A Phased TMDL For the Salmon Falls River Watershed
Use Attainability Analysis for the Lower Salmon Falls River
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Executive Summary

1. This report uses a water quality model (*Salmon Falls River Waste Load Allocation*, Maine DEP, Feb. 1994) and a subsequent basin wide seasonal sampling effort undertaken in 1995 (*Salmon Falls / Piscataqua River Watershed TMDL Project Data Report*, Maine DEP, NEIWPCC, April 1996) to calculate allowable pollutant loads (Total Maximum Daily Load or TMDL) to the Salmon Falls River watershed.

2. Both data collected in five independent years throughout the 1990's and predictions of the water quality model reveal the following:

- A 12.5 mile section (5.5 riverine and 7 estuarine) has historically failed to meet Maine's minimum class B and SB dissolved oxygen criteria.
- 7.5 of the 12.5 miles did not meet dissolved oxygen criteria of the next lowest classification class C and SC.
- The 5.5 riverine miles in non-attainment of dissolved oxygen criteria includes two impoundments (3 river miles) below major point sources and two impoundments (2 river miles) above major point sources.
- Point source discharges, sediment oxygen demand, and the presence of many dams are the major cause of water quality problems.
- Severe algae blooms develop in the two impoundments located below point sources and intensify at the head of tidal waters.
- The summer flow volume of the Salmon Falls River is too small to adequately dilute conventional secondary treated waste from five point sources, which collectively are 20% of the river flow.
- Unsteady river flows from hydropower facilities has historically contributed to dissolved oxygen non-attainment
- The continual damming of the Salmon Falls River contributes to the dissolved oxygen non-attainment and development of algae blooms by creating unfavorable physical conditions to assimilate wastewater discharges.
- Some non-attainment of dissolved oxygen criteria is possible even with complete removal of point source discharges
- A toxic problem has historically occurred as a result of ammonia discharged from the Berwick and Somersworth discharges. This has caused non-attainment of Maine's class B aquatic life criteria.

3. It is deduced depressed dissolved oxygen in impoundments above major point sources that fail to meet class B dissolved oxygen criteria are a result of inputs of natural background and tributary ultimate BOD, long river travel times and low reaeration in a continuous series of many man made impoundments that occur in a 24 mile stretch of river from Milton to South Berwick.

4. With the recent issuance of the hydropower FERC license at the South Berwick dam and the FERC ruling at the Lower Great Falls dam, flow at all dams on the entire Salmon Falls River is regulated in a steady (run of river) mode at summer low flow conditions. River flow regulation from dams is no longer contributing to water quality problems still experienced on the Salmon Falls River.

5. Both the dissolved oxygen data in upper Salmon Falls impoundments and predictions by the water quality model suggest that within reasonable constraints Maine's class B goal is unattainable for a 5.5 mile segment of the Salmon Falls River from Berwick (route 9 bridge) to South Berwick (head of tide). Implementation of a Use Attainability Analysis (UAA) which results in a downgrade in classification is necessary, for this 5.5 mile segment. It is recommended that the most stringent criteria of Maine and New Hampshire's class C and B, respectively be adopted as goals for this segment.

6. An analysis of loads inputted into the Salmon Falls River in 1995 indicates that point source discharges are responsible for about 90% and non-point sources about 10% of the total pollutant loads (phosphorus, BOD, and ammonia) in the Salmon Falls River. Large point sources (Berwick and Somersworth) are collectively responsible for 75% to 80% of the total, and small point sources (Milton, Rollinsford, and South Berwick) are collectively responsible for 10% to 15% of the total.

7. A modeling analysis of various advanced waste treatment alternatives for five point sources resulted in the following TMDL (total maximum daily load) or calculation of allowable pollutant loads for the lower Salmon Falls River:

Phased TMDL for the Lower Salmon Falls River - Applies in Summer					
Phase 1 of TMDL	Design Flow (mgd)	NH3-N (lb/day)	Ultimate CBOD (lb/day)	BOD5 (lb/day)	Total Phosphorus (lb/day)
Milton, NH*	0.1	N / A	34	16	0.5
Berwick, ME	1.1	65.4	429	131	4.4
Somersworth, NH	2.4	142.6	225	285	9.5
Rollinsford, NH	0.15	N / A	38	24	1.2
South Berwick, ME	0.6	N / A	228	95	4.8
Natural Background NPS	18.5	3.1	478	N / A	1.4
Tributary Non-Point Source**	0.3	0.1	8	N / A	2.5
Reserve Capacity (5%)		10.9	50	29	1.1
Total = TMDL		222	1490		25.3
Other Recommendations	1. Include performance based TSS in point source permit limits.				
	2. Non-Point Sources - Implement BMP's on Great Works River Watershed as a priority				
	3. Non-Point Sources - Implement BMP's throughout Salmon Falls watershed, where feasible.				
	4. Implement simultaneous top and bottom releases from Lower Great Falls, Rollinsford, and South Berwick dams during summer low flow period				
	5. After implementation of TMDL, begin ambient summer compliance monitoring.				
	6. Re-evaluate 1st phase of TMDL after five years. If non-compliance of water quality standards continues to occur, modify TMDL. If compliance of standards occur, the phased TMDL becomes final.				
* The Milton inputs to the TMDL include assimilation losses from Milton to Berwick of 33% and 30% for TP and BOD, respectively					
** The BOD and ammonia TMDL only include tributary flow to head of tide (0.3 mgd). The TP TMDL includes additional flow of 9.8 mgd from the Great Works River.					

8. The TMDL results in the following recommendation for federal (NPDES) permit limits for the five point sources:

Recommended Permit Limits for Phase 1 of TMDL							
	Ammonia (lb/day) Weekly Ave.	Ammonia (lb/day) Mo. Ave.	Ammonia (ppm) Mo. Ave.*	Total Phosphorus (ppm) Mo. Ave.	BOD5 / TSS (lb/day) Mo.Ave.	BOD5 / TSS (lb/day) Weekly Ave.	BOD5 / TSS (lb/day) Daily Maximum
Milton, NH	None	None	None	1	11	16	18
Berwick, ME	65	174	28	0.5	87	131	146
Somersworth, NH	143	380	28	0.5	190	285	317
Rollinsford, NH	None	None	None	1	16	24	27
S. Berwick, ME	None	None	None	1	63	95	106
Limits Apply	6/1 to 9/30	10/1 to 5/31	Year Round	5/1 to 9/30	June 1 to Sept 30		

9. An evaluation of alternatives for the UAA reveals that there are no cost effective or practical alternatives to avoid re-classification of a 5.5 mile segment of the Salmon Falls River.

10. An economic analysis for the UAA indicates that all non-treatment alternatives considered for the re-classified segment (dam removals, outfall relocations, and in-stream aeration) can be rejected due to high costs, or uncertainty whether or not the alternatives could result in meeting water quality goals.

11. The recommended TMDL, although resulting in an adoption of subcategories of classification (less stringent criteria) for a 5.5 mile segment still maintains all designated uses of classification.

12. The economic analysis estimates that the total cost of the chosen alternative included in the TMDL is $3.8 million. The expected increase in sewer user costs of less than 10% for small point sources and less than 20% for large point sources are deemed to be affordable.

13. Although two higher treatment levels investigated for point sources are affordable, they are not recommended due to the lack of significant water quality benefits expected from further reductions of point sources and the escalating costs (double and triple the cost of recommended treatment).

Introduction

The Salmon Falls River forms the boundary between Maine and New Hampshire for its entire length of more than 40 miles. In the tidal estuary, its name changes to the Piscataqua and similarly forms the state boundary for more than 10 miles. Flow for the entire river is regulated at its headwaters at Milton Pond. There are four dams in the first five riverine miles which include South Berwick (RM 0.0), Rollinsford (RM 1.1), Lower Great Falls (RM 3.4) and Somersworth (RM 4.9) (RM = river miles above head of tide). Both Berwick's and Somersworth's effluents discharge to the Rollinsford impoundment and Rollinsford's effluent discharges to the South Berwick impoundment. South Berwick's effluent discharges just below the South Berwick dam at head of tide and Dover's effluent discharges in the estuary about five miles below head of tide. The town of Milton discharges to the river just below Spaulding Pond at about twenty miles above head of tide.

In the mid to late 1980's, and throughout the 1990’s a dissolved oxygen problem became evident on the lower portion of the Salmon Falls River, since sampling always indicated some non attainment of Maine's dissolved oxygen standards. A water quality model was developed in 1994 to determine the source of the problem and possible solutions to correct the problem. A report was developed discussing the water quality model and recommending initial waste load allocations for point sources and additional studies that were needed *(Salmon Falls River Waste Load Allocation,* Feb 1994). As a result of recommendations for additional studies, additional fieldwork was undertaken in 1995 with the intention of fine tuning model results for an eventual TMDL for this waterway. A data report was developed in 1996 that discussed the 1995 sampling effort *(Salmon Falls Piscataqua River Watershed TMDL Project Data Report*, April 1996).

For reader convenience, the highlights of the two reports are summarized next. The remaining portion of this report discusses the TMDL that is recommended for cleanup of the Salmon Falls River. A necessary ingredient of the TMDL is the downgrade in classification of a 5.5 mile river segment from class B to C. A downgrade in classification requires a Use Attainability Analysis (UAA) and public hearing (which was held Feb. 10, 1999). The UAA discusses the cleanup alternatives and their costs and is the final portion of the report.

Salmon Falls River Waste Load Allocation, Feb 1994

The sampling effort for the model calibration data included three intensive surveys that were planned for low flow summer conditions. One was conducted in July of 1991 and two additional surveys were conducted in 1992, one in July and the other in August. The data were collected by Maine DEP personnel with assistance from EPA Region 1 and citizen volunteers. The following conclusions were deduced from this data :

- a 12.5 mile section (5.5 riverine and 7 estuarine) failed to meet Maine's minimum class B and SB dissolved oxygen criteria.
- 7.5 of these 12.5 miles did not even meet dissolved oxygen criteria of the next lowest classification class C and SC.
- Elevated chlorophyll a readings indicate severe algae blooms occur annually in the Rollinsford and South Berwick impoundments and the upper estuary. Background chlorophyll a levels were always low.
- Background water quality in two impoundments upstream of major point sources also failed to meet dissolved oxygen standards

The EPA supported model WASP4 was used in the development of a water quality model of this system. Some of the conclusions of the modeling were

- Point source phosphorus, sediment oxygen demand, and the presence of many dams are the major cause of water quality degradation
- An ammonia toxicity problem occurs from the Berwick and Somersworth discharges
- Unsteady river flows from hydropower facilities contribute to the problem

- Some non-attainment of dissolved oxygen standards is possible even with complete removal of point source discharges
- Point source phosphorus and ammonia reductions of 95% and 70% may be necessary

Recommendations for additional data collection or river flow management included:

- A pilot study to collect water quality data when phosphorus was being removed through end of pipe treatment or pollution prevention at the Berwick, Somersworth, Rollinsford, and South Berwick treatment facilities.
- Additional studies to determine the cause of low upstream background dissolved oxygen
- A requirement for steadier river flow from all of the dams on the river
- Additional work to determine the significance of non point source loading

For a more detailed description, one should refer to the *Salmon Falls River Waste Load Allocation* report (Maine DEP, Paul Mitnik, Feb 1994). All of the additional work recommended in the Waste Load Allocation has been implemented. The pilot study, which experimented with point source phosphorus reductions, was undertaken in 1995 and a data report for this effort was released in April of 1996. The pilot study also included data collection to address the other deficiencies noted in the 1994 report.

<u>1995 Phosphorus Pilot Study</u>

The Salmon Falls River was monitored for a five month period in 1995 by Maine DEP, NEIWPCC summer interns, NHDES and USEPA personnel from May to September. Steady (run of river) flow was passed for the entire period and water was spilled over the three dams above head of tide for most of the study period to provide maximum reaeration of river water. During the first three months of this period, phosphorus removal was implemented at the Berwick, Somersworth, Rollinsford, and South Berwick treatment facilities with a goal of 1-ppm total phosphorus for the effluent. The phosphorus removal ended on July 31, and in the final two months, no phosphorus removal was implemented. The study involved the following components:

1. Grab samples were collected one day twice per month for flow, nutrients, chlorophyll a, BOD, dissolved oxygen, temperature, salinity, and secchi depth at many riverine and estuarine locations. Composite samples of six effluents were collected for flow, nutrients and BOD on the same days that ambient samples were collected.
2. Composite samples of total phosphorus were collected three times per week at Berwick, Somersworth, Rollinsford, and South Berwick and weekly composite samples of ammonia at Berwick and Somersworth.
3. To assess non-point impact, wet weather total phosphorus sampling was undertaken at four tributary and four main stem stations during three precipitation events.
4. Sediment oxygen demand and nutrient flux measurements were made three times at four locations.
5. Cross sectional data from Milton to Berwick at 23 locations and tidal stage data were taken from low to high tide at a spring tide in June at three estuary locations.

Some important findings and conclusions reached from this data:

1. An extended drought occurred in early August through mid September in which no significant rain occurred for more than a month. Low flows representing a ten-year occurrence were experienced in the Salmon Falls watershed during the last three times it was sampled in late August and September. The total lack of runoff during this period resulted in ideal conditions to assess point source related impacts.

2. A 7-mile section of river and 5 mile section of estuary did not attain Maine's minimum B and SB dissolved oxygen standards at all depths, vertically. Some portions of this 12-mile segment also did not meet New Hampshire's class B dissolved oxygen standard. Dissolved oxygen standards were not met during both the phosphorus removal period (May to July) and non-treatment phosphorus period (August to September). Maine and New Hampshire point sources,

collectively were at 1/3 of their licensed flow and 14% of the licensed mass BOD loads during this period.

3. Non attainment of Maine's Class C dissolved oxygen criteria and New Hampshire's class B daily minimum criteria was limited to the deeper portions of the Lower Great Falls, Rollinsford, and South Berwick impoundments during the phosphorus treatment period. During the non-treatment phosphorus period, dissolved oxygen criteria were not met in the Rollinsford impoundment at all depths, and a sampling station below the Berwick discharge at all depths and the deeper portions of all three impoundments representing a total distance of about 4 miles. Maine’s class SC criteria were not met in deeper portions of the estuary at the Hamilton House during both treatment and non-treatment periods.

4. Each of the four treatment plants except the smallest plant, Rollinsford, met the final effluent goal of 1-ppm total phosphorus as an average for the three-month period. South Berwick had the lowest levels of total phosphorus. Overall, the program was considered a success, since total phosphorus levels from all four plants averaged 0.7 ppm over the three months. A significant improvement in river water quality was achieved.

5. The wet weather sampling in 1995 did not show any widespread significant contribution of non-point phosphorus loading to the Salmon Falls River for the storms sampled when compared to point source inputs.

6. General observations, limited chlorophyll a data and dissolved oxygen PM readings that were often supersaturated indicated the presence of severe algae blooms as experienced in previous years. The blooms were less severe during the treatment period.

7. Based upon observations and flow gaging data of the Salmon Falls River and its tributaries at 7Q10 flow conditions, a new 7Q10 of 28.7 cfs at Berwick and Somersworth was calculated. This is lower than the value of 36.4 cfs used in the 1994 Waste Load Allocation.

A major disappointment of this sampling effort developed when all of the chlorophyll a data had to be rejected due to an instrumentation malfunction in the laboratory, which analyzed these samples. Limited data from a different study (Great Bay, Jackson Lab) confirmed the rejected levels of 110 ppb and 140 ppb in the South Berwick impoundment (route 4 bridge at head of tide) and route 101 bridge (about 3 miles below head of tide), respectively in mid September of 1995 and clearly demonstrates the severity of the problem. Since eutrophication and nutrient controls were identified as a major issue in the prior modeling effort, any additional modeling with the 1995 data could not be done without this crucial data. It was originally intended to use the 1995 data to re-calibrate the model and then fine tune model predictive results when implementing point source controls in the final TMDL to this watershed. The subsequent re-calibrating and fine-tuning of the model with the 1995 data had to be aborted due to the lack of reliable chlorophyll a data.

Discussion of Upper Salmon Falls Watershed

One of the recommendations of the 1994 report was to undertake additional studies to determine the source of the low dissolved oxygen in impoundments above all the major point source discharges. In all of the data (summers of 1991, 1992, 1995), Maine's class B dissolved oxygen standard of 7 ppm and 75% of saturation was routinely not attained from the surface to the bottom of the Lower Great Falls and Somersworth impoundments. In addition, Maine's class C dissolved oxygen standard of 5 ppm and 60% of saturation and New Hampshire's class B dissolved oxygen standard were routinely not met in the deeper portions of these two impoundments.

The 1995 sampling effort was expanded upriver from prior sampling efforts in 1991 and 1992 to cover eighteen additional miles from Milton to Berwick. Ideally, in a water quality intensive survey the most upstream station should be free from impacts other than those considered to be from natural conditions.

The four upper basin stations (Milton, Copps Bridge, Rte 202 South Lebanon, Route 9, Berwick / Somersworth) were sampled to determine the reason for lower than expected dissolved oxygen. When the data for the four upper basin stations is examined, ultimate BOD was slightly elevated in the beginning of the study, usually in the range of 4 to 5 ppm, and declined in the late summer about 1 ppm to a range of approximately 3 to 4 ppm (figure 1). (A total UBOD of 3 ppm or less is a typical value for unpolluted waters in Maine.) When the ultimate BOD data are compared from station to station on a given sampling day, there is no consistent trend, i.e. one station always being the highest or lowest.

When considering non-point source loads, there is the issue of how much of the load is of natural origin and how much is from non-point source pollution. This is often difficult to determine. The seasonal sampling from the 1995 sampling effort gives some insight to this issue. Since virtually no precipitation occurred during early August to mid September, this dry weather BOD data in the Salmon Falls River can be used as a representation of natural conditions. The dry weather average BOD value (3.2 ppm) can be considered a natural BOD level and is within background values typically measured on other rivers (3 ppm). The BOD data taken earlier in the summer averaged 1.2 ppm higher than the dry weather data and was as much as 2 ppm higher than the dry weather data. Hence BOD from non-point source pollution is about 1.2 ppm and can be as high as 2 ppm. It can be seen that virtually all of the dry weather BOD is of natural origin and even the majority wet weather BOD (73%) is of natural origin.

