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NITROGEN REDUCTION COST ESTIMATION STUDY Final Summary Report

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Prepared by
Kleinfelder, Inc.

Prepared for
Delaware River Basin Commission

Managing, Protecting and Improving the Water Resources of the Delaware River Basin since 1961

60 years 1961–2021

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

NITROGEN REDUCTION COST ESTIMATION STUDY

SUMMARY REPORT

Delaware River Basin Commission

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FINAL

PREPARED BY:
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1.0 INTRODUCTION

The Delaware River has experienced a significant revitalization due to the Clean Water Act of 1972 and the wastewater treatment improvements that were subsequently implemented. While the water quality improvements of the Delaware River have been dramatic, water quality concerns still remain, including dissolved oxygen levels in the Delaware Estuary.

As a result of this specific concern, the Delaware River Basin Commission (DRBC) established a project to evaluate the attainability of higher levels of dissolved oxygen in the Delaware Estuary. A key component of this project is the nitrogen reduction cost estimation study requested by DRBC to evaluate the capital and operating and maintenance costs for the twelve (12) largest dischargers to the lower Delaware River to attain various levels of nitrogen reduction. While ammonia-nitrogen (NH_3-N is the parameter of primary concern related to this study, DRBC is also interested in understanding the additional cost to remove the nitrate-nitrogen generated by the nitrification process, thereby removing total nitrogen (TN).

The available funding for this study was limited, considering the number of plants involved and the number of upgrade scenarios for each plant to attain various levels of nitrogen reduction. As a result, the same approach for efficiently developing cost estimates was utilized for this nitrogen reduction cost study that was previously utilized successfully for a similar nutrient reduction cost study for the New York-New Jersey harbor estuary program.

This approach is based on a two-step process that begins with developing generic plant descriptions (presented in Section 2.0). The purpose of the generic plant descriptions is to establish the representative/average characteristics of the three (3) plant types within the group of twelve (12) plants being studied, i.e., conventional activated sludge, pure oxygen activated sludge (also referred to as high purity oxygen activated sludge) , and fixed film (trickling filters and rotating biological contactors).

The generic plant descriptions are used in the process of developing the three (3) effluent levels for NH_3-N reduction and one (1) level of TN reduction (presented in Section 3.0) and in developing technology recommendations for each plant type to achieve the NH_3-N and TN effluent levels (presented in Section 4.0). The resulting effluent levels and technology recommendations serve as the basis for developing generic plant budgetary capital cost estimates for each plant type and for the three levels of NH_3-N removal and one level of TN removal (presented in Section 5).

The generic plant budgetary capital cost estimates are then used in conjunction with the design basis flows for the three (3) generic plants to establish for each plant type the budgetary capital costs on a $/gpd basis to achieve each of the three (3) ammonia-nitrogen effluent levels and one (1) total nitrogen effluent level.

The generic plant budgetary capital cost estimates on a $/gpd basis are used as the starting point in Step 2 to develop plant specific budgetary capital cost estimates for each individual plant. Budgetary operating and maintenance (O&M) costs are also developed and used to estimate budgetary total present costs, which are the sum of capital costs plus the present worth of annual O&M cost, and budgetary annualized costs, which are the budgetary annual debt service costs plus budgetary annual O&M costs. The total present cost and total annualized cost for each upgrade scenario are depicted in cost removal curves for each individual plant and for the sum of all twelve (12) plants (presented in Section 6.0) Because improvements to remove nitrogen will also result in additional BOD removal, the estimated BOD reduction resulting from each nitrogen removal level is presented in Section 7.0.

2.0 GENERIC PLANT DESCRIPTIONS

The data and information utilized to develop the generic plant descriptions was obtained through publicly available sources, such as discharge monitoring reports, as well as information received directly from representatives of the individual plants in response to a data request from Kleinfelder that was emailed to each of the plant representatives. Detailed recycle stream flow and ammonia-nitrogen concentration data were not widely available. Therefore, the generic plant values established for recycle flow and strength were based on limited data from the twelve (12) plants together with literature values.

The generic plant descriptions follow.

2.1 Generic Pure Oxygen Activated Sludge Plant

Three (3) of the twelve (12) plants are pure oxygen activated sludge plants as listed below:

1. Philadelphia Water Department (PWD) Southwest Water Pollution Control Plant (SWWPCP).
2. Camden County Municipal Utilities Authority (CCMUA) Delaware No. 1 Water Pollution Control Plant (WPCP).
3. Morrisville Borough Municipal Authority (MMA) Wastewater Treatment Plant (WWTP).

As previously noted, pure oxygen activated sludge is also referred to as high purity oxygen (HPO) activated sludge.

It is also noted that the PWD Southeast Water Pollution Control Plant (SEWPCP) was originally designed as a pure oxygen activated sludge plant but has been operating as a conventional air activated sludge plant for many years. Therefore, this plant is currently characterized as a conventional activated sludge plant.

As shown in Plant Data Summary in Appendix A, the permitted capacity of the three (3) pure oxygen activated sludge plants range from 8.7 mgd to 200 mgd, and in 2018 they collectively contributed approximately 50% of the total ammonia-nitrogen load discharged by the twelve (12) plants.

Each of these plants have multiple primary settling tanks, multiple oxygenation tanks and multiple final clarifiers. Two (2) of the three plants currently have anaerobic digesters (i.e. the PWD SWWPCP and MMA WWTP) and anaerobic digesters are currently being constructed at the CCMUA WPCP. Anaerobic digesters are of interest because while they provide significant operational cost benefits, the dewatering of anaerobically digested sludge results in recycle streams high in ammonia-nitrogen concentration. All three plants have processes to thicken and dewater primary and waste activated sludge.

Due to the fundamental nature of pure oxygen activated sludge systems (low design hydraulic detention time, low design solids retention time, and low pH resulting from carbon dioxide entrainment within the enclosed oxygenation tanks), process control adjustments are not typically feasible to achieve nitrification. Consequently, add-on processes are generally required to achieve ammonia-nitrogen removal and total nitrogen removal at pure oxygen activated sludge plants. Therefore, for the generic activated sludge plant, it will be assumed that add-on processes will be required to achieve the three (3) levels of ammonia-nitrogen removal and one (1) level of total nitrogen removal. As a result, the characteristics most relevant to developing budgetary capital costs to upgrade the pure oxygen plants are plant flows, current effluent ammonia-nitrogen concentrations, and recycle stream ammonia-nitrogen loads. Also, as further described in the Effluent Levels Technical Memorandum, the plant upgrade improvements will be sized to achieve the effluent levels each month of the summer season defined as May 1 through October 31, rather than each month of the year. Therefore, the summer season minimum monthly average wastewater temperature is also relevant to the generic plant descriptions. The recommended values for the generic pure oxygen activated sludge plant are presented in the table below:

Table 2-1: Generic Pure Oxygen Activated Sludge Plant Characteristics

Parameter	Value
Influent Annual Average Flow	83 mgd
Influent Maximum Monthly (30 day average) Flow	97 mgd
Influent Maximum Daily (24 hour average) Flow	170 mgd
Influent Average CBOD Concentration	220 mg/L
Influent Average TSS Concentration	250 mg/L
Influent Average NH_3-N Concentration	25 mg/L
Recycle Average Flow from Thickening and Dewatering	8 mgd
Recycle Flow Average CBOD Concentration	800 mg/L
Recycle Flow Average TSS Concentration	500 mg/L
Recycle Flow Average NH_3-N Concentration	120 mg/L
Effluent Average CBOD Concentration	5 mg/L
Effluent Average TSS Concentration	6 mg/L
Effluent Summer Max. Monthly Average NH_3-N Concentration	26 mg/l
Effluent Average NH_3-N Concentration	19 mg/L
Effluent Min. Monthly Summer Temperature (C)	18°

2.2 Generic Fixed Film Plant

Three (3) of the twelve (12) plants are fixed film plants as listed below:

1. Trenton Sewer Utility Wastewater Treatment Plant (WWTP)
2. Hamilton Township Water Pollution Control Plant (WPCP)
3. Willingboro MUA Water Pollution Control Facility (WPCF)

As shown in the attached Plant Data Summary in Appendix A, the permitted capacity of these plants ranges from 5.22 mgd to 20 mgd, and in 2018 they collectively contributed approximately 3.6% of the total ammonia-nitrogen load discharged by the twelve (12) plants.

Two (2) of these plants utilize trickling filters as the fixed film process (Trenton Sewer Utility WWTP and Willingboro MUA WPCF) while the Hamilton Township WPCP utilizes rotating biological contactors (RBCs) as its main fixed film process but also utilizes a trickling filter to pretreat recycle flow from the sludge thickening and dewatering processes and a portion of the influent flow before directing pretreated flow to the main RBC treatment process.

Each of these plants have multiple primary settling tanks, multiple fixed film treatment units, and multiple final clarifiers. Two (2) of the three (3) plants have anaerobic digesters (i.e., the Hamilton Township WPCP and Willingboro MUA WPCF. These two (2) plants also have processes to thicken and/or dewater sludge. The Trenton Sewer Utility WWTP does not have anaerobic digesters or processes to thicken or dewater its sludge prior to disposal.

Unlike conventional activated sludge plants that can be controlled to operate at different biomass inventories (i.e., at various mixed liquor suspended solids concentrations and solids retention times) and thus achieve varying degrees of performance, trickling filters and RBCs cannot be controlled to achieve varying biomass inventories except by removing units from service or by placing standby units into service. Thus, the maximum degree of treatment occurs when all units are in service. Because most fixed film plants operate with all units in service, achieving higher levels of ammonia-nitrogen removal or total nitrogen removal in fixed film plants generally requires the use of add-on processes.

Therefore, for the generic fixed film plant, it will be assumed that add-on processes will be required to achieve the three (3) levels of ammonia-nitrogen removal and one (1) level of total nitrogen removal. As a result, the characteristics most relevant to developing budgetary capital costs to upgrade the fixed film plants are plant flows, current effluent ammonia-nitrogen concentrations, and recycle stream ammonia-nitrogen loads. Also, as further described in the Effluent Levels Technical Memorandum, the plant upgrade improvements will be sized to achieve the effluent levels each month of the summer season defined as May 1 through October 31, rather than each month of the year. Therefore, the summer season minimum monthly average wastewater temperature is also relevant to the generic plant description.

The recommended values for the generic fixed film plant are presented in table 2-2.

Table 2-2: Generic Fixed Film Plant Characteristics

Parameter	Value
Influent Annual Average Flow	9 mgd
Influent Maximum Monthly (30 day average) Flow	11 mgd
Influent Maximum Daily (24 hour average) Flow	15 mgd
Influent Average BOD Concentration	270 mg/L
Influent Average TSS Concentration	250 mg/L
Influent Average NH_3-N Concentration	30 mg/L
Recycle Average Flow from Thickening and Dewatering	1 mgd
Recycle Flow Average BOD Concentration	800 mg/L
Recycle Flow Average TSS Concentration	500 mg/L
Recycle Flow Average NH_3-NConcentration	120 mg/L
Effluent average BOD Concentration	19 mg/L
Effluent Average TSS Concentration	14 mg/L
Effluent Summer Max. Monthly Average NH_3-N Concentration	17 mg/l
Effluent Average NH_3-N Concentration	16 mg/L
Effluent Min. Monthly Summer Temperature (C)	18°

2.3 Generic Conventional Activated Sludge Plant

Six (6) of the twelve (12) plants are conventional activated sludge plants as listed below:

PWD Northeast Water Pollution Control Plant (NEWPCP)

1. City of Wilmington WWTP
2. Delaware County Regional Water Pollution Control Authority (DELCORA) Western Regional Treatment Plant (WRTP)
3. Gloucester County Utilities Authority (GCUA) WWTP
4. Lower Bucks County Joint Municipal Authority (LBCJMA) WWTP
5. PWD Southeast Water Pollution Control Plant (SEWPCP).

As shown in the attached Data Summary, the permitted capacity of these plants ranges from 10 mgd to 210 mgd, and in 2018 they collectively contributed approximately 46% of the total ammonia-nitrogen load discharged by the twelve (12) plants.

Each of the conventional activated sludge plants have multiple primary settling tanks, multiple aeration tanks, and multiple final clarifiers. Four (4) of the six (6) plants have anaerobic digesters (i.e., the PWD NEWPCP, the City of Wilmington WWTP, the GCUA WWTP, and the LBCJMA WWTP). All conventional activated sludge plants except the PWD SEWPCP have on-site processes to thicken and/or dewater sludge. Sludge from the SEWPCP is pumped to the SWWPCP for thickening and anaerobic digestion. The DELCORA WRTP has multiple hearth sludge incinerators while the City of Wilmington WWTP has a thermal drying process to produce Class A biosolids. PWD has a separate facility (i.e. the Biosolids Recycling Center or “BRC”) to dewater, thermally dry and produce Class A biosolids from sludge generated at NEWPCP, SEWPCP and SWWPCP. The BRC is located adjacent to the SWWPCP which receives recycle streams from the BRC’s dewatering and thermal drying processes.

The aeration tanks at several of the plants have the flexibility to be operated in different configurations (i.e., plug flow, step feed, contact stabilization or completely mixed) while other plants do not have such flexibility. The flexibility to operate in step feed and contact stabilization modes is beneficial in terms of being able to maximize biomass inventories (and thus maximizing performance) while preventing excessive loss of biomass during wet weather events.

Typically, conventional activated sludge plants that were designed for secondary treatment only and which are operating near the design flow for the plant will have several capacity limiting bottlenecks with respect to achieving significant removal of ammonia-nitrogen or total nitrogen. These bottlenecks typically include the following: (1) insufficient final clarifier capacity to handle the higher MLSS concentrations required for nitrification; (2) insufficient aeration tank volume to operate at a reasonable MLSS concentration while controlling the process at the higher solids retention time required for nitrification; (3) insufficient process air supply to satisfy the substantial increase in oxygen demand associated with nitrification; and (4) insufficient return sludge pumping capacity. In addition to the issues described above, there may also be a need to add an external source of alkalinity to compensate for the alkalinity consumption associated with nitrification.

In summary, there are typically a greater number of options to achieve ammonia-nitrogen and total nitrogen reduction in conventional activated sludge plants compared to pure oxygen activated sludge and fixed film plants depending upon the conservatism used in the original design of the plant, the flexibly to operate the aeration tanks in different modes, and how close the actual influent flows and loads are to the design basis flows and loads for the plant.

As a result, there are additional characteristics relevant to developing budgetary capital costs to upgrade the generic conventional activated sludge plants than there are for the generic fixed film plant or the generic pure oxygen activated sludge plant. The recommended characteristics and values for the generic conventional activated sludge plant are presented in the table below:

Table 2-3: Generic Conventional Activated Sludge Plant Characteristics

Parameter	Value
Influent Annual Average Flow	72 mgd
Influent Maximum Monthly (30 day average) Flow	87 mgd
Influent Maximum Daily (24 hour average) Flow	163 mgd
Influent Average CBOD Concentration	240 mg/L
Influent Average TSS Concentration	220 mg/L
Influent Average NH_3-N Concentration	25 mg/L

Primary Effluent Average Flow	79 mgd
Primary Effluent Average CBOD Concentration	200 mg/L
Primary Effluent Average TSS Concentration	150 mg/L
Primary Effluent Average NH_3-N Concentration.	33 mg/L
Recycle Average Flow from Thickening and Dewatering	7 mgd
Recycle Flow Average CBOD Concentration	800 mg/L
Recycle Flow Average TSS Concentration	500 mg/L
Recycle Flow Average NH_3-N Concentration	120 mg/L
Effluent average CBOD Concentration	7 mg/L
Effluent Average TSS Concentration	9 mg/L
Effluent Summer Max. Monthly Average NH_3-N Concentration	18 mg/l
Effluent Average NH_3-N Concentration	10 mg/L
Effluent Min. Monthly Summer Temperature (C)	18°

3.0 EFFLUENT LEVELS

The effluent levels selected for use in this study will have a direct impact on upgrade costs and will be used to develop a nitrogen removal cost curve which will be based on the aggregate cost of the twelve (12) plants to achieve each effluent level. The cost curve will enable an assessment of cost versus water quality benefit in achieving increasing levels of NH_3-N reduction and whether reduction in TN provides additional water quality benefits that justify the additional cost of TN removal. To enable development of the desired cost curve, three levels of NH_3-N reduction (low, medium, and high) will be utilized in one level of TN reduction.

Development of the specific numerical NH_3-N effluent levels corresponding to low, medium, and high levels of NH_3-N reduction and the numerical effluent level for TN removal are described below:

3.1 Numerical NH_3-N Effluent Levels for Cost Curve Development

As the first step in developing the numerical effluent levels corresponding to low, medium, and high levels of NH_3-N reduction, the NH_3-N effluent levels currently being discharged by the twelve (12) plants were identified and summarized in the Plant Data Summary in Appendix A. As indicated, there is wide variability in NH_3-N effluent levels currently being discharged by the twelve (12) plants. As also indicated, the overall average daily NH_3-N load of the combined average daily flow of 706 mgd discharged by the twelve (12) plants in 2018 was 77,322 pounds per day, resulting in an overall average daily NH_3-N concentration of 13.14 mg/L.

Therefore, a numerical effluent level of 10 mg/L would represent approximately a 3 mg/L reduction in the overall average NH_3-N concentration currently being discharged, resulting in approximately a 30% reduction in the NH_3-N load currently being discharged by the twelve (12) plants. Based on discussion with DRBC during a consensus-building meeting, it was agreed that this is a reasonable low level reduction for purposes of developing a cost curve for NH_3-N removal.

Based on the 2018 annual average effluent NH_3-N concentrations presented in the attached Plant Data Summary, six (6) of the twelve (12) plants achieved an annual average effluent NH_3-N concentration less than 10 mg/L in 2018 (PWD NEWPCP, DELCORA, PWD SEWPCP, Morrisville, Trenton and Willingboro). However, only two (2) of the plants (PWD NEWPCP and Willingboro) achieved annual average effluent NH_3-N concentrations less than 10 mg/L in both 2018 and 2017. Therefore, the scope and cost of improvements to reliably attain an effluent level of 10 mg/L for NH_3-N is expected to vary widely between plants, including a few plants that likely will not require upgrades.

Regarding the high level of NH_3-N reduction, during the same consensus-building meeting, it was agreed that a numerical value of 1.5 mg/L, should be used for the high level of NH_3-N removal because it represents approximately a 90% reduction in the current NH_3-N load, which is an appropriate end point for the NH_3-N removal cost curve.

Based on the 2018 annual average effluent NH_3-N concentrations presented in the attached Data Summary, none of the twelve (12) plants are currently achieving an effluent NH_3-N concentration of 1.5 mg/L. Therefore, it is anticipated that all plants will require significant upgrades to attain an effluent NH_3-N level of 1.5 mg/L.

Regarding the medium level of NH_3-N reduction, it was agreed that 5 mg/L is the appropriate mid-point for development of the NH_3-N cost removal curve and thus will be utilized as the medium level of NH_3-N reduction.

Based on the annual average effluent NH_3-N data presented in the attached Data Summary, only one (1) plant (Willingboro) achieved annual average effluent concentrations less than 5 mg/L in both 2017 and 2018. Therefore, it is anticipated that eleven (11) of the twelve (12) plants may require significant upgrades to reliably attain an effluent NH_3-N level of 5 mg/L.

In summary, the numerical NH_3-N effluent levels that will be used for cost curve development corresponding to low, medium, and high levels of NH_3-N reduction are 10 mg/L, 5 mg/L and 1.5 mg/L, respectively.

3.2 Numerical TN Effluent Level for Cost Curve Development

To achieve TN removal, the nitrate-nitrogen (NO_3-N) produced by the biological nitrification process, which converts NH_3-N to NO_3-N, must be converted to nitrogen gas via the biological denitrification process. While there are processes that can shorten this two-step conversion of NH_3-N to nitrogen gas, to date they have only been applied to high strength recycle streams at WWTPs, not to the full flow through a WWTP.

Based on discussions during the consensus-building meeting with DRBC, it was agreed that a numerical TN effluent level of 4 mg/L will be utilized for cost curve development because it is the rounded value based on 90% removal of a conservative NO_3-N concentration of 23 mg/L estimated to be produced when nitrifying to achieve an effluent NH_3-N level of 1.5 mg/L while also allowing for a nominal amount of organic nitrogen in the effluent.

3.3 Related Issues

The sizing and cost of NH_3-N and TN removal improvements will be influenced by the design basis temperature for the biological treatment process, i.e., whether the effluent levels are year-round values requiring that the biological process be sized for summer and winter temperatures, or seasonal values requiring that the biological process be sized only for summer temperatures. During the consensus-building meeting with DRBC, it was decided that the effluent levels should be considered seasonal monthly average levels applicable to the summer period defined as May

1 through October 31. Therefore, the NH_3-N and TN removal improvements will not be sized for winter temperatures.

The sizing and cost of NH_3-N and TN improvements will also be influenced by the design basis peak flow for the improvements, i.e., whether all peak wet-weather flow entering the plant must be treated by the NH_3-N and TN removal processes to achieve a daily maximum effluent level. During the consensus-building meeting with DRBC, it was decided that the improvements will not need to be sized to achieve daily maximum effluent levels; only to achieve the effluent levels described above on a monthly average basis during the summer season. Therefore, to the extent practicable considering the nature of the NH_3-N and TN removal improvements, a portion of the peak wet-weather flow could be diverted around the NH_3-N and TN removal process, provided the effluent levels described above are attained on a monthly average basis.

4.0 TECHNOLOGY RECOMMENDATIONS

The key objective in developing technology recommendations is to utilize proven technologies with long-term records of performance to ensure a reasonable degree of confidence in plant upgrade performance and the ability to appropriately estimate construction and operating costs. Emerging technologies, such as the granular activated sludge process, were not considered because while they have the potential to be attractive in terms of performance and cost, the lack of a long term track record results in an increased risk of underestimating construction and operating costs to achieve a desired degree of performance.

For cost estimating efficiency, a second key objective is to utilize the same upgrade technology for each category of plant type, i.e., pure oxygen activated sludge, fixed film, and conventional activated sludge.

It is important to note that the objective is not to identify the most cost effective upgrade alternative for each individual plant, but rather to establish appropriately conservative upgrade costs based on proven technologies applied uniformly to each category of plant type for cost curve development. If effluent limits for NH_3-N or TN are ultimately established in the future, each plant should conduct an evaluation of alternatives to determine if a lower cost approach will achieve the effluent limit based on information and proven technologies available at that time.

4.1 Technology Recommendations for Pure Oxygen Activated Sludge Plants

Three (3) of the twelve (12) plants are pure oxygen activated sludge plants: PWD SWWPCP, CCMUA Delaware WPCP and Morrisville Borough MUA. The generic pure oxygen activated sludge plant has multiple primary settling tanks, oxygenation tanks and final clarifiers, as well as anaerobic digesters and sludge thickening and dewatering processes. The basic influent wastewater characteristics and performance of the generic pure oxygen activated sludge plant are presented in the Table 2-1 in Section 2 of this report.

Due to the fundamental nature of pure oxygen systems (low design hydraulic detention time, low design solids retention time, and low pH resulting from carbon dioxide entrainment within the enclosed oxygenation tanks), process control adjustments are not feasible to achieve significant NH_3-N or TN removal in the generic pure oxygen activated sludge plant. Therefore, for the generic pure oxygen activated sludge process, add-on processes will be used to achieve the NH_3N effluent levels of 10 mg/L, 5 mg/L, 1.5 mg/L and the TN effluent level of 4 mg/L.

Potential add-on processes to achieve NH_3-N removal are listed and briefly described below:

1. Conversion of the oxygenation tanks to conventional aeration tanks together with construction of additional aeration tanks to provide the total bioreactor volume required to operate at the solids retention time needed for nitrification and to do so at a reasonable mixed liquor suspended solids (MLSS) concentration.
2. Addition of a nitrifying conventional activated sludge process downstream of the pure oxygen activated sludge process resulting in a two-stage activated sludge process, i.e., Stage 1 for BOD removal and Stage 2 for NH_3-N removal.
3. Addition of a moving bed biofilm reactor (MBBR) downstream of the pure oxygen activated sludge process. A MBBR is a biological process in which biofilm carriers are placed and retained in a tank with diffused aeration such that a nitrifying biofilm grows on the media and provides nitrification of the NH_3-N in wastewater that flows through the MBBR tank. Clarifiers follow the MBBR processes but unlike an activated sludge process, settled sludge from the clarifiers in not returned to the MBBR tanks. There are multiple manufacturers of MBBR processes with different shape biofilm carriers.
4. Addition of a biological aerated filter (BAF) (also referred to as biologically active filter) downstream of the pure oxygen activated sludge process. Like the MBBR, a BAF is also a biofilm process, but in this case, the biofilm grows on the granular media of a filter. As

a result, clarifiers are not needed downstream of a BAF. However, because of the headloss associated with a BAF, a low lift pumping station is typically required, unless the plant's hydraulic profile was originally designed to accommodate the future addition of an effluent filter. There are a variety of configurations (e.g., upflow and downflow) and manufacturers of BAF systems. An added benefit of the BAF is that it will enhance the removal of TSS compared to final clarifiers, thereby reducing the particulate fraction of BOD discharged from the plant.

5. Addition of a sidestream treatment process to treat the relatively low volume but high strength recycle stream from the thickening and dewatering processes. While a variety of treatment processes have been utilized for sidestream treatment, according to the latest edition of WEF Manual of Practice No. 8 (Ref. 1), deammonification systems "have gained traction and represent effectively all of the new designs in North America." There are several different configurations of deammonification processes for sidestream treatment, but in general, the process utilizes ammonia-oxidizing bacteria to convert a portion of the NH_3-N to nitrite-nitrogen and anammox bacteria to convert the nitrite-nitrogen and remaining NH_3-N to nitrogen gas. However, for the sidestream treatment process to reduce the generic pure oxygen activated sludge plant's effluent NH_3-N concentration from 19 mg/L to 10 mg/L, approximately 50% of the NH_3-N load through the plant would have to be from the recycle stream. Because the recycle stream of NH_3-N in the generic pure oxygen activated sludge plant is less than 50% of the NH_3-N load through the plant, it is not a viable option for the generic pure oxygen activated sludge plant to achieve an effluent NH_3-N concentration of 10 mg/L, unless combined with additional improvements. To achieve the 5 mg/L and 1.5 mg/L effluent levels, additional substantial improvements would be needed.

Because it is a compact and well proven technology with the added benefit of enhancing TSS removal and thereby also enhancing the removal of particulate BOD, the recommended technology for upgrading the pure oxygen activated sludge plants to achieve the three (3) effluent levels for NH_3-N for cost curve development is the BAF process.

To achieve an effluent NH_3-N concentration of 10 mg/L, approximately 50% of the plant effluent will need to be treated by a fully nitrifying BAF. To achieve an effluent NH_3-N concentration of 5 mg/L, approximately 75% of the plant effluent will need to be treated by a fully nitrifying BAF, and to achieve an effluent NH_3-N concentration of 1.5 mg/L, the entire plant effluent flow will need to be treated by a fully nitrifying BAF.

To achieve an effluent TN concentration of 4 mg/L, the plant effluent must first be nitrified to convert NH_3-N to NO_3-N, and the NO_3-N must then be converted to nitrogen gas via denitrification (the deammonification process described above for sidestream treatment has not yet been applied to full flow treatment and is therefore not a proven technology for consideration in this application). Options to denitrify the NO_3-N produced by the nitrifying BAF are listed and briefly described below:

1. Addition of an anoxic denitrifying activated sludge process downstream of the nitrifying BAF. Clarifiers would need to follow the anoxic reactors, and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
2. Addition of an anoxic denitrifying MBBR downstream of the nitrifying BAF. Clarifiers would need to follow the MBBR, and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
3. Addition of a denitrification filter downstream of the nitrifying BAF. A carbon source would be added to supply food for the denitrifying bacteria. The low lift pumping station sized for the nitrifying BAF would need to be sized to handle the additional headloss associated with the denitrification filters.

Because it is the most compact of options to achieve a TN effluent level of 4 mg/L and is well proven in this application, the recommended technology for achieving an effluent TN concentration of 4 mg/L for the pure oxygen activated sludge plants for cost curve development is a nitrifying BAF sized for the full plant flow downstream of the pure oxygen activated sludge process followed by denitrification filters also sized for the full plant flow.

4.2 Technology Recommendations for Fixed Film Plants

Three (3) of the twelve (12) plants are fixed film plants (i.e. trickling filter and RBC): Trenton Sewer Utility WWTP, Hamilton Township WPCP and Willingboro MUA WPCF. The generic fixed film plant has multiple primary settling tanks, fixed film treatment units, and final clarifiers, as well as anaerobic digestion and thickening and dewatering processes.

The basic influent wastewater characteristics and performance of the generic fixed film plant are presented in the Table 2-2 in Section 2.0 of this report.

Unlike conventional activated sludge plants that can be controlled to operate at different biomass inventories (i.e., at various MLSS concentrations and solids retention times) and thus achieve varying degrees of performance, trickling filters and RBCs cannot be controlled to achieve varying biomass inventories except by removing units from service or by placing standby units into service. Thus, the maximum degree of treatment occurs when all units are in service. Because the generic fixed film plant is operating with all units in service, add-on processes are required to upgrade the generic fixed film plant to achieve the NH_3-N effluent levels of 10 mg/L, 5 mg/L and 1.5 mg/L, and the TN level effluent level of 4 mg/L.

Potential add-on processes to achieve NH_3-N removal are listed and briefly describe below:

1. Construction of additional fixed film units of the same type as the existing fixed film units in parallel with the existing fixed film units.
2. Construction of additional fixed film units and final clarifier downstream of the existing fixed film clarifiers.
3. Addition of a nitrifying conventional activated sludge process downstream of the fixed film process.
4. Addition of a MBBR (as previously described) downstream of the fixed film process.
5. Addition of a nitrifying BAF (as previously described) downstream of the fixed film process.
6. Addition of a deammonification sidestream treatment process (as previously described) to treat the relatively low volume but high strength recycle stream from the thickening and dewatering processes. However, consistent with the generic pure oxygen activated sludge plant, the NH_3-N recycle loads in the generic fixed film plant are not a high enough percentage of the total NH_3-N loads through the plant to enable the effluent NH_3-N concentration to be reduced to 10 mg/L by treating the sidestream flow only. Therefore, sidestream treatment is not a viable treatment option for the generic fixed film plant to achieve an effluent NH_3-N concentration of 10 mg/L without also implementing additional improvements. Achieving the 5 mg/L and 1.5 mg/L levels would require additional substantial improvements.

Because it is a compact and well proven technology with the added benefit of enhancing TSS removal and thereby also enhancing the removal of particulate BOD, the recommended technology for upgrading the fixed film plants to achieve the three (3) effluent levels for NH_3-N for cost curve development is the BAF process.

To achieve an effluent NH_3-N concentration of 10 mg/L, approximately 45% of the plant effluent will need to be treated by a fully nitrifying BAF followed by blending. To achieve an effluent NH_3-N concentration of 5 mg/L, approximately 70% of the plant effluent will need to be treated by a fully nitrifying BAF, and to achieve an effluent NH_3-N concentration of 1.5 mg/L, the entire plant effluent flow will need to be treated by a fully nitrifying BAF.

To achieve an effluent TN concentration of 4 mg/L, the plant effluent must first be nitrified to convert NH_3-N to NO_3-N, and the NO_3-N must then be converted to nitrogen gas via denitrification. Options to denitrify the NO_3-N produced by the nitrifying BAF are listed and briefly described below:

1. Addition of an anoxic denitrifying activated sludge process downstream of the nitrifying BAF. Clarifiers would need to follow the anoxic reactors, and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
2. Addition of an anoxic denitrifying MBBR downstream of the nitrifying BAF. Clarifiers would need to follow the MBBR, and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
3. Addition of a denitrification filter downstream of the nitrifying BAF. A carbon source would be added to supply food for the denitrifying bacteria. The low lift pumping station sized for the nitrifying BAF would need to be sized to handle the additional headloss associated with the denitrification filters.

Because it is the most compact of options to achieve a TN effluent level of 4 mg/L and is well proven in this application, the recommended technology for achieving an effluent TN concentration of 4 mg/L for the fixed film plants is a nitrifying BAF downstream of the fixed film process and sized for the full plant flow followed by denitrification filters also sized for the full plant flow.

4.3 Technology Recommendations for Conventional Activated Sludge Plants

Six (6) of the twelve (12) plants are conventional activated sludge plants (PWD NEWPCP, Wilmington WWTP, DELCORA WRTP, GCUA WWTP, LBCJMA WWTP and PWD SEWPCP). The generic conventional activated sludge plant has multiple primary settling tanks, aeration tanks, and final clarifiers as well as anaerobic digestion and sludge thickening and dewatering processes. The generic activated sludge plant has the flexibility to operate the aeration tanks in multiple configurations (plug flow and contact stabilization) by repositioning feed gates for primary effluent and is operating near its design capacity, i.e., without significant surplus capacity. The basic influent wastewater characteristics and performance of the generic conventional activated sludge plant are presented in Table 2-3 in Section 2.0 of this report.

Typically, conventional activated sludge plants that were designed for secondary treatment only and which are operating near the design flow for the plant will have several capacity limiting bottlenecks with respect to achieving significant removal of NH_3-N. These bottlenecks generally include the following: (1) insufficient final clarifier capacity to handle the higher MLSS concentrations required for nitrification; (2) insufficient aeration tank volume to operate at a reasonable MLSS concentration while controlling the process at the higher solids retention time required for nitrification; (3) insufficient process air supply to satisfy the substantial increase in oxygen demand associated with nitrification; and (4) insufficient return sludge pumping capacity for the additional solids loading to the final clarifiers. In addition to the issues described above, there may also be a need to add an external source of alkalinity to compensate for the alkalinity consumption associated with nitrification. In addition to correcting the typical bottlenecks for NH_3-N removal described above, additional options are available for increasing the NH_3-N removal capacity of a conventional activated sludge plant, including the following:

1. Conversion of the convention activated sludge process to an Integrated Fixed Film Activated Sludge (IFAS) process by adding fixed or floating media to the aeration tanks for the growth of biofilm resulting in the simultaneous treatment of wastewater by both the conventional activated sludge process and a biofilm treatment process, analogous to the combination of activated sludge and a MBBR in the same tankage. There are several different configurations and manufacturers of IFAS media, and this is a well proven technology that is particularly applicable to confined sites with insufficient space to construct additional aeration tanks and/or final clarifiers.
2. Addition of a downstream activated sludge process to remove NH_3-N resulting in a two-stage activated sludge process for NH_3-N removal.
3. Addition of a downstream MBBR.
4. Addition of a downstream BAF.

5. Addition of an upstream treatment process, such as a roughing trickling filter, to remove a portion of the BOD thereby enabling the conventional activated sludge process to remove additional NH_3-N.
6. Addition of a deammonification sidestream treatment process to treat the relatively low volume but high strength recycle stream from the thickening and dewatering processes.

As shown in Table 2-3, the generic conventional activated sludge plant is currently achieving an annual average effluent NH_3-N concentration of 10 mg/L. However, to accommodate variations in monthly performance, the following improvements are conservatively recommended for the generic conventional activated sludge plant to reliably achieve a 10 mg/L effluent NH_3-N level on a monthly average basis: (1) replacement of the existing process air system with a new process air system sized for BOD removal and partial NH_3-N removal; (2) construction of additional final clarifiers such that the combined final clarifier surface area is increased by approximately 20% to enable the activated sludge system to operate at a higher SRT and MLSS concentration during certain months of the year without creating an excessive solids loading rate to the final clarifiers; and (3) modification of the return activated sludge system to accommodate the additional final clarifiers.

For the generic conventional activated sludge plant to achieve higher levels of NH_3-N removal, conversion to the IFAS process is recommended due to space constraints. The extent of fixed or floating IFAS media added to the aeration tanks would be less for the NH_3-N effluent level of 5 mg/L than for the NH_3-N effluent level of 1.5 mg/L.

To achieve an effluent TN concentration of 4 mg/L, the generic conventional activated sludge plant effluent must first be nitrified to convert NH_3-N to NO_3-N, and the NO_3-N must then be converted to nitrogen gas via denitrification. Options to denitrify the NO_3-N produced by the IFAS process are listed and briefly described below:

1. Conversion of the conventional activated sludge process to a four stage Bardenpho™ process with two aerobic zones and two anoxic zones. This conversion would require a significant increase in reactor tankage together with the construction of additional final clarifiers, return sludge pumping system modifications, process air system modifications, and an external carbon source for the second stage anoxic tank.

2. Addition of an anoxic activated sludge process downstream of the IFAS process and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
3. Addition of an anoxic MBBR downstream of the IFAS process. Clarifiers would need to follow the MBBR, and an external carbon source (such as methanol) would be added to supply food for the denitrifying bacteria.
4. Addition of a denitrification filter process downstream of the IFAS process. A carbon source would be added to supply food for the denitrifying bacteria. A low lift pumping station would likely be required to accommodate the headloss associated with the denitrification filters.

Because it is the most compact of options to achieve a TN effluent level of 4 mg/L and is well proven in this application, the recommended technology for achieving an effluent TN concentration of 4 mg/L for the generic conventional activated sludge plant is a conversion to the IFAS process followed by denitrification filters.

4.4 Summary of Technology Recommendations

Table 4-1 on the following page presents a summary of the recommended technologies for each category of plant types.

4.5 Additional Technology Related Sizing and Cost Issues

The sizing and cost of NH_3-N and TN removal improvements will be influenced by the design basis temperature for the biological treatment process, i.e., whether the effluent levels are year-round values requiring that the biological process be sized for summer and winter temperatures, or seasonal values requiring that the biological process be sized only for summer temperatures. As previously described, the effluent levels will be considered seasonal monthly average levels applicable to the summer period defined as May 1 through October 31. Therefore, the NH_3-N and TN removal improvements will not need to be sized for winter temperatures. In addition, because the effluent levels apply to each month of the summer season, the maximum monthly average flow is the appropriate flow for process sizing.

