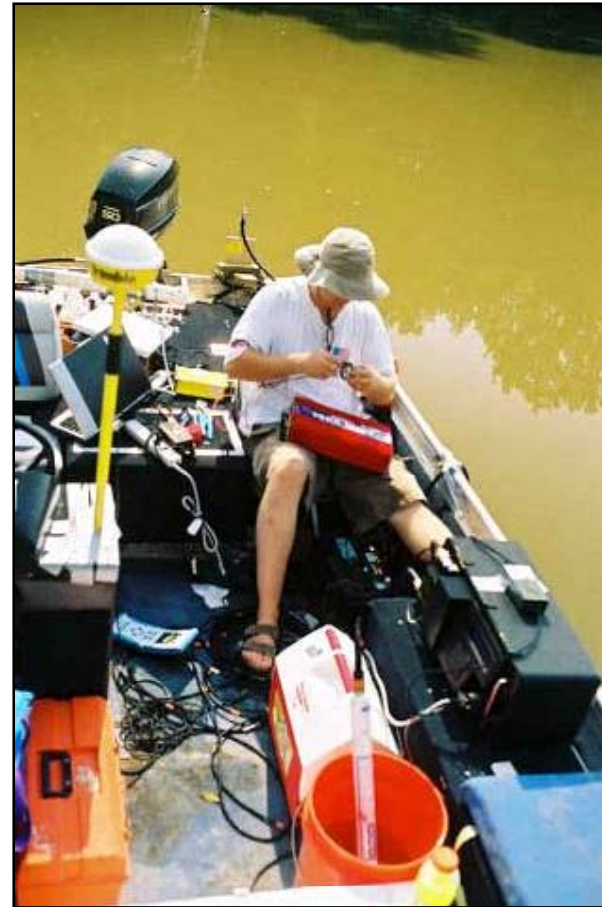
Flow and Velocity Measurements



Bathymetry

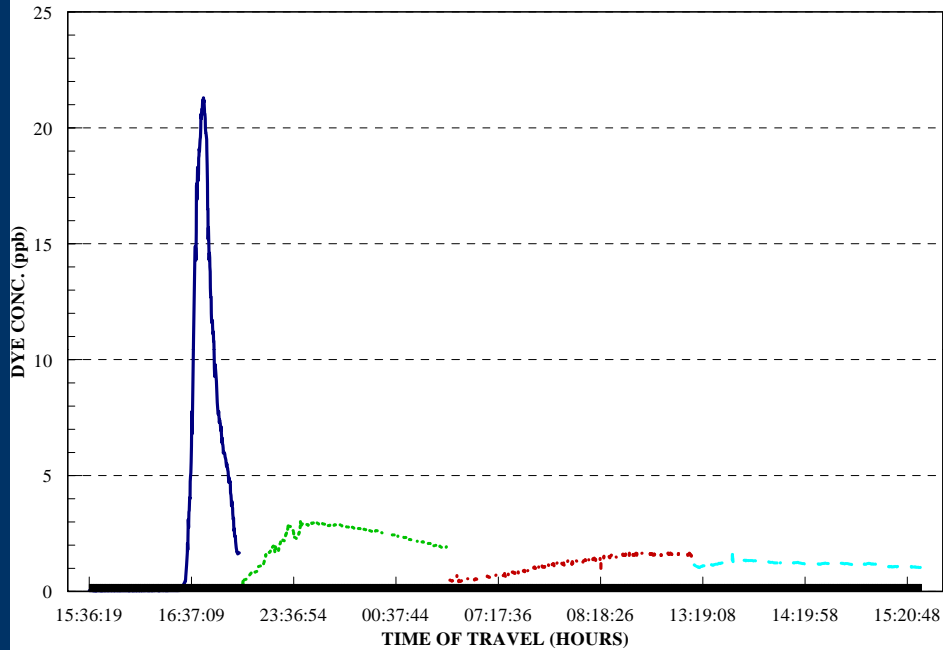


Dye Time of Travel



Dye Time of Travel Calculations

RIVER TIME OF TRAVEL STUDY
RRM 461 TO RRM 431.5

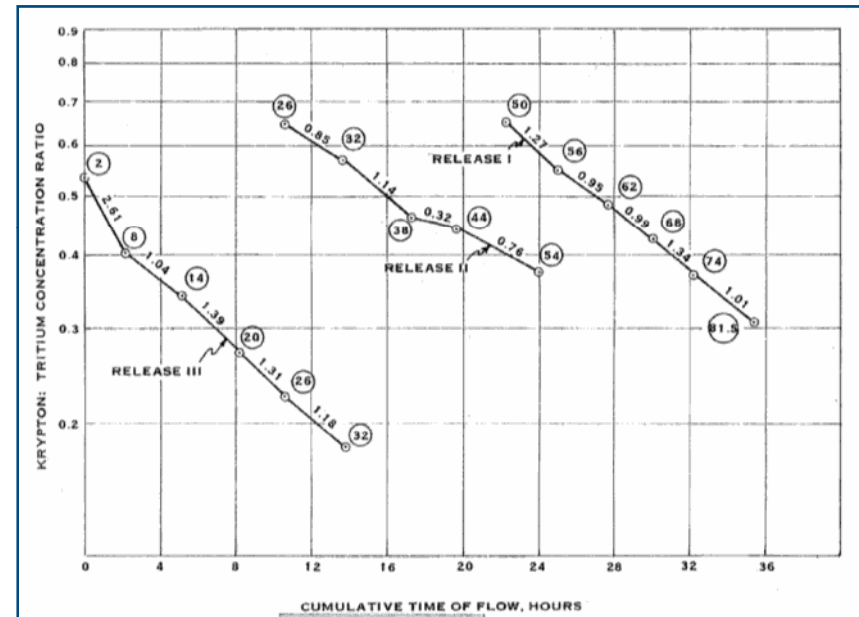
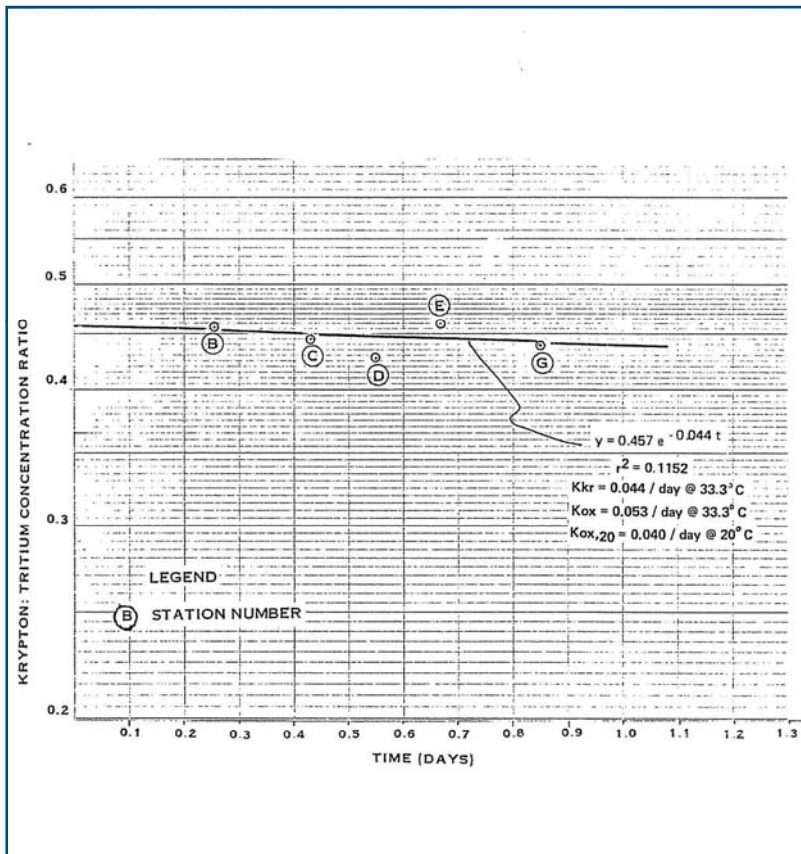


