Kennebec River Modeling Report
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Executive Summary

The Kennebec River was sampled intensively during 1997 and 1998. The 1997 data were presented in the report Kennebec River Data Report (preliminary), May 1998. The 1998 data were presented in the report Kennebec River Data Report 1998 Survey (Data Only), May 1999. This report details the updating and re-calibration of the MDEP's Kennebec River water quality model using the 1997 and 1998 data. The model was then used to evaluate water quality in terms of existing permitted point source discharges and nonpoint source loads. The results are discussed and recommendations provided.

Based on the 1997 and 1998 water quality surveys and the subsequent modeling the following are concluded/recommended:

(1) Dissolved oxygen criteria are attained at all locations under existing discharge permits and non point loading, although there is only marginal attainment at the lower end of the upper class B segment (below Showhegan).

(2) Dissolved oxygen levels are predicted as being increased as a result of the removal of Edwards dam, supporting a recent water quality classification upgrade of the former impoundment.

(3) In general the major impacts to the non tidal river in order of significance are plants/nutrients, point sources, SOD and non point sources. Within the tidal portion the impacts are SOD, point sources, plants/nutrients and non point sources.

(4) The majority of the phosphorous loading to the river is from point sources. There are indications that nutrient loading may become a major water quality issue in the future.

(5) The paper mills are the major source of phosphorous. MDEP should work with the paper mills to investigate methods to reduce phosphorous loading through process controls. Investigation of nutrient reduction may have to be extended to municipal plants as well.

(6) The Kennebec model should be expanded to include simulation of nutrient/algae/DO interactions for use when evaluating discharge permits.

(7) Any nonpoint work should focus on Wesserunsett Stream.

(8) Follow-up sampling should be made below Waterville (including the estuary) to investigate the effects of dam removal.

Introduction

As a part of the evaluation of the tools used in analyzing waste discharge licenses, the existing MDEP Kennebec River water quality model (1988) was reviewed. This review uncovered a number of problems with the model, therefore it was decided that the model would be updated using both the original 1985-1987 data and new data. Subsequently two complete river datasets were collected during 1997 and 1998.

The following table lists the problems with the existing model and the corrective action taken:

Table 1 Existing Model Review

Problem Encountered	Action Taken
Hydraulics:	
Rivermiles of segments and locations of several features (point sources, dams etc.) required adjustment	Entire modeled portion of the river was scaled off from USGS maps and the model segmentation adjusted; point source locations adjusted
Reach segmentation did not always correspond with tributary location and river hydrology (free flowing vs. impoundment)	See above
Hydraulic coefficients did not always reflect river hydrology (free flowing vs. impoundment)	Model was completely recalibrated to available dye study results; model depth and velocity output was checked against previously existing and new depth and velocity data; model hydraulic coefficients were adjusted
No depth/velocity data available for reaches above Skowhegan (although the dye studies did include this section)	Rely on dye study calibration.
Hydro-Kennebec dam redeveloped (impoundment elevation increased) after 1988 model was developed	After calibration of hydraulics to dye studies, increase depth of appropriate model segment to reflect increase in impoundment.
Estuary hydraulics plotted from NOAA charts. Tidal dispersion not represented.	Estuary transects obtained, downstream boundary conditions set up in model to simulate tidal dispersion
Removal of Edwards dam.	Collected post dam removal transect data. Adjusted calibrated model to reflect dam removal (calibration data was collected prior to dam removal)
Tree Free not modeled as withdrawing process water from the river.	Withdrawal added and model calibration re-checked.
Data:	
1985 data is outdated. Hydro dam and discharge licenses have been updated/reissued.	Recalibrated model using 1997-1998 data and current permits
Several gaps in SOD specification.	SOD data was reviewed, additional SOD data collected and the model values adjusted
Calibration:	
NBOD not modeled	Model adjusted to include NBOD (modeled as ammonia)

Project Description

The Kennebec River originates at Moosehead Lake and flows 145 miles to Merrymeeting Bay where it joins the Androscoggin River and then empties into the Atlantic Ocean below Bath, Maine. The Kennebec River basin has a drainage area of 5893 mi.^{2} at Abagadassett Point above the confluence with the Androscoggin River. The last 24 miles, from head of tide at the Augusta dam site to Abagadassett Point is tidal, but remains essentially freshwater. The segment of interest in regard to waste loading extends approximately 75 miles from Anson-Madison to Abagadassett Point, below Richmond. Within this segment there are 9 (one license has been recently retired) licensed point source wastewater discharges, 6 mainstem dams (Edwards Dam recently removed) and 6 tributaries over 80 mi.^{2} in drainage area. A list of tributaries, dams and point sources are shown in tables 2 through 5.

Table 2
Major Tributaries in the Kennebec River Study Area

Tributary	Drainage Area, mi.^{2}	Model River Mile
Sandy River	596	48.3
Wesserunsett Stream	142	34.8
Carrabassett Stream	85.1	28.9
Sebasticook River	946	16.5
Messalonskee Stream	207	15
Cobbosseecontee Stream	217	-7

Table 3
Dams on the Kennebec River

Dam	FERC#	Location	Ownership	Hydraulic Capacity, cfs
Moosehead Outlets	2671	T1R1 & T1R7	Kennebec Water Power Co.	20,500
Harris	2142	T1R6	FLP (CMP)	7100
Wyman	2329	Moscow	FLP (CMP)	8500
Williams	2335	Solon	FLP (CMP)	4300
Anson	2365	Anson/Madison	Madison Paper	5400
Abenaki	2364	Anson/Madison	Madison Paper	4980
Weston	2325	Skowhegan	FLP (CMP)	5960
Shawmut	2322	Fairfield	FLP (CMP)	6600
Hydro-Kennebec	2611	Waterville/Winslow	Kimberly-Clark Corp & UAH Hydro-Kennebec Ltd. Partnership	7500
Lockwood	2574	Waterville/Winslow	Merimil Ltd. Partnership	4920
Edwards*	2389	Augusta	Edwards Manufacturing Co. & City of Augusta	3300

*removed 1999

Table 4
STATE permit requirements

Facility	#	issue date	period	flow MGD	BOD5, lb/day (mg/l) mon ave	wk ave	daily max
AMSD	W002710	7/22/99	6/1-10/31	5.0	2780	-	5000
			11/1-5/31	5.0	2780	-	5275
after paper machine #4			6/1-10/31	7.84	6345	-	11200
after paper machine #4			11/1-5/31	7.84	6345	-	11835
SDW (SAPPI)	W000385	5/1/95	7/1-10/31	46.5	9400	-	16660
			11/1-6/30	46.5	14850	-	32670
Kimberly Clark (Scott)	Retired	-	-	-	-	-	-
Tree Free (Statler)	W000247	5/17/96	Tier I*	6.0	1850	-	3555
			Tier II*	6.0	3330	-	6400
Norridgewock	W007742	4/8/97	-	0.193	48(30)	72(45)	80(50)
Skowhegan	W002645	4/6/98	-	1.44	360(30)	540(45)	(50)
KSTD	W000687	4/8/98	-	12.7	3179(30)	4769(45)	(50)
Augusta	W002695	4/5/99	-	(12)	2502(25)**	4003(40)**	(45)**
Gardiner	W002655	6/3/99	-	4.5	1126(30)	1689(45)	(50)
Richmond	W002616	4/14/98	-	0.3	75(30)	113(45)	125(50)

*Tier I for 0-100 tons/day; Tier II for >100 tons/day
**CBOD5

Table 5
EPA permit requirements

Facility	#	issue date	period	flow MGD	BOD5, lb/day (mg/l) mon ave	wk ave	daily max
AMSD	ME0101389	8/21/91	6/1-10/31	-	2780	-	5000
			11/1-5/31	-	2780	-	5275
after paper machine #4			6/1-10/31	7.84	6345	-	11200
after paper machine #4			11/1-5/31	7.84	6345	-	11835
SDW (SAPPI)	ME0021521	1/14/94	6/1-10/31	46.5	9400	-	13500
			11/1-5/31	46.5	14850	-	32670
Kimberly Clark (Scott)	ME0002178	9/30/93	-	10.5	4085	-	7750
Tree Free (Statler)	ME0002224	8/29/90	-	6.0	3330	-	6400
Norridgewock	ME0102334	9/14/92	-	0.193	48(30)	73(45)	81(50)
Skowhegan	ME0100625	10/6/98	-	1.44	360(30)	540(45)	(50)
KSTD	ME0100854	8/21/98	-	-	3179(30)	4769(45)	(50)
Augusta	ME0100013	10/28/90	-	7.95	1659(25)*	2654(40)*	(45)*
				16.0 max			
Gardiner	ME0101702	9/30/98	-	4.5 max	1126(30)	1689(45)	1877(50)
Richmond	ME0100587	12/26/84	-	-	75(30)	113(45)	125(50)

*CBOD5

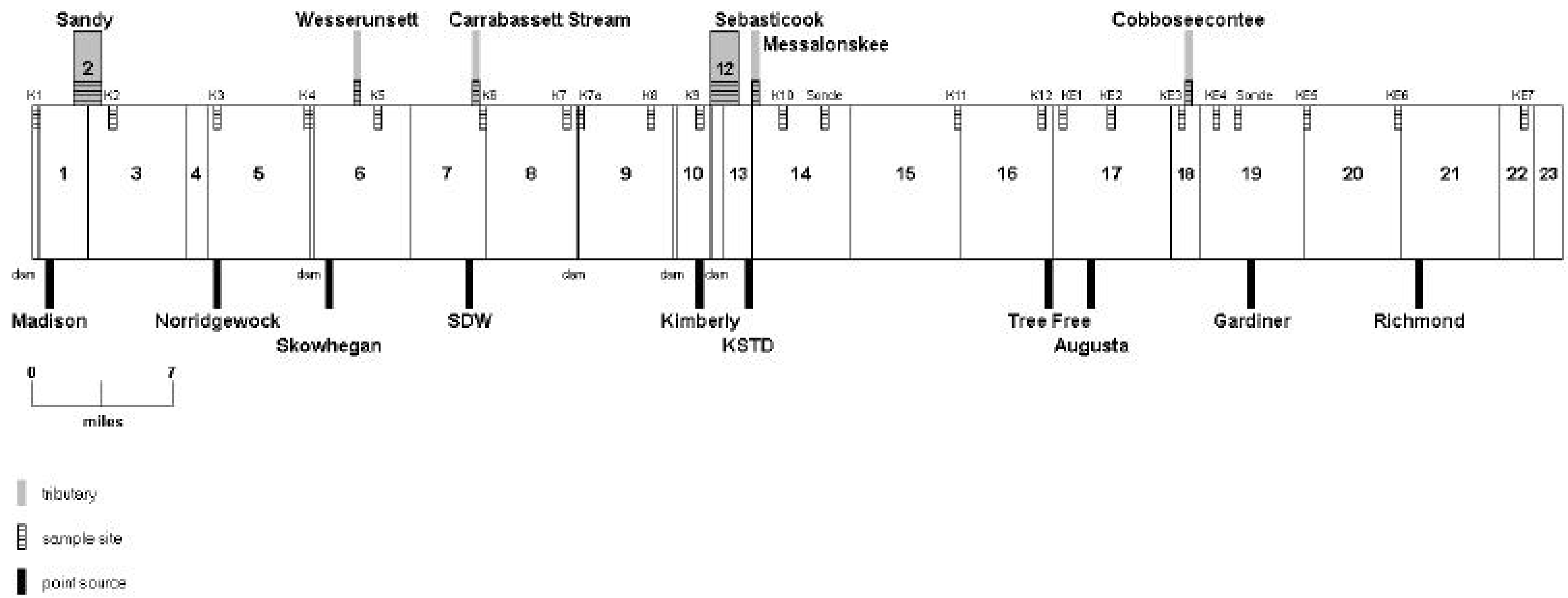
Modeling of the Kennebec and Sebasticook was performed during the mid 1970's. More recent modeling was made by MDEP during 1985-1988 (Lower Kennebec River Waste Load Allocation, Allen, 1988).

Much of the Kennebec River water quality classification was upgraded in 1988 and again in 1998-99. Within the proposed study area the segments between Madison and the Skowhegan/Fairfield boundary and between the confluence with Messalonskee Stream and the Augusta boundary were upgraded from C to B. More recently the segment from the Augusta/Sidney line to the Father Curran bridge was upgraded from C to B. Little water quality data had been collected between 1987 and 1997, with essentially no sampling made within the tidal portion. The bulk of the data has been from a discontinued 4 parameter monitor at Sidney. Based on data from this monitor minimum daily dissolved oxygen (DO) was often only marginally meeting standards during most summer periods. During these periods discharges are usually well below license limits.

Model Development Summary

Work began with the 1988 model. This model was set up using the QUAL2EU framework which is supported by EPA. In general this framework represents the river as a series of discrete well mixed elements and allows for the simulation of instream dissolved oxygen taking into consideration a number of sources and sinks (see figure A for the Kennebec model setup). For this study the model was run steady state and therefore represents daily average conditions. The model simulated river hydrology, dissolved oxygen, sediment oxygen demand (SOD), ultimate carbonaceous biochemical oxygen demand (CBODu) and ultimate nitrogenous biochemical oxygen demand (NBODu). Ultimate refers to long term BOD represented by tests lasting 60 days or more. A brief description of the QUAL2EU model is given in the earlier report (Lower Kennebec River Waste Load Allocation, Allen, 1988) and detailed information for this framework is given in the EPA QUAL2EU documentation (The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual, EPA/600/3-87/007, May 1987). For this effort version 3.22 (May 1996) of QUAL2EU was used.

The 1988 model reaches and elements (reaches are hydraulically distinct segments of the river made up of smaller elements of a given length, in this case 0.35 miles) were plotted on USGS topographic maps and the model structure adjusted where necessary to accurately depict tributary and point source locations. Reach boundaries were then adjusted to correctly represent river hydraulics such as impoundment vs. free flowing. The model hydraulics were then extensively tested and adjusted using available dye study and depth/velocity data (see tables 6, 7 and 8). Longitudinal dispersion was re-calculated using dye study data. Model reach 9 was then adjusted to reflect the redevelopment of the Hydro Kennebec dam at Winslow which occurred subsequent to the dye studies. Estuary hydraulics were developed using 1998 transect data and assuming an average tidal condition (see table 9). The two channels around Swan Island at Richmond were represented as a single model channel (transect data from the two channels were combined). The model representation of estuary velocity is based on river flow only because on an average daily basis this is the flow that contributes to downstream transport. Model estuary reaeration factors were then increased to account for the effect of higher tidal velocities which actually occur during specific periods of the tidal cycle. A summary of the calibration model hydraulic factors is given in table 9A.



Sandy
Wesserunsett
Carrabassett Stream
Sebasticook
Messalonskee
Cobboseecontee
2
12
K1
K2
K3
K4
K5
K6
K7
K7a
K8
K9
K10
Sonde
K11
K12
KE1
KE2
KE3
KE4
Sonde
KE5
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KE7
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23
dam
dam
dam
dam
dam
Madison
Norridgewock
Skowhegan
SDW
Kimberly
KSTD
Tree Free
Augusta
Gardiner
Richmond
0
7
miles
tributary
sample site
point source

Table 6 Hydraulics Comparison (DMR data)

Model Reach	River Flow, cfs	DMR Data*		Model*	
		Ave. Depth, ft.	Ave. Velocity, fps	Depth, ft.	Velocity, fps
13	5900	3.8 (15)	1.34 (13)	3.9	1.28
14	5900	7.0 (46)	1.15 (7)	7.0	1.14
15	4670	18.7 (48)	0.91 (7)	18.7	0.5
16	4694	21.2 (40)	-	21.2	0.5

()=number of transects
*before Edwards dam removal

Table 7
Hydraulics Comparison
(SDW/SAPPI data)

Model Reach	River Flow, cfs	SDW Data Ave. Depth, ft.	Model Depth, ft.
6	3976	10.5 (2)	9.7
7	3976	19.0 (3)	19.0
8	3927	20.0 (4)	20.0
9*	4906	7.6 (5)	6.2
10	5561	24.0 (1)	12.8
11	5121	6.0 (2)	3.8
13	5270	6.0 (1)	3.8
14**	5270	7.6 (5)	6.9
15**	5125	17.2 (5)	18.9
16**	4980	19.0 (5)	21.3

()=number of transects
*before H-K dam redevelopment
**before Edwards dam removal

Table 8
Dye Study Evaluation

Study	River Segment	Flow @ Skowhegan	Dye Study			Model			% velocity difference	Ave. %	Comment
			Dist. miles	Time hours	Ave. Vel. ft/sec	Dist. miles	Time hours	Ave. Vel. ft/sec			
1986	Madison-Skowhegan	5291	14.1	33.0	0.63	14.0	33.2	0.62	-1.3%		
1973, DEP	Madison-Skowhegan (Island)	3825	10.8	36.3	0.44	10.5	34.2	0.45	3.2%	0.94%	
1973, DEP	Norr.-Skowhegan (Island)	3994	2.6	21.4	0.18	-	-	-	-		bad study??
1973, EPA	Madison-Skowhegan	8900	13.3	18.9	1.03	13.0	18.9	1.01	-2.5%		high flow
1986	Skowhegan-Hinckley	5402	9.0	32.3	0.41	8.8	29.5	0.44	6.5%		
1973, DEP	Skowhegan (Rt. 2)-Shawmut	4255	13.5	61.7	0.32	13.3	62.6	0.31	-2.9%	1.83%	
1973, EPA	Skowhegan-Shawmut	12300	14.0	17.8	1.15	13.3	23.0	0.85	-26.5%		high flow
1986	Hinckley-Shawmut	5497	4.8	20.2	0.35	4.6	19.7	0.34	-2.8%		
1973, DEP	Rt. 23-Shawmut	4304	4.6	26.2	0.26	4.6	25.3	0.26	2.4%	-0.17%	
1986	Shawmut-Waterville	5544	5.5	8.3	0.98	6.3	7.8	1.18	**21.2%**		?
1973, DEP	Shawmut-Waterville	4522	4.5	6.3	1.05	4.6	6.6	1.02	-3.1%	9.05%	
1973, EPA	Shawmut-Waterville	7800	6.3	6.3	1.47	6.3	6.1	1.53	4.1%		High flow
1986	Waterville-Augusta	5597	18.8	32.0	0.86	17.5	29.7	0.87	0.4%		
1973, DEP	Waterville-Augusta	4453	17.5	34.6	0.74	17.2	36.5	0.69	-7.2%	-3.40%	
1973, EPA	Waterville-Augusta	9200	11.0	9.1	1.77	17.2	22.3	1.13	-36.4%		high flow,bad stdy?
1973, EPA	Sidney Gravel Pit-Augusta	9200	6.4	8.7	1.08	8.1	13.2	0.89	-17.1%		High flow

