CITY OF TAMPA

HOWARD F. CURREN AWTP PHASE 2 MASTER PLAN REPORT

FINAL DRAFT—VOLUME 1 | RFQ 15-D-00013

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TABLE OF CONTENTS

Volume 1

Executive Summary ES-1

ES.1 Purpose ES-1

ES.2 Process Improvements ES-1

ES.3 Capital Improvement Plan and Projected Costs ES-22

ES.4 Schedule for Improvements ES-23

Section 1.0 Introduction 1-1

1.1 Purpose and Background 1-1

1.2 Phase 1 Summary and Updates 1-1

1.3 Phase 2 Report Introduction 1-2

Section 2.0 Process Model Sampling and Calibration 2-1

2.1 Sampling Results 2-1

2.2 Mass Balance 2-2

2.3 Observed Yields 2-2

2.4 Model Set Up and Calibration 2-2

Section 3.0 Site Improvements 3-1

Technical Memorandum 4.0 Flow Equalization 4-1

4.1 Purpose and Background 4-1

4.2 Evaluation 4-1

4.3 Equalization Tank Design Concepts 4-5

4.4 Recommendation 4-6

Technical Memorandum 5.0 Preliminary Treatment Evaluation 5-1

5.1 Purpose and Background 5-1

5.2 Odor Control System Replacement 5-12

5.3 Improve Ventilation in Screen and Grit Building No. 2 5-34
5.4 Grit Removal 5-39
5.5 Sewage Receiving 5-45
Technical Memorandum 6.0 Primary Treatment Evaluation 6-1
6.1 Introduction 6-1
6.2. Evaluation 6-2
6.3 Alternatives Evaluation 6-14
6.4 Recommendation 6-19
6.5 Additional Primary Treatment Considerations 6-21
6.6 PSTs 1-4 Dewatering 6-26
6.7 Sludge Blanket Monitors 6-27
6.8 Recycle Stream Improvements 6-28
Technical Memorandum 7.0 BNR Process Evaluation 7-1
7.1 Purpose and Background 7-1
7.2 Design Criteria and Assumptions 7-14
7.3 Alternatives Screening 7-21
7.4 Alternatives Evaluation 7-28
7.5 Selected Core Process Enhancements 7-52
Technical Memorandum 8.0 Denitrification Filter Evaluation 8-1
8.1 Purpose and Background 8-1
8.2 Evaluation 8-2
8.3 Recommended Improvements 8-3
8.4 Capital Cost Estimate 8-4
Technical Memorandum 9.0 Disinfection Alternatives Evaluation 9-1
9.1 Purpose and Background 9-1
9.2 Current Disinfection System 9-1
9.3 Disinfection Alternatives 9-3

9.4 Alternatives Evaluation 9-16
9.5 Recommendation 9-20
9.6 Additional Disinfection Improvements 9-21
Technical Memorandum 10.0 Sidestream Treatment Evaluation 10-1
10.1 Introduction and Background 10-1
10.2 Conventional Sidestream Treatment 10-1
10.3 Deammonification 10-1
10.4 Sidestream Deammonification Process at HFC AWTP 10-8
10.5 Recommendations 10-15
Technical Memorandum 11.0 Biosolids System Alternatives Evaluation 11-1
11.1 Purpose and Background 11-1
11.2 Sludge Conditioning and Thickening 11-2
11.3 Digestion 11-5
11.4 Centralized Heating System Enhancement 11-35
11.5 Dewatering Facility 11-36
Technical Memorandum 12.0 Biogas Utilization Evaluation 12-1
12.1 Purpose and Background 12-1
12.2 Existing Conditions and Current Biogas Utilization 12-1
12.3 Treatment Alternatives Analysis 12-4
12.4 Biogas Alternatives Description 12-8
12.5 High Strength Waste 12-28
12.6 Project Delivery Alternatives 12-28
12.7 Biogas Alternatives Analysis 12-29
12.8 Recommendations 12-33
Technical Memorandum 13.0 High Strength Waste Evaluation 13-1
13.1 Purpose and Background 13-1
13.2 Available Supply 13-1

13.3 Alternative Regional Disposal Options 13-3
13.4 Anticipated Quality 13-5
13.5 Typical Tipping Fees 13-5
13.6 Potential Receiving Facility Design 13-6
13.7 Cost Summary for HSW Receiving Station 13-11
Technical Memorandum 14.0 Partial Discharge Testing 14-1
14.1 Purpose and Background 14-1
Technical Memorandum 15.0 Standby Generator Capacity Analysis 15-1
15.1 Purpose and Background 15-1
15.2 EPA Requirements for Installation of Generator Reciprocating Internal Combustion Engine 15-9
15.3 Standby Power Capacity Analysis – Fuel Storage Capacity 15-15
15.4 Recommendations 15-18
Technical Memorandum 16.0 Instrumentation and Controls, SCADA Automation Evaluation 16-1
16.1 Purpose and Background 16-1
16.2 Current SCADA System 16-1
16.3 SCADA System Status 16-5
16.4 Plant Control Network Review 16-7
16.5 Plant Process Modifications 16-9
16.6 Recommendations 16-11
Technical Memorandum 17.0 Regionalization Evaluation 17-1
17.1 Purpose and Background 17-1
17.2 Equipment Acquisition 17-1
17.3 Raw Wastewater 17-3
17.4 Septage 17-4
17.5 Fats, Oils, and Grease 17-5

17.6 Sludge and Biosolids 17-5

17.7 Conclusions and Recommendations 17-6

Section 18.0 Overall Process Selection and Summary of Recommendations 18-1

18.1 Preliminary Treatment 18-1

18.2 Primary Treatment 18-1

18.3 Biological Nutrient Removal 18-1

18.4 Tertiary Treatment 18-2

18.5 Disinfection 18.2

18.6 Biosolids 18-2

18.7 Biogas Utilization 18-2

18.8 Standby Power Systems 18-3

18.9 Plant Automation 18-3

Section 19.0 Capital Improvements Plan and Project Costs 19-1

19.1 Purpose and Background 19-1

19.2 Summary 19-2

19.3 Sequencing 19-3

List of Tables

Table ES.2-1 Core Process Alternatives ES-7
Table ES.2-2 Digestion Process Alternatives ES-14
Table ES.3-1 Capital Improvement Projects Totals by Process Area ES-22
Table ES.4-1 Capital Improvement Projects Totals by Planning Year ES-23
Table 1.3-1 Design Influent Flows and Loads 1-3
Table 1.3-2 Design Effluent Nutrient Concentrations 1-3
Table 4.2-1 Dry Weather Diurnal Flow Equalization 4-2
Table 4.3-1 Conceptual Cost Estimate for Flow Equalization 4-6
Table 5.1-1 Existing Design Criteria of JC1 5-4
Table 5.1-2 Advantages and Disadvantages of Aeration & Mixing Alternatives 5-9
Table 5.1-3 Conceptual Cost Estimate for Pre-Aeration System Alternative 1 5-10
Table 5.1-4 Conceptual Cost Estimate for Pre-Aeration System Alternative 3 5-10
Table 5.1-5 Estimated O&M Costs for Alternatives 1 and 3 5-11
Table 5.1-6 Alternatives Total Cost Comparison 5-11
Table 5.2.1 Summary of H_2S Concentrations at the Odor Control System 5-13
Table 5.2-2 Summary of Existing Odor Control System 5-14
Table 5.2-3 Oxidation Potential of Common Oxidants 5-19
Table 5.2-4 Advantages vs Disadvantages of Odor Control Technologies 5-21
Table 5.2-5 Estimated Operational Performance for Alternative 1 5-22
Table 5.2-6 Conceptual Capital Cost estimate for Alternative 1 5-23
Table 5.2-7 Conceptual O&M Cost Estimate for Alternative 1 5-23
Table 5.2-8 Estimated Operational Performance for Alternative 2 5-24
Table 5.2-9 Conceptual Capital Cost Estimate for Alternative 2 5-25
Table 5.2-10 Conceptual O&M Cost Estimate for Alternative 2 5-25
Table 5.2-11 Estimated Operational Performance for Alternative 3 5-26
Table 5.2-12 Conceptual Capital Cost Estimate for Alternative 3 5-27
Table 5.2-13 Conceptual O&M Cost Estimate for Alternative 3 5-27
Table 5.2-14 Estimated Operational Performance for Alternative 4 5-28
Table 5.2-15 Conceptual Capital Cost Estimate for Alternative 4 5-29

Table 5.2-16 Conceptual O&M Cost Estimate for Alternative 4 5-29
Table 5.2-17 Total Cost Comparison for Odor Control Alternatives 5-30
Table 5.2-18 Odor Control Alternatives Evaluation Matrix 5-32
Table 5.3-1 Ventilation Capacity in Screen and Grit Buildings 5-36
Table 5.3-2 Proposed Ventilation Rates for S&G Building No. 2 to Match S&G Building No. 1 5-37
Table 5.3-3 Conceptual Capital Cost Estimate for Ventilation Improvements at S&G Building No. 2 5-38
Table 5.4-1 Existing Grit Removal Tanks Design Data 5-40
Table 5.5-1 Level 1 Automation for Sewage Receiving Station 5-47
Table 5.5-2 Level 2 Automation for Sewage Receiving Station 5-48
Table 5.5-3 Level 3 Automation for Sewage Receiving Station 5-48
Table 5.5-4 Cost Estimate for Proposed Sewage Receiving Station 5-50
Table 6.2-1 PST Performance at Existing Flow Conditions: Surface Overflow Rate 6-3
Table 6.2-2 PST Performance at Existing Flow Conditions: Weir Loading Rate 6-3
Table 6.2-3 PST Removal Efficiency: Existing Flow Conditions 6-3
Table 6.2-4 PST Performance at Future Flow Conditions: Surface Overflow Rate 6-4
Table 6.2-5 PST Performance at Future Flow Conditions: Weir Loading Rate 6-4
Table 6.2-6 Removal Rates Empirical Constants 6-4
Table 6.2-7 PST Removal Efficiency – Future Flow Conditions 6-5
Table 6.2-8 PST Expansion: Surface Overflow Rate 6-8
Table 6.2-9 PST Expansion: Weir Loading Rate 6-8
Table 6.2-10 PST Expansion: Removal Efficiency 6-8
Table 6.2-11 Primary Filter Addition: Removal Efficiency 6-11
Table 6.2-12 Captivator: Removal Efficiency 6-13
Table 6.3-1 Conceptual Cost Estimate: Expansion of PSTs 6-15
Table 6.3-2 Conceptual Cost Estimate: Primary Filters 6-16
Table 6.3-3 Conceptual Cost Estimate: Captivator 6-17
Table 6.3-4 Estimated O&M Costs for Alternatives 6-18
Table 6.3-5 Alternatives Cost Comparison 6-18
Table 6.4-1 Primary Treatment Alternatives Evaluation Matrix 6-21

Table 6.5-1 Conceptual Cost Estimate: PST 1-4 Upgrades....6-23
Table 6.5-2 Conceptual Cost Estimate: PST 5-8 Upgrades....6-24
Table 6.5-3 Conceptual Cost Estimate: Primary Sludge Pump Station No. 1 Upgrades....6-25
Table 6.5-4 Conceptual Cost Estimate: Primary Sludge Pump Station No. 2 Upgrades....6-26
Table 6.6-1 Conceptual Cost Estimate: Dewatering Pump Station (PST 1-4) Addition....6-27
Table 6.8-1 Conceptual Cost Estimate: Recycle Stream Improvements....6-29
Table 6.7-1 Conceptual Cost Estimate: Sludge Blanket Monitors....6-28
Table 7.1-1 Core Process Alternatives....7-6
Table 7.2-1 Design Influent Flows and Loads....7-14
Table 7.2-2 Design Influent Flows and Loads....7-15
Table 7.2-3 Design Effluent Nutrient Concentrations and Loads....7-16
Table 7.2-4 Estimated Future PST SORs....7-18
Table 7.2-5 Design SVI for Alternatives Evaluation....7-20
Table 7.2-6 Design MLSS Concentrations for Proposed Configurations....7-20
Table 7.3-1 Core Alternatives Evaluated During Screening....7-21
Table 7.3-2 Surface Overflow Rates for Final Settling Tanks for Each Alternative....7-22
Table 7.3-3 Updated Design Maximum MLSS Concentrations....7-23
Table 7.3-4 Primary Effluent Flow Split and Aerobic SRT for Each Alternative....7-24
Table 7.3-5 pH and Effluent Nitrogen Predictions for North Reactors with Existing HPO Configuration....7-26
Table 7.3-6 Screened Alternatives....7-28
Table 7.4-1 Alternative 1 – Optimize Existing Model Results....7-30
Table 7.4-2 Alternative 1 – Optimize Existing Capital Cost Estimate....7-31
Table 7.4-3 Alternative 1 – Optimize Existing Operational Costs....7-33
Table 7.4-4 Alternative 2 - MLE In Parallel Model Results....7-35
Table 7.4-5 Alternative 2(H) – MLE in Parallel (Keep HPO) Capital Cost Estimate....7-36
Table 7.4-6 Alternative 2(H) – MLE in Parallel (Keep HPO) Operational Costs....7-39
Table 7.4-7 Alternative 2(D) – MLE in Parallel (Convert to Diffused Air) Capital Cost Estimate....7-40
Table 7.4-8 Alternative 2D - MLE in Parallel (Convert to Diffused Air) Operational Costs....7-42

Table 7.4-9 Alternative 3 – Step Feed BNR in Parallel Model Results 7-45

Table 7.4-10 Alternative 3(D) – Step Feed in Parallel (Convert to Diffused Air) Capital Cost Estimate 7-46

Table 7.4-11 Alternative 3(D) Step Feed in Parallel (Keep HPO) Operational Costs..... 7-47

Table 7.4-12 Summary of Capital and Operational Costs for the Alternatives..... 7-48

Table 7.4-13 Decision Matrix 7-51

Table 7.5-1 Oxygen Generation Life Cycle Cost Analysis 7-56

Table 8.4-1 Conceptual Cost Estimate for Denitrification Filter Improvements 8-5

Table 9.2-1 Summary of Current NPDES Permit Effluent Limitations for Chlorine Disinfection..... 9-1

Table 9.3-1 Estimated Capital and Present Worth of O&M Costs for Conversion to Sodium Hypochlorite Disinfection 9-6

Table 9.3-2 Estimated Capital and Present Worth of O&M Costs for Conversion to PAA Disinfection 9-10

Table 9.3-3 Estimated Capital and Present Worth of O&M Costs for Conversion to UV Disinfection 9-13

Table 9.3-4 Estimated Capital and Present Worth of O&M Costs for Conversion to Ozone Disinfection 9-15

Table 9.3-5 Estimated Capital and Present Worth of O&M Costs to Extend the Life of the Existing Chlorine Gas Disinfection System..... 9-16

Table 9.4-1 Disinfection Alternatives Evaluation Matrix 9-19

Table 9.4-2 Disinfection Alternatives Capital, O&M Life Cycle and Present Worth Cost Comparison 9-20

Table 9.6-1 Estimated Capital Costs for Relocation of Post-Aeration 9-21

Table 9.6-2 Estimated Cost for CCT Center Baffle Walls 9-23

Table 9.6-3 Estimated Costs to Resolve High Flow Surcharging..... 9-27

Table 10.3-1 Overview of Commercially Available Sidestream Deammonificaitons Processes 10-3

Table 10.4-1 Denitrification Filters Required Based on Nitrate Loading 10-8

Table 10.4-2 Sidestream Treatment Equipment Costs 10-8

Table 10.4-3 Sidestream Deammonification Treatment System Design Criteria 10-10

Table 10.4-4 Design Parameters for ANITATM Mox MBBR 10-10
Table 10.4-5 Capital Cost Estimate for Sidestream Treatment 10-13
Table 10.4-6 O&M Cost Estimate for Sidestream Treatment 10-15
Table 10.5-1 Summary of Capital Costs, Life Cycle Costs and Payback Period for Sidestream Treatment 10-16
Table 11.2-1 Capital Cost Estimate Third Thickener Train 11-3
Table 11.2-2 Capital Cost Estimate Gravity Thickener Polymer System 11-4
Table 11.3-1 Table 11.3-1: Existing HFC AWTP Anaerobic Digesters 11-6
Table 11.3-2 Projected HFC AWTP Anaerobic Digester Long-Term Organic Loads 11-7
Table 11.3-3 Projected HFC AWTP Anaerobic Digester Performance 11-7
Table 11.3-4 Digestion Process Alternatives 11-8
Table 11.3-5 Upgraded Digestion Gas Storage Capacity 11-10
Table 11.3-6 Capital Cost Estimate Baseline Anaerobic Digestion 11-12
Table 11.3-7 O&M Cost Estimate Baseline Anaerobic Digestion 11-14
Table 11.3-8 Net Operating Costs Baseline Anaerobic Digestion 11-14
Table 11.3-9 Anaerobic Digester Volatile Solids Reduction Parameters 11-15
Table 11.3-10 Minimum HRT for Temperature-Phased Anaerobic Digestion 11-16
Table 11.3-11 Proposed HRT for TPAD Configuration 11-17
Table 11.3-12 Projected Digestion Performance with Temperature-Phased Anaerobic Digestion 11-18
Table 11.3-13 Capital Cost Estimate Temperature-Phased Anaerobic Digestion 11-19
Table 11.3-14 O&M Cost Estimate Temperature-Phased Anaerobic Digestion 11-20
Table 11.3-15 Net Present Total Costs Temperature-Phased Anaerobic Digestion 11-20
Table 11.3-16 Anaerobic Digester Volatile Solids Reduction Parameters 11-22
Table 11.3-17 Minimum HRT for Acid-Gas Phased Anaerobic Digestion 11-22
Table 11.3-18 Proposed HRT for AGMD Configuration 11-23
Table 11.3-19 Projected Digestion Performance with Acid-Gas Phased Anaerobic Digestion 11-24
Table 11.3-20 Capital Cost Estimate Acid-Gas Phased Anaerobic Digestion 11-25
Table 11.3-21 O&M Cost Estimate Acid-Gas Phased Anaerobic Digestion 11-26
Table 11.3-22 Net Operating Costs Acid-Gas Phased Anaerobic Digestion 11-26

Table 11.3-23 Thermal Hydrolysis System Design Criteria 11-29
Table 11.3-24 Anaerobic Digester Volatile Solids Reduction Parameters 11-29
Table 11.3-25 Proposed HRT for THP Configuration 11-30
Table 11.3-26 Projected Digestion Performance with THP Anaerobic Digestion 11-31
Table 11.3-27 Capital Cost Estimate THP Anaerobic Digestion 11-32
Table 11.3-28 Net Present Costs of Annual O&M Costs THP Anaerobic Digestion 11-33
Table 11.3-29 Net Operating Costs THP Anaerobic Digestion 11-33
Table 11.3-30 Summary of Anaerobic Digestion Alternatives Present Value 11-34
Table 11.3-31 Digestion Alternatives Decision Matrix 11-35
Table 11.4-1 Capital Cost Estimate Centralized Digester Heating System 11-36
Table 11.5-1 Construction Cost Estimate Biosolids Dewatering Facility 11-37
Table 12.2-1 Current Biogas Production 12-2
Table 12.4-1 Alternative 0 Summary 12-8
Table 12.4-2 Alternative 1 Summary 12-9
Table 12.4-3 CHP Benefit Evaluation Assumptions 12-11
Table 12.4-4 Alternative 2a Summary 12-12
Table 12.4-5 Alternative 2b Summary 12-15
Table 12.4-6 Alternative 2c Summary 12-16
Table 12.4-7 Digester Gas Upgrading Technology Summary 12-22
Table 12.4-8 Alternative 3 Summary 12-28
Table 12.7-1 Estimated Capital Costs 12-29
Table 12.7-2 Estimated O&M Costs (Base Conditions) 12-30
Table 12.7-3 Net Operating Costs (Base Conditions) 12-30
Table 13.2-1 Receiving Facilities in Hillsborough, Pinellas and Polk County Areas 13-2
Table 13.4-1 Results from August 22, 2017 sample of Grease Depot's thickened grease 13-5
Table 13.5-1 Nearby Tipping Fees 13-6
Table 13.7-1 Conceptual Opinion of Probable Construction Cost for HSW Receiving Facility 13-11
Table 13.7-2 20-year Life Cycle Cost for the HSW Facility 13-12
Table 13.7-3 Total Net Operating Costs 13-13

Table 15.1-1 Capacity Recommendations 15-7
Table 15.2-1 2MW EPA Tier 2 Diesel Generator Capital Costs 15-11
Table 15.2-2 2MW EPA Tier 4 Diesel Engine Capital Costs 15-11
Table 15.2-3 2MW Standby Natural Gas Generator Capital Costs 15-12
Table 15.2-4 Budgetary CHP Capital Costs 15-12
Table 15.2-5 Rate Comparison SBFT vs. GSDT 15-13
Table 15.2-6 Based TECO Feb 2017 SBFT Billing 15-14
Table 15.3-1 Fuel Storage Requirements 15-17
Table 15.4-1 Conceptual Cost Estimate for Diesel Fuel Storage Improvements 15-19
Table 17.2-1 Dryer Operation Summary 17-2
Table 17.4-1 Septage Disposal Rates by Nearby Municipalities and Haulers 17-5
Table 17.5-1 FOG Disposal Rates by Nearby Municipalities and Haulers 17-5
Table 17.6-1 Sludge Disposal Rates for Nearby Municipalities 17-6
Table 19.2-1 Distribution of Capital Improvement Projects 19-2
Table 19.2-2 Capital Improvement Projects by Process Area 19-3

List of Figures

Figure ES.2-1 Flow Diagram of Hybrid Odor Control System ES-3
Figure ES.2-2 Proposed Sewage Receiving Station Layout ES-4
Figure ES.2-3 Additional PST Area of Construction ES-5
Figure ES.2-4 Alternative 1 – Optimize Existing ES-8
Figure ES.2-5 Recommended Enhancements for Selected Alternative (Optimize Existing) ... ES-8
Figure ES.2-6 CFD Modeling with Proposed CCT Center Baffle Wall ES-11
Figure ES.2-7 Proposed Location for ANITATM Mox MBBR and EQ Tank ES-12
Figure ES.2-8 Existing HFC AWTP Process Schematic ES-13
Figure ES.2-9 Net Revenue Cost/Benefit ES-16
Figure ES.2-10 Footprint of Aboveground Fuel Storage Tanks ES-19
Figure 2.4-1 GPS-X Model Set-Up 2-3
Figure 4.2-1 February 28, 2015 Mass Diagram 4-2
Figure 4.2-2 November 25, 2014 Mass Diagram 4-3
Figure 4.2-3 March 29, 2014 Mass Diagram 4-3
Figure 4.2-4 February 24, 2016 Mass Diagram 4-4
Figure 4.2-5 October 4, 2015 Mass Diagram 4-4
Figure 5.1-1 Junction Chamber No. 1 5-2
Figure 5.1-2 Junction Chamber No. 1 Flow Diagram 5-2
Figure 5.1-3 Record Drawing of JC1 (Not Including Tank No. 3) 5-3
Figure 5.1-4 Pre-Aeration Tank Cross Section Showing Rotational Mixing Pattern 5-5
Figure 5.1-5 Example Jet Aeration System by MTS 5-6
Figure 5.1-6 Proposed Layout for Alternative 3 5-7
Figure 5.1-7 Photo of EDI HexAir Coarse Bubble Diffusers 5-7
Figure 5.1-8 Proposed Layout for Alternative 4 5-8
Figure 5.2-1 Photo of Existing Odor Control System 5-12
Figure 5.2-2 Existing Odor Control System Flow Diagram 5-13
Figure 5.2-3 Generally Accepted Toxicity Spectrum for Hydrogen Sulfide Gas 5-15
Figure 5.2-4 Schematic of a Typical Deep-Bed Carbon Asorber 5-16
Figure 5.2-5 Diagram of a Typical Low-Profile Three-Stage Chemical Scrubber 5-17
Figure 5.2-6 Schematic of a Typical Biotrickling Filter 5-18

Figure 5.2-7 Diagram of a Hydroxyl Radical Oxidation System 5-19
Figure 5.2-8 Flow Diagram of Alternative 1-Chemical Scrubbing System 5-22
Figure 5.2.9 Flow Diagram of Alternative 2- Biotrickling Filters 5-24
Figure 5.2-10 Flow Diagram of Alternative 3- Hybrid 5-26
Figure 5.2-11 Flow Diagram of Alternative 4- Hydroxyl Radical (OH-) Oxidation 5-28
Figure 5.3-1 Photo of S&G Buildings 5-35
Figure 5.3-2 Existing Ventilation in S&G Building No. 1 5-35
Figure 5.3-3 Existing Ventilation in S&G Building No. 2 5-36
Figure 5.3-4 S&G Building No. 2 Fan Improvements to Increase Ventilation 5-38
Figure 5.4-1 Photo of Existing Grit Removal Equipment 5-39
Figure 5.4-2 Picture of Eutek Slurry Cup™ and Grit Snail® 5-41
Figure 5.4-3 Picture of WEMCO Hydrogritter® 5-41
Figure 5.4-4 Huber COANDA Grit Washer 5-42
Figure 5.4-5 Comparison of Particle Size at 95% Removal Efficiency 5-43
Figure 5.5-1 Aerial of Sewage receiving Station Location 5-45
Figure 5.5-2 Aerial of Existing Leachate Discharge Station 5-46
Figure 5.5-3 Existing Location of Industrial Waste Stations at HFC AWTP 5-46
Figure 5.5-4 Sewage Receiving Station Automation Spectrum 5-47
Figure 5.5-5 Proposed Sewage Receiving Station Layout 5-51
Figure 6.1-1 Existing Primary Sedimentation Tanks 6-1
Figure 6.2-2 Junction Chamber No. 2 Diagram 6-6
Figure 6.2-3 Additional PST Area of Construction 6-7
Figure 6.2-4 Primary Filter (Left Picture: AquaPrime; Right Picture: Salsnes) 6-9
Figure 6.2-5 Similar Aqua Aerobic System Installation 6-10
Figure 6.2-6 Primary Filter Area of Construction 6-10
Figure 6.2-7 Captivator Process 6-12
Figure 6.2-8 Captivator Area of Construction 6-13
Figure 7.1-1 Existing HFC AWTP Process Schematic 7-2
Figure 7.1-2 Separate Stage Denitrification 7-3
Figure 7.1-3 Modified Ludzack Ettinger (MLE) 7-3
Figure 7.1-4 Step Feed Configuration 7-4

Figure 7.1-5 Stage Operation: Series vs. Parallel 7-5
Figure 7.1-6 Potential Process Enhancements 7-6
Figure 7.1-7 Alternative 1 – Optimize Existing 7-7
Figure 7.1-8 Alternative 2A – MLE in Series 7-8
Figure 7.1-9 Alternative 2B – MLE in Parallel 7-9
Figure 7.1-10 Alternative 3A – Step Feed in Series 7-10
Figure 7.1-11 Alternative 3B – Step Feed in Parallel 7-11
Figure 7.1-12 Alternative 4A– Next Generation Nitrogen Removal in Series 7-12
Figure 7.1-13 Alternative 4B – Next Generation Nitrogen Removal in Parallel 7-13
Figure 7.2-1 Daily Average Flows for 2015 Storm Event 7-15
Figure 7.2-2 GPS-X® Layout for BNR Process Evaluation 7-17
Figure 7.2-3 South Settling Tank Performance at Peak SORs 7-19
Figure 7.3-1 Correlation Between pH and Maximum Growth Rates of Nitrifying Bacteria 7-25
Figure 7.4-1 Summary of Improvements Required for Alternative 1 7-29
Figure 7.4-2 Summary of Capital Improvements Req. for Alternative 2H-MLE In Parallel (Keep HPO) 7-37
Figure 7.4-3 Summary of Capital Improvements Req. for Alternative 2D-MLE In Parallel (Diffused Air) 7-41
Figure 7.4-4 Summary of Capital Improvements Required for Alternative 3D – Step Feed BNR in Parallel (Diffused Air) 7-44
Figure 7.5-1 Selected Alternative: Optimize Existing 7-52
Figure 8.1-1 Existing Denitrification Filters 8-1
Figure 9.6-1 JMS Eco-AIR Low Profile Step Aerator 9-22
Figure 9.6-2 Existing CCT Surcharging at Peak Hourly Flow 9-24
Figure 9.6-3 Combined Hydraulic Model Improvements 9-26
Figure 9.6-4 Motorized Gates Hydraulic Improvements 9-26
Figure 9.6-5 Second 96-inch Pipe Between JC 4 and Overflow Structure Hydraulic Improvements 9-27
Figure 10.2-1 Nitrification and Denitrification Pathway for Nitrogen Removal 10-1
Figure 10.3-1 Deammonification Pathway for Nitrogen Removal 10-2

Figure 10.3-2 Process Control Strategy for DEMON® SBR Process (Courtesy of World Water Works) 10-4
Figure 10.3-3 DEMON® SBR Schematic. Note that Anammox in the figure is used to reference AnAOB. 10-4
Figure 10.3-4 DEMON® Continuous Flow Schematic. Note that Anammox in the figure is used to reference AnAOB. 10-5
Figure 10.3-5 ANITA™ Mox (MBBR) Biofilm Configuration and Theoretical Diffusion Patterns. Note that Anammox in the figure is used to reference AnAOB 10-6
Figure 10.3-6 ANITA™ Mox (IFAS) Biofilm Configuration and Theoretical Diffusion Patterns. Note that Anammox in the figure is used to reference AnAOB. 10-7
Figure 10.3-7 AnammoPAQ™ Upflow Granular Process and Theoretical Diffusion Patterns 10-7
Figure 10.4-1 Proposed Location for ANITATM Mox MBBR and EQ Tank 10-11
Figure 10.4-2 Plan View of ANITATM Mox MBBR System 10-12
Figure 10.4-3 Profile View of ANITATM Mox MBBR System 10-12
Figure 10.5-1 Sidestream Treatment Payback Period 10-15
Figure 11.1-1 Existing HFC AWTP Process Schematic 11-2
Figure 11.2-1 Polymer System Payback Period 11-4
Figure 11.3-1 Solids Process Flow Schematic – Baseline Mesophilic Anaerobic Digestion 11-9
Figure 11.3-2 Site Plan – Existing HFC AWTP Solids Processing Facilities Improvements 11-12
Figure 11.3-3 Solids Process Flow Schematic – Temperature-Phased Anaerobic Digestion 11-15
Figure 11.3-4 Site Plan – Proposed TPAD Facilities 11-16
Figure 11.3-5 Solids Process Flow Schematic – Proposed AGMD Facilities 11-21
Figure 11.3-6 Site Plan – Proposed AGMD Facilities 11-23
Figure 11.3-7 Solids Process Flow Schematic – Proposed THP Anaerobic Digestion Facilities 11-27
Figure 11.3-8 CAMBI's Thermal Hydrolysis Process (www.cambi.no) 11-28
Figure 11.3-9 Site Plan – Proposed THP Facilities 11-30

Figure 12.2-1 Seasonal Digester Heating Demands 12-3
Figure 12.3-1 Mesophilic Biosolids Treatment Digester Gas Production 12-5
Figure 12.3-2 TPAD/Acid Gas Biosolids Treatment Digester Gas Production 12-5
Figure 12.3-3 THP+Meso Biosolids Treatment Digester Gas Production 12-6
Figure 12.3-4 Net Revenue Annualized Cost/Benefit 12-7
Figure 12.4-1 CHP Process Diagram 12-10
Figure 12.4-2 CHP Digester Gas Utilization (Optimize Existing Liquid Stream, Acid Gas Biosolids) 12-13
Figure 12.4-3 CHP Heating Demands and Production (Optimize Existing Liquid Stream, (Acid Gas Biosolids) 12-14
Figure 12.4-4 Typical PSA Process Flow Diagram (Guild Molecular Gate™ Example) 12-18
Figure 12.4-5 Typical Membrane Process Flow Diagram (Courtesy of Xebec) 12-20
Figure 12.4-6 Typical Water Scrubbing Process Flow Diagram (Courtesy of Greenlane) 12-21
Figure 12.4-7 Example Microgate PSA RNG System (75 SCFM) 12-22
Figure 12.4-8 RFS2 Renewable Fuel Target 12-23
Figure 12.4-9 Historical D3 and D5 RIN Prices 12-24
Figure 12.4-10 RNG and Electric Energy Market Comparison 12-25
Figure 12.4-11 Existing Natural Gas Pipeline 12-26
Figure 12.4-12 Estimated Annual RNG Production 12-27
Figure 12.7-1 Net Revenue Cost/Benefit 12-31
Figure 13.3-1 Alternative Regional Disposal Sites prior to July 1, 2017 13-3
Figure 13.3-2 Updated Alternative Regional Disposal Sites as of July 1, 2017 13-4
Figure 13.6-1 Potential Schematic of HSW Receiving Station 13-8
Figure 13.6-2 Proposed Location of the HSW Unloading Area and Receiving Station 13-9
Figure 13.6-3 Potential Layout of HSW Receiving Station 13-10
Figure 13.7-1 High Strength Waste Receiving Station Payback Period 13-13
Figure 15.1-1 Utility Billing Information January 2016 through January 2018 15-3
Figure 15.1-2 SkVA 15-4
Figure 15.3-1 Day Tank Fuel System and Fuel Radiators 15-16
Figure 15.4-1 Footprint of Aboveground Fuel Storage Tanks 15-18

Figure 16.2-1 Administration Building Network Rack 16-2
Figure 16.2-2 GE PLC Life Status Stage Definition 16-2
Figure 16.2-3 PLC-15 GE PACSystems RX3i PLC with GE 90-30 Remote I/O 16-3
Figure 16.2-4 PLC-5:33 GE 90-70 PLC with GE Genius I/O 16-3
Figure 16.2-5 HFC AWTP Fiber Optic & Off-Site Communications Network 16-4
Figure 17.2-1 Existing 2 (Two) Andritz DD50 Rotary Drum Dryers at Hillsborough County's NWWRF 17-2
Figure 17.3-1 Expected Growth Areas (Northern Wastewater Service Area) 17-3

Attachments

Attachment 8-A	Filter System Inspection- Denitrification Filters
Attachment 9-A	CFD Modeling Results
Attachment 10-A	Proposals for Sidestream Treatment
Attachment 11-A	Digester Structural Testing
Attachment 12-A	Assumptions of Life Cycle Costs Benefit Analysis
Attachment 12-B	Estimated Capital Costs
Attachment 12-C	Digester Gas Value Evaluation Tool
Attachment 16-A	PLC Hardware Inventory and Lifecycle Status
Attachment 17-A	Conceptual Level Cost Estimate Dryer Relocation and Installation
Attachment 17-B	Cost Estimate for Refurbishing the Existing Dryer System
Attachment 17-C	City of Tampa Wastewater Department Service Area
Attachment 19-A	CIP List arranged by Fiscal Year
Attachment 19-B	CIP List arranged by Building No.

Appendices

Volume 2

Appendix A	Tampa HFC AWTP Master Plan - Phase 1 Existing Systems Technical Memorandum of Findings, August 2016

Volume 3

Appendix B	Tampa HFC AWTP Master Plan - Process Model Sampling and Calibration Report, July 2017
Appendix C	Tampa HFC WWTP Online Partial Discharge Test Report, December 2017

List of Acronyms

Abbreviation	Definition
AA	annual average
AACE	Association for the Advancement of Cost Engineering
AADF	annual average daily flow
AGMD	acid-gas phased anaerobic digestion
AnAOB	anaerobic ammonia oxidizing bacteria
AOB	ammonia oxidizing bacteria
AWTP	advanced wastewater treatment plant
BNR	biological nitrogen removal (or biological nutrient removal)
BOD	biochemical oxygen demand
BTU	British Thermal Unit
$CaCO_3^-$	calcium carbonate
CARB	carbonaceous reactor (High Purity Oxygen Activated Sludge)
CBOD	carbonaceous biochemical oxygen demand
CCT	chlorine contact tanks
CEPT	chemically enhanced primary treatment
CF	cubic feet
CFD	computational fluid dynamics
CHP	combined heat and power
CIP	capital improvements program
City	City of Tampa
CNG	compressed natural gas
CO	carbon monoxide
COD	chemical oxygen demand
COT	City of Tampa
DAR	diffused air reactors
dB	Decibels
De Nora	De Nora Water Technologies
DO	dissolved oxygen
DPB	disinfection byproducts
DSO	digital storage oscilloscope
DT	dry ton
EBPR	enhanced biological phosphorus removal
EPA	Environmental Protection Agency
EQ	equalization
F.A.C.	Florida Administrative Code
FCS	FCS, Inc.
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FLA	full load amperage

Abbreviation	Definition
FOG	fats, oils and grease
FS	Florida Statute
FST	final sedimentation tank
gpd	gallons per day
GSDT	time of day general service demand
GTO	gravity thickener overflow
H_2S	hydrogen sulfide
HEX	heat exchanger
HFCT	high frequency current transformer
HPO	high purity oxygen
HPOAS	high-rate high purity oxygen activated sludge
HRT	hydraulic residence time
HSW	high strength waste
I&C	instrumentation and control
IFAS	integrated fixed-film activated sludge
JC	junction chamber
kg	kilograms
kWh	kilowatt hour
lbs	pounds (mass)
LCCA	life cycle cost analysis
LEL	lower explosive limit
MBBR	moving bed biofilm reactor
MCRT	mean cell residence time
MD	maximum day
MG	million gallons
mg/L	milligrams per liter
MGD	million gallons per day
mgd	million gallons per day
MLE	Modified Ludzack Ettinger
MLSS	mixed liquor suspended solids
MPS	main pump station
MV	medium voltage
NETA	International Electrical Testing Association
NH_3-N	ammonia nitrogen
NH_4-N	ammonium nitrogen
NIOSH	Institute for Occupational Safety and Health
NIT	nitrification tanks (dissolved air reactor)
nm	nanometer
NMP	nutrient management plans
NO_2-N	nitrite nitrogen
NO_3-N	nitrate nitrogen

Abbreviation	Definition
NOB	nitrite oxidizing bacteria
NOC	net operating cost
NOx-N	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NRC	nitrogen release cycles
O&M	operation and maintenance
O_2	oxygen
OH^-	hydroxyl radicals
OLPD	online partial discharge
PAO	polyphosphate accumulating organisms
pC	picocoulomb
PD	positive replacement
PD	partial discharge
PHF	peak hour flow
PLC	programmable logic controllers
PO_4-P	ortho-phosphate
POA	points of attachment
ppd	pounds per day
ppm	parts per million
PS	primary sludge
PSI	pounds per square inch
PST	primary sedimentation tank
QA/QC	quality assurance and quality control
RAS	return activated sludge
RFS2	renewable fuel standards
RICE	reciprocating internal combustion engine
RIN	renewable identification numbers
RNG	renewable natural gas
RVO	renewable volume obligations
S&G	screen & grit
SBFT	time of day firm standby and supplemental service
sBOD5	soluble biochemical oxygen demand
SBR	sequencing batch reactor
scfm	cubic feet per minute at standard conditions
sCOD	soluble chemical oxygen demand
SkVA	starting kilo-volt amps
SM	Standard Methods
SOP	standard operating procedure
SOR	surface overflow rate
SPA	state point analysis

Abbreviation	Definition
SRS	septage receiving station
SRT	solids retention time
SVI	sludge volume index
TAP	Tampa Augmentation Program
TECO	Tampa Electric Company
TEV	transient earth voltage
THD	total harmonic distortion
THP	thermal hydrolysis pretreatment
TIN	total inorganic nitrogen
TKN	Total Kjeldahl Nitrogen
TN	total nitrogen
TP	total phosphorus
TPAD	temperature-phased (thermophilic-mesophilic) anaerobic digestion
TPS	thickened primary sludge
TS	total solids
TSS	total suspended solids
TWAS	thickened waste activated sludge
UHF	ultra-high frequency
UV	Ultraviolet
VFA	volatile fatty acids
VFD	variable frequency drive
VOCs	volatile organic compounds
VPSA	vacuum pressure swing adsorption
VS	volatile solids
VSR	volatile solids reduction
VSS	volatile suspended solids
WAS	waste activated sludge
WERF	Water Environment and Reuse Foundation
WLR	weir loading rate
WWD	wastewater department
WWTP	wastewater treatment plant

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Executive Summary

ES.1 Purpose

The City of Tampa (City) Howard F. Curren Advanced Wastewater Treatment Plant (HFC AWTP) is permitted to treat 96-MGD with a Type I two-stage, high rate (pure oxygen and fine bubble aeration) activated sludge biological nitrification/ denitrification domestic wastewater treatment plant. This plant is operated to discharge advanced wastewater treated (AWT), high-level disinfected and dechlorinated effluent to Hillsborough Bay. Residuals generated by this facility can be heat dried to meet Class AA standards for distribution and marketing or can be dewatered for land application as a Class B residual. Currently, annual average daily flows (AADF) are 60 MGD with peak hourly flows (PHF) of 190 MGD. Plant influent projected flows and loads were established based on recently measured historical data and projections for future growth over the next 20 years based on the Phase 1 Master Plan Report (**Appendix A**). Analyses in the Master Plan used AADF starting at 60 MGD and increasing to 80 MGD over the twenty-year planning period. The peaking factor for PHF used in the Master Plan was 2.93, based on historical flows, and the corresponding increase in PHF over the twenty-year period was used. Estimated costs developed in the Master Plan were generated in 2018 dollars. Estimated costs for the Capital Improvements Projects (CIP) list include a 3% increase per year starting in planning year 2 and continuing through year 20.

This report provides an overall master plan to coordinate and prioritize recommended improvements that incorporates past studies, completed improvements, future improvements to:

- maintain system reliability
- address current and potential regulatory requirements
- enhance plant performance to reduce operational costs and incorporate process enhancements.

ES.2 Process Improvements

The overall facility was evaluated by treatment process areas to assess recommended improvements to meet the above stated purposes.

ES.2.1 Process Model Sampling and Calibration

The existing GPS-X® process model was improved to proceed with the treatment process alternative analysis. The calibration of the updated and expanded model to steady-state and dynamic conditions was conducted using historical and special sampling data as documented in the *Process Model Sampling and Calibration Report* provided in **Appendix B**. A full week of process sampling (and partial sampling during a second week) was completed to gather information necessary for process model calibration. The calibration of the model met the criteria for a Level 3 Calibration based upon the criteria presented in the Water Environment and Reuse Foundation Tiered Calibration Approach.

ES.2.2 Site Improvements

Site improvements associated with the improvements to the HFC AWTP over the planning period detailed in the master plan will be incidental to each project. Based on the layout of the

existing plant and the improvements recommended in this document, it is further assumed that new roads, parking, and access roads will not be needed.

ES.2.3 Flow Equalization

Flow equalization is used to reduce the impacts from variations in flow, either wet weather induced flows or diurnal flows; thereby achieving a more consistent flow as well as loading through the plant. The evaluation focused on dampening diurnal flows to promote a more constant flow rate and constituent mass loading rate downstream of the equalization tank to improve efficiency, reliability, and provide greater control over physical, biological, and chemical processes. Using flow data from historically dry weather months, it was determined that an equalization tank volume of approximately 12 million gallons satisfied the mass balance analysis. The cost to construct and operate an equalization tank is not justified when the individual processes can treat the fluctuating flows and loads associated with the diurnal flow pattern at the HFC AWTP. Therefore, at this time, construction of an equalization tank is not recommended. In addition, sidestream treatment is recommended to specifically reduce the impacts from high nitrogen load from sidestreams associated with anaerobic digestion and digested sludge dewatering. Process modeling and subsequent recommendations to improve process performance assume that diurnal flow equalization is not provided.

ES.2.3 Preliminary Treatment

Improvements to the preliminary treatment systems are recommended to:

- Improve odor control for preliminary treatment
- Improve ventilation Screen and Grit Building No. 2 to reduce corrosion
- Minimize sugar sand in the digesters
- Improve industrial waste receiving
- Replace equipment that has reached the end of its useful life

Recommended improvements to the preliminary treatment odor control system include installation of new biotrickling filters followed by chemical scrubbing for polishing (named hybrid alternative in the evaluation). The existing odor control system has reached the end of its useful life. This alternative was estimated to have a lower present worth than biotrickling filters and chemical scrubbing alternatives alone and has an inherent backup system with system technologies in series. A hydroxyl radical system was also included in the evaluation; however, it was not recommended due to a level of uncertainty of treatment performance as a new technology. The City may want to consider pilot testing a hydroxyl radical system to overcome the unknowns, since this alterative had the lowest present worth, approximately three times less than the recommended hybrid alternative. **Figure ES.2-1** is a flow diagram of the proposed hybrid system.

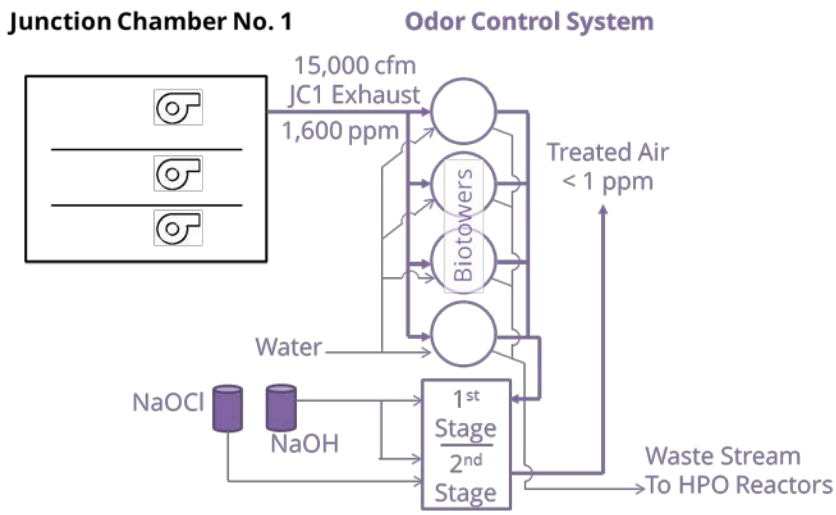

Figure ES.2-1: Flow Diagram of Hybrid Odor Control System

Recommended improvements to Screen & Grit Building No. 2 include additional supply and exhaust fans to increase ventilation rates to match Screen & Grit Building No. 1 where hydrogen sulfide levels and corrosion is acceptable.

Recommended improvements to reduce sugar sand in the digesters include new grit conditioning systems (grit washing and classifiers) to minimize resuspension of grit removed by the Detritor units. The existing grit conditioning systems have reached the end of their useful life. The City has completed a design for the new grit conditioning systems and is in the process of awarding contracts. If the recommended grit conditioning systems do not reduce the downstream sugar sand problem, it would be recommended that the City consider replacing the Detritor units with new vortex grit removal systems. This would include a grit classification study, hydraulics analysis and new pump stations.

A new sewage receiving station is recommended to be located outside of the security fence along Maritime Boulevard to automate volume and water quality tracking and alleviate traffic within the facility. **Figure ES.2-2** shows a proposed location and layout.

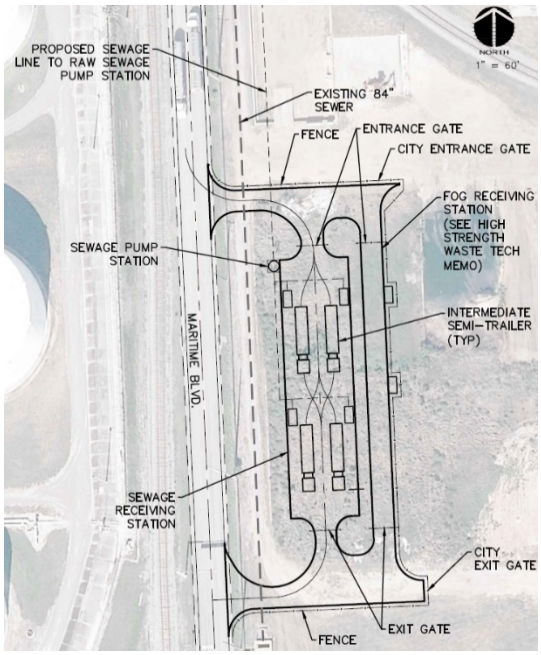

Figure ES.2-2: Proposed Sewage Receiving Station Layout

The total estimated cost of recommended preliminary treatment improvements is $9,190,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.4 Primary Treatment

The existing eight primary sedimentation tanks (PST), split into two trains of four, do not meet industry standards for removal efficiency of BOD and TSS, surface overflow rate and weir loading rate at existing and future PHF conditions. The peak flow for the existing PSTs is hydraulically limited to 160 MGD, discussed in the Phase 1 TM (**Appendix A**), and any screened and de-gritted flow above this is bypassed directly to the main pump station. Three alternatives were evaluated to eliminate hydraulic limitations and improve treatment performance so that more carbon is diverted to digesters for increased gas production and reduce aeration costs in secondary treatment. Increasing BOD and TSS removal will lower the loading rate on the downstream aeration system and increase the quantity of primary sludge, leading to the production of more biogas. The three alternatives evaluated include:

1. The addition of four PSTs as a third treatment train to add 80 MGD of treatment capacity thereby increasing the peak flow that can hydraulically pass through the PSTs to 240 MGD.
2. Add primary filters as a third treatment train for 80 MGD of additional treatment capacity
3. Convert the existing primary sedimentation tanks to a Captivator system by Evoqua Water Technologies to treat the full future PHF of 234 MGD.

For all the alternatives, Junction Chamber No. 2 would require modification and use of the existing fourth outlet which is not currently in use. The additional four PSTs could be located in the open area south of the existing primary sedimentation tanks 5-8 as shown in **Figure ES.2-3**. With the additional four PSTs, the surface overflow rate and weir loading rate would still exceed

the recommended industry standards at future AADF and future PHF conditions respectively; however, sampling revealed that the existing PSTs have adequate removal at existing flow conditions. The additional four PSTs would improve the overall treatment performance for BOD and TSS removal at existing and future flow conditions.

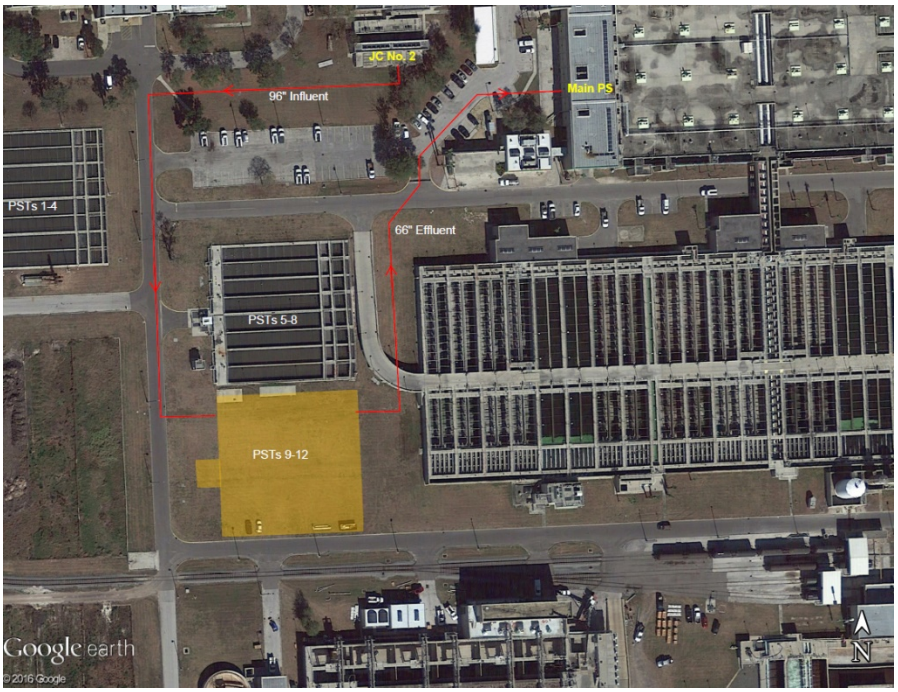

Figure ES.2-3: Additional PST Area of Construction

Primary filters could be added as a third treatment train which would reduce the flow and improve performance of the existing PSTs. Multiple primary filter configurations are available from multiple manufacturers; however, the evaluation focused on the use of Aqua Aerobic Systems AquaPrime™. Primary filters would require a pump station to operate in parallel with the existing PSTs. Primary filters inherently have greater removal efficiency than PSTs. Primary filters would have a smaller footprint compared to four additional PSTs and could be located adjacent to Junction Chamber No. 2. The addition of primary filters would improve the treatment performance of the existing primary sedimentation tanks and add 80 MGD of higher performance treatment for overall improvement in TSS and BOD removal estimated to be greater than additional PSTs and less than the Captivator option.

The evaluation also considered the Captivator system for primary treatment. The Captivator process utilizes a combination of contact aeration and dissolved air flotation to extract BOD prior to the activated sludge process. The Captivator process can treat the design PHF of 234 MGD, and therefore would replace the existing two PST trains, utilizing the existing tankage for process conversion. The Captivator process has the advantage of not requiring any additional footprint as it would make use of six of the eight existing PSTs. Removal rates for the Captivator process are typically between 65% to 75% for TSS and 50 to 60% for BOD, much higher than the other options considered. The use of the Captivator process would result in the highest removal efficiencies of the three alternatives considered.

The primary treatment alternatives were evaluated. The addition of four new primary sedimentation tanks received the highest score in the evaluation process and is recommended to improve the primary treatment process and subsequent secondary processes and biosolids processes.

Additional improvements recommended in the evaluation include:

- Replacement of equipment in the existing primary sedimentation tanks and primary sludge pump stations due to age;
- The addition of a dewatering pump station for primary sedimentation tanks 1-4; and
- The addition of sludge blanket monitors in the primary sedimentation tanks to help improve treatment operations.

The total estimated cost of recommended primary treatment improvements is $26,580,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.5 Biological Nutrient Removal

The HFC AWTP GPS-X® process calibrated model was used to evaluate the BNR process at HFC AWTP and identify feasible alternatives for achieving more efficient and reliable nitrogen removal with the option to incorporate phosphorus removal in the future. A framework of criteria was developed to identify process alternatives for the BNR process evaluation.

In order to narrow down the list of process alternatives, the core process components were distinguished from process enhancements which could be evaluated as additions to the final core process configuration. The core process components include:

- The nitrogen removal process
- The carbon management strategy
- The stage operation (series vs. parallel).

Seven core process alternatives were identified for the BNR evaluation (**Table ES.2-1**). Alternatives 4A and 4B were not considered for near term implementation but were considered for a potential future phase from one of the other core process alternatives evaluated.

Table ES.2-1: Core Process Alternatives

Alt #	Description	Nitrogen Removal Configuration	Carbon Management Strategy	Stage Operation
1	Optimize Existing	MLE in South	BNR / Digestion	Series
2A	MLE (Series)	MLE in North and South	Optimize BNR	Series
2B	MLE (Parallel)	MLE in North and South	Optimize BNR	Parallel
3A	Step Feed (Series)	Step Feed in North and South	Optimize BNR	Series
3B	Step Feed (Parallel)	Step Feed in North and South	Optimize BNR	Parallel
4A	Next Generation Nitrogen Removal (Series)	Mainstream Deammonification	Divert to Digestion	Series
4B	Next Generation Nitrogen Removal (Parallel)	Mainstream Deammonification	Divert to Digestion	Parallel

Based upon the results of this evaluation, the City decided to move forward with Alternative 1 (Optimize Existing) as the selected core process. Alternative 1 includes optimizing the existing process configuration with some minor process improvements (**Figure ES.2-4**). The North and South reactors will continue to be operated in series. The North reactors would continue to be operated at a very short SRT for a high fraction of carbon diversion to digestion. The South reactors would continue to be operated for full nitrification with improvements similar to what has been implemented in South Tank No. 1. These improvements include optimization of the spike line to the DARs, the addition of mixers to the first three zones to ensure proper mixing under anoxic operation, installation of new fine bubble diffusers, and installation of an IMLR pump to recycle nitrate back to the head of the anoxic zone; all to improve denitrification upstream of the denitrification filters.

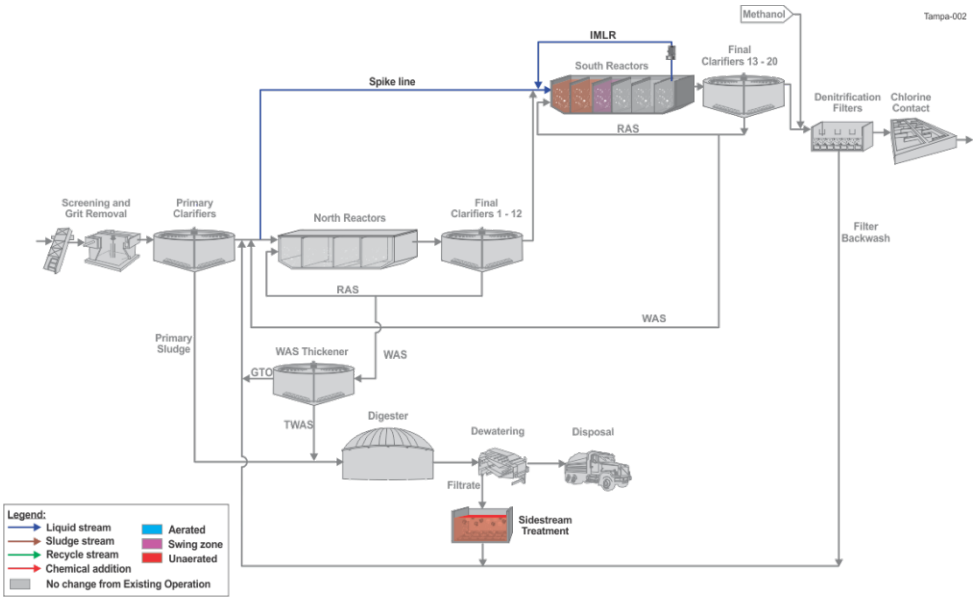

Figure ES.2-4: Alternative 1 – Optimize Existing

The total estimated cost of recommended biological nitrogen removal improvements is $61,300,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

A summary of the recommended enhancements are highlighted in **Figure ES.2-5**.

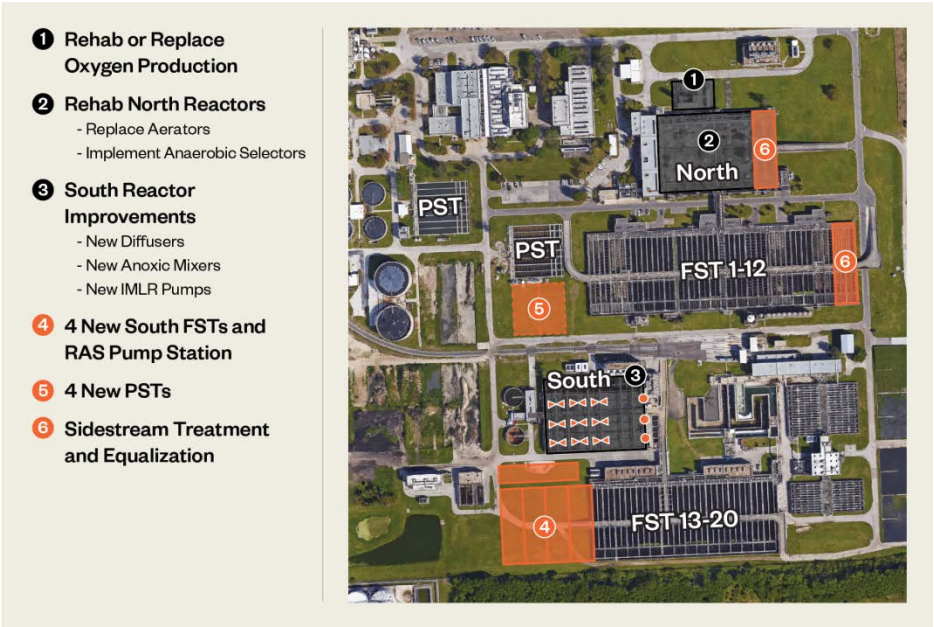

Figure ES.2-5: Recommended Enhancements for Selected Alternative (Optimize Existing)

ES.2.5.1 North Reactor Improvements

Anaerobic Selector

Implementing an anaerobic selector at the head of the North Reactors is recommended to help improve settling conditions and to control foam. The existing aerators are already in need of repair or replacement, so it would be advantageous to replace the surface aerators in the first stage of each of the North Reactors with a submerged mixer. The oxygen feed controls will need to be shifted to Stage 2. To address loss of oxygen transfer in Stage 1, more North Reactors would be brought online, or larger aerators may be considered for installation in Stages 2 – 4. The preferred approach is larger aerators with variable frequency drive controls to maximize efficiency. The aerators in Reactor #3 will be replaced soon as part of an ongoing project. These aerators may require modifications to be consistent with the other reactors if the anaerobic selector is implemented. An oxygen dissolution evaluation is recommended during design to determine the new horsepower requirements for these stages.

Oxygen Generation Improvements

The use of the High Purity Oxygen Activated Sludge (HPOAS) process is still considered suitable for the short SRT operation, but there may be some opportunities to improve energy efficiency in the oxygen generation system. HFC AWTP currently uses a cryogenic oxygen generation system. The calculated oxygen requirements on an annual average basis are around 25 tpd, and on average 27-44 tpd are provided to the tanks due to limited turndown and process control. Additional rehabilitation of the existing oxygen generation system will be necessary in the future, so considerations should be given to replacing the cryogenic system with an alternative technology, such as a vacuum pressure swing adsorption (VPSA) system.

ES.2.5.2 South Reactor Improvements

Modifications to the South Reactors is recommended to reflect the MLE configuration, including new mixers for anoxic operation in Stages No. 1 through 3, New Fine Bubble Diffusers, and IMLR pumps to send nitrate back to the anoxic zones.

Recommended Aeration Improvements

It is recommended that the City consider the installation of disc-type membrane fine bubble diffusers for Tanks No. 2-4 since these require less operating pressure. Off-gas testing is also recommended to assess the benefits and savings associated with switching from the panel type to the disc type diffusers. There are multiple blower technology options that would provide additional energy savings as compared with the existing system that should be considered. A detailed blower net present worth evaluation of these different blower types during design is recommended to identify the best solution for the City. In addition, ammonia probes in each basin are recommended for implementation of ammonia based aeration control (ABAC).

Recommended IMLR Improvements

In Tank No. 1, the IMLR pump currently discharges into the influent line and is not monitored for flow. The current configuration is suspected to limit the IMLR flow capacity, so it is recommended that separate IMLR piping and separate flow measurement be installed for each

tank to allow for more flexibility and control of the IMLR flow. Online nitrate measurement in these basins would allow for more targeted control of denitrification in these basins.

ES.2.5.3 New South Final Sedimentation Tanks

The South final sedimentation tanks (FSTs) are currently limiting the wet weather treatment capacity at the HFC AWTP. Two new FSTs are recommended to be built in the near term and two additional FSTs are recommended to be built to handle future wet weather flows. A new RAS pump station should be constructed in the near term to service the new FSTs. The addition of RAS pumps can be phased in to correspond to the number of FSTs required.

ES.2.6 Tertiary Treatment

Existing denitrification filters provide both solids removal and nitrogen removal. The filters were designed to meet the surface water annual average permit limits of 5 mg/L TSS and 3 mg/L TN. The facility's permit includes a 5-year average TN loading limit into Hillsborough Bay of 213.2 tons/year, which limits the TN concentration to 2.53 mg/L based on the AADF of 60 MGD (excludes 5 MGD discharged to the reclaimed water system). As the AADF increase to 80 MGD, this equates to a TN limit of 1.86 mg/L based on the current 5-year average limit for TN tons/yr. As AADF increases, the average TN concentration in the filter effluent will need to be reduced below current levels (approx. 2.1 mg/L). The facility has experienced hydraulic limitations in the denitrification filters during storm events due to nitrogen gas binding. DeNora Water Technologies and McKim & Creed performed an evaluation of the existing denitrification filter system. Recommended improvements to the denitrification filters include:

- Reducing the nitrate loading to the filters to a maximum of 16,000 lb./day by upstream improvements to the BNR processes
- Optimization of the nitrogen release cycles to improve hydraulic throughput
- Backwash sequence optimization to improve media life.

The latter two can be implemented by facility staff at no cost. Improvements to the methanol dosing controls are recommended to meet total nitrogen limits as annual average flows increase. Additional denitrification filters are recommended as AADF approaches 80 MGD since estimated filter loading will exceed 16,000 lb./day after recommended biological nutrient removal improvements are made to the secondary process. A total of nine new filters are recommended without the recommended new side-stream treatment system, and two new filters are recommended with the new side-stream treatment. Additional recommended improvements are the replacement of aging equipment including backwash blowers and pumps, valves, flow meters, and air piping.

The total estimated cost of recommended tertiary treatment improvements is $18,836,000 in 2018 dollars.

ES.2.7 Disinfection

Improvements to the existing chlorine gas disinfection system are recommended to improve safety and to prepare for the possibility of regulation changes preventing the use of chlorine gas. The existing disinfection system uses chlorine gas and sulfur dioxide gas supplied in 90-ton

rail cars. Some of the major equipment was determined to be at or near its useful life in the Phase 1 TM. An evaluation was conducted to determine a viable alternative to chlorine gas disinfection. The alternatives evaluated include:

- Sodium hypochlorite (bulk delivery by rail and onsite generation)
- UV
- Peracetic acid
- Ozone

The high estimated capital costs for UV and ozone ruled these alternatives out for further consideration. The alternatives were evaluated against cost and non-cost criteria. Sodium hypochlorite scored the highest in the evaluation. The existing chlorine gas disinfection system is recommended to be replaced with a sodium hypochlorite system supplied in bulk by rail.

Additional improvements include:

- New center baffle walls for the existing chlorine contact tanks
- Relocation of the post aeration system to improve disinfection performance
- Motorized gates
- A possible second pipeline from Junction Chamber No. 4 to the Overflow structure to prevent surcharging of chlorine contact tanks.

Figure ES.2-6 is a schematic from the computational fluid dynamics modeling of the chlorine contact tanks with the proposed center baffle wall.

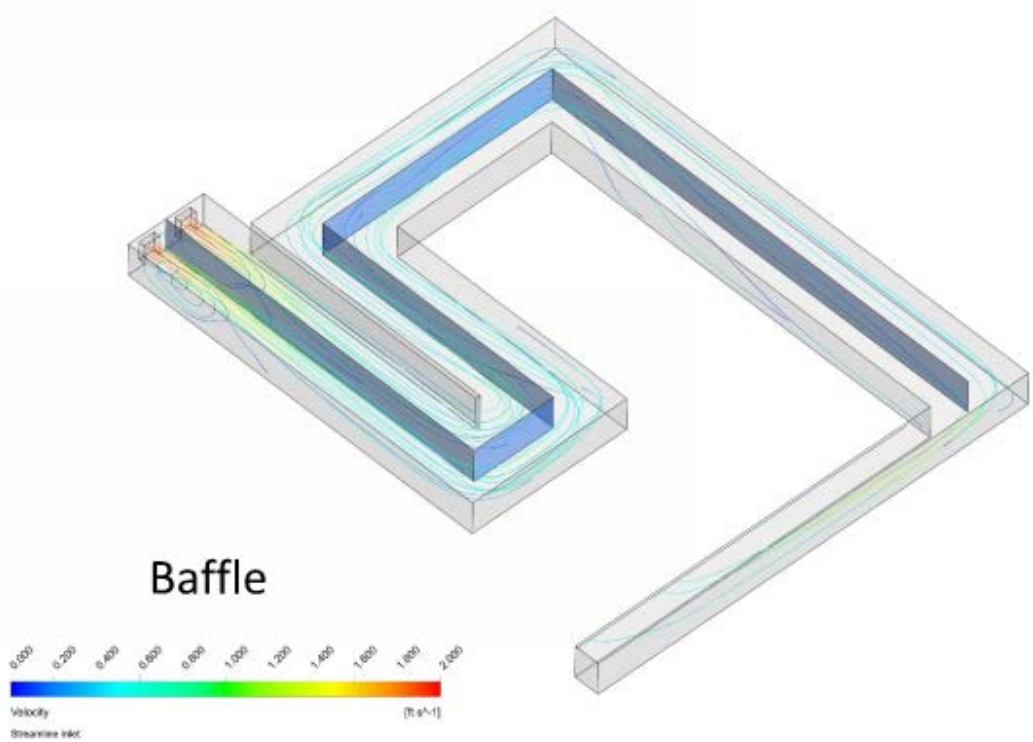

Figure ES.2-6: CFD Modeling with Proposed CCT Center Baffle Wall

The total estimated cost of recommended disinfection and effluent disposal improvements is $12,523,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.8 Sidestream Treatment

Sidestream flows at the HFC AWTP, typically account for 15 to 30 percent of the total influent nitrogen load . Regardless of the technology selected, sidestream deammonification processes at the HFC AWTP are expected to remove 80-90% ammonium nitrogen (NH_4-N) and 70-85% total inorganic nitrogen (TIN) from sidestream. Treatment of this sidestream can help minimize the impact of the load to the main plant operation. In addition, the reduction in nitrogen from the sidestream flow translates to a cost savings in the main plant from the reduction of methanol addition at the denitrification filters and a reduction in aeration costs associated with nitrification in the south reactors. In addition, the denitrification filters have an influent load limitation, irrespective of allowable effluent NOx-N concentration or the flow to the filters, which is due to binding created by the nitrogen gas formation, which can be avoided with the addition of sidestream treatment. Without sidestream treatment and an increase in plant flow, additional denitrification filters will be needed. The use of sidestream treatment will reduce the need for an additional nine filters at future AADF peak loads to only two filters.

The ANITA™ Mox MBBR system was used as an example for illustrating implementation of sidestream deammonification. In this assessment, it was determined that sidestream deammonification would require two separate process trains with a total reactor volume of 78,000 gallons. In addition to reactor volume, sidestream equalization (EQ) is recommended to reduce the number of interruptions in flow to the process caused by changes in sludge dewatering. The proposed location for the sidestream treatment reactor is in the re-purposed high purity oxygen (HPO) reactors and the proposed location of the equalization basin (EQ) is within the re-purposed final sedimentation tanks (FSTs) **Figure ES.2-7**.

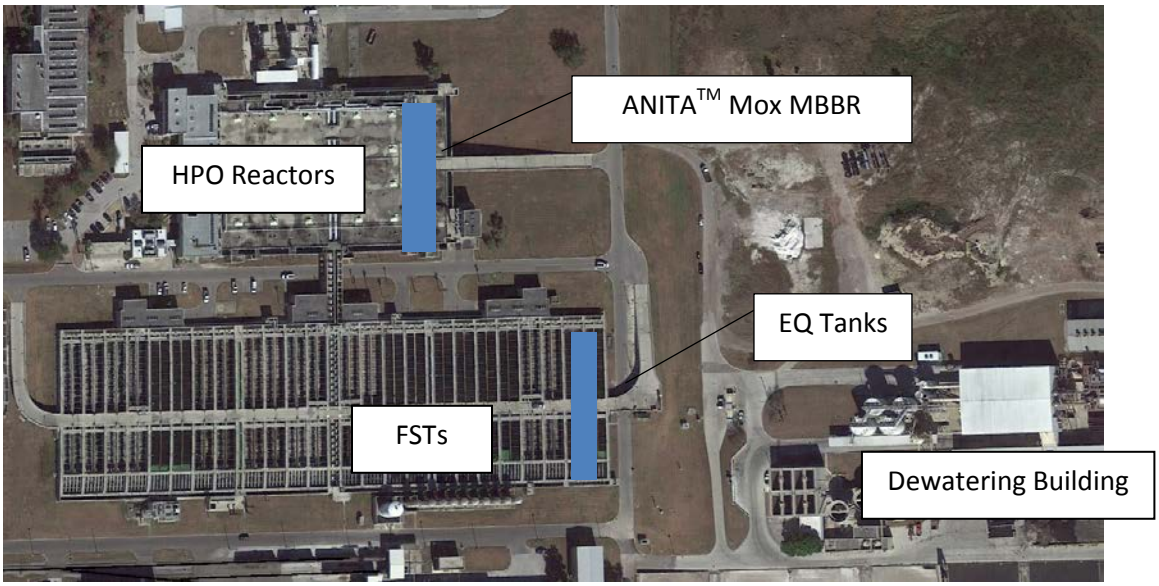

Figure ES.2-7: Proposed Location for ANITA™ Mox MBBR and EQ Tank

Based on the estimated capital cost and the O&M costs and savings, including the capital offset of seven (7) new denitrification filters, a payback on an ANITA™ Mox system could be seen within seven (7) years.

The total estimated cost of recommended sidestream treatment improvements is between $10,800,000 and $13,000,000 in 2018 dollars, depending on the sidestream technology chosen.

ES.2.9 Biosolids System

The existing biosolids treatment system at the HFC AWTP processes the solids produced from the primary clarification and secondary clarification processes, as shown in **Figure ES.2-8**. Secondary waste activated sludge (WAS) is sent from the high purity oxygen system to gravity thickeners, to anaerobic digesters, then dewatered ahead of drying or direct hauling of the dried cake for Class B land application.

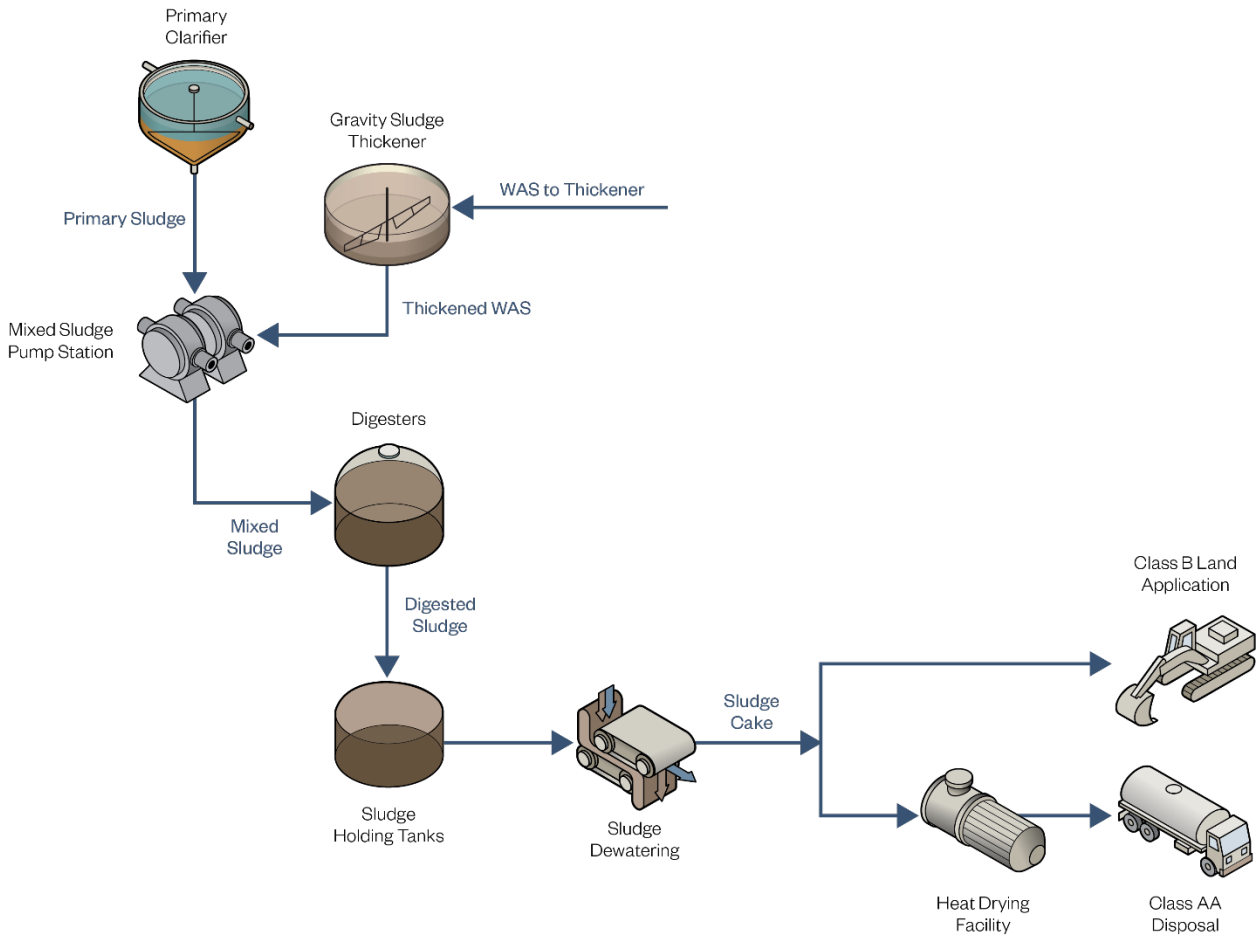

FIGURE ES.2-8: Existing HFC AWTP Process Schematic

ES.2.9.1 Sludge Conditioning and Thickening

The evaluation of the gravity thickening equipment indicates that it is being overloaded with respect to hydraulics and solids loading, and a third equally sized thickener train (consisting of a new tank, two TWAS pumps, and associated appurtenances) is recommended to provide

redundancy and improve loading rates. It is also recommended that the polymer system be replaced with a more efficient system. The potential operational cost savings from less polymer use indicates a 5 to 7-year payback period for the associated capital investment of the more efficient replacement polymer systems. A similar new polymer system is recommended to replace the existing bed polymer system located by the sludge storage tanks which is 30 years old and in fairly poor condition. The total estimated cost of recommended gravity thickening and sludge conditioning improvements is $5,456,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.9.2 Digester Improvements

A blend of thickened primary sludge and thickened waste activated (TWAS+PS) sludge is typically pumped from the Mixed Sludge Pumping Station to the existing digestion facilities which consist of seven (7) digesters (aggregate volume of 9.2 MG) and three (3) digester control buildings (A, B and C). Digester control buildings house heated sludge recirculation pumps, digested sludge transfer pumps, back-up boilers, sludge to hot water heat exchangers, and process piping and appurtenances.

A digestion evaluation was conducted to identify and evaluate alternatives for achieving efficient and reliable volatile solids destruction and biogas production and better control of foaming in the future, with consideration for future implementation to achieve Class A biosolids. Four anaerobic digestion process alternatives were identified for the digestion evaluation as summarized in **Table ES.2-2**.

Table ES.2-2: Digestion Process Alternatives

Alt #	Abbreviation	Description
1	Baseline	Maintain/upgrade mesophilic anaerobic digestion process
2	TPAD	Conversion from a conventional mesophilic anaerobic digestion process to a temperature-phased (thermophilic-mesophilic) anaerobic digestion process
3	AGMD	Conversion from a conventional mesophilic anaerobic digestion process to an acid-gas phased anaerobic digestion process
4	THP	Addition of Thermal Hydrolysis Pretreatment

Based upon the results of this evaluation, it was determined that Alternative 3 (Acid-Gas) and Alternative 1 (Upgraded Mesophilic) are both a good fit for the City. The Acid-Gas alternative was chosen, and it is recommended that the design include consideration for infrastructure to easily convert back to Upgraded Mesophilic (baseline).

The total estimated cost of recommended acid-gas phased anaerobic digestion improvements is $29,052,000 in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.9.3 Centralized Heating System Enhancement

An enhancement to the digestion system is a centralized heating system located in a new boiler Building D. The centralized heating system will be used to heat all digesters and includes new boilers with the ability to use natural gas or digester gas, air separator, expansion tank, primary hot water loop pumps, feed tank, new heat exchangers (located within Buildings A, B and C), hot water pipeline to Buildings A, B and C, and a new natural gas pipeline connection.

The total estimated cost of recommended centralized heating system enhancement is $4,330,000 in 2018 dollars.

ES.2.9.4 Dewatering Facility

An assessment of the dewatering system had previously been completed, and a new dewatering project had been recommended which includes five (5) centrifuges, grinders, feed pumps, conveyors, piping, polymer system, electrical and I&C upgrades. The Acid-Gas Phased Digestion alternative will have little impact on the overall downstream biosolids processing. Therefore, it is recommended to locate the new dewatering building near the existing dewatering building. This simplifies maintenance of plant operations during construction of the new facility, allows for continued use of the existing sludge holding tanks and sludge drying beds, is in close proximity to the heat dryers if brought back online, and limits traffic within the plant site.

The total estimated cost of recommended dewatering facility improvements is $12,960,000 in 2018 dollars.

ES.2.10 Biogas Utilization

The HFC AWTP currently flares all biogas generated by the anaerobic digesters. Prior to March 2017, the biogas was utilized by fueling a combined heat and power (CHP) system using reciprocating internal combustion engines (RICE) to offset the plant's energy demands. An evaluation was performed to determine how the City could best utilize this valuable resource.

The liquid and biosolids treatment alternatives were modeled using Hazen's Energy Balance Analysis Tool (EBAT) for the CHP and RNG biogas utilization alternatives. The liquid stream treatment alternatives were found to have the largest impact on biogas production as well as the annualized cost/benefit. The biosolids treatment alternatives did not have a large impact on the biogas gas production. The biogas production contributed to the selection of the liquid stream treatment alternatives. Optimizing the existing liquid stream (Alt 1) produces the most biogas, which can be utilized in the most beneficial way possible and has the potential to produce the most revenue for the plant.

After discussions with the City, the following biogas utilization alternatives were evaluated:

- Alternative 0 – Flare all Biogas – All biogas is flared and natural gas is purchased to provide digester heating.
- Alternative 1 – Biogas Fueled Boilers – Utilize digester gas to provide digester heating by using boilers and flare all unused gas.
- Alternative 2 – Combined Heat and Power (CHP) – Utilize biogas fueled engines to generate electric and thermal energy to offset the plant's energy demands
- Alternative 3 – Biogas to Renewable Natural Gas (RNG) for Vehicle Fueling – Recover and condition/compress biogas to be used in the City's CNG capable vehicles.

Conceptual level capital and O&M cost estimates were developed for each alternative. The 20-year life cycle evaluation results provided in **Figure ES.2-9** show that the CHP and Vehicle Fueling/RNG biogas utilization strategies have a positive net revenue and could produce revenue for the plant. The other biogas utilization alternatives investigated produce a negative revenue.

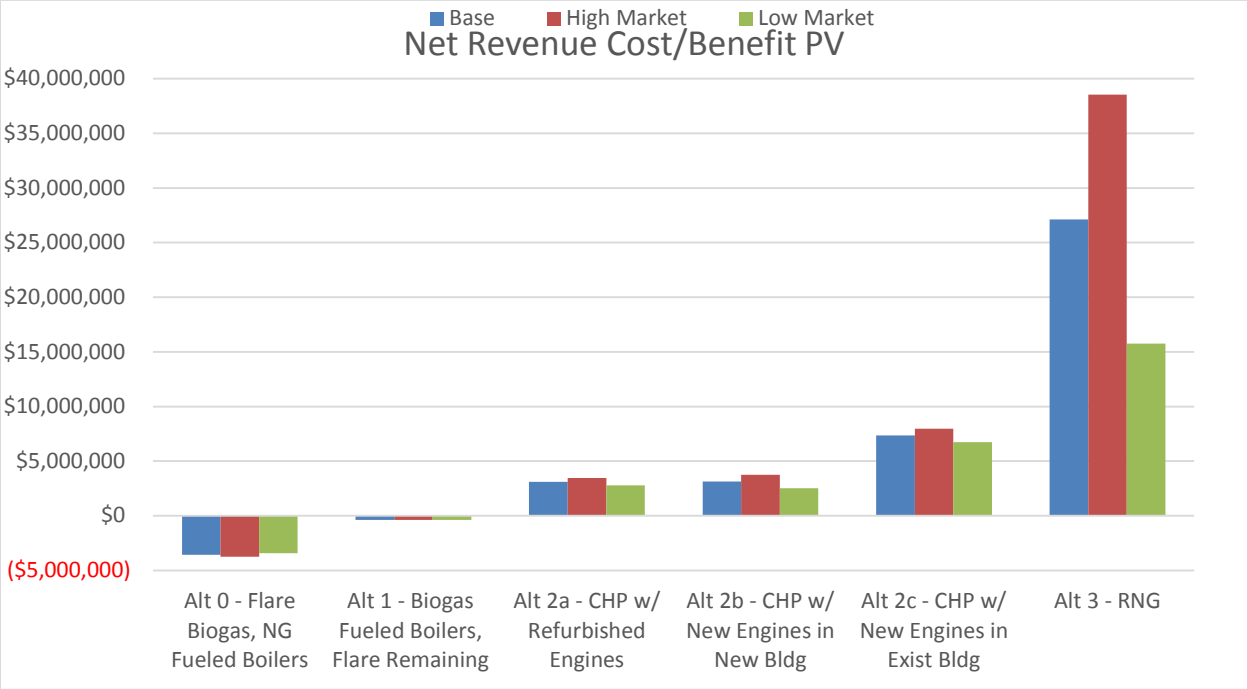

Figure ES.2-9: Net Revenue Cost/Benefit

The RNG alternative could produce greater revenue than the CHP alternative under the market conditions at the time of this report. It is important to note that the RNG alternative can have a higher revenue potential but this potential has a high level of volatility due to the uncertainly on the long-term health of the Renewable Identification Number (RIN) market. Therefore, it is recommended that the RNG alternative be investigated further with TECO. It is recommended that the following next steps be taken:

- Initiate a detailed utility pipeline assessment with TECO. This will determine if there is a nearby injection point for the plant or if a pipeline extension would be required.

- If the first step is viable, an interconnection capacity study can be initiated to determine if there is capacity in the pipeline for the additional natural gas.

In addition, a discussion was held between the City's wastewater and solid waste departments to discuss opportunities to supply RNG directly to the City refuse trucks from the HFC AWTP. It was concluded that this was not feasible due to the logistics with accessing the port to reach the plant site. A feasibility evaluation was performed on providing a dedicated RNG pipeline from the HFC AWTP to the McKay Bay solid waste facility to fuel the Compressed Natural Gas (CNG) trucks directly from RNG produced at the HFC AWTP. However, based on the estimated annual RNG demand, the RNG production potential from the HFC AWTP exceeds the SWD's CNG demand by 13,000 MMBTUs/Yr resulting in 17,500 MMBTUs/Yr of biogas being unused/flared. Considering the limitations, it is recommended the City focus on injecting RNG into the natural gas network and consider direct fueling only if a pipeline injection is deemed not feasible. It should be noted that the RNG can still be "wheeled" through TECOs pipeline to the City's CNG fueling stations which would allow the City to use the RNG credits without the limitations of the truck fueling schedule.

