APPENDIX 15

Kleinfelder 132 MGD Wet Weather Treatment Design Memo

KIWWTP 132 mgd Wet-Weather Treatment System Concept Design Memorandum - Draft

To: Philip DePoe

From: Timothy D. Bradley, P.E.

Date: January 20, 2025

cc: Brian Chamberlain

Re: **Kline's Island Wastewater Treatment Plant (KIWWTP) Wet-Weather Treatment System via the Temporary Parallel Operation of the PMTF and RMTF – 132 mgd**

This concept design memorandum presents the design concept and budgetary capital cost estimate for improvements to increase the peak wet-weather treatment capacity of the Kline's Island Wastewater Treatment Plant (KIWWTP) from 100 mgd (i.e., the capacity that will exist after implementing the 100 mgd peak flow project that is currently being designed) to 132 mgd, by enabling the plastic media trickling filters (PMTFs) and rock media trickling filters (RMTFs) to be temporarily operated in a parallel mode of operation rather than a series mode of operation during a storm event. The concept design memorandum is arranged into the sections listed below:

1.0 BACKGROUND AND OBJECTIVE

As part of the Act 537 Plan development process, the Lehigh County Authority (LCA) and its consultants have evaluated alternatives to increase PEAK wet-weather treatment capacity to mitigate sanitary sewer overflows (SSOs) within the Kline's Island Sewer System. Alternatives included treatment of the additional peak wet-weather flow using the Bioactiflow process, and peak flow storage.

The objective of this concept design memorandum is to present the design concept and budgetary capital cost estimate for one of the alternatives being considered for increasing the KIWWTP's wet-weather treatment capacity by 32 mgd, from 100 mgd (i.e., the peak wet-weather treatment capacity that will be achieved by implementation of a project currently in the final design phase) to 132 mgd.

With this proposed alternative, the increase in peak wet-weather treatment capacity to 132 mgd would be achieved by implementing improvements to enable the PMTFs and RMTFs to be temporarily operated in parallel during a storm event rather than in series.

With this approach, during significant storm events, 32 mgd of additional peak flow entering the KIWWTP will undergo grit removal in new aerated grit chamber and primary treatment in two (2) new wet-weather primary clarifiers and will be pumped via a new supplemental primary effluent pump station to the RMTFs for biological treatment followed by clarification in the existing final clarifiers and disinfection in the existing chlorine contact tank (CCT).

Concurrently, the 100 mgd of peak flow that will enter the KIWWTP (after implementation of the current project to increase the peak wet-weather treatment capacity to 100 mgd) will continue to undergo grit removal in the existing aerated grit chambers, primary treatment in the existing primary clarifiers, and biological treatment in the existing PMTFs. However, the biologically treated effluent from the PMTFs will be temporarily routed for clarification and disinfection as follows: approximately 50 mgd of PMTF effluent will be routed directly to the existing final clarifiers through a new trickling filter paralleling line that will be installed as part of the current project to increase peak flow capacity to 100 mgd, and following final clarification, will receive disinfection in the existing CCT. The other approximately 50 mgd of PMTF effluent will be pumped by the existing PMFT effluent pumps to the intermediate setting tanks (ISTs) for clarification, and the IST effluent will be routed directly to the CCT for disinfection.

In summary, 132 mgd will receive primary treatment followed by biological treatment. Approximately 82 mgd of the biologically treated flow will be clarified in the existing final clarifiers followed by disinfection in the existing CCT, and approximately 50 mgd will be clarified in the ISTs with the clarified IST effluent routed directly to the existing CCT for disinfection.

This concept design memorandum and corresponding budgetary capital cost estimate does not include the improvements to convey 32 mgd of additional peak flow to the KIWWTP, which at the current time is likely the combination of a Klines' Island Relief Interceptor (KRI) and extension of the Park Pump Station force main directly to the KIWWTP.

2.0 OVERVIEW OF EXISTING KIWWTP

The KIWWTP has been in operation since 1928. Many improvements have been implemented over its long period of service to address various needs including capacity expansion, enhancing the level of treatment, and rehabilitating or replacing aging infrastructure. An aerial site plan of the existing KIWWTP is presented as Drawing 1 in Appendix A. The levee that surrounds the KIWWTP as shown in Drawing 1 provides flood protection. The KIWWTP discharges to the Lehigh River through Outfall 001. Outfall 003 is an emergency bypass to the Little Lehigh Creek designed to protect the KIWWTP during severe wet-weather events and maintenance emergencies. As previously noted, some of the many improvements that have been implemented over the years have increased the peak flow capacity of the KIWWTP, thereby reducing the activation frequency and volume of discharge through Outfall 003. In addition, operating procedures have been implemented to maximize collection system storage capacity, which also serves to reduce the Outfall 003 activation frequency and volume.

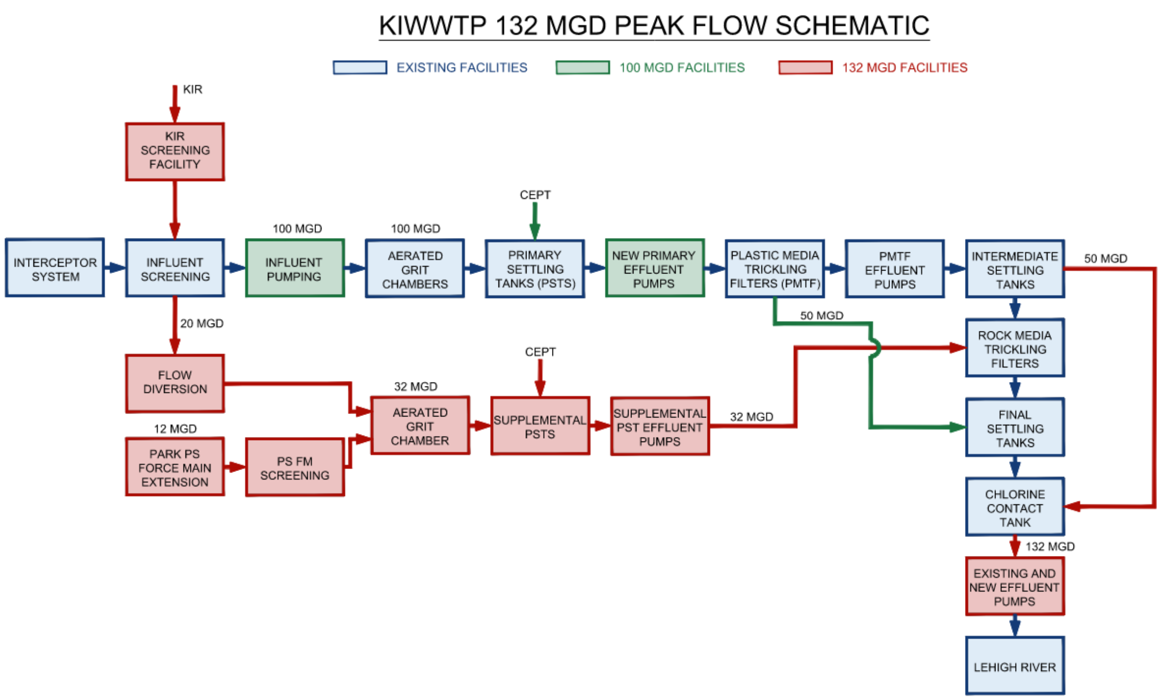
The current peak flow capacity of the KIWWTP is approximately 86 mgd. However, improvements are currently being designed that will increase the wet-weather treatment capacity to 100 mgd.

