7. Water Quality Improvements Resulting from Treatment and Non Treatment Alternatives

7.1. Introduction

The modeling performed as part of the Jamaica Bay Eutrophication Study provided a preliminary analysis of remediation alternatives for nitrogen control in Jamaica Bay. These analyses were completed using a high nitrogen loading to the bay, and were completed before the Nitrogen Order-on-Consent was executed by the NYSDEC and the Department.

Additional water quality model projection runs were completed for the Comprehensive Jamaica Bay Report for a more thorough analysis of abatement alternatives, which could then be used to develop cost-attainment curves. These curves can be used to find the "knee-of-the-curve" alternative that would be the most cost-effective way to reduce nitrogen loads and improve water quality in the bay.

The modeling projection runs that were completed included treatment and non-treatment alternatives and combinations of both. Treatment alternatives included various BNR levels of treatment and combinations of BNR levels of treatment at the four Jamaica Bay WPCPs. Non-treatment alternatives included outfall relocation, bathymetric recontouring, and aeration. Combinations of treatment and non-treatment alternatives were also modeled.

Modeling and remediation alternative evaluation efforts took place over a period of several years. Initial modeling efforts were conducted with what was believed to be the best available information at the time. During the coarse of the project, new information (with respect to WPCP effluent discharge volumes and locations, and wastewater effluent concentrations), became available that might have altered the way the modeling would have been conducted had the information been known at the beginning of the project. However, due to the amount of work that had been completed at the point when the new information became available, it was decided to continue working with the older information to be consistent with the previous work. It should be noted that as this new information became available, sensitivity analyses were performed which indicated that use of the new information would have resulted in only small changes to the model results.

The first issue deals with the flow distribution from the existing Jamaica WPCP outfalls. During the 1995-96 calibration period, eighty percent of the Jamaica WPCP effluent was discharged into Bergen Basin with the remainder discharged into Grassy Bay. Due to changes in plant operations in 2000, the majority of the Jamaica WPCP effluent currently discharges into Grassy Bay. The outfall location was not changed to the current location from Bergen Basin in the model for this analysis. A sensitivity model run was completed with the outfall in the post-calibration location, and only minor differences in the modeling results were observed. The sensitivity analysis was based upon Level 2 BNR treatment at the Jamaica WPCP. The largest difference was observed in Grassy Bay during the summer where the summer average attainment of the current DO standard changed from 46.3 percent with the discharge in Bergen Basin to 47.0 percent with the discharge into Grassy Bay. Annual and bay-wide differences were smaller.

The second issue deals with the slight differences in the estimated model nitrogen load developed from two separate BioWin models being run. The Department ran the baseline conditions, while Hazen and Sawyer ran all of the BNR alternatives for the Comprehensive Jamaica Bay Report. At the time modeling activities were initiated, the Department loading estimates were the best available information. As the work proceeded, Hazen and Sawyer developed the loading estimates for the BNR projections based upon established AWT modeling criteria. The Department work based on 1999 loadings was conducted approximately one year before the Hazen and Sawyer work that was based on loading from the period 1998-2002. This resulted in a slightly different distribution of nitrogen loading between the WPCPs for the baseline and BNR runs.

The impacts of these issues change the results in DO compliance by a few percentage points. These changes are well within the model's ability to accurately calculate percent attainment. Since the model projection runs were performed in a consistent manner, the comparison between the results of the projection runs is valid, and can be used to evaluate alternatives for the Comprehensive Jamaica Bay Report.

7.2. Water Quality Modeling Analysis of Alternatives

7.2.1. Baseline

The establishment of the modeling baseline was discussed in Section 3.0. This section will present the comparison of the baseline to the various alternatives that were analyzed. Figures will be presented for the summer average DIN concentration, the annual and summer percent of time the DO concentration is greater than the NYSDEC DO water quality standard, and the estimated annual chlorophyll-a concentrations. It should be understood, that the model does not estimate the exact percentage or concentrations of future conditions, and should be used for comparison of alternatives against one another.

The next subsections will present a comparison of the three conditions that were considered for the baseline. The subsections that follow will present comparisons to the chosen baseline.

7.2.1.1. Dissolved Inorganic Nitrogen

High nitrogen loading to the bay is one of the drivers of poor water quality within the bay. The Michaelis number for nitrogen is the dissolved inorganic nitrogen (DIN) concentration at which the maximum possible algal growth rate is decreased by half due to nutrient limitation. The value assigned to this number is a concentration of 10 ug/L. At a concentration of approximately 40 ug/L, the maximum growth rate is reduced by 20 percent and algae begin to become nutrient limited. Figure 7-1 presents the summer surface DIN concentrations for the baseline condition. Most of the central, northern, and eastern portions of the bay have a summer average DIN concentration of greater than 700 ug/L. While the permit conditions (baseline), existing conditions and 1995-96 conditions have varying annual average DIN conditions, they all have concentrations well above what would limit algal growth. It is apparent that significant reductions in the nitrogen load are necessary if the goal is to limit algal growth in Jamaica Bay.

7.2.1.2. Dissolved Oxygen

Figure 7-2 presents a comparison between the existing conditions, permit loading, and 1995-96 loading alternatives for annual percent of time the DO concentrations are greater than the NYSDEC DO standards in the bottom layer, where the concentrations tend to be the lowest. The permit conditions baseline shows 70 to 75 percent of the DO concentrations greater than 5.0 mg/L in Grassy Bay, 85 to 95 percent greater than the standard in Grassy Hassock Channel, and generally 95 percent or greater in the remaining portion of the open waters of Jamaica Bay. In the original calibration of the model, DO concentrations were overestimated in the North Channel. Therefore, it is likely that DO concentrations are overestimated in all of the alternatives in this area. Based upon a sensitivity analysis, it is estimated that the annual baywide DO water quality standard attainment is overestimated by 0.6 percent (95.9 versus 95.3) and the summer DO water quality standard attainment is overestimated by 1.9 percent (85.5 versus 83.6) under baseline conditions.

The existing condition alternative shows a slightly higher percentage of DO concentrations greater than the water quality standard in the northwestern portion of Grassy Bay then the baseline, but the remaining areas are fairly similar between the two alternatives. With the 1995-96 loadings, areas in Grassy Bay, Grass Hassock Channel and the western portions of the bay have a lower percentage of DO concentrations less than the standard when compared to the baseline. The results are fairly similar between the alternatives because nitrogen is in such excess that even large changes in nitrogen loading do not result in large differences between the alternatives.

The percentage of bottom DO concentrations greater then the standard on a summer basis for these alternatives is presented in Figure 7-3. The differences between the three alternatives on a summer basis are similar to the differences on an annual basis; only the percentages are lower. The majority of DO concentrations calculated to be less than the standards occur during the summer as shown by the low percentages in Grassy Bay.

7.2.1.3. Chlorophyll-a

The high nitrogen loading also leads to high chlorophyll-a concentrations. Figure 7-4 presents the computed annual average surface chlorophyll-a concentrations for the baseline as well as the existing conditions and 1995-96 conditions. For the baseline, areas in the north and northeast of Jamaica Bay have annual average chlorophyll-a concentrations greater than 30 ug/L. These concentrations decrease in the direction of the Rockaway Inlet where the annual average chlorophyll-a concentration is closer to 20 ug/L. As it is generally recognized that a concentration of 10 ug/L indicates a eutrophic system, Jamaica Bay is highly eutrophic.

7.2.2. Treatment Alternatives

The WPCPs are the largest contributors of nitrogen to the bay. An obvious way to reduce nitrogen loading to the bay is to provide treatment at the WPCPs. The decision as to what level of treatment is required could be based on a cost-attainment analysis. These model runs were performed to estimate the attainment portion of the analysis.

7.2.2.1. Treatment Alternative Descriptions

Several levels of nitrogen removal were applied to each of the WPCPs for the modeling evaluation. These include Level 1 BNR, which is defined as a low level of nitrogen removal. Additional nitrogen removal is achieved through Level 2 and Level 3 BNR. The highest level of nitrogen removal in this modeling analysis is limit of technology (LOT) BNR.

Additional specific nitrogen removal strategies were also evaluated. Currently, a contract (Contract 12) is in effect for upgrades to the 26th Ward WPCP. Contract 12 at the 26th Ward WPCP is a plant stabilization contract that will provide added reliability for the facility to maintain operation of step-feed BNR with separate centrate treatment. These upgrades are currently under construction. For some alternatives "Contract 12" BNR was applied to the 26th Ward WPCP. Contract 12 BNR provides similar removal levels as Level 2 BNR. At the Jamaica WPCP, different levels of nitrification were applied. "Alternative A" included totally oxic nitrification while "Alternative B" involved a partially oxic system.

Although previously defined, a synopsis of each of the alternatives is provided below.

Level 1 BNR

The effluent TN ranges from 11.5 to 16.0 mg/L depending on the WPCP. The total loading to the bay from the four WPCPs is 34,800 lb/day. For this alternative, Level 1 BNR is applied to all four WPCPs.

Level 2 BNR

The effluent TN ranges from 8.5 to 12.6 mg/L depending on the WPCP. The total loading to the bay from the four WPCPs is 27,600 lb/day. For this alternative, Level 2 BNR is applied to all four WPCPs.

Level 3 BNR

The effluent TN ranges from 5.3 to 8.5 mg/L depending on the WPCP. The total loading to the bay from the four WPCPs is 18,300 lb/day. For this alternative, Level 3 BNR is applied to all four WPCPs.

Limit of Technology BNR

For LOT BNR, the effluent TN ranges from 4.1 to 4.4 mg/L depending on the WPCP. Two alternatives were modeled. For one alternative, LOT BNR is applied to all four WPCPs. The total loading to the bay from the four WPCPs is 10,800 lb/day. The second alternative includes LOT BNR at only Jamaica and 26th Ward WPCPs.

Contract 12 + Alternative A

In this alternative, nitrification occurring within the aeration tank at the Jamaica WPCP is under totally oxic conditions. In this alternative all of the ammonia from the Jamaica WPCP is converted to

nitrate with little nitrogen removal. Upgrades to the 26th Ward WPCP are applied according to the current Contract 12 upgrades. The TN load for this alternative is 41,700 lb/day.

Contract 12 + Alternative B

In this alternative the Jamaica WPCP approaches Level 2 removals with nitrification under partially oxic conditions. In this alternative some of the ammonia from the Jamaica WPCP is converted to nitrate and there is some TN removal. Upgrades to the 26th Ward WPCP are applied according to the current contract 12 upgrades. The TN load for this alternative is 35,400 lb/day.

The nitrogen loading for the model runs described above were calculated by using concentrations estimated by the BioWin model runs performed by Hazen and Sawyer with the lone exception of the baseline that was run by the Department. The nitrogen concentrations used for each run are presented in Tables 7-1 (winter) and 7-2 (summer) and the resulting loads are presented in Table 7-3.

7.2.2.2. Dissolved Inorganic Nitrogen

Figure 7-5 compares the baseline summer average DIN concentrations with Level 1, 2, and 3 BNR annual average DIN concentrations. It is apparent that with each successive increase in the level of treatment, the DIN concentration in Jamaica Bay is reduced. At Level 3 BNR, the nitrogen loading to Jamaica Bay is decreased by more than half. The DIN concentrations calculated for this alternative are nearly half of the baseline. However, the resulting in-bay DIN concentrations that are computed are still well above the 40 ug/L level that would begin to significantly limit phytoplankton growth.

Additional nitrogen reduction alternatives are compared to the baseline in Figure 7-6. Nitrification Alternative B at the Jamaica WPCP reduces DIN concentrations to levels slightly below Level 2 BNR. LOT BNR at the 26th Ward and Jamaica WPCPs reduces the average summer DIN concentration to between 200 and 300 ug/L. LOT BNR at all four WPCPs reduces the DIN concentrations in Jamaica Bay even further to between 100 and 300 ug/L. These levels are still well above the 40 ug/L that would begin to limit phytoplankton growth.

The DIN figures show that most BNR alternatives do not reduce DIN levels to a concentration that would limit phytoplankton growth. However, some small improvements in DO standard attainment are computed with BNR treatment. These improvements do not appear to be caused by changes in phytoplankton growth, but are due to reductions in dissolved oxygen demand associated with reductions in nitrification that occurs in the water column due to reduced ammonia loading to the bay. The nitrification process involves the conversion of ammonia to nitrite and nitrate by bacteria. This process requires oxygen and thus is an oxygen "sink" in the water column. As ammonia concentrations are reduced the amount of nitrification in the bay is reduced as well. The reduction of ammonia loading to the bay results in some improvement in oxygen levels in the bay.

7.2.2.3. Dissolved Oxygen

A comparison of annual percent of bottom DO concentrations greater than the standards between the baseline and three nitrogen removal alternatives is presented in Figure 7-7. The results from the various BNR alternatives show an improvement of approximately five percent in DO concentrations

greater than the standard on an annual basis. This small improvement occurs despite the fact that nitrogen loads are decreased by more than half in the case of Level 3 BNR. This occurs because nitrogen is not reduced to levels that limit algal growth. Light remains the limiting factor for algal growth. As discussed in section 2.3.3, nitrogen loading would have to be reduced by up to a factor of ten before nitrogen becomes the limiting factor for phytoplankton growth.