The total estimated cost of recommended biogas improvements ranges from $9,102,000 (CHP with new engines, existing building) to $19,457,000 (RNG) in 2018 dollars. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.11 High Strength Waste Receiving

High strength waste (HSW) contains fats, oils and grease (FOG), and other organic components not usually found in residential wastewater. A HSW receiving station evaluation was conducted to determine the payback period as related to the savings in power production to offset the related capital and O&M costs for accepting HSW. A secondary benefit of the receiving station would be to provide the community with an additional facility to unload HSW.

An evaluation of available HSW supply in the area indicated that FCS, Inc. (FCS) is the most likely source of HSW supply to the HFC AWTP. FCS currently hauls FOG from Hillsborough and Pinellas Counties and thickens it at their facility, Grease Depot. A sample of thickened FOG from FCS was analyzed and as expected, the thickened FOG has a much higher total and volatile solids content which is beneficial for gas production. FCS has shown interest in directing about 10,000 gpd of thickened FOG to the HFC AWTP. If all seven digesters are online at HFC AWTP, there will be sufficient operating volume for up to about 10,000 gpd of HSW while maintaining the 15 days HRT required for Class B biosolids. Additional negotiations between FCS and the City would need to be addressed to work out logistical issues.

A conceptual design of a HSW receiving station includes two unloading stations to provide redundancy. Conceptual level capital and O&M cost estimates were developed, and the benefits of a HSW facility were quantified by assessing the energy savings from an increased methane production in the digesters due to the addition of HSW. Based on an increase in methane production of approximately 24%, the payback will occur within year 15. The payback period is sensitive to the quality and quantity of HSW received and the operator and maintenance personnel hours required. This system is not being recommended due to the long payback

period, the high risk associated with relying heavily on one main supplier, and with port access concerns.

ES.2.12 Partial Discharge Testing

Partial discharge testing was performed by C.E. Testing, Inc. to determine the condition of the HFC AWTP's medium voltage switchgear and cable systems. The purpose for the testing was to detect and characterize partial discharge activity occurring in the medium voltage cable distribution circuits at plant. Partial discharges cause deterioration and erosion of electrical insulation systems of medium voltage cables, switchgear, transformers and other electrical apparatus. A total of 102 Points of Attachment were analyzed at the plant. The test data was gathered from temporary sensors affixed to each of the Points of Attachment test locations. Results of the partial discharge testing are provided in **Appendix C**, and observations and recommended actions for specific POA's are listed in Chapter 5 of the attachment.

ES.2.13 Standby Power and Fuel Storage Capacity

The existing standby power capacity at the facility consists of four 2,000 kW diesel generators for a total of 8MW of connected standby power. The facility also has five 500 kW biogas fueled "Base Load" generators that, when operating, can supply up to 2,000 kW. The biogas fueled generators are meant to run in parallel with the TECO feed and to operate at all times to supplement normal power. The biogas fueled generators are currently off-line and are evaluated in the Biogas Utilization Evaluation Technical Memorandum.

An evaluation was conducted to determine if the starting capacity of the four existing diesel generators was sufficient to meet the current load conditions. The evaluation included a live test completed in July of 2017 of starting the HPO system while on standby power. Both the evaluation and the test concluded that the existing startup capacity was sufficient at current loads as long as the facility load is 6MW or less. The City recently added an interlock starting function for the HPO system to disable attempted starts above a 6MW plant power loading threshold while on standby.

An evaluation was also conducted to determine future standby power capacity requirements considering future flows and additional loads from recommended improvements included in the Master Plan. The evaluation concluded that an additional 2MW of power is required to meet current loads with N+1 reliability. A second 2MW of power will be required to meet future loads with N+1 reliability.

Three types of generators were evaluated including: 2MW EPA Tier 2 Diesel Generator, 2MW EPA Tier 4 Diesel Engine, and a 2MW Combined Heat and Power Generator. The recommendation calls for the addition of a 2MW EPA Tier 2 Diesel Generator as soon as possible to provide the N+1 reliability and the addition of 2 MW future generator capacity as funding becomes available. The type of generators added should be evaluated further including discussions with TECO and an analysis of TECO rate structures corresponding to generator type. The current TECO rate structure is Time-Of-Day Firm Standby and Supplemental Service. It is for self-generating customers whose generating capacity (exclusive of emergency generating equipment) exceeds 20% of their site load in kilowatts.

The facility currently has 24,000 gallons of diesel fuel storage for the existing standby power generator system. An evaluation was performed to determine fuel storage requirements for five days supply for current and future conditions. The results concluded that an additional 51,000 gallons of fuel storage is required for current conditions. A possible location is shown in **Figure ES.2-10**. An additional 17,000 gallons of fuel is required with the installation of a new 2MW diesel generator for future loads, for a total of additional storage required 68,000 gallons. A tank fill station is recommended to off load fuel trucks quickly, and a fuel maintenance and polishing system is recommended to extend fuel life.

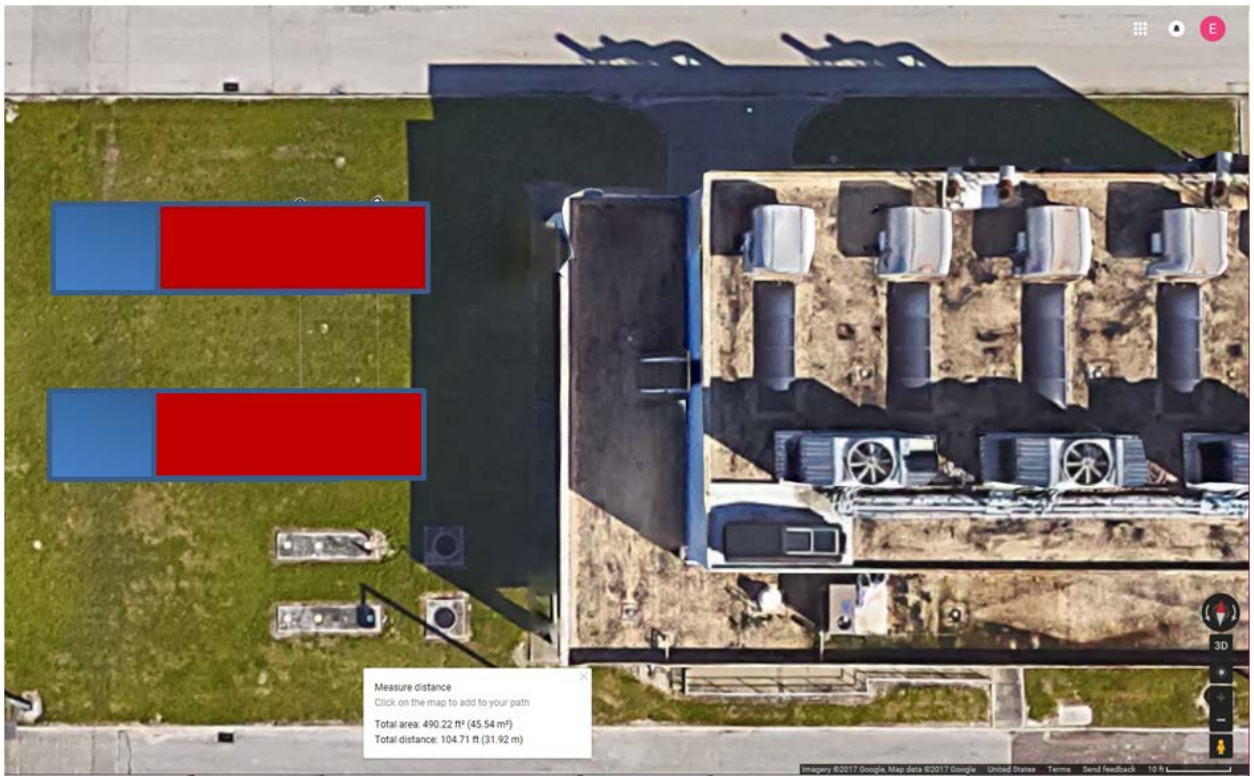

Figure ES.2-10: Footprint of Aboveground Fuel Storage Tanks

[1]25,000 gallon aboveground fuel storage tanks are shown in red
[2]35,000 gallon aboveground fuel storage tanks are shown in blue

The total estimated cost of recommended standby power and fuel capacity improvements is $3,840,000 in 2018 dollars. This cost includes one 2MW generator for the N+1 reliability under current loads and additional fuel storage capacity to accommodate 5 days fuel consumption with the future in service generator. This does not include repair and replacement projects that have been included in the CIP to address equipment that has failed or has reached the end of its useful life.

ES.2.14 Instrumentation and Controls, SCADA Automation

The City has begun the process of upgrading and testing the remote site SCADA system VTScada software. As the City gains confidence in the performance of the software, it is recommended

to migrate away from the HSQ software and Open VMS operating system in favor of VTScada software and Microsoft Windows operating system for in-plant systems.

The plant control system includes an installation of GE PLCs for control of plant processes. While many of these PLCs are at active technology level, some are still at the mature or discontinued level. It is recommended the City move forward with replacement of remaining discontinued level devices and implement planning for replacement of mature level devices as a priority program.

Documentation and drawings for plant control panels, network configurations, fiber optic cable routing and application software have not been maintained to reflect system modifications and upgrades performed over time. Therefore, it is recommended the City implement a program to verify and update documentation to have it reflect current conditions and maintain the documentation into the future.

SCADA system disaster event recovery should be planned for in advance with procedures, documentation and software backups. It is recommended the City implement and test a system of disaster recovery procedures for the SCADA system including individual servers, computers, programmable controllers and managed network devices.

The City is considering the use of industrial tablets for use in plant operations. The intent is to utilize cellular communications for connection to City networks, which has some concerns for security and connectivity. The City has also installed limited Wi-Fi connectivity in the plant for network extensions, which have similar concerns. It is recommended that the City perform a comprehensive evaluation of both cellular and Wi-Fi technology for use with industrial tablets and other devices for SCADA system operation and other networking needs.

The plant SCADA system network is implemented as a tiered modified star configuration. Review of the existing fiber optic cable routing indicates implementation of plant wide or sectional fault tolerant fiber optic rings would not provide improved reliability without a complete reconstruction of the network paths and replacement of most network hardware. The most effective and cost effective method to improve and maintain network reliability is to standardize on industrial network components and develop availability of shelf and vendor spares to support plant operations.

The plant SCADA system communicates using fiber optic cable with some segments as old as twenty-five years. To ensure the cable is still performing to original manufacturer specifications and within calculated fiber optic link budgets, the City should implement a program for fiber optic cable testing as a baseline with the intent to replace cable that does not perform within specification.

Improvements to existing or new process specific instrumentation, control panel modifications and/or additions and software updates for monitoring and control should be included in each CIP project. The project costs presented in each technical memorandum include an allowance for associated instrumentation and controls.

ES.2.15 Regionalization

A regionalization evaluation was conducted consisting of aggregating resources between municipalities/utilities to serve a mutual interest by optimizing systems to be more efficient, economically beneficial, and better serving to its customers. The following categories were evaluated for regionalization:

1. Equipment acquisition from other municipalities
2. Receiving/transmitting raw wastewater from/to other municipal or industrial sources.
3. Receiving/transmitting septage
4. Receiving/transmitting fats, oils, and greases (FOG)
5. Receiving/transmitting sludge/Biosolids

Equipment that was identified as having potential for a regionalization approach was limited since most of the equipment recommended for replacement or refurbishment at HFC AWTP is not practical due to its size and relatively low costs. Hillsborough County's Northwest Regional Water Reclamation Facility is currently undergoing an expansion and plans to demolish its biosolids dryer facility including two lightly used rotary drum dryers, Andritz DD50 units, which are rated for approximately 5,500 kilograms (kg) (12,100 lbs) of evaporation of water per hour each. These units could meet the biosolids processing needs of the City. A more detailed assessment of the actual costs to procure the dryers from Hillsborough County and improvements required at HFC AWTP for retrofitting is recommended. The acquisition of the Hillsborough County dryers would provide the City the benefit of having a relatively unused dryer system with updated control systems, hot air recycle, and likely a longer service life.

HFC AWTP has available capacity to accept additional raw wastewater from neighboring municipalities with respect to base flow but is limited at peak flows due to infiltration and inflow. The City has already undergone some regionalization as its wastewater service area extends beyond the corporate limits of the City to Temple Terrace and Hillsborough County. The wastewater service area is nearly built out and adjacent counties and municipalities have already begun to expand their collection and treatment systems in response to current needs and to meet estimated future growth. Increases in raw wastewater flow from outside City limits is seen to be limited to existing or new interconnections with Temple Terrace and Hillsborough County because of the economic feasibility through minimizing infrastructure improvements for raw wastewater transmission and conveyance. Additional wastewater flow from Temple Terrace, based on anticipated growth, is a small percentage increase to the City's influent flow rate. As the annual increase in wastewater flow from Temple Terrace is minimal, major infrastructure improvements are not likely required; however, should be periodically evaluated as flows increase with growth. Increase in wastewater flow from Hillsborough County is likely to be on a larger magnitude than that of Temple Terrace. It is recommended that the City evaluate infrastructure improvements necessary to convey and treat additional flows and set limitations on flow rates from Hillsborough County accordingly.

Because of more strict regulations for land application of biosolids and diminishing capacity at landfills, there is a significant potential for the City to accept additional biosolids for processing. The HFC AWTP has the advantage of being able to produce multiple biosolids end-products. Should land application or landfilling of Class B biosolids continue to become increasingly difficult and expensive due to land application site restrictions and diminishing landfill capacity, the City can rehabilitate and recommission the thermal dryers to create a product of significantly less volume than dewatered biosolids and can create revenue from disposal.

An opportunity to treat additional septage and FOG from regional haulers for treatment exists. However, the recommendation from the High Strength Waste TM is not to pursue this.

ES.3 Capital Improvement Plan and Projected Costs

As part of the preparation of the Master Plan, a capital improvement projects (CIP) list was developed. The CIP list includes repair and replacement (R&R) projects identified during the Phase 1 evaluation of the existing facility, recommended improvements to various process areas identified in the Phase 2 evaluations, as well as projects identified by City staff. The CIP list identifies projects by "Building". In addition, there are several plant-wide projects, for example miscellaneous equipment repairs throughout the plant. The various projects were grouped by process area in **Table ES.3-1**.

Table ES.3-1: Capital Improvement Projects Totals by Process Area

Process Area	Number of Projects	Total Estimated Project Cost[1]
Preliminary Treatment Improvements	19	$ 66,124,000
Primary Treatment Improvements	11	$ 30,502,000
BNR Process Improvements	29	$160,473,000
Tertiary Treatment Improvements	9	$ 27,426,000
Disinfection and Discharge Improvements	7	$ 19,160,000
Biosolids Systems Improvements	39	$ 92,260,550
Electrical Systems Improvements	18	$ 15,573,250
I&C and SCADA Improvements	3	$ 4,300,000
Plant-Wide Improvements	75	$141,258,000
Total	**210**	**$557,076,800**

[1] The total project cost includes an additional seven percent (7%) of the construction to cover the costs associated with administration of the contracts, inspection, and other related costs. Costs shown are in future inflated dollars based on the planning year for which each project is programmed. Estimated costs developed in the CIP were generated in 2018 dollars with a 3% annual increase starting in year 2.

ES.4 Schedule for Improvements

Working with the City, the projects identified in the CIP list were prioritized and scheduled over the 20-year planning period. The priority and schedule are based on several factors, including:

- criticality;
- expected remaining life/condition;
- plant operations and need to maintain capacity;
- ability to meet regulatory requirements;
- correlation with other impacted process improvements; and
- the need to distribute costs over the planning period.

The CIP list assigns projects by Year 0 through Year 20, with Year 0 equal to FY 2019. For the majority of the capital improvement projects listed, a "design project" is identified in Year N with the associated "construction project" in Year N+1.

As can be expected, the number of projects, and subsequently the total cost of the projects by year are skewed towards the first ten years of the planning period. This is due to the need to make immediate improvements as a significant amount of major equipment has reached, or will reach the end of its useful life in the near future. There is also the potential to group several projects into larger projects, related by either process and/or physical location, should the City elect to do so.

Table ES.4-1 summarizes the capital improvement projects by planning year.

Table ES.4-1: Capital Improvement Projects Totals by Planning Year

Planning Year	No. of Projects	Total Cost[2]	Planning Year	No. of Projects	Total Estimated Project Cost[2]
0[1]	7	$ 7,543,500	11	4	$ 7,350,000
1	18	$ 21,603,300	12	5	$ 10,250,000
2	27	$ 69,940,000	13	5	$ 10,560,000
3	26	$ 79,870,000	14	5	$ 8,670,000
4	19	$ 72,090,000	15	7	$ 19,240,000
5	10	$ 27,500,000	16	6	$ 16,530,000
6	15	$ 33,730,000	17	5	$ 17,700,000
7	12	$ 34,520,000	18	5	$ 12,590,000
8	10	$ 34,340,000	19	5	$ 39,920,000
9	8	$ 14,900,000	20	4	$ 9,580,000
10	7	$ 8,650,000	**Total**	**210**	**$557,076,800**

[1] Projects are already programmed for FY 2019

[2] The total project cost includes an additional seven percent (7%) of the construction to cover the costs associated with administration of the contracts, inspection, and other related costs. Costs shown are in future inflated dollars based on the planning year for which each project is programmed. Estimated costs developed in the CIP were generated in 2018 dollars with a 3% annual increase starting in year 2.

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Section 1.0 Introduction

1.1 Purpose and Background

The City of Tampa (City) Howard F. Curren Advanced Wastewater Treatment Plant (HFC AWTP) is permitted under Florida Department of Environmental Protection (FDEP) Permit No. FL0020940 to treat 96 million gallons per day (MGD) annual average daily flow (AADF) with a Type I two-stage, high rate (pure oxygen and fine bubble aeration) activated sludge biological nitrification/denitrification domestic wastewater treatment plant. This plant is operated to discharge AWT, high-level disinfected and dechlorinated effluent to Hillsborough Bay and chlorinated reclaimed water to industrial customers, McKay Bay and Mosaic, and public access reuse customers. Residuals generated by this facility can be dewatered for land application as a Class B residual or may be heat dried to meet Class AA standards for distribution and marketing, however the City's dryer is currently not functional. Currently, annual average daily flows are 60 MGD with peak flows of 190 MGD.

The last master plan for the HFC AWTP was completed in January 1989. The emphasis of that plan was to provide improvements to increase plant capacity while meeting new upcoming regulatory treatment requirements. Several of the improvements identified in the old plan have been completed, increasing the capacity of the plant to the current permit limits of 96 MGD AADF and 221 MGD peak hourly flow (PHF). In May 2015, a capacity analysis was completed to assess current flow rates and estimate future flow rates. Based on the results, additional improvements to increase the capacity of the plant are not needed. Since the completion of the projects to increase plant capacity, the City of Tampa Wastewater Department (WWD) has also completed several additional system improvement projects, equipment replacement projects, and treatment process studies to maintain system reliability and improve overall facility operating reliability and efficiency.

The updated master plan incorporates these studies, as well as completed improvements, and identifies recommended future improvements necessary to maintain system reliability, while addressing current and projected regulatory requirements and identifying measures to increase overall operating efficiency of HFC AWTP. The master plan was completed in two phases.

1.2 Phase 1 Summary and Updates

Phase 1 of the Master Plan of the Howard F. Curren AWTP consisted of the evaluation of existing facility systems and the creation of a technical memorandum to detail these findings. The investigation and subsequent summary were completed and submitted to the City of Tampa and titled "City of Tampa, Howard F. Curren AWTP Master Plan, RFQ 15-D-00013, Existing Systems Technical Memorandum of Findings, August 2016 Final."

The report detailing Phase 1 technical findings focused on existing conditions at the facility and the following were examined:

- Population Projections
- Historic and Future Flow Data
- Industrial Waste Loads
- Wet Weather Determination

- Historic and Future Water Quality Data
- Historic and Projected Influent Loading
- Plant Hydraulics
- High Flow Protocol Evaluation
- Regulatory Review
- Unit Process Evaluation
- Biosolids
- Biogas Utilization
- Sludge Dewatering and Drying
- Dewatering Sidestream Treatment Options
- Alternative Disposal Options
- Electrical Systems
- Electrical Equipment Assessment
- Instrumentation & Control
- Plant SCADA Overview
- Communications Network Systems
- Structural Evaluation

Within the Phase 1 document (**Appendix A**), Section 8 summarizes the Phase 1 findings and provides recommendations for the future phase, which is the Phase 2 investigation. The next steps are outlined and broken down into:

- Calibrated Process Model,
- Technology Review, and
- Financial Planning.

1.3 Phase 2 Report Introduction

Following the completion of the Phase 1 Existing System Technical Memorandum of Findings, Phase 2 of the Master Plan commenced. The objective of Phase 2 is to identify improvements to each process component as well as the overall plant that will reduce operating costs, restore and maintain reliability, improve treatment and hydraulic limitations, improve efficiencies, and continue to meet existing permit conditions. This is to be accomplished through overall plant process modeling, computation fluid dynamic modeling, and other tools that are used to evaluate process alternatives and technologies. These improvements, along with the previous equipment assessments, are used to develop a list of recommended plant improvements, supplemented with cost estimates and a schedule for completion. Plant influent projected flows and loads were established based on recently measured historical data and projections for future growth over the next 20 years based on the Phase 1 Master Plan Report (**Appendix A**). Analyses in the Master Plan used AADF starting at 60 MGD and increasing to 80 MGD over the twenty-year planning period. The peaking factor for PHF used in the Master Plan was 2.93, based on historical flows, and the corresponding increase in PHF over the twenty-year period was used.

Three influent loading scenarios were selected to evaluate process performance: Current Annual Average, Future Annual Average, Future Maximum 30 day as shown in **Table 1.3-1**. The current loads were established using the most recent year of data available (May 2016 – April 2017). This period was

considered to most accurately represent current conditions based on more representative influent sampling techniques implemented in Summer 2016 and the model calibration results.

Table 1.3-1: Design Influent Flows and Loads

	Current Annual Average		Future Annual Average		Future Maximum 30 Day	
Influent Flow, mgd	60		80		112.9	
	Load (ppd)	Conc. (mg/L)	Load (ppd)	Conc. (mg/L)	Load (ppd)	Conc. (mg/L)
Influent TSS	94,600	189	126,000	189	157,000	167
Influent BOD	97,700	195	130,000	195	163,000	173
Influent TKN	19,200	38.2	25,600	38.2	31,900	33.9
Influent TP	2,670	5.34	3,570	5.34	4,450	4.73

Effluent nutrient requirements shown in **Table 1.3-**2 were established based on the existing permit and expected future developments. The current annual average TN concentration is a targeted concentration based on the permitted 5 year average TN mass loading to the bay. The future annual average TN concentration of 3.0 mg/L is predicated on increasing the amount of reuse from the plant. There is currently a waiver on effluent TP limits based upon Bay modeling, however the potential for meeting an effluent TP of 1 mg/L was considered.

Table 1.3-2: Design Effluent Nutrient Concentrations

Parameters	Current Annual Average	Future Annual Average
Effluent Flow, mgd	60	80
Effluent TN Concentration, mg/L	2.3	3.0
Potential Effluent TP Concentration, mg/L	1.0	1.0

The overall Phase 2 Master Plan Report organization consists of individual Technical Memoranda that are placed in order of the liquid flow path within the facility starting with preliminary treatment through tertiary treatment then including other processes such as biosolids and instrumentation. The individual Technical Memoranda allow for a focused and detailed evaluation of each process with specific recommendations to meet the Phase 2 objectives.

The Phase 2 Master Plan Report organization starts with a description of the updating of the City's process model for the HFCAWTP. The first step in this process required special sampling throughout the plant and a model calibration update. A summary of the effort is provided, and the full report is included in **Appendix B**. Once the calibration was completed, the model was then used to evaluate the plant holistically, and this process is fully described in Technical Memorandum 7, Biological Nutrient Removal, which is referenced within the report as the secondary treatment process.

Within each technical memorandum, alternatives in process configuration and technologies are analyzed and a final recommendation is provided for each process. However, many of the processes are interrelated, and these interrelations are covered by the overall plant process modeling and Section 18, Overall Process Selection and Summary of Recommendations. This Section includes the prioritization and phasing of projects needed to implement the project while maintaining plant operations through construction. The priority and schedule are based on remaining useful life of equipment, criticality, capacity needs, regulatory requirements, and possible interrelations with other plant process improvements.

Following the overall process selection, Section 19, Capital Improvements Plan and Projected Costs, provides a list of the recommendations that can be incorporated into the City's Capital Improvements Program (CIP). The list of capital improvements includes a detailed description, year of implementation, and estimated capital cost for each project for the next 20-year planning horizon. Estimated costs developed in the Master Plan were generated in 2018 dollars. Estimated costs for the Capital Improvements Projects (CIP) list include a 3% increase per year starting in planning Year 2 and through Year 20.

Section 2.0 Process Model Sampling and Calibration

The existing GPS-X® process model was improved to proceed with analyzing various treatment alternatives. The original model was developed for the diffused air reactors (DAR) Aeration Improvements Project, which was updated and expanded to include the entire treatment process for this master plan update. Some of these improvements included adding primary, tertiary, and biosolids treatment. A preliminary calibration, which was focused on sludge production, of the process model was completed based only on historical data. Detailed calibration of the process model requires a good understanding of the biological process and accurate characterization of the wastewater which is accomplished by evaluation of process sampling results.

2.1 Sampling Results

A full week and follow up week in February 2017 and April 2017, respectively, of process sampling was completed to gather information necessary for process model calibration. A sampling plan (included in **Appendix B**) was developed from the WERF project "Methods for Wastewater Characterization in Activated Sludge Modeling" with City staff and was followed to capture details of significant processes. The sampling effort included composites, process grabs, diurnals, and sidestream samples. Approximately 1,800 analyses were performed during the special sampling week. The sampling result data was compiled and reviewed (see **Appendix B**) and screened for obvious outliers. Mass balances were calculated around different unit processes using the special sampling data.

2.1.1 Composite Samples

Composite samples are representative of daily average samples used to characterize loadings to the biological processes. The relative relationships between the influent parameters were mostly consistent with expected and/or historical values. Influent soluble Total Kjeldahl Nitrogen (TKN) was reported to be very close and in some cases lower than the influent ammonia nitrogen (NH_3-N) concentrations. For the purposes of model calibration, influent NH_3-N values were considered to be accurate and a relationship between NH_3-N and soluble TKN was used. Primary effluent data was consistent with a primary sedimentation tank (clarifier) solids removal of about 70%. The additional data collected in April confirmed primary sedimentation tank removals, which provided confidence in model input development. The measured carbonaceous effluent concentration reflected the typical expected treatment for the carbonaceous clarifier (biochemical oxygen demand (BOD) removal with no nitrification). There was some BOD carryover (approximately 30 mg/L) into the Nitrification Reactor which was consistent with historical averages. The nitrification clarifier effluent showed complete nitrification and a small amount of denitrification occurring in those tanks. The final effluent was similar to historical averages, reflecting good nitrogen removal performance.

2.1.2 Process Grab Samples

Process grab samples were collected in the morning and afternoon on two different weekdays throughout the plant to characterize process performance under low and high loadings. The influent, primary effluent, main pump station (MPS) and final effluent average grab data were similar to the composite data. The Nitrification Reactor samples along with dissolved oxygen

(DO) data were used for comparison during model calibration. Ortho-Phosphate (PO_4-P) profiles confirmed no biological phosphorus removal was occurring in the nitrification reactor tanks.

2.1.3 Solids and Sidestream Samples

Solids and sidestream samples are intended to capture solids handling process performance and recycle stream loading. The Carbonaceous Reactor mixed liquor suspended solids (MLSS) was typical for historical values, and the Nitrification Reactor MLSS reflected typical concentration during dry weather mode operation. The sludge concentrations were similar to historical averages.

2.1.4 Diurnal Grab Samples

Discrete samples were collected on the influent at Junction Chamber No. 1 (JC-1) and final effluent every two hours on two different weekdays to characterize the variation in influent load and process performance. Influent load peaking factors were calculated based on the results. The load peaking factors reflected a pattern consistent for a typical plant of this size. The final effluent results were used to evaluate the model calibration on a dynamic basis. Effluent total suspended solids (TSS) and nitrate nitrogen (NO_3-N) increased around the daily flow peak. NH_3-N and nitrite nitrogen (NO_2-N) were consistently non-detectable.

2.2 Mass Balance

The primary clarifier mass balance was reasonable for the sampling week, providing confidence in the measured influent and primary effluent concentrations and estimated primary sludge loading. The mass balance around the Carbonaceous Clarifiers was reasonable but indicated that there were 14% more solids entering the clarifiers than leaving. The mass balance around the Nitrification Clarifiers was reasonable, but indicated that there were 10% more solids entering the clarifiers than leaving. Similar to the Carbonaceous Clarifiers this was likely due to uncertainty regarding the influent flows which are calculated values. The mass balance around the gravity thickener was reasonable, confirming waste activated sludge (WAS) and thickened waste activated sludge (TWAS) loads were relatively accurate. The mass balance around the dewatering belt filter presses was good, which provided confidence in overall solids production values.

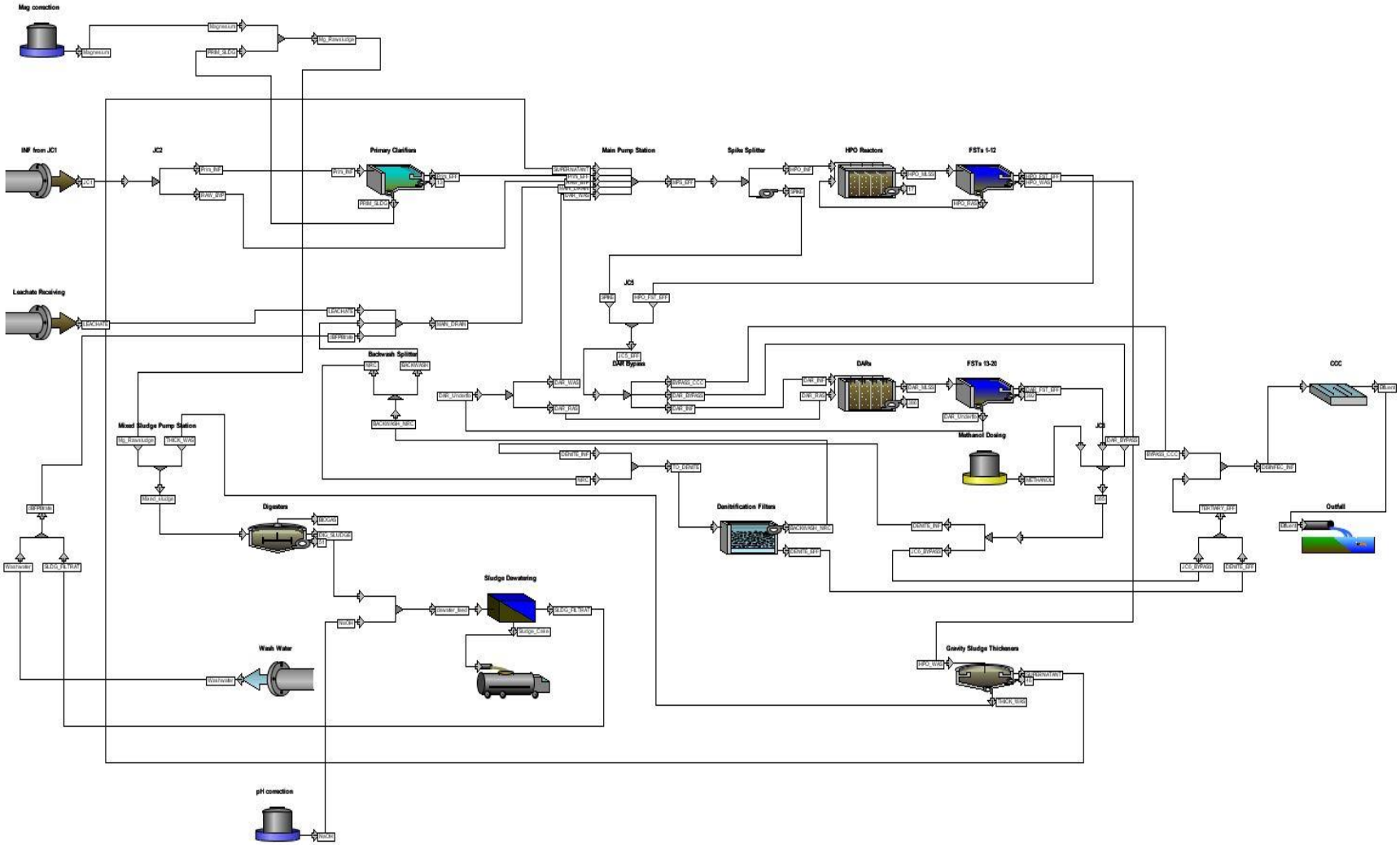
2.3 Observed Yields

Total yields were calculated and were consistent with expected values.

2.4 Model Set Up and Calibration

The various treatment processes were added to the HFC AWTP model and set up in the model for: primary clarifiers, main pump station, spike splitter, carbonaceous reactors, carbonaceous clarifiers 1-12, nitrification reactors, nitrification clarifiers 13-20, methanol dosing, denitrification filters, chlorine contact chambers, gravity sludge thickeners, anaerobic digesters, and belt filter press dewatering. The schematic layout of the HFC AWTP GPS-X® model is shown in **Figure 2.4-1**.

Figure 2.4-1: GPS-X® Model Set Up



The calibration of the HFC AWTP model met the criteria for a Level 3 Calibration based upon the criteria in the Water Environment and Reuse Foundation Tiered Calibration Approach. Calibration of the model for the HFC AWTP generally followed the following steps, starting with periods of the most data and moving to those with the least amount of data.

1. Obtained agreement between the model and special sampling data (steady-state calibration).
2. Evaluated the model dynamically on an hourly basis with special sampling data.
3. Validated the model using steady state simulation to a time period outside the sampling week.
4. Validated the model dynamically using a time period outside the sampling week.

The calibration process and validation results are detailed in **Appendix B**.

Section 3.0 Site Improvements

Site improvements associated with the improvements to the Howard F. Curren AWTP over the planning period detailed in the master plan will be incidental to each project. Based on the layout of the existing plant and the improvements recommended in this document, it is further assumed that new roads, parking, and access roads will not be needed.

Tankage that will be added through the planning period will be open, as a result the hard surface added will be zero and the need for additional storm water storage negated.

For onsite improvements where new tankage is installed, the relocation of existing yard piping or franchise utilities, as necessary, will become part of the individual project. All requisite soil erosion, Environmental Resource, and City permits for site work will be obtained prior to construction as part of the project that the site work is associated with.

Miscellaneous maintenance items associated with normal wear and tear on existing AWTP structures such as windows, roofs, new paint and landscaping will be considered site work for the purpose of the master plan with a budget for the same allotted on a yearly basis.

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Technical Memorandum 4.0 Flow Equalization

4.1 Purpose and Background

The HFC AWTP is not currently equipped with flow equalization. As a result, the HFC AWTP sees variability in hydraulic and nutrient loads from high wet weather flows and from diurnal peaks. This evaluation discusses the potential impacts from installing flow equalization at the plant to dampen the diurnal loads.

Influent flows and loads used for the process modeling performed in Phase 2 are based on recently measured historical data and projections for future growth developed in Phase 1 of the project. The current loads were established using the data from May 2016 through April 2017. This period is considered to more accurately represent conditions based on more representative influent sampling techniques implemented in the summer of 2016, and the model calibration results. It should be noted that the process modeling, and subsequent process reviews and recommendations were performed assuming no flow equalization.

4.2 Evaluation

Flow equalization is used to reduce the impacts from variations in flow, either wet weather induced flows or diurnal flows, thereby achieving a more consistent flow, as well as loading, through the plant. For this analysis, flow equalization to address high wet weather induced flows is not evaluated. The peak day flows, while high, are still within the hydraulic capacity of the treatment plant. In addition, the City has on going collection system rehabilitation program and has identified the need for the rehabilitation of numerous pipelines and manholes to restore their structural integrity. These projects will also reduce the inflow and infiltration (I&I) in the collection system. This evaluation focuses on dampening diurnal flows to promote a more constant flow rate and constituent mass loading rate downstream of the equalization tank to improve efficiency, reliability, and provide greater control over physical, biological, and chemical processes.

Flow equalization downstream of the primary clarifiers is the most economical and trouble free application as the wastewater is screened and de-gritted and the heavier solids are allowed to settle in the primary clarifiers prior to being introduced to flow equalization. Primary clarifiers are also less susceptible to diurnal flows. Equalization may be in-line, where all flow passes through the equalization tank, or side-line, where only the flow above the daily average passes through the equalization tank. The in-line design has the advantage of more effectively reducing peak organic loads, whereas the side-line design has the advantage of requiring less physical tankage and possibly, equipment (i.e. pumps, mixers, etc.). This evaluation is based on in-line equalization.

In order to determine the size of flow equalization required, the historically dry weather months of October through April from the previous 3 years were used to normalize diurnal flow patterns. Hydrographs were created to depict actual flow on an hourly basis, and flow was equalized for the specific day to create a theoretical mass balance for the equalization tank. The equalizing volume was calculated as the largest difference between the average hourly equalized inflow and the actual inflow for each hour recorded. The equalizing volumes were analyzed for dry weather days and plotted to yield an equalization tank design capacity of 11.8 million gallons (MGal). This value includes the highest

calculated dry weather capacity plus 20% additional capacity to account for plant recycle, minimum operating levels, and freeboard.

A summary of the equalization tank sizing evaluation and design hydrographs are shown in **Table 4.2-1** and **Figure 4.2-1, Figure 4.2-2, Figure 4.2-3, Figure 4.2-4,** and **Figure 4.2-5**. This data includes the 5 largest dry-weather equalizing volumes in recent years and the corresponding mass balance diagrams that were used to calculate design capacity.

Table 4.2-1: Dry Weather Diurnal Flow Equalization

Magnitude	Date Recorded	Equalizing Volume (MGal)	Average Equalizing Flow (MGD)
1	2/28/2015	9.83	65.1
2	11/25/2014	9.74	67.7
3	3/29/2014	8.12	67.5
4	2/24/2016	7.50	67.6
5	10/4/2015	6.77	70.3

Largest diurnal equalizing volume = 9.83 MGal
Design equalization volume with 20% additional capacity = 9.83 x 1.2 = 11.8 MGal

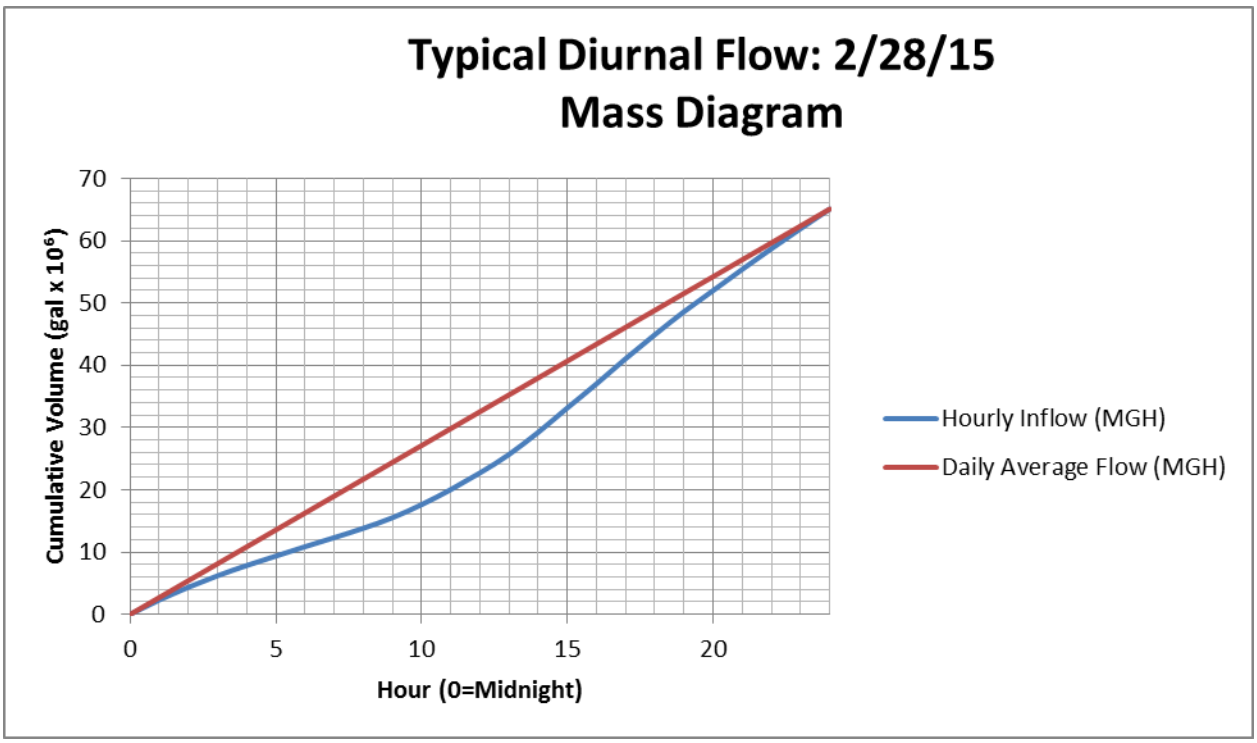


Figure 4.2-1: February 28, 2015 Mass Diagram

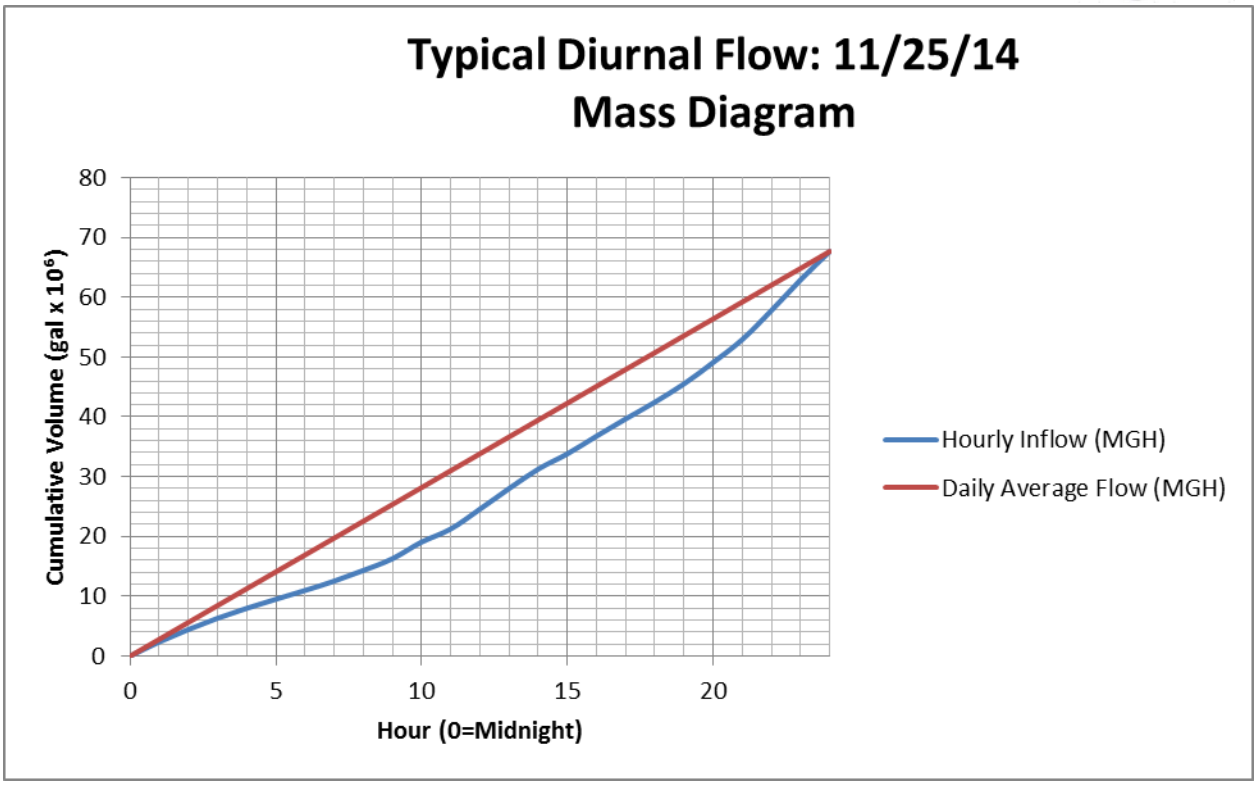


Figure 4.2-2: November 25, 2014 Mass Diagram

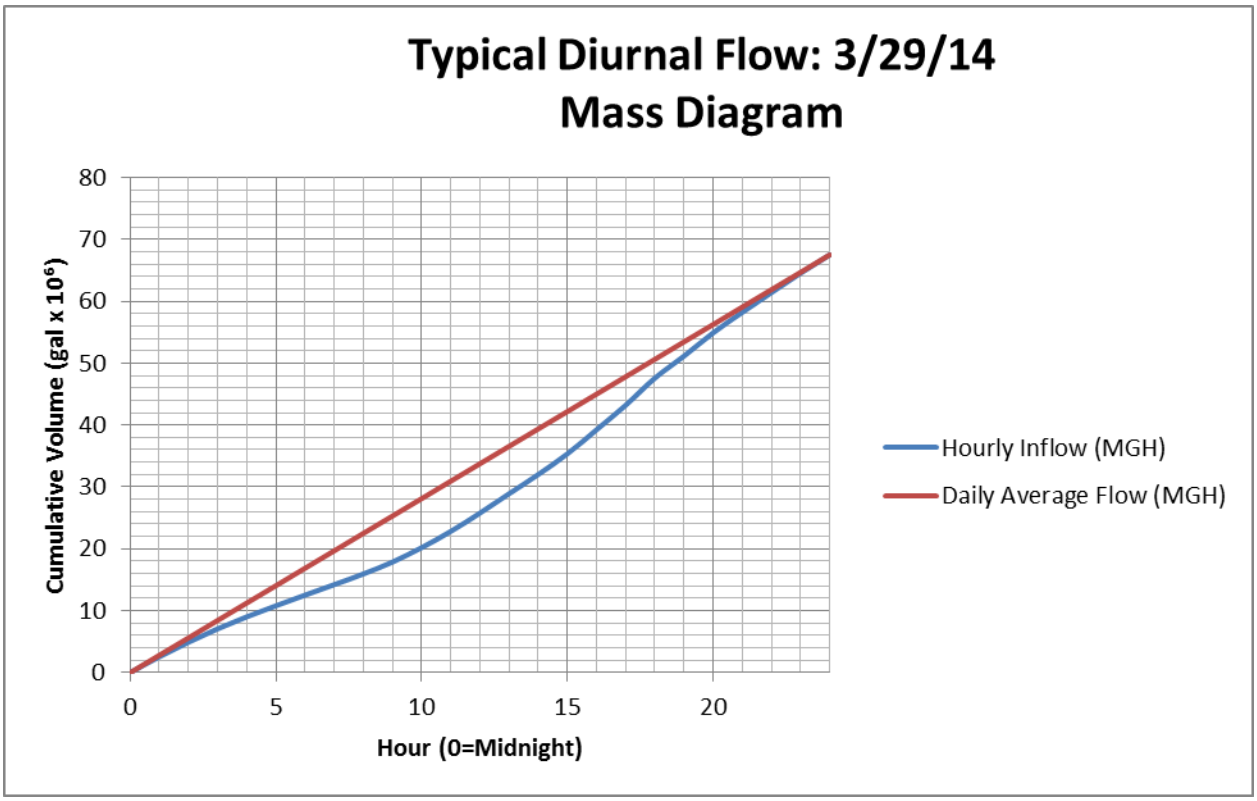


Figure 4.2-3: March 29, 2014 Mass Diagram

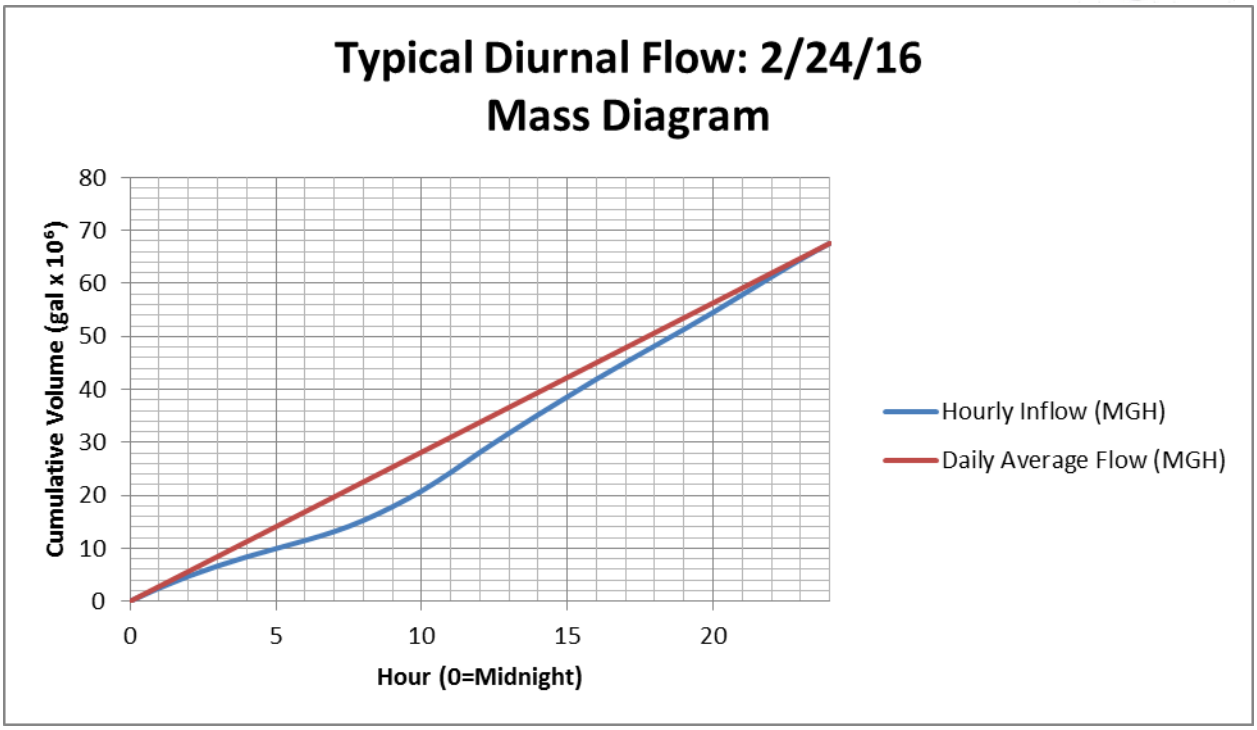


Figure 4.2-4: February 24, 2016 Mass Diagram

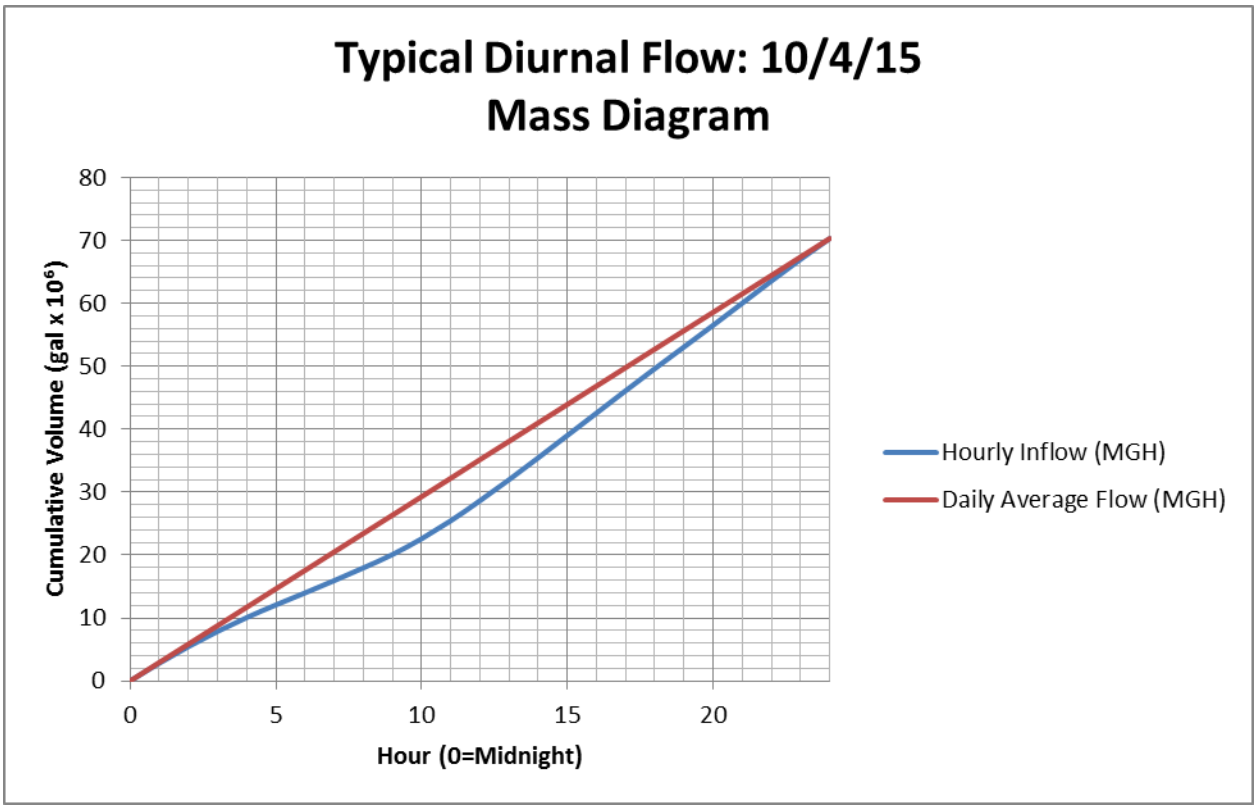


Figure 4.2-5: October 4, 2015 Mass Diagram

4.3 Equalization Tank Design Concepts

An equalization tank with a design capacity of 11.8 MGal will require a large site footprint for construction. A typical design may include a cylindrical or rectangular concrete structure, preferably constructed above grade due to ground water management issues and plant hydraulics, with a wall depth of approximately 25-feet. To conceptualize the design, a tank with the capacity to hold the design volume of 11.8 MGal would be sized with inside dimensions of 250-feet W x 250-feet L x 25-feet H (square tank) or 285-feet Dia x 25-feet H (cylindrical tank). The tank footprint would be approximately 1.5 acres in area by these dimensional parameters.

Additional head requirements in the HFC AWTP are also expected and supplementary pumping may be required. The existing Main Pump Station may be outfitted to provide influent pumping to the equalization basin, however flows in excess of the design peak diurnal flow should not be sent to the basin to keep the necessary pipe/channel sizing to a minimum. Additional equalization pumps or gravity discharge apparatus, dependent on the hydraulic head requirements, may then be utilized to provide equalized flow downstream to other processes. Automatically controlled flow-regulating devices are highly recommended at the equalization tank outlet.

Mixers and aeration are also recommended in the equalization tank design. Aerators are intended to prevent influent wastewater from becoming septic. Mixers should have the capacity to keep solids suspended within the equalization tank. Mixers may be of mechanical or jet type typically. A conceptual cost estimate for an 11.8 MGal flow equalization tank is shown in **Table 4.3-1.**

Table 4.3-1: Conceptual Cost Estimate for Flow Equalization

Item Description	Cost
250' x 250' x 25' concrete tank	$ 5,500,000
Pile foundation	$ 5,000,000
Equalization tank aeration/mixing sytem[3]	$ 1,800,000
Installation of aeration/mixing system[4]	$ 720,000
Tank coating system	$ 125,000
Influent and effluent pipe (allowance)	$ 1,000,000
Tank Drain pumps (2)	$ 200,000
Effluent flow meter	$ 50,000
Instrumentation & Control	$ 415,000
Electrical	$ 415,000
Sum of Bare Construction Costs	$15,225,000
30% Contingencies	$ 4,567,500
Bare Construction Cost	$19,792,500
20% OH&P & GCs	$ 3,958,500
Total Construction Cost	**$23,751,000**
20% Management and Engineering[2]	$ 4,750,000
Total Capital Cost[1]	**$28,501,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.
[3]Cost based on budgetary estimate received for a BioMix™ coarse bubble mixing system and includes in-tank air piping, headers and nozzles, two 75 hp rotary screw air compressors, control panel.
[4]Assumed installation of aeration/mixing system at 40% of equipment cost.

4.4 Recommendation

At this time, construction of an equalization basin is not recommended. As previously noted, the process modeling, and subsequent recommendations to improve process performance are based on the assumption that diurnal flow equalization is not provided. Furthermore, sidestream treatment is recommended to specifically reduce the impacts from high nitrogen load from sidestreams associated with anaerobic digestion and digested sludge dewatering. With an estimated cost to construct of approximately $28 million, it is difficult to justify this cost when the individual processes are capable of treating the fluctuating flows and loads associated with the diurnal flow pattern at the HFC AWTP.

Technical Memorandum 5.0 Preliminary Treatment Evaluation

5.1 Purpose and Background

This section evaluates alternatives for addressing points of concern in the preliminary treatment train. This train includes pre-aeration in Junction Chamber No. 1, Screening, Grit Removal, Grit Conditioning, and Sewage Receiving. After preliminary treatment, wastewater flows to the primary sedimentation tanks for primary treatment. The preliminary treatment items that were evaluated are summarized in the following subsections.

5.1.0 Preliminary Treatment Evaluation Objectives

1. Junction Chamber No. 1 Improvements (JC 1) – Evaluate options for mitigating solids settling in the pre-aeration tanks.

2. Odor Control System Replacement – Evaluate methods to improve the performance of the existing JC 1 odor control system. Evaluate alternative technologies to replace the JC 1 odor control system.

3. Ventilate Screen & Grit Building No. 2 – Investigate the need for improved building ventilation in the Screen and Grit Building No. 2.

4. Sugar Sand – Evaluate the possible causes of sugar sand in the digesters. The City plans on replacing the grit washing equipment over the next two (2) fiscal years.

5. Industrial Waste Receiving Stations Improvements – Evaluate options for automating the industrial waste receiving stations. Evaluate options for multiple automated septage receiving stations at the AWTP (at least two or more). Traffic pattern configurations and facilities that would accommodate both small vehicles and tractor-trailer rigs in discharging near JC1 will be evaluated. An accurate account for volume being discharged will be recommended, and for security concerns changing the entrance location will be reviewed.

5.1.1 Evaluation

Wastewater enters the HFCAWTP at Junction Chamber No. 1 (JC1), located in the northwest corner of the property depicted in **Figure 5.1-1**.

Figure 5.1-1: Junction Chamber No. 1

The chamber is an enclosed above ground structure that is fed by five large force mains from City lift stations and the Raw Sewage Pump Station located onsite, just south of JC1, as shown in **Figure 5.1-2**. The main purpose of JC1 is to pre-aerate the influent for hydrogen sulfide (H_2S) stripping. Removing H_2S at the head of the plant helps mitigate corrosion downstream. Exhaust from JC1 is captured and sent to the Odor Control System. When the Odor Control System is out of service, hydrogen sulfide laden air in the junction chamber is discharged to the atmosphere by three exhaust fans (one per pre-aeration tank).

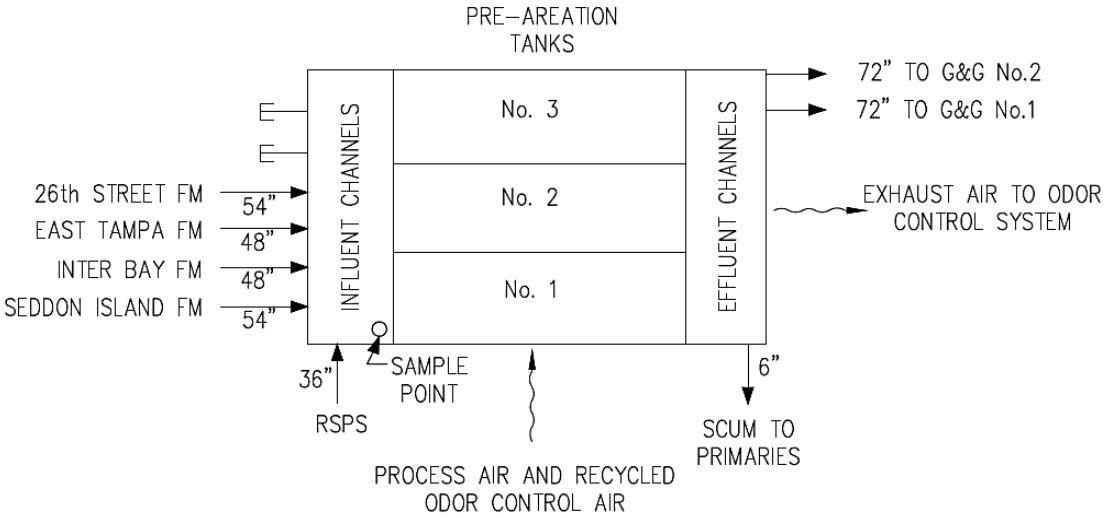


Figure 5.1-2: Junction Chamber No. 1 Flow Diagram

The existing pre-aeration system is arranged in a grid pattern with coarse air bubble diffusers that provide full-floor coverage across the channels – see **Figure 5.1-3**. The diffusers sit approximately 24'' above the bottom of the channels and discharge air vertically. A summary of the existing design characteristics is given in **Table 5.1-1**.

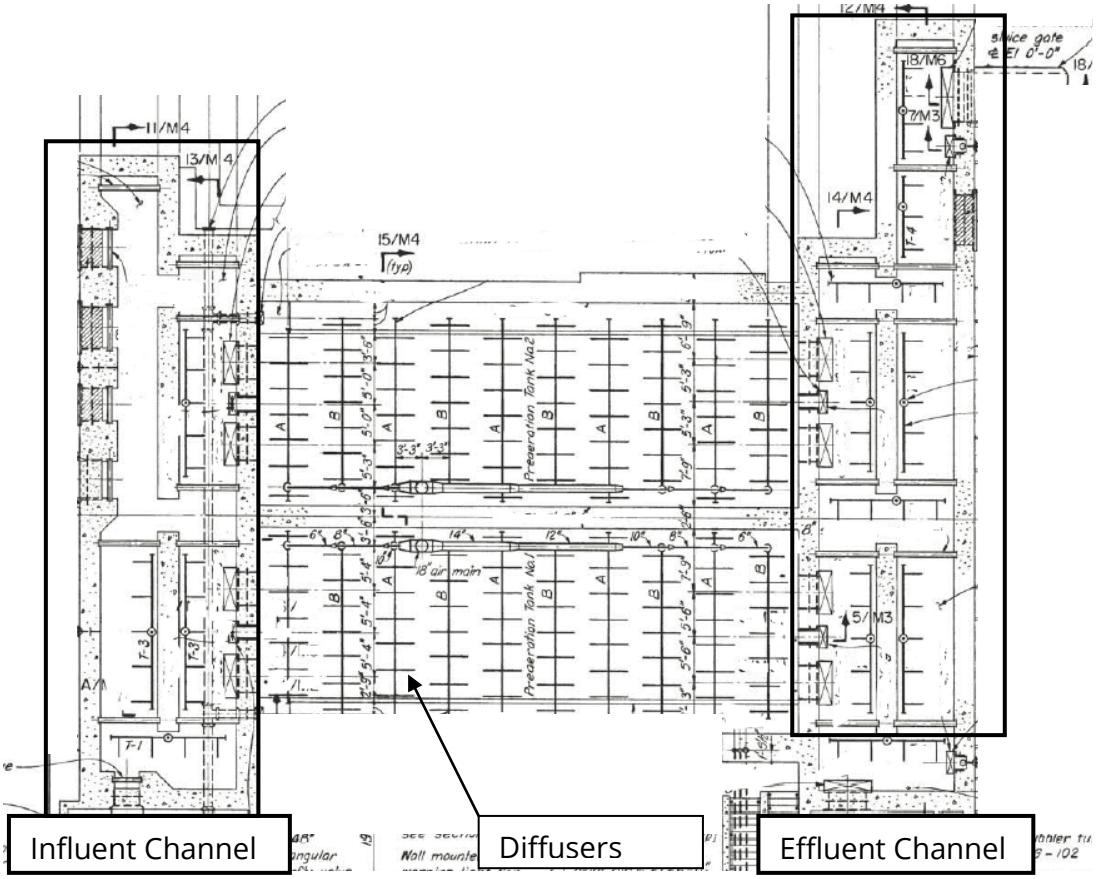


Figure 5.1-3: Record Drawing of Junction Chamber No. 1 (Not Including Tank No. 3)

Table 5.1-1: Existing Design Criteria of JC1

Description	Criteria
Existing Design Influent Flow Rates for JC1[1]	96 MGD-Average 220.8 MGD-Peak
Design Detention Time	10.1 Minutes (at 96 MGD influent) 7.5 Minutes (at 128.6 MGD influent) 4.4 (at 220.8 MGD influent)
Tank Sizes	25'x66' (Tank No. 1 & No. 2) 30'x66' (Tank No. 3)
Normal Operation	All tanks in service at all times
Total Design Volume	89,760 CF 0.67 MG
Blower Capacity (Pre-aeration Tanks 1 & 2)	Two 250 HP blowers @ 3,600 acfm each (at discharge 8.9 psig) JC-AB-1 & 2 – both duty blowers
Blower Capacity (Pre-aeration Tank 3)	Two 250 HP blowers 4,320 acfm each (at discharge 8.7 psig) JC-AB-3 & 4 – one duty, one standby
Water Depth	16.25 Feet (Minimum) 17.00 Feet (Design) 19.91 Feet (Maximum)
Air Blowers No. 1 & 2 Rated Discharge Pressure	8.9 psig @ 100 F°, 80% Rel-Humidity, 14.7 psia
Air Blowers No. 3 & 4 Rated Discharge Pressure	8.7 psig @ 100 F°, 80% Rel-Humidity, 14.7 psia
Air Supply Rate	86 cfm/ 1000 cf

[1] Design influent flow obtained from the 1999 Howard F. Curren AWTP Operation and Maintenance Manual

5.1.2 Objectives

The City has expressed concern about solids settling on the bottom of the pre-aeration tanks. When tanks are maintenanced, giant rag deposits, rocks, and big debris can be found. Solids accumulation in the tanks can decrease the capacity of the tanks and heavy accumulation can require time consuming maintenance. As such, the main objective at the pre-aeration tanks was to investigate options for mitigating solids settling.

While investigating the pre-aeration system, some components (including blowers, piping, and electrical systems) were found to be over 20 years old and approaching the end of their useful life. According to City comments, the existing diffusers and blowers are in acceptable condition and may not need replacement for another 10 years. It is recommended that the City plan to replace them in the next 5 to 10 years.

Alternatives were evaluated that meet the following two objectives:

1. Evaluate options to mitigate solids settling in the pre-aeration tanks.
2. Evaluate options to replace the existing pre-aeration system.

5.1.3 Aeration and Mixing Alternatives

Five alternatives to address both objectives were evaluated. In order to be a feasible alternative, three main criteria needed to be met which include:

1. Match the existing air flow rate provided by existing air blowers (11,520 cfm) to keep pace with existing H_2S stripping capacity;
2. Improve solids suspension; and
3. Be suitable for raw sewage and a highly corrosive environment.

Alternative 1 – Lower Diffusers

The simplest alternative to improve solids suspension is lowering the diffusers. The existing diffusers are horizontally level and sit approximately 1.5 to 2 feet above the sloped floor in Pre-aeration Tank No. 3. In Pre-aeration Tanks No. 1 and 2, the existing diffusers are approximately 2 to 2.2 feet above the sloped floor. For this alternative, the existing pre-aeration system would be replaced with a similar full floor coverage system and the diffusers would be lowered to reduce the depth of the tank's dead zone and provide aeration to a greater volume of water. Diffusers can be lowered to 1-foot above the high point of the tank floors based on Sanitaire D-24 diffusers, which have a 12'' mount. Installing diffusers 1-foot off the floor also provides space under the diffusers for repair and installation. Lowering the diffusers would likely only provide minimal improvement because grit and heavy solids would continue to settle below the diffusers due to specific gravity, detention time, and the aerated environment.

Alternative 2 - Rotational Mixing

One method to adding mixing along the bottom of the tank is to induce rotational mixing. The expected rotational flow pattern moves solids within its zone of reach and is shown in **Figure 5.1-4**. As shown in the Figure, grit and heavy solids can still settle in neutral zones or dead spots. After discussions with several manufacturers, rotational mixing is not expected to provide any better mixing than full floor coverage and *is therefore not recommended*.

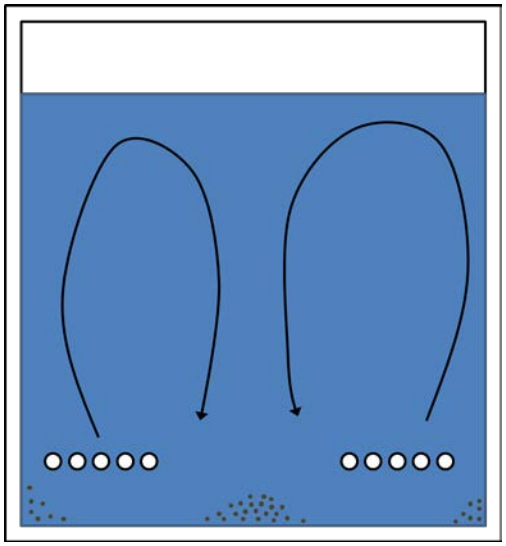


Figure 5.1-4: Pre-Aeration Tank Cross Section Showing Rotational Mixing Pattern

Alternative 3 – Jet Aeration

Jet aeration achieves hydraulic mixing and aeration through one nozzle. This nozzle consists of a primary (inner) and secondary (outer) nozzle. One system could be comprised of many such nozzles. A chopper recirculation pump pulls water from the pre-aeration tank, into a header, and ejects it back into the tank through the primary nozzles at a high velocity to induce high rate mixing. Chopper recirculation pumps are able to break up the solids that may enter the intake pipe and process the raw wastewater. Air is fed into the secondary nozzles through an air header that runs along the liquid header. Coarse bubble diffusers would not be needed. A photo of an example of this type of system is shown in **Figure 5.1-5**. The layout that would be proposed for this alternative is provided in **Figure 5.1-6**. Tanks 1 and 2 are narrow enough for a single directional header that ejects the air and liquid stream perpendicular to the line of flow. However, Tank 3 is too wide for a single directional discharge and a bi-directional header would be needed. Both configurations would be expected to provide a much greater level of solids suspension than the existing configuration. Solids suspension would not be expected to be complete; because heavy solids, such as rocks, would still settle. However, this would be the case for any alternative; jet aeration is considered a feasible alternative.

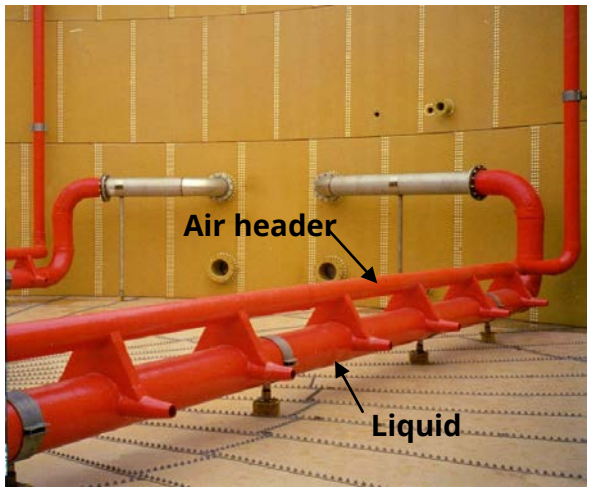


Figure 5.1-5: Example Jet Aeration System by MTS

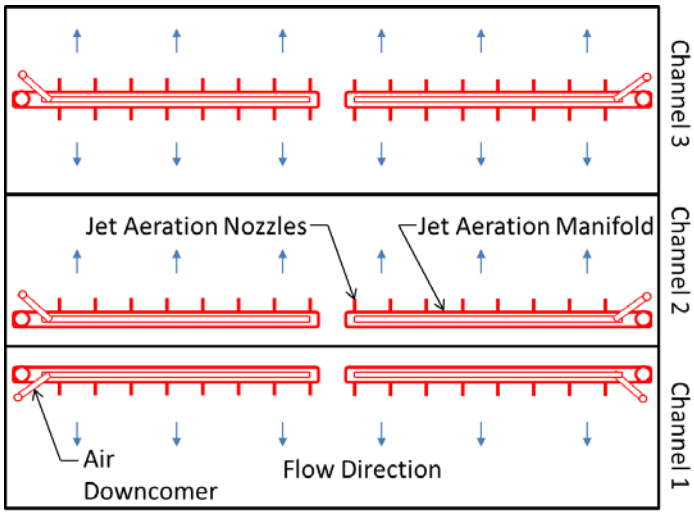


Figure 5.1-6: Proposed Layout for Alternative 3

Alternative 4 – Nozzle Mixing

This alternative would keep solids in suspension by vertical mixing. Flow is recirculated through a chopper pump and ejected through nozzles to mix the contents in the tank. This alternative will require special coarse bubble diffusers that can tolerate the hydraulic forces generated by the nozzles. One possible diffuser technology would be EDI HexAir Coarse Bubble Diffusers that drop down from the top of the tank as shown in **Figure 5.1-7**. A layout of the combined nozzle and diffuser system is provided in **Figure 5.1-8**. A concern with this configuration is that the diffused air flowing vertically could disrupt the mixing pattern, making the nozzle mixing less effective. Though it could provide some level of mixing, it would not be expected to provide enough to be recommended over a more efficient option like Alternative 3 – Jet Aeration. Theferore, nozzle mixing is not considered feasible nor included for further evaluation.

Figure 5.1-7: Photo of EDI HexAir Coarse Bubble Diffusers

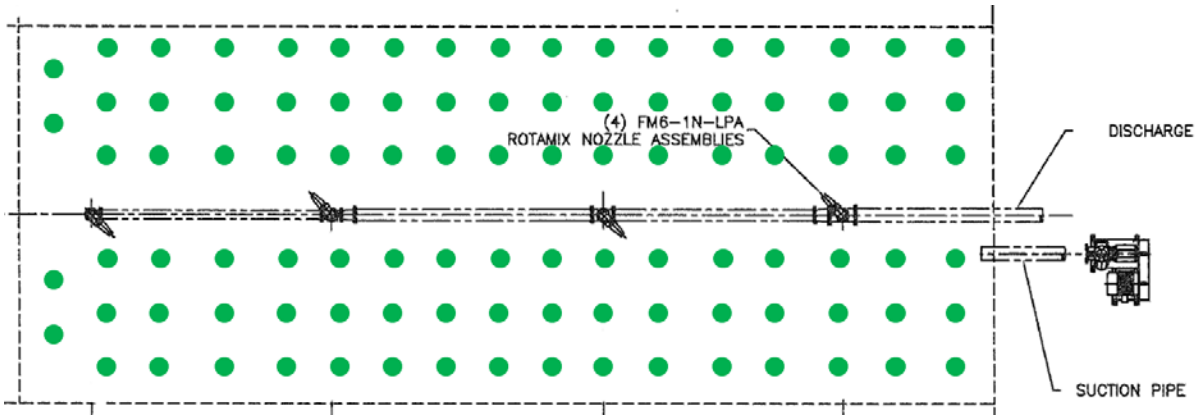


Figure 5.1-8: Proposed Layout for Alternative 3

Alternative 5 – Mechanical Mixer-Aerators

Another option for improving solids suspension and replacing the existing aeration system is to install mechanical mixers that aerate in the same direction they mix. This combination would be expected to provide a much greater level of solids suspension than the existing configuration. Solids suspension would not be expected to be complete; because heavy solids, such as rocks, would still settle. There are many different types of mechanical mixers available. However, the manufacturer representatives acknowledge that ragging can be an issue for any type of mechanical mixer, even hyperbolic mixers which are advertised as "non-ragging." One rag can catch on a shaft and collect more rags until the flow pulls the rags and thereby pulls the shaft. Overtime, this can create an imbalance that disrupts the function of the gearbox and reduce the effective life of the mixer. This is a major concern for this alternative.

Another concern with this alternative is its poor constructability. A hyperbolic mixer-aerator impeller is large and would not fit in the existing access hatch that is approximately 3-feet by 3-feet. A large opening would need to be cut out of the top slab in each tank to fit approximately 8-foot diameter impellers. Holes in the top slab for the mixer shafts would also need to be cut and located within the existing blower building so that two to three mixers could be spaced along the center of the tanks. Due to the constructability and ragging concerns, mechanical mixer-aerators was not considered feasible for further evaluation.

5.1.4 Aeration and Mixing Alternatives Evaluation

Of the five alternatives, Alternatives 1 and 3 are determined feasible to improve solids suspension and replace the existing pre-aeration system. Whichever alternative is selected, it is recommended that the City inspect the tanks every five years for signs of corrosion of the interior concrete and diffusers or nozzles that may be malfunctioning. During such inspections, the City should also remove any large debris or heavy solids, such as rocks, that accumulate. Designing the alternatives to suspend these heavy solids would not be economically feasible. A summary of the advantages and disadvantages of the two recommended alternatives is provided in **Table 5.1-2**.

Table 5.1-2: Advantages and Disadvantages of Aeration & Mixing Alternatives

	Advantages	Disadvantages
Alternative 1 **Lower Diffusers**	1. No liquid pumps needed 2. Less expensive	1. Improves solids suspension, but only minimally
Alternative 3 **Jet Aeration**	1. Maximum mixing improvement 2. Easier to clean bottom of tank	1. New pumps to operate & maintain 2. More expensive

5.1.5 Aeration and Mixing Alternative Cost Evaluation

Alternative 1 – Lower Diffusers

Lowering the diffusers would include demolishing the aged existing pre-aeration system from the blowers' intake down to the diffusers, not including the piping within concrete. The tanks would need to be taken offline one at a time, cleaned, and inspected before installing new blowers and coarse air bubble diffuser systems. Operating the Alternative 1 pre-aeration system would be similar to existing operations. The main annual costs would be the power usage for the air blowers. A summary of the main components for this alternative and their estimated costs are given in **Table 5.1-3**.

Alternative 3 – Jet Aeration

Jet Aeration would have the same demolition requirements as Alternative 1. The tanks would also need to be taken offline one at a time for cleaning, inspection, and installing the new jet-aeration headers, piping, liquid recirculation chopper pumps, and air blower systems. New wall penetrations would be needed to install the liquid pump lines and widening of the access openings if submersible pumps are selected. Operating the jet-aeration system would be comparable to existing operations with the addition of monitoring liquid pumps. The main annual costs would include the power usage for the air blowers and liquid pumps. A summary of the main components for this alternative and their estimated costs are given in **Table 5.1-4**.

Table 5.1-3: Conceptual Cost Estimate for Pre-Aeration System Alternative 1

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 43,000
Demolition	$ 60,000
New Coarse Bubble Diffusers	$ 238,000
Three New 200 HP Hybrid Air Blowers and Associated Equipment	$ 471,000
Instrumentation & Control	$ 64,000
Electrical	$ 64,000
Installation	$ 168,000
Sum of Bare Construction Costs	$ 1,107,000
30% Contingencies	$ 333,000
Bare Construction Cost	$ 1,440,000
20% OH&P & GCs	$ 288,000
Total Construction Cost	$ 1,730,000
20% Management and Engineering[2]	$ 346,000
Total Capital Cost[1]	**$ 2,080,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

Table 5.1-4: Conceptual Cost Estimate for Pre-Aeration System Alternative 3

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 90,000
Demolition	$ 60,000
Jet Aeration System	$ 1,095,000
Three New 200 HP Hybrid Air Blowers and Associated Equipment	$ 471,000
Instrumentation & Control	$ 110,000
Electrical	$ 110,000
Installation	$ 358,000
Sum of Bare Construction Costs	$ 2,294,000
30% Contingencies	$ 689,000
Bare Construction Cost	$ 2,983,000
20% OH&P & GCs	$ 597,000
Total Construction Cost	$ 3,580,000
20% Management and Engineering[2]	$ 716,000
Total Capital Cost[1]	**$ 4,300,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

There are multiple blower technologies available to provide aeration for this application and would need to be further investigated during preliminary design. The existing blowers are set up to take recirculated air from the odor control system, but they are not operated this way and are not expected to in the future. For the purpose of this evaluation, costs for hybrid positive displacement (PD) blowers capable of handling recirculated air from the odor control system were used for both alternatives. Hybrid PD blowers have a higher capital cost than conventional PD blowers, but a lower power usage due to their higher efficiency. The new blowers needed are estimated to be 200 HP each. The rated power of all pumps and blowers necessary for each alternative was used to calculate the annual O&M costs. This results in a conservative estimate, because the actual power consumption would be lower than the motor rating. Estimating the actual power consumption depends on the pre-aeration system manufacturer and blower technologies selected for final design. It is recommended to use 316 stainless steel material due to the highly corrosive environment.

A comparison of the estimated operational and maintenance (O&M) costs and 20-year cost for each alternative is given in **Table 5.1-5** and **Table 5.1-6**, respectively. Neither alternative will be able to suspend heavy solids such as rocks and grit, however Alternative 3 would be expected to provide greater solids suspension. This would come at a cost approximately 1.7 times greater than the cost to replace the existing pre-aeration system with a new coarse air bubble diffusers configuration (Alternative 1).

Table 5.1-5: Estimated O&M Costs for Alternatives 1 and 3

Cost Description	Alternative 1 Lower Diffusers	Alternative 3 Jet Aeration
Electricity 20-Year Cost[1]	$ 7,720,000	$ 12,339,000
Maintenance 20-Year Cost[2]	$ 242,000	$ 242,000
Total O&M 20-Year Cost	$ 7,970,000	$ 12,590,000
Total O&M 20-Year Cost Present Value[3]	**$ 4,420,000**	**$ 6,980,000**

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%. Assumed 100% run time for blowers.
[2] Operations/Maintenance labor cost of $40/hr and annual inflation rate of 3%.
[3] Used an annual interest rate of 3%.

Table 5.1-6: Alternatives Total Cost Comparison

Cost Description	Alternative 1 Lower Diffusers	Alternative 3 Jet Aeration
Total Capital Cost[1]	$ 2,080,000	$ 4,300,000
Total O&M 20-Year Cost Present Value	$ 4,420,000	$ 6,980,000
Total 20-Year Cost Present Value	**$ 6,500,000**	**$ 11,280,000**

[1] Assumes no residual value after 20 years and capital outlay occurs in the year it is constructed.

5.1.6 Aeration and Mixing System Recommendation

The cost of Alternative 3 – Jet Aeration is disproportional to its expected benefit, therefore it is not recommended. Alternative 1 would then be preferred over Alternative 3; however the anticipated mixing improvement is still only minimal compared to the existing system and is therefore not recommended. Mitigating solids settling in JC 1 is still going to be cost effectively

best achieved by regular City maintenance every five years to inspect tank condition and removal of any large debris or heavy solids that accumulate.

While replacing the existing diffuser system will improve mixing in the pre-aeration tanks only minimally, it was noted in the Phase 1 evaluation that the existing aeration system, including the diffusers, is approaching the end of its useful life. It is recommended that the City plan to replace the aeration system in the next 5 to 10 years. The cost for this is comparable to the cost for Alternative 1.

5.2 Odor Control System Replacement

Influent wastewater enters Junction Chamber No. 1 (JC1) where it is aerated intensely to strip hydrogen sulfide (H_2S) from the water. The H_2S collects in the headspace of JC1 and is pulled into the adjacent odor control system shown in **Figure 5.2-1**. Removing as much of the H_2S here as affordable helps to mitigate corrosion downstream. The existing odor control system consists of three-stage chemical scrubbing utilizing three standalone reactor towers. In the first two towers, the H_2S moves into liquid phase with the addition of sodium hydroxide (caustic) by increasing the pH above 10. The third reactor was designed to dose the air stream with sodium hypochlorite to oxidize H_2S and other odorous chemicals, but the last time it was operated that way is unknown. Currently the third stage does not dose with sodium hypochlorite. Scrubber blowdown is sent to the high purity oxygen (HPO) reactors. The flow diagram for the existing system is provided in **Figure 5.2-2**.

Figure 5.2-1: Photo of Existing Odor Control System

The design of this system is unique in that treated air from the reaction chambers can be split in two directions before being discharged to the atmosphere. Approximately 75% of the treated air can be recirculated back to the JC1 air blowers and the rest is diluted with outside air then discharged through the 48-foot high exhaust stack. However, the option to recirculate treated air has not been used according to the City. The system treats an average of 600 ppm-H_2S and exhausts an average of 50 ppm-H_2S after dilution, for an H_2S reduction of approximately 92%. Since the exhausted air is a mixture of treated air and outside air, the 92% reduction is not achieved by the chemical chambers alone. Treated

air is combined with approximately 30,000 cfm of outside air. This means that the existing reaction chambers are not reducing the H_2S concentration to 50 ppm, but to approximately 150 ppm. Thus, the existing chemical chambers are only removing approximately 75% of the H_2S. This is very inefficient compared to the industry standard of 99%. The existing chambers' removal efficiency may be lower due to the use of mist towers instead of packed bed towers and the absence of sodium hypochlorite use in the third reactor. Historic H_2S concentrations are given in **Table 5.2-1** and the existing system characteristics are summarized in **Table 5.2-2**.