STUDY PERIOD 10/21/96 TO 10/22/96

STATION NO.	RRM	DISTANCE BETWEEN STATIONS (mi)	PEAK TIME OF TRAVEL (hrs)	AVERAGE TIME OF TRAVEL (hrs)	TIME BETWEEN STATIONS (hrs)	AVERAGE VELOCITY BETWEEN STATIONS (ft/sec)
0	461	0.0	0.00	0.00	0.00	0.00
1	459.4	1.6	1.74	1.78	1.78	1.32
2	450	9.4	8.83	9.18	7.4	1.86
3	437	13	17.97	21.24	12.06	1.58
4	431.5	5.5	22.73	27.37	6.13	1.32



Ouachita River and Black Creek Radiotracer Reaeration Measurements



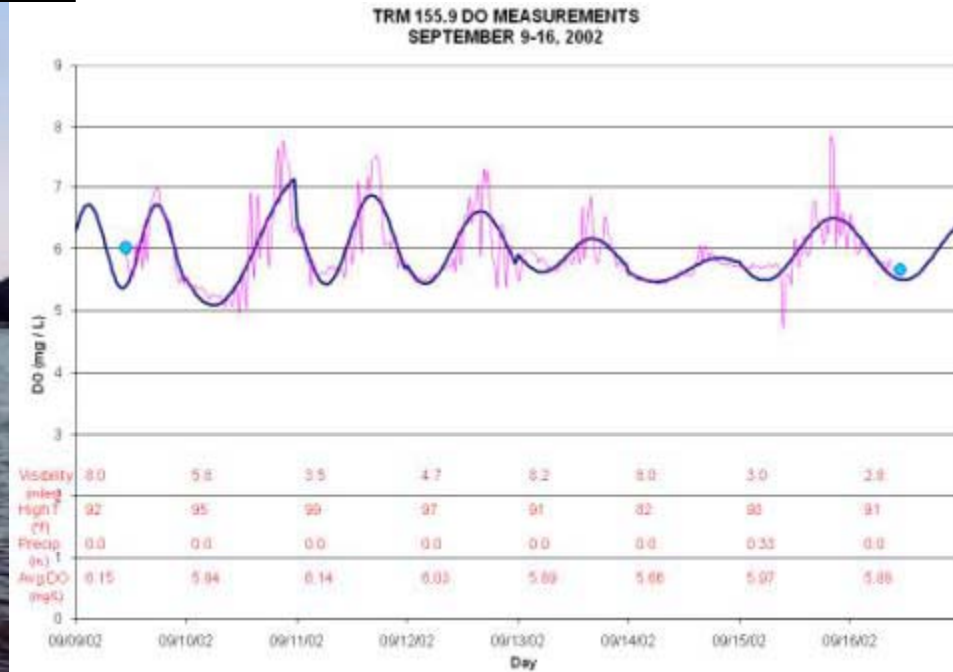
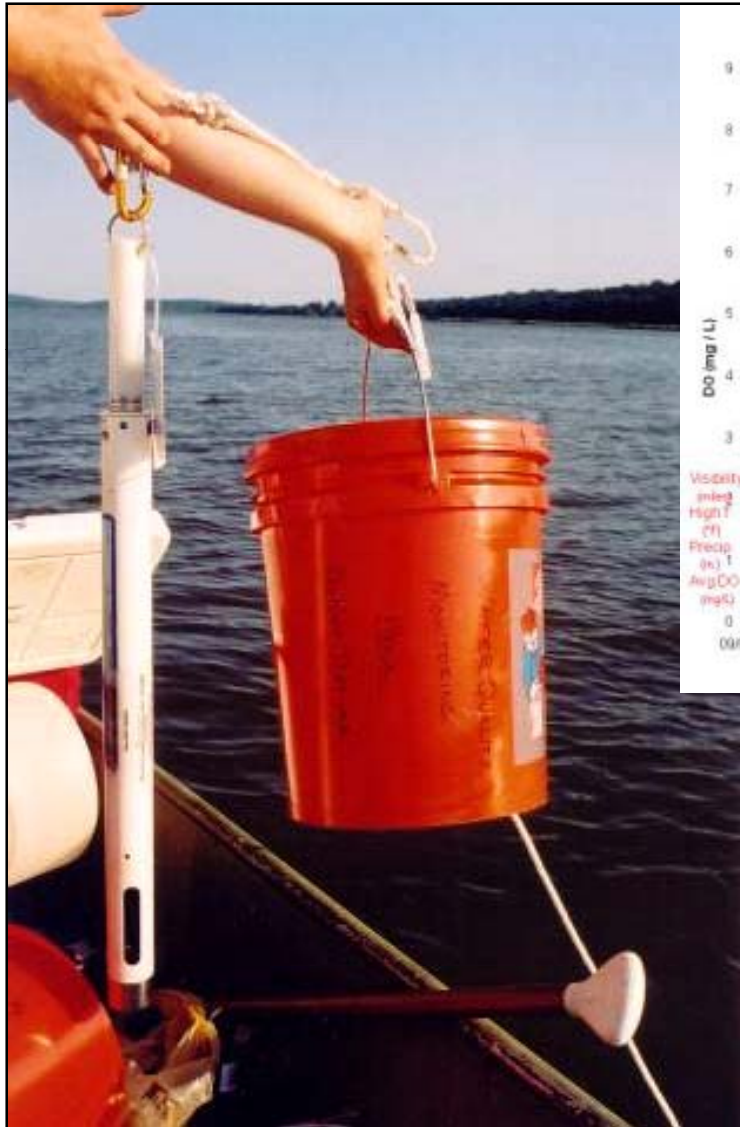
Comparison Between Measured and Calculated Reaeration Coefficients