Table 9 Kennebec Estuary Hydraulics

Reach	Ave area, ft2	ave depth, ft.	model hydraulic factors			
			a*	b*	c	d
17	5435	6.3	0.00018	1	6.3	0
18	9222	12.4	0.00011	1	12.4	0
19	13117	12.7	0.00008	1	12.7	0
20	16166	12.3	0.00006	1	12.3	0
21**	23607	9.6	0.00004	1	9.6	0
22	35890	12.6	0.00003	1	12.6	0
23	36462	11.8	0.00003	1	11.8	0

*for travel time, does not consider tidal velocities
(therefore reaeration coefficients were increased)
**two channels modeled as one

Table 9A
Kennebec River Model Hydraulic Factors

	Hydraulic Factor*			
Reach	a	b	c	d
1	0.00018	0.95	5.0	0.05
2**	0.0733	0.3	0.2	0.6
3	0.00018	0.95	7.0	0.05
4	0.00018	0.95	9.0	0.05
5	0.00018	0.95	11.0	0.05
6	0.00018	0.905	5.0	0.08
7	0.00018	0.905	9.8	0.08
8	0.000065	0.99	20.0	0.0
9	0.0022	0.7	0.9	0.25
10	0.0027	0.7	0.9607	0.3
11	0.0027	0.71	0.75	0.19
12**	0.02	0.4	0.32	0.5
13	0.0027	0.71	0.75	0.19
14	0.0013	0.78	2.25	0.13
15	0.00053	0.81	8.05	0.1
16	0.00053	0.81	9.1	0.1
17	0.00018	1.0	6.3	0.0
18	0.00011	1.0	12.4	0.0
19	0.00008	1.0	12.7	0.0
20	0.00006	1.0	12.3	0.0
21	0.00004	1.0	9.6	0.0
22	0.00003	1.0	12.6	0.0
23	0.00003	1.0	11.8	0.0

* velocity $=a(Q)^b$ depth$=c(Q)^d$ Q=river flow
**tributary segment not explicitly modeled

After the model hydraulics were established, the model was then set up for the 1997 dataset. These data were presented in the Kennebec River Data Report (preliminary), Miller, May 1998. River flow balances, boundary conditions and loads representing the 1997 survey period were incorporated into the model. An additional load was added to the KSTD point load to represent a break in the sewer line that crossed the river from Winslow to Waterville. The model was run and model CBODu decay rate was adjusted until a good fit with the CBODu data within the non-tidal reaches was achieved. As part of this process it was decided to not include the 8/14/97 CBODu data value for sample site K1 in the average for the model upper boundary as it appeared to be an outlier which had a large impact upon model calibration. Because the tide water is freshwater, salinity could not be used to calibrate tidal dispersion in the estuary reaches. Instead, downstream boundary conditions were set using high tide data and then estuary dispersion inputs were adjusted until model CBODu matched the CBODu data in the estuary. This calibration procedure was then repeated for NBODu calibration.

Finally DO calibration was checked. Initial values for reaeration factor, Ka, for the non tidal reaches were based on O'Connor/Dobbins formulation:

$$Ka^{20}=(D_m\ u)^{0.5}/d^{1.5}$$

Where: Ka^{20}=reaeration factor (20^o C), day^{-1}
$D_m=1.91x10^3\ (1.037)^{T-20}$
u=average velocity, fps
d=depth, ft
T=temperature

Ka within the tidal segments was calculated based upon estimated tidal velocities and depths. Initial values for SOD (sediment oxygen demand) were added to the model based on data. The SOD data, both recent (not included in the data reports) and earlier, are shown in the appendix. The model was run and Ka and SOD adjusted within a narrow range until a good match to the DO data was achieved. In this process the Ka of the impoundments had to be increased; this is justified by a formula for minimum Ka based on water depth and by the probable contribution of wind induced reaeration:

$$Ka^{20}=c/d \qquad Ka^{20}=bW/d$$

Where:
Ka^{20}=reaeration factor (20^o C), day^{-1}
c=2 to 3
d=depth, ft
b=0.25 to 0.5
W=wind velocity, MPH

The non tidal SOD data from 1985-86 provided a better calibration than the more recent data from 1998. The tidal SOD data from 1985-86 and 1998 agreed much better. The Ka factors (adjusted for temperature) used in the model for each dataset run as well as the final 7Q10 model run are shown in table 9B.

Table 9B
Ka Factors, day^{-1}

Reach	1997 Conditions	1998 Conditions	7Q10 Conditions
1	0.38	0.45	0.38
2	0 (not modeled)	0 (not modeled)	0 (not modeled)
3	0.24	0.28	0.23
4	0.17	0.19	0.16
5	0.12	0.14	0.12
6	0.23	0.26	0.23
7	0.22	0.21	0.22
8	0.22	0.21	0.22
9	0.63	0.62	0.65
10	0.35	0.33	0.37
11	1.98	1.98	2.00
12	0 (not modeled)	0 (not modeled)	0 (not modeled)
13	1.99	2.00	2.00
14	0.73	0.77	2.00
15	0.11	0.12	0.62
16	0.10	0.10	0.39
17	0.71	0.80	0.62
18	0.27	0.27	0.28
19	0.27	0.27	0.28
20	0.33	0.32	0.33
21	0.55	0.54	0.56
22	0.38	0.38	0.39
23	0.38	0.38	0.39

Models for large rivers (long, large travel time) may not account for natural benthic CBOD input so that when the model is run without any licensed wastewater discharges, the modeled instream CBOD falls well below measured background levels and may approach zero. In QUAL2EU, benthic CBOD sources can be simulated using a negative settling rate. The 1997 (and 1998) calibration model was run with no permitted point sources and the minimum instream CBOD was found to be maintained at >90% of the background input. It was concluded that the model adequately represents the system without the use of negative settling factor. It should be noted that no CBOD settling is used in the model. In effect the model is representing net benthic transport as zero with settling and re-suspention canceling each other.

Model runs were then made for the 1998 dataset. These data were presented in the Kennebec River Data Report 1998 Survey (Data Only), Miller, May 1999. The process was similar to above except that additional reaeration due to spillage over the Shawmut dam was included.

The two dataset runs were then reconciled to result in a calibrated/verified Kennebec River model. The resulting CBOD decay rate (Kd) and NBOD decay rate were 0.015 day^{-1} and 0.05 day^{-1} respectively. The results of the calibrated/verified model runs for the 1997 and 1998 surveys are plotted in the following figures along with the survey data. These plots show the average data as “dots” bracketed by the maximum and minimum data values and the model prediction as the line plot. In general the model produced good agreement with the average daily data. The model fell short in representing the increased aeration due to spillage at the Shawmut dam during the 1998 survey but this spillage is not a normal occurrence under low flow conditions and will not be included in the low flow predictive model.

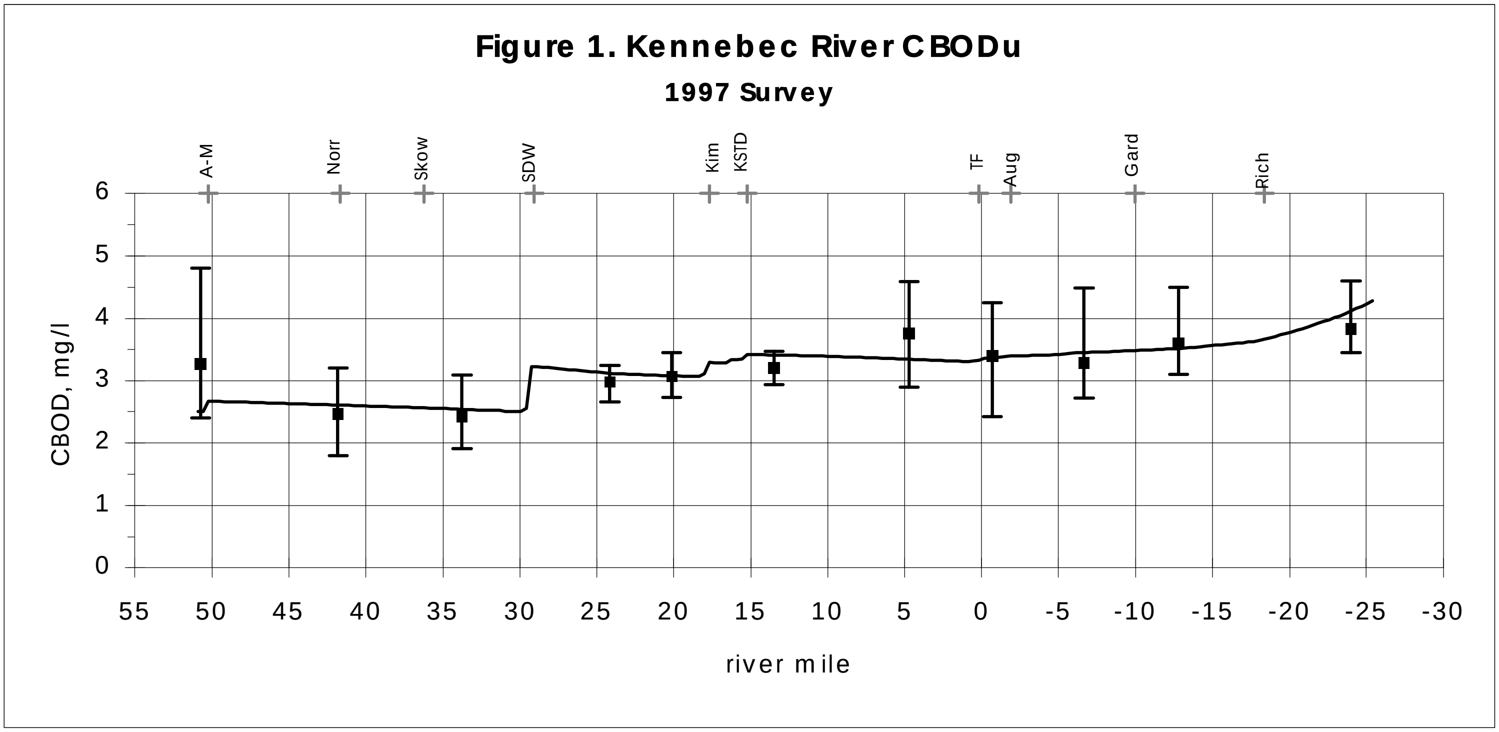


Figure 1. Kennebec River CBODu
1997 Survey
A-M
Norr
Skow
SDW
Kim
KSTD
TF
Aug
Gard
Rich
CBOD, mg/l
river mile

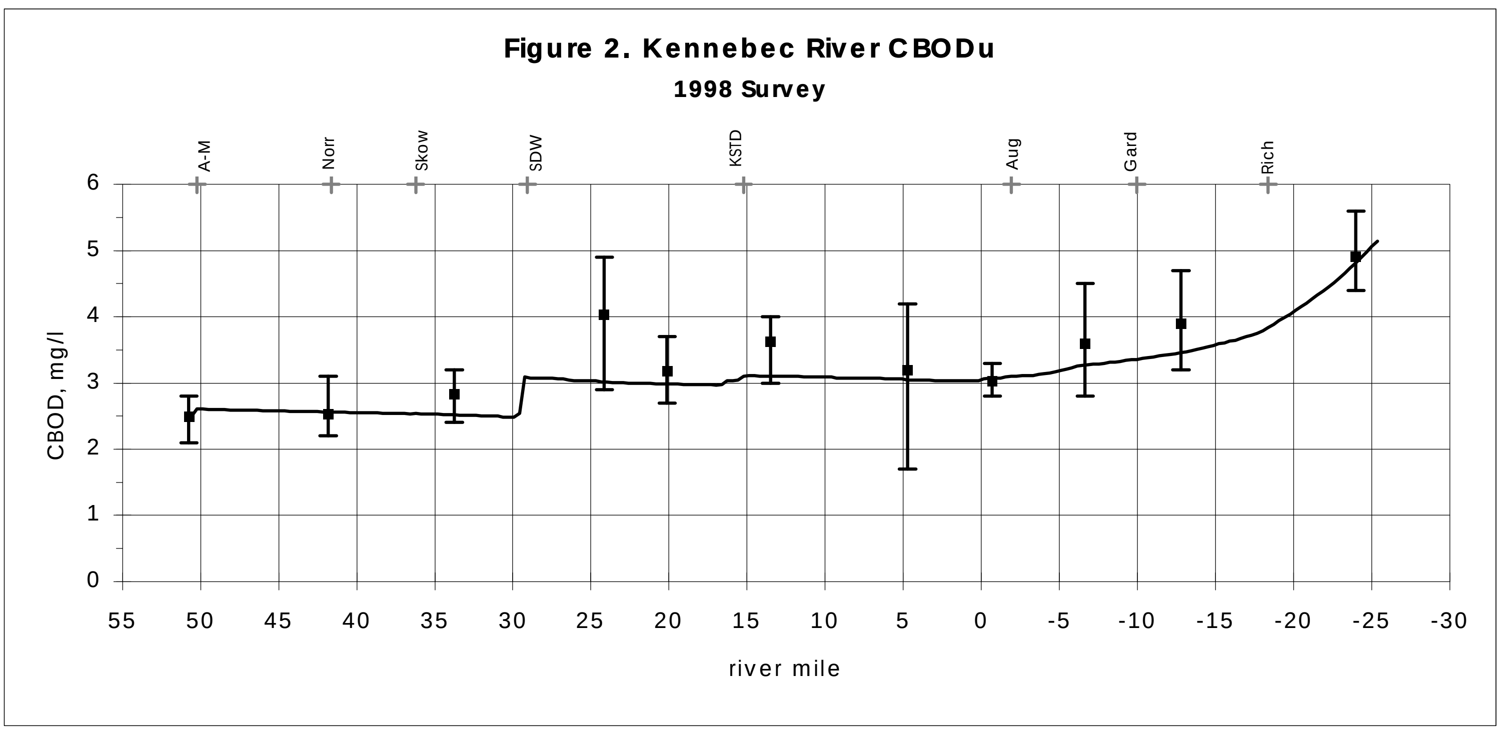


Figure 2. Kennebec River CBODu
1998 Survey
A-M
Norr
Skow
SDW
KSTD
Aug
Gard
Rich
CBOD, mg/l
river mile

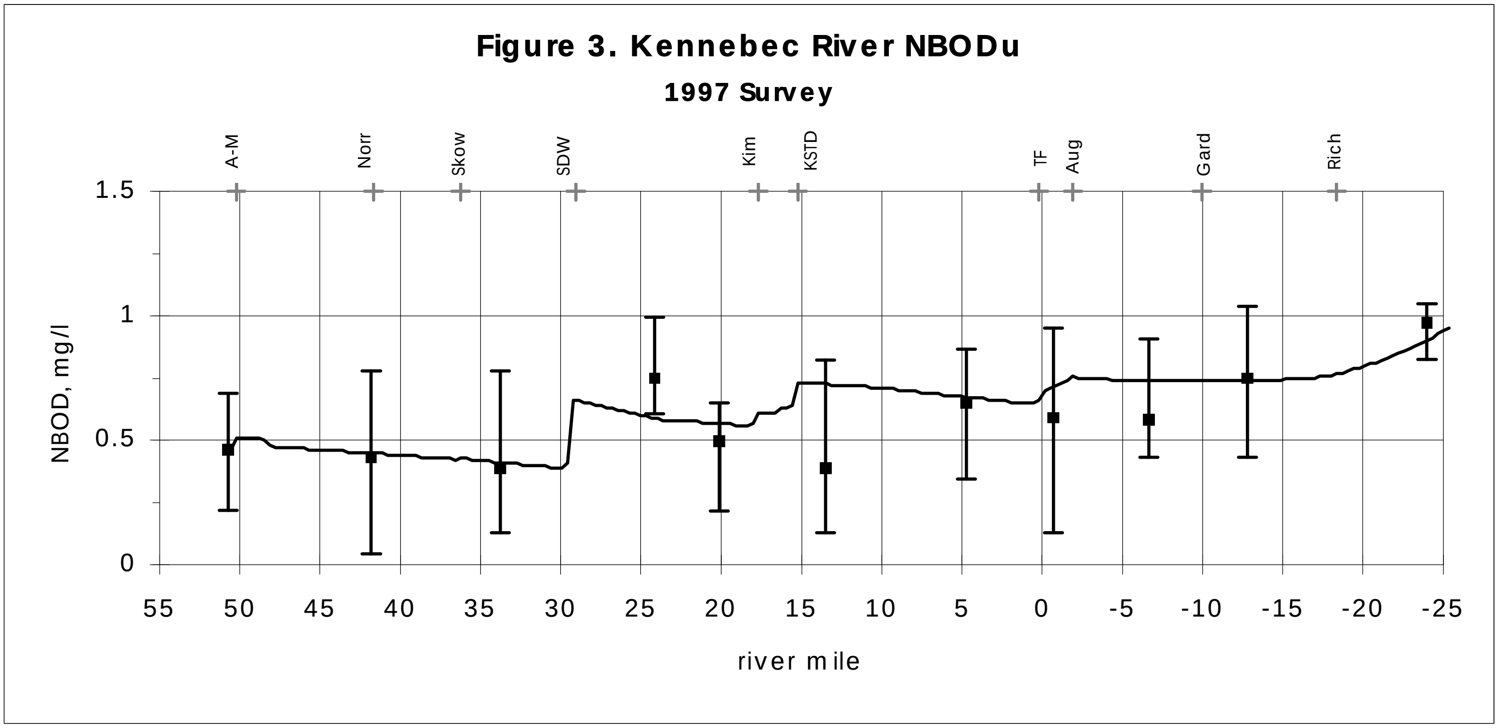


Figure 3. Kennebec River NBODu
1997 Survey
A-M
Norr
Skow
SDW
Kim
KSTD
TF
Aug
Gard
Rich
1.5
1
0.5
0
NBOD, mg/l
55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25
river mile