This is expected, since much of this watershed contains tributaries that drain wetlands, which is a natural source of BOD. The upper watershed is mostly forested and should be free from agricultural and residential impact of significant non-point pollution. There is limited tributary (Little River, Worster Brook, Great Works River, Cocheco River) ultimate BOD data taken as pre-storm or dry weather data during the three wet weather storm events that were sampled. The tributary UBOD's were often in the range of 6 to 8 ppm and can be considered to be moderately high levels (figure 1). Due to the small volume of flow from the tributaries when compared to the Salmon Falls River flows, tributary BOD is not significantly affecting the river BOD levels during low river flow conditions .

The town of Milton discharges here, but their relatively small discharge volume allows a dilution factor of 164:1 at 7Q10 river flow conditions. If Milton was discharging at their permitted BOD at 7Q10 river flow, about 0.8 ppm UBOD would be attributable to their discharge. However they are usually at one-half or less of their mass permitted BOD so probably less than 0.5 ppm ultimate BOD is typically attributable to their discharge. Milton’s discharge is responsible for 10% to 15% of the total UBOD here at low flow conditions.

Sediment oxygen demand (SOD) measurements were taken by USEPA in the summer of 1995 in the first four impoundments above head of tide (South Berwick, Rollinsford, Lower Great Falls, and Somersworth) in June and in the upper two impoundment Lower Great Falls, Somersworth) in September. This work was duplicated for the upper two impoundments, which are above all of the major discharges due to the fact that no previous data was gathered here. These data are plotted with earlier data taken in 1992 by USEPA for comparative purposes (figure 1a). When the data are analyzed, it can be seen that SOD is not very high in three of the four points sampled in the Lower Great Falls and Somersworth impoundments. It is concluded that SOD is probably not a major factor in surface layer dissolved oxygen depletion in these impoundments, but still could be significant in deeper layers due to chemical stratification in these impoundments. There is generally a low vertical transfer of oxygen in these impoundments, which can result in low deeper level dissolved oxygen, despite SOD levels that were not very high.

The 1995 dissolved oxygen data for the upper Salmon Falls River reveals that levels are good from Milton Pond to South Lebanon and both Maine's and New Hampshire's class B dissolved oxygen standards can be expected to be attained here. When the Somersworth impoundment is encountered, levels gradually decline, reaching the lowest levels in this impoundment above the dam near the route 9 bridge. The levels are similarly low above the Lower Great Falls dam. It is deduced that the lower than expected dissolved oxygen levels are a combination of decay from primarily natural UBOD, and man made impoundments and in deeper waters, sediment oxygen demand. There are eight dams on a 24-mile river segment from Milton to South Berwick that results in continuous impoundments. The impoundments increase river travel time

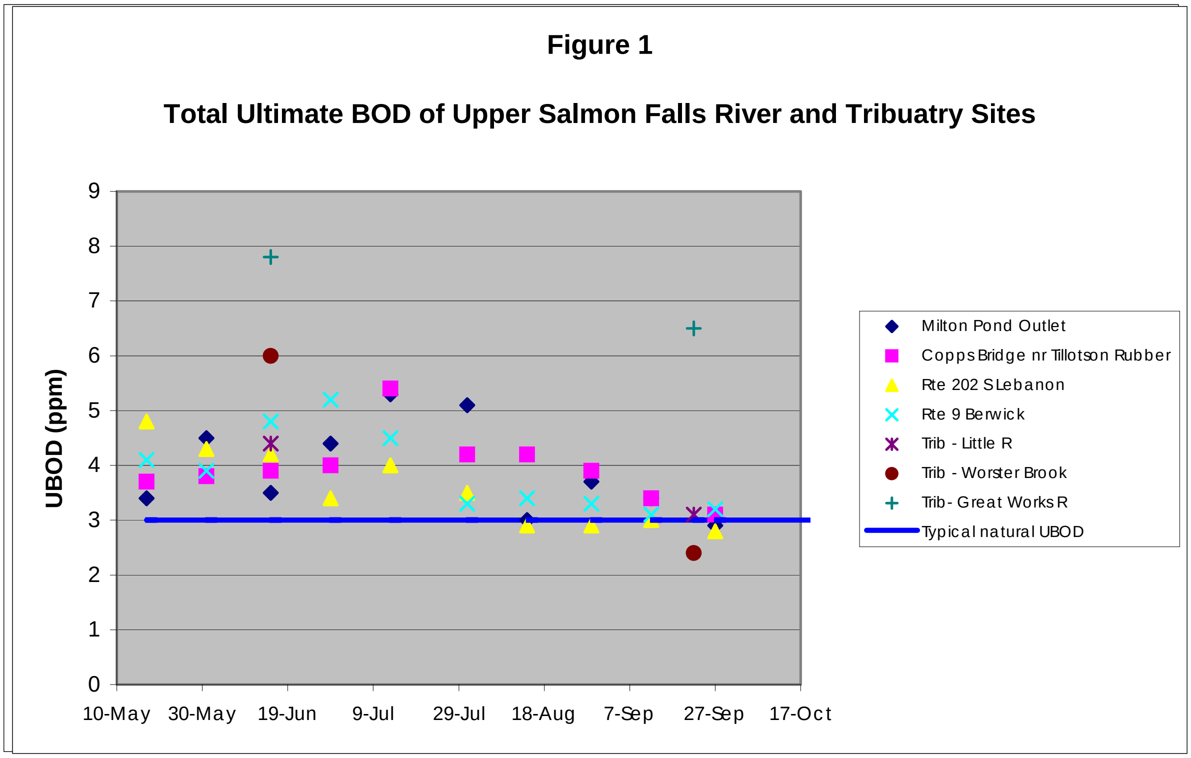


Figure 1
Total Ultimate BOD of Upper Salmon Falls River and Tribuatry Sites
UBOD (ppm)
0
1
2
3
4
5
6
7
8
9
10-May
30-May
19-Jun
9-Jul
29-Jul
18-Aug
7-Sep
27-Sep
17-Oct
Milton Pond Outlet
Copps Bridge nr Tillotson Rubber
Rte 202 S Lebanon
Rte 9 Berwick
Trib - Little R
Trib - Worster Brook
Trib - Great Works R
Typical natural UBOD

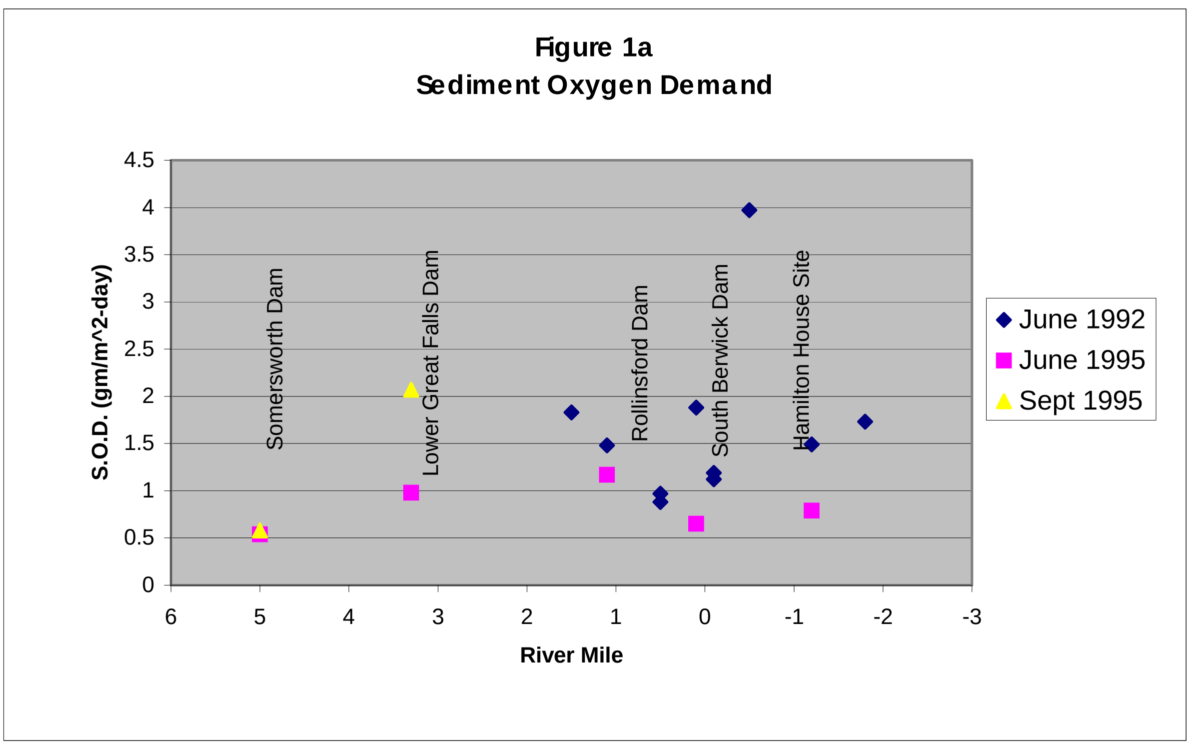


Figure 1a
Sediment Oxygen Demand
S.O.D. (gm/m^2-day)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Somersworth Dam
Lower Great Falls Dam
Rollinsford Dam
South Berwick Dam
Hamilton House Site
6
5
4
3
2
1
0
-1
-2
-3
River Mile
June 1992
June 1995
Sept 1995

and lower natural reaeration thus severely impinging upon the self-purification of natural waste. This results in BOD typical of natural conditions depleting oxygen in the river much more than what would ordinarily occur. This cannot be considered natural phenomena, however, since dams are man-made structures, and even if some of these dams were removed, water quality problems would not be eliminated.

River Flow Regulation

Another requirement recommended in the 1994 WLA for the Salmon Falls was for steady run of river flows from all dams, since the report identified the store and release of river flow on some of the dams retrofitted for hydropower to be contributing to water quality degradation. With the recent issuance of water quality certification at the South Berwick dam and the recent Federal Energy Regulatory Commission (FERC) ruling at the Lower Great Falls dam, the entire Salmon Falls River is now essentially run of river at summer low flow conditions.

For many years, the Lower Great Falls impoundment was run in a store and release mode of river flow regulation. Since hydropower turbines are sized for higher river flows, in order to generate power during low flow conditions, releases of water must be made in large volume, and short duration spurts. In this mode, flow is typically released in large flow quantities for a few hours daily to generate peaking hydropower which results in inflow to the impoundment being less than outflow and ultimately a lowering of impoundment levels below dam crest height. In the storing mode, the impoundment is allowed to refill back up to crest dam height, which results in only a low leakage flow being released below the dam for periods of many hours. The storing of flow usually occurs for a much longer duration each day than the releasing of flow. For example, the river flow below the Lower Great Falls dam was usually greater than 100 cfs when generating power, but only 6 cfs when not generating power. It is the storing of river water and reduction of downstream flows that often result in undesirable chemical water quality impacts to parameters such as dissolved oxygen.

In November of 1995, FERC ruled that the Lower Great Falls dam was licensed to be operated as run of river with impoundment inflow equal to outflow at all times. This was due to the fact that the hydropower dam owner originally proposed run of river mode of operation in its licensing application. Even though there was no specific article in the license requiring the run of river mode, FERC ruled that its licensing order approved the licensee's original proposal and they were bound to operate by their proposal.

The South Berwick impoundment was similarly operated in a store and release mode for many years and typically passed 150 cfs or more below the dam when generating power but only 3 cfs when not generating power. In May of 1995, water quality certification was issued by the Maine DEP which resulted in improvements. The hydropower licensee's were required to pass a year round minimum flow of 44 cfs and from June 1 to Sept 30 are required to operate in a run of river mode during low flow and high temperature periods (defined by the product of flow duration and temperature > 1500). This essentially results in run of river mode when there is more likelihood of water quality problems in the river and estuary. In December of 1997, the FERC license was issued requiring run of river flow year round. The table below summarizes flow requirement from all FERC licensed dams on the Salmon Falls River.

Table 1- River Flow Regulation from Salmon Falls River Dams	
Dam	Minimum Flow Requirement
Milton Three Ponds	No guaranteed minimum but 35 cfs targeted minimum dependent upon lake levels
South Milton	58 cfs or inflow
North Rochester	66 cfs or inflow
Boston Felt	70 cfs or inflow
Somersworth	110 cfs or inflow
Lower Great Falls	Inflow (run of river)
Rollinsford	Inflow (run of river)
South Berwick	Inflow (run of river)

Calculation of 7 Day 10 year Low Flow (7Q10)

A 7Q10 flow of 36.4 cfs at Berwick / Somersworth was used in the 1994 modeling study. This was derived by the 7Q10 flow at the Milton gage and an incremental drainage adjustment factor. The 1995 data showed that the incremental drainage adjustment factor in-between Milton and Berwick in this analysis was too high and the newly corrected value of 28.7 cfs should be used in all subsequent analysis. The newly derived 7Q10 at Berwick and Somersworth was derived using the Lamprey river gage to prorate unregulated incremental drainage between Milton and Berwick and then add this value to the 7Q10 flow at the USGS gage at Milton of 25.4 cfs (derived by New Hampshire USGS using a Log Pearson type three statistical distribution). This results in the following equation:

$7Q10_{Berwick} = 7Q10_{Milton} + 7Q10_{Lamprey}$ x (incremental D.A. Milton to Berwick) / D.A. Lamprey
$7Q10_{Berwick} =$ 25.4 cfs + 5.3 cfs x 113 mi^2 /183 mi^2 = **28.7 cfs**

The decision to use the Lamprey River gage for prorating intervening drainage between Milton and Berwick was based upon the need to use a gage with a long period of continuous record and a comparison of tributary and Salmon Falls River gaging data in the summer of 1995. The Lamprey River flow gage has a period of record of 60 years. USGS gages also are located on the Cocheco River at Dover and Rochester and a gage on the Great Works River is operated by the North Berwick Sanitary District but its rating curve (stage Vs discharge) was derived by USGS. None of these gage have a long period of record (all < 10 years).

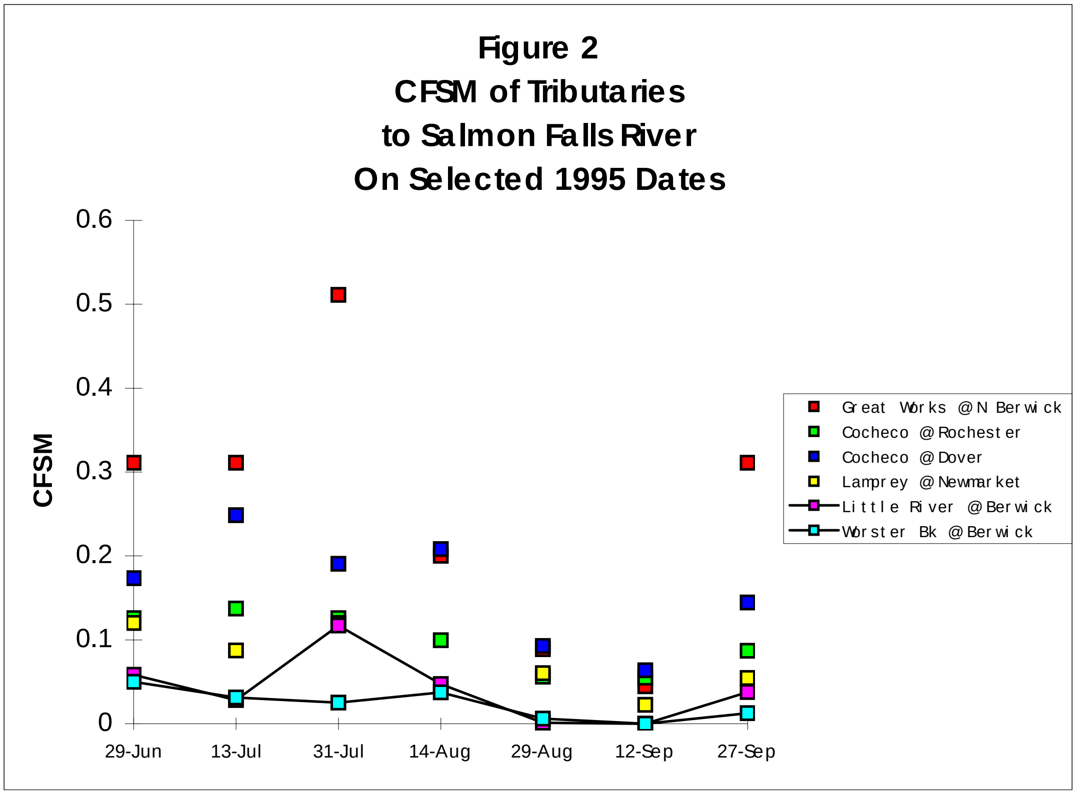
In addition to these gages, the Maine DEP made gaging measurements on Worster Brook, the Little River and the Salmon Falls River at Berwick twice per month in 1995. The Little River and Worster Brook are tributaries that are located in-between Milton and Berwick and together result in 54% of the intervening drainage. When this gaging data is compared to the other continuous gaging information, it can be seen that the Lamprey River gage compares most favorably to the Worster Brook and Little River pro-ration factors (CFSM or cubic feet per second per square mile of drainage) (figure 2). In addition the Salmon Falls River gaging data at Berwick confirms that there are not any more tributary inputs in-between Berwick and Milton with significant flow quantity and hence Worster Brook and the Little River are representative tributaries inputs in-between Milton and Berwick.

A Phased TMDL for the Salmon Falls River Watershed

The rejection of the chlorophyll a data in 1995 and subsequent unsuitability of the 1995 data to further refine the model resulted in another major hurdle to delay cleanup of the river. Given the time commitment of more than eight years already invested by various state and federal agencies here, it is prudent to move

CFSM of Salmon Falls River Tributaries on Selected 1995 Dates

	Great Works @ N Berwick	Cocheco @ Rochester	Cocheco @ Dover	Lamprey @ Newmarket	Little River @ Berwick	Worster Bk @ Berwick
17-May	2.467	1.396	1.358	1.279	1.774	2.375
31-May	1.589	0.984	0.827	0.699	1.170	0.788
15-Jun	1.222	0.526	0.486	0.328	0.132	0.438
29-Jun	0.311	0.126	0.173	0.120	0.058	0.050
13-Jul	0.311	0.137	0.249	0.087	0.028	0.031
31-Jul	0.511	0.126	0.191	0.120	0.117	0.025
14-Aug	0.200	0.100	0.208		0.047	0.038
29-Aug	0.089	0.056	0.092	0.060	0.001	0.006
12-Sep	0.044	0.055	0.064	0.022	0.000	0.000
27-Sep	0.311	0.087	0.145	0.055	0.038	0.013



forward with a decisive strategy to improve water quality conditions that would have a reasonable chance of meeting goals mandated by state and federal laws.