SAN GABRIEL RIVER

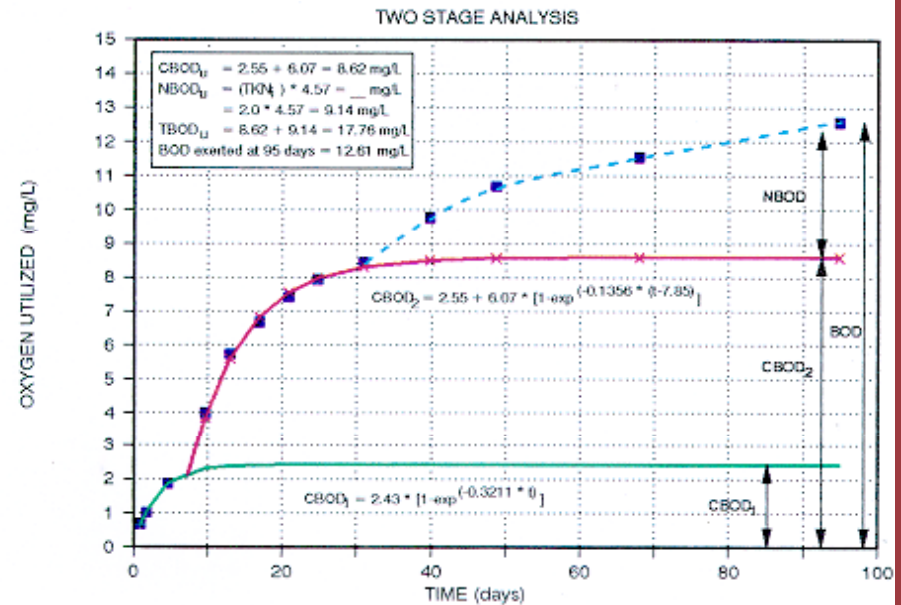
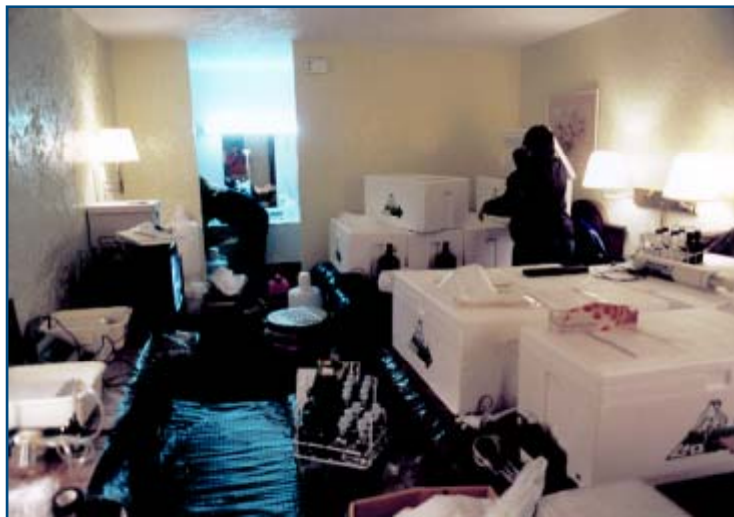
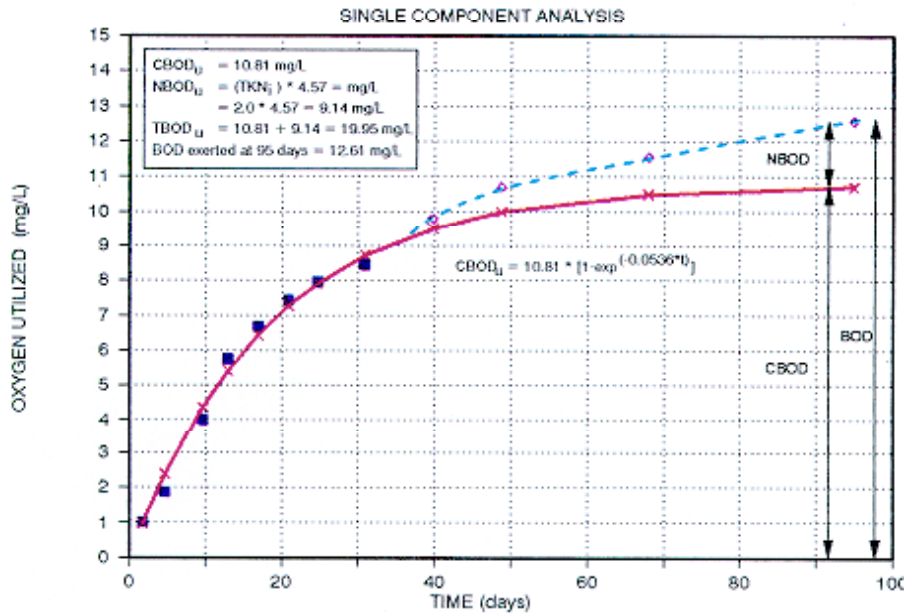
STREAM REACH	FIELD MEASURED VALUES			EMPIRICAL PREDICTIONS OF K_2			
	DEPTH (feet)	VELOCITY (fps)	REAERATION RATE (K_2)	O'CONNOR	OWENS	CHURCHILL	LANGBIEN
1	0.375	0.0620	4.194	14.050	20.700	4.040	1.750
2	0.706	0.0490	2.890	4.810	5.450	1.020	0.028
3	0.620	0.0530	2.840	6.080	7.310	1.370	0.763
4	1.700	0.0096	0.277	0.573	0.361	0.053	0.036
5	0.860	0.0450	1.950	3.580	3.580	0.670	0.420
6	0.440	0.0620	2.817	11.000	15.310	2.830	1.408
BRUSHY CREEK							
1	1.140	0.4300	1.500	6.950	9.630	4.010	2.750
2	1.280	0.4000	1.380	5.630	7.400	7.400	2.260
3	1.420	0.3300	1.250	4.380	5.370	5.370	1.580