Table 4-1: Technology Recommendations Summary

Effluent Level	Conventional Activated Sludge Plants	Pure Oxygen Activated Sludge Plants	Fixed Film (RBC and TF) Plants
NH_3-N – 10 mg/L	Replace process air system, construct additional final clarifiers, and modify RAS system	Add downstream BAF sized for approximately 50% of plant flow	Add downstream BAF sized for approximately 45% of plant flow
NH_3-N – 5 mg/L	Conversion to IFAS with medium level of media addition to aeration tanks	Add downstream BAF sized for approximately 75% of plant flow	Add downstream BAF sized for approximately 70% of plant flow
NH_3-N – 1.5 mg/L	Conversion to IFAS with high level of media addition to aeration tanks	Add downstream BAF sized for 100% of plant flow	Add downstream BAF sized for 100% of plant flow
TN – 4 mg/L	Conversion to IFAS with high level of media addition plus downstream DF	Add downstream BAF sized for 100% of plant flow plus DF	Add downstream BAF sized for 100% of plant flow plus DF

The sizing and cost of NH_3-N and TN improvements will also be influenced by the design basis peak flow for the improvements, i.e., whether all peak wet-weather flow entering the plant must be treated by the NH_3-N and TN removal processes to achieve a daily maximum effluent level. As previously described, the improvements will not need to be sized to achieve daily maximum effluent levels; only to achieve the effluent levels on a monthly average basis during the summer season. Therefore, to the extent practicable considering the nature of the NH_3-N and TN removal improvements, a portion of the peak wet-weather flow could be diverted around the NH_3-N and TN removal process, provided the effluent levels described above are attained each month of the summer season.

Because of the significant variability in performance of the twelve (12) plants, adjustments will be made as appropriate to the technology recommendations when developing the plant specific cost estimates.

5.0 GENERIC PLANT CAPITAL COST ESTIMATES

This section of the report presents budgetary capital cost estimates to upgrade the three (3) generic plants described in Section 2.0 to achieve the three (3) effluent levels for ammonia-nitrogen (NH_3-N) reduction and the one (1) effluent level for total nitrogen (TN) reduction described in Section 3.0. utilizing the technology recommendations described in Section 4.0.

The resulting generic plant budgetary capital cost estimates are used in conjunction with the annual average flows for the three (3) generic plants to establish the budgetary capital costs on a $/gpd basis to achieve each effluent level.

As described in Section 1.0, the generic plant budgetary capital cost estimates on a $/gpd basis will be used as the starting point to develop plant-specific capital cost estimates for each of the twelve (12) plants as will be further described in Section 6.0.

5.1 Basis for Generic Plant Budgetary Capital Cost Estimates

The generic plant budgetary capital cost estimates presented herein are based on the following:

- Major equipment costs utilizing budgetary quotes from non-proprietary equipment manufacturers and typical installation cost as a percentage of equipment cost per Kleinfelder's experience.
- Estimated quantities and unit costs for:
  - Cast-in-place concrete
  - Earth excavation and backfill
  - Buildings
- Typical percentages for: site work, site piping, electrical, and instrumentation and control (I&C) based on nature of the upgrades and Kleinfelder's experience.
- Contractor Overhead and Profit of 24%, which includes mobilization, demobilization, and Contractor general conditions.
- Contingency of 30% to reflect a pre-design planning level of accuracy.
- Engineering, Legal and Administrative costs of 20%.

Based on the cost estimating methodology describe above, the generic plant cost estimates are consistent with the American Association of Cost Estimating (AACE) Level 4 estimate, which is the appropriate level for the study phase of a project. Therefore, consistent with the level of accuracy defined by AACE for a level 4 cost estimate, the level of accuracy is -15% to -30% on the low side to +20% to +50% on the high side.

The generic plant capital cost estimates are in 2019 dollars corresponding to the Engineering News Record (ENR) Twenty City Cost Index of 11311. This index can be used in the future to update the budgetary 2019 costs due to the inflation of construction costs between 2019 and the future date.

The budgetary generic plant capital cost estimates do not include costs for the following, which will be included in the plant specific cost estimates as appropriate:

- Land acquisition
- Rock excavation
- Pile-supported foundations
- Sheeting or dewatering
- Additional sludge processing equipment

The generic plant capital cost estimates follow, beginning with the Generic Pure Oxygen Activated Sludge Plant Capital Cost Estimates.

5.2 Generic Pure Oxygen Activated Sludge Plant Capital Cost

The characteristics of the generic pure oxygen activated sludge plant are presented in Table 2-1 in Section 2.0. As further described in the Effluent Levels Technical Memorandum, the plant upgrade improvements will be sized to achieve the effluent levels each month of the summer season defined as May 1 through October 31, rather than each month of the year. Therefore, the improvements for each effluent level will be sized for the maximum monthly average (i.e., maximum 30-day average flow) rather than the annual average flow and will be sized for the minimum temperature that occurs in the summer season rather than the minimum temperature that occurs in the winter.

The resulting sizing criteria for the biological aerated filter (BAF) process are summarized in Table 5-1.

Table 5-1: Generic Pure Oxygen Plant BAF Design/Sizing Criteria

Effluent Level	BAF Influent NH_3-N	BAF Influent BOD	Max. Monthly Average Flow	Minimum Monthly Avg. Temperature	Required BAF Effluent NH_3-N
10 mg/L NH_3-N	19 mg/L	5 mg/L	49 mgd	18 deg C	1.5 mg/L
5 mg/L NH_3-N	19 mg/L	5 mg/L	73 mgd	18 deg C	1.5 mg/L
1.5 mg/L NH_3-N	19 mg/L	5 mg/L	97 mgd	18 deg C	1.5 mg/L

Similarly, the resulting sizing criteria for the Generic Pure Oxygen Plant denitrification filter are summarized in Table 5-2.

Table 5-2: Generic Pure Oxygen Plant Denitrification Filter Design/Sizing Criteria

Effluent Level	DF Influent NH_3-N	DF Influent NO_3-N	DF Influent BOD	Max. Monthly Average Flow	Minimum Monthly Avg. Temperature	Required DF Effluent TN
4 mg/L TN	1.5 mg/L	17.5 mg/L	2 mg/L	97 mgd	18 deg C	4 mg/L

To support the addition of BAFs and a denitrification filter, the additional improvements listed in Table 5-3 have been included for the Generic Pure Oxygen Plant and will be modified as appropriate for the plant specific cost estimates.

Table 5-3: Generic Pure Oxygen Plant – Related Additional Improvements

Effluent Level	Additional Improvements
NH_3-N – 10 mg/L	Intermediate Pump Station – 49 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash pumping station
NH_3-N – 5 mg/L	Intermediate Pump Station – 73 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash pumping station
NH_3-N – 1.5 mg/L	Intermediate Pump Station – 97 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash Pumping Station
TN – 4 mg/L	Intermediate Pump Station - 97 mgd firm capacity and TDH based on BAF +DF headloss Alkalinity Storage and Feed System and new Chemical Building Methanol Storage and Feed System and New Chemical Building BAF Gallery Building, DF Gallery Building and Backwash pumping stations

The Generic Pure Oxygen Activated Sludge Plant capital cost estimates for the four (4) effluent limit scenarios follow.

Table 5-4: Generic Pure Oxygen Plant Capital Cost Estimate for NH_3-N of 10 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
49 MGD BAF System	1	LS	$ 11,700,000	$ 11,700,000	Quote from Kruger
New BAF feed pumps	3	LS	$ 230,000	$ 690,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 365,000	$ 365,000	Quote from PEP
Piping, valves and accessories @20%				$ 2,551,000	
			Subtotal	*$ 15,306,000*	
Installation	25%			$ 3,826,500	
			Major Equipment & Systems Subtotal	***19,132,500***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	240	CY	$ 950	$ 228,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	225	CY	$ 600	$ 135,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	2730	CY	$ 950	$ 2,593,500	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	2040	CY	$ 600	$ 1,224,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	2365	CY	$ 58	$ 137,170	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	6290	CY	$ 58	$ 364,820	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***4,882,490***	
Buildings					
Chemical Building - Alkalinity	3300	SF	$ 350	$ 1,155,000	Complete with lighting and HVAC
BAF - Gallery Building	5320	SF	$ 350	$ 1,862,000	Complete with lighting and HVAC
BAF feed pump building	2700	SF	$ 350	$ 945,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 3,962,000***	
Bulk Work Percentage					
Civil Site	10%			$ 2,798,000	
Electrical	20%			$ 5,595,000	
Instrumentation & Controls	10%			$ 2,798,000	
Site Piping	15%			$ 4,197,000	
			Bulk Work Subtotal	***15,388,000***	
Subtotal Direct Costs				**$ 43,365,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 10,408,000	Also includes General Conditions
Contingency	30%			$ 13,010,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 66,783,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 13,356,600	
TOTAL BUDGETARY CAPITAL COST				**$80,140,000**	

Table 5-5: Generic Pure Oxygen Plant Capital Cost Estimate for NH_3-N of 5 mg/L

Item/Description	*Quantity*	*Unit/Basis*	*Unit Budgetary Cost*	*Item Budgetary Cost*	*Comments*
Major Equipment & Systems					
73 MGD BAF System	1	LS	$ 15,400,000	$ 15,400,000	Quote from Kruger
New BAF feed pumps	4	LS	$ 230,000	$ 920,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 530,000	$ 530,000	Quote from PEP
Piping, valves and accessories @20%				$ 3,370,000	
			Subtotal	*$ 20,220,000*	
Installation	25%			$ 5,055,000	
Major Equipment & Systems Subtotal				***25,275,000***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	325	CY	$ 950	$ 308,750	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	300	CY	$ 600	$ 180,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	3630	CY	$ 950	$ 3,448,500	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	2860	CY	$ 600	$ 1,716,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	3150	CY	$ 58	$ 182,700	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	9020	CY	$ 58	$ 523,160	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
Unit Price & Other Item Subtotal				***6,559,110***	
Buildings					
Chemical Building - Alkalinity	5000	SF	$ 350	$ 1,750,000	Complete with lighting and HVAC
BAF - Gallery Building	5840	SF	$ 350	$ 2,044,000	Complete with lighting and HVAC
BAF feed pump building	3375	SF	$ 350	$ 1,181,250	Complete with lighting and HVAC
Buildings Subtotal				***$ 4,975,250***	
Bulk Work Percentage					
Civil Site	10%			$ 3,681,000	
Electrical	20%			$ 7,362,000	
Instrumentation & Controls	10%			$ 3,681,000	
Site Piping	15%			$ 5,521,000	
Bulk Work Subtotal				***20,245,000***	
Subtotal Direct Costs				**$ 57,054,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 13,693,000	Also includes General Conditions
Contingency	30%			$ 17,116,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 87,863,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 17,572,600	
TOTAL BUDGETARY CAPITAL COST				**$ 105,436,000**	

Table 5-6: Generic Pure Oxygen Plant Capital Cost Estimate for NH_3-N of 1.5 mg/L

Item/Description	*Quantity*	*Unit/Basis*	*Unit Budgetary Cost*	*Item Budgetary Cost*	*Comments*
Major Equipment & Systems					
97 MGD BAF System	1	LS	$ 19,800,000	$ 19,800,000	Quote from Kruger
New BAF feed pumps	5	LS	$ 230,000	$ 1,150,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 695,000	$ 695,000	Quote from PEP
Piping, valves and accessories @20%				$ 4,329,000	
			Subtotal	*$ 25,974,000*	
Installation	25%			$ 6,493,500	
			Major Equipment & Systems Subtotal	***32,467,500***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	410	CY	$ 950	$ 389,500	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	380	CY	$ 600	$ 228,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	4885	CY	$ 950	$ 4,640,750	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	3920	CY	$ 600	$ 2,352,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	3950	CY	$ 58	$ 229,100	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	12570	CY	$ 58	$ 729,060	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***8,768,410***	
Buildings					
Chemical Building - Alkalinity	5500	SF	$ 350	$ 1,925,000	Complete with lighting and HVAC
BAF - Gallery Building	6080	SF	$ 350	$ 2,128,000	Complete with lighting and HVAC
BAF feed pump building	4050	SF	$ 350	$ 1,417,500	Complete with lighting and HVAC
			Buildings Subtotal	***$ 5,470,500***	
Bulk Work Percentage					
Civil Site	10%			$ 4,671,000	
Electrical	20%			$ 9,341,000	
Instrumentation & Controls	10%			$ 4,671,000	
Site Piping	15%			$ 7,006,000	
			Bulk Work Subtotal	***25,689,000***	
Subtotal Direct Costs				**$ 72,395,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 17,375,000	Also includes General Conditions
Contingency	30%			$ 21,719,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 111,489,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 22,297,800	
TOTAL BUDGETARY CAPITAL COST				**$ 133,787,000**	

Table 5-7: Generic Pure Oxygen Plant Capital Cost Estimate for TN of 4 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
97 MGD BAF System	1	LS	$ 19,800,000	$ 19,800,000	Quote from Kruger
New BAF feed pumps	5	LS	$ 230,000	$ 1,150,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 695,000	$ 695,000	Quote from PEP
New Denite filter feed pumps	5	LS	$ 230,000	$ 1,150,000	Quote from ABS
Denite filters w/BW pumps, blowers and methanol storage	1	LS	$ 29,000,000	$ 29,000,000	Quote from DeNora
Piping, valves and accessories @20%				$ 10,359,000	
			Subtotal	*$ 62,154,000*	
Installation	25%			$ 15,538,500	
			Major Equipment & Systems Subtotal	***77,692,500***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	820	CY	$ 950	$ 779,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	760	CY	$ 600	$ 456,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	4885	CY	$ 950	$ 4,640,750	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	3920	CY	$ 600	$ 2,352,000	Unit quote from similar project
Cast in Place Conc. - Denite Filter	17530	CY	$ 950	$ 16,653,500	Unit quote from similar project
Cast in Place Conc. Foundation -Denite Filter	7230	CY	$ 600	$ 4,338,000	Unit quote from similar project
Methanol Storage pad w/ containment	960	CY	$ 600	$ 576,000	Unit quote from similar project
Excavation/Backfill - BAF and Denite feed PS	7900	CY	$ 58	$ 458,200	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	12570	CY	$ 58	$ 729,060	RSMeans 2019 Estimate
Excavation/Backfill - Denite Filter	8375	CY	$ 58	$ 485,750	RSMeans 2019 Estimate
Excavation - Methanol storage system	3850	CY	$ 58	$ 223,300	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***31,891,560***	
Buildings					
Chemical Building - Alkalinity	5500	SF	$ 350	$ 1,925,000	Complete with lighting and HVAC
BAF - Gallery Building	6080	SF	$ 350	$ 2,128,000	Complete with lighting and HVAC
Denitrification Filter - Gallery Building	2500	SF	$ 350	$ 875,000	Complete with lighting and HVAC
BAF and Denite feed pump building	8100	SF	$ 350	$ 2,835,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 7,763,000***	
Bulk Work Percentage					
Civil Site	10%			$ 11,735,000	
Electrical	20%			$ 23,469,000	
Instrumentation & Controls	10%			$ 11,735,000	
Site Piping	15%			$ 17,602,000	
			Bulk Work Subtotal	***64,541,000***	
Subtotal Direct Costs				**$ 181,888,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 43,653,000	Also includes General Conditions
Contingency	30%			$ 54,566,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 280,107,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 56,021,400	I
TOTAL BUDGETARY CAPITAL COST				**$ 336,128,000**	

Table 5-8 presents a summary of the Generic Pure Oxygen Activated Sludge Plant capital cost estimates for each effluent level, and the resulting capital costs on a $/gpd basis utilizing the generic plant's annual average flow of 83 mgd.

Table 5-8: Generic Pure Oxygen Plant Summary of Capital Costs

Effluent Level	Capital Cost Estimate	$/gpd of capacity
NH_3-N = 10 mg/L	$80 million	1.0
NH_3-N = 5 mg/L	$105 million	1.3
NH_3-N = 1.5 mg/L	$134 million	1.6
TN = 4 mg/L	$336 million	4.0

5.3 Generic Fixed Film Plant Capital Cost

The generic fixed film plant characteristics are summarized in Table 2-2 of Section 2.0. For the same reasons described in Section 5.2, the generic fixed film plant improvements for each effluent level will be sized for the maximum monthly average rather than the annual average flow and will be sized for the minimum temperature that occurs in the summer season rather than the minimum temperature that occurs in the winter. The resulting sizing criteria for the BAF process for the Generic Fixed Film Plant are summarized in Table 5-9

Table 5-9: Generic Fixed Film Plant BAF Design/Sizing Criteria

Effluent Levels	BAF Influent NH_3-N	BAF Influent BOD	Maximum Monthly Average Flow	Minimum Monthly Avg Temperature	Required BAF Effluent NH_3-N
10 mg/L NH_3-N	16 mg/L	19 mg/L	5 mgd	18 deg C	1.5 mg/L
5 mg/L NH_3-N	16 mg/L	19 mg/L	8 mgd	18 deg C	1.5 mg/L
1.5 mg/L NH_3-N	16 mg/L	19 mg/L	11 mgd	18 deg C	1.5 mg/L

Similarly, the resulting sizing criteria for the Generic Fixed Film Plant denitrification filter are summarized in Table 5-10.

Table 5-10: Generic Fixed Film Plant Denitrification Filter Design/Sizing Criteria

Effluent Level	DF Influent NH_3-N	DF Influent NO_3-N	DF Influent BOD	Max. Monthly Average Flow	Minimum Monthly Avg. Temperature	Required DF Effluent TN
4 mg/L TN	1.5 mg/L	14.5 mg/L	2 mg/L	11 mgd	18 deg C	4 mg/L

To support the addition of BAFs and a denitrification filter, the additional improvements presented in Table 5-11 have been included for the Generic Fixed Film Plant. These additional improvements will be modified as appropriate for the plant specific cost estimates.

Table 5-11: Generic Fixed Film Plant – Related Additional Improvements

Scenario	Additional Improvements
NH_3-N – 10 mg/L	Intermediate Pump Station – 5 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash Pumping Station
NH_3-N – 5 mg/L	Intermediate Pump Station – 8 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash Pumping Station
NH_3-N – 1.5 mg/L	Intermediate Pump Station – 11 mgd firm capacity and TDH based on BAF headloss Alkalinity Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash Pumping Station
TN – 4 mg/L	Intermediate Pump Station – 11 mgd firm capacity and TDH based on BAF + DF headloss Alkalinity Storage and Feed System and new Chemical Building Methanol Storage and Feed System and new Chemical Building BAF Gallery Building and Backwash Pumping Station DF Gallery Building and Backwash Pumping Station

The Generic Fixed Film Plant capital cost estimates for the four (4) effluent level scenarios follow.

Table 5-12: Generic Fixed Film Plant Capital Cost Estimate for NH_3-N of 10 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
5 MGD BAF System w/blowers and BW pumps	1	LS	$ 3,500,000	$ 3,500,000	Quote from Kruger
New BAF feed pumps	2	LS	$ 65,000	$ 130,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 36,000	$ 36,000	Quote from PEP
Piping, valves and accessories @20%				$ 733,200	
			Subtotal	*$ 4,399,200*	
Installation	25%			$ 1,099,800	
			Major Equipment & Systems Subtotal	***5,499,000***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	170	CY	$ 950	$ 161,500	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	100	CY	$ 600	$ 60,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	880	CY	$ 950	$ 836,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	525	CY	$ 600	$ 315,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	870	CY	$ 58	$ 50,460	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	1240	CY	$ 58	$ 71,920	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***1,694,880***	
Buildings					
Chemical Building - (for alkalinity control)	800	SF	$ 350	$ 280,000	Complete with lighting and HVAC
BAF - Gallery Building	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
BAF feed pump building	900	SF	$ 350	$ 315,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 1,120,000***	
Bulk Work Percentage					
Civil Site	10%			$ 831,000	
Electrical	20%			$ 1,663,000	
Instrumentation & Controls	10%			$ 831,000	
Yard Piping	15%			$ 1,247,000	
			Bulk Work Subtotal	***4,572,000***	
Subtotal Direct Costs				**$ 12,886,000**	Also includes General Conditions
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 3,093,000	
Contingency	30%			$ 3,866,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 19,845,000**	
Engineering, Permitting, Legal, and Administration	15%			$ 2,976,750	
TOTAL BUDGETARY CAPITAL COST				**$22,822,000**	

Table 5-13: Generic Fixed Film Plant Capital Cost Estimate for NH_3-N of 5 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
8 MGD BAF System w/blowers and BW pumps	1	LS	$ 4,300,000	$ 4,300,000	Quote from Kruger
New BAF feed pumps	3	LS	$ 45,000	$ 135,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 43,500	$ 43,500	Quote from PEP
Piping, valves and accessories @20%				$ 895,700	
			Subtotal	*$ 5,374,200*	
Installation	25%			$ 1,343,550	
			Major Equipment & Systems Subtotal	***6,717,750***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	160	CY	$ 950	$ 152,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	100	CY	$ 600	$ 60,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	1000	CY	$ 950	$ 950,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	625	CY	$ 600	$ 375,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	750	CY	$ 58	$ 43,500	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	1580	CY	$ 58	$ 91,640	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***1,872,140***	
Buildings					
Chemical Building - (for alkalinity control)	1125	SF	$ 350	$ 393,750	Complete with lighting and HVAC
BAF - Gallery Building	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
BAF feed pump building	720	SF	$ 350	$ 252,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 1,170,750***	
Bulk Work Percentage					
Civil Site	10%			$ 976,000	
Electrical	20%			$ 1,952,000	
Instrumentation & Controls	10%			$ 976,000	
Yard Piping	15%			$ 1,464,000	
			Bulk Work Subtotal	***5,368,000***	
Subtotal Direct Costs				**$ 15,129,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 3,631,000	Also includes General Conditions
Contingency	30%			$ 4,539,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 23,299,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 4,659,800	
TOTAL BUDGETARY CAPITAL COST				**$27,959,000**	

Table 5-14: Generic Fixed Film Plant Capital Cost Estimate for NH_3-N of 1.5 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
11 MGD BAF System w/blowers and BW pumps	1	LS	$ 5,000,000	$ 5,000,000	Quote from Kruger
New BAF feed pumps	3	LS	$ 65,000	$ 195,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 51,000	$ 51,000	Quote from PEP
Piping, valves and accessories @20%				$ 1,049,200	
			Subtotal	*$ 6,295,200*	
Installation	25%			$ 1,573,800	
			Major Equipment & Systems Subtotal	***7,869,000***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	225	CY	$ 950	$ 213,750	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	150	CY	$ 600	$ 90,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	1140	CY	$ 950	$ 1,083,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	745	CY	$ 600	$ 447,000	Unit quote from similar project
Excavation/Backfill - BAF feed PS	1250	CY	$ 58	$ 72,500	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	1980	CY	$ 58	$ 114,840	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***2,221,090***	
Buildings					
Chemical Building - (for alkalinity control)	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
BAF - Gallery Building	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
BAF feed pump building	1350	SF	$ 350	$ 472,500	Complete with lighting and HVAC
			Buildings Subtotal	***$ 1,522,500***	
Bulk Work Percentage					
Civil Site	10%			$ 1,161,000	
Electrical	20%			$ 2,323,000	
Instrumentation & Controls	10%			$ 1,161,000	
Yard Piping	15%			$ 1,742,000	
			Bulk Work Subtotal	***6,387,000***	
Subtotal Direct Costs				**$ 18,000,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 4,320,000	Also includes General Conditions
Contingency	30%			$ 5,400,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 27,720,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 5,544,000	
TOTAL BUDGETARY CAPITAL COST				**$33,264,000**	

Table 5-15: Generic Fixed Film Plant Capital Cost Estimate for TN of 4 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
11 MGD BAF System w/blowers and BW pumps	1	LS	$ 5,000,000	$ 5,000,000	Quote from Kruger
New BAF feed pumps	3	LS	$ 65,000	$ 195,000	Quote from ABS
Alkalinity Storage and Feed System	1	EA	$ 51,000	$ 51,000	Quote from PEP
New Denite filter feed pumps	3	LS	$ 65,000	$ 195,000	Quote from ABS
Denite filters w/BW pumps, blowers and methanol storage	1	LS	$ 2,600,000	$ 2,600,000	Quote from DeNora
Piping, valves and accessories @20%				$ 1,608,200	
			Subtotal	*$ 9,649,200*	
Installation	25%			$ 2,412,300	
			Major Equipment & Systems Subtotal	***12,061,500***	
Unit Price & Other Items					
Cast in Place Conc. Walls - BAF feed PS	450	CY	$ 950	$ 427,500	Unit quote from similar project
Cast in Place Conc. Foundation - BAF feed PS	300	CY	$ 600	$ 180,000	Unit quote from similar project
Cast in Place Conc. Walls - BAF System	1140	CY	$ 950	$ 1,083,000	Unit quote from similar project
Cast in Place Conc. Foundation - BAF System	745	CY	$ 600	$ 447,000	Unit quote from similar project
Cast in Place Conc. Walls - Denite Filter	1970	CY	$ 900	$ 1,773,000	Unit quote from similar project
Cast in Place Conc. Foundation -Denite Filter	895	CY	$ 600	$ 537,000	Unit quote from similar project
Methanol Storage pad w/ containment	225	CY	$ 600	$ 135,000	Unit quote from similar project
Excavation/Backfill - BAF and Denite feed PS	2500	CY	$ 58	$ 145,000	RSMeans 2019 Estimate
Excavation/Backfill - BAF System	1980	CY	$ 58	$ 114,840	RSMeans 2019 Estimate
Excavation/Backfill - Denite Filter	930	CY	$ 58	$ 53,940	RSMeans 2019 Estimate
Excavation/Backfill - Methanol storage system	675	CY	$ 58	$ 39,150	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	
			Unit Price & Other Item Subtotal	***5,135,430***	
Buildings					
Chemical Building - (for alkalinity control)	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
BAF - Gallery Building	1500	SF	$ 350	$ 525,000	Complete with lighting and HVAC
Denitrification Filter - Gallery Building	2000	SF	$ 350	$ 700,000	Complete with lighting and HVAC
BAF and Denite feed pump building	2700	SF	$ 350	$ 945,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 2,695,000***	
Bulk Work Percentage					
Civil Site	10%			$ 1,989,000	
Electrical	20%			$ 3,978,000	
Instrumentation & Controls	10%			$ 1,989,000	
Yard Piping	15%			$ 2,984,000	
			Bulk Work Subtotal	***10,940,000***	
Subtotal Direct Costs				**$ 30,832,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 7,400,000	Also includes General Conditions
Contingency	30%			$ 9,250,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 47,482,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 9,496,400	
TOTAL BUDGETARY CAPITAL COST				**$56,978,000**	

Table 5-16 presents a summary of the Generic Fixed Film Plant capital cost estimates for each effluent level, and the resulting capital costs on a $/gpd basis utilizing the Generic Fixed Film Plant's annual average flow of 9 mgd.

Table 5-16: Generic Fixed Film Plant Summary of Capital Costs

Effluent Level	Capital Cost Estimate	$/gpd of capacity
NH_3-N = 10 mg/L	$23 million	2.5
NH_3-N = 5 mg/L	$28 million	3.1
NH_3-N = 1.5 mg/L	$33 million	3.7
TN = 4 mg/L	$57 million	6.3

5.4 Generic Conventional Activated Sludge Plant Capital Cost

The generic conventional activated sludge characteristics are presented in Table 2-3 in Section 2.0. For the same reasons described in Section 5.2, the generic conventional activated sludge plant improvements for each effluent level will be sized for the maximum monthly average rather than the annual average flow and will be sized for the minimum temperature that occurs in the summer season rather than the minimum temperature that occurs in the winter. The resulting sizing criteria for integrated fixed film activated sludge (IFAS) process applicable to two (2) of the three (3) effluent NH_3-N levels are summarized in Table 5-17.

Table 5-17: Generic Conventional Activated Sludge Plant IFAS Design/Sizing Criteria

Effluent Level	Current Effluent NH_3-N	Current Effluent BOD	Current MLSS	Max. Monthly Average Flow	Minimum Monthly Avg. Temperature	Required Effluent NH_3-N
5 mg/L NH_3-N	10 mg/L	7 mg/L	3,000 mg/L	87 mgd	18 deg C	5 mg/L
1.5 mg/L NH_3-N	10 mg/L	7 mg/L	3,000 mg/L	87 mgd	18 deg C	1.5 mg/L

Unlike the Generic Pure Oxygen Activated Sludge and Fixed Film Plants, which utilize add-on processes downstream of the existing plant to achieve the various effluent levels, improvements to the Generic Conventional Activated Sludge Plant to achieve the three effluent levels are integrated with, rather than an added downstream of, the existing biological treatment system. Therefore, the number and size of the Generic Conventional Activated Sludge Plant's aeration basins and final clarifiers is relevant to the improvements required and the corresponding budgetary capital cost estimates.

In this regard, the Generic Conventional Activated Sludge Plant has a total of six (6) aeration basins, each with a volume of approximately 2.4 million gallons, and four (4) final clarifiers, each with a diameter of 140 feet.

The sizing criteria for the Generic Conventional Activated Sludge Plant's denitrification filter are summarized in Table 5-18.

Table 5-18: Generic Conventional Activated Sludge Plant DF Design/Sizing Criteria

Effluent Level	DF Influent NH_3-N	DF Influent NO_3-N	DF Influent BOD	Max Monthly Average Flow	Minimum Monthly Avg Temperature	Required DF Effluent TN
4 mg/L TN	1.5 mg/L	16.5 mg/L	2 mg/L	11 mgd	18 deg C	4 mg/L

The improvements recommended to achieve the 10 mg/L effluent NH_3-N level, and the improvements to support the IFAS process and denitrification filter, are listed in Table 5-19. These additional improvements will be modified as appropriate for the plant specific cost estimates.

Table 5-19: Generic Conventional AS Plant – Related Additional Improvements

Effluent Level	Additional Improvements
NH_3-N – 10 mg/L	Modify the existing blowers and ceramic disc diffusers to supply additional air to meet the oxygen demand associated with removing NH_3-N to 10 mg/L Construction of two (2) additional 140-foot-diameter final clarifiers to reduce the SOR for partial nitrification Increase RAS pumping capacity to be able to return sludge at 75% during maximum monthly average flow
NH_3-N – 5 mg/L	Additional Blowers and new Blower Building Replacement of RAS Pumps with new Higher Capacity Pumps Alkalinity Storage and Feed System and new Chemical Building Structural Modifications to Existing Aeration Tanks
NH_3-N – 1.5 mg/L	Additional Blowers and new Blower Building Replacement of RAS Pumps with new Higher Capacity Pumps Alkalinity Storage and Feed System and new Chemical Building Structural Modifications to Existing Aeration Tanks
TN – 4 mg/L	Additional Blowers and new Blower Building Replacement of RAS Pump with new Higher Capacity Pumps Structural Modifications to Existing Aeration Tanks Intermediate Pump Station – 87 mgd firm capacity and TDH based on DF HL Alkalinity Storage and Feed System and new Chemical Building Methanol Storage and Feed System and new Chemical Building DF Gallery Building and Backwash Pumping Station

The Generic Conventional Plant capital cost estimates for the four (4) effluent level scenarios follow. It is noted that the cost estimates are based on the use of free floating IFAS media. Similar costs would apply to the use of fixed IFAS media.

Table 5-20: Generic Conventional AS Plant Capital Cost Estimate for NH_3-N of 10 mg/L

Item/Description	*Quantity*	*Unit/Basis*	*Unit Budgetary Cost*	*Item Budgetary Cost*	*Comments*
Major Equipment & Systems					
New ceramic finebubble diffusers for additional nitrification	1	LS	$ 600,000	$ 600,000	Quote from Sanitaire
New 140' dia. Final Clarifier collector w/ density current baffle	2	EA	$ 380,000	$ 760,000	Quote from Envirodyne
New Blowers Process Air System	2	EA	$ 622,000	$ 1,244,000	Quote from Turblex
New RAS Pumps	3	EA	$ 180,000	$ 540,000	Quote from Sultzer
Mag Storage and Feed System for alkalinity control	1	EA	$ 248,000	$ 248,000	4X10000 gallons double contained HDPE tanks
Piping, valves and accessories @20%				$ 678,400	
			Subtotal	*$ 4,070,400*	
Installation	25%			$ 1,017,600	
			Major Equipment & Systems Subtotal	***5,088,000***	
Unit Price & Other Items					
Cast in Place Conc. Walls - Final Clarifiers	1270	CY	$ 950	$ 1,206,500	Unit quote from similar project
Cast in Place Conc. Foundation - Final Clarifiers	2880	CY	$ 600	$ 1,728,000	Unit quote from similar project
Cast in Place Conc. Walls - RAS Bldg	169	CY	$ 950	$ 160,550	Unit quote from similar project
Cast in Place Conc. Foundation - RAS Bldg	194	CY	$ 600	$ 116,400	Unit quote from similar project
Excavation/Backfill - New Final Clarifiers	16380	CY	$ 58	$ 950,040	RSMeans 2019 Estimate
Excavation/Backfill - RAS Building	1142	CY	$ 58	$ 66,236	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 100,000	$ 100,000	KLF Estimate
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	KLF Estimate
			Unit Price & Other Item Subtotal	***4,427,726***	
Buildings					
Chemical Building - (for alkalinity control)	2250	SF	$ 350	$ 787,500	Complete with lighting and HVAC
RAS Building	2625	SF	$ 350	$ 918,750	Complete with lighting and HVAC
Blower Building	2700	SF	$ 350	$ 945,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 2,651,250***	
Bulk Work Percentage					
Civil Site	10%			$ 1,217,000	
Electrical	20%			$ 2,433,000	
Instrumentation & Controls	10%			$ 1,217,000	
Yard Piping	15%			$ 1,825,046	
			Bulk Work Subtotal	***6,692,046***	
Subtotal Direct Costs				**$ 18,859,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 4,526,000	Also includes General Conditions
Contingency	30%			$ 5,658,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 29,043,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 5,808,600	
TOTAL BUDGETARY CAPITAL COST				**$ 34,852,000**	

Table 5-21: Generic Conventional AS Plant Capital Cost Estimate for NH_3-N of 5 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
New 1/4-inch raw WW influent screen w/washer-compactor	1	LS	$ 725,000	$ 725,000	Quote from Duperon
IFAS System w/floating media, diffusers and screens	1	LS	$ 9,990,000	$ 9,990,000	Quote from Kruger
New 140' dia. Final Clarifier collector w/ density current baffle	2	EA	$ 380,000	$ 760,000	Quote from Envirodyne
New Blowers Process Air System	6	EA	$ 622,000	$ 3,732,000	Quote from Turblex
New RAS Pumps	3	EA	$ 180,000	$ 540,000	Quote from Sultzer
Mag Storage and Feed System for alkalinity control	1	EA	$ 365,000	$ 365,000	6X10000 gallons double contained HDPE tanks
Piping, valves and accessories @20%				$ 3,222,400	
			Subtotal	*$ 19,334,400*	
Installation	25%			$ 4,833,600	
			Major Equipment & Systems Subtotal	***24,168,000***	
Unit Price & Other Items					
Cast in Place Conc. - Modification to Aeration tank	3230	CY	$ 2,000	$ 6,460,000	complicated structural modifications
Cast in Place Conc. Walls - Final Clarifiers	1270	CY	$ 950	$ 1,206,500	Unit quote from similar project
Cast in Place Conc. Foundation - Final Clarifiers	2880	CY	$ 600	$ 1,728,000	Unit quote from similar project
Cast in Place Conc. Walls - RAS Bldg	169	CY	$ 950	$ 160,550	Unit quote from similar project
Cast in Place Conc. Foundation - RAS Bldg	194	CY	$ 600	$ 116,400	Unit quote from similar project
Excavation/Backfill - New Final Clarifiers	16380	CY	$ 58	$ 950,040	RSMeans 2019 Estimate
Excavation/Backfill - RAS Building	1142	CY	$ 58	$ 66,236	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 200,000	$ 200,000	KLF Estimate
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	KLF Estimate
			Unit Price & Other Item Subtotal	***10,987,726***	
Buildings					
Chemical Building - (for alkalinity control)	3300	SF	$ 350	$ 1,155,000	Complete with lighting and HVAC
RAS Building	2625	SF	$ 350	$ 918,750	Complete with lighting and HVAC
Blower Building	6300	SF	$ 350	$ 2,205,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 4,278,750***	
Bulk Work Percentage					
Civil Site	10%			$ 3,943,000	
Electrical	20%			$ 7,887,000	
Instrumentation & Controls	10%			$ 3,943,000	
Yard Piping	15%			$ 5,915,171	
			Bulk Work Subtotal	***21,688,171***	
Subtotal Direct Costs				**$ 61,123,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 14,670,000	Also includes General Conditions
Contingency	30%			$ 18,337,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 94,130,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 18,826,000	
TOTAL BUDGETARY CAPITAL COST				**$112,956,000**	

Table 5-22: Generic Conventional AS Plant Capital Cost Estimate for NH_3-N of 1.5 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
New 1/4-inch raw WW influent screen w/washer-compactor	1	LS	$ 725,000	$ 725,000	Quote from Duperon
IFAS System w/floating media, diffusers and screens	1	LS	$ 13,800,000	$ 13,800,000	Quote from Kruger
New 140' dia. Final Clarifier collector w/ density current baffle	2	EA	$ 380,000	$ 760,000	Quote from Envirodyne
New Blowers Process Air System	6	EA	$ 622,000	$ 3,732,000	Quote from Turblex
New RAS Pumps	3	EA	$ 180,000	$ 540,000	Quote from Sultzer
Mag Storage and Feed System for alkalinity control	1	EA	$ 420,000	$ 420,000	7X10000 gallons double contained HDPE tanks
Piping, valves and accessories @20%				$ 3,995,400	
			Subtotal	*$ 23,972,400*	
Installation	25%			$ 5,993,100	
			Major Equipment & Systems Subtotal	***29,965,500***	
Unit Price & Other Items					
Cast in Place Conc. - Modification to Aeration tank	3230	CY	$ 2,000	$ 6,460,000	complicated structural modifications
Cast in Place Conc. Walls - Final Clarifiers	1270	CY	$ 950	$ 1,206,500	Unit quote from similar project
Cast in Place Conc. Foundation - Final Clarifiers	2880	CY	$ 600	$ 1,728,000	Unit quote from similar project
Cast in Place Conc. Walls - RAS Bldg	169	CY	$ 950	$ 160,550	Unit quote from similar project
Cast in Place Conc. Foundation - RAS Bldg	194	CY	$ 600	$ 116,400	Unit quote from similar project
Excavation/Backfill - New Final Clarifiers	16380	CY	$ 58	$ 950,040	RSMeans 2019 Estimate
Excavation/Backfill - RAS Building	1142	CY	$ 58	$ 66,236	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 200,000	$ 200,000	KLF Estimate
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	KLF Estimate
			Unit Price & Other Item Subtotal	***10,987,726***	
Buildings					
Chemical Building - (for alkalinity control)	3750	SF	$ 350	$ 1,312,500	Complete with lighting and HVAC
RAS Building	2625	SF	$ 350	$ 918,750	Complete with lighting and HVAC
Blower Building	6300	SF	$ 350	$ 2,205,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 4,436,250***	
Bulk Work Percentage					
Civil Site	10%			$ 4,539,000	
Electrical	20%			$ 9,078,000	
Instrumentation & Controls	10%			$ 4,539,000	
Yard Piping	15%			$ 6,808,421	
			Bulk Work Subtotal	***24,964,421***	
Subtotal Direct Costs				**$ 70,354,000**	Also includes General Conditions
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 16,885,000	
Contingency	30%			$ 21,106,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 108,345,000**	
Engineering, Permitting, Legal, and Administration	20%			$ 21,669,000	
TOTAL BUDGETARY CAPITAL COST				**$130,014,000**	

Table 5-23: Generic Conventional AS Plant Capital Cost Estimate for TN of 4 mg/L

Item/Description	Quantity	Unit/Basis	Unit Budgetary Cost	Item Budgetary Cost	Comments
Major Equipment & Systems					
New 1/4-inch raw WW influent screen w/washer-compactor	1	LS	$ 725,000	$ 725,000	Quote from Duperon
IFAS System w/floating media, diffusers and screens	1	LS	$ 13,800,000	$ 13,800,000	Quote from Kruger
New 140' dia. Final Clarifier drive mechanism w/DCB	2	EA	$ 380,000	$ 760,000	Quote from Envirodyne
New Blowers Process Air System	6	EA	$ 622,000	$ 3,732,000	Quote from Turblex
New RAS Pumps	3	EA	$ 180,000	$ 540,000	Quote from Sultzer
Mag Storage and Feed System for alkalinity control	1	EA	$ 420,000	$ 420,000	7X10000 gallons double contained HDPE tanks
New Denite filter w/BW pump, blowers and methanol storage	1	LS	$ 18,000,000	$ 18,000,000	Quote from DeNora
Dnite filter feed pumps	4	EA	$ 190,000	$ 760,000	Quote from ABS
Piping, valves and accessories @20%				$ 7,747,400	
			Subtotal	*$ 46,484,400*	
Installation	25%			$ 11,621,100	
			Major Equipment & Systems Subtotal	***58,105,500***	
Unit Price & Other Items					
Cast in Place Conc. - Modification to Aeration tank	3230	CY	$ 2,000	$ 6,460,000	complicated structural modifications
Cast in Place Conc. Walls - Final Clarifiers	1270	CY	$ 900	$ 1,143,000	Unit quote from similar project
Cast in Place Conc. Foundation - Final Clarifiers	2880	CY	$ 600	$ 1,728,000	Unit quote from similar project
Cast in Place Conc. Walls - RAS Bldg	169	CY	$ 900	$ 152,100	Unit quote from similar project
Cast in Place Conc. Foundation - RAS Bldg	194	CY	$ 600	$ 116,400	Unit quote from similar project
Cast in Place Conc. Foundation - PS w/ valve chamber + Dnite filter	5220	CY	$ 600	$ 3,132,000	Unit quote from similar project
Cast in Place Conc. Walls - PS w/ valve chamber + Dnite filter	9945	CY	$ 900	$ 8,950,500	Unit quote from similar project
Methanol Storage pad w/ containment	850	CY	$ 600	$ 510,000	Unit quote from similar project
Excavation/Backfill - New Final Clarifiers	16380	CY	$ 58	$ 950,040	RSMeans 2019 Estimate
Excavation/Backfill - RAS Building	1142	CY	$ 58	$ 66,236	RSMeans 2019 Estimate
Excavation/Backfill - Denitrification Filter + Dnite feed PS	8069	CY	$ 58	$ 468,002	RSMeans 2019 Estimate
Excavation/Backfill - Methanol storage system	3000	CY	$ 58	$ 174,000	RSMeans 2019 Estimate
Misc. Conc. Repair	1	LS	$ 200,000	$ 200,000	KLF Estimate
Misc. metal (grating, platforms, and stairs)	1	LS	$ 100,000	$ 100,000	KLF Estimate
			Unit Price & Other Item Subtotal	***24,150,278***	
Buildings					
Chemical Building - (for alkalinity control)	3750	SF	$ 350	$ 1,312,500	Complete with lighting and HVAC
RAS Building	2625	SF	$ 350	$ 918,750	Complete with lighting and HVAC
Denitrification Filter - Gallery Building	2000	SF	$ 350	$ 700,000	Complete with lighting and HVAC
Denite feed PS building	3375	SF	$ 350	$ 1,181,250	Complete with lighting and HVAC
Blower Building	6300	SF	$ 350	$ 2,205,000	Complete with lighting and HVAC
			Buildings Subtotal	***$ 6,317,500***	
Bulk Work Percentage					
Civil Site	10%			$ 8,857,000	
Electrical	20%			$ 17,715,000	
Instrumentation & Controls	10%			$ 8,857,000	
Yard Piping	15%			$ 13,285,992	
			Bulk Work Subtotal	***48,714,992***	
Subtotal Direct Costs				**$ 137,288,000**	
CG OH&P with Bonds, Insurance, Mobilization/Demobilization	24%			$ 32,949,000	
Contingency	30%			$ 41,186,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 211,423,000**	
Engineering, Permitting, Legal, and Administration	15%			$ 31,713,450	
TOTAL BUDGETARY CAPITAL COST				**$243,136,000**	

Table 5-24 presents a summary of the Generic Conventional Activated Sludge Plant capital cost estimates for each effluent level, and the corresponding capital cost on a $/gpd basis utilizing the Generic Conventional Plant's annual average flow of 72 mgd.

