Table 5: Summary of Scenarios Analyzed

Regime	Scenario Description	Abbreviation
Actual Flows	Baseline condition based on WWTP inputs developed during the model construction and calibration phases of the project.	Current
	WWTP inputs developed based on actual flow conditions and 2001 NPDES permits (Upgrade 1, Table 3).	UP1
	WWTP inputs developed based on actual flow conditions and 2008 NPDES permits (Upgrade 2, Table 3).	UP2
	No UBWPAD load; Woonsocket load based on actual flow and 2001 NPDES permits (Upgrade 1, Table 3).	ZeroUB
	WWTP inputs developed based on actual flow conditions and 2001 NPDES permits (Upgrade 1, Table 3) plus a 20% uniform reduction in NPS across the basin.	UP1NPS
Design Flows	WWTP inputs developed based on the observed effluent concentrations during the simulation period converted to a load based on daily design flow conditions.	Current DF
	WWTP inputs developed based on design flow conditions and 2001 NPDES permits (Upgrade 1, Table 3).	UP1 DF
	WWTP inputs developed based on design flow conditions and 2008 NPDES permits (Upgrade 2, Table 3).	UP2 DF
	No UBWPAD load; Woonsocket load based on design flow and 2001 NPDES permits (Upgrade 1, Table 3).	Zero UB
	WWTP inputs developed based on design flow conditions and 2001 NPDES permits (Upgrade 1, Table 3) plus a 20% uniform reduction in NPS across the basin.	UP1NPS DF

3.1 Actual Flow Regime Scenario Set

WWTP nutrient loads were estimated on a daily basis by pairing the observed historical effluent flows with observed historic effluent concentration values. These data were utilized in the HSPF model to simulate "actual" water quality conditions along the river; the results serve as a basis of comparison for potential future water quality conditions. Future water quality conditions were simulated by reducing the effluent concentration values, recalculating WWTP nutrient loads based on the observed historical effluent flows, and re-running the HSPF model. The simulated scenarios are described in more detail below.

Baseline Conditions (Current Scenario)

The baseline conditions, referred to as the current scenario, are simulated using the WWTP inputs developed during the model construction and calibration phases of the project. This scenario provides water quality information that serves as a basis of comparison for potential future water quality conditions resulting from nutrient loading reductions due to WWTP upgrades.

Upgrades in accordance with the 2001 NPDES permit (Upgrade 1)

As previously stated, the UBWPAD is undergoing upgrades to its facility in response to the NPDES permit issued in 2001. The permit requires seasonal limits of 0.75 mg/L for TP and reporting for TN effluent concentrations. However, the upgrades will also typically achieve TN concentrations of 8 mg/L and has been designed to operate year round. Therefore, the Upgrade 1 simulation uses effluent limits applied throughout the year. Operators at the plant state that in order to account for variations in performance and flow regimes, the plant will need to be run at 80 percent of the effluent limits, resulting in effective effluent concentrations of 0.6 and 8 mg/L for TP and TN respectively. For this scenario, the effective 2001 effluent limit concentrations of 0.6 mg/L TP and 8 mg/L TN were used to calculate load (instead of measured effluent concentration values) except when the observed historic effluent concentrations were lower than the 2001 effective effluent permit limits. For such days, the reported effluent concentration values were used to estimate the daily load. This methodology is used to represent the periods when the plant historically performed better than mandated by the 2001 effluent limits. The effluent limits were applied to both the UBWPAD and Woonsocket WWTPs over the modeling period of record (POR) for the study, 1996 - 2007.

Proposed Upgrades in accordance with 2008 NPDES permit (Upgrade 2)

In the summer of 2008, the UBWPAD was issued a NPDES permit requiring seasonal reductions of TN and TP effluent concentrations to 5 and 0.1 mg/L respectively while maintaining an effluent level of 1.0 mg/L of TP over the remainder of the year. Additionally, under their 2008 NPDES permit, Woonsocket expects to achieve seasonal reductions in TN and TP to 3 and 0.1 mg/L respectively. These newly established limits were applied from April 1 to October 31 for each plant. The increase in process technology is expected to allow operators to run the plant at 90 percent of the effluent concentration limit. However, it may not be possible to reach 90% of the limit of 0.1 mg/L TP or 3.0 mg/L TN consistently. Regardless, for this scenario, effective TN and TP effluent concentrations of 4.5 and 0.09 for UBWPAD and 2.7 and 0.09 mg/L for Woonsocket were used, respectively. The Upgrade 1 effluent limits were applied to the remainder of the year at both facilities. As with the Upgrade 1 scenario, if the plant performed better than the effluent limits on a given day, the lower effluent concentration was used to develop the WWTP loading input read into the model.

Zero Load at UBWPAD (ZeroUB)

A scenario that simulated a zero nutrient loading at the UBWPAD was developed to determine the impact of removing all water quality constituents (nutrients, biological oxygen demand, and total suspended solids) from the UBWPAD while preserving the flow from the plant, allowing for the hydraulics of the system to be maintained. The WWTP loading values at the Woonsocket WWTP were set at Upgrade 1 levels. This scenario allows for the investigation of the best, although unattainable water quality in the system through reductions in the UBWPAD effluent.

