1.5

EXHIBIT E

BLACKSTONE RIVER WATERSHED

DISSOLVED OXYGEN WASTELOAD ALLOCATION

for

MASSACHUSETTS AND RHODE ISLAND

(NOVEMBER 1997)

Coordinated Effort by the USEPA, MADEP and RIDEM

Model developed by Dr. Raymond Wright
University of Rhode Island

INTRODUCTION:

The purpose of a wasteload allocation (WLA) is to establish effluent discharge limits for point sources in a given watershed that will ensure compliance with water quality standards. This WLA addresses dissolved oxygen (DO) and eutrophication concerns in the Blackstone River. The pollutants targeted in the WLA include biochemical oxygen demand (BOD), ammonia (NH_3), and phosphorus (P). The discharges affected by this WLA include two large municipal wastewater treatment facilities (WWTFs), Upper Blackstone Water Pollution Abatement District (UBWPAD) and Woonsocket, and four smaller municipal WWTFs, Millbury, Grafton, Northbridge, and Uxbridge. Municipal treatment plants discharging to large tributaries to the Blackstone River were determined to have a minor impact on water quality in the main stem of the river and were not included in this WLA. Limits have been established separately for these facilities to ensure that water quality standards are achieved in the tributaries.

This WLA is based on a DO model developed by the University of Rhode Island and funded by EPA, MADEP, and RIDEM. The DO model QUAL2E was calibrated and verified using low flow dry weather ambient and discharge data collected in July and August of 1991. This data is contained in the document Phase 1: Dry Weather Assessment-Interim Report of Data 1991. The DO model development is discussed in the report entitled Dissolved Oxygen Modeling of the Blackstone River in Massachusetts and Rhode Island (Wright, 1994).

WLA's are required by Section 303(d) of the Clean Water Act. This WLA was a joint effort by the US Environmental Protection Agency (EPA), the Massachusetts Department of Environmental Protection (MADEP), and the Rhode Island Department of Environmental Management (RIDEM).

Remediation and restoration work in the Blackstone River watershed needs to be addressed on a number of levels to control both point and nonpoint sources. This report addresses only the wasteload allocation to control municipal wastewater, which is the primary contributor to the dissolved oxygen and eutrophication impacts. It should be kept in mind that additional work is being undertaken concurrently to address impacts from industrial wastewater, municipal and industrial stormwater, and nonpoint sources of pollution in the watershed. These include increased efforts in stormwater permitting/enforcement and CSO remediation, as well as efforts to attenuate resuspension of contaminated sediments. Grants have also been awarded to support projects in these areas. These additional projects are discussed later in this report.

HISTORICAL PERSPECTIVE:

Development of an interstate WLA for the Blackstone River is one segment of a comprehensive initiative which began in the watershed in 1991. The original basis for selecting the Blackstone River as a target for extensive study and restoration resulted from the identification of this watershed system as key to the health of Narragansett Bay. The Bay has been recognized as an important and highly threatened resource for the Northeast. As a result of visible and measurable changes to the water quality and resources of the Bay a number of actions were taken:

1. The USEPA created the Narragansett Bay Project (NBP) as part of the National Estuary Program. The NBP produced a Comprehensive Conservation and Management Plan (CCMP) which summarized the "blueprint" for present and long-term management actions which should be undertaken by governmental and local agencies and authorities. The CCMP targeted an interstate assessment and cleanup of the Blackstone River system as key to maintaining the health of Narragansett Bay.

2. To implement this recommendation, the USEPA established the Blackstone River Initiative (BRI) in 1991. This Initiative, coordinated by the USEPA, the University of Rhode Island, the MADEP, and the RIDEM focused on an intensive environmental sampling and assessment program. The program was designed to describe interstate water quality, biology, and toxicity in the river system, under both low flow and stormwater conditions. The information was to be used to develop low flow models for dissolved oxygen and metals that are capable of predicting water quality under a variety of receiving water and pollutant loading conditions and for identifying wet weather pollutant sources in order to target cleanup efforts.

3. To underscore the importance of the Blackstone River projects, the Governors of the Commonwealth of Massachusetts and the State of Rhode Island signed a Memorandum of Understanding in 1992 which stated their support for these projects and the continued cooperation of MA and RI in the restoration of the watershed system and the attenuation of pollutants to Narragansett Bay.

4. To further support these efforts, the Office of Watershed Management of the MADEP established an interdepartmental team to perform follow up assessments, provide outreach, and implement recommendations from the BRI report. The RIDEM targeted similar efforts to key subwatershed areas in RI.

A previous WLA was developed for the MA segment of the river using a Stream 7B model developed in the late 1970s. This WLA established the level of treatment necessary for the UBWPAD discharge which is in effect today.

The current URI modeling effort included a post audit of the older Stream 7B model predictions. This was done in order to verify that the water quality conditions predicted under this model were accurate and that treatment levels required of the UBWPAD were appropriate. The post calibration matched very closely with the Stream 7B model predictions. Unfortunately, the Stream 7B model only covered the MA portion of the river and did not simulate algal growth which has a significant impact on DO in the Blackstone River.

The current modeling effort, which simulates algal growth and includes the RI portion of the river, indicates that significant problems in the river still need to be addressed. The postcalibration of the earlier model enhances confidence in the current model and model outputs.

MODEL DEVELOPMENT:

The inability to sample the river under critical flow and pollutant loading conditions, as well as access limitations to several critical DO sag points, necessitated the development of a mathematical model. The model simulates water quality parameters under critical river flow and discharge loading conditions in order to determine compliance with water quality standards. Seasonal differences in river flow and temperature were also evaluated.

The water quality surveys conducted in 1991 indicate a significant DO affect resulting from phosphorus driven algal growth and respiration. This is evidenced by the large chlorophyll a values and the daily variations in DO, including frequent occurrences of DO values greater than saturation levels (see Tables I and II and Figures I-III). Water quality station locations are given in Table III and Figure IV. The algal growth also has a significant affect on pH values, often resulting in violations of the pH standard (see Tables IV and V). The algal growth potential in the Blackstone River is enhanced by the numerous dams (see Table VI) which reduce the flow velocity in the river and increase the water temperature.

The model is capable of being run in a steady state or dynamic mode. In addition to simulations resulting from the steady state mode, the dynamic mode simulates the daily variations in DO caused by algal photosynthesis and respiration. This is necessary in order that the daily minimum DO values can be compared to the water quality standard, which is 5.0 mg/l minimum. The climatological data used in the algal simulations for the critical summer period represents typical August conditions.

TABLE I

DISSOLVED OXYGEN (mg/l)

STATION	RIVER MILE	JULY 10				JULY 11			
		400	1000	1600	2200	400	1000	1600	2200
BLK01	45.7	6.4	7.7	7.8	6.4	6.4	7.1	8.3	6.5
BLK02	43.9	6.3	7.2	7.2	6.4	6.8	7.2	8.2	6.7
BLK03	41.3	7.5	7.9	8.0	7.4	7.3	7.9	7.9	7.5
BLK04	39.8	8.1	8.1	8.0	7.9	8.0	8.0	7.8	8.0
BLK06	36.3	7.1	8.4	8.5	7.3	7.1	8.1	8.7	7.4
BLK07	31.9	7.3	7.6	10.0	9.2	7.9	10.5	12.7	8.8
BLK07.1							8.3	8.5	
BLK08	27.8	6.1	9.8	13.0	6.9	6.0	10.2	12.9	7.9
BLK08.1							9.4	10.5	
BLK11	23.2	6.6	9.6	9.5	6.4	6.9	9.6	10.2	7.4
BLK12	19.1	6.9	11.2	11.5	8.2	7.0	12.0	11.8	8.4
BLK13	16.6	8.2	10.7	11.0	9.3	9.1	12.0	12.2	9.9
BLK17	12.8	7.5	9.5	8.9	7.1	7.3	9.4	8.8	7.0
BLK18	9.9	8.0	8.0	7.9	8.0	8.1	8.0	8.0	7.7
BLK19	8.1	7.6	8.1	8.0	7.3	7.2	7.9	7.8	7.3
BLK20	3.7	5.6	8.1	9.1	6.4	5.3	8.5	10.2	6.4
BLK21	0.2	7.0	8.9	9.0	7.2	7.3	8.7	9.2	6.8
TRIBUTARIES									
BLK05	36.7,2.1	6.0	6.8	7.0	5.5	5.7	6.5	6.8	5.4
BLK09	25.5,0.6	5.4	7.1	8.0	8.6	5.5	6.1	10.0	8.8
BLK09.1		7.6	7.8	10.0	7.8	7.5	7.7	8.0	8.2
BLK10	24.2,0.6	6.3	6.9	7.0	6.0	6.3	6.5	7.5	6.2
BLK14	17.4,0.8	7.2	7.7	7.8	6.9	7.0	8.0	7.9	7.1
BLK15	13.3,0.7	6.8	8.1	7.9	6.7	7.8	8.1	7.9	6.6
BLK16	13.1,1.1	5.1	4.9	6.2	4.9	5.2	5.3	6.7	5.4

TABLE II

DISSOLVED OXYGEN (mg/l)

Note: Meter readings were used for Stations 2, 3, 4, 5, 6, 7, 8 and 9.1 on August 14 at 1000 hr.