Table 5-24: Generic Conventional Activated Sludge Plant Summary of Capital Costs

Effluent Level	Capital Cost Estimate	$/gpd of capacity
NH_3-N = 10 mg/L	$35 million	0.5
NH_3-N = 5 mg/L	$113 million	1.6
NH_3-N = 1.5 mg/L	$130 million	1.8
TN = 4 mg/L	$243 million	3.4

5.5 Summary of Generic Plant Capital Cost Estimates

Table 5-25 presents a summary of the capital cost estimates and corresponding cost on a $/gpd basis for each generic plant at each effluent level.

Table 5-25: Summary of Generic Plant Capital Costs

Effluent Level	Capital Cost Estimate	$/gpd of capacity
Generic Pure Oxygen Activated Sludge Plant (Avg Flow: 83 mgd)		
NH_3-N = 10 mg/L	$80 million	1.0
NH_3-N = 5 mg/L	$105 million	1.3
NH_3-N = 1.5 mg/L	$134 million	1.6
TN = 4 mg/L	$336 million	4.0
Generic Fixed Film Plant (Avg Flow: 9 mgd)		
NH_3-N = 10 mg/L	$23 million	2.5
NH_3-N = 5 mg/L	$28 million	3.1
NH_3-N = 1.5 mg/L	$33 million	3.7
TN = 4 mg/L	$57 million	6.3
Generic Conventional Activated Sludge Plant (Avg Flow: 72 mgd)		
NH_3-N = 10 mg/L	$35 million	0.5
NH_3-N = 5 mg/L	$113 million	1.6
NH_3-N = 1.5 mg/L	$130 million	1.8
TN = 4 mg/L	$243 million	3.4

6.0 PLANT SPECIFIC COST ESTIMATES AND COST CURVES

6.1 Introduction

This section of the report presents the development of plant specific cost estimates and cost curves for achieving the three (3) previously described effluent levels for ammonia-nitrogen (NH_3-N) and the one (1) effluent level for total nitrogen (TN) at the twelve (12) plants listed below by plant type that discharge to the lower Delaware River.

Pure Oxygen Activated Sludge

- Delaware #1 WPCP / CCMUA
- MMA
- PWD SWWPCP

Fixed Film

- Hamilton Township Water Pollution Control Facility
- Trenton Sewer Utility
- Willingboro MUA Water Pollution Control Plant

Conventional Activated Sludge

- City of Wilmington
- DELCORA (Western Regional Treatment Plant)
- GCUA
- LBCJMA
- PWD SEWPCP
- PWD NEWPCP

As previously described in Section 1.0, plant specific cost estimates were developed through a two-step process beginning with preparation of generic plant capital cost estimates for the three (3) generic plants as described in Section 5.0. The generic plant capital cost estimates on a $/gpd of capacity basis for each effluent level were used as the starting point to develop the plant specific capital cost estimates. Adjustments were made as appropriate based on significances differences in flow and current performance between the generic plant and the specific plant. Additional capital costs were then added as appropriate based on the specific plant's issues, constraints, and needs, such as the need for pile foundations, sheeting, dewatering, rock excavation, purchase of additional land and reduced construction productivity on confined sites. Similarly, cost deductions were applied when a specific plant was already achieving one or more of the effluent levels.

As previously described in several sections of this report, the plant upgrade improvements were sized to achieve the effluent levels each month of the summer season defined as May 1 through October 31, rather than each month of the year. Therefore, the improvements for each effluent level are sized for the maximum monthly average (i.e., maximum 30-day average) flow corresponding to the annual average flow and are sized for the minimum temperature that occurs in the summer season rather than the minimum temperature that occurs in the winter.

As described in Section 5.0, the generic plant cost estimates are consistent with the AACE Level 4 estimate, which is the appropriate level for the study phase of a project. Therefore, consistent with the level of accuracy defined by AACE for a Level 4 estimate, the generic plant capital cost estimates are budgetary estimates with an accuracy of -15% to -30% on the low side to +20% to +50% on the high side.

The generic plant capital cost estimates are in 2019 dollars corresponding to the Engineering News Record (ENR) Twenty City Cost Index of 11311. This index can be used in the future to update the budgetary 2019 costs due to the inflation of construction costs between 2019 and the future date. Because the plant specific cost estimates are largely based on the generic plant capital cost estimates, they should also be viewed as budgetary capital cost estimates in 2019 dollars corresponding to the Engineering News Record (ENR) Twenty City Cost Index of 11311.

Plant specific operations and maintenance (O&M) cost estimates were also developed, as further described below, along with the resulting total present costs and total annualized costs. The plant specific total present cost is the sum of the plant specific capital cost plus the present worth of annual O&M costs (in 2019 dollars). Plant specific total annualized costs is the sum of the annual debt service cost (associated with amortization of capital costs) plus annual O&M costs.

Plant specific cost curves show the relationship between effluent level and the total present costs and between effluent level and total annualized costs.

As previously described in Section 4.0, It is important to note that the objective is not to identify the most cost effective upgrade alternative for each individual plant, but rather to establish appropriately conservative upgrade costs based on proven technologies applied uniformly to each category of plant type for cost curve development. If effluent limits for NH_3-N or TN are ultimately established in the future, each plant should conduct an evaluation of alternatives to determine if a lower cost approach will achieve the effluent limit based on information and proven technologies available at that time.

6.2 Plant Specific Capital Cost Adjustment Factors

The following unit costs not included in the generic plant capital cost estimates were developed for use in adjusting the plant specific capital cost estimates where appropriate, based on site specific information. The unit costs include percentages for contractor, overhead and profit, and contingency, as applicable.

- Pile Foundations – $120/SF
- Rock Excavation – $200/CY
- Sheeting – $37/SF
- Dewatering setup and operation - $9/SF (assuming a 2-year dewatering period)
- Productivity reduction factor for confined sites – 4.5% of total construction costs
- Land Acquisition:
    - Low value - $30/SF
    - High value - $150/SF

Unit costs for pile foundations, rock excavation, sheeting, and dewatering were estimated from RS Means construction estimating information and from actual costs of recently completed projects. An upper and lower range of land values was estimated from assessments of adjacent land values at each of the twelve (12) plants.

6.3 Operations and Maintenance Cost Estimation Methodology

Plant specific annual O&M cost estimates for each level of nutrient removal upgrade incorporate the following categories of O&M costs:

- Additional Staffing Needs
- Chemicals

- Energy
- Sludge Processing and Disposal
- Maintenance

The assumptions and methodology related to each O&M cost category are presented below:

6.3.1 Additional Staffing

The anticipated number of additional full-time staff for each level of upgrade for the pure oxygen, fixed film, and conventional activated sludge plants are summarized in Tables 6-1, 6-2 and 6-3, respectively and are based on engineering judgement,

Table 6-1: Anticipated Additional Staff for Pure Oxygen Plants

Scenario	Pure Oxygen Plants		
	MMA	**PWD SWWPCP**	**CCMUA**
NH_3-N – 10 mg/L			
Operator	1	3	1
Maintenance	0	1	1
NH_3-N – 5 mg/L			
Operator	1	3	1
Maintenance	0	1	1
NH_3-N – 1.5 mg/L			
Operator	1	3	1
Maintenance	1	2	1
NH_3-N – 1.5 mg/L and TN – 4.0 mg/L			
Operator	1	4	2
Maintenance	1	3	1

Table 6-2: Anticipated Additional Staff for Fixed Film Plants

Scenario	Fixed Film Plants		
	Trenton Sewer Utility	**Hamilton Township WPCF**	**Willingboro MUA WPCP**
NH_3-N – 10 mg/L			
Operator	0	1	0
Maintenance	0	0	0
NH_3-N – 5 mg/L			
Operator	1	1	0
Maintenance	0	0	0
NH_3-N – 1.5 mg/L			
Operator	1	1	1
Maintenance	1	1	0
NH_3-N – 1.5 mg/L and TN – 4.0 mg/L			
Operator	1	1	1
Maintenance	1	1	0

Table 6-3: Anticipated Additional Staff for Conventional Activated Sludge Plants

Scenario	Conventional Activated Sludge Plants					
	PWD NEWPCP	**Wilmington**	**DELCORA WRTP**	**GCUA**	**LBCJMA**	**PWD SEWPCP**
NH_3-N – 10 mg/L						
Operator	0	0	0	0	0	1
Maintenance	0	0	0	0	0	1
NH_3-N – 5 mg/L						
Operator	1	1	1	0	0	1
Maintenance		1	0	0	0	1
NH_3-N – 1.5 mg/L						
Operator	2	1	1	0	0	1
Maintenance	1	1	0	0	0	1
NH_3-N – 1.5 mg/L and TN – 4.0 mg/L						
Operator	3	2	2	1	1	2
Maintenance	2	2	1	1	1	1

A total salary cost (salary plus fringe benefits) of $88,000 per year per additional plant staff was utilized based on a survey of position postings in New Jersey, Eastern Pennsylvania and Northern Delaware, indicating a salary (excluding fringe benefits) of $55,000 to which was added 60% for fringe benefits.

6.3.2 Chemicals

Chemical costs were estimated based on the following assumptions:

- Alkalinity addition to nitrifying systems utilizing magnesium hydroxide as the external source of alkalinity.
- Carbon addition to denitrifying systems utilizing methanol as the external carbon source.

- Additional polymer consumption for processing additional sludge produced by higher levels of treatment.

Magnesium hydroxide demand was calculated based on an alkalinity consumption of 7.14 lbs per pound of NH_3-N nitrified. A unit cost of $625 per ton was assumed delivered as a minimum 55% (w/w) solution with 98% magnesium content. Methanol demand was calculated based on a dose of 3.5 lbs per pound of nitrate denitrified in the denitrifying filters. A methanol cost of $1.15/gal was assumed. For each of the sludge thickening and dewatering unit processes, polymer consumption was assumed to be 12 pounds per ton of dry solids. A polymer cost of $1.5??? per pound was assumed.

6.3.3 Energy

Energy consumption, on a horsepower (hp) per mgd basis, was developed for each of the following plant components:

- IFAS system process air blowers - 80 hp/mgd.
- BAF system feed pumps - 15 hp/mgd.
- Denitrification (Denite) Filter feed pumps - 12 hp/mgd.
- BAF system blowers (rotary lobe for flows up to 20 mgd) – 25 hp/mgd.
- BAF system blowers (turbo blowers for flow greater than 20 mgd) – 16.4 hp/mgd.
- BAF backwash return pumps (for flows up to 20 mgd) – 1 hp/mgd.
- BAF backwash return pumps (for flows greater than 20 mgd) – 1.5 hp/mgd.
- Magnesium hydroxide feed system (for flows up to 20 mgd) – 0.5 hp/mgd.
- Magnesium hydroxide feed system (for flows greater than 20 mgd) – 1 hp/mgd.
- Methanol feed system (for flows up to 20 mgd) – 0.5 mgd.
- Methanol feed system (for flows greater than 20 mgd) – 1 hp/mgd.
- Denite filter backwash air blower (for flows less than 20 mgd) – 16 hp/mgd.
- Denite filter backwash air blower (for flows greater than 20 mgd) – 14 hp/mgd.
- Denite filter backwash pump (for flows less than 20 mgd) – 4 hp/mgd.
- Denite filter backwash pump (for flows greater than 20 mgd) – 1 hp/mgd.

- Denite filter mudwell pump (for flows less than 20 mgd) – 0.6 hp/mgd.
- Denite filter mudwell pump (for flows greater than 20 mgd) – 0.3 hp/mgd.
- Allowance for miscellaneous buildings (HVAC and lighting), site lighting, valve actuators, etc. – 10% of total additional hp.

Based on the plant specific average flow, the total hp was calculated using the hp-per-mgd power consumption factors. The corresponding total annual energy cost was then calculated based on an assumed energy cost of $0.08 per KWHr, inclusive of demand charges.

6.3.4 Sludge Processing and Disposal

The impact of each upgrade scenario on sludge production was evaluated based on the following assumptions:

- Additional TSS removed through the various filter technologies is based on the difference between current average plant effluent TSS and effluent TSS associated with the specific treatment technology used.
- For nitrification using the BAF process, effluent TSS was assumed to be 10 mg/l.
- For denitrification filters, effluent TSS was assumed to be 5 mg/l.
- For conventional activated sludge plants:
    - Additional waste activated sludge from removal of additional BOD in the IFAS system is based on a VSS yield of 0.6 pounds per pound of soluble BOD removed, and a corresponding TSS yield based on 85% VSS. The effluent SBOD from a nitrifying IFAS system assumed to be 1 mg/L.
    - Biological growth in denitrification filters attributable to carbon (methanol) addition is assumed to be 0.18 pounds of VSS produced per pound of COD applied, based on 1.5 lb COD per pound of methanol added for denitrification. The VSS assumed to be 85% of TSS.
- In pure oxygen activated sludge and trickling filter plants:
    - Additional waste sludge from removal of additional soluble BOD in nitrifying BAF is based on a VSS yield of 0.6 pounds per pound of soluble BOD removed, and a corresponding TSS yield based on 85% VSS. The SBOD to BAF is assumed to be

equal to the effluent total BOD, minus the particulate BOD, which is assumed to be equal to 60% of the effluent TSS. The SBOD from nitrifying BAF is assumed to be 1 mg/L.

- o Sludge yield in the BAF nitrification filter was assumed to be 0.12 lb of VSS per pound of ammonia-nitrogen oxidized. The VSS assumed to be 85% of TSS.
- o Growth in denitrification filter attributable to carbon (methanol) addition is assumed to be 0.18 pounds of VSS produced per pound of COD applied, based on 1.5 lb COD per pound of methanol added for denitrification. The VSS assumed to be 85% of TSS.

- Backwash water produced from BAF and Denite filters is assumed to be returned to head of the plant. TSS associated with the backwash water was assumed to settle in primary clarifiers.
- Primary sludge and thickened sludge solids concentrations were assumed to be 5%.
- Aerobic or anaerobic sludge digestion process, where applicable, was assumed to reduce volatile solids by 50%.
- Dewatering operation was assumed to produce sludge cake with 20% total solids (TS) concentration for offsite disposal.

The cost to dispose of the additional sludge produced is based on the following assumptions:

- Transportation and disposal fees of $0.08/gal for thickened sludge.
- Transportation and disposal fees of $90/wet ton for sludge cake.
- Transportation and disposal fees of $80/ton for dried biosolids.

The cost of polymer to thicken and dewater the additional sludge was calculated and included as a chemical cost.

6.3.5 Maintenance

An annual maintenance cost for consumables (oil, grease, etc.), and scheduled replacement of component parts, etc. is calculated based on 1% of total direct capital material costs.

6.4 Present Cost and Annualized Cost Estimating Methodology

The present worth of annual operating costs is calculated assuming a 25-year operating period, an interest rate of 5% and an inflation rate of 3.5%, resulting in a discount rate of 1.5% (5% minus 3.5%). Based on i =1.5% and n = 25 years, the uniform series present worth factor is 20.7, therefore, the present worth of the O&M costs are 20.7 times the annual O&M costs.

The total present cost is equal to the sum of the plant specific capital costs plus the present worth of annual O&M costs.

6.5 Plant Specific Cost Estimate Summaries and Cost Curves

This section summarizes the plant specific capital cost, total present cost (capital plus present worth of annual O&M costs), and total annualized cost (annual debt service cost plus annual O&M cost) to achieve the three (3) effluent levels for NH_3-N reduction and the one (1) effluent level for TN at each plant. Also included are the resulting cost curves for total present costs and for total annualized cost. A summary of the site-specific issue and factors that served as the basis for the plant specific costs are also described.

As previously described, all plant specific costs are in 2019 dollars corresponding to the Engineering News Record (ENR) Twenty City Cost Index of 11311.

The plants are in order of flow capacity within each category of plant type beginning with the pure oxygen activated sludge plants. For each plant, breakdowns of capital and O&M costs for each effluent level are presented in a referenced Appendix together with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/l effluent TN concentration. It is noted that the purpose of the site conceptual aerial site plans is to identify potential location of each major structure. However, they are not optimized site plans with respect to potential subsurface interferences, as the development of optimized site plans requires a design level analysis.

<u>PURE OXYGEN ACTIVATED SLUDGE PLANTS</u>

6.5.1 MORRISVILLE BOROUGH MUNICIPAL AUTHORITY

MMA's plant specific costs are summarized in Table 6-4. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-4 as Figures 6-1 and 6-2, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix B along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/l effluent TN concentration.

Table 6-4: MMA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	25	9	33	2	0.4	2
NH_3-N - 5 mg/L	28	12	40	2	1	2
NH_3-N - 1.5 mg/L	31	16	46	2	1	3
TN - 4 mg/L	55	28	83	4	1	5

Figure 6-1: MMA Plant Specific Total Present Cost Curve

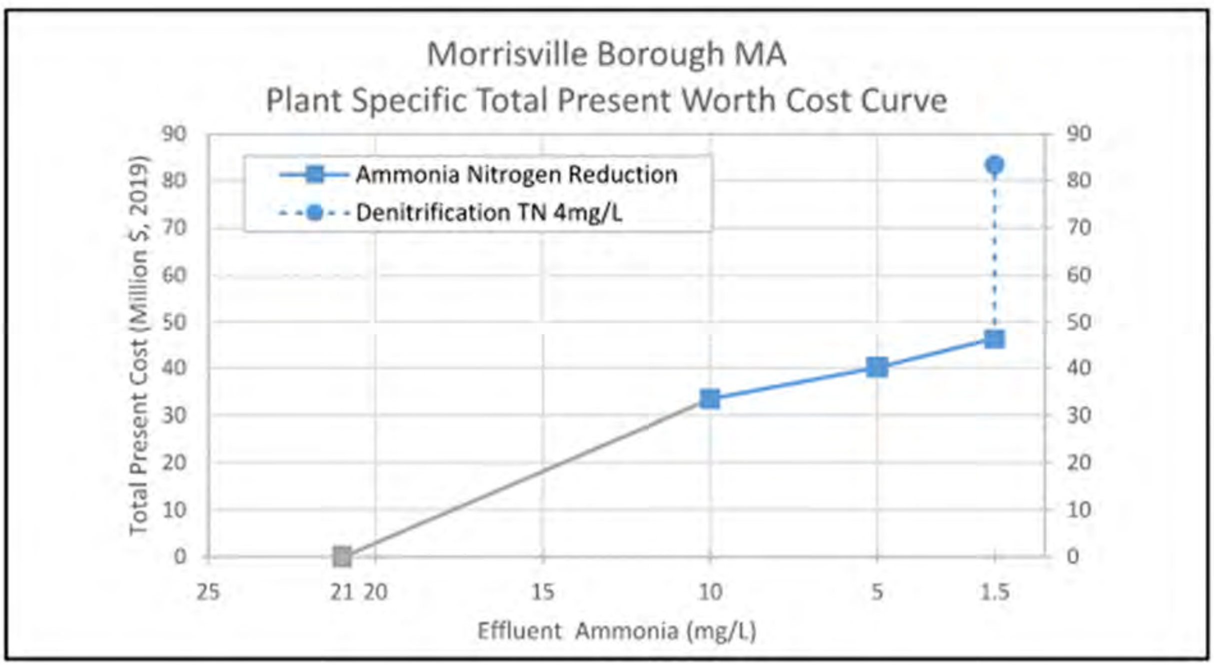
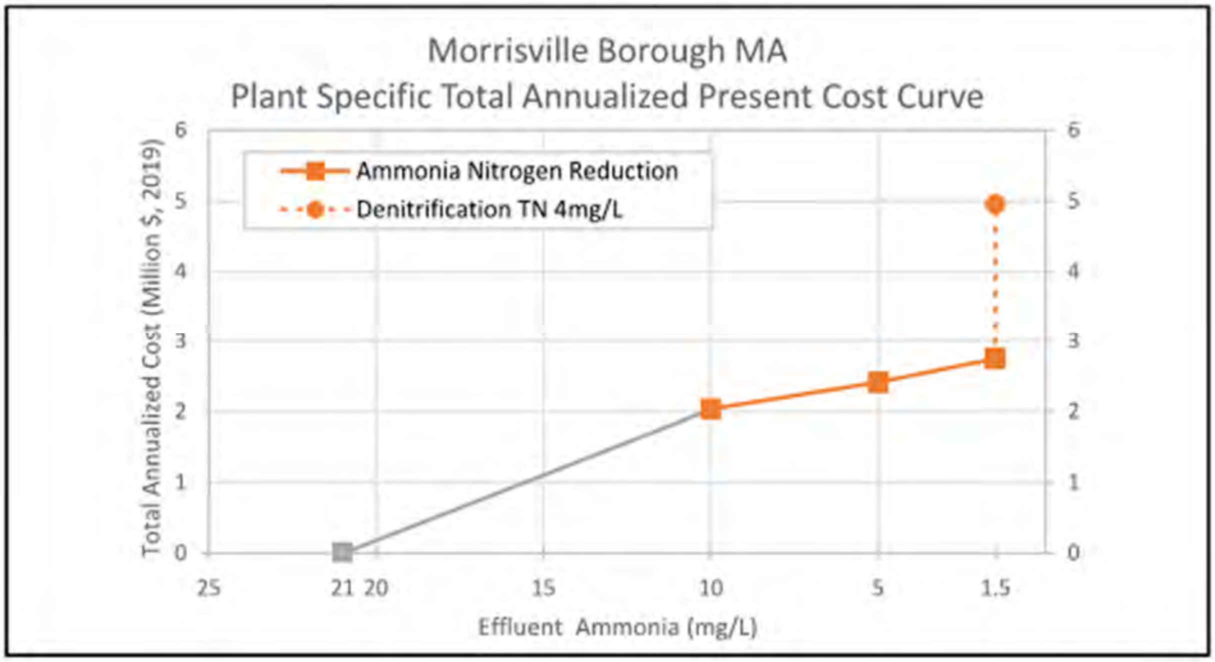


Figure 6-2: MMA Plant Specific Total Annual Cost Curve



The MMA site-specific information, issues and factors that served as the basis for the plant specific costs and resulting cost curves are listed below:

PERMITTED CAPACITY:	8.70 MGD
2018 ANNUAL AVG FLOW:	5.98 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	7.77 MGD

- Because the permitted capacity of 8.7 mgd exceeds the 2018 maximum monthly average flow of 7.77 mgd, the permitted capacity was conservatively used to size the improvements.
- A maximum monthly summer average ammonia concentration of 11.7 mg/L which is lower in strength than the generic plant's maximum monthly average concentration.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentrations by blending with non-BAF treated secondary effluent as summarized below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	4.9
5 mg/L	7.2
1.5 mg/L	8.7

- All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- Groundwater will be encountered at a depth of approximately 10 ft, with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.

It is noted that the MMA is currently planning to replace the existing plant with a new plant at a different site because of the age and condition of the existing plant. Because the timing and cost is uncertain and the portion of new plant costs attributable to achieving a higher level of treatment is also uncertain, the budgetary costs presented herein should be viewed as appropriately conservative costs to attain the various effluent levels, regardless of whether they are costs to upgrades or costs associated with the new plant to attain the various effluent levels.

6.5.2 CCMUA

CCMUA's plant specific costs are summarized in Table 6-5. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-5 as Figures 6-3 and 6-4, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix C along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/l effluent TN concentration.

Table 6-5: CCMUA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	94	128	221	6	6	12
NH_3-N - 5 mg/L	114	164	278	7	8	15
NH_3-N - 1.5 mg/L	129	189	318	8	9	18
TN - 4 mg/L	310	316	626	20	15	35

Figure 6-3: CCMUA Plant Specific Total Present Cost Curve

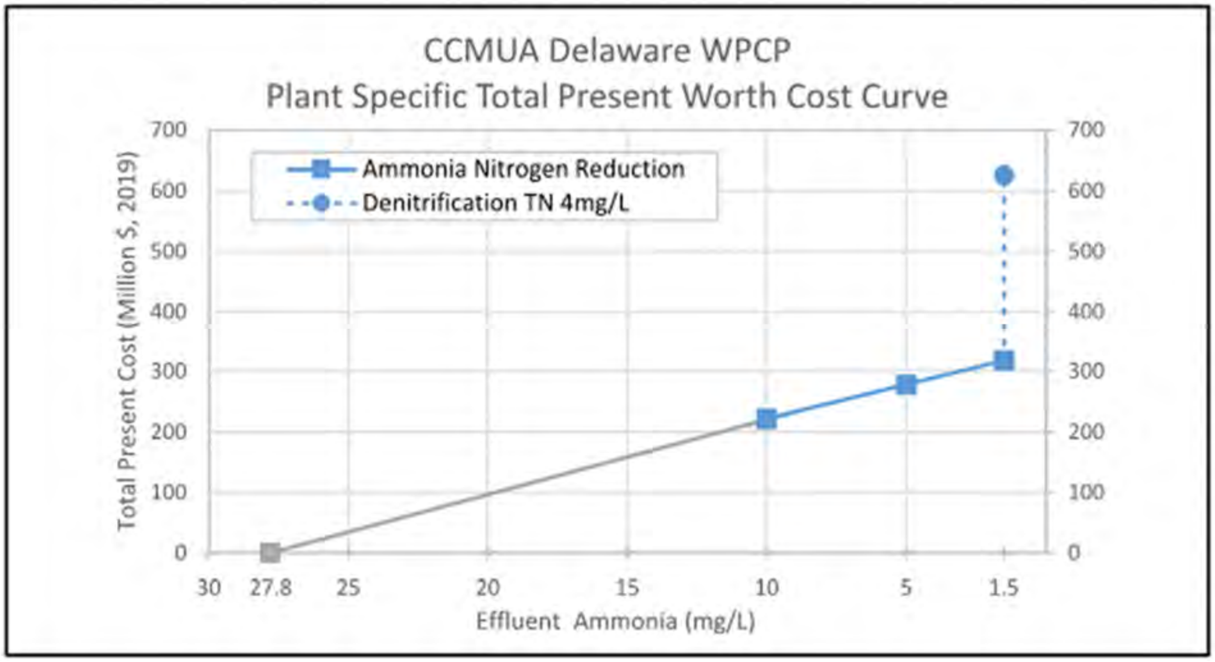
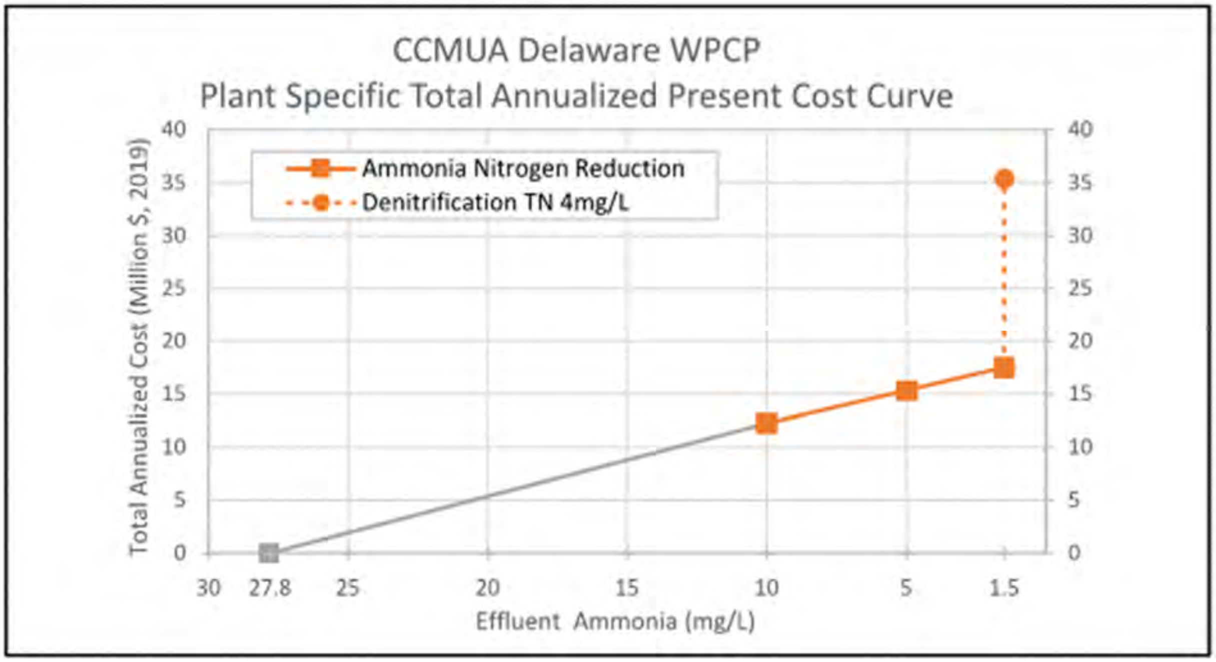


Figure 6-4: CCMUA Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the CCMUA plant specific cost summary table are listed below:

PERMITTED CAPACITY:	80.00 MGD
2018 ANNUAL AVG FLOW:	58.66 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	71.50 MGD

- Because the permitted capacity of 80 mgd exceeds the 2018 maximum monthly average flow of 71.5 mgd, the permitted capacity was used to conservatively size the improvements.
- A maximum monthly summer average ammonia concentration of 27.8 mg/L which is nominally higher than the generic plant's maximum monthly summer average ammonia concentration.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentrations by blending with non-BAF treated secondary effluent as summarized below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	54.2
5 mg/L	69.45
1.5 mg/L	80.00

- o All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- o Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- o Pile supported foundations will be required for all new structures.
- o Sheeting will be required for all structure excavation.
- o Reduction in productivity factor due to confined work area.
- o Land acquisition required for the BAF and denitrification structures using adjacent property values in the area.

6.5.3 PWD SWWPCP

PWD's SWWPCP plant specific costs are summarized in Table 6-6. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-6 as Figures 6-5 and 6-6, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix D along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-6: PWD SWWPCP Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	209	274	483	14	13	27
NH_3-N - 5 mg/L	270	362	632	18	17	35
NH_3-N - 1.5 mg/L	313	427	740	20	21	41
TN - 4 mg/L	788	739	1,527	51	36	87

Figure 6-5: PWD SWWPCP Plant Specific Total Present Cost Curve

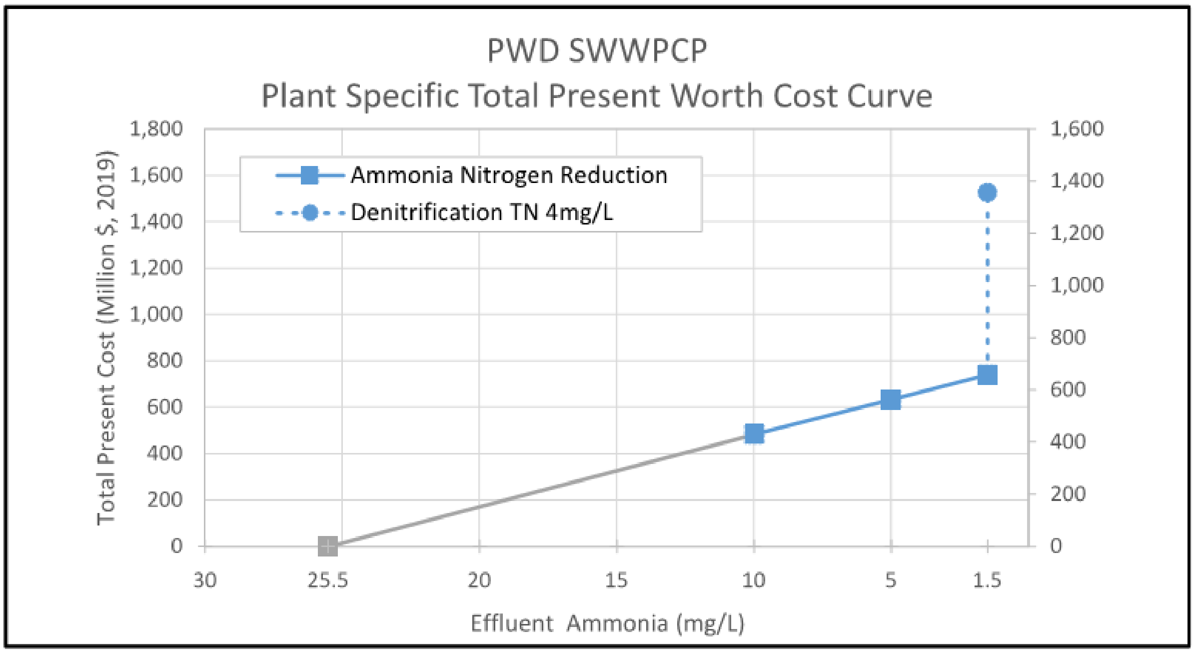
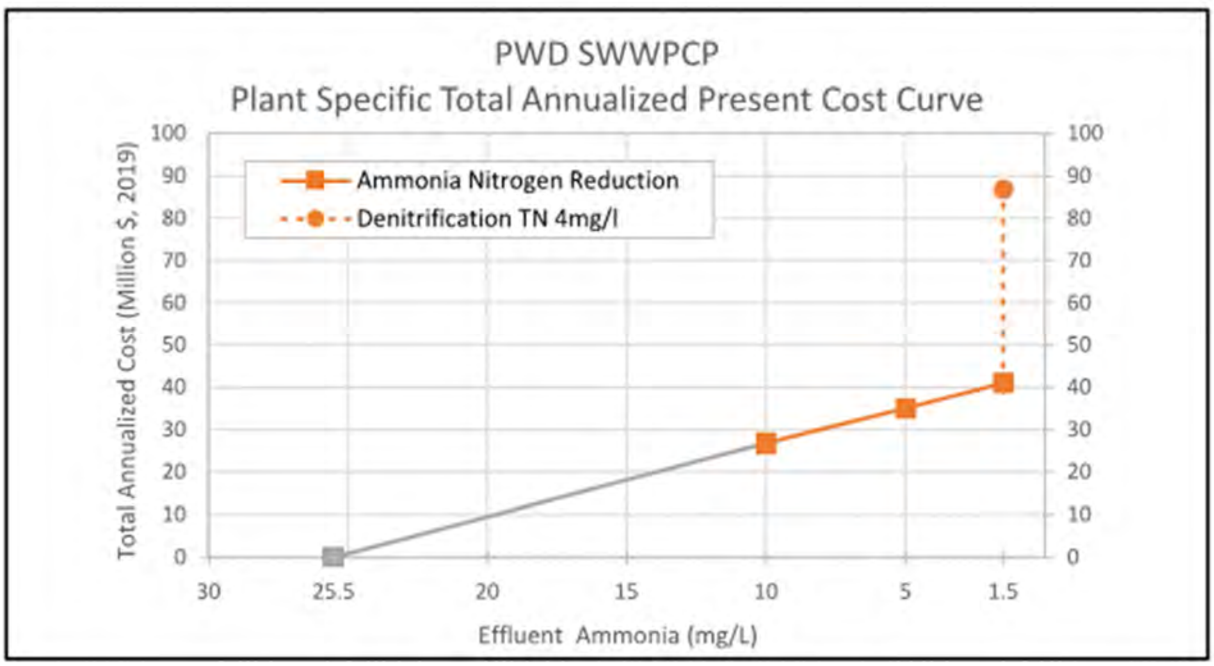


Figure 6-6: PWD SWWPCP Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the PWD SWWPCP plant specific cost summary table are listed below:

PERMITTED CAPACITY:	200.00 MGD
2018 ANNUAL AVG FLOW:	183.17 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	212.00 MGD

- The 2018 maximum monthly average flow of 212 mgd was used to size the improvements.
- A maximum monthly summer average effluent ammonia concentration of 25.5 mg/L which is essentially the same as for the generic pure oxygen activated sludge plant.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentrations by blending with non-BAF treated secondary effluent as summarized below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	129.23
5 mg/L	170.86
1.5 mg/L	212.00

- All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.
- Land acquisition required for the BAF and denitrification structures.