NPS Reductions plus 2001 NPDES permit (UP1NPS)
This scenario reduces NPS uniformly across the basin by 20% in addition to applying the effective 2001 effluent limit concentrations of 0.6 mg/L TP and 8 mg/L TN. Results for this scenario are not presented for all analyses. The effective effluent limits were used to calculate load (instead of measured effluent concentration values) except when the observed historic effluent concentrations were lower than the 2001 effective effluent permit limits. For such days, the reported effluent concentration values were used to estimate the daily load. This methodology is used to represent the periods when the plant historically performed better than mandated by the 2001 effluent limits. The effluent limits were applied to both the UBWPAD and Woonsocket WWTPs over the modeling period of record (POR) for the study, 1996 - 2007.

3.2 Design Flow (DF) Scenario Set
The above baseline condition and three potential future scenarios were also run using WWTP loads developed for the UBWPAD and Woonsocket WWTPs using the estimated daily values for design flow conditions. During the design flow scenarios, all concentrations were left at the NPDES mandated effluent concentration levels. No accounting was made for the plant performing better than the effluent limits in the NPDES permits during the design flow scenario analyses. This was summarized in Table 4 above.

3.3 Benthic Nutrient Release Concentration Adjustment
The considerable differences in PS loading between the Baseline Actual Flow conditions and the simulated pollutant reduction scenarios are anticipated to result in significant difference in the benthic community and associated fluxes. In particular, benthic releases of nutrients may decrease as effluent permit levels were decreased. In HSPF, such decreases must be accounted for manually. For Upgrades 1 and 2, adjustments were made to benthic parameters using Equation 2 below,

$$NBP_n = \left(PSL_n / PSL_i \right) NBP_i \qquad \text{Equation 2}$$

where NBP_i is the initial calibrated value of the parameter, PSL_i is the PS loading under baseline conditions, PSL_n is the PS loading under the scenario in question and NBP_n is the estimated appropriate adjusted value of the parameter used in the scenario analysis. Four benthic parameters were adjusted in this manner (1) the benthal release rate of ammonia under aerobic conditions, (2) the benthal release rate of ammonia under anaerobic conditions, (3) the benthal release rate of ortho-phosphorus under aerobic conditions, and (3) the benthal release rate of ortho-phosphorus under anaerobic conditions.These parameter adjustments were applied solely to the main stem reaches of the model. As the tributary reaches are only affected by changes to smaller WWTPs or NPS loadings, it was felt that they should be left at the values chosen during the calibration process. The resulting benthic release rate parameter values used in the HSPF model for each of the scenarios are presented in Table 6.

Table 6: Benthic Release of Nutrient Parameters as Adjusted for the various Loading Scenarios

Scenario	Aerobic NH4 mg/m²·hr	Anaerobic NH4 mg/m²·hr	Aerobic PO4 mg/m²·hr	Anaerobic PO4 mg/m²·hr
Current	1.50	1.50	0.020	0.20
UP1	1.11	1.11	0.009	0.09
UP2	0.92	0.92	0.006	0.06
UP1noUB	0.42	0.42	0.004	0.04
Current DF	2.04	2.04	0.031	0.31
UP1DF	1.50	1.50	0.011	0.11
UP2DF	1.16	1.16	0.007	0.07
UP1DFnoUB	0.60	0.60	0.005	0.05

4 Evaluation of Water Quality and Loading Improvements

Nutrient inputs from external sources were determined and compared for the studied scenarios both over the simulation period and on an annual basis. Several techniques were used to evaluate anticipated improvements in in-stream water quality due to WWTP upgrades. These included along stream plots of average TN and TP concentrations as well as concentration cumulative frequency duration curves for select reaches along the mainstem. Load reductions to Narragansett Bay were also examined. Results are presented for TN, TP, DO and Chl-a.

4.1 Nutrient Inputs over the Simulation Period

Total nitrogen and total phosphorus loads to the river from the UBWPAD and Woonsocket WWTP were calculated for the two flow regime sets and scenarios. These results are presented in Table 7 for TN and in Table 8 for TP. In each table, columns on the left represent the loads under the various scenarios based on actual flows while columns on the right represent the maximum potential loads from UBWPAD and Woonsocket, assuming they operate at their average annual daily design flow. These results are also presented graphically in Figures 1 and 2. As expected, the design flow scenario results are greater than the corresponding actual flow regime results. The largest difference between the flow regime loads occurs at the Woonsocket WWTP for the Current scenario. In this instance, the design flow TP load at Woonsocket is actually larger than the UBWPAD load. The underlying cause of the doubling in load over current conditions is the average annual design, which is more than double the observed annual average flow. UBWPAD, Woonsocket, and the resulting total point source loads increase by 123%, 220%, and 136%, respectively, for TN and by 124%, 218%, and 153% respectively, for TP when design flow conditions are applied.