A TMDL is a calculation of the assimilative capacity, or the maximum allowable pollutant loads for a watershed that will result in water quality standards being maintained. A TMDL includes point source, non-point source, and background inputs. Federal regulations require that a TMDL include an adequate margin of safety (MOS) to compensate for the uncertainty in the calculations. The margin of safety could be expressed as an actual load. i.e. 10% of the assimilative capacity reserved for MOS, or conservative assumptions used in the modeling analysis. TMDL is as follows:

TMDL = PS + NPS + Background + MOS

where TMDL = Maximum pollutant load that allows attainment of water quality standards
PS= Sum of all point source loads to waterbody
NPS= Sum of all non-point source loads to waterbody
Background = Inputs of natural origin
MOS = Margin of safety

A phased TMDL is a method that allows for immediate river cleanup in stepped reductions and ongoing ambient compliance monitoring in situations involving much uncertainty over benefits received from various degrees of river cleanup. This appears to be a method that is well suited for the Salmon Falls River.

A phased TMDL is an approach supported by the USEPA and is explained in their guidance document to TMDL development. It is often used in situations where there is a large degree of uncertainty such as non-point source TMDL's. It is equally applicable in this case due to the high degree of complexity in modeling eutrophication and estuarine systems. It is likely that even with a completed and polished final model of this system, a phased approach would still be necessary. The following excerpt from the EPA guidance document for TMDL's (Guidance for Water Quality-based Decisions: The TMDL Process, EPA 440/4-91-001, April 1991, page 22) explains the phased approach as follows:

"Under the phased approach, the TMDL has LAs and WLAs calculated with margins of safety to meet water quality standards. The allocations are based on estimates, which use available data and information, but monitoring for the collection of new data is required. The phased approach provides for further pollution reduction without waiting for new data collection and analysis. The margin of safety developed for the TMDL under the phased approach should reflect the adequacy of data and the degree of uncertainty about the relationship between load allocations and receiving water quality."

"The TMDL under the phased approach includes (1) WLAs that confirm existing limits or would lead to new limits for point sources and (2) LAs that confirm existing controls or include implementing new controls for non point sources. This TMDL requires additional data to be collected to determine if the load reductions required by the TMDL lead to the attainment of water quality standards. Data collection may also be required to more accurately determine assimilative capacities and pollution allocations."

"In addition to the allocations for point and non point sources, a TMDL under the phased approach will establish the schedule or timetable for the installation and evaluation of point and non point source controls measures, data collection, the assessment for water quality standards attainment, and if needed, additional predictive modeling."

A TMDL will be developed for the Salmon Falls River by use of a model developed in 1994 and comparing model results to data collected in 1995, 1997, and 1998. The 1995 data are valuable and unique compared to most river modeling studies in that data was actually collected at three independent 7Q10 flow events. Although the 1995 data cannot be used to re-calibrate the model (due to rejected chlorophyll a), it can still be used as a valuable supplemental comparison to model predictions at 7Q10 flow. As discussed earlier, the data deficiencies earlier noted for the model have been eliminated and has resulted in a more credible model.

Additional model runs will be made investigating a number of advanced treatment levels for five point sources. This should include not only phosphorus controls, but also ammonia and BOD controls that will ultimately result in attainment of dissolved oxygen, aquatic life, and toxic ambient water quality criteria. Attainment of water quality standards will be evaluated through an ongoing ambient monitoring effort undertaken each summer until the next round of licensing. The TMDL will be revised if monitoring data indicates noncompliance of water quality standards.

Major obstacles to developing a TMDL for the Salmon Falls are both the data collected over many years and predictive modeling indicate that there are probably no reasonable available options that will completely result in attainment of all of Maine’s class B criteria. Therefore a TMDL to meet class B water

quality standards cannot be calculated unless a Use Attainability Analysis (UAA) is undertaken. A UAA is a structured scientific assessment of the physical, chemical, biological, and economic factors affecting the attainment of a designated use in a water body. A UAA is usually undertaken in situations, when after considering all available and affordable options, existing water quality classifications are still believed to be
unattainable. A UAA allows for removal of designated uses that are not existing uses or adoption of subcategories of classification (i.e., less stringent criteria). The evaluation of the cost of alternatives of river clean up is an important and necessary ingredient of a UAA.

The establishment of goal uses for reclassification under a UAA and eventual numerical or narrative criteria is a requirement of a UAA. However the numeric and narrative criteria are also necessary to implement a TMDL. The recommended classification goals are discussed in the next section. The remaining portion of the UAA is discussed at the end of this report.

Water Quality Standards for Lower Salmon Falls

The existing classifications for the Salmon Falls River are class B and SB in Maine for tidal and non-tidal waters, respectively, and class B in New Hampshire for both tidal and non-tidal waters. Another dilemma that has developed in establishing water quality goals for the Salmon Falls River is the differences in Maine and New Hampshire's standards for the same body of water. Both Maine and New Hampshire standards will have to be met before NPDES waste discharge permits could be issued for point sources. Federal Law (Clean Water Act) requires a state to acknowledge water quality standards of an adjoining state which shares the same waterbody (CFR 131.10b). The water quality goals for this river should incorporate both standards with the more stringent standards for each state prevailing. The final result will be a single standard or goal that will meet both states' objective.

The list of necessary classification criteria to develop the TMDL for both states (Table 2) illustrates the differences when comparing the state's criteria. For example, Maine's class B minimum dissolved oxygen criteria (7 ppm and 75% saturation) are more restrictive than NH's minimum class B criteria (5 ppm) and Maine's minimum class C criteria (5 ppm and 60% saturation) are similar to NH's minimum class B criteria. It is not believed that Maine's class B criteria are an achievable goal within realistic and affordable constraints. (This is discussed later in the UAA portion of this report.)

The difficulty in maintaining class B standards in the 5.5 mile segment can be illustrated by an examination of available data and logical scientific deduction. Data collected over many summers (91, 92, 95, 97, 98) have shown that during the summer time, both the Somersworth impoundment (RM 4.9 or the dam is 4.9 river miles above head of tide) and Lower Great Falls impoundments (RM 3.4) routinely do not meet Maine's minimum class B dissolved oxygen standard of 7 ppm. The deeper portions of these impoundments almost always do not meet class B dissolved oxygen, and occasionally dissolved oxygen criteria are not met at all depths from impoundment surface to bottom. Maine's minimum class C dissolved oxygen standards of 5 ppm and 60% of saturation are often not met in the deeper portions of these impoundments. Both of these impoundments are above all major point source discharges.

The Rollinsford impoundment (RM 1.1) receives point source inputs from Berwick and Somersworth. The South Berwick impoundment (RM 0.0) receives point source inputs from Rollinsford and South Berwick discharges just below the dam. Point source inputs usually result in a further diminishment of water quality. A dissolved oxygen sag point (dissolved oxygen sag) is the location of the minimum point of dissolved oxygen in a river. Below a point source, the river dissolved oxygen typically declines in the downstream direction reaching a minimum at the dissolved oxygen sag point location. On the Salmon Falls River, the dissolved oxygen sag is typically in the Rollinsford impoundment but can also be above the South Berwick dam or at the Hamilton House (in tidal waters 1-mile below the dam).

There is a large volume of point sources in the Salmon Falls River when compared to river low flow (7Q10) conditions. About 20% of the volume of the Salmon Falls River would be utilized by point sources

Table 2 Summary of Classification Criteria Maine and New Hampshire

Maine Water Quality Standards

Fresh Waters	Designated uses	Dissolved Oxygen Criteria	Aquatic Life	Bacteria
Class B	Drinking water supply after treatment, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation (with restrictions), navagation, habitat for fish and other aquatic life.	Daily minimum > 7 ppm and 75% saturation Identified fish spawning areas from Oct 1 to May 14 the 7-day mean D.O. > 9.5 ppm and 1-Day min > 8 ppm	Discharges should not cause adverse impact to aquatic life in that the receiving waters shall be of suffcient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the residental biological changes in the residental biological	From 5/15 - 9/30 E Coli of human origin Geo. Mean < 64/ 100 ml Instantaneous < 427 / 100 ml
Class C	Same as Class B	Daily Minimum > 5 ppm and 60% saturation Monthly average > 6.5 ppm Identified fish spawning areas from Oct 1 to May 14 sufficient water quality for fish spawning, egg incubation, and early life stages must be maintained.	Discharges 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 communuty.	From 5/15 - 9/30 E Coli of human origin Geo. Mean < 142 / 100 ml Instantant. < 949 / 100 ml
Tidal Waters	**Designated uses**	**Dissolved Oxygen Criteria**	**Aquatic Life**	**Bacteria**
Class SB	Aquaculture, propagation and harvesting of shellfish, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation (with restrictions), navagation, habitat for fish and other estuarine and marine life	Daily minimum > 85% of saturation	Discharges should not cause adverse impact to estuarine and marine life in that the receiving waters shall be of sufficient quality to support all estuarine and marine species indigenouos to the receiving water without detrimental changes to the resident biological community. New discharges cannot cause the closure of an	From 5/15 - 9/30 Enterococci of human origin Geo. Mean < 8 / 100 ml Instantant. < 54 / 100 ml Meet USDA shellfish standards
Class SC	Same as Class SB, except resticted harvesting of shellfish	Daily minimum >70% of saturation	Discharges may cause some changes to estaurine and marine 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 communuty.	From 5/15 - 9/30 E Coli of human origin Geo. Mean < 14 / 100 ml Instantant. < 94 / 100 ml Meet USDA shellfish standards

New Hampshire Water Quality Standards

All Water	Designated Uses	D.O. Criteria	Aquatic Life	Bacteria
Class B	Fishing, swimming, and other recrerational purposes and, after adequate treatment, for use as water supplies.	In all free flowing waters and unless naturally occurring, the top 25% depth of impoundments not thermally stratified, and the epilimnion of thermally stratified Minimum D.O. > 5 ppm; Daily ave. D.O. > 75% satutation In the bottom 75% depth of impoundments not thermally stratified and the hypolimnion of thermally stratified impoundments. D.O. shall be as naturally occurs.* In cold water fish spawning areas, from 10/1 to 5/14 the 7-Day mean D.O. > 9.5 ppm; Instantaneous D.O. > 8 ppm	The surface water quality of the state shall support a healthy and diverse community of organisms that are in balance with their existing habitat and are indicative of a healthy ecosystem. Unless naturally occurring, only nondetrimental changes in community structure and function shall occur.	Fresh waters E Coli. for areas not designated as beaches Geo. Mean < 126 Instantaneous < 406, unless naturally occurring Tidal waters enterococci Geo. Mean < 35 Instantaneous < 104, unless naturally occurring

* The NHDES interprets this as meaning no numeric standards are required in the mentioned deeper portions of impoundments

	Total Phosphorus Narrative Standards	Chronic Ammonia Criteria
Maine	Support designated uses of water contact recreation	Both states use USEPA ambient water quality criteria at pH 7 NH3-N conc < **3.08** ppm
NH	No phosphorus in concentration that would impair useage, unless naturally occurring. Existing discharges containing phosphorus which encourage cultural eutrophication shall be treated to remove phosphorus to ensure attainment and maintenance of water quality standards.	

discharging at design flow. Further diminishment of water quality conditions below background conditions can be expected. Since background conditions are often below class B criteria, the diminishment of water quality due to point source discharges should result in dissolved oxygen levels being even further below Maine's class B standard than background conditions. It is evident that Maine's class B goal, especially for the two impoundments (Rollinsford, South Berwick) below discharges, is not a realistic goal for this river. The difficulty in meeting Maine's B is also supported by the 1994 modeling effort which concluded that 5 riverine and 2 estuarine miles may not meet Maine's class B and SB dissolved oxygen standards, respectively, even with outright removal of all point sources.

For these reasons it is recommended that Maine's class C dissolved oxygen standard and New Hampshire's class B dissolved oxygen standard be adopted as goals for a 5.5 mile segment (route 9 bridge, Berwick, to head of tide). Outside of the boundaries of this segment considered for reclassification, it is believed that existing classifications for Maine and New Hampshire can be maintained, provided that the recommended TMDL is implemented. A summary of the water quality standards to be adopted for the entire Salmon Falls / Piscataqua River uses the most stringent of Maine / New Hampshire water quality criteria (table 3).

This would require minimum dissolved oxygen levels of 5 ppm and 60% of saturation and a daily average dissolved oxygen of 75% of saturation in the 5.5 mile segment. This is considered an ambitious goal that will be difficult to attain in the deeper portions of impoundments. However maintaining the Salmon Falls River at the lowest classification level for both states (rather than levels lower than this) has the advantage of maintaining all designated uses specified for the current classification, and still preserving fishable, swimmable goals specified by the Clean Water Act. Hence the UAA for this 5.5 segment would establish subcategories (lower criteria) rather than removing designated uses.

Both the data and the model indicate that dissolved oxygen criteria will be difficult to meet in bottom waters of a deep hole in very small portion of the estuary, approximately 1 mile below head of tide. However, in the remaining portion of the estuary Maine's class SB criteria can be maintained after implementation of the TMDL. The requirement for steady river flow conditions in the hydropower re-licensing of the South Berwick dam and spillage of water over the dam at low flow conditions has improved dissolved oxygen in the estuary to the extent that 4.5 of the 5 miles formerly in non-attainment of dissolved oxygen criteria currently attain criteria. It is believed the non-attainment at the Hamilton House deep hole in bottom waters is a natural phenomenon. (This is supported by water quality modeling and is later discussed.) Both Maine's (Title 38, chap 464, 4C) and New Hampshire's water quality standards allow for exceptions in meeting numeric dissolved oxygen criteria where natural conditions cause the violation of standards.

Neither Maine nor New Hampshire has numerical water quality criteria for total phosphorus or chlorophyll a. Both states have narrative language that allows for requiring phosphorus controls on point source and non-point source inputs in eutrophic waters. The level of chlorophyll a could also be indirectly controlled through its impact on dissolved oxygen. In particular, higher levels of chlorophyll a often result in lower daily minimum dissolved oxygen in the early morning hours. For Maine lakes 8 ppb for chlorophyll a is generally regarded as an indication of the threshold of bloom conditions. In rivers the threshold value is probably somewhat higher. A range of 10 to 20 ppb will be used as a target chlorophyll a level and for values exceeding this, it will be assumed that the associated algae bloom condition will inhibit designated uses.

USEPA ambient water quality criteria for ammonia have recently been changed. The allowable concentration level is higher than previous criteria. The new criteria have dropped the temperature dependence relationship that the former criteria had but have maintained the pH dependence. The chronic criteria for ammonia that will be used to establish an ammonia TMDL is 3.08 ppm (pH=7). Requiring lower levels of ammonia than those dictated by toxic criteria will be considered, since ammonia also affects dissolved oxygen depletion through nitrification to nitrate.

Table 3 Recommended Water Quality Standards

From the outlet of Great East Lake to the Route 9 bridge, Berwick

Fresh Waters	Designated uses	D.O. Criteria	Aquatic Life	Bacteria
ME Class B NH Class B	Drinking water supply after treatment, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation (with restrictions), navagation, habitat for fish and other aquatic life.	Daily minimum > 7 ppm and 75% saturation Identified fish spawning areas from Oct 1 to May 14 the 7-day mean D.O. > 9.5 ppm and 1-Day min > 8 ppm	Discharges should not cause adverse impact to aquatic life in that the receiving waters shall be of suffcient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the residental biological changes in the residental biological	From 5/15 - 9/30 E Coli of human origin Geo. Mean < 64/ 100 ml Instantaneous < 406 / 100 ml

Phosphorus - Support designated uses
P-Removal required for discharges which encourage cultural eutrophication

Ammonia - USEPA chronic AWQC @ pH 7 = **3.08 ppm**

Berwick, Route 9 bridge to South Berwick, head of tide (5 miles)

Fresh Waters	Designated uses	D.O. Criteria	Aquatic Life	Bacteria
ME Class C* NH Class B	Drinking water supply after treatment, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation (with restrictions), navagation, habitat for fish and other aquatic life.	Daily Minimum > 5 ppm and 60% saturation Daily Ave. > 75% saturation; Monthly ave. > 6.5 ppm Identified fish spawning areas from Oct 1 to May 14 the 7-day mean D.O. > 9.5 ppm and 1-Day min > 8 ppm	Discharges 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 communuty.	E Coli Geo. Mean < 126 / 100 ml Instantant. < 406 / 100 ml

\#

Phosphorus - Support designated uses
P-Removal required for discharges which encourage cultural eutrophication

Ammonia - USEPA chronic AWQC @ pH 7 = **3.08 ppm**

***Since this segment is currently class B under current Maine law, a UAA is necessary for a downgrade of classification.**

Salmon Falls / Piscataqua - All Tidal Waters

Tidal Waters	Designated uses	D.O. Criteria	Aquatic Life	Bacteria
ME Class SB NH Class B	Aquaculture, propagation and harvesting of shellfish, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation (with restrictions), navagation, habitat for fish and other estuarine and marine life	Daily minimum > 85% of saturation	Discharges should not cause adverse impact to estuarine and marine life in that the receiving waters shall be of sufficient quality to support all estuarine and marine species indigenouos to the receiving water without detrimental changes to the resident biological community. New discharges cannot cause the closure of an	Enterococci Geo. Mean < 8 / 100 ml Instantant. < 54 / 100 ml Meet USDA shellfish standards

Phosphorus - Support designated uses
P-Removal required for discharges which encourage cultural eutrophication

Calculation of Point and Non-point Loads to Salmon Falls River for BOD and Phosphorus

The flow and total phosphorus concentration data of all point source and tributary inputs taken seasonally over the five month period in 1995 (see *Salmon Falls / Piscataqua River Watershed TMDL Project Data Report*, Maine DEP, April, 1996) can be used to calculate phosphorus loads to the Salmon Falls River. These loads can then be compared and give a relative estimate of point source and non-point source contributions of phosphorus, which is the limiting nutrient of algae in this system. This addresses one of the deficiencies identified in the 1994 report, which recommended additional investigation to determine the significance of non-point source loading.

The flow gaging data in 1995 at continuous gages and instantaneous measurements made by Maine DEP were used in this analysis (table 4). The continuous gaging data used includes the USGS gage on the Salmon Falls River at Milton, the USGS gage on the Cocheco River at Dover, and a gage on the Great Works River maintained by the North Berwick Sanitary District but calibrated by USGS. In addition, instantaneous measurements were made on the Salmon Falls River at Berwick, the Little River at Berwick, and Worster Brook at Berwick. Flows were derived for ungaged tributaries by a flow balance of the watershed, which involved proportioning the difference of flow from Milton to Berwick on the Salmon Falls by drainage area of the various tributaries.