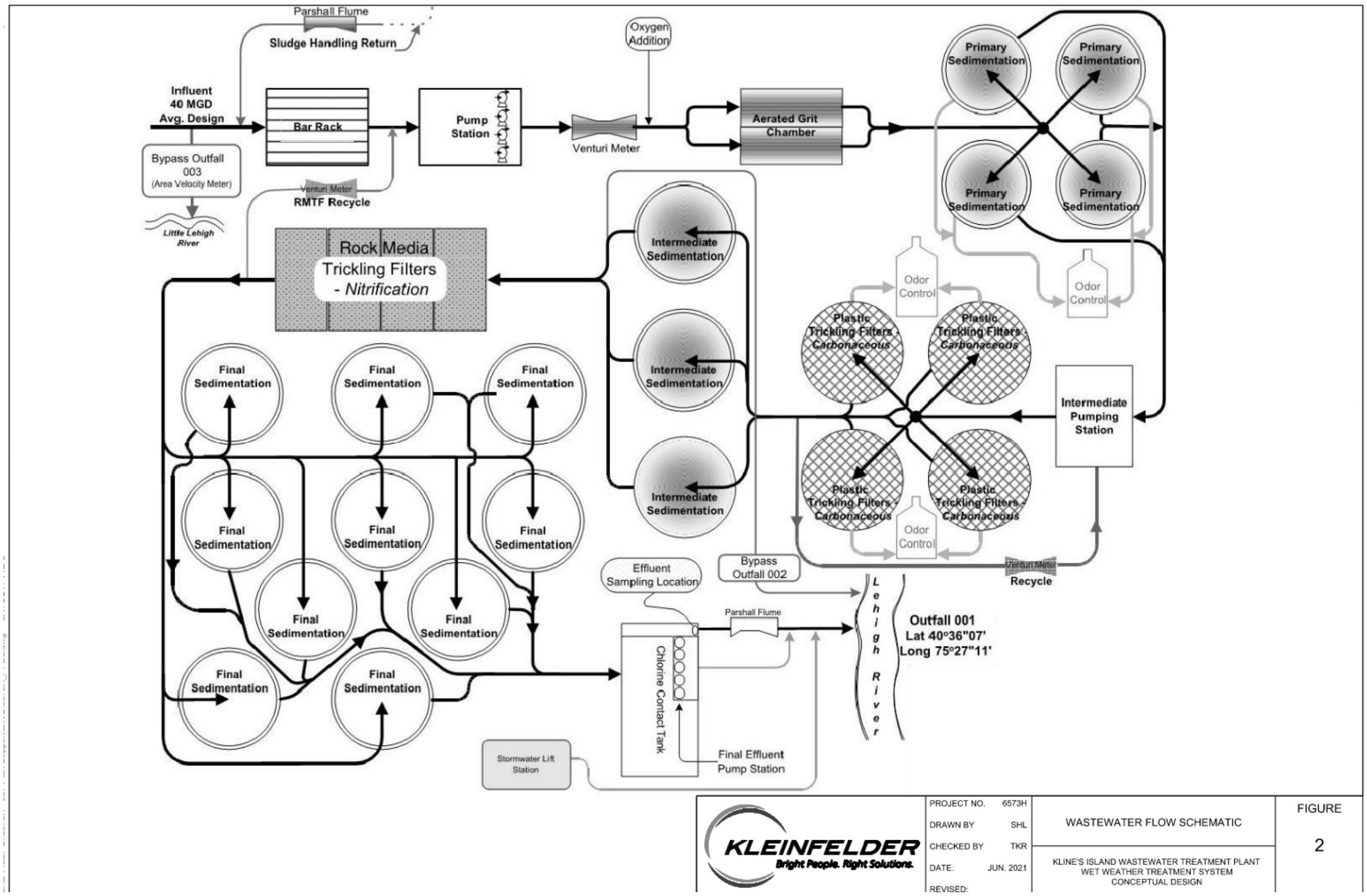
Figure 1 presents a flow diagram of the existing KIWWTP together with the improvements to increase peak wet-weather flow treatment capacity to 100 mgd and to 132 mgd. In figure 1, the existing components of the KIWWTP are in a light blue color, the components to increase peak flow capacity to 100 mgd are in a light green color, and the 132 mgd facilities are in a red color. As also shown in Figure 1, CEPT (chemically enhanced primary treatment) is shown being added to the primary clarifiers. In the CEPT process, a coagulant is added to significantly enhance TSS and BOD removal in the primary clarifiers which will reduces the BOD and TSS load to the trickling filters.

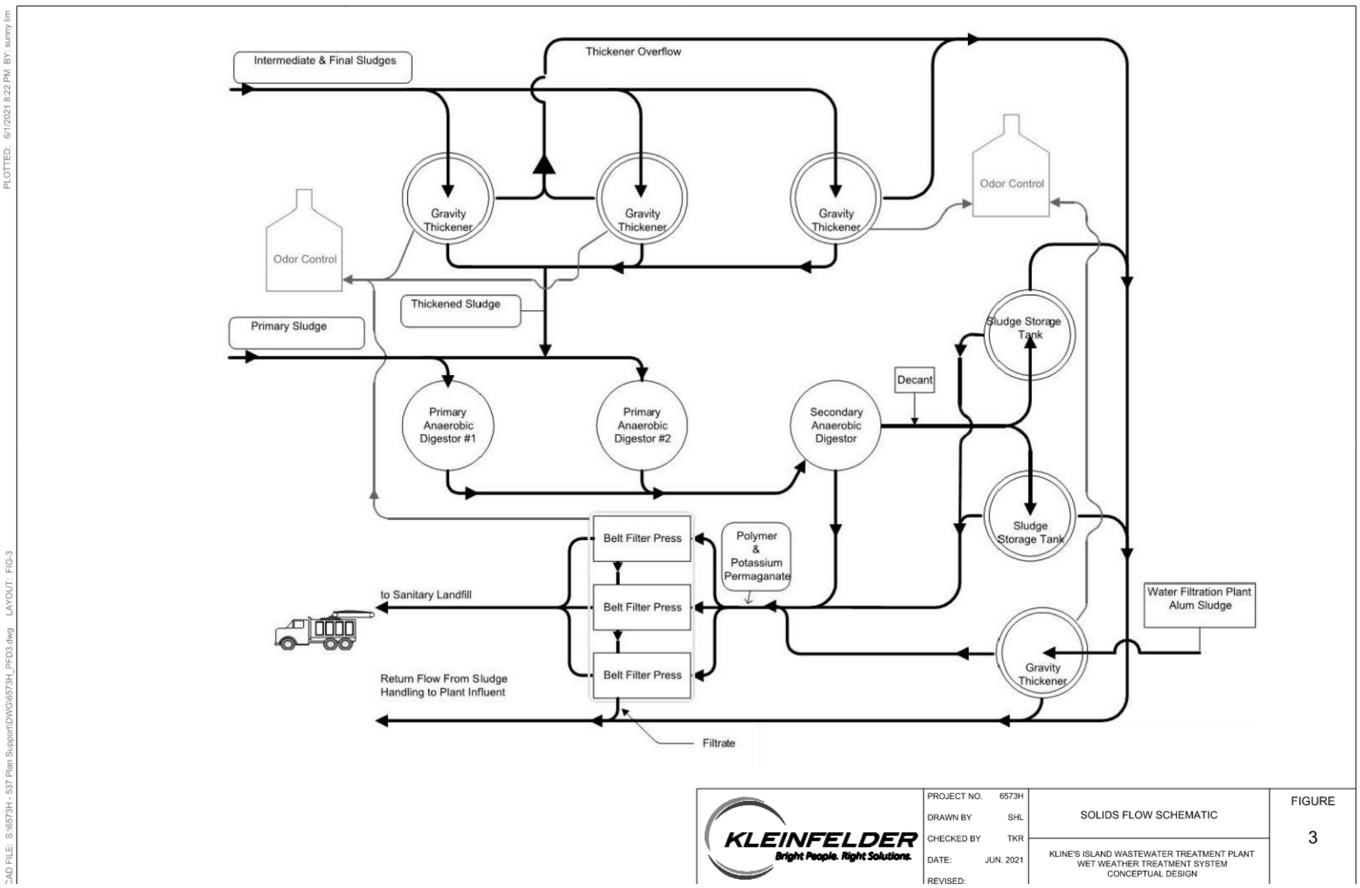
Figure 2 which follows is a more detailed wastewater flow schematic of the existing KIWWTP.

Figure 3 which also follows is a solids flow schematic of the existing KIWWTP.

Figure 1: Flow Diagram




Parshall Flume
Sludge Handling Return
Oxygen Addition
Influent
40 MGD
Avg. Design
Bar Rack
Pump Station
Venturi Meter
Aerated Grit Chamber
Primary Sedimentation
Primary Sedimentation
Primary Sedimentation
Primary Sedimentation
Bypass Outfall
003
(Area Velocity Meter)
Little Lehigh River
Venturi Meter
RMTF Recycle
Rock Media
Trickling Filters
- Nitrification
Intermediate Sedimentation
Intermediate Sedimentation
Intermediate Sedimentation
Odor Control
Odor Control
Odor Control
Plastic Trickling Filters - Carbonaceous
Plastic Trickling Filters - Carbonaceous
Plastic Trickling Filters - Carbonaceous
Plastic Trickling Filters - Carbonaceous
Intermediate Pumping Station
Final Sedimentation
Venturi Meter
Recycle
Bypass Outfall 002
Effluent Sampling Location
Parshall Flume
Lehigh River
Outfall 001
Lat 40°36"07'
Long 75°27"11'
Chlorine Contact Tank
Final Effluent Pump Station
Stormwater Lift Station
KLEINFELDER
Bright People. Right Solutions.
PROJECT NO. 6573H
DRAWN BY SHL
CHECKED BY TKR
DATE: JUN. 2021
REVISED:
WASTEWATER FLOW SCHEMATIC
KLINE'S ISLAND WASTEWATER TREATMENT PLANT
WET WEATHER TREATMENT SYSTEM
CONCEPTUAL DESIGN
FIGURE
2



As reported in the Kline's Island Wastewater Treatment Plant Evaluation of Increase in Peak Flow Capacity report dated October 2020, there were a total of thirteen (13) activations of Outfall 003 between August 2011 and May 2020, with the maximum duration of activation during this period being 23.5 hours and the average duration of activation being 7.0 hours.

Outfall 002 is an emergency bypass around the RMTFs, final settling tanks and CCT. There are several valves that isolate the individual treatment processes from the outfall line. This outfall has not been used since 1999.