Table 7: Point source TN Load (10^6 kg) over simulation period, by scenario

WWTP	Actual Flow Regime: Current	UP1	UP2	ZeroUB	Design Flow Regime: Current	UP1	UP2	ZeroUB
UBWPAD	6.26	4.61	3.63	0.00	7.70	5.97	4.50	0.00
Woonsocket	1.84	0.91	0.58	0.91	4.04	2.12	1.31	2.12
Other WWTPs	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
TOTAL	10.00	7.44	6.13	2.83	13.70	10.00	7.73	4.05

Table 8: Point source TP load (10^3 kg) over simulation period, by scenario

WWTP	Actual Flow Regime: Current	UP1	UP2	ZeroUB	Design Flow Regime: Current	UP1	UP2	ZeroUB
UBWPAD	765	355	185	0	946	448	233	0
Woonsocket	512	68.4	36.8	68.4	1120	159	81.1	159
Other WWTPs	218	218	218	218	218	218	218	218
TOTAL	1495	641	440	286	2284	825	532	377

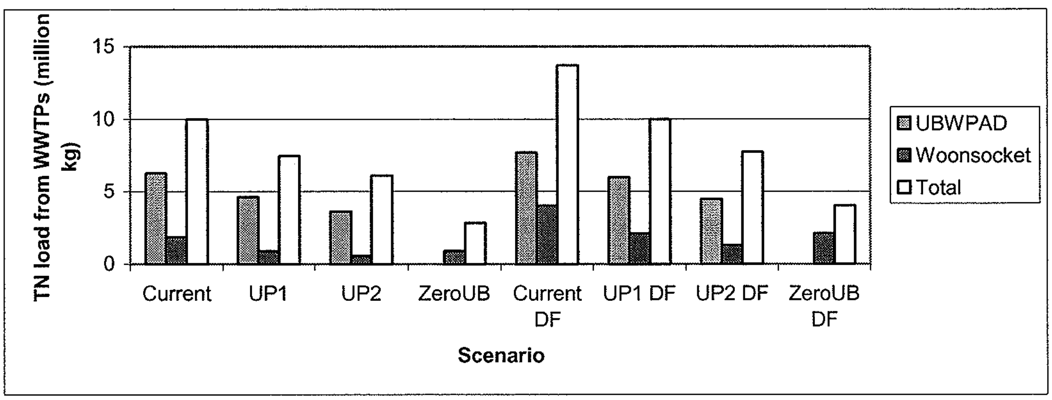

Figure 1: Point source TN load (10^3 kg) over simulation period

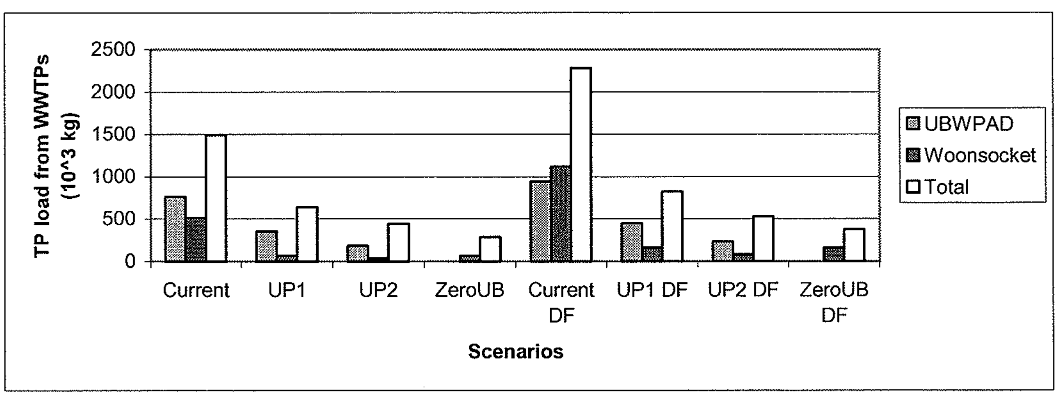

Figure 2: Point source TP load (10^3 kg) over simulation period

It is evident from Figures 1 and 2 that point source loads continue to decrease as more stringent effluent standards are promulgated under both flow regimes. The decreases in point source loads over the simulation period were also compared on a percent basis, as presented in Tables 9 and 10 for TN and TP, respectively, under the actual flow regime. When design flow conditions are applied, the relative percents change slightly, as presented in Tables 11 and 12. In these tables, the current scenario is used as the reference condition and is thus always 100%. For the ZeroUB scenario, load is 0% of the current load because the effluent has been replaced by nutrient free water. UP1 and UP2 are always a fraction of the load under the current scenario.

Based on analysis of the WWTP facility input data under the various scenarios under the actual flow regime, TN loads will be reduced by approximately 25% at UBWPAD as the facilities for the 2001 NPDES limits come on-line and by an additional 16%, relative to current conditions, as the 2008 NPDES limits are applied. Upgrade 2 results in a 22% reduction of the UBWPAD Upgrade 1 TN loads over the simulation period (not shown in a table). The numbers differ slightly when the design flow conditions are considered, with load reductions of approximately 20% at UBWPAD as the facility implements the 2001 NPDES limits and another 20%, relative to current conditions, as the 2008 NPDES limits are applied. Upgrade 2 translates into a 25% reduction relative to the Upgrade 1 TN load. Point source load reductions for TP are greater on a percent basis. TP loads will be reduced by approximately 54% at UBWPAD as the facilities for the 2001 NPDES limits come on-line and by an additional 22%, relative to current conditions, as the 2008 NPDES limits are applied. Upgrade 2 results in a 52% reduction of the UBWPAD TP loads over the simulation period (not shown in table). Percent reductions for the design flow regime are comparable. Differences between the actual and design flow regime load estimates over the simulation period decrease as more stringent effluent limits are applied.