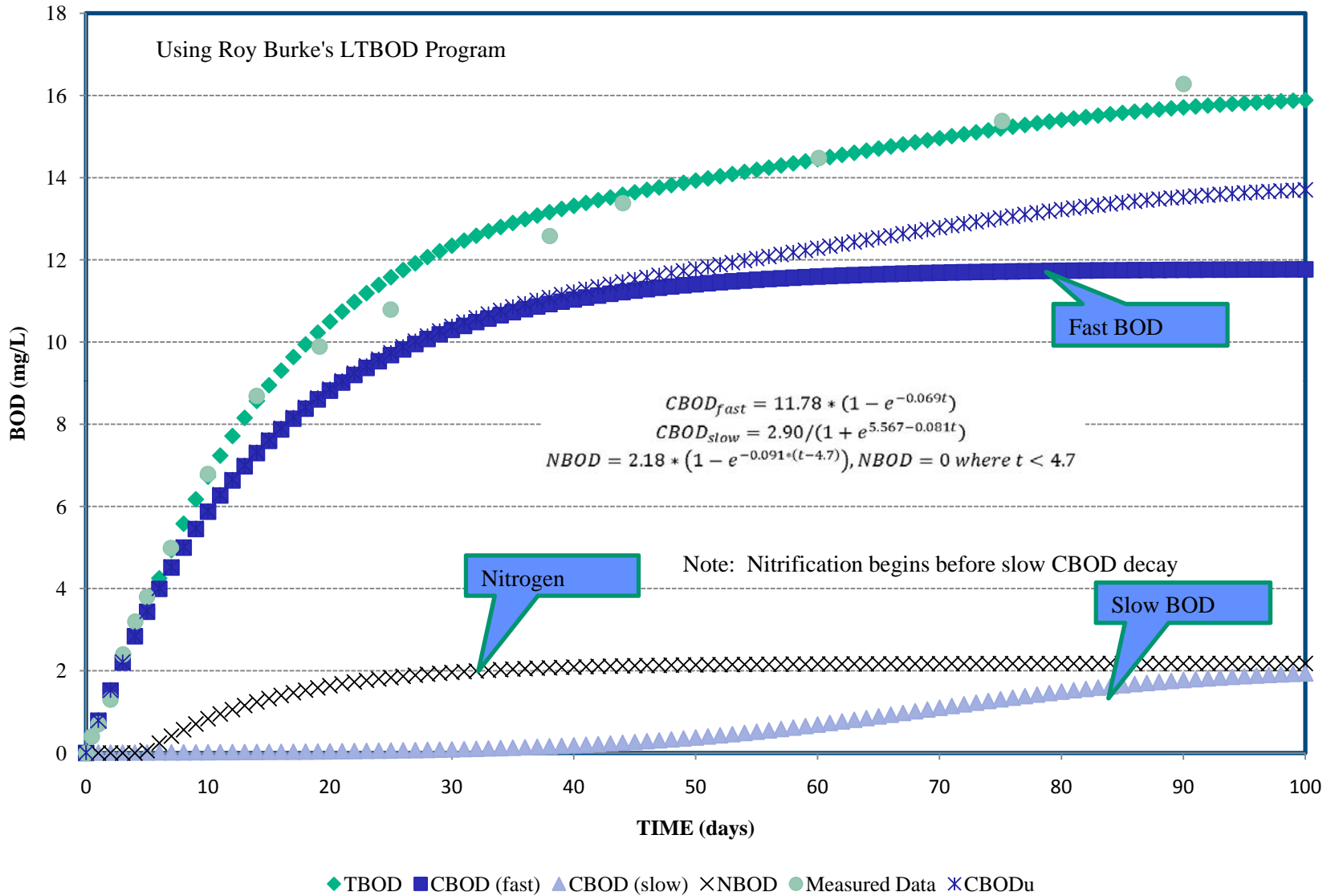
Water Quality and Dissolved Oxygen (DO) Results (Fixed Station Diurnal DO)