Additional nitrogen removal alternatives are presented in Figure 7-8. The alternative with Contract 12 upgrades to the 26th Ward WPCP and partial nitrification at the Jamaica WPCP produces similar results to the previous BNR alternatives presented. Upgrading to LOT provides some additional improvement in DO concentrations. Areas in Grassy Bay show 80 to 85 percent of the annual DO concentrations greater than the standard. Upgrading to LOT at all four WPCPs does not show much more improvement than with upgrading only the 26th Ward and Jamaica WPCPs. This is due primarily to the locations of the four plants in the bay. The 26th Ward and Jamaica plants are in areas of the bay where tidal flushing is not as good as the western and southern portions of the bay where the Coney Island and Rockaway WPCPs are located.

Summer modeling results for the BNR alternatives shown in Figure 7-9 indicate that despite significant nitrogen load reductions, DO concentrations are greater than the standard less than 40 percent of the time during the summer in the majority of Grassy Bay. Of the alternatives presented in Figure 7-10, only the LOT alternatives begin to show improvement in summer DO concentrations. Again, the computed improvements are more related to reductions in ammonia loading than reductions in algal biomass.

7.2.2.4. Chlorophyll-a

Annual average surface chlorophyll-a modeling results for three BNR alternatives compared against the baseline are presented in Figure 7-11. Baseline conditions show chlorophyll-a concentrations in excess of 28 ug/L in the eastern half of the bay. Level 1 BNR results in only minor changes to the average chlorophyll-a concentration. Additional declines in chlorophyll-a concentrations result from Levels 2 and 3 BNR. At Level 3 BNR only Grassy Bay and a portion of the North Channel have annual average chlorophyll-a greater than 24 ug/L.

Figure 7-12 presents the results for surface annual chlorophyll-a for three additional BNR alternatives. Nitrification Alternative B results are similar to Level 2 BNR. LOT at the 26th Ward and Jamaica WPCPs reduces the annual average chlorophyll-a to less than 24 ug/L. LOT BNR at all four WPCPs reduces the surface annual average chlorophyll-a to less than 20 ug/L baywide.

Since the nitrogen figures indicate that, despite nitrogen loading reductions, DIN concentrations are not low enough to cause nutrient limitation, why would chlorophyll-a concentrations change at all? There are two answers to this question. The first is that only summer average conditions are presented. There can be periods of time when nutrient concentrations are low enough to be limiting. Nitrogen is not limiting over a longer average. The second reason is due to the way the model calculates nutrient limitation. When nitrogen is the potentially limiting nutrient, the growth rate is multiplied by the DIN concentration divided by the DIN concentration plus the Michaelis number (10 ug/L). If the DIN concentration is 800 ug/L, the growth rate is multiplied by 0.988. If the DIN concentration is 150 ug/L, the growth rate is multiplied by 0.938. Over time this can result in

different chlorophyll-a concentrations even if the DIN concentration is not technically defined as limiting.

7.2.3. Outfall Relocation

While BNR treatment is one way to reduce nitrogen loading to the bay, another effective way of reducing loading is to relocate the source to another location. The following runs estimate the benefits of outfall relocation.

7.2.3.1. Outfall Relocation Alternative Descriptions

Outfall relocation involves moving one or more outfalls either to the ocean, where they are assumed to no longer impact Jamaica Bay, or to the Rockaway Inlet. Alternatives that were examined included pumping the effluent through the outfall or using gravity flow. Below is a synopsis of the modeling alternatives that were analyzed.

Relocate Jamaica to Ocean

In this alternative the Jamaica WPCP outfall is relocated to the ocean, and 20,600 lb. TN/day are removed from Jamaica Bay. Due to its loading and existing outfall location into Grassy Bay, the Jamaica WPCP has the largest impact on bay water quality of any of the Jamaica Bay WPCPs.

Relocate Jamaica and 26th Ward to Ocean

In this alternative the Jamaica and 26th Ward WPCP outfalls are relocated to the ocean, and 26,300 lb. TN/day are removed from Jamaica Bay. Two versions of this analysis were conducted, one were the effluent is pumped and the other where the effluent flows via gravity. The 26th Ward WPCP also has a large impact on bay water quality due to its outfall location.

Relocate Jamaica, 26th Ward, and Rockaway to Ocean

In this alternative the Jamaica, 26th Ward and Rockaway WPCP outfalls are relocated to the ocean, and 29,100 lb. TN/day are removed from Jamaica Bay. Rockaway is added as the next WPCP to be removed from the bay because any outfall tunnel from the 26th Ward or Jamaica WPCPs to the ocean pass adjacent to the Rockaway WPCP.

Relocate All WPCPs to Ocean

All WPCP effluent is removed from Jamaica Bay. The Coney Island WPCP outfall is the last to be removed from the bay despite having the second largest nitrogen load to the bay. This is because the Coney Island WPCP outfall is located in the Rockaway Inlet so much of it's treated effluent is flushed out of the bay.

Relocate Jamaica and 26th Ward to Rockaway Inlet

In this alternative the Jamaica and 26th Ward WPCP outfalls are relocated to the Rockaway Inlet near the Coney Island WPCP outfall. No load is removed from the bay. The impacts of the load are

reduced due to tidal flushing and export to the Atlantic Ocean. This alternative also had pumping and gravity alternatives.

All WPCP Outfalls to Rockaway Inlet

All WPCP outfalls are relocated near the Coney Island WPCP outfall.

7.2.3.2. Dissolved Inorganic Nitrogen

A comparison between summer average DIN model results for the baseline and three outfall relocation to the ocean alternatives is presented in Figure 7-13. When the Jamaica WPCP outfall is relocated to the ocean, the DIN concentrations are dramatically reduced in Jamaica Bay, especially in Grassy Bay. The 26th Ward WPCP becomes the most obvious source of DIN in the bay. Once the 26th Ward WPCP outfall is relocated to the ocean, the DIN concentration becomes fairly uniform throughout the bay at between 100 and 200 ug/L. Removing the Rockaway WPCP outfall results in additional reductions in the calculated surface DIN concentrations, especially in Grassy Bay.

Figure 7-14 presents the surface DIN results for three additional outfall relocation alternatives. When all WPCP outfalls are relocated to the ocean, much of Grassy Bay, the North Channel, and Beach Channel have average surface DIN concentrations less than 100 ug/L. Relocating WPCP outfalls to the Rockaway Inlet rather than the ocean is also an effective way to reduce DIN concentrations in the bay, but not as effective as outfall relocation. Relocation to the inlet results in DIN concentrations on order of 50-100 ug/L greater in the inlet than outfall relocation to the ocean.

7.2.3.3. Dissolved Oxygen

Figure 7-15 presents the annual percentage of bottom DO concentrations that are greater than the standard for three alternatives for outfall relocation to the ocean. Relocating only the Jamaica WPCP to the ocean shows a greater improvement in water quality than upgrading all four WPCPs to LOT nitrogen removal. DO concentrations greater than the standard were calculated to be more than 80 percent in all open water areas of the bay.

Additional outfall relocation alternatives are presented in Figure 7-16. All outfalls to the ocean provide minor improvements over relocating just three WPCPs to the ocean. Modeling results indicate that the Coney Island WPCP does not have a significant impact on improving DO concentrations to greater than 5.0 mg/L in Jamaica Bay.

If siting an outfall in the Atlantic Ocean is difficult, it may be easier to relocate plant outfalls to the Rockaway Inlet where the Coney Island WPCP outfall is currently located. Figure 7-16 shows that relocating outfalls to the Rockaway Inlet is nearly as effective as relocating outfalls to the ocean. By moving the Jamaica and 26th Ward WPCPs to the Rockaway Inlet, only one small area has DO concentrations greater than 5.0 mg/L less than 90 percent of the time on an annual basis. Moving all four WPCP outfalls to the Rockaway Inlet results in all open water areas of the bay having DO concentrations greater than 5.0 mg/L more than 90 percent of the time.

Figures 7-17 and 7-18 present the percent bottom DO concentrations greater than the standards for the summer period for the same six outfall relocation alternatives. When relocating only the Jamaica

WPCP to the ocean, there are still some areas with less than 50 percent of the calculated concentrations greater than the standard during the summer. Relocating both the 26th Ward and Jamaica WPCPs to the ocean results in no areas having less than 60 percent of the calculated concentrations greater than 5.0 mg/L during the summer. Additional improvements are calculated for relocating three and four WPCPs to the ocean. Relocating WPCPs to the Inlet show significantly improved percentages when compared to the baseline, but slightly less than similar ocean outfall alternatives.

7.2.3.4. Chlorophyll-a

Since outfall relocation can greatly reduce the nitrogen loading, it is an effective way to reduce the chlorophyll-a concentrations in the bay. Figure 7-19 presents the annual surface chlorophyll-a results for three outfall relocation alternatives. Relocating the Jamaica WPCP outfall reduces the chlorophyll-a concentrations by nearly half in Grassy Bay. Under these conditions the highest chlorophyll-a concentrations are found in the western portion of the bay due to the influence of the 26th Ward WPCP. Relocating the Jamaica and 26th Ward WPCPs to the ocean reduces the average chlorophyll-a concentration to less than 16 ug/L in Grassy Bay. The western portion of the bay has the higher chlorophyll-a concentrations under this alternative. Relocating three WPCP outfalls further reduces chlorophyll-a levels in the bay.

Annual surface chlorophyll-a results for the other three outfall relocation alternatives are presented in Figure 7-20. Relocating all four WPCP outfalls to the ocean reduces chlorophyll –a concentrations in the majority of the eastern portion of the bay to less than 12 ug/L. Relocating the outfalls to the Rockaway Inlet is not as effective in reducing chlorophyll-a levels as some DIN gets transported back into the bay due to tidal action.

The boundary conditions used for this analysis were somewhat conservative and thus tended to be on the high side of the spectrum. A sensitivity analysis was conducted using lower boundary conditions based on results from the Long Outfall Eutrophication Model (LOEM), which is discussed in section 7.3.3. Figure 7-21 presents a comparison of the modeling results for chlorophyll-a using the two sets of boundary conditions for the all outfalls relocated to the ocean alternative. This figure shows that using the LOEM boundary conditions reduces chlorophyll-a concentrations by approximately half of the levels computed for the Comprehensive Jamaica Bay Report analysis. What this indicates is that the Comprehensive Jamaica Bay Report analysis is conservative, and reductions in chlorophyll-a may be greater than presented.

7.2.4. Bathymetric Recontouring

Poor flushing in the back end of the bay, resulting from past sand mining activities contributes to the water quality problems in the bay. Recontouring the back end of the bay to shallower depths will improve flushing and reduce retention times. The shallower that Grassy Bay is made, the more rapidly the bay will flush. Unfortunately, recontouring the bay does not reduce nitrogen loading. In some cases, despite increased flushing, less dilution will occur, so the nitrogen concentration in portions of the bay will increase. In addition, a shallower depth could also lead to light penetration to the bottom sediment. This could allow the growth of *Ulva* in areas where it could not grow before. With these factors in mind, it is important to find the proper depth to which Grassy Bay and/or North Channel should be recontoured.

7.2.4.1. Alternative Descriptions

Recontour Grassy Bay to 4ft below MLW

In this alternative Grassy Bay is filled to 4 ft below mean low water (MLW). This is the shallowest depth that was examined. It is likely that this depth would allow enough light penetration to support *Ulva* growth in the recontoured area. It is unlikely that the bay would be recontoured to this depth.

Recontour Grassy Bay to 8ft below MLW

In this alternative Grassy Bay is recontoured to a depth of 8 ft below MLW. If recontouring occurs this is the more likely depth because light should not reach the bottom sediments, and thus, *Ulva* would be limited in its ability to grow.

Recontour Grassy Bay and North Channel to 8 ft below MLW

This alternative adds the recontouring of the North Channel to the previous alternative. While water quality is not as poor in the North Channel as it is in Grassy Bay, the North Channel could show improved water quality with filling.

7.2.4.2. Dissolved Inorganic Nitrogen

Figure 7-22 presents the surface summer DIN results for the baseline versus three recontouring alternatives. No nitrogen loading is removed in these alternatives. The changes in DIN concentrations are due to increased flushing and decreased dilution volume. In general, DIN concentrations greater than 900 ug/L expand further into the bay due to recontouring Grassy Bay and the North Channel, although recontouring Grassy Bay to 8 ft below MLW is similar to the baseline.

7.2.4.3. Dissolved Oxygen

Figure 7-23 presents the annual percentage of bottom DO concentrations greater than the standards for the recontouring alternatives. When Grassy Bay is recontoured to 4 ft below MLW, there is improvement in the percentage of DO greater than 5.0 mg/L in that area. There is an increase from less than 75 percent to greater than 85 percent of the time. If Grassy Bay were recontoured to 8 ft below MLW, the improvement in DO is less at 80 to 85 percent on an annual basis. Recontouring the North Channel as well results in the least improvement in Grassy Bay of the recontouring alternatives.

The summer percentage of DO greater than the standards for the recontouring alternatives is presented in Figure 7-24. Recontouring Grassy Bay to four feet below MLW increases the summer percentage of DO greater than 5.0 mg/L in Grassy Bay from less than 40 percent to more than 50 percent. Recontouring Grassy Bay to eight feet below MLW also improves DO in Grassy Bay. Recontouring both Grassy Bay and the North Channel to eight feet below MLW improves DO in Grassy Bay, but the North Channel is calculated to have lower DO then recontouring Grassy Bay only.