The Lehigh River is a tributary to the Lower Delaware River (LDR), which was designated by the Delaware River Basin Commission (DRBC) as Special Protection Waters (SPW) in January 2005. The goal of the SPW designation is to ensure that No Measurable Change (NMC) occurs to the existing water quality of the LDR, as defined by the in-stream concentration of numerous parameters, measured during the summer of 2004. The SPW regulations do not apply to the loads that existed in 2004, only to the additional loads above the loads that existed in 2004. Therefore, the KIWWTP loads that existed in 2004 are "grandfathered" in and exempt from the SPW regulations. However, the term "Grandfathered" is no longer utilized by DRBC.

SPW regulations apply to all proposed new dischargers and to existing dischargers when the facility undergoes “substantial alterations or additions,” except those improvements intended solely to address wet-weather flow issues are excluded from triggering these requirements.

3.0 NPDES PERMIT EFFLUENT LIMITS

The KIWWTP is authorized to discharge treated effluent to the Lehigh River in accordance with National Pollutant Discharge Elimination System (NPDES) Permit No. PA-0026000. The key effluent limitations stipulated by the NPDES permit are presented in Table 1.

As described in Part A of the NPDES permit, the effluent limits presented in Table 1 were determined by the Pennsylvania Department of Environmental Protection (PADEP) using an effluent discharge rate of 40 mgd.

Table 1: KIWWTP Key NPDES Permit Effluent Limits

Parameter	Monthly Average Effluent Limit	Weekly Average Effluent Limit	Instantaneous (Daily) Maximum Effluent Limit
Flow	(1)	(1)	(1)
$CBOD_5$	20 mg/L & 6,672 lbs/day	30 mg/L & 10,008 lbs/day	40 mg/L
TSS	30 mg/L & 10,008 lbs/day	45 mg/L & 15,012 lbs/day	60 mg/L
NH_3 (5/1 – 10/31)	5 mg/L & 5,004 lbs/day	-	10 mg/L
NH_3 (11/1 – 4/30)	15 mg/L	-	30 mg/L
Fecal Coliform (5/1 – 9/30)	200/100 ml geometric mean (2)		
Fecal Coliform (10/1 – 4/30)	2,000/100 ml geometric mean		
Residual Chlorine	0.5 mg/L	-	1.0 mg/L
pH	6.0 to 9.0 SU		
Dissolved Oxygen	5.0 mg/L minimum		

(1) Flow is not a regulated parameter, requiring only continuous monitoring.
(2) Not more than 10% of the samples shall have a fecal coliform concentration greater than 1,000/100 ml.

4.0 WET-WEATHER TREATMENT SYSTEM CONCEPT DESIGN

The wet-weather treatment system concept design is presented below by describing the modifications required to each existing unit process of the KIWWTP, as well as the new facilities required to implement the 132 mgd wet-weather treatment system.

4.1 Main and Auxiliary Pump Stations

The current combined firm capacity of the existing Main and Auxiliary pump stations is approximately 85 mgd, which increases to 88 mgd at the high wet well level corresponding to activation of Outfall 003.

Improvements are currently being designed to the Main and Auxiliary pump stations that will increase the firm capacity to 100 mgd. No additional Main and Auxiliary pump station improvements are required for the 132 mgd wet-weather treatment system.

4.2 Influent Screening

Coarse screening is currently being provided upstream of the Main and Auxiliary pump stations via two (2) climber-type screens with ¾-inch spacing between bars, each with a design capacity of 88 mgd. Both screens are normally in use, resulting in a combined capacity of 176 mgd. No screening improvements will be implemented as part of the current design to increase wet-weather treatment capacity to 100 mgd, because if one screen is out of service during a rare peak flow of `100 mgd, 100 mgd can be pushed through one screen without adverse consequences.

If the KRI is constructed to convey additional peak flow to the KIWWTP to contribute to a peak flow of 132 mgd, the potential need for screening of the KRI will be addressed as part of the separate KRI project which is not included in this concept design.

Included in the budgetary cost estimate for this project, is the cost of a 20 mgd screening system for flow from the Park Pump Station Force Main Extension which will terminate on the KIWWTP site just upstream of the aerated grit chambers. This screening system is shown in the Figure 1 Flow Diagram.

4.3 Grit Removal

The KIWWTP has two (2) aerated grit chambers that are each 52 feet long, 18 feet wide, and 12 feet deep, resulting in a combined volume of approximately 168,000 gallons.

Aerated grit chambers are sized to achieve a minimum acceptable hydraulic detention time (HDT) at peak flow. The PADEP Domestic Wastewater Facilities Manual (DWFM) does not specifically present sizing/design parameters for aerated grit chambers. The Metcalf & Eddy (M&E) Wastewater Engineering Textbook recommends an HDT of 2 to 5 minutes at peak hourly flow.

For the project currently being designed to increase the wet-weather treatment capacity to 100 mgd, the HDT at 100 mgd is 2.4 minutes, which is within the range of peak flow HDTs recommended by the M&E Wastewater Engineering Textbook. Hydraulic analysis has also indicated that 100 mgd is the maximum flow that can be conveyed through the two (2) existing aerated grit chambers by gravity. Therefore, a third aerated grit chamber is proposed for the 132 mgd wet-weather improvements project. While an aerated grit chamber less than half the size of the two (2) existing aerated grit chambers would be sufficient for the additional 30 mgd of flow, to be conservative, an aerated grit chamber of the same size as the two (2) existing aerated grit chambers is recommended. The proposed additional aerated grit chamber is shown on the Figure 1 flow diagram and in the aerial site plan presented as Drawing 1 in Appendix A.

Liquid oxygen is currently fed to influent wastewater upstream of the aerated grit chambers to prevent odor generation in the aerated grit chambers. Because peak wet-weather flows will occur infrequently and will be of short duration, it is anticipated that additional oxygen will not need to be fed to the influent flow during these infrequent events to prevent odor generation.

4.4 Primary Clarification

The KIWWTP has four (4) primary clarifiers, each 120 feet in diameter and 12 feet deep, resulting in a combined surface area of approximately 45,239 sf.

Primary clarifiers are sized to achieve certain specific surface overflow rates (SORs) at average and peak flow. SOR is the flow rate per square foot of tank surface area expressed in gpd/sf.

While outdated publications present guidelines for weir loading rates, the M&E Wastewater Engineering Textbook states that "weir loading rates have little effect on the efficiency of primary sedimentation tanks and should not be considered when reviewing the appropriateness of clarifier design." Therefore, the primary clarifier capacity assessment will consider SOR only.

The DWFM recommends that the SOR at peak flow should not exceed 2,500 gpd/sf (including recirculation flows). The M&E Wastewater Engineering Textbook recommendation is an SOR of 2,000 to 3,000 gpd/sf at peak flow.

Based on the DWFM peak flow SOR of 2,500 gpd/sf, the peak flow capacity of the four (4) existing primary clarifiers is 113 mgd. However, the gravity conveyance capacity between the aerated grit chambers and existing primary settling tanks is approximately 100 mgd, which effectively restricts the peak flow capacity of the existing primary clarifiers to 100 mgd. Therefore, to achieve a peak flow primary treatment capacity of 132 mgd, 32 mgd of additional peak flow capacity is required.

Due to site constraints, it is not possible to construct additional primary clarifiers that are 120 feet in diameter; rather, the largest diameter primary clarifiers that can be constructed are 84 feet in diameter. Based on the high level of performance of the existing primary clarifiers as documented in the KIWWTP Hydraulic Design Capacity Evaluation dated December 2020, and the fact that PADEP has in other instances accepted sizing criteria that exceed the DWFM recommendation based on widely utilized technical sources such as the M&E Wastewater Engineering Textbook, it is reasonable to conclude that a peak flow SOR of 3,000 gpd/sf will be acceptable for the additional wet-weather primary clarifiers, particularly considering that CEPT can be expected to significantly increase the TSS and BOD removal efficiencies of the primary clarifiers.

At an SOR of 3,000 gpd/sf, two (2) one 84-foot-diameter primary clarifier has a peak flow capacity of 32.2 mgd.

The location of the two (2) additional wet-weather primary clarifiers is presented on the conceptual site plan, which is Drawing 1 in spandex and in the Figure 1 flow diagram.

Flow to the existing and new primary clarifiers will be controlled via a new flow diversion chamber such that approximately 100 mgd will be conveyed to the existing primary clarifiers and approximately 30 mgd to the new primary clarifiers.

The flow diversion structure will be passive and will simply divert flow into the new primary clarifiers via an overflow weir as the water surface level increases to the point that 100 mgd is being conveyed to the existing primary clarifiers. However, the overflow weir will be adjustable rather than fixed.

Approximately 100 mgd of primary effluent from the existing primary clarifiers will flow to the primary effluent pumping system located in the Intermediate Pump Station (IPS). The existing primary effluent pumps will be replaced as part of the current design to increase peak flow capacity to 100 mgd. The new pumps will provide a capacity of 100 mgd with all pumps in service and approximately 92 mgd with one pump out of service.