Time-Series BOD Analysis



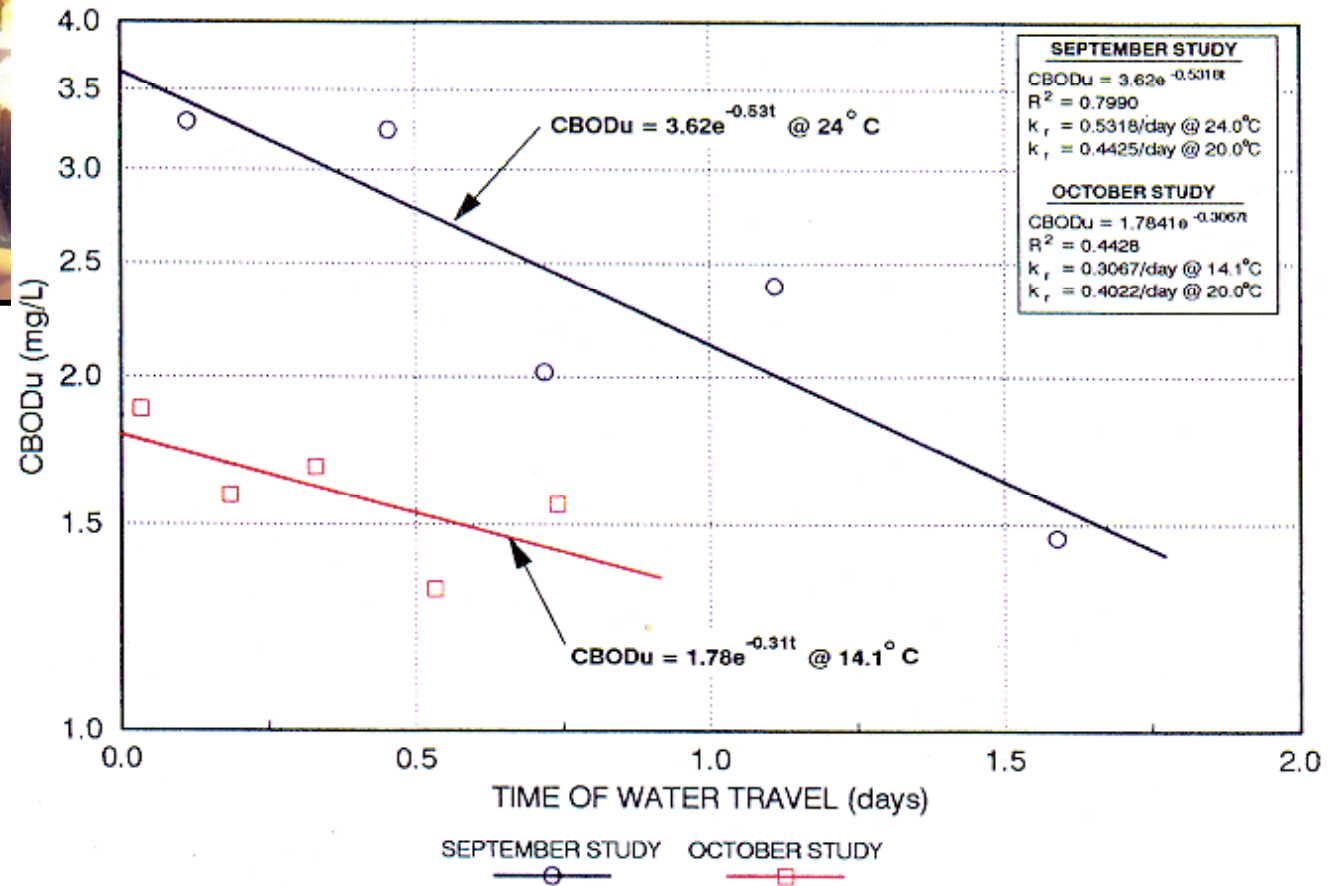
BOD ANALYSIS - MILL MIXED WITH BACKGROUND RIVER WATER



Determination of River CBOD_u Deoxygenation Rate



Note: Calibration
 $k_r = 0.44/\text{day}$
 Verification
 $k_r = 0.40/\text{day}$



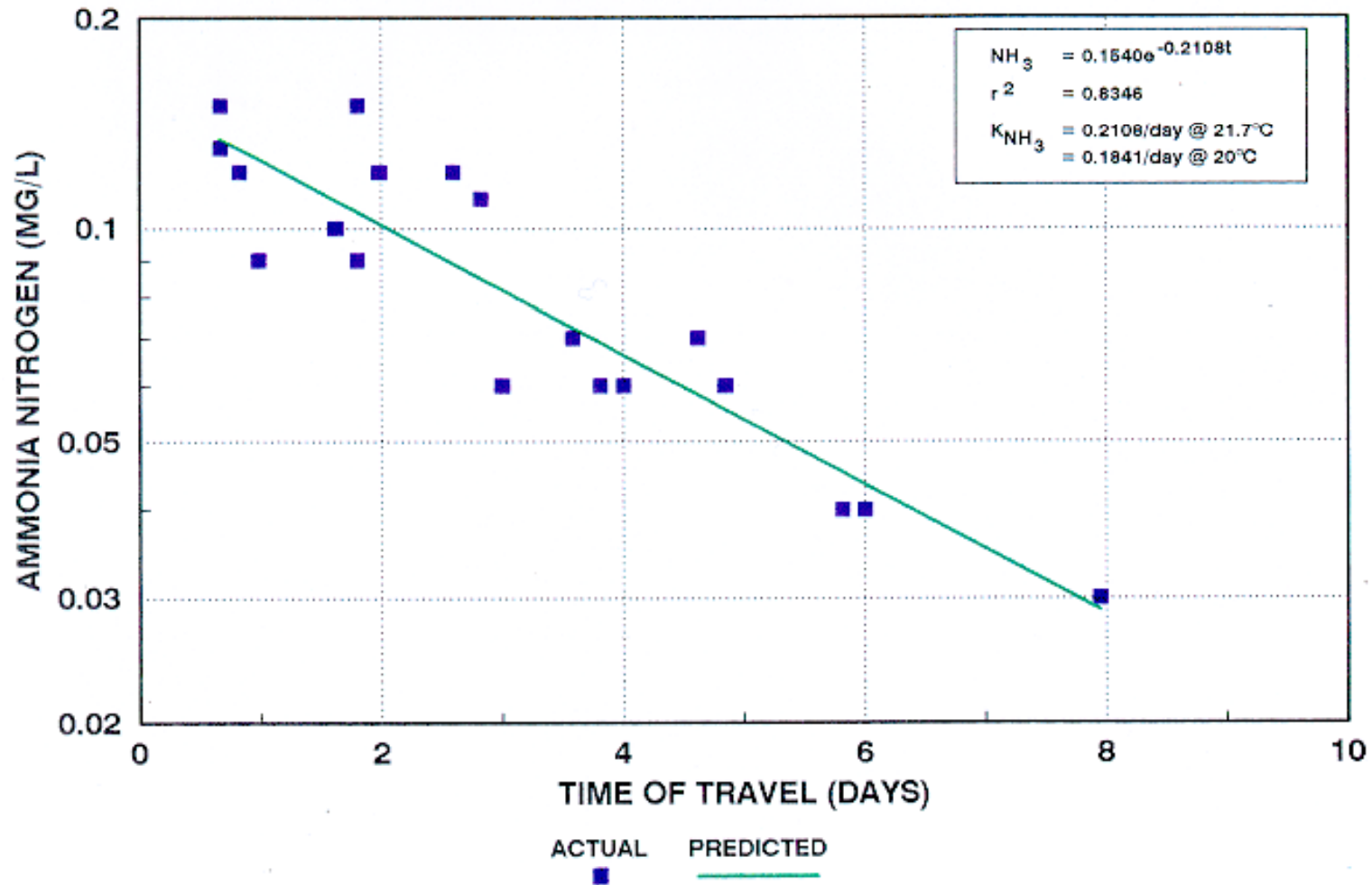
Actual CBOD_u River Rates Measured with Time of Travel