Table 9: Percent of current scenario TN load under the actual flow regime

	Actual Flow Regime			
Point Source	**Current**	**UP1**	**UP2**	**ZeroUB**
UBWPAD	100 %	74 %	58 %	0 %
Woonsocket	100 %	49 %	32 %	49 %
TOTAL	100 %	74 %	61 %	28 %

Table 10: Percent of current scenario TP load under the actual flow regime

	Actual Flow Regime			
Point Source	**Current**	**UP1**	**UP2**	**ZeroUB**
UBWPAD	100 %	46 %	24 %	0 %
Woonsocket	100 %	13 %	7 %	13 %
TOTAL	100 %	43 %	29 %	19 %

Table 11: Percent of current scenario TN load under the design flow regime

	Design Flow Regime			
Point Source	**Current DF**	**UP1 DF**	**UP2 DF**	**ZeroUB DF**
UBWPAD	100 %	78 %	58 %	0 %
Woonsocket	100 %	53 %	32 %	53 %
TOTAL	100 %	73 %	57 %	30 %

Table 12: Percent of current scenario TP load under the design flow regime

	Design Flow Regime			
Point Source	**Current DF**	**UP1 DF**	**UP2 DF**	**ZeroUB DF**
UBWPAD	100 %	47 %	25 %	0 %
Woonsocket	100 %	14 %	7 %	14 %
TOTAL	100 %	36 %	23 %	17 %

4.2 Average Annual Nutrient Inputs

Nutrient inputs to the river from all point sources for all scenarios were compared against nonpoint sources (NPSs) on an average annual basis, Figures 3 and 4. Only external loads (e.g., inputs from the watershed to the water column) are accounted for in these NPS numbers. Exchanges between the river bed and water column are not included. The results illustrate the impacts of each scenario on average annual nutrient load as well as the change in magnitude of PS loads in comparison to NPS load among the various loading scenarios. For comparison purposes, one additional scenario has been added where external NPS load is reduced by twenty percent. The solid bars represent the average annual load observed for each scenario across the simulation period. The high-low lines represent the maximum and minimum, respectively, annual load observed during 1996 to 2007 for each scenario. Additional plot showing the relative contributions of PS and external NPS loads on an annual basis for the actual flow regime scenarios are provided in Appendix A.

Total nitrogen external load comparisons for the scenarios are shown in Figure 3. Scenario results for both flow regimes are presented on the same figure, with the results scenarios coupled such that the design flow results for a given scenario, denoted with a "DF", appear to the left of the comparable actual flow results. As also noted for total load over the simulation period, on an annual basis design flow regime loads are higher than the comparable actual flow regime load. However, the inter-annual variation in TN load is small for the design flow scenarios in comparison to the actual flow scenarios. The larger design flows tend to reduce the importance of variations in effluent concentrations. Inter-annual variation is also reduced as effluent limits become more stringent. Smaller annual variation occurs as effluent limits become more stringent because the WWTPs are assumed to operate at the limit more often than below the limit to provide a conservative estimate.

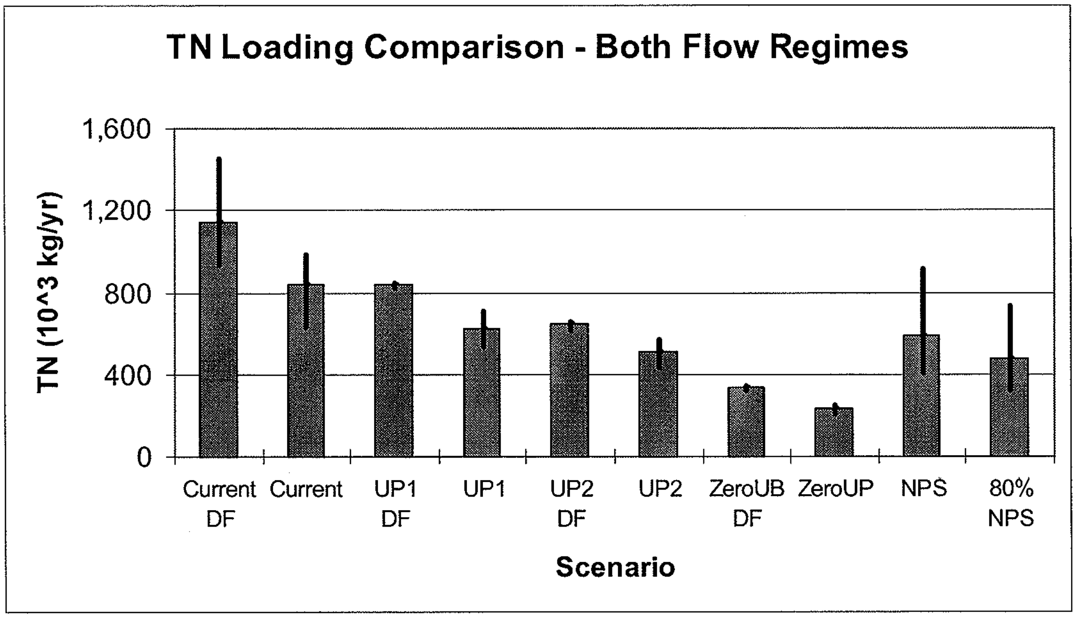

Figure 3: Annual TN external load comparison for studied scenarios

It is apparent in both flow regimes that there is a decrease, approximately 25% on average, in annual TN load to the river between the Current and Upgrade 1 scenarios. In both flow regimes, there is an additional, but smaller, decrease in annual TN load between the Upgrade 1 and Upgrade 2. In the actual flow regime set, the Upgrade 1 reduces PS nitrogen loads to the range of annual NPS loadings. This is even more apparent in the Appendix A plots, which also show that under the UP2 scenario, NPS are typically (9 out of 12 years) greater than PS loads to the river. However, under the design flow regime, it is not until the WWTPs are subjected to the Upgrade 2 effluent limits that PS nitrogen loadings are on par with the NPS nitrogen loads. This shift is likely due in part to the large increase in the flow, and thus the load, from Woonsocket under the design flow regime.