Approximately 32 mgd of flow from the new wet-weather primary clarifiers will be directed to the new supplemental primary effluent pumping station. As shown in the conceptual process flow diagram in Appendix A (Drawing 2), the concept design includes an interconnection between the wet well of the existing primary effluent pumping system and the wet well of the supplemental primary effluent pumping system. This will provide operational resiliency and flexibility, such that if one of the primary effluent pumps in the IPS is out of service for maintenance during a storm event (which will reduce the capacity of the IPS primary effluent pumping system to 92 mgd), approximately 8 mgd of the 100 mgd of flow from the existing primary clarifiers could be directed to the supplemental primary effluent pumping station. To enable this redundancy, the supplemental primary effluent pump station will be sized for 32 mgd plus 10 mgd, i.e., 42 mgd.

Following the severe storm event, sludge that settles in the new primary settling tanks will flow through a tank drain (after the drain valve is opened) that will tie into the drain system of the existing primary settling tanks, which leads to an existing pumping system that will pump the sludge into the existing primary distribution box for settling in the existing primary clarifiers and subsequent pumping to the anaerobic digesters.

The existing primary clarifiers are covered and vented to an odor control system to prevent odor release from the primary clarifiers. Because the supplemental primary clarifiers will be utilized only once or twice per year and will be receiving dilute influent wastewater, the relatively small amount of primary sludge that settles in the supplemental primary clarifies should be readily drainable in sufficient time to prevent odor generation. However, having covers would avoid the nuisance accumulation of precipitation in the supplemental primary clarifiers. It is recommended that a final decision on whether to provide covers for the supplemental primary clarifiers be deferred to the preliminary design phase of the project.

4.5 Existing Primary Effluent Pumping System

The existing primary effluent pumping system is in the IPS and consists of five (5) Johnston two-stage vertical turbine type pumps rated for 15,000 gpm at 44 feet of total dynamic head (at pump bowl) operating at 880 rpm with 200 HP motors. Three (3) of the five (5) pumps have variable frequency drives, and two (2) of the pumps are constant speed. As noted above, these pumps will be replaced with new pumps as part of the project currently being designed to increase KIWWTP wet-weather capacity to 100 mgd. With all five (5) of the new pumps in operation, the capacity will be nominally greater than 100 mgd, and with one (1) pump out of service, the capacity will be approximately 92 mgd.

No additional improvements to the primary effluent pumping system beyond the improvements that will be implemented as part of the 100 mgd peak flow project will be required to increase the KIWWTP's wet-weather treatment capacity to 132 mgd.

However, to help ensure a reliable wet-weather capacity of 132 mgd, the supplemental primary effluent pump station will be sized to pump an additional 10 mgd of flow to compensate for the scenario that one (1) of the primary effluent pumps is out of service for maintenance during a severe storm event. If a primary effluent pump is out of service for maintenance, 92 mgd would be pumped to the PMTF by the primary effluent pumps in the IPS, and 40 mgd would be pumped by the supplemental primary effluent pumping station to the RMTFs.

4.6 Supplemental Primary Effluent Pumping System

As noted above, during a 132 mgd flow event, a new supplemental primary effluent pumping station will normally convey 32 mgd of primary effluent to the RMTF if one (1) primary effluent pump in the IPS is out of service resulting in a capacity of 92 mgd, the supplemental primary effluent pump station will pump 40 mgd to the RMTFs, or if one (1) PMTF effluent pump is out of service for maintenance, it will pump 40 mgd to the RMTFs, rather than 32 mgd.

As further described in Section 4.8, if one of the PMTFs is out of service during a 132 mgd peak flow, the capacity of the PMTFs will be reduced to 90 mgd. If this occurs, an additional 10 mgd of primary effluent will be pumped by the PMTFs by the supplemental primary effluent pump station.

The conceptual location of the new supplemental primary effluent pumping station is shown on the conceptual aerial site plan in Appendix A (Drawing 1) and in the Figure 1 flow diagram.

A total of two (2) low-lift propeller type pumps are proposed, one (1) operating and one (1) standby. Each pump will have a capacity of 42 mgd with 175 HP motors, resulting in a firm capacity of 42 mgd.

4.7 Plastic Media Trickling Filters

The PMTFs do not require modification. As previously described, during wet-weather events, the PMTFs will receive and provide biological treatment for 100 mgd of primary effluent from the primary effluent pumps located in the IPS.

4.8 Plastic Media Trickling Filter Effluent Pumping System

The PMTF effluent pumping system consists of the same five (5) Johnston pumps as originally installed for the primary effluent pumping system. As part of the project currently being designed to increase the wet-weather treatment capacity of the KIWWTP to 100 mgd, a trickling filter paralleling line will be implemented as described below.

In 1998, a new 48-inch line to the ISTs was constructed parallel to the 54-inch PMTF effluent force main. During construction of the 48-inch line to the ISTs, a temporary bypass line was constructed to route PMTF effluent directly to the final settling tanks from the 48-inch line. Although the temporary bypass line was subsequently removed, two (2) tee connections, one (1) located on the 48-inch line near the RMTFs and the other located on the 60-inch RMTFs effluent line near FC -7 and 8, were not removed, but rather left in place with blind flanges to enable future connections. As part of the project currently being designed to increase the wet-weather treatment capacity to 100 mgd, these two (2) tee connections will be reused by interconnecting with a 48-inch pipe to divert a portion of the PMTF effluent to the final clarifiers and a portion directly to the final setting tanks. A new valve will be installed in the 48-inch line for isolation and flow control with all five (5) PMTF effluent pumps in operation. The capacity will be nominally greater than 100 mgd, of which approximately 50 mgd will flow through the ISTs and the remaining 50 mgd will flow through the 48-inch bypass line to the final settling tanks. This trickling filter paralleling line does not require modification for the increase in wet-weather treatment capacity to 132 mgd. However, the IST effluent will be temporarily routed directly to the chlorine contact tank, rather than to the RMTFs, as further described in Section 4.9.

Under the unlikely scenario that one (1) of the PMTF effluent pumps is out of service for maintenance during a severe wet-weather event, the pumping capacity will be reduced to approximately 90 mgd, of which approximately 45 mgd will be directed to the ISTs and the remaining 45 mgd will pass through the 48-inch bypass line to the final settling tanks. During this unlikely scenario, the supplemental primary effluent pumping system can pump an additional 10 mgd of primary effluent to the RMTFs for biological treatment.

4.9 Intermediate Settling Tanks

There are three (3) existing intermediate settling tanks each 138 feet in diameter with a sidewall depth of 12 feet. The combined surface area of the three (3) ISTs is 44,870 sf. As previously described, during a severe wet-weather event, the existing ISTs will temporarily serve as final settling tanks for approximately 50 mgd of flow that will be routed directly to the CCT for disinfection following clarification in the ISTs. The IST SOR based on a 50 mgd flow and total surface area of 44,870 sf is 1,100 gpd/sf, which is below the DWFM peak flow SOR of 1,200 gpd/sf for trickling filter final clarifiers.

There are no IST modifications required for the increase in wet-weather treatment capacity to 132 mgd. However, as previously described, during a severe wet-weather event, approximately 50 mgd of clarified IST effluent will be routed directly to the CCT via the Outfall 002 pipeline. To prevent the IST effluent from being discharged into the Lehigh River, an existing valve along the Outfall 002 pipeline will need to be closed, and to allow IST effluent to be diverted into the Outfall 002 pipeline, an existing valve will need to be opened. To facilitate the opening and closing of these two (2) existing valves, motorized actuators will be installed for both valves. No other modifications are required.

4.10 Rock Media Trickling Filters

The existing RMTFs do not require modification for the increase in wet-weather treatment capacity to 120 mgd. As previously described, during severe wet-weather events, the RMTFs will receive and provide biological treatment for approximately 32 mgd of primary effluent from the proposed supplemental primary effluent pumping station.

4.11 Final Clarifiers

There is a total of ten (10) existing final clarifiers with varying diameters and a combined surface area of 80,020 sf. Based on the DWFM SOR recommendation of 1,200 gpd/sf at peak hourly flow, the corresponding peak flow capacity is 96 mgd. As previously described, during the 1132 mgd peak wet-weather flow, a total flow of approximately 82 mgd will be directed to the final clarifiers. Modifications to the final clarifiers are not required.

4.12 Chlorine Contact Tank

The KIWWTP has one (1) CCT, 194 feet by 83 feet and 11 feet deep, resulting in a volume of 1,324,900 gallons.

The DWFM recommends a contact time of 15 minutes at peak hourly flow. Based on the CCT volume of 1,324,900 gallons, the contact time at 132 mgd is 14.45 MINTUES, which is nominally less than 15 minutes. However, disinfection performance is not just related to contact time, but rather the combination of contact time and sodium hypochlorite dose. Therefore, the 14.45-minute contact time can be compensated for by increasing the sodium hypochlorite dose. This "CT" approach is standard in drinking water disinfection and is also recommended for wastewater disinfection in the M&E Wastewater Engineering Textbook.

To calculate the required dose at a 14.45-minute contact time at a peak flow of 132 mgd, Kleinfelder used the United States Environmental Protection Agency (EPA) formula, which is based on the CT approach with fecal coliform as the bacteria to be disinfected and assumes disinfection following primary and secondary treatment during a severe wet-weather event. The calculated dose based on the EPA formula is 3.0 mg/L. Based on 12% sodium hypochlorite,

the corresponding feed rate of sodium hypochlorite is 111 gallons per hour (gph). For dechlorination, the corresponding 40% sodium bisulfite feed rate is approximately 30.4 gph.