STATION	RIVER MILE	AUGUST 14				AUGUST 15			
		400	1000	1600	2200	400	1000	1600	2200
BLK01	45.7	6.2	7.2	7.2	5.9	6.0	6.9	7.0	4.9
BLK02	43.9	6.2	10.2	7.5	6.3	6.0	7.2	7.4	6.4
BLK03	41.3	7.1	10.1	7.7	7.1	7.0	7.8	7.9	7.4
BLK04	39.8	7.8	10.2	7.8	7.4	7.2	7.7	8.0	7.7
BLK06	36.3	7.2	10.0	8.1	7.0	6.8	7.9	8.3	7.4
BLK07	31.9	7.4	9.3	12.0	8.8	7.9	7.0	7.9	8.0
BLK07.1									
BLK08	27.8	6.2	10.0	10.3	6.2	5.6	7.9	9.4	6.3
BLK08.1			9.9				7.9	8.9	
BLK11	23.2	6.4	8.8	7.7	6.8	6.4	7.8	8.5	6.9
BLK12	19.1	6.3	9.3	9.3	6.9	6.2	7.5	9.7	7.7
BLK13	16.6	7.3	8.9	8.8	8.0	7.4	8.5	9.0	8.1
BLK17	12.8	7.4	8.7	8.5	7.1	8.0	8.1	8.8	7.1
BLK18	9.9	7.7	7.4	7.8	7.8	7.6	7.5	7.4	7.5
BLK19	8.1	7.7	8.0	7.7	7.4	7.1	7.6	7.5	7.2
BLK20	3.7	6.2	9.1	9.0	6.5	5.5	6.5	8.3	6.4
BLK21	0.2	7.3	9.2	8.8	7.3	7.1	7.5	8.6	7.2
TRIBUTARIES									
BLK05	36.7,2.1	6.3	10.2	6.9	5.9	5.8	7.1	6.9	5.9
BLK09	25.5,0.6	4.7	9.6	9.0	5.6	4.4	5.7	8.2	6.8
BLK09.1		7.3	8.7	7.7	7.2	7.2	7.2	7.5	7.6
BLK10	24.2,0.6	6.0	6.2	5.8	5.8	5.6	5.8	5.9	5.9
BLK14	17.4,0.8	6.9	7.5	7.8	6.6	6.8	7.2	7.7	6.8
BLK15	13.3,0.7	6.6	8.3	7.3	6.4	6.4	7.5	7.8	6.8
BLK16	13.1,1.1	6.4	6.1	6.4	5.6	5.6	5.8	5.8	5.1

FIGURE I

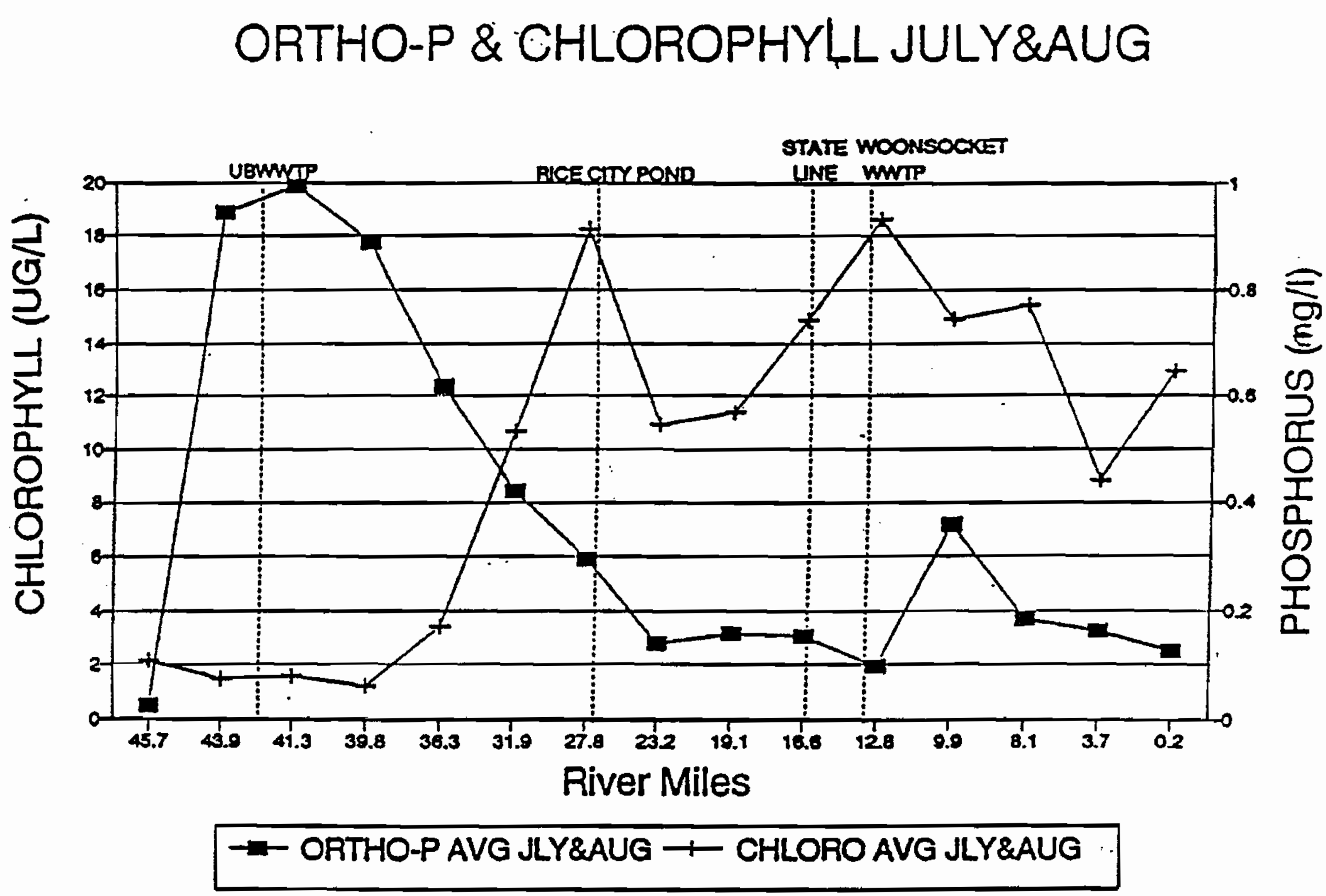

ORTHO-P & CHLOROPHYLL JULY&AUG
STATE LINE
WOONSOCKET WWTP
UBWWTP
RICE CITY POND
CHLOROPHYLL (UG/L)
PHOSPHORUS (mg/l)
River Miles
45.7 43.9 41.3 39.8 36.3 31.9 27.8 23.2 19.1 16.6 12.8 9.9 8.1 3.7 0.2
0 2 4 6 8 10 12 14 16 18 20
0 0.2 0.4 0.6 0.8 1
ORTHO-P AVG JLY&AUG
CHLORO AVG JLY&AUG