7.2.4.4. Chlorophyll-a

Recontouring Grassy Bay and the North Channel does not change the annual average surface chlorophyll-a concentrations very much when compared to the baseline (Figure 7-25). A decrease on the order of 5 ug/L in the annual chlorophyll-a concentration is calculated when Grassy Bay is recontoured to four feet below MLW. Recontouring Grassy Bay to 8 ft results in similar chlorophyll-a concentrations to the baseline. Recontouring both Grassy Bay and the North Channel to 8 ft below MLW results in enlarging the area with chlorophyll-a concentrations greater than 30 ug/L.

7.2.5. Aeration

Aeration of Grassy Bay was examined as a cost-effective alternative for achieving attainment of the DO standard. In this modeling effort a DO load was applied to the bottom layer of the model in an effort to reach 100 percent attainment. No effort was made, as part of the modeling, to determine how the oxygen would be transferred to the water column. No turbulence was included in the model due to the aeration of the water column. Thus, any increased mixing due to aeration that might add to the efficiency of atmospheric reaeration was not applied. Also, no changes in the DIN, unionized ammonia, and chlorophyll-a concentrations were assumed.

Through an iterative process, an oxygen load of 100,000 lb/day was estimated to be required for the period when DO concentrations were calculated to be below 5.0 mg/L, which is May through September. In actuality, 100,000 lb/day of oxygen transfer would not be required for the entire May through September timeframe. During some portions of this timeframe, the oxygen requirements would be less. In general, Grassy Bay was projected to have a DO concentration greater than 5.0 mg/L during the year, but areas outside of Grassy Bay did not benefit from aeration. If areas outside of Grassy Bay had DO concentrations less than 5.0 mg/L during the year, these areas remained below 5.0 mg/L in the aeration alternative.

7.2.6. Combinations

While virtually all of the alternatives examined would result in improvement to the water quality in Jamaica Bay, almost none of the alternatives achieve full attainment of all of the standards. A combination of alternatives could potentially result in attainment of the standards. This section presents the results of a few of the combinations of alternatives that were examined.

7.2.6.1. Alternative Descriptions

26th Ward WPCP (Contract 12) Jamaica WPCP Level 2 (modified flow split; partially oxic) plus Recontour Grassy Bay and North Channel to 8 ft below MLW

Grassy Bay has the least attainment of water quality standards in the open waters of Jamaica Bay. Recontouring Grassy Bay would alleviate the current DO problem.

Limit of Technology BNR and Recontour Grassy Bay to 4 ft below MLW

Limit of Technology BNR does not achieve full attainment of the DO standard. Recontouring Grassy Bay to four feet below MLW improves dissolved oxygen. The combination of these two alternatives could alleviate both issues.

Level 2 BNR and 26th Ward and Jamaica WPCP outfalls to the Rockaway Inlet

It is likely that some level of nitrogen removal will be required in Jamaica Bay. This alternative examines Level 2 BNR at all four WPCPs along with outfall relocation to the inlet.

Recontour Grassy Bay to 8 ft below MLW and 26th Ward and Jamaica Relocated to the Rockaway Inlet

This combination alternative examines the water quality improvement due to recontouring and outfall relocation.

7.2.6.2. Dissolved Inorganic Nitrogen

Figure 7-26 shows the summer average DIN concentrations for three combination alternatives and the baseline. The nitrification alternative has the smallest reduction of nitrogen loading of the combination alternatives presented. Small reductions in the DIN concentrations are calculated for this alternative. The Level 2 BNR alternative reduces the DIN concentrations to less than 200 ug/L in most of the bay. Recontouring Grassy Bay along with outfall relocation is not as effective in reducing DIN concentrations as outfall relocation and Level 2 BNR.

7.2.6.3. Dissolved Oxygen

All of the combination alternatives are effective in increasing the percentage of DO concentrations greater than 5.0 mg/L in the bay (Figures 7-27 and 7-28). The nitrification alternative increases annual DO percentage in Grassy Bay to over 85 percent. The two outfall relocation alternatives improve DO concentrations significantly and show that recontouring Grassy Bay is more effective in improving DO compliance than additional nitrogen removal for these outfall relocation alternatives.

7.2.6.4. Chlorophyll-a

Results for the surface chlorophyll-a for the combination alternatives are displayed in Figure 7-29. The nitrification alternative has only a small impact on chlorophyll-a levels. The relocation alternatives reduce the chlorophyll-a concentrations in Grassy Bay even further. The recontouring plus relocation alternative has higher chlorophyll-a concentrations in the western portion of the bay than the Level 2 plus relocation alternative.

7.2.7. Summary

The color figures of DIN concentrations, the percent of DO concentrations greater than the standard, and chlorophyll-a concentrations provide a good summary of the modeling results. However, it is sometimes difficult to compare the alternatives using the figures. Tables 7-4 through 7-8 provide a

summary of the modeling results for the DO standards and can be used to numerically compare the results of the various alternatives. Comparing the results to the baseline shows the benefits resulting from each alternative.

In Table 7-4, which presents the results for the potential baselines, the differences in results between the potential baselines do not vary much on an annual bay-wide basis. The largest differences occur in Grassy Bay during the summer.

Results for the BNR alternatives are presented in Table 7-5. There are improvements in the percentage of time the DO concentration is greater than 5.0 mg/L due to nitrogen removal, but there is additional room for improvement. The summer percentages in Grassy Bay improve from 32.4 percent of the time for the baseline to 66.6 percent of the time for LOT.

Table 7-6 presents the results from the outfall relocation alternatives. The improvements in the percentage of time the DO concentration is greater than the class SB standard improves dramatically. The percentage of time the DO concentration is greater than 5.0 mg/L in the bottom waters during the summer increases from 32.4 percent for the baseline, to 78.2 percent of the time for relocating the Jamaica outfall, to 95.3 percent for the alternative where all outfalls are relocated to the ocean.

Mixed results occur due to recontouring Grassy Bay. Table 7-7 shows that the amount of time the DO concentration is greater than 5.0 mg/L increases with bay recontouring. The shallower the depth in Grassy Bay the greater the improvement. Recontouring the North Channel as well results in smaller improvements than recontouring Grassy Bay alone.

Results for combination alternatives are presented in Table 7-8. All of the combination alternatives result in significant improvements over baseline conditions. Combinations that provide greater improvements in water quality involve greater levels of remediation including high level treatment, outfall relocation, and bay recontouring.

7.3. Ocean Outfall

7.3.1. Introduction

The Jamaica Bay Eutrophication Study and the JEM modeling showed that outfall relocation was an effective way to improve water quality in Jamaica Bay. The results of the JEM analysis led to the funding of the Long Outfall Project. The Long Outfall Project was used to assess the potential impacts of an ocean outfall on water quality near the outfall. The project included water quality sampling, modeling, outfall design and costing.

This section focuses on the results of the various modeling components of the project. The modeling tasks include: 1) the use of the Cornell Mixing Model (CORMIX) to determine the characteristics of the outfall effluent plume, 2) the development of a far field model, which computed the water quality that would be expected to occur due to the relocation of the effluent to the Atlantic Ocean, and 3) a nitrogen flux balance of the New York Harbor area.

CORMIX modeling was completed to assess the effluent plume dynamics and to determine the maximum segment size that could be used in the far field model to accurately define the size of the plume. CORMIX was also used, in part, to site the diffuser location. Part of the decision for the diffuser siting was to locate the diffuser in deep enough water so that the plume would be trapped at the pycnocline during the summer to prevent nutrients, being discharged from the outfall, from becoming available for phytoplankton growth.

The far-field model, the Long Outfall Eutrophication Model (LOEM, a modified version of the System-Wide Eutrophication Model (SWEM)), was used to compute the water quality effects of moving the effluent from the Jamaica Bay WPCPs to the Atlantic Ocean. Specifically, the analyses assessed impacts of WPCP effluent on dissolved oxygen, chlorophyll, pathogen bacteria, total residual chlorine (TRC) and unionized ammonia on water quality around the outfall. Pathogen bacteria were modeled to determine if the discharge of effluent into the ocean would result in high bacteria levels reaching the bathing beaches along the Rockaway Peninsula and New Jersey. LOEM was also used to conduct the nitrogen flux balance.

The nitrogen flux balance was conducted to show how moving the nitrogen load from Jamaica Bay to the Atlantic Ocean would affect the harbor-wide nitrogen distribution. One possible reason for deciding not to build the long outfall from Jamaica Bay to the Atlantic Ocean would be that the outfall adversely affects the distribution of nitrogen in the New York Bight. In a previous study conducted by HydroQual (1995) for the City of Boston's, Deer Island WPCP outfall relocation project, it was shown that moving the outfall from Boston Harbor to Massachusetts Bay had little impact on the overall nitrogen balance in the bay.

7.3.2. The CORMIX Analysis

7.3.2.1. Introduction

The Cornell Mixing Model (CORMIX) is a simulation package that can calculate steady-state solutions for plume characteristics of an outfall discharge. CORMIX requires input including discharge flow and temperature, water column characteristics such as depth and degree of density stratification, and outfall characteristics such as diffuser length and number of ports. For this study, CORMIX was used to help determine the outfall location and preliminary design of the diffuser. Relocating effluent from four WPCPs from Jamaica Bay to the ocean will result in additional nutrients being available locally around the outfall. Under the right conditions the additional nutrients could result in increased algal blooms near the outfall, and could potentially lead to lower dissolved oxygen levels when these algae die, settle, and contribute to the sediment oxygen demand.

To reduce the effect of the additional nutrients in the water column it is desirable to place the outfall in a location where there is enough density stratification to "trap" the plume below the level where there is enough light to encourage algal growth. If there is not enough available light for phytoplankton to grow, the additional nutrients will not be used near the outfall and will be diluted over a larger area. Additionally, if the outfall is located in deeper water there is a better likelihood of the plume being trapped below the surface. However, there is a cost associated with constructing a longer, deeper outfall tunnel. For this reason, CORMIX was used to help optimize the length of the tunnel to provide enough depth to trap the plume, but also minimize the length of the outfall tunnel.

This section will present the results of the CORMIX modeling. CORMIX provides information on the dilution of the plume, as well as, the width, rise height, and thickness of the plume. For this case study, discharge subsystem CORMIX2, of CORMIX, was used to simulate a multiport submerged outfall.

CORMIX requires several pieces of input in order to complete a simulation. The model requires information on the characteristics of the effluent discharge including the flow and temperature. No attempt was made to determine how the effluent temperature might change during its travel through the outfall tunnel. Since CORMIX is a steady-state model, the model was run for several different flows ranging from 100 to 780 MGD to simulate the range of flows that may occur. The effluent temperature was based on daily WPCP records for the Jamaica, 26th Ward, Coney Island and Rockaway WPCPs. Characteristics of the water column are also required by CORMIX. Current velocities contribute to the dilution and spreading of the plume. Initially, these velocities were assigned using results from the Estuarine, Coastal and Ocean Model (ECOM) SWEM for 1988 conditions. These velocities were later verified by field ADCP measurements. CORMIX also requires the specification of the degree of water column stratification as well as the shape of the density profile. Again, because CORMIX is a steady-state model it was assigned differing degrees of stratification including well-mixed, intermediate, and stratified conditions. These degrees of stratification were assigned based on ECOM SWEM and CTD data. The density profile was assigned as Type A in CORMIX, a linear density profile. The water column and effluent characteristics are described in Table 7-9. U is the ambient current velocity and sigma-t defines the density of the water column. Velocities were based on average conditions in the bottom of the model.

Diffuser information is also required by CORMIX. These inputs include diffuser length, number of risers, distance between risers, the number and size of the exit ports, and the shape of the diffuser and the orientation to the current. Several diffuser designs were modeled. The final configuration characteristics are presented in Table 7-10.

7.3.2.2. Result

CORMIX is a steady-state model that is run for one particular current velocity at a time. Since the diffusers will be located in a tidal area, the actual system being modeled is not at steady state. The model was run at the average velocity to determine the plume dynamics. The current velocities in the ocean will change with time resulting in more or less trapping than is presented below. Also, since the tidal currents will change the direction in which the plume will travel, only the results up to the edge of the nearfield region (as defined by CORMIX) were reviewed. CORMIX results outside this area were ignored, since the LOEM model was available to make more realistic projections of expected water quality.

Ideally, the diffuser depth and design should trap the effluent plume below the photic zone so that the effluent nutrients cannot fuel phytoplankton growth. The photic zone is often defined as the area between the water's surface and the depth to which one percent of surface light reaches (one percent light level). This is the area where phytoplankton photosynthesis exceeds phytoplankton respiration so that the net primary productivity is positive. Sparse data indicate the extinction coefficient in the area around the proposed outfalls is approximately 0.8/m. Results from SWEM suggest the extinction coefficient is 0.45/m. This would place the one percent light level between 6 and 10 meters (20-33 ft) below the surface. Since the slope of the ocean bottom is very shallow off the coast

of Long Island it would be difficult to trap the plume all of the time, even under stratified conditions, without locating the diffuser many miles from shore. Therefore, to reduce costs, an attempt was made to trap the plume under normal WPCP operating conditions, but not necessarily for extreme events (ex. rain events). The locations chosen as potential outfall locations were based on preliminary CORMIX results indicating how deep the outfall would need to be to trap the plume.