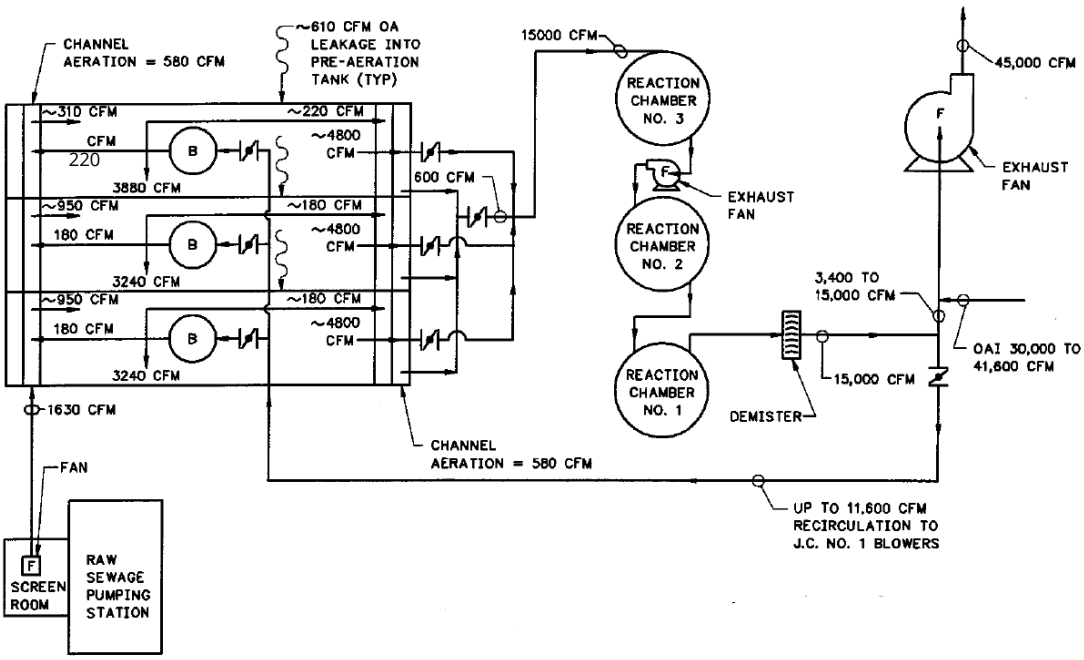


Figure 5.2-2: Existing Odor Control System Flow Diagram

Table 5.2-1: Summary of H_2S Concentrations at the Odor Control System

Year	Average Daily H_2S In (ppm-ADF)	Average Daily H_2S Out (ppm-ADF)	Average Daily Removal	Peak Hour H_2S In (ppm)	Peak Hour H_2S Out (ppm)	Max Day H_2S In (ppm)
2010	395	66	82%	1200	300	1000
2011	318	57	74%	1300	500	898
2012	421	55	85%	1050	500	1000
2013	541	54	90%	1550	350	1192
2014	598	33	93%	1800	160	1283
2015[1]	707	55	92%	1300	500	1300
2010-2014 Average	500	60	85%	1400	370	1100
2013-2015 Average	600	50	92%	1600	300	1300

[1]Data provided ended on October 26, 2015

Table 5.2-2: Summary of Existing Odor Control System

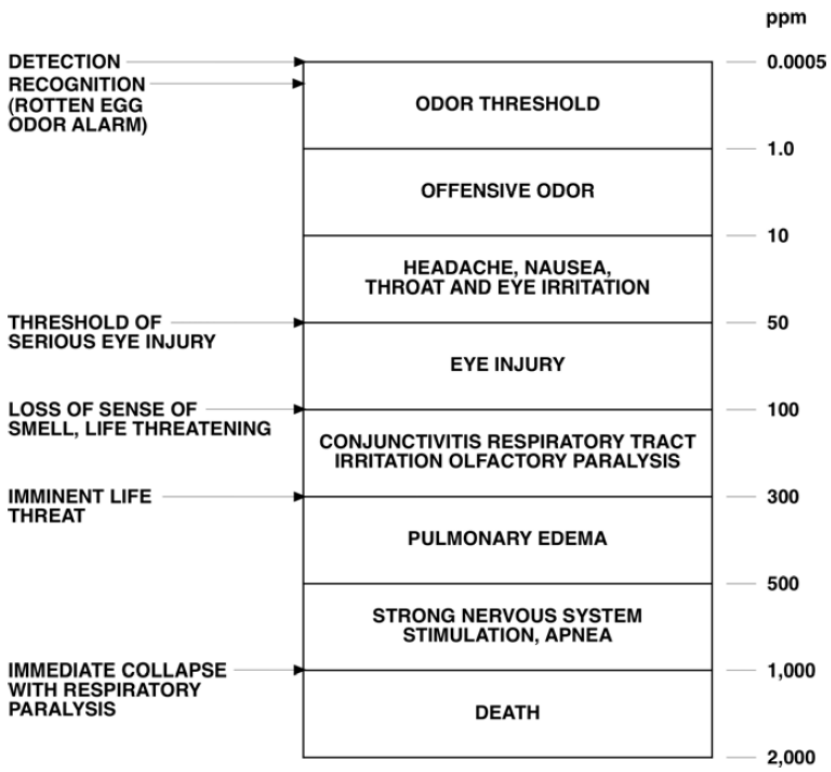
Description	Criteria
Install Date	Reaction Chamber No. 1 – January 1994 Reaction Chamber No. 2 – October 1987 Reaction Chamber No. 3 – October 1987
Manufacturer	Quad Environmental Technologies Corp.
Type	3-Stage Caustic Scrubbers
Size	15-ft Diameter[2] (Chamber 1) 12-ft Diameter (Chambers 2 & 3) 39-ft High
Max Design Chemical Dosage Rates	50% Sodium Hydroxide (Caustic) = 40 gph 12% Sodium Hypochlorite = 230 gph
Intake Air Flow Rate/JC1 Aeration	15,000 cfm
H_2S In Concentration	1,600 ppm (Max) 600 ppm (Avg)
Average H_2S Out Concentration[1]	50 ppm
Average H_2S Removal[1]	92%

[1] The H_2S Out Concentration is measured in the final exhaust stack after dilution.
[2] Scaled from record drawings.

In May 2017, one of the odor control manufacturers monitored H_2S concentrations inside JC1 continuously for a week. The results of that study showed an average concentration of 720 ppm and a peak of 1,500 ppm. The average is higher than the design average of 600 ppm, which could be due to the warm and dry temperature in May. Historic data shows that H_2S concentrations in May typically are higher than the annual average. Therefore, the design H_2S concentrations of 600 ppm-average, 1,300 ppm-max day, and 1,600 ppm-peak were used to evaluate odor control alternatives.

5.2.1 Objectives

1. Replace Existing System
   The existing system is approaching the end of its useful life being over 20 years old and needs to be replaced.
2. Improve H_2S Removal
   The existing system (including dilution with outside air) has only been achieving 92% H_2S removal and exhausting a very high concentration of H_2S. Investigate options for best management practices to improve efficiency. Design criteria for a new system is assumed to include keeping H_2S peaks below 10 ppm and maintaining an industry standard average of 99% H_2S removal.
3. Safety
   Hydrogen sulfide concentrations have been recorded in the odor control intake at lethal concentrations if inhaled. They range from an average of 600 ppm to peaks of 1,600 ppm – as seen in **Table 5.2-2**. Health effects at increasing exposure are outlined in **Figure 5.2-3**. The safety at the junction chamber was considered.



Source: WERF 2007 Minimization of Odors and Corrosion in Collection Systems, pg 2-8

Figure 5.2-3: Generally Accepted Toxicity Spectrum for Hydrogen Sulfide Gas

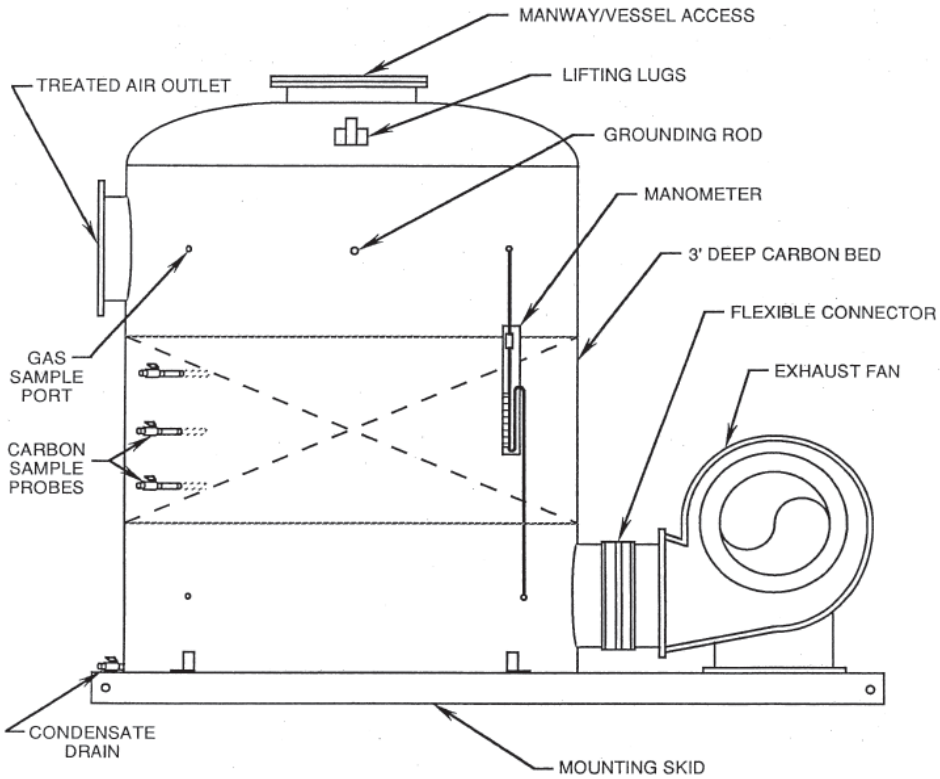
5.2.2 Odor Control Technology Review

In order to replace the existing system and improve H_2S removal, a new system that can reliably remove H_2S is needed. There are multiple odor control technologies for treating JC1 exhaust which include:

- Activated Carbon Adsorption;
- Chemical scrubbers;
- Biotrickling Filters; and
- Hydroxyl Radical Oxidation.

5.2.3 Activated Carbon Adsorption

Activated Carbon systems use raw materials such as coal, peat, wood, or other carbon material to absorb H_2S. It is effective on most odorous compounds and does not use chemicals. However, it is more commonly used at low H_2S concentrations (10 ppm±) and the carbon media must be regenerated periodically. Since the high H_2S loading at JC1 would require large volumes of media, this technology is not considered a feasible option for the HFC AWTP. **Figure 5.2-4** depicts a typical carbon absorber.

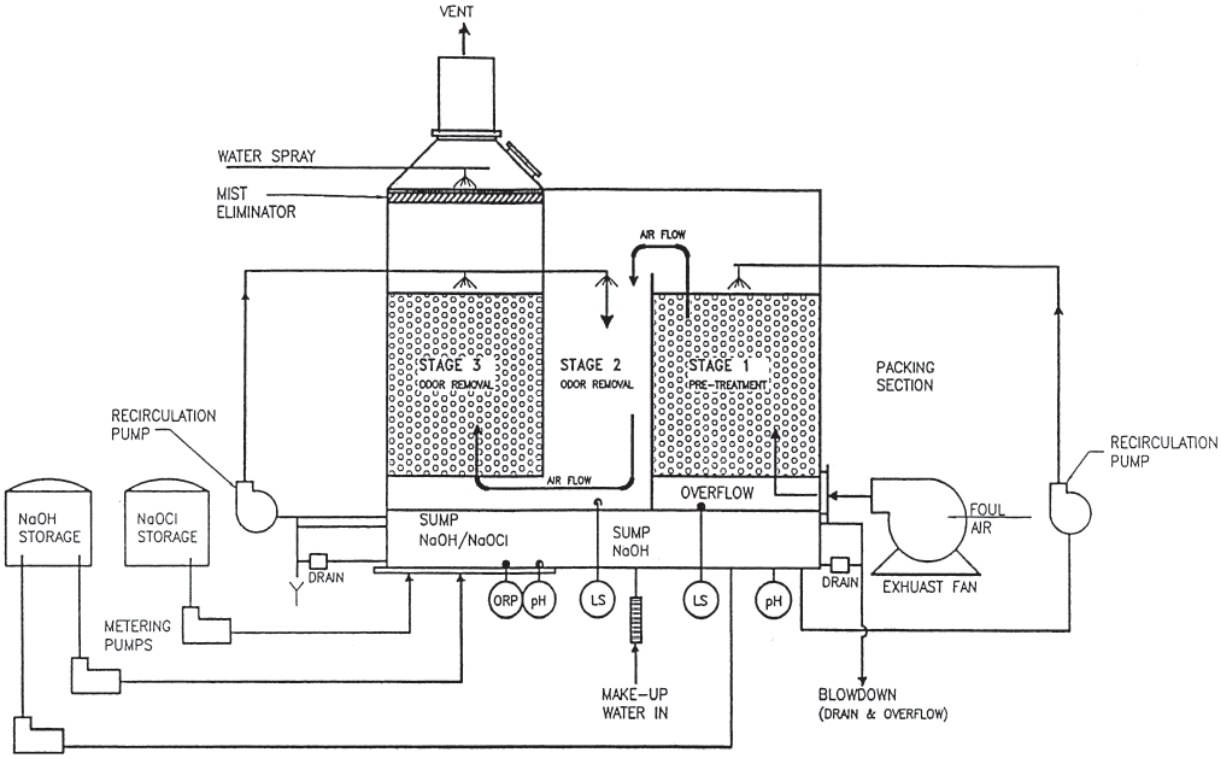


Source: WEF Manual Of Practice 8 Figure 7.41

Figure 5.2-4: Schematic of a Typical Deep-Bed Carbon Asorber

5.2.4 Chemical Scrubbing

Chemical scrubbing is the technology currently used at the HFC AWTP with mist towers; however, packed towers or a combination would be used, depending on the manufacturer selected. Chemical scrubbing has been one of the most common technologies used in the industry for many years. Because of the high H_2S concentration, the plant would need a multi-stage scrubber as opposed to the existing system which only doses caustic. In Stage 1 and 2, the exhaust air would be sprayed with a caustic solution to raise the pH and cause a larger percentage of the H_2S to move into solution as sodium sulfide. In the final stage, sodium hypochlorite can be added to further remove H_2S by oxidation. See **Figure 5.2-5** for an example diagram of this process. The system adjusts sodium hydroxide dosage to reach a pH of 10 in the scrubber solution and sodium hypochlorite based on incoming H_2S concentration, in order to remove the varying H_2S. Therefore, this system can reliably treat peak concentrations. Multi-stage chemical scrubbers can be expected to remove over 99% of the H_2S as well as other malodorous compounds. However, the chemical usage associated with the high pH and multi-chemical system can be very costly. A summary of the advantages and disadvantages for chemical scrubbers is provided in **Table 5.2-4**.



Source: WEF Manual Of Practice 8 Figure 7.39

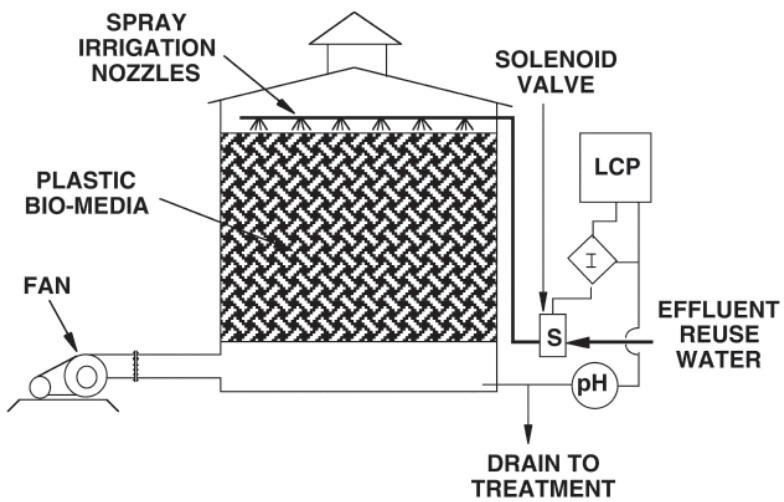
Figure 5.2-5: Diagram of a Typical Low-Profile Three-Stage Chemical Scrubber

5.2.5 Biotrickling Filters

Biotrickling filters work by blowing odorous air through a tower packed with media and bacteria as shown in **Figure 5.2-6**. The bacteria prefer a low pH environment and are capable of acclimating with peaks in H_2S to a limited degree, especially limited in high H_2S applications such as the one at JC1. The media can last between 10 to 20 years and is sprayed with water and nutrients to help the bacteria grow. If the plant effluent water meets manufacturer criteria, then it can be used in lieu of added nutrients. Biotrickling filters can be designed to remove both inorganic (e.g., H_2S) and organic sulfide (e.g., methyl mercaptans) compounds according to manufacturers. Sometimes these systems can give off a musty or earthy odor and may need polishing depending on the proximity and sensitivity of neighbors (WERF 2007), but the HFC AWTP is located in an industrial zone, so this is not an anticipated problem.

Biotrickling filters have become more popular in the last decade with improved system design. In the past, these filters used to have a much larger footprint than chemical scrubbers and the biological H_2S removal was not quite as efficient as the chemical scrubbers. With the new media and bacteria technology, biotrickling filters are now a much more competitive alternative to chemical scrubbing. Though the capital costs are still higher, the biotrickling filters operational costs are low enough to often result in a 3 to 5-year payback as compared to chemical scrubbers.

However, biological treatment is not suitable for all applications. For instance, long downtimes could upset the bacteria. Since JC1 is operated continuously, this is not expected to be a concern. If the system does need to be taken down for a period of time, there are ways to keep the bacteria healthy until the system is returned online. After discussion with an owner of a biotrickling system that also treats extremely high H_2S concentrations, it was concluded that this technology needs to be designed conservatively. For the purposes of this evaluation, biotrickling filters will be assessed for treating max day concentrations. It should be noted that there are only a few known biotrickling filter systems in the world that treat concentrations as high as the JC1 max day concentration. According to a global installation list supplied by BioAir, there are only three (3) installations designed to treat H2S concentrations over 1,000 ppm. These are located in the United Arab Emirates, and their design airflow rates do not exceed 1,521 cfm. A summary of the advantages and disadvantages for biotrickling filters is given in **Table 5.2-4**.



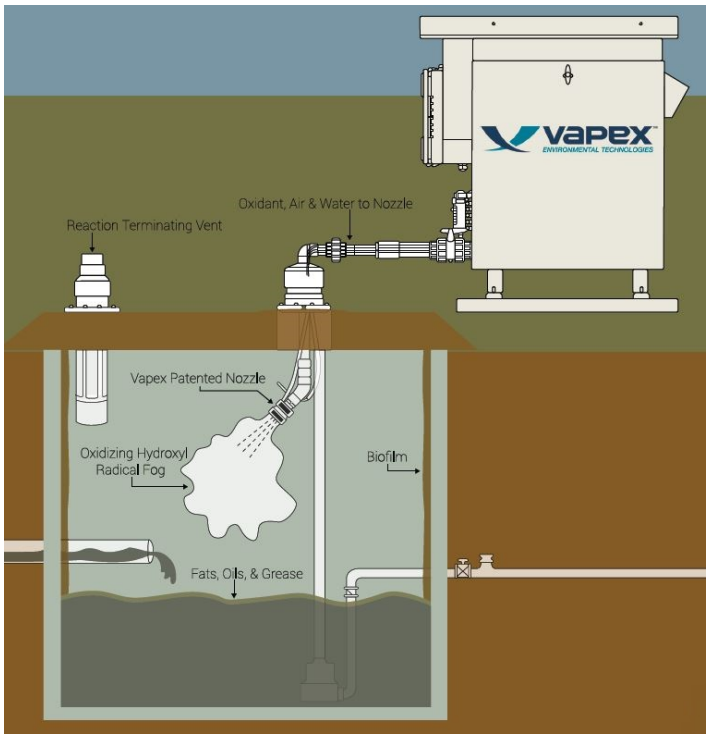
Source: WEF Manual Of Practice 8 Figure 7.34

Figure 5.2-6: Schematic of a Typical Biotrickling Filter

5.2.6 Hydroxyl Radical Oxidation

This technology is more commonly used at lift stations or in the residential and commercial industry for restoration projects that require odor removal. However, it is also successfully used at some wastewater treatment plants. According to Vapex™ Environmental Technologies, there are twenty-four (24) units for municipal applications in Florida. Though not as common at wastewater treatment plants as chemical scrubbers, this technology has the potential to be cost effective.

Depending on the manufacturer, this type of technology generates hydroxyl radicals and either emits them through a mist into contaminated air or pulls contaminated air into the unit and exhausts the treated air from there. A system provided by Vapex™ Environmental Technologies is shown in **Figure 5.2-7** as an example. Hydroxyl radicals (OH-) are one of the strongest oxidizing agents available – even stronger than ozone, as seen in **Table 5.2-3**.



Source: Vapex Environmental Technologies Brochure

Figure 5.2-7: Diagram of a Hydroxyl Radical Oxidation System

Table 5.2-3: Oxidation Potential of Common Oxidants

Oxidant	Oxidation Potential
Hydroxyl Radical (OH^-)	2.8
Ozone (O_3)	2.07
Hydrogen Peroxide (H_2O_2)	1.78
Chlorine Dioxide (ClO_2)	1.57
Oxygen (O_2)	1.23
Sodium Hypochlorite (NaOCl)	0.94

Adapted from Leusink J. (2016)

Hydroxyl radicals are naturally found in the environment. When ultraviolet rays from the sun react with oxygen (O_2) and water (H_2O), hydroxyl radicals are formed. These act to remove volatile organic compounds (VOCs) from the atmosphere. A similar process is used in hydroxyl radical odor control. This oxidant quickly destroys a wide variety of chemicals and spreads through the treatment area by causing chain reactions. (McArdle 2013) Units have a very small footprint (on the order of 4-feet by 3-feet) and are added based on the volume of air and concentration of H_2S to be treated.

These systems are used all over the country, including in Florida. Two owners with Vapex™ hydroxyl radical systems were contacted and reported satisfactory performance. This system has been used for two years at the City of Santa Cruz WWTP, which is adjacent to a commercial area. The odor control system treats off-gas from their influent channel, septage receiving, primary clarification, secondary treatment, sludge dewatering, and gravity thickening units. The H_2S levels they were experiencing prior to installing the Vapex™ system was not available. However, they were receiving odor complaints even though they were treating air in chemical scrubbers. After installing the Vapex™ system, complaints have ceased, and they have been recording 0 ppm output on all but the septage receiving facility, which has been exhausting 1.7 ppm. These are good results showing that the Vapex™ system has been very effective for them.

Baltimore County also uses this system in several lift stations and reports that no H_2S odor is detected while standing on their wet well. As soon as they installed the hydroxyl radical system, odor complaints ceased. Both owners reported ease of maintenance and that it was relatively safe to work with. In addition, Vapex™ recently completed a pilot study in the Town of Southington, CT. They studied odor control in a sludge retention tank where H_2S levels as high as 1,800 ppm have been recorded. During the study, results showed that the Vapex™ system kept H_2S levels below 20 ppm and the average was 1 ppm. Therefore, this technology has enough support to be further investigated and was evaluated for its potentially lower cost. A summary of the advantages and disadvantages for hydroxyl radical oxidation is given in **Table 5.2-4**.

5.2.7 Summary of Evaluated Odor Control Technologies

A summary of the advantages and disadvantages for the evaluated odor control technologies provided in **Table 5.2-4**.

Table 5.2-4: Advantages vs Disadvantages of Odor Control Technologies

Technology	Advantages	Disadvantages
Chemical Scrubbers	• >99% removal efficiency • Highest H_2S capacity and able to treat large spikes • Effective on all odor causing contaminants • Not susceptible to upsets • Automatic, continuous operation • Low capital cost	• High chemical costs • More complicated process • Greater maintenance • Chemical storage • Waste stream
Biotrickling Filters	• 99% removal efficiency No chemical usage • Low operating cost • Sustainable technology • Low maintenance	• High capital cost • Susceptible to biological upsets • Poor adaptability to peaks • Not commonly used in extremely high H2S applications
Hydroxyl Radical Oxidation	• Effective removal of a large variety of chemicals • Low capital cost • Low operational cost • Low maintenance • Small footprint • No chemical usage or storage • No media to replace • No waste stream • No tall towers	• Potentially lower H_2S removal efficiency • Newer technology • Uncommon application • No feedback loop (have to design for peak) • Currently no way to measure H_2S concentration being treated. Can still measure H_2S out.

5.2.7 Odor Control Alternatives Evaluation

Four alternatives for replacing the existing odor control system were evaluated and include:

Alternative 1 – Chemical Scrubbing
Alternative 2 – Biotrickling Filters
Alternative 3 – Biological and Chemical (Hybrid Alternative)
Alternative 4 – Hydroxyl Radical Oxidation

It is anticipated that the existing odor control site and the adjacent site to the east would be required for construction. However, Alternative 4 could be constructed around the existing odor control system due to its very small footprint. According to the record drawings, there is a TECO easement north of the site and therefore that area would not be available for use with any of these alternatives.

A water supply will be needed for all four alternatives. It is possible that the facility's reclaimed water could be used and therefore at no cost to the City, but this will need to be determined with the manufacturer during preliminary design. For the purpose of this report, a water usage fee was assumed for conservative cost estimating.

5.2.8 Alternative 1 – Chemical Scrubbing

This alternative would include completely replacing the existing odor control system. It would consist of a new multi-stage chemical scrubbing system including a 15,000 cfm air handling fan, multi-stage treatment towers (the number of towers depends on the manufacturer selected), chemical recirculation pumps, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, and other associated equipment. The system could be capable of removing greater than 99% of H_2S, but chemical dosage and associated costs could be reduced if designed for 99% removal. In order to further reduce the H_2S concentration before discharging to the atmosphere, a 45,000 cfm exhaust dilution fan similar to the existing system would be installed. A flow diagram for this alternative is given in **Figure 5.2-8**. The estimated operational performance is summarized in **Table 5.2-5**. Conceptual cost estimates for capital and O&M are outlined in **Table 5.2-6** and **Table 5.2-7**, respectively.

Showing Estimated Peak Conditions

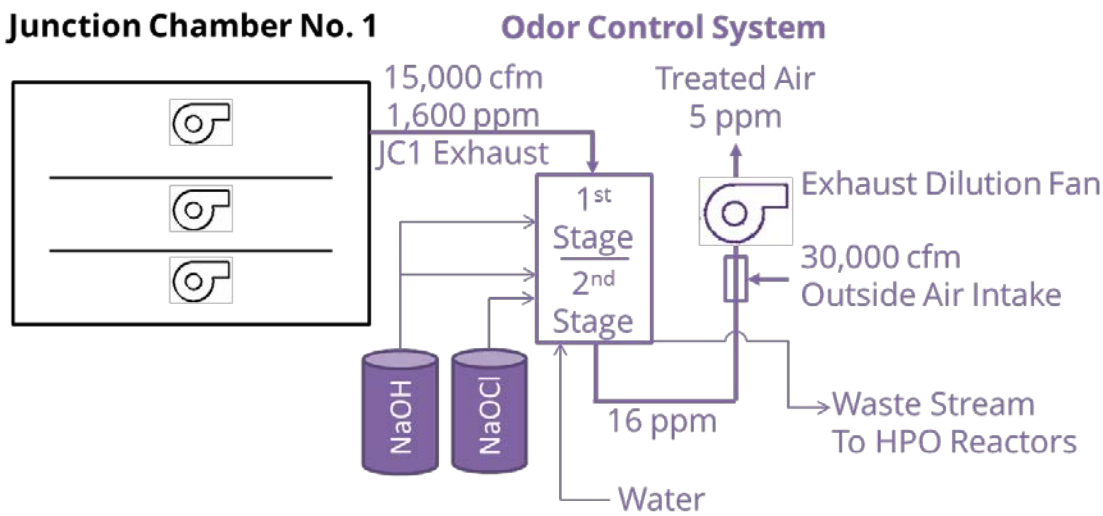


Figure 5.2-8: Flow Diagram of Alternative 1 – Chemical Scrubbing System

Table 5.2-5: Estimated Operational Performance for Alternative 1

Description	Quantity[1]
Removal Efficiency at 600 ppm-H_2S	99%[2]
Removal Efficiency at 1,600 ppm-H_2S	99%[2]
Average Chemical Usage	25% Sodium Hydroxide (NaOH) – 55 gph 12.5% Sodium Hypochlorite (NaOCl) – 82 gph
Power Usage	85 HP
Reclaim Water Usage	7,200 gallons/day

[1]Quantity shown per manufacturer data – subject to change with different manufacturer systems.
[2]Not including dilution.

Table 5.2-6: Conceptual Capital Cost Estimate for Alternative 1

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 63,000
Sitework & Demolition	$ 96,000
Chemical Scrubber Towers & Associated Equipment	$ 325,000
Ductwork	$ 60,000
Exhaust Dilution Fan	$ 15,000
Chemical Feed System	$ 305,000
Instrumentation & Control	$ 91,000
Electrical	$ 97,000
Installation	$ 179,000
Sum of Bare Construction Costs	$ 1,231,000
30% Contingencies	$ 370,000
Bare Construction Cost	$ 1,601,000
20% OH&P & GCs	$ 321,000
Total Construction Cost	$ 1,930,000
20% Management and Engineering[2]	$ 386,000
Total Capital Cost[1]	**$ 2,320,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal and administrative costs.

Table 5.2-7: Conceptual O&M Cost Estimate for Alternative 1

Cost Description	Estimate
Electricity 20-Year Cost[1]	$ 1,094,000
Chemicals 20-Year Cost[2]	$ 21,497,000
Water Usage 20-Year Cost[3]	$ 108,000
Maintenance 20-Year Cost[4]	$ 381,000
Total O&M 20-Year Cost[5]	$ 23,080,000
Total O&M 20-Year Cost Present Value[6]	$ 12,780,000

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2] Estimated $0.75/gallon for 25% Caustic and $0.60/gallon for 12.5% Sodium Hypochlorite per manufacturer
[3] Assumed $1.20/kgal – actual cost to be determined in preliminary design.
[4]Operations/Maintenance labor cost of $40/hr. Includes annual maintenance and media replacement at Year 10.
[5]20-Year costs included an annual general inflation rate of 3% except for electricity as noted in Footnote #1.
[6]Used an annual interest rate of 3%.

5.2.9 Alternative 2 – Biotrickling Filters

It is anticipated that the high average H_2S level from JC1 reduces the bacteria's ability to treat the high peaks. Therefore, in order to estimate a cost for a system that can reliably remove 99% H_2S at peak levels, the biotrickling filters were evaluated for a removal efficiency of 99% at the max day H_2S concentration of 1,300 ppm. According to one manufacturer, this could require as many as eight (8) 14-feet diameter by 34-feet tall biotrickling filter towers. Therefore, the footprint for this system would require the existing odor control system site and the adjacent area to the east.

This alternative would completely replace the existing odor control system. It would consist of a new biotrickling filters system including a 15,000 cfm air handling fan, parallel treatment towers, recirculation pumps for each tower, blowdown pump station, wash water connection, and other associated equipment. In order to further reduce the H_2S concentration, a 45,000 cfm exhaust dilution fan similar to existing would be installed. A flow diagram for this alternative is provided in **Figure 5.2-9**. The estimated performance of this alternative is given in **Table 5.2-8**.

Showing Estimated Peak Conditions

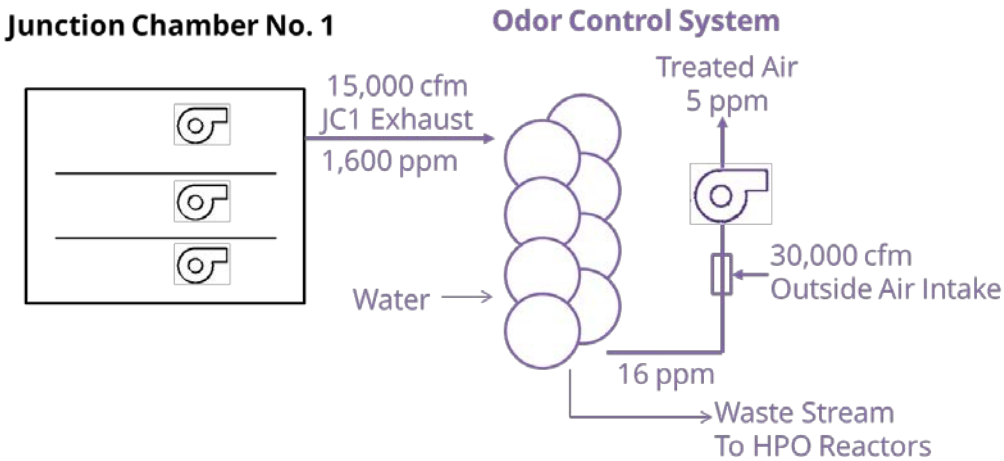


Figure 5.2-9: Flow Diagram of Alternative 2 Biotrickling Filters

Table 5.2-8: Estimated Operational Performance for Alternative 2

Description	Quantity[1]
Removal Efficiency at 600 ppm-H_2S	99%[2]
Removal Efficiency at 1,600 ppm-H_2S	99%[2]
Average Chemical Usage	None
Power Usage	125 HP
Reclaim Water Usage	172,000 gallons/day

[1]Quantity shown per manufacturer data – subject to change for different manufacturer systems.
[2]Not including dilution.

By having multiple towers in parallel, this alternative offers the City with a degree of redundancy. If one tower went offline, JC1 exhaust could still be treated by the other towers. However, with the increased air flow per tower, the H_2S removal rate would decrease. If only two towers were online, it is estimated that they could remove approximately 86% H_2S at average concentration and four towers could remove 80% H_2S at peak concentration, according to discussions with manufacturers. Conceptual cost estimates for capital and O&M are given in **Table 5.2-9** and **Table 5.2-10**, respectively.

Table 5.2-9: Conceptual Capital Cost Estimate for Alternative 2

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 222,000
Sitework & Demolition	$ 205,000
Biological Scrubber Towers & Associated Equipment	$ 2,750,000
Ductwork	$ 90,000
Exhaust Dilution Fan	$ 15,000
Scrubber Blowdown Station	$ 29,000
Instrumentation & Control	$ 140,000
Electrical	$ 140,000
Installation	$ 633,000
Sum of Bare Construction Costs	$ 4,224,000
30% Contingencies	$ 1,268,000
Bare Construction Cost	$ 5,492,000
20% OH&P & GCs	$ 1,099,000
Total Construction Cost	$ 6,600,000
20% Management and Engineering[2]	$ 1,320,000
Total Capital Cost[1]	**$ 7,920,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal and administrative costs.

Table 5.2-10: Conceptual O&M Cost Estimate for Alternative 2

Cost Description	Estimate
Electricity 20-Year Cost[1]	$ 1,609,000
Water Usage 20-Year Cost[2]	$ 2,655,000
Maintenance 20-Year Cost[3]	$ 746,000
Total O&M 20-Year Cost[4]	$ 5,010,000
Total O&M 20-Year Cost Present Value[5]	$ 2,780,000

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2] Assumed $1.20/kgal – actual cost to be determined in preliminary design.
[3] Operations/Maintenance labor cost of $40/hr. Includes annual maintenance and media replacement at Year 10.
[4]20-Year costs included an annual general inflation rate of 3% except for electricity as noted in Footnote #1.
[5]Used an annual interest rate of 3%.

5.2.10 Alternative 3 – Hybrid Alternative

This alternative would include completely replacing the existing odor control system. It would consist of new biotrickling filters followed by a chemical scrubber. For the purposes of this evaluation, it is estimated that four biotrickling filters towers would be able to provide 99% removal at average H_2S concentrations and 80% removal at peak H_2S concentrations based on a conversation with a manufacturer. Therefore, the chemical scrubber would serve as a polishing unit and would treat an average of 6 ppm-H_2S and a peak of 320 ppm-H_2S. Dilution of the treated air would not be required in this alternative, because the chemical scrubber polisher would be capable of approximately 99.9% H_2S removal. If the biotrickling filters ever went

offline for repair, the dosage in the chemical scrubbers could be increased to treat the H_2S from JC1.

The system would include a 15,000 cfm air handling fan, parallel biological towers, multi-stage chemical scrubbing towers, recirculation pumps for each tower, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, blowdown pump station, ductwork, and other associated equipment. The number of scrubbing towers needed would depend on the manufacturer selected. The footprint for this system would require the existing odor control system site and area adjacent to it. The estimated performance is summarized in **Table 5.2-11** and a flow diagram for this alternative is provided in **Figure 5.2-10**. Conceptual cost estimates for capital and O&M are given in **Table 5.2-12** and **Table 5.2-13**, respectively.

Table 5.2-11: Estimated Operational Performance for Alternative 3

Description	Quantity[1]
Removal Efficiency at Avg 600ppm-H_2S	99.9%
Removal Efficiency at Peak 1,600ppm-H_2S	99.9%
Average Chemical Usage for Chemical Scrubber	25% Sodium Hydroxide (NaOH) – 3 gph 12.5% Sodium Hypochlorite (NaOCl) –2 gph
Total Power Usage	120 HP
Reclaim Water Usage	95,000 gallons/day

[1]Quantity shown per manufacturer data – subject to change for different manufacturer systems.

Showing Estimated Peak Conditions

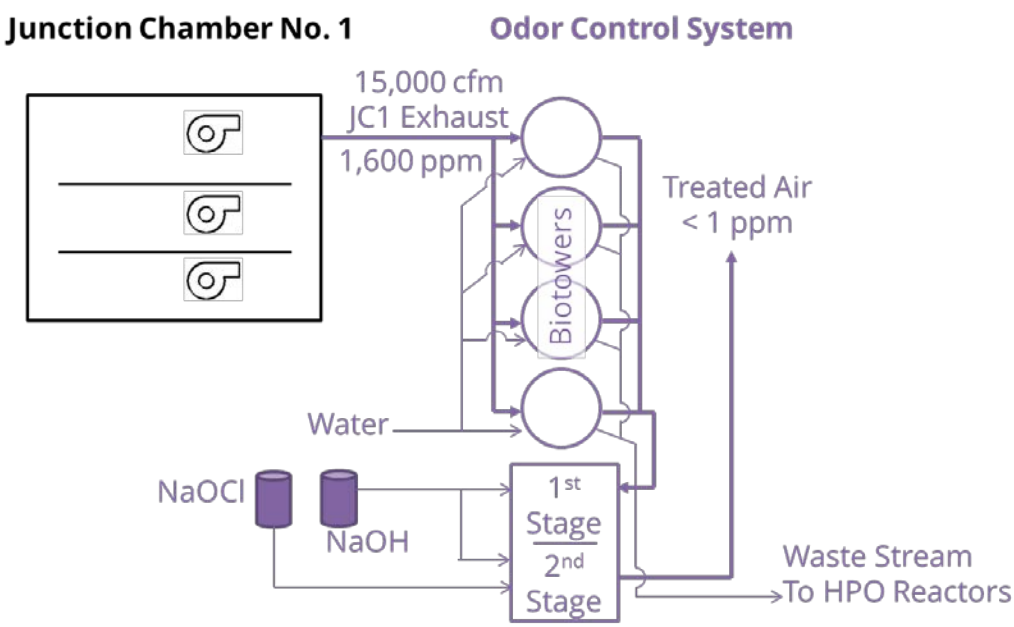


Figure 5.2-10: Flow Diagram of Alternative 3 Hybrid

Table 5.2-12: Conceptual Capital Cost Estimate for Alternative 3

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 122,000
Sitework & Demolition	$ 150,000
Hybrid Scrubber System & Associated Equipment	$ 1,565,000
Ductwork	$ 90,000
Exhaust Dilution Fan	$ 15,000
Chemical Feed System	$ 120,000
Instrumentation & Control	$ 119,000
Electrical	$ 119,000
Installation	$ 406,000
Sum of Bare Construction Costs	$ 2,706,000
30% Contingencies	$ 812,000
Bare Construction Cost	$ 3,518,000
20% OH&P & GCs	$ 704,000
Total Construction Cost	$ 4,230,000
20% Management and Engineering[2]	$ 846,000
Total Capital Cost[1]	**$ 5,080,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

Table 5.2-13: Conceptual O&M Cost Estimate for Alternative 3

Cost Description	Estimate
Electricity 20-Year Cost[1]	$ 1,544,000
Chemicals 20-Year Cost[2]	$ 833,000
Water Usage 20-Year Cost[3]	$ 1,468,000
Maintenance 20-Year Cost[4]	$ 824,000
Total O&M 20-Year Cost[5]	$ 4,670,000
Total O&M 20-Year Cost Present Value[6]	$ 2,590,000

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2] Estimated $0.75/gallon for 25% Caustic and $0.60/gallon for 12.5% Sodium Hypochlorite per manufacturer
[3] Assumed $1.20/kgal – actual cost to be determined in preliminary design.
[4]Operations/Maintenance labor cost of $40/hr. Includes annual maintenance and media replacement at Year 10.
[5]20-Year costs included an annual general inflation rate of 3% except for electricity as noted in Footnote #1.
[6]Used an annual interest rate of 3%.

5.2.11 Alternative 4 – Hydroxyl Radical Oxidation

This alternative would consist of hydroxyl radical units that treat the head space of JC1, similar to how these systems are used at wet wells. Because the head space would be treated, it is anticipated that the air flow could be reduced from 15,000 cfm to 12,000 cfm for 10 air changes per hour. Plenum pressure will remain negative since the air supply in JC1 will remain 11,520 cfm. One advantage in lowering the air flow is to increase the contact time with the hydroxyl

radicals. Lowering the air flow rate will increase the H_2S concentration because less outside air will be diluting the H_2S released from the wastewater. After discussion with a manufacturer, it is anticipated that the H_2S concentration in the treated air will not exceed 30 ppm. This would equate to approximately 98.5% removal. The second advantage in lowering the air flow rate is that there is less volume to dilute. By diluting with 30,000 cfm of outside air before exhausting to the atmosphere, the estimated peak H_2S concentration discharged would be less than 10 ppm and the average would be 3 ppm or less. Therefore, this alternative has viable potential to effectively treat odor at the HFC AWTP within the design criteria. The estimated performance is summarized in **Table 5.2-14** and a process diagram is shown in **Figure 5.2-11**.

Table 5.2-14: Estimated Operational Performance for Alternative 4

Description	Quantity[1]
Removal Efficiency at Avg 600ppm-H_2S	>98.5%[2]
Removal Efficiency at Peak 1,600ppm-H_2S	98.5%[2]
Chemical Usage	None
Power Usage	75 HP
Reclaim Water Usage	3,460 gallons/day

[1]Quantity shown per manufacturer data – subject to change for different manufacturer systems.
[2]Not including dilution.

Showing Estimated Peak Conditions

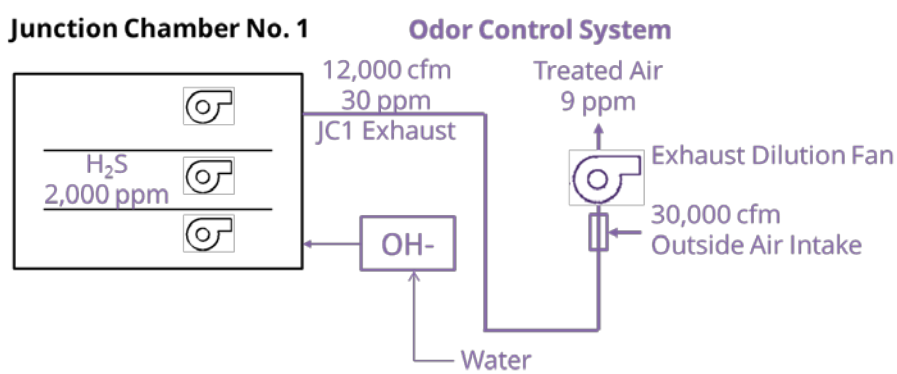


Figure 5.2-11: Flow Diagram of Alternative 4 Hydroxyl Radical (OH-) Oxidation

The hydroxyl radical oxidation units vary by manufacturer in the way they treat and in their exact dimensions. However, they are not much different in size, which is approximately 4-feet by 3-feet by 4-feet. It is estimated that three units would be needed and could fit inside an existing nearby building or in a small enclosure. Small diameter access ports would need to be constructed in the top slab of JC1 for the hydroxyl radical hoses or pipes. It is estimated that eighteen (18) ports would be needed (4 per train, 3 in the influent channel, and 3 in the effluent channel). Special nozzles that eject the hydroxyl radicals in a mist would be installed at each port. These nozzles are made of engineered polymer specifically for harsh wastewater environments that have been highly reliable over the years, reportedly never experiencing any

degradation or failure, according to the manufacturer. Conceptual cost estimates for capital and O&M are given in **Table 5.2-15** and **Table 5.2-16**, respectively.

Table 5.2-15: Conceptual Capital Cost Estimate for Alternative 4

Vendor Costs and Direct Costs	Estimate
Mobilization	$ 34,000
Sitework & Demolition	$ 89,000
Three Milli Unit System	$ 497,000
Ductwork	$ 60,000
Exhaust Dilution Fan	$ 15,000
Instrumentation & Control	$ 52,000
Electrical	$ 52,000
Installation	$ 136,000
Sum of Bare Construction Costs	$ 935,000
30% Contingencies	$ 281,000
Bare Construction Cost	$ 1,216,000
20% OH&P & GCs	$ 244,000
Total Construction Cost	$ 1,460,000
20% Management and Engineering[2]	$ 292,000
Total Capital Cost[1]	**$ 1,760,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

Table 5.2-16: Conceptual O&M Cost Estimate for Alternative 4

Cost Description	Estimate
Electricity 20-Year Cost[1]	$ 955,000
Water Usage 20-Year Cost[2]	$ 54,000
Maintenance 20-Year Cost[3]	$ 189,000
Total O&M 20-Year Cost[4]	$ 1,200,000
Total O&M 20-Year Cost Present Value[5]	$ 665,000

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2] Assumed $1.20/kgal – actual cost to be determined in preliminary design.
[3]Operations/Maintenance labor cost of $40/hr. Includes annual maintenance and media replacement at Year 10.
[4]20-Year costs included an annual general inflation rate of 3% except for electricity as noted in Footnote #1.
[5]Used an annual interest rate of 3%.

5.2.12 Cost Evaluation

The total estimated conceptual costs associated with each alternative is summarized in **Table 5.2-17**. The useful life expected for the chemical and biological scrubber media is 10 years, and the cost of one replacement was included in the cost analysis. These estimates include a one (1) year warranty, do not intend to include spare parts, and do not include any maintenance contracts, though some manufacturers do provide that option. As seen, Alternative 4 – Hydroxyl Radical Oxidation is the most cost effective option with a 20-year present value that is 70% lower than the next lowest alternative.

Table 5.2-17: Total Cost Comparison for Odor Control Alternatives

Cost Description	Alternative 1 Chemical Scrubbing	Alternative 2 Biotrickling Filters	Alternative 3 Hybrid Alternative	Alternative 4 Hydroxyl Radical Oxidation
Total Capital Cost[1]	$ 2,320,000	$ 7,920,000	$ 5,080,000	$ 1,760,000
Total O&M 20-Year Cost Present Value	$ 12,780,000	$ 2,780,000	$ 2,590,000	$ 665,000
Total 20-Year Cost Present Value	$ 15,100,000	$ 10,700,000	$ 7,670,000	$ 2,425,000

[1] Assumes no residual value after 20 years and capital outlay occurs in the year it is constructed.

5.2.13 Alternative Evaluation

Each alternative was evaluated for selection based on three main criteria including:

- Cost;
- Maintenance; and
- Other Success Factors – most importantly, Proven Implementation.

An evaluation matrix was created to help identify the most suitable alternative based on the above criteria. Each alternative was scored 1 to 10, with 10 being the best for each criterion. The score for each criterion was multiplied by a weighting factor and the weighted scores were totaled at the bottom. **Table 5.2-18** presents the findings of the evaluation, and the following is a brief summary of each criterion, with respect to the alternatives.

Cost

The cost of the alternatives is one of the most important factors in making a selection. This criterion used the Total 20-Year Present Value in order to evaluate the long term financial impacts of each alternative. The Total 20-Year Present Values used in calculating the scores were estimated in the preceding sections and summarized in **Table 5.2-17.**

Maintenance Intensity

An alternative that is easier and less demanding to operate and maintain is preferred. In order to objectively score the criterion, it was assumed that the regular annual maintenance cost would reflect the system complexity and represent the level of operating requirements for each alternative. The regular annual maintenance costs were provided by manufacturers and are shown in **Table 5.2-18**. As expected, operating Alternative 2 would be the least demanding because biological trickling filters are relatively simple systems. Alternative 4 is the next least demanding because the hydroxyl radical units are set for the design peak H_2S concentration and do not need to be adjusted throughout the day. Also, current owners have reported that these units are easy to work with if something does go wrong. The other two alternatives are much more complex due to having more parts and requiring chemical monitoring, storage and management.

Other Success Factors

Treatment Performance – All alternatives can provide better treatment than the existing system. They will all be able to provide treatment within the design criteria for odor control; therefore this criterion was given a low weight. Better treatment is an advantage, but not a strong factor in selecting between alternatives, since they all are able to meet the design criteria.

Proven Implementation – The chosen alternative must already be installed at similar applications and performing satisfactorily. Chemical scrubbers and biotrickling filters have been in use for years, and therefore received higher scores. However Alternative 2 was scored an 8, since there are few biotrickling filters applications that treat H_2S concentrations and air flow as high as the HFC AWTP. It was not given a lower score, because Alternative 2 would be designed conservatively so that air flow is split and each tower treats a more manageable volume. Alternative 4 was scored a 2 because hydroxyl radical oxidation is not a common technology for use in applications similar to JC1. It was not scored lower, because the City of Santa Cruz WWTP has reported that their system works successfully and the Town of Southington, CT pilot study showed that the technology has the ability to treat H_2S concentrations as high as the concentrations at JC1 (see discussion in **Section 5.2.6**). It is recommended that this alternative be tested for the specific application at JC1 before being seriously considered. Once tests prove successful performance, the score for this criterion would increase and would give Alternative 4 the highest total weighted score. Testing is further discussed in **Section 5.2.14**.

Footprint – This criterion was given a low weight, because it is anticipated that every alternative would be able to be constructed within the area consisting of the existing odor control site and the adjacent open area to the east. However, a smaller footprint is preferred, and Alternative 4 would be the favored alternative in this regard. In fact, Alternative 4 could be constructed within the existing system footprint.

Process Reliability

It is important that once in place, the alternative consistently provides the expected treatment performance. Just a small reduction in performance could result in discharging levels of H_2S that could cause a nuisance to neighbors depending on their proximity and other surrounding odors. Alternatives 1 and 3 will be the most reliable because of the effectiveness of chemical treatment. Alternative 2 is expected to be very reliable as well since it is designed for max day H_2S levels, but it was given an 8 because bacteria are not as quick to adjust to fast peaks as compared to chemical treatment. Alternative 4 utilizes one of the strongest oxidants available for chemical treatment, and it would be designed to dose for peak H_2S levels so that adjustments to fluctuating H_2S concentrations would not be a concern. However, it was given an 8 because its effectiveness on the JC1 air flow is uncertain and needs to be tested as further discussed in **Section 5.2.14**.

Table 5.2-18: Odor Control Alternatives Evaluation Matrix

	Alternative 1 Chemical Scrubbing			Alternative 2 Biotrickling Filters		Alternative 3 Hybrid Alternative		Alternative 4 Hydroxyl Radical Oxidation	
Criteria	Weight	Score[1]	Weighted Score	Score[1]	Weighted Score	Score[1]	Weighted Score	Score[1]	Weighted Score
Cost									
Total 20-Year Cost Present Value[2]	$ 15,100,000			$10,700,000		$ 7,670,000		$ 2,425,000	
	40%	1.61	0.64	2.27	0.91	3.16	1.26	10.00	4.00
Maintenance									
Maintenance Intensity[3]	$ 13,000			$ 5,000		$ 18,000		$ 7,000	
	5%	3.85	0.19	10.00	0.50	2.78	0.14	7.14	0.36
Other Success Factors									
Treatment Performance[4]	99%			99%		99.9%		98.5%	
	5%	9.91	0.50	9.91	0.50	10.00	0.50	9.86	0.49
Proven Implementation	40%	10	4.00	8	3.20	10	4.00	2	0.80
Footprint	5%	6	0.30	1	0.05	4	0.20	10	0.50
Process Reliability	5%	10	0.50	8	0.40	10	0.50	8	0.40
Total	100%	41.4	**6.13**	39.2	**5.55**	39.9	**6.60**	47.0	**6.55**

[1] Scored from 1 (worst) to 10 (best)

[2] Costs from **Table 5.2-17** were used here to calculate scores.

[3] Regular annual maintenance costs shown here were given by manufacturers and used to calculate the Maintenance Intensity Scores.

[4] Treatment Performance scores were calculated using the expected H_2S removal efficiency for each alternative.

5.2.14 Recommended Alternative

Based on the assumptions and data available for this evaluation, Alternative 3 - Hybrid Alternative has the highest evaluation score, as shown in **Table 5.2-18,** and is therefore the recommended alternative. The hybrid alternative utilizes biotrickling filters followed by chemical scrubbers for polishing which both are proven technologies. Alternative 3 is estimated to have a lower cost than Alternative 1 and 2, and it has an inherent back-up system by utilizing two technologies in series. However, the advantages of Alternative 4 may outweigh the reliability of Alternative 3 if tests can prove its effectiveness at JC1. The hydroxyl radical oxidation alternative is estimated to be the most cost effective. Even though the hydroxyl radical oxidation system is a newer technology and there is a level of uncertainty for how it will actually perform at the HFC AWTP, it has good reviews from two interviewed owners. It may be in the City's best interest to further investigate this alternative before making a final selection.

An investigation could include a pilot study or a full-scale study with the existing odor control system in place. One key point of concern would be the effect that air flow rate has on the removal efficiency. Based on the results of a study, the existing chemical scrubbers could be demolished, new chemical scrubbers could be installed for polishing if needed, or, if the results do not prove the technology effective in JC1, then the hydroxyl radical oxidation units could be removed and relocated to City lift stations, an application where they have proven effective. Even if the results conclude that a polishing unit is required, this option would still be the most cost effective alternative at a conservative conceptual estimate of approximately $5 million for 10-year present worth if chemical scrubbers are the chosen polishing technology.

While these recommendations are considered, the City should be able to improve their H_2S removal in the existing system by utilizing sodium hypochlorite in the third reactor per the original design. It is expected that this will increase the H_2S removal percentage with the sodium hypochlorite oxidizing the H_2S carried over from the second reactor.

5.2.15 Other Considerations

If the City wishes to treat the JC1 exhaust air for other malodorous chemicals besides H_2S, then an odor characterization study would be recommended. This would help determine whether other malodorous chemicals, such as methyl mercaptan, are in the air stream and at what levels. Based on this information, a carbon unit or small chemical scrubber could be specially designed to polish the treated air. However, the biotrickling filters should be able to provide greater than 99% removal on their own, and the dilution fan would help lower the final exhaust levels even further. Therefore, the polishing units may not be needed depending on the results of the odor characterization study. Currently the City does not oxidize air in the odor control system, therefore removal of other malodorous chemicals is negligible. If there is currently not a problem with odor from other chemicals, then an odor characterization study may not be required.

The final technology decision and system design will need to be evaluated based on a study of upstream liquid-phase H_2S treatment. If the City incorporates treatment upstream of the HFC AWTP, then the H_2S levels in JC1 may decrease and the odor control system may not need to be designed to the high levels evaluated in this report. If the H_2S design criteria levels decrease, then a lower cost system might be possible to replace the existing system.

5.2.16 Safety Improvement Recommendations

A number of safety measures are currently being taken at JC1 to protect workers from the strong H_2S gas inside the pre-aeration tanks. First of all, the tanks are enclosed, air tight access hatches are kept closed, an odor control exhaust fan maintains a negative pressure within the junction chamber and any H_2S that leaks from the tank mixes with the outside air. Also, operators wear a hand held H_2S monitor when working at JC1. So, if the exhaust air leaking from the tanks rises too high, the monitor alarm will go off and workers can take precautionary measures.

However, Evoqua performed air monitoring in May 2017 and found elevated H_2S levels on top of JC1 ranging between 10 to 20 ppm. According to **Figure 5.2-3**, this could cause headaches, nausea, throat and eye irritation. These concentrations are an indication that there may be some leaks in the top slab at locations of dead zones in the head space where negative pressure is not as effective and JC1 exhaust is leaking up through the roof. It could also be an indication that some H_2S from the exhaust stack is sinking to the JC1 level.

The pre-aeration tanks are monitored with oxygen and combustible gas detectors. Likely combustible gases in the tanks include gasoline vapor and methane. According to the National Institute for Occupational Safety and Health (NIOSH), gasoline has a lower explosive limit (LEL) of 1.4% by volume, and methane has an LEL of 5.0% by volume. If the detectors measure levels within 25% of the LEL, an alarm will go off. Since there are no known reports of alarm activation, it is assumed that gasoline and methane are well below their explosive limits, and JC1 equipment does not need to be explosion proof.

It would be in the best interest of the City to consider implementing additional safety measures at JC1, as follows:

1. Continuously monitor H_2S on JC1 so that workers can be aware of concentrations before entering the JC1 area.
2. Release and treat more H_2S upstream of the plant to reduce concentrations being stripped in the pre-aeration chambers.
3. Adding liquid phase chemical treatment upstream to oxidize H_2S or reduce the formation with upstream chemical treatment.
4. Conduct smoke test to check for leaks in the junction chamber top slab. Repair as needed.

5.3 Improve Ventilation in Screen and Grit Building No. 2

After flowing through JC1, wastewater is conveyed to the screen and grit buildings. Flow is split evenly between Screen and Grit (S&G) Building No. 1 (new building) and S&G Building No. 2 (old building). Both buildings closely mirror each other in layout as shown in **Figure 5.3-1**, but there are some differences.

Figure 5.3-1: Photo of S&G Buildings

S&G Building No. 2 only has two influent channels with screens and S&G Building No. 1 has three. Also, ventilation systems and volumes in each building are different. The rooms and ventilation in S&G Building No. 1 are shown in **Figure 5.3-2**.

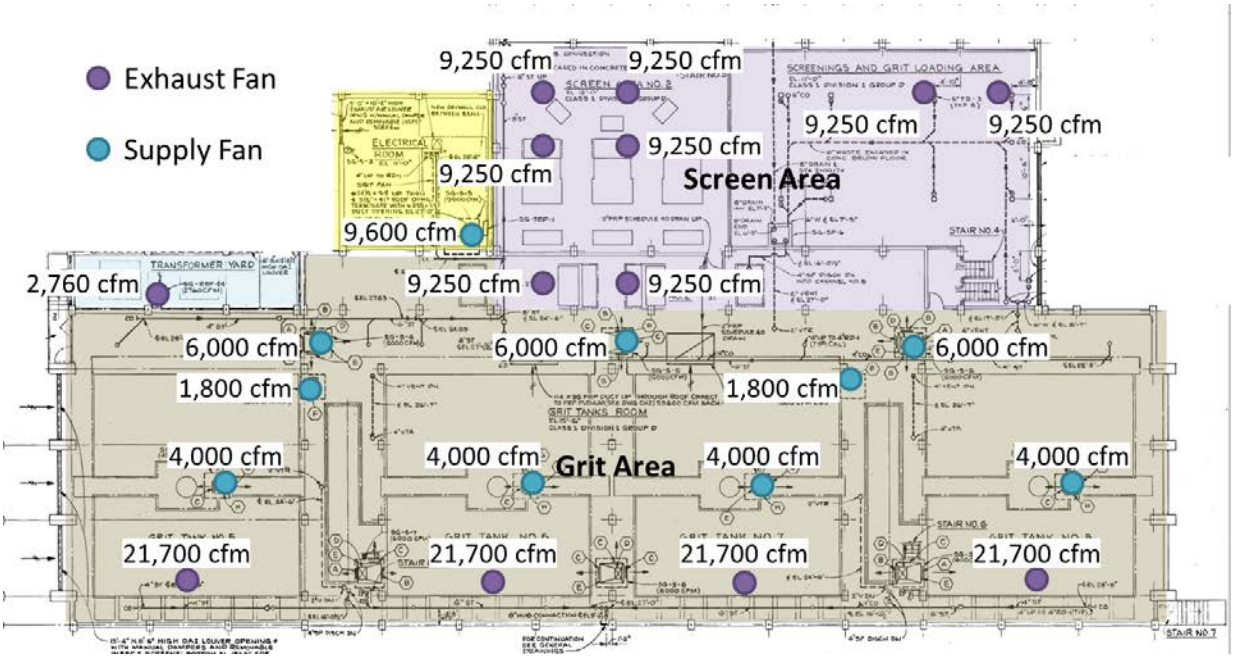


Figure 5.3-2: Existing Ventilation in S&G Building No. 1

There is an existing large 72-inch diameter exhaust system at the center of S&G Building No. 1 that is not identified in **Figure 5.3-2** because it is not used. The outdoor portion of this exhaust system can be seen on the roof in the aerial picture included at the beginning of this section. The rooms and ventilation in S&G Building No. 2 are shown in **Figure 5.3-3**. For the purposes of ventilation calculations, the Screen

and Grit Areas were accounted for as one room because they are not closed off from each other. They are identified as two separate areas due to their different heights. The volumes and air changes calculated for each building was based on the dimensions given in record drawings and are summarized in **Table 5.3-1**.

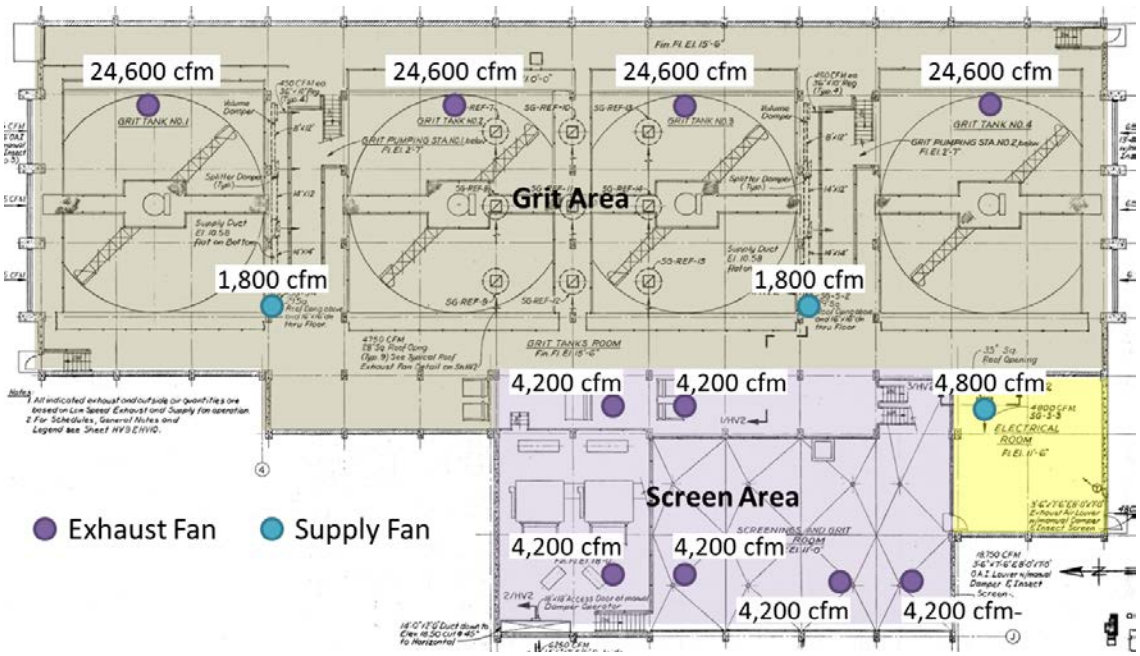


Figure 5.3-3: Existing Ventilation in S&G Building No. 2

Table 5.3-1 also shows the exhaust and outside air supply capacities for each building. Building No. 1 has approximately 40% greater rated exhaust capacity than Building No. 2 in the screen and grit area.

Table 5.3-1: Ventilation Capacity in Screen and Grit Buildings

Room	Approximate Volume (CF)	Rated Exhaust Capacity (cfm)	Rated Supply Capacity (cfm)	Air Changes Per Hour
S&G Building No. 1				
Screen & Grit Area	453,949	160,800	37,600	21
Electrical Room	18,358	-	9,600	31
Transformer Yard	10,716	2,760	-	15
S&G Building No. 2				
Screen & Grit Area	490,130	123,600	3,600	15
Electrical Room	18,434	-	4,800	16

Ventilation in the screen and grit buildings is important to remove H_2S laden air from the buildings. The H_2S is released from the wastewater at points of turbulence which occurs predominately at the screens, sharp channel bends, and over the effluent weirs. This H_2S leads to corrosion of exposed equipment and must be pulled out by exhaust fans to minimize its impact. The H_2S concentration must also be controlled in order to maintain a safe and acceptable work environment. While visiting the S&G Building

No. 2, a gas detection monitor was reading approximately 9 ppm of H_2S with fluctuations. Whereas, the S&G Building No. 1 monitor reported a H_2S concentration of 1 ppm in the Grit Tank Area.

The 10 State Standards recommends 12 air changes per hour for wet well applications. While the NFPA 820 recommendation for Class I, Division 2 enclosed spaces with wastewater exposed to the room atmosphere is equal to or greater than 12. For a room exposed to H_2S, an air change per hour of 20 would be acceptable. Also, 30 air changes per hour in electrical rooms may be used for extra protection. Therefore, the ventilation rates in S&G Building No. 1 are acceptable, but improvements are needed in S&G Building No. 2. Improvements will not be limited by the existing intake louvers, which have more than sufficient capacity to accommodate the increased ventilation described in the following section.

5.3.1 Conclusion and Cost Estimate

Even though the ventilation rate in Building No. 2 is relatively high, there is still a considerable amount of H_2S in the air and corrosion as seen on the equipment. Therefore, there is a need to increase ventilation to reduce the concentration of H_2S in order to improve the work environment. Increased ventilation will also provide a degree of corrosion mitigation. By mitigating corrosion, the equipment useful life will increase.

One possible option for improving the building environment is to increase ventilation rate to match the ventilation system in S&G Building No. 1. The new ventilation rates this would require are provided in **Table 5.3-2** and a figure showing possible new fan improvements is shown in **Figure 5.3-4**. The locations were selected to maximize use of existing roof openings. The estimated conceptual construction cost for these improvements is given in **Table 5.3-3**.

Table 5.3-2: Proposed Ventilation Rates for S&G Building No. 2 to Match S&G Building No. 1

Room	Rated Exhaust Capacity (cfm)	Rated Supply Capacity (cfm)	Air Changes Per Hour
S&G Building No. 2			
Screen & Grit Area	169,400	43,600	21
Electrical Room	-	9,600	31

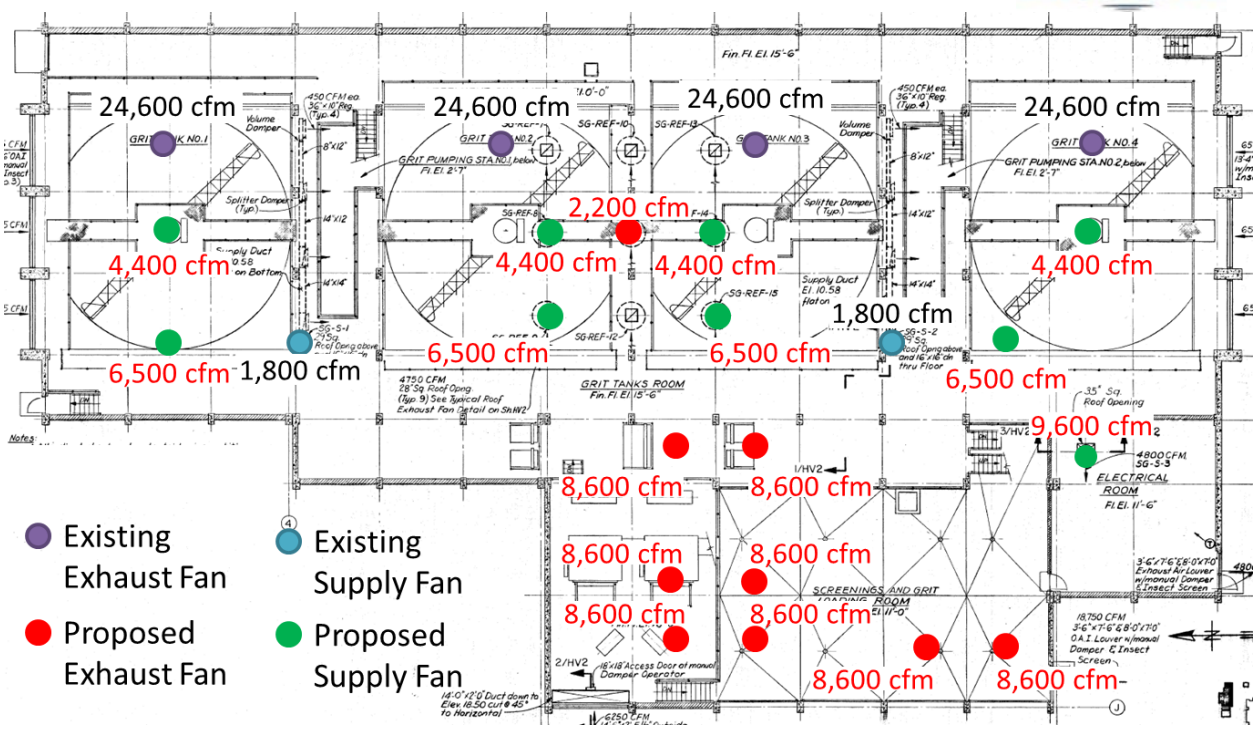


Figure 5.3-4: S&G Building No. 2 Fan Improvements to Increase Ventilation

Table 5.3-3: Conceptual Capital Cost Estimate for Ventilation Improvements at S&G Building No. 2

Vendor Costs and Direct Costs	**Estimate**
Mobilization	$ 14,000
New Roof Exhaust Fans (9 total)	$ 135,000
New Roof Supply Fans (9 total)	$ 135,000
Structural	$ 14,000
Instrumentation & Control	$ 14,000
Repair to roofing system	$ 30,000
Intake ductwork	$ 20,000
Electrical	$ 27,000
Installation	$ 75,000
Sum of Bare Construction Costs	$ 464,000
30% Contingencies	$ 140,000
Bare Construction Cost	$ 604,000
20% OH&P & GCs	$ 121,000
Total Construction Cost	$ 730,000
20% Management and Engineering[2]	$ 146,000
Total Capital Cost[1]	**$ 880,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal and administrative costs.

5.4 Grit Removal

After flowing through JC1, raw sewage enters the screen and grit buildings. Grit that is removed in the Detritor tanks is pumped to the Grit Conditioning System where it is dewatered and organics are washed out before grit is dumped and sent to landfill **Figure 5.4-1**. The liquid stream from the grit conditioning system is sent back to the main process upstream of the screens. The purpose of this system is to remove grit to protect downstream systems from the abrasion grit can cause if left in the water. Also, grit is dewatered and washed to remove volatile organics and reduce the volume of grit hauled away. A summary of the existing grit removal tanks characteristics is given in **Table 5.4-1**.

Figure 5.4-1: Photo of Existing Grit Removal Equipment

It has been reported that sugar sand is showing up in the digesters. Based on the information available at this time, the cause for this would have to be at the grit removal system because digester sludge comes from primary and secondary processes only. If sugar sand is coming from those processes, then it is likely not being effectively removed in the grit removal system. This could be confirmed with a grit characterization study.

It is possible that the existing grit washers have deteriorated to the point that they are actually re-suspending sugar sand into the liquid stream that is being sent back into the grit tanks. Therefore, the volume of sugar sand could be high enough that the 10% of grit not captured in the grit tanks is significant enough to cause problems in the digesters. By improving the grit conditioning system, it is expected that the sugar sand removal should greatly increase and should result in much less sugar sand in the digesters. This will need to be monitored when a new grit conditioning system starts running.

Table 5.4-1: Existing Grit Removal Tanks Design Data

Description	Value
Quantity	8 Total 4 Each Building
Manufacturer	DORRCLONE
Type	Velocity Controlled Settling Tanks
Install Date	1978 (Building 2) 1991 (Building 1)
Diameter	45 feet
Nominal Water Depth	6 feet
Capacity (Each)	15 MGD Minimum 27.6 MGD Design 30 MGD Maximum
Typical Target Flow	20 MGD
Operation	Continuous Day
Design Capture	90 % sg 2.65 150-mesh (100 microns)
Grit Removal	2.23 CF/MG 214 CF/Day 25.7 1000lbs/Day (assumes 120 lbs/CF)
Grit Rake Rate	0.14 revolutions/minute
Grit Disposal	Sent to Grit Conditioning System

5.4.1 Grit Conditioning

There are several technologies available for grit conditioning. Grit clarification can be achieved by vortex separation, cyclones, or clarifier and dewatering conveyors. There are many manufacturers of this equipment but Hydro International, WEMCO, and Huber which are well known and further evaluated to compare the different technologies.

Hydro International –
This system includes the Eutek Slurry Cup™ and Grit Snail® shown in **Figure 5.4-2**. The Slurry Cup™ is a vortex grit washing unit and the Grit Snail® is a clarifier that allows grit to settle and dewatered when lifted out of the inclined cleated belt conveyor.

Figure 5.4-2: Picture of Eutek Slurry Cup™ and Grit Snail®

<u>WEMCO</u>

The WEMCO Hydrogritter ® system includes a cyclone that concentrates the grit and a screw conveyor that dewaters the grit as it is pushed out of the classifier. Performance is limited by balancing the speed of the screw with a speed fast enough to remove organics and slow enough to remove grit. The process is depicted in **Figure 5.4-3**.

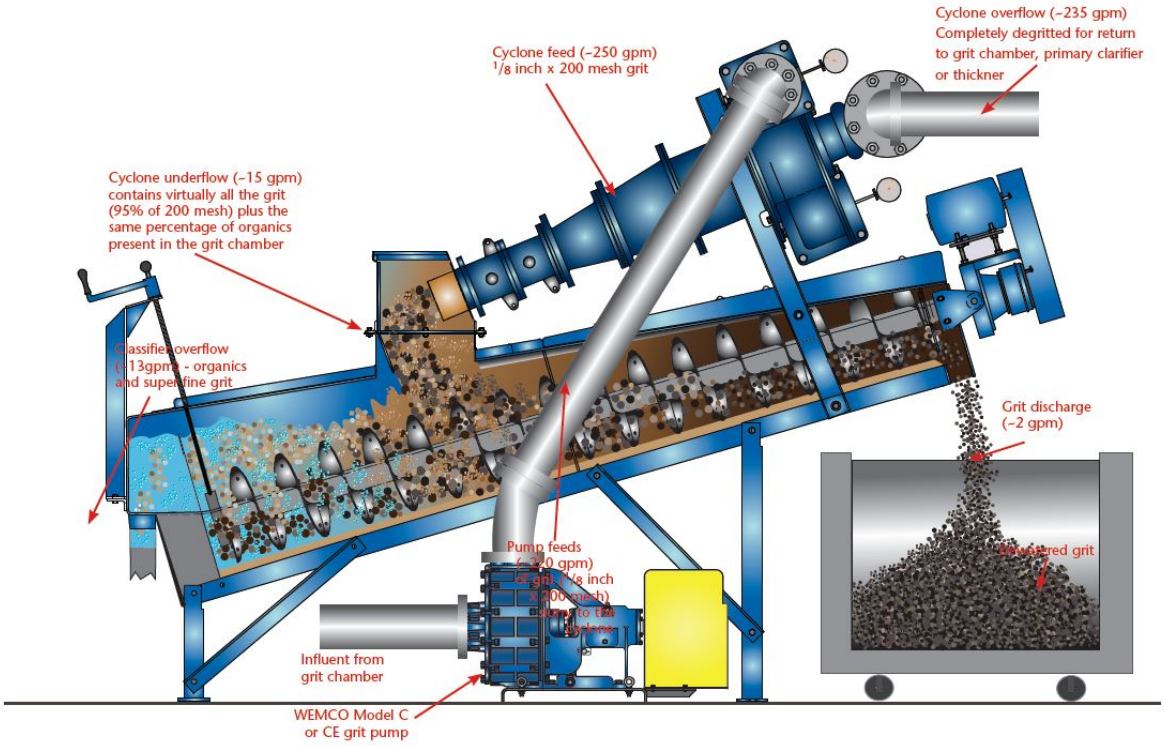


Figure 5.4-3: Picture of WEMCO Hydrogritter®

Huber

Grit is washed and dewatered in the Huber COANDA Grit Washer shown in **Figure 5.4-4**. Grit enters the vortex chamber and is horizontally dispersed by the COANDA Tulip at the top of the clarifier. The grit settles and liquid flows over the circumferential weir. Grit is fluidized with an upward flow of wash water and central stirrer. The rubbing that occurs between the grit causes the volatile organics to fall off. Washed grit is then removed by a screw conveyor.

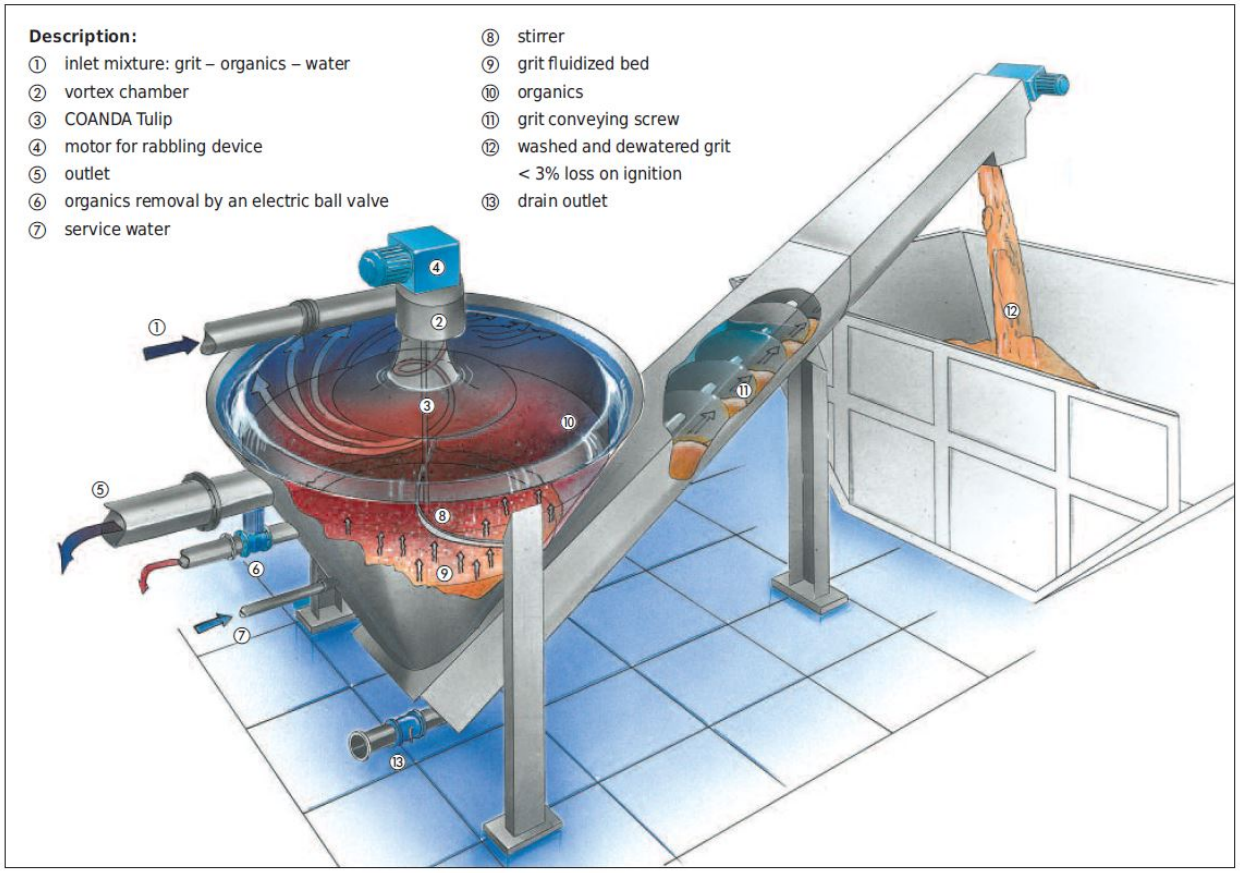
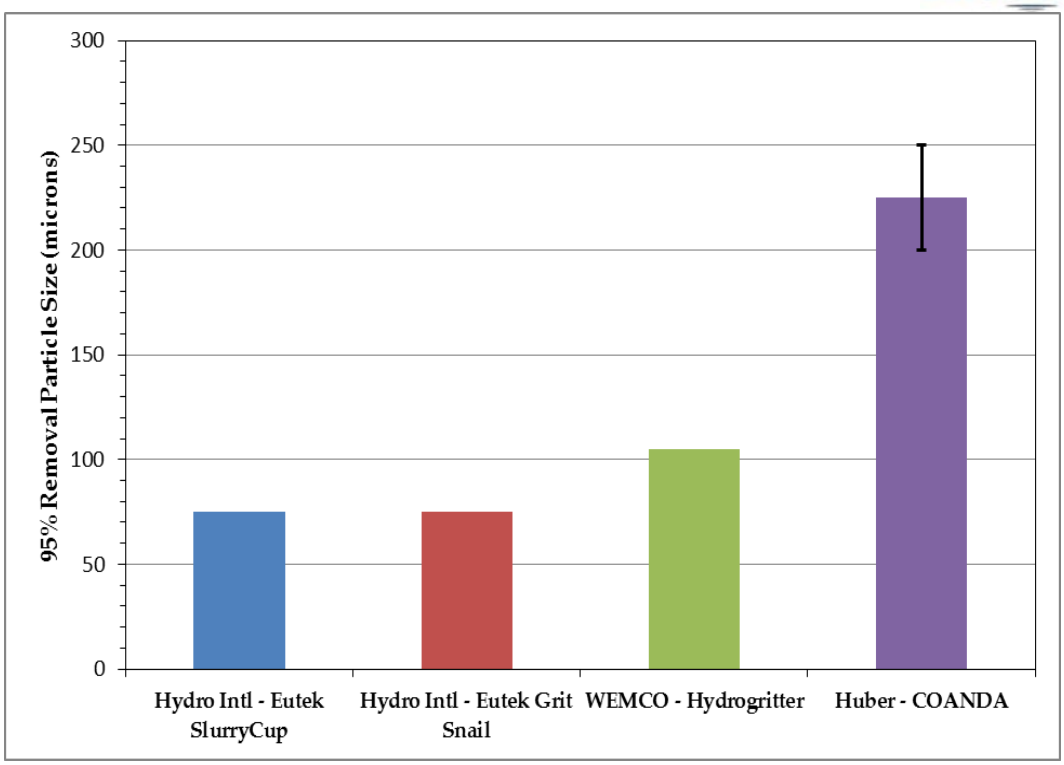


Figure 5.4-4: Huber COANDA Grit Washer

The three technologies are all designed to remove a certain percentage of the grit. The expected removal performances are compared in **Figure 5.4-5.**



1) Huber COANDA 95% removal is over a range of particle sizes from 200 to 250 microns.

Figure 5.4-5: Comparison of Particle Size at 95% Removal Efficiency[1]

Based on the comparison of removal efficiencies, the Eutek grit conditioning system is designed to remove the smallest grit at the highest efficiency. The footprint of this system would fit in the current grit conditioning system making this a feasible option. Therefore, the Eutek Slurry Cup™ and Grit Snail® are the recommended grit washers and dewatering system to replace the existing grit conditioning system. This system has already been designed for both screen and grit buildings. The low bid price for one building was $2.6 million.

5.4.2 Grit removal and Flow Imbalance

Grit Removal

Other considerations for improving sugar sand removal include retrofitting the existing detritus grit removal tanks with a new technology. There are several technologies available to choose from, which include:

1. Aerated Grit Removal
2. Mechanical Vortex Grit Removal Systems
3. Induced Vortex Grit Removal Systems
4. Multi-Tray Vortex Grit Removal Systems

Aerated grit chambers would be costly and provide little to no improvement for sugar sand removal. Some vortex systems have the capability of removing 95% of particles 105 microns and greater. Two other vortex systems, the Hydro International Eutek TeaCup and Eutek HeadCell, are both supposed to have the capability to remove 95% of 75 microns or larger. This would provide the most sugar sand removal of all available technologies.

Grit Removal Conclusion

After discussions with the manufacturer, it was concluded that retrofitting Eutek units into the existing detritus tanks is not feasible without increasing the hydraulic grade line due to height constrictions. This means a new facility to pump influent wastewater to the elevation of the units would need to be constructed, but this would be very costly. If replacing the grit conditioning system does not help reduce sugar sand in the digesters to an acceptable level, then the City could consider investing in vortex grit removal versus continuing without them.

Flow Imbalance

In Phase 1, it was reported that the southern screens in both screen and grit buildings were seeing greater run times than the other screens. The more frequent run times may result in the southern screens requiring maintenance before the other screens. The different run times seems to indicate that there is some type of flow imbalance between the northern screen channels and the southern screen channels. There are several possible causes for this, which include, but are not limited to, the following:

1. Abnormal screen controls – The southern screens could operate more if they were set to run at a lower pressure differential.
2. Wash water from drain – The screening compactors drain their wash water to the influent screen channels. If they disproportionately drain into the southern channel, then this would increase flow through southern screen and possibly cause screen to operate more.
3. Structural imbalance – If the channels that convey water through the screens and to the grit chambers are asymmetric in length or cross section, then this could lead to a possible flow imbalance.
4. Channel sluice gates interference – If the sluice gates in the influent channels to the grit chambers are not fully open or closed, they could be interfering with flow imbalance by increasing head loss to one channel versus another.
5. Flow momentum from influent 72-inch – The influent 72-inch pipes that feed each building convey flow from the north. These influent pipes tie into a riser that then discharges wastewater into the influent channels, which split symmetrically from the riser. Though they are symmetric, it is possible that momentum from the southerly influent flow continues to push some flow and associated solids towards the southern channel.

Flow Imbalance Conclusion

After discussion with the manufacturer representative, possible cause number 1 and 2 above do not seem to be the problem. They checked the controls and made the recommendation to route compactor drainage water to each screen channel. A recent site visit found that this drainage piping is now draining to each channel, though it is not known how long the drainage has been re-routed and what kind of effect it has had on the flow imbalance, if any.

Record drawings were reviewed to evaluate possible cause number 3. The screen and grit building channels are shown to be symmetric and do not appear to be the problem. During a site visit, operation of the sluice gates was said to be fully open or closed and so possible cause number 4 does not seem to be a problem either. Possible cause number 5 remains as the most likely cause for the flow imbalance through the southern screens. The riser should dissipate the southerly flow momentum, but it is possible that this does not have a complete effect. Conducting a tracer study or computational fluid dynamics (CFD) modeling could better evaluate the cause(s) of the flow imbalance and its possible impact on maintenance and effectiveness.