FIGURE IIa

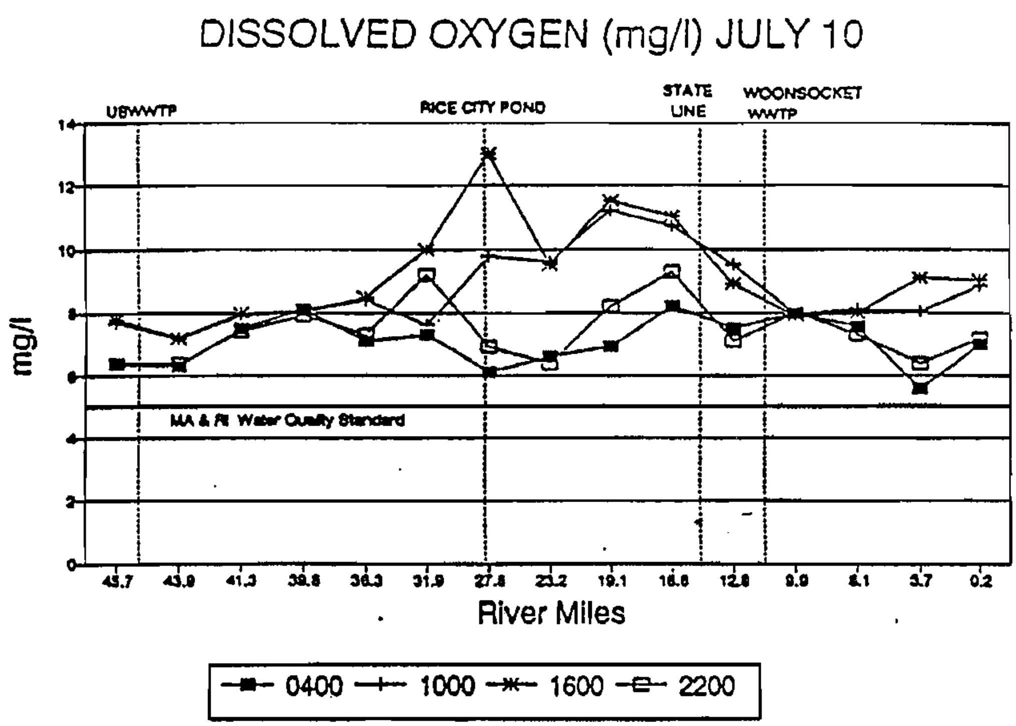


FIGURE IIb

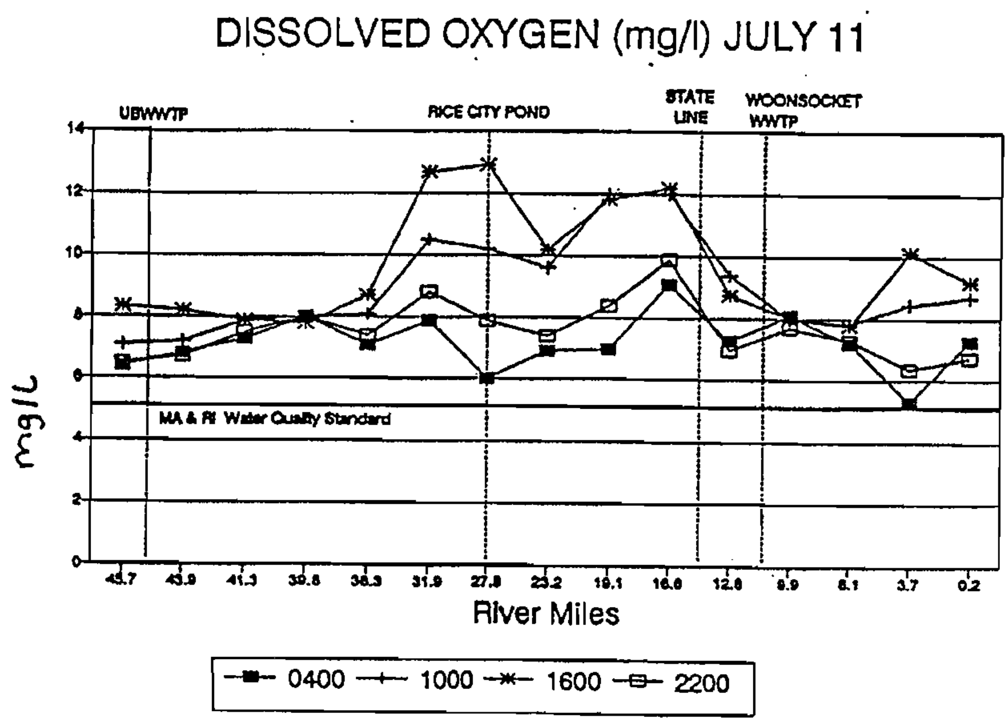


FIGURE IIIa

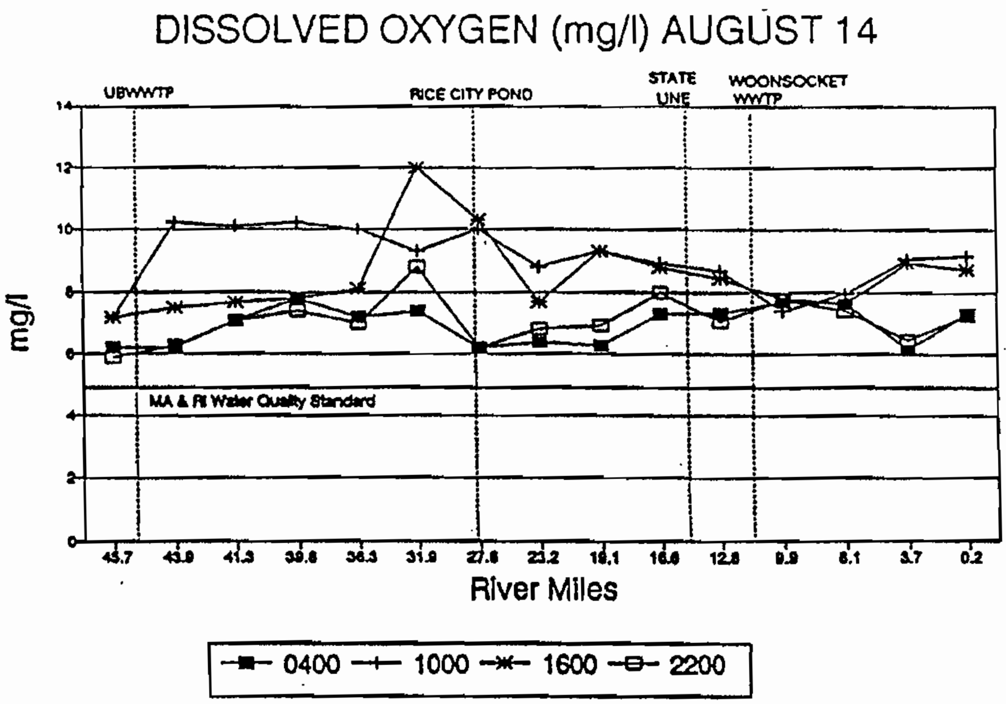


FIGURE IIIb

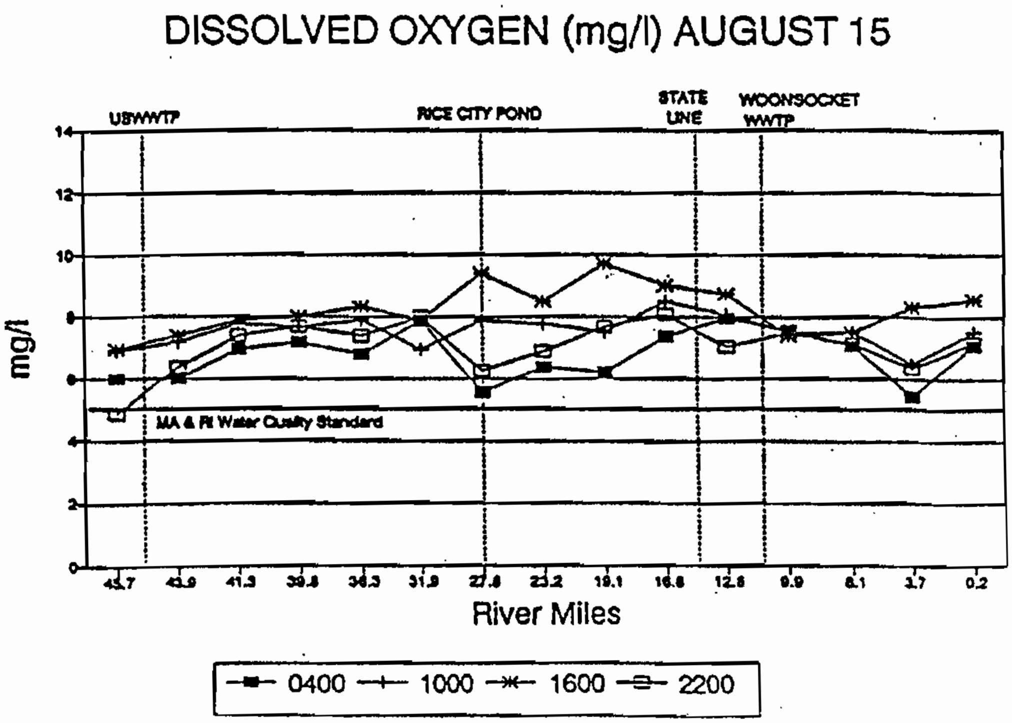


TABLE III

WATER QUALITY STATION LOCATIONS

STATION	DESCRIPTION	TOWN	KM	MI
BLK1	Millbury St.	Worcester	73.7	45.7
BLK2	McCraken Rd.	Millbury	70.7	43.9
BLK3	Riverlin St.	Millbury	66.6	41.3
BLK4	Blackstone St. (Singing Dam)	Sutton	64.2	39.8
BLK5:QR	Millbury St.	Grafton	59.2:3.4	36.7:2.1
BLK6	Route 122A	Grafton (Fisherville)	58.6	36.3
BLK7	Riverdale St.	Northbridge (Riverdale)	51.5	31.9
BLK8	Hartford St. (Rice City Pond)	Uxbridge	44.9	27.8
BLK9:MR	Mendon St. (Rt. 16)	Uxbridge	41.2:1.0	25.5:0.6
BLK10:WR	Hecla St. (Off Rt. 16)	Uxbridge (Centerville)	39.1:1.0	24.2:0.6
BLK11	Route 122 Bridge	Uxbridge	37.4	23.2
BLK12	Route 122 (First RR bridge south of Millville Center)	Millville	30.8	19.1
BLK13	Bridge St.	Blackstone	26.7	16.6
BLK14:BR	Route 146A	Forestdale	28.01:1.3	17.4:0.8
BLK15:MI	Privilege St.	Woonsocket	21.4:1.2	13.3:0.7
BLK16:PR	Route 114 (Diamond Hill Rd.)	Woonsocket	21.2:1.8	13.1:1.1
BLK17	Route 122 (upstream POTW)	Woonsocket	20.6	12.8
BLK18	Manville Hill Rd. (Main St.)	Cumberland	15.9	9.9
BLK19	School St./Albion Rd.	Cumberland (Albion)	13.1	8.1
BLK20	Whipple Bridge, Lonsdale Ave./Mendon Rd.	Cumberland (Lonsdale)	5.9	3.7
BLK21	Exchange St. (Old Slater Mill)	Pawtucket	0.3	0.2