Tables 7-11 and 7-12 present the results for the intermediate and maximum stratification alternatives, respectively. The dilution is at the edge of the plume in what CORMIX defines as the nearfield region. The plume width includes the diffuser length, which in most cases is 1,225 m (4,000 ft). The nearfield regions x, y, and z represent the distance the centerline of the plume has traveled from the diffuser (z is the rise height of the center of the plume). The plume height was calculated by adding half of the plume thickness to z. If this value was greater than the water column depth, the plume height was expressed as the water column depth.

Table 7-11 presents the results for the intermediate stratification conditions. Intermediate stratification occurs during the spring when stratification begins to set up due to warmer temperatures, and in the fall before overturn occurs. Three depths were chosen for modeling: 18.3 meters (60 ft; Jamaica WPCP only), 22.4 meters (73.5 ft; Jamaica + 26th Ward WPCPs), and 30.2 meters (99 ft; All WPCPs) to simulate the conditions of the potential outfall sites. For each depth, eight flows were modeled in 100 MGD increments from 100 to 700 MGD plus 780 MGD (the maximum possible flow). The maximum flows for each plant are Jamaica (250 MGD), 26th Ward (250 MGD), Coney Island (200 MGD) and Rockaway (80 MGD). Only the applicable flows are presented in Table 7-11.

At the shallowest water depth (18.3 m) only the Jamaica WPCP effluent would be discharged. Under current operating conditions the plant discharges approximately 80 MGD. Under these flow and stratification conditions the plume would reach a height of less than 13.5 meters. However, the dilution that would occur is over 200 to 1. At the maximum flowrate of 250 MGD, during storm events, the plume would most likely reach the surface, but with a dilution of over 130 to 1.

With the Jamaica and 26th Ward WPCP discharging at the intermediate depth, the normal flowrate would be approximately 150 MGD with a maximum flow of 500 MGD. During normal WPCP operations the plume would be trapped approximately six meters below the surface. At a maximum flowrate of 500 MGD it appears that the plume would travel several hundred meters from the diffuser. Two additional simulations were conducted with longer diffusers (1,500 and 2,000 m). While the plume would still reach the surface with a longer diffuser the dilution is greater (~130:1 vs. 100:1). It is likely that fine-tuning the diffuser design would result in improved dilution and plume trapping. Additional diffuser design is recommended should this option be chosen for outfall relocation.

With all four WPCPs discharging to the ocean, the flowrates vary between approximately 275 MGD (dry weather) and 780 MGD (wet weather). At the normal dry-weather flow for all four WPCPs the plume remains trapped below the photic zone. At the maximum flow rate the plume remains five meters below the surface. The dilution that would occur at this location for the various flowrates ranges from approximately 160:1 to 120:1.

Table 7-12 presents the CORMIX results for the maximum stratification conditions. For the 18.3 m depth, the plume height is approximately 0.4 m less than for intermediate conditions, but the dilution is slightly less (112 vs. 130). This result is logical since the effluent plume is confined to a smaller volume under the most stratified conditions. At the 22.4 m location CORMIX computes lower plume

heights for the maximum stratification conditions versus the intermediate conditions. Under dry-weather conditions the plume rise height is one to two meters less under maximum stratified conditions. However, the dilution is less under maximum stratified conditions. At the deepest outfall site, plume heights range from 0.1 to 1.7 m less than under maximum stratification conditions. CORMIX results from all three sites show that the plume height will be less and the dilution will be smaller during the maximum stratification versus intermediate stratification conditions. The rise height differences are generally less than two meters and the dilution difference is less than 20 percent.

While CORMIX provides some insight as to how the plume will behave, it does not predict how the plume will affect water quality. Section 7.3.3 presents how these discharges may impact water quality in the NY Bight region using the far-field model LOEM. While CORMIX cannot accurately predict the far-field impacts of the outfall, it is important for LOEM to at least approximate the near-field mixing that occurs before the far field mixing takes place. A comparison of the two models is presented in Section 7.3.3.2.

7.3.2.3. Discussion of CORMIX Results

The CORMIX results indicate that the diffuser effluent plume will occasionally rise into the photic zone. There is reason to believe that these CORMIX results are conservative due to the stratification that was assigned in the input. The decision was made to use the stratification that was computed by the hydrodynamic model (ECOM) rather than available data, so that CORMIX and LOEM would be comparable. However, the available data indicate that ECOM may underestimate the vertical stratification. Figure 7-30 presents a comparison of density (sigma-t) data collected in 2003, represented by the circles, with model results from 1988 represented by the filled squares. The model results are an average of sigma-t for the month with the range of sigma-t during the month. The data are from one sampling event during each month. Data stations were chosen based on similarity in depth and proximity to the potential outfall locations. Station A5 approximates the 57 ft location; A4 approximates the 73 ft location, and A11 approximates the 99 ft location.

While it is possible that 2003 was a more stratified year than 1988, it is clear that in many cases that the level of stratification indicated by the data exceeds the model predicted average monthly stratification and in some cases exceeds the monthly range of stratification. It is very unlikely that the density data sampling captured the period of greatest stratification; so on occasion the water column may have been more stratified than the data indicate. Based on these results it is likely that the estimated plume rise heights computed by CORMIX are conservative.

7.3.3. Far Field Model

7.3.3.1. Introduction

A modeling analysis was completed to determine the potential effects of moving the effluent discharges of the Jamaica, 26th Ward, Rockaway, and Coney Island WPCPs from Jamaica Bay to the Atlantic Ocean and to provide guidance for the outfall diffuser depth and location. The goal of the analysis was to find a location that would result in minimal impacts to the outfall site and the surrounding areas. To reduce the potential impact of the outfall it is desirable for the effluent plume to be trapped below the photic zone during periods when the water column is stratified. Trapping the

plume below the photic zone results in trapping the nutrients contained within the effluent, which could fuel a phytoplankton bloom, below the level where light can contribute to algal growth. By trapping the plume, the nutrients are not available for phytoplankton uptake. Nutrients that reach the surface could potentially fuel algal blooms including Harmful Algal Blooms (HABs). The effluent plume consists of fresh water that is more buoyant than the surrounding ocean water. Providing enough depth and mixing of the effluent reduces the buoyancy of the plume and can prevent it from reaching the photic zone.

The analyses were completed using a resegmented version of the System-wide Eutrophication Model (SWEM) named LOEM (Long Outfall Eutrophication Model). SWEM was resegmented for this analysis because the model grid was too coarse in the location of the proposed outfall. The original SWEM grid contained model segments that were on the order of two miles by three miles in this area. Based on CORMIX modeling, the estimated width of the effluent plume would be on the order of 3,000 feet. In order to properly represent the effluent plume in the model, segmentation was reduced to approximately 3,000 feet by 3,000 feet. This resulted in increasing the SWEM segmentation from 49 x 84 surface segments to 66 x 91 surface segments in LOEM. CORMIX can only provide characteristics of the effluent plume in steady-state conditions. However, it provides plume characteristics that LOEM should reproduce. LOEM was used to assess the impacts of the Atlantic Ocean discharge on phytoplankton biomass, nutrient dynamics and fluxes, dissolved oxygen and pathogen bacteria. Figure 7-31 presents the entire LOEM grid and Figure 7-32 presents a close-up of the modified portion of the LOEM grid and the locations tested for the possible outfall diffuser location.

7.3.3.2. Results

Originally, it was hoped that the length of the outfall pipe would be on the order of three miles so that tunneling costs could be kept down. The initial analysis of the plume characteristics was conducted using CORMIX as described in Section 7.3.2. CORMIX indicated that the outfall site would have to be at least 50 feet deep. Dye runs were completed using ECOM and RCA (LOEM) to verify this depth. ECOM is a time-variable hydrodynamic model that computes changing flow rates and vertical stratification. The modeling analyses using LOEM showed that a depth of 50 ft would not be feasible and a longer outfall pipe would be required. A dye run indicated that this depth would not be adequate because the plume was not trapped enough. A series of additional dye runs were conducted to determine the most appropriate depth for the outfall. Table 7-13 provides a listing of the dye runs that were completed.

The results of the dye runs using ECOM and RCA indicated that 50 feet would not be deep enough to trap the plume (Figure 7-33). ECOM and RCA indicated that a depth of 100 feet would be required to trap the effluent plume during the stratified period (Figure 7-34) if all four WPCPs were included in the outfall. This depth is similar to the depth of the Deer Island wastewater Treatment Plant outfall diffuser in Boston, which consistently results in plume trapping during stratified periods. Other alternatives with fewer WPCP outfalls being relocated were also examined. In particular, the Jamaica WPCP by itself, and the Jamaica and 26th Ward WPCPs together were examined. This latter alternative was chosen for the comparison between CORMIX and ECOM results. This alternative includes the effluent from the Jamaica and 26th Ward WPCPs at a depth of 73 feet and a distance of approximately 6.5 miles from shore. The basis for the CORMIX runs is discussed in Section 7.3.2.

The RCA model results for the top five layers of the discharge segment for the Jamaica and 26th Ward discharge alternative are presented in Figure 7-35. The top two model layers have relatively low dye concentrations based on an effluent concentration of 18 mg/L (This value was chosen to mimic the TN effluent concentration of a WPCP). During the period of strongest stratification, there are a few periods in May, July and August where elevated concentrations are computed by the model. Overall, the plume is trapped fairly well. The red dots indicate interpolated CORMIX results. The CORMIX results are from the intermediate and maximum conditions for all of the flow rates considered. The concentrations and rise heights computed by CORMIX were used to interpolate the concentration and RCA model layer for the actual flows used in ECOM. This provided a basis with which to compare RCA and CORMIX results. While several factors determine the rise height of the plume, the effluent flow was the most reliable factor to predict rise height.

There is a reasonably favorable comparison between the two models. While the RCA results are presented for the entire year, the CORMIX results are presented only for the intermediate and most stratified periods. During the most stratified period, CORMIX predicts few excursions of the plume above layer four in the model (approximately 25 ft). During the period of intermediate stratification the plume reaches layer three more consistently (approximately 18 ft). CORMIX and RCA concentrations generally agree within a factor of two, and generally compute a similar rise height of the plume.

Since ECOM and RCA appear to reproduce the general characteristics of the outfall discharge plume, as determined by CORMIX, the far field model can be used to determine how the pollutants in the plume will disperse within the far field model domain.

7.3.3.3. Far Field Model Results

7.3.3.3.1 Introduction

Several alternatives were run with the full eutrophication model to determine the impacts of the effluent discharge on water quality and help determine the depth and location of the outfall diffuser. The depth and location were chosen based on the ability to trap the effluent plume below the photic zone (the water depth at which there is sufficient sunlight for photosynthesis to occur) during stratified conditions.

A baseline was run using the original SWEM inputs with some minor modifications. Loads were relocated based on the new segmentation, as appropriate. The TN loading discharge from the four Jamaica Bay WPCPs was reduced to 45,300 lb/day on an annual basis to reflect the maximum permitted load to the bay. It should be noted that these simulations were conducted before BioWin results became available, so the distribution of the nitrogen loads between the WPCPs in LOEM is different than the distribution used in JEM. The additional alternatives were compared to the baseline to determine the effect of moving the outfall on the area around the outfall. Three projected ocean outfall simulations were conducted. They are: Jamaica WPCP to an ocean outfall of depth 57 ft, Jamaica and 26th Ward WPCPs to 73 ft and all Jamaica Bay WPCPs to 99 ft.

The following sections will examine how WPCP flows, loads and ocean outfall depth affect the levels of dissolved inorganic nitrogen (DIN), chlorophyll-a, dissolved oxygen (DO) in the water column and the magnitude of the sediment oxygen demand (SOD) and particulate organic carbon flux (Jpoc).

7.3.3.3.2 Dissolved Inorganic Nitrogen (DIN)

Nitrogen is an important nutrient for phytoplankton growth. In most estuaries, nitrogen is the potentially limiting nutrient for phytoplankton. That is in most cases phytoplankton will deplete the available nitrogen before they deplete the available phosphorus. For this reason the impact of outfall relocation on DIN levels in the Atlantic Ocean was examined.

7.3.3.3.2.1 Jamaica WPCP to Ocean Outfall (57 ft)

Figure 7-36 shows DIN (mg/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at the water column surface, mid-depth and bottom during March. The figure depicts DIN averaged over a 10-day period in March. March was chosen as a period of interest because the water column in the Atlantic Ocean is not stratified at this time of the year. The Atlantic Ocean, where the projected outfall might be located, as well as Jamaica Bay, are depicted so that any changes near the outfall location and in Jamaica Bay may be noted.

When comparing the outfall projection to the baseline, it is unclear from the increase of DIN, in the bottom two layers of the water column depicted, whether the ocean outfall plume is trapped in March. DIN concentrations increased from less than 0.05 mg/L to approximately 0.15 mg/L at the ocean outfall location at the ocean floor. Similar increases can be seen at the mid-depth location. However, an increase in surface DIN cannot be observed.

Due to the proximity of beaches, an increase of DIN at the shoreline parallel to Jamaica Bay would be significant. Though it should be noted that Lawrence WPCP and Long Beach WPCP currently discharge into the Atlantic Ocean along the shoreline, the introduction of the ocean outfall at the 57 ft depth does not increase the DIN concentration along the shoreline significantly.