FIXED FILM PLANTS

6.5.4 WILLINGBORO MUA

The Willingboro MUA's plant specific costs are summarized in Table 6-7. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-7 as Figures 6-7 and 6-8, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix E along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-7: Willingboro MUA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	0	0	0	0	0	0
NH_3-N - 5 mg/L	0	0	0	0	0	0
NH_3-N - 1.5 mg/L	26	5	31	2	0.3	2
TN - 4 mg/L	40	12	52	3	1	3

Figure 6-7: Willingboro MUA Plant Specific Total Present Cost Curve

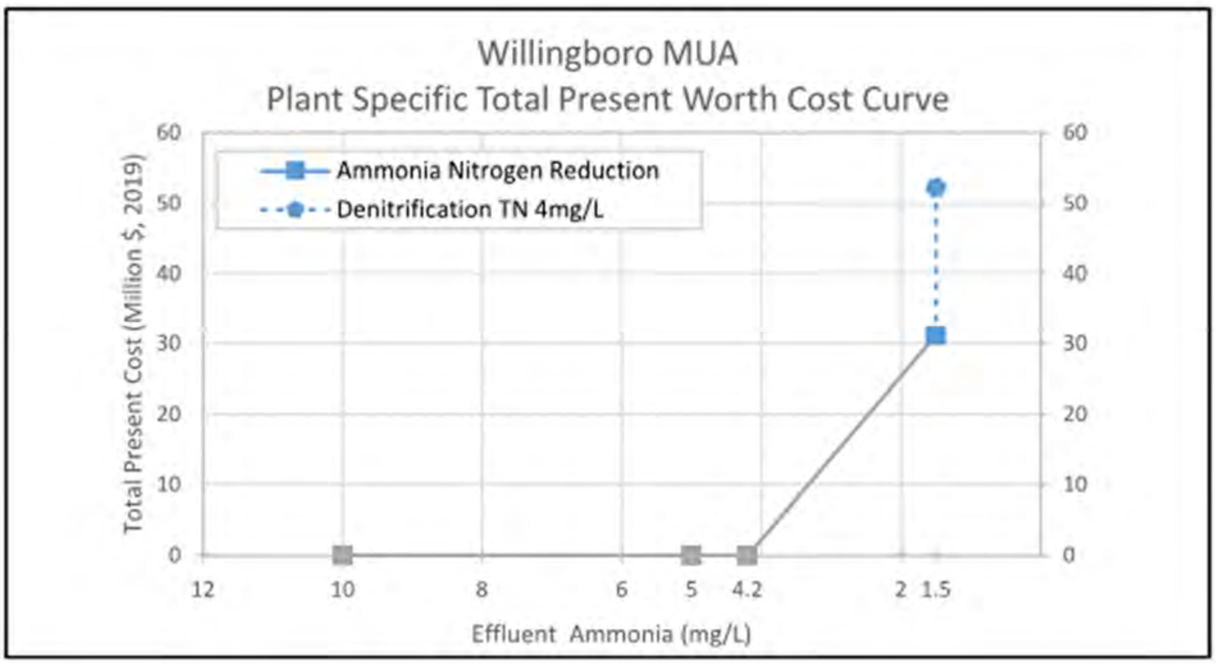
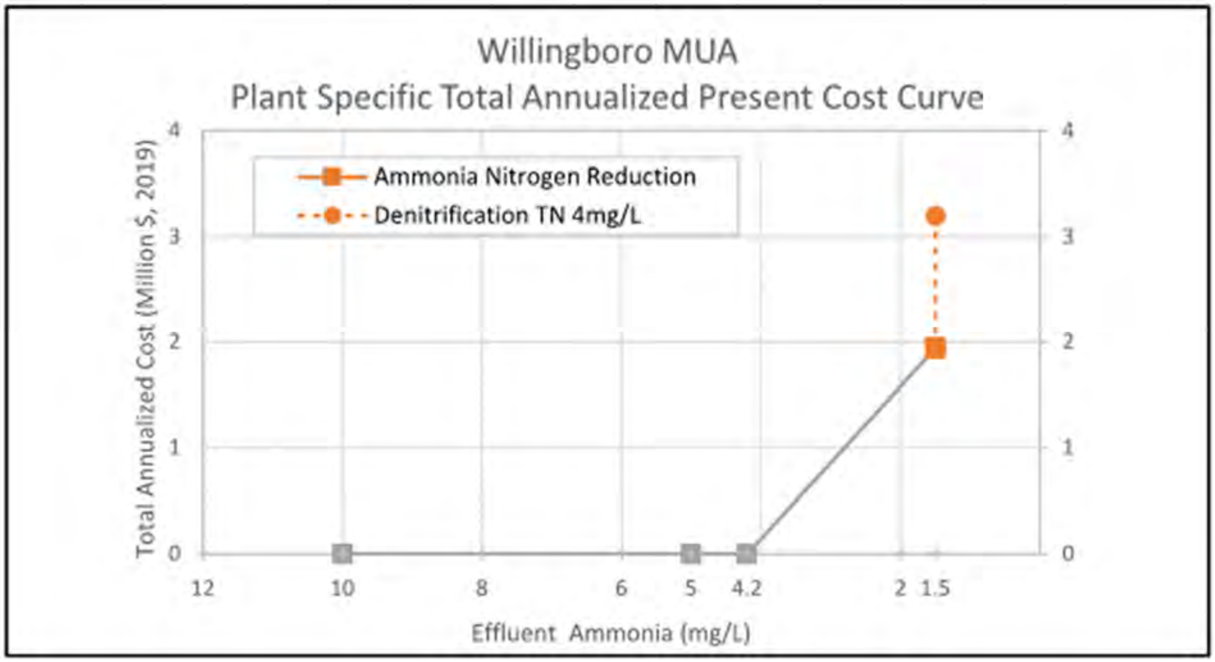


Figure 6-8: Willingboro MUA Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the Willingboro MUA plant specific cost summary table are listed below:

PERMITTED CAPACITY:	5.22 MGD
2018 ANNUAL AVG FLOW:	4.10 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	5.22 MGD

- The maximum monthly average flow, which equaled the permitted capacity, was used to size the plant improvements.
- Based on the maximum monthly summer average effluent ammonia concentration of 4.20 mg/L; the Willingboro MUA plant does not need to implement improvements to achieve the 10 mg/L or 5 mg/L effluent NH_3-N levels.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentration of 1.5 mg/L by blending with non-BAF treated secondary effluent is presented below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	0
5 mg/L	0
1.5 mg/L	5.22

- All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- Groundwater will be encountered at a depth of approximately 10 ft., with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new major structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.

6.5.5 HAMILTON TOWNSHIP

The Hamilton Township plant specific costs are summarized in Table 6-8. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-8 as Figures 6-9 and 6-10, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix F along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-8: Hamilton Township Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	30	26	56	2	1	3
NH_3-N - 5 mg/L	33	32	66	2	2	4
NH_3-N - 1.5 mg/L	35	39	74	2	2	4
TN - 4 mg/L	58	62	120	4	3	7

Figure 6-9: Hamilton Township Plant Specific Total Present Cost Curve

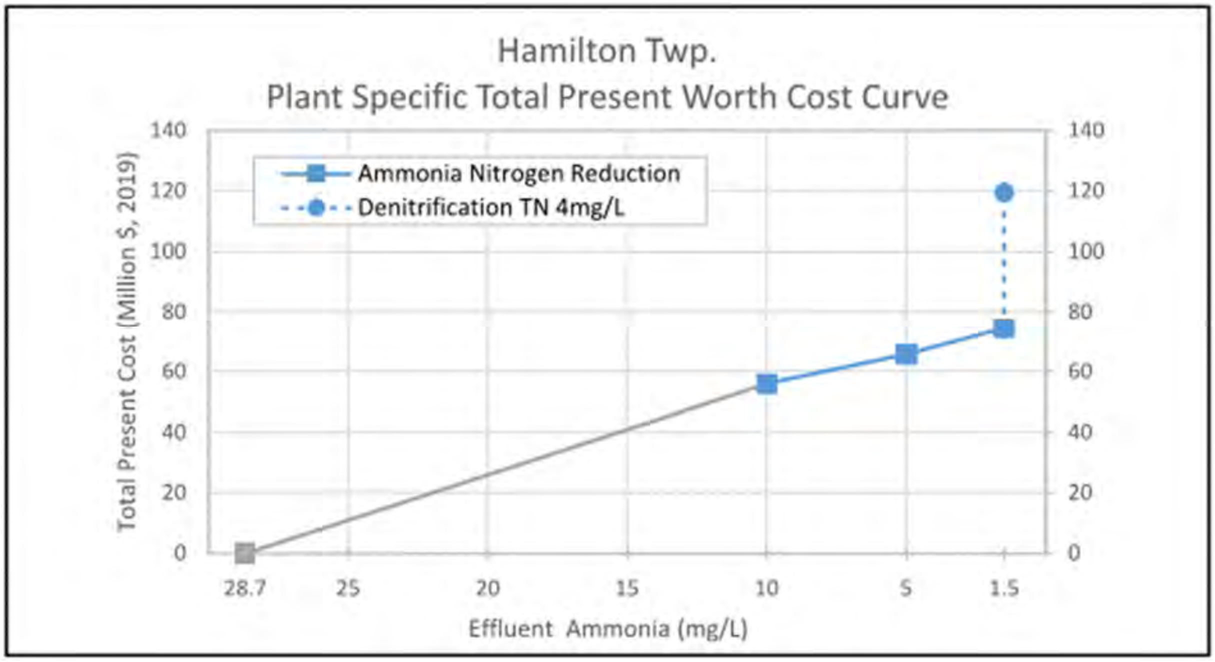
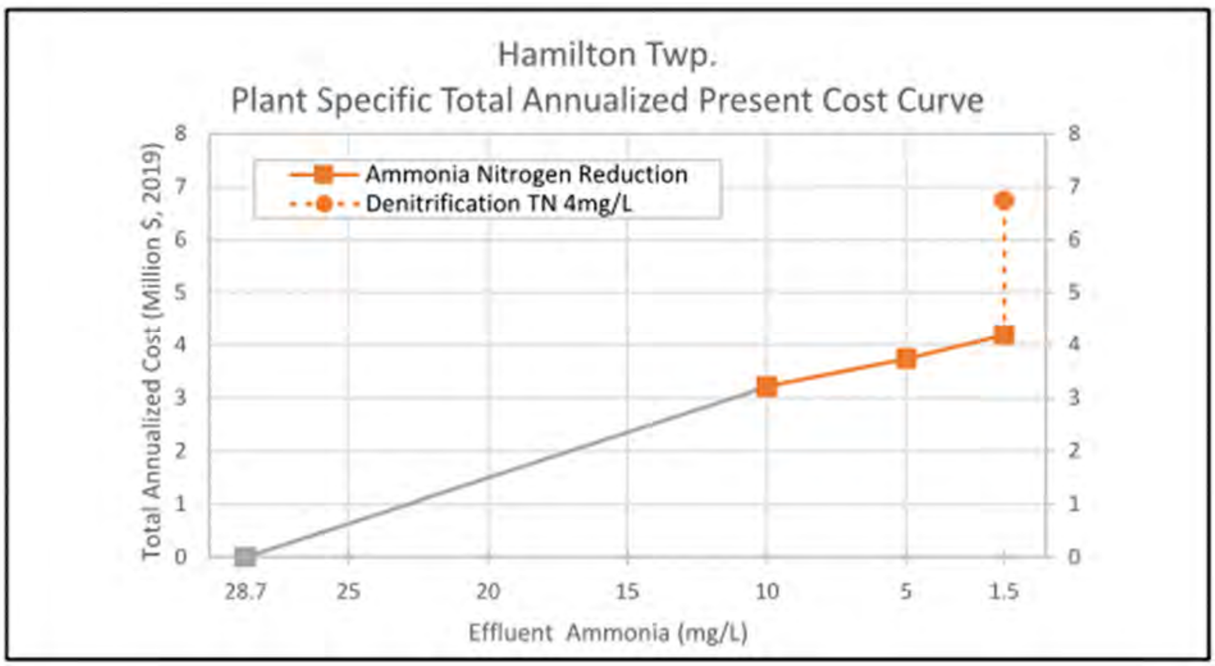


Figure 6-10: Hamilton Township Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the Hamilton Township WPCP plant specific cost summary table are listed below:

PERMITTED CAPACITY:	16.00 MGD
2018 ANNUAL AVG FLOW:	9.01 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	12.03 MGD

- The Mercer County Wastewater Management Plan indicates a buildout future flow for the Hamilton Township WPCP of 12.74 mgd which nominally exceeds the maximum monthly average flow of 12.03 mgd and will be used to size the improvements.
- A maximum monthly summer average ammonia effluent concentration of 28.7 mg/L, which is significantly higher than the generic fixed film plant's maximum monthly summer average effluent ammonia concentration.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentrations by blending with non-BAF treated secondary effluent is presented below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	8.8
5 mg/L	11.1
1.5 mg/L	12.74

- All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Approximately 10 feet of rock excavation will be required for the major structures.
- Sheeting is required for all structure excavation.
- No reduction in productivity factor due to confined work area.

6.5.6 TRENTON SEWER UTILITY

The Trenton Sewer Utility plant specific costs are summarized in Table 6-9. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-9 as Figures 6-11 and 6-12, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix G along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-9: Trenton Sewer Utility Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	1	0.5	2	0.1	0.02	0.1
NH_3-N - 5 mg/L	31	8	38	2	0.4	2
NH_3-N - 1.5 mg/L	39	14	53	3	1	3
TN - 4 mg/L	64	29	93	4	1	6

Figure 6-11: Trenton Sewer Utility Plant Specific Total Present Cost Curve

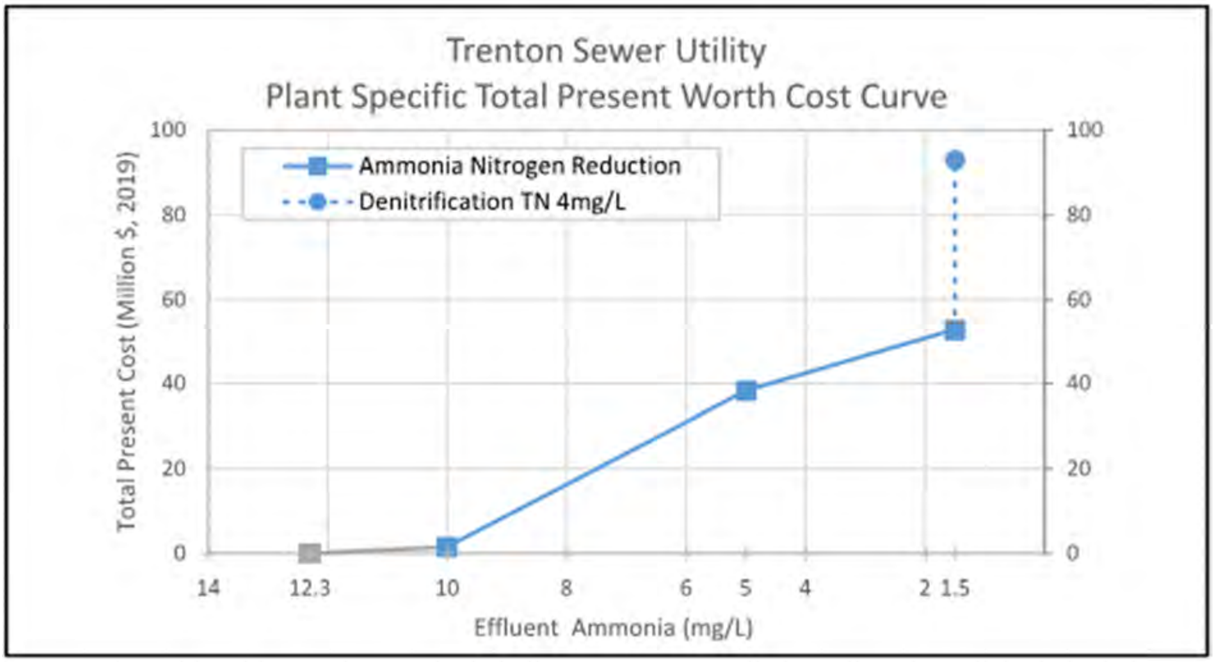
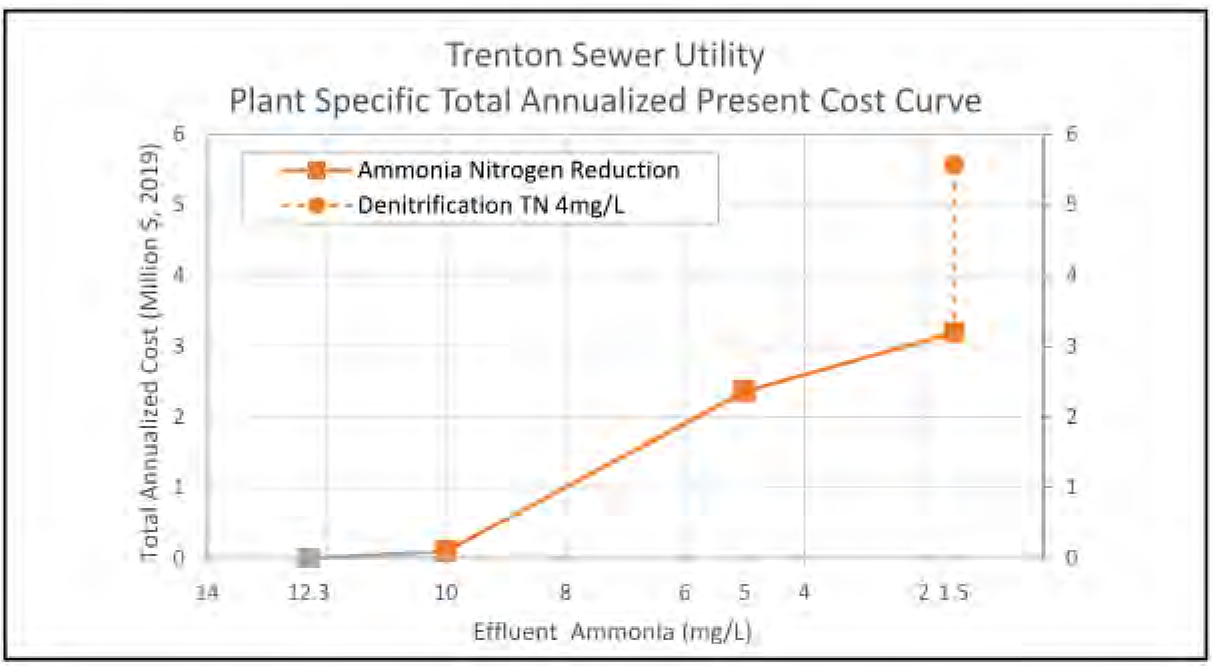


Figure 6-12: Trenton Sewer Utility Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the Trenton Sewer Utility plant specific cost summary table are listed below:

PERMITTED CAPACITY:	20.00 MGD
2018 ANNUAL AVG FLOW:	12.38 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	14.85 MGD

- The Mercer County Wastewater Management Plan indicates a future buildout flow for Trenton Sewer Utility at 12.88 mgd which is less than the maximum monthly average flow of 14.85 mgd. Therefore, the improvements were sized for a maximum monthly average flow of 14.85 mgd.
- The maximum monthly summer average effluent ammonia concentration of 12.3 mg/l which is lower than the generic fixed film plant's maximum monthly average effluent concentration.
- By placing the third trickling filter into continuous operation, the 10 mg/L effluent level will be achieved without the need to construct improvements.
- The effluent flow rate requiring BAF treatment to achieve the targeted effluent ammonia concentrations by blending with non-BAF treated secondary effluent are presented below:

NH_3-N Treatment Level	Flow (mgd) to be treated by BAF
10 mg/L	0
5 mg/L	8.7
1.5 mg/L	14.85

- All major structures (BAF building, denitrification building, and associated pump stations) will be constructed to a depth of approximately 20 ft.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.

CONVENTIONAL ACTIVATED SLUDGE PLANTS

6.5.7 LBCJMA

The LBCJMA plant specific costs are summarized in Table 6-10. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-10 as Figures 6-13 and 6-14, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix H along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-10: LBCJMA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	13	18	31	0.9	0.9	2
NH_3-N - 5 mg/L	13	27	41	1	1	2
NH_3-N - 1.5 mg/L	13	34	47	1	2	2
TN - 4 mg/L	38	59	97	2	3	5

Figure 6-13: LBCJMA Plant Specific Total Present Cost Curve

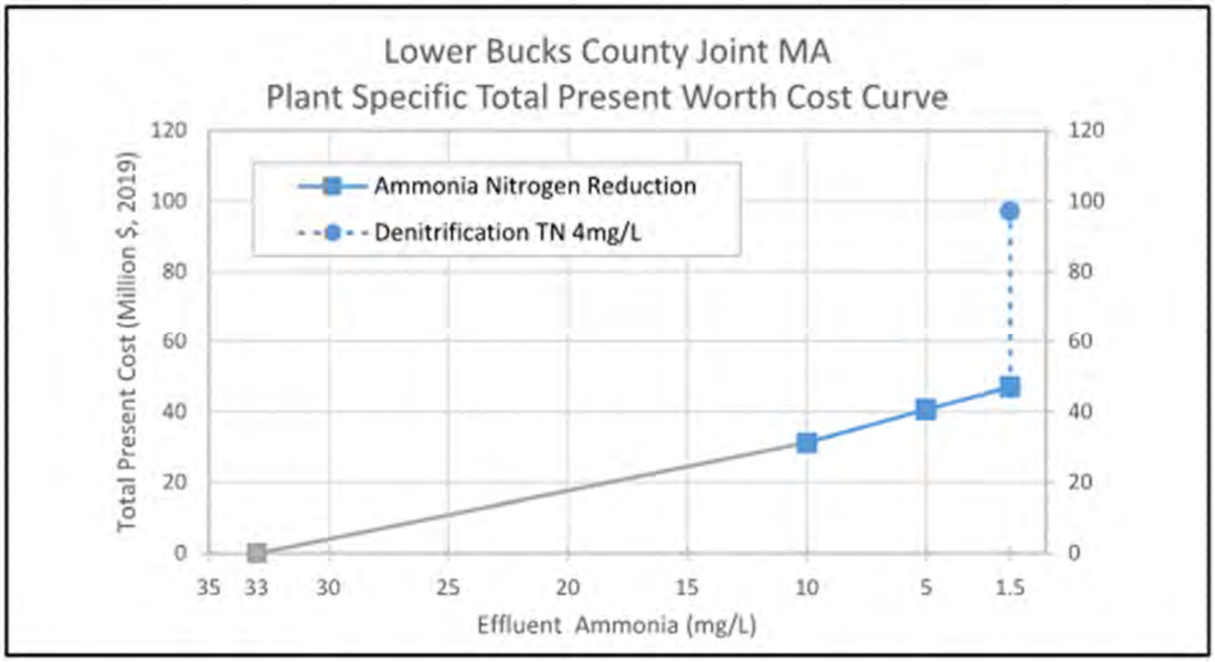
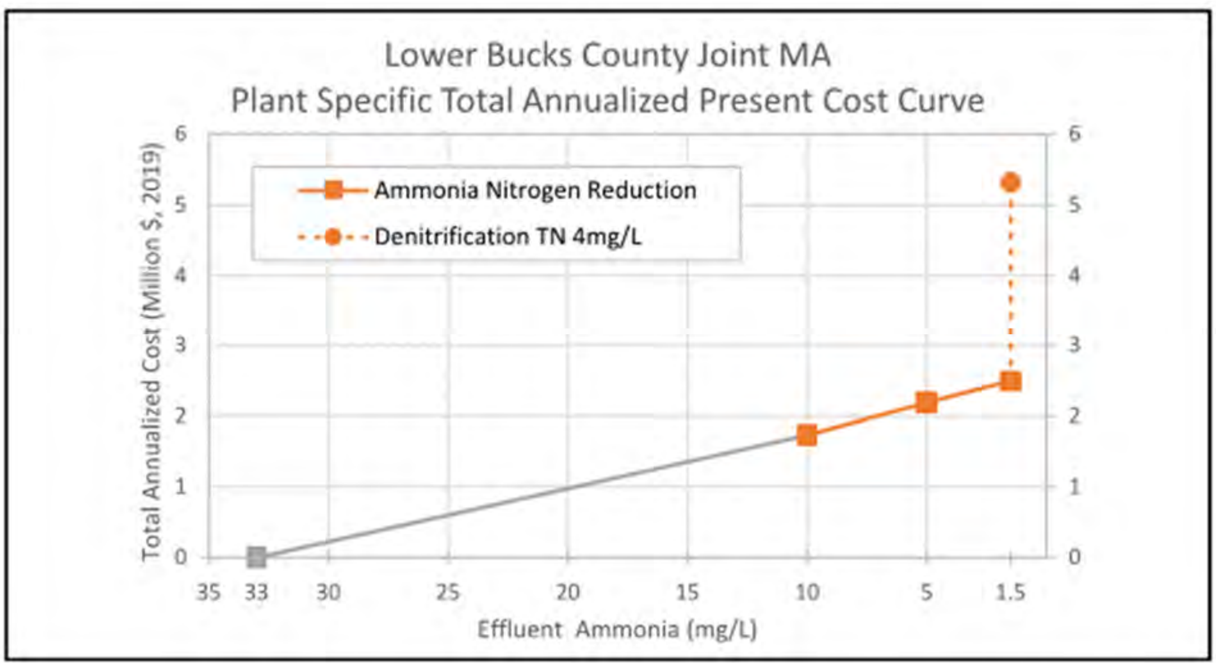


Figure 6-14: LBCJMA Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the LBCJMA plant specific cost summary table are listed below:

PERMITTED CAPACITY:	11.20 MGD
2018 ANNUAL AVG FLOW:	8.42 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	11.20 MGD

- The maximum monthly average flow of 11.2 mgd, which equaled the permitted capacity, was used to size the improvements.
- A maximum monthly summer average effluent ammonia concentration of 33.00 mg/L, which is higher than the generic conventional activated sludge plant's maximum summer average effluent ammonia concentration.
- Based on preliminary process modeling utilizing Biowin process simulation software, operating the existing activated sludge system aeration tanks at a higher mixed liquor suspended solids (MLSS) concentration of approximately 3,000 mg/L during the summer months will result in full nitrification and a summer monthly average effluent ammonia concentration less than 1.5 mg/L. The improvements required to enable operation at a higher MLSS concentration of approximately 3,000 mg/L are the same as the generic conventional activated sludge plant improvements summarized in Table 4-1 for an effluent ammonia level of 10 mg/L, i.e., additional final clarifiers, higher capacity process air system (blowers and fine bubble diffusers), increase in return activated sludge pumping capacity and supplemental alkalinity feed system (magnesium hydroxide).
- To achieve an effluent TN level of 4 mg/L, a denitrification filter will be added to the system.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- Reduction in productivity factor due to confined work area.

6.5.8 GCUA

The GCUA plant specific costs are summarized in Table 6-11. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-11 as Figures 6-15 and 6-16, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix I along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-11: GCUA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	19	41	61	1	2	3
NH_3-N - 5 mg/L	19	64	84	1	3	4
NH_3-N - 1.5 mg/L	19	80	99	1	4	5
TN - 4 mg/L	67	132	199	4	6	11

Figure 6-15: GCUA Plant Specific Total Present Cost Curve

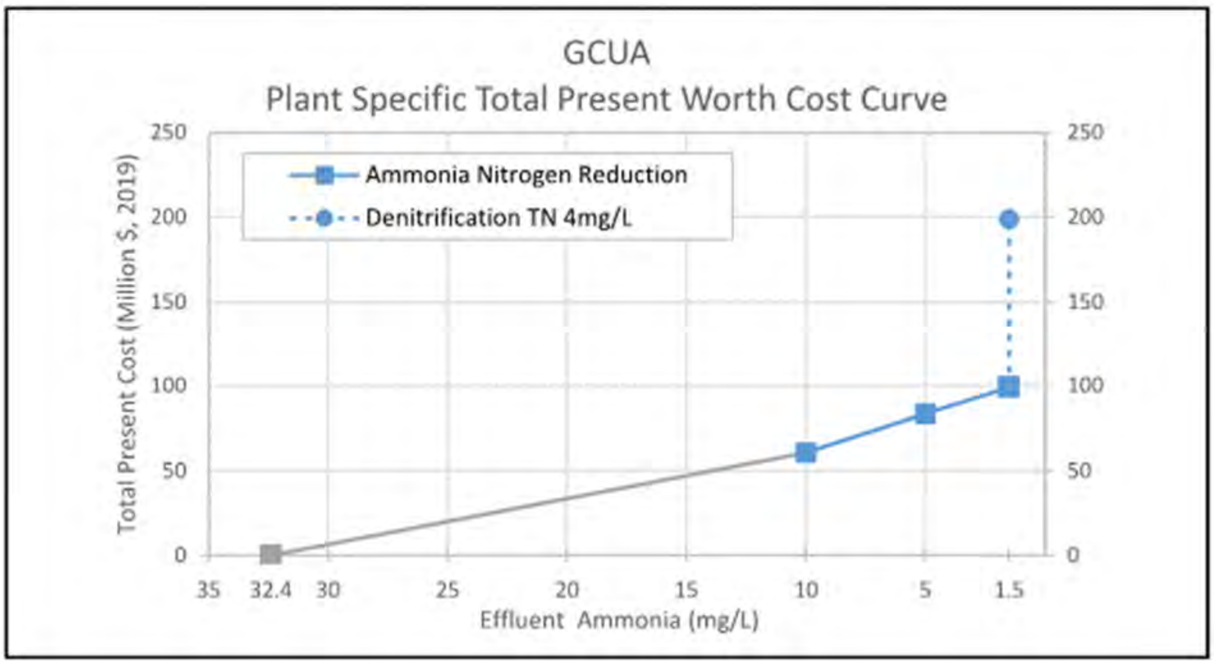
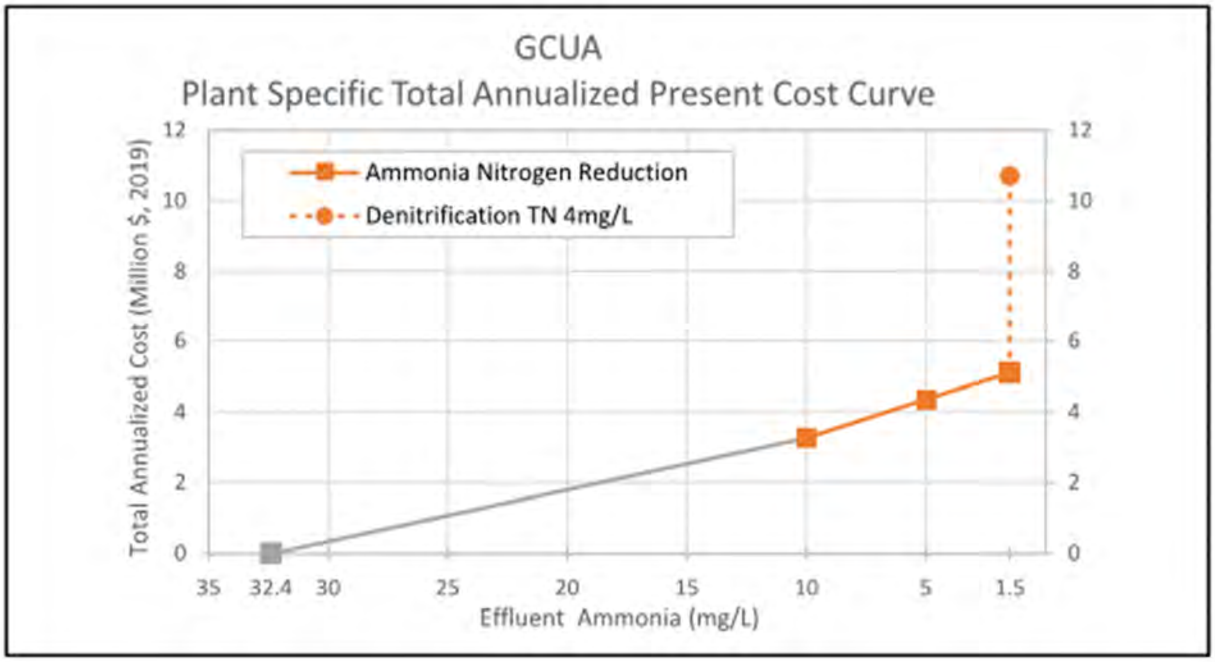


Figure 6-16: GCUA Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the GCUA plant specific cost summary table are listed below:

PERMITTED CAPACITY:	27.00 MGD
2018 ANNUAL AVG FLOW:	20.43 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	25.10 MGD

- Because the permitted capacity is only nominally greater than the current maximum monthly average flow, the permitted flow (27 mgd) was used to size the improvements.
- A maximum monthly summer average effluent ammonia concentration of 32.40 mg/L which is higher in concentration than the generic conventional activated sludge plant's maximum monthly summer average effluent concentration.
- Based on preliminary process modeling utilizing Biowin process simulation software, operating the existing activated sludge system aeration tanks at a higher MLSS concentration of approximately 3,000 mg/L during the summer months will result in full nitrification and a summer monthly average effluent ammonia concentration less than 1.5 mg/L. The improvements required to enable operation at a higher MLSS concentration of

approximately 3,000 mg/L are the same as the generic conventional activated sludge plant improvements summarized in Table 4-1 for an effluent ammonia level of 10 mg/L, i.e. additional final clarifiers, higher capacity process air system (blowers and fine bubble diffusers), increase in return activated sludge pumping capacity and supplemental alkalinity feed system (magnesium hydroxide)

- To achieve an effluent TN level of 4 mg/L, a denitrification filter will be added to the system.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- Reduction in productivity factor due to confined work area.