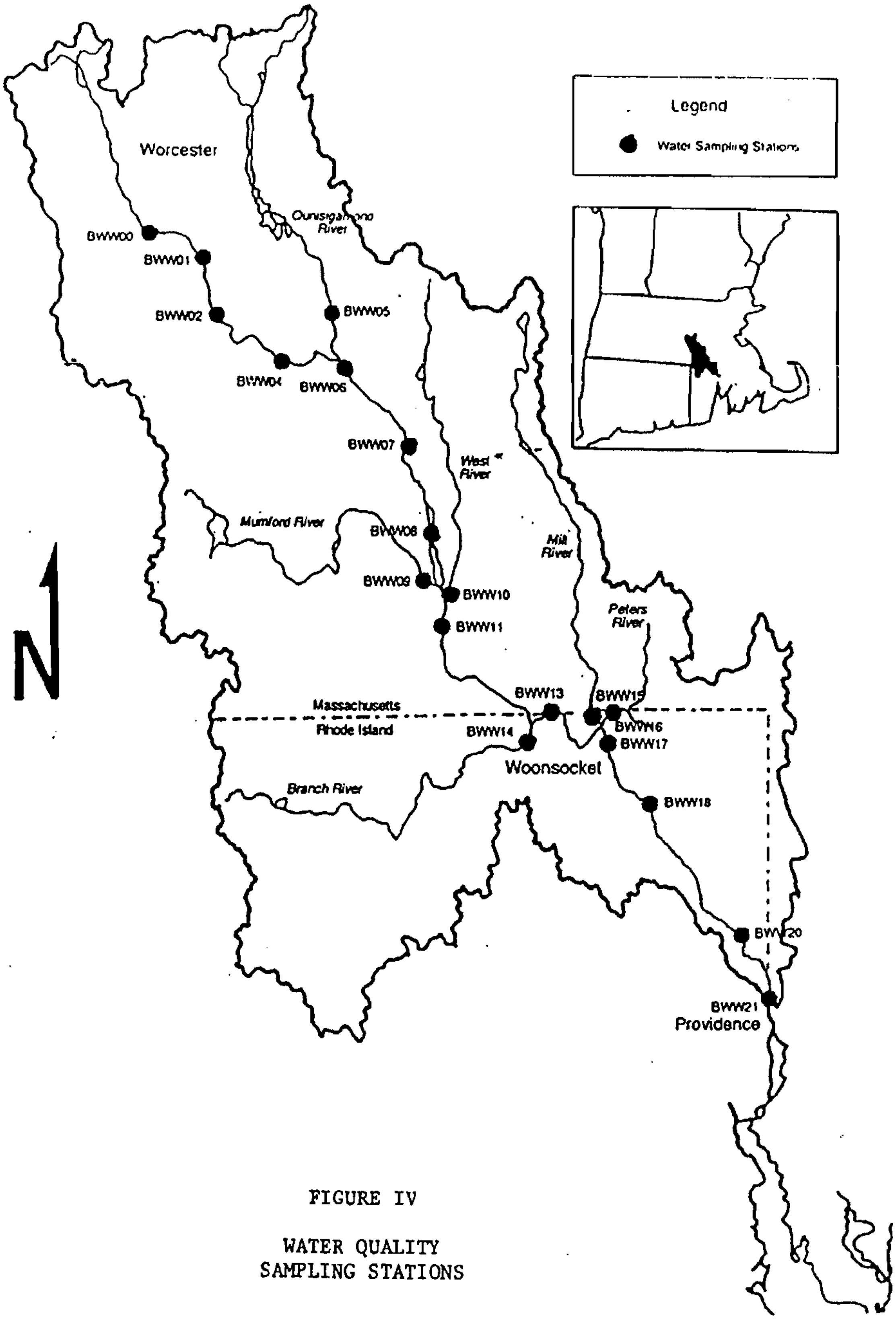


FIGURE IV

WATER QUALITY
SAMPLING STATIONS

TABLE IV

STATION	RIVER MILE	JULY 10				JULY 11			
		400	1000	1600	2200	400	1000	1600	2200
BLK01	45.7	7.0	7.2	7.2	7.0	7.0	7.1	7.2	7.1
BLK02	43.9	6.9	7.0	6.8	6.7	6.8	6.9	6.8	6.8
BLK03	41.3	6.9	7.4	7.3	7.1	7.2	7.3	7.5	7.2
BLK04	39.8	7.2	7.4	7.5	7.4	7.3	7.3	7.7	7.4
BLK06	36.3	7.2	7.6	8.4	7.3	7.2	7.4	7.9	7.4
BLK07	31.9	7.2	7.4	8.0	7.8	7.3	7.8	9.1	7.5
BLK07.1							7.6	8.2	
BLK08	27.8	7.1	8.1	8.6	7.2	7.1	7.9	9.4	7.4
BLK08.1							8.2	9.2	
BLK11	23.2	7.2	8.8	7.6	7.5	6.8	8.1	8.6	7.5
BLK12	19.1	7.2	8.7	8.0	7.2	6.8	9.1	9.3	8.1
BLK13	16.6	7.4	8.6	8.0	8.4	7.4	9.2	9.4	8.9
BLK17	12.8	6.8	8.7	9.3	8.3	7.8	9.1	9.4	8.7
BLK18	9.9	7.2	7.9	8.2	7.8	7.3	7.9	8.1	7.6
BLK19	8.1	7.3	7.6	8.6	7.7	7.4	7.8	8.0	7.5
BLK20	3.7	7.0	7.0	7.5	7.3	7.0	7.6	8.3	7.2
BLK21	0.2	7.1	7.1	8.0	7.3	7.2	7.7	8.7	7.3
TRIBUTARIES									
BLK05	36.7,2.1	7.1	7.5	7.2	7.2	7.1	7.2	7.2	7.2
BLK09	25.5,0.6	6.9	7.1	7.5	7.5	6.3	7.0	8.0	7.5
BLK09.1		7.0	7.5	7.1	7.6	6.5	7.1	7.7	7.4
BLK10	24.2,0.6	6.8	7.2	6.3	6.9	6.3	6.9	7.0	6.9
BLK14	17.4,0.8	6.5	6.7	6.7	6.9	7.0	7.4	7.5	6.8
BLK15	13.3,0.7	6.8	6.5	7.3	7.2	7.0	7.4	7.6	7.3
BLK16	13.1,1.1	6.8	6.5	6.6	6.9	6.6	7.0	6.9	6.9

pH MEASUREMENTS (standard units)

TABLE V

pH MEASUREMENTS (standard units)

STATION	RIVER MILE	OCTOBER 2				OCTOBER 3			
		400	1000	1600	2200	400	1000	1600	2200
BLK01	45.7	7.1	7.4	7.3	7.1	7.0	7.1	6.7	7.1
BLK02	43.9	7.0	7.1	6.6	6.9	6.9	7.0	6.6	7.1
BLK03	41.3	7.3	7.4	7.1	7.2	7.2	7.3	6.9	7.3
BLK04	39.8	7.4	7.5	7.2	7.4	7.4	7.5	7.2	7.2
BLK06	36.3	7.2	7.3	7.1	7.3	7.3	7.3	7.1	7.2
BLK07	31.9	7.2	7.1	7.0	7.2	7.2	7.2	7.2	6.2
BLK07.1		7.2	7.4	7.1		7.4	7.4	7.3	
BLK08	27.8	7.2	7.1	6.8	7.1	7.2	7.2	7.2	6.2
BLK08.1		7.3	7.1	6.9		7.2	7.2	7.3	
BLK11	23.2	7.1	7.2	6.6	7.0	7.1	7.1	6.9	7.2
BLK12	19.1	7.4	7.2	6.7	7.1	7.1	7.2	7.0	7.5
BLK13	16.6	7.2	7.2	6.7	7.0	7.1	7.1	6.9	7.4
BLK17	12.8	7.1	7.2	7.2	7.2	7.1	7.2	7.2	7.1
BLK18	9.9	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.1
BLK19	8.1	7.2	7.3	7.3	7.3	7.3	7.3	7.2	7.3
BLK20	3.7	7.1	7.2	7.2	7.1	7.1	7.1	7.1	7.1
BLK21	0.2	7.1	7.3	7.2	7.2	7.2	7.2	7.2	7.1
TRIBUTARIES									
BLK05	36.7,2.1	7.3	7.4	7.1	7.3	7.4	7.4	7.0	7.2
BLK09	25.5,0.6	6.9	7.1	6.8	6.8	7.2	7.0	6.7	6.7
BLK09.1		7.2	7.2	6.8	8.7	7.2	7.1	6.6	6.7
BLK10	24.2,0.6	6.8	6.9	6.4	6.6	6.8	6.7	6.5	7.0
BLK14	17.4,0.8	6.8	6.8	6.9	6.8	6.8	6.9	6.9	6.8
BLK15	13.3,0.7	7.1	7.1	7.1	7.0	7.0	7.3	7.1	7.0
BLK16	13.1,1.1	6.7	6.8	6.7	6.7	6.7	6.8	6.7	6.7

TABLE VI

No	Name	River Mile	Reach	Reach Element Below Dam	Height (ft)	Ref
1	McCracken Rd.	43.9	2	2	4	2
2	Millbury Electric Substation	41.0	3	3	4	3
3	Singing Dam	39.8	5	2	14	2
4	Wilkinsonville	39.2	5	4	4	3
5	Saundersville	38.7	5	7	4	3
6	Fisherville	36.5	7	3	4	2
7	Farnumsville	35.6	7	7	4	3
8	Riverdale	31.9	9	2	10	2
9	Rice City Pond	27.8	11	2	10	2
10	Tupperware	17.8	16	3	15	2
11	Blackstone	16.5	18	2	4	3
12	Thundermist	14.3	19	2	18	2
13	Manville	9.9	21	2	17	2
14	Albion	8.2	22	2	6	2
15	Ashton	6.8	23	2	7	3
16	Lonsdale	4.1	23	15	4	1
17	Central Falls	2.0	25	2	13	1
18	Pawtucket	0.8	25	7	14	1
19	Slaters Mill	0.0	25	10	18	1

Ref. = Reference; 1 = Army Corps of Engineers (1973); 2 = Personal communication (MADEP 1992); 3 = Field Survey

TABLE VII

BLACKSTONE RIVER WLA - BASELINE CONDITIONS FOR POINT SOURCE INPUTS

Point Source	Flow cfs	DO mg/l	BOD mg/l	NH3 mg/l	Phos mg/l	Chlor a ug/l
Headwaters	6.52	6.8	1.4	0.4	0.02	2.2
Quinsig. River	3.03	6.5	1.2	0.2	0.04	1.5
Mumford River	5.89	7.8	1.2	0.1	0.05	1.5
West River	3.22	6.2	1.2	0.2	0.04	1.5
UBWPAD	86.60	6.0	10.0	2.0	2.4	
Millbury	1.85	5.0	30.0	15.0	3.3	
Grafton	2.46	5.0	30.0	15.0	1.9	
Northbridge	2.77	5.0	30.0	15.0	3.2	
Uxbridge	3.88	5.0	30.0	15.0	3.7	
Branch River	13.76	7.3	1.3	0.2	0.05	2.4
Mill River	1.97	7.3	1.6	0.2	0.04	4.6
Peters River	1.00	5.6	1.2	0.2	0.03	3.1
Woonsocket	24.64	5.0	30.0	5.8	3.8	

1. Headwater and tributary flows are from the 7Q10 flow balance in the model and WWTF flows are current design flows.

2. Headwater and tributary dissolved oxygen values are an average of the 1991 July and August survey data and WWTF dissolved oxygen values are estimated, with the exception of UBWPAD which is based on a permit limit.

3. Headwater and tributary BOD and NH3 values are an average of the 1991 July and August survey data. WWTF BOD values are based on permit limits. WWTF NH3 values are based on permit limits. A value of 15 mg/l was used for secondary treatment plants without permit limits.

4. Headwater and tributary phosphorus values are an average of the 1991 July and August survey data with the exception of the Mumford River value which was reduced to reflect recent source reductions. WWTF phosphorus values for UBWPAD and Woonsocket are an average of the 1991 July and August survey data and values for all other WWTFs are from data collected by MDEP in 1988.

5. Headwater and tributary chlorophyll a values are an average of the 1991 July and August survey data.

WASTE LOAD ALLOCATION:

All simulations were conducted using the dynamic mode for estimating the DO level at 6:00 a.m., which was determined to be the minimum daily value. The initial simulation was designed to reflect DO levels at critical low flow and current permitted discharge loadings. The initial assumptions for this baseline condition are detailed in Table VII.

The results of this simulation indicate that the dissolved oxygen standard will be violated for 4.4 river miles in Massachusetts and 1.6 river miles in Rhode Island. There are a total of 28 river miles in Massachusetts and 18 river miles in Rhode Island. The critical areas for DO in the Massachusetts section are Fisherville impoundment in Grafton and Rice City Pond in Uxbridge. The critical area for DO in the Rhode Island section is Central Falls, upstream of a series of three large dams. The minimum projected DO values are 4.1 mg/l in Massachusetts and 2.7 mg/l in Rhode Island.

In Massachusetts, the DO sag is primarily driven by sediment oxygen demand (SOD) and BOD/NH_3 decay. In Rhode Island, the DO sag is primarily driven by phosphorus, SOD, and NH_3 decay. The chlorophyll a values in Rhode Island are indicative of highly eutrophic conditions. Projected DO and chlorophyll a values for the baseline conditions are graphed in Figure V.

During development of the wasteload allocation, three facilities on the mainstem river in Massachusetts (Millbury, Grafton and Northbridge) requested increases in their discharge flow. These flow increases are included under scenario #1 and are used as the basis for all future WLA scenarios. Flow increases are tabulated below.

	Present Flows		Requested Flows	
Millbury	1.85 cfs	1.2 mgd	4.19 cfs	2.7 mgd
Grafton	2.46 cfs	1.6 mgd	3.72 cfs	2.4 mgd
Northbridge	2.77 cfs	1.8 mgd	3.1 cfs	2.0 mgd
TOTAL WWTF FLOWS	7.08 cfs	4.6 mgd	11 cfs	7.1 mgd

Successive simulations were designed to demonstrate the water quality improvements resulting from various levels of additional treatment for the WWTF discharges. The treatment level for each scenario was selected based on the component analysis of the model which indicates the parameters contributing the most to the DO sag, including the relative importance of these components. These simulations are summarized in Table VIII. A comparative analysis of effluent treatment levels by scenario is provided in Table IX. DO graphs are included for selected simulations (Figures VI-XI).