With the Jamaica WPCP discharge relocation to the Atlantic Ocean, DIN concentrations decrease in Jamaica Bay. Jamaica Bay WPCP discharges total nitrogen and DIN loads of 18,350 and 13,230 lb/day respectively into Jamaica Bay. As a result of moving these loads to the Atlantic Ocean, areas such as Grassy Bay see decreases from DIN concentrations greater than 0.4 mg/L to DIN concentrations of approximately 0.30 mg/L under March conditions. Levels of DIN also decrease in the Rockaway Inlet and along the western portion of Jamaica Bay.

Figure 7-37 shows DIN (mg/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at the water column surface, mid-depth and bottom during July. The figure depicts DIN averaged over a 10-day period in July. July was chosen as a period of interest because in July the Atlantic Ocean is stratified with respect to density.

The increased levels of DIN in the bottom and mid-depth, but not in the surface of the water column, indicates that the outfall plume is trapped below the surface for the period depicted in Figure 7-37. The stratification in the ocean is enough to keep nutrients out of the photic zone and, therefore, these nutrients will not contribute to a phytoplankton bloom during the summer months.

Although there is a slight increase in DIN levels along the shoreline of the Atlantic Ocean parallel to Jamaica Bay in the bottom and mid-depth of the water column, there is very little increase in the surface. This can be attributed to the outfall plume being trapped sufficiently during the July period of interest.

With the Jamaica WPCP discharge relocation to the Atlantic Ocean, DIN concentrations decrease in Jamaica Bay. Areas such as Grassy Bay see decreases from DIN concentrations greater than 0.3 mg/L to DIN concentrations of approximately 0.1 mg/L under July conditions. This is a significant decrease for the relocation of only the Jamaica WPCP to the ocean.

7.3.3.3.2.2 Jamaica and 26th Ward WPCPs to Ocean Outfall (73 ft)

Figure 7-38 shows DIN (mg/L) for the Baseline and the Jamaica and 26th Ward WPCP to ocean outfall (73 ft) alternatives at the water column surface, mid-depth and bottom during March. The figure depicts DIN averaged over a 10-day period in March. Again, March was chosen as a period of interest because during March the Atlantic Ocean is generally not stratified. The Atlantic Ocean, where the projected outfall might be located, as well as Jamaica Bay, are depicted so that any changes near the outfall location and in Jamaica Bay may be noted.

The increase of DIN in the ocean near the outfall location, in all three layers of the water column depicted, show that the ocean outfall plume is not trapped in March. DIN concentration increased from less than 0.05 mg/L to approximately 0.15 mg/L at the ocean outfall location at the ocean floor. Figure 7-38 shows the plume spreading southwest and northeast. Increases in the DIN concentration can be seen at the mid-depth as well as the surface layer. There is no significant increase of DIN is at the shoreline parallel to Jamaica Bay. This is due to the distance of the outfall from the shoreline.

With the Jamaica and 26th Ward WPCP discharges relocated to the Atlantic Ocean, DIN concentrations decrease in Jamaica Bay. Jamaica Bay and 26th Ward WPCPs discharge 30,640 and 21,830 lb/day of TN and DIN, respectively. Areas such as Grassy Bay see decreases from DIN concentrations greater than 0.4 mg/L to DIN concentrations of approximately 0.15 mg/L. Levels of DIN also decrease in the Rockaway Inlet, along the Western shore of Jamaica Bay and in the tributaries.

Figure 7-39 shows DIN (mg/L) for the Baseline and Jamaica and 26th Ward WPCP to ocean outfall (73 ft) alternatives at the water column surface, mid-depth and bottom during July. The figure depicts DIN averaged over a 10-day period in July. July was chosen as a period of interest because in July the Atlantic Ocean is stratified.

The increased levels of DIN in the bottom and mid-depth, but not in the surface of the water column, indicates that the outfall plume is trapped for the period depicted in Figure 7-39. The stratification in the ocean is enough to keep nutrients out of the photic zone and, therefore, not contribute to a phytoplankton bloom during the summer months.

Although there is an increase in DIN levels along the shoreline of the Atlantic Ocean parallel to Jamaica Bay in the bottom and mid-depth of the water column, there is no increase in the surface. The increase observed along the shoreline at the mid-depth and bottom can be attributed to the

trapping of the plume in the lower portion of the water column and mixing towards the shoreline parallel to Jamaica Bay.

With the Jamaica WPCP discharge relocation to the Atlantic Ocean, DIN concentrations decrease in Jamaica Bay. Areas such as Grassy Bay see a decrease in DIN concentrations from greater than 0.3 mg/L to DIN concentrations less than 0.10 mg/L. This is a greater decrease than the relocation of only Jamaica WPCP to the ocean.

7.3.3.3.2.3 All Jamaica Bay WPCPs to Ocean Outfall (99 ft)

Figure 7-40 presents DIN (mg/L) for the Baseline and the All Jamaica Bay WPCPs to the ocean outfall (99 ft) alternatives at the water column surface, mid-depth and bottom during March. The figure depicts DIN averaged over a 10-day period in March.

The increased level of DIN in only the bottom and mid-depth portion of the water column indicates that the outfall plume is trapped for the March period. Although March is not a stratified period, the depth of the 99 ft outfall and the gradient from the bottom to the surface is enough to trap the outfall plume. There is no significant increase of DIN at the shoreline parallel to Jamaica Bay. This is due to the distance of the outfall location from the shoreline.

With the All Jamaica Bay WPCPs outfalls relocated to the Atlantic Ocean alternative, DIN concentrations decrease significantly in Jamaica Bay. The Jamaica Bay WPCPs contribute 46,300 and 33,510 lb/day of TN and DIN respectively into Jamaica Bay. With the removal of the WPCPs loads, areas such as Grassy Bay see decreases from DIN concentrations greater than 0.4 mg/L to DIN concentrations of less than 0.1 mg/L. Levels of DIN also decrease in the Rockaway Inlet, along the western shore of Jamaica Bay and in the tributaries.

Figure 7-41 shows DIN (mg/L) for the Baseline and the All Jamaica Bay WPCPs to the ocean outfall (99 ft) alternatives at the water column surface, mid-depth and bottom during July. The figure depicts DIN averaged over a 10-day period in July.

The increased levels of DIN in the bottom and mid-depth but not in the surface of the water column indicates that the outfall plume is trapped for the period depicted in Figure 7-41. The stratification in the ocean is enough to keep nutrients out of the photic zone and, therefore, not contribute to a phytoplankton bloom during the summer months.

Although there is an increase in DIN levels along the shoreline of the Atlantic Ocean parallel to Jamaica Bay in the bottom and mid-depth of the water column, there is no significant increase in the surface. The increase observed at the bottom and mid-depths can be attributed to the plume trapping and dispersing to the shoreline.

With the Jamaica Bay WPCPs outfall relocation to the Atlantic Ocean alternative, DIN concentrations decrease in Jamaica Bay. Jamaica Bay as a whole shows decreases in DIN concentrations from greater than 0.3 mg/L to DIN concentrations less than 0.05 mg/L. This alternative results in the largest decrease of DIN concentrations of all the ocean outfall projections conducted.

7.3.3.3.3 Chlorophyll-a

The second water quality variable of interest in assessing the impacts of ocean relocation is chlorophyll-a, the surrogate for algal biomass. One wants to be sure that outfall relocation does not simply move the water quality problems associated with nutrient over-enrichment from Jamaica Bay to the ocean.

7.3.3.3.3.1 Jamaica WPCP to Ocean Outfall (57 ft)

Figure 7-42 shows chlorophyll-a (ug/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at the water column surface, mid-depth and bottom during March. The figure depicts chlorophyll-a averaged over a 10-day period in March. The Atlantic Ocean, where the proposed outfall might be located, as well as Jamaica Bay, are depicted so that any changes near the outfall location and in Jamaica Bay may be noted.

When comparing the outfall projection to the baseline, only small differences are computed in a few segments in all three layers presented. In some segments the chlorophyll-a levels have increased, in others the chlorophyll-a has decreased. Generally, at mid-depth the chlorophyll-a concentration has decreased over the outfall due to dilution from the plume.

The introduction of the ocean outfall at the 57 ft depth does not increase the chlorophyll-a concentration along the shoreline significantly parallel to Jamaica Bay. With the removal of Jamaica Bay WPCP load to the Atlantic Ocean, there is a decrease in chlorophyll-a concentrations inside of Jamaica Bay. The scale used in Figure 7-42 was chosen to identify chlorophyll-a changes in the Atlantic Ocean. The scale does not show chlorophyll-a changes in Jamaica Bay because chlorophyll-a concentrations in Jamaica Bay are significantly higher than those in the Atlantic Ocean.

The increase in concentrations of chlorophyll-a computed between the Baseline and Jamaica WPCP relocation alternatives can be directly related to the increase of DIN in Figure 7-36. Because nitrogen is an important nutrient in phytoplankton growth and the limiting nutrient in most estuarine bodies, it would follow that an increase of DIN would result in an increase of phytoplankton. Increases in phytoplankton will result in an increase of chlorophyll-a, which can be observed in Figure 7-42.

Figure 7-43 shows chlorophyll-a (ug/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at the water column surface, mid-depth and bottom during July. Moving the Jamaica WPCP outfall results in slightly higher chlorophyll-a concentrations near the shore and lower chlorophyll-a levels in the southern portion of the model domain that is shown. Chlorophyll-a levels at the mid-depth both increase and decrease. Dilution of chlorophyll-a levels is observed over the outfall. In the bottom waters, chlorophyll-a levels increase south of the outfall.

Although there is a slight increase in chlorophyll-a levels along the shoreline of the Atlantic Ocean parallel to Jamaica Bay in the bottom and mid-depth of the water column, there is very little increase in the surface. This can be attributed to the outfall plume being trapped sufficiently during the July period of interest so only small amounts of nutrients reach algae in the surface of the Atlantic Ocean and no increase of algae can be observed.

Figure 7-44 shows chlorophyll-a (ug/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at the water column surface, mid-depth and bottom during October. October was chosen

as a period of interest because in October the Atlantic Ocean has gone through the fall overturn and is well mixed. Also, fall blooms can occur during this period.

The increased levels of chlorophyll-a, throughout the water column, indicate the outfall plume is not trapped for the period depicted in Figure 7-44. During this well mixed period after the fall overturn, there is not enough stratification in the ocean to keep nutrients out of the photic zone and, therefore, these nutrients will contribute to phytoplankton growth during the fall months. Increases in chlorophyll-a throughout the surface of water column supports that the Jamaica WPCP discharge plume is not trapped in October.

The increased levels of surface chlorophyll-a can also be observed at the shoreline parallel to Jamaica Bay. At certain locations the chlorophyll-a concentration increases from approximately 4.0 ug/L to approximately 6.0 ug/L. While chlorophyll-a levels do increase slightly, the absolute magnitude of the increase is small and the 6 ug/L value is below the eutrophication threshold (10 ug/L) and, therefore, should not be considered a phytoplankton bloom.

7.3.3.3.3.2 Jamaica and 26th Ward WPCPs to Ocean Outfall (73 ft)

Figure 7-45 shows chlorophyll-a (ug/L) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at the water column surface, mid-depth and bottom during March. The Atlantic Ocean, where the projected outfall might be located, as well as Jamaica Bay are depicted so that any changes near the outfall location and in Jamaica Bay may be noted.

The increase of chlorophyll-a, in all three layers of the water column depicted, shows that the ocean outfall plume is not trapped in March. In the bottom and mid-depth layers most of the increases are observed near the outfall. In the surface layer, the model computes increased chlorophyll-a east of the outfall. There is no significant increase of chlorophyll-a at the shoreline parallel to Jamaica Bay. This is due to the distance of the outfall from the shoreline.

Figure 7-46 shows chlorophyll-a (ug/L) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at the water column surface, mid-depth and bottom during July. There are small differences, on the order of 2 ug/L, observed between the baseline and projection results. There is no significant increase of chlorophyll-a at the shoreline parallel to Jamaica Bay. In fact, decreased chlorophyll-a concentrations are computed east of Jamaica Bay along the shoreline. This can be attributed to the distance of the outfall from the shoreline

Figure 7-47 presents chlorophyll-a (ug/L) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at the water column surface, mid-depth and bottom during October. October was chosen as a period of interest because in October the Atlantic Ocean has gone through the fall overturn and is well mixed.

The increased levels of chlorophyll-a, throughout the water column, indicate the outfall plume is not trapped during this October period. During this well mixed period after the fall overturn, there is not enough stratification in the ocean to keep nutrients out of the photic zone and therefore these nutrients will contribute to phytoplankton growth during the fall months. Increases in chlorophyll-a throughout the surface of the water column supports that the Jamaica and 26th Ward WPCPs discharge plume is not trapped in October.

The increase levels of surface chlorophyll-a can also be observed at the shoreline parallel to Jamaica Bay. At certain locations the chlorophyll-a concentration increases by approximately 2 ug/L.