Total phosphorus external load comparisons for the scenarios are shown in Figure 4. Scenario results for both flow regimes are presented on the same figure, with the results scenarios coupled such that the design flow results for a given scenario, denoted with a "DF", appear to the left of the comparable actual flow results. As also noted for total load over the simulation period, on an annual basis design flow regime TP loads are higher then the comparable actual flow regime load. The largest difference between the two regimes occurs for the current scenario. As also noted for TN loads, the range of observed TP annual load is smaller for the design flow set scenarios. In general, inter-annual variability is less for TP than for TN.

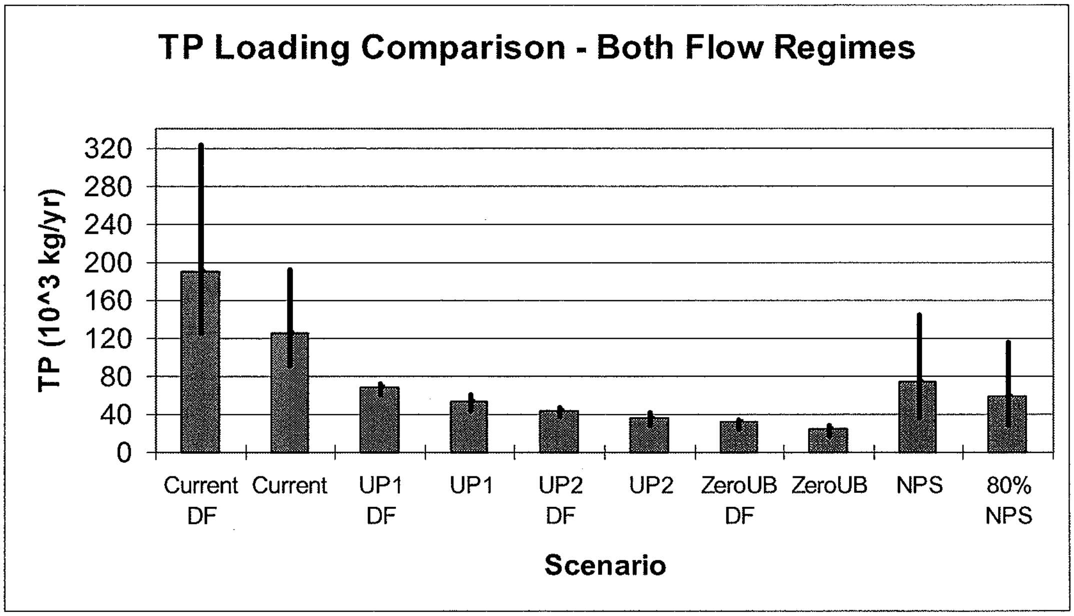

Figure 4: Annual TP external load comparison for studied scenarios

It is apparent in both flow regimes that there is a decrease, approximately 60% on average, in annual TP load to the river between the Current and Upgrade 1 scenarios. In both flow regimes, there is an additional, but smaller, decrease in annual TP load between the Upgrade 1 and Upgrade 2. This decrease is on the order of 30% of the UP1 load, equivalent to an additional 13% reduction of the Current scenario load. Implementation of Upgrade 1 results in the reduction of average annual phosphorus PS loads to the same level as external phosphorus NPS loads in both the actual and design flow analysis sets. The actual flow regime UP1 scenario is essentially equivalent to 80% of the NPS load. This is even more apparent in the Appendix A figures.

4.3 Along Stream Average Nutrient Concentrations

Average water quality constituent concentrations were calculated over the simulation period at segments along the main stem of the river for the scenarios and both flow regimes. In addition, average summer (July – September) concentrations were calculated. It is important to recall that the basis for these calculations were the model outputs of ***average daily concentrations***. Only the average summer concentrations under actual flow conditions are presented in the following section. Average summer concentrations under design flow conditions are presented in Appendix B, average annual actual flow regime results are presented in Appendix C, and average annual design flow regime results are presented in Appendix D. Results are presented and discussed for TN, TP, dissolved oxygen (DO), and Chlorophyll a (Chl-a) concentrations. As noted in the Blackstone River HSPF Water Quality Model Calibration Report (UMass and CDM, August 2008), model calibration of DO and Chl-a will be undergoing further refinement; the results for these parameters should thus be considered as interim. However, although model calibration refinement may alter specific values, trends and relative behavior under the studied scenarios are anticipated to be similar. In addition, averages were only calculated at every

10 reach segments, starting with the basin outlet (river mile 0) and continuing upstream. The average constituent concentrations were calculated at the MA/RI state border as well. In addition, it is important to recall that for concentration results, daily average concentration model results were used as the basis for calculation. A list of dams, impoundments, hydroelectric plants, and WWTPs on the mainstem river is provided in Table 13 along with their associated river mile relative to the outlet. The Blackstone River HSPF Model Schematic is presented in Appendix G for reference.