5.5 Sewage Receiving

Figure 5.5-1: Aerial of Sewage Receiving Station Location

The HFC AWTP accepts industrial waste from a variety of third party haulers, including:

- Septage
- Portable toilet waste
- Greywater
- Ship & Marina water
- Tampa Bay Fisheries
- Pasco County Leachate
- Tampa Bay Water Desalination
- Plant Washwater

The location of the sewage receiving station is depicted in **Figure 5.5-2**. Leachate and desalination washwater haulers dump at a station adjacent to the existing heat drying facility shown in **Figure 5.5-2** and **5.5-3**. All other haulers dump in a sewage receiving station adjacent to the raw sewage pump station as shown in **Figure 5.5-3**. Both stations have a drain in the concrete pavement that haulers discharge into. The sewage receiving station drains to the raw sewage pump station and the leachate discharge station drains to the master pump station.

Objectives:

1. Automation - Currently, haulers report their estimated volume and waste water quality and pay accordingly. The City would like to automate their industrial waste stations to track the volume of loads accurately.
2. Improve Traffic Pattern - Current routing through the plant does not easily accommodate large truck haulers. A traffic pattern needs to be evaluated that accommodates both small vehicles and tractor-trailer rigs. In addition, options to improve security will be reviewed including changing entrance location.

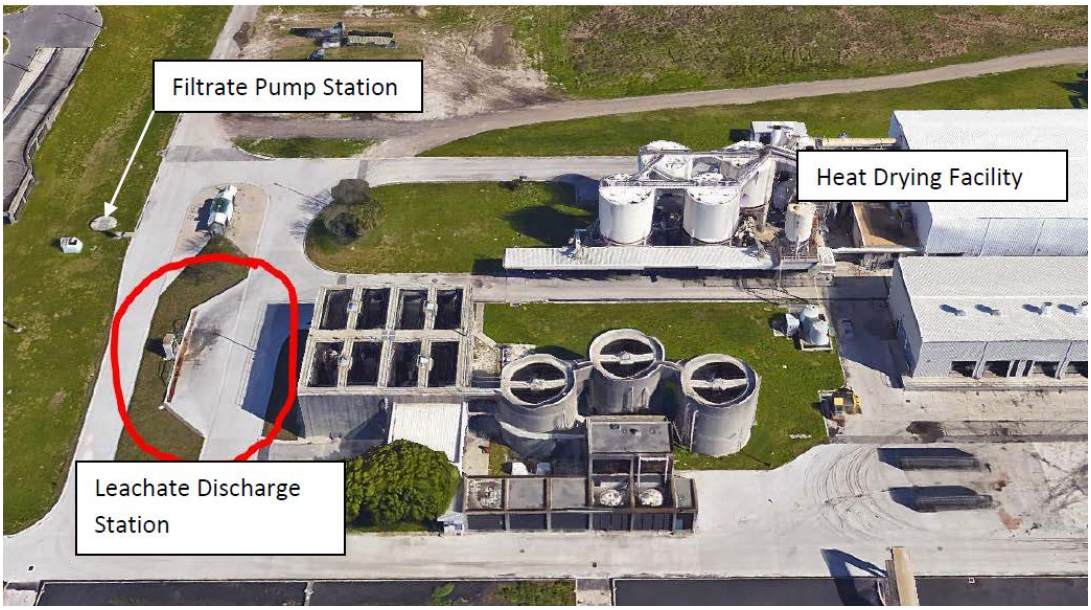


Figure 5.5-2: Aerial of Existing Leachate Discharge Station

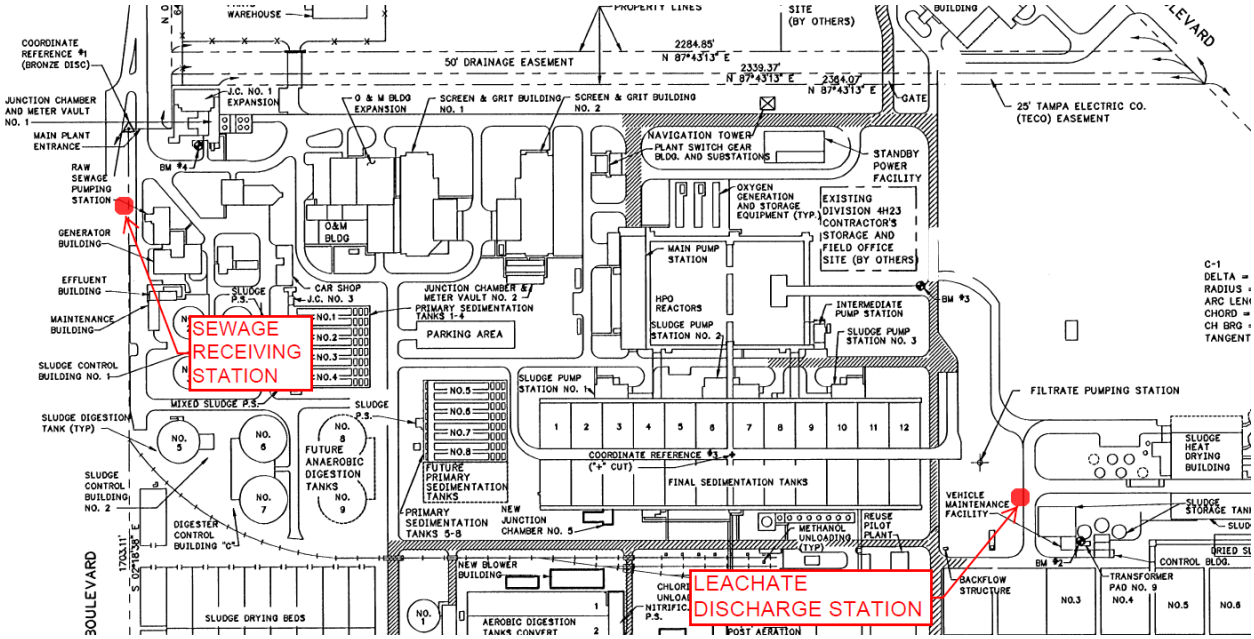


Figure 5.5-3: Existing Location of Industrial Waste Stations at HFC AWTP

5.5.1 Automation Evaluation

There is wide spectrum of layers for automating sewage receiving at HFC AWTP. These layers are depicted in **Figure 5.5-4**. The City can choose any combination of the layers of automation they need to achieve their objectives.

Figure 5.5-4: Sewage Receiving Station Automation Spectrum

Level 1 Automation

The first step in automating the system is installing administration software, a security access panel, and an actuated valve. The panel is installed at the receiving location where haulers must log in for the actuated valve to open and allow them to dump their sewage. It is recommended to use pin numbers for access as opposed to access cards. The cards tend to be misplaced and new cards have to be ordered to replace them. The administration software can track how many times a hauler dumps. When finished dumping, a hauler can press stop to shut the valve. Level 1 automation components are summarized in **Table 5.5-1**

Table 5.5-1: Level 1 Automation for Sewage Receiving Station

Level 1 Automation Included Components
Administration Software
Security Access Panel
Actuated Valve

Level 2 Automation

The second step in automating the system is adding a flow meter just downstream of the actuated valve in Level 1. This flow meter can be programmed to report the flow dumped by each hauler via the administration software. Some programs include a totalizer that shows the accumulating volume of sewage being dumped. It is possible to program the valve to shut off

when no flow is read by the flow meter after a certain period of time. A summary of Level 2 automation is given **Table 5.5-2**.

Table 5.5-2: Level 2 Automation for Sewage Receiving Station

Level 2 Automation Included Components
Administration Software
Security Access Panel
Actuated Valve
Flow Meter

Level 3 Automation

The third level of automation for the system is adding an automatic sampler and pH monitor. The frequency at which samples are pulled per hauler can be programmed with the software. Each sample would be tied to one hauler and one transaction and kept refrigerated until plant staff could pick up the samples and take them to the lab for analysis. A summary of components included in Level 3 automation is provided in **Table 5.5-3.**

Table 5.5-3: Level 3 Automation for Sewage Receiving Station

Level 3 Automation Included Components
Administration Software
Security Access Panel
Actuated Valve
Flow Meter
pH Monitor
Refrigerated Sampler

The City has identified that Level 3 automation is preferred with the following additional features:

- Haulers would enter a code specific for a company through a keypad interface.
- Haulers would enter a code specific to themselves through a keypad interface.
- Haulers would enter a code identifying the characteristics of the wastewater (e.g., greywater, septage, portable toilet, leachate, etc.).
- The system would accurately meter the volume discharged.
- The system would create a receipt (paper or electronic) for the driver.
- The system would create monthly billing invoices based on the number of loads and volume discharged, and based on the characteristics of the wastewater discharged.
- The system would store all of the data for a period of time as determined acceptable by the City, and be transferrable to another device (e.g., PC, etc.).

- The system would electronically send notification to AWTP (e.g., Industrial Waste, Process Control) when a driver interfaces with the system keypad.

5.5.2 Traffic Evaluation

It is not uncommon for the City to have three haulers dumping sewage at a time. The existing sites can only allow one hauler to dump at a time. Therefore, a new site is needed that could accommodate intermediate semi-trailers. These vehicles have a design turning radius of 41 feet to their center line according to "A Policy on Geometric Design of Highways and Streets" by ASHTOO. The new site would also need to meet the following parameters given by the City:

- The area would be fenced off from the treatment plant site, but still provide access from inside the treatment plant.
- There would be a secure, one-way entrance gate.
- There would be a one-way exit gate.
- There would be a surveillance camera monitoring the site.
- There would be at least 2 or 3 automated disposal systems, designed with the following considerations:
  - There can be as many as 30 loads discharged in a day;
  - Tankers can take 20 minutes or longer to discharge; and
  - Redundancy if one system is down.
- There would be rinse water available.
- There would be small drains for washdown.

5.5.3 Sewage Receiving Recommendation

A site that meets the criteria above was found to be in the southwest corner of the plant property. There is a vacant grassy area just south of the railroad tracks and next to Maritime Blvd where both the sewage receiving station and proposed FOG receiving station (see High Strength Waste Tech Memo) could be constructed adjacent to each other. The sewage receiving station would consist of four standalone, automated sewage receiving stations that drain to one pump station. The sewage pump station could pump into a small force main that discharges at the Raw Sewage Pump Station, a manhole, or the Junction Chamber 1 influent channel. A conceptual layout of this new sewage receiving station is provided in **Figure 5.5-5.** The estimated project cost is given in **Table 5.5-4**.

Table 5.5-4: Cost Estimate for Proposed Sewage Receiving Station

Vendor Costs and Direct Costs	Estimate
Automated Disposal Systems (x4)	$ 352,000
Sewage Pump Station	$ 125,000
Piping	$ 77,000
Fence	$ 18,000
Motorized Gates (x4)	$ 4,000
Road Surface	$ 980,000
Electrical	$ 21,000
Instrumentation & Control	$ 41,000
Installation	$ 100,000
Sum of Bare Construction Costs	$ 1,718,00
30% Contingencies	$ 516,000
Bare Construction Cost	$ 2,234,000
20% OH&P & GCs	$ 447,000
Total Construction Cost	$ 2,690,000
20% Management and Engineering[2]	$ 538,000
Total Capital Cost[1]	**$3,230,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal and administrative costs.

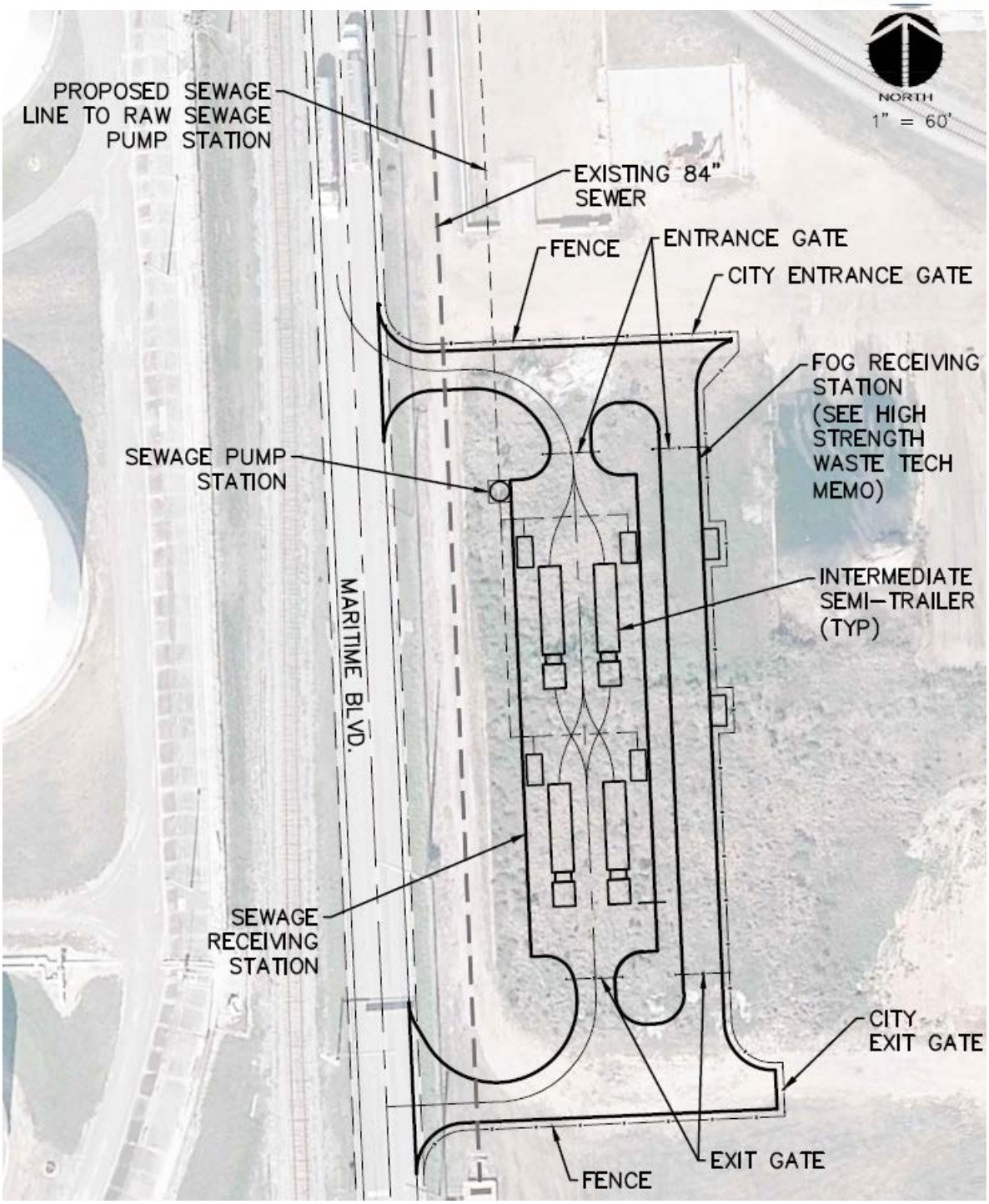


Figure 5.5-5: Proposed Sewage Receiving Station Layout

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Technical Memorandum 6.0 Primary Treatment Evaluation

6.1 Introduction

Following screening, grit removal, and flow metering, the City utilizes eight (8) rectangular primary sedimentation tanks (PSTs) for primary treatment of wastewater. The eight (8) PSTs are divided into two process trains, PSTs 1-4 and PSTs 5-8 as shown in **Figure 6.1-1**. The PSTs are designed to reduce BOD and TSS loading to the secondary treatment process by settling out readily settleable suspended solids. Fats, oils, grease, and other floatables are also removed in the PSTs by surface skimming and scum collection equipment.

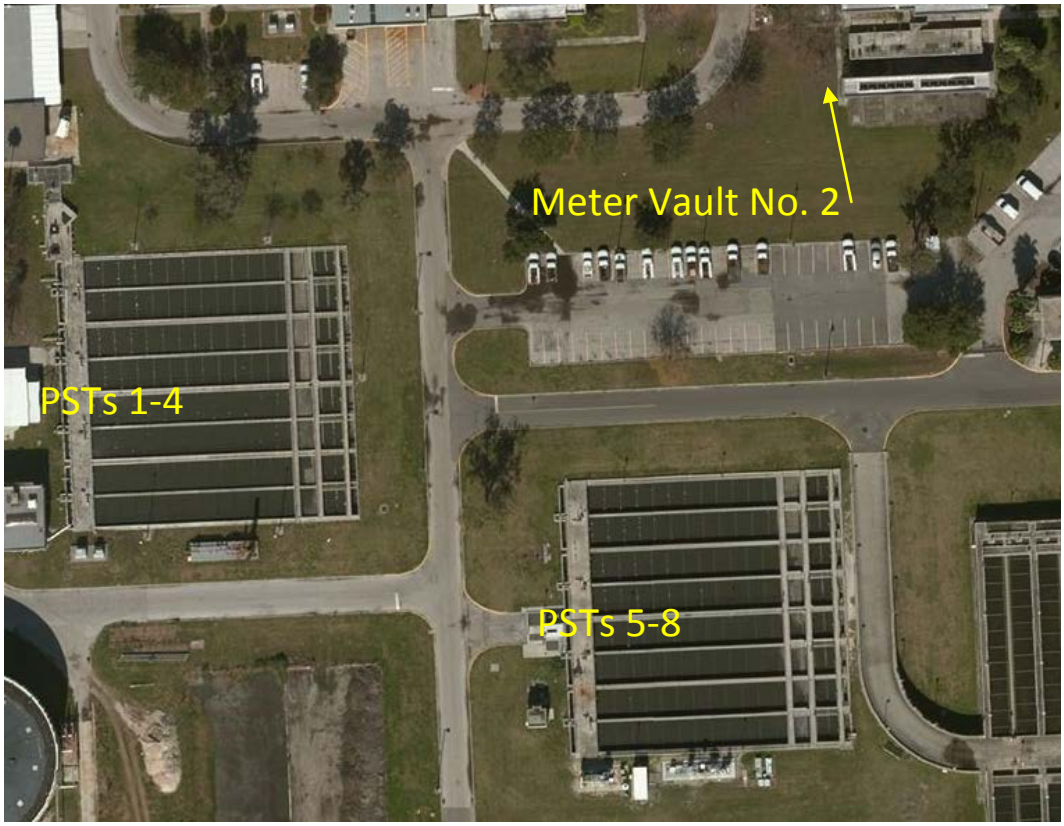

Figure 6.1-1: Existing Primary Sedimentation Tanks

Under current operation, all eight (8) PSTs receive raw wastewater from Junction Chamber No. 2 and Meter Vault No. 2 at approximately equal rates. Recycle streams from downstream processes are recycled to points upstream and downstream of the PSTs. Historically, streams recycled downstream of the PSTs have led to a build-up of solids in the HPO reactors. The City has noted the desire to recycle streams upstream of the PSTs to allow larger solids to settle in the PSTs rather than the HPO reactors. However, it is noted that this could lead to inert solids building up in the Digesters, ultimately transferring the issue from the HPO reactors to the Digesters. Based on process modeling that was conducted, the following recycle streams were assumed to be rerouted, after required modifications are made, upstream of the PSTs, as will be discussed later in the memorandum: filter backwash; south

waste activated sludge (WAS); gravity thickener overflow (GTO). The total flow rate of these recycle streams used in the process model were:

- Current ADF (60 MGD) – 6.16 MGD
- Future ADF (80 MGD) – 8.04 MGD
- PHF (234 MGD) – 10 MGD

As will be discussed later in this memorandum, the recommended PST expansion will provide up to 240 MGD of hydraulic treatment capacity. As is shown above if the full recycle stream is sent upstream of the PSTs (at PHF), the total flow would be 244 MGD. Based on this, it is noted that under PHF conditions, the City may choose to limit the recycle return rates to stay within the 240 MGD hydraulic capacity of the PSTs. It should also be noted that the concept of redirecting recycle flows is presented later in this memorandum.

Under current operation, the raw wastewater flow to each process train (PSTs 1-4 and PSTs 5-8) from Meter Vault No. 2 does not exceed 80 MGD due to hydraulic limitations within PSTs 1-4 and PSTs 5-8 (desire to maintain a minimum 1 ft of freeboard). Raw wastewater flow from the Screen and Grit Buildings to Meter Vault No. 2 that exceeds 160 MGD bypasses the PST process and, instead, is sent to the Main Pumping Station.

The following items related to primary treatment will be evaluated in the remainder of this memorandum:

- Primary Treatment Alternatives – Evaluate means of improving primary treatment removal rates and weir loading rates to reduce loading on the High Purity Oxygen reactors.
- Final Sedimentation Tank Scum – Evaluate feasibility of eliminating the recycle of FST scum to the PSTs and redirect.
- Existing Equipment Replacement – Consideration to replacing existing PST equipment, including chain and flight, sludge pumping, and dewatering pumping equipment.
- PST 1-4 Dewatering – Evaluate providing permanent means to completely drain PSTs 1-4.
- Sludge Blanket Monitors – Investigate adding sludge blanket level monitors to existing PSTs to improve operations.

6.2 Evaluation

The existing PST process was evaluated to determine its overall performance. Performance of primary treatment via sedimentation tanks is evaluated based on three industry standard criteria:

- Removal efficiency (BOD and TSS)
- Surface Overflow Rate (SOR)
- Weir Loading Rate (WLR)

Table 6.2-1 through **Table 6.2-3** below provide summaries of the above criteria based on the existing primary treatment process in relation to industry standards established in Recommended Standards for Wastewater Facilities (2014 Edition). It is noted that each PST has a surface area of approximately 6,308 ft^2 (50,464 ft^2 total) and an effluent weir length of approximately 181 linear feet (1,448 linear feet total).

Table 6.2-1: PST Performance at Existing Flow Conditions: Surface Overflow Rate

Flow Condition	Total Flow (MGD)	No. of PSTs	Surface Area (ft^2)	Existing SOR (gpd/ft^2)	Recommended SOR[1] (gpd/ft^2)
Current AADF	66.2[2]	8	50,464	1,236	**1,000**

[1]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[2]Per process model calibration and BNR Memo

Table 6.2-2: PST Performance at Existing Flow Conditions: Weir Loading Rate

Flow Condition	Total Flow (MGD)	No. of PSTs	Weir Length (ft)	Existing WLR (gpd/ft)	Recommended WLR[1] (gpd/ft)
Current PHF	160[2]	8	1,448	110,500	**30,000**

[1]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[2]Based on max flow that existing PSTs can handle

Table 6.2-3: PST Removal Efficiency: Existing Flow Conditions

Parameter	Plant Influent Reading (mg/L)	PST Effluent Reading (mg/L)	Reported Removal Efficiency[1]	Typical Removal Efficiency[2]
BOD	263	163	38%	**25% - 40%**
TSS	230	57.4	60%[3]	**50% - 70%**

[1]Based on results from Process Modeling Sampling and Calibration Report
[2]Obtained from Design of Municipal Wastewater Treatment Plants MOP 8, Fifth Edition
[3]BNR Process Evaluation memorandum further refined TSS removal from 75% to 60% based on model results

As shown in **Table 6.2-1 and Table 6.2-2**, under current flows, the SOR and WLR are above recommended levels. However, despite operating above recommended levels, **Table 6.2-3** shows that the PSTs are still providing removal rates within typical ranges. The removal rates presented in **Table 6.2-3** were collected as part of the February 2017 sampling program and are only applicable for current AADF. As flow to the existing PSTs increases above the current AADF, the removal efficiency will decrease. **Tables 6.2-4 and 6.2-5** below provide the SOR and WLR, respectively, for future flow conditions.

Table 6.2-4: PST Performance at Future Flow Conditions: Surface Overflow Rate

Flow Condition	Total Flow (MGD)	No. of PSTs	Surface Area (ft^2)	Existing SOR (gpd/ft^2)	Recommended SOR[1] (gpd/ft^2)
Design AADF	88.0[2]	8	50,464	1,743	**1,000**
Design PHF	160[3]	8	50,464	3,170	**1,500 – 2,000**
Class I – Design AADF[4]	44.0	7	44,156	996	**1,000**
Class I – Design PHF[4]	80	7	44,156	1,811	**1,500 – 2,000**

[1]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[2]Per process model calibration and BNR Memo
[3]Based on max flow that existing PSTs can handle
[4]Class I Reliability: 50% of the design flows must be treated with one unit out of service

Table 6.2-5: PST Performance at Future Flow Conditions: Weir Loading Rate

Flow Condition	Total Flow (MGD)	No. of PSTs	Weir Length (ft)	Existing WLR (gpd/ft)	Recommended WLR[1] (gpd/ft)
Design PHF	160[2]	8	1,448	110,500	**30,000**
Class I – Design PHF[3]	80	7	1,267	63,141	

[1]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[2]Based on max flow that existing PSTs can handle
[3]Class I Reliability: 50% of the design flows must be treated with one unit out of service

As shown in **Tables 6.2-5 and 6.2-6**, the SOR and WLR are above recommended ranges at nearly all flow conditions. In order to determine performance at future flows, with respect to BOD and TSS removal, an empirical formula was used to calculate the removal rates at the various flow conditions. The formula was obtained from Wastewater Engineering Treatment and Resource Recovery (Metcalf & Eddy), Fifth Edition. The formula is presented below for reference.

$$R = \frac{t}{a + bt}$$

Where R = expected removal efficiency
t = nominal detention time, t
a,b = empirical constants

Typical values for the empirical constants are as presented below in **Table 6.2-6**, and were also obtained from Wastewater Engineering Treatment and Resource Recovery (Metcalf & Eddy), Fifth Edition.

Table 6.2-6: Removal Rates Empirical Constants

Item	b	a
BOD	0.020	0.018
TSS	0.014	0.0075

Using the formula, removal rates for BOD and TSS were calculated and are presented in **Table 6.2-7**.

Table 6.2-7: PST Removal Efficiency – Future Flow Conditions

Flow Condition	Total Flow (MGD)	No. of PSTs	Calculated BOD Removal	*Typical BOD Removal Efficiency*[1]	Calculated TSS Removal	Typical TSS Removal Efficiency[1]
Design AADF	88.0[2]	8	29.4%	***25% - 40%***	50.4%	**50% - 70%**
Design PHF	160[3]	8	22.0%		40.7%	
AADF – Capacity Reduction[4]	88.0	7	27.8%		48.4%	
PHF – Capacity Reduction[4]	160	7	20.4%		38.3%	

[1]Obtained from Design of Municipal Wastewater Treatment Plants MOP 8, Fifth Edition
[2]Per process model calibration and BNR Memo
[3]Based on max flow that existing PSTs can handle
[4]One unit out of service

As shown in **Table 6.2-7**, the removal efficiency for BOD and TSS decrease as flow to the existing PSTs increase. In order to maintain removal rates similar to those listed in **Table 6.2-3**, the City will either have to: add more treatment capacity; switch to a more efficient treatment process; or a combination of both.

In addition to the criteria discussed above, hydraulic limitations were also noted when evaluating the existing PST process. Based on hydraulic evaluations, the existing PSTs are limited to a total flow of 160 MGD (80 MGD per train). Flows above 160 MGD are bypassed around the PSTs to the Main Pumping Station.

6.2-1 Primary Treatment Alternatives

Alternative primary treatment options were evaluated to supplement/replace the existing PST treatment process. The evaluation had two main goals:

Eliminate Hydraulic Limitations – The evaluation sought to eliminate the 160 MGD hydraulic limitation noted above by adding additional treatment capacity. An additional treatment capacity of 80 MGD was selected to provide the City with the ability to treat the full peak flow of 234 MGD thus avoiding the need to bypass flows above 160 MGD.

Maintain/Improve Treatment Performance – As discussed above, as flow increases, the treatment performance of the PSTs will decrease. It is important that the City maintain, or improve upon, the existing treatment performance as noted in **Table 6.2-3**, as the downstream treatment processes will benefit from a consistent composition in flow from the PSTs.

Additional treatment can be added to, or replace, the two (2) existing treatment trains. However, while influent flow meters MRC-1 and MRC-2 can measure flowrates of up to 100 MGD each, PSTs 1-4 and 5-8 are hydraulically limited to 80 MGD each. Therefore additional process modifications would be required to eliminate hydraulic limitations and accommodate the PHF of 234 MGD in only two treatment trains. Instead, additional treatment can be added as a third primary treatment train. Junction Chamber No. 2 has a total of four (4) outlets, as shown in **Figure 6.2-2**. Two (2) of the outlets, JC-2-SG-1 and JC-2-SG-2, are dedicated to primary

treatment, sending flow to PSTs 1-4 and PSTs 5-8, respectively, and a third outlet is used to bypass flows above 160 MGD to the Main Pumping Station. However, the fourth outlet is currently unused and could be used to direct flow to a third treatment train. If a third treatment train were added, flow would be evenly split between all three trains. Adding a third treatment train would also provide the City the additional benefits of providing process redundancy and operational flexibility. With a third treatment train, one entire train can be taken out of service for upgrades/repair and the City will still have 160 MGD of treatment capacity.

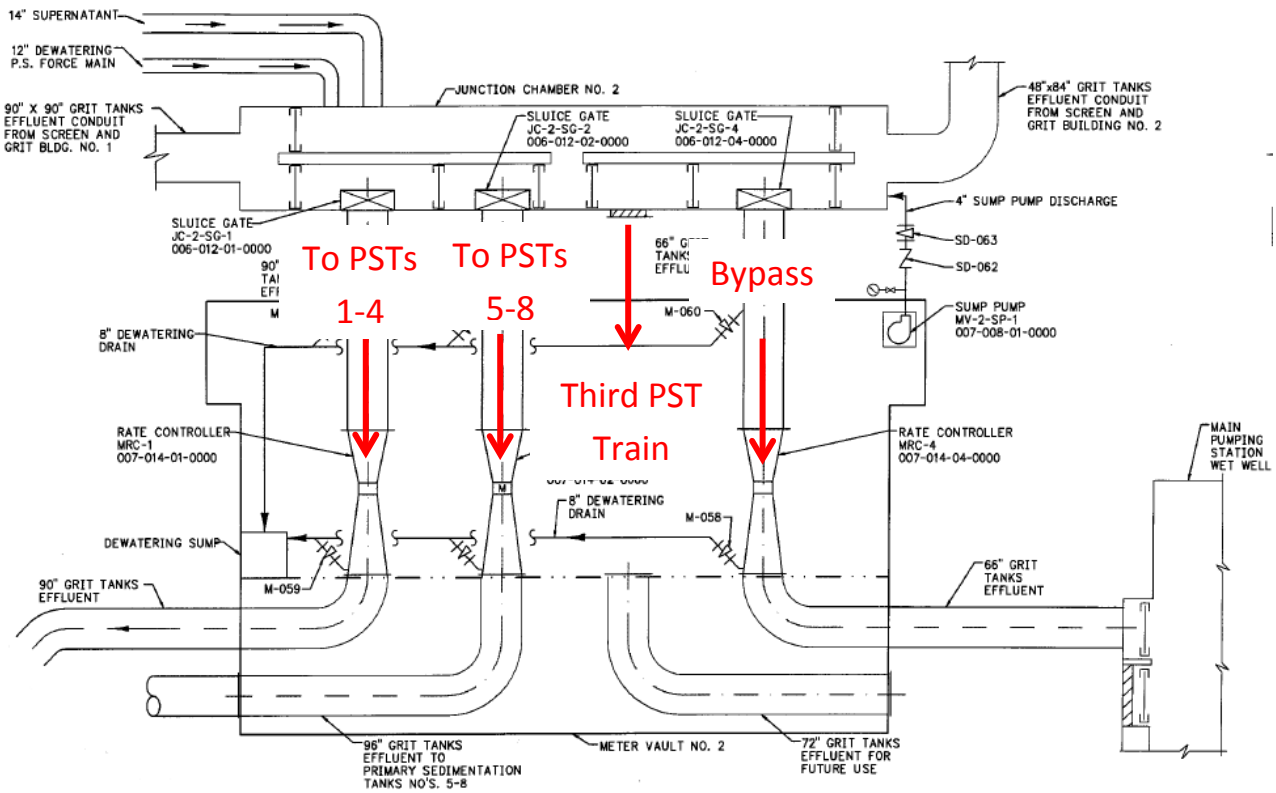

Figure 6.2-2: Junction Chamber No. 2 Diagram

Several alternative options were identified to supplement/replace the existing PST treatment process. Each option is discussed below.

6.2-2 Expansion of PSTs

The primary treatment process could be expanded with the addition of more PSTs. By increasing the number of PSTs, the amount of flow sent to the existing PSTs would be reduced, providing better removal rates and increasing all-around performance. An additional 80 MGD of treatment capacity would be added as a third treatment train, as discussed previously, providing the City with an added level of redundancy and flexibility.

<u>Location of PST Expansion</u>

The additional 80 MGD of PST treatment capacity would be configured to match the dimensions of the existing PSTs and would require a rectangular footprint of 30,000 sq ft. The additional treatment capacity could be constructed in circular sedimentation tanks; however, the required footprint would increase to 110,000 sq ft. The area due south of PSTs 5-8 appears large enough to accommodate an additional four (4) rectangular PSTs, as shown below in **Figure 6.2-3**.

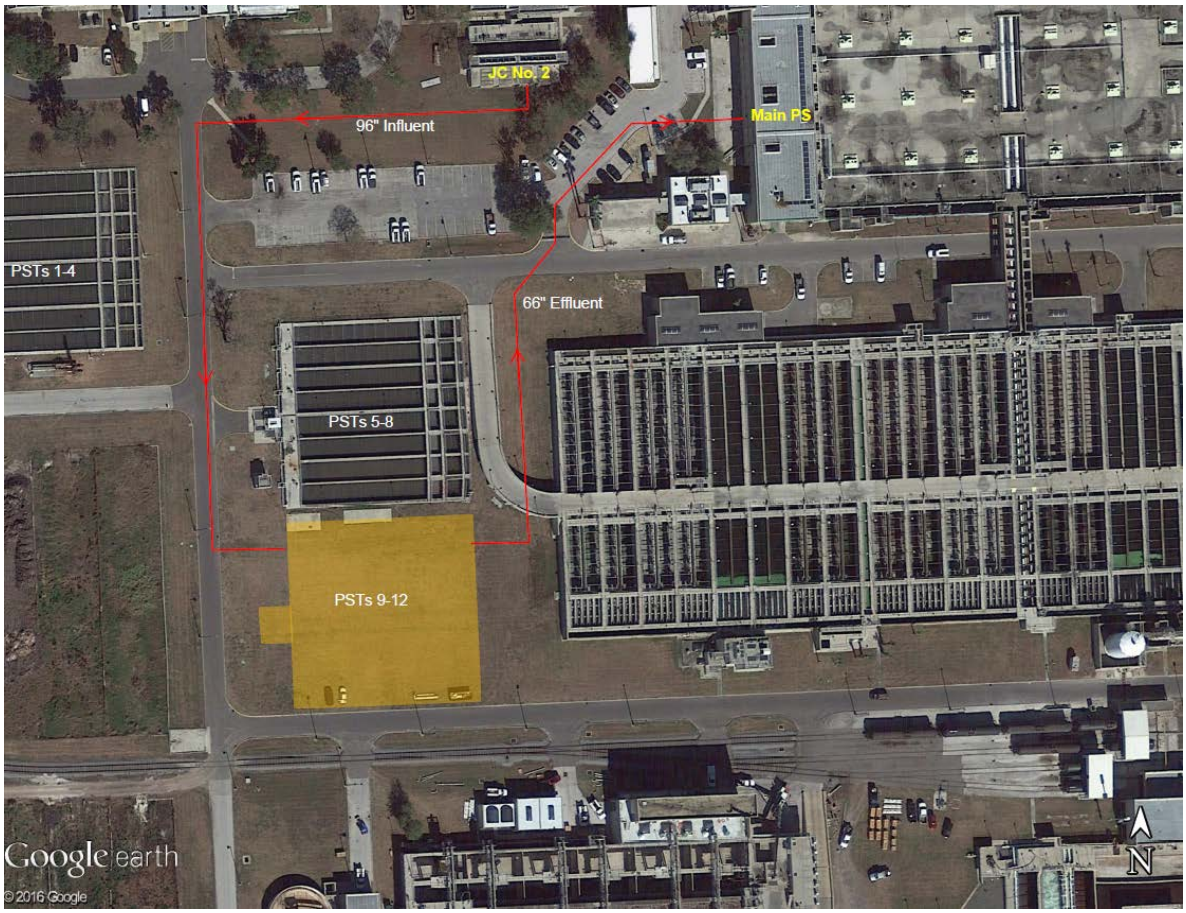

Figure 6.2-3: Additional PST Area of Construction

Treatment Performance

As noted previously, primary sedimentation tank treatment performance is related to the treatment surface area and weir length. PSTs 9-12 would be constructed to match the surface area and weir length of the existing PSTs, thereby matching the existing SOR and WLR when operating at full capacity refer to **Table 6.2-1 and Table 6.2-2**. **Tables 6.2-8** and **Table 6.2-9** summarize the SOR and WLR considering PST expansion.

Table 6.2-8: PST Expansion: Surface Overflow Rate

Flow Condition	Total Flow[1] (MGD)	PST 1-8 Surface Area (ft^2)	Additional PST Surface Area (ft^2)	Total Surface Area (ft^2)	PST 1-12 SOR (gpd/ft^2)	Recommended SOR[2] (gpd/ft^2)
Current AADF	66.2[3]	50,464	25,232	75,969	871	**1,000**
Design AADF	88.0[3]				1,158	
Design PHF	234[4]				3,080	**1,500 – 2,000**

[1]Assumes even flow split between all PSTs at AADF and PHF
[2]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[3]Per process model calibration and BNR Memo
[4] Assumes that during a PHF event the City will reduce or eliminate recycle flow for the duration of the event

Table 6.2-9: PST Expansion: Weir Loading Rate

Flow Condition	Total Flow[1] (MGD)	PST 1-8 Weir Length (ft)	Additional PST Weir Length (ft)	Total Weir Length (ft)	PST 1-12 WLR (gpd/ft^2)	Recommended WLR[2] (gpd/ft)
Design PHF	234[3]	1,448	732	2,180	107,340	**30,000**

[1]Assumes even flow split between all PSTs
[2]Obtained from Recommended Standards for Wastewater Facilities, 2014 Edition
[3] Assumes that during a PHF event the City will reduce or eliminate recycle flow for the duration of the event

As **Tables 6.2-8 and 6.2-9** show, at the current AADF, the addition of a third train would provide the City with the ability to decrease the SOR and WLR by operating all three trains simultaneously, as well as treat the full PHF capacity. As flows increase to the design AADF, the third train will help to keep the SOR and WLR near existing levels. **Table 6.2-10** below presents the removal efficiencies. It is noted that the same empirical formula presented earlier in this memorandum was used to calculate the values in the table below.

Table 6.2-10: PST Expansion: Removal Efficiency

Flow Condition	Total Flow[1] (MGD)	Existing PSTs 1-8		Additional PSTs		Existing + Additional PSTs[2]	
		BOD Removal	TSS Removal	BOD Removal	TSS Removal	BOD Removal	TSS Removal
Design AADF	88.0	34.1%	55.9%	34.1%	55.9%	34.1%	55.9%
Design PHF	234	22.3%	41.1%	22.3%	41.1%	22.3%	41.1%
Class I – Design AADF[3]	44.0	39.5%	61.7%	38.1%	60.3%	39.0%	61.2%
Class I – Design PHF[3]	117	29.3%	50.2%	27.4%	47.9%	28.6%	49.5%

[1] Assumes even flow split between all PSTs at AADF and PHF (2/3 flow to PSTs 1-8 and 1/3 flow to Additional PSTs)
[2]Composite removal rates for existing PSTs operating in parallel with new PSTs
[3]Class I Reliability: 50% of the design flows must be treated with one unit out of service

Table 6.2-10 shows that adding four additional PSTs as a third treatment train improves overall treatment performance when compared to the data presented in **Table 6.2-7**. It is noted that increasing BOD and TSS removal will lower the loading rate on the downstream aeration system and increase the quantity of primary sludge, leading to the production of more biogas.

6.2.3 Primary Filters

Primary filters could be added as a third train for primary treatment, similar to those shown in **Figure 6.2-4**. A peak hour capacity of 80 MGD would be utilized to reduce the amount of flow sent to the existing PSTs, thus providing better removal rates and increasing all-around performance. Adding a third treatment train would provide the City with an added level of redundancy and flexibility.

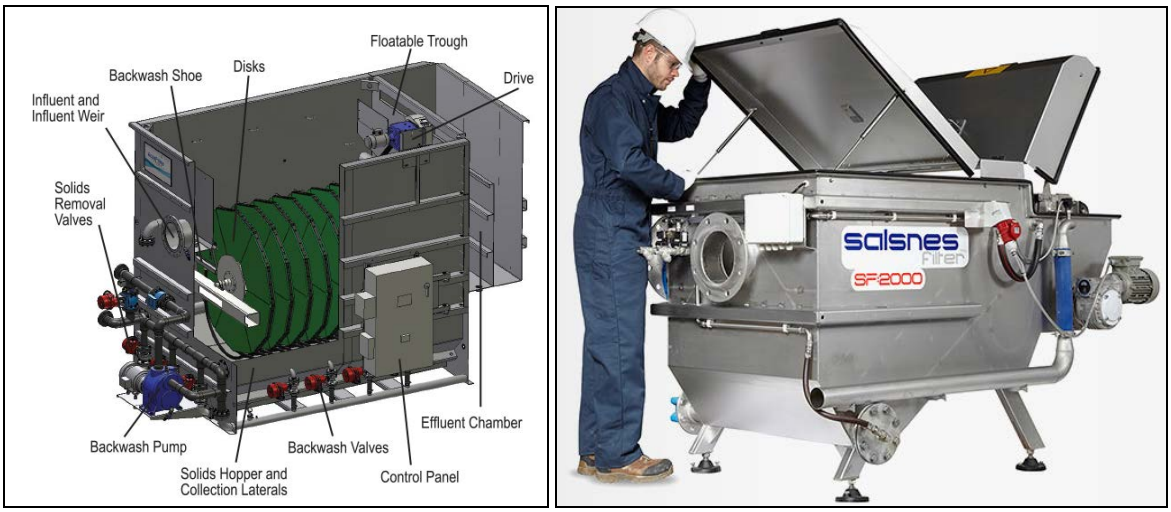

Figure 6.2-4: Primary Filter (Left Picture: AquaPrime; Right Picture: Salsnes)

Multiple primary filter configurations are available from multiple manufacturers. For this analysis, primary filters by Salsnes and Aqua Aerobic Systems were initially evaluated. However, upon evaluation, it was determined that the Salsnes filters maximum throughput capacity is 3 MGD, and therefore would require 27 units to meet the peak requirements of this alternative. The associated maintenance alone required for the upkeep of this many units made the Salsnes filters impractical. For this reason, the evaluation focused on the use of Aqua Aerobic Systems AquaPrime™, which has a maximum capacity of upwards of 15 MGD. The filters would require construction of a concrete channel for housing and an overhead canopy for protection. **Figure 6.2-5** shows a similar installation for reference.

It is noted that primary filters operate at a different hydraulic grade than the PSTs, due to the required operating head and headloss across the filters. As such, the primary filters will require a dedicated pump station in order to meet the necessary hydraulic grade line such that the effluent weir of the primary filters matches that of the existing PSTs.

Figure 6.2-5: Similar Aqua Aerobic System Installation

6.2.6 Location

Primary filters have the benefit of requiring a smaller footprint when compared with PSTs. The primary filter addition would require an overall footprint of approximately 9,000 square feet. **Figure 6.2-6** identifies one potential location for a filter addition.

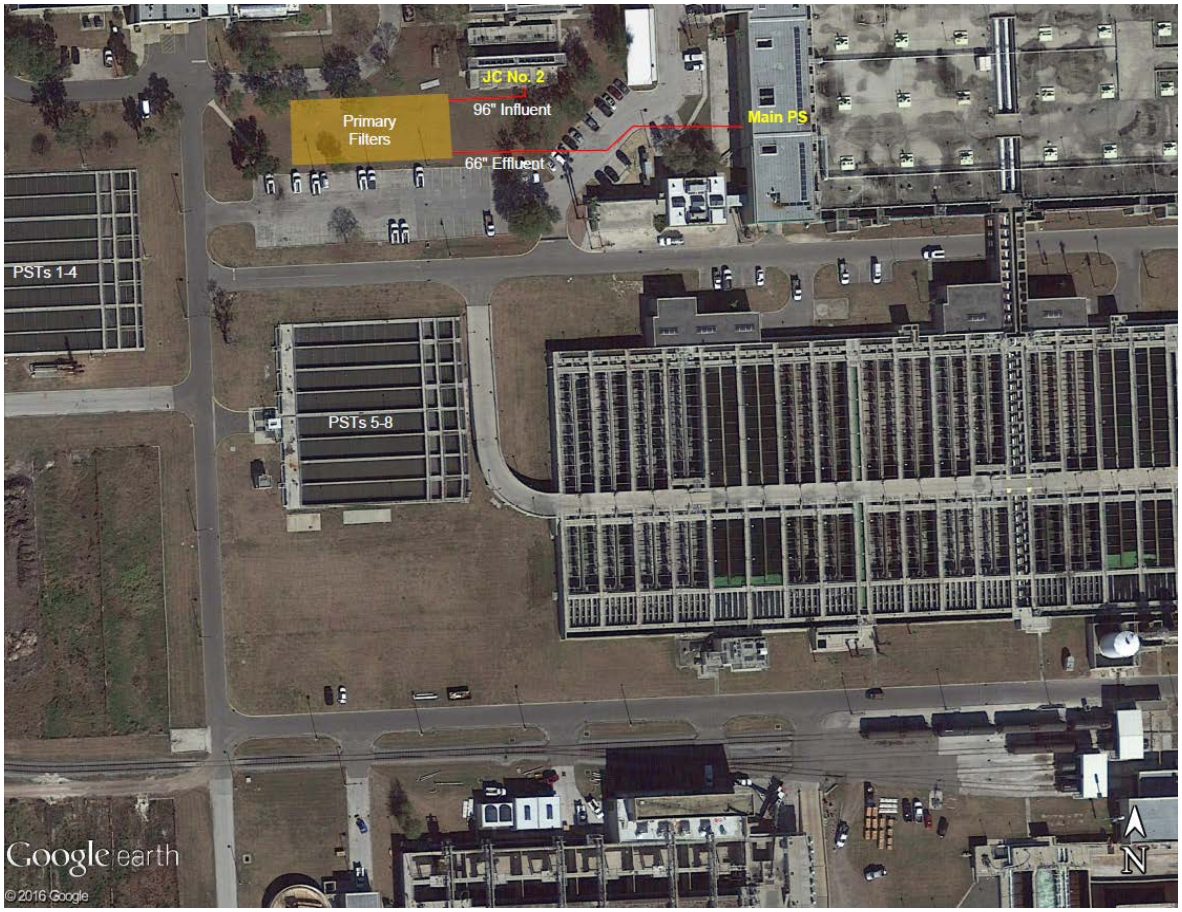

Figure 6.2-6: Primary Filter Area of Construction

6.2.7 Treatment Performance

Primary filters provide treatment by rejection; that is physical exclusion of solids larger than the nominal pore size of the filter media. These filters typically provide a means of self-cleaning to ensure proper operation and minimize downtime. Solids rejected by the filter media, along with backwash water will be sent to the Primary Sludge Pump Station. The AqauPrime™ filters make use of a 5 micron opening and are modular in design to allow filter "disks" to be removed and replaced without having to take the unit apart. Providing treatment via filtration greatly increases the level of treatment when compared with PSTs. Removal rates for primary filters are typically around 80% for TSS. BOD removal depends on the amount of BOD in the influent flow, however typically, for every mg/L reduction in TSS, BOD is reduced approximately 0.5-0.6 mg/L. Similar to the option to expand PSTs, the addition of primary filters would be added as a third train, treating flows up to 80 MGD. Providing a third treatment train that will achieve higher removal rates will ultimately increase the overall efficiency of the primary treatment process.

Primary filter performance is based largely on TSS and BOD removal. **Table 6.2-11** below provides a summary of the composite removal efficiencies for primary treatment assuming the existing PSTs are operated in parallel with primary filters. It is noted that the same empirical formula presented earlier in this memorandum was used to calculate the values in the table below.

Table 6.2-11: Primary Filter Addition: Removal Efficiency

Flow Condition	Total Flow[1] (MGD)	Existing PSTs 1-8		Primary Filters		Existing + Additional PSTs[2]	
		BOD Removal	TSS Removal	BOD Removal	TSS Removal	BOD Removal	TSS Removal
Design AADF	88.0	34.1%	55.9%	45%	80%	37.7%	63.9%
Design PHF	234	22.3%	41.1%			29.9%	54.1%
Class I – Design AADF[3]	44.0	39.5%	61.7%			41.3%	67.8%
Class I – Design PHF[3]	117	29.3%	50.2%			34.5%	60.2%

[1]Assumes even flow split between all PSTs at AADF and PHF (2/3 flow to PSTs 1-8 and 1/3 flow to Primary Filters)
[2]Composite removal rates for existing PSTs operating in parallel with Primary Filters
[3]Class I Reliability: 50% of the design flows must be treated with one unit out of service

The use of primary filters as a third treatment train improves the overall removal efficiencies of the primary treatment process.

6.2.8 Captivator

The evaluation also considered the Captivator system by Evoqua Water Technologies for primary treatment. The Captivator process utilizes a combination of contact aeration and dissolved air flotation to extract BOD prior to the activated sludge process. Additionally, WAS

from the activated sludge process that is sent back to the Captivator process, absorbs soluble BOD, resulting in an overall higher amount of BOD removed. The Captivator process can treat the design PHF of 234 MGD, and therefore would replace the existing two PST trains, utilizing the existing tankage for process conversion. The Captivator process would place eight (8) DAF tanks in four (4) existing PSTs (two per PST) and utilize two (2) of the remaining four PSTs for contact aeration. **Figure 6.2-7** below provides a schematic layout of the proposed Captivator process.

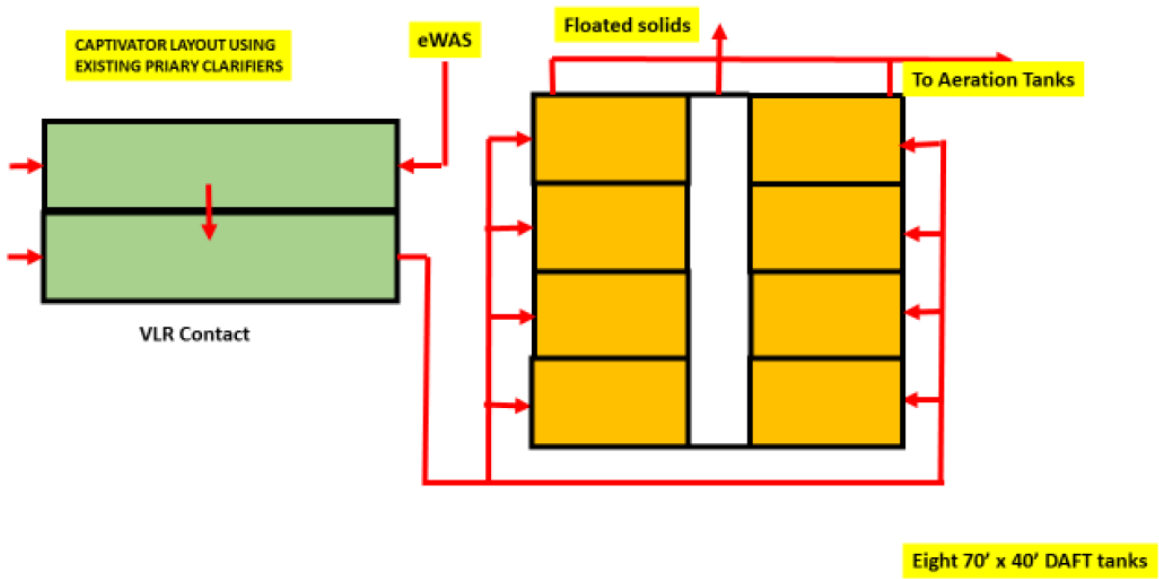

Figure 6.2-7: Captivator Process

6.2.9 Location

The Captivator process has the advantage of not requiring any additional footprint as it would make use of the existing PSTs. As noted previously, six of the eight PSTs would be used for the conversion. Existing PST influent/effluent piping alone is not large enough to handle the full PHF and therefore. An additional 120" influent pipe, (2) 120" transfer pipes (between Contact Aeration and DAF Tanks), 120" Effluent, and 36" WAS piping would be required to convey the full PHF. **Figure 6.2-8** below provides a potential arrangement for the Captivator Process including additional piping.

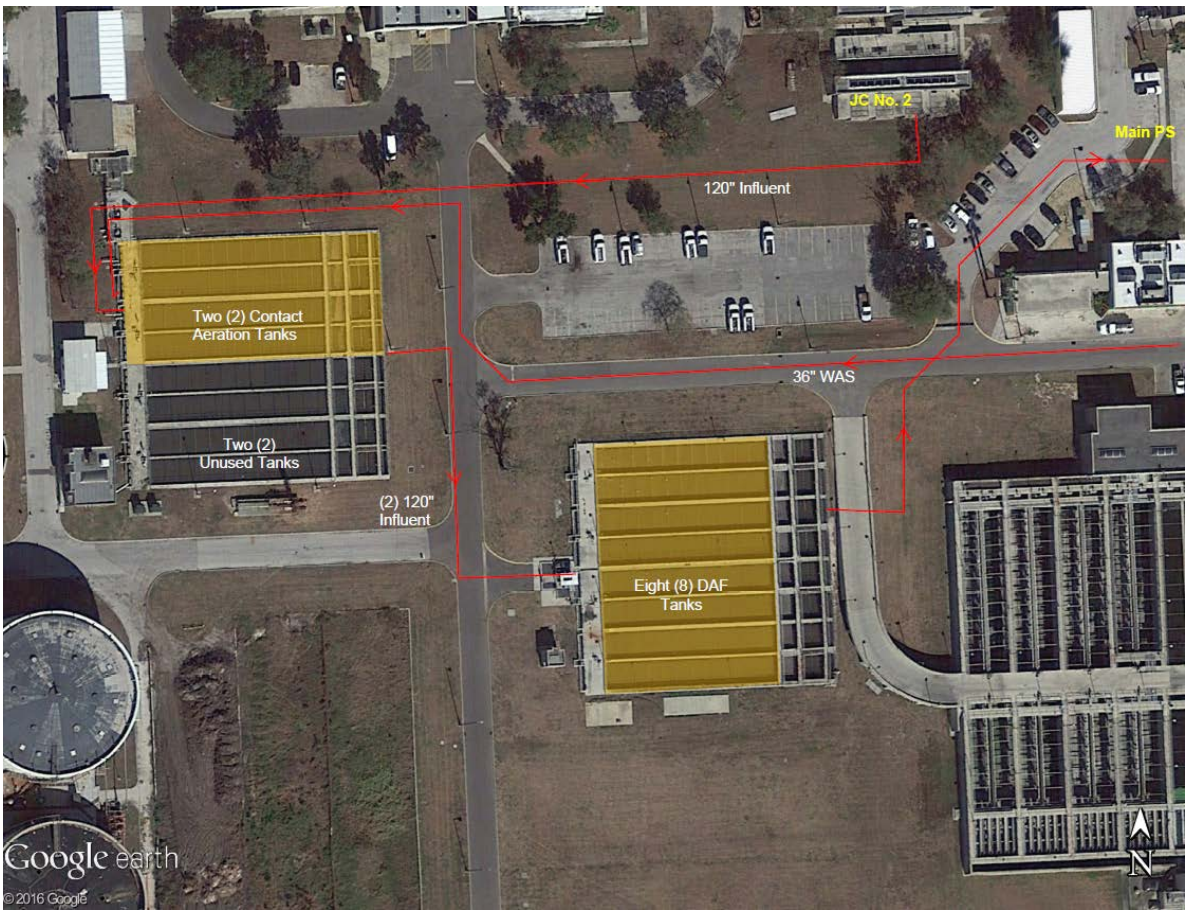

Figure 6.2-8: Captivator Area of Construction

6.2.10 Treatment Performance

Removal rates for the Captivator process are typically between 65% - 75% for TSS and 50 -60% for BOD. As opposed to the other options, these removal rates would apply to the entire flow with the conversion of primary treatment to the Captivator process. **Table 6.2-12** below provides a summary of the potential removal efficiencies, as provided by Evoqua, for the primary treatment process based on conversion to the Captivator process.

Table 6.2-12: Captivator: Removal Efficiency

Flow Condition	Total Flow (MGD)	Expected BOD Removal	Expected TSS Removal
Design AADF	88.0	51%	68%
Design PHF	234	35%	45%

It is important to note that the treatment efficiency of the Captivator process is, in part, a factor of the hydraulic residence time (HRT). As such, the reduced HRT during PHF results in a drop in removal efficiency, as shown in **Table 6.2-12**. While the drop is significant when compared with AADF conditions, it is still near removal rates currently being achieved in primary treatment. Additionally, meeting Class I redundancy requirements further reduces the HRT for each flow condition. Removal efficiencies were not provided in **Table 6.2-12** for Class I redundancy, as they were not provided by Evoqua. However, as noted above, given the reduced HRT, the removal rates will be slightly less than those listed in **Table 6.2-12** for each respective flow condition.

The use of the Captivator process would result in higher removal efficiencies of the primary treatment process than those currently achieved.

6.3 Alternatives Evaluation

Each alternative was evaluated based on three main criteria:

- Cost
- Operation & Maintenance
- Other Success Factors

Each criterion is discussed below with respect to each alternative.

6.3.1 Cost Criteria

A summary of the capital cost estimates for each alternative is presented below. These cost estimates were made with the best available data specific to the HFC AWTP.

Table 6.3-1: Conceptual Cost Estimate: Expansion of PSTs

Vendor Costs and Direct Costs	Estimate
Mobilization	$380,000
Structural	
Primary Sedimentation Tank	$3,600,000
Sludge Pump Station	$110,000
Drain Pump Station	$110,000
Equipment	
Primary Sedimentation Tank	$750,000
Sludge Pump Station	$104,000
Drain Pump Station	$270,000
Yard Piping	
96" Influent[1]	$2,000,000
66" Effluent	$580,000
Instrumentation & Control	$120,000
Electrical	$170,000
Installation	$230,000
Sum of Bare Construction Costs	**$8,424,000**
30% Contingencies	$2,530,000
Bare Construction Cost	**$10,954,000**
20% OH&P & GCs	$2,200,000
Total Construction Cost	**$13,154,000**
20% Management and Engineering[2]	$2,640,000
Total Capital Cost[3]	**$15,794,000**

[1]Includes cost for piles

[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[3]Includes COT management, legal and administrative costs.

Table 6.3-2: Conceptual Cost Estimate: Primary Filters

Vendor Costs and Direct Costs	Estimate
Mobilization	$480,000
Structural	
Primary Filter Channels	$2,670,000
Primary Filter Pump Station	$435,000
Equipment	
Primary Filters	$5,310,000
Primary Filter Pump Station	$820,000
Yard Piping	
96" Influent[1]	$210,000
66" Effluent	$270,000
Instrumentation & Control	$540,000
Electrical	$800,000
Installation	$1,070,000
Sum of Bare Construction Costs	**$12,605,000**
30% Contingencies	$3,790,000
Bare Construction Cost	**$16,395,000**
20% OH&P & GCs	$3,280,000
Total Construction Cost	**$19,675,000**
20% Management and Engineering[2]	$3,940,000
Total Capital Cost[3]	**$23,615,000**

[1]Includes cost for piles
[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[3]Includes COT management, legal and administrative costs.

Table 6.3-3: Conceptual Cost Estimate: Captivator

Vendor Costs and Direct Costs	Estimate
Mobilization	$480,000
Demolition	$90,000
Equipment	
Captivator Processes	$5,325,000
Yard Piping	
120" Influent[1]	$1,630,000
(2) 120" Transfer[1]	$1,390,000
120" Effluent[1]	1,110,000
36" WAS	630,000
Instrumentation & Control	$540,000
Electrical	$800,000
Installation	$1,070,000
Sum of Bare Construction Costs	**$13,065,000**
30% Contingencies	$3,920,000
Bare Construction Cost	**$16,985,000**
20% OH&P & GCs	$3,400,000
Total Construction Cost	**$20,385,000**
20% Management and Engineering[2]	$4,080,000
Total Capital Cost[3]	**$24,465,000**

[1]Includes cost for piles
[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[3]Includes COT management, legal and administrative costs.

6.3.2 Operation & Maintenance Criteria

The alternatives evaluation, with respect to O&M, considered staff familiarity with the given process and intensity/frequency of maintenance. The following discusses these criteria respective to each alternative.

- Expansion of PSTs – Expanding primary treatment with additional PSTs provides the greatest level of operator familiarity, and therefore eliminates the need to learn a new system. Additionally, PSTs are low maintenance and require minimal operator input/interaction.
- Primary Filters – Expansion with primary filters would introduce a new type of system to primary treatment, requiring staff to learn new operation and maintenance procedures. However, primary filters are automated units running off of SCADA and typically require little operator input. For example, backwash cycles are automated and don't require operator input. System maintenance is carried out by plant personnel, however training and input would be provided by the manufacturer prior to startup.
- Captivator – The Captivator process represents an entirely new primary treatment process that staff would have to become familiar with from both an operations and maintenance stand point. This would require the greatest amount of staff training as the process involves

multiple individual components (i.e VLR contact aeration, DAF, etc.). Implementing an entirely new process for primary treatment would be a break from the status quo. Additionally, given the number of components involved, the process overall would be the most maintenance intense.

A comparison of the estimated O&M costs and the 20-year lifecycle cost for each alternative is given in **Table 6.3-4** and **Table 6.3-5**, respectively.

Table 6.3-4: Estimated O&M Costs for Alternatives

O & M	PST Expansion	Primary Filters	Captivator Process
Electricity 20-Year Cost[1]	$ 503,000	$ 1,152,000	$ 5,606,000
Maintenance 20- Year Cost[2]	$ 1,128,000	$ 589,000	$ 1,269,000
Total O&M 20-Year Cost	$ 1,631,000	$ 1,741,000	$ 6,875,000
Total O&M 20-Year Cost Present Value[3]	**$ 910,000**	**$ 970,000**	**$ 3,810,000**

[1] Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2] Operations/Maintenance labor cost of $40/hr and annual inflation rate of 3%. Includes future parts replacement costs.
[3] Used an annual discount rate of 3%

Table 6.3-5: Alternatives Cost Comparison

Cost Description	PST Expansion	Primary Filters	Captivator Process
Total Capital Cost[1]	$ 15,794,000	$ 23,615,000	$ 24,465,000
Total O&M 20-Year Cost Present Value	$ 910,000	$ 970,000	$ 3,810,000
Total 20-year Cost Present Value	**$ 16,704,000**	**$ 24,585,000**	**$ 28,275,000**

[1] Assumes no residual after 20 years and capital outlay occurs in the year it is constructed

6.3.3 Other Success Factors

In addition to the above criteria listed, the evaluation also took into consideration: treatment performance; proven implementation; benefits to biosolids; and process reliability. The following discusses these criteria respective to each alternative.

- Expansion of PSTs – PSTs have a long history of providing reliable primary treatment for the City. As noted in the Phase I report, and previously in this memorandum, the existing PSTs provide nominal primary treatment given their configuration and the design flows of the plant. Increasing the PST footprint will provide improved treatment, but not to the same level as the other alternatives.

  Additionally, the PST process provides the least benefit to downstream processes. Lower removal rates can strain downstream processes and increase operating costs. Additionally, the lower BOD removal rates, coupled with the introduction of volatile suspended solids from WAS leads to a lower production of biogas in the digestion process and increases the amount of dewatered solids that need to be hauled away.

- Primary Filters – Primary filtration is a relatively new means of primary treatment and has limited installations throughout the United States. As noted previously, primary filters provide significantly higher removal than when compared with PSTs. However, as only 1/3rd

of the flow will be treated by the filters, the increase in performance is only slightly better than that of PST expansion.

Primary filters will have a greater benefit to downstream processes than simply expanding the PSTs. Solids removed in the filters can be introduced into the digestion process sooner, helping to produce more biogas and reduce dewatered solids. However, due to the increased removal rates of this process, it is possible that more carbon is needed for downstream processes. GPS-X modeling can be used to confirm if carbon diversion is needed, and if so, the process can be configured to blend some solids with the primary effluent stream. While this would ensure a sufficient amount of carbon is present in the secondary process, it also represents another metric that would require maintenance and operator attention.

- Captivator – The Captivator process employs several treatment processes (aeration, DAF) common to wastewater treatment. However, the arrangement and overall operation of the Captivator system is unique and has minimal installations in the United States. The process would improve the overall primary treatment performance benefiting downstream processes and would also increase biogas production. However, due to the increased removal rates of this process, it is probable that more carbon is needed for downstream processes. GPS-X modeling can be used to confirm if carbon diversion is needed, and if so, the process can be configured to blend some solids with the primary effluent stream. While this would ensure a sufficient amount of carbon is present in the secondary process, it also represents another metric that would require maintenance and operator attention.

6.4 Recommendation

It is imperative that each goal, noted above, is considered when selecting between viable alternatives. Some of the criteria can be readily quantified, while others are more qualitative and subjective in nature. One method for evaluating quantitative and qualitative criteria is to use a comparison matrix with weighted decision factors. **Table 6.4-1** presents the matrix with weighting of decision factors and scoring for each primary treatment alternative presented above. The scoring system is based on a scale of 1 to 10 with 10 being the most preferred option.

6.4.1 Capital Cost

Planning level capital costs were developed for each alternative. The costs for each alternative were translated into scores, assuming the lowest Capital Cost set at 10. It is also noted that the score presented in **Table 6.4-1** represents a weighting, hence the lowest Capital Cost alternative will only receive a weighted score of 2.5 (10 pts x 25% weighting = 2.5).

6.4.2 Annual Cost

Operational costs were developed based on cost to operate and maintain the alternatives. Operational requirements (such as electricity and routine maintenance) were provided by manufacturers representing each alternative evaluated. The costs for each alternative were

translated into scores, assuming the lowest Annual Cost set at 10. It is also noted that the score presented in **Table 6.4-1** represents a weighting, hence the lowest Annual Cost alternative will only receive a weighted score of 1.5 (10 pts x 15% weighting = 1.5).

6.4.3 Maintenance Intensity

The maintenance intensity considers inconvenience, duration, or frequency of planned maintenance activities. Additionally, maintenance considers how familiar operations staff is with the process. The more complex the alternative and the less familiar staff are with it will ultimately lead to maintenance becoming more cumbersome.

6.4.4 Treatment Performance

Treatment performance relates directly to the removal efficiency of the alternative, with respect to BOD and TSS removal.

6.4.5 Proven Implementation

The number/extents of similar installs was also considered. While some alternatives boast higher removal rates, their proven implementations may come from less and more recent installations. Given the sizeable investment the City will make to implement any one of the alternatives, it is important that the City can be confident that the chosen alternative will provide the anticipated removal rates.

6.4.6 Benefits to Biosolids

As noted previously in this memorandum, the primary treatment method must give consideration to the downstream processes. The alternatives were ranked based on their ability to increase the quantity/quality of biosolids sent to the digestion process.

6.4.7 Process Reliability

The alternatives were ranked based on their ability to reliably provide treatment. The more complex the system and the more individual pieces of equipment, the greater the chance that a relatively minor equipment malfunction can lead to a process upset.

Table 6.4-1: Primary Treatment Alternatives Evaluation Matrix

	Alternative Primary Treatment								
	Expansion of PSTs			Primary Filters			Captivator		
Primary Criteria	Weight	Score	Weighted Score	Weight	Score	Weighted Score	Weight	Score	Weighted Score
Cost									
Capital Cost	$ 15,794,000			$ 23,615,000			$ 24,465,000		
	25%	10.00	2.50	25%	6.69	1.67	25%	6.46	1.61
20-Year Present Value O&M Cost	$ 910,000			$ 970,000			$ 3,810,000		
	15%	10.00	1.50	15%	9.38	1.41	15%	2.39	0.36
Operation, Maintenance & Safety									
Maintenance Intensity	15%	10	1.50	15%	8	1.20	15%	4	0.60
Other Success Factors									
Treatment Performance	10%	6	0.60	10%	8	0.80	10%	10	1.00
Proven Implementation	15%	10	1.50	15%	4	0.60	15%	2	0.30
Benefits to Biosolids	10%	4	0.40	10%	7	0.70	10%	10	1.00
Process Reliability	10%	10	1.00	10%	8	0.80	10%	8	0.80
Total	**100%**	**60.0**	**9.00**	**100%**	**51.1**	**7.18**	**100%**	**42.8**	**5.67**

Based on the analysis presented above, it is recommended that the City expand the existing primary sedimentation process. As shown above, expanding primary treatment with PSTs scored more than 1.5 points higher than the next closest alternative. Additionally, the 20 year net present worth cost is $7M less than the other alternatives evaluated.

While the above analysis and recommendation is based on future buildout to a PHF of 240 MGD, the City should consider performing stress testing of the existing PSTs to evaluate the TSS removal efficiencies at higher SORs to determine the ability to phase the construction and the associated timing required for the new PSTs.

6.5 Additional Primary Treatment Considerations

6.5.1 Final Sedimentation Tank Scum

Under current operation, only a portion of FST scum is recycled to the primary treatment process. Scum from FSTs 13-20 is conveyed directly to PSTs 5 and 6. Ideally, the scum sent to the primary treatment process is removed by the skimmers and is conveyed to the Mixed Sludge Pumping Station where it is pumped to the digestion process, thereby removing it from the process stream altogether. Any scum not captured by the PST skimmers, is returned to the treatment process. Additionally, scum within the PST process takes up volume within the tank,

reducing the overall treatment capacity of the PSTs. Scum from FSTs 1-6 is collected and eventually drained to the Main Drain Pump Station, where it is reintroduced into the process stream. Scum from FSTs 7-12 is not collected as the scum tipping weirs have been removed.

While it is preferred to remove the FST scum from the biological process stream and convey the scum to the digestion process, based on discussions with the City, the FST scum is manageable. As such, the decision was made to continue the FST scum management process in its current state and not pursue modifications to remove the scum at this time.

6.5.2 Existing Equipment Replacement

The equipment utilized in the existing primary treatment process is aged and is near/has exceeded its useful life. It is recommended that the City replace the equipment. The replacement recommendations, along with capital costs are provided below.

- Primary Sedimentation Tank Nos. 1-4 – Replacement of: chain and flights; gearboxes and motors for influent sluice gate actuators (4); backflush sluice gates and actuators (8); sludge blanket monitor; effluent weirs and troughs; scum and gravity thickener overflow pipe; rehab of scum pit. Additionally, PSTs 1-4 require miscellaneous concrete repairs to the tanks, including the scum pit, concrete coating, and lining of the deck on the effluent side of the tanks. The 14" and 8" DAF scum and overflow pipes also will need to be removed from the ground up. Total capital costs for replacement/upgrades are presented below in **Table 6.5-1**.

Table 6.5-1: – Conceptual Cost Estimate: PST 1-4 Upgrades

Vendor Costs and Direct Costs	Estimate
Mobilization	$102,000
Demolition	$100,000
Chain & Flight System	$734,000
Valves and Gates	$348,000
Piping Modifications	$30,000
Sludge Blanket Monitors	$80,000
Miscellaneous Concrete	$270,000
Instrumentation & Control	$46,000
Electrical	$92,000
Installation	$461,000
Sum of Bare Construction Costs	**$2,263,000**
30% Contingencies	$680,000
Bare Construction Cost	**$2,943,000**
20% OH&P & GCs	$589,000
Total Construction Cost	**$3,532,000**
20% Management and Engineering[1]	$710,000
Total Capital Cost[2]	**$4,242,000**

[1]Includes COT management, legal and administrative costs.

[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

- Primary Sedimentation Tank Nos. 5-8 – Replacement of: chain and flights; gearboxes and motors for influent sluice gate actuators (4); backflush sluice gates and actuators (8); sludge blanket monitor to improve operations; effluent weirs and troughs; scum valves; dewatering line from DARs (16”) and NIT waste line (6”); rehab of scum pit. Additionally, PSTs 5-8 require miscellaneous concrete repairs to the tanks and concrete coating. The scum discharge piping from FSTs 13-20 also requires painting. Total capital costs for replacement/upgrades are presented below in **Table 6.5-2**.

Table 6.5-2: Conceptual Cost Estimate: PST 5-8 Upgrades

Vendor Costs and Direct Costs	Estimate
Mobilization	$102,000
Demolition	$100,000
Chain & Flight System	$734,000
Valves and Gates	$348,000
Piping Modifications	$30,000
Sludge Blanket Monitors	$80,000
Miscellaneous Concrete	$270,000
Instrumentation & Control	$46,000
Electrical	$92,000
Installation	$461,000
Sum of Bare Construction Costs	**$2,263,000**
30% Contingencies	$680,000
Bare Construction Cost	**$2,943,000**
20% OH&P & GCs	$589,000
Total Construction Cost	**$3,532,000**
20% Management and Engineering[1]	$710,000
Total Capital Cost[2]	**$4,242,000**

[1]Includes COT management, legal and administrative costs.

[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

- Dewatering Pump Station (PSTs 5-8) – Rehabilitation was completed in 2013 and included replacement of: pumps, valves, piping, concrete restoration.
- Primary Sludge Pump Station No. 1 – Replacement of: 200 gpm dry-pit pumps (2); valves; miscellaneous piping; weir gates; sluice gates; exhaust fan in lower level. Additionally, instrumentation upgrades are needed. Total capital costs for replacement/upgrades are presented below in **Table 6.5-3**.

Table 6.5-3: Conceptual Cost Estimate: Primary Sludge Pump Station No. 1 Upgrades

Vendor Costs and Direct Costs	Estimate
Mobilization	$6,000
Demolition	$25,000
200 gpm Dry-Pit Pumps[1]	$40,000
Valves and Appurtenances	$64,000
Miscellaneous Concrete	$50,000
Instrumentation & Control	$10,000
Electrical	$10,000
Installation	$32,000
Sum of Bare Construction Costs	**$237,000**
30% Contingencies	$80,000
Bare Construction Cost	**$317,000**
20% OH&P & GCs	$70,000
Total Construction Cost	**$387,000**
20% Management and Engineering[2]	$80,000
Total Capital Cost[3]	**$467,000**

[1]RSP-2 assumed to be 200 gpm to match RSP-1

[2]Includes COT management, legal and administrative costs.

[3]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

- Primary Sludge Pump Station No. 2 – Replacement of: 200 gpm submersible pumps (2); weir gates; sluice gates; existing MCC-48 & MCC-49. Additionally, instrumentation upgrades are needed as well as miscellaneous concrete repairs. Total capital costs for replacement/upgrades are presented below in **Table 6.5-4**.

Table 6.5-4: Conceptual Cost Estimate: Primary Sludge Pump Station No. 2 Upgrades

Vendor Costs and Direct Costs	Estimate
Mobilization	$6,000
Demolition	$25,000
200 gpm Submersible Pumps	$40,000
MCCs 48 & 49	$120,000
Gates	$15,000
Exhaust Fan	$5,000
Miscellaneous Concrete	$10,000
Instrumentation & Control	$17,000
Electrical	$25,000
Installation	$54,000
Sum of Bare Construction Costs	**$317,000**
30% Contingencies	$100,000
Bare Construction Cost	**$417,000**
20% OH&P & GCs	$90,000
Total Construction Cost	**$507,000**
20% Management and Engineering[1]	$110,000
Total Capital Cost[2]	**$617,000**

[1]Includes COT management, legal and administrative costs.

[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

6.6 PSTs 1-4 Dewatering

Under current operation, PSTs 1-4 are drained to the Raw Sewage Pumping Station via gravity. However, hydraulic limitations only allow approximately 85% of the volume to be drained via gravity. The remaining 15% has to be drained by manually dropping a submersible pump into each tank and pumping to the Raw Sewage Pumping Station.

The addition of a Dewatering Pump Station, similar to that associated with PSTs 5-8, would provide a permanent means of dewatering PSTs 1-4. The pump station layout would be similar to that of PSTs 5-8, including a wet well with two (2) 2,000 gpm submersible pumps and a valve box. Overall dimensions of the wet well and valve box would be approximately 10 ft x 10 ft by 15 ft deep and 8 ft x 10 ft by 6 ft deep, respectively. It is noted that piping modifications would be required and would consist of cutting in a tee to the existing drain line(s), and extending a new pipe from the branch of the tee to the new Dewatering Pump Station. Valves would be added to the existing and proposed lines and would be used to switch between gravity and pump dewatering. Based on a review of available data, the actual configuration of the existing drain line(s) is unknown and would need to be verified during design of the Dewatering Pump Station. Capital costs were developed and are presented in **Table 6.6-1** below.

Table 6.6-1: Conceptual Cost Estimate: Dewatering Pump Station (PSTs 1-4) Addition

Vendor Costs and Direct Costs	Estimate
Mobilization	$19,000
Dewatering	$50,000
2,000 gpm Submersible Pumps	$70,000
Valves and Appurtenances	$71,000
500 LF 12" DIP Discharge Force Main	$75,000
Structural Concrete	$110,000
Instrumentation & Control	$10,000
Electrical	$20,000
Installation	$43,000
Sum of Bare Construction Costs	**$468,000**
30% Contingencies	$150,000
Bare Construction Cost	**$618,000**
20% OH&P & GCs	$130,000
Total Construction Cost	**$748,000**
20% Management and Engineering[1]	$150,000
Total Capital Cost[2]	**$898,000**

[1]Includes COT management, legal and administrative costs.

[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

6.7 Sludge Blanket Monitors

Under current operation, the sludge blanket level is monitored manually by City staff. In an effort to automate the sludge monitoring system, the City could elect to install online sludge blanket monitors. Sludge blanket monitors continuously monitor the sludge blanket level, helping to improve treatment operations through optimization of sludge extraction and early warning of potential process upsets. Capital costs for the addition of eight (8) monitors are provided in **Table 6.7-1**. It is noted that these costs are also included in **Tables 6.5-1 and 6.5-2** above, but are broken out here to provide total capital cost of just the monitors. Multiple manufacturers make sludge blanket monitors including, Hach, Endress+Hauser, and Cerlic.

Table 6.7-1: Conceptual Cost Estimate: Sludge Blanket Monitors

Vendor Costs and Direct Costs	Estimate
Sludge Blanket Monitors (8 Total)	$160,000
Instrumentation & Control	$20,000
Electrical	$10,000
Installation	$10,000
Sum of Bare Construction Costs	**$200,000**
30% Contingencies	$60,000
Bare Construction Cost	**$260,000**
20% OH&P & GCs	$60,000
Total Capital Cost[1]	**$320,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

While the addition of sludge blanket monitors could help to optimize sludge extraction, it is important to note that proactive operational control is critical. In general, primary sedimentation tanks function on the principle of particle settling velocity. It is important that the velocity of the flow in the tank doesn't exceed the settling velocity of the particles, and that a sufficient hydraulic detention time is maintained to allow particles to separate from the wastewater. These operational parameters will ensure that at varying flows, solids can settle out of the clarifiers to the correct quantities and be removed at set times, without the sludge blanket reaching the effluent weir. The use of sludge blanket monitors will help optimize sludge extraction but is not a replacement for operational controls. The sludge blanket monitors have several features to help overcome some inherent challenges. A limit switch is installed with the sludge blanket monitor that will lift the monitor out of the path of the flight. Additionally, the sludge blanket monitor can be programmed to begin taking readings once it has reached a set depth, helping to avoid erroneous readings due to floating solids.

6.8 Recycle Stream Improvements

The North Reactors currently experience buildup of grit and solids in the bottom of the tanks, a portion of which is due to the sidestreams that are currently sent downstream of the primary settling tanks, including DAR WAS, filtrate, filter backwash, GTO supernatant. This can ultimately result in loss of treatment volume and significant maintenance costs to clean the North Reactors. It is recommended that these sidestreams be diverted upstream of the PSTs, and preferably upstream of the screening and grit removal, to remove inorganic solids within these sidestreams before this flow reaches the North Reactors.

It is recommended that the DAR WAS, filter backwash, and GTO supernatant be redirected to the Screen and Grit Building No. 2. (Filtrate from sludge dewatering will go to sidestream treatment.) Redirecting the sidestreams will require re-routing the specific gravity lines to a central location and the construction of a new pump station and force main to Screen and Grit Building No.2. **Table 6.8-1** provides the associated costs for redirecting recycle flows to the Screen and Grit Building No. 2.

Table 6.8-1: Conceptual Cost Estimate: Recycle Stream Improvements

Vendor Costs and Direct Costs	Estimate
Mobilization	$65,000
Filter Backwash Pump Station	-
Pumps	$300,000
Structural Concrete	$125,000
Excavation/Dewatering	$75,000
Yard Piping	-
Filter Backwash	$100,000
WAS	$200,000
GTO	$200,000
FM	$200,000
Conflict Resolution	$100,0000
Installation	$90,000
Electrical	$50,000
Instrumentation	$30,000
Sum of Bare Construction Costs	**$1,535,000**
30% Contingencies	$470,000
Bare Construction Cost	**$2,005,000**
20% OH&P & GCs	$410,000
Total Construction Costs	**$2,415,000**
20% Management and Engineering[1]	$490,000
Total Capital Cost[2]	**$2,905,000**

[1]Includes COT management, legal and administrative costs.
[2]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

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Technical Memorandum 7.0 BNR Process Evaluation

7.1 Purpose and Background

This report describes the Biological Nutrient Removal (BNR) Process Evaluation for the City of Tampa's (City) Howard F. Curren Advanced Wastewater Treatment Plant (HFC AWTP). This work was completed under the Phase 2 Master Plan Contract by Hazen and Sawyer as a subconsultant to McKim & Creed.

The HFC AWTP GPS-X® process model layout was updated and expanded under a previous task. The detailed sampling and model calibration is described in the Process Model Sampling and Calibration Report (**Appendix B**). The calibrated model was used to evaluate the BNR process at HFC AWTP and identify feasible alternatives for achieving more efficient and reliable nitrogen removal with the option to incorporate phosphorus removal in the future.

7.1.1 Existing BNR Process Overview

The HFC AWTP is rated for 96 mgd annual average daily flow (AADF) and currently treats approximately 60 mgd on an annual average basis. HFC AWTP currently meets an effluent TN limit through operation of a two-stage activated sludge system, followed by denitrification filters, as shown in **Figure 7.1-1**. The first stage is high purity oxygen activated sludge operated at a very short SRT (0.5 days) for carbon removal. The second stage is a conventional activated sludge configuration equipped with diffused aeration. This stage is operated at a higher SRT to achieve complete nitrification. In recent years the conventional activated sludge process has been operated to achieve some denitrification as well during part of the year, by operating the first two of the six zones as anoxic with a recycle of some of the nitrified effluent to the head of the reactors. Additional nitrogen removal is achieved in the denitrification filters through the addition of methanol. HFC AWTP is currently not required to meet a phosphorus limit, but it is possible that they may be required to meet an effluent TP limit of 1 mg/L in the future.

For the purposes of this evaluation, the notation for the different activated sludge reactors was modified to prevent confusion. These tanks are currently identified by either the method of aeration or the type of treatment completed in the reactors. Both the method of aeration and treatment occurring in each set of reactors may change with the different alternatives presented, therefore a notation based upon the location in the plant will be used instead. The reactors commonly referred to as the HPO (high purity oxygen) or CARB (carbonaceous removal) reactors will be referred to as the **North Reactors** for this evaluation. The reactors commonly referred to as the DAR (dissolved air reactors) or NIT (nitrification) reactors will be referred to as the **South Reactors** for this evaluation.

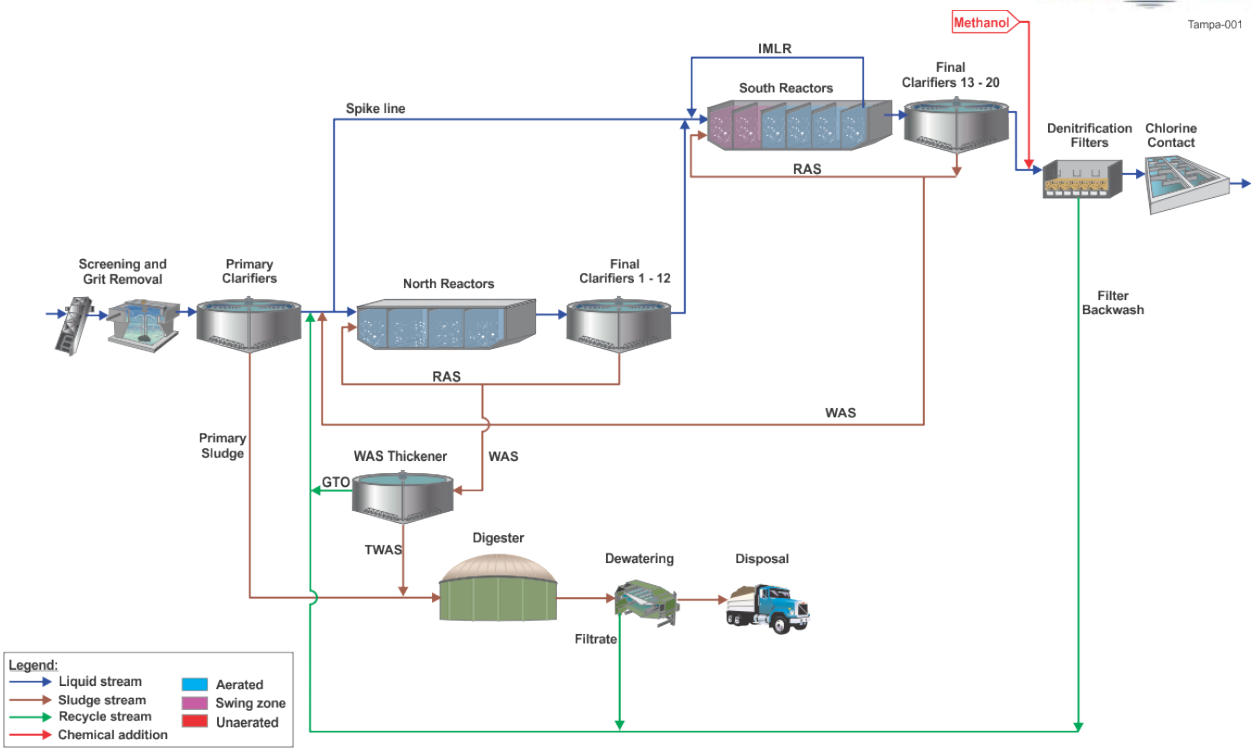

Figure 7.1-1: Existing HFC AWTP Process Schematic

7.1.2 Evaluation Framework

The overall goal of the evaluation is to identify and evaluate alternatives to achieve more efficient and reliable nitrogen removal in the future, with consideration for future implementation of an effluent phosphorus limit. A framework was developed to identify process alternatives for the BNR process evaluation. The following key project goals were identified for the BNR process evaluation:

- Maintain Process Reliability
- Increase Efficiency and Reduce Operating Costs
- Leverage Existing Assets (Minimize Capital Cost)
- Ease of Operation and Maintenance
- Provide Toxicity Resiliency
- Use Proven Technologies
- Meet Potential Future Regulations
- Reliably Manage Wet Weather Flows
- Flexibility for Future Improvements
- Consistency with other City Initiatives

In order to narrow down the list of process alternatives, the core process components were distinguished from process enhancements which could be evaluated as additions to the final core process configuration. The core process components include (1) the nitrogen removal process, (2) the carbon management strategy and (3) the stage operation (series vs. parallel).