TABLE VIII

BLACKSTONE RIVER DISSOLVED OXYGEN WLA SIMULATIONS

Scenario	Minimum DO (mg/l)	# of Miles Violated	Chla(ug/l)	Location	
Baseline: All WWTFs at current permitted levels (see Table VII)					
MA	4.5	0.8	0.5	Fisherville	(R7E1)
	4.7	1.2	0.9	Riverdale	(R9E1)
	4.1	2.4	3.0	Rice City Pond	(R10E7)
RI	2.7	1.6	61.4	Central Falls	(R9E9)
	* maximum chlorophyll a = 67.0 ug/l at R8E11 in RI				
Scenario #1: Baseline + Smaller MA WWTFs at higher requested flows					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.8	Rice City Pond	(R10E7)
RI	3.2	1.4	64.2	Central Falls	(R9E9)
	* maximum chlorophyll a = 67.7 ug/l at R9E1 in RI				
Scenario #2: Scenario #1 + Woonsocket with AT (BOD/NH3 = 10/2 mg/l)					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.8	Rice City Pond	(R10E7)
RI	3.7	1.2	64.2	Central Falls	(R9E9)
	* maximum chlorophyll a = 67.6 ug/l at R9E1 in RI				
Scenario #3: Scenario #2 + Woonsocket with phosphorus at 0.75 mg/l					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.8	Rice City Pond	(R10E7)
RI	3.1	1.4	47.4	Central Falls	(R9E9)
	* maximum chlorophyll a = 55.0 ug/l at R7E7 in RI				

TABLE VIII (Continued)

Scenario	Minimum DO (mg/l)	# of Miles Violated	Chla(ug/l)	Location	
Scenario #4: Scenario #3 + UBWPAD with phosphorus at 1.0 mg/l					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.6	Rice City Pond	(R10E7)
RI	4.8	0.2	27.7	Ashton	(R7E7)
	3.9	1.2	22.7	Central Falls	(R9E9)
	* maximum chlorophyll a = 31.9 ug/l at R6E4 in RI				
Scenario #5: Scenario #3 + UBWPAD with phosphorus at 0.75 mg/l					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.5	Rice City Pond	(R10E7)
RI	4.7	0.4	23.1	Ashton	(R7E7)
	4.2	1.0	19.0	Central Falls	(R9E9)
	* maximum chlorophyll a = 27.5 ug/l at R6E2 in RI				
Scenario #6: Scenario #5 + Woonsocket P at 1.00 mg/l					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.5	Rice City Pond	(R10E7)
RI	4.7	0.2	24.3	Ashton	(R7E7)
	4.1	1.2	20.0	Central Falls	(R9E9)
	* maximum chlorophyll a = 28.6 ug/l at R6E3 in RI				
Scenario #7: Scenario #6 + Smaller MA WWTFs with phosphorus at 1.0 mg/l					
MA	4.3	0.8	0.5	Fisherville	(R7E2)
	4.3	1.8	0.8	Riverdale	(R9E1)
	3.7	3.0	2.5	Rice City Pond	(R10E7)
RI	4.9	0.2	19.8	Ashton	(R7E1)
	4.7	0.4	18.1	Ashton	(R7E7)
	4.4	0.8	15.0	Central Falls	(R9E9)
	* maximum chlorophyll a = 22.2 ug/l at R5E14 in RI				

TABLE VIII (Continued)

Scenario	Minimum DO (mg/l)	# of Miles Violated	Chla(ug/l)	Location	
Scenario #8:	Scenario #7 + Smaller MA WWTFs at advanced secondary (BOD/NH3=20/5mg/l)				
MA	4.6	0.6	0.5	Fisherville	(R7E2)
	4.9	0.4	0.8	Riverdale	(R9E1)
	4.6	1.8	2.5	Rice City Pond	(R10E7)
RI	4.7	0.6	15.0	Central Falls	(R9E9)

* maximum chlorophyll a = 22.2 ug/l at R5E14 in RI

Scenario #9: Scenario #8 + SOD reduction of 25%

no miles in MA or RI violating WQS

* maximum chlorophyll a = 22.2 ug/l at R5E14 in RI

Scenario #9a: Scenario #8 + UBWPAD (BOD/NH3/P = 5/1/0.5 mg/l) and Woonsocket (BOD/NH3/P = 10/1/0.75 mg/l)

no river miles in MA or RI violating WQS

* maximum chlorophyll a = 16.3 ug/l at R5E13 in RI

Scenario #10: Scenario #8 + UBWPAD flow at 35 mgd (54.25 cfs)

MA	4.8	0.4	0.5	Singing Dam	(R5E1)
	3.9	1.0	0.9	Fisherville	(R7E1)
	4.7	1.2	1.5	Riverdale	(R9E1)
	4.9	1.0	5.6	Rice City Pond	(R10E4)
RI	4.4	0.8	14.7	Ashton	(R7E1)
	4.6	0.6	13.4	Ashton	(R7E7)
	4.5	0.8	11.0	Central Falls	(R9E9)

* maximum chlorophyll a = 18.0 ug/l at R3E6 in RI

TABLE IX
Comparative Analysis of Treatment Levels by Scenario

		BASEL INE	1* (B)	2 (1)	3 (2)	4 (3)	5 (3)	6 (5)	7 (6)	8 (7)	9 (8)	9A (8)	10 (8)	11 (10)
UBWPAD	DO	6	6	6	6	6	6	6	6	6	6	6	6	6
	BOD	10	10	10	10	10	10	10	10	10	10	5	10	10
	NH3	2	2	2	2	2	2	2	2	2	2	1	2	2
	P	2.4	2.4	2.4	2.4	1	.75	.75	.75	.75	.75	.5	.75	.75
	FLOW	56	56	56	56	56	56	56	56	56	56	56	35	35
WOONSOCKET	DO	5	5	5	5	5	5	5	5	5	5	5	5	5
	BOD	30	30	10	10	10	10	10	10	10	10	10	10	10
	NH3	5.8	5.8	2	2	2	2	2	2	2	2	1	2	2
	P	3.8	3.8	3.8	.75	.75	.75	1	1	1	1	.75	1	1
	FLOW	16	16	16	16	16	16	16	16	16	16	16	16	16
MILLBURY GRAFTON NORTHBRIDGE UXBRIDGE	DO	5	5	5	5	5	5	5	5	5	5	5	5	5
	BOD	30	30	30	30	30	30	30	30	20	20	20	20	20
	NH3	15	15	15	15	15	15	15	15	5	5	5	5	5
MILLBURY	PHOS	3.3	3.3	3.3	3.3	3.3	3.3	3.3	1	1	1	1	1	1
GRAFTON	PHOS	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1	1	1	1	1	1
NORTHBRIDGE	PHOS	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1	1	1	1	1	1
UXBRIDGE	PHOS	3.7	3.7	3.7	3.7	3.7	3.7	3.7	1	1	1	1	1	1
MILLBURY	FLOW	1.2	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
GRAFTON	FLOW	1.6	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
NORTHBRIDGE	FLOW	1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
UXBRIDGE	FLOW	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SOD		100%	100	100	100	100	100	100	100	100	-25%	100	100	-25%

NOTE: DO, BOD, NH3 and P are in mg/l and flow is in MGD.
* Number in () indicates which scenario was used as the basis from which to make changes.

Seasonal simulations were also conducted in order to reflect higher flows and lower temperatures representing critical conditions at different times of the year.

WASTE LOAD ALLOCATION RESULTS/DISCUSSION:

The greatest incremental improvement in water quality for the Massachusetts section of the river results from additional BOD and NH3 removal at the smaller WWTFs. The greatest incremental improvement in water quality for the Rhode Island section of the river results from phosphorus control at UBWPAD and Woonsocket, and additional NH3 removal at Woonsocket. Scenario #8 reflects all of these improvements and the result is a significant reduction in the number of miles for which DO criteria are violated. The minimum DO increases from 3.7 mg/l to 4.6 mg/l in Massachusetts and from 3.2 mg/l to 4.7 mg/l in Rhode Island, and the maximum chlorophyll a levels in the river reduce from 68 ug/l to 22 ug/l, as compared to scenario #1.

While the smaller WWTFs do not have a significant affect individually, collectively they have a significant affect as indicated by scenarios #7 and #8. When advanced secondary treatment (including phosphorus removal) was evaluated, the river miles not meeting standards dropped by 3.6 mi. In addition, the minimum DO in Massachusetts increased by 0.9 mg/l, and the minimum DO in Rhode Island increased by 0.6 mg/l. The maximum chlorophyll a was reduced by 7 ug/l.

Once the point source loads from the treatment facilities are reduced, sediment oxygen demand (SOD) becomes the remaining major component of the DO sag at several locations. Scenario #9 indicates that SOD would have to improve by 25% in order to meet DO standards with the treatment levels evaluated in scenario #8.

Assuming no improvement in SOD levels, scenario #9a indicates the amount of additional phosphorus, NH3, and BOD control required at the two larger treatment facilities in order to meet DO standards. This requires a reduction in the phosphorus discharge to 0.5 mg/l at UBWPAD and 0.75 mg/l at Woonsocket, a reduction in the NH3 discharge to 1.0 mg/l for UBWPAD and Woonsocket, and a reduction in the BOD to 5 mg/l for UBWPAD.

SOD and assumptions related to improvements in SOD over time are a significant issue. Information on SOD values is available through both the literature and actual field sampling in the Blackstone River. During the Blackstone River Initiative, SOD sampling was conducted at a number of sites. This information was used, in combination with the literature values, in the calibration and verification process for the model. The values used in the model closely resemble the values measured in the field and are well within the range of literature values. Literature values, average field data results, and the final numbers selected for the WLA model are summarized below.

Average Values of SOD from EPA Rates Manual

Bottom Type	Range**	Average**
WWTF outfall	2-10.0	4
WWTF downstream	1-2	1.5
Sandy bottom	0.2-1.0	0.5
Mineral Soils	0.05-0.1	0.07

** Uptake values (g O^2/m^2/day at 20 degrees Celsius)

Range of Values for SOD from the WLA

Massachusetts SOD values in WLA model	Rhode Island SOD values in WLA model
1.6-5.9 g O^2/m^2/day	1.6-4.0 g O^2/m^2/day

Range of Average Values for SOD Measured in the Blackstone River

Massachusetts SOD values measured instream	Rhode Island SOD values measured instream
1.5-6.0 g O^2/m^2/day	1.5-5.8 g O^2/m^2/day

Wet weather and dry weather sources of pollutants other than WWTF discharges are being dealt with on a number of levels in the watershed, especially in the upper reaches. The first two miles of the system were identified during the comprehensive Blackstone River Initiative sampling as contributing extensive solids during wet weather. The federal and state agencies are attempting to reduce these sources through the permit and grant process. The City of Worcester Stormwater Permit is under development and the City is moving forward with remediation efforts in their collection and distribution system. EPA is supporting source reduction activities in the City of Worcester through a grant for stormdrain and catchment identification and GIS mapping. The Worcester CSO facility is also being evaluated relative to the need for improvement of the quality of the discharge. In addition, EPA is funding an individual to assist in the implementation of state and federal stormwater regulations in the watershed and EOEA has given a Massachusetts Watershed Initiative Capacity Building Grant to develop and reinforce mechanisms for control on a local level.

Efforts are also being directed at moderating resuspension and movement of contaminated sediments. The USACOE is evaluating sediment stabilization as part of their ongoing work in the Blackstone watershed. In addition, a MADEP grant has been issued to moderate flow impacts in the Rice City Pond impoundment through changes to the dam and biostabilization of the sediments.