The sodium hypochlorite feed system at the KIWWTP includes four (4) storage tanks, each with a volume of 2,550 gallons, resulting in a total storage volume of 10,200 gallons, and four (4) feed pumps, each with a capacity of 150 gph.

The sodium bisulfite dechlorination system at the KIWWTP includes two (2) storage tanks, each with a volume of 2,550 gallons, resulting in a total storage volume of 5,100 gallons, and three (3) feed pumps, each with a capacity of 33.3 gph with a total farm capacity of ~67 gph.

Considering that the 132 mgd is a short duration and infrequent event, the existing sodium hypochlorite storage and feed systems have ample capacity to deliver the required dose at a contact time of 14.45 minutes. Therefore, disinfection improvements are not required for the 132 mgd wet-weather treatment system.

4.13 Effluent Pumping System

A total of five (5) Flygt submersible propeller pumps are installed at the CCT to discharge plant effluent during flooding of the Lehigh River when gravity flow through Outfall 001 is not possible. Each pump operates at 1,185 revolutions per minute (rpm) and is rated for 13,890 gallons per minute (gpm), or 20 mgd, at 26 feet total dynamic head (TDH) and driven by a 135 HP motor. The effluent pumping capacity with all five (5) pumps in service is 100 mgd, and 80 mgd with four pumps in service. For the increase in wet-weather treatment capacity to 100 mgd, Lehigh County Authority and the City of Allentown previously decided that it was not necessary to install an additional pump due to the low probability of one pump not being available during an infrequent and short duration peak flow of 100 mgd. For the 132 mgd wet-weather treatment systems, three (3) additional effluent pumps (2+1) will be installed, each rated for 26 mgd @26 feet TDH.

4.14 Solids Handling Unit Processes

Because of the infrequent occurrence of storm events that would generate a wet-weather flow of 120 mgd, and the short duration of these events, the wet-weather treatment system will not generate significant solids. Therefore, there are no required modifications to KIWWTP's solids handling unit processes.

4.15 System Startup and Shutdown

Startup of the wet-weather treatment system will require limited operator intervention consisting of the following:

1. Opening the motor-operated isolation valve of trickling filter paralleling line system.
2. Opening the motor-operated valve to temporarily divert IST effluent into the Outfall 002 pipeline while at the same time positioning the motor-operated valve to divert flow from the Outfall 002 pipeline into the CCT.
3. Checking that the supplemental primary effluent pump station is ready for operation.

Shutdown of the wet-weather treatment system will likewise require limited operator intervention consisting of the following:

1. Closing the motor-operated isolation valve of the trickling filter paralleling line.
2. Re-positioning the two (2) motor-operated valves along the Outfall 002 pipeline.
3. Sequentially draining the two (2) new wet weather primary clarifiers by opening the tank drain valves with washdown as required.

5.0 EXPECTED PERFORMANCE AND REGULATORY REQUIREMENTS

In assessing the expected performance of the wet-weather treatment system, it is first important to recognize that wet-weather flows that exceed the current 87 mgd wet-weather treatment capacity of the KIWWTP are infrequent and short duration events, as shown in Table 2 below, which is a summary of Outfall 003 activations between August 2011 and May 2020.

Table 2: Outfall 003 Activation History

		BYPASS					PLANT		TOTAL
BYPASS DATE	OUTFALL NUMBER	REASON FOR BYPASS	DURATION	TOTAL VOLUME	PEAK MINUTE	PEAK HOUR	PEAK MINUTE	PEAK HOUR	PEAK HOUR
5/25/2020	003	Power Outage	0.58	0.1163	-	-	-	-	-
4/29/2019	003	Power Outage - Human Error	0.10	0.0039	-	-	-	-	-
11/2/2018	003	Hydraulic Capacity Exceeded	5.82	3.389	22.94	22.31	86.88	83.10	104.14
8/22/2018	003	Hydraulic Capacity Exceeded	2.13	0.3407	8.02	6.04	85.43	82.80	88.22
8/13/2018	003	Hydraulic Capacity Exceeded	4.58	1.025	9.28	8.18	84.42	82.97	90.71
8/4/2018	003	Mechanical Problem - Pumps & Hydraulic Capacity Exceeded	14.0	9.22	30.82	28.28	87.29	84.82	98.26
2/24/2016	003	Mechanical Problem - Pumps & Hydraulic Capacity Exceeded	7.75	1.181	10.76	4.25	94.11	85.41	89.16
10/29/2014	003	Mechanical Problem - Bar Screens	0.58	0.0072	-	-	-	-	-
4/30/2014	003	Mechanical Problem - Bar Screens & Hydraulic Capacity Exceeded	11.33	1.17	9.27	6.50	89.97	87.60	89.34
8/5/2012	003	Power Outage - Severe Thunderstorm	0.17	0.0144	-	-	-	-	-
9/6/2011	003	Hydraulic Capacity Exceeded - Lee	23.50	2.09	7.27	6.10	89.91	88.27	92.46
8/28/2011	003	Hydraulic Capacity Exceeded - Irene	19.25	4.66	25.82	11.75	89.91	88.61	98.16
8/13/2011	003	Mechanical Problem - Pumps	1.17	0.40	30.58	9.95	87.30	77.33	81.17

As indicated, there were a total of thirteen (13) activations between August 2011 and May 2020, four (4) of which were not due to hydraulic overload but rather due solely to mechanical problems or power outages. As also indicated, the maximum duration of any activation during this period was 23.5 hours, and the average duration of the nine (9) activations that were due in whole or in part to exceedance of hydraulic capacity was 9.8 hours.

During the prior pursuit of the blending option, it was demonstrated that blending would enable compliance with the existing effluent limits. Under the blending approach, all primary effluent flow greater than 87 mgd would be routed around the PMTFs, RMTFs and final clarifiers and would flow directly to the CCT for blending with 87 mgd of fully treated effluent.

However, unlike other state regulatory agencies in other U.S. Environmental Protection Agency regions, the PADEP would not approve blending because of PADEP's requirement for "significant biological treatment."

The requirement for "significant biological treatment" is presented in Title 25, Chapter 92a, Section 92a.47 of the Pennsylvania Code, as follows:

> ***§ 92a.47. Sewage permit.***
>
> *(a) Sewage, except that discharged from a CSO that is in compliance with subsection (b), or as provided for in subsections (f)—(i), shall be given a minimum of secondary treatment. Secondary treatment for sewage is that treatment that includes significant biological treatment and accomplishes the following:*
>
> *(1) Monthly average discharge limitation for BOD_5 and TSS may not exceed 30 milligrams per liter. If $CBOD_5$ is specified instead of BOD_5 the limitation may not exceed 25 milligrams per liter.*
>
> *(2) Weekly average discharge limitation for BOD_5 and TSS may not exceed 45 milligrams per liter for POTW facilities. If $CBOD_5$ is specified instead of BOD_5 the limitation may not exceed 40 milligrams per liter.*
>
> *(3) On a concentration basis, the monthly average percent removal of BOD_5 or $CBOD_5$, and TSS, must be at least 85% for POTW facilities.*

"Significant biological treatment" is defined in the definition section 92a.2 as "the use of an aerobic or anaerobic biological treatment process in a treatment works to consistently achieve a 30-day average of at least 65% removal of BOD_5."

SIGNIFICANT BIOLOGICAL TREATMENT

As described above, "significant biological treatment" is defined in the definition section 92a.2 as "the use of an aerobic or anaerobic biological treatment process in a treatment works to consistently achieve a 30-day average of at least 65% removal of BOD_5."

PADEP has recently clarified that for the parallel Trane system, separate monitoring of the Plastic Media and Rock Media trickling filters will not be required, and that performance will be evaluated in the same manner as it is on dry days under series operation.

OVERVIEW OF PARALLEL TRANE BIOLOGICAL TREATMENT AT 132 MGD

100 mgd will receive screening, grit removal, primary treatment, and biological treatment in the plastic media trickling filters (PMTFs) with 50 mgd of PMTF effluent clarified in the intermediate settling tanks (ISTs) and 50 mgd in clarified in the final settling tanks FSTs), thus resulting in a lower Surface Overflow Rate (SOR) and thus improved settling of trickling filter solids than when operating in series.

32 mgd will receive screening, grit removal and, primary treatment and biological treatment in the rock media trickling filters (RMTFs) with settling of RMTF solids in the FSTs.

TEXTBOOK BOD LOADING CAPACITY (M&E WASTEWATER ENGINEERING, 4TH EDITION)

The M&E Wastewater Engineering Textbook presents design and sizing criteria for a wide range of treatment processes, the objective of which is to establish a basis under which the treatment process will perform as intended. In the case of biological treatment processes for BOD removal, the intent is to provide significant removal of BOD. The BOD loading capacities of the PMTFs and RMTFs based on the criteria presented in the M&E Wastewater Engineering Textbook are presented below.