Total phosphorus (TP) concentration data was then averaged by month (table 4). For the four point sources participating in the phosphorus removal program (Berwick, Somersworth, Rollinsford, and South Berwick) TP measurements were available three times per week and for other point sources (Milton, Dover) TP measurements were available twice per month. Tributary TP measurements for non-point sources were available for the Little River, Worster Brook, Great Works River, and Cocheco River twice per month. Non-point TP concentrations for unmeasured tributaries were derived by averaging the TP values from the Little River, Worster Brook, and Great Works.

The wet weather TP data sampled during three storm events in 1995 show that dry weather and wet weather concentrations are not significantly different and no first flush of pollutants was evident (see data report, April 1996). Therefore, the direct total phosphorus loads to the river can then be calculated by the product of flow, concentration, and a units conversion factor (table 5). In this analysis, the watershed below the route 101 bridge including the Dover discharge was excluded in the nutrient budget due to the fact that data consistently showed that algae blooms and dissolved oxygen problems were insignificant in the lower estuary due to the large amount of tidal dilution. It should be recognized that values derived in this table reflect lower point source load contributions than what is currently typically discharged in May, June, and July due to the experimental phosphorus removal project that summer.

To make the load comparisons more meaningful, percentage comparisons were derived during the period that point sources inputs were not treating for phosphorus removal. In this analysis, the data more typical of low flow conditions (August and September) were used to derive point and non-point load contributions (figure 3, table 5). The non-point source contributions calculated (tables 4, 5) reflect sources due to both natural background and non-point source pollution. This analysis clearly shows that point source phosphorus inputs are the most significant factor contributing to algae blooms on the Salmon Falls River, accounting for 90% of the total phosphorus load to the Salmon Falls River in 1995. The percentage contribution of TP load to the river in 1995 was Berwick 38%; Somersworth 35%; South Berwick about 9%; Milton and Rollinsford,4%; and non-point sources 10%. The Berwick and Somersworth mass phosphorus inputs are similar and collectively accounted for almost 3/4 of the total phosphorus load to the river in 1995. One important consideration is that point sources were at only 1/3 of their total design flow capacity in 1995. If percentage comparisons are made with point sources at design flow, the non-point contribution is reduced to 5% of the total phosphorus input to the river (figure 4).

Table 4 Flow and Concentration Data 1995 for Nutrient Budget											
Salmon Falls River Flows by month Ambient in cfs; Point Sources in mgd							**TP Concentration (ppb) by Month**				
	Drainage Area (square miles)	May	June	July	Aug	Sept	May	June	July	Aug	Sept
SFR below Spaulding P	119.3	119.59	94.00	37.03	33.59	25.51	9.5	11	10	8.25	6.25
Milton	Point Source	0.034	0.051	0.036	0.041	0.044	5200	5500	5950	6100	5400
Heath Brook +	4.9	6.96	2.63	0.82	0.58	0.21	37	37	29	23	23
Great Brook +	13.50	19.13	7.22	2.26	1.60	0.58	37	37	29	23	23
Keay Brook +	15.1	21.33	8.05	2.52	1.79	0.65	37	37	29	23	23
Little R	54	61.63	25.79	3.31	4.59	1.04	24	24	21	16	12
Tates+Lily +	7	9.90	3.73	1.17	0.83	0.30	37	37	29	23	23
Berwick	Point Source	0.583	0.583	0.414	0.631	0.504	383	467	2041	2663	6286
Worster	8	11.39	3.76	0.47	0.28	0.06	45	45	37	26	26
Somersworth	Point Source	1.360	1.190	1.120	1.210	1.120	776	605	688	1508	2290
Rollinsford	Point Source	0.07	0.06	0.06	0.06	0.06	2095	2572	1822	3610	3882
Driscoll Brook +	5.8	9.37	4.65	1.31	1.89	0.40	37	37	29	23	23
S Berwick	Point Source	0.275	0.239	0.214	0.211	0.212	423	376	547	2314	3021
Great Works	86.6	170.38	102.06	29.67	26.21	15.14	42	42	28	28	32
Berw - S Berw tribs	11.5	4.73	2.34	0.66	0.95	0.20	37	37	29	23	23

Table 5 Load and Percentage Comparisons of Nutrient Budget from 1995 Data

	(TP Loads) (lb/day)					Effluent TP 1 ppm	No P-Removal	% of Total Phosphorus Input					Effluent TP 1 ppm	No P-Removal
	May	June	July	Aug	Sept	May,June July	Aug Sept	May	June	July	Aug	Sept	May,June July	Aug Sept
Background	6.11	5.56	1.99	1.49	0.86	13.67	2.35	7.28%	10.84%	7.83%	3.38%	1.41%	8.50%	2.24%
Milton	1.45	2.35	1.80	2.10	1.96	5.61	4.06	1.73%	4.59%	7.08%	4.76%	3.22%	3.49%	3.87%
Heath Brook +	1.39	0.52	0.13	0.07	0.03	2.04	0.10	1.65%	1.02%	0.50%	0.16%	0.04%	1.27%	0.09%
Great Brook +	3.81	1.44	0.35	0.20	0.07	5.60	0.27	4.54%	2.80%	1.39%	0.45%	0.12%	3.48%	0.26%
Keay Brook +	4.25	1.60	0.39	0.22	0.08	6.24	0.30	5.06%	3.12%	1.55%	0.50%	0.13%	3.88%	0.29%
Little	7.96	3.33	0.37	0.40	0.07	11.66	0.46	9.48%	6.49%	1.47%	0.90%	0.11%	7.26%	0.44%
Tates+Lily +	1.97	0.74	0.18	0.10	0.04	2.90	0.14	2.35%	1.45%	0.72%	0.23%	0.06%	1.80%	0.13%
Berwick	1.86	2.27	7.05	14.01	26.42	11.18	40.44	2.22%	4.43%	27.68%	31.79%	43.35%	6.96%	38.49%
Worster	2.76	0.91	0.09	0.04	0.01	3.76	0.05	3.28%	1.77%	0.37%	0.09%	0.01%	2.34%	0.04%
Somersworth	8.80	6.00	6.43	15.22	21.39	21.23	36.61	10.49%	11.70%	25.24%	34.52%	35.09%	13.21%	34.85%
Rollinsford	1.29	1.37	0.91	1.87	2.01	3.58	3.87	1.54%	2.68%	3.58%	4.23%	3.29%	2.23%	3.69%
Driscoll Brook +	1.87	0.92	0.20	0.23	0.05	2.99	0.28	2.22%	1.80%	0.80%	0.53%	0.08%	1.86%	0.27%
S Berwick	0.97	0.75	0.98	4.07	5.34	2.70	9.41	1.16%	1.46%	3.83%	9.24%	8.76%	1.68%	8.96%
Great Works	38.50	23.06	4.47	3.95	2.61	66.03	6.56	45.87%	44.94%	17.56%	8.95%	4.28%	41.09%	6.24%
Berw - S Berw tribs	0.94	0.47	0.10	0.12	0.02	1.51	0.14	1.12%	0.91%	0.41%	0.27%	0.04%	0.94%	0.14%
sum	83.92	51.31	25.46	44.09	60.96	160.70	105.04							

						Effluent TP 1 ppm	No P-Removal						Effluent TP 1 ppm	No P-Removal
	May	June	July	Aug	Sept	May,June July	Aug Sept	May	June	July	Aug	Sept	May,June July	Aug Sept
Point Source	14.38	12.75	17.16	37.27	57.13	44.30	94.39	17.14%	24.85%	67.42%	84.53%	93.72%	27.57%	89.86%
Total Nonpoint Source	69.54	38.56	8.29	6.82	3.83	116.40	10.65	82.86%	75.15%	32.58%	15.47%	6.28%	72.43%	10.14%

Figure 3

**Percentage Comparison of Total Phosphorus Loads to Salmon Falls River
August, September 1995 Data
No Phosphorus Treatment**

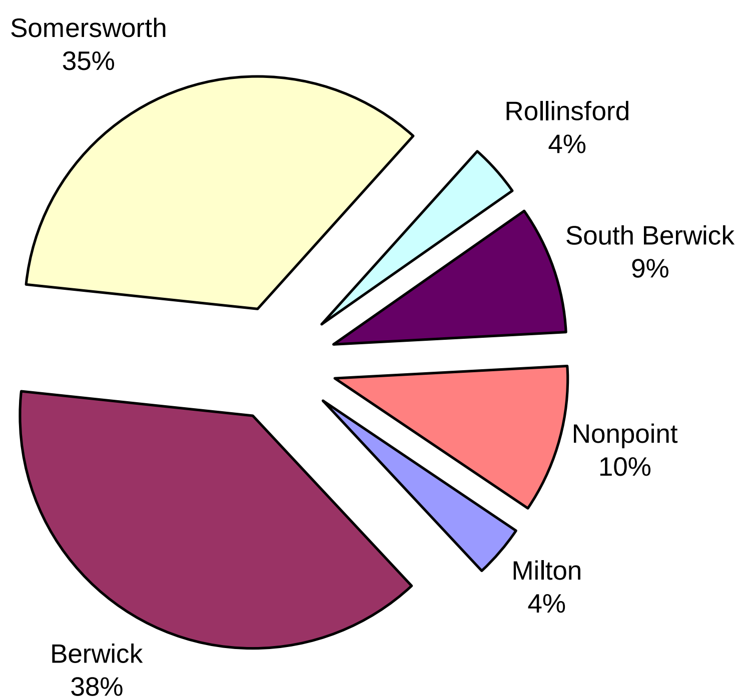
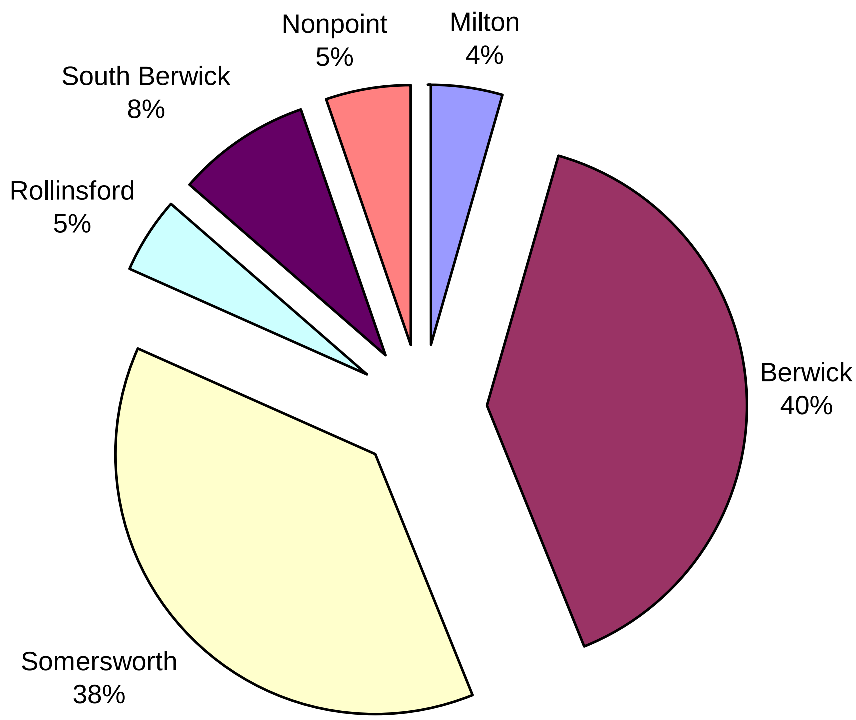


Figure 4
Percentage Comparison of Total Phosphorus Loads to Salmon Falls River at Design Treatment Plant Flows
No Phosphorus Treatment



The Great Works River is the most significant non-point input to this system due to its higher flow and slightly elevated TP concentration when compared to other tributaries and typically accounted for more than one-half of the entire non-point source loading to this system. Even though a point source discharge, Pratt

and Whitney Co., discharges phosphorus to this watershed, their contribution is considered insignificant. Their license allows for 0.034 lb/day phosphorus as a monthly average. At the lowest recorded river flow conditions in September of 1995, the increase in concentration of phosphorus in the Great Works River due to this discharge would be 0.4 ppb if Pratt and Whitney was discharging at licensed mass load. This would represent about 1% of the phosphorus in the Great Works River. Another point source discharge to this system, North Berwick, does not discharge in the summer.

The 1995 data can also be used to calculate non-point ultimate BOD loads into the Salmon Falls River which then can be compared to design licensed point source loads. Dry weather BOD data (late July to September in 1995) were used to characterize 7Q10 non-point source concentration values.

Table 6 Calculation of BOD Loads to 5.5 Mile Non-Attainment Segment					
Non-Point Loads	Drainage Area (mi2)	7Q10 Flow (cfs)	Ave Conc. 1995	Load (lb/day)	% Total
Salmon Falls R at Berwick	214	28.7	3.3	510	13.77%
Worster Brook	8	0.06	2.4	1	0.02%
Driscoll Brook + Intermittant	5.8	0.4	2.4	5	0.14%
Total NPS				**516**	13.93%
Point Sources Loads	Lic. Flow	Lic BOD5 (weekly ave.)	BODu/BOD5	Design Loads (lb/day)	% Total
Milton*	0.1	38	3.04	80	2.16%
Berwick**	1.1	702	3.28	2302	62.19%
Somersworth	2.41	904	0.79	715	19.30%
Rollinsford	0.15	56	1.59	90	2.42%
Total Point Source				**3186**	86.07%
*Milton BODU multiplied by .7 due to BOD lost through assimilation from Milton to Berwick					
**Weekly Ave. Load = .9 X Daily Maximum Load					

The non-point BOD loads calculated (table 6) represent sources due almost entirely to natural conditions, since concentration levels of ultimate BOD are representative of typical natural levels of ultimate BOD (3 ppm). Non-point BOD loads are only calculated for the non-tidal portion of the river where inputs could potentially be contributing to the dissolved oxygen non-attainment in the 5.5 mile segment above head of tide. (The phosphorus load calculations also included inputs to the first three miles of the tidal portion due to the algae blooms that are experienced here.) For point source BOD loads, values had to be converted to ultimate BOD loads by use of a BODu / BOD5 factor, which was derived from the 1995 data. The loads are calculated by multiplying ultimate BOD concentration values times the flow values in table 6 converted to mgd and then multiplying by a units conversion factor (8.34). The Milton discharge loses BOD through decay from Milton to Berwick. The dry weather BOD decay rate of 0.02 per day and the estimated travel time of 18 days were used in the BOD decay first order reaction rate equation to derive a factor of 0.7, i.e. 70% of the BOD remains in the river at Berwick. This factor was used in the calculations of Milton's ultimate BOD (table 6). Percentage comparisons of ultimate BOD loads (Table 6) indicate that the Berwick discharge is potentially the most significant BOD source in the Salmon Falls (due to tannery waste inputted into their treatment plant), but the Somersworth discharge also contributes significantly more BOD than Rollinsford, Milton, and South Berwick.

In summary, the calculation of BOD and phosphorus loads into the Salmon Falls River during the late summer of 1995 during a 7Q10 condition indicates that point sources at licensed loads account for nearly 90% of the pollutant load inputs of concern. Large point sources (Berwick and Somersworth) are the largest inputs in the river and collectively account for 70% to 80% of the total pollutant inputs of BOD and phosphorus. Small point sources (South Berwick, Rollinsford and Milton) collectively contribute 10% to 15% of the total pollutant load inputs of BOD and phosphorus and collectively are a significant source of pollution. It is deduced that all of these sources need to be controlled for an effective river cleanup.

Model Projections at Various Treatment Levels and Compared to 1995, 1997 and 1998 Data

A TMDL for ammonia initially involves using USEPA chronic toxic ambient water quality criteria (AWQC). The Somersworth and Berwick discharges were responsible for virtually all of the ammonia inputted into the Salmon Falls River that has resulted in noncompliance of the toxic chronic AWQC. Possible ammonia permit limits for these discharges were calculated using a conventional mass balance of flow and concentration at 7Q10 conditions. The older chronic AWQC for ammonia varied inversely as a function of temperature and pH. Ammonia criteria have recently been revised by USEPA (Aug 1998) resulting in less stringent AWQC. The new criteria have also dropped the temperature dependence but maintained the pH dependence. TMDL's are calculated for both the old and new criteria. An equal concentration for ammonia was initially assumed for each discharge. The results are summarized below:

Table 7 Ammonia Calculations

New EPA Chronic AWQC = 3.08 ppm @ pH 7

	Conc (ppm)	Flow (mgd)	Mass (lb/d)
Natural Background NPS	0.02	18.5	3
Berwick	19	1.1	174
Somersworth	19	2.4	380
Total	**3.04**	22	**558**

Old EPA Chronic AWQC = 1.23 ppm @ temp 25C, pH 7

	Conc (ppm)	Flow (mgd)	Mass (lb/d)
Natural Background NPS	0.02	18.5	3
Berwick	7.5	1.1	69
Somersworth	7.5	2.4	150
Total	**1.21**	22	**222**

Another important issue when considering the TMDL is ammonia's effect on dissolved oxygen depletion through nitrification to nitrate (nitrogenous BOD decay). Lower levels of ammonia than those dictated by toxic criteria will also be investigated for the TMDL due to the already mentioned dissolved oxygen non-attainment. The ammonia TMDL's generated in table 7 will be used initially for input to the model when investigating possible phosphorus and BOD allocations.

The allocation recommended for a phased TMDL for phosphorus (TP), BOD5, and TSS involves setting the smaller treatment plant (Milton, Rollinsford, and South Berwick) at a fixed level of reduced BOD, TSS, and TP and investigating more stringent reductions for the larger point sources (Berwick, and Somersworth). Although non-point sources are currently not a large input, when compared to point sources, the non-point sources will become more significant as point source reductions are implemented. If non-point sources are allowed to go unchecked and possibly increased, they could potentially undo the cleanup realized by point source reductions. It is recommended that best management practices (BMP's) be collectively implemented throughout the watershed, where it is feasible.

Milton's small discharge volume and distance of 15 miles from the non-attainment segments could possibly raise some doubt to the appropriateness of including Milton in the TMDL. Although the smallest discharge, Milton accounted for nearly as much TP loading as Rollinsford, and Milton and Rollinsford collectively contribute about the same TP input as South Berwick. Milton's large dilution factor of their effluent to the river 7Q10 flow (164:1) results in pollutant parameters such as BOD and ammonia (whose potential impact is measured in parts per million) as not being areas of concern. However phosphorus results in potential receiving water impacts when only increases of parts per billion are realized.