SOD will also benefit from the proposed point source reduction levels. In particular the decrease in phosphorus should result in decreased algal growth and therefore decreased deposition of organic matter.

Another issue of concern is that the UBWPAD discharge is unlikely to reach the design discharge volume which is traditionally used in developing WLA's. Scenario #10 evaluates water quality with a reduced UBWPAD flow volume. Under the reduced flow scenario, the DO profile is actually worse at most locations. This is primarily due to a decrease in flow velocities which can increase the impacts of algal respiration, SOD, BOD, and NH3.

In addition to establishing treatment requirements necessary to meet DO standards during the critical low flow and high temperature summer period of June - September, treatment requirements were evaluated for higher flow and lower temperature periods. Treatment requirements necessary to achieve DO standards throughout the year are given in the table below. In this table, the design flow of UBWPAD is used and the river flows reflect the flow at the Woonsocket gage.

Seasonal Limits

	June-Sept. 7Q10 77 deg	Oct. 7Q10 60 deg	Nov. 152 cfs 50 deg	Dec.-March 152 cfs 40 deg	April 152 cfs 50 deg	May 152 cfs 60 deg
	BOD/NH3 mg/l	BOD/NH3 mg/l	BOD/NH3 mg/l	BOD/NH3 mg/l	BOD/NH3 mg/l	BOD/NH3 mg/l
UBWPAD	10/2	20/4	30/8	30/15	30/8	20/5
Smaller WWTFs	20/5	20/10	30/10	30/15	30/10	20/10
Woon-socket	10/2	30/15	30/15	30/15	30/15	30/12

The major components affecting DO in the non-summer period are BOD/NH3 and SOD. Algal growth is insignificant due to the cooler water temperatures. All of the above treatment levels include the assumption that SOD will decrease by 25% over time.

RECOMMENDATIONS:

Under design discharge flow conditions, the treatment levels evaluated under scenario #9a would be required to meet water quality standards for DO. However, the importance of SOD at several of the critical DO sag points cannot be understated. It is reasonable to assume that SOD levels will decrease with improved discharge treatment levels and ongoing work to control other wet weather and dry weather sources of pollution. A SOD reduction of 25%, when combined with the discharge treatment levels evaluated in scenario #8, will achieve DO standards. In addition to significant improvements in DO, the recommended treatment levels will also result in a significant reduction in eutrophication and less extreme variations in DO and pH over a 24 hour period.

Treatment levels under Scenario #8 are outlined below:

	Flow MGD	DO mg/l	BOD mg/l	NH3 mg/l	Phos mg/l
UBWPAD	56.0	6.0	10	2.0	0.75
Millbury	2.7	5.0	20	5.0	1.00
Grafton	2.4	5.0	20	5.0	1.00
Northbridge	2.0	5.0	20	5.0	1.00
Uxbridge	2.5	5.0	20	5.0	1.00
Woonsocket	16.0	5.0	10	2.0	1.00

Although WLAs are generally developed for design discharge volumes, it is appropriate to evaluate water quality under reduced discharge volumes when actual discharge volumes are significantly lower than design volumes. This is the case with the UBWPAD discharge. Scenario #10 indicates that the DO profile is worse under the reduced discharge volume. With the 25% reduction in SOD, one remaining DO criteria violation exists at Fisherville Impoundment in Massachusetts (4.5 mg/l). The US Army Corps of Engineers is currently evaluating modifications at Fisherville Impoundment to enhance water quality and habitat.

The treatment levels evaluated in scenario #10 are still the recommended alternative. Given the uncertainties of SOD reduction levels and the potential for future modifications to the Fisherville Impoundment, additional treatment requirements may not be warranted at this time. This approach is consistent with the phased WLA approach identified in EPA guidance documents for developing WLAs. The phased approach requires post implementation monitoring to determine if additional treatment is required. Post implementation monitoring should focus on evaluating SOD reduction levels at key locations and the effect of any changes made to the Fisherville Dam, as well as how treatment improvements at the WWTFs are being translated into water quality improvements in the river.

Current requirements at all WWTFs during the non-summer period are for secondary treatment only. This WLA identifies the need for seasonal effluent limits more stringent than secondary limits. These limits are outlined in the table in the previous section. The method for incorporating these limits into permits should be addressed during the permit process.

As part of the permitting strategy, the Agencies (EPA, MADEP and RIDEM) will be conducting an informational workshop and public outreach effort. This effort will provide an opportunity to discuss the above recommendations, including the potential for alternative strategies for achieving the same desired environmental results.

The Blackstone River Initiative (BRI) and the Narragansett Bay studies have also shown that dry weather loadings of nitrogen to Narragansett Bay are significant and may be contributing to excessive productivity and DO concerns in the Bay. The BRI concluded that 78% of the annual nitrogen load to Narragansett Bay occurs during dry weather, and over 90% of the dry weather load is from point sources. A WLA for Narragansett Bay is currently under development. Once this WLA is completed, total nitrogen limits may be recommended for point sources discharging to the Blackstone River. Facility planning efforts should include an evaluation of denitrification options.