PMTFs: 62,329 pounds per day (ppd)
RMTs: 51,887 ppd

WET WEATHER WASTEWATER CHARACTERISTICS

Severe peak wet-weather flows are of short duration: the average duration of peak flow discharged through outfall 003 during severs storm event is less than 10 hours.

As presented in the table below, BOD concentrations are dilute during a severe storm event. The Table below present daily average BOD concentration data through the plant during the three (3) days surrounding the highest recent peak flow to the KIWWTP which was a peak flow of 104.4 mgd on November 2, 2023.

Date	24-hour Flow	Peak Flow	INF CBOD	PRI CBOD	IST CBOD	EFF CBOD
11-2-2018	35.7 mgd	82.2 mgd	141	86	23	7
11-3-2018	71.16 mgd	79.6 mgd	78	76	26	7
11-4-2018	45.1 mgd	50.7 mgd	110	71	35	4

As shown in above table, the highest 24-hour average flow resulting from this storm was 82.2 mgd on 11-2-2018.The resulting ratio of peak hourly flow to daily average flow was 1.27. On this day, the primary effluent BOD concentration was 86 mg/L and the IST effluent BOD concentration resulting from treatment; by the PMTFs and IST was 23 mg/L, and the RMTF together with the FST further reduced the Effluent BOD concentration to 7 mg/l, resulting in a combined BOD percent removal of 92%. The corresponding BOD load removed was 58,957 pounds, which is substantially less than the combined capacity of the PMTF and RMTF to remove BOD.

ANALYSIS

WET-WEATHER WASTEWATER CHARACTERISTICS AT 132 MGD WITH A CONSERVATIVE POTENTIAL 10,000 PPD LOAD SHIFT FROM THE PRETREATMENT PLANT (PTP)

Compared to the wet-weather characteristics resulting from the peak hourly flow of 104.4 mgd, at a future peak hourly flow of 132 mgd, the BOD concentration will be further diluted by the additional nearly 30 mgd of infiltration and inflow that would occur at 132 mgd compared to 104.4 mgd. It is also reasonable estimate the peak daily 24 hour average flow corresponding to a peak hourly flow of 132 mgd by using the 1.27 peaking factor described above. The resulting 24 hour average flow corresponding to a peak hourly flow of 132 mgd is 104 mgd which will be rounded to 110 mgd for conservatism. At 110 mgd, the primary effluent BOD concentration of 86 mg/L will be significantly diluted by the 24 hour average flow of 110 mgd compared to the 82.2 mgd presented in the table above. However, the 10,000 ppd load shift from the Pretreatment Plant (PTP) at a flow of 110 mgd will add a BOD concentration of 11 mg/L which will be conservatively assumed to offset the additional dilution occurring at 110 mgd, thus resulting in a primary effluent BOD concentration of 86 mg/L at a 24 hour average flow of 110 mgd.

However, the current plan to add chemically enhanced primary treatment (CEPT) to the KIWWTP will reduce the primary effluent BOD concentration by 20% resulting in BOD concentration of 71 mg/L.

At a 24 hour average flow of 110 mgd, 100 mgd will be treated by the PMTFs and 10 mgd will be treated by the RMTFs.

Based on the estimated primary effluent BOD concentration of 71 mg/L, the 100 mgd of flow treated by the PMTFs corresponds to a BOD load of 59,214 pounds which is less than the PMTF BOD loading capacity of 62,529 ppd, and the 10 mgd of flow treated by the RMTFs corresponds to BOD load of 5,921 pounds which is less than the 51,887 BOD loading capacity of the RMTFs. Therefore, because the BOD loads to the PMTF and RMTF were below the BOD loading capacity of the PMTFs and RMTFs, significant biological treatment will be achieved.

It is also noted that under the highly unlikely scenario that a peak hourly flow of 132 mgd results in 24 hourly average flow of 130 mgd, the PMTFs would continue to receive 100 mgd but the RMTFs would receive 30 mgd. While the BOD concentration at 130 mgd would be further diluted, conservatively assuming that it remains 71 mg/L, and the RMTF BOD load at 30 mgd and a BOD concentration of 71 mg/L, would be 17,764 ppd, which is significantly less than the BOD loading capacity of the RMTFs.

CONCLUSION

Based on the analysis presented above, the parallel Trane wet weather system will provide significant biological treatment during a storm event that generates a peak flow of 132 mgd and with the 10,000 ppd load shift from the PTP.

6.0 BUDGETARY CAPITAL COST ESTIMATE

A budgetary capital cost estimate was developed in 2022 dollars based on the following:

- Major equipment costs utilizing budgetary quotes from 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.
  - Yard piping and buildings.
- Typical percentages for: site work, electrical, and instrumentation and control (I&C) based on the nature of the upgrades and Kleinfelder's experience.
- Contractor overhead and profit of 22%, which includes mobilization, demobilization and contractor general conditions.
- Contingency of 330% to reflect a pre-design planning level of accuracy.
- Design, permitting and construction administration costs of 15%.

Based on the cost estimating methodology described above, the budgetary capital cost estimate is consistent with an American Association of Cost Estimating (AACE) Level 5 estimate, which is the appropriate level for the study phase of a project.

The table on the following Section 7.0 presents the budgetary capital cost estimate. As indicated, the budgetary capital cost estimate is approximately $40 million. As previously described, this cost estimate does not include the KRI or the Park Pump Station Force Main Extension.

7.0 SYSTEM ATTRIBUTES

The key attributes of the wet-weather treatment system described in this concept design memorandum are listed below.

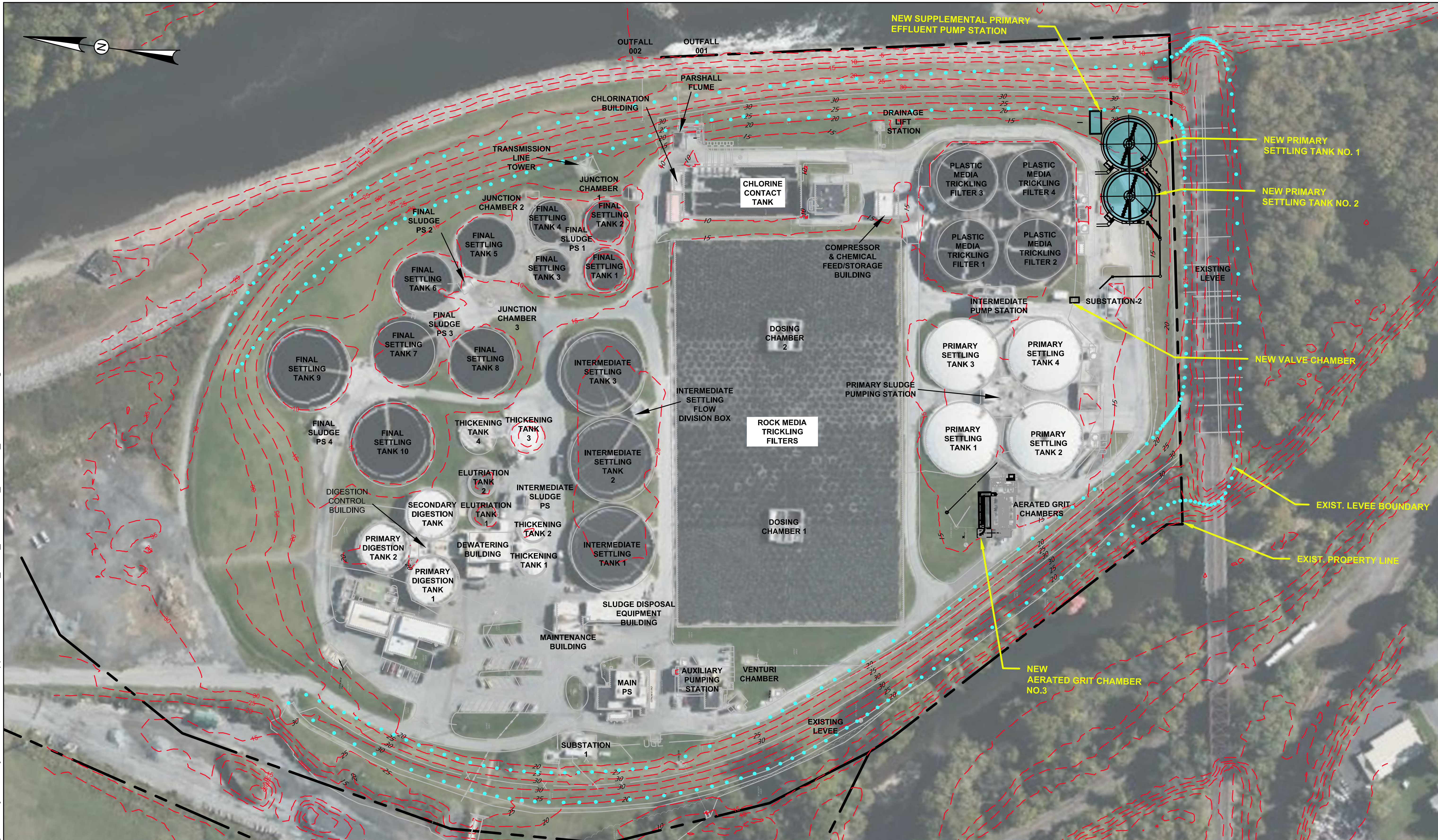
1. The wet-weather treatment system utilizes the existing treatment processes with which the plant staff are familiar, which avoids the need to be trained and periodically re-trained on new treatment processes that may only be used once per year.
2. Chemicals are not required.
3. System startup is relatively simple and quick, requiring only the re-positioning of three (3) motor-operated valves and verifying that the supplemental primary effluent pump station is ready for operation.
4. System shutdown is relatively simple, requiring the re-positioning of three (3) motor-operated valves and draining the two (2) new primary clarifiers.