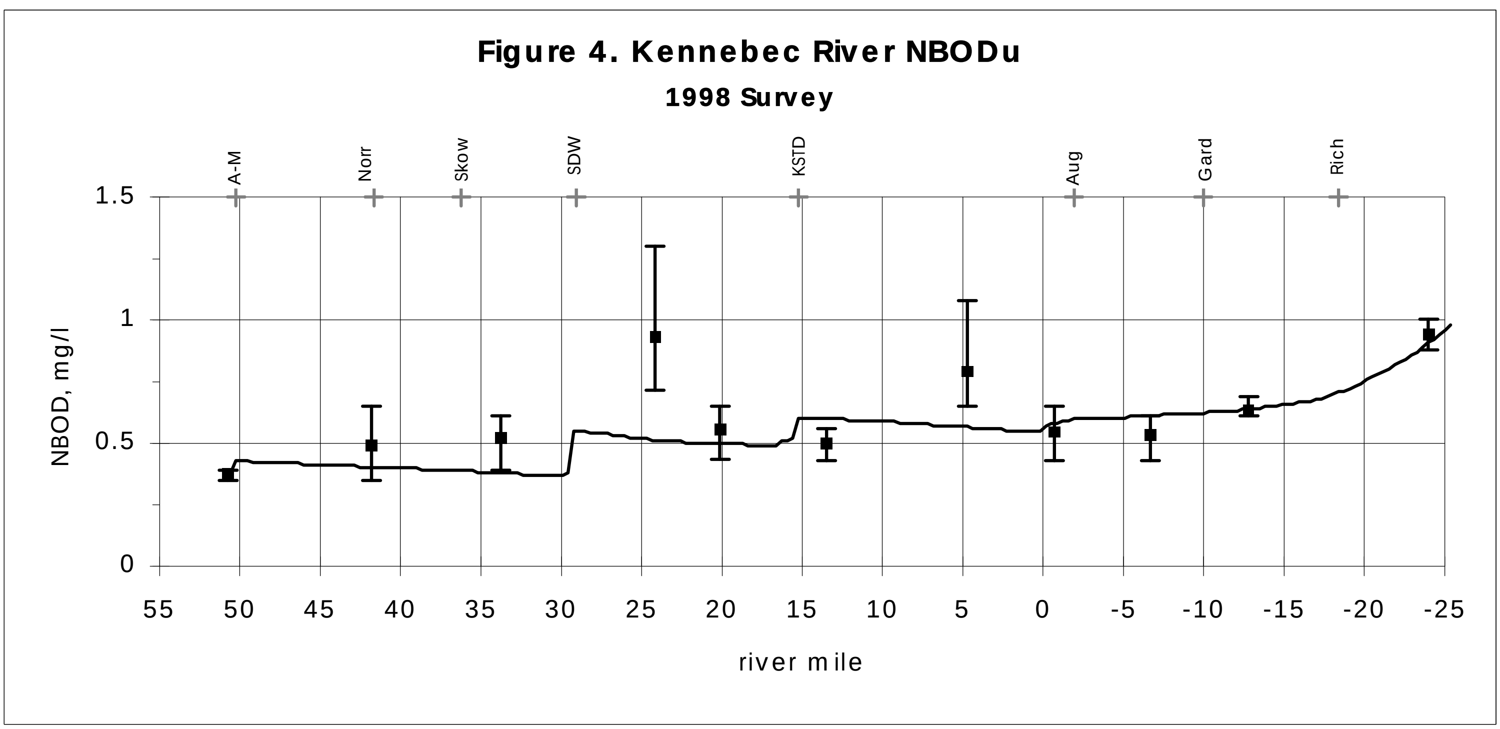


Figure 4. Kennebec River NBODu
1998 Survey
A-M
Norr
Skow
SDW
KSTD
Aug
Gard
Rich
1.5
1
0.5
0
NBOD, mg/l
55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25
river mile

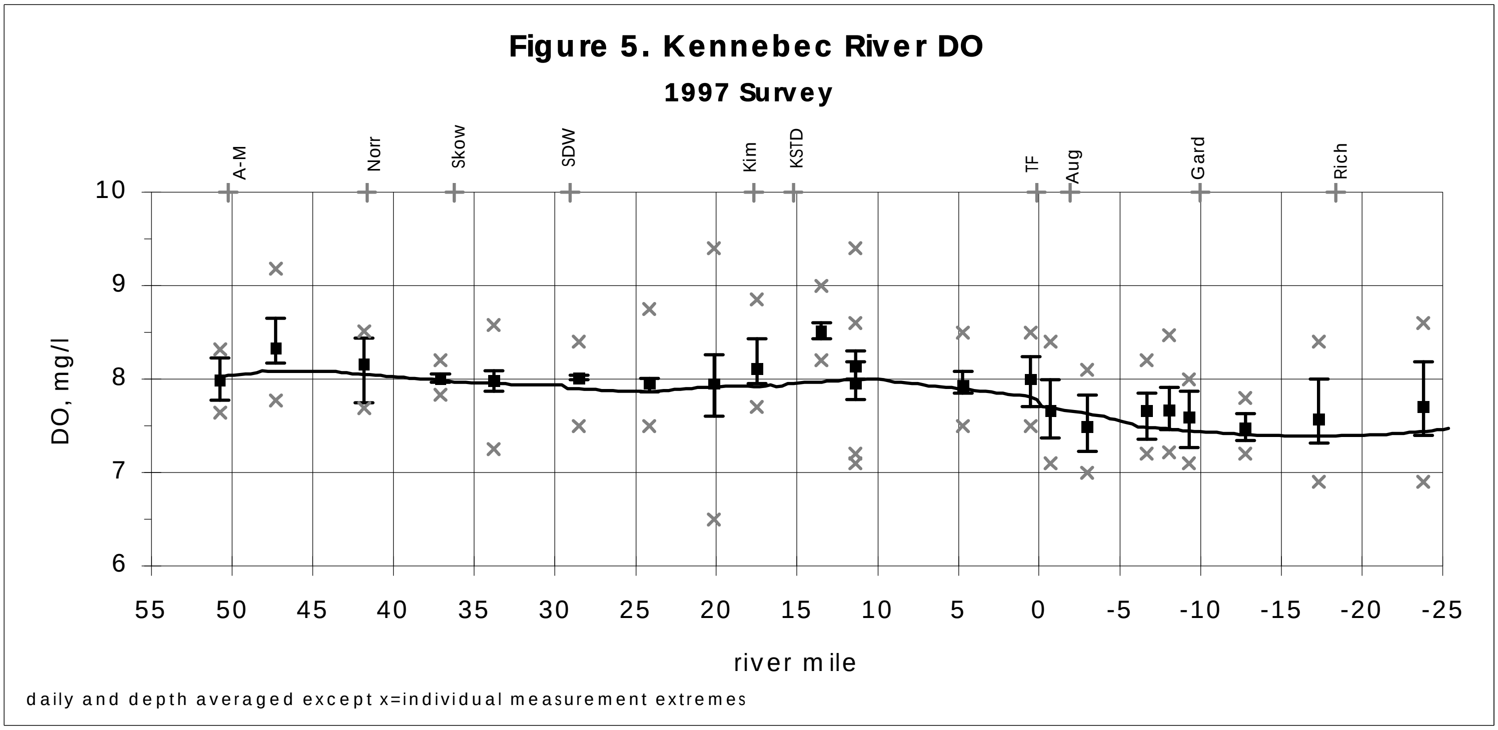


Figure 5. Kennebec River DO
1997 Survey
A-M
Norr
Skow
SDW
Kim
KSTD
TF
Aug
Gard
Rich
DO, mg/l
river mile
daily and depth averaged except x=individual measurement extremes

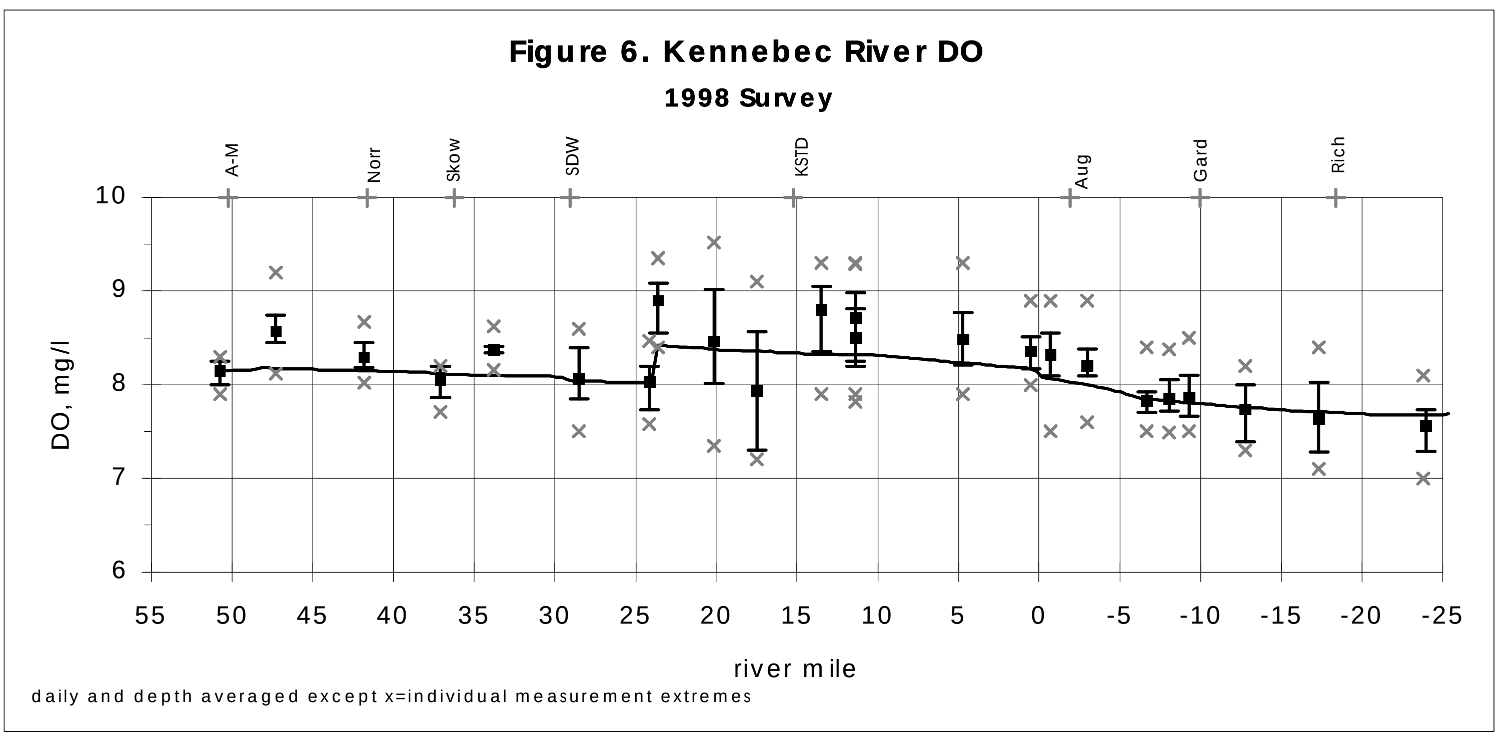


Figure 6. Kennebec River DO
1998 Survey
A-M
Norr
Skow
SDW
KSTD
Aug
Gard
Rich
DO, mg/l
river mile
daily and depth averaged except x=individual measurement extremes

Low Flow Modeling

For purposes of evaluating licensed wastewater discharges for compliance with water quality standards the calibrated and verified model described above is adjusted to model the impact on the river of full licensed loading under low river flow/high temperature conditions.

River Flows/Hydraulics

MDEP regulatory rules state that assimilative capacity analyses are made using the 7 day low flow that occurs once in 10 years (7Q10). For this condition weekly permit limits are normally used. In addition monthly license limits are evaluated using the 30Q10 flow. Evaluation of acute toxicity is based on 1Q10 flow or ¼of 1Q10 flow. Therefore an evaluation was made to establish these flows for the Kennebec River.

A statistical evaluation of the flow data from four major tributaries of the Kennebec using the entire period of record verses a more recent subset of the flow record showed that flow regulation on Cobbosseecontee Stream has changed in recent years while flows on the others (Carrabassett River, Sandy River and Sebasticook River) have remained consistent over the entire period of record. Therefore flow statistics for Cobbosseecontee Stream will be based on only recent flow data (last 21 years). The resulting low flow statistics for the Kennebec River and tributaries are shown in table 10.

The USGS has maintained main stem flow gages on the Kennebec River at Bingham, Sidney and Waterville. The Sidney and Waterville sites are within the model study area. The Sidney gage includes 14 years of data from 1979 through 1993. The Waterville gage includes 5 years of available flow data from 1993 through 1998 at the time of this report. The data from these two gages were combined to provide 19 years of recent flow data from which to calculate the flow statistics. The 1 day, 7 day and 30 day annual minimum flows for each of the years at the Waterville gage were pro-rated to the Sidney gage site. This was done by accounting for the difference in drainage area using the CFSM (flow in cfs per square mile drainage area) from unregulated tributary streams (Sandy River and Carrabassett River) for the same time periods.

Table 10
Low Flow Statistics

Site	Years	DA, mi.2	1Q10, cfs	7Q10, cfs	30Q10, cfs
Kennebec @ Sidney	19*	5403	2070*	2528*	2625*
Carrabassett	76	353	40.7	46.8	58.2
Sandy	60	514	41.2	46.7	59.9
Sebasticook	69	572	6.2	28.7	67.1
Cobbosseecontee	21	217	8.2	9.0	12.7

*includes recent Waterville site data

Subsequent to the data collection surveys of 1997 and 1998, the Edwards dam at Augusta was removed altering the river hydraulics between Messalonskee Stream and Augusta. As a result the calibrated model hydraulic factors for model reaches 14, 15 and 16 must be redefined for the low flow runs. During September 2, 1999 river transects were measured from just above the Sidney boat ramp down to Seven Mile Island. These data were used to define the hydraulics for model reach 15. From observation, the river between Messalonskee Stream and Sidney is now similar to the river between Waterville and Messalonskee Stream, therefore the hydraulic factors for model reach 14 were set equal to those of reach 13. The hydraulic factors for model reach 16 were set equal to the new reach 15 factors with an adjustment for a small increase in depth. The revised hydraulic factors are shown in table 11.

Table 11
Revised Model Hydraulic Factors-dam removal

Model reach	Dispersion, K	a	b	c	d
14	825	.0027	.71	0.75	0.19
15	825	.0026	.71	1.61	0.19
16	825	.0026	.71	2.2	0.19

The 7Q10 flow balance was set up and boundary flows for the model defined (see table 12). The Sidney gage site was used as the basis for the flows. Flow statistics of the Carrabassett and Sandy Rivers were used to pro-rate the Sidney flows to other locations based on drainage area. In other words any unregulated drainage area was represented by the Carrabassett and Sandy River drainages.

Table 12
7Q10 Flow Balance

Location	DA mi.^{2}	7Q10, cfs est.*	7Q10, cfs model**
Madison dam	3248	2287	2287
(Sandy River)	(596)	(54.2)	69
Norridgewock bridge	3864	2356	2356
Skowhegan dam	3894	2359	2356
(Wesserunsett Stream)	(142)	(15.9)	20
(Carrabassett Stream)	(85.1)	(9.51)	12
Route 23 bridge	4146	2388	2388
Shawmut dam	4212	2395	2388
Waterville dam	4228	2397	2388
above Sebasticook	4228	2397	2388
(Sebasticook River)	(946)	(47.5)	115
above Messalonskee (gage)	5179	2503	2503
(Messalonskee Stream)	(207)	(23.1)	25
North Sidney (gage)	**5403**	**2528**	2528
Augusta dam	5493	2538	2528
above Cobbosseecontee Stream	5535	2543	2528
(Cobbosseecontee Stream)	(217)	(9)	9
below Cobbosseecontee Stream	5752	2552	2537
Route 197 bridge	5823	2560	2537
inlet to Merrymeeting bay	5893	2567	2537

*pro-rated from Sidney gage using tributary data

**not including outfall flows

<u>Boundary and Point Source Loads</u>

Tributary and river boundary loads/conditions for the low flow modeling were based on the 1997 and 1998 datasets. Average values of CBODu and NBODu from the data sets were used for boundary inputs. A temperature of 76.1^{o}F (24.5^{o}C) was chosen for the low flow model runs. This temperature is slightly higher than that measured during the surveys. Average DO in terms of percent saturation was calculated for the boundaries and converted back to DO in mg/l using the model temperature. Non point model inputs are shown in table 13A.

Point source loadings are based on permit limits for discharge flow and five day BOD (BOD5) except that NBODu loading was based on the 1997 and 1998 TKN data using the conservative assumption that all TKN would oxidize as NBODu. The CBODu loadings were based on weekly permit limits for BOD5 and a factor for converting BOD5 to CBODu. These factors (see table 13) were derived from the 1997 and 1998 effluent data. The Kimberly-Clark permit has been retired and is not included in the model. For facilities with no weekly limits (industrial facilities), 90% of daily maximum limits was used. The Augusta permit is written in terms of CBOD5, therefore the conversion factor was based on the CBOD5:CBODu ratio. In general summer limits were used for those permits with seasonal limits and for facilities with conditional limits, the higher limit was used (tier II limits for Tree Free and paper machine #4 limits for Madison Paper). The input file for the 7Q10 model is included in the appendix.