The water quality model did not include the portion of the river from Milton to Berwick. It was decided that the Berwick background concentration values of BOD, dissolved oxygen, and nitrogen cycle parameters should not be affected by the Milton discharge. However there are increases to the background levels at Berwick of both total phosphorus and chlorophyll a as a result of the Milton's discharge, since when comparing the 1995 data at Milton and the Lower Great Falls impoundment, increases can be seen. If appropriate increases for phosphorus and chlorophyll a are input to the background at Berwick, the river does not need to be modeled in the segment from Milton to Berwick.

Average dry weather chlorophyll a levels of 3.3 and 6.9 ppb at Milton and the Lower Great Falls dam, respectively, were measured in 1995 without Milton treating for phosphorus. Since most of the incremental phosphorus in the river from Milton to Berwick is due to Milton's discharge (see spreadsheet calculations below), the increase in chlorophyll a from 3.3 to 6.9 ppb from Milton to Berwick can be assumed to be impact associated with phosphorus from Milton's discharge. Hence the background chlorophyll a at Berwick inputted into the model should be 3.3 ppb with Milton treating for phosphorus and 6.9 ppb with Milton not treating for phosphorus.

A spreadsheet was set up to calculate the appropriate total phosphorus levels for the river background conditions at Berwick. In this analysis, phosphorus assimilation losses are calibrated with the 1995 data and mass balance calculations of flow and phosphorus concentration. It can be seen from the calculations that as much as 36% and as little as 27% of the river phosphorus was lost from Milton to Berwick through assimilation. The average amount of phosphorus lost was 33%. The calibrated assimilation factor (.67) is then used to calculate the remaining phosphorus at Berwick after consideration of assimilation losses.

Table 7a - Mass Balance for Milton TP

	Milton Background 1995		Milton Effluent 1995		Calculation	Tributary Data 1995		1995 Data	Calculation	Assimilation
Date	Flow (cfs)	TP (ppb)	Flow (cfs)	TP (ppb)	TP below Milton (ppb)	Flow (cfs)	TP (ppb)	TP Berw.(ppb)	TP below Berw. (ppb)	TP(Berw) Meas/Calc
8/14/95	34	11	0.071	5800	23.06	11	24	15	23.29	0.644
8/29/95	27	7	0.0875	5600	25.07	0.2	16	17	25.00	0.680
9/12/95	24	6	0.083	5000	23.21	0	12	17	23.21	0.732
9/27/95	26	4	0.071	4700	16.79	8	32	13	20.36	0.638
									Ave	0.674
Treatment Level	Flow (cfs)	TP (ppb)	Flow (cfs)	TP (ppb)	TP below Milton (ppb)	Flow (cfs)	TP (ppb)	TP Berw.(ppb)	TP below Berw. (ppb)	Model Input*
Current	28.7	9	0.155	5300	37.42	3.3	23	N/A	35.94	24.21
TP=.5 ppm	28.7	9	0.155	500	11.64	3.3	23	N/A	12.80	8.63
TP=1 ppm	28.7	9	0.155	1000	14.32	3.3	23	N/A	15.21	10.25

*Includes assimilation factor, ie. 1/3 of TP is lost from Milton to Berwick through assimilation

Hence from this analysis it can be seen that the calculated background total phosphorus levels of 8.6 and 10.2 ppb for treatment levels at Milton of 0.5 and 1 ppm total phosphorus are very similar to the initial background total phosphorus of 9 ppb above Milton's discharge. However, if Milton is not treating for phosphorus, the background at Berwick would be raised to 24 ppb which could, in itself, be high enough to cause mild algae bloom conditions in the impoundments below the Berwick and Somersworth discharge. It can be concluded that without including Milton in the phosphorus TMDL, meeting water quality objectives will be much more difficult, and could result in additional treatment requirements for other point source discharges.

The inclusion of Milton and the other smaller point sources, and non-point sources of pollution in the TMDL is consistent with the watershed approach that is currently required in all TMDL development by USEPA. This approach is overwhelmingly supported by engineers, biologists, and environmental scientists. Even the smaller non-point sources and point source loads cannot be ignored. If their impact is considered individually it is usually small, but the collectively impact of all such sources usually proves to be significant.

The 1994 report estimated that algal respiration was the largest source of dissolved oxygen depletion in surface waters of impoundments accounting for more than one-half of the deficit from saturation. Point source BOD and sediment oxygen demand (SOD) were typically 20 to 25 percent of the dissolved oxygen deficit in surface waters of impoundments. Algal respiration and SOD are the major sources of dissolved oxygen depletion in deeper waters of impoundments accounting for more than 70% of the dissolved oxygen deficit, collectively. The dissolved oxygen deficit attributable to CBOD decay in bottom waters of impoundments was similar to that of surface waters or approximately 20% of the total deficit.

It can be concluded that the reduction of algae levels (that also contribute to SOD when dying algae settle to the river bottom) is the most important factor for improving dissolved oxygen in the Salmon Falls River, but BOD reductions and SOD reductions, could also result in significant benefits. Point sources are contributing more than 90% of the phosphorus inputted into the river which then promote summer eutrophic levels of algae. It is imperative to reduce the point source inputs of phosphorus, if a river cleanup is to be realized. TSS reductions are also appropriate, since TSS contribute to SOD and nutrient bottom sediment (which both contribute to algae blooms and oxygen depletion).

Earth Tech Inc. through a contract administered by NEIWPCC with EPA funding undertook an economic analysis of possible treatment and non-treatment alternatives for river clean-up. The economic analysis is a requirement of the UAA to assure undue economic and social hardship will not result from implementation of available options such as point source reductions. Details of the economic analysis and the UAA will be explained later in this report. For the purposes of the TMDL, four different treatment levels of phosphorus reductions were investigated for Berwick, and Somersworth, and South Berwick (Table 8). Effluent phosphorus concentration levels and costs associated for each treatment level were investigated at potential permit limits of 1, 0.5, 0.25, and 0.1 ppm. At each reduction level for phosphorus also resulted in expected reductions for BOD and TSS which were also included as potential permit limits. Although ammonia reductions were not an added benefit of increased treatment, reductions of ammonia are also factored into the analysis due to its diminishment upon dissolved oxygen levels.

In the economic analysis only the first treatment reduction level (1 ppm TP) for both the Rollinsford and Milton discharges were investigated. The decision to not require more treatment than this was due to the small size of these discharges. It was later decided that South Berwick should also be included with the small discharges rather than the large discharges due to the similar small impact upon the river when compared to Berwick and Somersworth. However it is important to require some reductions for all three small discharges, since collectively they are a significant source. The model was then run at five different point source treatment levels (table 8). It should be realized that this recommended method of allocating the waste loads in the TMDL is only one of several possible ways of reducing pollution loads to the river.

The model outputted values for dissolved oxygen represent a long-term average. The predicted model output for daily average or monthly average dissolved oxygen can be used directly, but a two step must be utilized to get the daily minimum dissolved oxygen After obtaining the daily average dissolved oxygen from the model output, a diurnal adjustment must be made to get the daily minimum dissolved oxygen The diurnal adjustment was derived from an empirical relationship derived from actual data in the 1994 modeling effort which involved the development of a power equation relationship of chlorophyll a to diurnal dissolved oxygen range (figure 31, 1994 WLA report, and appendix this report). The predicted model result for chlorophyll a is used to obtain the expected dissolved oxygen diurnal range (daily maximum – daily minimum) from the empirical relationship. For example, for a chlorophyll a of 30 ppb, the diurnal dissolved oxygen range from figure 31 is about 2.2 ppm. The diurnal adjustment or amount to be subtracted from the model result to obtain the daily minimum dissolved oxygen is one-half of the diurnal range, which equals 1.1 ppm of dissolved oxygen in the previous example.

The water quality model results for each treatment level is summarized as dissolved oxygen in ppm or percent saturation in potential non-attainment areas (table 9); chlorophyll a levels at locations most indicative of bloom conditions (table 10); and a description of the extent of the predicted non-attainment as a length in river miles and a percentage of the total volume of the impoundment (table 11). It is important to realize the potential limitations of the model when predicting actual dissolved oxygen values (table 9). In particular, it is estimated the minimum dissolved oxygen values could be in error by as much as 1 ppm and monthly and daily average values by as much as 0.5 ppm. (When one considers that measurement error for dissolved oxygen is probably about 0.3 ppm when utilizing good QC practices, it is difficult, if not impossible, to guarantee better accuracy than 0.5 ppm for any water quality model. The complexity of the Salmon Falls River situation, i.e. high algae, tidal dynamics, rapidly changing dissolved oxygen, result in more uncertainty than what is normally encountered when compared to models developed for other rivers in Maine.) For the cited reasons, it is believed that more attention should be given to the extent of non-attainment (table 11) which uses only attainment / non-attainment of dissolved oxygen criteria rather than prediction of the actual dissolved oxygen levels to the nearest 0.1 ppm (table 9). The dissolved oxygen levels (table 9) are more useful when considering actual incremental improvements in dissolved oxygen from increased waste treatment rather than the actual values of the dissolved oxygen. A summary of the model runs for each treatment level is discussed.

In the original model runs nutrient flux values for nitrogen and phosphorus had to be assumed as a function of sediment oxygen demand rates assigned to each segment (EPA Help and Limit Screen Manual), since results from the 1995 sampling were not yet available. The results of the phosphorus nutrient flux data indicate that values used as input to the model compare reasonably well to the anoxic benthic flux measurements (table 11a). The anoxic results reflect actual conditions in the Salmon Falls River impoundments currently, since dissolved oxygen levels near the bottom are usually low. A comparison of model results with calibrated and measured nutrient flux rates at level 2 treatment reveals that the different results obtained for chlorophyll a are insignificant (table 11a). For example, in the South Berwick impoundment, chlorophyll a is only changed from 22 to 20 ppb for anoxic conditions and down to 18 ppb for oxic conditions. Thus the nutrient flux rates are determined not to be a critical portion of the model. The model predictive runs use the oxic benthic phosphorus flux rates, except for the lower waste treatment levels (current and level 1), where anoxic conditions are used.

Table 8 Summary of Model Runs

		Level	TP	BOD5	TSS	NH3-N
			Treatment Levels (ppm) as Weekly Average			
Small Treatment Plants Held at 1 treatment level	Milton, Rollinsford S Berwick	1	1	20	20	None
Large Treatment Plants 5 treatment levels considered	Berwick Somersworth	1	1	20	20	19
		2a	0.5	15	15	19
		2	0.5	15	15	7.5
		3	0.25	10	10	7.5
		4	0.1	5	5	1

Table 9 Model Results - Summary of Dissolved Oxygen in Critical Areas

Point Source Treatment Level		Rollinsford Impoundment		S. Berw. Imp.	Rollinsford Impoundment	
Level for S Berw, Rollinsford, Milton	Level for Berwick and Somersworth	Min. D.O. Surface (ppm)	Min. D.O. Bottom (ppm)	Min. D.O. Bottom (ppm)	Daily Ave. D.O. Surface (% Sat.)	Monthly Ave D.O. (ppm)
Point Sources at Current Treatment		4.3	1.1	3.7	60%	5.7
1	1	5.4	3.1	3.2	72%	6.2
1	2a	5.5	3.3	2.5	73%	6.3
1	2	5.8	4.1	3.5	77%	6.6
1	3	6	4.3	3.6	78%	6.6
1	4	6.1	5	4.4	80%	6.7
Point Sources at Zero Discharge		6.6	5.5	4.9	87%	7.2
Required D.O. with UAA*		5	5	5	75%	6.5

Table 10 Model Projected Chlorophyll A		Maximum Chlorophyll a		
		Rollinsford Imp.	S Berwick Imp.	Tidal Waters
Point Sources at Current Treatment		30	88	89
1	1	15	37	47
1	2a	10	18	28
1	2	10	18	28
1	3	7	11	22
1	4	4	6	20
Point Sources at Zero Discharge		3	5	12
Goal is maintaining chlorophyll a < 10 to 20 ppb				

Table 11 Summary of Extent of Non-Attainment Areas*

Point Source Treatment Level		Rollinsford Impoundment		S. Berw. Imp.	Rollinsford Impoundment		Total Non-Att Roll + S Berw Impound.'s
Level for S Berw, Rollinsford, Milton	Level for Berwick and Somersworth	Min. D.O. Surface Distance Of N/A	Min. D.O. Bottom Extent Of Non-Att.	Min. D.O. Bottom Extent of Non-Att.	Daily Ave. D.O. Surface	Monthly Ave D.O. Surface	
Point Sources at Current Treatment		1 mi / 62% vol	.5 mi / 9% vol	0.8 mi / 16% vol.	1.2 mi / 62% vol	1 mi / 62% vol	2.3 mi / 45% vol
1	1	none	0.5 mi / 9% vol.	0.5 mi / 14% vol	1 mi / 60% vol	1 mi / 62% vol	2 mi / 42% vol
1	2a	none	0.5 mi / 9% vol.	0.5 mi / 14% vol	1.2 mi / 62% vol	1.2 mi / 62% vol	2.2 mi / 43% vol
1	2	none	0.5 mi / 9% vol.	0.5 mi / 14% vol	none	none	1 mi / 12% vol
1	3	none	0.5 mi / 9% vol.	0.5 mi / 14% vol	none	none	1 mi / 12% vol
1	4	none	none	0.3 mi / 12% vol.	none	none	0.3 mi / 6% vol.
Point Sources at Zero Discharge		none	none	0.3 mi / 12% vol.	none	none	0.3 mi / 6% vol.

*Most stringent criteria of Maine class C and NH class B

Table 11a Nutrient Flux Results

Benthic Phosphorus Flux Measurements 1995 (mg/m^2-day)

Anoxic Results

	Jun-95	Jul-95	Sep-95	Ave 95	Model
Lower Great Falls Impoundment	4	6	6	5	9
Rollinsford Impoundment	33	13	17	21	14
South Berwick Impoundment	5	15	8	9	17
Hamilton House Site	10	6	40	19	20

Oxic Results

	Jun-95	Jul-95	Sep-95	Ave 95
Lower Great Falls Impoundment	4	3	1	3
Rollinsford Impoundment	0	0	0	0
South Berwick Impoundment	2	5	1	3
Hamilton House Site	12	17	38	22

Comparison of Model Chlorophyll A with Different Phosphorus Flux Values

Model Run at 7Q10 Flow and Treatment Level 2 = 0.5 ppm TP Berw. And Somr.	Rollinsford Impoundment	South Berwick Impoundment	Tidal Waters
Model with Calibrated P-Flux	11	22	30
Model with Measured Anoxic P-Flux	11	20	29
Model with Measured Oxic P-Flux	10	18	28

An important consideration in modeling river cleanup conditions is that with reduced levels of algae and TSS in the river, both the nutrient flux rates and sediment oxygen demand should decrease. A reduction of 10% in both of these rates was assumed for each additional level of treatment resulting in SOD and nutrient flux rates of the following percentages of current values: level 1 treatment, 90%; level 2 treatment, 80%, level 3 treatment, 70%, level 4 treatment, 60%, and zero discharge, 50%.

River schematics are presented in the appendix to illustrate the locations of non-attainment areas (shaded) for dissolved oxygen and chlorophyll a (<10 to 20 ppb) for each level of treatment investigated. The schematics are drawn to scale with river miles downstream illustrated on the horizontal scale from left to right and the impoundment depths from surface to bottom illustrated in the vertical scale from top to bottom.

Point Sources at Current Treatment – If point sources are allowed to discharge at current levels with no additional improvements, the model projects that non-attainment of minimum dissolved oxygen standards (Maine class C) would occur in both surface and bottom areas of the Rollinsford impoundment and bottom areas of the South Berwick impoundments. In addition, daily average (75% saturation) and monthly average (6.5 ppm) criteria would not be met in surface and bottom areas of the Rollinsford impoundment. A length of 2.3 miles, which represents about 45% of the volume of both impoundments, would fail to meet dissolved oxygen criteria. The model also projects that a 0.5 mile segment in tidal waters would fail to meet minimum class SB dissolved oxygen criteria of 85% of saturation. Chlorophyll a is projected to reach levels of nearly 90 ppb in the South Berwick impoundment and Hamilton House area and exceed the stated goals of fewer than 10 to 20 ppb for a seven mile segment.

The model projection of 90 ppb compares well to measured chlorophyll a data (100 to 110 ppb) taken in September of 1995 during the non-treatment phosphorus period at 7Q10 flow conditions . The September 1995 data similarly indicated that non-attainment of dissolved oxygen standards occurred at current treatment levels when point sources were at only 14% of their licensed BOD5. For example, AM readings in the Rollinsford impoundment on Sept 27 ranged from surface layer readings of 5.2 ppm (52% of saturation) to bottom layer readings of 4.2 ppm (42% of saturation). Hence both the model and the 1995 data suggest that a reduction from current licensed limits is necessary.

Both the 1997 and 1998 data (see appendix) also suggest a continuing problem in eutrophication at current point source discharge levels. Maximum chlorophyll a levels both summers exceeded 40 ppb despite river flow conditions that were typically double 7Q10. Impoundment surface waters met ME-C/NH-B dissolved oxygen criteria in 1997 and 1998, but impoundment bottom waters continued to violate minimum criteria.

Level 1 All point sources at Treatment Level 1 (TP=1 ppm; BOD5/TSS=20 ppm);
Large point sources (Berw. And Somer.) (NH3-N = 19 ppm)

Some improvements in river water quality from current treatment levels are achieved. For example, non-attainment of minimum dissolved oxygen standards is eliminated in surface areas of the Rollinsford impoundment and the actual projected dissolved oxygen is expected to improve here by about 1 ppm. In addition, the dissolved oxygen non-attainment of minimum class SB standards in surface waters of a 0.5 mile segment in tidal waters is eliminated. However non-attainment of dissolved oxygen criteria for both the daily and monthly average, although improved, is still expected to occur in the Rollinsford impoundment. The overall extent of non-attainment of all dissolved oxygen criteria in fresh waters considered collectively is not expected to change that much from current treatment levels, since the length of the non-attainment predicted by the model is only reduced from 2.3 to 2 miles (13%) and the volume in non-attainment reduced from 45% to 42% (7%) (see column on far right, table 11).