- ◆ Red River 1990
- RR 1990 Predicted Rate
- ▲ Arkansas River 2003
- - AR 2003 Rate
- ✱ Pearl River 2005
- · - PR 2005 Rate
- + Paint Creek 1981 Calibration
- Paint Creek 1981 Verification
- ◇ W. Fork Stones River Sep-90
- - WFSR Sep-90 Rate
- W. Fork Stones River Oct-90
- WFSR Oct-90 Rate
- Duck River 1986
- - DR 1986 US WTF Rate
- DR 1986 DS WTF Rate



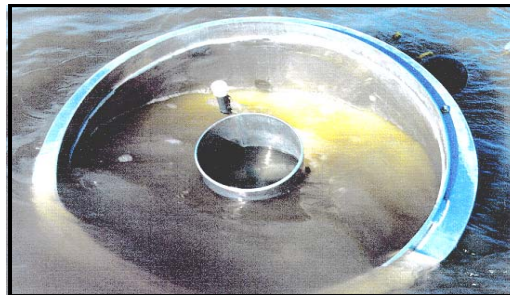
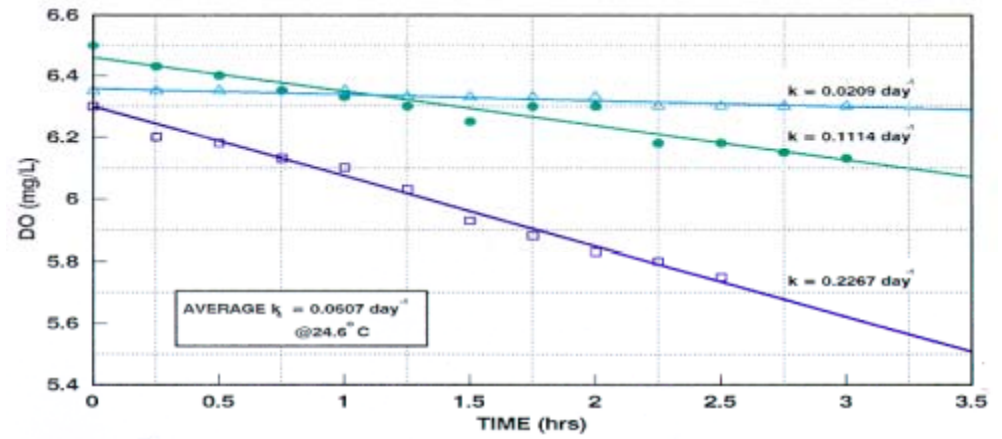
Ammonia Nitrogen Decay with Dye Time of Travel



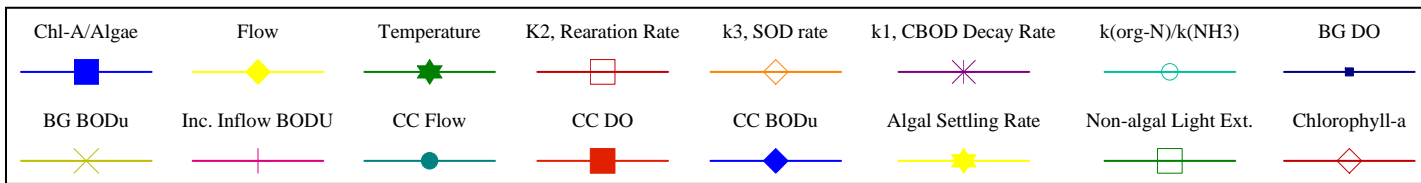
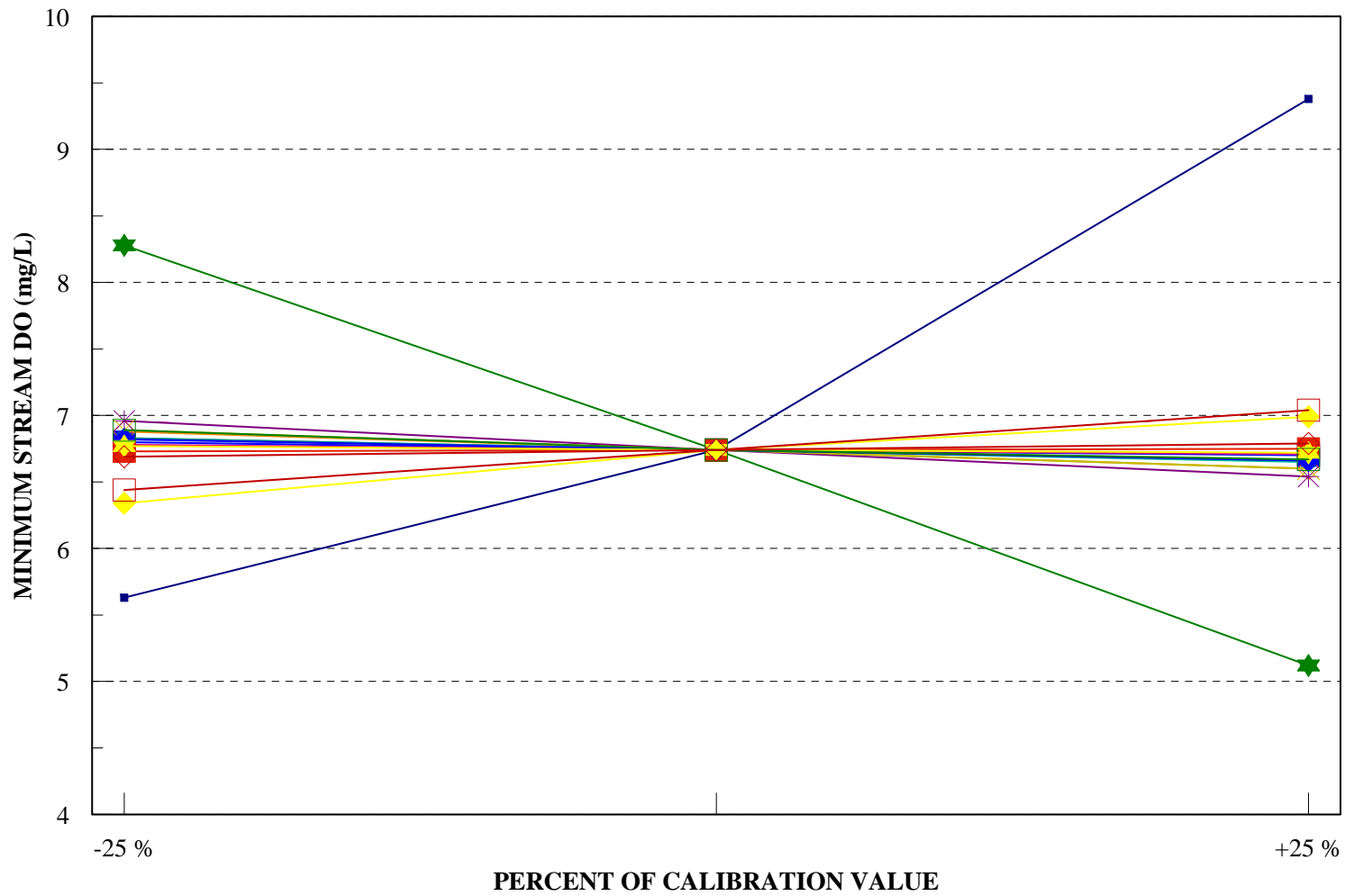
Recalcitrant Organic Nitrogen