Table 13 Point Load Model Factors

facility	CBODu/BOD5	CBOD (model input) mg/l	NBODu** (for model input) mg/l	Model rivermile
AMSD	2.7	416.2	35	50.23
Norridgewock	2.5	112.5	117	41.65
Skowhegan	2.7	121.5	22	36.22
SDW/SAPPI	3.9	152.3	30	29.05
KSTD	3.1	139.5	30	15.22
Tree Free (Statler)	1.6	181.9	9	0.18
Augusta	5.1*	204.0	74	-1.92
Gardiner	2.9	130.5	74	-9.98
Richmond	4.0	180.0	27	-18.38

*using CBOD5
**based on 1997 TKN data

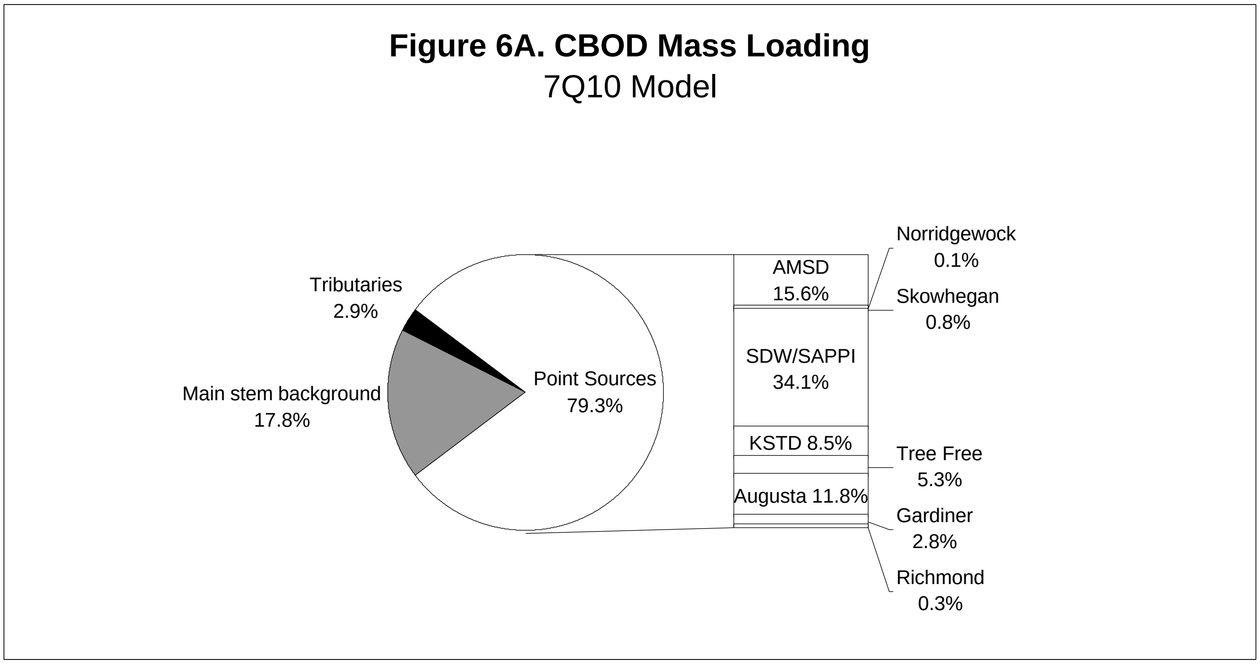
Table 13A Non Point 7Q10 Model Loads

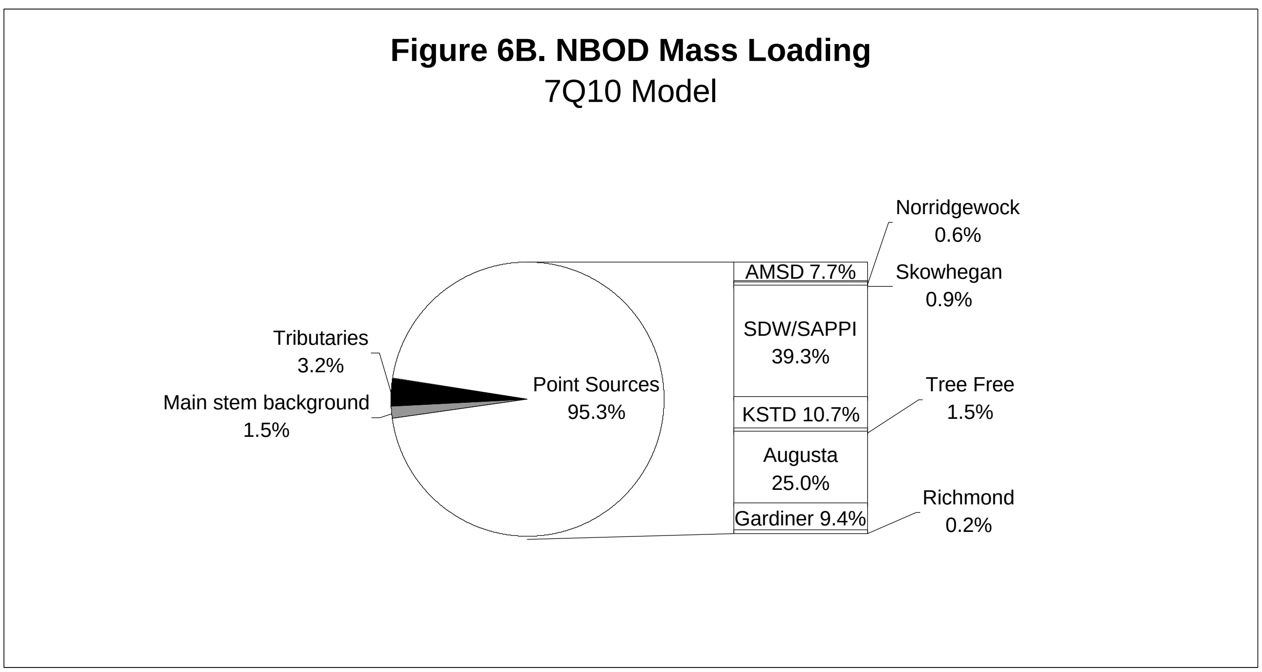
source	Flow, cfs	Concentration, mg/l		Mass, lbs/day	
		CBOD	NBOD	CBOD	NBOD
Main stem background	2287	2.50	.035	30823.5	431.5
Sandy River*	69	2.58	0.2	959.7	74.4
Wesserunsett Stream*	20	2.79	0.42	300.8	45.3
Carrabassett Stream*	12	4.00	0.5	258.8	32.3
Sebasticook River*	115	4.56	1.065	2827.8	660.3
Messalonskee Stream*	25	3.42	0.73	460.9	98.4

Cobbosseecontee Stream	9	4.40	0.82	213.5	39.8

*includes additional flow representing intervening drainage to mainstem

The following charts illustrate the relative mass loadings of CBODu and NBODu as established for the 7Q10 model:

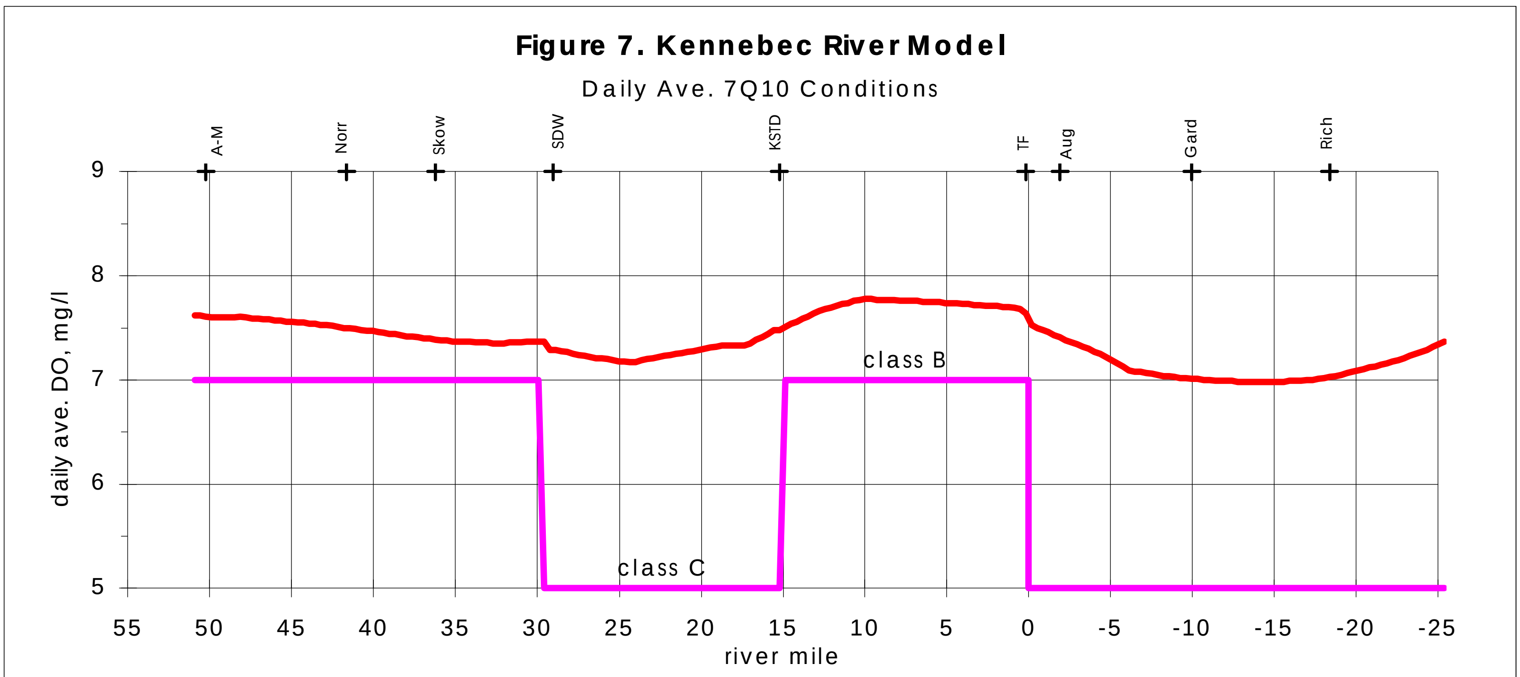




Model Results

<u>7Q10 Base Run</u>

The model was run under the low flow conditions (7Q10 river flow) and maximum loading conditions as described above. The results for average daily DO are shown on the following chart. Also shown on the chart is the DO water quality standard. The minimum daily DO predicted is 6.98 ppm which is greater than the class C monthly average standard of 6.5 ppm. Therefore a model run for 30Q10 river flow and monthly average permit discharge levels is not required.



Sensitivity Analyses

The 7Q10 model was evaluated for sensitivity of the results to changes in basic parameter rates. Model runs were made with each rate increased 50% and decreased 50%, one at a time, and the impact on model predictions noted. The results of this analysis are shown in the following table.

Table 14
Sensitivity Analysis Based on 7Q10 Model

		Concentration Difference in mg/l			
Condition	Constituent	Estuary Sag Point	River Sag Point	Max	Location*
Ka +50%	DO	0.33	0.30	0.33	20 & 10
Ka -50%	DO	-0.73	-0.52	-0.74	19
SOD +50%	DO	-0.37	-0.18	-0.37	20
SOD -50%	DO	0.37	0.18	0.37	20
Kd +50%	DO	-0.13	-0.19	-0.19	8
	CBOD	-0.53	-0.34	-0.56	19
Kd -50%	DO	0.15	0.2	0.21	8
	CBOD	0.58	0.36	0.61	19
Kn +50%	DO	-0.05	-0.07	-0.07	9
	NBOD	-0.20	-0.12	-0.20	19
Kn -50%	DO	0.07	0.09	0.09	8-9
	NBOD	0.26	0.15	0.27	19

*model reach (maximum may span multiple reaches)

Notes: Ka=reaeration rate
SOD=sediment oxygen demand
Kd=CBOD decay rate
Kn=NBOD decay rate

Diurnal Adjustment

As set up, the low flow model simulates average daily conditions only and does not account for variation within a period of a day. Plant photosynthesis and respiration result in diurnal cycles of DO concentration with minimum concentrations occurring at or near dawn and maximum concentrations occurring during mid to late afternoon. This is because plants produce excess oxygen during the day but only consume oxygen during the night. The magnitude of these variations depends upon the concentration of plants, available nutrients, available light, etc. Water quality standards dictate instantaneous minimum concentrations for DO, therefore the model must be able to predict daily minimum DO concentration. To achieve this the DO predicted by the model is bracketed by a diurnal range developed from the 1997 and 1998 datasets, generally using the maximum measured range at each sample site (see tables 15 and 16). This is not a perfect solution in that the diurnal variation that would occur under actual low flow, maximum load conditions may be greater than the variations measured during the surveys. The results of the low flow model including the diurnal brackets are shown on figure 8.

Table 15
DO Diurnal Variation, non-tidal

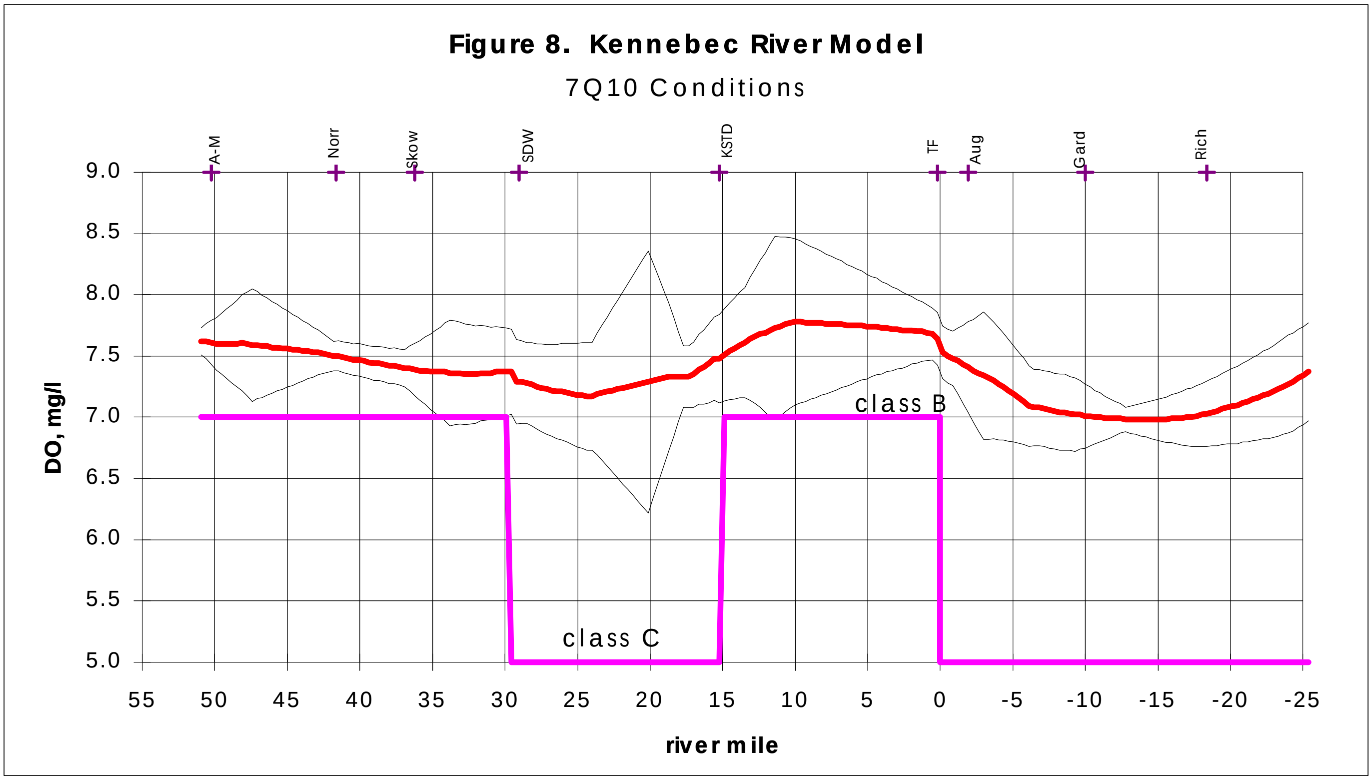
	Depth Averaged Diurnal DO Variation, mg/l							
	1998				1997			7Q10
Station	day 1	day 2	day 3	day 4	day 1	day 2	day 3	model
K1	0.12	0.20	0.10	-0.18	0.21	-0.03	0.12	0.21
K2	0.45	0.87	0.86	0.67	0.55	0.68	0.91	0.91
K3	-0.24	-0.15	-0.14	-0.31	0.03	0.00	0.23	0.23
K4	0.00	0.28	0.30	0.00	0.19	-0.22	0.27	0.3
K5	0.15	0.29	0.39	0.22	0.85	0.18	0.48	0.85
K6	0.65	-0.37	0.44	0.16	0.50	-0.03	0.13	0.65
K7	0.76	0.27	0.24	-0.05	0.88	0.25	-0.11	0.88
K8	1.29	0.37	0.86	0.97	2.13	0.78	0.83	2.13
K9	-0.09	-0.31	-0.04	-0.70	0.50	-0.42	-0.49	0.5
K10	0.90	0.73	0.50	0.55	0.15	0.00	0.80	0.9
K11	0.70	1.00	0.68*	0.45	1.5*	1.3*	1.15	1.5
K12	0.42	0.60	0.81	0.74	0.35	0.14	-0.19	0.81
K13	0.14	-0.06	0.20	0.39	0.21	0.10	0.42	0.42

*max from sonde

Table 16
DO Diurnal Variation, tidal

		Depth Averaged DO Variation, mg/l							
		1998				1997			7Q10
Station		day 1	Day 2	day 3	day 4	day 1	day 2	day 3	model
KE1	tide*	0.19	0.03	0.10	0.13	-	-0.06	0.42	0.44
	diurn**	0.35	0.42	0.86	0.50	0.44	-0.07	0.42	
KE2	tide*	0.68	0.98	-	-	-	-0.40	0.23	1.03
	diurn**	0.68	0.98	1.08	0.51	0.54	-0.15	0.23	
KE3	tide*	0.30	0.57	0.61	0.05	-	-0.31	0.04	0.61
	diurn**	0.30	0.57	0.61	0.05	-0.26	-0.55	0.04	
Sonde	tide*	0.16	0.38	0.61	0.19	-0.44	-0.38	-0.14	0.61
	diurn**	0.39	0.46	0.45	>.21	0.48	-0.58	0.39	
KE4	tide*	-	-	-	-	-	-	-	0.6
	diurn**	-0.07	0.21	0.40	0.6	0.00	0.48	0.20	
KE5	tide*	-	-	-	-	-	-	-	0.2
	diurn**	-0.02	-0.29	-0.22	0.2	-0.26	0.12	0.15	
KE6	tide*	-	-0.08	-0.04	-	-	-	-	0.48
	diurn**	0.18	-0.08	-0.04	0.42	-0.57	-0.12	0.48	
KE7	tide*	-	0.29	0.229	0.41	-0.67	-0.80	-	0.8
	diurn**	0.25	0.29	0.23	0.41	0.67	0.80	0.54	

*variation between high and low tide if data available
**variation between morning and afternoon readings



The 7Q10 model run with diurnal adjustment predicts that class B standards will not be met within a 4 mile segment from mile 34 to mile 31. Here the DO is within 0.07 ppm of the standard. The model calibrated well at this location. The minimum depth-averaged DO measured here was 7.3 (at <30% permit loading). The margin of 0.07 ppm is within measurement error. Based on these factors this segment can be considered in marginal attainment of DO.