6.5.9 DELCORA

The DELCORA plant specific costs are summarized in Table 6-12. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-12 as Figures 6-17 and 6-18, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix J along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-12: DELCORA Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	31	7	39	2	0.4	2
NH_3-N - 5 mg/L	89	36	125	6	2	8
NH_3-N - 1.5 mg/L	99	67	166	6	3	10
TN - 4 mg/L	189	142	331	12	7	19

Figure 6-17: DELCORA Plant Specific Total Present Cost Curve

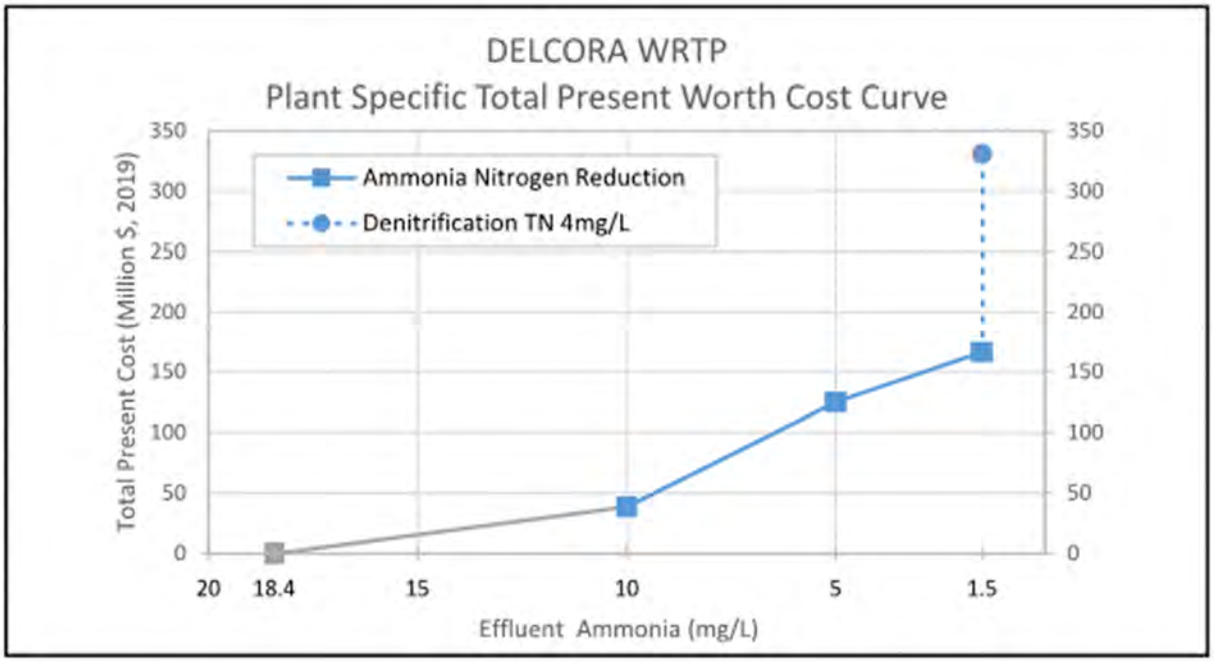
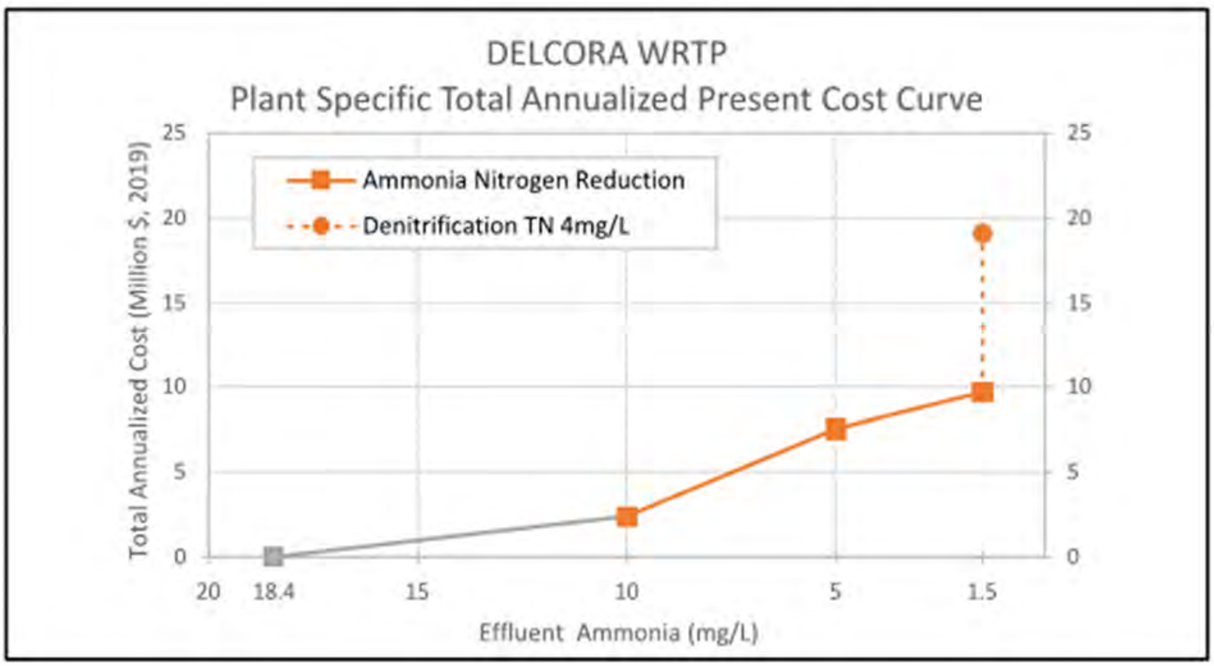


Figure 6-18: DELCORA Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the DELCORA plant specific cost summary table are listed below:

PERMITTED CAPACITY:	50.00 MGD
2018 ANNUAL AVG FLOW:	38.03 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	47.96 MGD

- Because the permitted capacity is only nominally greater than the current maximum monthly average flow, the permitted flow (50 mgd) was used to size the improvements.
- A maximum monthly summer average effluent ammonia concentration of 18.43 mg/L which is approximately the same strength as the generic conventional activated sludge plant's maximum monthly summer average effluent ammonia concentration. As a result, and because the DELCORA WRTP is also currently operating at a MLSS concentration of approximately 3,000 mg/L consistent with the MLSS concentration of the generic conventional activated sludge plant, the improvements for the DELCORA plant to achieve each effluent level will be the same as listed in Table 1 for the generic conventional activated sludge plant, i.e., additional final clarifiers, increased process air capacity and RAS pumping improvements for the 10 mg/L effluent ammonia level and IFAS for the 5 mg/L and 1.5 mg/l. effluent levels.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations are required for all new structures.
- Sheeting is required for all structure excavation.
- Reduction in productivity factor due to confined work area.

6.5.10 PWD SEWPCP

The PWD SEWPCP plant specific costs are summarized in Table 6-13. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-13 as Figures 6-19 and 6-20, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix K along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-13: PWD SEWPCP Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	66	8	73	4	0.4	5
NH_3-N - 5 mg/L	66	19	85	4	1	5
NH_3-N - 1.5 mg/L	209	28	237	14	1	15
TN - 4 mg/L	406	111	517	26	5	32

Figure 6-19: PWD SEWPCP Plant Specific Total Present Cost Curve

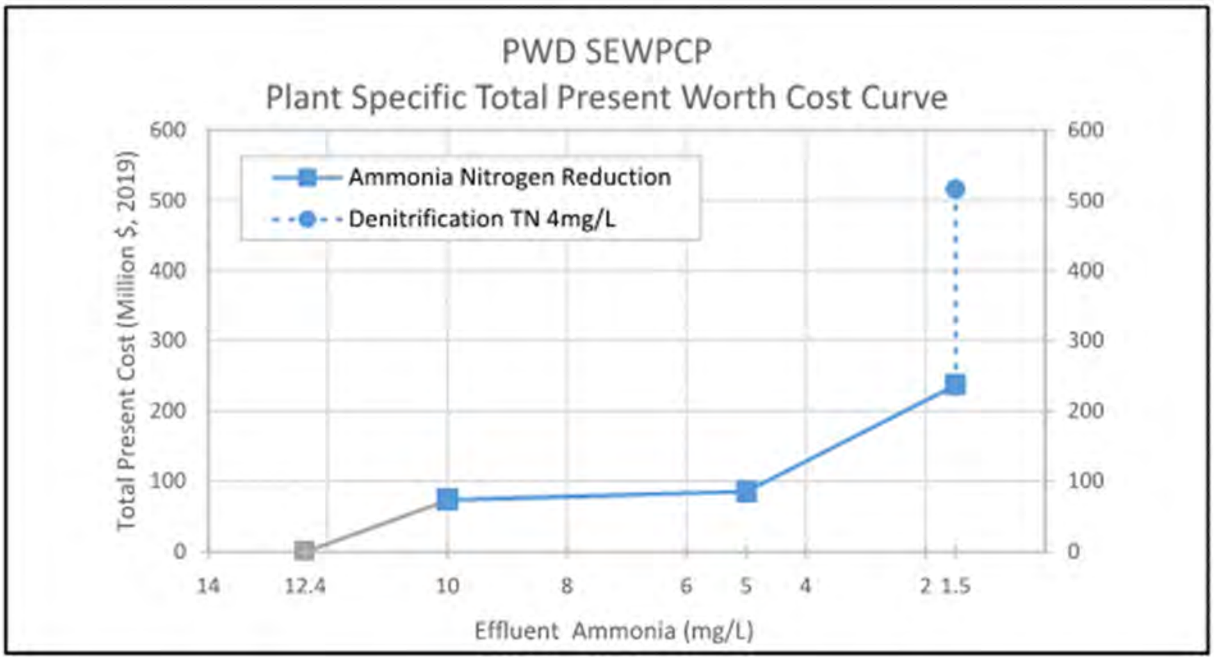
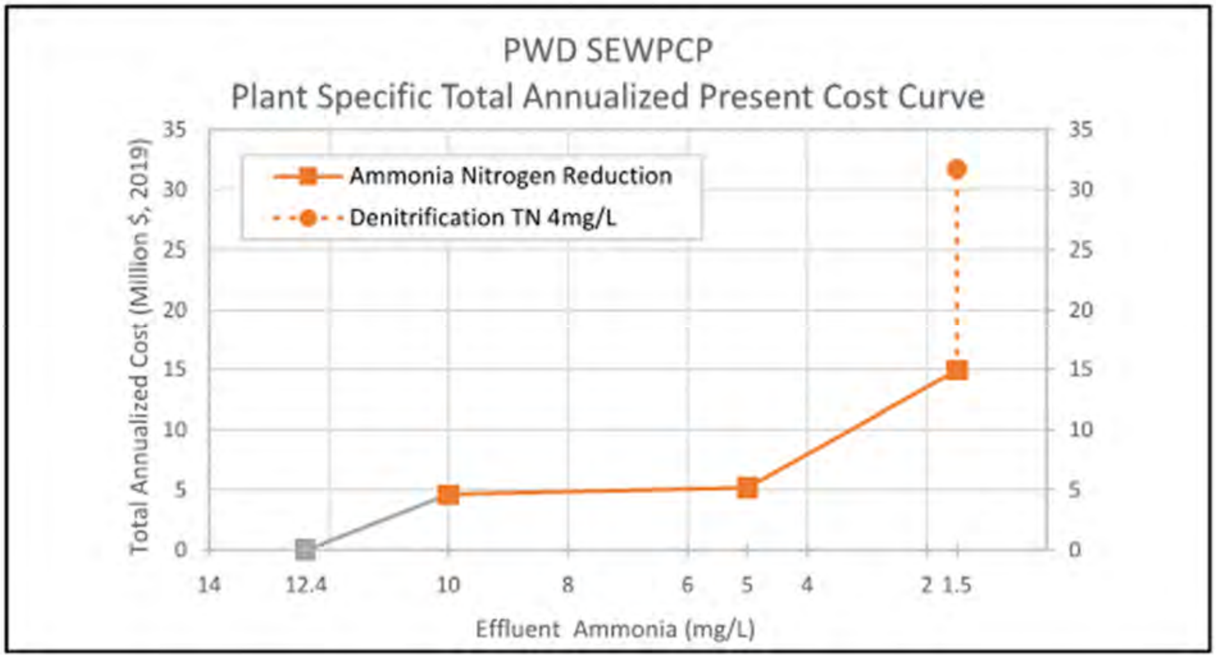


Figure 6-20: PWD SEWPCP Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the PWD SEWPCP plant specific cost summary table are listed below:

PERMITTED CAPACITY:	110.00 MGD
2018 ANNUAL AVG FLOW:	88.58 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	103.00 MGD

- o Because the permitted capacity is only nominally greater than the current maximum monthly average flow, the permitted flow (110 mgd) was used to size the improvements.
- o A maximum monthly summer average effluent ammonia concentration of 12.38 mg/L; which is less than the generic conventional activated sludge systems maximum monthly summer average effluent ammonia concentration.
- o Based on preliminary process modeling utilizing Biowin process simulation software, operating the existing activated sludge system aeration tanks at a higher MLSS concentration of approximately 3,000 mg/L during the summer months will result in partial nitrification and a summer monthly average effluent ammonia concentration of approximately 3 mg/L, which will achieve both the 10 mg/L and 5 mg/L effluent levels for ammonia, but will not achieve the 1.5 mg/L level.
- o The improvements required to enable operation at a higher MLSS concentration to achieve the 10 mg/L and 5 mg/L effluent levels are the same as the generic conventional

activated sludge plant improvements summarized in Table 1 for an effluent ammonia level of 10 mg/L, i.e. additional final clarifiers, higher capacity process air system (blowers and fine bubble diffusers), increase in return activated sludge pumping capacity and supplemental alkalinity feed system (magnesium hydroxide).

- The improvements to achieve the 1.5 mg/L effluent level will be the same as presented in Table 4-1 for generic conventional activated sludge plant to achieve a 1.5 mg/L effluent level, i.e. FAS with the volume of IFAS media required to reduce the summer effluent ammonia level to 1.5 mg/L.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for major structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.
- Due to concerns raised related to forward flow velocity and available head to accommodate the screens that must be added to retain floating media IFAS systems, a fixed media IFAS system is assumed.

6.5.11 WILMINGTON

The Wilmington plant specific costs are summarized in Table 6-14. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-14 as Figures 6-21 and 6-22, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix L along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-14: Wilmington Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	79	20	99	5	1	6
NH_3-N - 5 mg/L	233	106	340	15	5	20
NH_3-N - 1.5 mg/L	261	183	445	17	9	26
TN - 4 mg/L	498	334	832	32	16	49

Figure 6-21: Wilmington Plant Specific Total Present Cost Curve

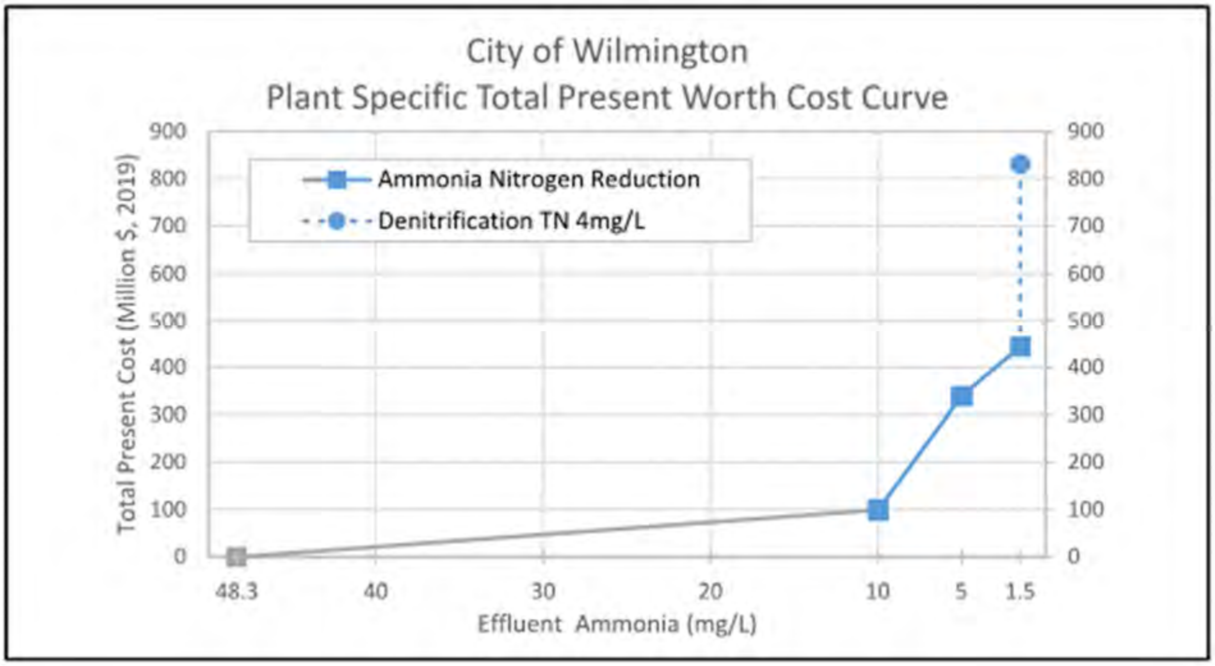
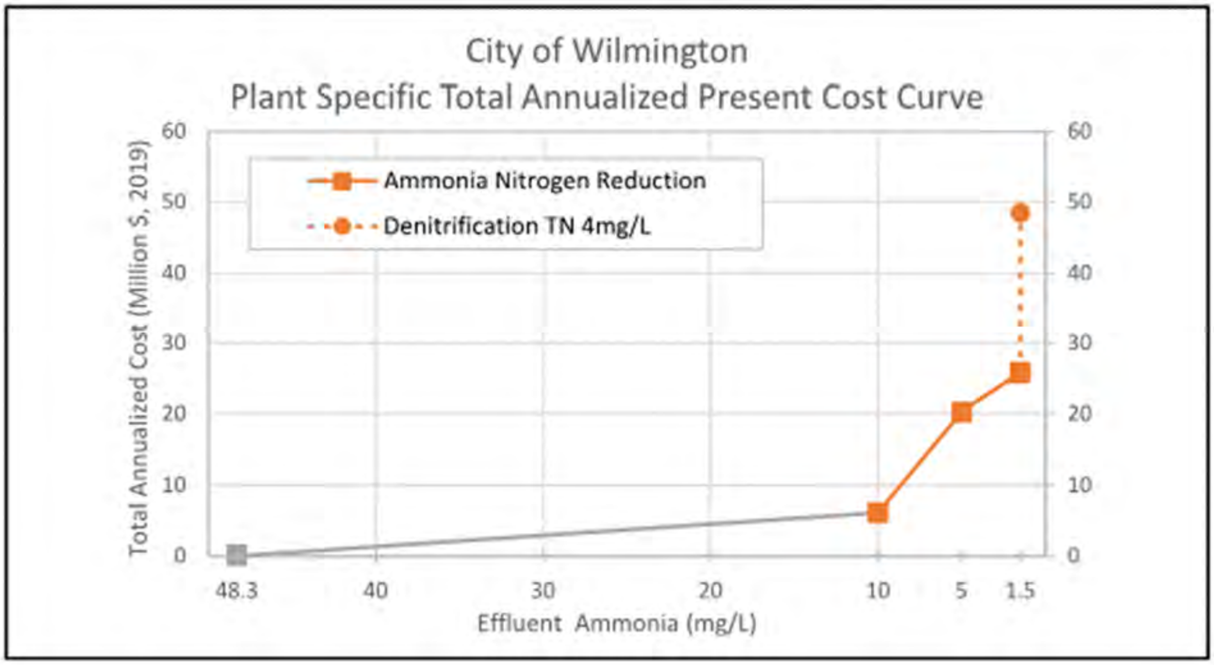


Figure 6-22: Wilmington Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the Wilmington plant specific cost summary table are listed below:

PERMITTED CAPACITY:	134.00 MGD
2018 ANNUAL AVG FLOW:	76.43 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	97.67 MGD

- The permitted flow of 134 mgd was conservatively used to size the improvements.
- A maximum monthly summer average effluent ammonia concentration of 48.30 mg/L; which is significantly greater than the generic conventional activated sludge plant's maximum monthly summer average effluent ammonia concentration.
- Based on preliminary process modeling utilizing Biowin process simulation software, operating the existing activated sludge system aeration tanks at a higher MLSS concentration of approximately 3,000 mg/L during the summer months will result in partial nitrification and a summer monthly average effluent ammonia concentration of

approximately 9 mg/L, which will achieve both the 10 mg/L effluent level for ammonia, but will not achieve the 5 mg/L or 1.5 mg/L level.

- o The improvements required to enable operation at a higher MLSS concentration to achieve the 10 mg/L effluent levels are the same as the generic conventional activated sludge plant improvements summarized in Table 4-1 for an effluent ammonia level of 10 mg/L, i.e. additional final clarifiers, higher capacity process air system (blowers and fine bubble diffusers), increase in return activated sludge pumping capacity and supplemental alkalinity feed system (magnesium hydroxide).
- o The improvements to achieve the 5 mg/L effluent level for ammonia will be the same as presented in Table 4-1 for generic conventional activated sludge plant to achieve a 5 mg/L effluent level, i.e. FAS with the volume of IFAS media required to reduce the summer effluent ammonia level to 5 mg/L.
- o The improvements to achieve the 1.5 mg/L effluent level will be the same as presented in Table 4-1 for generic conventional activated sludge plant to achieve a 1.5 mg/L effluent level, i.e. FAS with the volume of IFAS media required to reduce the summer effluent ammonia level to 1.5 mg/L.
- o Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for new structures (assuming well point dewatering).
- o Pile supported foundations will be are required for all new structures.
- o Sheeting is will be required for all structure excavation.
- o Reduction in productivity factor due to confined work area.

6.5.12 PWD NEWPCP

The PWD NEWPCP plant specific costs are summarized in Table 6-15. The corresponding cost curves, based on total present costs and total annualized costs follow Table 6-15 as Figures 6-23 and 6-24, respectively. Breakdowns of capital and O&M cost for each effluent level are presented in Appendix M along with two (2) conceptual aerial site plans, the first depicting the size and conceptual location of major new structures to achieve a 1.5 mg/L effluent NH_3-N concentration and the second depicting the size and location of major new structures to achieve the 4 mg/L effluent TN concentration.

Table 6-15: PWD NEWPCP Plant Specific Cost Estimates

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	0	0	0	0	0	0
NH_3-N - 5 mg/L	128	39	166	8	2	10
NH_3-N - 1.5 mg/L	386	61	447	25	3	28
TN - 4 mg/L	731	259	990	48	13	60

Figure 6-23: NEWPCP Plant Specific Total Present Cost Curve

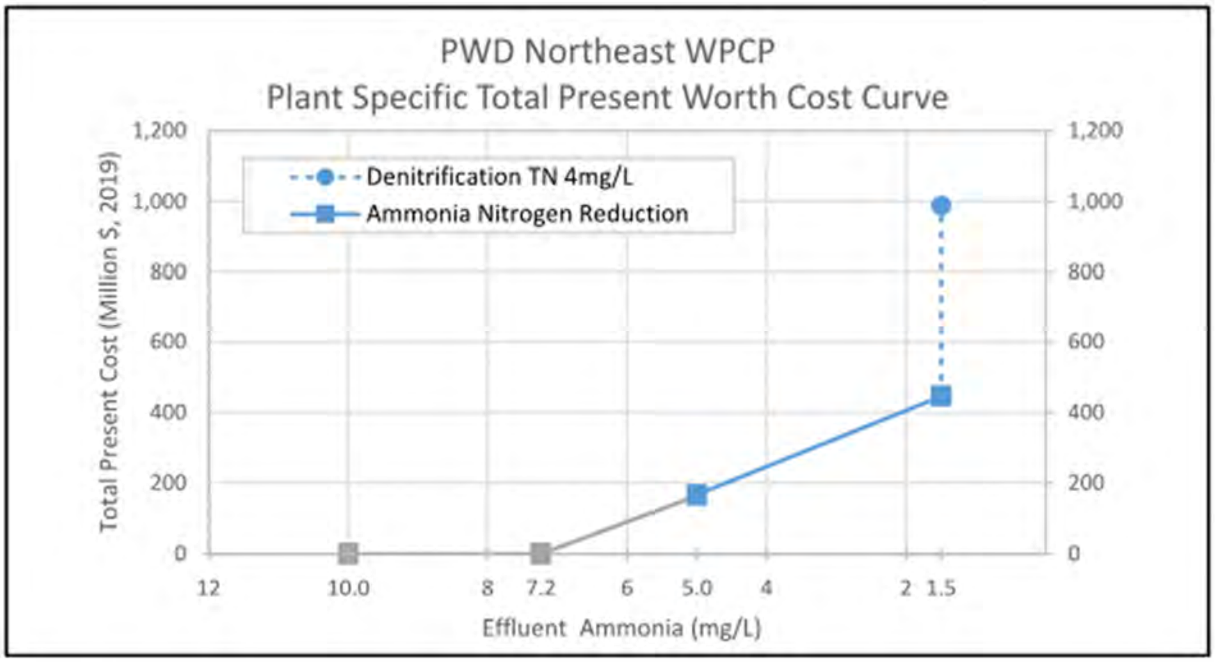
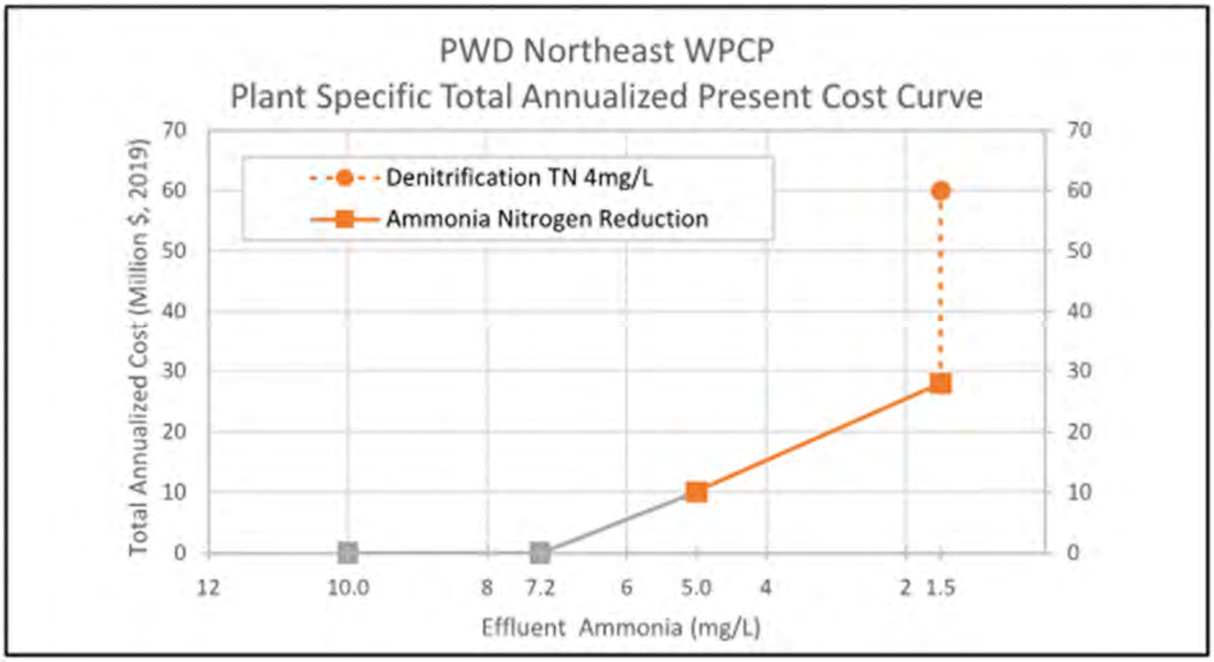


Figure 6-24: NEWPCP Plant Specific Total Annual Cost Curve



The site-specific information, issues and factors that served as the basis for the plant specific costs presented in the PWD NEWPCP plant specific cost summary table are listed below:

PERMITTED CAPACITY:	210.00 MGD
2018 ANNUAL AVG FLOW:	200.33 MGD
2016-2018 MAXIMUM MONTHLY FLOW:	235.00 MGD

- The maximum monthly flow of 235 mgd was used to size the improvements.
- A maximum monthly summer average ammonia concentration of 7.24 mg/L; which is below the 10 mg/L effluent level. Therefore, improvements are not required to achieve the 10 mg/L effluent level.
- Based on preliminary process modeling utilizing Biowin process simulation software, operating the existing activated sludge system aeration tanks at a higher average MLSS concentration of approximately 3,000 mg/L during the summer months will increase the extent of partial nitrification resulting in a summer monthly average effluent ammonia concentration of approximately 4 mg/L. which will achieve 5 mg/L effluent level for ammonia, but will not achieve the 1.5 mg/L level.

- The improvements required to enable operation at a higher MLSS concentration to achieve the 5 mg/L effluent level are the same as the generic conventional activated sludge plant improvements summarized in Table 4-1 for an effluent ammonia level of 10 mg/L, i.e. additional final clarifiers, higher capacity process air system (blowers and fine bubble diffusers), increase in return activated sludge pumping capacity and supplemental alkalinity feed system (magnesium hydroxide).
- The improvements to achieve the 1.5 mg/L effluent level will be the same as presented in Table 4-1 for generic conventional activated sludge plant to achieve a 1.5 mg/L effluent level, i.e. FAS with the volume of IFAS media required to reduce the summer effluent ammonia level to 1.5 mg/L.
- Groundwater will be encountered at a depth of approximately 10 ft. with dewatering required for new structures (assuming well point dewatering).
- Pile supported foundations will be required for all new structures.
- Sheeting will be required for all structure excavation.
- No reduction in productivity factor due to confined work area.
- Due to concerns raised related to forward flow velocity and available head to accommodate the screens that must be added to retain floating media IFAS systems, a fixed media IFAS system is assumed.

6.6 OVERALL SUMMARY OF PLANT SPECIFIC COSTS

The overall summary of plant specific costs is presented in Table 6-16. The costs presented in this table are the summation of the plant specific costs for the twelve (12) individual plants and thus represents the total program costs for achieving the three (3) effluent levels for NH_3-N and the one (1) effluent level for TN utilizing the selected treatment technologies. The corresponding cost curves, based on total present costs and total annualized costs are presented as Figures 6-25 and 6-26, respectively.

Table 6-16: Overall Summary of Plant Specific Costs

Effluent Level	Present Cost (Million $, 2019)			Annualized Present Cost (Million $/year, 2019)		
Scenario	Capital	O&M Present Worth	Total Present Worth Cost	Debt Service	Annual O&M	Total
NH_3-N - 10 mg/L	568	531	1,099	37	26	63
NH_3-N - 5 mg/L	1,025	869	1,894	67	42	109
NH_3-N - 1.5 mg/L	1,561	1,143	2,704	102	55	157
TN - 4 mg/L	3,243	2,223	5,466	211	107	318

Figure 6-25: Overall Summary of Plant Specific Total Present Cost Curve

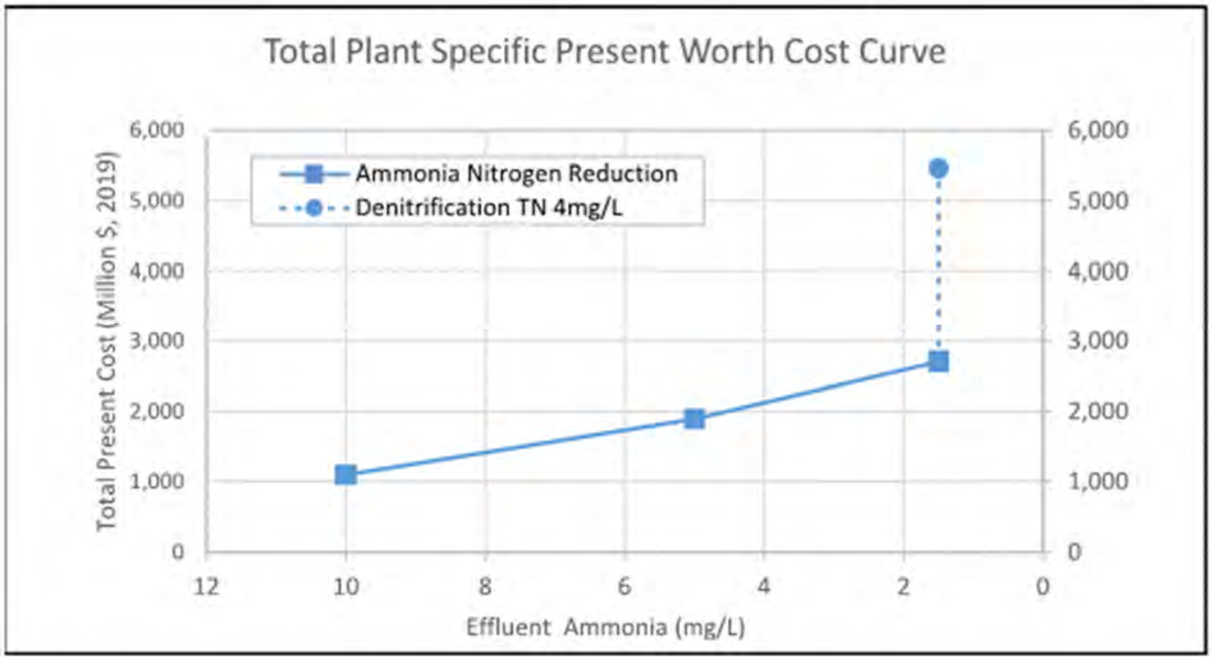
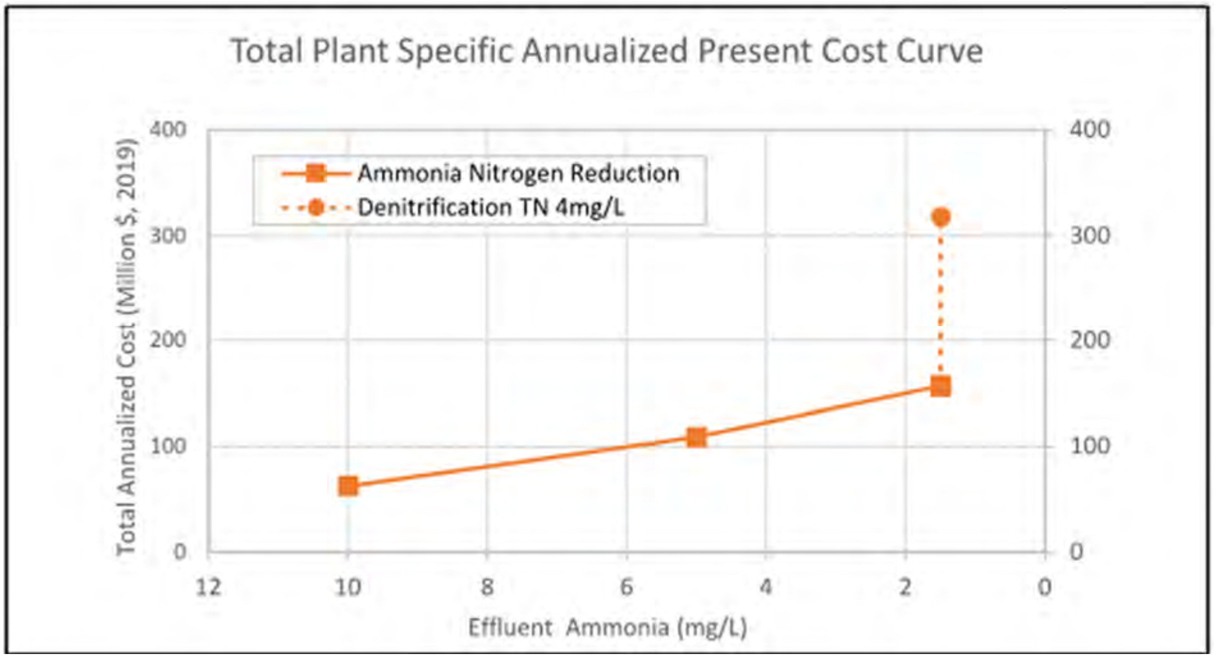


Figure 26: Overall Summary of Plant Specific Total Annual Cost Curve



7.0 BOD REDUCTION RESULTING FROM NITROGEN REMOVAL

As previously described, the improvements to implement NH_3-N removal will also result in BOD reduction, because to remove ammonia, an increase in biomass inventory is required, and the increase in biomass inventory will reduce the soluble fraction of BOD. In addition, processes that involve filtering, such as BAFs and denitrification filters will remove TSS which will reduce the particulate fraction of BOD.

The following assumptions have been made to estimate BOD reduction in the twelve (12) individual plants under each upgrade scenario:

1. For plants upgraded with BAF technology, the effluent BOD from the BAF is 3 mg/L and the portion of plant flow that is not directed to the BAF will not experience a BOD reduction.
2. For plants that are not upgraded with BAF technology and therefore do not include a filtering process for ammonia removal:
    a. Improvements implemented to reduce the effluent NH_3-N concentration to 10 mg/L will result in a 1 mg/L BOD reduction (due to a reduction in soluble BOD) relative to the current average effluent BOD concentration.

   b. Improvements implemented to reduce the effluent NH_3-N from 10 mg/L to 5 mg/L will result in a 1 mg/L BOD reduction.
   c. Improvements implemented to reduce the effluent NH_3-N from 5 mg/L to 1.5 mg/L will result in a 1 mg/L BOD reduction.
3. The effluent BOD from a denitrification filter is 3 mg/L.

Table 7-1 below presents the anticipated aggregate BOD reduction for the twelve (12) plants for each upgrade scenario. Table 2 on the following page presents the anticipated BOD reduction in each of the twelve plants for each effluent level

Table 7-1: Overall Summary of Anticipated BOD Reduction

EFFLUENT SCENARIO	BOD L0AD REDUCTION (lbs/day)
NH3-N - 10 mg/l	6,040
NH3-N - 5 mg/l	12,802
NH3-N - 1.5 mg/l	19,324
NH3-N - 1.5 mg/l , TN - 4 mg/l	23,841

Table 7-2: Plant Specific Summary of Anticipated BOD Reduction

	Conventional Activated Sludge						Pure Oxygen			Fixed Film		
	PWD NEWPCP[1]	City of Wilmington[1,4]	DELCORA WRTP[1]	GCUA[1]	Lower Bucks County Joint MA[1]	PWD SEWPCP[2]	Morrisville Borough MA[1]	PWD SWWPCP[1]	CCMUA Delaware WPCP[1]	Trenton Sewer Utility[2]	Hamilton Twp.[2]	Willingboro MUA[2]
Design Flow (MGD)	235	134	50	27	11.2	110	8.7	212	80	14.85	12.74	5.22
Average Annual Effluent BOD 2016-2018 (mg/l)	5.19	5.96	8.53	7.12	5.40	9.19	11.74	3.42	5.14	17.42	23.13	11.50
Portion of Flow Sent to BAF (if applicable)												
Nh3-N - 10 mg/l	N/A	N/A	N/A	N/A	N/A	0.00	4.91	136.98	54.14	0	8.76	0
Nh3-N - 5 mg/l	N/A	N/A	N/A	N/A	N/A	0.00	7.14	181.11	69.35	8.74	11.10	0
Nh3-N - 1.5 mg/l	N/A	N/A	N/A	N/A	N/A	0.00	8.70	212.00	80.00	14.85	12.74	5.22
Nh3-N - 1.5 mg/l , TN - 4 mg/l	N/A	N/A	N/A	N/A	N/A	0.00	8.70	212.00	80.00	14.85	12.74	5.22
BOD after Improvements (mg/l)												
Nh3-N - 10 mg/l	5.19	4.96	7.53	6.12	4.40	8.19	6.81	3.15	3.69	17.42	9.29	11.50
Nh3-N - 5 mg/l	4.19	3.96	6.53	5.12	3.40	7.19	4.57	3.06	3.28	8.94	5.59	11.50
Nh3-N - 1.5 mg/l	3.19	2.96	5.53	4.12	2.40	6.19	3.00	3.00	3.00	3.00	3.00	3.00
Nh3-N - 1.5 mg/l , TN - 4 mg/l	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
BOD Reduction (Effluent BOD - Improvements BOD, mg/l)												
Nh3-N - 10 mg/l	0.00	1.00	1.00	1.00	1.00	1.00	4.93	0.27	1.45	0.00	13.84	0.00
Nh3-N - 5 mg/l	1.00	2.00	2.00	2.00	2.00	2.00	7.17	0.36	1.85	8.48	17.54	0.00
Nh3-N - 1.5 mg/l	2.00	3.00	3.00	3.00	3.00	3.00	8.74	0.42	2.14	14.42	20.13	8.50
Nh3-N - 1.5 mg/l , TN - 4 mg/l	2.19	2.96	5.53	4.12	2.40	6.19	8.74	0.42	2.14	14.42	20.13	8.50
BOD Load Reduction (lbs/day)												
Nh3-N - 10 mg/l	0	1,118	417	225	93	917	358	476	966	0	1,470	0
Nh3-N - 5 mg/l	1,960	2,235	834	450	187	1,835	520	629	1,237	1,051	1,863	0
Nh3-N - 1.5 mg/l	3,920	3,353	1,251	676	280	2,752	634	737	1,427	1,786	2,139	370
Nh3-N - 1.5 mg/l , TN - 4 mg/l	4,301	3,306	2,307	927	224	5,683	634	737	1,427	1,786	2,139	370

The BAF and denitrification processes were assumed to produce an effluent BOD concentration of 3 mg/l

For non-BAF processes, the effluent BOD concentration was assumed to be reduced by 1 mg/l for each ammonia effluent level reduction achieved (10, 5, and 1.5 mg/l)

8.0 SUMMARY OF KEY ASSUMPTIONS

The key assumptions previously presented in this report are summarized below:

1. Plant upgrade improvements to achieve the three (3) effluent levels for NH_3-N and one (1) level of TN are sized to achieve the effluent levels on a monthly average basis during each month of the summer season defined as May 1 through October 31, rather than each month of the year.
2. Daily maximum values are not envisioned by DRBC and are not considered in cost estimate development. Therefore, to the extent practicable considering the nature of the NH_3-N and TN removal improvements, a portion of the peak wet weather flow can be diverted around the NH_3-N and TN removal process, provided the effluent levels are attained each month of the summer season. As a result, the capital cost estimates were based on diverting peak wet weather flow in excess of the maximum monthly average flow around the biologically active filters (BAFs) and denitrification filters (DN).
3. The technologies selected for cost estimate development are based on technologies with long-term records of performance to ensure a reasonable degree of confidence in plant upgrade performance and the ability to appropriately estimate construction and operating costs. Therefore, emerging technologies were not considered.
4. The objective is not to identify the most cost effective upgrade alternative for each individual plant, but rather to establish appropriately conservative upgrade costs based on proven technologies applied uniformly to each category of plant type for cost curve development. If effluent limits for NH_3-N or TN are ultimately established in the future, each plant should conduct an evaluation of alternatives to determine if a lower cost approach will achieve the effluent limit based on information and proven technologies available at that time.
5. Capital cost estimates are consistent with the American Association of Cost Estimating (AACE) Level 4 estimate, which is the appropriate level for the study phase of a project, i.e., at the pre-design phase of a project. Therefore, consistent with the level of accuracy defined by AACE for a level 4 cost estimate, the level of accuracy is -15% to -30% on the low side to +20% to +50% on the high side. The capital cost estimates are referred to

within the report as budgetary capital costs to reflect the pre-design level of accuracy during the study phase of a project.