DESCRIPTION	ORGANIC NITROGEN BY TKN DETERMINATION			ORGANIC NITROGEN BY NITRATE DETERMINATION		
	LABILE (mg/L)	RECALCITRANT		LABILE (mg/L)	RECALCITRANT	
		(mg/L)	(%)		(mg/L)	(%)
Background Pearl River	0.38	0.98	72	0.31	1.04	77
90:10 Mix, Day 1	0.87	0.80	48	0.76	0.91	55
TOT 1 a	0.57	1.18	68	0.66	1.08	62
TOT 1 b	0.96	0.79	45	0.56	1.18	68
Fair River	-	-	-	-	-	-
TOT 2	0.56	0.62	52	0.47	0.71	60
TOT 2 - Duplicate	0.19	0.75	80	0.55	0.39	42
Background Pearl River	0.07	0.53	88	0.38	0.22	37
TOT 3	0.37	0.61	62	0.50	0.48	49
TOT 4	0.37	0.71	66	0.51	0.57	53
90:10 Mix, Day 2	0.01	0.98	99	0.73	0.25	26
90:10 Mix, Day 2*	0.24	0.98	80	0.73	0.49	40
TOT 5 a	0.51	0.67	57	0.48	0.70	60
TOT 5 b	0.60	0.58	49	0.46	0.60	57
TOT 6	0.50	0.58	53	0.47	0.61	57
TOT 6 - Duplicate	0.54	0.64	54	0.48	0.70	60
Effluent, Day 1**	3.91	3.59		3.41	4.09	
Effluent, Day 2**	0.03	6.57		4.92	1.68	
Effluent, Day 2***	1.32	5.28		3.93	2.67	