Table 13: List of dams, impoundments, hydroelectric plants and WWTPs on the mainstem Blackstone River by rivermile, relative to the outlet

Rivermile	Description	Rivermile	Description
44.4	UBWPAD	22	Uxbridge WWTP
43.9	McCracken Rd Dam	17.8	Tupperware Dam
41	Millbury Electric Dam	16.5	Blackstone Dam
39.8	Singing Dam	15.5	Thundermist Hydro Dam
39.2	Wilkinsonville Dam	12.8	Hamlet Ave Dam
38.7	Saundersville Dam	12.4	Woonsocket WWTP
36.5	Fisherville Dam	9.9	Manville Dam
35.6	Farnumsville Hydro Dam	8.2	Albion Dam
35.4	Grafton WWTP	6.8	Ashton Dam
31.9	Riverdale Hydro Dam	4.1	Lonsdale Dam
29.2	Northbridge WWTP	2	Central Falls Dam
27.8	Rice City Pond Dam	0.8	Pawtucket Hydro Dam
		0	Slater's Mill Dam

Along Stream Average Summer Nutrient Concentration Results

The average nutrient concentrations during summer months over the simulation period at select along stream locations are presented on Figures 5 for TN and on Figure 6 for TP. Average summer design flow, average annual actual flow regime, and average annual design flow regime results are presented in the appendixes. The impact of both UBWPAD (mile marker 44.4) and Woonsocket WWTPs (mile marker 12.4) is shown by spikes in concentration downstream of those locations for both TN and TP. The ZeroUB scenario actually shows a dilution effect below UBWPAD from the addition of nutrient free water to the system. Both TN and TP exhibit a generally downward trend in concentration as you travel from upstream to downstream.

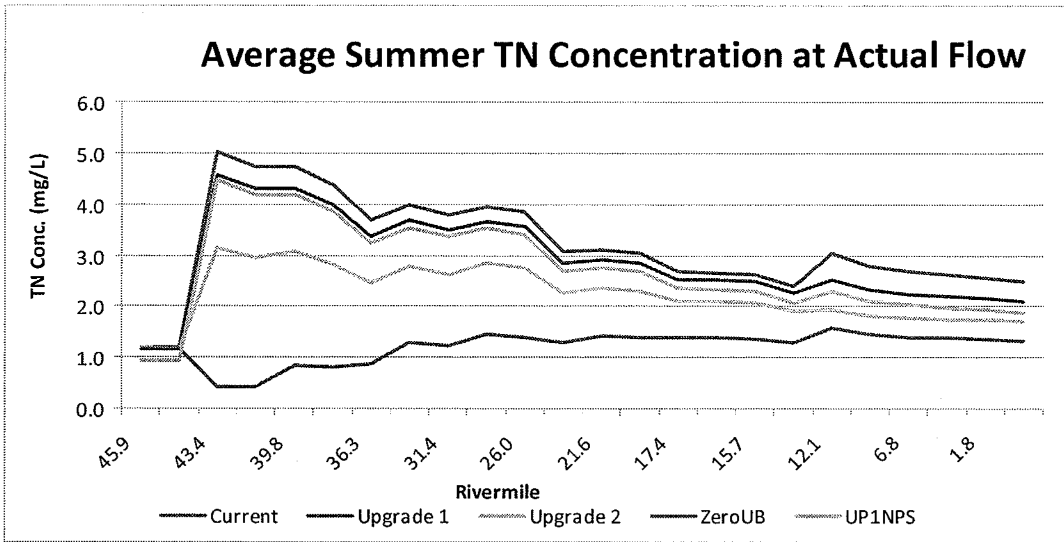

Figure 5: Along stream average summer TN concentrations for the actual flow regime

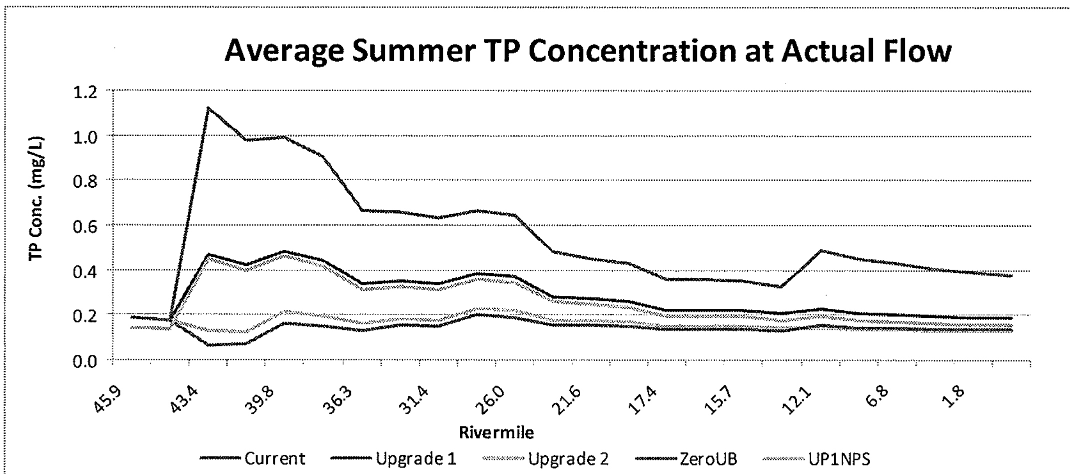

Figure 6: Along stream average summer TP concentration for the actual flow regime