6. Capital cost estimates include a 30% construction contingency and engineering, legal and administrative costs at 20% of construction costs.
7. Capital cost estimates are in 2019 dollars corresponding to the Engineering News Record (ENR) Twenty City Cost Index of 11311. This index can be used in the future to update the budgetary 2019 costs due to the inflation of construction costs between 2019 and the future date. Operations and maintenance (O&M) cost estimates are also in 2019 dollars.
8. Aging infrastructure improvements are not included in the capital cost estimates.
9. Annual debt service costs are based on amortization of capital costs over a 30 year term at an interest rate of 5%. While low interest loans are currently available at interest rates significantly less than 5%, through programs such as the New Jersey Water Bank and PENNVEST, because there is no guarantee that such programs will be available in the future conventional debt financing at 5% interest was assumed to be appropriately conservative.
10. The conceptual aerial site plans presented in Appendices B through M for each individual plant present a potential location for each major structure together with the approximate physical size of each major new structure. However, the location of each structure has not been optimized with respect to potential subsurface interferences because development of optimized site plans requires a design-level analysis.

Appendix A
Plant Data Summary

		Conventional Activated Sludge						Pure Oxygen			Fixed Film		
		PWD NEWPCP[1]	City of Wilmington[1,6]	DELCORA WRTP[1]	GCUA[1]	Lower Bucks County Joint MA[1]	PWD SEWPCP[2]	Morrisville Borough MA[1]	PWD SWWPCP[1]	CCMUA Delaware WPCP[1]	Trenton Sewer Utility[2]	Hamilton Twp.[2]	Willingboro MUA[2]
Permit Number		PA0026689-001	DE0020320-001	PA0027103-001	NJ0024686-001A	PA0026468-001	PA0026662-001	PA0026701-001	PA0026671-001	NJ0026182-001A	NJ0020923-001A	NJ0026301-001A	NJ0023361-001A
Permitted Flow (MGD)		**210**	**134**	**50**	**27**	**10**	**110**	**8.7**	**200**	**80**	**20**	**16**	**5.22**
Flow (MGD)													
Effluent Annual Average[3]	2018	200.33	76.43	38.03	20.43	8.42	88.58	5.96	183.17	58.66	12.38	9.01	4.10
	2017	152.58	61.85	30.98	16.52	6.44	72.83	4.72	149.67	50.54	10.25	7.35	3.11
	2016	148.75	64.92	30.91	16.71	6.07	75.75	4.30	152.75	52.60	10.07	7.76	3.38
12 Month Max Rolling Avg		200.33	76.43	38.03	20.43	8.42	88.58	5.96	183.17	58.66	12.38	9.01	4.10
Max Month		235.00	97.67	47.96	25.10	11.20	103.00	7.77	212.00	71.50	14.85	12.03	5.22
Max Day		380.00	245.64	80.00	33.91	17.00	221.00	11.11	387.00	114.00	20.87	14.84	8.95
BOD or CBOD (mg/l)													
Effluent Annual Average[3]	2018	5.92	6.42	8.18	7.92	5.43	10.25	7.40	2.75	6.33	17.14	25.00	10.17
	2017	4.92	5.60	9.58	6.17	5.47	9.00	8.33	3.17	5.25	17.29	24.05	11.83
	2016	4.75	5.86	7.83	7.27	5.31	8.33	18.32	4.33	3.83	17.83	20.33	12.50
Max Year(mg/l)		5.92	6.42	9.58	7.92	5.47	10.25	18.32	4.33	6.33	17.83	25.00	12.50
TSS (mg/L)													
Effluent Annual Average[3]	2018	9.83	7.67	12.75	14.17	7.98	7.25	5.57	4.25	11.17	9.12	16.67	13.25
	2017	5.08	6.17	12.50	13.21	7.75	6.00	6.95	4.08	7.33	10.12	15.67	14.67
	2016	5.50	7.35	11.25	13.74	8.08	5.75	20.97	4.50	5.25	8.48	12.75	14.50
Max Year (mg/l)		9.83	7.67	12.75	14.17	8.08	7.25	20.97	4.50	11.17	10.12	16.67	14.67
Ammonia (mg/l)													
Effluent Annual Average[3]	2018	6.37	18.63	5.34	22.44	22.48	8.43	9.46	18.52	20.29	8.26	24.98	2.18
	2017	7.63	22.26	10.86	24.06	26.67	10.10	11.73	21.97	24.57	10.20	25.92	3.38
	2016	6.42	17.36	5.21	28.22	28.83	9.87	14.60	23.50	25.64	10.58	25.25	3.16
Max. Monthly Average		13.90	48.30	21.00	35.40	33.00	12.98	19.37	30.70	30.70	17.30	30.00	8.10
Max. Monthly Summer Avg (May - Oct)		7.24	48.30	18.43	32.40	33.00	12.38	11.69	25.52	27.80	12.30	28.70	4.20
Average Summer (May - Oct)		5.44	19.06	4.83	22.96	25.45	9.48	10.69	20.72	23.84	7.76	25.65	1.53
Average Winter (Nov - April)		8.17	20.62	9.45	26.85	26.35	9.46	13.19	21.93	23.16	11.60	25.11	4.28
Effluent Annual Average[4]	2013	6.43	18.60	2.74	16.62	21.02	7.83	10.32	17.71	21.46	8.10	27.92	5.06
	2012	6.68	14.73	5.83	18.06	22.80	8.97	9.00	20.18	18.75	7.01	28.04	6.98
	2011	5.34	14.77	0.58	18.00	17.87	9.20	7.44	21.40	21.43	4.10	28.57	7.44
Average Summer (May - Oct)		5.82	15.90	4.24	17.68	20.18	8.60	9.69	16.68	19.45	5.55	24.49	5.27
Average Winter (Nov - April)		7.01	17.64	3.47	17.34	22.92	8.42	9.37	21.86	20.81	8.56	30.86	6.86
2018 Avg Ammonia Load (lb/day)[5]		10,641.48	11,872.58	1,693.61	3,822.88	1,578.88	6,229.19	443.40	28,283.70	9,926.90	852.75	1,876.34	74.38
% Ammonia Contribution		13.77%	15.36%	2.19%	4.95%	2.04%	8.06%	0.57%	36.59%	12.84%	1.10%	2.43%	0.10%
% Ammonia Contribution by Plant Type		46.37%						50.01%			3.63%		

2018 Sum of Average Flows (MGD)	705.50
2018 Sum of Ammonia Load (lb/day)	77,296
2018 Average Ammonia Conc (mg/l)	**13.14**

[1]Reported in CBOD
[2]Reported in BOD
[3]Flow, Ammonia, BOD/CBOD, and TSS data for 2016 through 2018 is from DMR data
[4]2011-2013 Ammonia Data from DRBC Study, data set does not necissarily include data for each month of the year
[5]Load calculated from 2018 Effluent Annual Average Flow and Concentration
[6]Effluent Ammonia compiled from additional sampling, not DMR data, 2018 sampling consisted of 4 samples

Appendix B

MMA Plant Specific Cost Estimates

and

Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

Morrisville Borough MA
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Base capital cost[1]:	$	8,700,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 8.70 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 21.00 mg/L		
subtotal	$	24,719,785
Plant-specific base captial cost additions[2]:		
Pile Foundations	$/SF	
Rock Excavation	$	-
Sheeting during Construction	$	161,172
Construction Dewatering	$	39,204
Land Acquisition	$	-
subtotal	$	200,376
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*24,920,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	88,000
Additional chemical costs	$	192,619
Additional energy costs	$	118,537
Additional sludge disposal costs	$	5,321
Additional maintenance costs	$	9,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	413,000
TOTAL PRESENT WORTH O&M COSTS	$	8,557,000
GRAND TOTAL PRESENT WORTH COST	**$**	**33,477,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Morrisville Borough MA
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Base capital cost[1]:	$ 11,310,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 8.70 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 21.00 mg/L	
subtotal	$ 27,383,323
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 748,920
Rock Excavation	$ -
Sheeting during Construction	$ 230,917
Construction Dewatering	$ 56,169
Land Acquisition	$ -
subtotal	$ 1,036,006
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*28,419,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 280,173
Additional energy costs	$ 172,417
Additional sludge disposal costs	$ 7,739
Additional maintenance costs	$ 17,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 565,000
TOTAL PRESENT WORTH O&M COSTS	$ 11,707,000
GRAND TOTAL PRESENT WORTH COST	**$ 40,126,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Morrisville Borough MA
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Base capital cost[1]:	$ 13,920,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 8.70 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 21.00 mg/L	
subtotal	$ 29,247,800
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 929,280
Rock Excavation	$ -
Sheeting during Construction	$ 286,528
Construction Dewatering	$ 69,696
Land Acquisition	$ -
subtotal	$ 1,285,504
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*30,533,304*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 341,461
Additional energy costs	$ 210,133
Additional sludge disposal costs	$ 9,432
Additional maintenance costs	$ 27,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 764,000
TOTAL PRESENT WORTH O&M COSTS	$ 15,830,000
GRAND TOTAL PRESENT WORTH COST	**$ 46,363,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

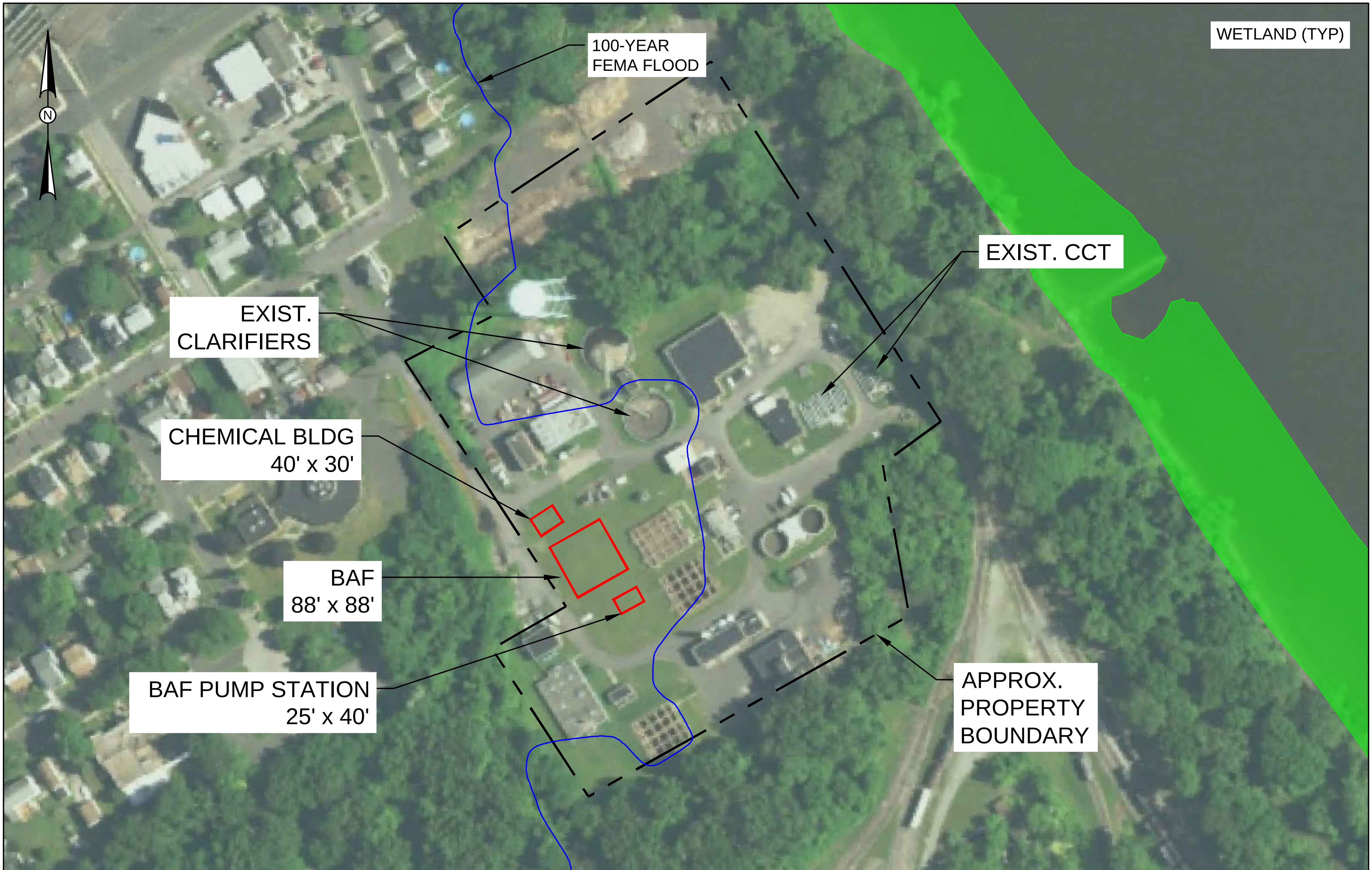
Morrisville Borough MA
Effluent Level: NH3-N = 1.5 mg/L and TN = 4 mg/L

Description	***Amount***
Base capital cost[1]:	$ 34,800,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 8.70 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 21.00 mg/L	
subtotal	$ 52,344,340
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 2,129,280
Rock Excavation	$ -
Sheeting during Construction	$ 656,528
Construction Dewatering	$ 159,696
Land Acquisition	$ -
subtotal	$ 2,945,504
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*55,290,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 643,759
Additional energy costs	$ 375,738
Additional sludge disposal costs	$ 97,036
Additional maintenance costs	$ 65,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,358,000
TOTAL PRESENT WORTH O&M COSTS	$ 28,137,000
GRAND TOTAL PRESENT WORTH COST	**$ 83,427,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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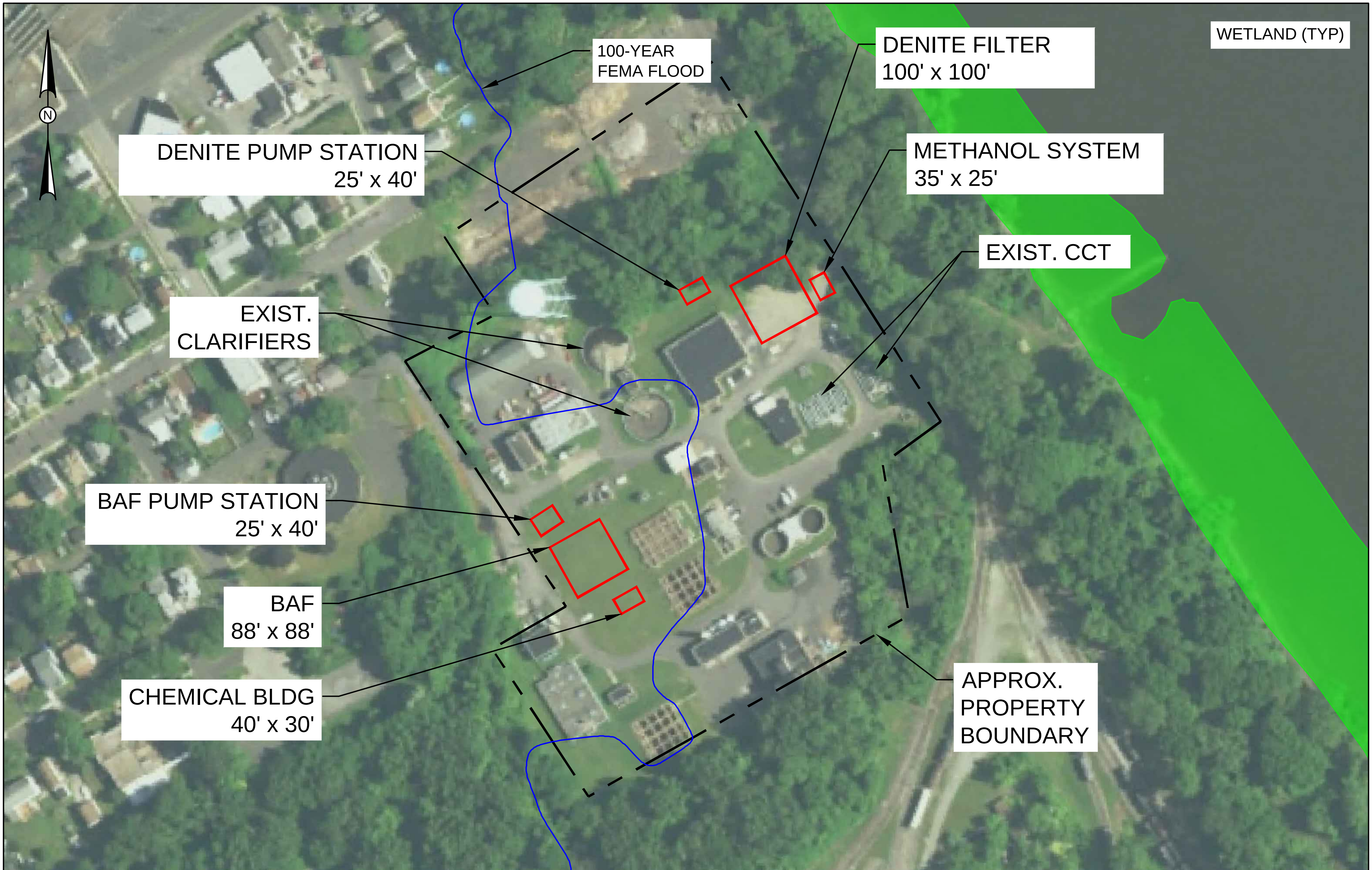
MORRISVILLE BORO MA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
B-1



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MORRISVILLE BORO MA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
B-2

Appendix C

CCMUA Plant Specific Cost Estimates

and

Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

CCMUA (Delaware #1 WPCP)
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	80,000,000
subtotal	$	80,000,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 80.00 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 27.8 mg/L		
subtotal	$	83,508,517
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	3,587,040
Rock Excavation	$	-
Sheeting during Construction	$	1,106,004
Construction Dewatering	$	269,028
Land Acquisition	$	1,120,950
subtotal	$	6,083,022
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	4,031,619
TOTAL PRESENT WORTH CAPITAL COST		*93,623,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	4,751,225
Additional energy costs	$	1,039,983
Additional sludge disposal costs	$	100,498
Additional maintenance costs	$	100,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	6,168,000
TOTAL PRESENT WORTH O&M COSTS	$	127,799,000
GRAND TOTAL PRESENT WORTH COST	**$**	**221,422,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

CCMUA (Delaware #1 WPCP)
Effluent Level: NH3-N = 5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	104,000,000
subtotal	$	104,000,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 80.00 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 27.8 mg/L		
subtotal	$	101,668,213
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	4,588,800
Rock Excavation	$	-
Sheeting during Construction	$	1,414,880
Construction Dewatering	$	344,160
Land Acquisition	$	1,434,000
subtotal	$	7,781,840
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	4,925,252
TOTAL PRESENT WORTH CAPITAL COST		*114,375,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	6,085,839
Additional energy costs	$	1,332,113
Additional sludge disposal costs	$	128,727
Additional maintenance costs	$	169,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	7,892,000
TOTAL PRESENT WORTH O&M COSTS	$	163,519,000
GRAND TOTAL PRESENT WORTH COST	**$**	**277,894,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

CCMUA (Delaware #1 WPCP)
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 128,000,000
subtotal	$ 128,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 80.00 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 27.8 mg/L	
subtotal	$ 114,380,000
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 5,273,640
Rock Excavation	$ -
Sheeting during Construction	$ 1,626,039
Construction Dewatering	$ 395,523
Land Acquisition	$ 1,648,013
subtotal	$ 8,943,215
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 5,549,545
TOTAL PRESENT WORTH CAPITAL COST	*128,873,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 7,020,069
Additional energy costs	$ 1,536,604
Additional sludge disposal costs	$ 148,488
Additional maintenance costs	$ 250,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 9,131,000
TOTAL PRESENT WORTH O&M COSTS	$ 189,191,000
GRAND TOTAL PRESENT WORTH COST	**$ 318,064,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

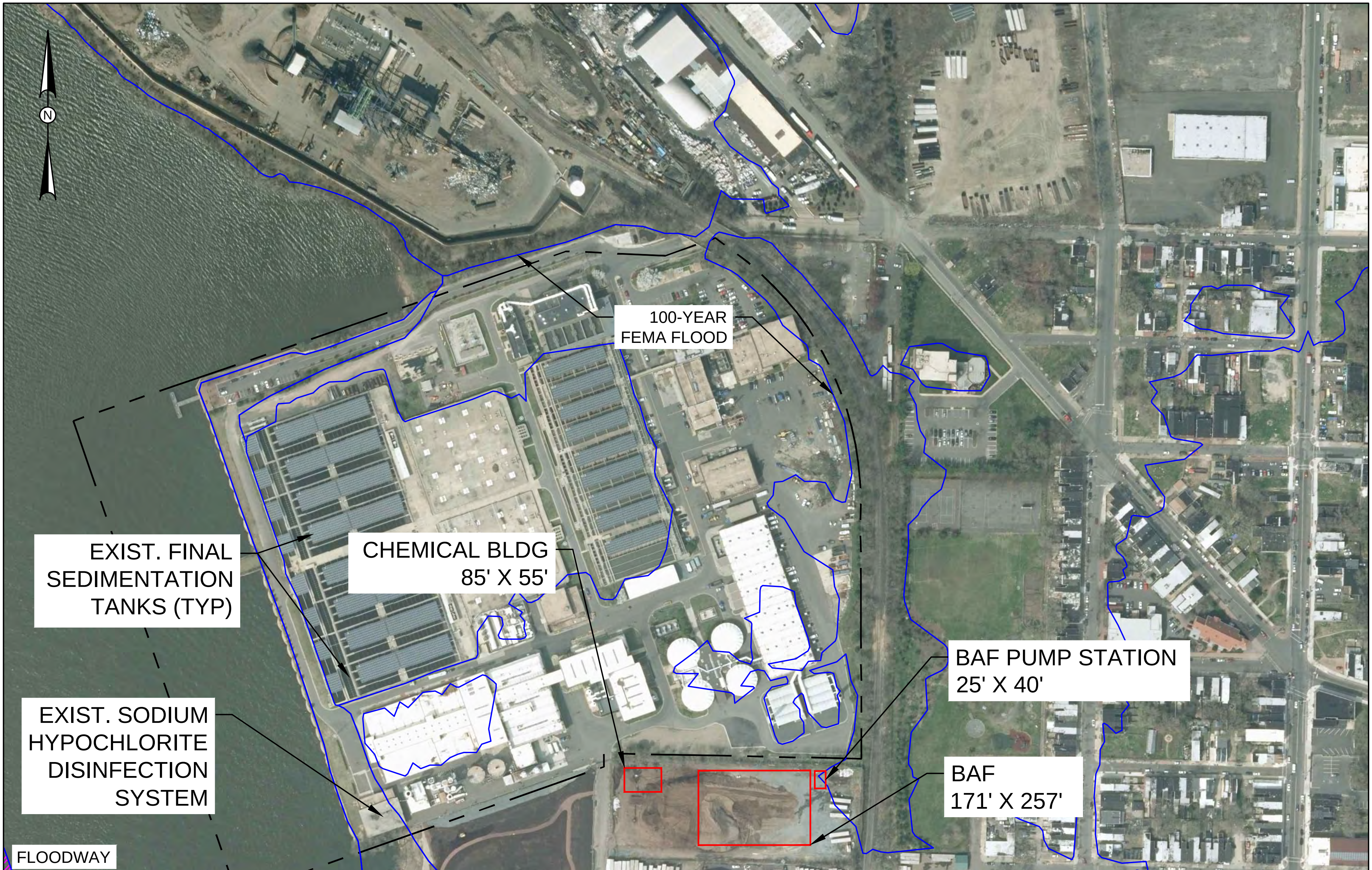
CCMUA (Delaware #1 WPCP)
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 320,000,000
subtotal	$ 320,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 80.00 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 27.8 mg/L	
subtotal	$ 275,612,863
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 12,473,640
Rock Excavation	$ -
Sheeting during Construction	$ 3,846,039
Construction Dewatering	$ 935,523
Land Acquisition	$ 3,898,013
subtotal	$ 21,153,215
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 13,354,473
TOTAL PRESENT WORTH CAPITAL COST	*310,121,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 264,000
Additional chemical costs	$ 10,819,252
Additional energy costs	$ 2,378,516
Additional sludge disposal costs	$ 1,192,222
Additional maintenance costs	$ 599,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 15,253,000
TOTAL PRESENT WORTH O&M COSTS	$ 316,036,000
GRAND TOTAL PRESENT WORTH COST	**$ 626,157,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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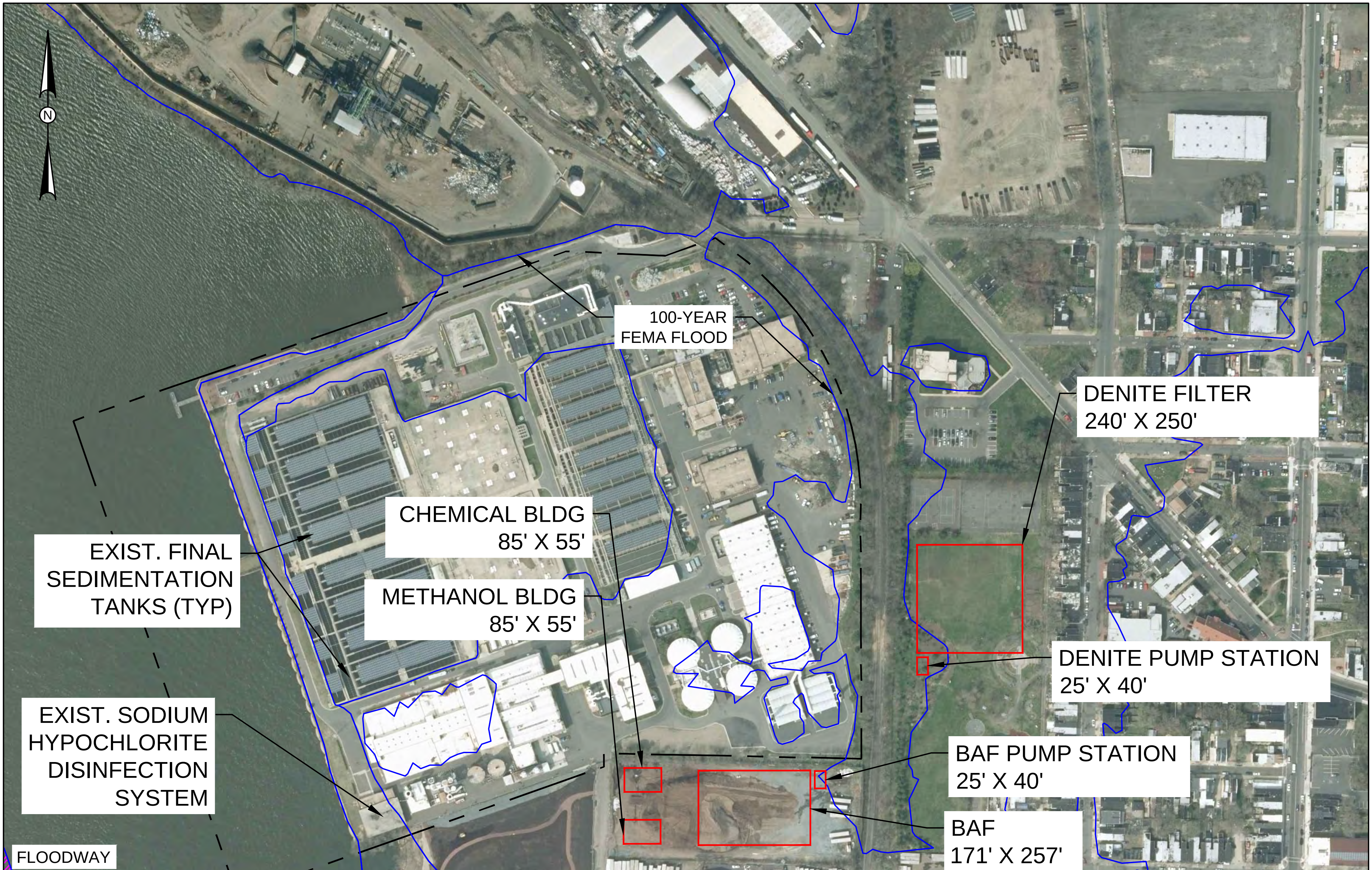
DELAWARE #1 WPCF (CCMUA)
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
C-1

CAD FILE: S:\6736 - DRBC Cost Study\DWG\05 - Delaware 1 Water Pollution Control Facility (Camden).dwg PLOTTED: 6/16/2020 2:14 PM BY: erin dovel



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DELAWARE #1 WPCF (CCMUA)
CONCEPTUAL SITE PLAN
NH_3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
C-2

Appendix D
PWD SWWPCP Plant Specific Cost Estimates
and
Conceptual Site Plans

PWD Southwest WPCP
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	212,000,000
subtotal	$	212,000,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 212 (Maximum Month)		
Max. Monthly Summer Average Ammonia (May-Oct) = 25.5 mg/L		
subtotal	$	182,413,146
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	9,055,920
Rock Excavation	$	-
Sheeting during Construction	$	2,792,242
Construction Dewatering	$	679,194
Land Acquisition	$	14,149,875
subtotal	$	26,677,231
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*209,090,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	352,000
Additional chemical costs	$	9,790,969
Additional energy costs	$	2,631,035
Additional sludge disposal costs	$	182,936
Additional maintenance costs	$	253,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	13,210,000
TOTAL PRESENT WORTH O&M COSTS	$	273,706,000
GRAND TOTAL PRESENT WORTH COST	**$**	**482,796,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

PWD Southwest WPCP
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 275,600,000
subtotal	$ 275,600,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 212 (Maximum Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 25.5 mg/L	
subtotal	$ 235,104,236
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 11,961,720
Rock Excavation	$ -
Sheeting during Construction	$ 3,688,197
Construction Dewatering	$ 897,129
Land Acquisition	$ 18,690,188
subtotal	$ 35,237,234
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*270,341,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 352,000
Additional chemical costs	$ 12,945,276
Additional energy costs	$ 3,478,662
Additional sludge disposal costs	$ 241,872
Additional maintenance costs	$ 441,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 17,459,000
TOTAL PRESENT WORTH O&M COSTS	$ 361,744,000
GRAND TOTAL PRESENT WORTH COST	**$ 632,085,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

PWD Southwest WPCP
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 339,200,000
subtotal	$ 339,200,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 212 (Maximum Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 25.5 mg/L	
subtotal	$ 271,988,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 14,026,320
Rock Excavation	$ -
Sheeting during Construction	$ 4,324,782
Construction Dewatering	$ 1,051,974
Land Acquisition	$ 21,916,125
subtotal	$ 41,319,201
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*313,307,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 440,000
Additional chemical costs	$ 15,153,290
Additional energy costs	$ 4,072,002
Additional sludge disposal costs	$ 283,126
Additional maintenance costs	$ 663,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 20,611,000
TOTAL PRESENT WORTH O&M COSTS	$ 427,052,000
GRAND TOTAL PRESENT WORTH COST	**$ 740,359,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

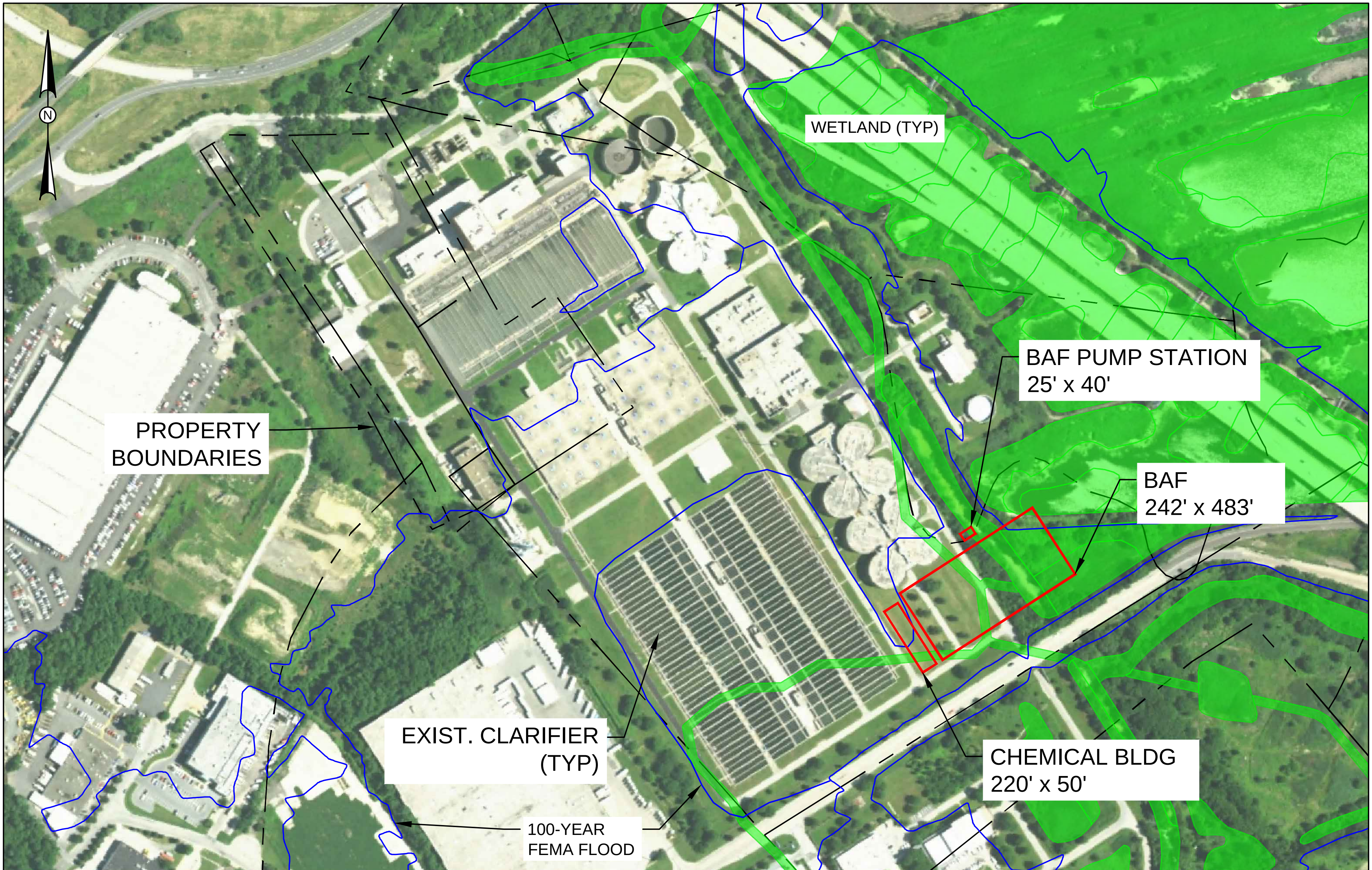
PWD Southwest WPCP
Effluent Level: NH3-N = 1.5 mg/L & TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 848,000,000
subtotal	$ 848,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 212 (Maximum Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 25.5 mg/L	
subtotal	$ 688,957,113
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 33,526,320
Rock Excavation	$ -
Sheeting during Construction	$ 10,337,282
Construction Dewatering	$ 2,514,474
Land Acquisition	$ 52,384,875
subtotal	$ 98,762,951
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*787,720,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 616,000
Additional chemical costs	$ 24,315,332
Additional energy costs	$ 6,303,068
Additional sludge disposal costs	$ 2,837,384
Additional maintenance costs	$ 1,588,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 35,660,000
TOTAL PRESENT WORTH O&M COSTS	$ 738,861,000
GRAND TOTAL PRESENT WORTH COST	**$ 1,526,581,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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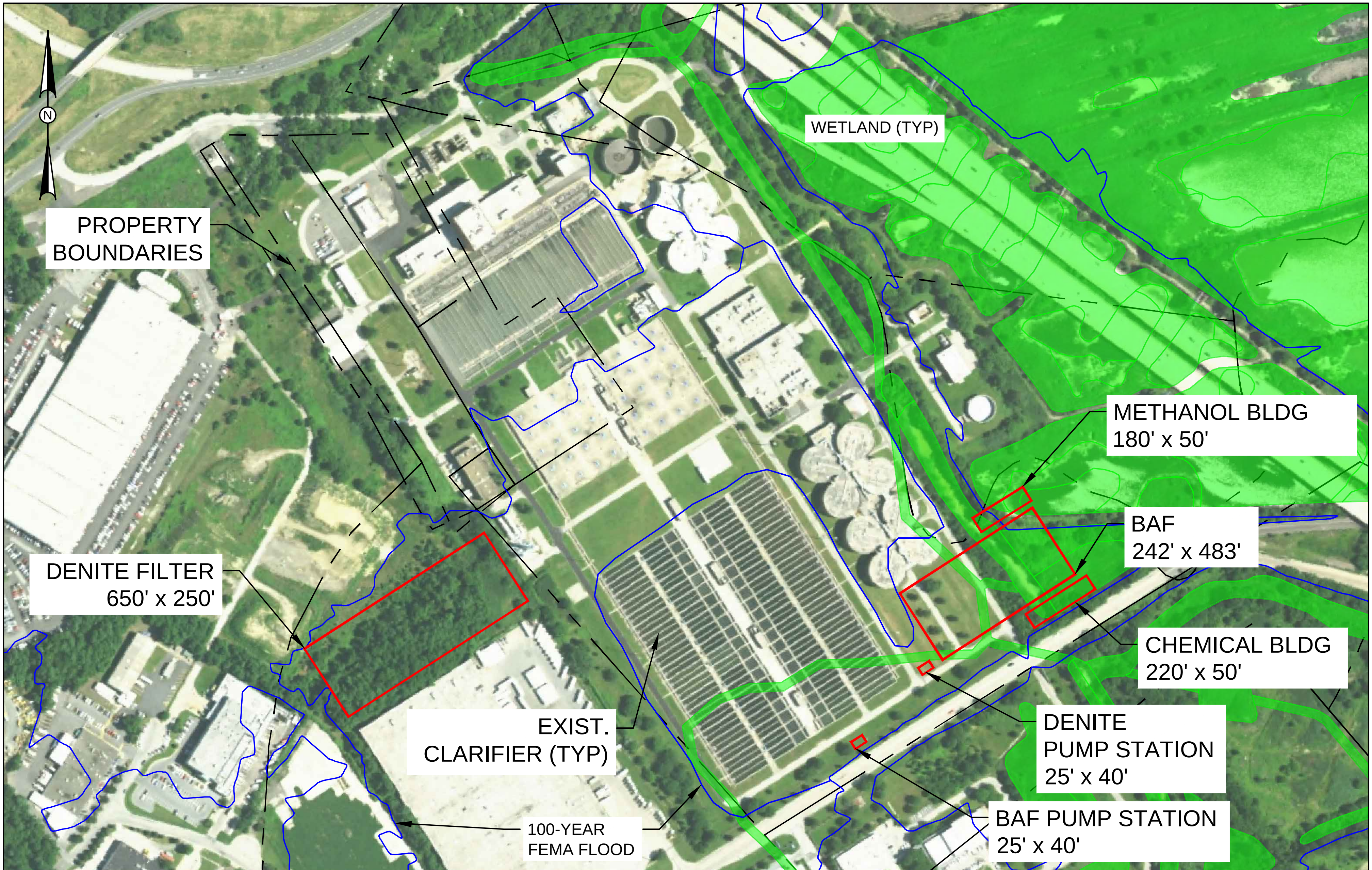
PWD SOUTHWEST WPCP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