7.3.3.3.3.3 All Jamaica Bay WPCPs to Ocean Outfall (99 ft)

Figure 7-48 presents chlorophyll-a (ug/L) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at the water column surface, mid-depth and bottom during March. In the surface layer, there are a few areas where the chlorophyll-a concentration has increased by approximately 3 ug/L. In the mid-layer, the yellow area at 12-15 ug/L has shifted slightly, but there does not seem to be a significant difference in the model results between the two alternatives. Dilution of the chlorophyll-a concentrations is computed at the outfall location. The bottom layer also indicates that there are only minor differences in the chlorophyll-a concentrations between the two alternatives. There is no significant increase of chlorophyll-a at the shoreline parallel to Jamaica Bay. This is due to the distance of the outfall location from the shoreline.

Figure 7-49 shows chlorophyll-a (ug/L) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at the water column surface, mid-depth and bottom during July. The increased levels of chlorophyll-a in the bottom and mid-depth, but not in the surface of the water column, indicates that the outfall plume is trapped. The stratification in the ocean is enough to keep nutrients out of the photic zone and, therefore, not contribute to a phytoplankton bloom during the summer months. It should be noted that there is actually a decreased level of chlorophyll-a computed at the surface of the Atlantic Ocean. This is most likely due to the fact that the nutrients exported out of Jamaica Bay in the Hudson River freshwater plume that used to be in the surface when they reached the ocean, are now trapped below the surface around the 99 ft outfall location. These trapped nutrients are prevented from reaching the photic zone. The result is a decrease in chlorophyll-a concentration in the surface of the water column.

Although there is an increase in chlorophyll-a levels along the shoreline of the Atlantic Ocean parallel to Jamaica Bay in the bottom and mid-depth of the water column, there is no significant increase in the surface. The increase observed at the bottom and mid-depths can be attributed to the plume trapping and dispersing to the shoreline, where there is shallower water.

Figure 7-50 shows chlorophyll-a (ug/L) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at the water column surface, mid-depth and bottom during October. The increased levels of chlorophyll-a, throughout the mid-depth and surface, but not the bottom of the water column, indicate the outfall plume is not trapped for this period during October. During this well mixed period after the fall overturn, there is not enough stratification in the ocean to keep nutrients out of the photic zone and therefore these nutrients will contribute to a phytoplankton bloom during the fall months. An increase in chlorophyll-a throughout the surface of water column supports that the outfall discharge plume is not trapped in October.

The increase levels of surface chlorophyll-a can also be observed at the shoreline parallel to Jamaica Bay. At certain locations the chlorophyll-a concentration increase by approximately 2.0 ug/L.

7.3.3.3.4 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the third water quality variable being used to asses the impacts of outfall relocation to the ocean.

7.3.3.3.4.1 Jamaica WPCP to Ocean Outfall (57 ft)

Figure 7-51 shows bottom DO (mg/L), with 10-day averaging, for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the entire model year of 1988. A scale of 0 to 10 mg/L was chosen to see the full range of DO concentration throughout the year. Bottom DO was chosen as a location of interest because generally DO concentrations are lowest at the ocean bottom. It also should be noted that the WPCP outfall flow is released at the ocean bottom.

Dissolved oxygen concentrations show a strong seasonal cycle with highest concentration observed in the winter and early spring, followed by decreasing levels into the summer and fall. This cycle is related to water temperature, primary production and respiration. The highest concentrations of DO are observed at the end of February, with concentrations almost reaching 10 mg/L. For the remainder of spring, through summer and approaching into fall there is a general downward trend that can be observed in the model results with some locations reaching minimum values of approximately 4 mg/L. Then in October through the end of the year, DO concentrations increase as the water temperature decreases and the fall overturn occurs.

In comparing the Baseline simulation and the Jamaica WPCP to ocean outfall alternative, there is little or no impact to the model results with the proposed outfall. DO levels either remain the same to the Baseline or are slightly higher with the addition of the outfall flow. It should be noted that an annual average Jamaica WPCP DO discharge concentration of 7.08 mg/L is associated with the outfall flow. This DO load, as well as the increased vertical mixing through the water column due to the addition of the outfall flow can explain the increase levels of DO for the projection simulation.

Figure 7-52 shows mid-depth DO (mg/L) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the entire model year of 1988. A scale of 2 to 12 mg/L was chosen to appropriately see the full range of DO concentration throughout the year. Mid-depth DO was chosen as a location of interest because at this depth, the effect of added nutrients and biological oxygen demand (BOD) from the outfall can be seen through a decrease in DO levels.

The highest concentrations of DO are observed at the end of February, similar to the bottom DO concentrations, with concentrations almost reaching 11 mg/L. For the remainder of spring, through summer, and approaching into fall, there is a general downward trend that can be observed in model computations with some locations reaching minimum values of approximately 6 mg/L. Then in October through the end of 1988, DO concentrations increase up to 8 mg/L.

In comparing the Baseline simulation and the Jamaica WPCP to ocean outfall alternative, there is, as noted with the bottom DO, little or no impact to the model results with the proposed outfall. DO levels either remain the same to the Baseline or are slightly lower with the addition of the outfall load. This diminished concentration of DO observed at the water column mid-depth, particularly apparent at the outfall location where the minimum DO concentration decreases from 6.2 mg/L to 5.7 mg/L,

and can be attributed to the carbon oxidation that occurs while the plume is trapped below the pycnocline.

7.3.3.3.4.2 Jamaica and 26th Ward WPCPs to Ocean Outfall (73 ft)

Figure 7-53 shows bottom DO (mg/L) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the entire model year of 1988 at the bottom of the water column. A scale of 0 to 10 mg/L was chosen so that the full range of DO concentrations throughout the year can be observed.

The highest concentrations of DO are observed during mid-April, with concentrations as high as 10 mg/L. For the remainder of spring, through summer and approaching the fall there is a general downward trend that can be observed in the model results with some locations reaching minimum values of approximately 4 mg/L. Then, during October, through the end of 1988, DO concentrations increase to 8.0 mg/L.

When comparing the Baseline simulation and the Jamaica and 26th Ward WPCPs to ocean outfall alternative, little or no impact to the model results with the proposed outfall can be observed. DO levels either remain the same to the Baseline or are slightly improved with the addition of the outfall flow. An annual average Jamaica and 26th Ward WPCP DO discharge concentration of 7.08 mg/L and 5.98 mg/L, respectively, are associated with the outfall flow. This DO load, as well as the increased vertical mixing through the water column due to the addition of the outfall flow can explain the increase levels of DO for the projection simulation.

Figure 7-54 shows DO (mg/L) for the Baseline and Jamaica and 26th Ward WPCP to ocean outfall (73 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the entire model year of 1988 at the mid-depth. A scale of 2 to 12 mg/L was chosen so that the full range of DO concentrations throughout the year can be viewed. Mid-depth DO was chosen as a location of interest because at this depth, the effect of added nutrients and BOD from the outfall can be seen through a decrease in DO levels.

The highest concentrations of DO are observed at the end of February, with concentrations just above 10 mg/L. For the remainder of spring, through summer and approaching into fall there is a general downward trend that can be observed of the model result with some locations reaching minimum values of approximately 5.8 mg/L. Then during October through the end of 1988, DO concentrations increase up to 8 mg/L.

In comparing the Baseline simulation and the Jamaica and 26th Ward WPCPs to ocean outfall alternative, there is, as noted with the previous figure, little or no impact to DO from the proposed outfall near the bottom. DO levels either remain the same to the Baseline or are slightly lower with the addition of the outfall load. A decrease in the concentration of DO is observed at the water column mid-depth, again particularly apparent at the outfall location where the concentration decreases from 5.8 mg/L to 5.1 mg/L. This additional DO deficit can be attributed to the increase in BOD concentrations, which may increase carbon oxidation.

7.3.3.3.4.3 All Jamaica Bay WPCPs to Ocean Outfall (99 ft)

Figure 7-55 presents DO (mg/L) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at locations surrounding the proposed outfall and the outfall location for the entire model year of 1988 at the ocean bottom. A scale of 0 to 10 mg/L was used so that observation of the full range of DO concentrations throughout the year can be made.

The highest concentrations of DO are observed during the middle of April, with concentrations almost reaching 10 mg/L. For the remainder of spring, through summer and approaching into fall there is a general downward trend that can be observed in the model results with some locations reaching minimum values of less than 4 mg/L. Then, in October, through the end of the year, DO concentrations increase up to 8.0 mg/L.

In comparing the Baseline simulation and the Jamaica Bay WPCPs to ocean outfall alternative, again there is little or no impact to the model results with the proposed outfall. DO levels either remain the same to the Baseline or are slightly improved with the addition of the outfall flow. The annual average Jamaica, 26th Ward, Coney Island and Rockaway WPCP DO discharge concentrations are 7.08, 5.98, 5.82 and 6.70 mg/L, respectively. This DO load being discharged to the ocean bottom, as well as the increased vertical mixing through the water column due to the addition of the outfall flow can explain the increase levels of DO for the projection simulation at the ocean bottom.

Figure 7-56 shows DO (mg/L) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at eight locations surrounding the proposed outfall and the outfall location for the entire model year of 1988 at the mid-depth of the water column. A scale of 2 to 12 mg/L was chosen to see the full range of DO concentrations throughout the year.

The highest concentrations of DO are observed at the end of February, with concentrations reaching 10 mg/L. The remainder of spring, through summer and approaching the fall there is a downward trend that can be observed of the model result with some locations reaching minimum values of approximately 6 mg/L. Finally, in October through the end of the year, DO concentrations increase up to 8 mg/L.

In comparing the Baseline simulation and the All Jamaica Bay WPCPs to ocean outfall alternative there is little or no impact to the model results with the proposed outfall. DO levels either remain the same as the Baseline or are slightly lower with the addition of the outfall load. This decline in concentration of DO observed at the water column mid-depth, especially at the outfall location where DO concentrations decrease from 5.9 mg/L to 5.3 mg/L, and can be attributed to the increased BOD concentrations due to the outfall discharge.

7.3.3.3.5 Particulate Organic Carbon Flux and Sediment Oxygen Demand (SOD)

Sediment oxygen demand (SOD) is due to the oxidation of organic matter in the bottom sediments. These benthic deposits come from several sources; wastewater particulates, allochthonous particulates as well as phytoplankton that settle, accumulate and decompose in the bottom sediments.

Along with temperature, SOD is affected by organic content of the sediment and oxygen concentration of the overlying water column. Particulate organic carbon (POC) is delivered to the sediment by settling. Within the anaerobic sediment, the organic carbon decomposes to yield

hydrogen sulfide. The hydrogen sulfide then diffuses upward to the aerobic zone where it is oxidized, generating SOD.

7.3.3.3.5.1 Jamaica WPCP to Ocean Outfall (57 ft)

Figure 7-57 shows POC flux (mg/m^2-d) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at locations surrounding the proposed outfall and the outfall location for the entire model year of 1988. The figure shows instantaneous POC flux calculations at daily intervals.

POC flux to the sediment show a strong seasonal spike with highest fluxes observed in the fall, and a smaller spike in the spring. These peaks are related to phytoplankton growth and deposition. In the fall, there is sometimes a phytoplankton bloom, characterized by high levels of Chlorophyll-a. POC fluxes reach as high as 330 and 200 mg/m^2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the Jamaica WPCP to ocean outfall alternative, there is a small impact to POC flux to the sediment with the proposed outfall. POC fluxes either remain the virtually the same to the Baseline in the areas surrounding the outfall, or are slightly higher at the outfall location. The annual average POC flux increased from 102 mg/m^2-d to 152 mg/m^2-d, and the POC flux maximum increased from 308 mg/m2-d to 333 mg/m^2-d in the outfall segment. This POC flux increase is expected due to the addition of organic matter being discharged into the outfall location from the Jamaica WPCP.

Figure 7-58 presents SOD (gm O2/m^2-d) for the Baseline and Jamaica WPCP to ocean outfall (57 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the model year of 1988. SOD flux to the sediment shows a strong seasonal spike with highest fluxes observed in the fall, and a smaller spike in late spring. This peak is related to temperature, the flux of POC to the sediment and is, therefore, related to phytoplankton growth and death. SOD fluxes reach as high as 0.75 and 0.3 gm O2/m^2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the Jamaica WPCP to ocean outfall alternative, there is little or no impact to the SOD with the proposed outfall. SOD fluxes either remain the same or almost the same to the Baseline in the areas surrounding the outfall. SOD are slightly increased at the outfall location from yearly average SOD flux of 0.23 gm O2/m^2-d to 0.26 gm O2/m2-d from the baseline to Jamaica WPCP to the Atlantic Ocean. This increase is expected due to the addition of organic matter being discharge into the outfall location from the Jamaica WPCP.

7.3.3.3.5.2 Jamaica and 26th Ward WPCPs to Ocean Outfall (73 ft)

Figure 7-59 shows POC flux (mg/m2-d) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at eight different locations surrounding the proposed outfall and the outfall location for the entire model year of 1988. POC flux to the sediment shows a strong seasonal spike with highest fluxes observed in the fall and a smaller spike in the spring. POC fluxes reach as high as 350 and 240 mg/m2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the Jamaica and 26th Ward WPCPs to ocean outfall alternative, there is a small impact to POC flux to the sediment with the proposed outfall. POC fluxes

remain virtually the same to the Baseline in the areas surrounding the outfall. The POC fluxes are slightly higher at the outfall location where the yearly average increases from 93 mg/m^2-d to 147 mg/m^2-d. This POC flux increase is expected due to the addition of organic matter being discharged into the outfall location from the Jamaica and 26th Ward WPCPs.