KIWWTP 132 mgd parallel trane Wet Weather Treatment System Level 5 Capital Cost Estimate August y 2024					
Item/Description	***Quantity***	***Unit/Basis***	***Unit Budgetary Cost***	***Item Budgetary Cost***	***Comments***
Major Equipment & Systems					
5' Sluice Gate	1	EA	$24,000	$ 24,000	Quote from Redvalve
6-inch Slide Gate with spindle and handwheel	1	EA	$5,400	$ 5,400	Quote from Redvalve
Influent screen for Park Pump station with washer/compactor	2	EA	$165,000	$ 330,000	Quote from Manufacturer
Influen/effluent isolation gates	4	EA	$24,000	$ 96,000	Quote from Manufacturer
Tideflex Mixing Assembly	1	EA	$23,000	$ 23,000	Quote from Manufacturer
Monorail & Support System	1	EA	$90,000	$ 90,000	Quote from Manufacturer
Davit Crane & Base	1	LS	$23,000	$ 23,000	Quote from Manufacturer
New Blower Equipment	2	EA	$34,200	$ 68,400	Quote from Manufacturer
Primary Settling Tank Equipment, 84 ft diameter	2	EA	$204,000	$ 408,000	Quote from Envirodyne
Influent Adjustable Weir	2	EA	$28,750	$ 57,500	Quote from Manufacturer
Ductile Iron Pipe 36" dia., Push Joint	100	LF	$230	$ 23,000	Quote from Manufacturer
6-inch Ductile Iron - Glass Lined Piping and Fittings	150	LF	$55	$ 8,280	Quote from Manufacturer
60" DI Butterfly Valve, Motor Operated	2	EA	$60,000	$ 120,000	Quote from Manufacturer
Motor Operated Scum Mixer	2	LS	$12,000	$ 24,000	Quote from Manufacturer
Full Port DIP Plug Valve, 6-inch	4	EA	$6,900	$ 27,600	Quote from Manufacturer
Ultrasonic level sensor	2	EA	$3,960	$ 7,920	Quote from Manufacturer
6-inch Ductile Iron - Glass Lined	700	LF	$55	$ 38,640	Quote from Manufacturer
Full Port DIP Plug Valve, 6-inch	2	EA	$6,900	$ 13,800	Quote from Manufacturer
New propeller pump and motor with VFD to feed RMTF	3	EA	$255,000	$ 765,000	KSB quote
New discharge check and motorized BFV	3	LS	$90,000	$ 270,000	Estimate
New 60-inch motorized BFVs for RMTF bypass	2	EA	$56,400	$ 112,800	Estimate
Line tappings w/bypass	4	EA	$40,250	$ 161,000	Estimate
Valve chambers w/motor operated valves	3	EA	$42,000	$ 126,000	Estimate
Flow measuring @IST influent weir	3	EA	$12,000	$ 36,000	Estimate
Bypass pumping	1	LS		$ 200,000	Estimate
New effluent pumps with motors, VFD and controls	3	EA	$ 317,000	$ 951,000	Quote from KSB
New expansion joints	3	EA	$ 28,000	$ 84,000	Quote from Manufacturer
New tilted disc check valves	3	EA	$50,000	$ 150,000	Quote from Manufacturer
New motorized discharge gate valve	3	EA	$55,000	$ 165,000	Quote from Manufacturer
Valves, fittings, misc. piping and accessories @15%				$ 661,401	
Subtotal				*$ 5,070,741*	
Installation	25%			$ 1,267,685	
Major Equipment & Systems Subtotal				***6,338,426***	
Unit Price & Other Items					
AGC #3 - Excavation, backfill, compaction	800	CY	$ 55	$ 44,000	
Cast-in-Place Concrete (Foundation/Flr Slabs/Columns/Beams, etc.)	450	CY	$ 1,400	$ 630,000	
PC - Excavtion, backfill, compaction	6500	CY	$ 55	$ 357,500	
Sheeting and Shoring (RS means assuming salvage)	4,000	SF	$ 15	$ 60,000	
PC concrete (combined)	1700	CY	$ 1,600	$ 2,720,000	
Valve chamber - Excavation, backfill and compaction	210	CY	$ 45	$ 9,450	
Valve chamber concrete (combined)	80	CY	$ 1,600	$ 128,000	
SPEPS - excavation/backfill and compaction	2400	CY	$ 55	$ 132,000	
SPEPS - concrete	300	CY	$ 1,600	$ 480,000	
60-inch DI pipe	980	LF	$ 1,045	$ 1,024,100	
42-inch DI pipe	160	LF	$ 660	$ 105,600	
48-inch hobas pipes	100	LF	$ 605	$ 60,500	
54-inch hobas pipes	150	LF	$ 770	$ 115,500	
60-inch hobas pipe	1100	LF	$ 1,000	$ 1,100,000	Estimate
Exavation/backfill/compaction for yard piping	20500	CY	$ 55	$ 1,127,500	
Concrete for screening building	1200	CY	$ 1,600	$ 1,920,000	
Miscellaneous concrete repair/patch work	1	LS	$ 200,000	$ 200,000	
Mobilization and Demobilization	1	LS	$ 50,000	$ 50,000	Esimate
Miscellaneous metal (grating, platforms, handrails and stairs)	1	LS	$ 250,000	$ 250,000	
Unit Price & Other Item Subtotal				***10,514,150***	
Buildings					
SPEPS	750	FT2	$ 400	$ 300,000	
Screening building	800	FT2	$ 400	$ 320,000	
Buildings Subtotal				***$ 620,000***	
Bulk Work Percentage and Other Items					
Site civil	8%			$ 1,397,806	
Electrical	18%			$ 3,145,064	
Instrumentation & Controls	5%			$ 873,629	
				$ -	
Bulk Work Subtotal				***5,416,499***	
Subtotal Direct Costs				**$ 22,889,000**	
GC Overhead and Profit	22.0%			$ 5,036,000	
Contingency	30%			$ 6,867,000	
TOTAL BUDGETARY CONSTRUCTION COST				**$ 34,792,000**	
CAPITAL Cost Esimate with 15% for Eng, Legal, admin, permittng and CA				**$40,011,000**	

APPENDIX A

CONCEPTUAL DRAWINGS

PLOTTED: 6/25/2024 4:08 PM BY: chelsey nettuno
LAYOUT: FIG-4
CAD FILE: S:\6573 - Lehigh County Authority\6573H - 537 Plan Support\DWG\Version 3_DWG_2024\6573H_132MGD_SITEPLANS.dwg



0 150 300

SCALE: 1" = 150' SCALE IN FEET

LEGEND

LEVEE BOUNDARY

PROPERTY BOUNDARY

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Bright People. Right Solutions.