D-1



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PWD SOUTHWEST WPCP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
D-2

Appendix E
Willingboro MUA Plant Specific Cost Estimates
and
Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

Willingboro MUA WWTP
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 19,314,000
subtotal	$ 19,314,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 5.22 (Permitted Flow)	
Max. Monthly Summer Average Ammonia (May-Oct) = 4.2 mg/L	
subtotal	$ 25,092,680
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 554,880
Rock Excavation	$ -
Sheeting during Construction	$ 171,088
Construction Dewatering	$ 41,616
Land Acquisition	$ -
subtotal	$ 767,584
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*25,860,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 278
Additional energy costs	$ 126,080
Additional sludge disposal costs	$ 6,951
Additional maintenance costs	$ 37,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 258,000
TOTAL PRESENT WORTH O&M COSTS	$ 5,346,000
GRAND TOTAL PRESENT WORTH COST	**$ 31,206,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

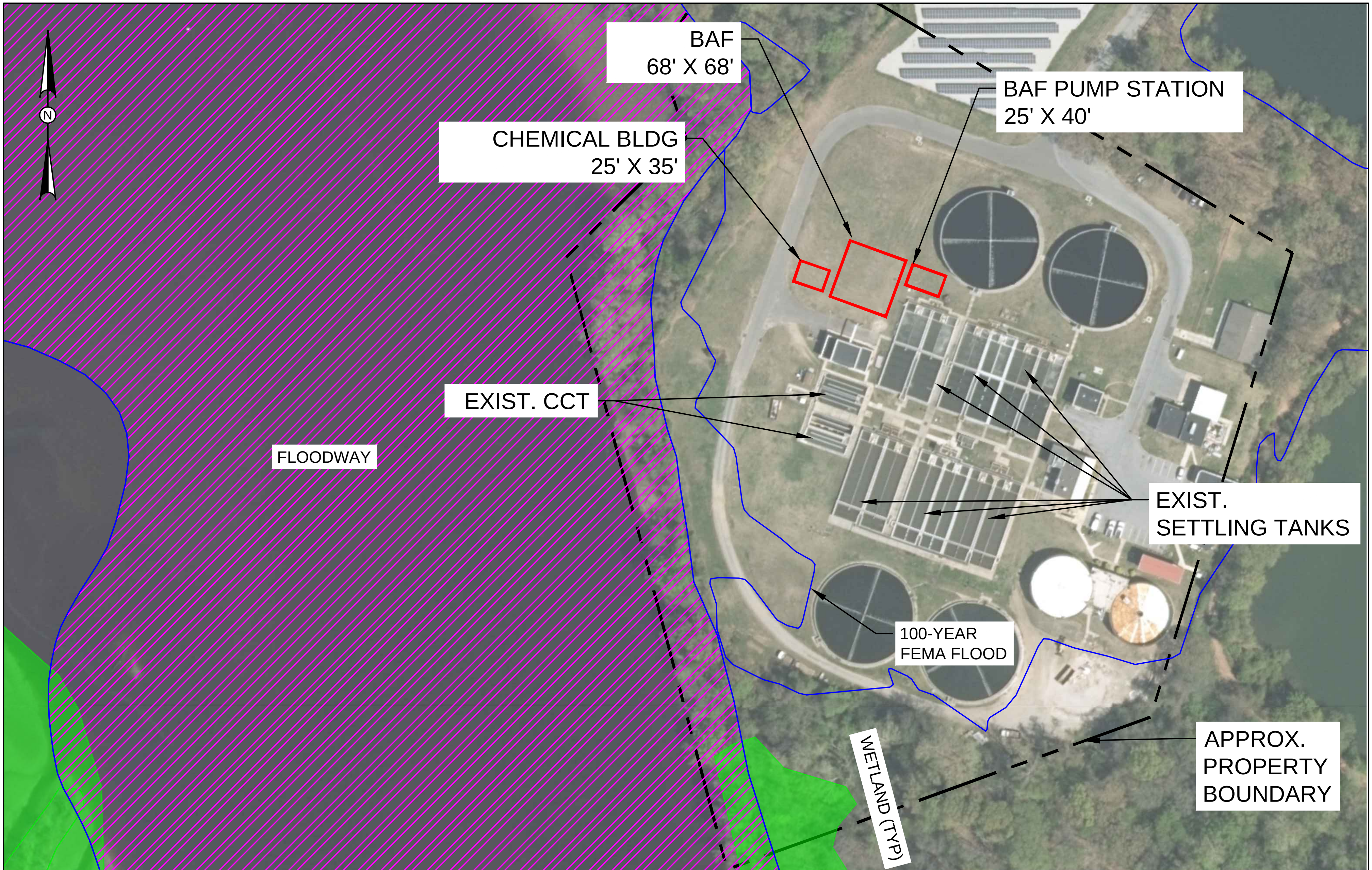
Willingboro MUA WWTP
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 32,886,000
subtotal	$ 32,886,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 5.22 (Permitted Flow)	
Max. Monthly Summer Average Ammonia (May-Oct) = 4.2 mg/L	
subtotal	$ 38,803,858
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 1,034,880
Rock Excavation	$ -
Sheeting during Construction	$ 319,088
Construction Dewatering	$ 77,616
Land Acquisition	$ -
subtotal	$ 1,431,584
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*40,235,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 157,202
Additional energy costs	$ 225,443
Additional sludge disposal costs	$ 53,799
Additional maintenance costs	$ 56,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 580,000
TOTAL PRESENT WORTH O&M COSTS	$ 12,017,000
GRAND TOTAL PRESENT WORTH COST	**$ 52,252,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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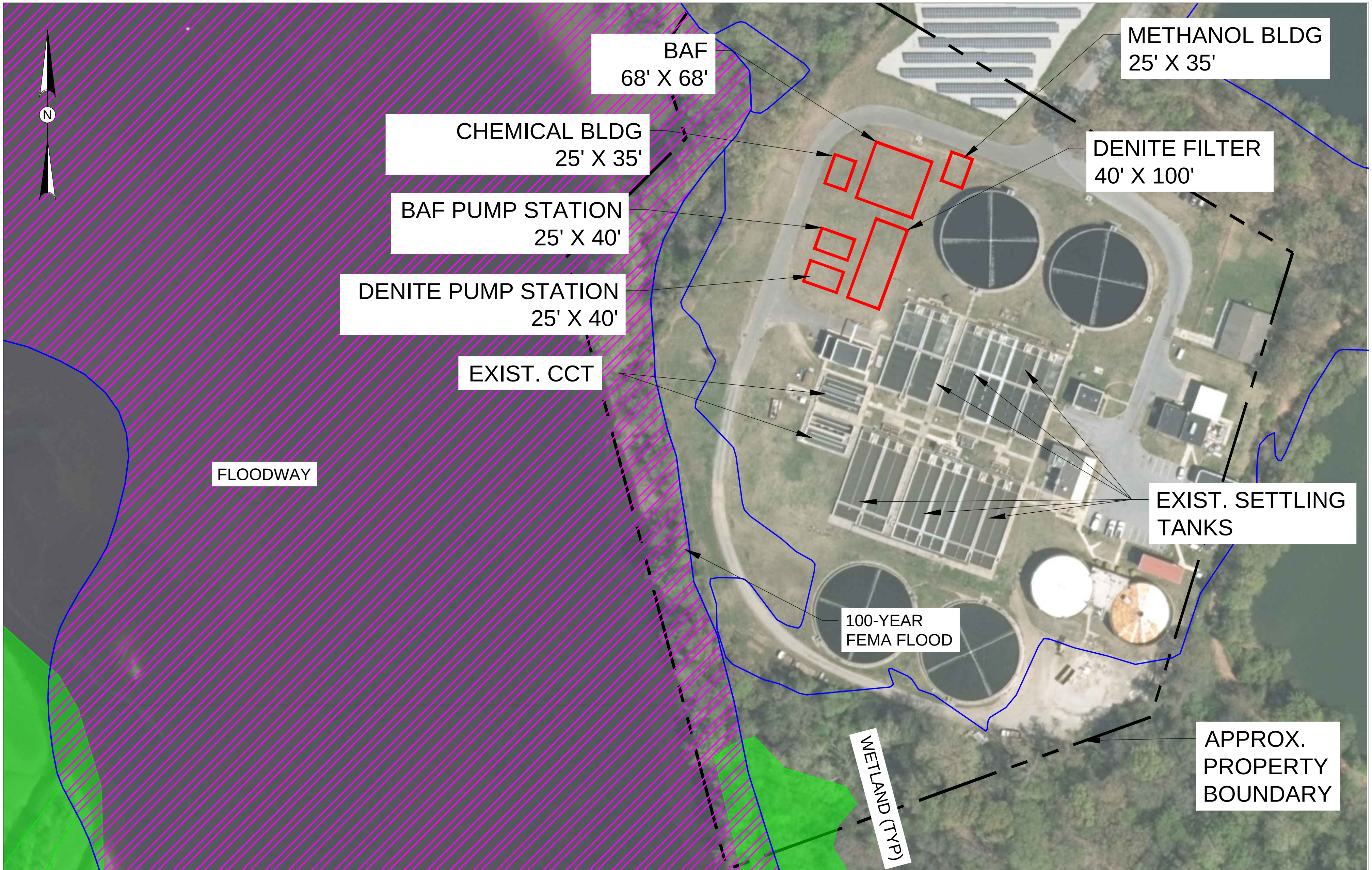
WILLINGBORO WPCF
CONCEPTUAL SITE PLAN
NH_3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
E-1



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WILLINGBORO WPCF
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

E-2

Appendix F
Hamilton Township Plant Specific Cost Estimates
and
Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

Hamilton Twp WWTP
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	31,850,000
subtotal	$	31,850,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 12.74 (Build-out Flow)		
Max. Monthly Summer Average Ammonia (May-Oct) = 28.7 mg/L		
subtotal	$	29,317,948
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	-
Rock Excavation	$	573,630
Sheeting during Construction	$	286,528
Construction Dewatering	$	69,696
Land Acquisition	$	-
subtotal	$	929,854
Plant-specific base capital cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*30,248,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	88,000
Additional chemical costs	$	827,203
Additional energy costs	$	211,582
Additional sludge disposal costs	$	73,926
Additional maintenance costs	$	43,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	1,244,000
TOTAL PRESENT WORTH O&M COSTS	$	25,775,000
GRAND TOTAL PRESENT WORTH COST	**$**	**56,023,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

Hamilton Twp WWTP
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 39,494,000
subtotal	$ 39,494,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 12.74 (Build-out Flow)	
Max. Monthly Summer Average Ammonia (May-Oct) = 28.7 mg/L	
subtotal	$ 32,114,190
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ -
Rock Excavation	$ 726,000
Sheeting during Construction	$ 362,637
Construction Dewatering	$ 88,209
Land Acquisition	$ -
subtotal	$ 1,176,846
Plant-specific base capital cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*33,291,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 1,048,168
Additional energy costs	$ 268,101
Additional sludge disposal costs	$ 93,674
Additional maintenance costs	$ 66,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,564,000
TOTAL PRESENT WORTH O&M COSTS	$ 32,405,000
GRAND TOTAL PRESENT WORTH COST	**$ 65,696,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Hamilton Twp WWTP
Effluent Level: NH3-N = 1.5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	47,138,000
subtotal	$	47,138,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 12.74 (Build-out Flow)		
Max. Monthly Summer Average Ammonia (May-Oct) = 28.7 mg/L		
subtotal	$	34,071,560
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	-
Rock Excavation	$	837,778
Sheeting during Construction	$	418,470
Construction Dewatering	$	101,790
Land Acquisition	$	-
subtotal	$	1,358,038
Plant-specific base capital cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*35,430,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	1,203,032
Additional energy costs	$	307,712
Additional sludge disposal costs	$	107,514
Additional maintenance costs	$	89,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	1,883,000
TOTAL PRESENT WORTH O&M COSTS	$	39,015,000
GRAND TOTAL PRESENT WORTH COST	**$**	**74,445,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

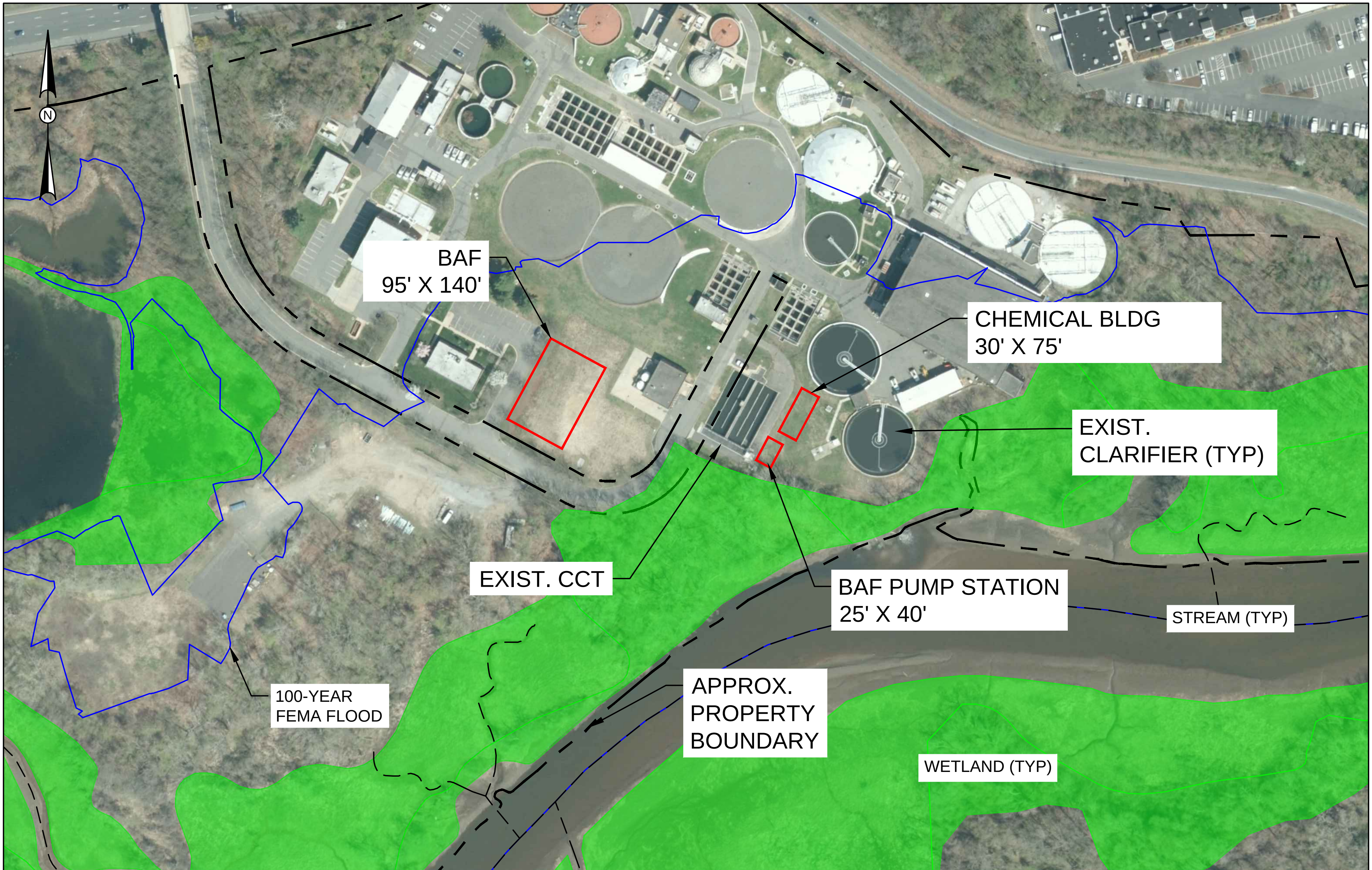
Hamilton Twp WWTP
Effluent Level: NH3-N = 1.5 mg/L and TN = 4 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 80,262,000
subtotal	$ 80,262,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 12.74 (Build-out Flow)	
Max. Monthly Summer Average Ammonia (May-Oct) = 28.7 mg/L	
subtotal	$ 55,501,939
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ -
Rock Excavation	$ 1,504,444
Sheeting during Construction	$ 751,470
Construction Dewatering	$ 182,790
Land Acquisition	$ -
subtotal	$ 2,438,704
Plant-specific base capital cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*57,941,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 1,829,539
Additional energy costs	$ 550,218
Additional sludge disposal costs	$ 278,749
Additional maintenance costs	$ 137,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 2,972,000
TOTAL PRESENT WORTH O&M COSTS	$ 61,579,000
GRAND TOTAL PRESENT WORTH COST	**$ 119,520,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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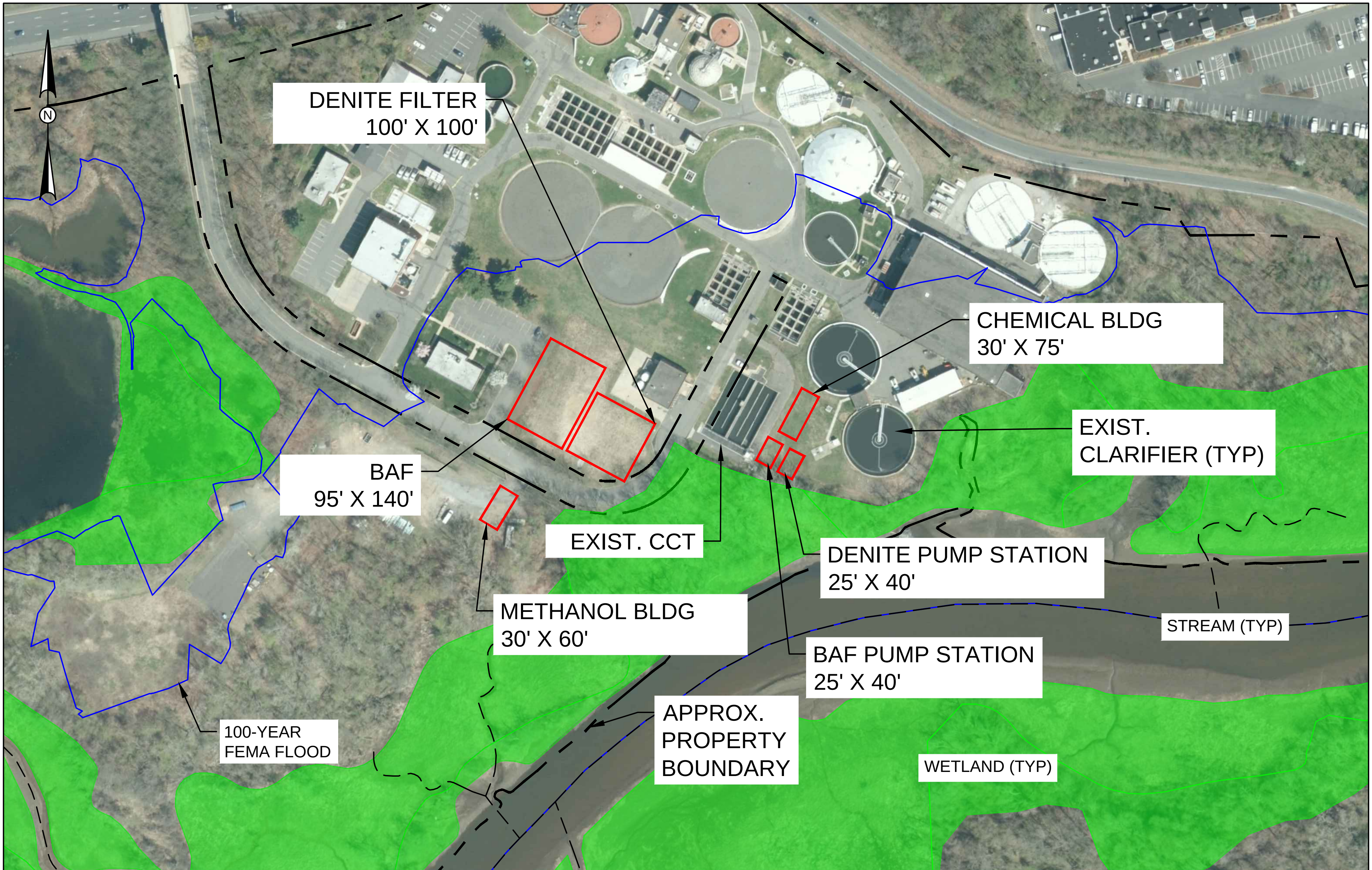
HAMILTON TWP WPCF
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

F-1



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HAMILTON TWP WPCF
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

F-2

Appendix G

Trenton Sewer Utility Plant Specific Cost Estimates

and

Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

Trenton Sewer Utility
Effluent Level: NH3-N = 10 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 37,125,000
subtotal	$ 37,125,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 15.46 (Future Flow multiplied by peaking factor)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.3 mg/L	
Assumed that the 3rd trickling filter would treat to 10 mg/L, no need for BAF; perform upgrades to Alkalinity Storage feed system	
subtotal	$ 1,100,000
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ -
Rock Excavation	$ -
Sheeting during Construction	$ -
Construction Dewatering	$ -
Land Acquisition	$ -
subtotal	$ -
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*1,100,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ -
Additional chemical costs	$ 76
Additional energy costs	$ 20,817
Additional sludge disposal costs	$ 1,899
Additional maintenance costs	$ -
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 23,000
TOTAL PRESENT WORTH O&M COSTS	$ 477,000
GRAND TOTAL PRESENT WORTH COST	**$ 1,577,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Trenton Sewer Utility
Effluent Level: NH_3-N = 5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	46,035,000
subtotal	$	46,035,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 15.46 (Future Flow multiplied by peaking factor)		
Max. Monthly Summer Average Ammonia (May-Oct) = 12.3 mg/L		
subtotal	$	29,289,941
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	929,280
Rock Excavation	$	-
Sheeting during Construction	$	286,528
Construction Dewatering	$	69,696
Land Acquisition	$	-
subtotal	$	1,285,504
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*30,575,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	88,000
Additional chemical costs	$	890
Additional energy costs	$	211,099
Additional sludge disposal costs	$	22,256
Additional maintenance costs	$	52,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	374,000
TOTAL PRESENT WORTH O&M COSTS	$	7,749,000
GRAND TOTAL PRESENT WORTH COST	**$**	**38,324,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Trenton Sewer Utility
Effluent Level: NH3-N = 1.5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	54,945,000
subtotal	$	54,945,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 15.46 (Future Flow multiplied by peaking factor)		
Max. Monthly Summer Average Ammonia (May-Oct) = 12.3 mg/L		
subtotal	$	36,590,900
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	1,562,400
Rock Excavation	$	-
Sheeting during Construction	$	481,740
Construction Dewatering	$	117,180
Land Acquisition	$	-
subtotal	$	2,161,320
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	-
TOTAL PRESENT WORTH CAPITAL COST		*38,752,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	1,513
Additional energy costs	$	358,675
Additional sludge disposal costs	$	37,815
Additional maintenance costs	$	104,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	678,000
TOTAL PRESENT WORTH O&M COSTS	$	14,048,000
GRAND TOTAL PRESENT WORTH COST	**$**	**52,800,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

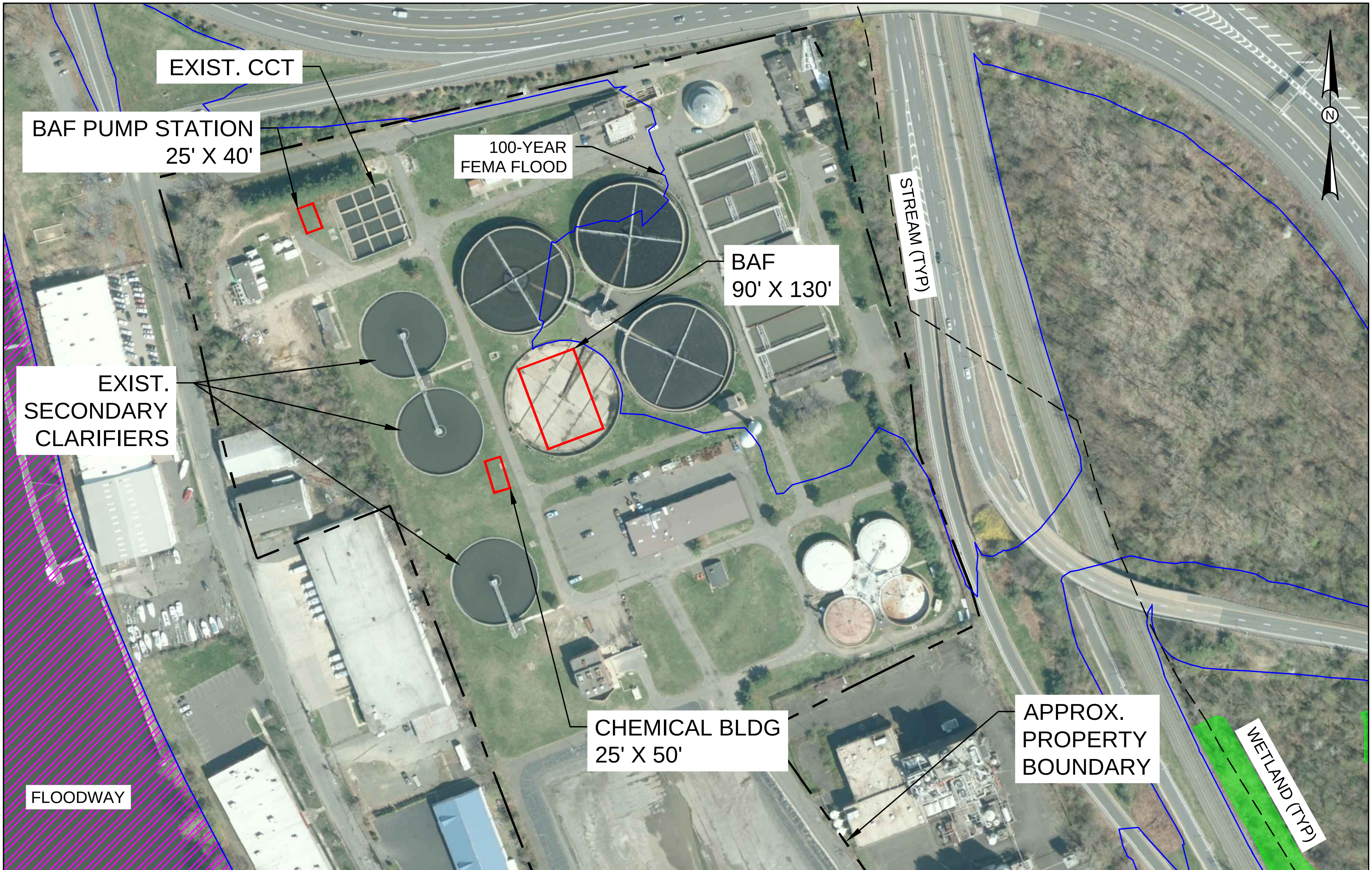
Trenton Sewer Utility
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 93,555,000
subtotal	$ 93,555,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 15.46 (Future Flow multiplied by peaking factor)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.3 mg/L	
subtotal	$ 60,536,913
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 2,762,400
Rock Excavation	$ -
Sheeting during Construction	$ 851,740
Construction Dewatering	$ 207,180
Land Acquisition	$ -
subtotal	$ 3,821,320
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*64,358,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 275,399
Additional energy costs	$ 641,345
Additional sludge disposal costs	$ 130,777
Additional maintenance costs	$ 159,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,383,000
TOTAL PRESENT WORTH O&M COSTS	$ 28,655,000
GRAND TOTAL PRESENT WORTH COST	**$ 93,013,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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TRENTON SEWER UTILITY
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
G-1

CAD FILE: S:\6736 - DRBC Cost Study\DWG\02 - Trenton Sewer Utility.dwg

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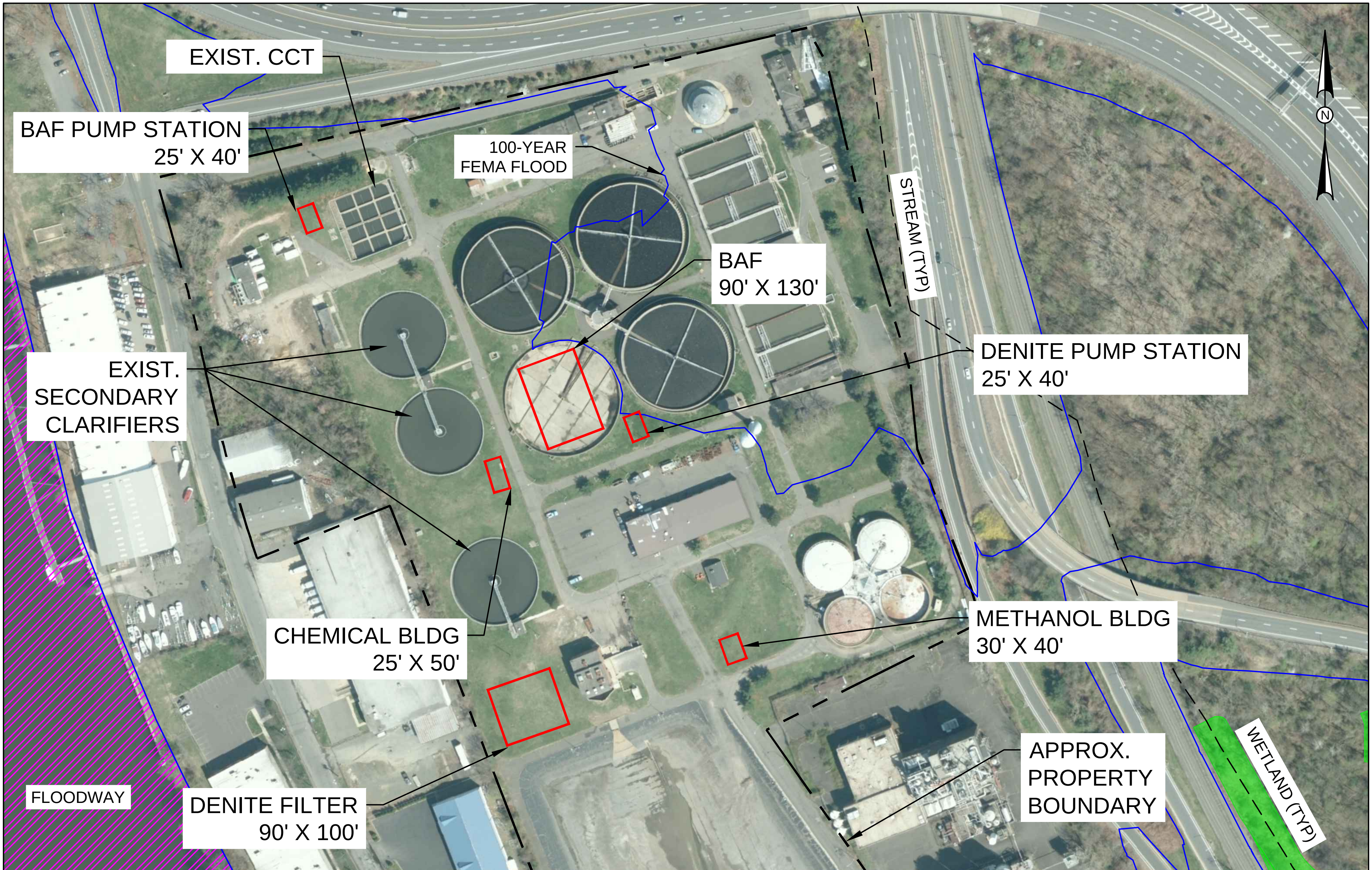

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TRENTON SEWER UTILITY
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

G-2

Appendix H

LBCJMA Plant Specific Cost Estimates

and

Conceptual Site Plans

Lower Bucks County Joint MA WWTP
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	5,600,000
subtotal	$	5,600,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 11.2 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 33 mg/L		
subtotal	$	5,600,000
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	3,694,560
Rock Excavation	$	-
Sheeting during Construction	$	1,139,156
Construction Dewatering	$	277,092
Land Acquisition	$	2,032,008
subtotal	$	7,142,816
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	573,427
TOTAL PRESENT WORTH CAPITAL COST		*13,316,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	-
Additional chemical costs	$	719,093
Additional energy costs	$	127,977
Additional sludge disposal costs	$	14,322
Additional maintenance costs	$	6,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	867,000
TOTAL PRESENT WORTH O&M COSTS	$	17,964,000
GRAND TOTAL PRESENT WORTH COST	**$**	**31,280,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Lower Bucks County Joint MA WWTP
Effluent Level: NH3-N = 5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	5,600,000
subtotal	$	5,600,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 11.2 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 33 mg/L		
subtotal	$	5,600,000
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	3,694,560
Rock Excavation	$	-
Sheeting during Construction	$	1,139,156
Construction Dewatering	$	277,092
Land Acquisition	$	2,032,008
subtotal	$	7,142,816
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	573,427
TOTAL PRESENT WORTH CAPITAL COST		*13,316,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	-
Additional chemical costs	$	1,118,396
Additional energy costs	$	155,098
Additional sludge disposal costs	$	17,436
Additional maintenance costs	$	30,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	1,321,000
TOTAL PRESENT WORTH O&M COSTS	$	27,371,000
GRAND TOTAL PRESENT WORTH COST	**$**	**40,687,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

Lower Bucks County Joint MA WWTP
Effluent Level: NH3-N = 1.5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	5,600,000
subtotal	$	5,600,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 11.2 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 33 mg/L		
subtotal	$	5,600,000
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	3,694,560
Rock Excavation	$	-
Sheeting during Construction	$	1,139,156
Construction Dewatering	$	277,092
Land Acquisition	$	2,032,008
subtotal	$	7,142,816
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	573,427
TOTAL PRESENT WORTH CAPITAL COST		*13,316,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	-
Additional chemical costs	$	1,397,908
Additional energy costs	$	174,083
Additional sludge disposal costs	$	19,616
Additional maintenance costs	$	37,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	1,629,000
TOTAL PRESENT WORTH O&M COSTS	$	33,752,000
GRAND TOTAL PRESENT WORTH COST	**$**	**47,068,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

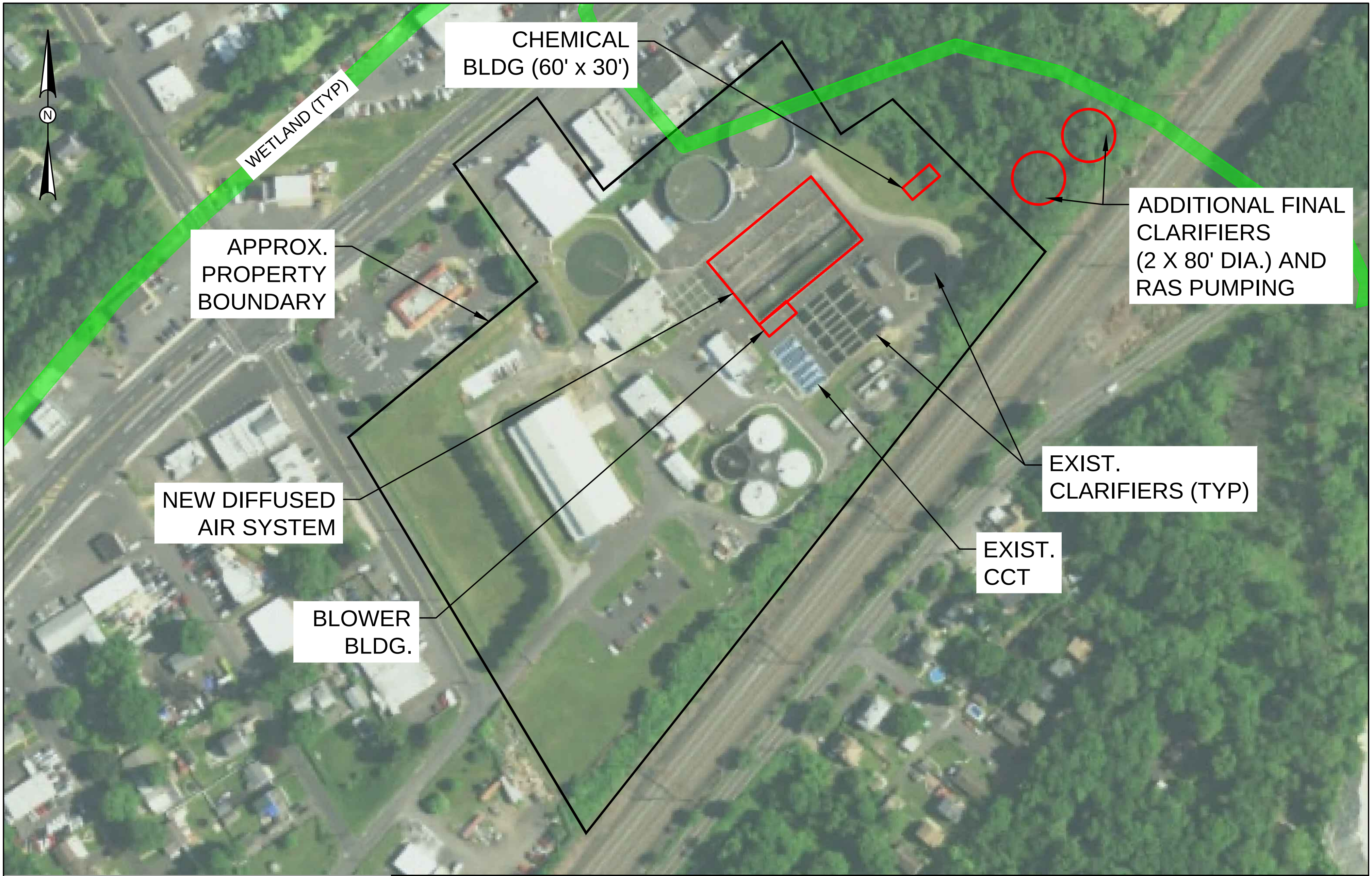
Lower Bucks County Joint MA WWTP
Effluent Level: NH_3-N = 1.5 mg/L and 4 mg/l TN