7.1.3 Nitrogen Removal Process

Several nitrogen removal configurations including Bardenpho, Anaerobic, Anoxic, Oxic Process (A2O), Virginia Initiative Plant (VIP), Johannesburg Process and Sequencing Batch Reactors were considered but eliminated during initial screening based on the stage configuration at HFCAWTP. Three different conventional nitrogen removal configurations were evaluated based on the available process volumes and configurations: (1) Separate Stage Denitrification, (2) Modified Ludzack Ettinger (MLE) and (3) Step Feed BNR.

HFC AWTP currently accomplishes complete nitrification in the South reactors and most of the denitrification in the denitrification filters as shown in **Figure 7.1-2**. This requires the addition of supplemental carbon because the influent carbon is utilized in the upstream activated sludge process. The two other nitrogen removal configurations considered leverage the carbon entering in the influent wastewater for denitrification, resulting in savings on supplemental carbon addition.

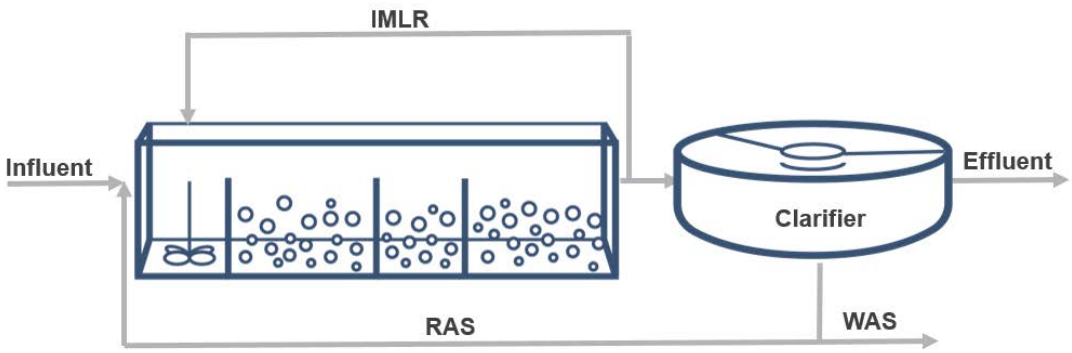

Figure 7.1-2: Separate Stage Denitrification

The MLE configuration consists of an unaerated zone upstream of an aerated zone within the activated sludge reactor **Figure 7.1-3**. Ammonia is converted to nitrate in the aerated portion of the reactor and nitrate is recycled from the end of the basin back to the anoxic zone through an Internal Mixed Liquor Recycle (IMLR) pump. Denitrification occurs at the head of the reactor in the presence of nitrate and carbon under anoxic conditions.

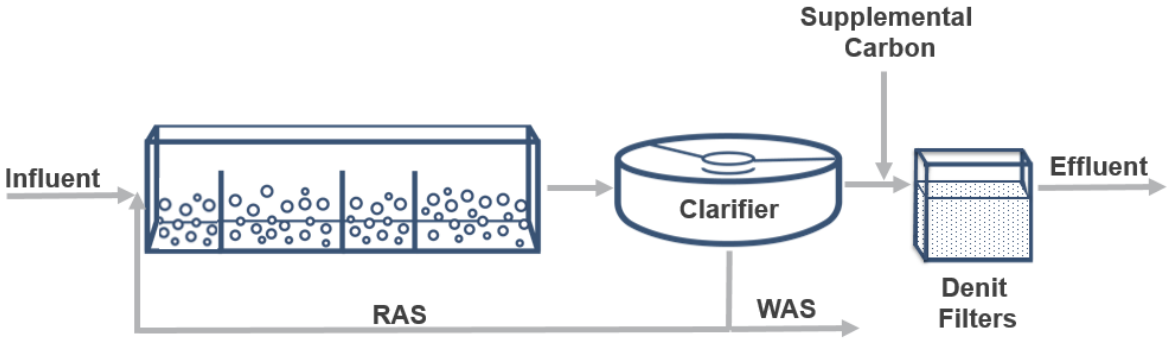

Figure 7.1-3: Modified Ludzack Ettinger (MLE)

The Step Feed configuration uses multiple anoxic zones created along the length of the reactor **Figure 7.1-4**. Nitrification occurs in the aerated zones and the nitrate that is created here is then denitrified in the downstream anoxic zones. Influent wastewater is split to the multiple anoxic zones to provide influent carbon needed for denitrification.

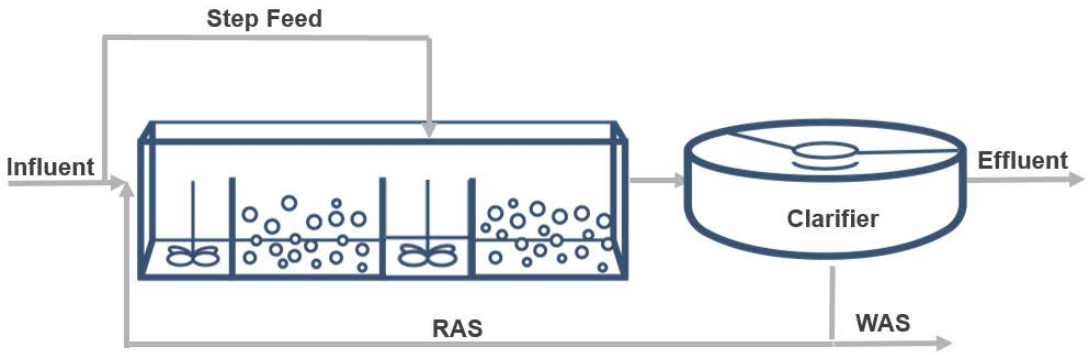

Figure 7.1-4: Step Feed Configuration

The use of lower energy pathways for nitrogen removal, such as mainstream deammonification were also discussed with the City. Use of these types of bacteria reduce the oxygen and can eliminate the carbon use requirement for nitrogen removal which would result in significant operational savings. This could be implemented in phases, but ultimately this process requires complex control strategies and has not yet demonstrated the ability to achieve reliable operation for mainstream treatment, particularly for very low TN limits. Consideration was given to the flexibility of the process options to transition in the future to a next generation nitrogen removal technology.

Sidestream treatment using an anammox based system was assumed for all process alternatives based on a relatively short payback period. The Sidestream treatment evaluation is described in *The Sidestream Treatment Evaluation Technical Memo*.

7.1.4 Carbon Management Strategy

Consideration was also given to the strategy for most effective use of the influent wastewater carbon. Currently HFC AWTP directs a large portion of the influent carbon to the digestion process through the high rate activated sludge process and primary clarification. This carbon diversion allows for a larger energy recovery of biogas from the digesters. The alternative strategy is to utilize the influent carbon for nitrogen removal as described in the section above, this allows for some savings on supplemental carbon addition, but a lower digester gas recovery. Future implementation of mainstream deammonification would minimize the carbon requirement associated with nitrogen removal and allow for even greater diversion of carbon to the digesters. The impacts of the fate of the carbon were accounted for in the evaluation through calculation of operations costs (methanol addition for denitrification and digester gas production).

7.1.5 Stage Operation

HFC AWTP is currently operated in series, therefore the majority of the influent flow passes through both the North Reactors and Final Sedimentation Tanks (FSTs) and the South Reactors and FSTs. Approximately 15-20 mgd is sent through the spike line directly to the South Reactors to facilitate denitrification in the anoxic stages during a portion of the year. During the BNR evaluation, operation of the two stages in parallel was also considered as shown in **Figure 7.1-5**. This provides a significant advantage under wet weather conditions, lowering the loading to the secondary FSTs.

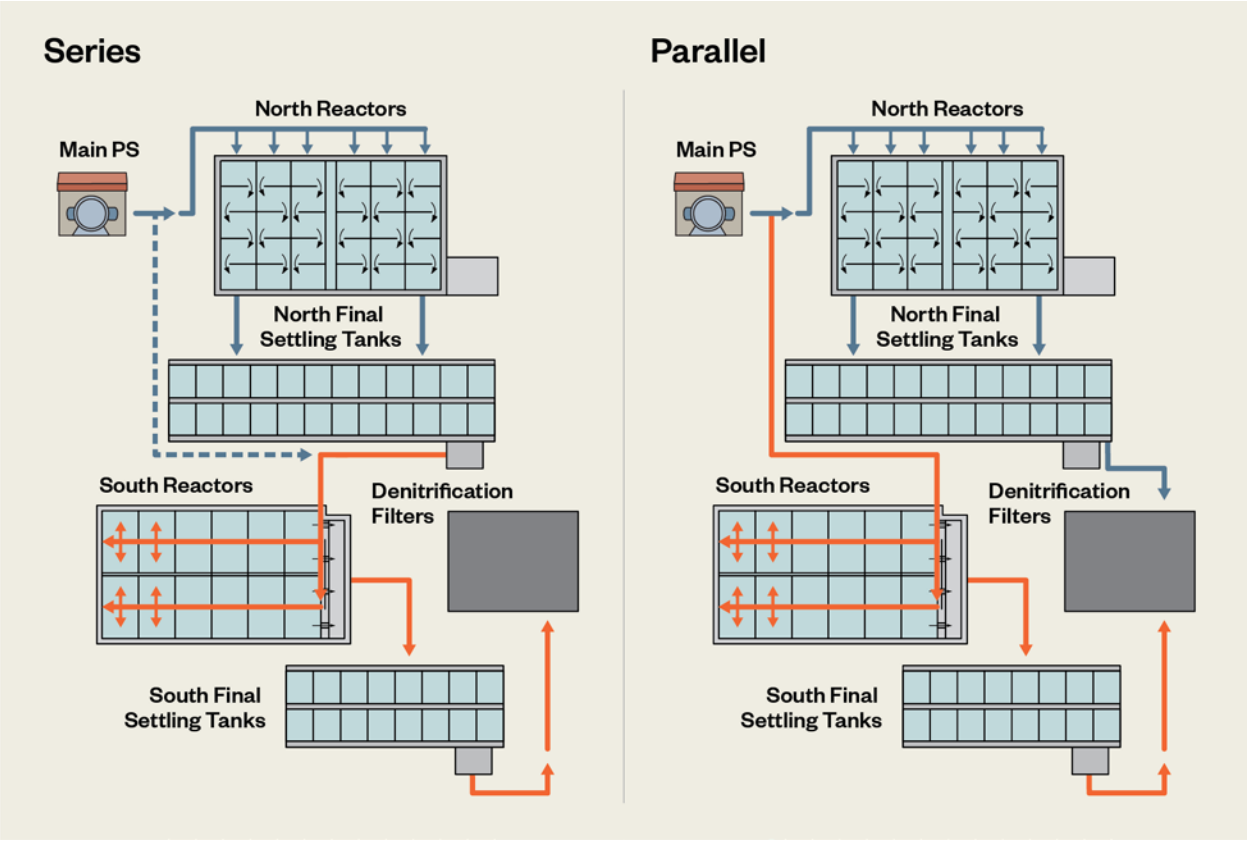

Figure 7.1-5: Stage Operation: Series vs. Parallel

7.1.6 Process Enhancements

Generally, enhancements were identified for the different process areas that might result in improved performance or energy savings. A few examples of process enhancements are shown in **Figure 7.1-6**. These alternatives are not considered core to the process chosen and therefore were evaluated as necessary once the Core Process was selected.

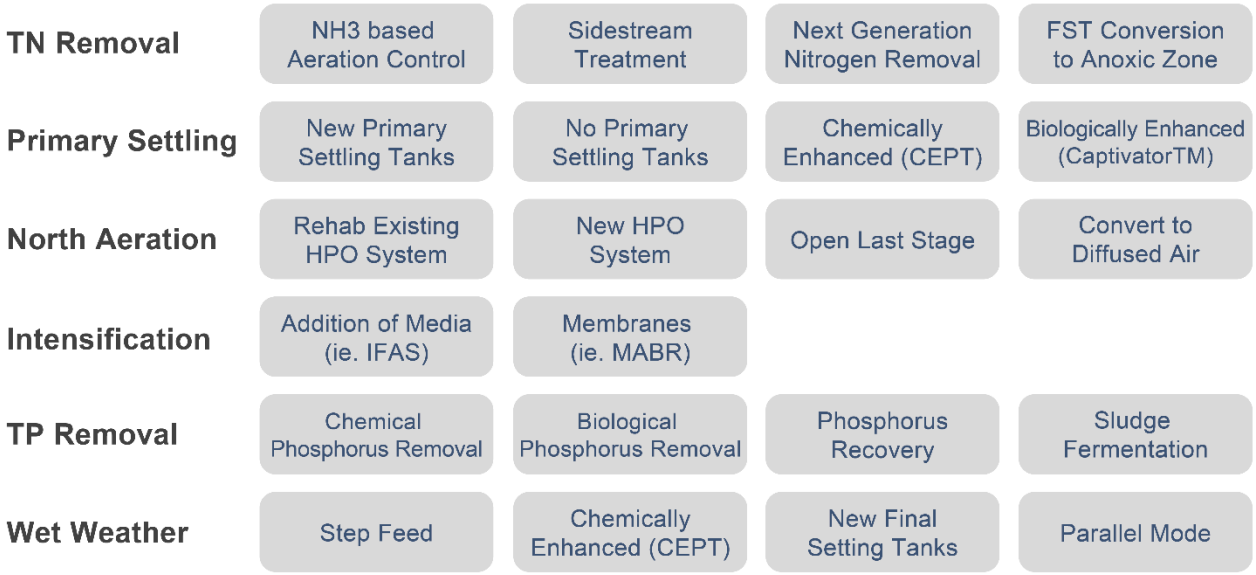

Figure 7.1-6: Potential Process Enhancements

7.1.7 Core Process Alternatives

Seven core process alternatives were identified for the BNR evaluation **Table 7.1-1**. Alternatives 4A and 4B, were not considered for near term implementation, but for potential future phase from one of the other core process alternatives evaluated.

Table 7.1-1: Core Process Alternatives

Alt #	Description	Nitrogen Removal Configuration	Carbon Management Strategy	Stage Operation
1	Optimize Existing	MLE in South	BNR / Digestion	Series
2A	MLE (Series)	MLE in North and South	Optimize BNR	Series
2B	MLE (Parallel)	MLE in North and South	Optimize BNR	Parallel
3A	Step Feed (Series)	Step Feed in North and South	Optimize BNR	Series
3B	Step Feed (Parallel)	Step Feed in North and South	Optimize BNR	Parallel
4A	Next Generation Nitrogen Removal (Series)	Mainstream Deammonification	Divert to Digestion	Series
4B	Next Generation Nitrogen Removal (Parallel)	Mainstream Deammonification	Divert to Digestion	Parallel

7.1.8 Alternative 1 – Optimize Existing

Alternative 1 includes optimizing the existing process configuration with some minor process improvements **Figure 7.1-7**. The North and South reactors will continue to be operated in series. The North reactors would continue to be operated at a very short SRT for a high fraction of carbon diversion to digestion. The South reactors would continue to be operated for full nitrification and improvements like what has been implemented in South Tank No. 1 (including anoxic mixers in stages 1-3, new fine bubble diffusers and IMLR pumps) are recommended to improve the denitrification possible upstream of the denitrification filters. These improvements include optimization of the spike line to the DARs, the addition of mixers to the first three zones to ensure proper mixing under anoxic operation, and installation of an IMLR pump to recycle nitrate back to the head of the anoxic zone.

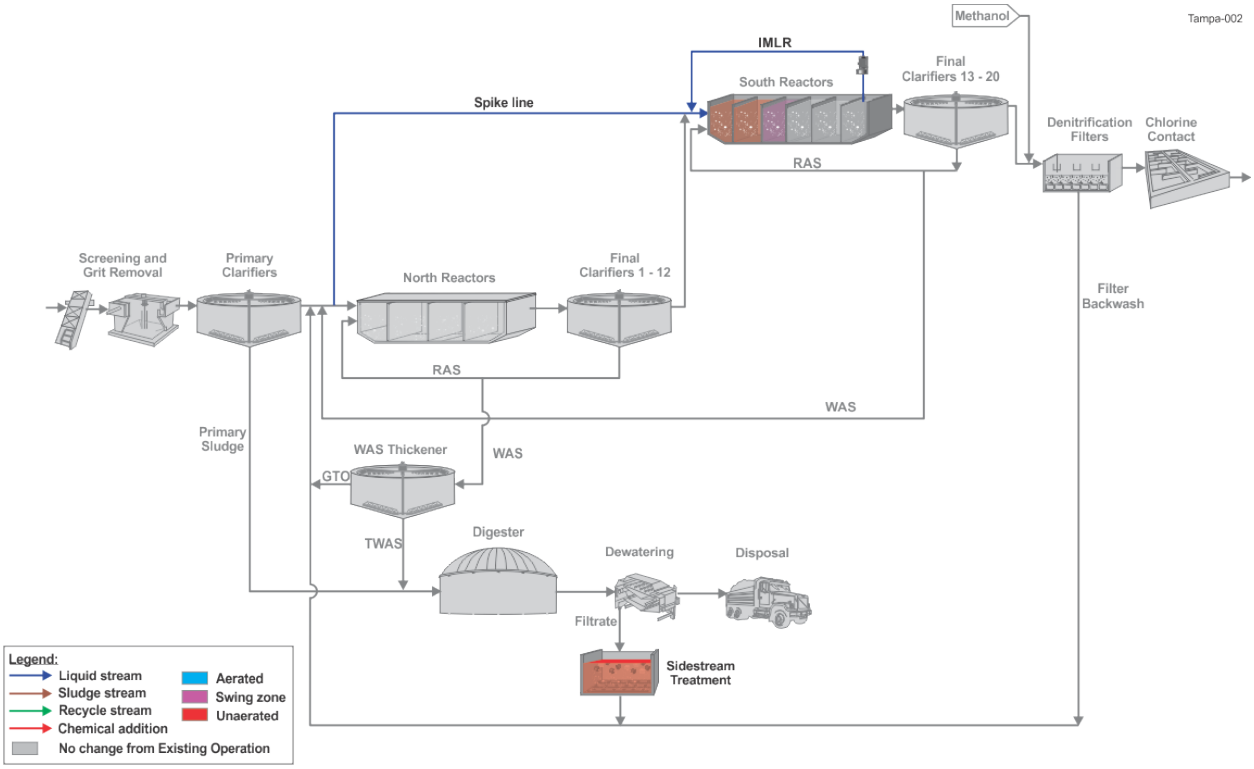

Figure 7.1-7: Alternative 1 – Optimize Existing

7.1.9 Alternative 2A – Two MLE in Series

Alternative 2A requires conversion of both the North and South reactors to MLE configurations for nitrogen removal and operating these two stages in series **Figure 7.1-8**. Conversion to an MLE includes the creation of anoxic zones at the head of both sets of reactors, installation of IMLR pumps to recycle nitrate/nitrite from the end of each tank back to the anoxic zone. Application of this concept requires at least partial nitrification be achieved in the North Reactors to take advantage of the nitrogen removal configuration in these tanks.

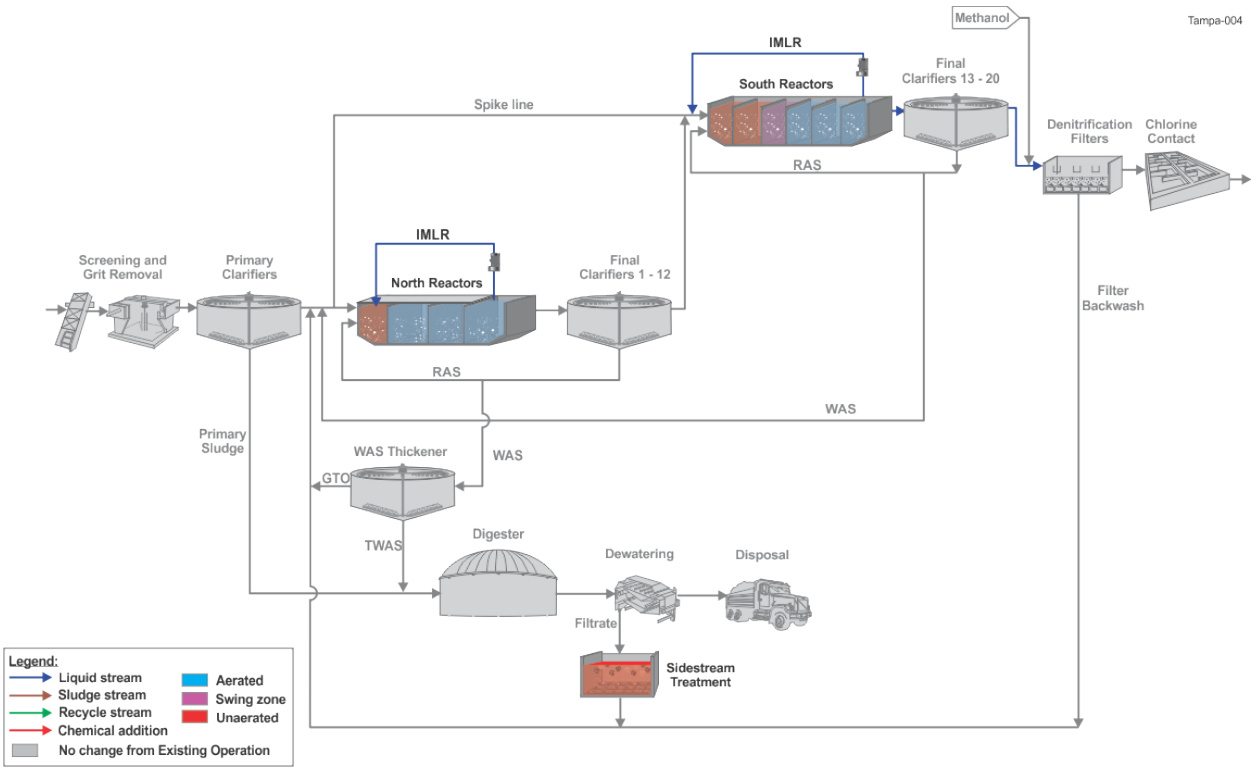

Figure 7.1-8: Alternative 2A – MLE in Series

7.1.10 Alternative 2B – Two MLE in Parallel

Alternative 2B requires conversion of both the North and South reactors to MLE configurations for nitrogen removal and operating these two stages in parallel **Figure 7.1-9**. Similar to Alternative 2A, this includes creation of anoxic zones at the head of both sets of reactors and installation of IMLR pumps to recycle nitrate/nitrite from the end of each tank back to the anoxic zone. Operation in parallel requires that each set of reactors achieve complete nitrification, since the effluent of each will be sent to the denitrification filters.

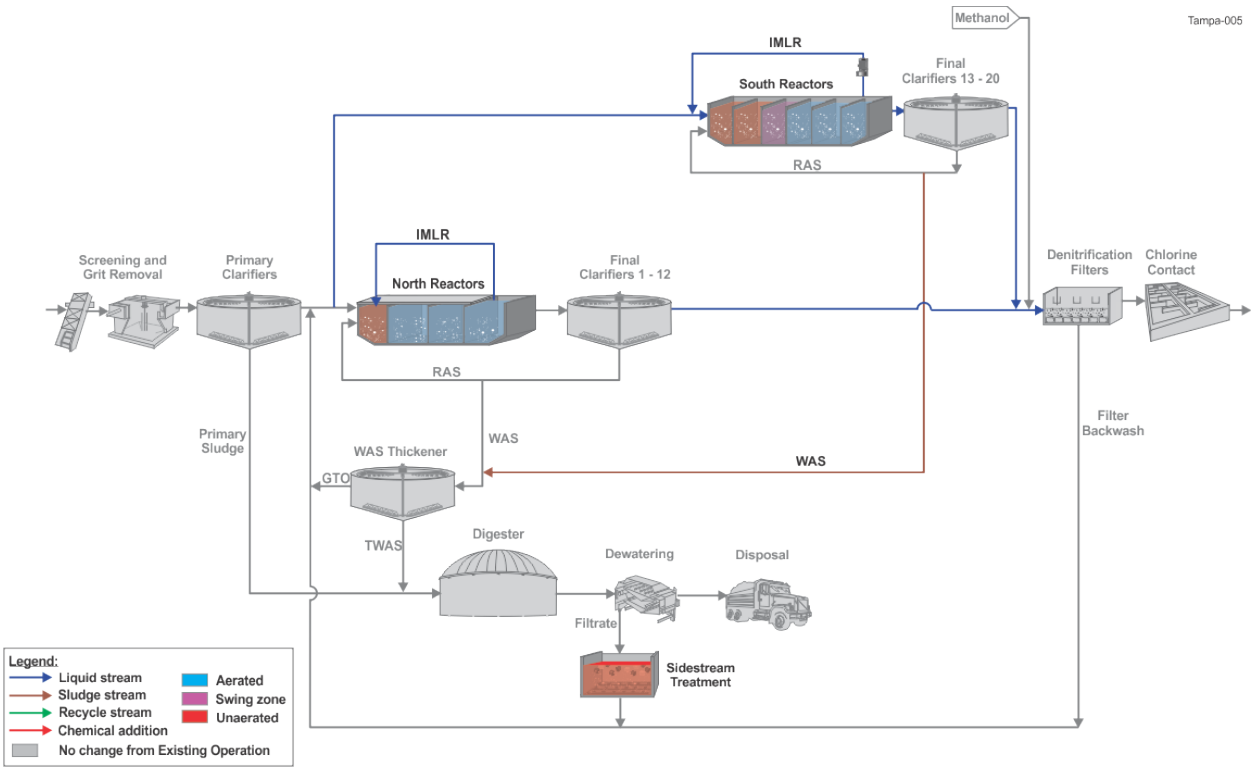

Figure 7.1-9: Alternative 2B – MLE in Parallel

7.1.11 Alternative 3A – Step Feed in Series

Alternative 3A requires implementation of step feed in both the North and South reactors and operating these two stages in series **Figure 7.1-10**. Additional piping will need to be installed to feed wastewater to multiple stages along the reactor. Mixers will need to be installed in the anoxic zones. Ideally at least partial nitrification would be achieved in the North Reactors to take advantage of multiple step feed points for lower effluent TN concentrations.

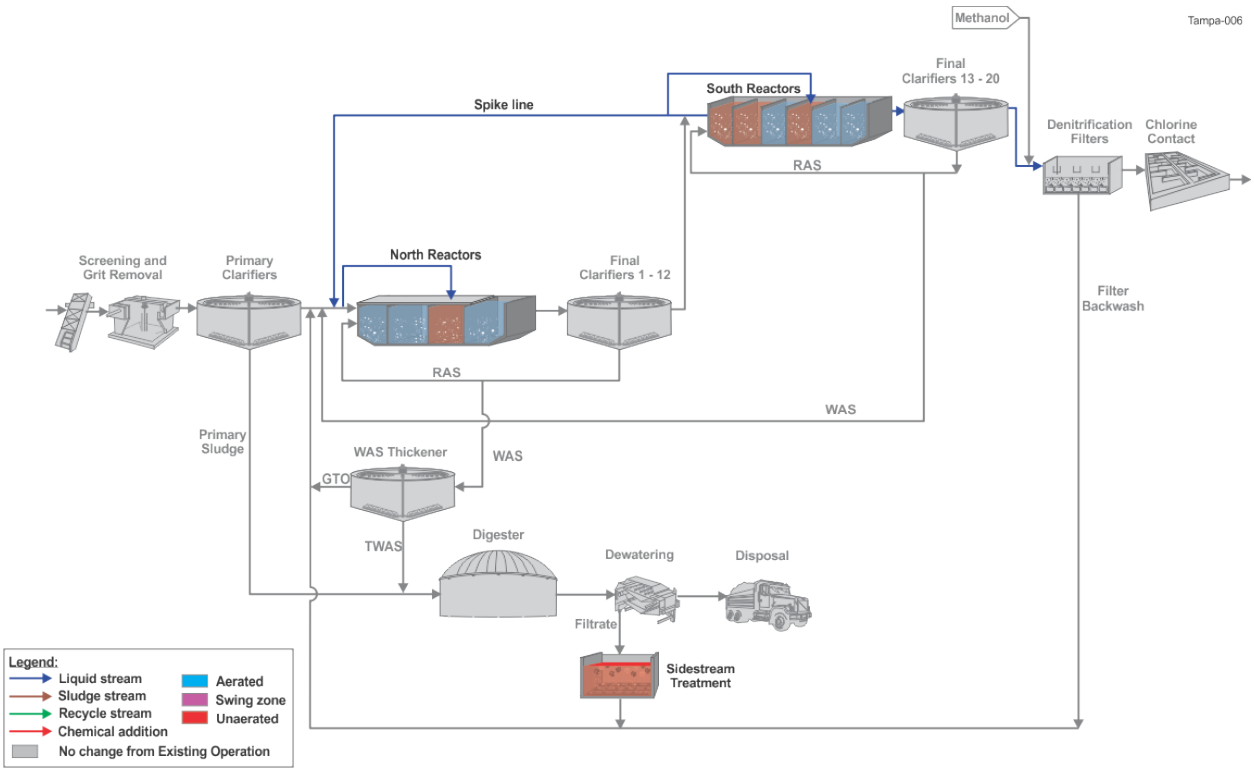

Figure 7.1-10: Alternative 3A – Step Feed in Series

7.1.12 Alternative 3B – Step Feed in Parallel

Alternative 3B requires implementation of step feed in both the North and South reactors and operating these two stages in parallel **Figure 7.1-11**. Similar to Alternative 3A, this includes creation of multiple anoxic zones along the reactors, and the addition of step feed piping to convey influent tank to each anoxic zone. A small anoxic zone at the head of each basin is recommended for denitrification of the RAS (not shown in Figure). Operation in parallel requires that each set of reactors achieve complete nitrification, since the effluent of each will be sent to the denitrification filters.

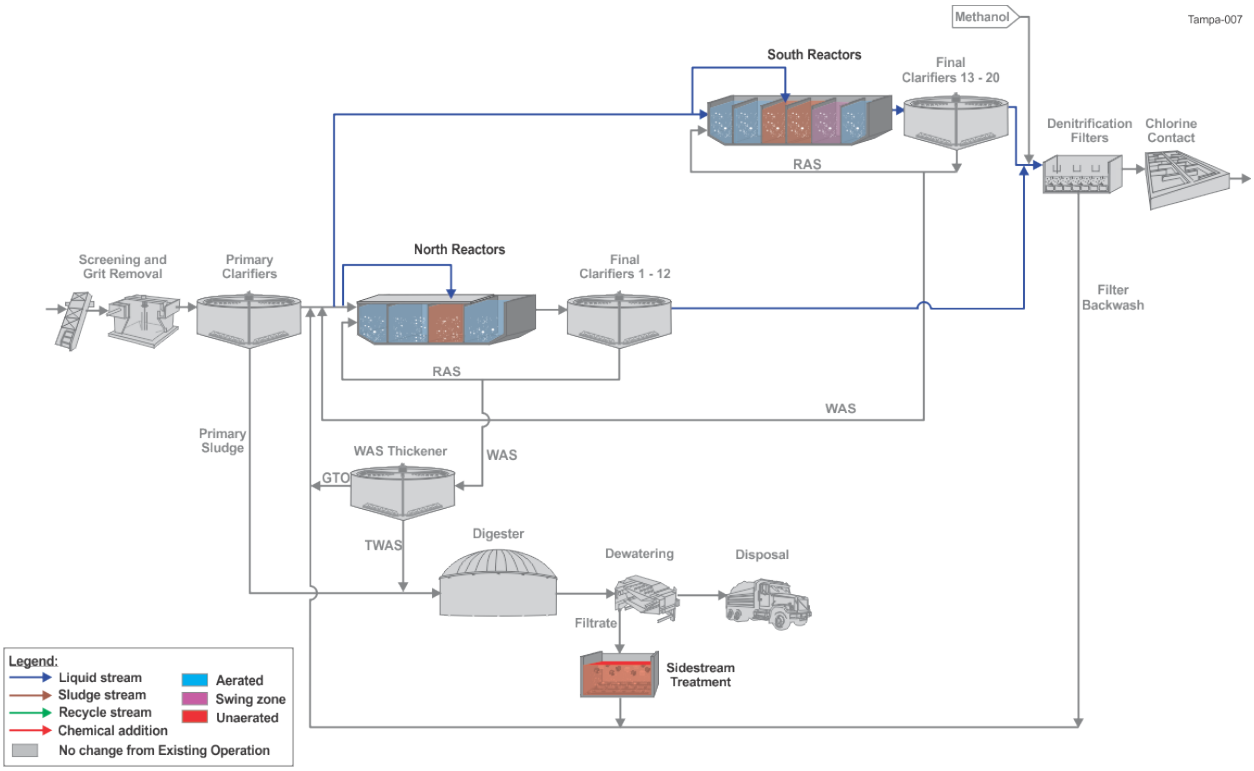

Figure 7.1-11: Alternative 3B – Step Feed in Parallel

7.1.13 Alternative 4A – Next Generation Nitrogen Removal in Series

Alternative 4A **Figure 7.1-12** involves maintaining series operation, with the high rate activated sludge system operating in the North Reactors as the A stage to remove most of the carbon and divert it to digestion. The B Stage requires conversion to mainstream deammonification in the existing South reactors. Sophisticated aeration control and seeding from a sidestream deammonification are recommended to encourage the growth of annamox bacteria in the mainstream process. Cyclones or micro screens would also be required for selection of the denser anammox bacteria. A downstream polishing step would also likely be required to remove any remaining ammonia. This technology is still being developed for the mainstream process, so this process is not being considered as an option for the near term, but is being considered for potential future implementation.

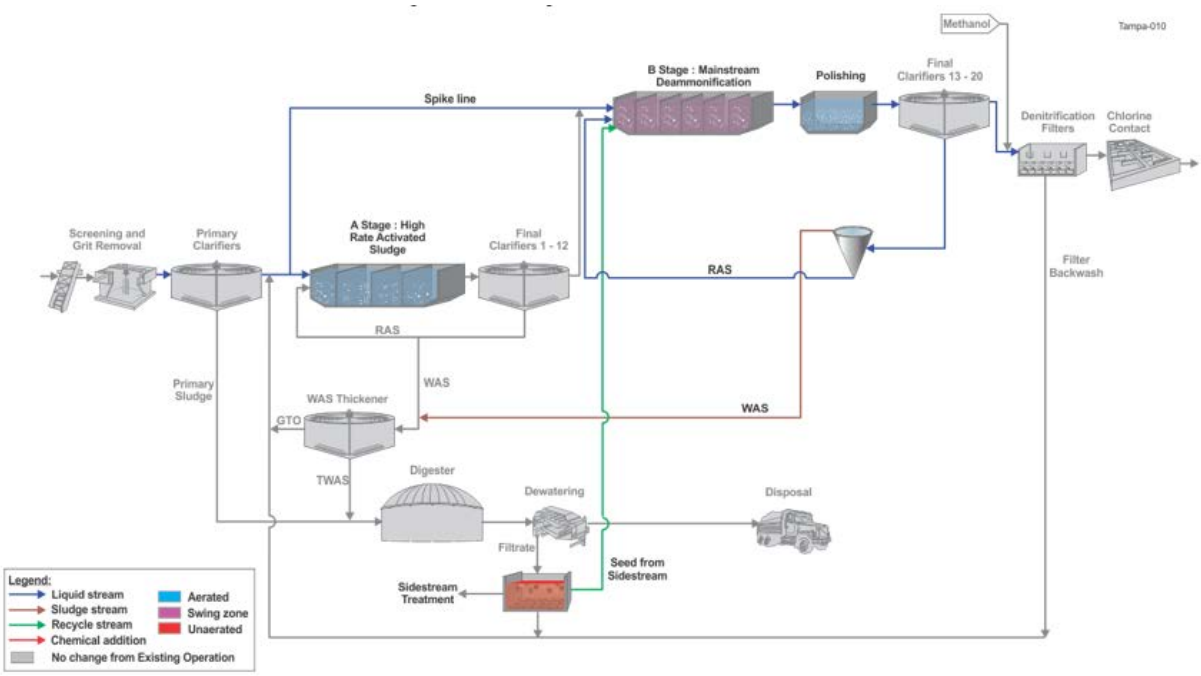

Figure 7.1-12: Alternative 4A– Next Generation Nitrogen Removal in Series

7.1.14 Alternative 4B – Next Generation Nitrogen Removal in Parallel

Alternative 4B **Figure 7.1-13** would involve converting both the North and South reactors to B stage mainstream deammonification, as described for Alternative 4A. An advanced primary clarification step could be incorporated such as chemically enhanced primary treatment (CEPT) to capture carbon upstream of the deammonification process. A downstream polishing step would also be implemented in both trains. This technology is still being developed for the mainstream process, so this process is not being considered as an option for the near term, but is being considered for potential future implementation.

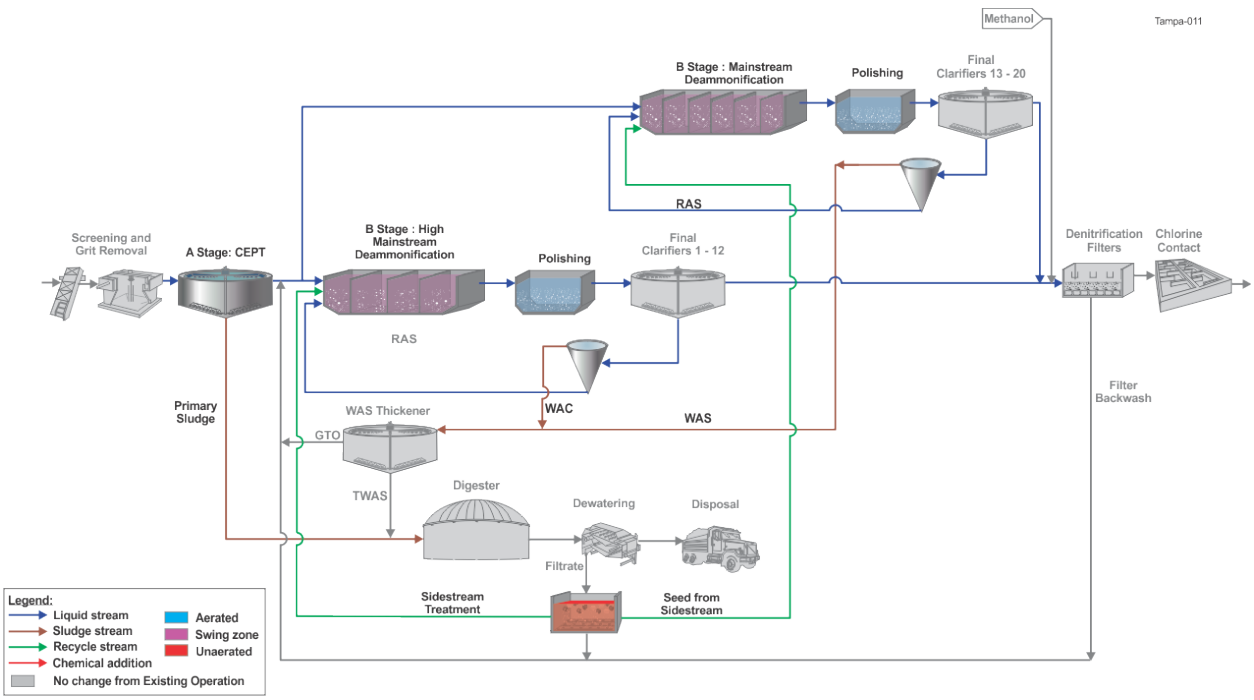

Figure 7.1-13: Alternative 4B – Next Generation Nitrogen Removal in Parallel

7.1.15 Evaluation Approach

The BNR process evaluation included the following steps:

1. Define Design Criteria and Assumptions
2. Screen Core Alternatives through Modeling Evaluation
3. Score Alternatives and Weight Criteria

7.2 Design Criteria and Assumptions

Prior to evaluating each alternative, the design criteria and process operating conditions were defined for current and future conditions.

7.2.1 Influent Flow and Loads

Plant influent flows and loads were established based on recently measured historical data and projections for future growth over the next 20 years based on the Phase 1 Master Plan Report. Three influent loading scenarios were selected to evaluate process performance: Current Annual Average, Future Annual Average, Future Maximum 30 day as shown in **Table 7.2-1**. The current loads were established using the most recent year of data available (May 2016 – April 2017). This period was considered to most accurately represent current conditions based on more representative influent sampling techniques implemented in Summer 2016 and the model calibration results. Peaking factors for maximum month flows and loads were developed based on statistical analysis of 2012 – 2016 data.

Table 7.2-1: Design Influent Flows and Loads

	Current Annual Average		Future Annual Average		Future Maximum 30 Day	
	Load (ppd)	Conc. (mg/L)	Load (ppd)	Conc. (mg/L)	Load (ppd)	Conc. (mg/L)
Influent Flow, mgd	60		80		112.9	
Influent TSS	94,600	189	126,000	189	157,000	167
Influent BOD	97,700	195	130,000	195	163,000	173
Influent TKN	19,200	38.2	25,600	38.2	31,900	33.9
Influent TP	2,670	5.34	3,570	5.34	4,450	4.73
Wastewater Temperature, ^{o} C	26.3 (Average)		26.3 (Average)		21.3 (Minimum Week)	

A summary of the historical flow and load peaking factors is presented in **Table 7.2-2**. The wet weather flow peaking factors were developed based on 2015 data which represented a significant wet weather event that is expected to be repeated in the future. A hydrograph of this storm event is presented in **Figure 7.2-1**.

Table 7.2-2: Design Influent Flows and Loads

Flow Criteria	Historical		
	Flow (MGD)	Flow Peaking Factor	Load Peaking Factor
Minimum Day	46.8	0.77	0.36
Average Annual	60.9	1.00	1.00
Maximum Month	81.1	1.33	1.22
Maximum 30-Day	86.3	1.41	1.25
Maximum 7-Day	102	1.67	1.37
Maximum Day	159[1]	2.46[1]	2.01
Peak Hour	190[1]	2.93[1]	0.36

[1]Historical Peaking factors for Maximum Day and Peak Hour from 2015

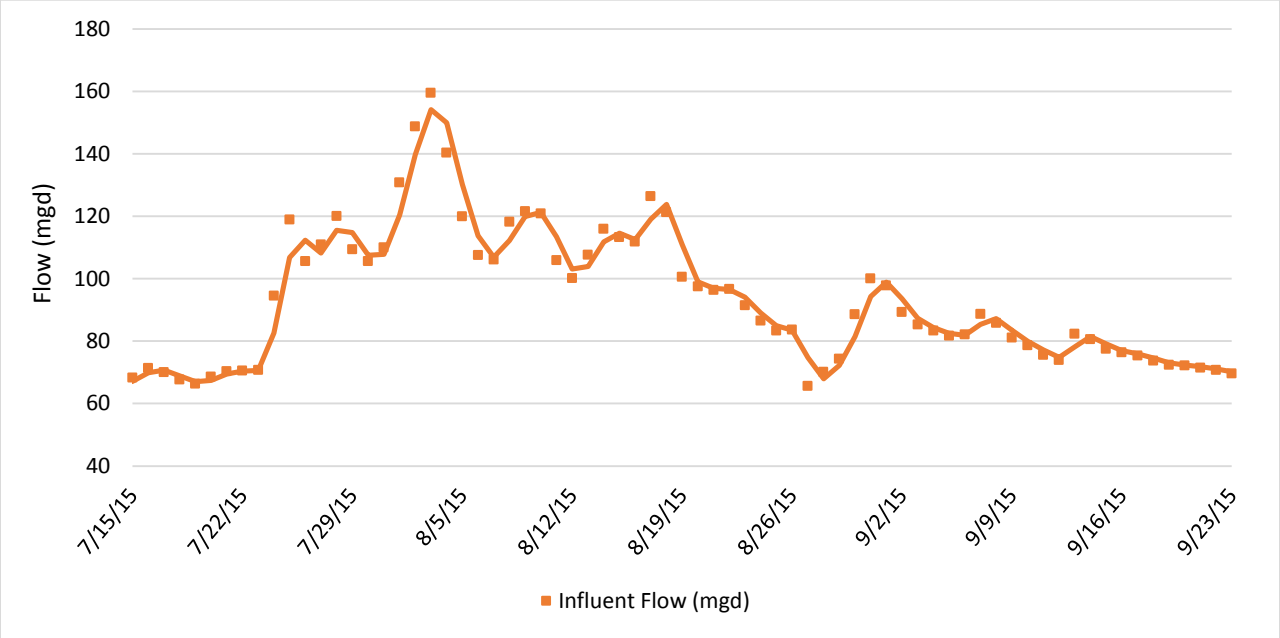

Figure 7.2-1: Daily Average Flows for 2015 Storm Event

7.2.2 Effluent Nutrient Quality

Effluent nutrient requirements were established based on the existing permit and expected future developments **Table 7.2-3**. The current effluent TN mass limit is 213 tons per year on a 5-year average basis, or a concentration limit of 2.3 mg/L at the current annual average flow of 60

mgd. Currently STAR and resource recovery uses about 5 mgd, allowing the City to meet the TN load requirement up to approximately 65 mgd. In the future, loading to the Bay is not anticipated to increase, but based on discussions with the City, it is anticipated that major reuse projects will allow the plant effluent TN concentration limit to increase to 3 mg/L at future flows. The loadings shown at future conditions are not expected to be applied to the Bay. There is currently a waiver on effluent TP limits based upon Bay modeling, however the potential for meeting an effluent TP of 1 mg/L was considered.

Table 7.2-3: Design Effluent Nutrient Concentrations and Loads

Parameters	Current Annual Average	Future Annual Average
Effluent Flow, mgd	60	80
Effluent TN Concentration, mg/L	2.3	3.0
Effluent TN Load, tons/year	213	366
Potential Effluent TP Concentration, mg/L	1.0	1.0
Potential Effluent TP Load, tons/year	91	122

7.2.3 Model Assumptions

GPS-X Model Updates

The calibrated GPS-X® model was used to evaluate the process performance for the different alternatives. Several small adjustments were made to the calibrated model prior to use in the BNR process evaluation, including:

- **Removal of the Denitrification Filters.** This process slows down model speed significantly, so this process was removed and instead the required methanol dose to meet the required TN limit was calculated using ratio calculated from historical data. A separate denitrification filter backwash input was added into the model to represent this flow.
- **Sidestream Treatment.** Sidestream treatment was assumed to be implemented for all options, providing 75% TN removal on the dewatering filtrate. A separate treated sidestream input was added to represent this flow.
- **Additional Flow Splitting.** Two new flow splits were added into the model to allow 1) the effluent from the North Reactors to go straight to the denitrification filters or to the South Reactors and 2) the WAS from the South Reactors to be sent to gravity thickening or to the head of the North Reactors.
- **Adjusted Nitrification pH Limitations** The low pH inhibition set points for the autotrophs in the North Reactors with High Purity Oxygen Activated Sludge (HPOAS) was adjusted to 6.3 SU. This is a refinement of the calibration. Under existing conditions, the HPOAS system in the North reactors was far below the required SRT to achieve nitrification, therefore this

value was not refined. For the BNR alternatives evaluation, this value was adjusted to more accurately reflect the inhibition expected within the closed HPOAS reactor when operating to achieve nitrification.

See **Figure 7.2-2** below for the updated process layout.

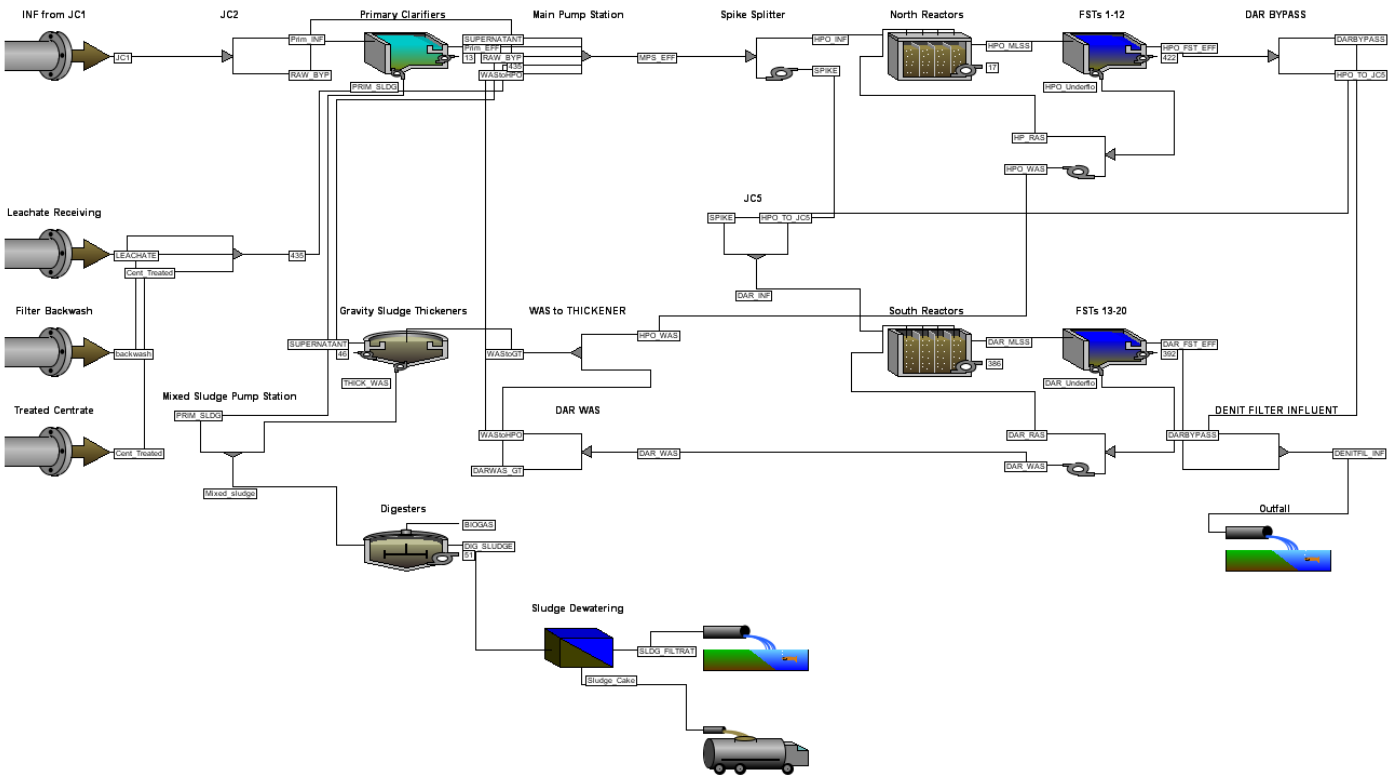

Figure 7.2-2: GPS-X® Layout for BNR Process Evaluation

Process Operating Conditions

Unit process operating set points or boundary conditions were set based existing process information or predicted performance under the projected flows and loads.

- **Primary Sedimentation Tanks** – The TSS Removal across the Primaries was assumed to be consistent with current operation (60%). See sedimentation tank limitations section for description of future assumptions. Primary Sludge TS concentration was also assumed to be similar to current operating (3.5%)
- **Spike Flow Split** – Adjusted to maximize denitrification in the South Reactors, while maintaining a minimum aerobic SRT of 5 days for nitrification.
- **North Reactors** – Operating MLSS was determined based on a State Point Analysis (SPA) for the North Sedimentation Tanks (describe below). Oxygen feed was based on maintaining a similar DO concentration to current operation.
- **South Reactors** - Operating MLSS was determined based on a SPA for the South Sedimentation Tanks (describe below). DO setpoints of 2 mg/L were set in all aerobic zones.

- **Secondary Sedimentation Tanks** – RAS flows were set between 0.5 – 0.75Q to maintain a RAS TSS concentration below 10,000 mg/L. Sedimentation tank effluent quality was assumed to be similar to current performance.
- **South WAS Flow Splitter** – South WAS flow was assumed to be sent to the North reactors when the process is operated in series and to the gravity thickeners when operated in parallel.
- **Gravity Thickeners** – 85% TSS removal assumed with 4.5%TS thickened sludge concentration to digestion.
- **Digestion** – Mesophilic operation is assumed (98°F). Full digester capacity was assumed to be available for operation.
- **Dewatering** – 95% TSS removal with 16% TS Cake, similar to existing performance.

7.2.4 Sedimentation Tank Limitations

Maximum Surface Overflow Rates

Future design surface overflow rates (SORs) were evaluated for both the primary and the final sedimentation tanks.

The primary sedimentation tanks currently achieve roughly 60% TSS removal at an SOR of 1200 gpd/ft^2 at annual average conditions. This is a relatively high overflow rate for average conditions. At future flows and higher SORs, the primary sedimentation tank performance is expected to decline. A summary of the projected future SORs with the existing primary sedimentation tanks are summarized in **Table 7.2-4**.

Table 7.2-4: Estimated Future PST SORs

Scenario	Flow (mgd)	SOR (gpd/ft2)
Current AA	60	1,200
Future AA	80	1,600
Future MM	113	2,200
Future MD[1]	197	3,900
Future Peak Hour[1]	234	4,600

[1] Flows above 160 MGD will bypass the primary sedimentation tanks

This has implications for the capacity of the downstream processes, so as stated in the above process operating conditions, it was assumed that the primary sedimentation tank TSS removal efficiencies were maintained at 60%. Addition of four additional primary sedimentation tanks would allow similar overflow rates to be achieved at the future projected flows. In addition to building new sedimentation tanks, stress testing can be performed to evaluate the TSS removal efficiencies at higher SORs to determine the timing and number of new primary sedimentation tanks that may be required in the future.

The final sedimentation tank surface overflow rates were also evaluated at future design flow rates. A Max Day SOR was selected based on engineering judgement and historical observations at HFC AWTP. The South FSTs experience higher SORs than the North, because there are fewer and the entire flow passes through them. **Figure 7.2-3** summarizes the South sedimentation tank performance at peak flows observed in 2015. At just over 1,000 gpd/ft^2, the effluent TSS begins to spike. 1,050 gpd/ft^2 was set as the Max Day SOR, above which additional sedimentation tanks are required to be built.

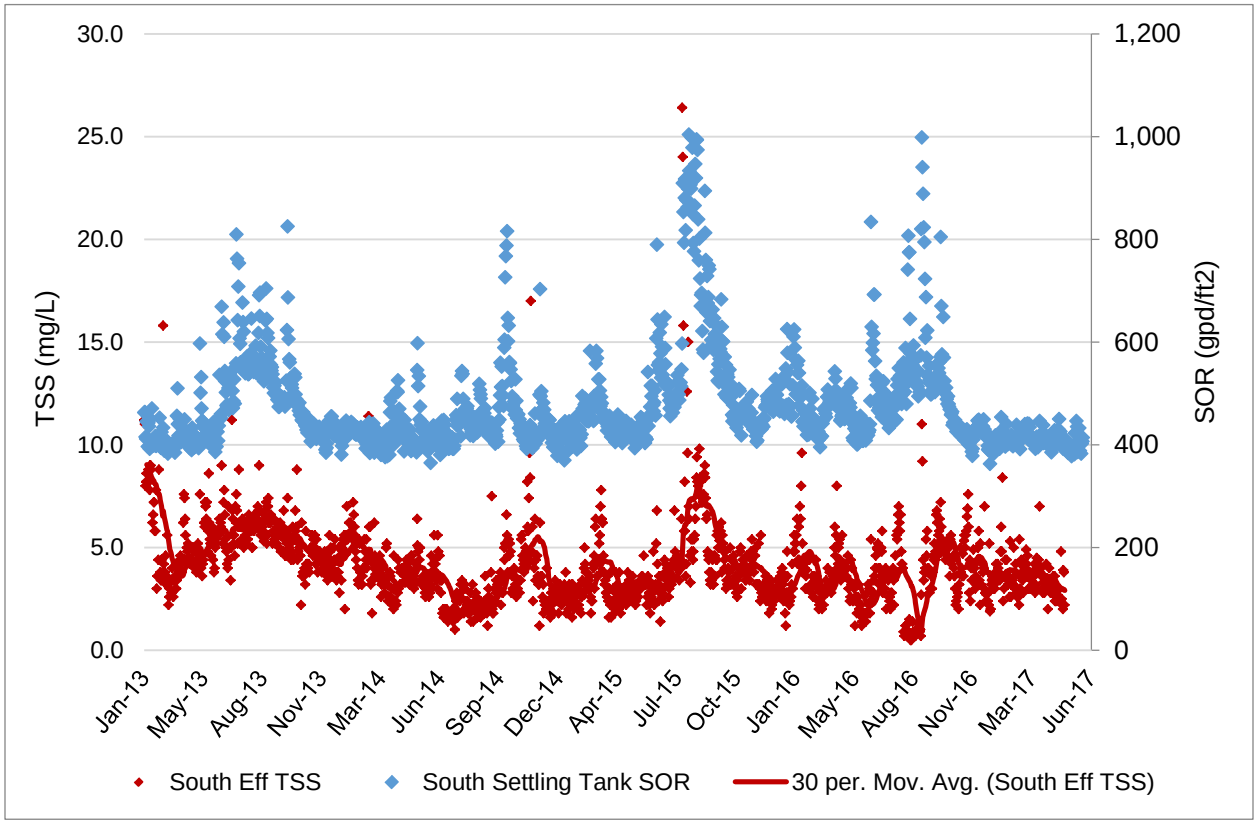

Figure 7.2-3: South Sedimentation Tank Performance at Peak SORs

<u>State Point Analysis for Secondary Settling</u>

The secondary sedimentation tanks performance was evaluated to identify the maximum allowable MLSS concentration for each scenario using a state point analysis (SPA). This criterion limits the achievable operating suspended SRT for each scenario which impacts the process capacity. Two flow and settling scenarios were evaluated:

- Maximum Day Flow, Annual Average MLSS and Average Sludge Volume Index (SVI)
- Maximum Month Flow, Maximum Month MLSS with 90th percentile SVI

Historical settling data was reviewed and design SVIs were established for each alternative, as shown in **Table 7.2-5**. The presence of an anaerobic selector improves the settling characteristics of the sludge. Slightly better settling performance was assumed for the South

Reactors when operated in series vs. parallel operation due to the reduction in BOD occurring in the first stage process.

Table 7.2-5: Design SVI for Alternatives Evaluation

	North Reactors		South Reactors	
SVI	No Selector	Selector	Selector	Selector
	Series	Parallel	Series	Parallel
Average SVI, mL/g	155	100	100	100
90% Percentile SVI, mL/g	206	120	100	120

All units were assumed to be in service. An ekama factor of 0.8 was assumed due to shallow depth. The RAS flow rates were assumed to up to 50% of the Peak flow or up to the existing capacity at Peak Hour Flows or no higher than 100% of the maximum month flow at maximum month conditions. The maximum month load peaking factor was assumed to be 1.25 based on historical data. The annual average MLSS was assumed to be maintained at 3,800 mg/L or below (or 4,800 mg/L at maximum month conditions, assuming a constant SRT).

Based on the solids flux analysis, a design MLSS for each scenario was developed for each alternative, as shown in **Table 7.2-6**.

Table 7.2-6: Design MLSS Concentrations for Proposed Configurations

Operating MLSS (mg/L)						
Scenario		North No Selector[1]	Current North Selector	Future North Selector	Current South Selector	Future South Selector
Series	AA	1,400	3,400	2,800	3,000	2,500
Parallel	AA	1,400	3,800	3,800	3,800	3,500

[1]*MLSS set to maintain high rate SRT of 0.5 days, not based upon maximum allowable solids loading rate (SLR)*

7.2.5 Reliability and Redundancy

For process reliability and redundancy, each alternative was also evaluated with one unit out of service at annual average conditions to make sure that the process requirements can be met. The process with the fewest number of process units are the South Reactors (which have only 4). Taking one tank (25% of the process volume) out of service was determined to be the worst-case scenario with respect to process impact. For each of the design scenarios evaluated during the alternatives screening, operation with one South Reactor out of service was evaluated to make sure the design criteria could still be met.

7.3 Alternatives Screening

The alternatives shown in **Table 7.3-1** were evaluated using the calibrated process model to identify performance limiting factors and assess the viability of each option. Each alternative was evaluated at the three design conditions to evaluate process performance: Current Annual Average (AA), Future Annual Average (AA), Future Maximum 30 day (M30).

Table 7.3-1: Core Alternatives Evaluated During Screening

Alt #	Description	Nitrogen Removal Configuration	Carbon Management Strategy	Stage Operation
1	Optimize Existing	MLE in South	BNR / Digestion	Series
2A	MLE (Series)	MLE in North and South	Optimize BNR	Series
2B	MLE (Parallel)	MLE in North and South	Optimize BNR	Parallel
3A	Step Feed (Series)	Step Feed in North and South	Optimize BNR	Series
3B	Step Feed (Parallel)	Step Feed in North and South	Optimize BNR	Parallel

7.3.1 Performance Limiting Factors

Wet Weather Performance

The first performance limiting factor that was identified was the wet weather limitations of the final sedimentation tanks. As described in Section 2, a Max Day SOR of 1,050 gpd/ft^2 was established to limit the hydraulic loading of the FSTs. The resulting SORs for each alternative are summarized in **Table 7.3-2**.

Table 7.3-2: Surface Overflow Rates for Final Sedimentation Tanks for Each Alternative

Parameter	units	Optimize Existing (Alt 1)		BNR in Series (Alt 2A / 3A)		BNR in Parallel (Alt 2B / 3B)	
		Current AA	Future AA	Current AA	Future AA	Current AA	Future AA
Influent Flow	mgd	60.0	80.0	60.0	80.0	60.0	80.0
North Reactors							
North MLSS to FSTs	mg/L	1,400	1,400	3,400	2,800	3,800	3,800
North Effluent Flow	mgd	41.9	72.0	43.9	71.1	33.9	44.3
Max Day FST 1-12 SOR	gpd/ft2	511	878	536	867	414	540
Max Day FST 1-12 SLR	ppd/ft2	10	15	26	32	26	33
South Reactors							
South MLSS to FSTs	mg/L	3,000	2,500	3,000	2,500	3,800	3,500
South Effluent Flow	mgd	63.6	84.8	63.7	84.8	29.8	40.6
Max Day FST 13-20 SOR	gpd/ft2	**1,160***	**1,550***	**1,170***	**1,550***	545	743
Max Day FST 13-20 SLR	ppd/ft2	44	49	44	49	36	44

* indicates that design criteria has not been met

When the stages are operated in series (either in the Optimize Existing Alterative or the BNR in Series Alternatives), almost all the flow must flow through both sets of FSTs. The second (South) stage has fewer FSTs than the first stage (8 versus 12) and therefore, the South FSTs experiences higher loading rates when operating in series mode if all tanks are used. As noted by in red text in **Table 7.3-2**, the South FST SORs exceed the Max Day SOR limit set in the design criteria. To meet this requirement, additional South FSTs need to be constructed. At current conditions, two (2) new FSTs are recommended and at future conditions four (4) new FSTs are needed. Stress testing may be performed during the design of the two new FSTs in the near-term to assess the clarifier capacity in more detail to assess whether clarifier modifications, such as baffling may provide better performance.

It was assumed moving forward in the evaluation that these new FSTs would be constructed for any option using series operation. As a result of addition of new FSTs, a higher solids loading rate is achievable, so an updated state point analysis was performed at this condition. The updated set of operating MLSS are presented in **Table 7.3-3**.

Table 7.3-3: Updated Design Maximum MLSS Concentrations

Scenario		Design MLSS (mg/L)				
		North – No Selector	Current North - Selector	Future North - Selector	Current South - Selector	Future South - Selector
Series	**Ex. FSTs**	1,400	3,400	2,800	3,000	2,500
Series	**New FSTs**	1,400	3,500	3,000	3,400	3,400

Aerobic SRT for Nitrification

The ability to reliably accomplish nitrification in the activated sludge process is key to meeting nitrogen limits. Currently carbon removal and nitrification are accomplished in separate stages, but Alternatives 2 and 3 consider accomplishing at least partial nitrification in the North tanks. The goal is to achieve more denitrification in the activated sludge process with the use of the influent carbon, as opposed to relying heavily on methanol addition in the downstream denitrification filters.

A minimum aerobic SRT of 5 days was established to ensure complete nitrification is achieved. The maximum allowable MLSS was set based on the allowable loading rates to the sedimentation tanks, the split of primary effluent flow between the North and the South reactors was adjusted for all scenarios to maximum denitrification while maintaining an aerobic SRT of 5 days in the South Reactors. The resulting flow split and aerobic SRT are presented in **Table 7.3-4**.

Table 7.3-4: Primary Effluent Flow Split and Aerobic SRT for Each Alternative

Parameter	units	Existing (Alt 1)		BNR in Series (Alt 2A / 3A)		BNR in Parallel (Alt 2B / 3B)	
		Current	Future	Current	Future	Current	Future
Influent Flow	mgd	60	80	60	80	60	80
PE to North	mgd	41	62	41	69	34	45
PE to South	mgd	25	25	24	17	30	41
North Reactors							
North MLSS to FSTs	mg/L	1,400	1,400	3,500	3,000	3,800	3,800
North Aerobic SRT	d	0.51	0.53	**4.3***	**2.3***	9.8	6.6
South Reactors							
South Influent Flow	mgd	64	85	64	85	30	41
South MLSS to FSTs	mg/L	3,000	2,500	3,400	3,400	3,800	3,500
South Aerobic SRT	d	5.2	5.2	5.3	5.1	12.4	6.9

* indicates that design criteria has not been met

The BNR in Parallel Alternatives (2B and 3B) allow for aerobic SRT operation of greater than 5 days. The projected SRTs are based upon operation at the maximum allowable MLSS as determined by the SPA. A lower MLSS could be operated in these tanks and still be within the aerobic SRT requirements for nitrification. Alternatively, additional anoxic volume operation may also be possible to further enhance nitrogen removal upstream of the denitrification filters. For the BNR in Series Alternatives (2A and 3A), it is not possible to maintain an aerobic SRT greater than 5 days in both the North and the South reactors. Based on site layout, it may be possible to add additional North Reactor volume to meet the nitrification requirements. It can be argued that achieving partial nitrification in the North Reactors may be suitable for the BNR in series alternatives (2A and 3A), because the flow passes through the second stage (South Reactors) where full nitrification can be met. A minimum aerobic SRT of 3 days would be required to achieve some consistent partial nitrification at ideal conditions. To meet between a 3 and 5 days aerobic SRT requirement (and account for the reliability and redundancy requirement of taking 1 South Reactor offline at annual average conditions), it is necessary to build between 3 and 6 new North Reactors, in addition to the 4 new South FSTs. Due to the expected high capital cost to implement these improvements, the BNR is Series Alternatives (2A and 3A) were not considered viable options moving forward and were removed from the list.

pH Inhibition and Oxygen Transfer in HPO Reactors

The final performance limiting factor identified in this evaluation is related to pH inhibition and oxygen transfer associated with High Purity Oxygen Activated Sludge. The North Reactors are currently configured as HPOAS reactors. High purity oxygen is generated on-site with a cryogenic system and pumped into the closed tank reactors. The oxygen in the headspace of the reactors is transferred to the wastewater through use of surface aerators in each stage.

The closed tank configuration of the HPOAS systems trap in the carbon dioxide gas (CO_2) that is generated during through the oxidation of carbon. The build-up of CO_2 results in alkalinity consumption and pH depression in the wastewater. Nitrifying bacteria are particularly sensitive to low alkalinity/pH environments, and it is common for HPOAS systems to struggle with reliable nitrification. **Figure 7.3-1** summarizes the correlation between pH and the maximum growth rate of nitrifying bacteria as defined by USEPA in the Process Design Manual for Nitrogen Control (1975).

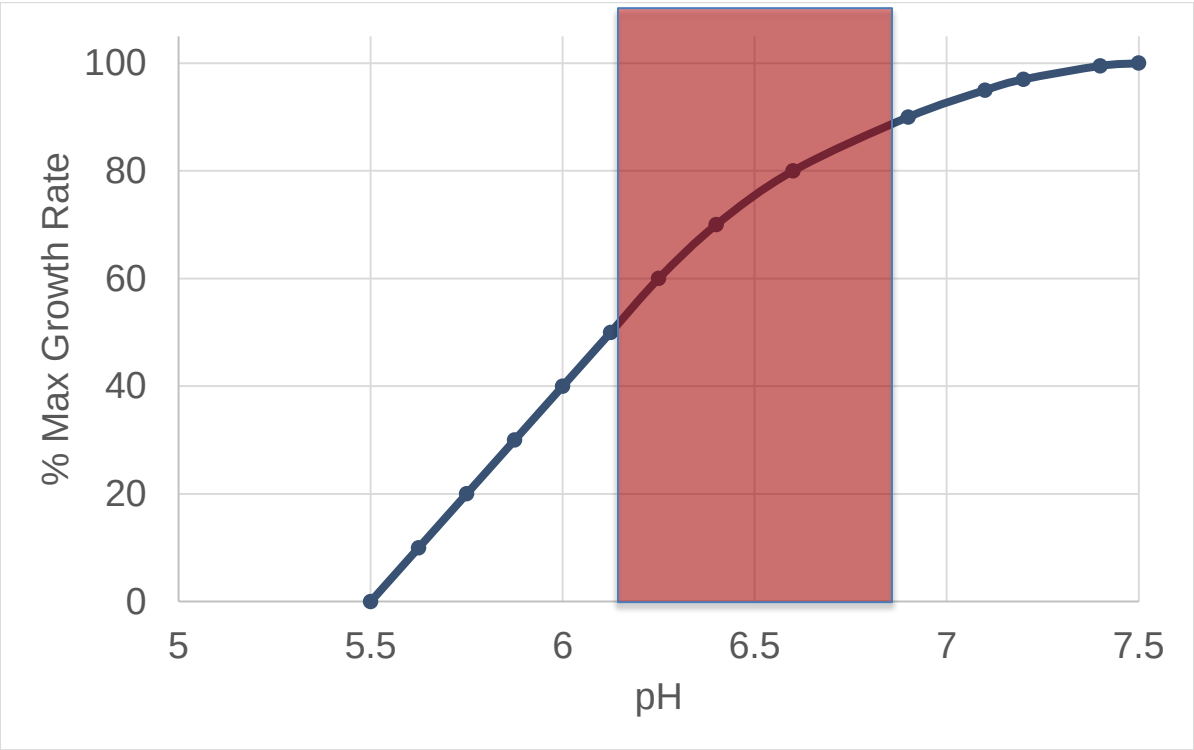

Figure 7.3-1: Correlation Between pH and Maximum Growth Rates of Nitrifying Bacteria

The predicted impact of pH on nitrification was estimated using the process model for the BNR in Parallel Alternatives **Table 7.3-5**.

Table 7.3-5: pH and Effluent Nitrogen Predictions for North Reactors with Existing HPO Configuration

Parameters	units	BNR in Parallel		
		Current	Future	Future
		AA	AA	M30
Influent Flow	mgd	60.0	80.0	112.9
North Reactors				
North MLSS to FSTs	mg/L	3,800	3,800	4,800
North pH #4	SU	6.2	6.2	6.4
North Aerobic SRT	days	9.0	6.1	5.6
North Effluent				
North Effluent NH3-N	mg/L	**2.3**	**6.3**	**15.4**
North Effluent NO3-N	mg/L	0.2	0.2	0.1
North Effluent NO2-N	mg/L	6.1	12.1	3.1

As shown in **Table 7.3-5**, operating the HPOAS system without any improvements is projected to cause a drop in pH between 6.2 and 6.4 in the final stage of the North reactors. This results in a loss of nitrification at higher loads and lower SRTs. There are multiple strategies that can be employed to reduce or eliminate the pH inhibition associated with HPOAS operation, including the addition of alkalinity, bioaugmentation (sending nitrifiers from the South reactors to the North reactors), or opening a stage of the North reactors to improve the CO_2 venting. Plant staff have noted that the North reactors fully nitrified during much of the 1980s.

7.3.2 Open Stage HPO Operation

The approach to opening a stage of the reactors has been employed at several other facilities successfully. The modifications required to implement this solution include: removing a portion of the top slab on the last stage, moving the vent from stage 4 to stage 3, and blocking the headspace between these stages to prevent loss of pure oxygen to atmosphere. Caution should be exercised when predicting the level of inhibition expected in the reactors because the model was not specifically calibrated to reflect the sensitivity of nitrification to pH and alkalinity and the model predicted pH is very sensitive to multiple factors such as assumed influent alkalinity, venting of the headspace. Due to the uncertainty regarding the potential pH increase that would

result, two scenarios were considered to evaluate what impact on nitrification and any subsequent improvements that might be necessary:

- If pH increases by 0.2 (pH = 6.4 - 6.6) - Full nitrification is not possible in existing volume. Several new reactors would need to be built and/or alkalinity addition to achieve nitrification
- If pH increases by 0.6 (pH = 6.8 – 7.0) - Predict full nitrification is possible. No additional tanks would be necessary.

Due to the uncertainty associated with the pH increase due to the open stage configuration, it is recommended that pilot testing (with an isolated train) be performed to confirm that this pH increase is possible, if moving forward with this option.

An additional concern related to accomplishing BNR in an HPOAS system is the ability to transfer sufficient oxygen into the aerated stages. For the BNR in Parallel alternatives, one stage would be opened to allow CO_2 venting and another is operated under anoxic conditions to accomplish some denitrification. Initial evaluations indicate the existing aerators in place are not large enough to transfer sufficient oxygen for complete carbon removal and nitrification into the 2 remaining stages. Larger aerators would be required. There is also a concern about the potential for poisoning the anoxic zone with very high DO returning in the IMLR flow, it is recommended that the IMLR flow be sent to an anoxic volume to de-aerate prior to return to the anoxic zone.

7.3.3 Conversion to Diffused Aeration

The other most viable solution to managing nitrification inhibition in the North Reactors is to completely convert from HPOAS to diffused aeration which eliminates any pH inhibition issue. The modifications required would be to open each of the stages in the North Reactors and install new fine bubble diffusers and blowers. The benefits include off-gassing of CO_2 to prevent the inhibition of the nitrifies, operation at a lower DO to prevent compromising anoxic zone operation and potential for better control and lower capital costs. The capital costs associated with this option are expected to be higher and there is a significant change to the operational strategy of these tanks (similar to what is done in the South Reactors).

For the BNR in Parallel Alternatives, both maintaining the use of HPO with the open stage to improve venting and complete conversion to diffused aeration were considered moving forward in the economic evaluation.

7.3.4 Viable Alternatives

The list of viable alternatives resulting from the screening process is summarized in **Table 7.3-6**.

Table 7.3-6: Screened Alternatives

Alt #	Description	Nitrogen Removal Configuration	Oxygen System in North Reactors	Stage Operation
1	Optimize Existing	MLE in South	HPO	Series
2(H)	Two MLE in Parallel (Keep HPO)	MLE in North and South	HPO	Parallel
2(D)	Two MLE in Parallel (Diffused Air)	MLE in North and South	Diffused Air	Parallel
3(D)	Step Feed in Parallel (Diffused Air)	Step Feed in North and South	Diffused Air	Parallel

7.4 Alternatives Evaluation

Each viable alternative was evaluated based on several cost and non-cost criteria. Planning level capital costs for the required improvements were developed based on relative differences between each alternative (not including projects common to all such as sidestream treatment). Operational costs were developed based on the process model predictions for aeration costs, pumping and mixing costs, chemical addition and digester gas production over a 20-year period. Both capital and operational costs are presented in 2017 dollars.

Non-cost factors such as ease of operation, required maintenance, and toxicity resiliency were developed with the City based on engineering judgement and previous experience with similar facilities. Future flexibility to meet more stringent nutrient limits was also assessed at a high level for each alternative, including implementation of phosphorus removal and next generation nitrogen removal.

7.4.1 Alternative 1 – Optimize Existing

For the Optimize Existing alternative, the North and South Reactors would continue to be operated in series as they are currently. The necessary improvements include:

- Modifications to South Reactors No. 2 – 4 to reflect the MLE configuration in place in Reactor No. 1., including new mixers for anoxic operation in Stages No. 1 through 3, new fine bubble diffusers, IMLR pumps to send nitrate back to the anoxic zones.
- Rehabilitation of the high purity oxygen generation system No. 1 and the North Reactor concrete structures. Replacement of North Reactor surface aerators.
- Four (4) new South Final Sedimentation Tanks and a new RAS pump station to accommodate projected peak flows in series mode.

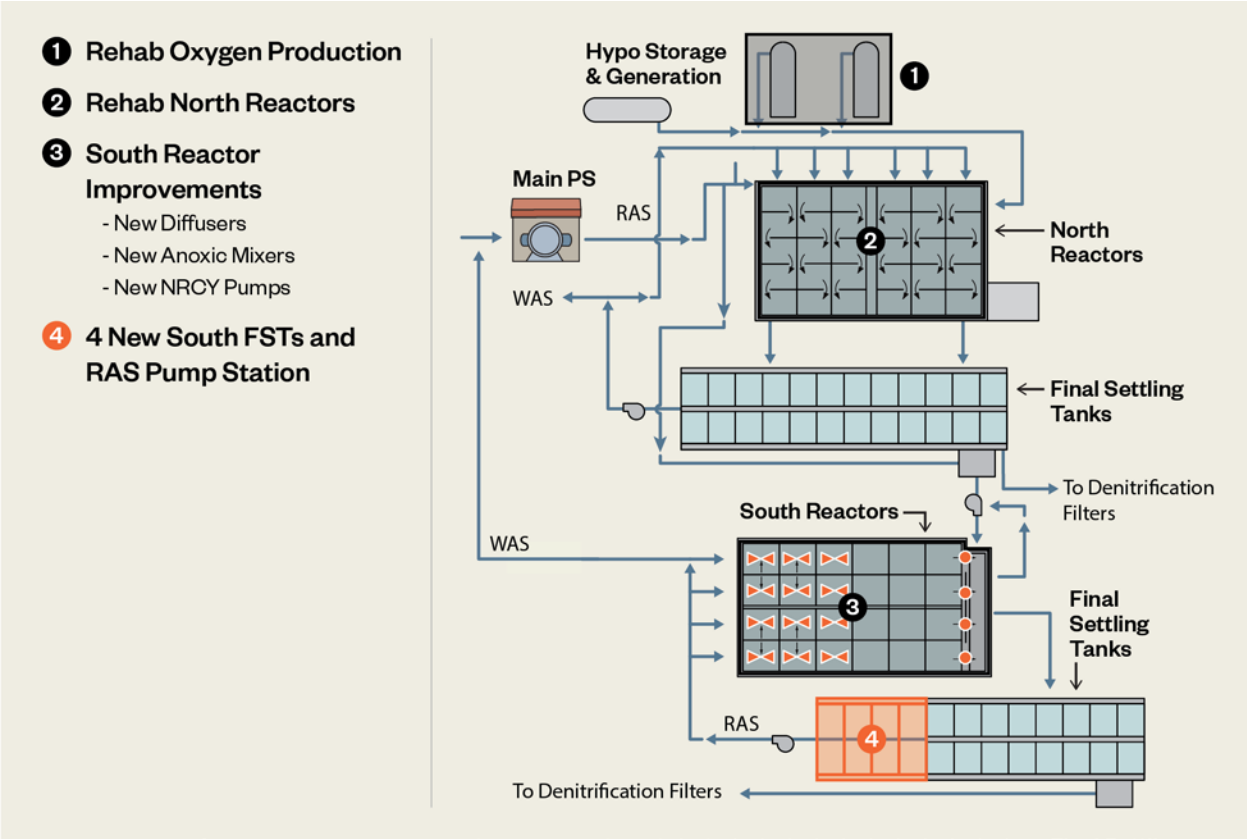

Figure 7.4-1: Summary of Improvements Required for Alternative 1

Predicted Performance

A summary of the key model results is presented in **Table 7.4-1**. The MLSS concentration in the North Reactor was set to maintain an SRT of 0.5 days similar to typical operation. Operating at a low SRT provides more carbon diversion and results in higher volatile solids reduction and digester gas production relative to longer SRT systems. Because of the lower SRT operation, little to no nitrification occurs in the North Reactors. Between 3 and 4 North Reactors are expected to be in operation at future design flows and loads.

The flow split of Primary Effluent to the South Reactors was increased to maximize denitrification in the anoxic zones, while maintaining a minimum aerobic SRT of 5 days. The IMLR flow for each reactor was set to be equal to the flow that was provided for South Reactor No. 1. Increasing this flow did not provide additional denitrification capacity in these tanks, the limitation is associated with the carbon that can be diverted here in the spike flow while maintaining the required aerobic SRT to obtain complete nitrification. The denitrification filters influent NOx-N load was used to evaluate the require methanol for denitrification to meet the permit limits.

Generally, the Optimize Existing series configuration with the short SRT North Reactor provides a higher level of toxicity resiliency and ability to recover from a toxic upset. This has been experienced at HFCAWTP in the past and is a concern of the City staff.

Table 7.4-1: Alternative 1 – Optimize Existing Model Results

Parameter	units	Current AA	Future AA	Future M30
Influent				
Influent Flow	mgd	60.0	80.0	112.9
PE flow to North Reactors	mgd	41.7	63.4	93.1
PE flow to South Reactors	mgd	24.0	24.0	29.0
North Reactors				
MLSS to FSTs	mg/L	1,400	1,400	1,400
SRT	days	0.50	0.52	0.55
North FST Effluent				
Effluent CBOD	mg/L	14.6	14.4	18.4
Effluent NH_3-N	mg/L	19.4	19.7	19.1
South Reactors				
MLSS to FSTs	mg/L	3,400	3,400	4,250
Internal Mixed Liquor Recycle Flow	mgd	31.0	31.0	31.0
Aerobic SRT	days	5.33	5.28	5.13
South FST Effluent				
Effluent CBOD	mg/L	1.6	1.7	2.4
Effluent NH3-N	mg/L	0.05	0.05	0.08
Effluent NO3-N	mg/L	10.5	13.2	13.1
Denitrification Filter Influent				
NOx Load	ppd	5,600	9,370	13,100
Digesters				
Volatile Solids Destruction	%	59%	58%	57%
Biogas Flow	cfm	620	837	1,032

Capital Cost Estimate

The following assumptions were used to develop an estimate of the capital costs for Alternative 1:

- Only four (4) of the North Reactors are expected to be needed for future operation. Reactor No. 3 is currently being rehabilitated, including concrete repair and new aerators in each stage. Concrete repair was assumed for the other five (5) of the north reactors, and new aerators were assumed in three (3) additional reactors.
- Rehabilitation of the high purity oxygen generation system No. 1 was based on recent costs to rehabilitate high purity oxygen generation system No. 2.

- South Reactor No. 2-4 improvement costs were based on costs to make improvements to South Reactor No. 1.
- Costs for FSTs assume similar dimensions to existing and includes pile foundation. The Engineering and Management for this portion of the project was assumed to be 10%.

A summary of the capital costs required for Alternative 1 are presented in **Table 7.4-2**.

Table 7.4-2: Alternative 1 – Optimize Existing Capital Cost Estimate

Item	Cost
NORTH REACTORS	
Cleaning and Rehab (5 tanks)	$ 1,000,000
Replace 12 aerators (3 tanks)	$ 2,500,000
Rehab HPO Generation System	$ 2,900,000
SOUTH REACTORS	
MLE improvements	$ 5,100,000
4 FSTs	$ 21,290,000
RAS PS	$ 1,904,000
Subtotal	**$ 34,700,000**
30% Contingency	$ 10,400,000
Bare Construction Costs	$ 45,100,000
20% Overhead and Profit; General Conditions	$ 9,020,000
Total Construction Costs	$ 54,120,000
20% Management and Engineering	$ 7,200,000
Total	**$ 61,300,000**

Operational Cost Estimate

Operating costs for Alternative 1 were generated by accounting for major pieces of equipment electrical costs, equipment maintenance costs, full time equivalent operator and maintenance personal costs. All costs were projected over a 20-year period, a yearly inflation rate cost of 3.0 % was allocated unless otherwise specified below. For Alternative 1, the following assumptions were used to generate costs:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over a 20-year period. This cost was used to determine power consumption costs for major pieces of equipment as listed below.
- HPO aerators power consumptions were generated by determining the power demand for each of the four stages within each reactor. For the Current AA scenario, two reactors are required to be in service, and for the Future AA scenario, three reactors are needed to be in service. From the power demand calculations, kWh needs were determined and used to forecast power costs.
- Equipment maintenance costs associated with lubrication, filters, minor replacement components, bearings, mechanical seals, or other necessary replacement parts was considered. A monetary cost per hourly run time was used in generating this cost.
- HPO oxygen generator power costs were calculated by using power metered data from year 2016. An average power consumption cost per million gallons per day value was calculated. This cost was projected over a 20-year period starting with the current annual average flow of 60 MGD to the future annual average flow of 80 MGD. The average power consumption cost of 14.83 KW/MGD was determined.
- HPO oxygen generator maintenance costs were included, cost associated with this effort were taken from Greeley and Hansen Jan 2012 Tech Memo, "Comparison of Alterative Process HPO Evaluation". This report provided an estimated maintenance cost and a yearly inflation rate was applied for use in the net present worth evaluation.
- The South Reactor power consumption estimates were generated by determining the power demand for the blowers. From the calculated power demand, KWh needs were calculated and used to determine power costs. Power demands were calculated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads.
- Full time equivalent operators and maintenances personnel were projected for full time operation all year round. Average operator and maintenance labor rates costs for direct salary were used, with a 3% inflation rate added for the 20-year period. A full time equivalent operator was assumed for the HPO system, and one full time equivalent operator was assumed for the South Reactor aeration system. Four full time equivalents were assumed for maintenance technician for both systems except for these costs were estimated based on 40-hour work weeks.
- Process pumping requirements for the IMLR needs for the South Reactor were determined over the 20-year period. Power demands were calculated based on preliminary horsepower estimates.
- Methanol operating costs were estimated by using the GPS-X model output nitrate loads. The ratio of required pounds of methanol per pounds of nitrate was assumed to be 3.4.