Figure 7-60 presents SOD (gm O2/m^2-d) for the Baseline and Jamaica and 26th Ward WPCPs to ocean outfall (73 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the model year of 1988. SOD flux to the sediment shows a strong seasonal spike with highest fluxes observed in the fall and a smaller spike in late spring. SOD fluxes reach as high as 0.75 and 0.4 gm O2/m^2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the Jamaica and 26th Ward WPCPs to ocean outfall alternative, there is little or no impact to SOD flux to the sediment with the proposed outfall. SOD fluxes either remain the almost the same to the Baseline or are slightly higher at the outfall location. The yearly average SOD flux increases from 0.24 gm O2/m^2-d to 0.29 gm O2/m^2-d. This increase is expected due to the addition of organic matter being discharged into the outfall location from the Jamaica and 26th Ward WPCPs.

7.3.3.3.5.3 All Jamaica Bay WPCPs to Ocean Outfall (99 ft)

Figure 7-61 presents the POC flux (mg/m2-d) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the entire model year of 1988. Similar to the previous set of figures, POC fluxes to the sediment show a strong seasonal spike with highest fluxes observed in the fall and a smaller spike in the spring. POC fluxes reach as high as 220 and 190 mg/m^2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the All Jamaica Bay WPCPs to ocean outfall alternative, there is little change to the POC flux to the sediment with the proposed outfall. POC fluxes virtually the same as the Baseline, as seen in the areas surrounding the outfall, or are slightly higher at the outfall location, where the annual POC flux increases from 80 mg/m2-d to 122 mg/m^2-d, and the areas just north and east to the outfall. This increase is expected due to the addition of organic matter being discharged into the outfall location from the Jamaica Bay WPCPs.

Figure 7-62 shows the SOD (gm O2/m^2-d) for the Baseline and All Jamaica Bay WPCPs to ocean outfall (99 ft) alternatives at various locations surrounding the proposed outfall and the outfall location for the model year of 1988. SOD flux to the sediment results show a strong seasonal spike with the highest fluxes observed in the fall, followed by a smaller spike in late spring. This peak is related to the flux of POC to the sediment and, therefore, related to phytoplankton growth and decomposition. SOD fluxes reach as high as 0.6 and 0.3 gm O2/m^2-d in the fall and spring, respectively.

In comparing the Baseline simulation and the Jamaica WPCP to ocean outfall alternative, there is little or no impact to SOD flux to the sediment with the proposed outfall. SOD fluxes either remain the almost the same to the Baseline, as seen in the areas surrounding the outfall, or are slightly higher at the outfall location. This increase is expected due to the addition of organic matter being discharged into the outfall location from the Jamaica Bay WPCPs.

7.3.3.3.6 Other Standards

In order to complete a thorough analysis of the impact of an ocean outfall on water quality, a modeling analysis was completed to determine if current or proposed water quality standards would be violated due to the effluent discharge. Three additional parameters were analyzed. These parameters include total residual chlorine (TRC), enterococci bacteria, and un-ionized ammonia (NH_3). As of the writing of this report, only a TRC standard was in place, and NYSDEC was considering implementation of the EPA criteria for enterococci and NH_3.

7.3.3.3.6.1 Total Residual Chlorine (TRC)

As part of the work conducted for the Jamaica Bay CSO Facility Planning Project the decay of the TRC was measured using the ambient water of the New York City area. Based on this analysis, a second-order decay rate was developed with a decay rate of 0.034 L/ug-d. This value was used for the modeling analysis of TRC in the Long Outfall Project.

The current NYSDEC standards for TRC include acute and chronic limits. The acute standard is a not to exceed concentration of 13 ug/L over an hour period. The chronic standard is a four-day average concentration not to exceed 7.5 ug/L. The far-field model LOEM was used to calculate the TRC concentration at each potential outfall location. The concentrations for TRC for each WPCP were based on the permit maximums presented in Table 7-14. Figure 7-63 presents results for the TRC in the bottom layer of the outfall segments assuming no decay in the outfall tunnel. For the Jamaica and 26th Ward WPCPs alternative, a violation of the acute standard would occur approximately one percent of the time on an annual basis. The other two alternatives show no violation of the acute standard.

The annual median is below the chronic standard for all three alternatives. It is unrealistic, however, to assume there is no decay in the outfall tunnel because the travel time can be several hours. Using minimum time of travel estimates made by O'Brien and Gere Engineers and a decay rate of 2.0/day, end of pipe TRC concentrations were assigned to the effluent discharges. These values are presented in Table 7-15. Figure 7-64 presents the model TRC concentrations in the bottom layer of the outfall location for each alternative. The model line represents hourly output over the entire year. The model indicates the TRC concentration will remain a factor of two below the acute TRC standard and the median TRC concentration is a factor of more than three below the chronic standard. The far-field modeling analysis indicates that there would be no violations of the TRC standard.

Due to the size of the model segments into which the outfall discharges were assigned, the far-field model probably overestimated the dilution of TRC around the outfall. To analyze the area around the outfall, a simple dilution calculation was made. The effluent concentrations listed in Table 7-15 were flow weighted (at maximum flow rates) and divided by 7.5 ug/L. The results were that the Jamaica WPCP only outfall would require a minimum dilution of 56:1, the Jamaica and 26th Ward WPCPs outfall would require a minimum dilution of 47:1, and the all WPCPs outfall would require a minimum dilution of 46:1.

7.3.3.3.6.2 Enterococci Bacteria

Enterococci were modeled using a simple first-order exponential decay rate in the same manner as total and fecal coliform bacteria. Enterococci were given a slightly slower base decay rate of 0.68/day versus 0.8/day used for total and fecal coliform, plus up to an additional 0.6/day based on salinity.

The proposed enterococci standard is a four-day geometric mean (GM) of 35 counts/100mL. USEPA also recommends a single sample maximum (SSM) of less than 105 counts/100mL at bathing beaches. Using a somewhat sparse data set from Jamaica Bay WPCP effluent enterococci concentrations, two methods were used to develop WPCP effluent concentrations in the model. An estimate of the mean (approximately the 85th percentile) concentration of 251 counts/100mL was calculated. This concentration was assigned as a constant concentration to all of the WPCPs. The second method involved developing a synthetic probability distribution to represent the range of observed enterococci data. (The second method was conceived when the proposed single sample maximum standard was being considered.) With both methods, no bacterial decay was assumed in the pipe.

Figure 7-65 presents the results of the enterococci modeling for the bottom layer of the outfall sites. The model results show that the enterococci concentrations would be well below the geometric mean and single sample maximum standards. The modeling analysis showed no violations of the proposed standard of a four-day geometric mean of 35 counts/100mL. Assuming the model overestimated the dilution around the outfall, the simple dilution calculation was completed. With an effluent concentration of 251 counts/100mL only a dilution of 7.2:1 is required to meet the standard.

7.3.3.3.7. Rockaway Inlet Outfall

Positive impacts on water quality in the open waters of Jamaica Bay occur due to outfall relocation to the Rockaway Inlet. JEM does not show much of a local impact in water quality in the area of the relocated outfalls. Under baseline conditions, the Coney Island WPCP, which is already located in the Rockaway Inlet, contributes 35 percent of the TN load to the bay. However, tidal flushing appears to be sufficient to keep the impact of the increased loading in the area to a minimum. The results from JEM cannot show the impact of outfall relocation to the Rockaway Inlet on areas outside of the bay. However, as the nitrogen load from the Jamaica Bay WPCPs currently exits the bay through the Inlet, no impact on outside areas is expected.

An analysis similar to that conducted for the ocean outfall was not completed for the Rockaway Inlet outfall. A CORMIX analysis was not conducted because the water column in the Inlet is relatively shallow and well mixed, so that it is not possible to trap the effluent plume. A flux analysis, presented in section 7.3.4, indicates that more than 75 percent of the TN discharged into Jamaica Bay exits through the Rockaway Inlet, and that Jamaica Bay contributes only 10 percent of the TN in the Hudson River Plume. Moving the outfall effluent closer to the mouth of Jamaica Bay would not substantially increase these percentages. However, the composition of the TN would change in that the percentage of DIN would increase as less DIN would be converted to PON by phytoplankton within the bay. The current estimate is that Jamaica Bay contributes approximately three percent of the DIN in the Hudson River plume.

A model run was completed with LOEM applying the flows and loads from the four Jamaica Bay WPCPs to the Rockaway Inlet. DIN concentrations decrease dramatically in Jamaica Bay with only small (less than 50 ug/L) increases outside of the bay. Increases in chlorophyll-a of less than 3 ug/L are computed in a few segments out side of the bay. However, DO concentrations outside of the bay are virtually unaffected by the relocation of the outfall to the Rockaway Inlet.

7.3.4. Nitrogen Flux Balance

7.3.4.1. Introduction

Relocation of the effluent from as many as four NYC WPCPs from Jamaica Bay to the Atlantic Ocean would result in a shift in the nitrogen transport throughout the New York Bight. Increased nitrogen concentrations in the ocean could lead to increased eutrophication and subsequently higher chlorophyll levels and lower dissolved oxygen levels. In order to assess the potential impact of relocating this effluent, a nitrogen flux balance was conducted in the New York Bight. For this analysis, a resegmented version of the System-Wide Eutrophication Model (SWEM) was used. This model has been named the Long Outfall Eutrophication Model (LOEM), which has finer segmentation in the area of the proposed outfall. Transects were chosen at several locations in the bight complex, and LOEM was used to calculate the net flux of both total nitrogen (TN) and dissolved inorganic nitrogen (DIN) across each transect. The magnitude of these fluxes across the various transects provide an indication as to how important the Jamaica Bay nitrogen loads are to the NY Bight area.

The nitrogen flux balance was completed for four different conditions, 1) All four Jamaica Bay WPCPs discharging to Jamaica Bay, 2) the Jamaica WPCP discharging into the Atlantic Ocean, 3) the Jamaica and 26th Ward WPCP's effluent discharged into the Atlantic Ocean, and 4) all four Jamaica Bay WPCPs discharging through the long outfall into the Atlantic Ocean. Alternative 1 was completed to assess how much of the nitrogen being discharged into Jamaica Bay is being exported to the Lower Bay through the Rockaway Inlet, and to serve as a baseline that could be compared to the other alternatives. These results were cross-checked with modeling results from the Jamaica Bay Eutrophication Model (JEM). The other alternatives were completed to assess the changes to the nitrogen flux balance due to the effluent relocation.

These alternatives were used to answer several important questions including the following questions. How much nitrogen is being exported from Jamaica Bay and how does this compare to the nitrogen being exported by other sources, such as the Hudson River? How much nitrogen is being exported toward the NJ shore, and how will the export change with the construction of the long outfall? How much nitrogen is being exported towards the south shores of eastern Long Island, and how will this export change with the construction of the long outfall? The answers to these questions have both environmental and political ramifications.

LOEM inputs were set up for the Use and Standards Attainment (USA) Project baseline conditions. These baseline conditions include 1988 meteorological and tidal conditions, year 2045 WPCP flows and year 2014 nitrogen loads. 1988 meteorological conditions reflect a good approximation of average rainfall conditions for the area. The future flow and nitrogen loads reflect anticipated future conditions. The results of this analysis can, therefore, be considered a reasonable approximation of average future conditions, but not of extreme conditions that may occur from time to time.

7.3.4.2. Results

Figure 7-66 presents the transects that were chosen for the nitrogen flux balance analysis. The transects were chosen at the Narrows between the Upper Bay and Lower Bay, the entrance to Raritan Bay, from Sandy Hook to the Rockaway Inlet, two transects perpendicular to Long Island, and along the New Jersey coastline. These transects were chosen to identify the individual components of the nitrogen flux in the bight.

Figure 7-66 also provides a summary of the annual flux of nitrogen for with all WPCPs discharging to Jamaica Bay. The flux calculations indicate that 112,000 kg N/day (246,900 lb N/day) are discharged from the Hudson River with another 39,200 kg N/day (86,400 lb N/day) exiting Raritan Bay on an annual basis. Jamaica Bay exports 18,400 kg N/day (40,600 lb N/day) based on LOEM calculations. This represents an amount equal to 90 percent of the total nitrogen load discharged from WPCPs to Jamaica Bay. These estimates are somewhat higher than computed by the Jamaica Bay Eutrophication Model - JEM (76 percent). JEM accounts for the uptake of nitrogen by the marshes, while LOEM does not. Overall, 177,100 kg N/day (390,400 lb N/day) are exported into the NY Bight from the NYC area. Of this amount, Jamaica Bay accounts for approximately 10 percent of the nitrogen being exported. The model also calculates a net flux of TN toward the east at the eastern edge of the transects that were analyzed, and a net flux towards the north at the southern edge of the transects that were analyzed.

Note that the sums of all of the fluxes into and out of each box are not equal. These differences are due to sources, sinks of TN in each box. Sinks include settling of nitrogen to the sediment. Sources include point source loads and atmospheric deposition. Another reason for the apparent imbalance is a net accumulation or loss of TN that occurs in each box during the year.