Average summer TN concentrations remain above 2.0 mg/L along the length of the river under the UP1 scenario despite the approximately 25% reduction in point source loads. The largest reductions in average summer TN concentrations occur immediately downstream of UBWPAD and Woonsocket WWTP, where concentrations are reduced by about 0.5 mg/L. Concentrations in the river above the Uxbridge WWTP (river mile 22) typically remain above 3.0 mg/L TN under the UP1 scenario. As the more stringent UP2 scenario effluent standards are applied, summer average concentrations tend to fall to below 3.0 mg/L along the length of the river. In the Rhode Island portion of the river (border at river mile 16.6), concentrations fall below 2.0 mg/L for this scenario, with minimum concentrations at the outlet of about 1.7 mg/L. Average TN concentrations over the year, Appendix C, tend to be slightly lower. Even under the ZeroUB scenario, TN concentrations along the river remain about 1.25 mg/L. In the upper portions of the river, in-stream concentrations under the UP1NPS scenario are similar to those under the UP1 scenario as the magnitude of NPS reductions is relatively small at this point. However, concentrations under the UP1NPS scenario approach those under the UP2 scenario in the downstream reaches of the river. Reductions of nonpoint source of TN could be an effective mechanism for water quality improvement, particularly for downstream reaches. More targeted reductions may be more effective, although these have not been studied to date.

Average summer TP concentrations remain above 0.1 mg/L along the length of the river under all scenarios despite the approximately 55% reduction in point source loads for UP1 and 70% reduction in point source loads for UP2. The largest reductions in average summer TP concentrations occur immediately downstream of UBWPAD, were concentrations are reduced by more than half. Concentrations in the river above the Uxbridge WWTP (river mile 22) remain above 0.3 mg/L TP under the UP1 scenario. As the more stringent UP2 scenario effluent standards are applied, summer average concentrations actually show a dilution affect immediately downstream of the UPBWAD. In-stream results for the UP2 scenario are equivalent to the ZeroUB scenario for the Rhode Island portions of the river. In addition, in the Rhode Island portion of the river (below mile 16.6), in-stream concentrations predicted under the three potential future scenarios tend to converge. The average summer TP concentrations observed at the outlet for UP1 is 0.19 mg/L TP while for UP2 it is 0.13 mg/L. Average annual concentration values tend to be slightly larger, with the exception of the UP2 scenario immediately downstream of the UBWPAD. This is due to the seasonal TP effluent concentrations mandated by the 2008 NPDES permit.

Along stream TN and TP seasonal average daily load plots (not presented), show that the average *daily* TN loads at the basin outlet over the simulation period range from 2500 to 4000 kg/day in the actual flow set scenarios and from 2500 to 5000 kg/day in the design flow set scenarios. Average *daily* TP loads at the basin outlet range from 200 to 500 kg/day in the actual flow set scenarios and from 200 to 650 kg/day in the design flow set scenarios.

Along Stream Dissolved Oxygen Concentration Results

The average DO concentrations during summer months over the simulation period at select along stream locations are presented on Figure 7. Recall that these values are calculated based on the model output of daily average DO concentrations. Average summer design flow, average annual actual flow regime, and average annual design flow regime results are presented in the appendixes. The impact of both UBWPAD (mile marker 44.4) and Woonsocket WWTPs (mile marker 12.4) is shown by increases in average daily DO downstream of those locations.

When considered over the summer season, average daily DO remains relatively constant along the river, remaining above 8.0 mg/L, and increase slightly in the Rhode Island portions of the river. Increases here, particularly immediately above river mile 6.8, are likely caused by the increase in algal activity in the region, as shown in the average Chl-a plots presented below. Average daily DO values of 12 mg/L (recall these are based on average daily values, not average maximum values) seem high and are indicative that further refinement of the DO calibration may be necessary. Concerns with the current DO calibration are detailed in the Blackstone River HSPF Water Quality Model Calibration Report (UMass and CDM, August 2008). While refinements to the model calibration may alter specific values, relative behavior under the studied scenarios is anticipated to remain similar. In the Massachusetts portions of the river, there is little variability in average summer DO concentrations between the scenarios studied. The average summer DO concentrations (daily average) observed at the outlet range from 8.5 to 9.5 mg/L. Average DO levels over the study period remain above 9 mg/L (see appendices).