It is also predicted that class B standards will not be met within a 0.5 mile segment near mile 11.4. This segment is within the former Edwards dam impoundment. Here the DO is within 0.02 ppm of the standard. This margin is within measurement error. In addition, the diurnal range at this location is based upon data collected when the dam was in place. Based on these this segment can be considered at least in marginal attainment of DO standards.

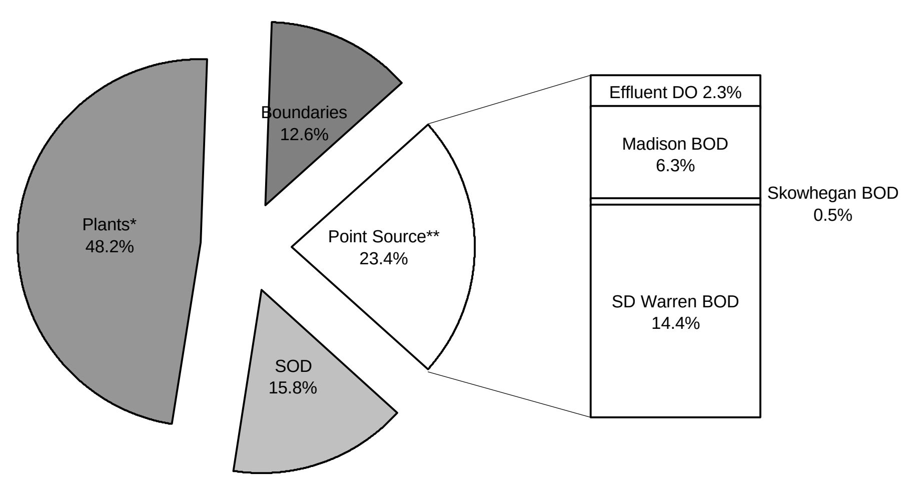
The model predicts that class C segments of the river will attain standards.

<u>Component Analyses</u>

The low flow model can be used to evaluate the relative contributions to the DO deficit through a component analysis. DO deficit is defined as the difference in DO concentration between the modeled result and the theoretical DO saturation level for the given temperature and salinity. A component analysis is performed by evaluating, one at a time, each loading that contributes to the DO deficit while zeroing out all other contributions. Component analyses were made at the location of minimum DO concentration within the non-tidal portion of the river (mile 20.1), the location of the minimum DO within the tidal portion of the river (mile -8.2) and the location of marginal DO attainment within the upper class B segment (mile 33.8) as indicated by the 7Q10 model.

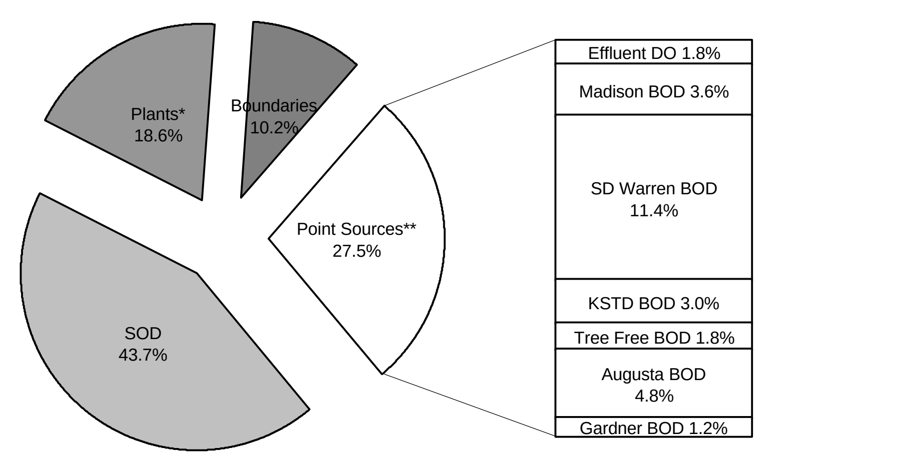
The results (shown on the following charts) indicate that within the non tidal river the major impacts to DO are plants and total point source BOD loading (note that point sources also contribute to plant growth through nutrient loading). Within the tidal estuary sediment oxygen demand (SOD) is the major source of DO depletion but plants and point source BOD loading are also significant players.

Figure 9. Dissolved Oxygen Deficit Components @ 7Q10 River Sag Point (mile 20.1)

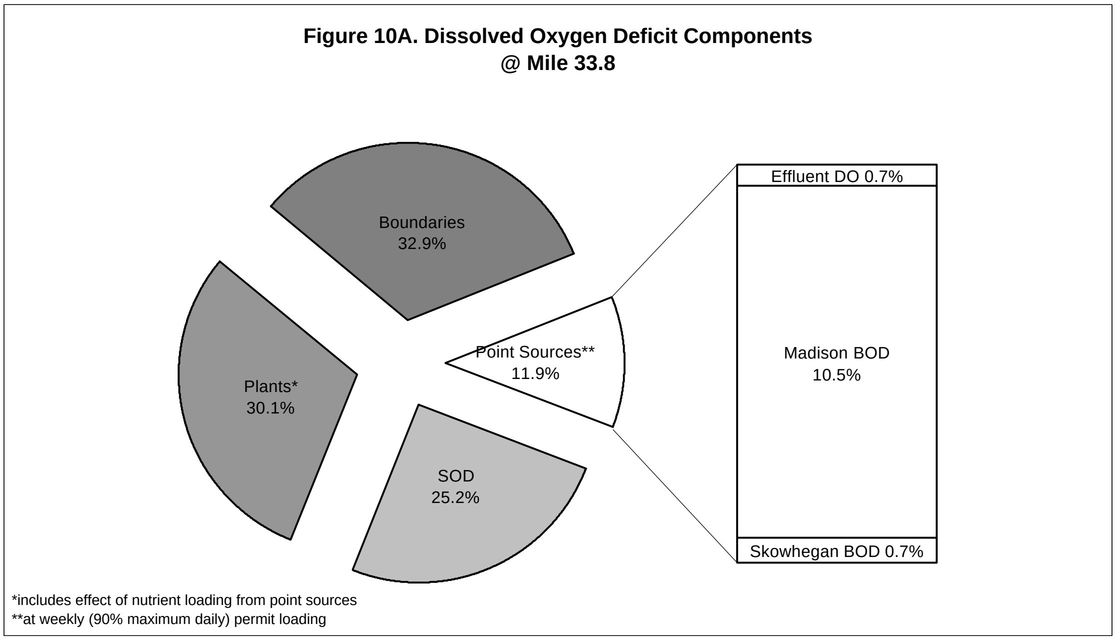


*includes effect of nutrient contributions from point sources
**at 90% maximum daily permit loading

Figure 10. Dissolved Oxygen Deficit Components @ 7Q10 Estuary Sag Point (mile -8.2)



*includes effect of nutrient loading from point sources
**at 90% maximum daily permit loading



Nutrient Analyses

Plant growth in the form of floating algae was not specifically simulated in the water quality model. The effects of plant growth were addressed using diurnal range (see section on diurnal DO). While this approach is less complex, it does not allow the modeler to evaluate the effect of nutrient loading reduction upon algae concentration and therefore on DO concentration. Plant growth is a function of available light and nutrients. Light limitation is a function of bank cover (for narrow streams) and water clarity. The nutrients of concern include nitrogen and phosphorous. In general it has been found that in fresh water systems phosphorous is the growth limiting nutrient while in marine systems nitrogen is the limiting nutrient.

Figure 11 depicts the chlorophyll-a (chl-a) data from the 1997 and 1998 surveys. Chl-a is a measure of the concentration of floating algae or phytoplankton in the water column. In terms of lakes, chl-a concentrations of >8 ppb is the level of concern for algae blooms. Note that these data represent the condition with Edwards dam in place (at mile 0).

The 1997 and 1998 survey data were used to assess nutrient loading to the Kennebec River. Figure 11A depicts the relative total phosphorous (TP) loading during the two surveys. Figures 12 and 13 show the TP concentrations measured in the Kennebec River during the surveys. Also shown on these charts are the model results for TP with TP modeled as a conservative constituent. Figures 14 and 15 show the relative contributions of phosphorous and nitrogen to the river in terms of mass.

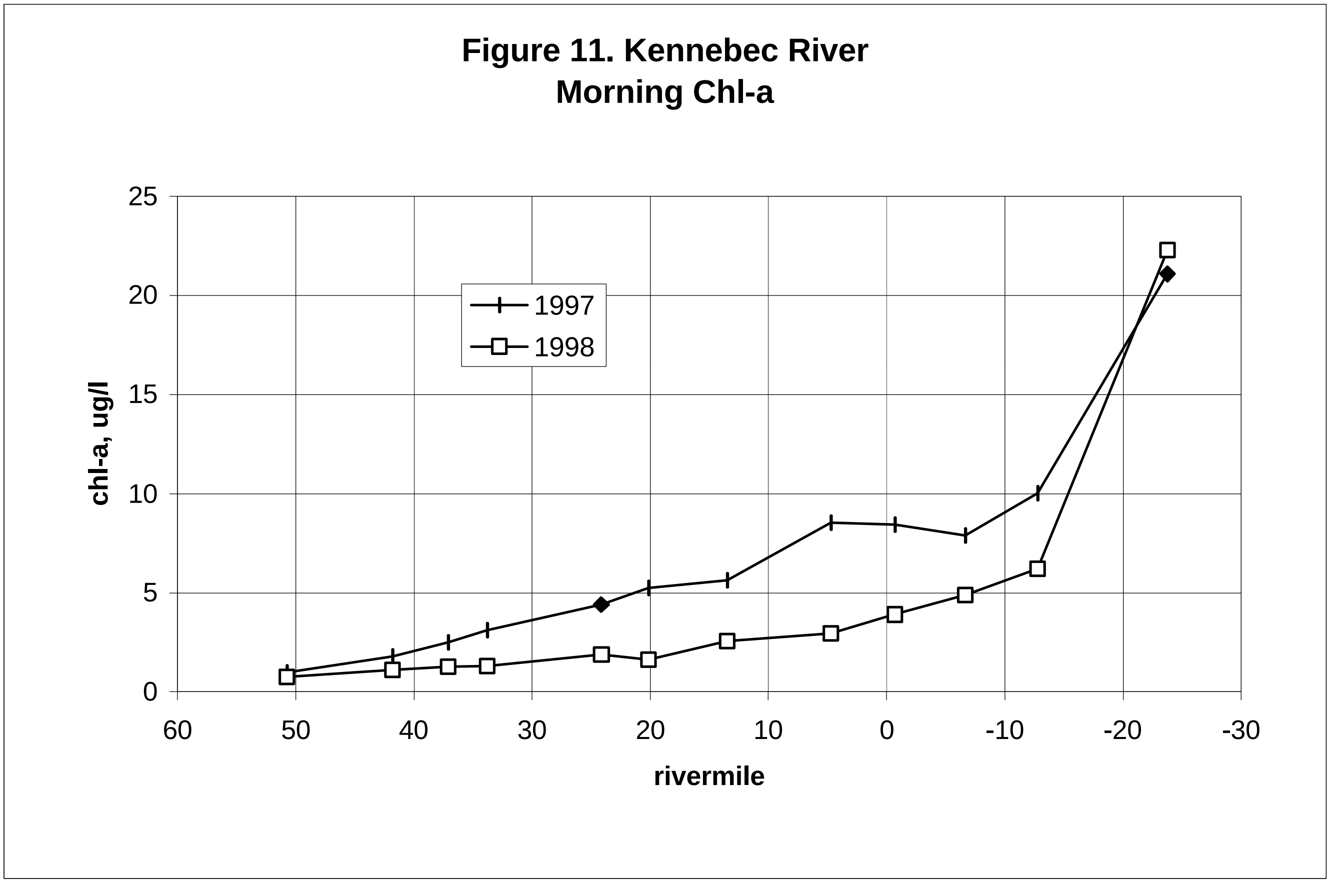


Figure 11. Kennebec River
Morning Chl-a
chl-a, ug/l
rivermile
1997
1998
0
5
10
15
20
25
60
50
40
30
20
10
0
-10
-20
-30

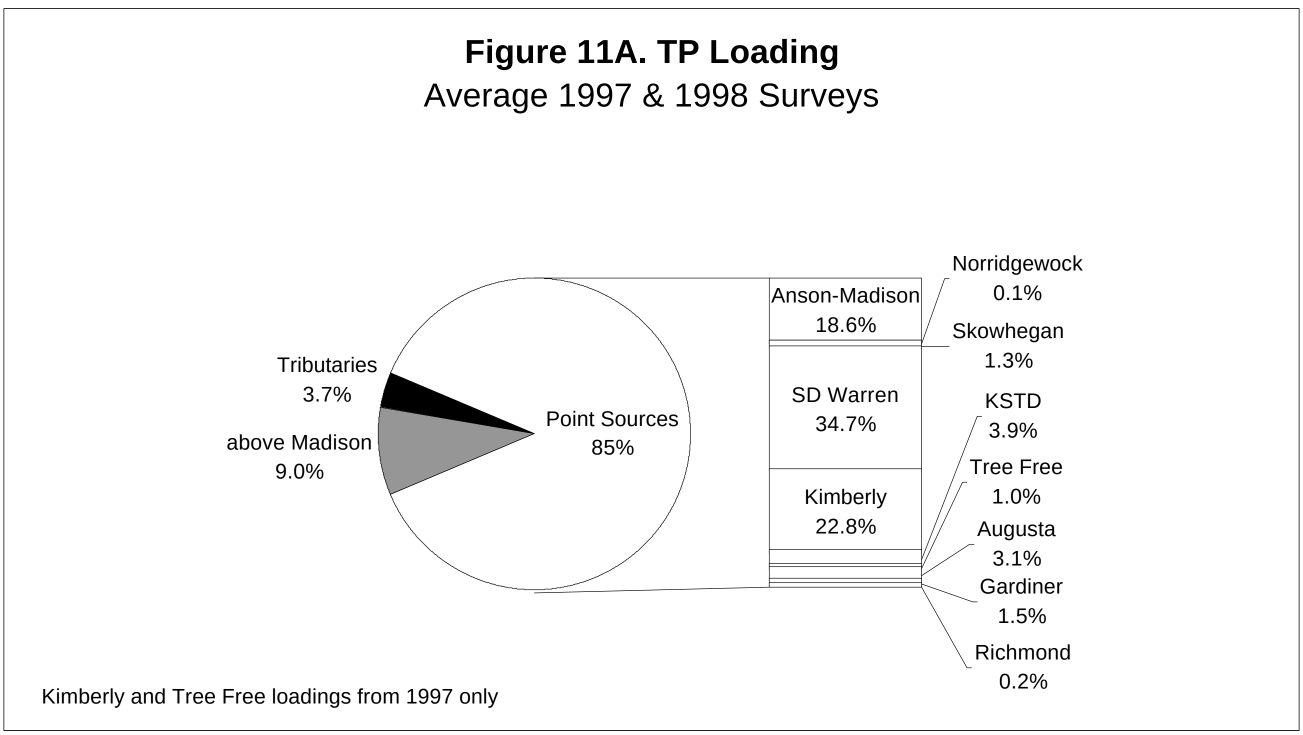


Figure 11A. TP Loading
Average 1997 & 1998 Surveys
Tributaries 3.7%
above Madison 9.0%
Point Sources 85%
Anson-Madison 18.6%
SD Warren 34.7%
Kimberly 22.8%
Norridgewock 0.1%
Skowhegan 1.3%
KSTD 3.9%
Tree Free 1.0%
Augusta 3.1%
Gardiner 1.5%
Richmond 0.2%
Kimberly and Tree Free loadings from 1997 only

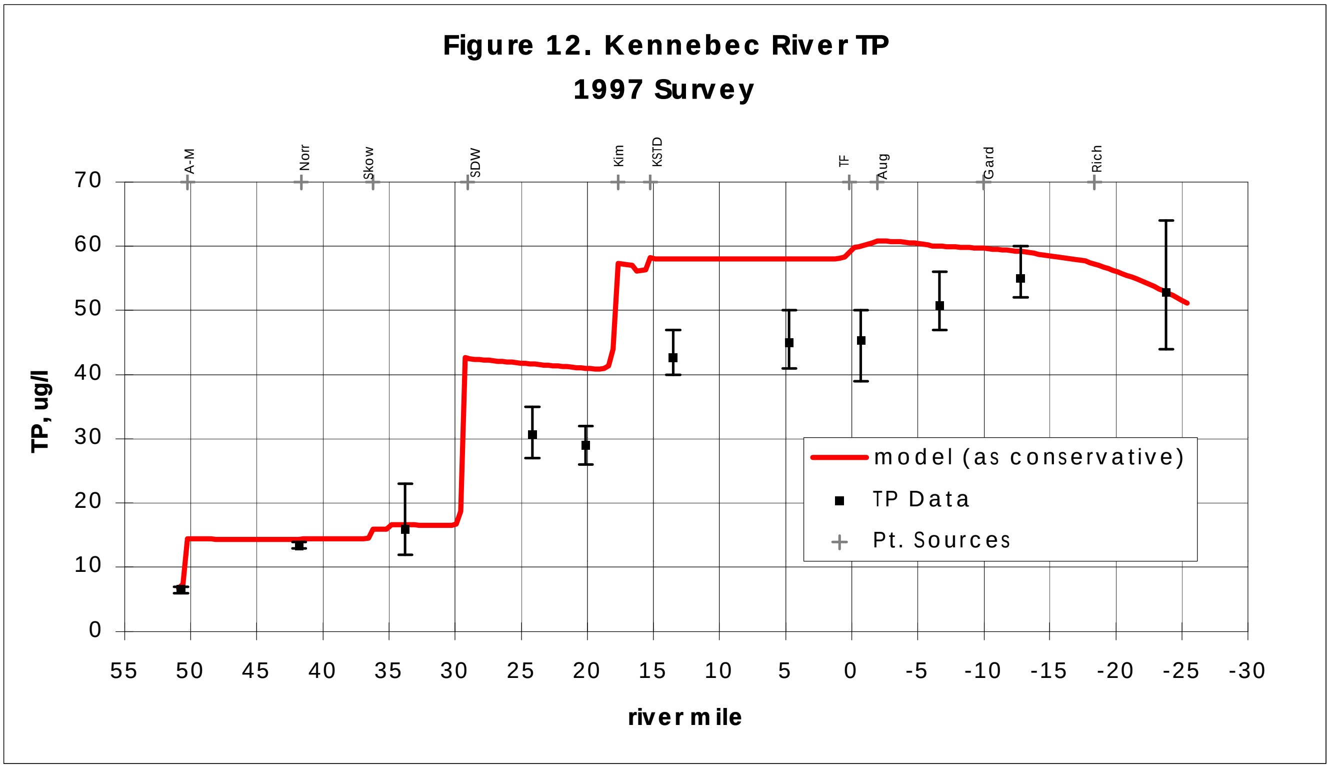


Figure 12. Kennebec River TP
1997 Survey
A-M
Norr
Skow
SDW
Kim
KSTD
TF
Aug
Gard
Rich
TP, ug/l
70
60
50
40
30
20
10
0
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
river mile
model (as conservative)
TP Data
Pt. Sources