Chlorophyll a predicted by the model is significantly reduced from current treatment levels by about 50%. But the levels predicted in the South Berwick impoundment (37 ppb) and Hamilton House (43 ppb) are still considered too high. The target chlorophyll a level (10 to 20 ppb) are exceeded for nearly 4 miles, and are indicative of algae bloom conditions that would not meet narrative criteria of supporting designated uses. The data in July of 1995 were taken during the phosphorus treatment period when levels of about 1 ppm were usually achieved. Although no actual chlorophyll a data were available during that period (due to the QC rejection of the chlorophyll a data that year), general observations and supersaturated dissolved oxygen readings indicate the presence of algae blooms.

The conclusion that can be reached is that although a 1 ppm TP effluent treatment level would improve water quality, this level of treatment is not sufficient to significantly improve chances of meeting water quality goals specified for the considered 5.5 mile segment. Additional treatment beyond this level is warranted.

Level 2 Small point sources (S. Berw., Rollin., Milton) at Treatment Level 1
Large point sources (Berw. And Somer.) at Treatment Level 2
(TP=0.5 ppm; BOD5/TSS=15 ppm; NH3-N = 7.5 ppm)

Significant improvements in dissolved oxygen are achieved from prior treatment levels investigated. Most significant is the elimination of non-attainment of dissolved oxygen in the surface areas of all impoundments. Non-attainment of dissolved oxygen criteria is still projected for a length of 0.5 miles in the bottom areas of the Rollinsford and South Berwick impoundments or about 9% and 14% of the volume, respectively. Collectively, dissolved oxygen criteria would not be met in bottom areas for about 1 mile of length and 12% of the volume of both impoundments.

Chlorophyll a is reduced to a maximum fresh water level of 18 ppb above the South Berwick dam and 28 ppb at the Hamilton House location. The values achieved in fresh waters sections meet target levels (10 to 20 ppb) for meeting narrative criteria of supported designated uses for chlorophyll a. The values at the Hamilton House location are still considered too high, since target levels are exceeded for 1.5 miles.
In summary, the level 2 treatment is much closer to meeting stated objectives, but additional treatment levels will be investigated.

Level 2a – Same as level 2 except Berwick and Somersworth at NH3-N= 19 ppm

Although this treatment level results in the same chlorophyll a as treatment level 2, the higher allowable discharge levels of ammonia for Berwick and Somersworth results in lower dissolved oxygen than level 2. The dissolved oxygen levels are more similar to those achieved in level 1 treatment. Hence the dissolved oxygen gained through additional phosphorus, BOD and TSS removal is lost by allowing more ammonia in the river and additional dissolved oxygen depletion through nitrification. The extent of non-attainment of dissolved oxygen criteria would be similar to level 1 and current treatment levels and similarly treatment level 2a is considered unacceptable.

Level 3 Small point sources (S. Berw., Rollin., Milton) at Treatment Level 1
Large point sources (Berw. And Somer.) at Treatment Level 3
(TP=0.25 ppm; BOD5/TSS=10 ppm; NH3-N = 7.5 ppm)

The model projected results (table 9) show that dissolved oxygen in the Rollinsford and South Berwick impoundments are insignificantly improved from level 2 treatment. In fact, the 0.1 to 0.2 ppm improvements projected from level 2 treatment levels are within measurement error of dissolved oxygen. The extent of non-attainment is also not reduced from level 2 treatment.

Chlorophyll a should be reduced from 18 to 11 ppb in the South Berwick impoundment and from 28 to 22 ppb at the Hamilton House site. The values of chlorophyll predicted at the South Berwick site for level 3 treatment are considered acceptable and will meet target levels of supporting designated uses. However, the predicted chlorophyll a of 22 ppb at the Hamilton House is still marginally too high and exceeds target levels for about 1 mile. Additional treatment levels should be investigated.

Level 4 Small point sources (S. Berw., Rollin., Milton) at Treatment Level 1
Large point sources (Berw. And Somer.) at Treatment Level 4
(TP=0.10 ppm; BOD5/TSS=5 ppm; NH3-N = 1 ppm)

Treatment level 4 resulted in nearly unmeasureable improvements in impoundment surface dissolved oxygen from level 3 (0.1 ppm) and level 2 (0.3 ppm). Improvement in impoundment bottom dissolved oxygen is less than 1 ppm. Non-attainment of dissolved oxygen criteria in the South Berwick impoundment is reduced only slightly from 14 % to 12% of the volume. Overall non-attainment is reduced for bottom impoundment areas from 1 mile to 0.3 mile of length, and as a percentage of the total volume from 12% to 6%, when considering both impoundments, collectively.

The model projects single digit chlorophyll a (< 10-ppb) should result from level 4 treatment in all fresh water areas. This is lower than target levels (10 to 20 ppb) of supporting designated uses and is considered acceptable. At the Hamilton House site in tidal waters, the model is projecting levels of 20 pbb, which is considered marginally acceptable

Zero Discharge of Point Sources – Although not considered as a viable option, model predictions at zero discharge are included as a comparison to other treatment levels investigated. The model predicts that at zero discharge, Maine's class B dissolved oxygen criteria cannot be met in both surface and bottom waters of impoundments and class C dissolved oxygen criteria cannot be met in bottom waters of the South Berwick impoundment which represents a similar volume (12%) as treatment level 4.

The water quality model results in the estuary project that Maine's current minimum class SB dissolved oxygen criteria of 85% of saturation could be met in the surface waters of the estuary everywhere for all treatment levels except current treatment. The model predicts a minimum dissolved oxygen of 77% of saturation for a 0.5-mile segment near the Hamilton House with current treatment levels. Both the 1997 and 1998 grab sampling data (see appendix) similarly did not meet Maine's minimum class SB dissolved oxygen criteria of 85% of saturation in surface waters. Dissolved oxygen values always exceeded 70% of saturation in surface waters both summers. A continuous monitor was placed at surface water and bottom water depths near the Hamilton House in 1998 for 20 days. The continuous data from surface waters met Maine's minimum class SB dissolved oxygen criteria in 17 of 20 days. The minimum dissolved oxygen experienced here all summer was 78% of saturation.

For all treatment levels including point sources at zero discharge , the model projects bottom waters of a deep hole near the Hamilton House will not meet Maine's minimum class SB dissolved oxygen criteria. The 1995, 1997, and 1998 grab sampling data similarly did not meet minimum class SB dissolved oxygen criteria in bottom waters at this location. The continuous data in 1998 did not meet minimum class SB dissolved oxygen criteria in bottom waters in 16 of the 20 days sampled. Attainment of criteria occurred only in late summer after September 1.

When the model runs of various treatment levels are compared, predictions in the bottom waters at the Hamilton House location do not change significantly; dissolved oxygen is predicted to be 5.5 to 5.7 ppm for all treatment levels. Since the model yields similar dissolved oxygen values for point sources at current treatment and zero discharge, it is deduced that the non-attainment at the Hamilton House deep hole in bottom waters is a natural phenomena due to a salt wedge which persists throughout the tidal cycle. The salt wedge remains at the bottom waters of the deep hole and impedes vertical mixing of the less saline surface waters. Hence this salinity induced stratification results in low dissolved oxygen at the bottom waters of the deep hole through stagnation and lack of mixing of surrounding waters. Both Maine's (Title 38, chap 464, 4C) and New Hampshire's water quality standards (table 3) allow for exceptions in meeting numeric dissolved oxygen criteria where natural conditions cause the violation of standards.

<u>Phased TMDL for Phosphorus, BOD5, TSS, and Ammonia</u>

Current treatment levels results in non-attainment of all class ME-C/NH-B dissolved oxygen criteria (minimum, daily average, and monthly average). Collectively, at least one of the three criteria would not be met in a 2.3 mile segment and nearly one-half of the volume of the Rollinsford and South Berwick impoundments. The non-attainment can be expected to occur to some degree in both surface and bottom impoundment sections. Algae levels measured as chlorophyll a can be expected to reach 90 ppb which is indicative of severe algae blooms. It is obvious that current treatment levels are unacceptable and cannot be licensed.

Both 1 and 2a treatment levels, although improving dissolved oxygen still result in nearly the same length and volume in non-attainment of at least one of the three dissolved oxygen criteria when compared to current treatment. For this reason, both of these options are rejected due to the increased cost of treatment and the lack of significant water quality benefits when compared to current treatment.

Treatment level 2 results in the greatest incremental benefits when compared to treatment levels of current, 1, and 2a. All of the impoundment surface dissolved oxygen non-attainment is eliminated with this option. When compared to the lower treatment options (current, 1, 2a), non-attainment of dissolved oxygen criteria is eliminated in more than 30% of the volume and 1 mile of length of the Rollinsford and South Berwick impoundments, collectively. When exploring only waste treatment alternatives, some dissolved oxygen non-attainment is still predicted in impoundment bottom areas, which collectively represent about 1 river mile of length and about 12% of the volume of both impoundments. Additional dam operational measures are proposed to bring impoundment bottom areas into compliance with dissolved oxygen criteria.

It is recommended that dam operational changes be implemented as a method of improving dissolved oxygen in impoundment bottom areas for one round of licensing (five years) as the first phase of the TMDL. During low flow conditions, the lower three impoundments of the Salmon Falls (South Berwick, Rollinsford, and Lower Great Falls) do not generate power and typically spill water. Although the spilling of water improves river dissolved oxygen below each dam, the routing of water over surface layers probably enhances chemical stratification in these impoundments which ultimately results in lower dissolved oxygen levels in bottom areas. It is proposed that a bottom release in addition to a surface release at each dam be implemented. This should result in lower layer dissolved oxygen complying with established criteria. It is not desirable to have entirely bottom releases at each dam, since this could lead to lower dissolved oxygen levels below each dam. The hydropower operator of these three dams, Consolidated Hydropower Inc., has expressed a willingness to voluntarily implement the bottom releases in cooperation with Maine DEP (see letter in appendix).

The model predicted maximum chlorophyll a in tidal waters for treatment levels 2, 3, and 4 of 28, 22, and 20 ppb, respectively are not significantly different when the model uncertainty is considered. If model results are accurate, it will be difficult to meet objectives for minimizing algae in tidal waters with only point source controls. Non-point source best management practices are recommended, in particular, for the

Great Works watershed. It is proposed that non-point source controls be the mechanism for making up the difference in stated goals for chlorophyll a in tidal waters. The compliance monitoring will be used as a check on the effectiveness of implementing both point and non-point source controls to chlorophyll a in tidal waters to the stated goal of 10 to 20 ppb.

Treatment level 2 results in maximum fresh water chlorophyll a being reduced from 37 (treatment level 1) to 18 ppb in fresh water sections. This is within target levels (10 to 20 ppb) considered to be acceptable. Although the predicted chlorophyll a is at the top of the acceptable range, given the model uncertainty, it is judged to be a good starting point in a phased TMDL. It is recommended to license phosphorus as concentration limits only for one round of licensing, since plant flows are not expected to increase dramatically in the next five years. Eventually mass limits may have to be established that are consistent with design flows.

Since treatment level 2 implemented collectively with non-point source controls, and dam operational changes results in compliance of water quality standards, implementation of level 3 or level 4 treatment is not recommended at this time. Given the model uncertainty and the modest improvements predicted by the model for dissolved oxygen, it is judged that additional expenditures by towns could not be warranted unless future compliance monitoring in the river shows this to be necessary. There are some improvements predicted by the model in chlorophyll a for both treatment levels 3 and 4 when compared to level 2 treatment. However the levels predicted by the model for level 2 treament are within the acceptable range and are even probably conservative in the short-term, due to the fact that treatment plants are typically at one-half their design flow at 7Q10 flow conditions

The chosen treatment level 2 should be used as the initial starting point in a phased TMDL. This results in the following TMDL for ammonia, BOD, and total phosphorus.

Table 12 Phased TMDL for the Lower Salmon Falls River - Applies in Summer

Phase 1 of TMDL	Design Flow (mgd)	NH3-N (lb/day)	Ultimate CBOD (lb/day)	BOD5 (lb/day)	Total Phosphorus (lb/day)
Milton, NH*	0.1	N / A	34	16	0.5
Berwick, ME	1.1	65.4	429	131	4.4
Somersworth, NH	2.4	142.6	225	285	9.5
Rollinsford, NH	0.15	N / A	38	24	1.2
South Berwick, ME	0.6	N / A	228	95	4.8
Natural Background NPS	18.5	3.1	478	N / A	1.4
Tributary Non-Point Source**	0.3	0.1	8	N / A	2.5
Reserve Capacity (5%)		10.9	50	29	1.1
Total = TMDL		222	1490		25.3
Other Recommendations	1. Include performance based TSS in point source permit limits.				
	2. Non-Point Sources - Implement BMP's on Great Works River Watershed as a priority				
	3. Non-Point Sources - Implement BMP's throughout Salmon Falls watershed, where feasible.				
	4. Implement simultaneous top and bottom releases from Lower Great Falls, Rollinsford, and South Berwick dams during summer low flow period				
	5. After implementation of TMDL, begin ambient summer compliance monitoring.				
	6. Re-evaluate 1st phase of TMDL after five years. If non-compliance of water quality standards continues to occur, modify TMDL. If compliance of standards occur, the phased TMDL becomes final.				

* The Milton inputs to the TMDL include assimilation losses from Milton to Berwick of 33% and 30% for TP and BOD, respectively

** The BOD and ammonia TMDL only include tributary flow to head of tide (0.3 mgd). The TP TMDL includes additional flow of 9.8 mgd from the Great Works River.

The recommended TMDL is allocated by the previously explained method which involves setting small point sources at a fixed reduction level (TP = 1 ppm) and investigating the necessary treatment (Level 2) for larger point sources. There are a number of other possible ways of allocating reductions for the TMDL. Any other methods would be acceptable, so long as the total TMDL calculated for various pollutants of the non-attainment segment is not exceeded.

Since algae growth is a longer term phenomena, the summer TMDL for phosphorus should be licensed as monthly average permit limits. Since both carbonaceous and nitrogenous BOD decay is a shorter term phenomenon and the model is run as a weekly average at 7Q10 flow, the summer TMDL for BOD and ammonia should be licensed as weekly average permit limits. In addition, BOD5 permit limits must be derived by dividing the ultimate BOD in the TMDL by the CBODu/BOD5 ratio derived for each effluent with the 1995 data. The CBODu/BOD5 ratios for each effluent are as follows: Milton, 3.04; Berwick, 3.28; Somersworth, 0.79; Rollinsford, 1.59; and South Berwick, 2.4. The monthly average and daily maximum permit limits for BOD and TSS are derived from the ratios to the weekly average that are ordinarily used in technology based licensed limits (.67 and 1.11, respectively). This results in the following recommendation for permit limits in the initial phase of the TMDL.

Table 13 Recommended Permit Limits for Phase 1 of TMDL

	Ammonia (lb/day) Weekly Ave.	Ammonia (lb/day) Mo. Ave.	Ammonia (ppm) Mo. Ave.*	Total Phosphorus (ppm) Mo. Ave.	BOD5 / TSS (lb/day) Mo.Ave.	BOD5 / TSS (lb/day) Weekly Ave.	BOD5 / TSS (lb/day) Daily Maximum
Milton, NH	None	None	None	1	11	16	18
Berwick, ME	65	174	28	0.5	87	131	146
Somersworth, NH	143	380	28	0.5	190	285	317
Rollinsford, NH	None	None	None	1	16	24	27
S. Berwick, ME	None	None	None	1	63	95	106
Limits Apply	6/1 to 9/30	10/1 to 5/31	Year Round	5/1 to 9/30	June 1 to Sept 30		

*Licensing policy dictates that Maine DEP include concentration limits on all toxic TMDL's. See text of report for explanation.

The weekly average limits assure that all daily minimum and daily average dissolved oxygen criteria will be met and monthly average limits assure that monthly average dissolved oxygen criteria will be met. The monthly average permit limits for total phosphorus assure that chlorophyll a will meet the specified goal and all dissolved oxygen criteria. The non-summer ammonia limits are necessary to assure chronic toxic ammonia criteria will be met. The limits for ammonia in the summer are more stringent due to its affect upon dissolved oxygen.

Although not included in table 13, the permit limits for parameters not within the time period specified, i.e. non-summer, should be technology based limits. Note that the summer limits for ammonia are lower than non-summer limits due to the basis used to derive the limits. The summer limits are derived by consideration of ammonia’s depletion of dissolved oxygen through nitrification and are more stringent than the non-summer limits derived by toxic criteria. Maine DEP also uses concentration limits in all toxic TMDL’s as a policy issue. The concentration is set at 1.5 times the concentration used to derive the mass limits.

EPA regulations require that TMDL's take into account a margin of safety (MOS) which takes into account such factors such as the accuracy of the water quality model, variability of the receiving water chemistry, and underlying assumptions built into the entire process. The margin of safety could be expressed as an actual load. i.e. 10% of the assimilative capacity reserved for MOS, or conservative assumptions used in the modeling analysis. A MOS in the Salmon Falls River TMDL was included by using conservative assumptions. A margin of safety is typically built into all TMDL's when one considers that the design conditions used to calculate a receiving water's assimilative capacity. The design treatment plant flows and and low river flow conditions (7 day 10 year low flow or 7Q10) are used to calculate a receiving water's assimilative capacity. Using design treatment plant flows in the model predictive runs results in a MOS, since treatment plant discharges are currently discharging at about one-half of their design flow. In addition, a high ambient water temperature typically experienced infrequently and licensed waste loads are assumed to occur simultaneously with 7Q10 flow. This results in a condition that will probably occur very infrequently (< 1% probability). Under most conditions dissolved oxygen will be higher than the worse case levels predicted by the model.

The calculation of phosphorus limits is an inexact process with much uncertainty, when compared to calculating BOD or ammonia limits. For this reason an additional margin of safety is being proposed for licensing. The phosphorus limits will initially be concentration limits rather than mass limits. Since the flow now experienced by the treatment plants is much less than design flow, this allows less phosphorus to be discharged than would be discharged with mass limits based upon what was inputted into the model simulation (0.5 ppm at design flow).

EPA regulations also require that TMDL's take into account seasonal variability. This is considered in the TMDL for the Salmon Falls River in many different ways. The ammonia limits are calculated as summer and non-summer limits due to the seasonality of nitrogenous BOD decay (NBOD decay typically does not occur in non-summer). The water quality based BOD limits are applied only in the summer due to the fact that dissolved oxygen depletion from BOD decay is generally only an issue when water temperatures are high. This results in lower water quality based effluent BOD limits in the summer and higher technology based BOD limits (not included in table 13) in the non-summer . Seasonal variability is also considered in the phosphorus effluent limits calculations which are specified only from May 1 to September 30 when eutrophication is an issue. In the non-summer the cooler water temperature greatly diminish algae growth to the point where it is no longer an issue.