Due to the freshwater from the Hudson River, the entrance to the NY Bight can be strongly stratified. This stratification can result in a two-layer flow as the tides change with freshwater flowing southeast on the surface and saltwater on the bottom flowing to the northwest and up the Hudson River. In an attempt to view this two layer flow pattern, the transect analysis was completed for the top five layers and the bottom five layers, without concern for the depth level at which the change in direction of the flow may occur. Figures 7-67 and 7-68 present the results of this analysis. The results from the surface layers show a different pattern from the entire water column. In the surface layer, there is a net flux in a southerly direction along the NJ coast and a consistent flux occurs in an easterly direction along the Long Island Coast. In the bottom layers this pattern is reversed in that there is a net flux of nitrogen toward the north along the NJ coast and a flux in a westerly direction along the western portion of Long Island. The net fluxes have also reversed in the Hudson River and Raritan Bay. Thus, it can be concluded that the majority of the net flux of nitrogen that enters the NY Bight from the northwest enters via the surface layers of the water column.

The major concern with regard to nitrogen loadings is the potential for eutrophication. This over enrichment of nutrients, such as nitrogen, can fuel phytoplankton blooms, which can lead to low DO levels in the water column. Flux analyses were completed for DIN to determine how this nutrient was moving through the NY Bight.

Figure 7-69 shows the flux analysis for the baseline conditions for DIN in all 10 layers of the model. Based on the DIN fluxes, it is apparent that a high percentage of the TN flux from the Hudson River

is DIN flux with lower percentages from Raritan Bay, and Jamaica Bay where the DIN is utilized by phytoplankton.

The Hudson River exports 89,900 kg N/day (198,200 lb N/day) of DIN, which is 80 percent of the TN flux from the river. Raritan Bay exports 4,500 kg N/day (9,900 lb N/day) of DIN, which is 11 percent of the TN flux from the bay. Jamaica Bay exports 5,600 kg N/day (12,300 lb N/day) of DIN, which is 30 percent of the TN flux from the bay. Overall, Jamaica Bay contributes only 3.2 percent of the DIN entering the NY Bight through the Rockaway Peninsula – Sandy Hook transect.

The DIN fluxes that were computed in the top and bottom five layers of the model are presented in Figures 7-70 and 7-71. The conclusions drawn for the DIN fluxes from these figures are essentially the same as for the TN fluxes. The net DIN flux out of the Lower Harbor occurs in the surface layers, and there is a net southerly flux down the NJ coastline. In the lower layers there is a net northerly DIN flux along the NJ coastline and net DIN fluxes into Raritan Bay and the Hudson River.

The same flux analyses were completed for each of the outfall alternatives. Since the results for TN and DIN are similar and DIN is the portion of TN that is available for phytoplankton growth. Only the DIN results will be discussed in the remainder of this section.

The Jamaica WPCP currently discharges more DIN into Jamaica Bay than any of the other Jamaica Bay WPCPs. Located in the northeastern corner of Jamaica Bay, the Jamaica WPCP discharges into the area of the bay with the longest detention time allowing phytoplankton more time to grow. Based on results from the Jamaica Bay Eutrophication Model (JEM), relocating the Jamaica WPCP outfall would have the greatest positive impact on Jamaica Bay of any of the WPCPs. A comparison of Figures 7-69 and 7-72 shows that relocation of the Jamaica WPCP outfall reduces the net flux of DIN from Jamaica Bay by 52 percent (from 5,600 kg N/day to 2,700 kg N/day). The impact on the area around the outfall is a decrease in the flux of DIN along the western portion of the Rockaway Peninsula (33 percent), an increase in the net DIN flux toward the peninsula (43 percent) and an increase in the DIN flux toward eastern Long Island (30 percent).

Figures 7-73 and 7-74 present results for layers 1-5 and 6-10, respectively. In the top half of the water column, there is a net decrease in the DIN flowing toward the east along the Rockaway Peninsula on the eastern side of the outfall as a result of the decrease in DIN being exported by Jamaica Bay. There is an increase in the net DIN flux flowing north from the outfall and east along Long Island. The bottom layers show a net increase in the DIN flux in the north and west directions from the outfall location and eastward along the Long Island coastline.

Analysis from JEM indicated that the next logical outfall to relocate from Jamaica Bay would be the 26th Ward WPCP. Figure 7-75 presents the DIN flux results for moving the Jamaica and 26th Ward WPCPs to an ocean outfall. The outfall is located in deeper water to keep the plume trapped with the higher flows of two WPCPs verses one. The flux analysis shows a 71 percent decrease in the DIN flux from Jamaica Bay (from 5,600 to 1,600 kg N/day). While there is an increase in the net DIN flux toward and along the Long Island coastline over the baseline conditions, the increase is smaller, in the segments along the coast than for the Jamaica WPCP only alternative.

Based on Figures 7-76 and 7-77, which show the flux analysis for layers 1-5 and 6-10, respectively, this increase toward and along the Long Island coastline is due to a decrease in the net surface flux

around the outfall for the Jamaica and 26th Ward WPCP relocation alternative. Because the outfall is further from the coastline, the fluxes that change the most are further from the coastline.

The final alternative that was analyzed was moving all of the Jamaica Bay WPCP outfalls to the ocean. Figure 7-78 presents the DIN flux results of this alternative for all ten layers. Since the outfall discharge flow is increased by including all of the WPCPs, the outfall is located further offshore in an effort to trap the plume. The relocation of the WPCP effluent from Jamaica Bay results in a net DIN flux into the bay rather than out of the bay. The outfall results in a greater flux of DIN toward the Rockaway Peninsula over the baseline conditions, but the increase is less than the other two outfall alternatives. Also, the net flux of DIN along the western Long Island coastline has decreased over the baseline conditions. The increases in DIN fluxes have occurred offshore. Analysis of the top and bottom five layers of the model (Figures 7-79 and 7-80) shows small differences between the baseline and all four WPCPs to the ocean near the coastline. The net eastward surface flux of DIN along western Long Island has decreased, while the net westward bottom flux in the same area has increased. Also, there is an increase in the net surface DIN flux toward the Long Island coast under the outfall alternative.

Ultimately, the changes in the net fluxes in the ocean are not great due to outfall relocation. However, there are major benefits to Jamaica Bay with outfall relocation as presented in Section 7.3.3.

7.3.4.3. Model Tracer Runs

Residents of the State of New Jersey might be concerned that an ocean outfall could increase the level of nutrients along the NJ shoreline leading to algal blooms. To provide further information as to the transport of nitrogen within the NY Bight, a series of model runs were completed using nitrogen as a conservative tracer. A component analysis was completed by running the model with only one source of nitrogen at a time. These individual sources included the open boundary, atmospheric deposition, the NJ shore, Jamaica Bay, the proposed ocean outfall, and the Hudson River (including all loads to the Long Island Sound). The outfall run was completed with all of the WPCPs relocated to the ocean. These runs were completed to assess the potential impact of the ocean outfall on the NJ shore compared with the other sources of nitrogen.

Figure 7-81 shows the results for TN in the surface layer for three locations along the NJ coastline. The model results are ten-day averages. Note the y-axis is on a log-scale. At all three locations, the open boundary is the largest contributor to the TN concentration with a larger percentage of the total TN closer to the boundary. The open boundary contributes approximately 0.3 mg N/L to the NJ coastal TN concentration. The next largest contributor to the TN load is the Hudson River plume. Off northern NJ, the Hudson River contribution to the TN is similar to the open boundary at approximately 0.2 mg N/L on an annual basis. Along the central NJ coast the contribution of the Hudson River is approximately 0.08 mg/L on an annual average, and off of southern NJ the Hudson River contributes approximately 0.04 mg/L. The next largest source of TN to the coastal NJ waters is atmospheric deposition. Atmospheric deposition accounts for approximately 0.01 mg N/L. The next three TN sources, the NJ shore, Jamaica Bay, and the ocean outfall are all of similar magnitude. Along the northern NJ shore the TN concentration due to each of these sources is 0.001 to 0.015 mg N/L with Jamaica Bay being the dominant source with an annual average of 0.006 mg N/L. Off of central NJ, the TN concentrations are lower ranging from 0.002 to 0.003 mg N/L on an annual average basis. Off of southern NJ, the concentrations are lower than the central NJ concentrations.

Some interesting features can be observed during June, July, and August, especially off of the central and southern portions of the coast. As a result of lower Hudson River flows, the TN concentrations are lower during this period. Not only does this reduce the loads from the Hudson River, but also the circulation in the NY Bight is affected resulting in less transport of other sources to the NJ coast. Other declines in the TN concentrations from some of the sources are observed in March and November, especially in southern NJ. A corresponding increase in the contribution from the boundary can be observed.

Figure 7-82 presents the same TN results for the bottom layer. The relative magnitude of the sources is the same. The open boundary remains the largest contributor and the Hudson River is the second largest source. However, the contribution from the Hudson River is smaller off of central and southern NJ.

The same analysis was completed for DIN and is presented in Figures 7-83 and 7-84 and the results are somewhat different. Along the northern NJ coastline, the Hudson River plume dominates the DIN concentration at approximately 0.08 mg N/L. The open boundary ranges from approximately 0.004 to 0.04 mg N/L and atmospheric deposition contributes approximately 0.01 mg/L. This concentration is the same as the Michaelis concentration assigned for nitrogen. The Michaelis concentration is the concentration at which the nitrogen concentration is low enough to limit phytoplankton growth to a point where its growth is half of the maximum growth rate. The other three sources (i.e., loadings from New Jersey sources and Jamaica Bay WPCPs discharging in Jamaica Bay or the Jamaica Bay WPCPs relocated to the ocean) generally less than 0.002 mg N/L. Therefore, these sources would do little to affect phytoplankton growth along the NJ shore. Along central NJ, the Hudson River load dominates during the cooler months, and is similar to the boundary contribution during the warmer months. Atmospheric deposition remains the third largest source. The other three sources are similar and generally less than 0.001 mg N/L. The results for southern NJ show a similar story. The bottom layer results generally produce the same conclusions as the surface layer. One exception is that in the top panel, the NJ shore sources clearly result in larger DIN concentrations than either Jamaica Bay or the outfall.

7.3.5. Conclusions

A modeling analysis was conducted to help determine if building an ocean outfall to relocate secondary treated effluent from Jamaica Bay to the Atlantic Ocean would be a feasible alternative for improving water quality in Jamaica Bay. The analysis was completed to determine if the ocean outfall would have detrimental impacts on ocean water quality in areas proximal to the outfall. Using CORMIX and LOEM, three alternatives were examined: 1) relocation of the Jamaica WPCP effluent to the ocean, 2) relocation of the Jamaica and 26th Ward WPCP effluent to the ocean, and 3) relocation of the effluent from all four WPCPs to the ocean.

Through the use of the models it was determined that a 1,225 m multiport diffuser located approximately three miles from Long Island at a depth of 57 ft would be adequate to trap the effluent plume from the Jamaica WPCP under normal operating conditions. A 1,500 m multiport diffuser located approximately four miles off of the coast of Long Island at a depth of 73 ft would be adequate to trap the effluent plume from the Jamaica and 26th Ward WPCPs under normal operating conditions. Also a 1,225 m multiport diffuser located approximately 6.5 miles off of the coast of Long Island at a depth of 99 ft would be adequate to trap the effluent plume from all four WPCPs

under normal operating conditions. During peak wet-weather events, the plumes would reach the surface, but the water quality impacts from these events would be small. All of the outfall diffusers examined should be able to obtain a dilution over 100 to 1.

The modeling analysis showed that provided the location, depth, and diffuser design are properly chosen, that all three alternatives could potentially be implemented. None of the three alternatives examined would have adverse affects on DO or chlorophyll-a, nor would the alternatives result in violations of the current TRC standard or the proposed enterococci or unionized ammonia standards outside of the initial zone of dilution of the diffuser. Effluent from the outfall would not have a significant impact on the NJ coastline.

7.3.6. Recommendations for Final Design

The locations of the diffusers for the various outfall relocation alternatives were based on a number of assumptions and model results. If one of the outfall relocation alternatives were chosen it is important to field verify the assumptions used in the model and used for placing the outfall diffusers. The following is a list of recommendations that should be completed before deciding on a final outfall diffuser location.

1) Verify the location of underground cables and pipelines. The length of the diffuser will affect the dilution of the effluent. A longer diffuser results in more dilution. If a shorter diffuser than required is necessary due to space limitations, the diffuser location may have to be moved.

2) Monitor the potential outfall location for currents and vertical stratification. The CORMIX modeling assumed currents and density stratification based on model results. Field data could show that the system has less or greater stratification than the far-field model predicted, or that the current speeds are different than the model calculated. If measurements show significant differences from the model results, the estimated impact of the outfall plume on water quality could change.

3) Monitor the potential outfall location for baseline water quality conditions. Baseline conditions in Massachusetts Bay were collected at dozens of water quality stations for several years before Boston's Deer Island WWTP outfall went on-line. Sampling for baseline conditions over several years shows the natural variation of water quality in the area. Understanding the natural variability of the area could help determine if differences in water quality that are observed after the Atlantic Ocean outfall goes on-line are due to natural variability or are due to the influences of the outfall plume.

4) Monitor water quality after the outfall goes on-line. The Deer Island WWTP permit requires water quality monitoring of the area around the diffuser to track the impact of the effluent plume on water quality. Contingency plans are required if water quality exceeds certain concentration limits. It is likely that a similar requirement would be placed on the Department for the Atlantic Ocean outfall.