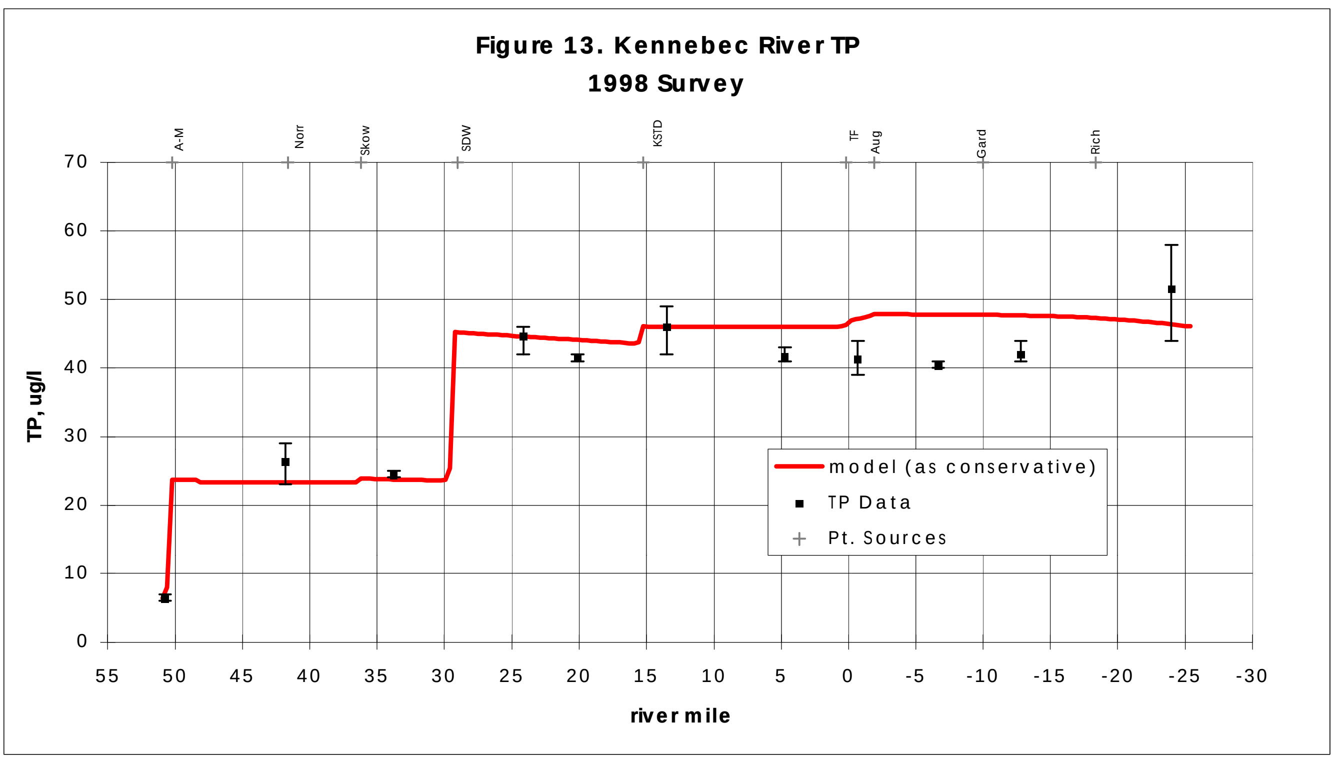


Figure 13. Kennebec River TP
1998 Survey
A-M
Norr
Skow
SDW
KSTD
TF
Aug
Gard
Rich
TP, ug/l
70
60
50
40
30
20
10
0
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
river mile
model (as conservative)
TP Data
Pt. Sources

Figure 14. Kennebec River
Total Phosphorous Loading

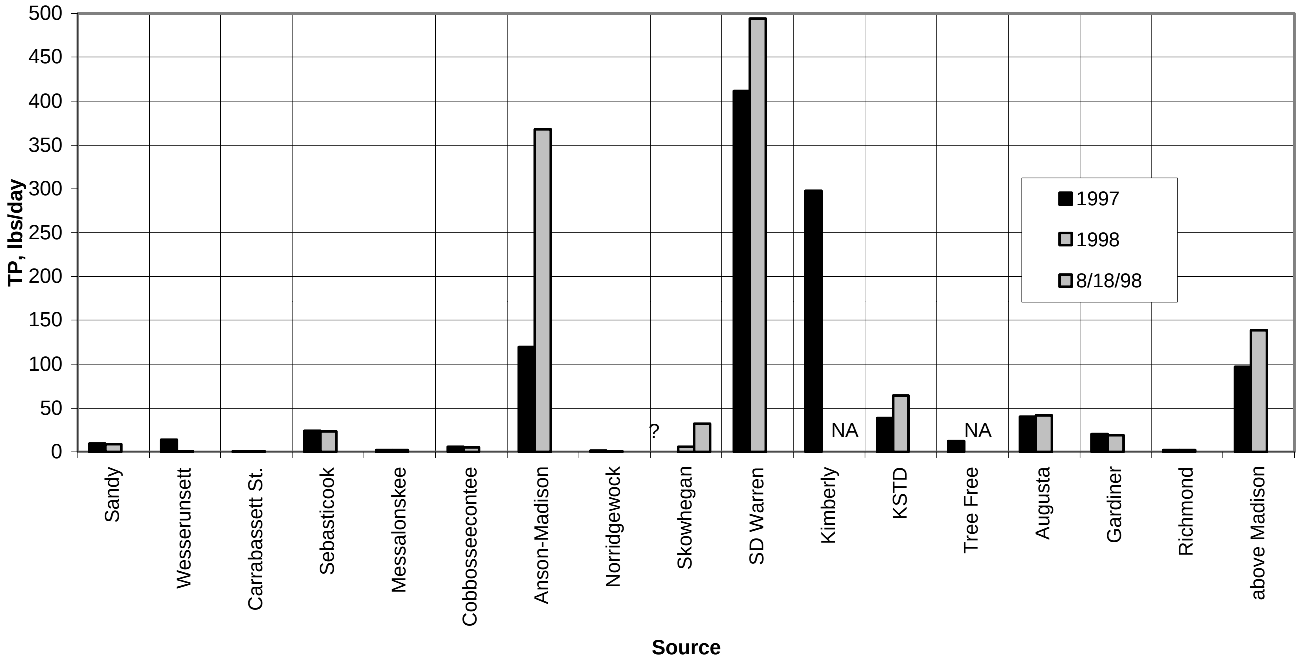
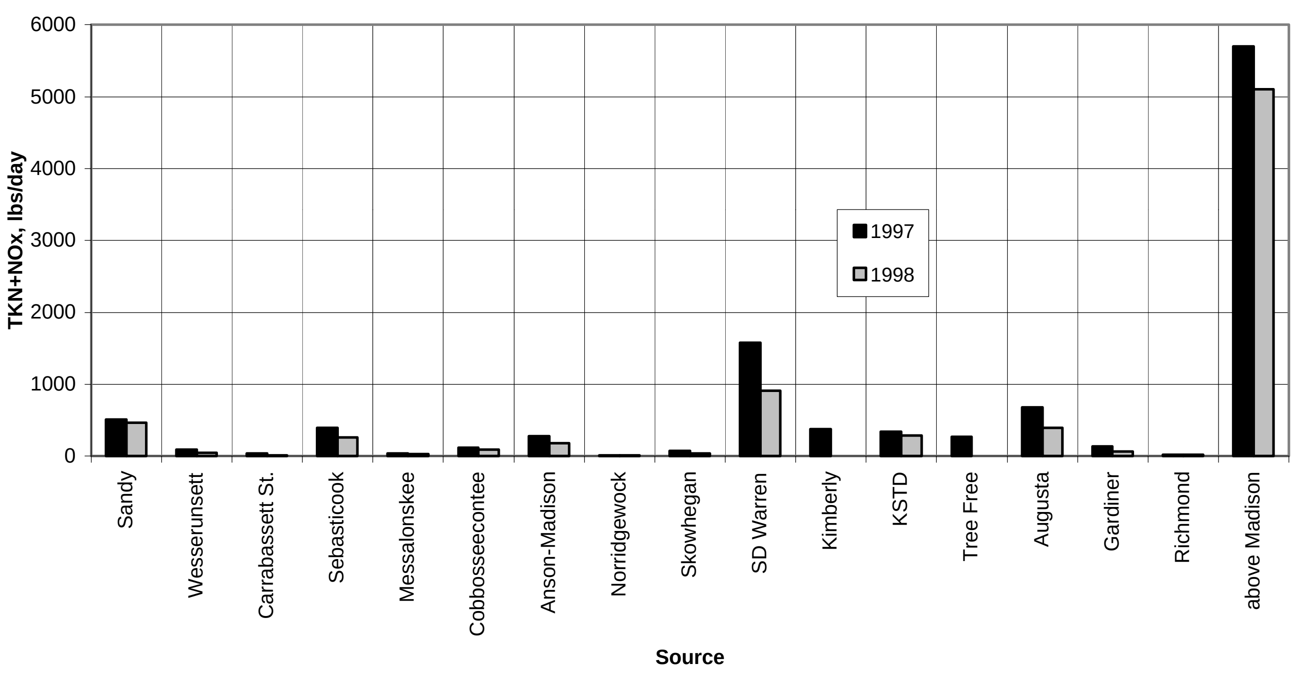


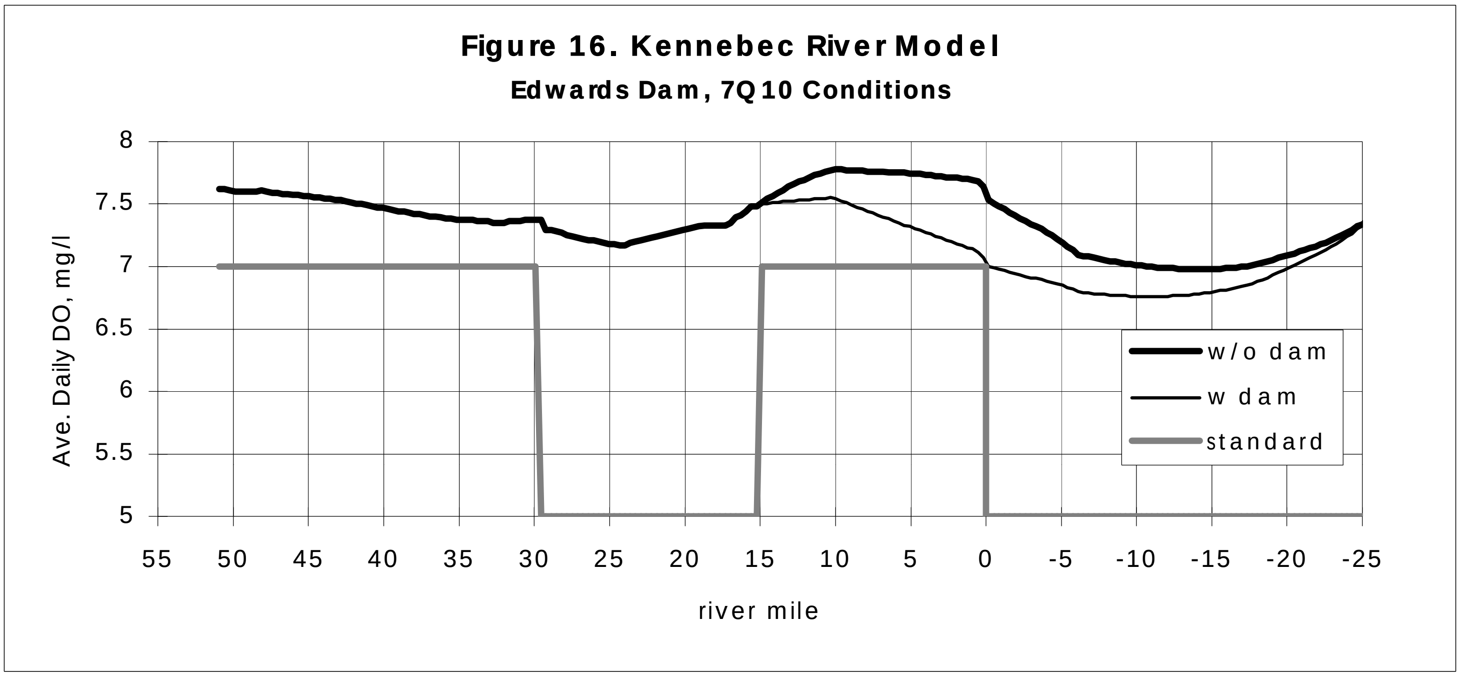
Figure 15. Kennebec River
Total Nitrogen Loading



Additional Modeling Scenarios

Dam vs. dam removed

The following chart compares low flow modeling runs made with and without Edwards Dam in place. The chart shows an increase in daily average DO of 0.6 mg/l with the dam removed. Travel time within the former Edwards impoundment (model reaches 14, 15 and 16) decreases from 60.8 hours with the dam to 31.7 hours without the dam at 7Q10 river flow.



A-M at existing permit (no paper machine #4)

The low flow model run indicates that the critical location in regard to attainment of DO standards is mile 33.8 just before river classification changes from B to C. Discharges upstream of this location include Anson-Madison, Norridgewock and Skowhegan. Figure 10A shows the DO deficit components for the mile 33.8 location. The loading from Anson-Madison was assumed to include the increase due to proposed paper machine #4 which is not yet on line. An additional run made under existing permit conditions without paper machine #4 shows an increase in DO of approximately 0.07 mg/l at mile 33.8. Table 17 contrasts the modeled DO with and without the existing permit provision for an increase in loading from proposed paper machine #4.

Table 17
Upper Class B Segment Sag Point

	DO, mg/l			
		model		
river mile	standard	w/o #4*	w/ #4**	difference
34.5	7.0	7.07	7.00	0.07
34.1	7.0	7.03	6.97	0.06
33.8	7.0	7.00	**6.93**	0.07
33.4	7.0	7.01	6.94	0.07
33.1	7.0	7.01	6.94	0.07
32.7	7.0	7.01	6.94	0.07
32.4	7.0	7.02	6.95	0.07
32.0	7.0	7.03	6.95	0.08
31.7	7.0	7.04	6.97	0.07
31.3	7.0	7.05	6.98	0.07
31.0	7.0	7.06	6.98	0.08
30.6	7.0	7.07	7.00	0.07

*Anson-Madison permit no #4 paper machine
**Anson-Madison permit with #4 paper machine

Discussion

The 1997-1998 survey data indicated attainment of DO standards at all locations. Conditions during the surveys included higher than 7Q10 river flow and less than permit loading from all point sources. The actual point source BOD5 loadings ranged from 2 to 31 percent of daily maximum permit levels with an average of 14 percent (refer to data reports). The 7Q10 modeling extends the evaluation to critical conditions of 7Q10 river flow and maximum permit loading. The modeling indicated two areas of marginal attainment: within a 4 mile segment from mile 34 to mile 31 and within a 0.5 mile segment near mile 11.4.

The first area is near the end of the class B segment below Skowhegan. No assimilative capacity remains in regard to loading to this segment. The major discharge to this segment is from Anson-Madison SD. Plant/nutrient impact is a major component here and the data indicate a significant phosphorous loading from the Anson-Madison discharge. The majority of flow to the SD is from Madison Paper and paper mills often must add nutrients in order to achieve good wastewater treatment. If this is the case it may be possible to better control the phosphorous levels in the effluent through tighter process control.

The second area is within the former Edwards dam impoundment. This is not believed to be a real problem because the diurnal range used in the model was that measured when the dam was in place. Additional data within this segment would verify this assumption.

The model predicts that class C segments of the river will attain class C DO standards of 5 ppm or 60%

saturation but is not predicted to attain class B standards of 7 ppm or 75% saturation.

Figure 11 shows a steady increase in chl-a, a measure of floating algae, downstream with significant levels occurring in the estuary. These data were collected with the dam in place so that it may be that with the dam removed the increased transport may result in increased levels of algae within the estuary.

In general the data and modeling indicate that nutrient loading and its effects on plant growth (and DO) may become the major water quality issue for the Kennebec in the near future. Licensed point source discharges account for the majority of phosphorous loading to the river. Although the modeling to date has not directly incorporated nutrient and algae simulations, the data are available to expand the model to include nutrient/algae/DO interactions.

The 1997 data indicate possible non point sources on Wesserunsett Stream where elevated bacteria, nitrate and phosphorous levels were found.

Recommendations

Based on the 1997 and 1998 water quality surveys and the subsequent modeling the following are concluded/recommended:

(1) MDEP should work with the paper mills to investigate methods to reduce P loading through process controls. Investigation of nutrient reduction may have to be extended to municipal plants as well.

(2) Expand the Kennebec Model to include simulation of nutrient/algae/DO interactions for use when evaluating discharge permits.

(3) Focus any non point work on Wesserunsett Stream.

(4) Perform follow-up sampling below Waterville (including the estuary) to investigate the effects of dam removal.