Historical unit price for bulk methanol costs was also determined by evaluating yearly average price from 1994 through 2017 to project potential future escalated costs. The future cost projection for 10 years into the 20-year period was conservatively used ($1.41 / gal). Operating costs also included pumping power costs, maintenance and labor costs.

- Digester biogas production were estimated by using the GPS-X biosolids production projections. Cogeneration equipment was assumed to be used for estimating power production ($/MMBTU).
- Solids hauling costs were generated by using the GPS-X biosolids production projections. From these projections anaerobically digested sludge production quantities were calculated. These sludge projections were used to generate dewatered cake quantities. Yearly estimates of wet tons of cake were used to determine land application hauling costs.

Table 7.4-3 summarizes the estimate operating costs for 20-year period.

Table 7.4-3: Alternative 1 – Optimize Existing Operational Costs

Items	Cost
HPO O2 Generator Cost	$ 32,843,000
HPO Aerators Cost	$ 7,642,000
HPO Maintenance Cost	$ 3,977,000
South Reactor Aeration Cost	$ 41,403,000
Pumping	$ 238,000
Methanol Usage	$ 37,000,000
Digester Gas Production	$ (23,829,000)
Solids Hauling	$ 29,605,000
Total Life Cycle Operational Cost	**$ 128,879,000**

7.4.2 Alternative 2 – MLE in Parallel

Alternative 2 involves conversion from a series operation of the North and South Stages to parallel operation. This provides a major benefit to wet weather operation of the final sedimentation tanks and therefore no new tanks are required for this option. Because the two stages are operated in parallel, each set of reactors must provide complete carbon oxidation, nitrification and ideally some denitrification to reduce the methanol addition costs. Both the North and South Reactors would be converted to MLE configurations with anoxic zone mixing and IMLR pumps. The effluent of the North and South Reactors will combine at Junction Chamber No. 6 upstream of the denitrification filters. The process modifications for Alternative 2 include:

- Modification to the Main Pump Station to allow for control of the flow split between the North and South Reactors. Two 9-foot wide downward acting, motor actuated weir gates can be installed in the Main Pump Station discharge channel, one at each end. Ultrasonic flow meters will provide the measurement of flow over each weir gate to the North Reactors (HPO Reactors) and the South Reactors. Programming can allow either a percentage of the total flow, or a specified flow rate be diverted through the spike

lines. Flow through both the 66-inch and the 20-inch spike lines can also be confirmed through their respective mag meters in Junction Chamber No. 5.

- Modifications to South Reactors No. 2 – 4 to reflect the MLE configuration in place in Reactor No. 1., including new mixers for anoxic operation in Stages No. 1 through 3, New Fine Bubble Diffusers, IMLR pumps rated for 4Q to send nitrate back to the anoxic zones. South Reactor No. 2-4 improvement costs were based on costs to make improvements to South Reactor No. 1. Additional cost incorporated for larger IMLR pump and piping in each Reactor.
- All six (6) of the North Reactors are expected to be needed for future operation. Concrete repair and aeration improvements were assumed for all six (6) reactors.
- Conversion of the North Reactors to the MLE configuration including, providing new mixers in the anoxic zone and IMLR pumps rated for 4Q.

Regarding aeration in the North Reactors, keeping the HPO system and converting to diffused aeration were both considered. If the HPO system is kept in place, modifications will be made to address the concerns related to low pH inhibition of the nitrifying bacteria. The specific process modifications for related to the aeration system for each alternative are described in the capital cost and operational cost sections below.

Predicted Performance

Regardless of the chosen method of aeration, similar effluent quality is expected to be achieved for the MLE in parallel mode of operation. A summary of the key model results is presented in **Table 7.4-4**. The flow split of primary effluent between the North and South reactors is balanced to achieve optimal denitrification while also maintaining the minimum aerobic SRT of 5 days for nitrification and the IMLR flow for each reactor was capped at 4Q. Both the North and South reactors achieve complete nitrification, as well as some denitrification. The North Reactors have a higher effluent nitrate concentration due to limited anoxic volume available in the 4-stage configuration. Overall the combined denitrification filter influent NOx-N load is much lower than the Optimize Existing Scenario. Due to the extended SRT system and utilization of carbon for nutrient removal in the liquid stream, there is lower solids destruction and gas production in the digesters.

Table 7.4-4: Alternative 2 - MLE In Parallel Model Results

Parameters		Current AA	Future AA	Future M30
Influent				
Influent Flow	mgd	60.0	80.0	112.9
PE flow to North Reactors	mgd	34.1	44.6	63.7
PE flow to South Reactors	ppd	30.0	41.0	56.0
North Reactors				
MLSS to FSTs	mg/L	3,800	3,800	4,800
Aerobic SRT	days	9.83	6.60	5.95
Internal Mixed Liquor Recycle Flow	mgd	140	180	180
North FST Effluent				
Carb Effluent CBOD	mg/L	4.2	4.9	6.6
Carb Effluent NH3-N	mg/L	0.1	0.1	0.2
Carb Effluent NO3-N	mg/L	5.9	6.0	6.1
South Reactors				
Nit MLSS to FSTs	mg/L	3,800	3,500	4,400
Nit Internal Recycle Flow	mgd	120.00	160.00	160.00
Nit Aerobic SRT	days	12.27	6.88	6.59
South FST Effluent				
Nit Effluent NH3-N	mg/L	0.07	0.08	0.12
Nit Effluent NO3-N	mg/L	4.4	4.5	4.7
Denit Filter Influent				
Denit Filter Influent NOx	ppd	2,827	3,831	5,616
Digesters				
Volatile Solids Destruction	%	52%	52%	51%
Biogas Flow	cfm	428	596	747

Capital Cost Estimate (Keep HPO)

In addition to the general MLE modifications described above, the improvements required to continue to operate the HPO system in this configuration include:

- New aerators were assumed for Stages 2-4 for five (5) of the North Reactors, because Reactor No. 3 is currently being rehabilitated, including concrete repair and new aerators in each stage.
- Rehabilitation of the high purity oxygen generation system No. 1 was based on recent costs to rehabilitate high purity oxygen generation system No. 2.
- Adjustments necessary to prevent nitrification inhibition include opening Stage 4 to provide increased venting of CO_2, moving the vent from stage 3 to stage 4 and blocking the headspace between these stages.

- Due to the high operating DO, it is recommended that the IMLR flow be held for de-aeration prior to returning to the anoxic zone, using 2 of the additional North Final Sedimentation Tanks.

A summary of the capital costs required for Alternative 2(H) are presented in **Table 7.4-5** and **Figure 7.4-2**.

Table 7.4-5: Alternative 2(H) – MLE in Parallel (Keep HPO) Capital Cost Estimate

Item	Cost
Spike Flow Control	$400,000
NORTH REACTORS	
Cleaning and Rehab (5 tanks)	$ 1,000,000
Replace 15 aerators (5 tanks)	$ 2,820,000
Rehab HPO Generation System	$ 2,900,000
MLE Improvements	$ 6,680,000
SOUTH REACTORS	
MLE improvements	$5,700,000
Subtotal	**$ 19,500,000**
30% Contingency	$ 5,800,000
Bare Construction Costs	$ 25,295,000
20% Overhead and Profit; General Conditions	$ 5,060,000
Total Construction Costs	$ 30,355,000
20% Management and Engineering	$ 6,070,000
Total	**$ 36,400,000**

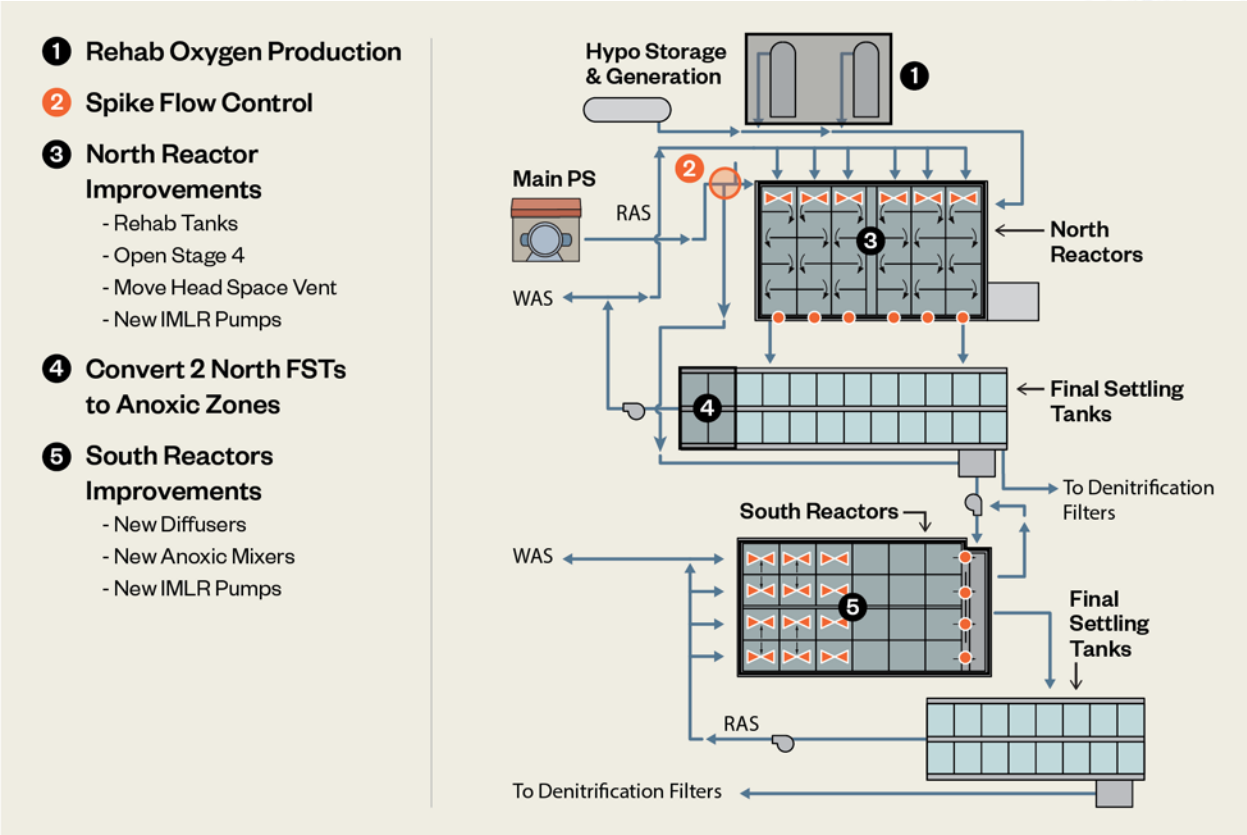

Figure 7.4-2: Summary of Capital Improvements Req. for Alternative 2H-MLE In Parallel (Keep HPO)

Operational Cost Estimate

Operating costs for Alternative 2(H) were generated by accounting for major pieces of equipment electrical costs, equipment maintenance costs, full time equivalent operator and maintenance personal costs. All costs were projected over a 20-year period, a yearly inflation rate cost of 3.0 % was allocated unless otherwise specified below. Similar to Alternative 1, the following assumptions to generate costs were used:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over a 20-year period. This cost was used to determine power consumption costs for major pieces of equipment as listed below.
- HPO aerators power consumptions were generated by determining the higher power demand for stage 2 and stage 3 within each reactor. For both the Current AA and the Future AA scenario, all six reactors are required to be in service. From the power demand calculations, kWh needs were determined and used to forecast power costs.
- Equipment maintenance costs associated with lubrication, filters, minor replacement components, bearings, mechanical seals, or other necessary replacement parts was considered. A monetary cost per hourly run time was used in generating this cost.

- HPO oxygen generator power costs were calculated by using power metered data from year 2016. An average power consumption cost per million gallons per day value was calculated. This cost was projected over a 20-year period starting with the Current AA flow of 60 MGD to the Future AA of 80 MGD. The average power consumption cost of 14.83 KW/MGD was determined.
- HPO oxygen generator maintenance costs were included, cost associated with this effort were taken from Greeley and Hansen Jan 2012 Tech Memo, "Comparison of Alterative Process HPO Evaluation". This report provided an estimated maintenance cost and a yearly inflation rate was applied for use in the net present worth evaluation.
- The South Reactor power consumption estimates were generated by determining the power demand for the blowers. From the calculated HP demand, KWh needs were calculated and used to determine power costs. Power demands were calculated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads.
- Full time equivalent operators and maintenances personnel were projected for full time operation all year round. Average operator and maintenance labor rates costs for direct salary were used, with a 3% inflation rate added for the 20-year period. A full time equivalent operator was assumed for the HPO system, and one full time equivalent operator was assumed for the South Reactor aeration system. Four full time equivalents were assumed for maintenance technician for both systems except for these costs were estimated based on 40-hour work weeks.
- Process pumping requirements for the IMLR needs for North and South Train Reactor were determined over the 20-year period. Power demands were calculated based on preliminary horsepower estimates.
- Methanol operating costs were estimated by using the GPS-X model output nitrate loads. The ratio of required pounds of methanol per pounds of nitrate was assumed to be 3.4. Historical unit price for bulk methanol costs was also determined by evaluating yearly average price from 1994 through 2017 to project potential future escalated costs. The future cost projection for 10 years into the 20-year period was conservatively used ($1.41 / gal). Operating costs also included pumping power costs, maintenance and labor costs.
- Digester biogas production were estimated using the GPS-X biosolids production projections. Cogeneration equipment was assumed to be used for estimating power production ($/MMBTU).
- Solids hauling costs were generated by using the GPS-X biosolids production projections. From these projections anaerobically digested sludge production quantities were calculated. These sludge projections were used to generate dewatered cake quantities. Yearly estimates of wet tons of cake were used to determine land application hauling costs.

Table 7.4-6 summarizes the estimate operating costs for 20-year period.

Table 7.4-6: Alternative 2(H) – MLE in Parallel (Keep HPO) Operational Costs

Items	Cost
HPO O2 Generator Cost	$ 32,843,000
HPO Aerators Cost	$ 20,690,000
HPO Maintenance Cost	$ 3,977,000
South Reactor Aeration Cost	$ 36,011,000
Pumping	$ 4,686,000
Methanol Usage	$ 17,400,000
Digester Gas Production	$ (16,161,000)
Solids Hauling	$ 26,741,000
Total Life Cycle Operational Cost	$ 126,187,000

Capital Cost Estimate (Convert to Diffused Air)

In addition to the general MLE modifications, the improvements required to convert to diffused aeration in this configuration include:

- Modifications to the North Aeration tanks to open the stages
- Addition of new fine bubble diffusers, turbo blowers and associated aeration piping. This cost also includes a new blower building.

A summary of the capital costs required for Alternative 2(D) are presented in **Table 7.4-7** and **Figure 7.4-3**.

Table 7.4-7: Alternative 2(D) – MLE in Parallel (Convert to Diffused Air) Capital Cost Estimate

Item	Cost
Spike Flow Control	$400,000
NORTH REACTORS	
Basin Rehab and Modification (6 tanks)	$5,500,000
New Diffused Aeration System	$6,775,000
MLE Improvements	$2,425,000
SOUTH REACTORS	
MLE improvements	$ 5,700,000
Subtotal	$ 20,800,000
30% Contingency	$ 5,400,000
Bare Construction Costs	$ 27,000,000
20% Overhead and Profit; General Conditions	$ 5,400,000
Total Construction Costs	$ 32,400,000
20% Management and Engineering	$ 6,480,000
Total	**$ 38,900,000**

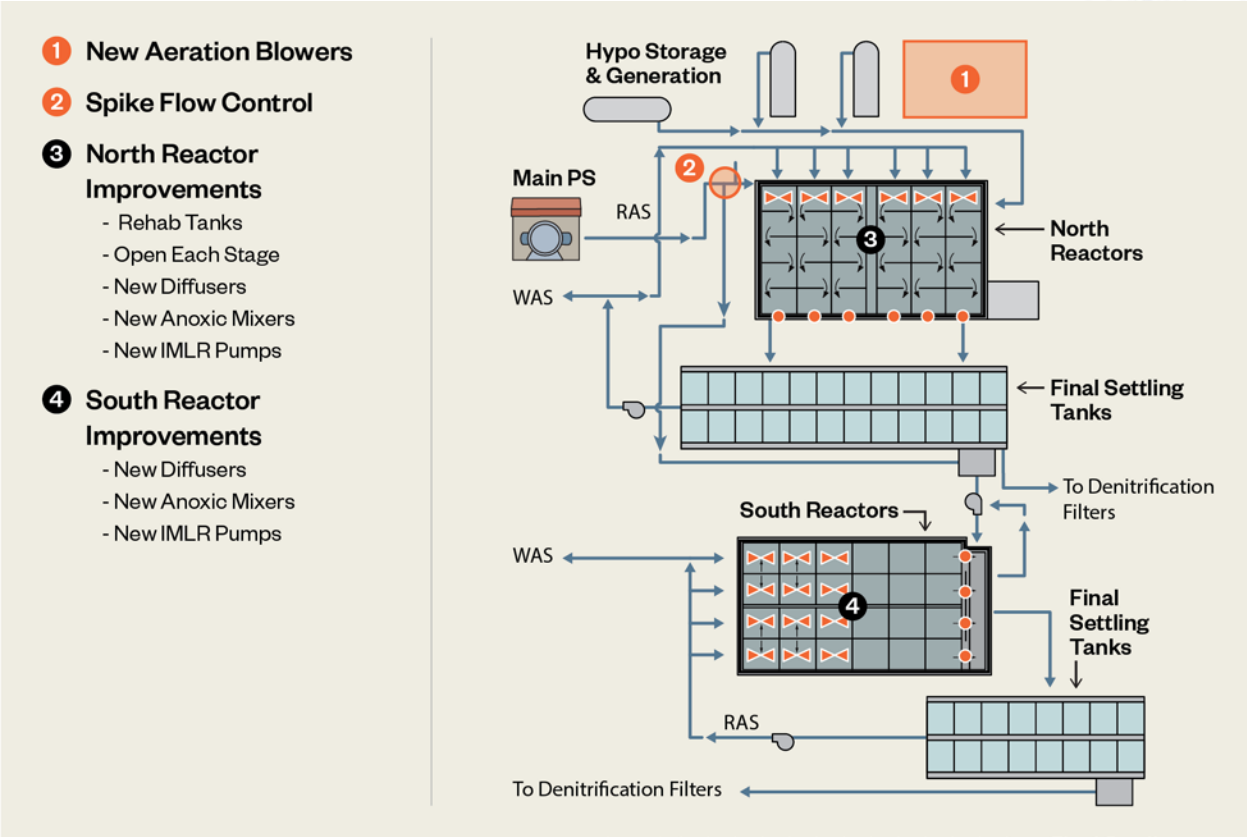

Figure 7.4-3: Summary of Capital Improvements Req. for Alternative 2D- MLE In Parallel (Diffused Air)

Operational Cost Estimate

Operating costs for Alternative 2D were generated by accounting for major pieces of equipment electrical costs, equipment maintenance costs, full time equivalent operator and maintenance personal costs. All costs were projected over a 20-year period, a yearly inflation rate cost of 3.0 % was allocated unless otherwise specified below. Similar to previous alternatives, this alternative accounts for slight variations in operational cost, the following assumptions to generate costs were used:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over a 20-year period. This cost was used to determine power consumption costs for major pieces of equipment as listed below.
- The North Reactor HPO system is converted to diffused air system. Power consumptions were generated by determining the power demand for new blowers. From the calculated power demand, KWh needs were calculated and used to determine power costs. Power demands were generated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads in this configuration.
- Equipment maintenance costs associated with lubrication, filters, minor replacement components, bearings, mechanical seals, or other necessary replacement parts was considered. A monetary cost per hourly run time was used in generating this cost.

- The South Reactor power consumption estimates were generated by determining the power demand for the blowers. From the calculated power demand, KWh needs were calculated and used to determine power costs. Power demands were calculated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads.
- Full time equivalent operators and maintenances personnel were projected for full time operation all year round. Average operator and maintenance labor rates costs for direct salary were used, with a 3% inflation rate added for the 20-year period. A full time equivalent operator was assumed for the North Reactor aeration system, and one full time equivalent operator was assumed for the South Reactor aeration system. Four full time equivalents were assumed for maintenance technician for both systems except for these costs were estimated based on 40-hour work weeks.
- Process pumping requirements for the IMLR needs for North and South Train Reactor were determined over the 20-year period. Power demands were calculated based on preliminary horsepower estimates.
- Methanol operating costs were estimated by using the GPS-X model output nitrate loads. The ratio of required pounds of methanol per pounds of nitrate was assumed to be 3.4. Historical unit price for bulk methanol costs was also determined by evaluating yearly average price from 1994 through 2017 to project potential future escalated costs. The future cost projection for 10 years into the 20-year period was conservatively used ($1.41 / gal). Operating costs also included pumping power costs, maintenance and labor costs.
- Digester biogas production were estimated using the GPS-X biosolids production projections. Cogeneration equipment was assumed to be used for estimating power production ($/MMBTU).
- Solids hauling costs were generated by using the GPS-X biosolids production projections. From these projections anaerobically digested sludge production quantities were calculated. These sludge projections were used to generate dewatered cake quantities. Yearly estimates for wet tons of cake were used to determine land application hauling costs.

Table 7.4-8 summarizes the estimate operating costs for 20-year period.

Table 7.4-8: Alternative 2D – MLE in Parallel (Convert to Diffused Air) Operational Costs

Items	Cost
North Reactor Aeration	$ 42,641,000
South Reactor Aeration	$ 36,011,000
Pumping	$ 4,686,000
Methanol Usage	$ 17,400,000.00
Digester Gas Production	$ (16,161,000)
Solids Hauling	$ 26,741,000
Total Life Cycle Operational Cost	**$ 111,318,000**

7.4.3 Alternative 3 – Step Feed in Parallel

Similar to Alternative 2, Alternative 3 also involves conversion from a series operation of the North and South Stages to parallel operation. Both the North and South Reactors would be converted to a step feed BNR configuration with anoxic zone mixing and piping to divert influent flow to the anoxic stages. In the case of the North Reactors, Stage 3 was chosen for the anoxic zone, and in the South Reactors, Stages 3 and 4 were designated as anoxic zones. The general process modifications for Alternative 3 include:

- Modification to the Main Pump Station to allow for control of the flow split between the North and South Reactors.
- All six (6) of the North Reactors are expected to be needed for future operation. Concrete repair was assumed for all six (6) reactors.
- Modifications to North Reactors to allow for step feed operation, including new mixers for anoxic operation in Stages No. 3, and piping for step feed flow to Stage 3.
- Modifications to South Reactors to allow for step feed operation, including new mixers for anoxic operation in Stages No. 3-5, New Fine Bubble Diffusers and piping for step feed flow to Stage 3.
- Modifications to the North Aeration tanks to open the stages
- Addition of new fine bubble diffusers, turbo blowers and associated aeration piping and a new blower building

Regarding aeration in the North Reactors converting to diffused aeration is presented below. The difference between converting to diffused air and continuing operation of the HPO was captured in the evaluation of Alternative 2. Either aeration option is a possibility for Step Feed BNR as well. The relative differences between operational and capital costs from the previous sections can be used for reference.

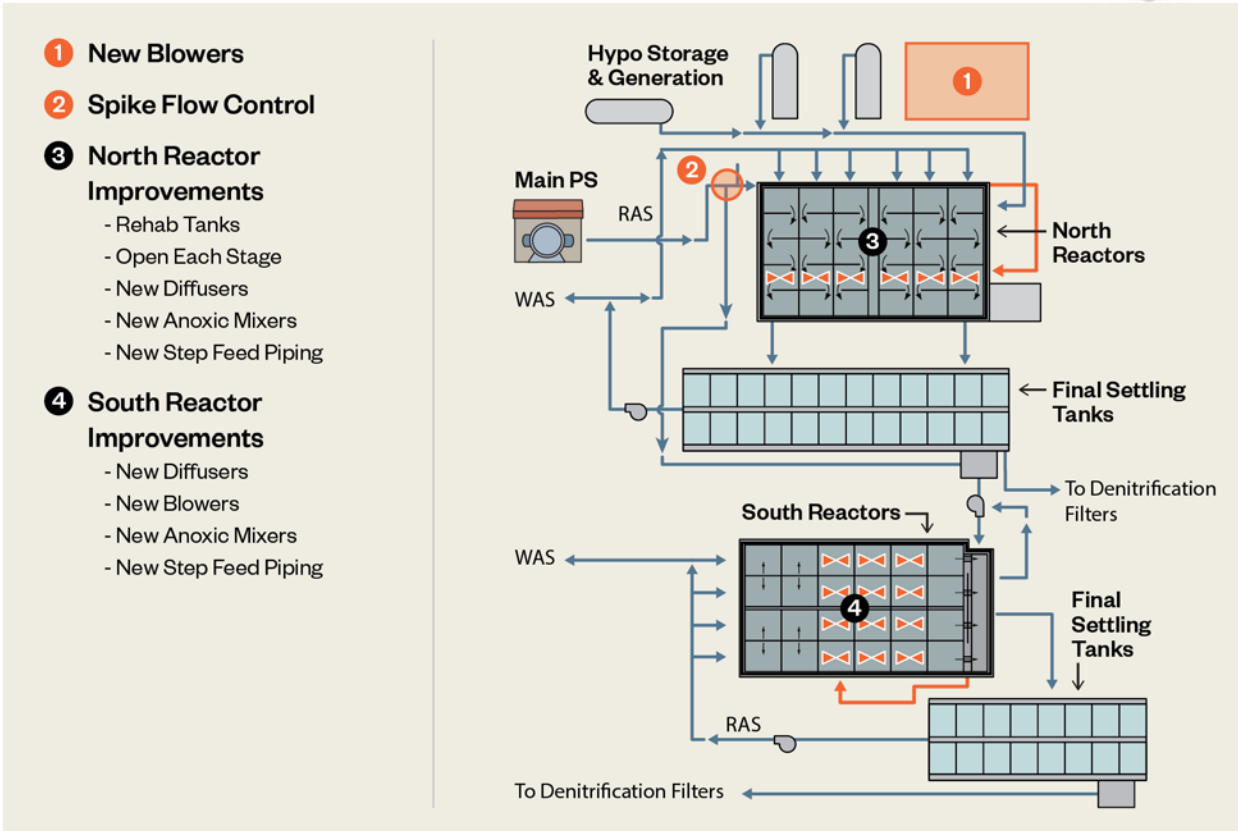

Figure 7.4-4: Summary of Capital Improvements Required for Alternative 3D - Step Feed BNR in Parallel (Diffused Air)

Predicted Performance

A summary of the key model results for the Step Feed BNR operation are presented in **Table 7.4-9**. The flow split of primary effluent between the North and South reactors is balanced to achieve optimal denitrification while also maintaining the minimum aerobic SRT of 5 days for nitrification. The percentage of step feed to the anoxic zones was varied to optimize denitrification while also achieving a low effluent NH_3-N concentration. Both the North and South Reactors achieve complete nitrification, as well as some denitrification. The North Reactors have a higher effluent nitrate concentration due to limited anoxic volume available in the 4-stage configuration. Overall the combined denitrification influent NOx-N load is lower than the Optimize Existing Alternative, but higher than the MLE configuration. This is because the reactor configuration is not ideal for step feed BNR. Typically, similar concentrations can be achieved with a step feed BNR and MLE configuration, but Step Feed requires multiple step feed points to optimize denitrification. A similar solids destruction and gas production in the digesters is achieved in the Step feed BNR and MLE configurations.

Table 7.4-9: Alternative 3 – Step Feed BNR in Parallel Model Results

Parameters		Current AA	Future AA	Future M30
Influent				
Influent Flow	mgd	60.0	80.0	112.9
PE flow to North Reactors	mgd	34.1	45.6	63.7
PE flow to South Reactors	ppd	30.0	40.0	56.0
North Reactors				
MLSS to FSTs	mg/L	3,800	3,800	4,800
Aerobic SRT	days	10.90	7.03	6.58
Step Feed % to Stage 3	%	30%	30%	30%
North FST Effluent				
Carb Effluent CBOD	mg/L	6.2	4.8	6.5
Carb Effluent NH3-N	mg/L	0.32	0.39	0.52
Carb Effluent NO3-N	mg/L	10.5	10.6	9.6
South Reactors				
Nit MLSS to FSTs	mg/L	3,800	3,500	4,400
Nit Aerobic SRT	days	13.51	7.82	7.20
Step Feed % to Stage 3	%	40%	40%	40%
South FST Effluent				
Nit Effluent NH3-N	mg/L	0.10	0.12	0.21
Nit Effluent NO3-N	mg/L	6.9	7.0	6.4
Denit Filter Influent				
Denit Filter Influent NOx	ppd	4,800	6,510	8,400
Digesters				
Volatile Solids Destruction	%	52%	51%	51%
Biogas Flow	cfm	412	593	743

Capital Cost Estimate (Convert to Diffused Air)

A summary of the capital costs required for Alternative 3(D) are presented in **Table 7.4-10**.

Table 7.4-10: Alternative 3(D) – Step Feed in Parallel (Convert to Diffused Air) Capital Cost Estimate

Item	Cost
Spike Flow Control	$400,000
NORTH REACTORS	
Basin Rehab and Modification (6 tanks)	$5,500,000
New Diffused Aeration System	$6,775,000
Step Feed Improvements	$1,425,000
SOUTH REACTORS	
Step Feed Improvements	$ 2,140,000
New Diffusers, Tank Modifications	$ 2,490,000
Subtotal	**$18,900,000**
30% Contingency	$ 5,700,000
Bare Construction Costs	$ 24,640,000
20% Overhead and Profit; General Conditions	$ 4,900,000
Total Construction Costs	$ 29,600,000
20% Management and Engineering	$ 5,910,000
Total	**$ 35,500,000**

Operational Cost Estimate

Operating cost for Alternative 3(D) were generated by accounting for major pieces of equipment electrical costs, equipment maintenance costs, full time equivalent operator and maintenance personal costs. All costs were projected over a 20-year period, a yearly inflation rate cost of 3.0 % was allocated unless otherwise specified below. Similar to previous alternatives the following assumptions to generate costs were used:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over a 20-year period. This cost was used to determine power consumption costs for major pieces of equipment as listed below.
- The North Reactor HPO system is converted to diffused air system. Power consumptions were generated by determining the HP demand for new blowers. From the calculated

power demand, KWh needs were calculated and used to determine power costs. HP demands were generated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads in this configuration.

- Equipment maintenance costs associated with lubrication, filters, minor replacement components, bearings, mechanical seals, or other necessary replacement parts was considered. A monetary cost per hourly run time was used in generating this cost.
- The South Reactors power consumptions were generated by determining the power demand for the blowers. From the calculated HP demand, KWh needs were calculated and used to determine power costs. Power demands were calculated based on air demand preliminary calculations to oxidize BOD and TKN at Current AA and Future AA loads.
- Full time equivalent operators and maintenances personnel were projected for full time operation all year round. Average operator and maintenance labor rates costs for direct salary were used, with a 3% inflation rate added for the 20-year period. A full time equivalent operator was assumed for the HPO system, and one full time equivalent operator was assumed for the South Reactor system. Four full time equivalents were assumed for maintenance technician for both systems except for these costs were estimated based on 40-hour work weeks.
- Methanol operating costs were estimated by using the GPS-X model output nitrate loads. The ratio of required pounds of methanol per pounds of nitrate was assumed to be 3.4. Historical unit price for bulk methanol costs was also determined by evaluating yearly average price from 1994 through 2017 to project potential future escalated costs. The future cost projection for 10 years into the 20-year period was conservatively used ($1.41 / gal). Operating costs also included pumping power costs, maintenance and labor costs.
- Digester biogas production were estimated using the GPS-X biosolids production projections. Cogeneration equipment was assumed to be used for estimating power production ($/MMBTU).
- Solids hauling costs were generated by using the GPS-X biosolids production projections. From these projections anaerobically digested sludge production quantities were calculated. These sludge projections were used to generate dewatered cake quantities. Yearly estimates for wet tons of cake were used to determine land application hauling costs.

Table 7.4-11 summarizes the estimate operating costs for 20-year period.

Table 7.4-11: Alternative 3(D) – Step Feed in Parallel (Keep HPO) Operational Costs

Item	Cost	
North Train Aeration	$	42,664,000
South Train Aeration	$	36,257,000
Methanol Usage	$	29,000,000
Digester Gas Production	$	(16,161,000)
Solids Hauling	$	26,330,000
Total Life Cycle Operational Cost	**$**	**118,090,000**

7.4.4 Summary of Capital and Operational Costs

Capital and Operational Costs for Alternatives 1-3 are presented in **Table 7.4-12**. The capital cost associated with Alternative 1: Optimize Existing is the highest due to the cost to add 4 new South FSTs and the lowest overall capital cost alternative is Alternative 3(D). The operations costs are lowest for Alternative 2D, which achieves the best nitrogen removal at the lowest aeration costs. Maintaining the existing HPO system is anticipated to have both a higher capital and operational cost than converting to diffused aeration, as shown in the difference between Alternatives 2(H) and 2(D). The capital and operational costs for each alternative were translated into a weighted ranking in the Scoring Alternatives Section below.

Table 7.4-12: Summary of Capital and Operational Costs for the Alternatives

Alternative		Capital Cost	Operational Cost (20 year)
1	Optimize Existing	$ 61.3 M	$ 128.9 M
2(H)	MLE in Parallel (Keep HPO)	$ 36.4 M	$ 126.2 M
2(D)	MLE in Parallel (Convert to Diffused Air)	$ 38.9 M	$ 111.3 M
3(D)	Step Feed in Parallel (Convert to Diffused Air)	$ 35.5 M	$ 118.1 M

7.4.5 Flexibility for Future Nutrient Removal Upgrades

The ability to implement future nutrient removal improvements, including mainstream deammonification and phosphorus removal, were considered as part of the evaluation criteria for each alternative.

7.4.6 Next Generation Nitrogen Removal

Based on review of the process requirements, status of the technology and discussions with the City at the workshops, mainstream deammonification was determined not to be a feasible option for HFCAWTP in the near term. However, it was considered important that the selected alternative does not preclude future implementation with a phased approach. The City would like to maintain the flexibility to potentially implement this process in the future as the technology matures and becomes more widely implemented. The benefits of this process include reduced aeration and significantly reduced carbon requirements for nitrogen removal, which also allows significant diversion of influent carbon to maximize digester gas production. The ideal configuration for this technology is an AB process, in which a very short SRT A stage process is operated for carbon removal upstream of a B stage operated for deammonification. The second stage requires the use of nutrient based aeration control in these reactors and seeding of anammox bacteria from the sidestream deammonification process. Cyclones or micro screens would also be required for selection of the denser anammox bacteria. A downstream polishing step to ensure complete ammonia removal and additional NOx polishing would be required to meet a TN of 3 mg/L.

For Alternative 1, the existing process can be operated as an AB process with minor process modifications. New and more complex aeration controls would need to be implemented in the South Reactors and a small aerobic reactor would be required downstream.

For Alternative 2 and 3, there are two options to achieve the AB process. One option is to return to the Series operation of the North and South Reactors, similar to Alternative 1. The ability to operate in Series mode would be maintained, however the improvements made to the reactors for parallel BNR operation would be abandoned. The other option is to maintain the parallel operation, implementing chemically enhanced primary treatment (CEPT) in the primary sedimentation tanks to achieve increased carbon removals. Both North and South Reactors would be required to be updated with nutrient based aeration controls and polishing reactor would be required downstream of each train. Implementing the AB process in parallel results in a greater capital cost than in series.

7.4.7 Phosphorus Removal

The City is currently not required to meet an effluent phosphorus limit; however, it is possible that a limit of 1 mg/L may be imposed in the future. Currently HFCAWTP discharges an effluent TP of between 2 and 3 mg/L on average. A conceptual level evaluation was performed to look at the options for each alternative. Phosphorus can be removed either chemically or biologically.

Chemical phosphorus removal is achieved through the addition of metal salts to the wastewater. Reactive phosphate forms a bond with the precipitates that are formed and are ultimately removed through solids separation processes (secondary clarification or filtration). Depending on the effluent target, metal salts may be added at one or several locations throughout the liquid stream or sidestreams. The required improvements would include chemical feed storage and feed facilities.

Enhanced biological phosphorus removal (EBPR) is achieved through the proliferation of a bacteria known as polyphosphate accumulating organisms (PAOs). PAOs have a unique metabolism which allows them to store large quantities of phosphorus in their cells when cycled through aerobic and anaerobic environments. To accomplish EBPR, it is necessary to create conditions to select for the growth of PAOs. Traditional EBPR design incorporates a separate, unaerated, mechanically-mixed tank to serve as the anaerobic zone located upstream of the anoxic and aerated reactors. The required anaerobic HRT is approximately 1 hour. The ability to implement EBPR into the treatment process was evaluated for the different alternatives.

For Alternative 1, the additional capacity in the North Reactors can be leveraged to create an anaerobic zone in the first stage of North reactors. These stages will require mechanical mixing, without aeration. A slightly higher SRT (1-2 days) would be required, therefore the operation of all six (6) North Reactors would be operated at future flows. A chemical feed system is recommended for trimming effluent phosphorus, and targeted application of chemical feed would be recommended on the filtrate to reduce the phosphorus loading back to the biological process.

For Alternatives 2 and 3, there is no additional volume available for use as an anaerobic zone. New volume and reconfiguration of the tanks would be required to provide the 1-hour HRT anaerobic zone. An alternative to biological phosphorus removal would be to accomplish phosphorus removal through the addition of chemical.

There is a path forward for implementing mainstream deammonification or phosphorus removal for each alternative, but Alternative 1 provides more flexibility as compared to Alternatives 2 and 3. Both biological and chemical phosphorus removal option are viable potential solutions for meeting a TP limit of 1 mg/L. If HFCAWTP receives a limit for total phosphorus removal in the future, it is recommended that both chemical and biological phosphorus removal be evaluated on a net present worth basis to identify the most cost-effective alternative for the selected core process alternative.

7.4.8 Scoring Alternatives

At the onset of the project, several goals were identified. These included the following.

- Ensuring reliability
- Increasing efficiency
- Lowering operating costs
- Reducing operational and maintenance complexity
- Using proven technologies
- Ensuring potential future regulation can be met
- Reliably managing wet weather flows
- Being consistent with other City initiatives
- Leveraging existing assets
- Providing toxicity resiliency

It is imperative that each of these goals are considered when selecting between viable alternatives. Some of these goals / criteria can be readily quantified. Others are more qualitative and subjective in nature. One method for evaluating quantitative and qualitative criteria is to use a comparison matrix with weighted decision factors. Multiple discussions with City staff resulted in the development of a decision matrix. **Table 7.4-13** is the matrix with weighting of decision factors and scoring for each alternative developed in consultation with the City. The scoring system is based on a scale of 1 to 10 with 10 being the most preferred option.

Life Cycle Operational Cost – Operational costs were developed based on the process model predictions for aeration costs, pumping and mixing costs, chemical addition and digester gas production over a 20-year period. The costs for each alternative were translated into scores, assuming the lowest Life Cycle Operational Cost set at 10.

Capital Cost – Planning level capital costs for the required improvements were developed for each alternative based on relative differences between each alternative (not including projects common to all such as sidestream treatment), as summarized above. The costs for each alternative were translated into scores, assuming the lowest Capital Cost set at 10

Ease of Operation – Ease of operations refers to the operational convenience associated with the alternatives. In general, operational ease accounts for the level of effort required during start-up/shut-down, automation, cleanup, shift operations, convenience, required man-hours, adjustments required during operations, and general everyday operations

Required Maintenance – Maintenance is partially accounted for in the Life Cycle Operational Cost valuation with estimated costs for planned and unplanned maintenance, as well as an allocation specific to parts. The valuation does not account for the inconvenience, duration, or frequency of planned or unplanned maintenance activities, which is the intangible components that the ease of maintenance attempts to quantify.

Future Flexibility - Future flexibility to meet more stringent future nutrient limits was assessed at a high level for each alternative. Scores were assigned based on the ease of implementation of phosphorus removal or next generation nitrogen removal.

Toxicity Resiliency – Toxicity Resiliency was scored for each alternative based on the ability of the process to recover from an inhibitory event. The existing two stage process with the upfront short SRT HPOAS process is considered more resilient to upsets than the longer SRT parallel operation.

Unknown Risks – This category accounts for the regional understanding associated with each alternative and the City's experience operating similar technologies. This non-economic category also accounts for number of installations within the field.

Table 7.4-13: Decision Matrix

Biological Process Alternative	Ranking of Alternatives for Screening								
	Weight %	20%	20%	10%	10%	10%	20%	10%	100%
		Life Cycle Operational Costs	Capital Cost	Ease of Operation	Required Maintenance	Future Flexibility	Toxicity Resiliency	Unknown Risks	Total Score
Optimize Existing	1	8.6	5.8	8	8	10	10	10	8.5
MLE in Parallel (HPO)	2H	8.8	9.8	4	9	7	7	4	7.5
MLE in Parallel (Diffused Air)	2D	10.0	9.1	10	10	7	7	6	8.5
Step Feed in Parallel (Diffused Air)	3D	9.4	10.0	8	9	7	7	6	8.3

As can be seen from the matrix, Alternatives 2(H) and 3(D) are the lowest ranked alternatives, and were removed from further consideration. Alternative 1 (Optimize the existing process) and Alternative 2(D) (Two MLE systems in parallel with conventional diffused air) both tied for the top score. As a result, either option is a good fit for the City.

7.5 Selected Core Process Enhancements

Based upon the results of this evaluation, the City has decided to move forward with Alternative 1: Optimize Existing as the Selected Core Process. A summary of the recommended enhancements is highlighted in **Figure 7.5-1** and are described in more detail below.

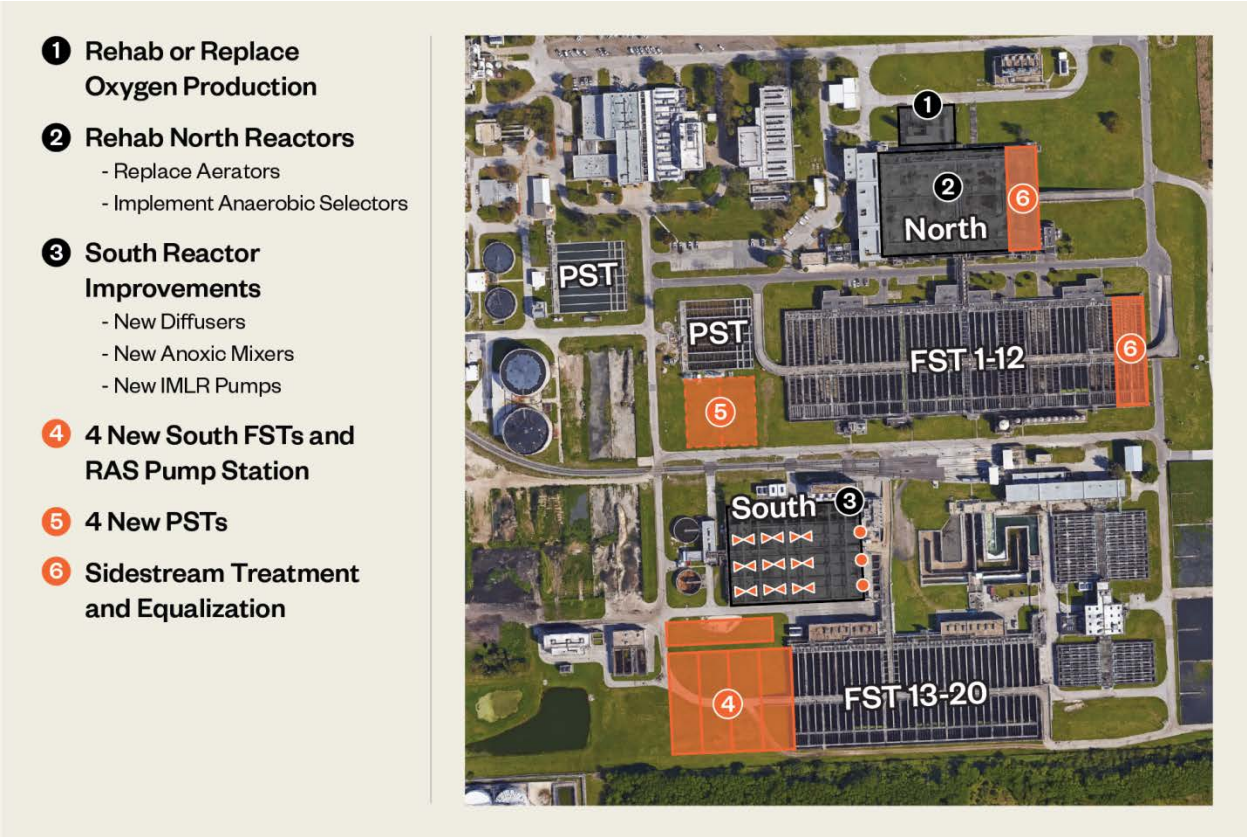

Figure 7.5-1: Selected Alternative: Optimize Existing

7.5.1 Primary Settling Improvements

As noted in Technical Memorandum 6.0 Primary Treatment, the PSTs are currently operated at a relatively high SOR at average conditions. Despite this condition, good solids removal is observed (60% on average). It is important that the PSTs continue to achieve good solids removal performance at future conditions to avoid lowering the capacity of the downstream treatment processes. In order to maintain similar performance that is currently observed, additional PSTs will be required to prevent a decline in the solids removal rate that is expected at higher overflow rates. The addition of four primary sedimentation tanks would provide the necessary surface area to achieve similar overflow rates to those that are experienced currently at the future projected flows. Stress testing and computational fluid dynamics (CFD) modeling of the primary sedimentation tanks is recommended to evaluate the TSS removal efficiencies at higher SORs to determine the timing and number of new primary sedimentation tanks that may

be required in the future. CFD could also be used to evaluate potential optimization of the existing units.

PST CFD model development and calibration will require approximately four (4) days of field investigations and samplings. Data is to be collected both during normal operating conditions and during stress testing (conducted by taking units offline). In general, the data that will be collected during these events include:

- Settling properties of the sludge: zone, discrete and compression rates
- Flocculation parameters
- Dispersed suspended solids (DSS) and flocculated suspended solids
- Sedimentation tank influent TSS
- Underflow suspended solids concentration
- Sludge blanket depth
- Clarifier solids profile
- Effluent flow and underflow rate

Based on data collected during the field sampling and stress testing, the consultant will calibrate a CFD model for the PSTs which will be used for the evaluation of the existing sedimentation tank capacity and planning of new sedimentation tank construction for the future. The costs associated with primary treatment recommendations is presented in a separate memo.

7.5.2 North Reactor Improvements

Anaerobic Selector

Implementing an anaerobic selector at the head of the North Reactors is recommended to help improve settling conditions and to control foam. The existing aerators are already in need of repair or replacement, so it would be advantageous to replace the surface aerators in the first stage of each of the North Reactors with a submerged mixer. The oxygen feed controls will need to be shifted to Stage 2. To address loss of oxygen transfer in Stage 1, more North Reactors would be brought online, or larger aerators may be considered for installation in Stages 2 – 4. The preferred approach is larger aerators with variable frequency drive controls to maximize efficiency. The aerators in Reactor #3 will be replaced soon as part of an ongoing project. These aerators may require modifications to be consistent with the other reactors if the anaerobic selector is implemented. An oxygen dissolution evaluation is recommended during design to determine the new horsepower requirements for Stages 2 - 4.

This process change is expected to improve settling and may also provide conditions to accomplish EBPR. It should be noted that if EBPR is implemented, some additional struvite mitigation may be necessary in the digesters. A technology such as AirPrexTM (manufactured by CNP) may be considered for controlled struvite recovery for use as a slow release fertilizer. This process not only prevents nuisance struvite precipitation throughout the plant but has the added benefit of increased sludge dewaterability.

Oxygen Generation Improvements

In the Optimize Existing scenario, the North Reactors will not be operated to achieve nitrification. The use of the HPOAS process is still considered suitable for the short SRT operation, but there may be some opportunities to improve energy efficiency in the oxygen generation system.

HFCAWTP currently uses a cryogenic oxygen generation system, with 2 units rated for 60 ton per day (tpd) capacity. The North Reactors are currently operated for BOD removal only at a 0.5-day SRT. The calculated oxygen requirements on an annual average basis are around 25 tpd, and on average 27-44 tpd are provided to the tanks due to limited turndown and process control. Additional rehabilitation of the existing oxygen generation system will be necessary in the near future, so considerations should be given to replacing the cryogenic system with an alternative technology, such as vacuum pressure swing adsorption (VPSA) system.

Vacuum Pressure Swing Adsorption (VPSA) Systems were first installed commercially in the 1960s, generally for lower flow, lower purity oxygen installations. Technological advances in the past few decades have made VPSA systems more cost-effective at higher flow rates and purities. A VPSA System generally operates with concurrent generation/regeneration cycles in parallel beds. Air enters the system through a blower and is pretreated. In the reaction vessel a zeolite material selectively adsorbs the nitrogen, leaving a concentrated oxygen stream which is delivered to the downstream processes. The adsorption occurs at near ambient temperatures and pressures reducing the energy demand of the system. Although VPSA systems tend to have higher capital costs, they can be turned down to 50% of total capacity which provides opportunity for operational savings. The VPSA System can also be automated to maintain dissolved oxygen set point in the reactors, allowing for more targeted control of the oxygen generation with the demand in the system. In general, electricity usage can be reduced by 30 to 70% as compared to a Cryogenic system.

VPSA units are usually skid mounted and provided in modular units. This modular design can also allow for incremental increases in capacity without replacing the entire system. Assuming supporting infrastructure is in place, the skid-mounting makes installation of the units simpler and faster than a correspondingly sized cryogenic plant. While a cryogenic plant can take hours to ramp up to full production, a VPSA can be fully operational in less than 1 hour. The VPSA units are designed for automatic operation; the unit is PLC controlled to adjust oxygen production based upon demand. This is a key feature of VPSA units as the PLC control allows them to achieve greater efficiency of operation by providing only the amount of oxygen required. This automatic operation may require additional instrumentation in the oxygenation tanks, depending upon the mode of current cryogenic operation. The PLC allows the VPSA to be tied into the existing plant SCADA so that operation can be monitored and controlled from a remote location without need for operators in the field to make adjustments. Generally, operators will only need to perform visual inspections of the equipment in the field.

Maintenance on a VPSA will be less intensive than a similarly sized cryogenic plant. The VPSA operates at a lower pressure and higher temperature than a cryogenic plant so there are fewer safety concerns during operation or maintenance. The lower pressure of a VPSA means that the

blower motors are correspondingly smaller and easier to maintain or replace than the compressor on a similarly sized cryogenic plant. The filter, or sieve, in a VPSA is proprietary; however, the sieve material will not be required to be changed-out over the expected life of the system. The other equipment in the process are items which plant staff are already familiar with, blowers, valves, PLCs, etc. The skid-mounting does allow for easy replacement of worn or damaged parts. Depending upon the manufacturer and unit, spare parts for cryogenic plants may be difficult to source, VPSA spares will generally be easier to come by.

A Life Cycle Cost Analysis (LCCA) was performed to determine whether the cost savings associated with VPSA will outweight the upfront capital cost. The LCCA was based upon historic plant energy usage, input from VPSA vendors and internal project experience, the results of this analysis are shown in **Table 7.5-1.** Three alternatives were evaluated:

1. **Rehab the Second Cryogenic Plant -** The second cryogenic plant will be rehabbed in 3 years and both plants operated for the 20-year life cycle analysis period without further rehabilitation
2. **Construct 2 new VPSA Plants -** Two 60 tpd VPSA plants will be constructed. The existing cryogenic plants will be abandoned in place
3. **Construct 1 new VPSA Plant -** One 60 tpd VPSA plant will be constructed. The existing rehabbed cryogenic plant will be kept operational for use during planned maintenance shutdowns of the VPSA. In lieu of rehabbing the second cryogenic plant, this plant will be abandoned in place

Table 7.5-1: Oxygen Generation Life Cycle Cost Analysis

	Repair Second Cryogenic Plant	Construct 2 New VPSA Plants	Construct 1 New VPSA Plant, Maintain Existing Cryogenic Plant
Subtotal	**$2,900,000**	**$9,100,000**	**$4,550,000**
30% Contingency	$870,000	$2,730,000	$1,370,000
Bare Construction Costs	$3,770,000	$11,830,000	$5,920,000
20% Overhead and Profit; General Conditions	$750,000	$2,370,000	$1,180,000
Total Construction Costs	$4,520,000	$14,200,000	$7,100,000
20% Management and Engineering	$900,000	$2,840,000	$1,420,000
Total Capital Cost	**$5,400,000**	**$17,000,000**	**$8,500,000**
Annual Energy Cost -Present Value	$620,000 [1]	$210,000	$270,000
Total O&M 20-Year Cost -Present Value	$11,200,000	$3,800,000	$4,900,000
Total 20-Year Cost - Present Value	**$16,600,000**	**$20,800,000**	**$13,400,000**

[1] This analysis is based on plant energy use data for 2016 and 2017. As of January 2018, plant staff have lowered energy consumption by approximately 20%.

Other key assumptions for the LCCA include:

- Cryogenic plant rehab is based upon current CIP budget amount. VPSA construction costs are based upon vendor budgetary quotes plus additional factors for ancillary equipment, OH&P (20%), contingency (30%) and Engineering and Management (20%)
- Cryogenic electricity usage is averaged from plant data daily power consumption from Jan 2016 through July 2017. VPSA power consumption is based upon vendor provided numbers for 32tpd (composite average AA over the 20-year period). VPSA/Cryogenic energy consumption assumes the VPSA is available 97% of the time over the 20-year period and assuming 50% turndown limitation.
- The net present worth is presented in 2017 dollars and assumes an electricity rate is $0.081/kW-hr; 3% discount rate over the period in question, subsequent years' electricity usage is subject to inflation at 2% per year.

Based upon the LCCA, it is recommended that the City consider constructing 1 new VPSA plant instead of repairing the second Cryogenic plant in order to take advantage of the operational savings associated with VPSA.

7.5.3 South Reactor Improvements

Modifications to the South Reactors is recommended to reflect the MLE configuration, including new mixers for anoxic operation in Stages No. 1 through 3, New Fine Bubble Diffusers, IMLR pumps to send nitrate back to the anoxic zones. Some improvements have been made to the existing South Reactor No. 1 to reflect this type of configuration, however the City has been experiencing some issues related to operation of some of the new equipment. A preliminary evaluation of the existing aeration equipment and project aeration requirements were performed for the South Reactors.

Existing Aeration Equipment

New panel type fine bubble diffusers were installed in Reactor No. 1. These diffusers have high headloss relative to other fine bubble diffusers and have resulted in increased operating pressure and temperatures for the aeration system. These diffusers have also experienced significant fouling since installation. Reactors No. 2-4, still have 9-inch diameter membrane disc diffusers that are nearing the end of their Service life and will require replacement in the near future.

The existing blowers that provide aeration to the South Reactors are constant speed multistage centrifugal blowers each with approximately 12,500 scfm of capacity. The multistage blowers have turndown of less than 50%, which results in potential gaps in the operating range. The existing blowers are scheduled to be replaced with more efficient blowers with greater turndown.

Air is currently distributed to the South Reactors using a cross header. One header serves each stage (1-6) of all four of the Reactors. For Reactors No 2-4, there is currently one control valve and flow meter per header, so this provides stage DO control across each basin, but no control over individual stages. In Reactor No. 1, a control valve and flow meter have been added to each drop leg for control of the panel type diffusers in each stage. The cross-header design generally promotes poor air distribution, particularly if the diffusers have different pressure requirements or experience different levels of fouling. Based on the current configuration, it is expected that air is flowing preferentially to Reactors No. 2-4 based on the different diffuser types.

Recommended Aeration Improvements

It is recommended that the City consider the installation of disc-type membrane fine bubble diffusers for Tanks No. 2-4 since these require less operating pressure. The discs and air piping will need to be mounted more securely than the previous installation, and new in-basin diffuser distribution piping is recommended. It is also recommended that the City consider replacement of the panel diffusers in Reactor No. 1 with membrane disc-type in the future in order to improve air distribution between the reactors and reduce future replacement costs. Off-gas

testing is also recommended to assess the benefits and savings associated with switching from the panel type to the disc type diffusers.

Improvements to the air distribution piping are recommended as well. Two alternatives should be considered:

1) Keep the existing cross header configuration. This would maintain the head piping as existing, but it is recommended that control valves and flow meters be added on each drop leg to the aerobic stages (4 through 6) in Reactors No. 2-4 (9 new control points total). One DO analyzer is recommended in each aerobic zone (9 total).
2) Replace cross headers with dedicated air headers per reactors with one control valve and flow meter per Reactor (3 total) and one or two DO analyzers in Reactors No. 2-4 (total of 3-6). Maintain the existing cross header and control valves that feed Reactors No. 1

Based on projections of future air requirements, 30,900 scfm of firm capacity is recommended. There are multiple blower technology options that would provide additional energy savings as compared with the existing system that should be considered. A detailed blower net present worth evaluation of these different blower types during design is recommended to identify the best solution for the City.

1) **Multistage centrifugal blowers** – If the City would like to maintain the same type of technology that they currently have, it is recommended that two different sizes of blowers be installed to provide sufficient turndown under low loading conditions. Installation of two (2) 9,200 scfm blowers and two (2) 12,500 scfm blowers would be recommended.
2) **Single-stage integrally-geared blowers** are more efficient and have better turndown than multistage centrifugal blowers, but tend to have a higher capital cost. Four of the same size blowers could be installed (10,300 scfm) to meet the future aeration requirements.
3) **High speed turbo blowers** also provide greater efficiency and slightly better turndown than the existing multistage blowers, but there is a limitation on the size of these blowers. There are two main types of bearing technologies to consider: magnetic and air bearing.

The addition of ammonia probes in each basin is recommended for implementation of ammonia-based aeration control (ABAC). The capital costs associated with these probes is relatively small and can result in significant operational savings by matching the required air with the process demand. This can also optimize nitrogen removal efficiency through simultaneous nitrification and denitrification at low DO. One new ammonia probe would be installed per Reactor. For the purpose of estimating costs for the Capital Improvement Program, it is assumed that single-stage integrally-geared blowers will be the best fit for the HFCAWTP. Implementation of new DAR blowers is expected to cost roughly $5.8M in current dollars.

Recommended IMLR Improvements

In Tank No. 1, the IMLR pump currently discharges into the influent line and is not monitored for flow. The current configuration is suspected to limit the IMLR flow capacity, so it is recommended that separate IMLR piping and separate flow measurement be installed for each tank to allow for more flexibility and control of the IMLR flow. Online nitrate measurement in

these basins would allow for more targeted control of denitrification in these basins. These improvements are anticipated to cost roughly $2.0M.

7.5.4 New South Final Sedimentation Tanks

The South FSTs are currently limiting the wet weather treatment capacity at HFCAWTP. It is recommended that new FSTs be constructed to maintain a Max Day SOR of 1,050 gpd/ft^2. Two new FSTs are recommended to be built in the near term and two additional FSTs are recommended to be built to handle future wet weather flows associated with the anticipated annual average flow of 80 mgd. A new RAS pump station should be constructed in the near term to service the new FSTs. The addition of RAS pumps can be phased in to correspond to the number of FSTs required.

Similar to the PSTs, stress testing and CFD modeling of the South FSTs is recommended prior to the design of the two new FSTs to assess whether clarifier modifications, such as internal baffling, may provide better performance and increased capacity in the future. Similar effort as described above for the PSTs is recommended to perform testing for CFD model development. Based on data collected during the field sampling and stress testing, the consultant will calibrate a CFD model for the FSTs which will be used for the evaluation of the existing settling capacity, evaluation of potential modifications to the sedimentation tanks, and planning of new sedimentation tank construction for the future.

7.5.5 Sidestream Treatment

The sidestreams from anaerobic digestion results in significant nitrogen loading back on the process. Treating the high strength sidestream waste separately can be a cost-effective way to reduce the nitrogen loading on the plant and ultimately the aeration and carbon costs associated with treatment in the main process. A new sidestream treatment system will also reduce the number of new denitrification filters needed in the future. Based upon the evaluation performed in Technical Memorandum 10.0 Sidestream Treatment Evaluation, a sidestream deammonification process is recommended to be implemented.

7.5.6 Recycle Stream Improvements

The North Reactors currently experience buildup of grit and solids in the bottom of the tanks. This can ultimately result in loss of treatment volume and significant maintenance costs to clean the North Reactors. In the past, solids from filter backwashing have contributed to this buildup. All the plant sidestreams are redirected downstream of the primary sedimentation tanks, including biosolids filtrate, filter backwash, and gravity thickener overflow. It is recommended that these sidestreams, excluding biosolids filtrate which will go to a future sidestream treatment system, be diverted to the screen and grit building for removal of solids upstream of the North Reactors. It is recommended that the main plant drain line be rerouted from the Main Pump Station wet well to the Screen and Grit Building No. 2 via a connection to the 72-inch effluent from Junction Chamber No. 1. Based on information obtained from the plant drawings, the main plant drain discharges into the Main Pump Station at elevation -6.33. The Screen and Grit Building No. 2 is at higher elevation than the main plant drain (elevation 7.0). Pumping is

required to transfer the flow to the Screen and Grit Building. Plant yard piping drawings indicate that the main plant drain pipe extends west of Sludge Pump Station No. 1. A new Main Plant Drain Pump Station could be located west of Sludge Pump Station No. 1 and the force main routed north and then east to the 72-inch pipe that feeds Screen and Grit Building No. 2. The new Main Plant Drain Pump Station could be either a submersible pump station or canned vertical turbine pump station sized to accommodate all recycle flows. The existing gravity drain to the Main Pump Station wet well should remain as a back-up to the new Main Plant Drain Pump Station.

Technical Memorandum 8.0 Denitrification Filter Evaluation

8.1 Purpose and Background

This report describes the Denitrification Filter Evaluation for HFC AWTP. While the filters have historically provided the nitrate and TSS removal required to meet permit limits, the ability of the filters to continue to meet these stringent limits, while reducing methanol cost, was investigated.

There are 32 coarse sand denitrification filters downstream of the BNR process at the HFC AWTP. These filters were designed to reduce the TSS and TN to meet the surface water annual average permit limits of 5 mg/L and 3 mg/L, respectively. The basis of design for the filters states that they were designed for average influent concentrations up to 11 mg/L TSS and 12 mg/L nitrate as nitrogen and effluent concentrations of 2.3 TSS and 1.0 mg/L nitrate as nitrogen. Although the permit allows for an annual average concentration for TN of 3.0 mg/L, the 5-year average of tons of TN per year based on the total maximum daily load to Hillsborough Bay is 213.2 tons/yr, which limits the TN concentration to 2.53 mg/L based on the AADF of 60 MGD. As the AADF increase to 80 MGD, this equates to a TN limit of 1.86 mg/L based on the current 5-year average limit for TN tons/yr.[1] As AADF increases, the average TN concentration in the filter effluent will need to be reduced below current levels (approx 2.1 mg/L).

DAR effluent is directed to the four banks of the Denitrification Filters. The groups of filters are shown in **Figure 8.1-1** with the older filters (which were installed in 1978) numbered 1-20 to the north and newer filters (installed in 1991) numbered 21-26 and 31-36 south of Filter Building 2 (note that filter numbering skips 27-30). Pumps and blowers associated with Filters 1-20 are located in Filter Building 1. Pumps and blowers associated with Filters 21-36 are located in Filter Building 2. The control room for all the filters is located in Filter Building 1. Each filter has a surface area of 1,050 square feet for a total filtration area of 33,600 square feet. The filters have 4.5-feet of 2 to 3 mm coarse sand and 1.17-feet of gravel on top of filter underdrain blocks by Severn Trent Services. The City replaced the media and filter underdrains for Filters 21-36 in 2016. The media and underdrains for Filters 1-20 were replaced in 2008.

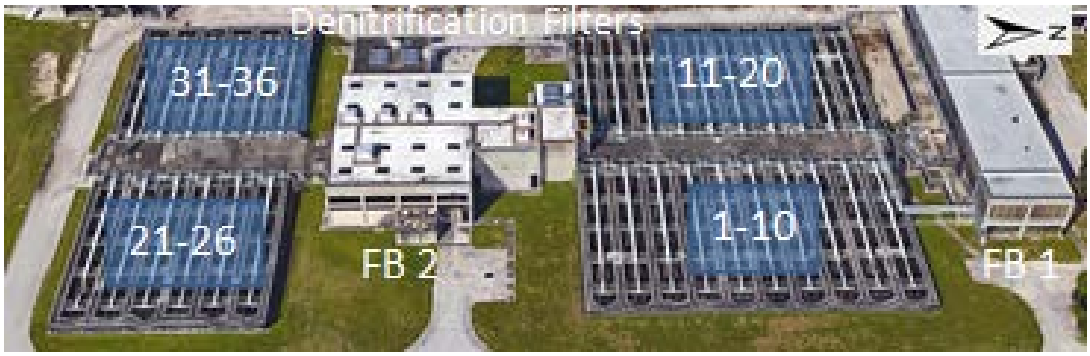

Figure 8.1-1: Existing Denitrification Filters

Methanol, dosed at a ratio of 2.5 M/N (mg methanol/mg nitrate) is provided as an additional carbon source. The methanol is stored in a 100,000 gal tank, and the four methanol feed pumps, which were replaced in 2015, are located to the north of Filter Building 1.

[1] Assumes no increase in the amount of RCW beyond the current 5 MGD which is counted at 10%.

8.2 Evaluation

The denitrification filters were designed for hydraulic loading rates (HLR) of 2.5 gpm/ft^2 at 121 MGD and 5.1 gpm/ft^2 at peak flow of 249 MGD (design flows for AADF and PHF plus recycle streams). Industry references from EPA and WERF suggest that HLR should be between 2 and 3.5 gpm/ft^2 at AADF and 3 to 7.5 gpm/ft^2 at PHF for denitrification filters. The filters are appropriately sized for the design flows based on this information. However, the facility has experienced such excessive head loss in the filters at flows from about 120 MGD to 150 MGD that the level in the filters has risen well above the weirs up to the top of the tanks at 19.0-feet. To maintain a minimum of 6-inches of freeboard in the filters, staff has sent a portion of the filter influent to empty Final Sedimentation Tanks downstream of the HPO Reactors through an old conduit. The tanks are subsequently drained at a time of lower flow to free up available volume for the next high flow event. The filters also experience excessive head loss at current AADF, which is well below the design HLR.

Some suspected reasons causing the filters to experience excessive head loss may include:

- High influent TSS concentrations;
- High influent nitrate concentrations;
- Faulty level control (effluent valves);
- Ineffective backwash cycles;
- Ineffective nitrogen release cycles (NRC);
- Uneven distribution of flow (influent knife gate valves); and
- Combination of more than one of the above.

To assist with the evaluation of the denitrification filters, De Nora Water Technologies (De Nora) was enlisted to examine the denitrification filter process. During the week of May 1, 2017, a representative from De Nora conducted various tests, with the City staff's assistance, to gain insight into process operations and limiting factors affecting filter performance. A copy of the *Filter System Inspection Report* prepared by De Nora is included as **Attachment 8-A** to this technical memorandum. Key findings from the report included:

- Influent TSS concentration observed averaged 3.8 mg/L while effluent averaged <0.4 mg/L, both being less than design.
- Influent nitrate levels observed were approximately 1 ½ times the design concentration and greater (18+ mg/L versus 12 mg/L).
- Freeboard driving force from top of influent weirs to top of filter media is only 4-feet. Most denitrification filters are now designed with at least 6 to 8-feet of freeboard. With high rate denitrification needed, the facility must sometimes utilize the extra freeboard above the influent weirs to push water through the filters. When filters operate above the influent weirs, filter flows and loadings become unequal.
- Doing a nitrogen release cycle (NRC) can more than double the flow capacity through a filter for some time. Frequently performing NRC's is key to greater average filtration flow capacity. De Nora recommends using an active NRC length of 1 minute (down from 2 minutes practiced at the time of the site visit) for optimum effectiveness and rapid progression through the filters.

- During the time of the site visit, the backwash cycle included a 5 minute air scour, a 5 minute air/water wash, and a 10 minute water-only rinse. De Nora recommends a 2 minute air scour, 11 minute air/water wash, and 4 minute water-only rinse for more efficient cleaning.
- Backwash frequency can be reduced with the longer air/water wash. DeNora calculated the interval between sequential filter backwashes to 1.32 hours, which equates to 18 filters backwashed in a 24 hour period.[2]
- There is a need to update methanol dosing techniques to achieve lower effluent NO_3-N concentrations to satisfy the tightened TN mass loading limits, including the need to reduce the filter effluent NO_3-N set point below the current 1.0 mg/L limit. Methanol dosing would be improved if a dynamic feedback interval were used.
- Backwash flow control improvements are recommended. Improvements include valve repair/replacement and adjusting flow rates.
- Installation of a blower unloading valve on the common piping downstream of each set of blowers will improve filter operation and could improve filter longevity.
- Increasing the 14-feet operating level to 16-feet decreased DO recorded in the filter cell. Decreased DO will reduce methanol consumption.
- Repair or replacement of failing valves (influent, effluent, backwash) and repair air leaks on pneumatic actuators will improve performance.

As noted in the Filter System Inspection Report (**Attachment 8-A**), the denitrification filters can filter at the rated peak flow of 5.1 gpm/ft^2 or higher for some time after a backwash or NRC, but the high influent nitrate spurs rapid gas production that soon begins to reduce this flow. The process can benefit by minimizing the time filters are almost gas-bound and filtering near 1 gpm/ft^2 or less. It should also be noted that the historical flow peaking factor, 2.93, is higher than the design flow peaking factor of 2.3. As such, even though the future AADF of 80 MGD is less than the design AADF of 96 MGD, the peak flow to the filters including recycle flows may exceed the 249 MGD, at which the filtration rate will exceed 5.1 gpm/ft^2.

8.3 Recommended Improvements

Additional denitrification filters are not required provided the nitrate plus nitrite (NOx) load to the filters does not exceed 16,000 ppd[3] and the City implements the operational changes recommended in the De Nora report, including optimization of the methanol dosing. However, the BNR and sidestream treatment evaluations estimate the denitrification filter NOx loading will exceed 16,000 ppd as the average daily flows to the denitrification filters increase, even with the implementation of the recommended improvements from the De Nora report. Two (2) additional denitrification filters are recommended if both the BNR and sidestream treatment improvements are implemented to ensure that nitrogen gas binding does not limit the hydraulic throughput of the filters; whereas nine (9)

[2] Assumptions include daily filtration flow of 59 MGD, a 3.8 mg/L influent TSS, 0.4 mg/L effluent TSS, 18.3 mg/L influent NO3-N, 0.5 mg/L effluent NO3-N, and 1050 sf filter surface area.

[3] 16,000 ppd NOx load is based on the loading limitation observed where the hydraulic performance of the filters is impacted by nitrogen gas blinding of the filters. This equates to a flow to the filters of approximately 160 MGD with an influent TN concentration at 12 mg/L.

additional denitrification filters are recommended if sidestream treatment improvements are not implemented.

As plant flows approach the projected AADF of 80 MGD, the City should re-evaluate the filter performance based on the actual reduced NOx loading to the filters resulting from nitrate reduction through sidestream treatment and improvements to the BNR process. In addition, with no change in the permitted 5-year average mass loading to the Bay and no increase in the volume of RCW produced, the peak filtration rate necessary to achieve lower effluent nitrate concentrations, as low as 0.5 mg/L, will require additional filters to reduce the peak hourly filtration rate to 3 gpm/ft^2.

Recommended improvements at this time included two (2) new denitrification filters (assumes sidestream treatment is implemented) and replacement of aging and failed equipment. Some of this equipment, for example backwash valves and air piping, has already been mentioned as it was noted in the Filter System Inspection Report prepared by De Nora. Other equipment which needs to be replaced was identified during the Phase 1 of the Master Plan Report and by City staff.

The equipment identified includes:

- Filter influent valves and actuators for all filters;
- Filter effluent valves and actuators for all filters;
- Backwash drain valves and actuators for all filters;
- Backwash water valves and actuators for all filters;
- Backwash air valves and actuators for all filters;
- Influent gate actuators for all filters;
- Backwash air blowers (two);
- Backwash, filter drain and sump pumps;
- 48-inch and 72-inch influent flow meters;
- Backwash flow meters;
- Air piping; and
- Instrumentation for level control, methanol dosing.

8.4 Capital Cost Estimate

For the purpose of preparing the capital cost estimate, the recommended improvements to the denitrification filters are separated into two projects. The first project addresses more immediate need to construct the recommended improvements to the existing denitrification filters, which primarily consist of replacing equipment and valves that have reached, or are nearing the end of their useful life. The costs for these improvements are presented in **Table 8.4-1**. The City also noted that the work required at the existing filters includes concrete repair where spalling and cracks are evident. An allowance is included in the cost estimate for miscellaneous concrete work.

The second project includes the design and construction of two (2) new denitrification filters and assumes the City implements sidestream treatment. The cost estimate for the two new denitrification filters is $6,200,000.

Table 8.4-1: Conceptual Cost Estimate for Denitrification Filter Improvements

Item Description	Cost
Filter influent valves and actuators (32 total)	$500,000
Filter effluent valves and actuators (52 total)	$525,000
Backwash drain valves and actuators (32 total)	$325,000
Backwash water valves and actuators (52 total)	$525,000
Backwash air valves and actuators (32 total)	$325,000
Backwash air blowers (2)	$300,000
Backwash pumps (6 total)	$900,000
Influent gate actuators (32)	$150,000
Filter Drain pumps (2)	$100,000
Influent flow meters	$100,000
Backwash meters and controllers (4)	$75,000
Effluent water pumps (2)	$300,000
Effluent water pipe	$300,000
Sump pumps (5)	$25,000
Air piping (allowance for replacement /repair)	$250,000
Filter media replacement (allowance)	$200,000
Miscellaneous facility improvements	$500,000
Concrete repair (allowance)	$400,000
Instrumentation & Control	$375,000
Electrical	$575,000
Sum of Bare Construction Costs	$6,750,000
30% Contingencies	$2,025,000
Bare Construction Cost	$8,775,000
20% OH&P & GCs	$1,755,000
Total Construction Cost	**$10,530,000**
20% Management and Engineering[2]	$2,106,000
Total Capital Cost[1]	**$12,636,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

With the addition of two new filters in the future, the total capital cost for the recommended improvements to the denitrification filters is $18,836,000.

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Attachment 8-A: Filter System Inspection Denitrification Filters

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HOWARD F. CURREN ADVANCED WASTEWATER TREATMENT PLANT

City of Tampa, Florida

FILTER SYSTEM INSPECTION
DENITRIFICATION FILTERS

1-4 May 2017

De Nora Water Technologies
Pittsburgh, PA
WO # 3268
September 13, 2017

INTRODUCTION

Howard F Curren Advanced Wastewater Treatment Plant (the Plant) is planning future improvements with assistance from consulting engineers McKim & Creed. They asked De Nora Water Technologies (De Nora) to examine the denitrification filter system for possible improvements in operation and equipment. Future plant permit discharge limits are tightening and require optimization of all Plant processes. De Nora originally supplied the filter system technology. The filter issues are centered on improving the ability of the filters to process flow, and achieving even lower filter effluent nitrate-nitrogen than before.

EXECUTIVE SUMMARY

High influent nitrate-nitrogen causes high gas production in the filters, reducing flow capacity. We did maximum flow testing showing the filters are capable of rated peak flows soon after they have done a Nitrogen Release Cycle (NRC). To maximize flow capacity, use an active NRC length of 1 minute (down from 2 minutes) for optimum effectiveness and rapid progression through the filters. Fix nine broken effluent valves on the original filters to increase the flow capacity of those filters significantly. For average conditions, do longer backwashes but do them less frequently. Have De Nora help optimize methanol dose control, and then change effluent NO3-N setpoint from 1.0 mg/L to 0.5 mg/l to help meet tightening effluent TN permit limits.

FILTER SYSTEM PERFORMANCE

There are 32 filters. The original section is filters 1-20. A later expansion added 12 more filters numbered 21-26 and 31-36. The spatial arrangement of the filters is:

	North	
11		**1**
12		**2**
13		**3**
14		**4**
15		**5**
16		**6**
17		**7**
18		**8**
19		**9**
20		**10**
31		**21**
32		**22**
33		**23**
34		**24**
35		**25**
36		**26**
	South	

Each filter has two cells 5 ft wide and 105 ft long (1050 ft^2 filtration area per filter). Some of the following plant-specific data comes from the McKim & Creed Master Plan review. Other data is from discussions with the operators.

The Plant is rated at 96 MGD ADF. Recent flow data suggests a 70 MGD daily high average (equivalent to 1.54 gpm/ft^2 with 30 filters operating). Normal low flow is 25 MGD, and AADF has been 60 MGD. Rainy weather infiltration can boost plant flow to 200 MGD, but only 150 MGD is directed to the filters (3.3 gpm/ft^2 if 30 filters online). The filters were said to have trouble handling flows above 120 MGD (2.65 gpm/ft^2 for 30 filters). The original peak design flow is 5.1 gpm/ft^2.

According to the Phase 1 Existing Systems Evaluation Report excerpts sent to De Nora by McKim & Creed, the permit for the Plant in effect requires a 2.15 mg/L effluent total nitrogen for up to 65 MGD AADF. The Plant achieved a 2.10 mg/L total nitrogen in 2014, which is great performance, but too close for comfort now. A direct way to satisfy the permit is to reduce the filter effluent NO3-N. The present filter effluent nitrate setpoint of 1.0 mg/L could be changed to perhaps 0.5 mg/L. We have had denitrification filter operate that low successfully. However, the Plant needs the filters and filter supporting equipment in excellent condition, using the best filter operating and methanol dosing techniques available to achieve this performance.

Influent TSS averages 3.8 mg/L while effluent TSS averages <0.4 mg/L, both well below design. Design nitrate removal is 12 mg/L in and 1 mg/L out, but recently has averaged more than 18 in and 1 mg/L out. Media depth is 4.5 ft. Many other filter plants are now built with 6 ft filter media bed depths or more. Water temperatures are 77 deg F winter, 90 deg F summer. The high water temperatures enable high denitrification rates in a compact media bed, but the filters are often gas-bound and flooded out from high denitrification gas production.

Key elevations in the filters are: 12' top of filter media; 14' current level setpoint; 16' top of influent weirs; 18.5' normal max; 19.2' point of overflow out of filter onto the ground. Freeboard driving force from top of influent weirs to top of filter media is only 4 feet. Most denitrification filters are now designed with at least 6 to 8 feet of freeboard.

With high rate denitrification needed, the Plant must sometimes depend on the extra freeboard above the influent weirs to push water through the filters. When the filters are operating below their influent weir elevations, equal flow splitting and nutrient load sharing occurs. When filters operate above the influent weirs, filter flows and loadings become unequal.

MAXIMUM FILTRATION RATE TESTING

To compute maximum unit filtration rates, De Nora closed the influent valve on various filters either at maximum level when they were overflowing to adjacent filters, or at the level of their influent weirs, and at various run times since they had been backwashed or received an NRC. We then opened the effluent valve wide open. Then we directly measured the rate of decrease in level through that filter. Here are the results:

Filter 4, just backwashed, pumped up to max overflow level (like an NRC), gave 6.89 gpm/ft^2 filtration flow.

Filter 6, 22.5 hrs since backwashed, pumped up to max overflow level (like an NRC), produced 3.48 gpm/ft^2 (but only 1 of the 2 effluent valves was working and open).

Filter 7, 22 hrs since backwashed, pumped up to max level (like an NRC), 5.3 gpm/ft^2, 2 effluent valves 100% open (52% more than filter 6 that had only one effluent valve open).

Filter 7, just backwashed, no recent NRC, natural fill to 16 ft level setpoint/top of influent weir, 5.06 gpm/ft^2

Filter 9, no recent backwash or NRC, only 1.09 gpm/ft^2

Filter 11, no recent backwash or NRC, only 0.74 gpm/ft^2

Filter 21, no recent NRC, time since backwash not recorded, natural fill to 16 ft level setpoint/top of influent weir, 1.32 gpm/ft^2

Filter 21, after NRC, natural fill to top of weir, 3.32 gpm/ft^2 (NRC increased flow capacity by 2.0 gpm/ft^2 or 152% greater than it had been).

The above data quantifies the large drop off in filtration flow the longer a filter operates since it has received an NRC. Doing an NRC can more than double the flow capacity through a filter for some time. **Frequently performing NRC's is a key to greater average filtration flow capacity**.

A recent backwash produces about the same flow benefit as an NRC (both employ/conclude with a pumped upward flow of water) but it takes much longer. See the two filter 7 flow data points.

The original filters have two smaller effluent valves. The comparison between filters 6 and 7 above shows it is important that both effluent valves are operable. The peak flow capability could increase by 52% with both of a filter's effluent valves operating. Later we found 9 of the 20 original filters have only one operable effluent valve. The Plant needs all these effluent valves working and open on high flow days. The Plant said it will do these repairs during the next winter dry season.

The data shows that the filters can filter at the rated peak flow of 5.1 gpm/ft^2 or higher for some time after a backwash or NRC, but the high influent nitrate spurs rapid gas production that soon begins to reduce this flow. The Plant can still benefit greatly by minimizing the time filters are almost gas-bound and filtering near 1 gpm/ft^2 or less. The actual flow capacity versus time since a filter received an NRC can be quantified by further maximum drawdown testing.

Filter 21 had a lower maximum flow than original filters 4 and 7 following NRC's done on each. It would be good to determine overall flow capacity of new versus original filters to make sure there is no issue. It would be good to do maximum flow testing on each filter at comparable conditions to detect possible other problems with individual filters.

NITROGEN RELEASE CYCLES

Nitrogen Release Cycles (NRC's) have so-called waterhog and watersaver modes at the Plant. The influent valve stays open and the dirty backwash valve stays closed in the watersaver mode, saving an estimated 11% of forward flow and methanol usage and possibly some execution time. This mode should be used as much as possible. All NRC's close the effluent valve and direct backwash water upward through the filter to release biological gases and open up flow passageways through stored solids and biomass.

Perform NRC's on the filters as often as possible. Another denitrification filter plant, with influent nitrate-nitrogen often exceeding 20 mg/L, (Littleton-Englewood, CO) required short NRC's every 30 minutes to pass a peak flow performance test with acceptable filter operating water levels.

We observed gas release during the Plant's NRC's. Most of the gas release occurs in the first 30 seconds. Gas release could be more than 90% complete in the first minute. The active length of the NRC, when backwash water is pumping into just one filter, should be 1 minute. At the beginning of our inspection, this step was 2 minutes long. Since so many NRC's are done daily, this really helps get through the filters quickly. We changed to 1 minute NRC's for several days during our visit with no apparent problems and much more frequent NRC's overall.

One other NRC feature that should be done is to allow at least 5 seconds for the backwash water inlet valve to open on the currently NRC'ed filter before closing the backwash water inlet valve on the previous filter. Currently there could be less separation. If a backwash inlet valve sticks briefly, sequencing these valves too rapidly could encourage deadheaded backwash pumps and backwash flow pressure surges.

BACKWASHING

At the start of our inspection, the filters were using a 5 minute air scour, a 5 minute air/water wash, and a 10 minute water-only rinse. Compared to air flow or water flow applied alone, solids are best removed by the air/water wash step. De Nora recommends a 2 min air scour, 11 minute air/water wash, and 4 minute water-only rinse for more efficient cleaning at the Plant. We set up similar step times during our visit and ran with no apparent problems. This provides the recommended two bed volumes of water changes per backwash. Our most common air/water wash length, for filters using 6 foot media bed depths, is 15 minutes of actual overflow from the filter. After our inspection visit, the Plant switched backwash step times to a 5 min air scour, 10 minute air/water wash and 5 minute rinse.

Operators were backwashing all 32 filters daily. Once Operators start a cycle, it does all 32. Under normal conditions, this is probably too many backwashes per day. Foam on backwashing filters started white and stayed white, indicating little TSS has accumulated. Dirty backwash foam should start out medium to light brown and then turn white as the filter cleans up. The Plant tested dirty backwash water samples for TSS for De Nora, and they definitely confirm clean filters even though they were done after about 22 run hours, close to the scheduled times. TSS test results are below:

Sample Location	Sample Collection Date	TSS (mg/L)
Filter 7 BW - 1 min	5/2/2017	169
Filter 7 BW - 5 min	5/2/2017	161
Filter 10 BW - 1 min	5/2/2017	131
Filter 10 BW - 5 min	5/2/2017	126
Filter 10 BW - 10 min	5/2/2017	105
Filter 10 BW - 15 min	5/2/2017	47
Filter 21 BW - 1 min	5/2/2017	220
Filter 21 BW - 5 min	5/2/2017	224
Filter 31 BW - 1 min	5/3/2017	186
Filter 31 BW - 5 min	5/3/2017	190

Normal backwashes should have initial dirty backwash TSS concentrations of about 1000 mg/L that decrease to around 200 mg/L by the end of the air/water backwash. Instead, the Howard Curren filters are starting off their backwashes near 200 mg/L and going down slightly from there.

We adjusted a filter 10 backwash to a longer 10 minute air/water wash and a shorter 5 minute rinse. All the numbers started low and stayed low, but they show additional cleaning with the longer air/water wash, and a step change down to a very low TSS level at the end of the 5 minute rinse (15 minute marked sample result above, 47 mg/L). Long rinses do not add much cleaning capability, especially for a filter design with a relatively compact filter bed and a small freeboard to flush out. The main function of the rinse step is to remove most of the backwash air bubbles from the filter media so that the filter is not so gas-bound after a backwash. This occurs fairly quickly.