Monitoring Plan

The monitoring plan that will be used to assess compliance is summarized in the table below:

Table 14 Ambient Compliance Monitoring Plan for Phased TMDL

Early morming grab sampling twice per month from June to September			
Station Code	River Mile	Location	Parameters
SF19	5	Route 9 Bridge Somersworth/ Berwick	D.O., Temperature, TP, PO4-P, Chl a, NH3-N, NO2+NO3-N
SF16	3.3	Above Lower Great Falls Dam	D.O., Temperature, TP, PO4-P, Chl a, NH3-N, NO2+NO3-N
SF15	3	Bridge above Somersworth WWTP	D.O. Temperature
SF11	1.1	Above Rollinsford Dam	D.O., Temperature, TP, PO4-P, Chl a, NH3-N, NO2+NO3-N
SF7	0.1	Above South Berwick Dam	D.O., Temperature, TP, PO4-P, Chl a, NH3-N, NO2+NO3-N
SF4	-1.2	Hamilton House Site	D.O., Temperature, Salinity TP, PO4-P, Chl a, NH3-N, NO2+NO3-N
Continuous Summer Monitoring			
SF11	1.1	Above Rollinsford Dam	D.O., Temperature at 2 Meter depth

The summer monitoring consists of early morning sampling two times per month of dissolved oxygen and temperature and (in the estuary) salinity at one-meter profiles and surface grab samples for nutrients (TP, PO4-P, NH3-N, NO2+NO3-N). Chlorophyll a should be sampled as a two meter integrated core sample. In addition, a continuous dissolved oxygen monitor should be established at the Rollinsford impoundment at a depth of 2 meters. The sampling should be undertaken every summer for the next five years. It is recommended that all ambient compliance monitoring be required as licensed conditions of the NPDES permits. Although the collection of the river compliance monitoring data would be the responsibility of permittees, state and federal regulatory agencies could assist the towns in both the design and collection of the river sampling program.

Use Attainability Analysis – Introductory Information

A Use Attainability Analysis (UAA) is a structured scientific assessment of the physical, chemical, biological, and economic factors affecting the attainment of a designated use in a water body. A UAA is usually undertaken in situations, when after considering all available and reasonable options, existing water quality standards are still believed to be unattainable. A UAA allows for removal of designated uses that are not existing uses or adoption of subcategories of classification (i.e., less stringent criteria). The evaluation of the cost of all possible alternatives of river clean up is an important and necessary ingredient of a UAA. The establishment of goal uses for reclassification under a UAA and eventual numerical or narrative criteria is a requirement of a UAA.

A UAA can remove designated uses that are not existing uses, but cannot remove existing uses. A UAA can also establish subcategories of classication or less stringent criteria. Subcategories of classification are being recommended for a 5.5 mile segment of the Salmon Falls River from Berwick (route 9 bridge) to South Berwick (head of tide). The recommended criteria to be adopted, the most stringent criteria of Maine's class C and NH's class B (see table 3) would still preserve all designated uses and maintain fishable and swimmable goals specified by the Clean Water Act. However this would also require that the 5.5 mile segment be downgraded in Maine's classification from class B to class C.

Federal Regulations (40CFR 131.10g) specify that removal of designated uses or the establishment of subcategories of classification can only be considered if the State can demonstrate that attaining the current classification is not feasible due to any one of six criteria specifically listed in the regulation. There are two criteria of the six that apply to the Salmon Falls River and are as follows:

1. Dams, diversions, or other types of hydrologic modifications preclude the attainment of the use and is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use.

2. Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

Non-tidal waters of the entire Salmon Falls River are currently class B and all tidal waters class SB. Both dams and point source inputs significantly influence water quality degradation on the Salmon Falls River and it is not believed that there are any cost effective or practicable alternatives to meet class B water quality standards on the 5.5 mile segment.

Given that a particular portion of a waterbody may have classification goals that are believed to be unattainable, a UAA then determines the highest level of water quality that can be obtained without causing substantial and widespread economic or social harm. This requires that a number of both treatment and non-treatment alternatives be considered and the cost of implementing alternatives estimated. Rather than establishing criteria in-between a Maine class C and B, establishment of criteria that will satisfy both a Maine class C and NH class B is being recommended due to a number of considerations that are believed to be unique.

1. The interstate nature of the river. Maine's downgrade to C is more consistent with NH's goals for the river, which EPA has already accepted.
2. Uncertainty associated with the model predictions. The complex and dynamic nature of physical and chemical parameters within the Salmon Falls River makes any modeling analysis inexact. The model results are considered more credible when considering attainment / non-attainment of classification criteria, but less credible when considering predictions of actual dissolved oxygen levels to the nearest 0.1 ppm.
3. The small incremental benefits achieved in water quality when comparing the recommended option (level 2) to higher removal waste treatment options (levels 3 and 4).
4. Difficulty of establishing incremental aquatic life criteria in-between a class B and C.
5. A phased approach to establishing the TMDL and permit limit reductions in point sources allows for stepped reductions and actual river monitoring to judge compliance, rather than relying totally on model predictions. The TMDL and downgrade in classification can be revisited, if after completion of the first stepped reduction, it is believed affordable options are still available that would result in demonstrative water quality benefits.

Finally it should be mentioned that the classification criteria (most stringent criteria of Maine class C and NH class B) recommended for this 5.5 mile segment, if adopted, would result in some criteria that are more stringent than the current statewide criteria for both states. For example, NH's class B dissolved oxygen criteria of 75% of saturation for a daily average is more stringent than Maine's class C dissolved oxygen criteria, which does not specify daily average numerical criteria for class C. Conversely, MDEP uses 6.5 ppm for a monthly average in class C waters, which is more stringent than NH's class B that does not specify monthly average numerical criteria for class B.

Assessment of Historical, Current, and Future Water Quality Conditions

A summary of historical water quality non-attainment problems already discussed in the report are repeated here for reader convenience.

- a 12.5 mile section (5.5riverine and 7 estuarine) failed to meet Maine's minimum class B and SB dissolved oxygen (dissolved oxygen) criteria.
- 7.5 of the 12.5 miles did not meet dissolved oxygen criteria of the next lowest classification class C and SC.

- Severe algae blooms develop in two impoundments located just above head of tide and intensify at the head of tidal waters.
- A toxic problem has historically occurred as a result of ammonia discharged from the Berwick and Somersworth discharges. This has caused non-attainment of Maine's class B aquatic life criteria.
- Some of the non-attainment of dissolved oxygen criteria occurs above all major point source discharges. Assuming complete removal of point source discharges, model results also predict non-attainment of dissolved oxygen criteria in river locations below current point source discharges.

As a result of river cleanup that has already occurred through operational changes required in the licensing of hydropower dams, all except 0.5 miles that formerly did not meet class SB dissolved oxygen standards now meet criteria. No changes in attainment status have resulted in non-tidal waters from those noted with the historical data and model predictions and hence 5.5 miles of non-tidal waters still do not meet Maine's class B dissolved oxygen criteria.

If the phased TMDL (including the six recommendations) is adopted and license permits issued, (see tables 12 and 13), it is deduced that the remaining 0.5 miles of tidal waters currently in non-attainment could meet class SB standards. Dissolved oxygen criteria in fresh waters could meet the established goal (ME-C / NH-B) in the 5.5 mile segment that is being considered for reclassification. Ammonia toxicity can be eliminated and it is believed Maine's class C aquatic life criteria could be met. Algae levels could be reduced to target goal levels of 10 to 20 ppb which will result in the elimination of severe bloom conditions and maintaining narrative classification criteria of meeting designated uses

Goals to Be Adopted for Re-Classification of 5.5 Mile Non-Attainment Segment

The goals that are recommended to be adopted for the 5.5 mile segment considered for re-classication are the most stringent of Maine's class C and NH's class B water quality criteria. This was formerly discussed in this report (see pp 11-14, table 3) and is summarized here.

1. Support all designated uses.	
2. Dissolved oxygen	Daily minimum > 5 ppm and 60% saturation Daily Average > 75% of saturation Monthly Average > 6.5 ppm Fish spawning (10/1 to 5/14) 7-Day mean > 9.5 ppm; 1-Day min. > 8 ppm Dissolved oxygen criteria apply to all areas of water column.
3. Aquatic Life	Meet Maine's class C narrative language and NH class B narrative language
4. Ammonia	Meet toxic criteria (3.08 ppm) and dissolved oxygen criteria (possibly< 3.08 ppm)
5. Phos. / Chl a	Meet designated uses; no cultural eutrophication; chlorophyll a < 10 to 20 ppb
6. Bacteria	E.Coli Geometric mean < 126 / 100 ml; Instantaneous < 406 / 100 ml

Alternatives Considered for the UAA

The alternatives considered for the UAA are discussed in a report (*Salmon Falls / Piscataqua River Economic Analysis*, Earth Tech, Inc., Jan 1999) except for the cost estimates for dam removals which were provided by Consolidated Hydro Inc (CHI) (see correspondence in appendix). A summary of alternatives and their estimated costs are as follows.

Table 15 – Alternatives Considered for UAA and Their Estimated Costs

<u>Non-Treatment Alternatives</u>	
Purchase and Removal of Lower Great Falls, Rollinsford, and South Berwick Dams	$18.9 million
Relocation Berwick and Somersworth Outfalls	$ 8.9 million
Relocation of Berwick, Somersworth, Rollinsford, and South Berwick Outfalls	$10.7 million
Consolidation of Rollinsford to South Berwick WWTP	$ 3.2 million
In-Stream Aeration at Three Locations	$ 8.3 million
<u>Advanced Waste Treatment Alternatives</u>	
Advanced Treatment Level 1	$ 1.4 million
Advanced Treatment Level 2	$ 3.8 million
Advanced Treatment Level 3	$ 8.5 million
Advanced Treatment Level 4	$11.1 million

The dam removal option involves both the purchase cost ($12.3 million) and removal cost ($6.6 million). There are also many legal and procedural requirements which would probably make this option more costly than estimated and could make dam removal impossible.

- The Lower Great Falls and Rollinsford dams are owned by the municipalities of Somersworth, and Rollinsford, respectively. The owners of these dams would have to agree to sell them and might have to be compensated for their interests in the dams.
- All three dams are licensed by FERC and would require permits for decommissioning. Dam removals would also require various permits from the Corp of Engineers, Maine DEP, NHDES, and possibly local town approvals.
- The estimated costs of dam removals include only the costs of physical removal. The cost of studies required for permit approvals and the mitigation measures such as outfall relocations are not included.
- There is no guarantee that CHI or the municipalities would be willing to sell their interests.

The dam removal option could not result in meeting Maine's class B water quality standards in the 5.5 mile segment. It is likely that without phosphorus reductions to point sources, most of the phytoplankton (floating algae) currently found in impoundments would be replaced by bottom attached or benthic algae in free flowing waters. There would still likely be daily minimum dissolved oxygen readings that would not meet Maine's minimum class B criteria of 7 ppm. (There are point sources currently licensed in Maine where advanced treatment for phosphorus removal is required due to low dissolved oxygen from attached algae in free flowing waters.) It is also deduced by DEP biologists (best professional judgement) that even with dam removals, class B aquatic life standards could not be met due to the high volume of waste water discharged here (20% of 7Q10 river flow). The dam removals option is rejected as an option to avoid re-classification due to the projected non-attainment of class B dissolved oxygen and aquatic life criteria.

It is deduced that the stated goals for the UAA re-classification (ME-C / NH-B) could be met with the dam removals. Assuming the 5.5 mile river segment gets re-classified to class C, dam removals would not be a recommended option due to their higher costs when compared to waste treatment options. The estimated dam removal costs have been questioned by EPA and others, who believe the removal costs are inflated. But even if only purchase costs are considered, the cost is more than three times the cost of the recommended advanced treatment alternative. The economic factors for dam removals could change in the future when power contracts are re-negotiated with public utilities. It is suggested that dam removals be re-visited should the ambient compliance monitoring in the phased TMDL shows that the recommended actions do not go far enough.

The options relocating outfalls to tidal waters below the confluence with the Cocheco River bridge (four river miles below head of tide) are also rejected as options to avoid re-classification due the expectation that this would just result in the relocation of a water quality problem rather than the desired result of attainment of water quality standards everywhere. There are already large point source waste loads inputted nearby from Dover (Piscataqua River) and Rochester (Cocheco River). Additional waste loads inputted into this area could result in non-attainment of Maine's minimum SB dissolved oxygen criteria of 85% of saturation, despite the high tidal dilution encountered here. There could also possibly result in a newly created eutrophication problem into this area.

The consolidation of Rollinsford to the South Berwick treatment plant is not considered an option by itself but as a supplement to other possible actions. When the cost of consolidation ($3.2 million) is compared to the cost of the additional treatment being recommended for Rollinsford ($0.23 million), it is clear that consolidation is not a good option.

In-stream aeration is also rejected, since it only addresses one of the three water quality problems associated with the river. Although in-stream aeration could result in meeting dissolved oxygen criteria, algae blooms would continue to occur and narrative criteria of meeting designated uses could not be met. Supplemental waste treatment involving phosphorus reductions would still be necessary. Toxic criteria and aquatic life standards would also not be attained unless additional waste treatment measures were taken.

In summary, all of the treatment and non-treatment alternatives can be rejected as options to avoid re-classification due to their failure to meet class B water quality standards. Non-treatment alternatives can be rejected as options for re-classification due to their higher costs when compared with treatment options. Re-classification of the 5.5 mile segment and the most cost effective treatment option that results in attainment of water quality standards should be implemented for river cleanup.

Options Considered for Re-Classification

Four advanced treatment levels were investigated in Earth Tech's Economic Analysis Report for the Somersworth and Berwick discharges. The total cost of the additional treatment from the Economic Analysis report is repeated here and compared to model predicted water quality (table 16). The individual cost for each municipality and the effect upon annual sewer user rates are also discussed in the economic analysis report and are repeated here (table 17).

The chosen alternative, treatment level 2, has an overall cost of $3.8 million dollars of which $3.68 million of the cost (97%) would be the responsibility of Berwick and Somersworth. The increase in sewer rates expected from this option would be under 10% for the three smallest plants (Milton, 9%; Rollinsford, 7%; and South Berwick, 1%). The increase in sewer rates for the two larger plants would be under 20% (Berwick, 19%; Somersworth, 15%). It is obvious that the recommended option should not result in undue economic hardship for any of the municipalities included in the TMDL.

A requirement of a UAA is to achieve the highest water quality possible without causing undue economic and social hardship. The state of Maine uses 2% of the median household income as as threshold level for sewer user rates when assessing affordability to sewer users. The median incomes for Berwick and South Berwick of $35,370 and $37,770, respectively (1990 census) would result in affordable sewer rates of $707 and $755, respectively using the 2% criteria. Hence South Berwick's sewer rate by the recommended option of level 1 treatment ($720) is barely affordable and Berwick's sewer rate at level 4 treatment ($545) is affordable by these criteria. There is no immediate information available on how the state NH determines affordability, but Somersworth's potential sewer rate at level 4 treatment ($314) is about 1% of the median household income ($32886, 1990 census). As an issue of fairness, if it is assumed that sewer rates of over $700 are affordable for Berwick and South Berwick, one would presume that $314 for sewer rates is affordable for Somersworth.

As discussed earlier in this report, existing information reveals that, within the uncertainty of the model predictions, there are no significant benefits in water quality to the Salmon Falls River when comparing the model predicted results from level 2 to level 4 treatment (table 16). Since the recommended TMDL should result in attainment of water quality standards, additional expenditures (level 3 treatment and level 4 treatment are double and triple level 2 treatment, respectively) are not warranted in the first phase of the TMDL, unless the subsequent monitoring reveals more treatment is needed.

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Table 16 Summary of Alternatives - Benefits and Total Costs

Treatment Alternative	Treatment Add-on's	Effluent Limits as Weekly Average (ppm)				Model Water Quality Predictions		
		TP	BOD/TSS	TP	BOD/TSS			
		Milton, Rollinsford, S Berwick		Somersworth and Berwick		Total Non-Att. ME-C / NH-B D.O. Rollinsford + S Berwick impoundments		Max. Rive Chl. A (p
Current	None	None	45	None	45	2.3 mi	45% volume	88
Level 1	Chemical Addition	1	20	1	20	2 mi	42% volume	37
Level 2	Chemical Addition + Tertiary Clarifer	1	20	0.5	15	1 mi	12 % volume	18
Level 3	Effluent Filtration	1	20	0.25	10	1 mi	12 % volume	11
Level 4	Effluent Filtration + Tertiary Clarifier	1	20	0.1	5	0.3 mi	6 % volume	6
TMDL	Level 2 Treatment + NPS Reductions + Dam Operational Changes	1	20	0.5	15	0 mi	0% volume	18

Table 17 - Individual Cost of Advanced Waste Treatment Alternatives

Waste Water Treatment Facility	Flow (mgd) Design/Current	Total Cost for Each Facility (Million $)				Expected Annual Sewer User Rate in $ and (% incre			
		TP = 1	**TP = .5**	**TP = .25**	**TP = .1**	Current Sewer Rate	**TP = 1**	**TP = .5**	**TP = .2**
Milton	0.1 / .05	0.39				$150	$164 (9%)	N/A	N/A
Berwick	1.1/ 0.67	0.24	1.45	3.68	4.66	$370	390 (5%)	$439 (19%)	$505 (36
Somersworth	2.41 / 1.44	0.43	2.23	4.73	6.3	$221	$229 (4%)	$255 (15%)	$291 (45
Rollinsford	0.15 / 0.1	0.23				$480	$514 (7%)	N/A	N/A
South Berwick	0.6 / 0.35	0.13				$710	$720 (1%)	N/A	N/A