Appendix A

Sediment Oxygen Demand (SOD) Data

Station	1998* $g/M^2/day$	1998* $g/ft^2/day$
Norridgewock	2.68	0.25
Shawmut	5.62	0.52
Hinckley	0.94	0.09
Sydney	2.32	0.22
Augusta	1.90	0.18
Hallowell	2.53	0.24
Richmond	1.80	0.17

*2 to 4.5 hour tests, no circulation

	data $g/ft^2/day$	model $g/ft^2/day$
estuary, all data	0.12	0.10
river, EPA 1998	0.27	0.03
river, DEP 1985	0.03	

			SOD@20C, gm/m2/day								SOD@20C
		Test	DEP		SDW@			NA**			
Station	Location	Date	10*	0*	10*	2*	0*	L	D	ave***	g/ft2/day
1	Farmingdale	Jun-86	4.20	1.935	0.615	1.02	1.215	-	-	1.58	0.15
2	South Gardiner	Jun-86	2.52	1.34	1.81	2.78	0.32	-	-	0.83	0.08
3	below Sands island	Jun-86	2.10	1.43	1.76	1.05	1.73	-	-	1.58	0.15
4	below (3)	Jun-86	2.60	1.51	0.88	2.14	1.02	-	-	1.27	0.12
5	above Richmond bridge	Jun-86	3.015	0.105	0.57	1.56	1.515	-	-	0.81	0.08
6	Abby Point	Jun-86	8.56	1.18	0.48	1.19	0.83	-	-	1.01	0.09
K1	Madison	Aug-85	0.19		-	-	-	0.08	0.88	0.54	0.05
K6	Nye's Corner, Fairfield	Aug-85	0.33		-	-	-	#	#	0.33	0.03
K7	Shawmut	Aug-85	0.30		-	-	-	0.65	0.53	0.42	0.04
K19	Augusta dam	Aug-85	0.10		-	-	-	0.06	##	0.10	0.01
K21	Hallowell	Aug-85	-		-	-	-	#	0.04	0.04	0.004
K22	Hallowell-Gardiner	Aug-85	0.39		-	-	-	1.18	0.78	0.59	0.05
K27	Richmond	Aug-85	0.23		-	-	-	4.72	1.71	0.97	0.09

*turnover rate, min.
**in situ, stirred; L=light, D=dark
***static, dark test results only
#increase in DO
##meter out of tolerance
@dark test, average of 6 cores