Operators should perform backwashes less frequently but use longer air/water wash steps when they do. Vary backwash interval according to flow and loading. Use the example calculation shown in the section below to estimate backwash interval. Doing NRC's more frequently may make it easier to backwash less often.

Improve backwash scheduling programming to make it easier to vary backwash interval. Change the backwash scheduling controls to allow Operators to select how many filters to backwash per day without requiring manual stops and restarts of the complete plant backwash cycle.

BACKWASH INTERVAL CALCULATION

As the filter system removes suspended solids from the wastewater, the resistance to flow increases in each filter. The accumulation of material in the filter eventually will approach the maximum loading capacity of the filter. The specific loading of the Howard Curren filters with a 4.5 ft filter media bed depth could be about 0.5 $lb/ft^2 \cdot bw$. This is extrapolated from what most plants use for normal operations, and then reduced by about 1/3 due to the filter freeboard driving force available at Howard Curren.

Assume daily filtration flow of 59 MGD, a 3.8 mg/L influent TSS, 0.4 mg/L effluent TSS, 18.3 mg/L influent NO3-N, and 0.5 mg/L effluent NO3-N. A single filter's top surface area is 10 x 105 = 1050 ft^2. Nitrate removal is assumed to grow biomass by a 90% factor. The time interval between any

two filter backwashes can be calculated as follows.

$$\text{Backwash Interval} = \frac{\text{Specific solids loading x single filter area x conversion factors}}{\text{Solids and nitrate reduction x filtration plant flow}}$$

Substituting values, backwash interval is:

$$\frac{0.5\ \text{lb/ft}^2\cdot\text{bw x (10 ft x 105 ft) x 1000 mg/g x 454 g/lb x MGD/}10^6\ \text{gal/day x 24 hr/day x gal/3.785}}{\{(3.8 - 0.4) + [.90 \text{ x } (18.3 - 0.5)]\}\ \text{mg/L x 59 MGD}}$$

The top terms can be treated as a constant for this plant with a value of 1511.

$$\text{BW Interval} = \frac{1511}{\{(3.8 - 0.4) + [.90 \text{ x } (18.3 - 0.5)]\}\ \text{mg/L x 59 MGD}}$$

BW Interval = 1.32 hours between any two backwashes

Dividing a 24 hour day by 1.32 hour intervals, there would be 18 backwashes done daily.

Substitute current TSS and NO3-N removal and average filtration flow into the bottom line of the simplified equation above to calculate backwash interval for current conditions.

METHANOL DOSING PROGRAMMING

The Plant should update its methanol dosing techniques, to achieve lower effluent NO3-N concentrations to satisfy the tightened plant permit.

The Plant has filter influent flowmeters and a Chemscan nitrate-nitrogen analyzer to check influent and effluent nitrate-nitrogen. These inputs are used in an algorithm to pace methanol feed to the filters. Feedback from the effluent nitrate of the filters was said to be performed at a set interval of 1.5 hours.

Methanol dosing would be improved if a dynamic feedback interval were used. The algorithm should accurately correct the dose more frequently when plant flow is high, and less frequently when plant flow is low. The algorithm should even detect when plant flow is changing quickly so that the corrections are made on time. De Nora has continued to refine such techniques for its own carbon dosing control systems and should work with the Plant to optimize all aspects of methanol dosing. The Plant said it might consider this after upstream processes are optimized.

BACKWASH WATER FLOW CONTROL

De Nora found that all four of the backwash flow control valves had been running in manual mode. Operators said that in auto mode the flow control valves travelled wide open when the backwash pumps were not running. When the pumps came on, flow to the filters was too high until the valves throttled. Operators were right to take the action that they did to save the filters.

However the best solution is better backwash flow control programming. First of all the backwash flow control valves should have an upper limit of movement that allows no more than 9000 gpm flow. This limit should be both electronic and by using a mechanical stop on the valve.

When the backwash pumps are not running, the backwash flow control valves should go to a minimum set position. This minimum position becomes the starting position when the backwash pumps are again called to run. The minimum position should provide about half the normal backwash rinse or NRC flow, or about 4200 gpm out of 8400 gpm. After 10 seconds, the flow control valve should open to a valve position that almost gives the proper backwash flow. This would be 6300 gpm for an air/water wash backwash step, or 8400 gpm for backwash rinse or NRC. After 20 seconds at the second fixed position, the flow control loop should be enabled to allow fine adjustments to the backwash flow rate.

If a backwash pump fails and is turned off, the backwash flow control should again go through the above steps to ramp up backwash flow. This will reduce chance of surging or damaging the filters with backwash water.

De Nora conducted a series of backwash water flow rise rate tests in various filters. We started a pump and then measured the water rise in the filter with a tape measure over a 1 to 2 minutes period. Here were the results:

Filter 2, 8320 gpm indicated on the control screen, 8516 gpm actual from rise rate test (8.11 gpm/ft^2), using backwash (bw) pump #2 and east side flow meter. Good agreement between flowmeter and rise rate test, but high flow overall. If a single manual flow needs to be chosen for now, it should be 7350 gpm (7.00 gpm/ft^2)

Filter 11, 8650 gpm indicated, 10538 gpm actual from rise rate test (10.04 gpm/ft^2), using bw pump #3, and original filters west side flow meter. Flowmeter is reading much lower than actual flow.

Repeat Filter 11, 8650 gpm indicated, 9823 gpm actual from rise rate test (9.36 gpm/ft^2), using bw pump #3, low flow reading confirmed, at least 14% higher actual flow than indicated.

Filter 21, 8475 gpm indicated, 8186 gpm actual from rise rate test (7.80 gpm/ft^2), bw pump #4, good agreement.

Filter 31, 8450 gpm indicated, 8840 gpm actual from rise rate test (8.42 gpm/ft^2), bw pump #5, good agreement

Filters 11-20 were getting by far the most backwash water, high enough to possibly damage gravel layers over time. It would be good at some point to drain all the filters, especially filters 11-20, to check the media surface for high and low spots or eruptions of support gravel.

All filters were receiving too much backwash water, especially if flow control is going to remain in manual for some time. De Nora reduced the opening of the original filters 11-20 west side flow control valve by about 7% until 6500 gpm was indicated. This was estimated to give an actual flow of 7350 gpm or 7 gpm/ft^2. The other three flow control valves were reduced by about 4-5% until 7350 gpm was indicated directly.

Calibrate the existing west side flowmeter for filters 11-20, and then verify calibration with rise rate tests.

When the Plant is upgraded, remove the original old venturi meters and flow control valves for filters 1-20 and replace them with more reliable magnetic flow meters, and new flow control valves that have settable maximum openings and true feedback of their positions.

Alarm low flow less than 85% below intended flow that lasts for 30 seconds or more any time the backwash pump is running. If flow exceeds 115% of intended flow for 10 seconds during the air/water backwash step, alarm and abandon that backwash.

BACKWASH AIR BLOWERS

The preferred design for backwash air blower systems now includes both unloading valves and pressure relief valves. The Plant has pressure relief valves only. Pressure relief valves mainly protect the blower from overpressure. Unloading valves can reduce the starting load on both the blower and the filter being backwashed.

The Plant has original piloted pressure relief valves on three of four backwash air blowers. One piloted relief valve on one of the original filter blowers has failed and was replaced by a weighted pressure relief valve. Weighted relief valves are probably the most reliable type of pressure relief valve, but they should be disassembled and oiled several times a year to avoid corrosion or wear.

When backwash air flow starts in these filters, it is rather sudden and abrupt. Approximately 10% of the water volume in the filter must be displaced by the air bubble volume in just a few seconds. This is thought to have the potential to slowly upset the gravel support layers. A blower unloading valve would eliminate this air surge.

An unloading valve could be located downstream of the blowers. It usually has an electric actuator and is open when the blower is not running. The blower can start and come up to speed in an unloaded or low/no-pressure state. Sometimes the unloading valve is sized to give a reduced blower pressure that will not trip the separate pressure relief valve.

The possibly easier option is to size the unloading valve a little larger for a no-pressure start. Shortly after blower start, the unloading valve is closed by a percentage, possibly 60% closed, as determined by a little trial and error. It should close just enough so that it reliably causes about half the air flow to be able to make it into even a full filter and form a full air pattern gently. This process may take about a minute. Then the unloading valve is closed the rest of the way with little to no surge forces generated in the filter as the air pattern transitions to full flow.

10 seconds before a backwash air blower is called to stop, the unloading valve should open again. This will depressurize the air header and make sure the blower does not have a tendency to spin backward as it coasts to a stop. This is better for soft-start motor controls if the blowers have them or will have them in the future. Reducing pressure in the air header will also reduce air seepage into filters where a backwash air valve may be leaking. This can reduce a source of air-binding in filters after a backwash.

De Nora recommends that the Plant install a blower unloading valve on the common piping downstream of each set of blowers. This will improve filter operation and could improve filter longevity.

RECENT METHANOL CONSUMPTION

From the Master Plan data and Operator discussions, 2010-2015 yearly consumption of methanol has been 1.74 million gallons, with a $1,882,000 yearly cost. When the water saver NRC was proposed in approximately 1999, it was estimated that single change would save 11% of yearly methanol usage at that time, because methanol-dosed water is not drained from the filter. If 10% methanol savings has been realized for the past 15 years, the cumulative savings could be $3,135,000 to date at $209,000 per year. It is important to use the water saver NRC as much as possible to realize such savings. Operators said they still occasionally use the other NRC cycle when they want to flush floating material off the filters.

The methanol to nitrate-nitrogen consumption ratio was estimated at 2.95 to 1 in the 1990's and earlier. A rough calculation suggests that the recent consumption ratio may be 2.55 to 1. The Plant should verify all these figures. If correct, this is a 13.5% reduction in methanol consumption from the past.

FILTER OPERATING LEVEL SETPOINTS

At the time of our inspection, the filter level setpoints were 14 ft, about 2 ft below the influent weirs. This might have been done long ago to make it easier to transition to a watersaver NRC that did not drain the backwash trough. McKim & Creed pointed out the design operating level of filters was originally 16 ft and asked if this could be restored to minimize potential DO pickup and methanol consumption. In actual fact many filters were operating well above the 14 ft setpoint or flooded out, due to denitrification gas binding.

De Nora observed many NRC's done at 16 ft or higher filter levels and no apparent damage was being done as water overflowed to adjacent filters or flowed backward through the open influent

valve as intended. It does not appear necessary to have a lower filter operating level to perform watersaver NRC's. The operating level setpoint can be restored to as high as 16 ft if level controls are recalibrated to allow accurate level control.

From our observations, level controls could be off by as much as 1 ft from actual levels in some cases. Other level indicators had jumpy readings or did not seem to be controlling level. This will make it difficult to control levels close to the overflow weirs for DO reduction. Calibrate all filter level indicators. As a compromise, for the last two days of our visit we tested an operating level of 15 ft on all the filters with the level controls in their present condition and did not observe any problems caused for NRC's and backwashes. Recently bumped filters operated with less water fall distance over the weirs.

Operators later tested a 15 ft operating level for two weeks which seemed to work OK. However they had some concerns with that operating level during higher flow periods. It was not known if more frequent NRC cycles were being run yet, which would have helped the level control. The ability to process high flow should depend on the accumulated solids and gas load in the filter, not the particular level setpoint chosen.

DISSOLVED OXYGEN TESTING

This section will try to compute the methanol cost savings from operating the filters at a 16 foot level setpoint, instead of a 14 ft setpoint.

Dissolved oxygen measurements (DO) were taken 1 foot below water surface in several filter influent troughs, and then 1 foot below the water surface in the filters themselves:

For Filter 11, operating at 14 ft level, we measured 4.84 mg/L DO in the influent trough, and 5.2 mg/L in the filter cell (0.36 mg/L or 7% increase)

For Filter 12, operating at 16 ft level, we measured 5.07 mg/L DO in the trough and 3.99 mg/L in the filter cell (1.08 mg/L or 21% decrease)

For Filter 9, operating at 16 ft level, we measured 5.44 mg/L in the trough and 4.32 mg/L in the filter cell (1.12 mg/L or 21% decrease)

The average DO of the three influent trough measurements was 5.12 mg/L.

The 14 ft operating level does show an increase in DO from water falling into the filter cell. At the 16 ft operating level an actual decrease in DO was recorded in the cell. The decrease could be caused by rapid gas production causing air lift transport of very low DO water from deep in the filters to the position where we were taking our DO measurements in the filter cells. At 14 ft, the increase in DO from falling water could have been large enough to mask any decrease from mixing.

Add absolute differences 7% plus 21% for a possible 28% rise in DO pickup from operating the filters at 14 ft versus 16 ft. Then theoretically with a 14 ft operating level DO would rise from 5.12 mg/L in the filter influent trough to 6.55 mg/L in the filter cell, before the effects of mixing in the filter reduces the reading. At 16 ft operating level there should be no net DO increase.

Use the McCarty equation to compute theoretical methanol consumption at the two DO concentrations. Assume filter influent NO3-N of 18.3 mg/L and 0.2 mg/L NO2-N for each:

2.47(18.3) + 1.53(0.2) + 0.87 (6.55) = 51.20 mg/L methanol dose at 14 ft operating level

2.47(18.3) + 1.53(0.2) + 0.87 (5.12) = 49.96 mg/L at 16 ft operating level or 2.4% less methanol

Assume that the filters currently operate 50% of the time at their 14 ft setpoint level and the other 50% already flooded out from gas binding. Thus raising operating level from 14 ft to 16 ft could save up to 1.2% of present methanol consumption or $22,600 yearly. This could raise the yearly benefit of using the watersaver NRC from $209,000 to $231,600.

FILTER EQUIPMENT CONDITION

As we spent several days evaluating the filtration plant, we had many discussions with Operators about the filter plant operation and equipment. We began noticing equipment or controls that could work better. Here were our observations:

Failing Filter Valves

The original filters 1-20 each have two parallel effluent valves that are pneumatically actuated. Looking at the effluent valves from the pipe gallery end of the filter, there is an effluent valve on the left (L) and right (R) sides. Effluent valves were not working on these original filters 1-20: 1L, 6R, 8L, 10R, 13L, 14L, 16R, 17R, 19L. 8L and 10R actuators have actually been removed from their valve shafts. Maximum filtration rate testing showed that max flow from filters 1-20 is greatly restricted if only one effluent valve is available.

The single remaining #10 effluent valve stayed closed after a NRC nitrogen release cycle, causing an alarm. Check wiring to this valve and the actuator response.

Effluent valve 7R and 9R, and dirty backwash 18L have poor valve shaft seals, with water dripping from them. These are in danger of seizing up at some point and should be replaced.

The newer filters 21-36 use electric actuators for the effluent valves. Filters #31 and #35 effluent valve actuators are too active, constantly moving back and forth as if responding to their position signal poorly. #35 actuator is also loose on the bolted mountings to its valve. That entire actuator is twisting on the valve stem as it actuates back and forth. Plant mechanics said failed circuit boards in these actuators are responsible for their constant hunting movement.

Operators said they were aware of the effluent valve problems and that they needed a period set aside to stop flow to the filters to pull and replace effluent valves that have totally failed. Other effluent valves may be repairable by working on the actuators alone. They said they would work on the valves during the next winter dry season.

The Plant needs all of the filter effluent valves working and able to open to help pass flow on high flow days.

Filter #17 backwash air valve failed to open two backwashes in a row, interrupting its backwash. The valve worked OK if manually stroked. Check control wiring connections and valve solenoid response.

Pneumatic Valves Leaking Air

All the main filter valves are pneumatically operated except for the electric effluent valves on the 12 newer filters. There are about 188 pneumatic valves. Some were observed leaking air:

Filter # 7 filter influent solenoid valve was sticky and venting air.

Filter # 2 and #36 backwash air valves, and #36 influent valve: instrument air regulators leaking air.

Bottom cylinder seal leaking air on #24 and #26 influent valves.

Repair these leaks for greater reliability. Check throughout the filter building for other instrument air leaks. Check air drying systems frequently to make sure clean dry instrument air is always delivered to valves, level bubblers and other instruments.

Valves Leak Testing Deferred

Detecting leaking valves was originally going to be focused on in De Nora's filter inspection. Evaluation of the filtration process and overall operation took precedence. Valve condition should be evaluated more closely in a follow-up trip. There are systematic ways to detect any type of valve leak. Valve leaks can drain away significant amounts of backwash air or backwash water, disrupting filtration performance and backwash efficiency.

Control System Issues

Compare available filter system data trending packages when considering future control system upgrades.

Filter 36 filter level control was not working well in automatic. The effluent valve was showing 100% open on the screen but the filter was flooded out taking much less water than it should, if any. There may be a false indication of valve position. Compare screen and actual valve position to be sure. We got control restarted temporarily by adjusting level setpoint down and back up.

Also check for poor/loose wire connection. If this filter is not doing its share, the filtration plant has lost valuable flow and treatment capacity.

Filter 7 water level indicator was observed to jump from 13.9 ft to 15.8 ft in just 5 seconds, which cannot be true. Something is wrong with the level indicator. If level cannot be read correctly, it could prevent the effluent valve from opening after NRC, send an alarm, and will reduce filtration capacity until fixed.

Level control was observed for some time and found to be too reactive on filters 1-20, with effluent valves shifting position way too much and way too often, without enough time for levels in these filters to react. Level control was then found to be too sluggish on filters 21-36. Those filters would go past their level setpoints in both directions when trying to control level. We examined controller programming and saw the original and new filters were using opposite proportional/integral control settings compared to each other. De Nora and a Plant Operator adjusted all controllers to use the same balanced tuning. This reduced valve movements and wear and tear on filters 1-20 effluent actuators, and reduced overshoot/undershoot of water levels on filters 21-36. More optimization could be possible with longer term observation.

Filtration Flow Distribution Testing Deferred

Flow distribution problems between filters are surprisingly common. This was another focus that had to be put off to a recommended future De Nora visit. We did see some indication of excess flow into filter 31. De Nora could do rise rate checks in each filter to confirm if any flow distribution problems exist. If they do, influent valve open travel could be adjusted to produce better flow distribution during high average flow conditions. Better load sharing would improve overall filtration and denitrification performance.

Upstream Issues

The facility has an ongoing project to improve denitrification in the diffused air reactors. Once completed, the filter influent nitrate is expected to be in the high teens to low twenties in mg/L NO3-N.

Upstream anoxic basins normally remove 5-7 mg/L NO3-N, but for rainy weather high plant flow they must cease this removal, reducing mixed liquor concentration from 5000 mg/L to 2500 mg/L. Nitrate concentrations may temporarily increase to the filters at the start of large rain events and then become diluted by rain infiltration water.

Having more reliable and more capable nitrate removal processes upstream of the filters should be an important future design goal for the Plant. This would definitely help the filters operate better and save the Plant significant operating cost. Removing about 2/3 of the potential nitrate in anoxic zones is much less costly than using denitrification filters for most of it. Denitrification filters make the most sense for removing the final 5 to 10 mg/L nitrate that is harder for upstream systems to treat.

CONCLUSIONS

1. The filters are partially gas-bound much of the time due to high filter influent nitrate nitrogen (18 mg/L or more, vs 12 mg/L design).

2. Doing more frequent nitrogen release cycles will maximize filtration capacity. NRC's can boost flow more than 100%, with individual filters nearing design max flow for a period.

3. A shortened NRC is just as effective as a longer one and is the best way to progress through the filters more rapidly.

4. Additional flow capacity can be restored by getting all dual effluent valves working on the original 20 filters. An original filter with two effluent valves was able to pass 52% more water at peak flow than another filter with one effluent valve closed off.

5. Frequent short backwashes were leaving very little solids buildup in the filters as shown by TSS testing. Less frequent but longer backwashes should be more effective.

6. To meet a tightened permit, the filters will need to remove nitrate to an even lower concentration than before. This is possible with good equipment condition, good operation, and improved methanol dosing control.

7. The backwash flow control valves are in manual and backwash flows were found to be high. The manual valve openings were adjusted about 1000 gpm lower to produce about 7350 gpm flow rate (7 gpm/ft^2) until equipment can be upgraded.

8. The backwash flowmeter for filters 11-20 read at least 14% low. These filters had the highest backwash flow rates, which were potentially damaging to the filter gravel layers.

9. When backwash air flow starts in the filters, it is all at once and there is an abrupt upward flow as 10% of the filter water volume is displaced by the backwash air bubbles.

10. Several filter valves were failing in addition to the closed original filters effluent valves.

11. Problems were found with filter level control. We improved level control programming for all filters but other problems remain.

12. Methanol use may be significantly lower than in the 1990's. The watersaver NRC does not send methanol-dosed water back upstream, possibly saving over $3 million since 1999.

RECOMMENDATIONS

1. Start doing shorter but more frequent nitrogen release cycles. Use an active NRC length of 1 minute per filter instead of the recent 2 minutes.

2. Fix the nine failed and closed effluent valves on the original filters to help boost peak filtration flow capacity. The Plant said this would be done during the winter dry season.

3. After increasing NRC frequency, start doing longer but less frequent backwashes. Use an air scour length of 2 minutes, an air/water wash step length of 11 minutes, and a water-only rinse of 4 minutes.

4. Use the backwash interval calculation in this report to estimate how many backwashes to do daily.

5. Modify backwash scheduling program to make it easy to set up the number of daily backwashes.

6. Optimize methanol dosing programming, especially effluent NO3-N concentration feedback techniques, with De Nora assistance. The Plant said this will be considered after upstream upgrades have been determined.

7. Set the filter effluent NO3-N setpoint to 0.5 mg/L to help meet the tightened permit's TN requirements.

8. Calibrate the original filters' west side venturi backwash flow meter. Verify with rise rate tests. The Plant said this problem has now been resolved.

9. Repair observed failing valves. This included valves which did not move when commanded, pneumatic valves with air leaks, and water dripping from valve shaft seals.

10. Check for instrument air leaks throughout the filter buildings. Check air drying systems to make sure clean dry instrument air is delivered to valves, level bubblers and other instruments at all times.

11. Upgrade the original filter backwash flowmeters to magnetic flowmeters, and provide new more capable backwash flow control valves with adjustable maximum opening and true feedback position. Verify optimum backwash flow control.

12. Calibrate all filter level indicators to read correctly at the influent weir level. Some just seem to give an offset level. Filter 7 level indication jumped 2 ft higher in a few seconds. Filter 36 level control did not seem to be working at all at times. After calibration, reset filter level setpoints to about 16 feet to minimize dissolved oxygen pickup and to reduce methanol consumption.

13. Troubleshoot and repair other control system problems identified during this inspection. Operators also could benefit from better data trending systems.

14. Install an unloading valve downstream of each set of backwash air blowers to reduce starting load on the blowers and initial air surges into the filters. Operate the unloading valve as detailed in this report.

15. To uncover individual filter problems, do maximum flow, flow distribution and valve leak tests on all filters.

16. Drain down and inspect the filter media surfaces. Look for filter media or gravel disturbances, especially in filters 11-20 which have experienced very high backwash flows.

17. Install additional robust nitrate removal processes upstream to take up to 2/3 load off of the denitrification filters and to significantly reduce ongoing operating costs.

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Technical Memorandum 9.0 Disinfection Alternatives Evaluation

9.1 Purpose and Background

As part of the Phase I Master Plan for the HFC AWTP, the disinfection system was reviewed and a high level evaluation was conducted to determine its overall ability to meet performance goals and regulatory requirements, operation and safety and reduce operating costs. This technical memorandum is a desktop evaluation of alternative cost effective means of disinfection to reduce the risks and hazards associated with chlorine and sulfur dioxide gases and potentially eliminate generation of disinfection byproducts (DPBs). Additionally, the evaluation includes a cost/benefit analysis, considers chemical availability, and effects on the City's reclaimed water system and Tampa Augmentation Project (TAP) project.

9.2 Current Disinfection System

The HFC AWTP utilizes chlorine gas for primary disinfection and sulfur dioxide gas for dechlorination. Both chemicals are delivered in pressurized rail cars. Both chemicals are heated through evaporators to convert the liquid chemical to the gas phase before being mixed with plant reuse water and injected to the effluent water. The chlorine disinfectant solution is injected into the Final Effluent Channel, just upstream of the three (3) Chlorine Contact Tanks (CCTs) through a diffuser followed by a static mixer. The sulfur dioxide dechlorination solution is injected just downstream of the CCTs in Junction Chamber No. 4. The CCTs were designed to provide 15 minutes of contact time at peak hour flow (PHF) of 221 MGD as required by FAC 62-600-440. Approximately 10% of the final effluent water from HFC AWTP is sent to a reclaimed water system, while the majority of the flow is sent to a surface water discharge system following dechlorination.

The existing disinfection system brings with it two main areas of regulatory compliance: National Pollutant Discharge Elimination System (NPDES) permit and EPA Risk Management Plan. Each of these is briefly discussed below.

9.2.1 FDEP NPDES

The HFC AWTP is permitted to discharge 96 MGD AADF of treated municipal and industrial wastewater to Tampa Bay and 12.6 MGD AADF to reuse water systems under the current FDEP NPDES permit issued on December 7, 2016 (FL0020940-019-DW1P/NR). The facility is held to stringent effluent limits for surface water discharge into Hillsborough Bay. **Table 9.2-1** summarizes the effluent limits associated with chlorine disinfection for surface water and reclaimed water discharges.

Table 9.2-1: Summary of Current NPDES Permit Effluent Limitations for Chlorine Disinfection

Constituent	Surface Water Discharge Limit	Reclaimed Water Limit
Total Chlorine Residual (for disinfection) (single sample)	1.0 mg/L (Min)	1.0 mg/L (Min)
Total Chlorine Residual (for dechlorination) (single sample)	0.01 mg/L (Max)	-
Dichlorobromomethane (annual average)	50.4 µg/L (Max)	-
Dibromochloromethane (annual average)	59.3 µg/L (Max)	-

The NDPES permit grants the facility mixing zones for surface water discharge into Hillsborough Bay for dichlorobromomethane and dibromochloromethane. The effluent limits for the two trihalomethanes were increased with the latest permit revision based on a recent mixing zone study. The mixing zone allows for higher effluent limits than the Florida's Surface Water Quality Standards due to mixing zone dispersion and dilution. The facility had a history of exceedances for both of these trihalomethanes in the past at lower limits but is currently under the limits for dichlorobromomethane and dibromochloromethane after revisions to the permit.

9.2.2 Existing Chlorine Contact Tank Performance

The facility typically maintains a Total Chlorine Residual in the CCTs of 3.0 mg/L, which is three times the required level. While it is common practice to ensure the chlorine residual is above the minimum and avoid non-compliance, the excess chlorine contributes to the production of DBPs. Also, it is assumed that the poor plug flow performance of the CCTs is one reason why a higher level of chlorine residual is needed for adequate disinfection. Computational fluid dynamics (CFD) modeling was performed to determine potential CCT modification to improve the plug flow characteristics of the tanks. Results of the CFD modeling are included in **Attachment 9-A**. The CFD modeling looked at the contact time, T_{10}, in the CCT, defined as the time the first 10% of the flow passes through the tank and the baffling factor, BF, defined as T_{10}/T_{th}, where T_{th} is the theoretical hydraulic detention time, or volume divided by flow. A baffling factor equal to 1 indicates ideal plug flow conditions.

9.2.3 Risk Management Plan

As noted previously, the HFC AWTP receives liquefied chlorine gas and liquefied sulfur dioxide gas in 90-ton rail cars. A leak from either one of the toxic gases could cause injury or death to affected personnel at the facility and others in the surrounding area. Due to the quantity of these chemicals stored onsite, the facility must have a registered Risk Management Plan (RMP) with the EPA and submit updates every five years. This was last updated in September 22, 2014 according to the EPA facility information and an update must be submitted prior to the end of the five year anniversary date. The RMP includes analysis of worst case scenario accidental releases as well as information about safety systems and operations to meet EPA's Accidental Release Prevention Rule and other applicable federal and state regulations. Some of the additional requirements the facility must meet to receive and store these gases in rail cars include the following:

- Rail cars must meet federal CFR guidelines;
- The facility must own a private railway to receive and store cars;
- Leak sensors and motoring systems must be installed in the rail car unloading area and chlorination room;
- The facility cannot store more than 135 tons combined of chlorine and sulfur dioxide gas onsite or exceed an annual daily average of 57.5 tons; and
- Staff must have Chlorine Institute training.

As noted above, the use of chlorine and sulfur dioxide for disinfection and dechlorination has led to NPDES permit exceedances for DBPs at this facility in the past and possibly posed health risks to personnel. The large quantities of liquefied chlorine and sulfur dioxide gases stored onsite

require a RMP. While chlorine gas has historically been the lowest cost disinfectant used for wastewater per gallon treated, other viable disinfectant alternatives exist. Additionally, more stringent regulations on chlorine gas may decrease its overall availability to the City. The remainder of this memorandum provides a summary of the alternative disinfectants evaluated.

9.3 Disinfection Alternatives

Several disinfection alternatives were evaluated as part of this memorandum. As noted above, alternative means for disinfection were evaluated for the following reasons:

- Human health risks associated with the use of chlorine gas and sulfur dioxide gas;
- Possible restriction or ban on chlorine gas by Port of Tampa, shipping regulations or other future regulation changes;
- Added operational costs for personnel training and maintaining RMP; and
- Historical issues with DBP exceedances associated with the use of chlorine-based disinfection.

Alternative disinfection methods were evaluated including liquid sodium hypochlorite (NaOCl), peracetic acid (PAA), ultra violet (UV) and ozone. A brief summary of each alternative is provided below. Other methods, such as chlorine dioxide, ferrate, bromine compounds were not considered viable alternatives at this time due to the lack of acceptance in the industry. Peracetic acid is considered a developing technology. However, it is the only alternative with multiple full-scale installations for wastewater disinfection in Florida and more throughout the United States.

The Grizzle-Figg Statute, Section 403.086, F. S. requires that the HFC AWTP achieve high level disinfection due to its discharge to Tampa Bay. As such, costs presented for all disinfection alternatives reflect achieving high level disinfection.

9.3.1 Sodium Hypochlorite (Bulk and On-site Generation)

Liquid sodium hypochlorite disinfects water with the same chemical oxidants produced from chlorine gas, hypochlorous acid and hypochlorite ions. Hypochlorous acid and hypochlorite exist in equilibrium in solution based on pH. The formation of hypochlorous acid is shown in the following equation:

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

Hypochlorite salts are typically available in liquid form as sodium hypochlorite in various concentrations. Sodium hypochlorite can be delivered to the facility in bulk or can be generated on-site. The effluent stream will need additional treatment to dechlorinate prior to discharge to surface water. The main advantage of sodium hypochlorite over chlorine gas is the ability to utilize the disinfecting power of chlorine without the safety concerns associated with chlorine gas. However, there would be no change in the effluent dichlorobromomethane and dibromochloromethane concentrations when compared with current disinfection techniques. Note that improvements to the CCTs based on CFD modeling should reduce chlorine dose by improving plug-flow through the CCT, which in turn, should reduce effluent concentrations of DBPs and annual chemical costs for both chlorine and the dechlorination agent.

It is important to note that a sodium bisulfite (NaHSO3) system will also be required for dechlorination of the effluent water.

The volume of liquid sodium hypochlorite and sodium bisulfite used each day at the facility could create a logistics challenge for the facility and the supplier. The current average daily chlorine demand at the facility is just under 8,000 lbs/day. This equates to 8,000 gal/day of 12.5% sodium hypochlorite. Odyssey Manufacturing, a leading local supplier, proposed to deliver the sodium hypochlorite to the site at 22% solution in rail cars. This would eliminate truck traffic for deliveries and cut the frequency of deliveries in half. This is an option that should be evaluated further if liquid sodium hypochlorite is considered.

Capital costs for the disinfection alternatives include cost of equipment installation, including any civil, structural, electrical, and instrumentation improvements necessary. The capital costs also include 30% for contingency, 20% for overhead, profit and general conditions and 20% for management and engineering. These cost estimates were made with the best available current data specific to the HFC AWTP. It is noted that capital costs are based on equipment required to meet PHF of 234 MGD.

Present worth cost was developed for each alternative based on the capital costs developed and 20-year O&M costs for starting at the current 60 MGD AADF to the future 80 MGD AADF, including, estimated chemical costs, power costs and replacement costs within the 20-year period. The presented 20-year O&M costs are the present value cost of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within a 20-year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2% was used.

The estimated capital costs to convert the facility to sodium hypochlorite disinfection are shown below in **Table 9.3-1.** These costs include the relocation of the post aeration system and the addition of center baffle walls in the CCTs, both of which are discussed in more detail later in this TM. The capital costs for onsite generation were estimated to be significantly higher than bulk delivery. The 20-year O&M cost for onsite generation was also estimated to be slightly more than bulk delivery. Odyssey Manufacturing Company (Odyssey) is only miles away from the facility and has the ability to deliver bulk product in rail cars. This made the O&M costs similar between the two sodium hypochlorite options. Therefore, only bulk sodium hypochlorite was compared to other disinfection alternatives for the remainder of this TM. The following equipment is recommended for the conversion. This list is not intended to be a comprehensive list for design.

- A temporary storage and feed system may be necessary during construction.
- Partial or complete demolition of chlorine gas and sulfur dioxide gas equipment and piping in the existing buildings is recommended to reuse one or both rooms for the new feed equipment or future use.
- Bulk storage tanks and containment. The capital cost estimate included four 40,000 FRP sodium hypochlorite storage tanks within a concrete containment area for two weeks of storage at the permitted 96 MGD and estimated annual usage at this flow rate. Also included in the estimate were three 6,500 gallon double walled sodium bisulfite tanks.
- The capital cost estimate includes schedule 80 PVC supply and feed piping.
- Pump skids for sodium hypochlorite and sodium bisulfite.
- Eyewash/safety showers at the new bulk storage tank locations.
- Electrical and instrumentation and controls.

The following information was used to calculate the present worth of the 20-year O&M cost for the sodium hypochlorite bulk delivery option by rail car:

- Annual sodium hypochlorite costs: Assumes a bulk price of $0.46/gallon (City of Tampa currently pays $0.482/gallon according to Odyssey). Per Odyssey cost of $0.50/gallon is average and reduced by $0.04/gallon via railcar delivery. Assumes 302 gallons/hr dose at average flows. Also included is $15,000/yr for feed pump maintenance
- Annual sodium bisulfite costs: Assumes using 600 gallons per day at $1.40 per gallon due to railcar delivery. Also included is $15,000/yr for feed pump maintenance.
- Future equipment replacement costs: Assumes replacement cost of tank and piping ($400,000 each) at the 10-year mark. Also an additional $200,000 was added for miscellaneous costs at year 10.

The following information was used to calculate the present worth of the 20-year O&M cost for the sodium hypochlorite onsite generation option:

- Per Odyssey about 3.8 lbs of salt consumed per equivalent pound of chlorine gas utilized. Per Odyssey cost is $140/ton. 2,642,278 lbs/yr = 1,321 tons/yr
- Per Odyssey assume using 600 gallons per day at $2.10 per gallon. Also included is $15,000/yr for feed pump maintenance.
- Per Odyssey (3) kWh per equivalent lb of Cl2 gas (7,238 lb Cl2/Day * 3 kWh/lb Cl2 * 365 day/yr * $/kWh). Assume (3) 20 hp pumps operating at all times (20 hp * 0.7457 kw/hp * 3 * 8760 * $/kWh). Assume (5) 7.5 hp blowers operating at all times (7.5 hp * 0.7457 kw/hp * 5 * 8760 * $/kWh).
- Per Odyssey assume cost $0.04/lb Cl2 to replace the cells (7,238 lb Cl2/day * 365 day/yr * 7 yr * $0.04/lb Cl2 = $740,000) every 7 years.
- Assume $1,000,000 in equipment replacement every 10 years.

Table 9.3-1: Estimated Capital and Present Worth of O&M Costs for Conversion to Sodium Hypochlorite Disinfection

Item	Bulk Delivery Cost	Onsite Generation Cost
Capital Costs		
NaOCl and NaHSO3 Equipment	$1,737,000	$5,774,000
Demolition and Structural Improvements	$80,000	$80,000
CCT Center Baffle Walls	$675,000	$675,000
Relocate Post-Aeration	$779,000	$779,000
Electrical and I&C	$435,000	$1,444,000
Installation	$504,000	$1,311,000
Subtotal	**$4,210,000**	**$10,063,000**
30% Contingency	$1,263,000	$3,019,000
Bare Construction Costs	**$5,473,000**	**$13,082,000**
20% Overhead and Profit, General Conditions	$1,095,000	$2,617,000
Total Construction Costs	**$6,568,000**	**$15,699,000**
20% Management and Engineering	$1,314,000	$3,140,000
Total Capital Costs	**$7,882,000**	**$18,839,000**
O&M Cost		
Present Worth of 20-Year O&M Cost[1]	**$25,578,000**	**$22,404,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

9.3.2 Peracetic Acid

Peracetic acid (PAA) is an organic peroxide compound formed when acetic acid and hydrogen peroxide are combined, as shown in the following equilibrium equation:

$$CH_3CO_2H + H_2O_2 \longleftrightarrow CH_3CO_3H + H_2O$$

(Note: PAA and H_2O_2 both exist in equilibrium, 12 to 22% PAA depending on brand)

PAA is a strong oxidant and disinfectant, and has an oxidation potential higher than that of chlorine. PAA does not produce the regulated DBPs and does not require quenching for surface water discharge. PAA naturally breaks down in the environment into acetic acid and hydrogen peroxide and then to oxygen and water. It does add five-day biochemical oxygen demand (BOD_5), but other wastewater facilities that use methanol for denitrification and have a limit of 5 mg/L have successfully used PAA without exceeding the BOD_5 limit. It has been widely used in food and pharmaceutical disinfection applications for decades, has been used in Europe for municipal wastewater disinfection for many years, and in recent years formulations have been approved by the U.S. Environmental Protection Agency for wastewater disinfection. PAA offers the following benefits:

- Can be retrofitted to an existing chlorine disinfection system without major changes;
- Does not result in regulated disinfection byproducts;

- Does not require a quenching chemical downstream prior to surface water discharge. Therefore, a single chemical can be used compared to chlorination and dechlorination.
- Does not require RMP by EPA;
- Has been shown to have lower dosing requirements than that of chlorine;
- Highly effective as a bactericide and viricide;
- Due to lower dose onsite storage requirements are less than that of sodium hypochlorite;
- Increases DO in the effluent; and
- Very slow degradation rate compared to sodium hypochlorite.

The following is a list of some of the major disadvantages for PAA

- Higher chemical cost than sodium hypochlorite.
- Chlorine residual is recommended for the reclaimed water distribution system. Some chlorine quenching is expected by dosing chlorine after PAA (chlorine should be dosed at the end or after of CCTs) . This will increase chlorine usage for the reclaimed system. Note that the flow of the reclaimed water system is about 10% of the total plant flow; and
- New technology.

PAA is a relatively new technology for wastewater disinfection in North America and has a small number of installations. The following is a list of facilities in North America that are currently using PAA:

- NW Langley WWTP in Metro Vancouver, British Columbia
- St. Augustine WWTP in St. Augustine, FL
- City of Steubenville WWTP in Steubenville, OH
- Mayport Naval Facility in Jacksonville, FL
- Greenville WWTP in Greenville, KY
- Whitehouse WWTP in Whitehouse, TN
- Flagler Beach WWTP in Flagler Beach, FL
- Three Rivers Regional WWTP in Longview, WA
- Tri Cities WWTP in Clackamas, OR
- Largo WWRF in Largo, FL

Critical success factors for converting to PAA include the following:

- Proper design and maintenance of storage and handling facilities are required to ensure safety. This can be accomplished with sufficient research during design and operator training.
- A commitment of product availability and reliability from one or multiple PAA vendors must be obtained prior to final design. Discussions with vendors during this evaluation included the possibility of adding a new distribution facility closer to Tampa. This may be necessary to ensure a reliable supply of PAA to the facility.
- Both PAA and methanol dosing must be closely controlled to avoid exceedances in effluent BOD_5.
- Consideration for shipping cost.

The PAA dosage required to effectively disinfect the effluent stream is highly dependent on water quality (as with all types of disinfection products used). Water quality data, reflective of

existing conditions for HFC AWTP was not used in determining the PAA dose for this memorandum. Proposals were based on industry standards and took into consideration the facility's average chlorine dosage rate from 2016 of 14 ppm. The average dose used to determine overall amount of PAA required on an annual average basis for O&M costs was estimated to be 3.0 mg/L based on the FDEP approved doses for the Largo WWRF and the Mayport Naval facility (based on full scale pilot testing FDEP approved 3.0 mg/L at 12.6% PAA solution, US Naval Mayport Station Wastewater Treatment Facility permitted for minimum dose of 2.5 mg/L at 15% PAA by FDEP).

It is important to note that the PAA dose chosen for this desktop study was based on two other facilities in Florida permitted for PAA disinfection. An extensive study was conducted for the Largo WWRF to establish the 3.0 mg/L FDEP required dose. The Largo WWRF has a similar collection system, primary clarification, biological nutrient removal secondary process, tertiary denitrification filters, high level disinfection required and discharges to Tampa Bay similar to HFC AWTP. Based on this information the permit required PAA dose for HFC AWTP is anticipated to be similar to Largo WWRF. Also noted that after multiple studies, the Largo WWRF was converted to PAA disinfection and UV was not cost effective.

Another consideration for the cost of PAA for this evaluation is the shipping cost. The closest manufacturing facility for the manufacturer used as a basis for this evaluation, PeroxyChem, at this time is in Memphis, TN. At the time of this memo PAA is delivered in totes by truck. Much of the cost per gallon of PAA delivered to the facility is shipping costs at this time. If a manufacturing facility were to be built in Florida in the future, shipping cost would be greatly reduced. This is an important consideration for the O&M costs for PAA, and new quotes should be solicited during the initial stages of the future disinfection improvements project. At the time of this memo four commercial PAA products are approved by the EPA for municipal wastewater disinfection (Proxitane© WW-12, VigorOx© WWT II, BioSide™ HS 15%, Peragreen© 22WW). Sufficient research into available PAA sources and testing at bench-scale and pilot-scale will likely be required if PAA is selected as a viable alternative prior to permitting and design.

The estimated capital costs to convert the facility to PAA disinfection are provided below in **Table 9.3-2**. These costs include the relocation of the post aeration system discussed in more detail later in the TM. However, PAA adds DO, and it is possible that the post-aeration system may not be needed at all if the facility switches to PAA. This would have to be confirmed with PAA pilot testing. It is important to note that a bulk sodium hypochlorite system is recommended to provide a chlorine residual in the reclaimed water supply and was included in both capital and annual costs for this alternative. The sizing of sodium hypochlorite system was based on current chlorine demands at a total reclaimed water flow of 12.5 MGD. The following equipment is recommended for the conversion. This list is not intended to be a comprehensive list for design.

- A temporary storage and feed system may be necessary during construction.
- Partial or complete demolition of chlorine gas and sulfur dioxide gas equipment and piping in the existing buildings is recommended to reuse one or both rooms for the new feed equipment or future use.
- Bulk storage tanks. The capital cost estimate included stainless steel bulk storage tanks with level and temperature instrumentation.

- PAA feed pump skid.
- PAA online residual analyzer.
- Truck unloading pumping system.
- Electrical and instrumentation and controls.
- Sodium Hypochlorite System for Reuse:
  - Two double walled 5,200 gallon sodium hypochlorite bulk storage tanks were included in the cost estimate.
  - Sodium hypochlorite feed pump skid.
  - Schedule 80 PVC piping.

The following information was used to calculate the present worth of the 20-year O&M cost for the PAA alternative:

- 3 mg/L 100% PAA converted to lb/y and multiplied by vendor cost per pound equating to $0.67/lb VigorOx.
- Per Peroxy Chem, assume $1,000/yr for peristaltic pump maintenance, $700/yr on centrifugal pump maintenance, $1,100/yr on SST Tank inspection and instrumentation replacement.
- Sodium hypochlorite for reuse - Assumes a bulk price of $0.50/gallon, City of Tampa currently pays $0.482/gallon. Assumes 26 gallons/hr dose at peak reuse flows of 12.5 MGD. Also included is $5,000/yr for feed pump maintenance.
- Shipping is driving the current cost of delivered PAA. As demand for PAA increases in Florida the potential for manufacturing PAA in the state will increase, and the delivered cost will then likely decrease. If a new manufacturing facility for PAA is constructed prior to the design of a new disinfection system for HFC AWTP, PAA may become less expensive.

Table 9.3-2: Estimated Capital and Present Worth of O&M Costs for Conversion to PAA Disinfection

Item	Cost
Capital Costs	
PAA Equipment	$715,000
Demolition and Structural Improvements	$80,000
Relocate Post-Aeration	$779,000
Reuse Disinfection System	$396,000
Electrical and I&C	$278,000
Installation	$662,000
Subtotal	**$2,910,000**
30% Contingency	$873,000
Bare Construction Costs	**$3,783,000**
20% Overhead and Profit, General Conditions	$757,000
Total Construction Costs	**$4,540,000**
20% Management and Engineering	$908,000
Pilot Study and Preliminary Engineering Report	$300,000
Total Capital Costs	**$5,748,000**
O&M Life Cycle Costs	
20-Year O&M Life Cycle Costs[1]	**$44,315,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

9.3.3 UV Light

UV light radiation is a physical disinfection process that works by inducing photochemical changes within a microorganism, damaging the cellular nucleic acids. Over the past decade, UV technology has improved in several areas that has increased the overall system reliability and decreased equipment costs. Improvements include: increased efficiency of UV lamps and reliability; enhanced reactor design and validation allowing for fewer lamps and less power consumption; standardized testing protocol by third parties. UV offers the following advantages:

- Proven disinfection technology;
- Small footprint;
- Does not produce DBPs;
- Does not require a quenching chemical prior to surface water discharge;
- Safe and cost effective; and
- Does not require RMP by EPA.

There are several critical factors that must be considered in an UV application, including:

- The number and type of UV lamps;
- Reactor hydraulics;
- Inactivation requirements;

- Impacts of water quality and variability; and
- Instrumentation and controls.

Water quality plays a major role in UV application. Several of the key water quality parameters and their effect on the UV process are discussed below. UV transmittance (UVT) is a key operating parameter of an UV system. UVT is the ability of UV light to penetrate water and is unique to each water stream, as it is dependent on the water's physical (TSS) and chemical (hardness, iron, etc.) makeup. In general, UVT between 40 and 65 percent is common for biologically treated wastewater, and it increases as wastewater quality improves. TSS also affects an UV systems' overall performance by scattering and absorbing UV light or by shielding organisms from the UV light. Dissolved iron and manganese can readily absorb UV energy, preventing it from reaching target organisms. Higher concentrations of TSS, metals and organics (TOC), in the water, contribute to lower UVT. The overall amount of equipment is influenced by the UVT of the water stream. UVT was not measured for this evaluation and proposals are based on a UVT of 65% based on the upstream unit processes at this facility. Measuring the actual UVT will be required if UV is the, or one of the, selected alternatives, for design and permitting and to validate capital and O&M costs. This can be done rapidly over a 6-month period through grab samples taken at the filter effluent and using a spectrophotometer. It is important to note that it is recommended that UVT be measured for at least 6 months for use in design and permitting. Present worth costs for UV were calculated for both UVT of 50% and UVT of 65%, presented later in this memorandum, in order to provide the City with a basis of the effect actual UVT can have on the overall cost of a UV system. UVT was measured continuously at the facility in 2006 for six months and resulted in an average or 62% with the lowest 10% of the data at 57% UVT. The costs presented in this TM which are based on UVT of 65% represent a more favorable comparison with other disinfection technologies. Presented later in this TM, capital costs for UV are very high compared to the other technologies considered. Knowing that the actual UVT will most likely be lower than 65%, capital and annual costs will be even higher. UV costs at 50% UVT are also presented later in the TM to encompass the anticipated range of UVT.

The facility's NPDES requires high level disinfection for both surface water discharge and reclaimed water. UV costs were based on a dose of 100 mJ/cm^2 to meet this requirement.

The UV systems considered for this TM do have some impact on the plant hydraulics. Both systems increase the water level upstream by about 12-inches at peak flow. The plant hydraulics between the denitrification filters and the surface water discharge was defined as a problem in the Phase 1 TM of the Master Plan. Later in this TM, recommendations are made to improve plant hydraulics in this area. These recommendations provide additional freeboard to allow the CCT weirs to be lowered 12-inches which negate the increase across the UV modules. The cost of these hydraulic improvements is included in the UV capital costs.

Several items are important to note related to the costs presented throughout this TM:

- A 2005 study on control of THMs conducted for the City by MWH concluded a UV system would have a $43.5M capital cost to construct. Greeley and Hansen also did a UV study around the same time that determined that UV was cost prohibitive at the time. The reduction in capital cost calculated for this analysis is reflective of the improvements made to UV disinfection over the past decade, however remains high due to the requirement for high level disinfection as noted above.

- UV costs assuming a UVT of 50% were added to **Table 9.3-3** for reference. As noted previously, testing would be necessary to determine the actual UVT of the effluent. This is meant to provide an example of how sensitive UV costs can be related to UVT. The facility measured 62% average UVT and 56% UVT or higher 90% of the time for a six month period in 2006 for tertiary effluent.

The estimated capital costs to convert the facility to UV disinfection are shown below in **Table 9.3-3**. These costs include an uninterruptible power supply, additional emergency generator, required electrical and I&C improvements, structural improvements including CCT modifications, channel grating and canopies, downstream hydraulic improvements discussed in more detail later in the TM lowering of weir height, and a reclaimed water bulk sodium hypochlorite system. The table includes estimated costs for a UV system designed for 65% UVT and 50% UVT to show the expected range.

The following information was used to calculate the present worth of the 20-year O&M cost for the UV alternative:

- Averaged estimated annual electrical usage provided by Wedeco and Trojan
- Sodium hypochlorite for reuse - Assumes a bulk price of $0.50/gallon, City of Tampa currently pays $0.482/gallon. Assumes 26 gallons/hr dose at peak reuse flows of 12.5 MGD. Also included is $5,000/yr for feed pump maintenance.

Due to the high capital costs, UV was not considered a viable disinfection alternative and not included in the evaluation matrix later in the TM.

Table 9.3-3: Estimated Capital and Present Worth of O&M Costs for Conversion to UV Disinfection

Item	65% UVT	50% UVT
	Cost	Cost
Capital Costs		
UV Equipment	$12,010,000	$15,613,000
Uninterruptible Power Supply	$3,000,000	$3,000,000
Emergency Generator	$250,000	$250,000
Other Electrical and I&C	$550,000	$550,000
Demolition and Structural Improvements	$735,000	$735,000
Hydraulic improvements	$4,088,000	$4,088,000
Reuse Disinfection System	$396,000	$396,000
Installation	$2,431,000	$2,972,000
Subtotal	**$23,460,000**	**$27,604,000**
30% Contingency	$7,038,000	$8,282,000
Bare Construction Costs	**$30,498,000**	**$35,886,000**
20% Overhead and Profit, General Conditions	$6,100,000	$7,178,000
Total Construction Costs	**$36,598,000**	**$43,064,000**
20% Management and Engineering	$7,320,000	$8,613,000
Total Capital Costs	**$43,918,000**	**$51,677,000**
O&M Life Cycle Costs		
20-Year O&M Life Cycle Costs[1]	**$19,666,000**	**$29,546,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

9.3.4 Ozone

Ozone (O_3) is produced when oxygen molecules (O_2) are dissociated by an energy source into oxygen atoms (O) and subsequently collide with an oxygen molecule to form an unstable gas, ozone. Ozone is not only an extremely reactive oxidant that directly causes cell lysis, but also a strong virucide that is known to be more effective than chlorine. Historically, ozone is primarily used for the disinfection of industrial wastewater and drinking water, approximately 25% of the drinking water is treated with ozone in the U.S. In contrast, applications in domestic wastewater treatment is not very popular, historically mostly consists of small and medium sized plants. However, recent advances in ozone generation and solution technology in addition to the unique situation at HFC AWTP where excess source gas (high purity oxygen) is already produced onsite make ozone disinfection worth looking into as an alternative. Ozone offers the following advantages:

- Effective disinfectant;
- Removes color, odor, iron, and manganese;
- Increases effluent dissolved oxygen concentration;
- Reduces effluent COD; and
- No regrowth of microorganisms.

In the wastewater application, the components of an ozone disinfection system include feed-gas preparation, ozone generation, ozone contacting, and ozone destruction. Extremely dry air or pure oxygen with dew point below -80 °F is used as feed-gas source for ozone generation. Subsequently, ozone is fed into a down-flow contact chamber containing treated wastewater to be disinfected. The off-gasses from the contact chamber must be collected to convert any remaining ozone back to oxygen before release into the atmosphere or recycled to supplement the aeration treatment, since ozone is highly irritating and toxic even at very low levels.

The effectiveness of ozone disinfection depends on the susceptibility of the target organisms, the contact time, and the concentration of the ozone. The actual key parameters will have to be determined through pilot testing, but for the purpose of this TM, the design criteria is based on the peak hourly flow rate, assuming target ozone dose of 5 mg/L at 12% concentration, which requires an oxygen feed-gas flow rate of approximately 645 scfm (35 tons/day). The assumption of the ozone target dose is based on ozone being 1.3 times stronger than chlorine. It is also assumed, per manufacturer, that 85% of oxygen feed-gas used to generate ozone can be recovered after the off-gas destruct units and returned to supplement aeration in the secondary treatment. A significant portion of the 85% oxygen recirculation comes from the feed oxygen that does not get converted when achieving target ozone dose in the ozone generation process due to the limited efficiency in today's technology. Only a small portion of the 85% return rate is a result of ozone residual treatment since the operation goal is to maintain an optimal ozone dosage to maximize disinfection efficiency.

At the HFC AWTP, there are two existing cryogenic oxygen generators (cryogenic plant), one has a capacity of 60 tons/day and the other has a capacity of 80 tons/day. According to the Phase I report, the current operation is producing more oxygen than the demand of the high purity oxygen (HPO) reactors. If implementing ozone disinfection at HFC AWTP with assumed design conditions, under the current operation, the cryogenic plant is still generating more than enough oxygen to meet the demands of both treatment processes under AADF conditions, because of the 85% oxygen recirculation capability of the ozone disinfection system. If future peak condition is considered, the smaller cryogenic plant will be sufficient enough to meet the overall oxygen demand.

Although ozone application can take advantage of the existing facilities for oxygen supply, there are several other critical elements that must be considered in this TM, including: ring compressors for both oxygen feed and return; a chilling unit to cool the feed-gas to the desired temperature before passing to the ozone generation; the long distance of oxygen gas conveyance for the needs of supply and recirculation not only adds to the capital cost, but also poses a major safety concern due to the explosiveness of oxygen; and an ozone disinfection system is relatively complex to operate and maintain especially with the goal of achieving maximum efficiency in oxygen generation to sustain both downstream treatment processes. Also, ozone residual monitoring and recording require more time and training from the operators than they do with chlorine.

In addition, the existing CCTs require significant modifications to accommodate the ozone disinfection system. Some of the biggest expenses include air tight tank coverage, weir reconfigurations to create head space for off-gas collection and corrosion-resistant coatings for concrete to protect reinforcing steel in structures. It is also noted that hypochlorite injection at

the end of the ozone treatment is recommended to provide chlorine residual effect to meet the permit requirements on reclaimed water treatment.

Table 9.3-4 below shows the estimated capital and O&M life cycle costs for ozone disinfection. Although the facility has a unique opportunity to use excess oxygen supplied by the HPO generators, the overall capital costs for an ozone disinfection system are very high compared to those of some other alternatives considered. Therefore, ozone was not considered a viable disinfection alternative to be included in the evaluation matrix later in the TM.

The following information was used to calculate the present worth of the 20-year O&M cost for the ozone alternative:

- HPO electrical cost estimated to be $36,000/yr for 15% of 11 ton/d O2 based on previous reports.
- Ozone equipment electrical costs - Per Wedeco, 4.5 kw-h/lb O3 x 2916 PPD O3 x 365 days.
- Blower electrical costs for oxygen feed and recirculation - 30hp / 1.34 x 24 hrs x 365 days, 60hp/1.34 x 24 hrs x 365 days.

Table 9.3-4: Estimated Capital and Present Worth of O&M Costs for Conversion to Ozone Disinfection

Item	Cost
Capital Costs	
Ozone Generation Equipment	$7,100,000
O2 Transfer Compressors and Air Piping	$3,000,000
Demolition and Structural Improvements	$3,700,000
Emergency Generator	$2,500,000
Electrical and I&C	$2,200,000
Reuse Disinfection System	$396,000
Installation	$3,780,000
Subtotal	**$22,676,000**
30% Contingency	$6,803,000
Bare Construction Costs	**$29,479,000**
20% Overhead and Profit, General Conditions	$5,896,000
Total Construction Costs	**$35,375,000**
20% Management and Engineering	$7,075,000
Total Capital Costs	**$42,450,000**
O&M Cost	
Present Worth of 20-Year O&M Cost[1]	**$5,919,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

9.3.5 Existing Chlorine Gas System

Capital and O&M costs were estimated for comparison with other alternatives. Capital costs to stay with the chlorine gas system include the cost to relocate the post-aeration system and center baffle wall addition in CCTs. Also, the cost to replace aging chlorine and sulfur dioxide gas equipment over the next twenty years was estimated. O&M costs were estimated based on historical chemical usage and estimated current power usage scaled up for future AADF plus 15% increase in chemical costs. **Table 9.3-5** below shows cost breakdown.

Table 9.3-5: Estimated Capital and Present Worth of O&M Costs to Extend the Life of the Existing Chlorine Gas Disinfection System

Item	Cost
Capital Costs	
Replacement Equipment Including Installation	$500,000
CCT Center Baffle Walls	$675,000
Relocate Post-Aeration	$779,000
Subtotal	**$1,954,000**
30% Contingency	$587,000
Bare Construction Costs	**$2,541,000**
20% Overhead and Profit, General Conditions	$509,000
Total Construction Costs	**$3,050,000**
20% Management and Engineering	$610,000
Total Capital Costs	**$3,660,000**
O&M Life Cycle Costs	
20-Year O&M Life Cycle Costs[1]	**$13,029,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

9.4 Alternatives Evaluation

Each alternative was evaluated based on cost and non-cost criteria. Estimated capital costs and O&M costs for the alternatives were discussed earlier in the TM for each disinfection alternative. 20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within the 20-year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.

An evaluation matrix was created to help identify the most suitable option based on the capital and O&M life cycle costs discussed and the following non-cost criteria. Each alternative was scored 1 to 10, with 10 being the best for each criterion. The score for each criterion was multiplied by a weighting factor and the weighted scores were totaled at the bottom. A brief summary of each non-cost criterion is discussed below.

9.4.1 Non-Cost Criteria

Safety, Required Maintenance and Onsite Storage Requirements Criteria

The overall O&M of the systems evaluated the safety, operator training, intensity/frequency of maintenance and onsite storage requirements. The following discusses these criteria respective to each alternative. Safety was given a 20% weighting factor, since improving the safety of the facility personnel and the surrounding area was a primary goal for this evaluation.

- Sodium Hypochlorite – The implementation of sodium hypochlorite would eliminate the need for a RMP, however it still poses risk to employees if proper protective equipment is not worn when handling. In addition to a sodium hypochlorite system, a sodium bisulfite feed system would also be required for dechlorination. The introduction of two new chemicals would require employees to familiarize themselves with associated hazards and safety protocols, but on a different scale as compared to chlorine gas. Both sodium hypochlorite and sodium bisulfite are injected using similar equipment to that used for chlorine and sulfur dioxide injection, and therefore would reduce the amount of operator training required. Additionally, the liquid feed systems have few components, and therefore require a relatively low amount of maintenance. The onsite storage volume requirement for sodium hypochlorite is greater and degrades faster than PAA. Therefore, sodium hypochlorite was scored higher for safety, the highest possible for required maintenance, since it is the most similar to the existing chlorine gas system, and the lowest possible for onsite storage requirements due to the most storage required of all the alternatives.
- PAA - Similar to sodium hypochlorite, implementation of PAA for disinfection would eliminate the need for a RMP. Handling would still require employees to wear proper protective equipment, and employees would need to familiarize themselves with the hazards and safety protocols associated with handling of a new chemical. PAA does require special storage/venting requirements and has an explosion risk. Considering that the facility has been using methanol for years the fire and explosion risk for PAA feed systems are similar to that used for chlorine injection and have few moving parts, thus requiring a relatively low amount of maintenance. As noted above, a small sodium hypochlorite system is required for reuse water, requiring additional limited maintenance and chemical handling. The onsite storage volume requirement for PAA is significantly less than for sodium hypochlorite due to an estimated dose of 3 mg/L for PAA compared to 14 mg/L for sodium hypochlorite at similar strength. PAA can be mitigated with proper O&M. Therefore, PAA was scored below NaOCl in safety, between NaCOl and chlorine gas for required maintenance, and a higher score than NaCOl for onsite storage requirements.
- Chlorine Gas – Chorine gas received a safety score of 1 out of 10 for the previously discussed concerns regarding exposure to facility personnel and the surrounding area. Required maintenance received a score of 4 due to Chlorine Institute training requirement, and Onsite Storage Requirements received a 10, since no storage is required beyond feeding gases directly from the rail cars.

9.4.2 Other Success Factors

Several other factors were evaluated with regards to each alternative and are discussed below. The potential that chlorine gas could be banned from delivery to the facility was discovered during this evaluation. Therefore, the Future Availability & Process Reliability criterion was given a 15% weighting factor.

- Potential for DBP Generation – DBP generation is a concern with chlorine disinfection. The use of sodium hypochlorite presents the same concerns with DBP generation as chlorine gas, and as such, the dosage level would need to be fine-tuned to control the generation potential. PAA does not have the associated risk of generating DBPs. All the alternatives were scored a 1 or 10 for potential to create DBPs or not.

  DBP generation may have impacts on the City's TAP project. The TAP project, if implemented, represents indirect potable reuse (IPR) by redirecting effluent to areas that drain to the Tampa Bypass Canal, one of the City's drinking water sources. Tampa Bay Water is also considering using effluent from HFC AWTP for a direct potable reuse (DPR) project. The state does not currently have regulations for IPR and DPR. Therefore, it is assumed that only primary and secondary drinking water standards apply at this time. These standards include maximum containment levels for total trihalomethanes and haloacetic acids, which can be formed by chlorine disinfection. DBPs can also be formed due long durations in a pipeline while a chlorine residual is maintained. The fate of these compounds in the IPR and DPR treatment processes and pipelines was not analyzed with this evaluation. However, minimizing these compounds in the source water to a potable reuse treatment system seems logical.

- Future Availability & Process Reliability – Being the most common wastewater disinfectants, sodium hypochlorite and chlorine gas are also the most readily available. However, information at the time of this evaluation suggests that there is a good chance that chlorine gas will no longer be available for deliver to the site due to local regulatory changes. Chlorine gas received a 2 in this category for this reason. Odyssey did indicate that they could provide a reliable supply of sodium hypochlorite and sodium bisulfite to the facility due to the vicinity and the potential use of rail cars for delivery. However, there is some risk of supply shortages due the quantity of liquid sodium hypochlorite required. Therefore, sodium hypochlorite received a score of 8. Both sodium hypochlorite and PAA are injected in a similar manner to the current disinfection systems, and therefore could allow for continued use of the existing system until a new system is operational. It is important to note that PAA is reliable as well, but slightly less so than sodium hypochlorite and chlorine gas. PAA isn't as widely manufactured here in the United States, potentially creating complications with regards to delivery or shortages. However, PAA manufacturers suggested that a distribution facility may be built if HFC AWTP makes the switch to PAA. The alternatives were scored accordingly.

The evaluation matrix, comprised of cost and non-cost criteria, is shown below in **Table 9.4-1**. It shows that sodium hypochlorite received the highest overall score in the evaluation matrix followed by chlorine gas and PAA.

Table 9.4-1: Disinfection Alternatives Evaluation Matrix

Alternative Disinfectant							
	Sodium Hypochlorite			PAA		Chlorine Gas	
Primary Criteria	Weighting Factor	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost Criteria							
Capital Cost		$ 7,882,000		$ 5,748,000		$ 3,660,000	
	20%	6.00	1.20	8.00	1.60	10.00	2.00
Life Cycle Cost		$ 25,578,000		$ 44,315,000		$ 13,029,000	
	20%	5.00	1.00	1.00	0.20	10.00	2.00
Cost Subtotal	40%	11.00	**2.20**	9.00	**1.80**	20.00	**4.00**
Non-cost Criteria							
Safety	20%	8	1.6	6	1.20	1	0.20
Required Maintenance	10%	10	1	6	0.60	4	0.40
Onsite Storage Requirements	10%	4	0.4	8	0.80	10	1.00
Potential for DBP Generation	5%	1	0.05	10	0.50	1	0.05
Future Availability & Process Reliability	15%	8	1.2	6	0.90	2	0.30
Non-Cost Subtotal	60%	31	4.25	36	4.00	18	1.95
Total	100%	42.00	**6.45**	45.00	**5.80**	38.00	**5.95**

Table 9.4-2 below summarizes the capital, O&M life cycle and total present worth costs for each alternative included in the evaluation matrix. Chlorine gas has the lowest total present worth compared to the alternatives evaluated. PAA has the lowest capital cost and the highest total present worth cost due to the high O&M cost. Bulk delivery sodium hypochlorite has the lowest total present worth cost of any of the disinfection alternatives to chlorine gas.

Table 9.4-2: Disinfection Alternatives Capital, O&M Life Cycle and Present Worth Cost Comparison

	Sodium Hypochlorite		PAA	Chlorine Gas
	Bulk Railcar Delivery	Onsite Generation		
Capital Cost	$7,882,000	$18,839,000	$5,748,000	$3,660,000[2]
Present Worth O&M Cost[1]	$25,578,000	$22,404,000	$44,315,000	$13,029,000
Total Present Worth Cost	**$33,460,000**	**$41,243,000**	**$50,063,000**	**$16,689,000**

[1]20-Year O&M Cost represents the Present Worth of annual chemical and electric costs and equipment replacement cost at intervals recommended by equipment manufacturers within 20 year period including 3% inflation per year. Electrical cost of $0.081/kWh with an annual inflation rate of 2%.
[2]Refer to section 9.3.5 for information on capital cost estimate for chlorine gas.

9.4.3 Other Considerations

It is possible that chlorine gas may be banned by the Tampa Bay Port Authority. If this does happen, the City should be prepared to immediately move forward with design and construction of the recommended disinfection alternative.

9.5 Recommendation

None of the disinfection alternatives had lower estimated total present worth cost than maintaining and improving the chlorine gas system. The O&M cost for PAA is triple that of chlorine gas, and the capital costs for UV and ozone systems are many times higher than all the alternatives. Therefore, converting to a disinfection system that would generate no regulated DBPs cannot be justified at this time. The two other goals of this evaluation were to improve public safety and determine alternate disinfection due to potential regulation changes that would prevent the use of chlorine gas. The recommendation is to convert to sodium hypochlorite disinfection prior to major replacement and repair costs are required to maintain the existing chlorine gas system. The asset inventory evaluation from Phase 1 determined that some of the existing disinfection equipment was nearing the end of useful life. Continuing to use this equipment more than another ten years is not recommended. Although the O&M cost for onsite generation of sodium hypochlorite was estimated to be a little less than bulk delivery, the capital cost was estimated to be almost 2.5 times that of bulk delivery. With a commitment on availability, reliability and delivery method from Odyssey or another local supplier of bulk sodium hypochlorite, the capital cost savings of a bulk delivery system can be justified.

9.6 Additional Disinfection Improvements

In addition to evaluating alternative means of disinfection, the memorandum also includes an analysis of several system improvements. Each improvement is discussed below.

9.6.1 Post-Aeration

Under current operation, post-aeration is located in the first 90-feet of the CCTs. As noted in the Phase I report, the post-aeration system strips some of the chlorine from solution, increasing chlorine usage and causes unwanted dispersion in the reactors. For this reason, it is recommended that post-aeration be moved out of this portion of the CCTs. It is noted, that the recommendation for relocation would be the same if the City were to convert to either PAA or NaOCl, as contact time would be reduced.

Several options were explored for post-aeration and are discussed below.

- The aerators and associated piping could be relocated to the effluent channel of the CCTs. This would eliminate stripping and dispersion. The cost estimate for this includes new coarse bubble diffusers installed in the CCT effluent channel, new blowers and air piping. New blowers will be required due to the variable water level in this channel. All sections of this channel will have to remain active. The existing DO monitoring system could be modified to monitor the new system. It is anticipated that the system could be turned down or all altogether turned off when there is enough DO entrainment from the drop over the CCT weirs. Assuming this, the estimated cost is shown below in **Table 9.6-1.**

Table 9.6-1: Estimated Capital Costs for Relocation of Post-Aeration

Item	Cost
New Diffusers and PD Blowers	$455,000
Air Piping	$100,000
Electrical and I&C	$57,000
Installation	$167,000
30% Contingency	$233,700
Bare Construction Costs	**$1,012,700**
20% Overhead and Profit, General Conditions	$202,540
Total Construction Costs	**$1,215,240**
20% Management and Engineering	$243,048
Total Capital Costs	**$1,458,288**

While the existing system is effective at meeting the DO requirement of 5.0 mg/L, blower operation can be costly. A static aeration system could be constructed to meet the DO requirements, without the use of blowers. The JMS Eco-AIR low profile step aerator shown below in **Figure 9.6-1** was considered for this. However, upon initial investigation, it was determined that a footprint of 150-feet by 350-feet would be required to treat the peak flow of 221 MGD. Additionally, the concrete structure and aerator would cost approximately $3.8M. Based on footprint requirements and overall capital costs, this option is considered not feasible.

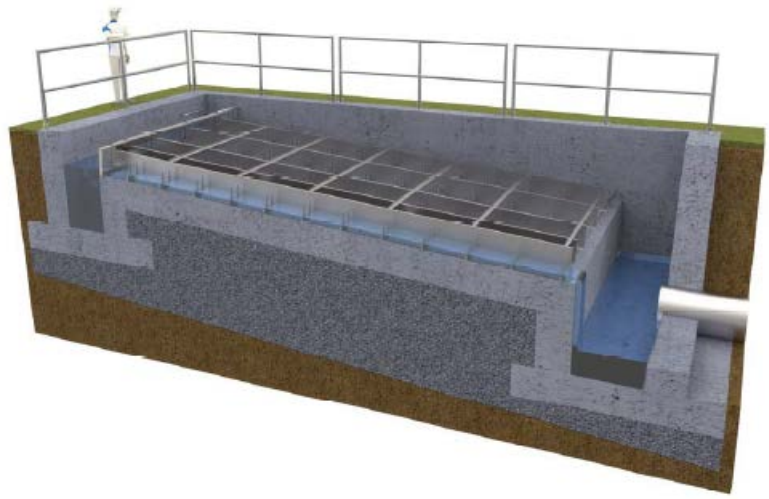

Figure 9.6-1: **JMS Eco-AIR Low Profile Step Aerator**

- A third option was also explored that considered a hybrid between the previous options. In this option, a low profile step aerator would be constructed and used to treat up to 80 MGD. A bypass channel would be constructed around the step aerator for flows over 80 MGD. The existing aerators would be relocated to the bypass channel to provide DO to high flows. The cost to relocate the aerator and piping would be approximately $100,000, with the cost for the step aerator adding an additional $1.8M. This option was also not recommended from a cost standpoint.

Under current operation, air for post-aeration is provided via blowers located in the Main Pumping Station. These blowers also meet the needs of the other air processes throughout the treatment plant. It is anticipated that future projects will move post-aeration to dedicated blowers. It is important to note that electrical costs associated with aeration were not factored into the above costs given the infeasibility of the step aerator option.

The recommendation is to relocate the diffusers to the effluent channel of the CCTs.

9.6.2 Channel Improvements

As previously mentioned, poor plug flow performance in the CCTs will contribute to the need to maintain a higher level of chlorine residual for adequate disinfection. Computational fluid dynamics (CFD) modeling was performed to determine potential CCT modifications to improve the plug flow characteristics of the tanks. The CFD modeling looked at the contact time, T_{10}, in the CCT, defined as the time the first 10% of the flow passes through the tank and the baffling factor, BF, defined as T_{10}/T_{th}, where T_{th} is the theoretical hydraulic detention time, or volume divided by flow. A BF equal to 1 indicates ideal plug flow conditions. A baffling factor in the 0.65 to 0.75 range is more realistic and considered a well baffled tank. Lower baffling factors indicate short circuiting with in the tank.

The CFD modeling was performed for high flow and low flow conditions. High flow conditions assumed a flow of 221 MGD through the three CCTs based on the current design PHF, or 73.6 MGD per tank with a water depth in the tanks of 10.5 ft. Low flow conditions assumed a flow of

15.6 MGD per tank. (Using the projected PHF flow of 234 MGD would not change the comparison of the evaluated modifications to improve plug flow conditions.) The modeling was performed for the following:

- Existing CCTs
  - Assumed that existing post aeration system must be relocated and not modeled
- Interior baffle wall
- Corners fillets (on exterior walls)
- Turning Vanes

Results of the CFD modeling are included in **Attachment 9-A**. While the baffling factor of the existing CCT is 0.67 under the high flow condition and 0.69 under the low flow condition, the baffling factors are at the low end of a well baffled tank. Air diffusers are known for and used for mixing in tanks, and therefore, negatively impact plug flow performance. Thus, the existing post aeration system was not included in the model. The addition of either a center baffle or turning vanes increased the baffling factor to 0.76 under the high flow condition and 0.79 under the low flow condition. Note that the location of the existing reclaimed water pump station will need to be considered in design. The estimated cost to add a center baffle wall in each CCT is shown below in **Table 9.6-2**.

Table 9.6-2: Estimated Cost for CCT Center Baffle Walls

Item	Cost
Center Baffle Walls	$675,000
30% Contingency	$202,500
Bare Construction Costs	**$877,500**
20% Overhead and Profit, General Conditions	$175,500
Total Construction Costs	**$1,053,000**
20% Management and Engineering	$210,600
Total Capital Costs	**$1,263,600**

Based on the results of the CFD modeling, the addition of either a center baffle or turning vanes is recommended should the City choose to stay with chlorine disinfection. Converting to PAA or UV would not necessarily require the improvement of the plug flow condition of the CCTs, since these disinfectants do not produce DBPs.

9.6.3 High Flow Surcharging

Under normal conditions, effluent from the CCTs overflows a weir, passes through Junction Chamber No. 4 (JC 4) and through a 96-inch diameter conduit before entering the Overflow Structure. Once in the Overflow Structure, the effluent discharges through the primary 78-inch outfall until the water level in the Overflow Structure overtops the weirs feeding the other two outfalls. An analysis of the hydraulic profile in the Phase 1 TM indicated that during high flow scenarios (flows over 163 MGD at mean high high water tide, before reaching current design peak hourly flow (PHF) 221 MGD at mean tide and flows lower than 163 MGD at storm tides recorded up to 4.3-feet above mean high high tide) the effluent weir of the CCTs would surcharge. Surcharging of the CCTs directly impacts the level in the denitrification filters. Since the denitrification filters have hydraulic limitations, see *Denitrification Filter Evaluation*,

surcharging of the CCTs has greater impacts upstream than just disinfection effectiveness and should be avoided with hydraulic improvements. Two items were noted to be contributing factors to the surcharging:

1. the single 96-inch conduit between JC 4 and the Overflow Structure
2. the weirs in the Overflow Structure.

Figure 9.6-2 below provides a snapshot of the hydraulic profile to highlight the issue with surcharging. The purple numbers and line correspond to predicted water surface elevations and hydraulic grade level (HGL) at the current design PHF of 221 MGD, and the blue numbers and line correspond to predicted elevations and HGL at the design AADF of 96 MGD.

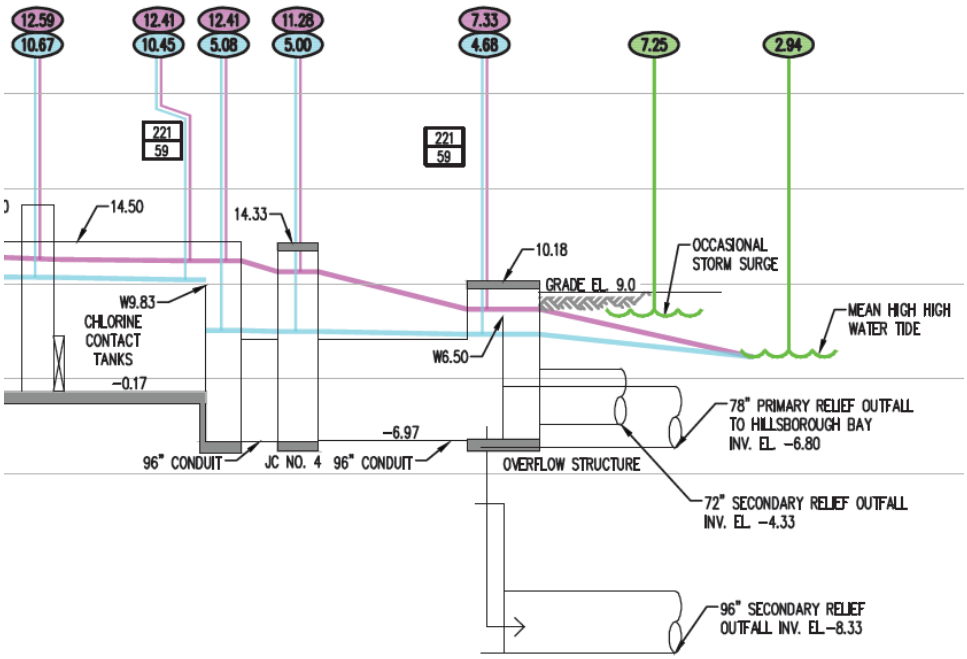

Figure 9.6-2: Existing CCT Surcharging at Peak Hourly Flow

During the existing design PHF of 221 MGD discussed in the Phase 1 TM, the velocity in the 96-inch conduit between JC No. 4 and the Overflow Structure increases to nearly 7 fps and generates nearly 4-feet of headloss, as shown in **Figure 9.6-2**. Additionally, as previously noted, effluent must overflow a series of weirs in the Overflow Structure prior to discharge. During periods of high flow, the headloss in the 96-inch pipe added to the overflow weir level results in CCT surcharging. It is important to note that there are manually operated sluice gates in the Overflow Structure that bypass the weirs. However, they were inoperable during a recent site visit during the Phase 1 evaluation and remain closed under all conditions.

Two improvements could be made to eliminate surcharging of the CCTs. First, a second 96-inch conduit could be installed between JC No. 4 and the Overflow Structure to reduce headloss during high flows. Analysis of this option showed that the addition of a second 96-inch conduit would reduce the headloss from 4-feet to 1-foot. Secondly, the manually operated sluice gates in the Overflow Structure could be replaced with motorized sluice gates. The sluice gates could then be tied to SCADA and be operated based on either level or flow. Note that the flow measurement to the two relief outfalls is currently determined by the water level in the

structure assumed to equal height over the weirs. Water level in the structure could still be used for flow measurement when the motorized gates are open with programming changes to the flow calculations for orifices rather than weirs. During periods of high flow, the sluice gates could be called to open, bypassing the need to flow over the weir, further reducing the possibility of surcharging. **Figure 9.6-2** has been modified as shown in **Figure 9.6-3** to show approximately how these improvements would change the hydraulic profile. The red line in **Figure 9.6-3** represents the new hydraulic profile beginning downstream of the CCT effluent weir. As **Figure 9.6-3** shows, with the improvements discussed, the hydraulic profile at design PHF 221 MGD will mimic the existing hydraulic profile at average flows. Note that the BNR Improvements Evaluation as part of the Phase 2 Master Plan identified that the PHF would increase to 234 MGD. The additional 13 MGD made little difference in the predicted elevations and HGL shown in the Figures. However, design for these improvements should incorporate future design flows and future tide levels. **Figure 9.6-4** shows the hydraulic profile with only the motorized gate improvements in the Overflow Structure. These improvements alone are predicted to prevent surcharging of the CCTs at 221 MGD at current mean high high water receiving tide. At higher storm surge tides and with future sea level rise, additional hydraulic improvements may be needed. **Figure 9.6-5** shows the hydraulic profile with only the second 96-inch conduit installed for comparison. A third improvement discovered is that there is a single 96-inch conduit between the CCT effluent channel and JC 4. The hydraulic analysis from Phase 1 predicts 1.12-feet of headloss through this short conduit. It appears that both structures were designed for a second 96-inch conduit between them. This lowers the headloss between the CCT effluent channel and JC 4 by 0.84-feet to 0.28-feet of headloss. This may be a much lower cost improvement in addition to motorized gates rather than a second 96-inch conduit between JC 4 and the Overflow Structure. However, the additional dechlorination injection and mixing equipment will require evaluation if this third improvement is considered.

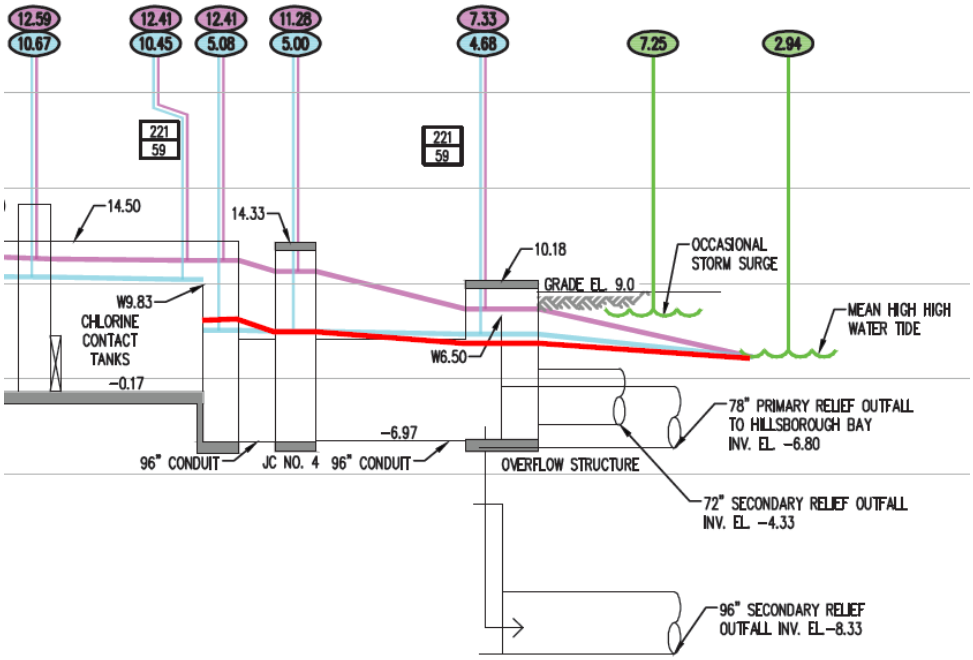

Figure 9.6-3: Combined Hydraulic Model Improvements

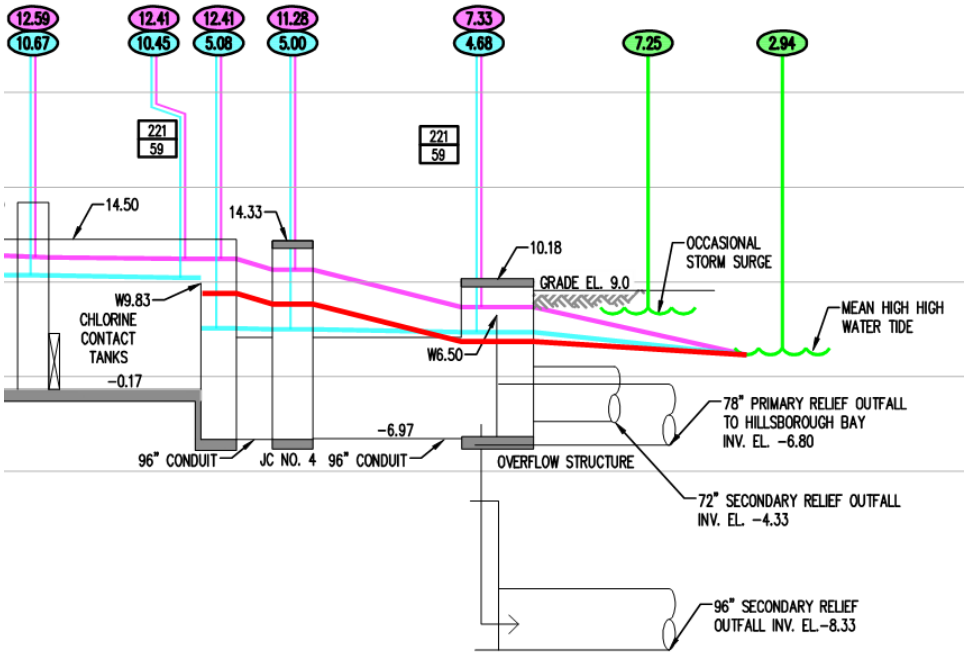

Figure 9.6-4: Motorized Gates Hydraulic Improvements

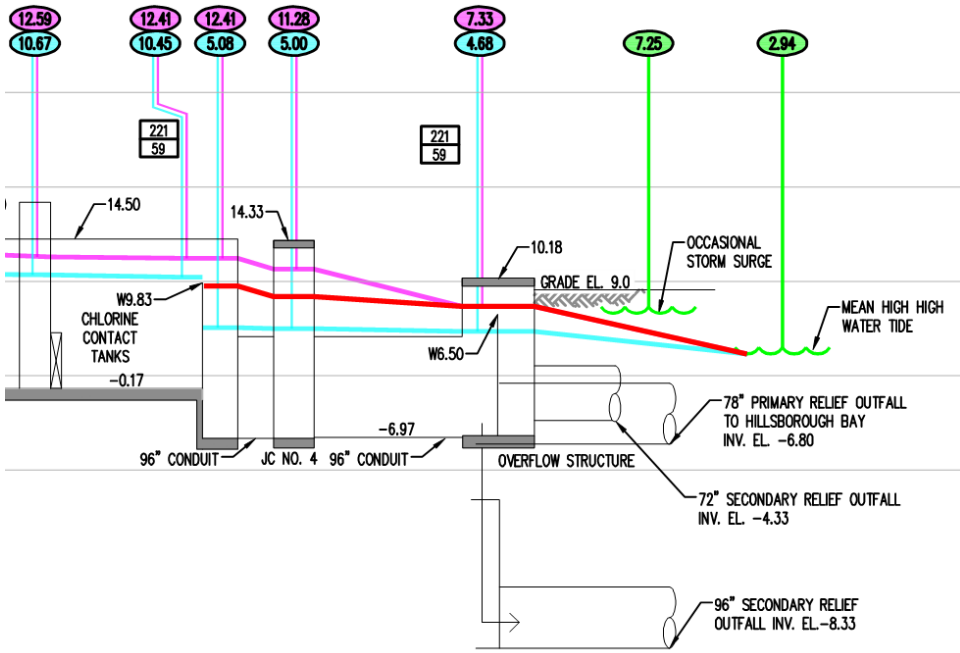

Figure 9.6-5: Second 96-inch Pipe Between JC 4 and Overflow Structure Hydraulic Improvements

The approximate cost of these improvements is shown below in **Table 9.6-3**. The recommendation is to implement both improvements. The cost of the 96-inch conduit includes the cost of support piles. Either improvement separately will resolve the CCT surcharging at current mean high high water tides, but only the combination of the two will provide additional hydraulic relief for storm surge tides and rising sea levels.