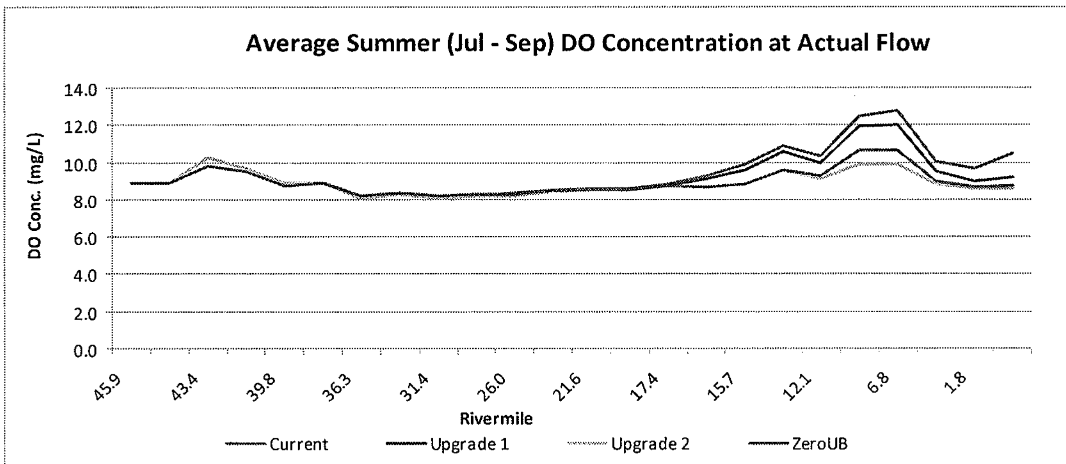

Figure 7: Along stream average summer DO concentrations for the actual flow regime

Along Stream Chlorophyll a Concentration Results

Average Chl-a concentrations during summer months over the simulation period at select along stream locations are presented on Figure 8. In addition, maximum Chl-a concentrations occurring during the summer months are presented on Figure 9. Average summer design flow, average annual actual flow regime, and average annual design flow regime results are presented in the appendixes. The values presented are calculated based on daily average concentrations. As noted in the Blackstone River HSPF Water Quality Model Calibration Report (UMass and CDM, August 2008), further refinement of the model calibration for Chl-a is planned; the results presented here should thus be considered as interim. However, although model calibration refinement may alter specific values, trends and relative behavior under the studied scenarios are anticipated to be similar.

Average summer Chl-a remains low, typically less than 5 μg/L, upstream of Fisherville Pond. Downstream of this point, Chl-a values increase steadily along the river. Levels increase more steeply along the Rhode Island portion of the river, below river mile 16.6, and are typically above 20 μg/L. The increased levels of Chl-a are likely related to the presence of large dams and impoundments in the RI section of the river. Large differences in average summer Chl-a concentrations between the scenarios also do not appear until the MA RI border and, in particular, below the Woonsocket WWTP (river mile 12.4). Average summer Chl-a concentrations drop from over 60 µg/L at the outlet under current conditions to approximately 45 µg/L under UP1 to approximately 35 µg/L under UP2.

Maximum summertime Chl-a concentrations follow similar along-stream trends, but sharp increasing trends occur further upstream, below the Riverdale Hydroelectric dam. Under current conditions in the river, model results suggest concentrations as high as 160µg/L may occur during the summer. Available data support the existence of high Chl-a values in these reaches; the highest measured chlorophyll value in the river is 137µg/L and was measured at Lonsdale Avenue (Reach 218), near the river outlet (note that this reach is not represented in the Figure 8, which summarizes the average conditions every 10 reaches, thus skipping reach 218). However, as detailed in the Blackstone River HSPF Water Quality Model Calibration Report (UMass and CDM, 2008), the model is not always able to simulate rapid changes in measured values along stream, and thus further calibration refinement is warranted. As more stringent nutrient effluent limits are applied, maximum levels along the stream drop to approximately 120 µg/L for UP1 and 90 µg/L for UP2. Maximum Chl-a concentrations tend to decrease in the downstream direction below river mile 26 for the UP2 scenario. Under the UP2 scenario, maximum Chl-a summer concentrations predicted at the outlet are comparable to the ZeroUB scenario value of about 60 µg/L.

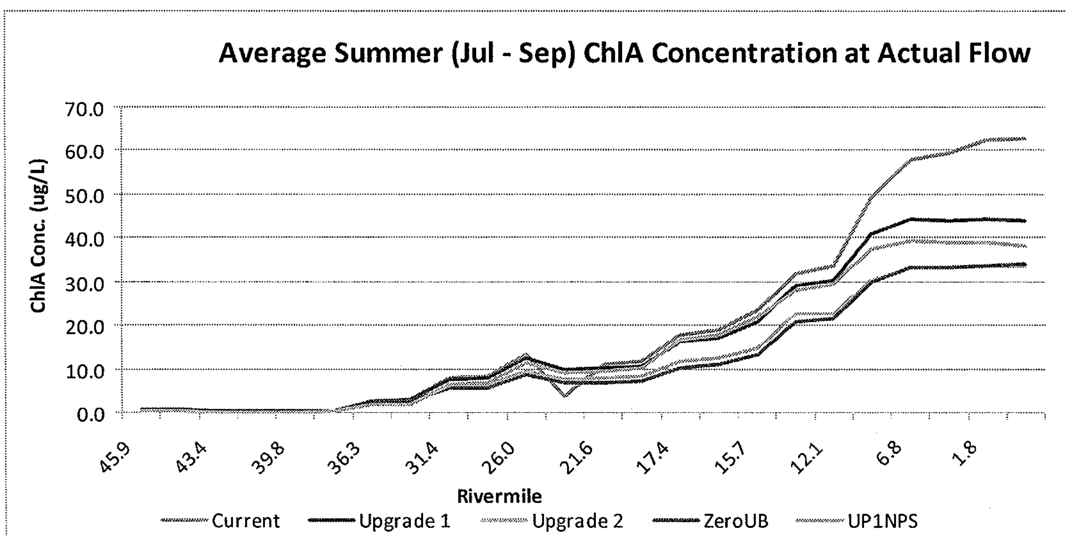

Figure 8: Along stream average summer Chl-a concentrations for the actual flow regime