SEDIMENT OXYGEN DEMAND

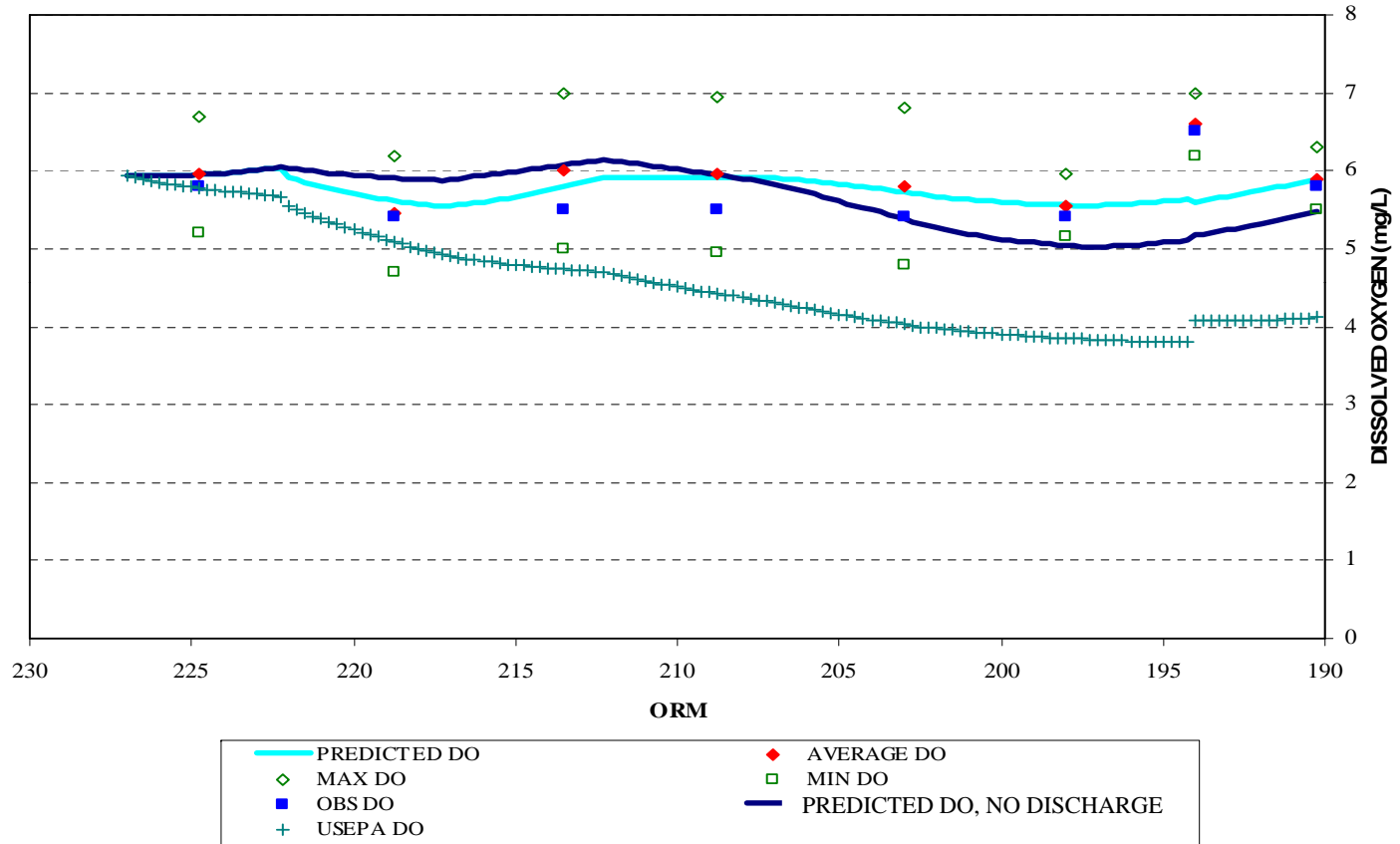


QUAL2E Sensitivity Analyses



Ouachita River Calibration Model

AUGUST 27, 1998 CALIBRATION MODEL
OUACHITA RIVER NEAR CROSSETT, AR



Monthly BOD₅ Loadings

Ouachita River Downstream from Coffee Creek

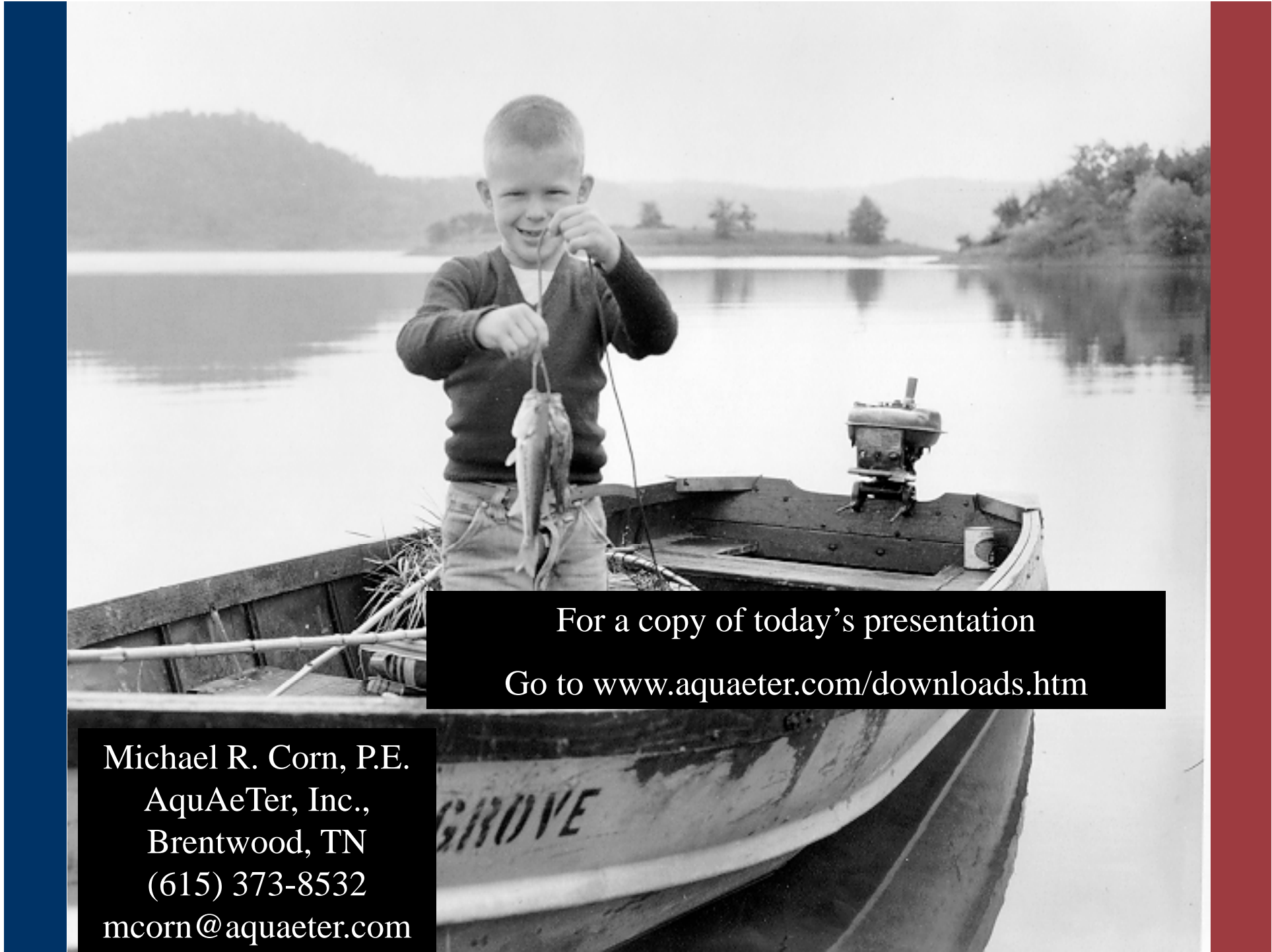
MONTH	7Q10 (cfs)	90 th PERCENTILE WATER TEMPERATURE (°C)	WLA BOD ₅ (lbs/day)	PERMIT BOD ₅ (lbs/day)
January	2,658	<18	53,539	8,000
February	5,269	<18	102,142	8,000
March	4,037	<18	79,435	8,000
April	2,436	25.1	24,614	8,000
May	1,591	26.5	21,591	8,000
June	1,049	31.0	22,706	8,000
July	894	31.9	14,605	8,000
August	802	31.6	8,069	7,262
September	829	29.8	6,568	5,911
October	822	25.1	10,423	8,000
November	1,231	18.0	25,888	8,000
December	2,059	<18	42,071	8,000

Note: CBOD_u/BOD₅ = 4



Water Quality Models

- **DO**
 - QUAL2E – Steady-state
 - WASP with EFDC – Dynamic; Rivers, Lakes, or Estuaries
 - CE-QUAL– Dynamic; Reservoirs
 - RIVI – HYD and WQ – Dynamic; Reservoirs
- **Nutrients**
 - WASP
 - CE-QUAL
 - HSPF – Hydrological Simulation Program; hydrology and water quality
- **Metals/dioxins/organics**
 - WASP- Contaminate fate & transport; Water and sediments
 - EXAMS – Fate, transport, and exposure concentrations
 - HSPF
 - FGETS – Fish uptake model
- **Sediments**
 - HSCTM2D – Hydrodynamic sediments and contaminant transport
 - USLE – Universal Soil Loss Equation
 - HEC–6 – Scour and deposition in reservoirs and rivers



For a copy of today's presentation
Go to www.aquaeter.com/downloads.htm

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