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	26,978,695
subtotal	$	26,978,695
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 11.2 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 33 mg/L		
subtotal	$	26,978,695
Plant-specific base captial cost additions[2]:		
Pile Foundations	$	4,774,560
Rock Excavation	$	-
Sheeting during Construction	$	1,472,156
Construction Dewatering	$	358,092
Land Acquisition	$	2,626,008
subtotal	$	9,230,816
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	1,629,428
TOTAL PRESENT WORTH CAPITAL COST		*37,839,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	2,038,933
Additional energy costs	$	387,275
Additional sludge disposal costs	$	191,239
Additional maintenance costs	$	72,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	2,865,000
TOTAL PRESENT WORTH O&M COSTS	$	59,362,000
GRAND TOTAL PRESENT WORTH COST	**$**	**97,201,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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DATE:	05-20-2020
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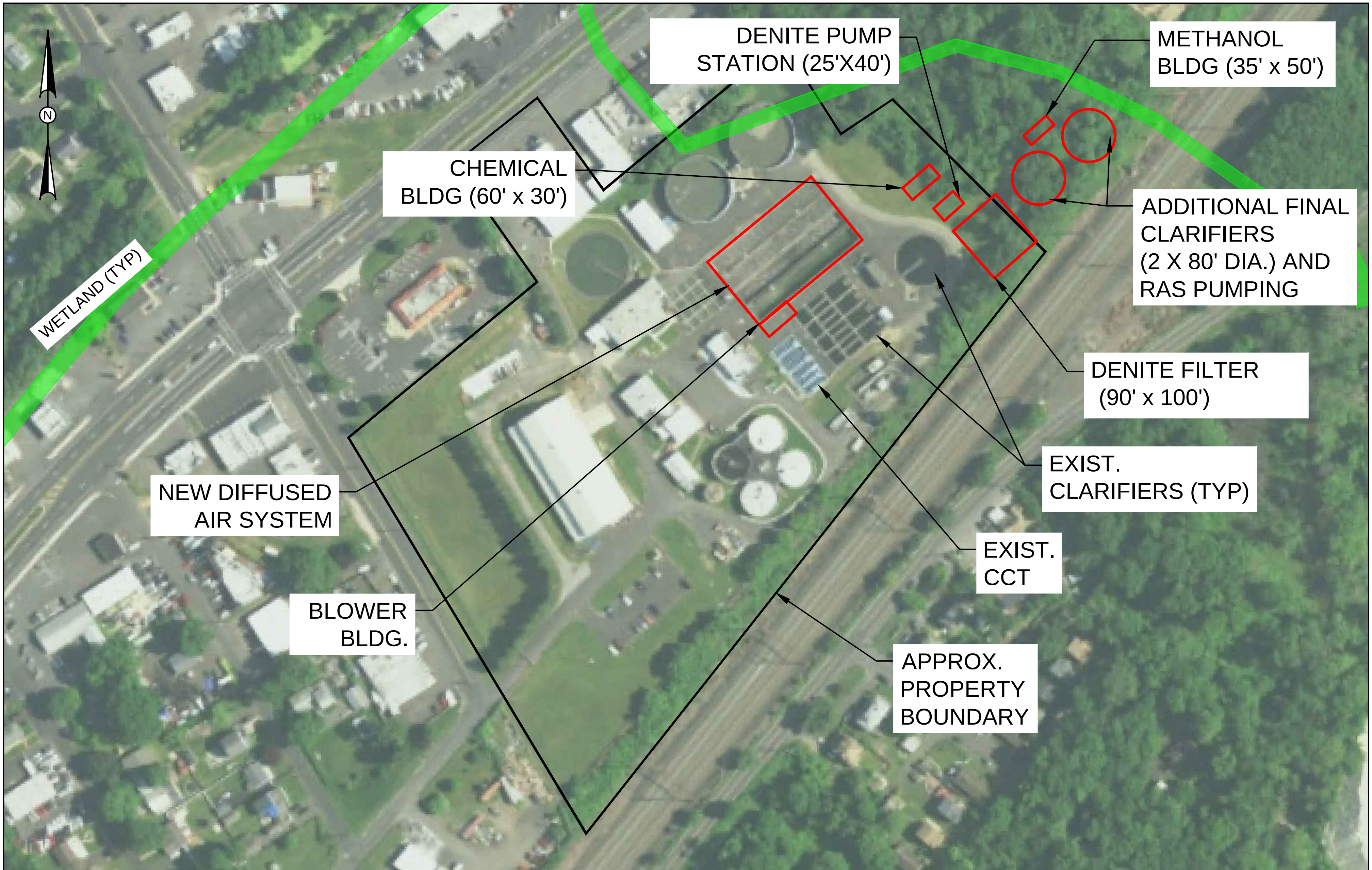
LOWER BUCKS COUNTY JOINT MA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
H-1



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LOWER BUCKS COUNTY JOINT MA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

H-2

Appendix I

GCUA Plant Specific Cost Estimates

and

Conceptual Site Plans

GCUA
Effluent Level: NH3-N = 10 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	13,500,000
subtotal	$	13,500,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 27 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 32.40 mg/L		
subtotal	$	13,500,000
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	3,694,560
Rock Excavation	$	-
Sheeting during Construction	$	1,139,156
Construction Dewatering	$	277,092
Land Acquisition	$	-
subtotal	$	5,110,808
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	837,486
TOTAL PRESENT WORTH CAPITAL COST		*19,448,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	-
Additional chemical costs	$	1,618,016
Additional energy costs	$	330,965
Additional sludge disposal costs	$	33,627
Additional maintenance costs	$	15,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	1,998,000
TOTAL PRESENT WORTH O&M COSTS	$	41,398,000
GRAND TOTAL PRESENT WORTH COST	**$**	**60,846,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

GCUA
Effluent Level: NH_3-N = 5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	13,500,000
subtotal	$	13,500,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 27 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 32.40 mg/L		
subtotal	$	13,500,000
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	3,694,560
Rock Excavation	$	-
Sheeting during Construction	$	1,139,156
Construction Dewatering	$	277,092
Land Acquisition	$	-
subtotal	$	5,110,808
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	837,486
TOTAL PRESENT WORTH CAPITAL COST		*19,448,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	-
Additional chemical costs	$	2,580,621
Additional energy costs	$	401,376
Additional sludge disposal costs	$	41,133
Additional maintenance costs	$	73,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	3,096,000
TOTAL PRESENT WORTH O&M COSTS	$	64,148,000
GRAND TOTAL PRESENT WORTH COST	**$**	**83,596,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

GCUA
Effluent Level: NH_3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 13,500,000
subtotal	$ 13,500,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 27 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 32.40 mg/L	
subtotal	$ 13,500,000
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ -
subtotal	$ 5,110,808
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 837,486
TOTAL PRESENT WORTH CAPITAL COST	*19,448,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ -
Additional chemical costs	$ 3,254,444
Additional energy costs	$ 450,663
Additional sludge disposal costs	$ 46,387
Additional maintenance costs	$ 90,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 3,841,000
TOTAL PRESENT WORTH O&M COSTS	$ 79,584,000
GRAND TOTAL PRESENT WORTH COST	**$ 99,032,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

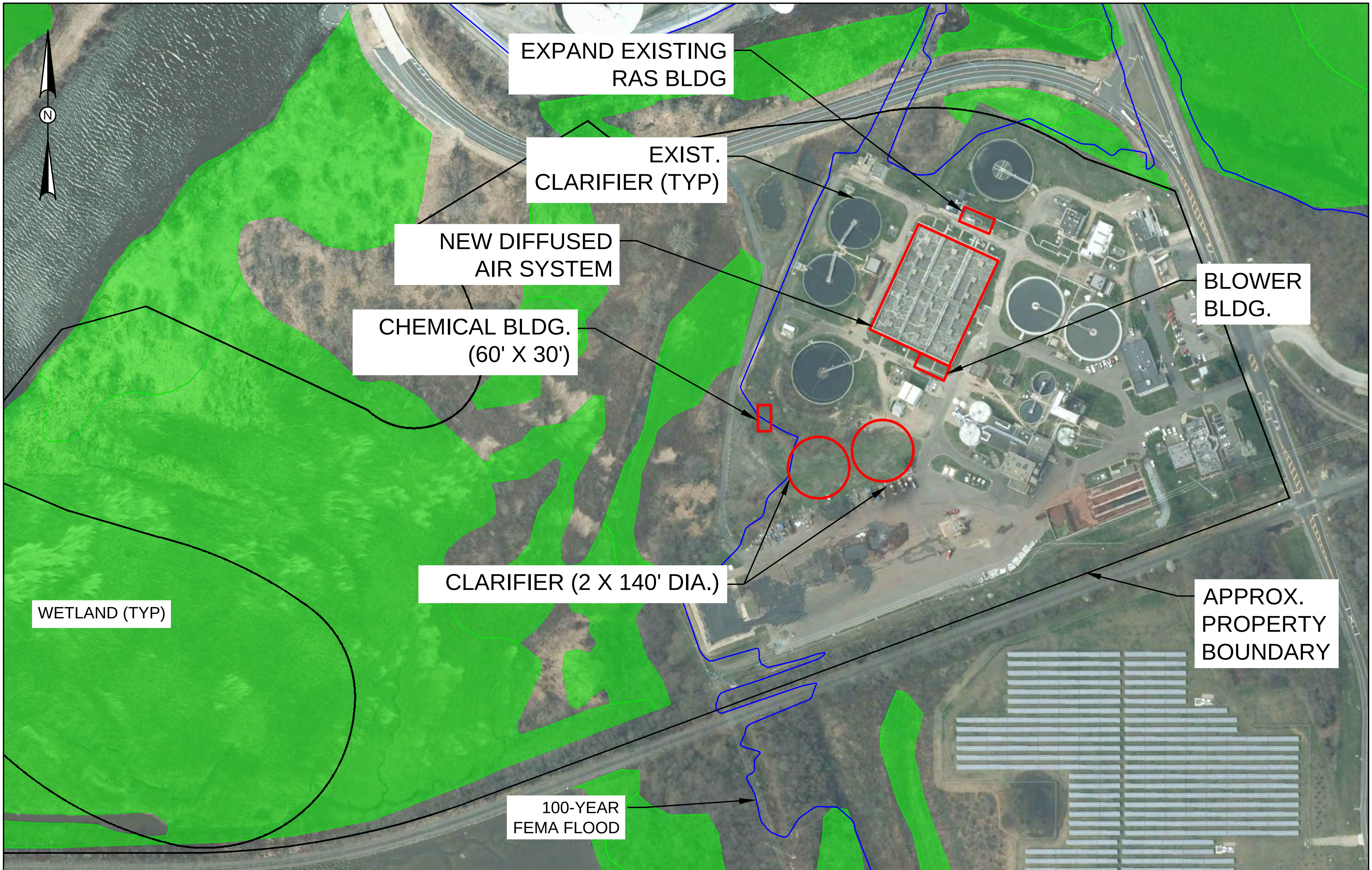
GCUA
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	56,233,380
subtotal	$	56,233,380
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 27 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 32.40 mg/L		
subtotal	$	56,233,380
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	5,806,560
Rock Excavation	$	-
Sheeting during Construction	$	1,790,356
Construction Dewatering	$	435,492
Land Acquisition	$	-
subtotal	$	8,032,408
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	2,891,960
TOTAL PRESENT WORTH CAPITAL COST		*67,158,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	4,771,115
Additional energy costs	$	734,808
Additional sludge disposal costs	$	495,561
Additional maintenance costs	$	174,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	6,351,000
TOTAL PRESENT WORTH O&M COSTS	$	131,590,000
GRAND TOTAL PRESENT WORTH COST	**$**	**198,748,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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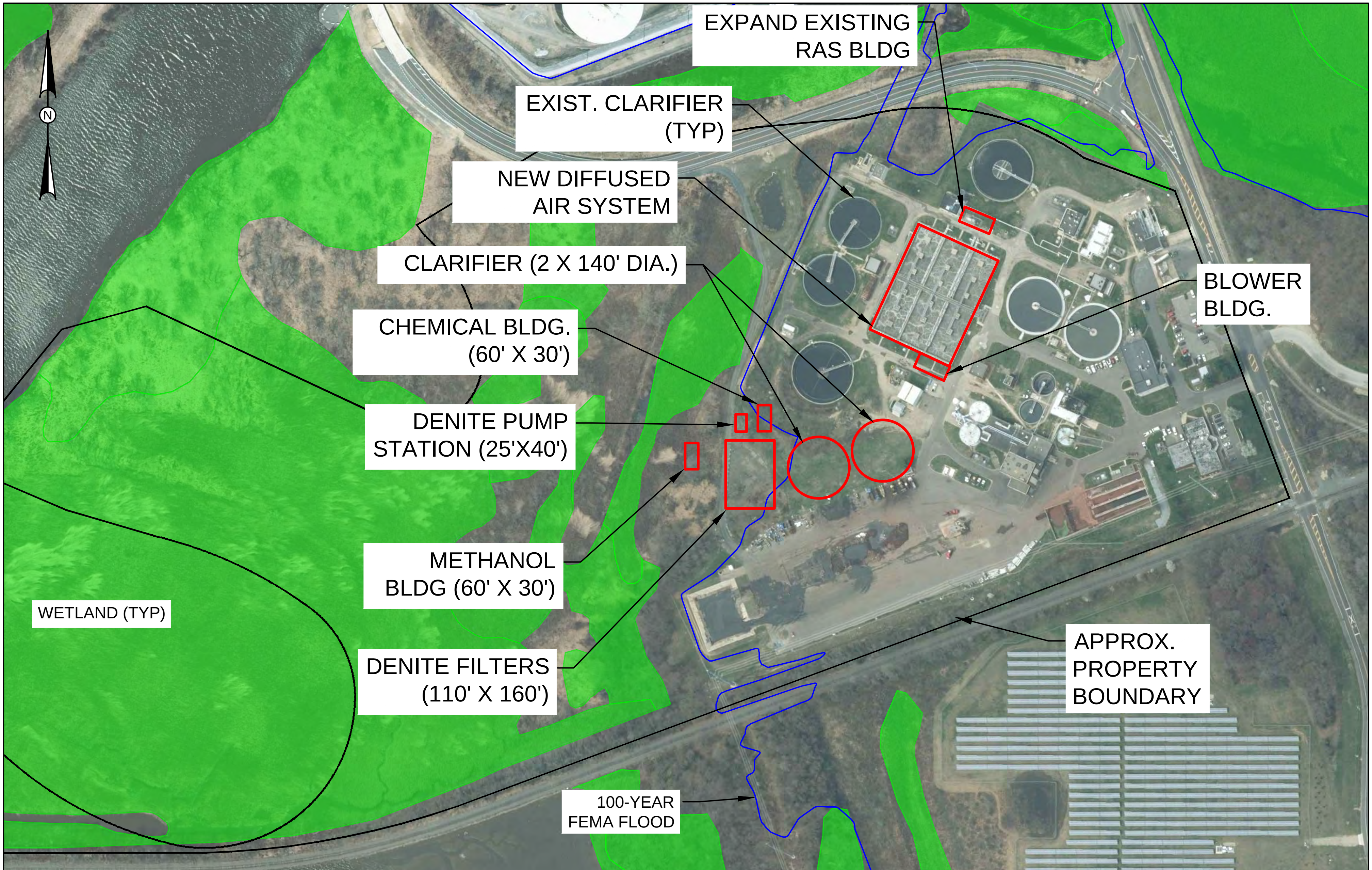
GCUA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
I-1



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GCUA
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
I-2

Appendix J
DELCORA Plant Specific Cost Estimates
and
Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

DELCORA
Effluent Level: NH3-N = 10 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 25,000,000
subtotal	$ 25,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 50 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 18.43 mg/L	
subtotal	$ 25,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ -
subtotal	$ 5,110,808
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 1,354,986
TOTAL PRESENT WORTH CAPITAL COST	*31,466,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ -
Additional chemical costs	$ 2,321
Additional energy costs	$ 268,057
Additional sludge disposal costs	$ 54,100
Additional maintenance costs	$ 28,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 352,000
TOTAL PRESENT WORTH O&M COSTS	$ 7,293,000
GRAND TOTAL PRESENT WORTH COST	**$ 38,759,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

DELCORA
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 80,000,000
subtotal	$ 80,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 50 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 18.43 mg/L	
subtotal	$ 80,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ -
subtotal	$ 5,110,808
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 3,829,986
TOTAL PRESENT WORTH CAPITAL COST	*88,941,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 1,072,515
Additional energy costs	$ 367,766
Additional sludge disposal costs	$ 76,642
Additional maintenance costs	$ 134,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,739,000
TOTAL PRESENT WORTH O&M COSTS	$ 36,031,000
GRAND TOTAL PRESENT WORTH COST	**$ 124,972,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DELCORA
Effluent Level: NH_3-N = 1.5 mg/L

Description	***Amount***
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 90,000,000
subtotal	$ 90,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 50 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 18.43 mg/L	
subtotal	$ 90,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ -
subtotal	$ 5,110,808
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 4,279,986
TOTAL PRESENT WORTH CAPITAL COST	*99,391,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 2,320,623
Additional energy costs	$ 558,974
Additional sludge disposal costs	$ 92,421
Additional maintenance costs	$ 166,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 3,226,000
TOTAL PRESENT WORTH O&M COSTS	$ 66,841,000
GRAND TOTAL PRESENT WORTH COST	**$ 166,232,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DELCORA
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 170,000,000
subtotal	$ 170,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 50 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 18.43 mg/L	
subtotal	$ 170,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 7,534,560
Rock Excavation	$ -
Sheeting during Construction	$ 2,323,156
Construction Dewatering	$ 565,092
Land Acquisition	$ -
subtotal	$ 10,422,808
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 8,119,026
TOTAL PRESENT WORTH CAPITAL COST	*188,542,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 264,000
Additional chemical costs	$ 4,170,623
Additional energy costs	$ 1,085,169
Additional sludge disposal costs	$ 1,024,240
Additional maintenance costs	$ 323,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 6,867,000
TOTAL PRESENT WORTH O&M COSTS	$ 142,282,000
GRAND TOTAL PRESENT WORTH COST	**$ 330,824,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

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DELCORA WRTP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

J-1

CAD FILE: \\princeton.kleinfelder.com\princeton-data\Shared\6736 - DRBC Cost Study\DWG\12 - DELCORA.dwg

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DELCORA WRTP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

J-2

Appendix K
PWD SEWPCP Plant Specific Cost Estimates
and
Conceptual Site Plans

PWD Southeast WPCP
Effluent Level: NH3-N = 10 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 55,000,000
subtotal	$ 55,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 110.0 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.38 mg/L	
subtotal	$ 55,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ 5,772,750
subtotal	$ 10,883,558
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*65,884,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 245
Additional energy costs	$ 120,630
Additional sludge disposal costs	$ 6,116
Additional maintenance costs	$ 62,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 365,000
TOTAL PRESENT WORTH O&M COSTS	$ 7,563,000
GRAND TOTAL PRESENT WORTH COST	**$ 73,447,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

PWD Southeast WPCP
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 55,000,000
subtotal	$ 55,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 110.0 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.38 mg/L	
subtotal	$ 55,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ 5,772,750
subtotal	$ 10,883,558
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*65,884,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 1,468
Additional energy costs	$ 407,487
Additional sludge disposal costs	$ 36,696
Additional maintenance costs	$ 295,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 917,000
TOTAL PRESENT WORTH O&M COSTS	$ 19,000,000
GRAND TOTAL PRESENT WORTH COST	**$ 84,884,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

PWD Southeast WPCP
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 198,000,000
subtotal	$ 198,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 110.0 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.38 mg/L	
subtotal	$ 198,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 3,694,560
Rock Excavation	$ -
Sheeting during Construction	$ 1,139,156
Construction Dewatering	$ 277,092
Land Acquisition	$ 5,772,750
subtotal	$ 10,883,558
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*208,884,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 176,000
Additional chemical costs	$ 2,324
Additional energy costs	$ 755,952
Additional sludge disposal costs	$ 58,102
Additional maintenance costs	$ 366,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,358,000
TOTAL PRESENT WORTH O&M COSTS	$ 28,137,000
GRAND TOTAL PRESENT WORTH COST	**$ 237,021,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

PWD Southeast WPCP
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 374,000,000
subtotal	$ 374,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 110.0 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 12.38 mg/L	
subtotal	$ 374,000,000
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 10,894,560
Rock Excavation	$ -
Sheeting during Construction	$ 3,359,156
Construction Dewatering	$ 817,092
Land Acquisition	$ 17,022,750
subtotal	$ 32,093,558
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*406,094,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 264,000
Additional chemical costs	$ 1,763,135
Additional energy costs	$ 1,913,581
Additional sludge disposal costs	$ 684,095
Additional maintenance costs	$ 710,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 5,335,000
TOTAL PRESENT WORTH O&M COSTS	$ 110,539,000
GRAND TOTAL PRESENT WORTH COST	**$ 516,633,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

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PWD SOUTHEAST WPCP
CONCEPTUAL SITE PLAN
NH_3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
K-1

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0 400 800

SCALE: 1" = 400' SCALE IN FEET

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PWD SOUTHEAST WPCP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

K-2

Appendix L

Wilmington Plant Specific Cost Estimates

and

Conceptual Site Plans

DRBC Nitrogen Reduction Cost Estimation Study

City of Wilmington WWTP
Effluent Level: NH3-N = 10 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 67,000,000
subtotal	$ 67,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 134 (Permitted Capacity)	
Max. Monthly Summer Average Ammonia (May-Oct) = 48.30 mg/L	
Final Clarifier required footprint increase from generic plant	$ 2,282,060
subtotal	$ 69,282,060
Plant-specific base capital cost additions[2]:	
Pile Foundations	$ 4,776,960
Rock Excavation	$ -
Sheeting during Construction	$ 1,472,896
Construction Dewatering	$ 358,272
Land Acquisition	$ -
subtotal	$ 6,608,128
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ 3,415,058
TOTAL PRESENT WORTH CAPITAL COST	*79,305,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ -
Additional chemical costs	$ 3,653
Additional energy costs	$ 872,508
Additional sludge disposal costs	$ 20,293
Additional maintenance costs	$ 76,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 972,000
TOTAL PRESENT WORTH O&M COSTS	$ 20,139,000
GRAND TOTAL PRESENT WORTH COST	**$ 99,444,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

City of Wilmington WWTP
Effluent Level: NH3-N = 5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	214,400,000
subtotal	$	214,400,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 134 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 48.30 mg/L		
Final Clarifier required footprint increase from generic plant	$	2,282,060
subtotal	$	216,682,060
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	4,776,960
Rock Excavation	$	-
Sheeting during Construction	$	1,472,896
Construction Dewatering	$	358,272
Land Acquisition	$	-
subtotal	$	6,608,128
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	10,048,058
TOTAL PRESENT WORTH CAPITAL COST		*233,338,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	3,116,288
Additional energy costs	$	1,455,463
Additional sludge disposal costs	$	28,571
Additional maintenance costs	$	360,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	5,136,000
TOTAL PRESENT WORTH O&M COSTS	$	106,416,000
GRAND TOTAL PRESENT WORTH COST	**$**	**339,754,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

City of Wilmington WWTP
Effluent Level: NH3-N = 1.5 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	241,200,000
subtotal	$	241,200,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 134 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 48.30 mg/L		
Final Clarifier required footprint increase from generic plant	$	2,282,060
subtotal	$	243,482,060
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	4,776,960
Rock Excavation	$	-
Sheeting during Construction	$	1,472,896
Construction Dewatering	$	358,272
Land Acquisition	$	-
subtotal	$	6,608,128
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	11,254,058
TOTAL PRESENT WORTH CAPITAL COST		*261,344,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	176,000
Additional chemical costs	$	6,460,447
Additional energy costs	$	1,726,379
Additional sludge disposal costs	$	34,366
Additional maintenance costs	$	446,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	8,843,000
TOTAL PRESENT WORTH O&M COSTS	$	183,224,000
GRAND TOTAL PRESENT WORTH COST	**$**	**444,568,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

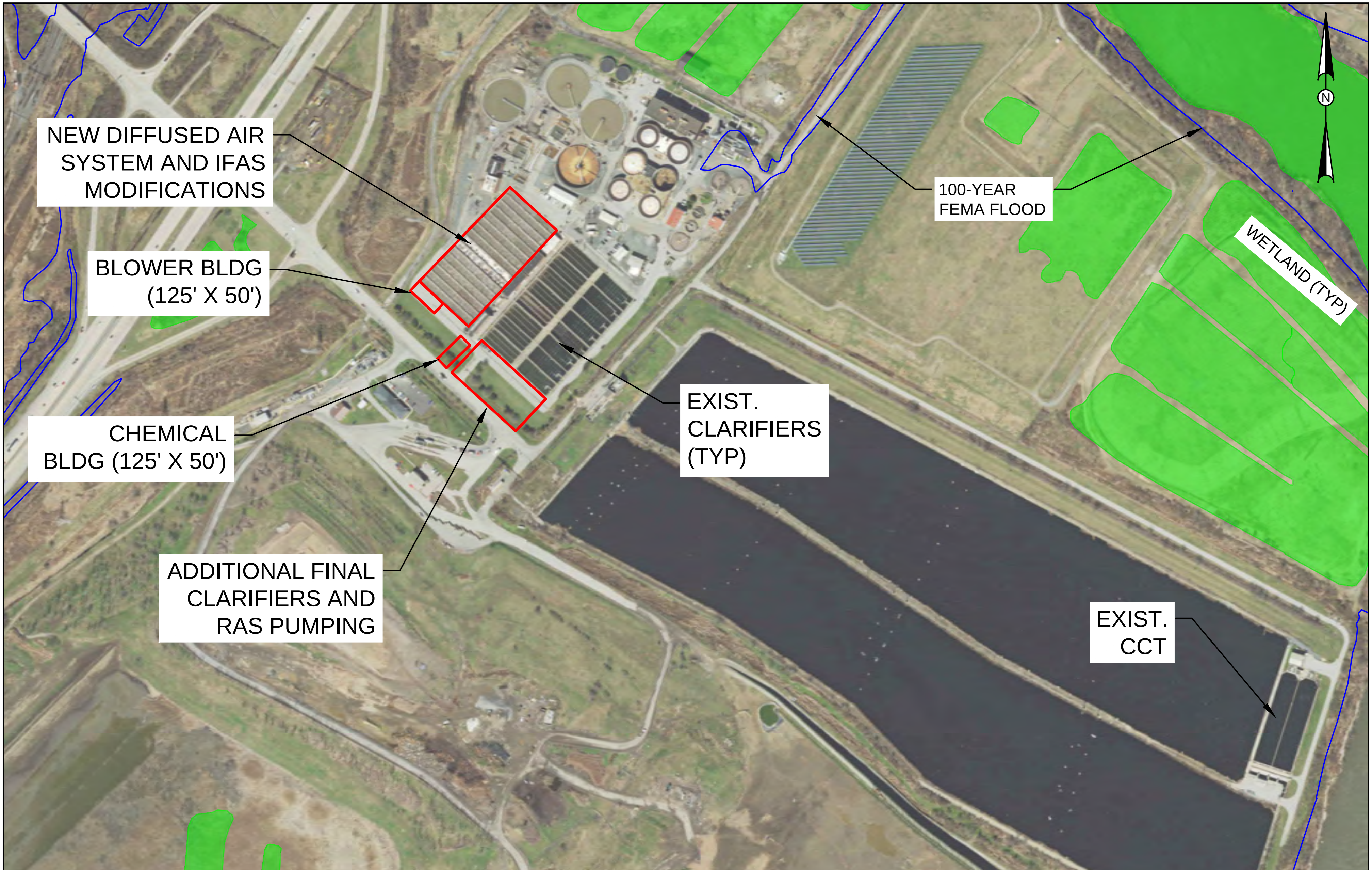
City of Wilmington WWTP
Effluent Level: NH_3-N = 1.5 mg/L and TN = 4.0 mg/L

Description		*Amount*
Plant-specific base capital cost[1]:		
Base capital cost per generic plant	$	455,600,000
subtotal	$	455,600,000
Plant-Specific Issues Requiring Cost Adjustments		
Design Flow = 134 (Permitted Capacity)		
Max. Monthly Summer Average Ammonia (May-Oct) = 48.30 mg/L		
Final Clarifier required footprint increase from generic plant	$	2,282,060
subtotal	$	457,882,060
Plant-specific base capital cost additions[2]:		
Pile Foundations	$	13,176,960
Rock Excavation	$	-
Sheeting during Construction	$	4,062,896
Construction Dewatering	$	988,272
Land Acquisition	$	-
subtotal	$	18,228,128
Plant-specific base captial cost deductions[3]:		
None		
subtotal	$	-
Reduced productivity adjustment	$	21,424,958
TOTAL PRESENT WORTH CAPITAL COST		*497,535,000*
Plant-specific annual O&M costs:		
Additional personnel costs	$	352,000
Additional chemical costs	$	11,432,214
Additional energy costs	$	3,136,582
Additional sludge disposal costs	$	350,599
Additional maintenance costs	$	865,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$	16,136,000
TOTAL PRESENT WORTH O&M COSTS	$	334,332,000
GRAND TOTAL PRESENT WORTH COST	**$**	**831,867,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate



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SCALE: 1" = 500' SCALE IN FEET

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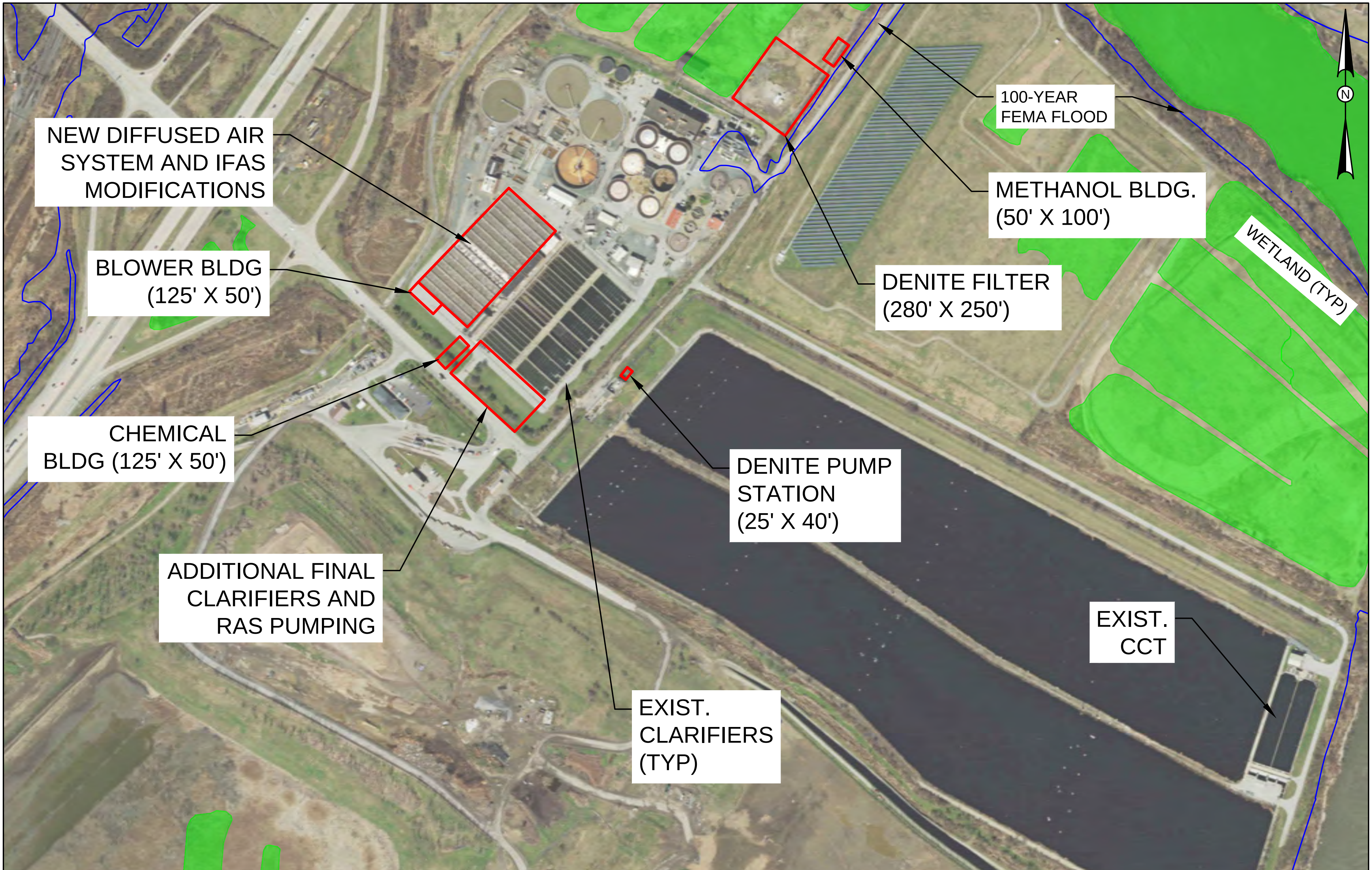
CITY OF WILMINGTON STP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE

L-1



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CITY OF WILMINGTON STP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
L-2

Appendix M

PWD NEWPCP Plant Specific Cost Estimates

and

Conceptual Site Plans

PWD Northeast WPCP
Effluent Level: NH3-N = 5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 117,500,000
subtotal	$ 117,500,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 235 (Max Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 7.24 mg/L	
Final Clarifier required footprint increase from generic plant	$ 2,958,076
subtotal	$ 120,458,076
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 5,097,600
Rock Excavation	$ -
Sheeting during Construction	$ 1,571,760
Construction Dewatering	$ 382,320
Land Acquisition	$ -
subtotal	$ 7,051,680
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*127,510,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 88,000
Additional chemical costs	$ 4,181
Additional energy costs	$ 1,045,634
Additional sludge disposal costs	$ 104,527
Additional maintenance costs	$ 631,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 1,873,000
TOTAL PRESENT WORTH O&M COSTS	$ 38,808,000
GRAND TOTAL PRESENT WORTH COST	**$ 166,318,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

DRBC Nitrogen Reduction Cost Estimation Study

PWD Northeast WPCP
Effluent Level: NH3-N = 1.5 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 376,000,000
subtotal	$ 376,000,000
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 235 (Max Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 7.24 mg/L	
Final Clarifier required footprint increase from generic plant	$ 2,958,076
subtotal	$ 378,958,076
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 5,097,600
Rock Excavation	$ -
Sheeting during Construction	$ 1,571,760
Construction Dewatering	$ 382,320
Land Acquisition	$ -
subtotal	$ 7,051,680
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*386,010,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 264,000
Additional chemical costs	$ 6,010
Additional energy costs	$ 1,738,853
Additional sludge disposal costs	$ 150,258
Additional maintenance costs	$ 782,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 2,941,000
TOTAL PRESENT WORTH O&M COSTS	$ 60,936,000
GRAND TOTAL PRESENT WORTH COST	**$ 446,946,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

PWD Northeast WPCP
Effluent Level: NH3-N = 1.5 mg/L and TN = 4.0 mg/L

Description	*Amount*
Plant-specific base capital cost[1]:	
Base capital cost per generic plant	$ 699,858,354
subtotal	$ 699,858,354
Plant-Specific Issues Requiring Cost Adjustments	
Design Flow = 235 (Max Month)	
Max. Monthly Summer Average Ammonia (May-Oct) = 7.24 mg/L	
Final Clarifier required footprint increase from generic plant	$ 2,958,076
subtotal	$ 702,816,430
Plant-specific base captial cost additions[2]:	
Pile Foundations	$ 20,097,600
Rock Excavation	$ -
Sheeting during Construction	$ 6,196,760
Construction Dewatering	$ 1,507,320
Land Acquisition	$ -
subtotal	$ 27,801,680
Plant-specific base captial cost deductions[3]:	
None	
subtotal	$ -
Reduced productivity adjustment	$ -
TOTAL PRESENT WORTH CAPITAL COST	*730,618,000*
Plant-specific annual O&M costs:	
Additional personnel costs	$ 440,000
Additional chemical costs	$ 4,648,501
Additional energy costs	$ 4,211,969
Additional sludge disposal costs	$ 1,693,396
Additional maintenance costs	$ 1,517,000
TOTAL PLANT-SPECIFIC ANNUAL O&M COSTS	$ 12,511,000
TOTAL PRESENT WORTH O&M COSTS	$ 259,223,000
GRAND TOTAL PRESENT WORTH COST	**$ 989,841,000**

[1]See Generic Plant Capital Cost Estimates Technical Memorandum

[2]For plant specific costs not included in generic plant capital cost estimates

[3]For generic plant costs not required in plant-specific cost estimate

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PWD NORTHEAST WPCP
CONCEPTUAL SITE PLAN
NH3-N = 1.5 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
M-1

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PWD NORTHEAST WPCP
CONCEPTUAL SITE PLAN
NH_3-N = 1.5 mg/l & TN = 4.0 mg/l

NITROGEN REDUCTION
COST ESTIMATION STUDY
DELAWARE RIVER BASIN COMMISSION

FIGURE
M-2