Figure V

Blackstone River Wasteload Allocation - Baseline

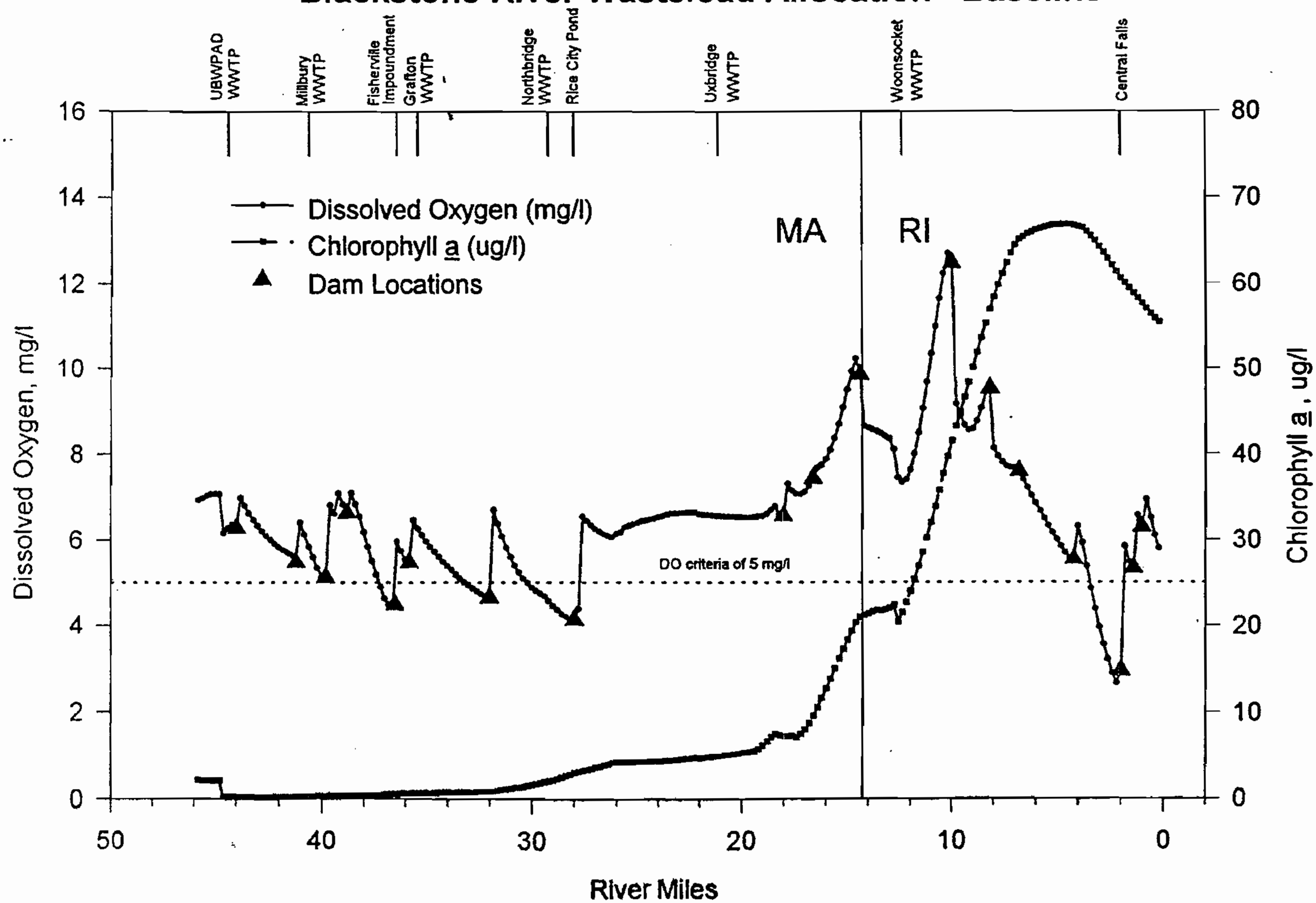


Figure VI

Blackstone River Wasteload Allocation - Scenario 1

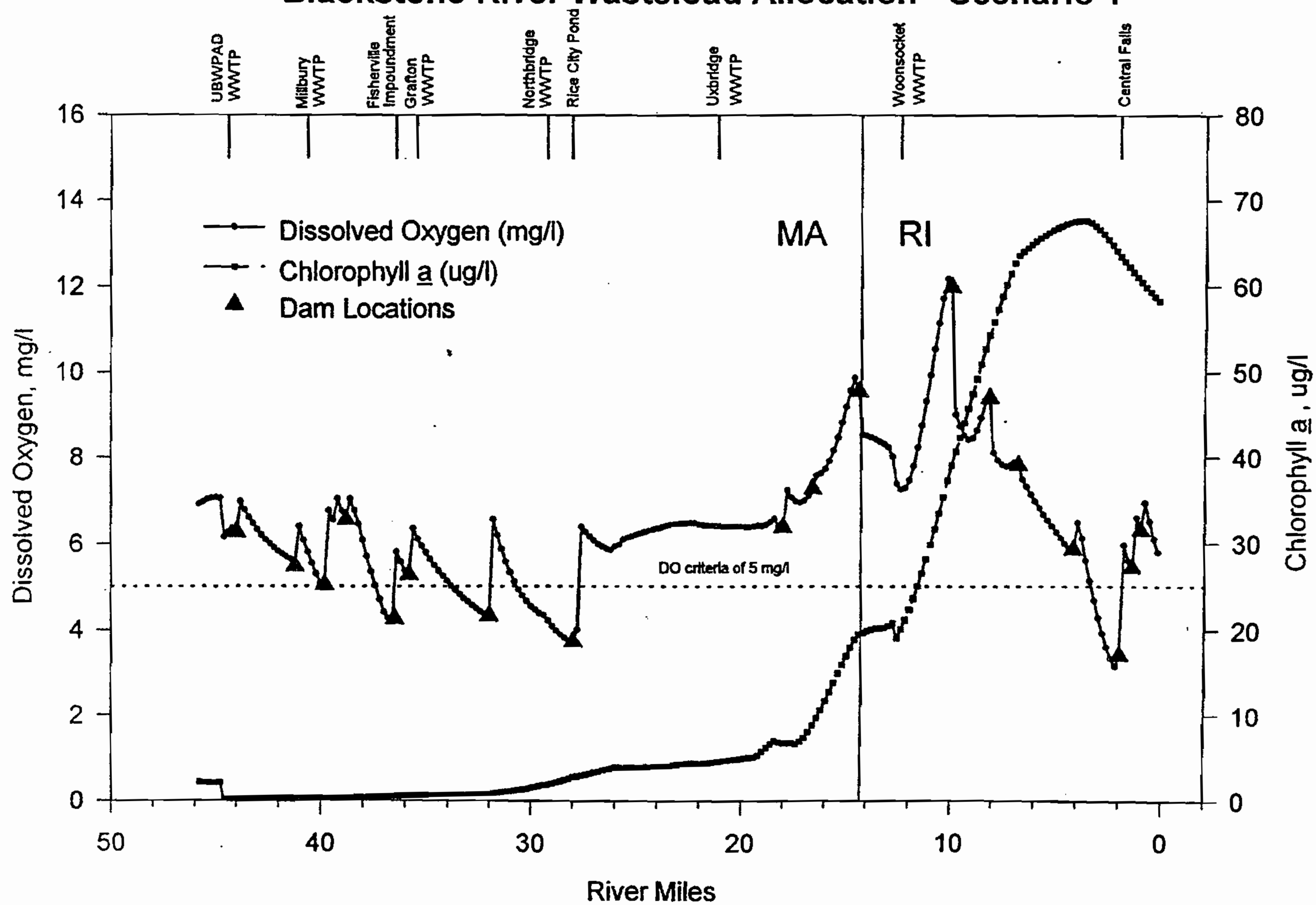


Figure VII

Blackstone River Wasteload Allocation - Scenario 4

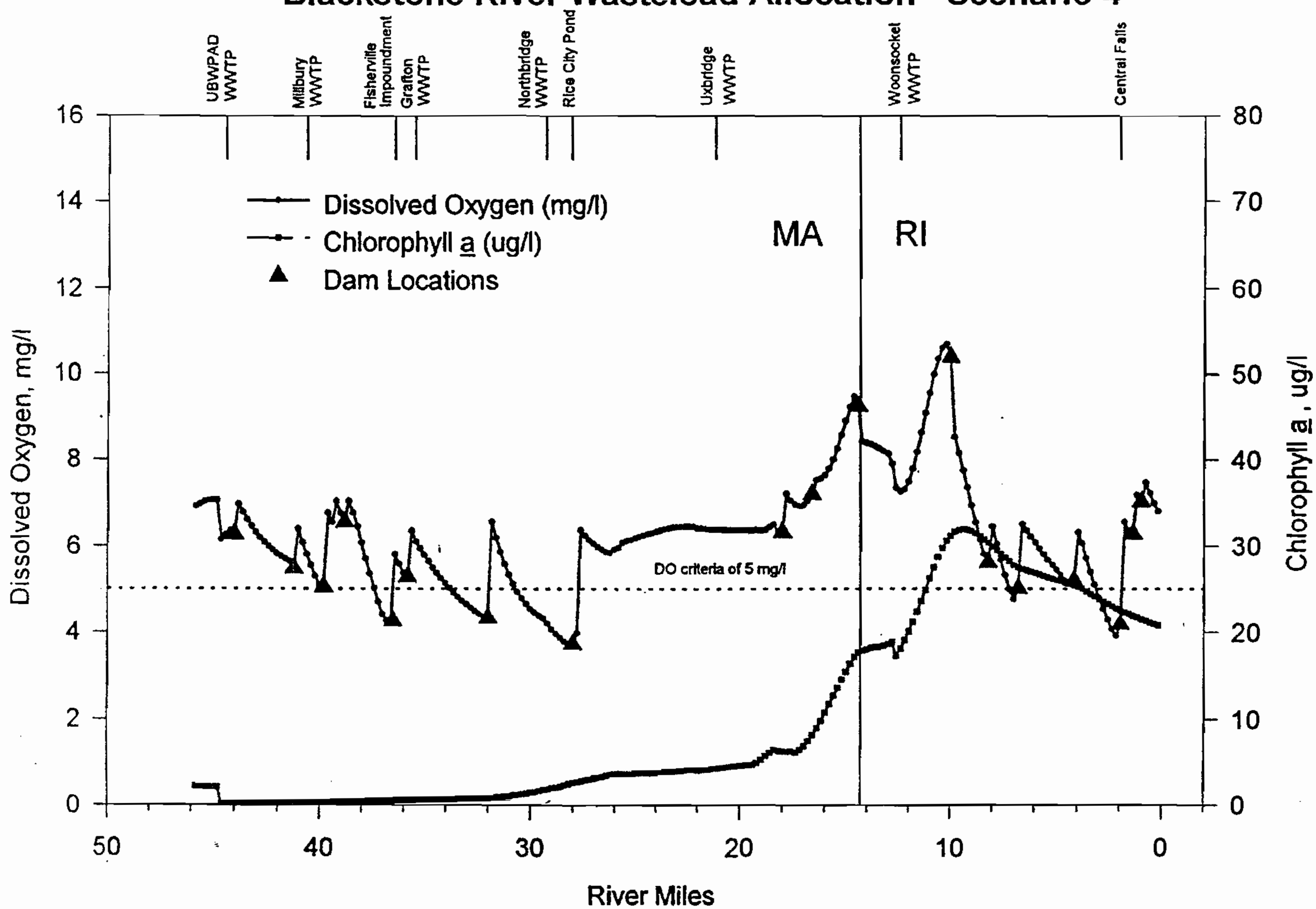


Figure VIII

Blackstone River Wasteload Allocation - Scenario 5