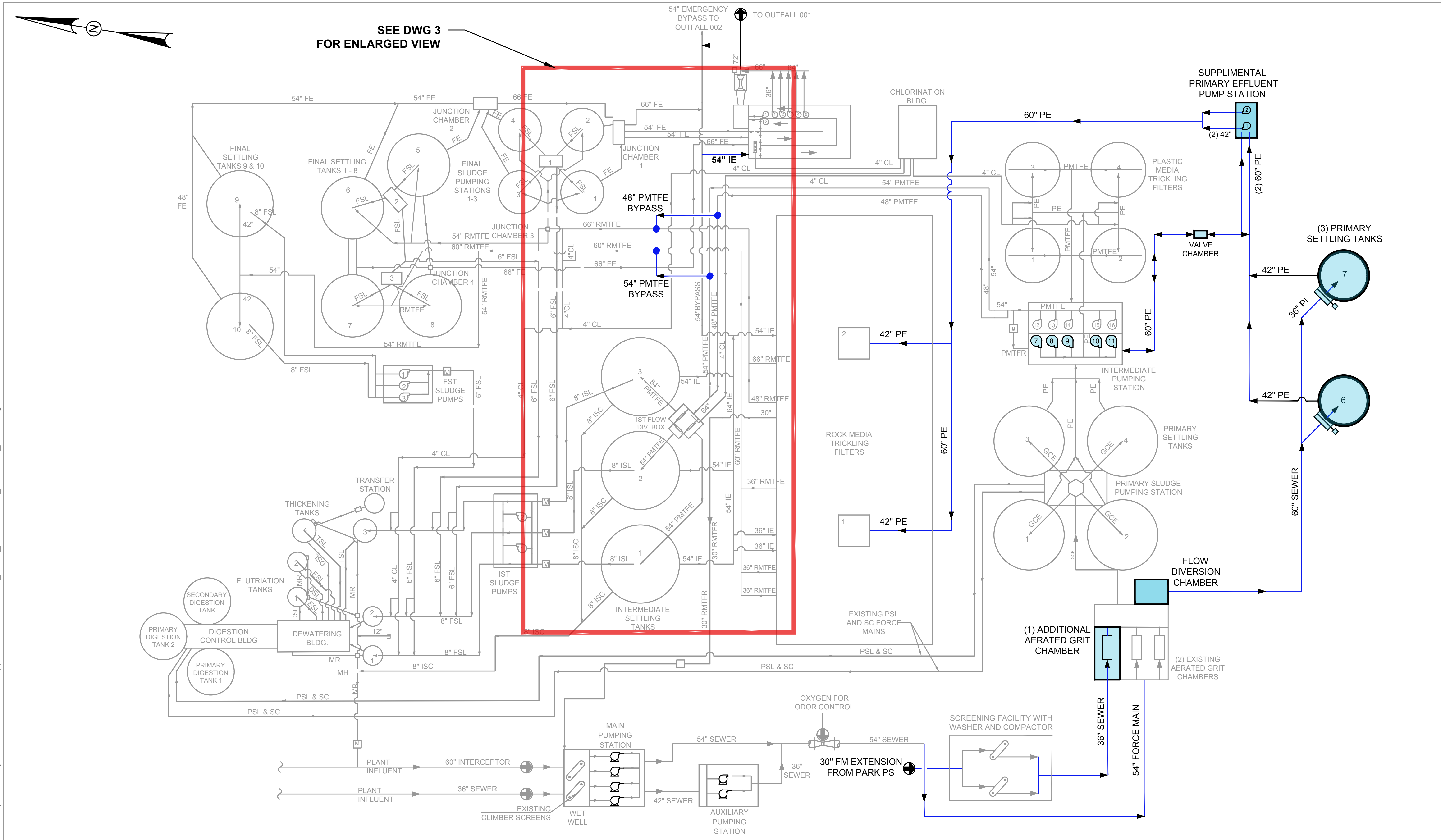
PROJECT NO.	6573H
DRAWN BY	CAN
CHECKED BY	TKR
DATE:	JUNE 2024
REVISED:	REVISION-3

SITE PLAN IMPROVEMENTS
AERIAL VIEW 132 MGD UPGRADE

KLINE'S ISLAND WASTEWATER TREATMENT PLANT
WET WEATHER TREATMENT SYSTEM
CONCEPTUAL DESIGN

DRAWING

1



LEGEND

- PROPOSED LIQUID FLOW
- EXISTING RMTFE AND PMTFE
- NEW STRUTURE/EQUIPMENTS

NOTES:

1. NEW SYSTEM AND EQUIPMENT ARE SHOWN IN BOLD.
2. THIS DRAWING IS BASED UPON ACER 1998 "AS-BUILT" DRAWINGS.
3. UTILIZE EXISTING IST AS FST DURING STORM EVENT.

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DRAWN BY	CAN
CHECKED BY	TKR
DATE:	JUNE 2024
REVISED:	REVISION - 3

OVERALL 132 MGD LIQUID STREAM PROCESS FLOW DIAGRAM

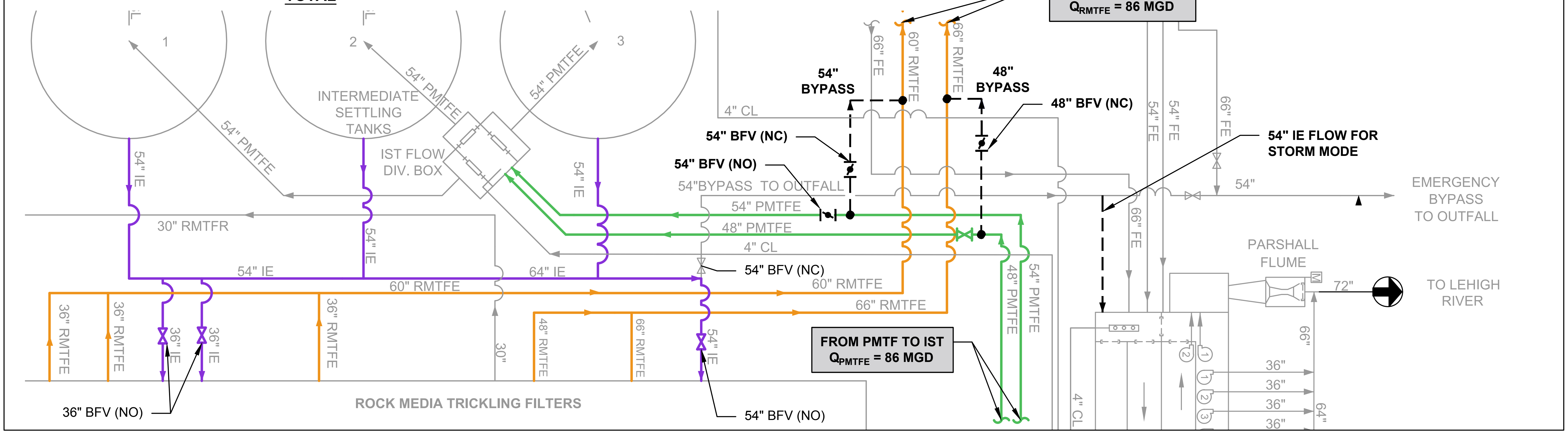
KLINE'S ISLAND WASTEWATER TREATMENT PLANT
WET WEATHER TREATMENT SYSTEM
CONCEPTUAL DESIGN

DRAWING

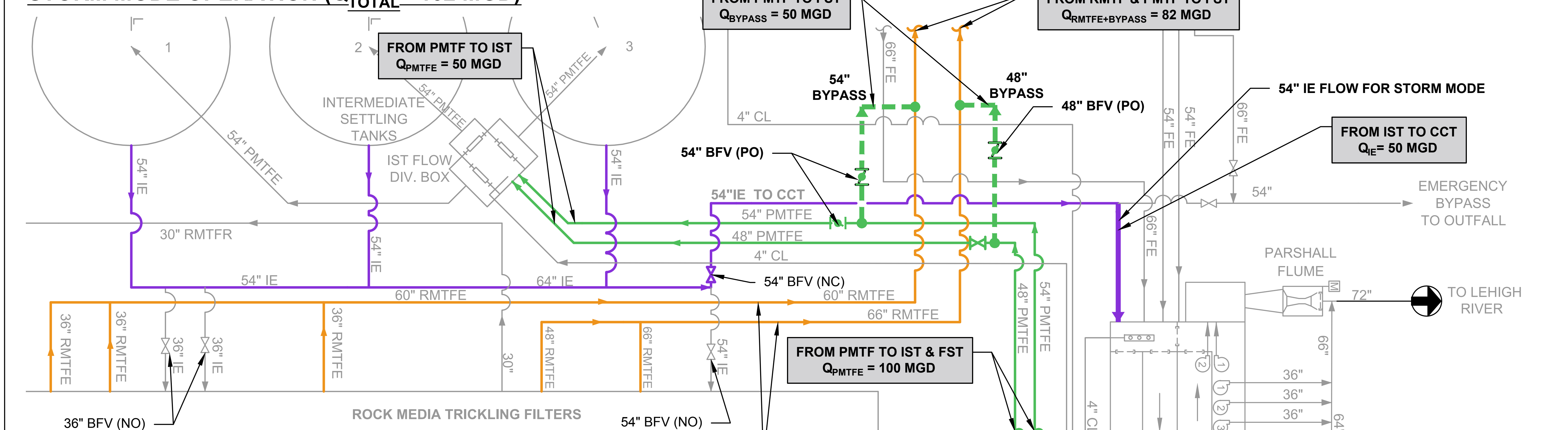
2

PLOTTED: 6/24/2024 4:01 PM BY: chelsey nettuno
LAYOUT: DWG-3
CAD FILE: S:\6573 - Lehigh County Authority\6573H - 537 Plan Support\DWG\Version 3_DWG_2024\6573H_132MGD_PFD.dwg

NORMAL OPERATION (Q_{TOTAL} = 86 MGD)



STORM MODE OPERATION (Q_{TOTAL}= 132 MGD)



FROM RMTF TO FST
Q_{RMTFE} = 32 MGD

LEGEND

PROPOSED LIQUID	PMTFE FLOW PATH
WET WEATHER BYPASS LIQUID	RMTFE FLOW PATH
EXISTING LIQUID FLOW	IE FLOW PATH
	STORM FLOW EFFLUENT

NOTES:
1. NEW SYSTEM AND EQUIPMENT ARE SHOWN IN BOLD.
2. REVISION 3 - UTILIZE EXISTING IST AS FST DURING STORM EVENT.

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REVISED:	REVISION - 3

132 MGD LIQUID STREAM - DETAIL 1
NORMAL AND STORM MODE OPERATION

KLINE'S ISLAND WASTEWATER TREATMENT PLANT
WET WEATHER TREATMENT SYSTEM
CONCEPTUAL DESIGN

DRAWING
3

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