Notes: Duplicate core samples collected for the DEP/SWD June 1986 testing.
SDW report recommended use of static results (0 turnover).
Unclear whether 1985 testing was adjusted to 20°C.
1985 DEP testing apparently average of 4 cores

```
TITLE01              KENNEBEC RIVER MODEL Nov. 1999
TITLE02              7Q10 model
TITLE03   NO         CONSERVATIVE MINERAL I
TITLE04   NO         CONSERVATIVE MINERAL II
TITLE05   NO         CONSERVATIVE MINERAL III
TITLE06   NO         TEMPERATURE
TITLE07  YES         BIOCHEMICAL OXYGEN DEMAND
TITLE08   NO         ALGAE AS CHL-A IN UG/L
TITLE09   NO         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P; DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N; AMMONIA-N; NITRITE-N; NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14   NO         FECAL COLIFORM IN NO/100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE
qIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
DISCHARGE COEFFICIENTS
NO PRINT SOLAR/LCD DATE
NO PLOT DO AND BOD
FIXED DOWNSTREAM CONC    1.0                5D-ULT BOD CONV RATE     0.23
INPUT METRIC             0.0                OUTPUT METRIC            0.0
NUMBER OF REACHES        23.                NUMBER OF JUNCTIONS      2.
NUM OF HEADWATERS        3.                 NUMBER OF POINT LOADS    18.
TIME STEP (HOURS)                           LNTH COMP ELEMENTS       0.35
MAXIMUM ROUTE TIME (HRS) 30.                TIME INC FOR RPTZ (HRS)
ENDATA1
O UPTAKE BY NH3 OXYD(mgO/mgN) = 1.0      O UPTAKE BY NO2            = 0.0
O PROD BY ALGAE               =          O UPTAKE BY ALGAE          =
N CONTENT OF ALGAE            =          P CONTENT OF ALGAE         =
ALG MAX SPEC GROWTH RATE      =          ALGAE RESP RATE            =
N HALF SATURATION             =          P HALF SATURATION          =
LIN ALG SHADE COEF            =          NLIN SHADE                 =
LIGHT FUNCTION OPTION         =          LIGHT SATURATION COEF      =
DAILY AVERAGING OPTION        =          LIGHT AVERAGING FACTOR     =
NUMBER OF DAYLIGHT HOURS      =          TOTAL DAILY SOLAR RAD      =
ALGY GROWTH CALC OPTION       =          ALGAL PREF FOR NH3         =
ALG/TEMP SOLR RAD FACTOR      =          NITRIFICATION INHIB COEF   = 10.
ENDATA1A
         SOD RATE 1.06
ENDATA1B
STREAM REACH   1.       A-MAD - SANDY R   FROM   51.10         TO    48.30
STREAM REACH   2.       SANDY RIVER       FROM    0.35         TO     0.00
STREAM REACH   3.       SANDY R-          FROM   48.30         TO    43.40
STREAM REACH   4.              -NORWOK    FROM   43.40         TO    42.35
STREAM REACH   5.       NORWOK-WESTON     FROM   42.35         TO    37.10
STREAM REACH   6.       WESTON-EATON RG   FROM   37.10         TO    32.20
STREAM REACH   7.       EATON  -HINKLEY   FROM   32.20         TO    28.35
STREAM REACH   8.       HINKLEY-SHAWMUT   FROM   28.35         TO    23.80
STREAM REACH   9.       SHAWMUT-RR YARD   FROM   23.80         TO    18.90
STREAM REACH   10.     RR YRD-201 BRDG    FROM   18.90         TO    17.15
STREAM REACH   11.      201 - SEBASTIC    FROM   17.15         TO    16.45
STREAM REACH   12.      SEBASTICOOK RIV   FROM    0.35         TO     0.00
STREAM REACH   13.      SEB -MESSALONSK   FROM   16.45         TO    15.05
STREAM REACH   14.      MESSALON-VASSAL   FROM   15.05         TO    10.15
STREAM REACH   15.      VASSAL-7 MILE I   FROM   10.15         TO     4.55
STREAM REACH   16.      7 MILE I-AUG DM   FROM    4.55         TO     0.00
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STREAM REACH   17.       AUG DAM-FARMDAL   FROM    0.00         TO    -5.95
STREAM REACH   18.       FARMDAL-GARDNER   FROM   -5.95         TO    -7.35
STREAM REACH   19.       GARDNER-SANDS I   FROM   -7.35         TO    -12.60
STREAM REACH   20.       SANDS I-RICH BR   FROM   -12.6         TO    -17.50
STREAM REACH   21.       SWANS IS,2 CHAN   FROM   -17.5         TO    -22.40
STREAM REACH   22.              -ABBY PT   FROM   -22.4         TO    -24.15
STREAM REACH   23.       ABBY PT-CHOPS     FROM   -24.15        TO    -25.55
ENDATA2
ENDATA3
FLAG FIELD     1.        8.             1.7.6.2.2.2.2.3.
FLAG FIELD     2.        1.             1.
FLAG FIELD     3.        14.            4.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     4.        3.             2.2.2.
FLAG FIELD     5.        15.            2.2.6.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     6.        14.            2.2.6.2.2.2.6.2.2.2.2.2.2.2.
FLAG FIELD     7.        11.            2.2.2.2.2.2.2.7.6.6.2.
FLAG FIELD     8.        13.            2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     9.        14.            2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     10.        5.            2.7.2.6.2.
FLAG FIELD     11.        2.            2.3.
FLAG FIELD     12.        1.            1.
FLAG FIELD     13.        4.            4.2.2.6.
FLAG FIELD     14.       14.            6.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     15.       16.            2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     16.       13.            2.2.2.2.2.2.2.2.2.2.2.7.6.
FLAG FIELD     17.       17.            2.2.2.2.2.6.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     18.       4.             2.2.2.6.
FLAG FIELD     19.       15.            2.2.2.2.2.2.2.6.2.2.2.2.2.2.2.
FLAG FIELD     20.       14.            2.2.2.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     21.       14.            2.2.6.2.2.2.2.2.2.2.2.2.2.2.
FLAG FIELD     22.        5.            2.2.2.2.2.
FLAG FIELD     23.        4.            2.2.2.5.
ENDATA4
HYDRAULICS     1.     482.0   .00018    0.95      5.0       0.05
HYDRAULICS     2.       0.0   .0733     0.3       0.2       0.6
HYDRAULICS     3.     482.0   .00018    0.95      7.0       0.05
HYDRAULICS     4.     482.0   .00018    0.95      9.0       0.05
HYDRAULICS     5.     482.0   .00018    0.95      11.0      0.05
HYDRAULICS     6.     195.0   .00018    0.905     5.0       0.08
HYDRAULICS     7.     195.0   .00018    0.905     9.8       0.08
HYDRAULICS     8.     195.0   .000065   0.99      20.0      0.0
HYDRAULICS     9.     887.0   .0022     0.7       0.9       0.25
HYDRAULICS     10.    825.0   .0027     0.7       0.9607    0.3
HYDRAULICS     11.    825.0   .0027     0.71      0.75      0.19
HYDRAULICS     12.      0.0   .02       0.4       0.32      0.5
HYDRAULICS     13.    825.0   .0027     0.71      0.75      0.19
HYDRAULICS     14.    825.0   .0027     0.71      0.75      0.19
HYDRAULICS     15.    825.0   .0026     0.71      1.61      0.19
HYDRAULICS     16.    825.0   .0026     0.71      2.2       0.19
HYDRAULICS     17.    30000   .00018    1.0       6.3       0.0
HYDRAULICS     18.    120000  .00011    1.0       12.4      0.0
HYDRAULICS     19.    150000  .00008    1.0       12.7      0.0
HYDRAULICS     20.    150000  .00006    1.0       12.3      0.0
HYDRAULICS     21.    150000  .00004    1.0       9.6       0.0
HYDRAULICS     22.    150000  .00003    1.0       12.6      0.0
HYDTAULICS     23.    150000  .00003    1.0       11.8      0.0
ENDATA5
ENDATA5A
REACT COEF     1.   0.015   0.00    .030    3.
REACT COEF     2.   0.00    0.00    .000    1.  0.
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REACT COEF      3.   0.015   0.00    .030    3.
REACT COEF      4.   0.015   0.00    .030    3.
REACT COEF      5.   0.015   0.00    .030    3.
REACT COEF      6.   0.015   0.00    .030    3.
REACT COEF      7.   0.015   0.00    .030    1.  .2
REACT COEF      8.   0.015   0.00    .030    1.  .2
REACT COEF      9.   0.015   0.00    .030    3.
REACT COEF      10.  0.015   0.00    .030    3.
REACT COEF      11.  0.015   0.00    .030    3.
REACT COEF      12.  0.00    0.00    .000    1.  0.
REACT COEF      13.  0.015   0.00    .030    3.
REACT COEF      14.  0.015   0.00    .030    3.
REACT COEF      15.  0.015   0.00    .030    3.
REACT COEF      16.  0.015   0.00    .030    3.
REACT COEF      17.  0.015   0.00    .100    3.
REACT COEF      18.  0.015   0.00    .100    1.  0.25
REACT COEF      19.  0.015   0.00    .100    1.  0.25
REACT COEF      20.  0.015   0.00    .100    1.  0.3
REACT COEF      21.  0.015   0.00    .100    1.  0.5
REACT COEF      22.  0.015   0.00    .100    1.  0.35
REACT COEF      23.  0.015   0.00    .100    1.  0.35
ENDATA6
N AND P COEF         1.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         2.  0.0     0.0     0.00   0.0     0.0     0.0     0.0     0.0
N AND P COEF         3.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         4.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         5.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         6.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         7.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         8.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF         9.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        10.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        11.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        12.  0.0     0.0     0.00   0.0     0.0     0.0     0.0     0.0
N AND P COEF        13.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        14.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        15.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        16.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        17.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        18.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        19.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        20.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        21.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        22.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
N AND P COEF        23.  0.0     0.0     0.05   0.0     0.0     0.0     0.0     0.0
ENDATA6A
ALG/OTHER COEF       1.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       2.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       3.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       4.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       5.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       6.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       7.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       8.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF       9.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF      10.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF      11.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF      12.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF      13.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
ALG/OTHER COEF      14.  0.0     0.0     0.0    0.0     0.0     0.0     0.0
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ALG/OTHER COEF     15.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     16.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     17.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     18.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     19.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     20.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     21.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     22.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ALG/OTHER COEF     23.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ENDATA6B
INITIAL COND-1     1.   76.1   8.20   2.50
INITIAL COND-1     2.   76.1   8.53   2.50
INITIAL COND-1     3.   76.1
INITIAL COND-1     4.   76.1
INITIAL COND-1     5.   76.1
INITIAL COND-1     6.   76.1
INITIAL COND-1     7.   76.1
INITIAL COND-1     8.   76.1
INITIAL COND-1     9.   76.1
INITIAL COND-1     10.  76.1
INITIAL COND-1     11.  76.1
INITIAL COND-1     12.  76.1   7.90   4.76
INITIAL COND-1     13.  76.1
INITIAL COND-1     14.  76.1
INITIAL COND-1     15.  76.1
INITIAL COND-1     16.  76.1
INITIAL CONC-1     17.  76.1
INITIAL COND-1     18.  76.1
INITIAL COND-1     19.  76.1
INITIAL COND-1     20.  76.1
INITIAL COND-1     21.  76.1
INITIAL COND-1     22.  76.1
INITIAL COND-1     23.  76.1
ENDATA7
INITIAL COND-2      1.  0.0    0.0    0.38   0.0    0.0    0.0    0.0
INITIAL COND-2      2.  0.0    0.0    0.4    0.0    0.0    0.0    0.0
INITIAL COND-2      3.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      4.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      5.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      6.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      7.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      8.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2      9.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     10.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     11.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     12.  0.0    0.0    0.96   0.0    0.0    0.0    0.0
INITIAL COND-2     13.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     14.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     15.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     16.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     17.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     18.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     19.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     20.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     21.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     22.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
INITIAL COND-2     23.  0.0    0.0    0.0    0.0    0.0    0.0    0.0
ENDATA7A
INCR INFLOW-1  RCH=1.   0.0
INCR INFLOW-1  RCH=2.   0.0
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INCR INFLOW-1  RCH=3.   0.0
INCR INFLOW-1  RCH=4.   0.0
INCR INFLOW-1  RCH=5.   0.0
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INCR INFLOW-1  RCH=7.   0.0
INCR INFLOW-1  RCH=8.   0.0
INCR INFLOW-1  RCH=9.   0.0
INCR INFLOW-1  RCH=10.  0.0
INCR INFLOW-1  RCH=11.  0.0
INCR INFLOW-1  RCH=12.  0.0
INCR INFLOW-1  RCH=13.  0.0
INCR INFLOW-1  RCH=14.  0.0
INCR INFLOW-1  RCH=15.  0.0
INCR INFLOW-1  RCH=16.  0.0
INCR INFLOW-1  RCH=17.  0.0
INCR INFLOW-1  RCH=18.  0.0
INCR INFLOW-1  RCH=19.  0.0
INCR INFLOW-1  RCH=20.  0.0
INCR INFLOW-1  RCH=21.  0.0
INCR INFLOW-1  RCH=22.  0.0
INCR INFLOW-1  RCH=23.  0.0
ENDATA8
INCR INFLOW-2  RCH=1.   0.0
INCR INFLOW-2  RCH=2.   0.0
INCR INFLOW-2  RCH=3.   0.0
INCR INFLOW-2  RCH=4.   0.0
INCR INFLOW-2  RCH=5.   0.0
INCR INFLOW-2  RCH=6.   0.0
INCR INFLOW-2  RCH=7.   0.0
INCR INFLOW-2  RCH=8.   0.0
INCR INFLOW-2  RCH=9.   0.0
INCR INFLOW-2  RCH=10.  0.0
INCR INFLOW-2  RCH=11.  0.0
INCR INFLOW-2  RCH=12.  0.0
INCR INFLOW-2  RCH=13.  0.0
INCR INFLOW-2  RCH=14.  0.0
INCR INFLOW-2  RCH=15.  0.0
INCR INFLOW-2  RCH=16.  0.0
INCR INFLOW-2  RCH=17.  0.0
INCR INFLOW-2  RCH=18.  0.0
INCR INFLOW-2  RCH=19.  0.0
INCR INFLOW-2  RCH=20.  0.0
INCR INFLOW-2  RCH=21.  0.0
INCR INFLOW-2  RCH=22.  0.0
INCR INFLOW-2  RCH=23.  0.0
ENDATA8A
STREAM JUNCTION     1.0           JNC=SANDY R.         8.        10.       9.
STREAM JUNCTION     2.0           JNC=SEBAST  R.       100.      102.      101.
ENDATA9
HEADWTR-1     1.   ANSON-MAD       2287.0   76.1  7.62  2.50
HEADWTR-1     2.   SANDY RIV.        69.0   76.1  8.26  2.58
HEADWTR-1     3.   SEBASTICOK       115.0   76.1  7.58  4.56
ENDATA10
HEADWTR-2      1.   0.0   0.0   0.0   0.0   0.305 0.0   0.0   0.0   0.0
HEADWTR-2      2.   0.0   0.0   0.0   0.0   0.20  0.0   0.0   0.0   0.0
HEADWTR-2      3.   0.0   0.0   0.0   0.0   1.065 0.0   0.0   0.0   0.0
ENDATA10A
POINTLD-1      1.  MADISON WITH     -12.13         7.0   3.0
POINTLD-1      2.  AN-MAD STD       12.13          5.0   416.2
POINTLD-1      3.  NORIDGEWOCK      0.3            4.1   112.5
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POINTLD-1      4.  SKOW. MUNI.      2.23         3.8   121.5
POINTLD-1      5.  WESSERUNSETT      20.         7.81  2.79
POINTLD-1      6.  S.D.WARREN -     -71.94       7.0   3.0
POINTLD-1      7.  S.D.WARREN +     71.94        5.0   152.3
POINTLD-1      8.  CARRABASSETT      12.         8.31  4.00
POINTLD-1      9.  KIM   WITHDR     -0.00        7.0   3.0
POINTLD-1      10. KIM   DISCHG     0.00         0.0   0.0
POINTLD-1      11. KSTD DISCHGE     19.65        3.28  139.5
POINTLD-1      12. MESSALONSKEE     25.0         7.88  3.42
POINTLD-1      13. TREE FREE        -9.28        7.0   3.0
POINTLD-1      14. TREE FREE        9.28         3.0   181.9
POINTLD-1      15. AUGUSTA STP      18.56        4.0   204.0
POINTLD-1      16. COBBOSEECONT      9.0         7.78  4.40
POINTLD-1      17. GARDINER STP     6.96         4.0   130.5
POINTLD-1      18. RICHMOND         0.46         6.5   180.
ENDATA11
POINTLD-2      1.   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
POINTLD-2      2.   0.0   0.0   0.0   0.0   35.   0.0   0.0   0.0   0.0
POINTLD-2      3.   0.0   0.0   0.0   0.0   117.  0.0   0.0   0.0   0.0
POINTLD-2      4.   0.0   0.0   0.0   0.0   22.   0.0   0.0   0.0   0.0
POINTLD-2      5.   0.0   0.0   0.0   0.0   0.42  0.0   0.0   0.0   0.0
POINTLD-2      6.   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
POINTLD-2      7.   0.0   0.0   0.0   0.0   30.0  0.0   0.0   0.0   0.0
POINTLD-2      8.   0.0   0.0   0.0   0.0   0.50  0.0   0.0   0.0   0.0
POINTLD-2      9.   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
POINTLD-2      10.  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
POINTLD-2      11.  0.0   0.0   0.0   0.0   30.0  0.0   0.0   0.0   0.0
POINTLD-2      12.  0.0   0.0   0.0   0.0   0.73  0.0   0.0   0.0   0.0
POINTLD-2      13.  0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
POINTLD-2      14.  0.0   0.0   0.0   0.0   9.0   0.0   0.0   0.0   0.0
POINTLD-2      15.  0.0   0.0   0.0   0.0   74.0  0.0   0.0   0.0   0.0
POINTLD-2      16.  0.0   0.0   0.0   0.0   0.82  0.0   0.0   0.0   0.0
POINTLD-2      17.  0.0   0.0   0.0   0.0   74.0  0.0   0.0   0.0   0.0
POINTLD-2      18.  0.0   0.0   0.0   0.0   27.0  0.0   0.0   0.0   0.0
ENDATA11A
DAM DATA ANSON     1.   1.    2.    1.25  1.00  0.00  24.5
DAM DATA ABANAKI   2.   1.    4.    1.25  1.00  0.00  20.0
DAM DATA WESTON    3.   6.    1.    1.25  1.00  0.00  32.0
DAM DATA SHAWMUT   4.   9.    1.    1.25  1.00  0.00  14.7
DAM DATA SCOTT     5.   10.   2.    1.25  1.00  0.00  23.0
DAM DATA LOCKWOOD  6.   11.   1.    1.25  1.00  0.00  21.0
ENDATA12
                        76.1   7.40   4.78   0.0    0.0    0.0    0.0
ENDATA13
                        0.0    0.0    .985   0.0    0.0    0.0    0.0
ENDATA13A
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Appendix B

Responses to Comments

Sappi

R1. An updated dye study should be conducted in the lower section of the river to provide more accurate hydraulic data.

Response: Two river segments experienced changes subsequent to the dye studies: The Hydro-Kennebec dam was redeveloped (impoundment elevation raised) and Edwards dam was removed.

In the first case the hydraulic factors were revised to reflect the change in water elevation. The change was based on the increase in impoundment depth and length specified in the FERC license. A sensitivity run showed a maximum change in model prediction of -0.1 mg/l DO (at reach 9, element 14) with this change in factors. This adjustment resulted in a change of -0.04 mg/l at the lower class B sag point and no change in DO at the estuary sag point. Based on the low sensitivity of the change it is believed that no further calibration is required.

In the second case, the entire reach comprising the former impoundment was inspected by canoe after dam removal. In addition, updated transect data (widths and depths) for a large portion of the former impoundment were collected. River flow was less than 7Q10 flow during this data collection (2100-2150 cfs). Although dye study data is used when available, most of our studies make use of transect data for specification of QUAL2 model hydraulic factors. Using these data and judgement based upon the inspection, the model hydraulic factors were adjusted to reflect the after dam condition. While further verification of the model for the former Edwards impoundment would be desirable and will probably be addressed in the future as resources permit, it is believed that the current model provides an acceptable representation.

R2. The laboratory BOD decay rate should be computed for the samples, and this laboratory value compared to the force-fit value.

Response: Lab BOD data show an average bottle decay rate of 0.020 day^{-1} for the 1998 main stem river BOD samples. The range in values was 0.007 to 0.037 day^{-1}. The lab test gives the total BOD decay rate which includes both CBOD and NBOD. Given the model CBOD decay rate of 0.015 day^{-1}, the model NBOD decay rate of 0.05 day^{-1} and the fact that CBOD makes up the greater portion of the total BOD; the model rates compare well with the lab data.

The 1997 data were not used for this evaluation. As explained in the data report, the 1997 BOD tests were run in 60 ml bottles which were found to be contaminated with NH_3. A correction was applied (based upon blank results) for determination of the CBODu and NBODu values but the bottle decay rates cannot be compared to ambient rates.

R3. Adjust the SOD rate by model reach to account for site-specific variations and better depict true conditions, since the model is very sensitive to SOD.

Response: While SOD is a sensitive parameter it is also the most difficult to quantify. Even a large study results in covering only a small percentage of the river bottom area; for example, areas of ledge would reduce the average SOD for a given reach. SOD values may vary greatly depending upon the type of soil sampled. Also, attached plant growth may supply a net daily gain in DO to the water column but is not measured in a typical SOD test.

BOD decay rates and reaeration rates are understood to a high degree and specifications of these parameters can be made with much more confidence than SOD. SOD becomes more of a calibration parameter with data being used to establish the range of values (reality check).

R4. Modify the 1998 calibration model's input, parameter FDAM in data type 13, to include dam spillage during the survey.

Response: The dam parameters are data type 12. The coefficients were in fact adjusted for the 1998 calibration runs (ADAM=1.80, BDAM=1.05 and FDAM=1.0). These adjustments are not part of the low flow model (and were not given in the report) because it is assumed that spillage does not occur during low flow and that the critical condition occurs when there is no spillage.

R5. Modify the model water temperatures to represent observed conditions.

Response: The calibration runs used actual measured temperatures (daily and depth average). The low flow model must account for critical low flow, high temperature conditions that occur at 7Q10. The surveys were made at less than critical conditions (flow>7q10), therefore a temperature greater than that measured should be used. Maximum survey temperature reading during 1997 was 24.8 C with a maximum site average of 24.0 C. Maximum survey temperature reading during 1998 was 24.9 C with a maximum site average of 23.2 C. A judgement was made regarding choice of a model temperature and it was believed that the temperature chosen for the 7Q10 model (24.5 C) was reasonable based upon the 1997 and 1998 survey data.

Data from the discontinued North Sidney USGS monitor was reviewed :

		Approx. Daily Temp. C			
Year	Flow, cfs	Min.	Mean	Max.	Week
1991	3100+/-	25	26	27	July 21-28
1992	3000+/-	22.5	22.5	23	Aug 24-31
1993	4000+/-	23.5	25	26	July 9-16
1994	5000+/-	24.5	25	25.5	Aug 1-7

Based on these data the 24.5°C is probably appropriate for the cooler upper segments but may be somewhat low for the lower segments. [Note: a change in 7Q10 model temperature of +1.9 F (about 1 C) results in a maximum change in DO of 0.2 mg/l]

R6. The diurnal effects of temperature change need to be included in the discussion. … Furthermore, there is a possibility that attached plant growth, not measured as Chlorophyll-a in the water column, contribute to the diurnal DO effect.

Response: The model is an average daily model requiring average daily temperature. Note that standards require minimum DO of 7.0 mg/l or 75% whichever is greater for class B (5.0 mg/l or 60% for class C). For the ranges of temperature of this study the 7.0 mg/l concentration standard governs for class B (at temperatures less than 24.5 C the 60% standard would govern for class C).

As water column temperature decreases, the DO concentration should not change significantly, although the percent saturation would change. Change in actual DO concentration as a result in temperature change would result from a change in transfer rate to the atmosphere. The reaeration rate may change with change in water temperature (due to effect on exchange rate with the atmosphere as well as the driving force associated with difference in % saturation), but any effect from this on water column DO concentration would be slow to occur and probably insignificant.

It is agreed that diurnal DO may be the result of attached growth as well as phytoplankton. The model does not distinguish between attached growth and phytoplankton in terms of the diurnal adjustment. The calibration of SOD rate probably incorporates any daily net effect of attached growth upon DO in the water column during the surveys. Any future attempts to model nutrient/chl-a must address the issue of attached growth.

R7. The diurnal range should be measured again in the area of influence of the Edwards Dam, now that it has been removed.

Response: Agreed. As resources permit.

R8. Provide a more thorough and scientific approach to and discussion of, the diurnal modeling including the causes of these DO swings.

Response: It is believed that this is adequately addressed in the report (page 18).

R9. Recommend interchanging the element types 6 and 7 in the model input file, and make appropriate changes in the Point Load data.

Response: The model currently has the 12th element as a withdrawal element (7) and the 13th element as an input element (6) for reach 16 (Tree Free) and this is represented as such in data groups 11 and 11A. It is believed this is correct, but any information to the contrary will be considered.

R10. Recommend re-evaluating model hydraulic parameter input.

Response: In general, an extensive calibration was made to existing dye studies resulting in a high degree of confidence in velocity specifications. Model depths were compared to available data with reasonable comparisons. Width values are not used by the model in any calculations and width factors are not explicitly specified by the user but are calculated indirectly within the model from the velocity and depth factors. Bottom area is calculated from water volume and depth. Water volume is determined from flow, length and velocity. As such, specification of depth and velocity do effect SOD and reaeration.

With regard to Reach 1 (Anson-Madison to Sandy River): The calibration to the dye studies for the river segment from Madison to Skowhegan was very good (maximum difference in average velocity of 3.2%). The hydraulic factors for reach 1 were generally a carryover from the previous model with adjustments made during the dye study re-calibration. No specific data were available for this reach other than the dye study. Any available data for this reach would be considered, but given the good calibration to the dye study and good DO calibration at the DO sag point below reach 1, it is believed that the model provides good results at the sag points, if not within reach 1. (see also comment Q2)

Q1. Since significant weight is being placed on the CBOD data, how representative is it throughout the cross section of the river. Is this data depth integrated? What about NBOD data?

Response: Water samples were taken at mid channel 1-2 feet below the surface in areas of higher velocity. Complete mixing is assumed. The major discharges are either located above dams (good mixing assumed to occur through turbines or spilling over dam), in riffles or discharged through multiport diffusers. Sample station locations were chosen well below major discharges. Site K7 may be questionable (see related question Q11).

Q2. (Figures 5 and 6) The model is not matching up with actual data in the areas of marginal attainment around miles 33 (Figures 5 and 6) and 47 (Figure 6). Any ideas?

Response: It is agreed that matches to DO data at mile 47 are not ideal, but calibration to following downstream sites is very good and mile 47 is not a sag point. Attempts to match this point would have to involve modeling a relatively rapid increase in DO followed by a rapid decrease in DO. Manipulation of the model in this manner is not desirable unless this was an area of specific concern. As for reasons: Confluence of the Sandy River could be a factor. Also previous comments regarding hydraulic factors of reach 1 may offer some explanation but do not explain the rapid decrease in DO below mile 47.

Mile 33 matches well to the 1997 data but is low when compared to 1998 data. In both cases there is good agreement to adjacent sites. Manipulation of the model to match one data-site at the expense of others is not warranted.

Q3. (p. 15) What was the basis for using 90% of daily maximum limits to estimate weekly limits for industrial facilities?

Response: Industrial facility permits do not normally specify a weekly limit so that the same ratio (weekly BOD:daily maximum BOD) that is used for municipal facilities is used as a default (45/50=0.9). We would consider any data provided, depicting actual weekly average/daily maximum ratios for use in evaluating impact of industrial discharges. We would require at least three years of daily maximum and weekly average BOD5 data for determination of the ratio. The use of 90% is probably conservative (based on some industrial data from the Penobscot study).

Q4. (p. 15) Where were the data obtained for Table 13A?

Response: These concentration data are averages of the intensive surveys.

Q5. (Table 13) How were the CBODu/BOD5 ratios calculated?

Response: Effluent CBODu and BOD5 data from the 1997 and 1998 surveys were used, including the BOD5 values reported by each facility.

Q6. It is not clear what TKN data was used for the Somerset Mill discharge. It appears that some overly conservative assumptions were applied here. Please explain your methodology.

Q7. (p. 16, Figure 6B) why were 1997 NBOD data used, while 1998 data were ignored, for the Somerset mill?

Response: In general it was necessary to establish a method of estimating NBODu at full license loading conditions. It is presumed that NBODu at full license loading conditions would be greater than NBODu measured during the surveys when BOD5 loading was much less that permitted levels. NBODu:TBODu and NBODu:BOD5 ratios were examined but these resulted in unrealistically high values – higher than potential NBODu from measured TKN concentrations. It was decided to use the NBODu that would theoretically result from complete oxidation of TKN as represented by the 1997 data (note also that TKN would probably be greater under full loading conditions than the values measured during the 1997 survey). This method allows for an assumed increase of NBODu at full license loading compared to measured NBODu, but also includes the reality check of using measured TKN as a maximum threshold.

1997 TKN data were used. As noted in the 1999 data report (1998 data), TKN analyses were run by a second lab and some results (although not the Somerset data) were not consistent with NH3 results. Also the 1998 data were in most cases significantly less than 1997 effluent results. It was decided not to use these 1998 results.

Q8. (p. 19, Table 15) The 7Q10 model diurnal variation at Station K8 applied to figure 8 was 2.23 mg/l, not 1.29 mg/l.

Response: Table 15 is in error.

Q9. Were the chlorophyll-a values corrected for chl-a degradation products?

Response: No.

Q10. (Figure 12) This figure shows a poor fit of the model to TP data in 1997. This appears to be caused by an over-prediction of P input from the Somerset mill. Is it possible that suspended P is settling out in the impoundment?

Response: This mismatched was recognized. Possible explanations would include settling and uptake by attached growth, although a high percentage of the Somerset TP is dissolved (PO4) and would not tend to settle. This may be problematic when expanding the model to include nutrient and chl-a simulation.

Q11. The model does not match actual data in Figures 2, 3 and 4 around mile 24. This should be explained.

Response: Not clear why the NBOD and CBOD is high at this sample site when compared to the model. This is the impoundment site above Shawmut dam (K7). This site is characterized as wide with a number of islands. It is possible that mixing was incomplete.

Q12. (p. 15, Table 13) Calculation of NBODu for the model point loads uses a conservative assumption that all TKN is oxidized as NBOD. A more thorough explanation of this conversion appears to be required because the bottle NBODu measurements do not match this assumption.

Response: See response to Q6, Q7.

Charles Cleaver

1. Request for definitions of abbreviations. Relation of DO, BOD, SOD, TP etc. to water quality classification.

Response: In general, abbreviations were defined as they were introduced into the text. The model was briefly discussed on page 4 with reference to additional sources for more information in regard to the representation of the various sources and sinks of dissolved oxygen. Attached is a list of definitions, including water quality classifications.

2. Confusion in regard to wording –did plants refer to industrial plants or biological plants.

Response: Comment noted.

3. Question about effluent DO as a deficit component.

Response: Effluent dissolved oxygen (DO) concentration is often less than that of the receiving water and therefore reducing the instream levels after mixing. The impact of this effect was broken out as a component in the model evaluation.

4. Why doesn't TP rise as it did in 1997 as one progresses down the river? (Fig 13)

Response: Probably the major factor is that Kimberly and Tree Free were discharging during 1997 but not during 1998. (also see comment Q10 above)

5. Define “near future” (p. 28).

Response: It has become apparent that point sources are generally well treated in terms of CBOD and that the major water quality impacts we are now seeing are related to nutrient loading, habitat impairment (minimum flows, sediment loading, etc.) and toxics. Secondary treatment was not designed to address these issues. Also as development and sprawl increases, so does the impact of non point sources.

“Near future” is not defined, but the intent was to draw attention to these issues so that they can be addressed (possibly through pollution prevention and other voluntary measures) before problems occur.

Copy of actual comment letters available

Appendix C

Definitions

BOD	biochemical oxygen demand
BOD5	5 day biochemical oxygen demand
CBODu	ultimate carbonaceous biochemical oxygen demand
CBOD5	5 day carbonaceous biochemical oxygen demand
DMR	Department of Marine Resources
DO	dissolved oxygen
KSTD	Kennebec Sanitary Treatment District
NBODu	ultimate nitrogenous biochemical oxygen demand
SOD	sediment oxygen demand
TBOD	total biochemical oxygen demand
TKN	total Kjeldahl nitrogen
TP	total phosphorous
USGS	United states Geological survey

Appendix D

Water Quality Classifications B & C

Class B

A. Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life. The habitat shall be characterized as unimpaired.

B. The dissolved oxygen content of Class B waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration shall not be less than 9.5 parts per million and the 1-day minimum dissolved oxygen concentration shall not be less than 8.0 parts per million in identified fish spawning areas. Between May 15th and September 30th, the number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 64 per 100 milliliters or an instantaneous level of 427 per 100 milliliters.

C. Discharges to Class B waters shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.

Class C

A. Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; and navigation; and as habitat for fish and other aquatic life.

B. The dissolved oxygen content of Class C water may be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning, egg incubation and survival of early life stages, that water quality sufficient for these purposes must be protected. Between May 15th and September 30th, the number of Escherichia coli bacteria of human origin in these waters may not exceed a geometric mean of 142 per 100 milliliters or an instantaneous level of 949 per 100 milliliters. The board shall promulgate rules governing the procedure for designation of spawning areas. Those rules must include provision for periodic review of designated spawning areas and consultation with affected persons prior to designation of a stretch of water as a spawning area.

C. Discharges to Class C waters may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.