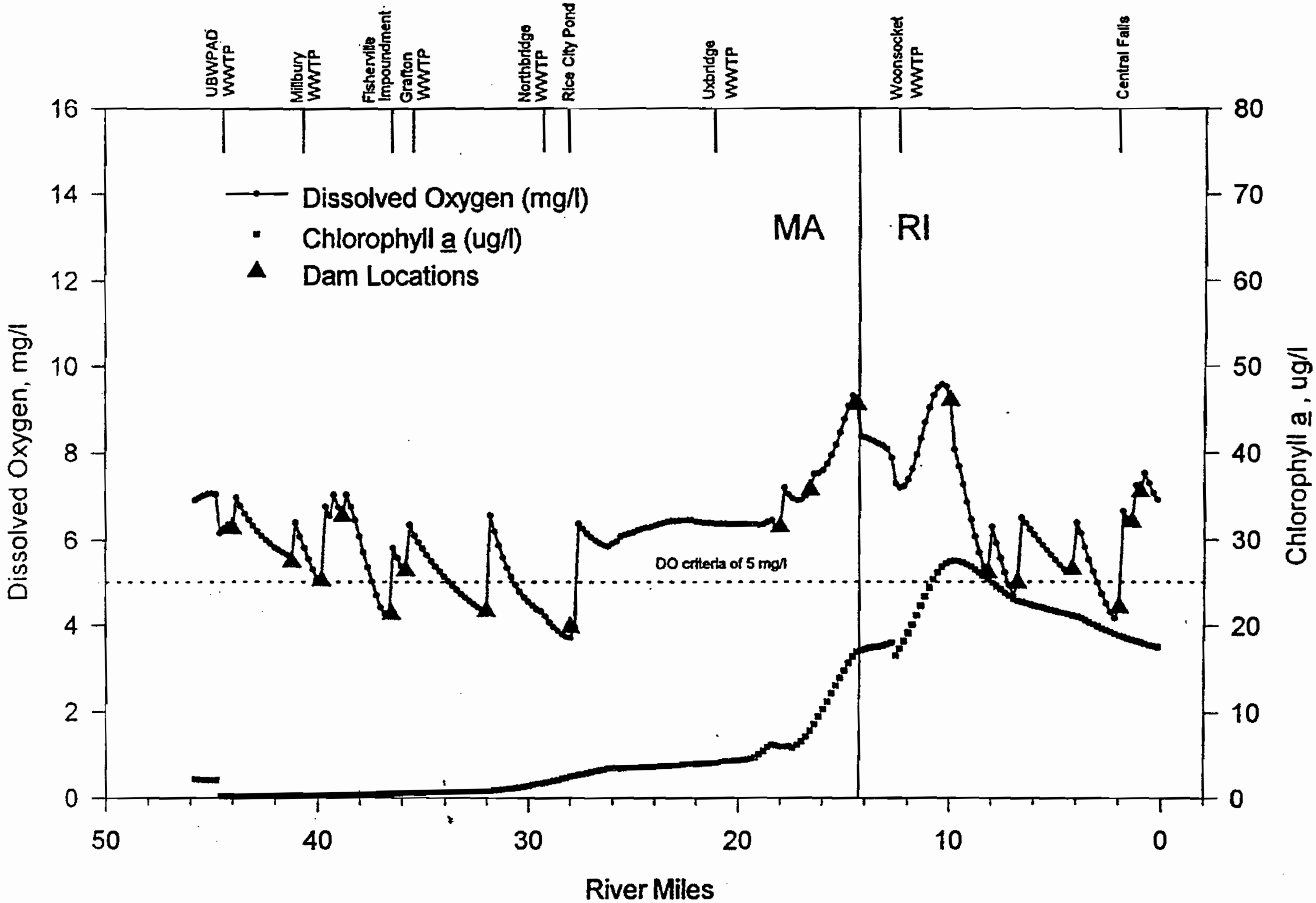


Figure IX

Blackstone River Wasteload Allocation - Scenario 8

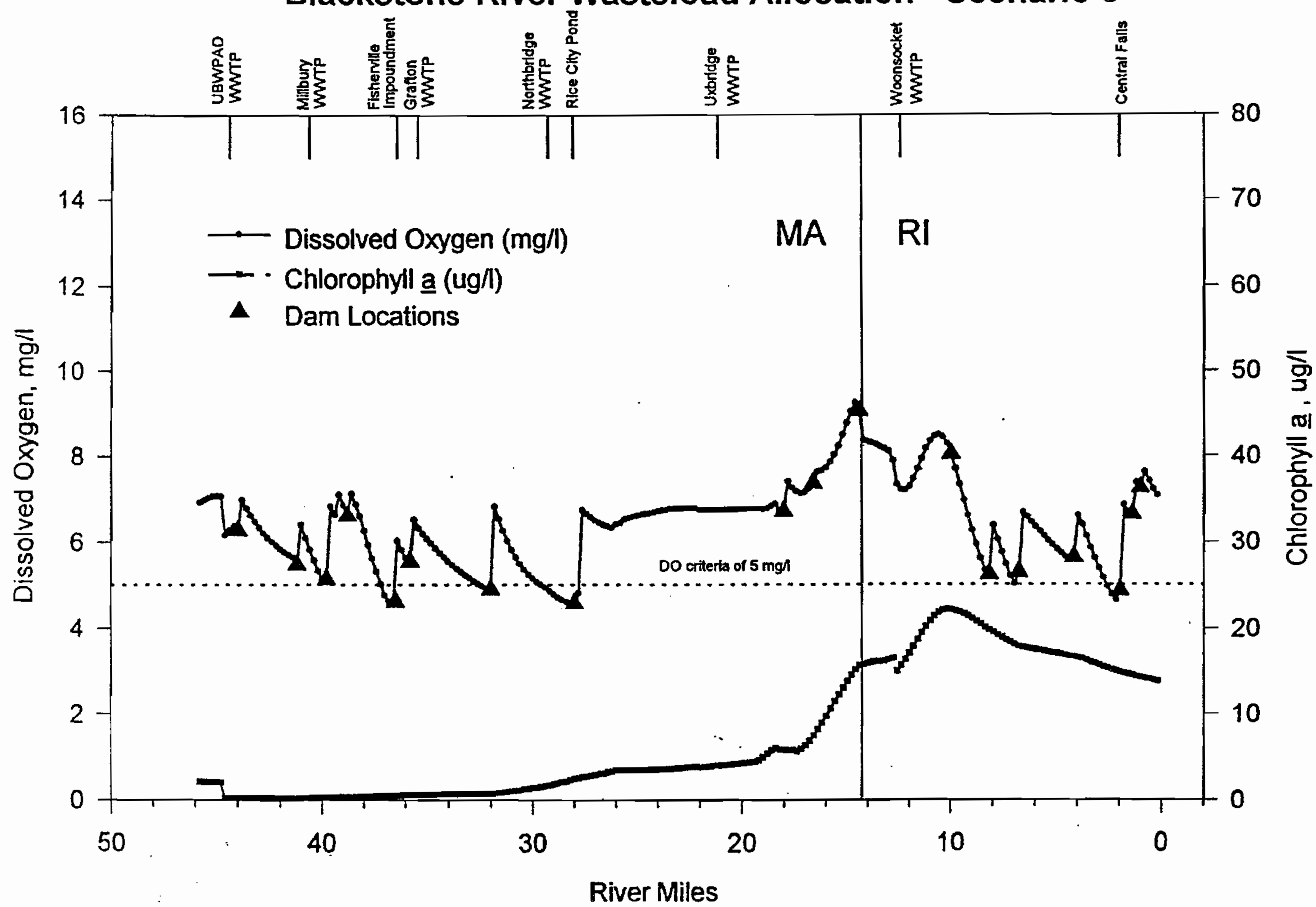


Figure X

Blackstone River Wasteload Allocation - Scenario 9

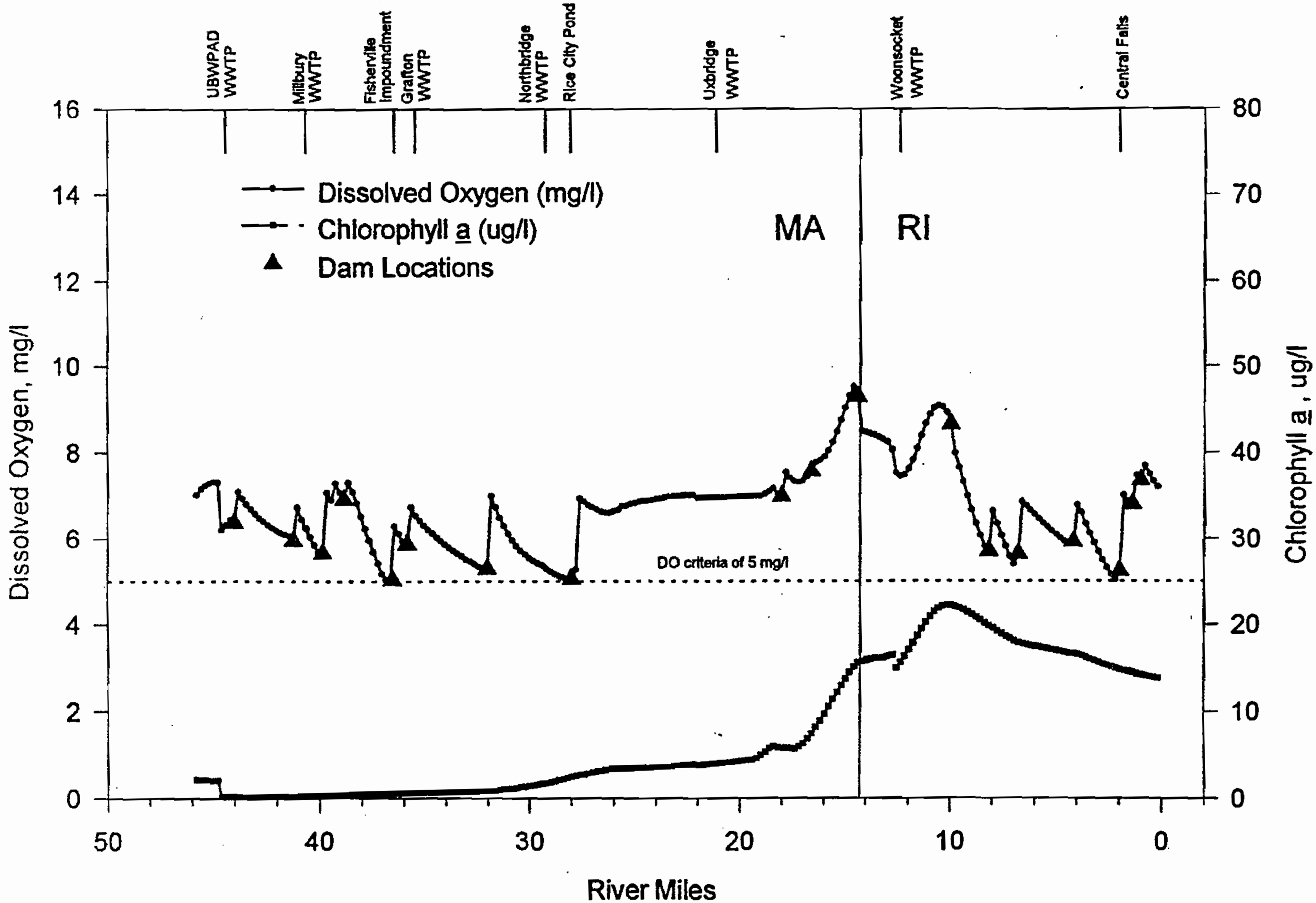
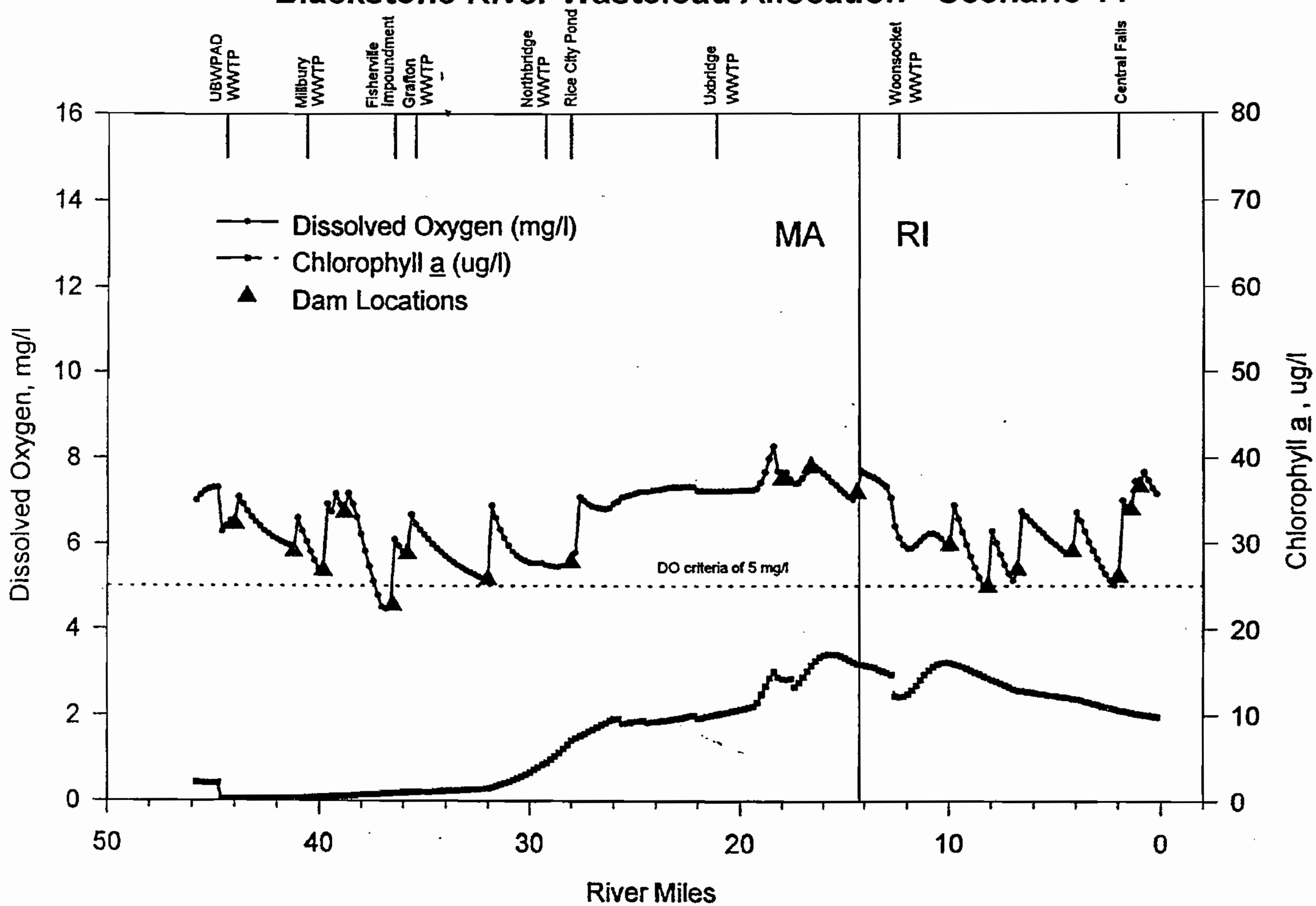


Figure XI

Blackstone River Wasteload Allocation - Scenario 11



Blackstone River Model - WLA 0 (Baseline Condition)