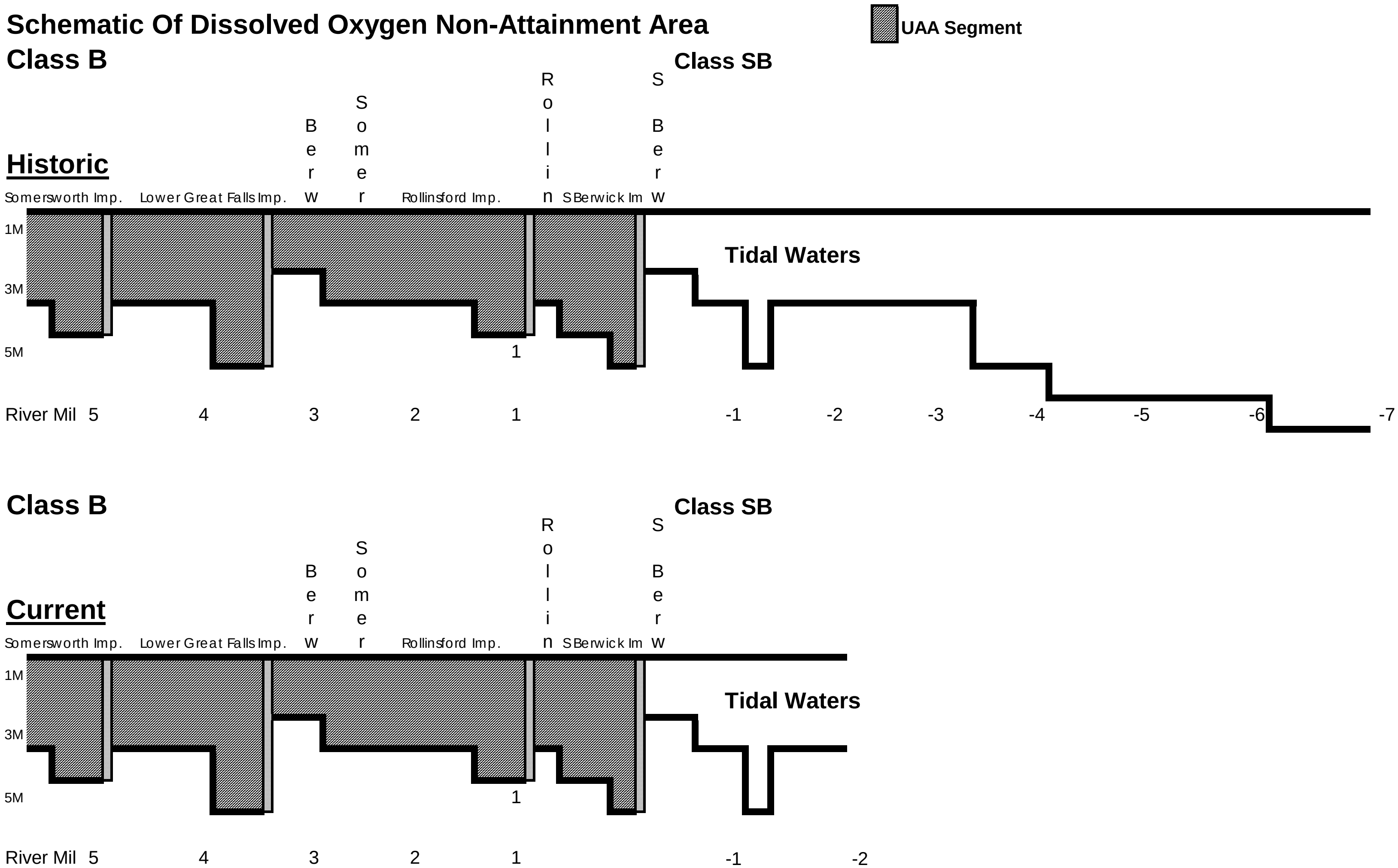
In summary, eight years of efforts on the Salmon Falls/Piscataqua River have resulted in the following:

- Five years of water quality data collected through the 1990's;
- Flow at all dams on the river regulated in a steady (run of river) mode at summer low flow conditions;
- A water quality model which indicates that:
  - Point source discharges are responsible for about 90% of the total pollutant loads of phosphorus, BOD, and ammonia, and
  - Maine class B water quality standards are too ambitious for this 5.5 mile stretch of the river, but a new standard based on the more stringent criteria for Maine class C and New Hampshire class B is achievable and will provide good water quality;
- An economic report that analyzes costs of various treatment alternatives;
- A TMDL which will enable discharge permits to be updated for five dischargers that, in conjunction with dam operational changes and non-point source controls, will result in much improved water quality and attainment of water quality standards.

Appendix 1

River Schematics of Model Predictions and Non-Attainment Areas

Schematic Of Dissolved Oxygen Non-Attainment Area

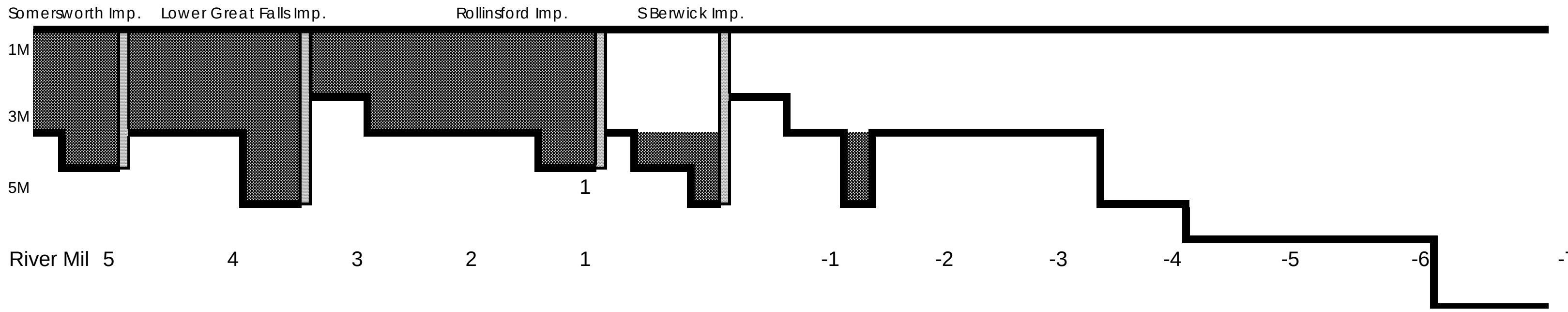


Summary of Dissolved Oxygen Non-Attainment

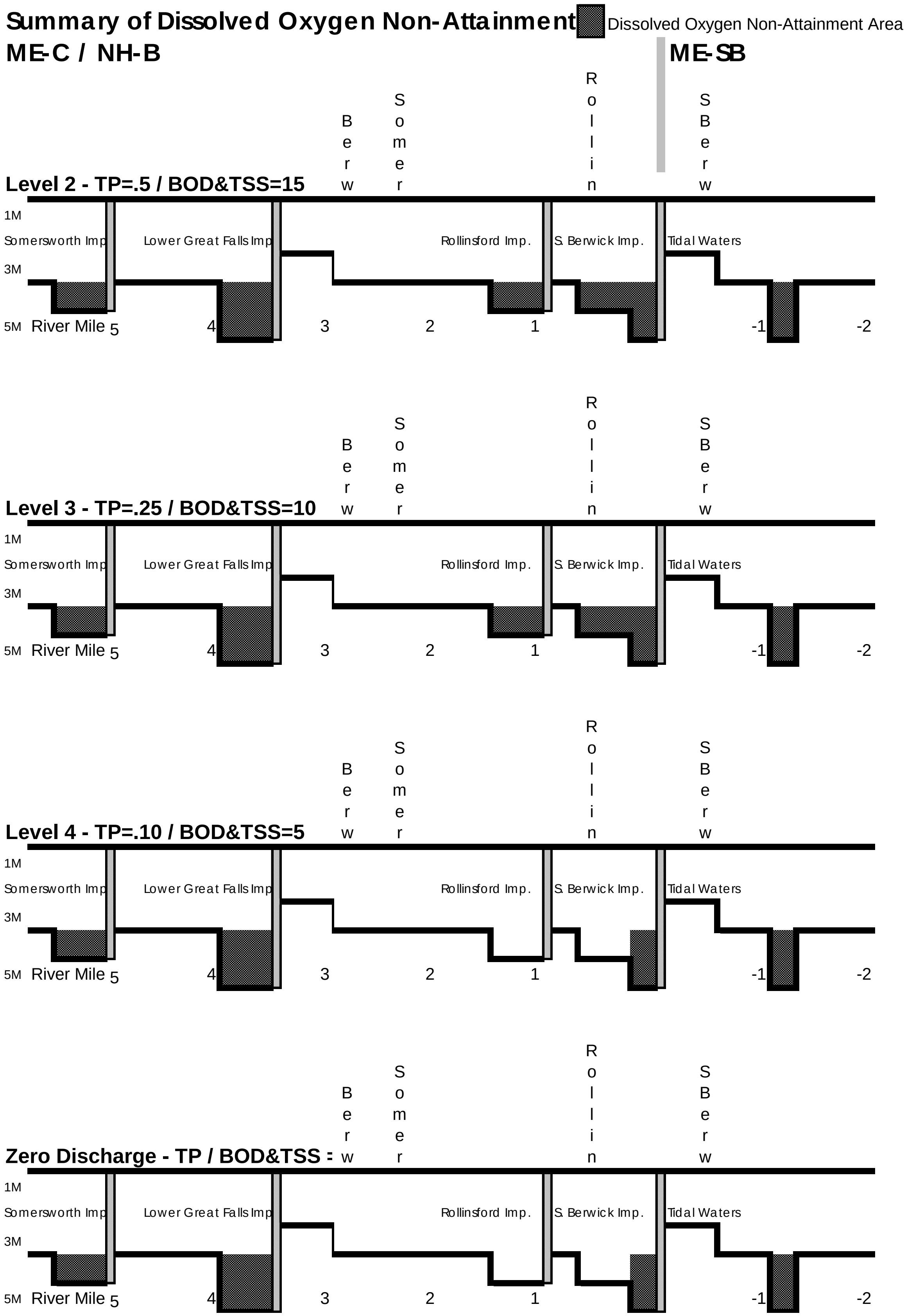
Class B **Class SB**

Dissolved Oxygen Non-Attainment Area

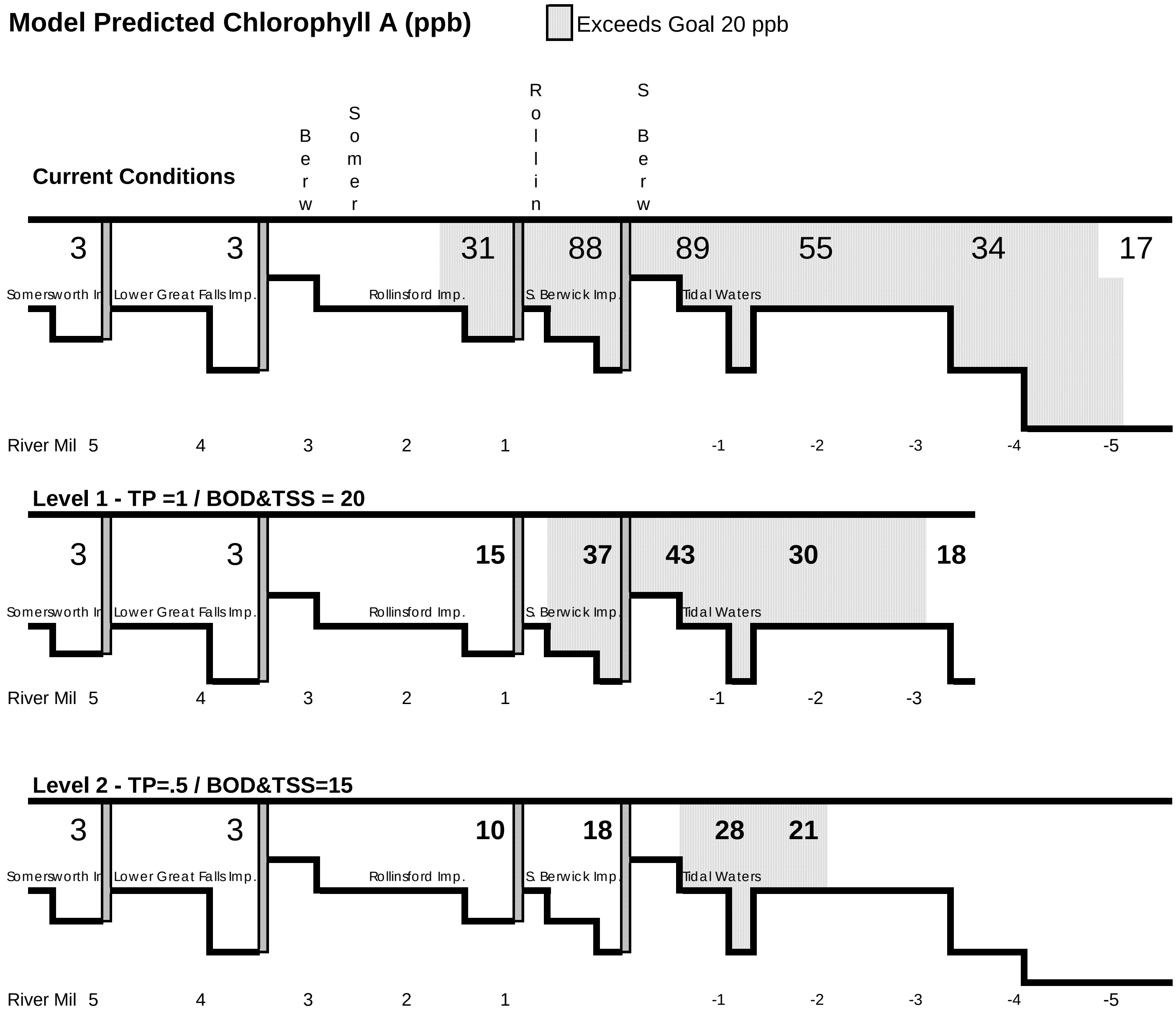
(Level 2 , Level 3, Level 4, Zero Discharge)




Summary of Dissolved Oxygen Non-Attainment
Model Predictions
ME-C / NH-B
Dissolved Oxygen Non-Attainment Area
ME-SB
Current Conditions
Berw
Somer
Rollin
S Berw
1M
3M
5M
Somersworth Imp
Lower Great Falls Imp
Rollinsford Im
S. Berwick Imp.
Tidal Waters
River Mile 5
4
3
2
1
-1
-2
Level 1 - TP =1 / BOD&TSS = 2
Rollinsford Imp.
Level 2 - TP=.5 / BOD&TSS=15

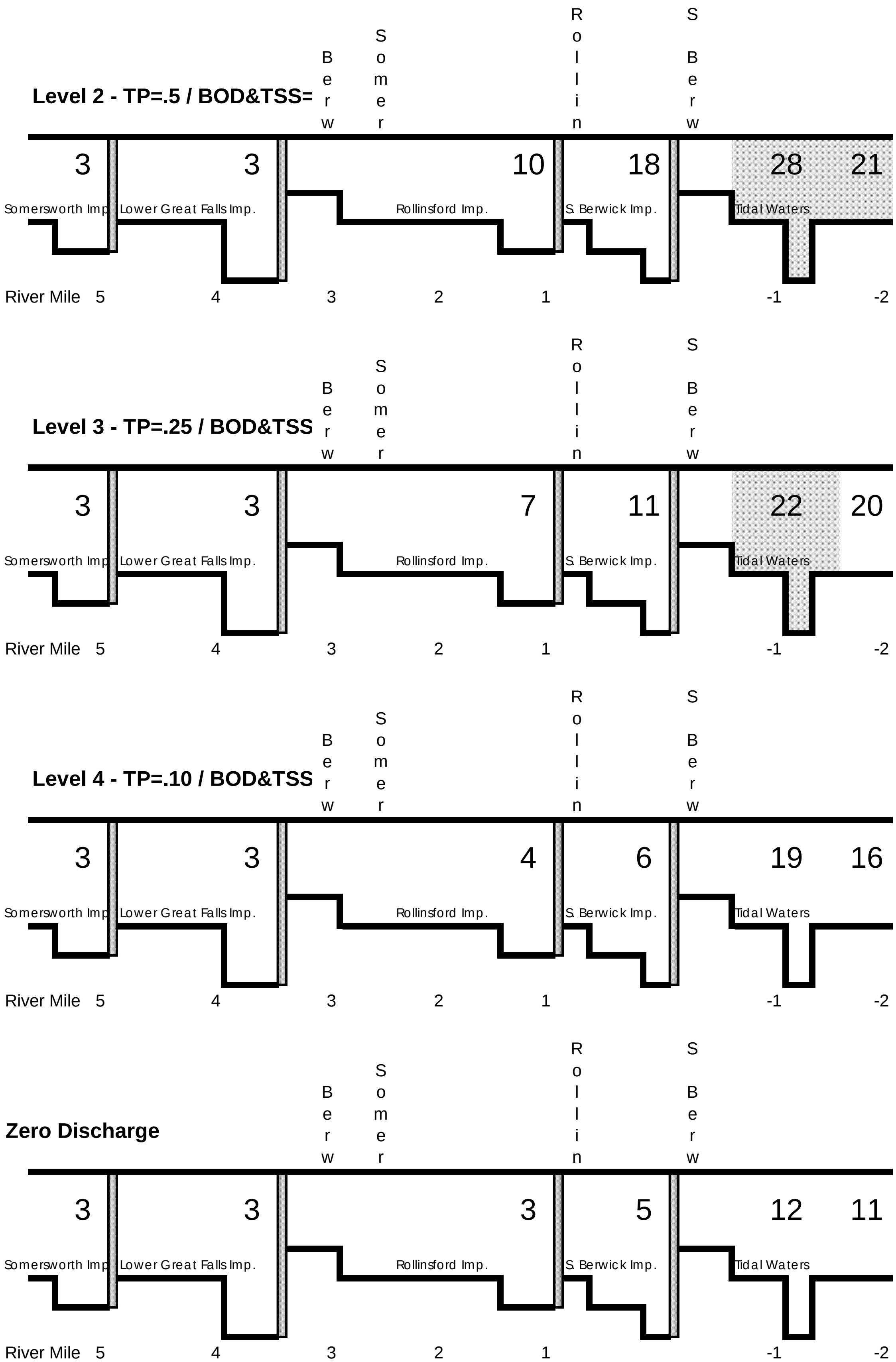

Summary of Dissolved Oxygen Non-Attainment
Dissolved Oxygen Non-Attainment Area
ME-C / NH-B
ME-SB
Level 2 - TP=.5 / BOD&TSS=15
Level 3 - TP=.25 / BOD&TSS=10
Level 4 - TP=.10 / BOD&TSS=5
Zero Discharge - TP / BOD&TSS =
Berw
Somer
Rollin
SBerw
1M
3M
5M
Somersworth Imp
Lower Great Falls Imp
Rollinsford Imp.
S. Berwick Imp.
Tidal Waters
River Mile 5
4
3
2
1
-1
-2

Model Predicted Chlorophyll A (ppb)



Model Predicted Chlorophyll A (ppb)

Exceeds Goal 20 ppb



Appendix 2

1997 and 1998 Data

Appendix 3

Figures From 1994 Report

Appendix 4

Dam Purchase and Cost Estimates – Correspondence

Dam Operation Agreement with CHI