Table 9.6-3: Estimated Costs to Resolve High Flow Surcharging

Item	Cost
Motorized Gates	$132,000
96" Pipeline	$3,800,000
30% Contingency	$1,179,600
Bare Construction Costs	**$5,111,600**
20% Overhead and Profit, General Conditions	$1,022,320
Total Construction Costs	**$6,133,920**
20% Management and Engineering	$1,226,784
Total Capital Costs	**$7,360,704**

9.6.4 High Flow Protocol

Under current operation, a set protocol is enacted during high flow scenarios. As part of the Phase I report, the high flow protocol was reviewed. The current High Flow Protocol uses a flow formula to determine the percent open of the influent gates to the CCTs. As was noted in the

Phase I report, the formulas used have led to an uneven distribution of flow across the CCTs. It is recommended that the formulas, and any mention of them, be deleted from the High Flow Protocol. Instead the influent gates should be fully opened once high flow scenarios are reached. Opening and closing of the gates should be tied to plant flow rate via SCADA utilizing the in-channel flow meters just upstream of the chlorine injection point. This change to the High Flow Protocol is valid for any of the disinfection alternatives evaluated in this memo.

Attachment 9-A: CFD Modeling Results

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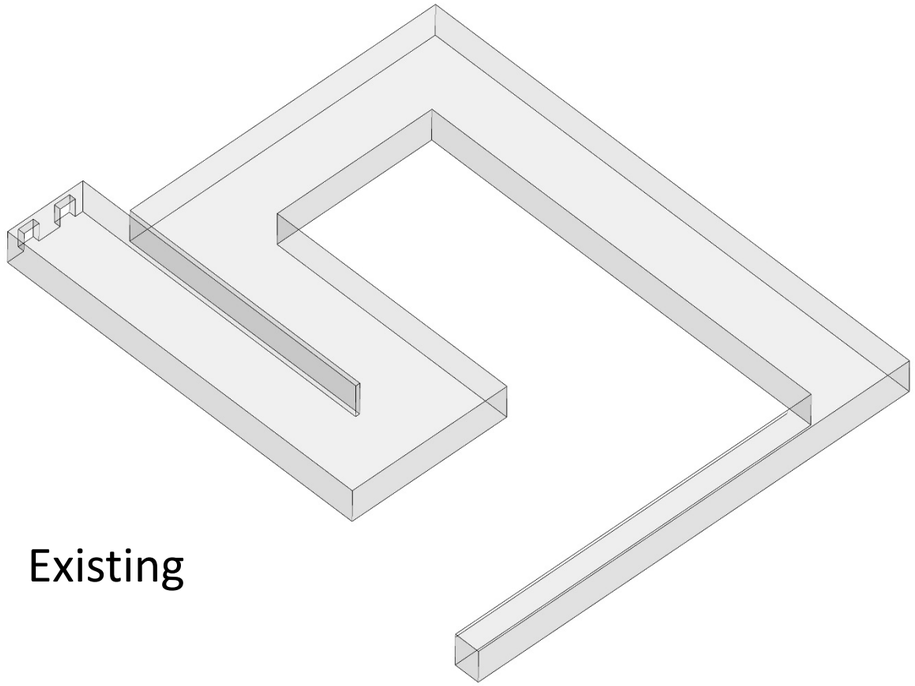
High flow model runs

Notes:

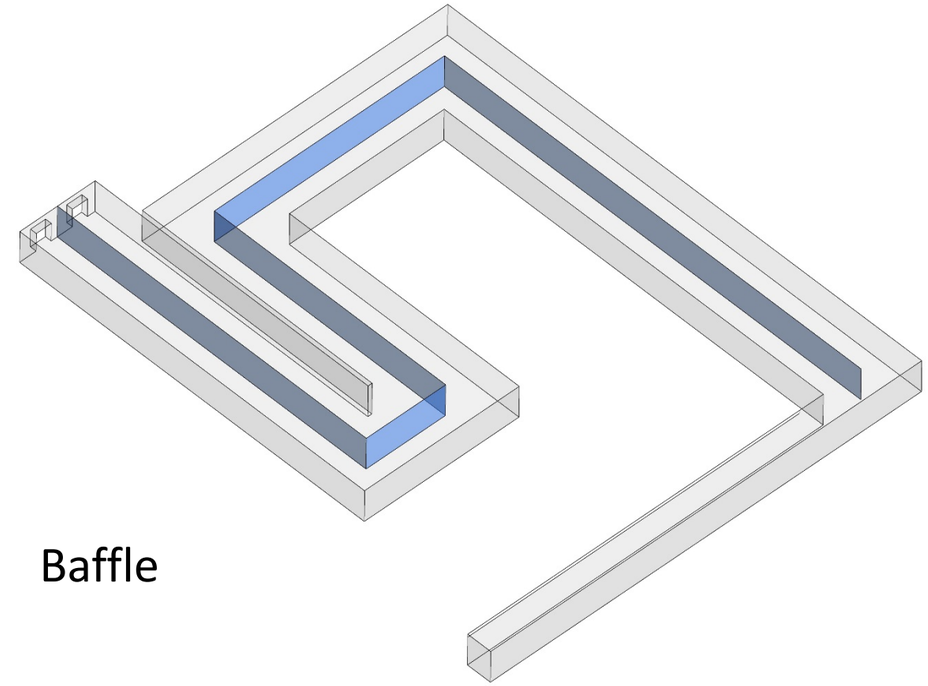
- The high flow is 220.8 MGD total or 73.6 MGD to each CCT. On the images, the color range is 0 - 2.0 fps. The breakthrough curves length is 60 minutes.

- WSE is 10.5’.

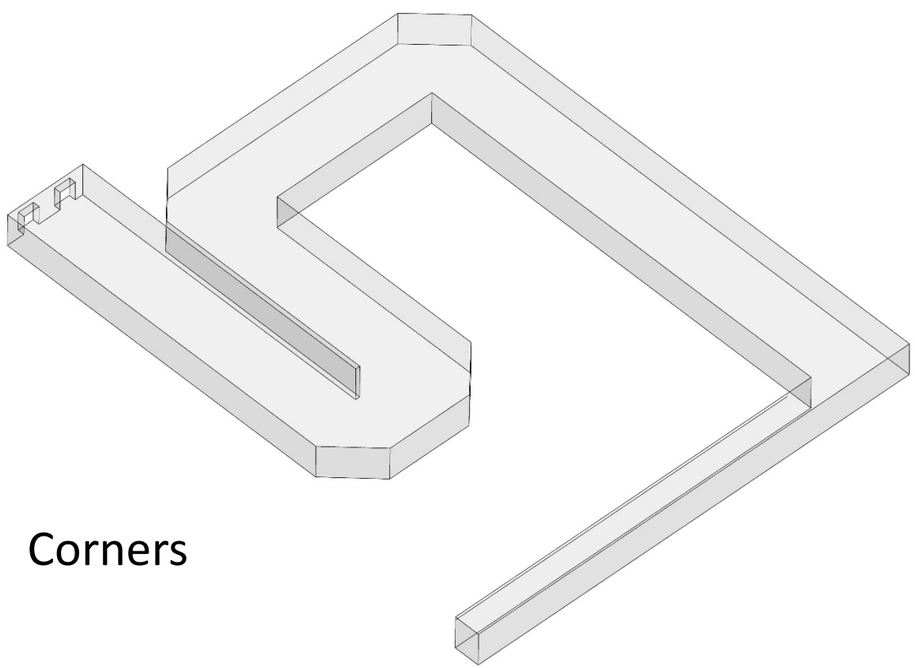
- Higher values for T10 and baffling factors are indicative of better disinfection performance.



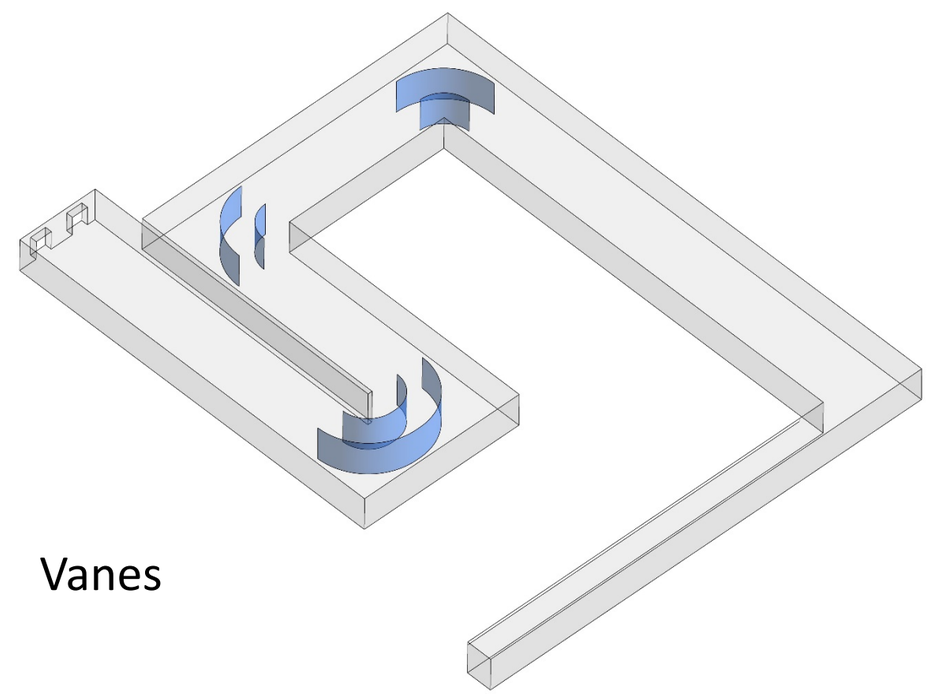
Existing



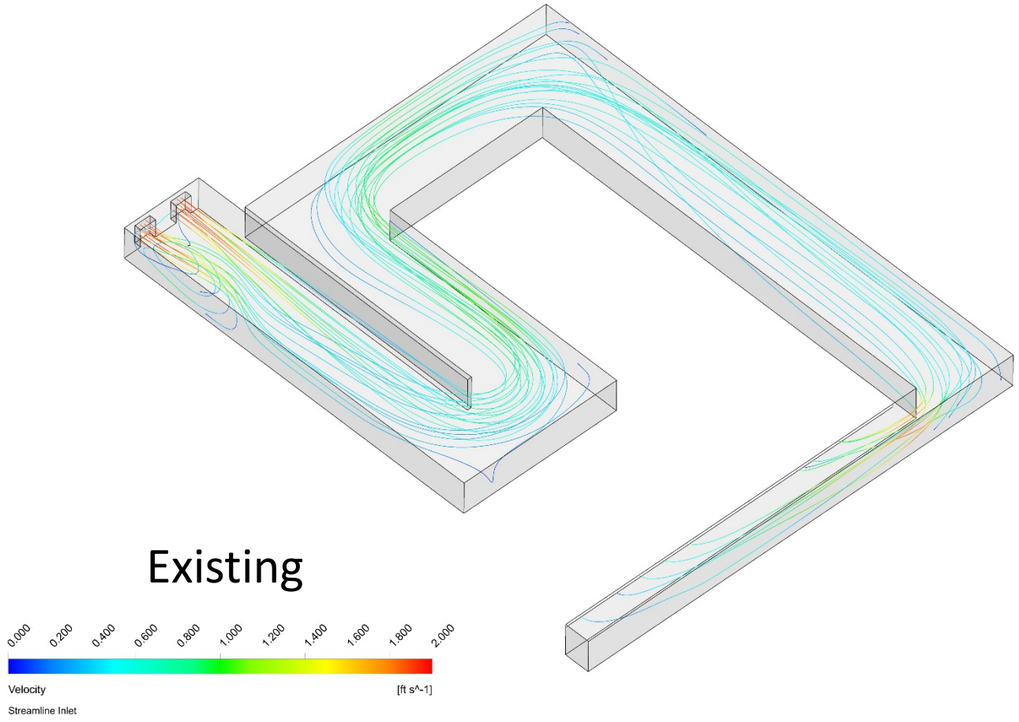
Baffle



Corners



Vanes



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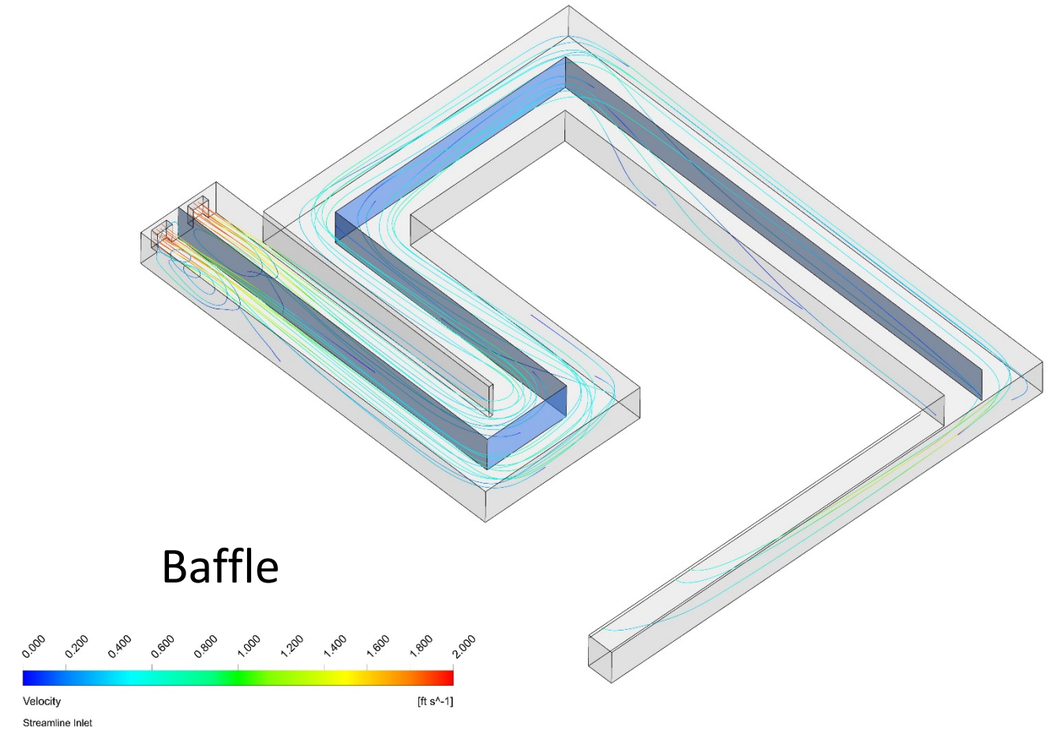

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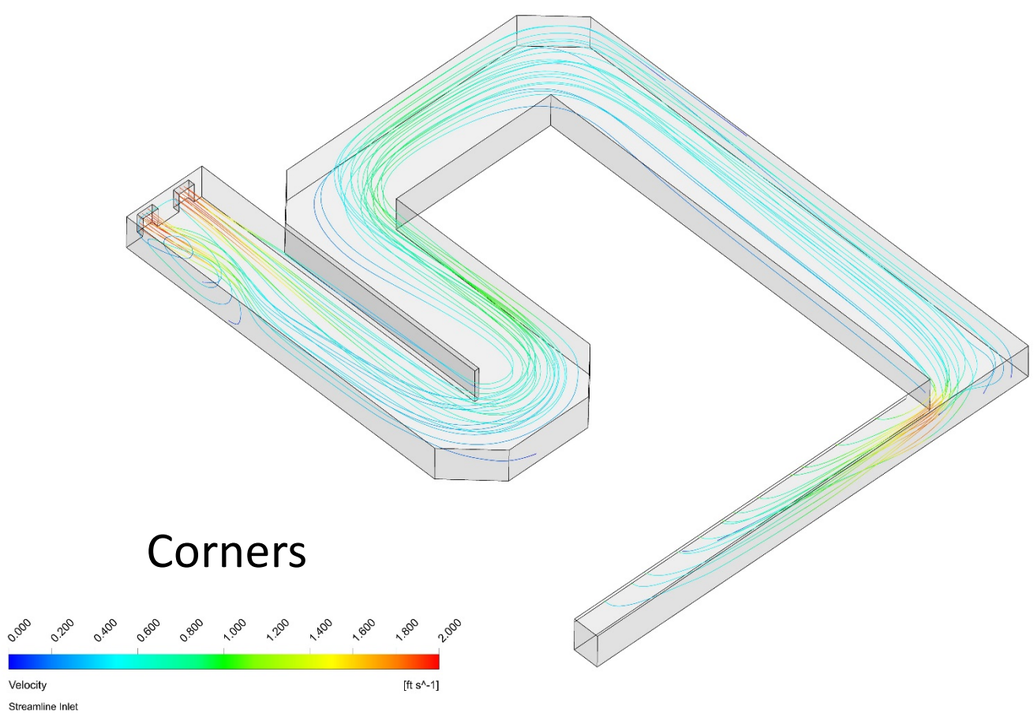
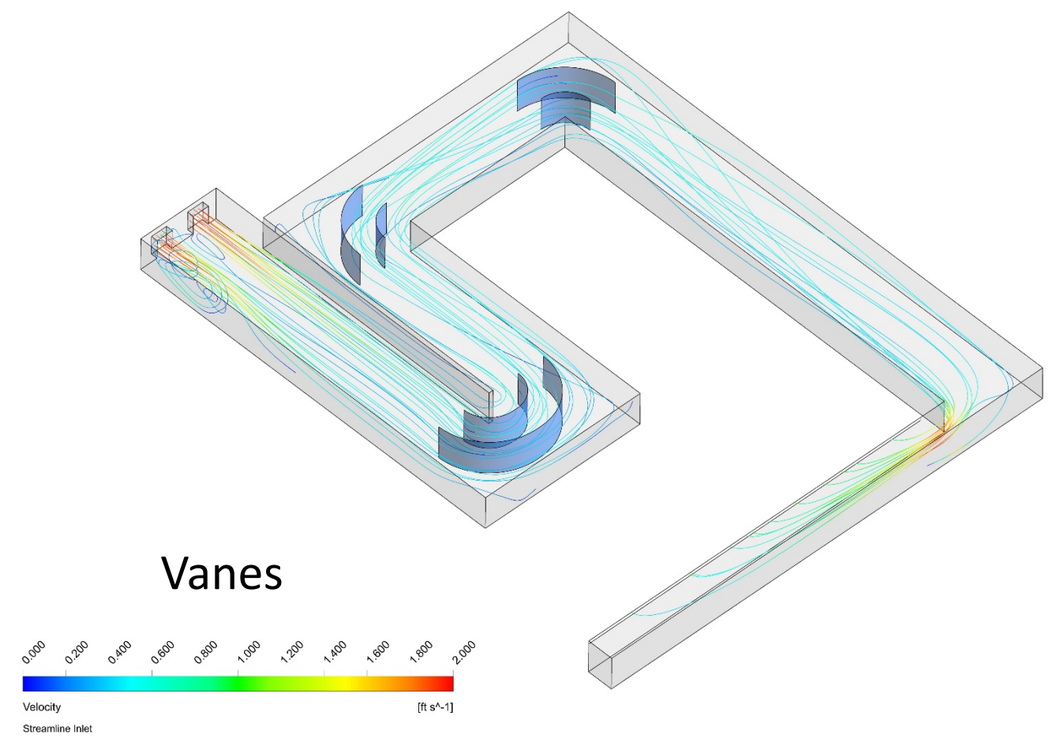
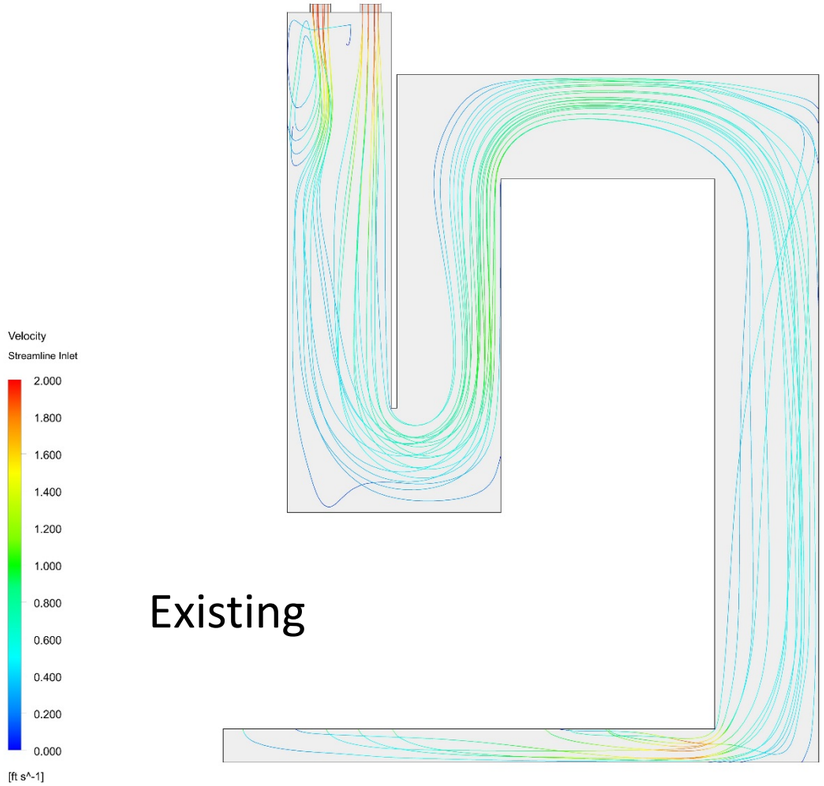


Corners



Vanes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Streamline Inlet
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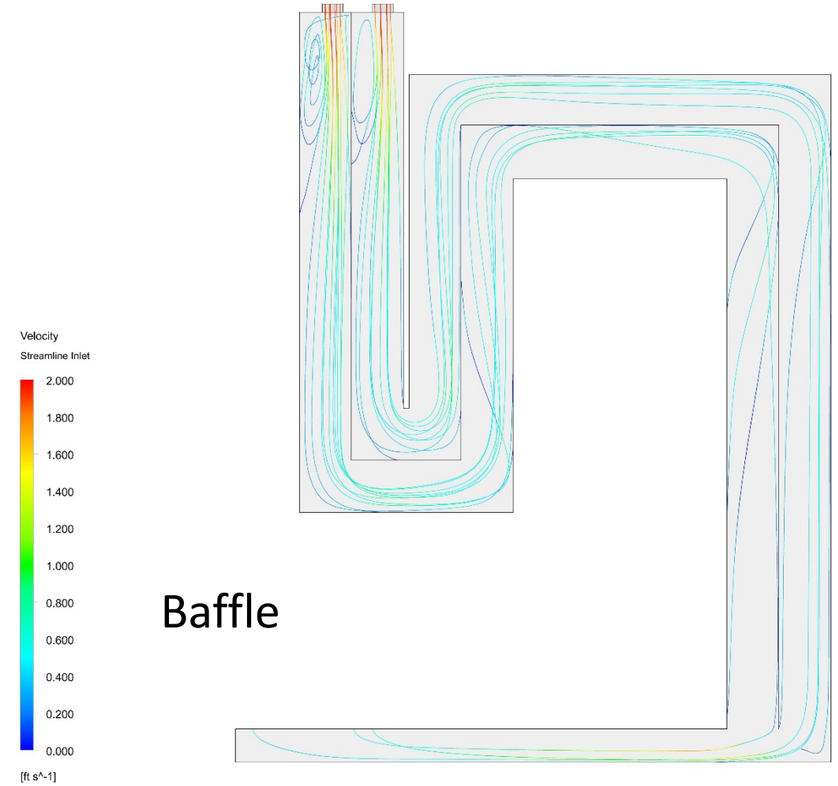
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Existing


Velocity
Streamline Inlet
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1.800
1.600
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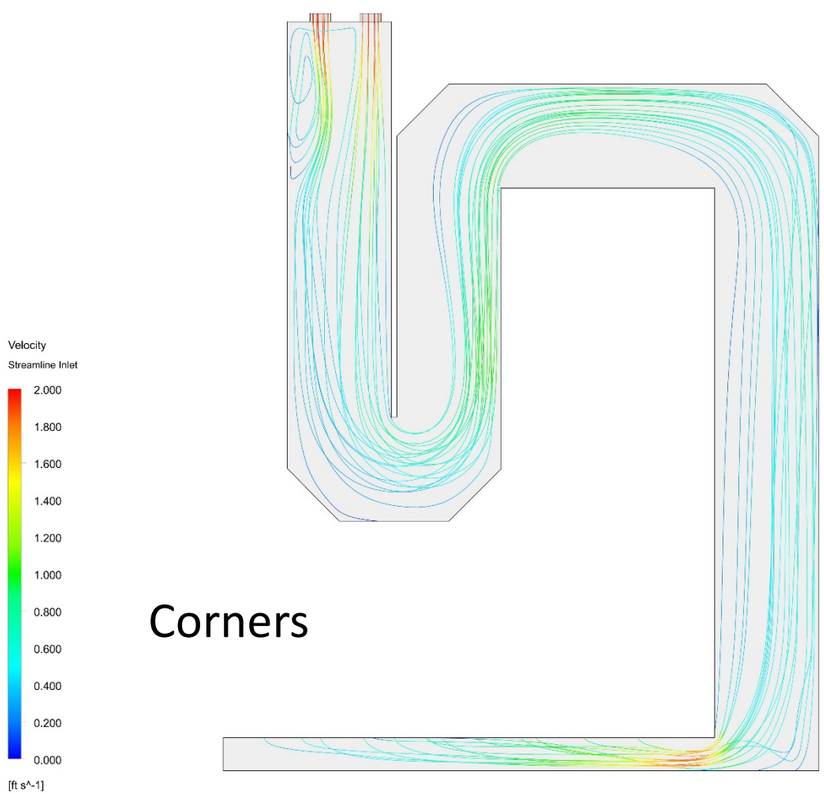
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Baffle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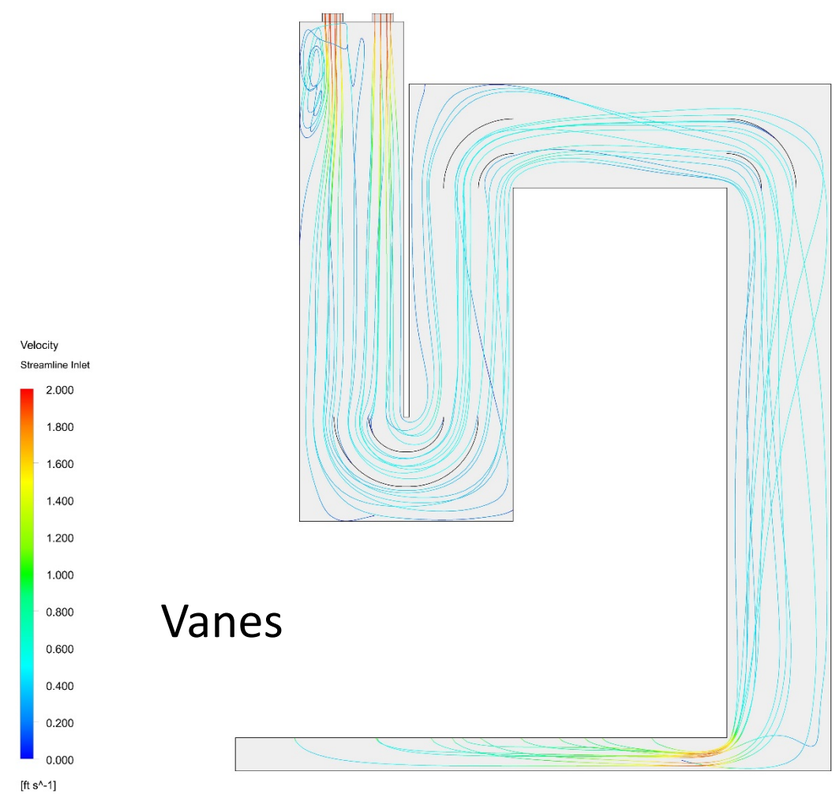
Streamline Inlet
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Corners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Streamline Inlet
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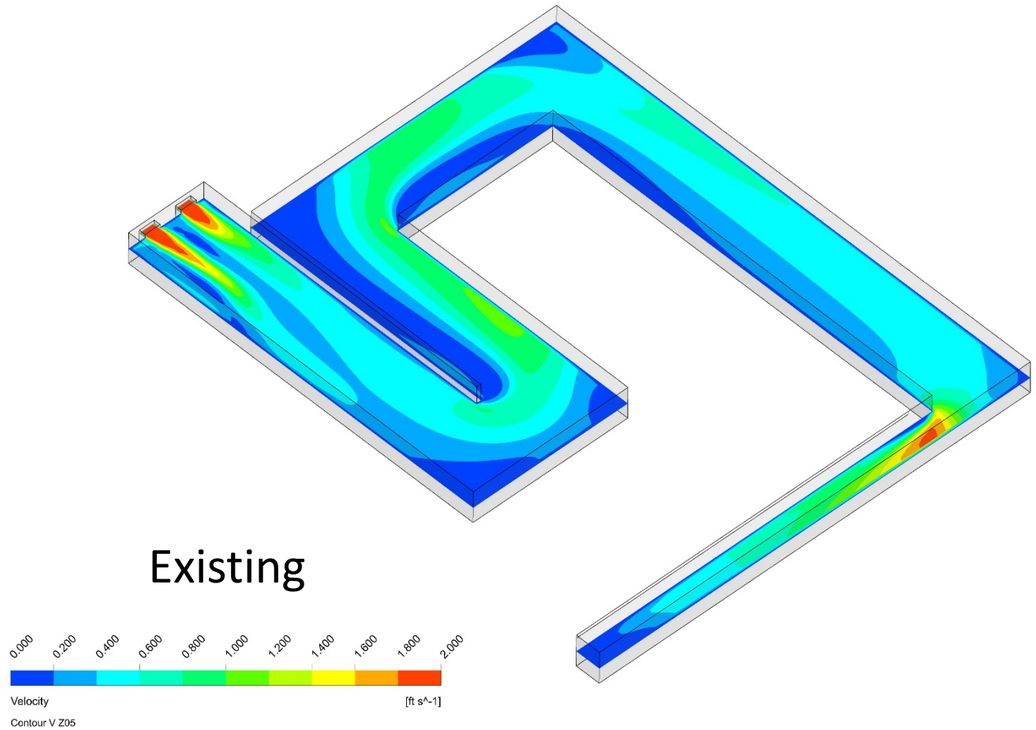
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Vanes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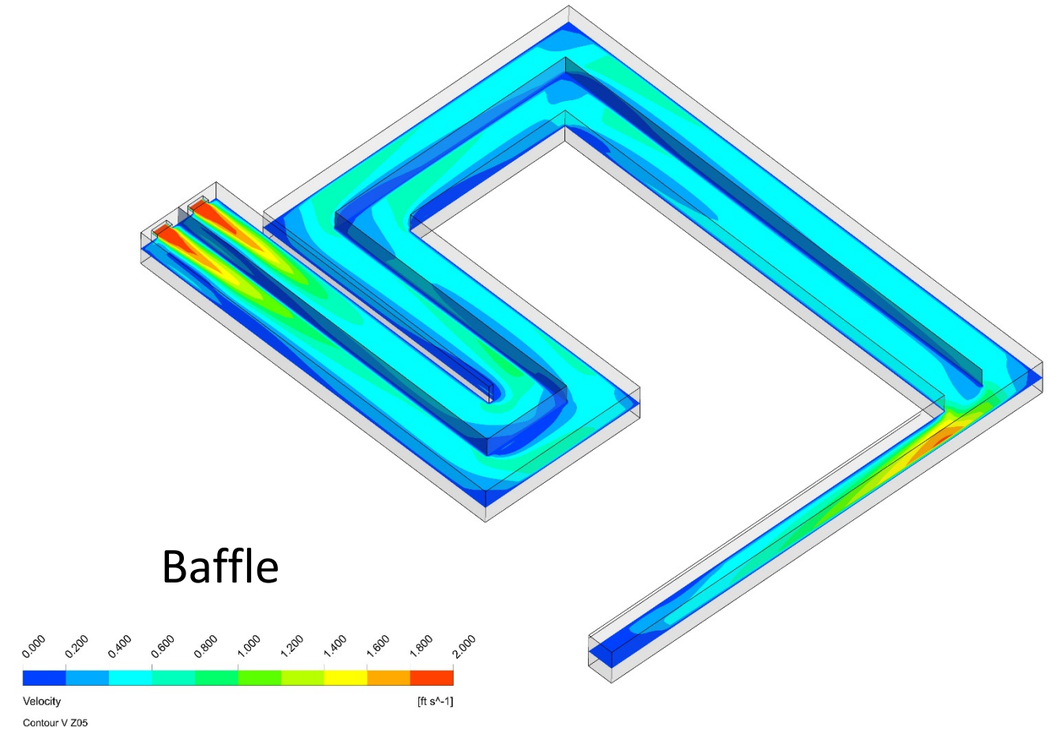
Velocity
[ft s^-1]
Contour V Z05


Baffle
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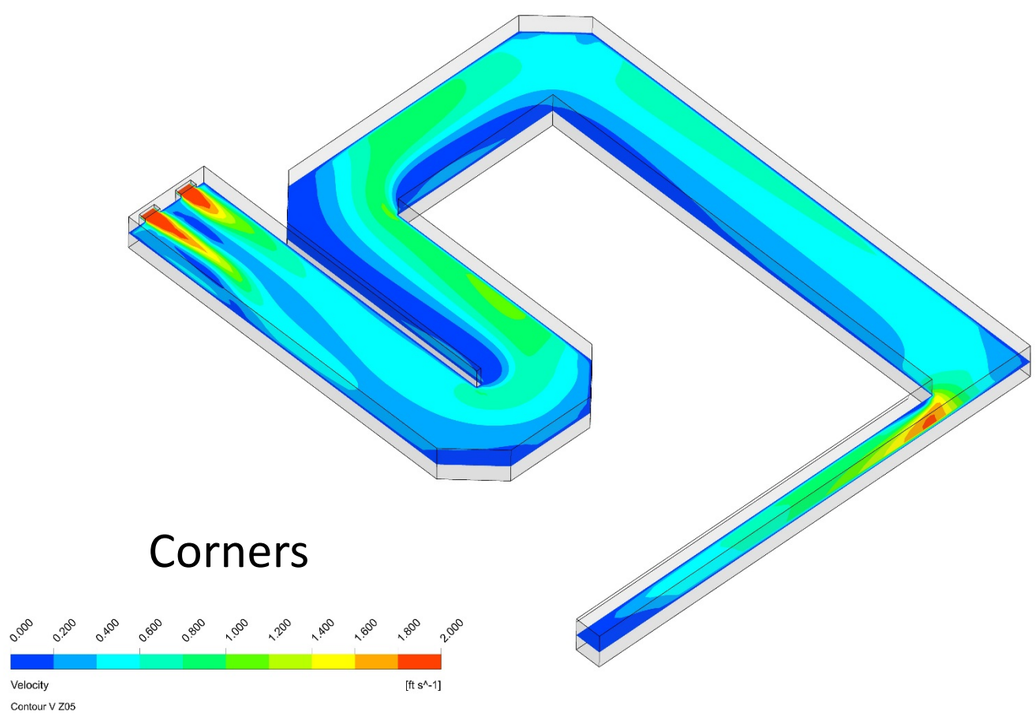
Velocity
[ft s^-1]
Contour V Z05


Corners
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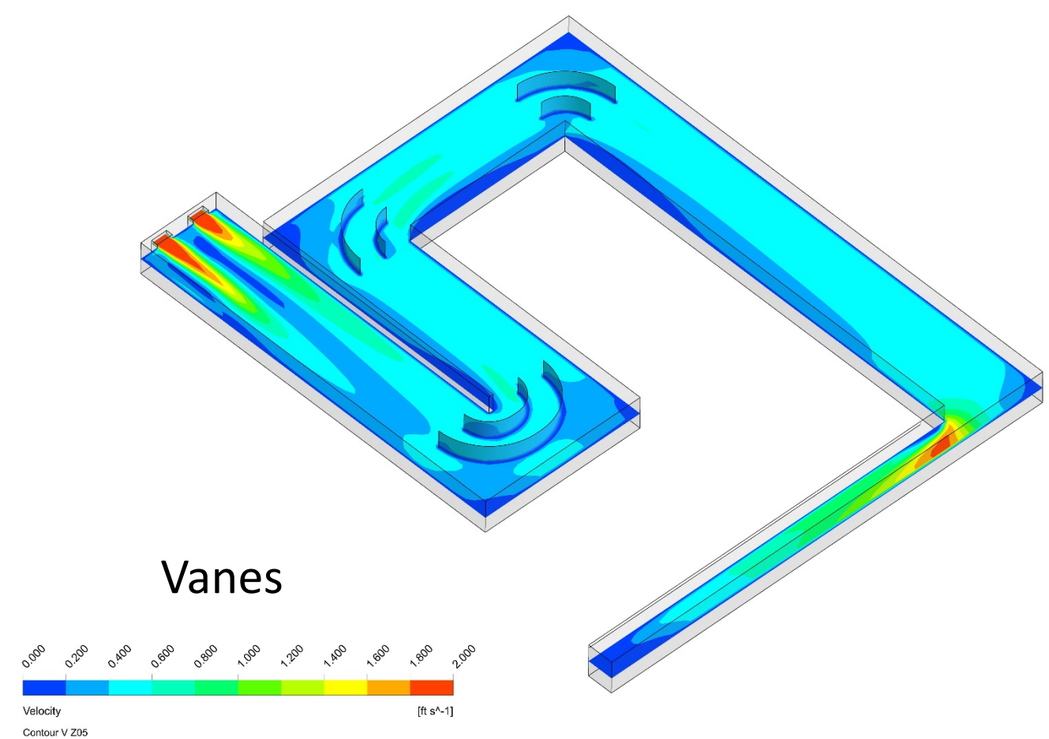
Velocity
[ft s^-1]
Contour V Z05


Vanes
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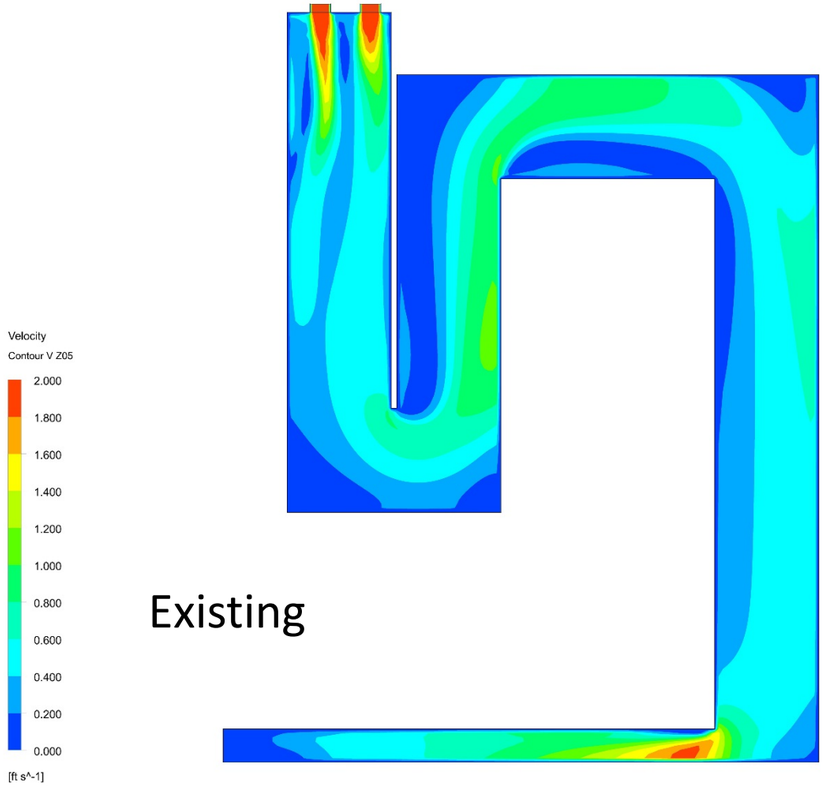
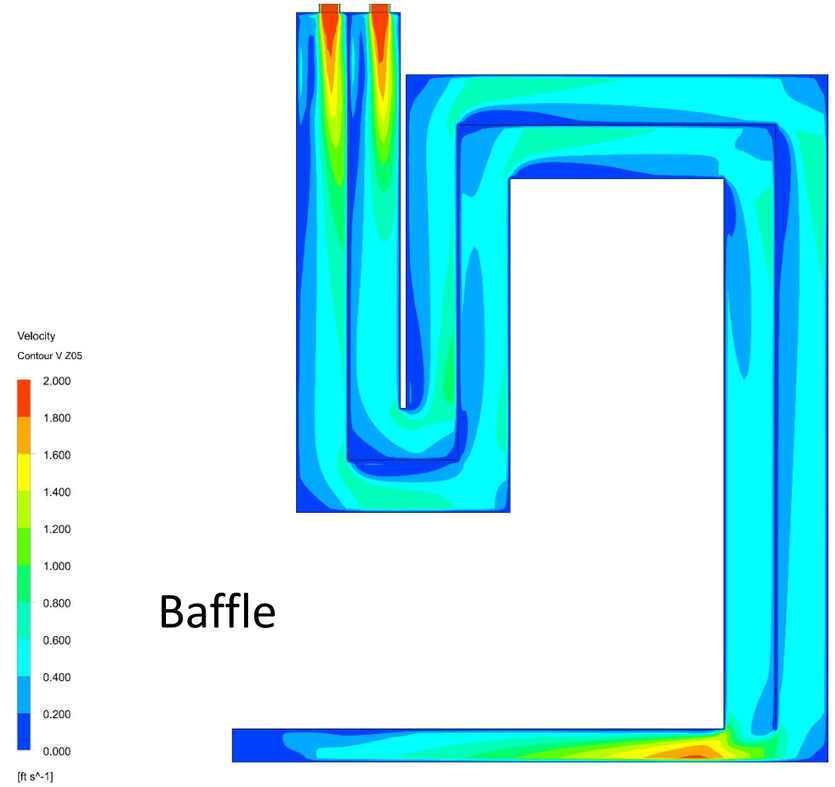
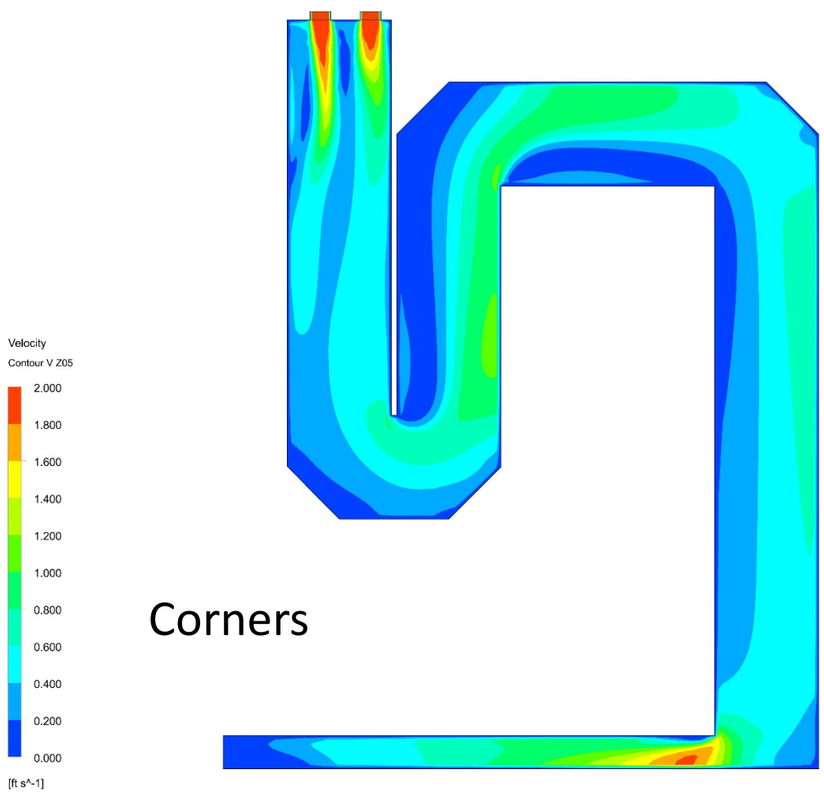
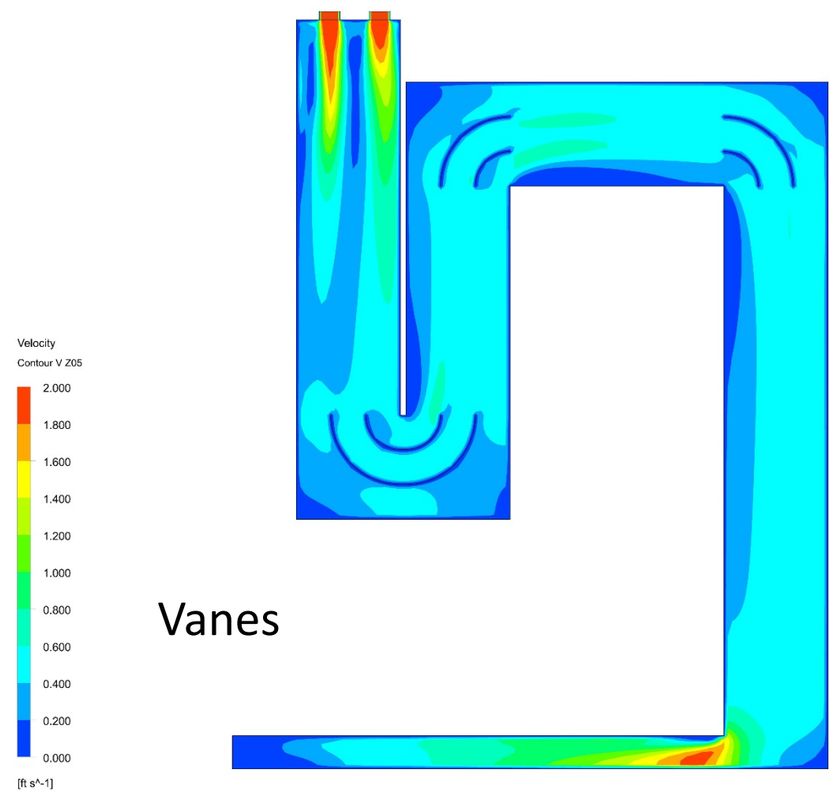
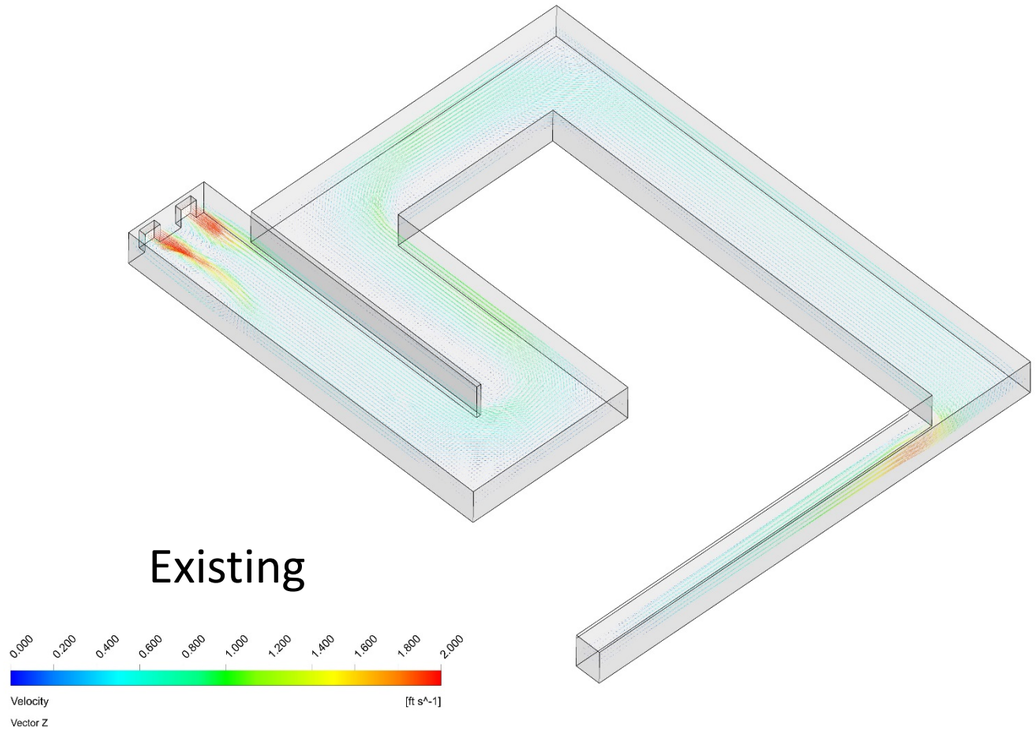
Velocity
[ft s^-1]
Contour V Z05


Velocity
Contour V Z05
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Existing


Velocity
Contour V Z05
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Baffle


Velocity
Contour V Z05
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Corners


Velocity
Contour V Z05
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Vanes


Existing
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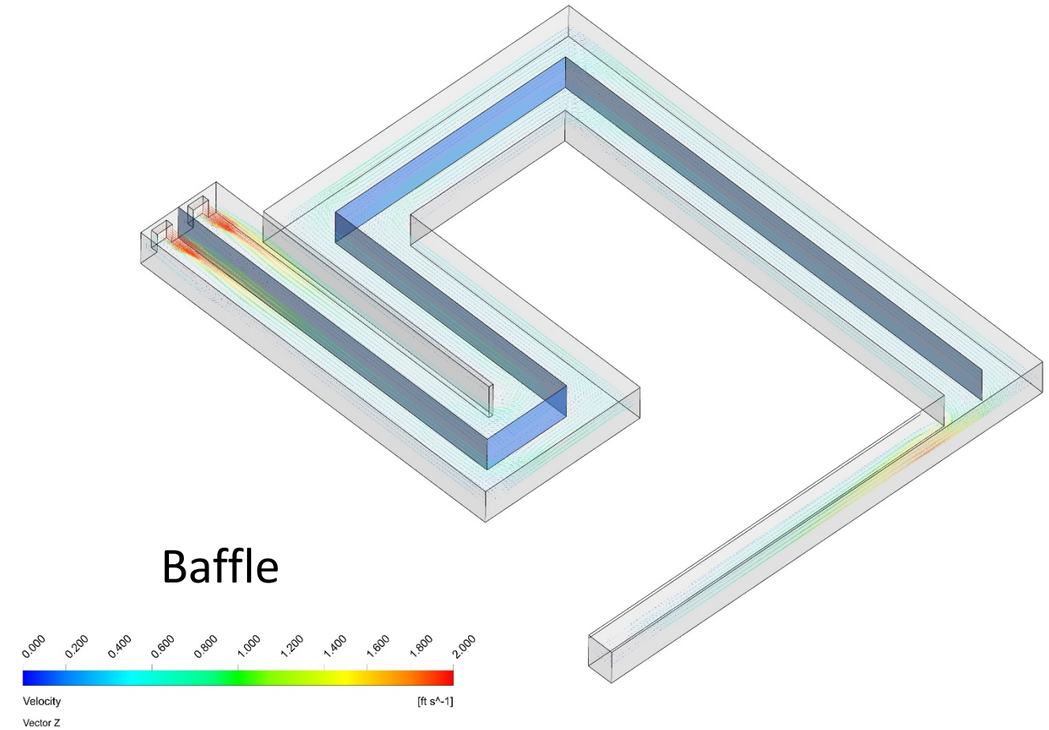
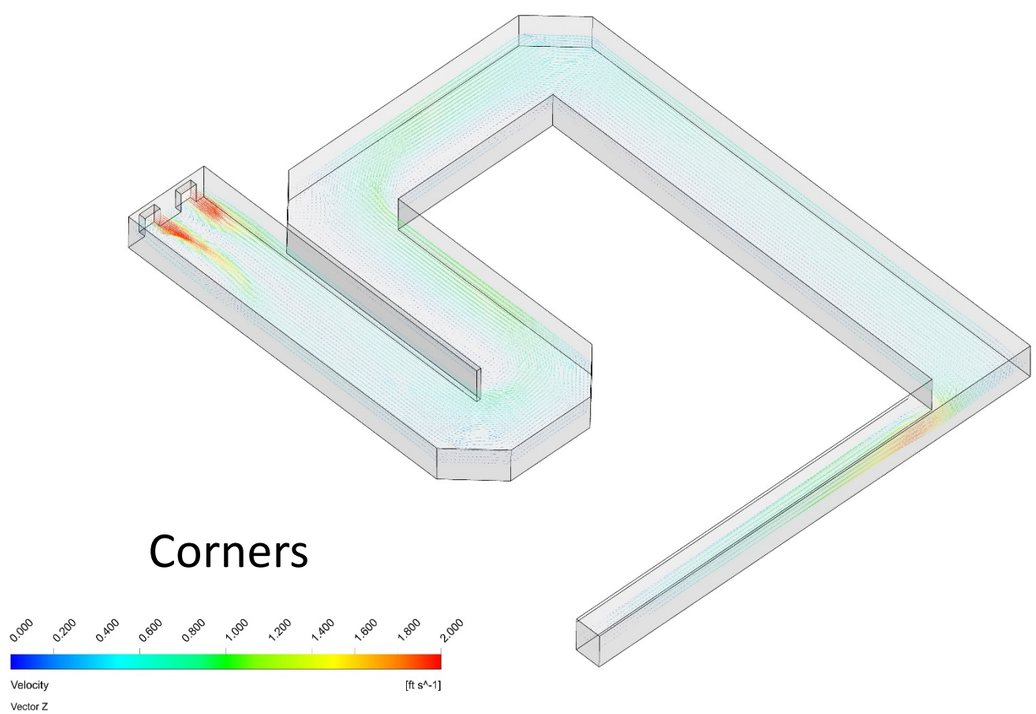
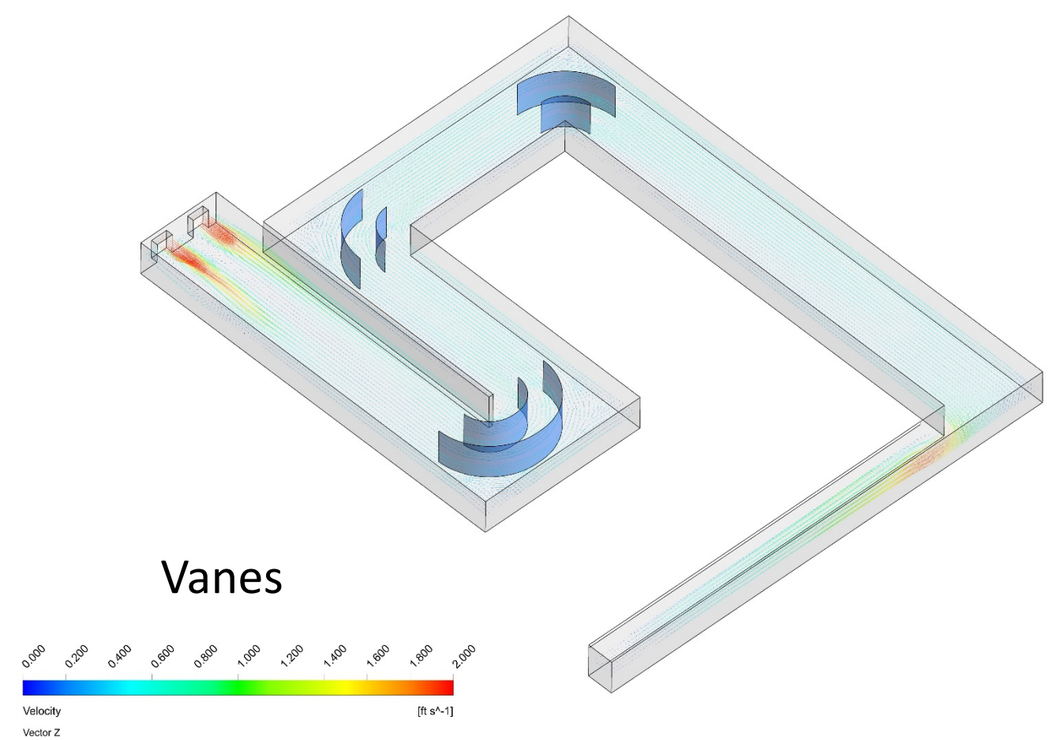
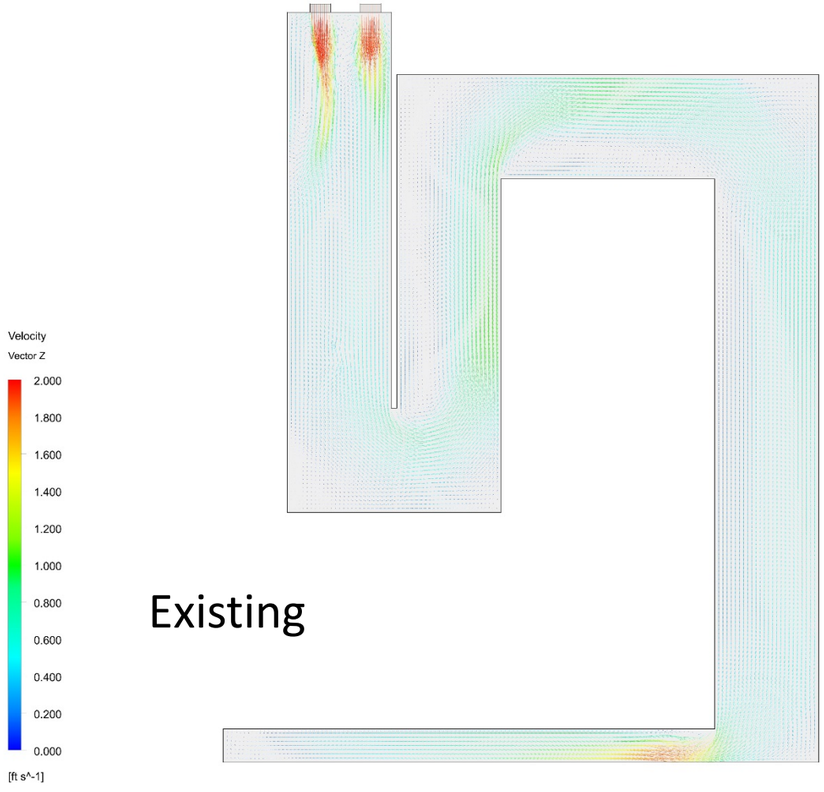
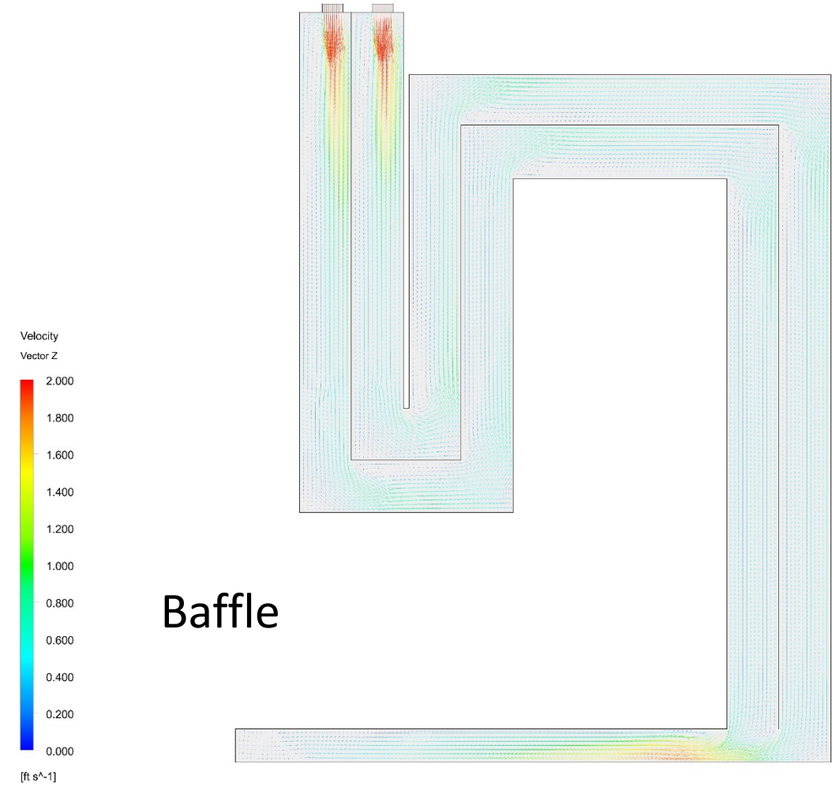
Velocity
[ft s^-1]
Vector Z

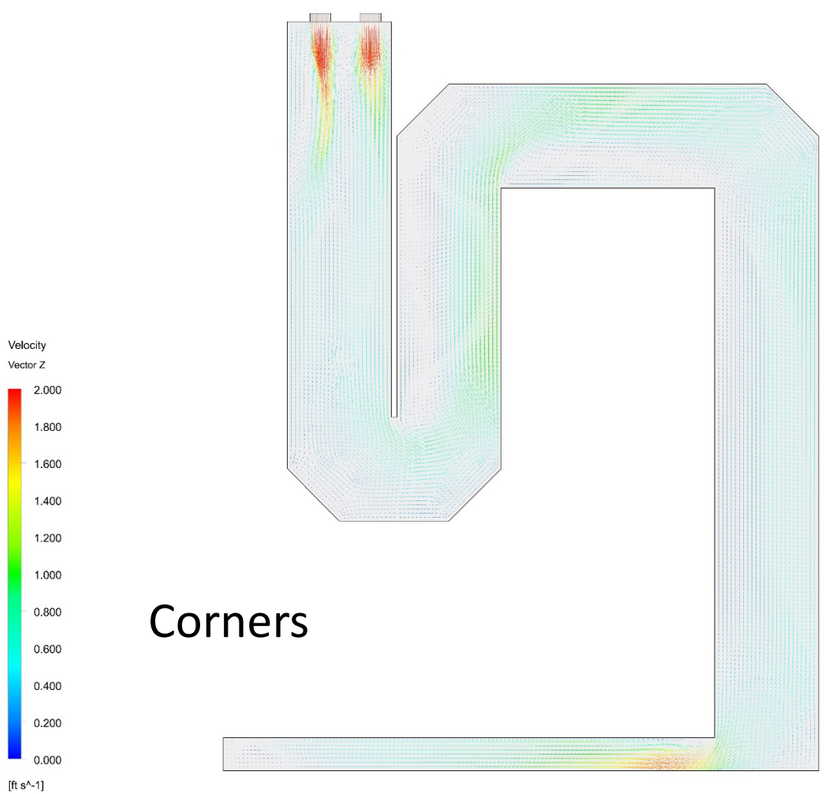

Baffle
0.000 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600 1.800 2.000
Velocity
[ft s^-1]
Vector Z

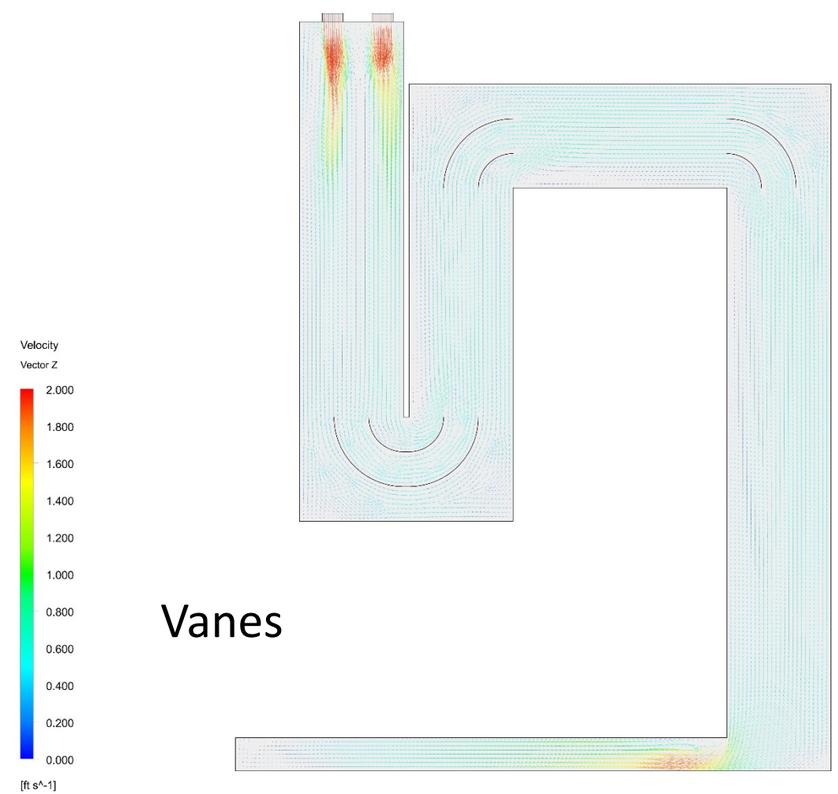

Corners
0.000 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600 1.800 2.000
Velocity
[ft s^-1]
Vector Z

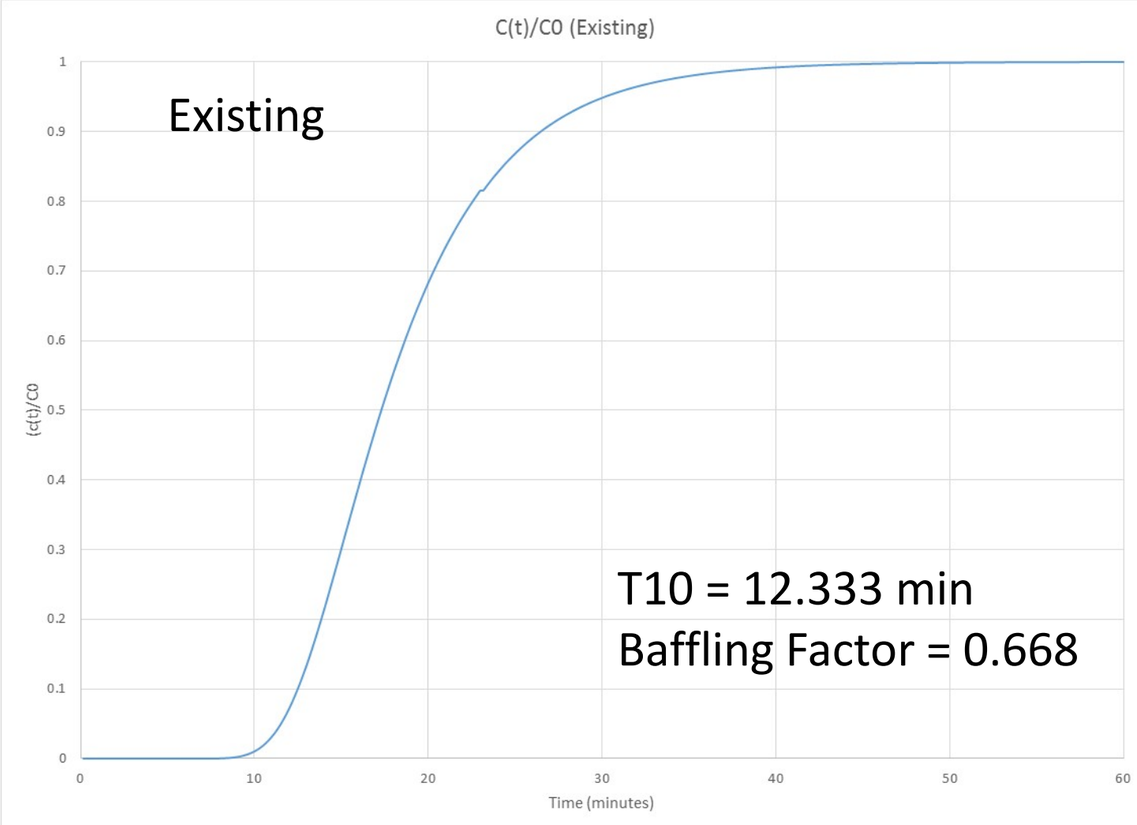

Vanes
0.000 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600 1.800 2.000
Velocity
[ft s^-1]
Vector Z

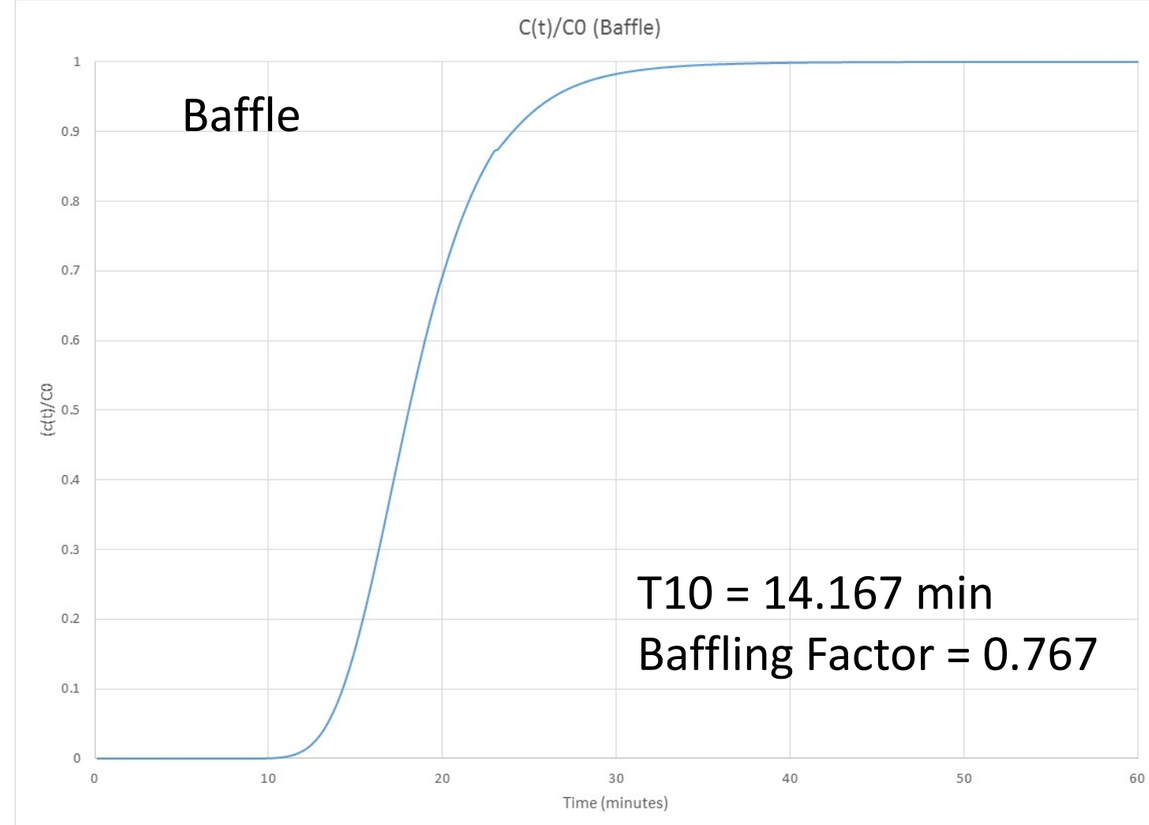

Velocity
Vector Z
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Existing

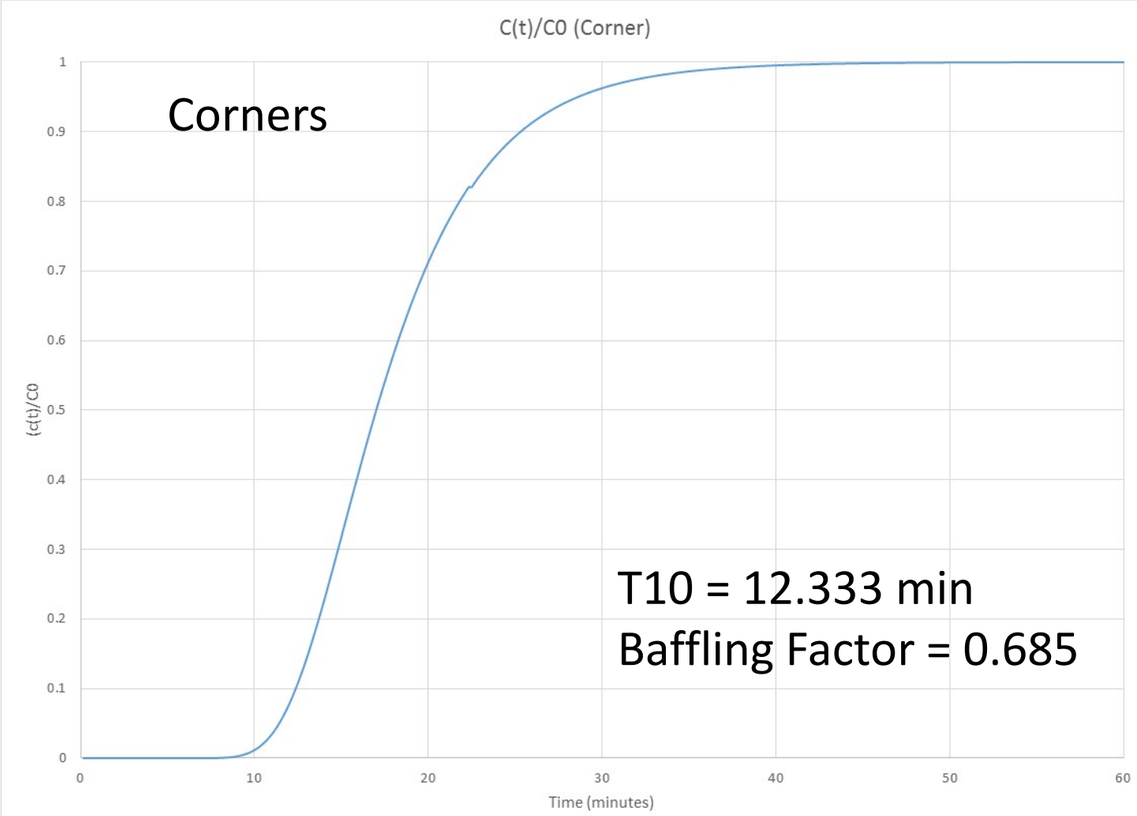

Velocity
Vector Z
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Baffle

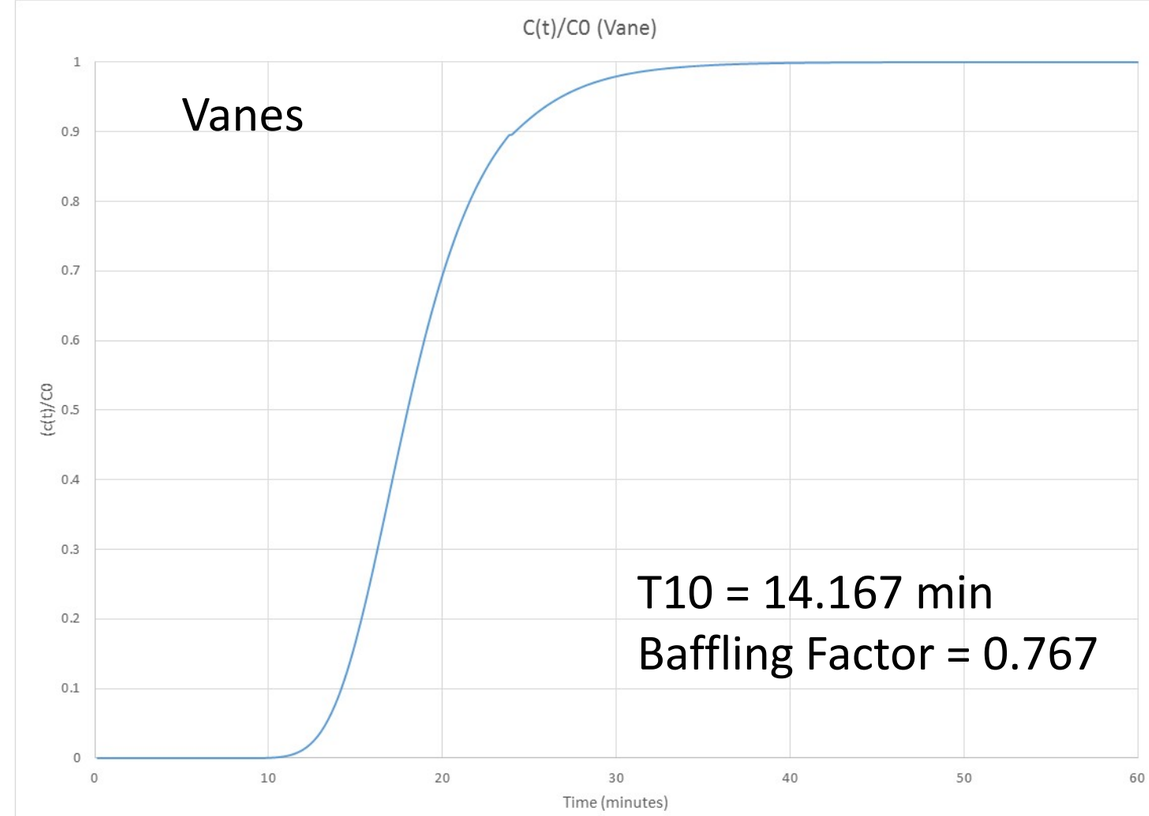

Velocity
Vector Z
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Corners


Velocity
Vector Z
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
[ft s^-1]
Vanes


C(t)/C0 (Existing)
Existing
T10 = 12.333 min
Baffling Factor = 0.668
(c(t)/C0
Time (minutes)


C(t)/C0 (Baffle)
Baffle
T10 = 14.167 min
Baffling Factor = 0.767
(c(t)/C0
Time (minutes)


C(t)/C0 (Corner)
Corners
T10 = 12.333 min
Baffling Factor = 0.685
(c(t)/C0
Time (minutes)


C(t)/C0 (Vane)
Vanes
T10 = 14.167 min
Baffling Factor = 0.767
(c(t)/C0
Time (minutes)

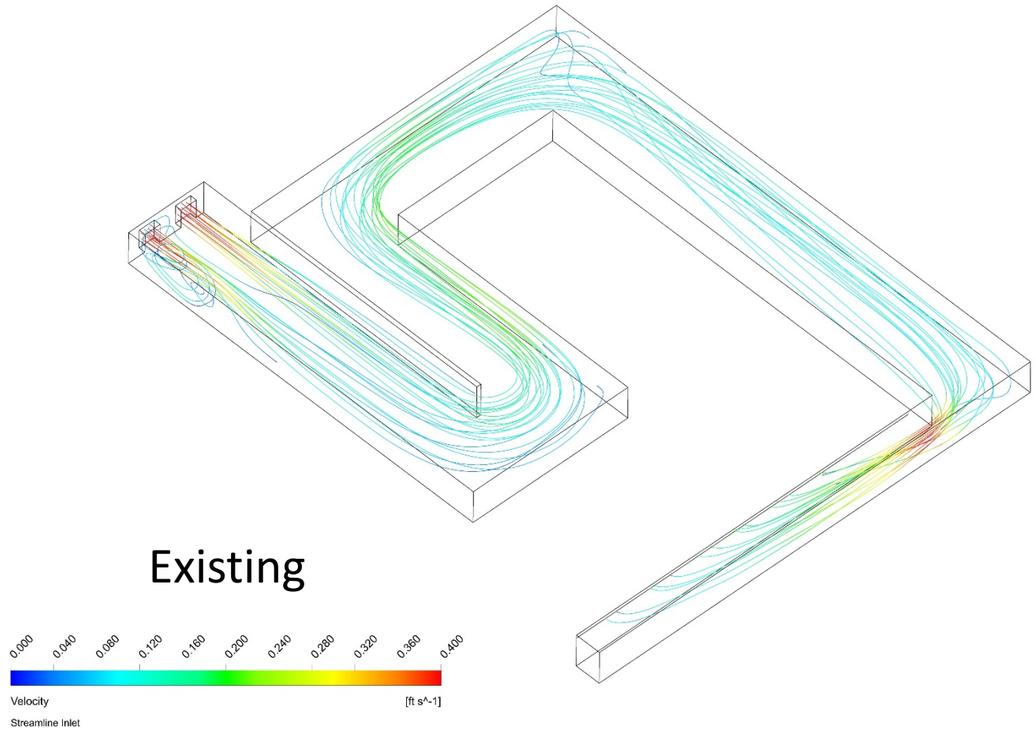
Low flow model runs

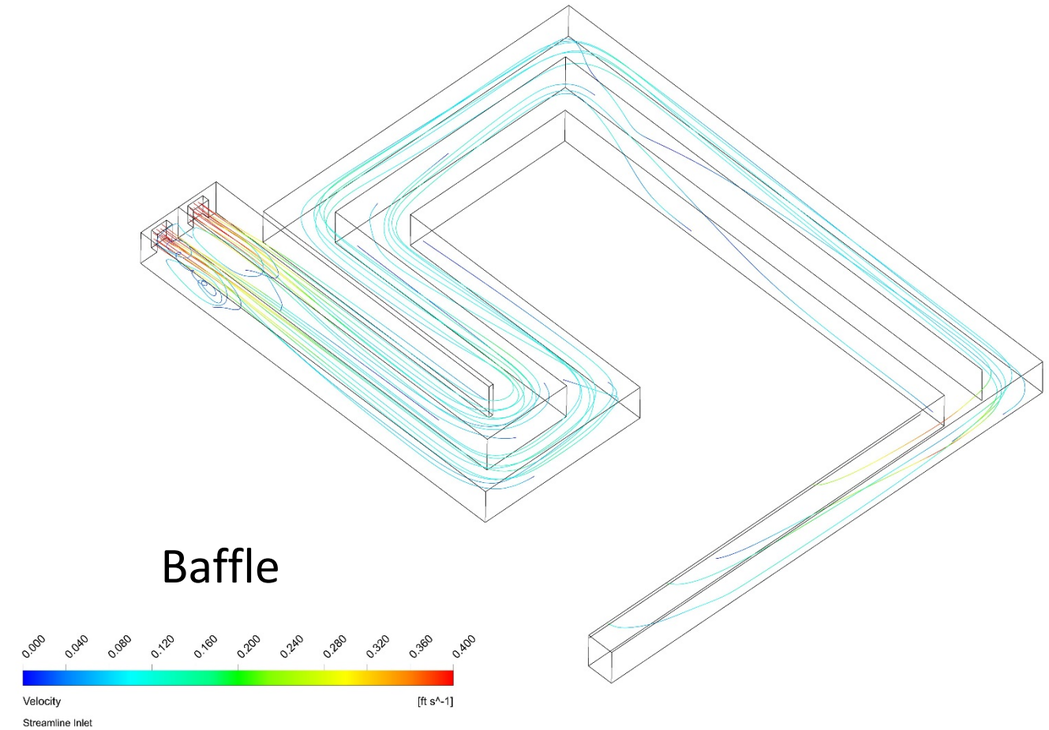
Notes:

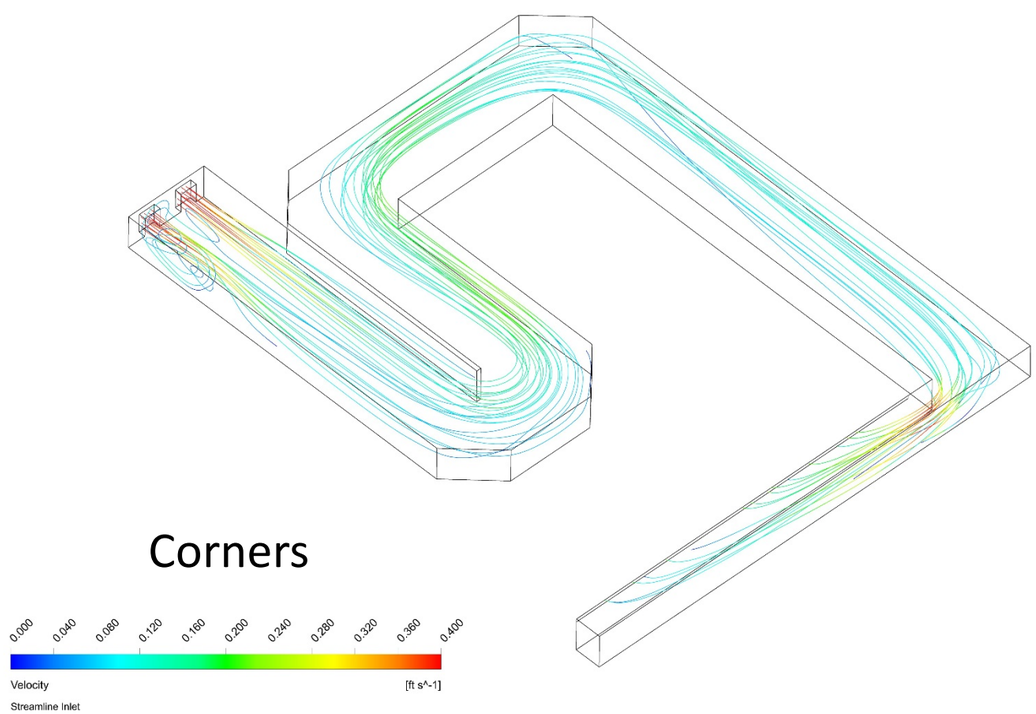
- The low flow is about 1/5 of the high flow or about 15.63 MGD each. On the images, the color range is 0-0.4fps. The breakthrough curves length is 300 minutes.

- WSE is kept at 10.5’ for both low flow and high flow. Baffling factor is a dimensionless number, the impact of WSE is small.

- T10s are longer as expected, baffling factors have similar trend with high flows runs. For disinfection purpose, high flow is more critical to get the required T10.


Existing
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Streamline Inlet


Baffle
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Streamline Inlet


Corners
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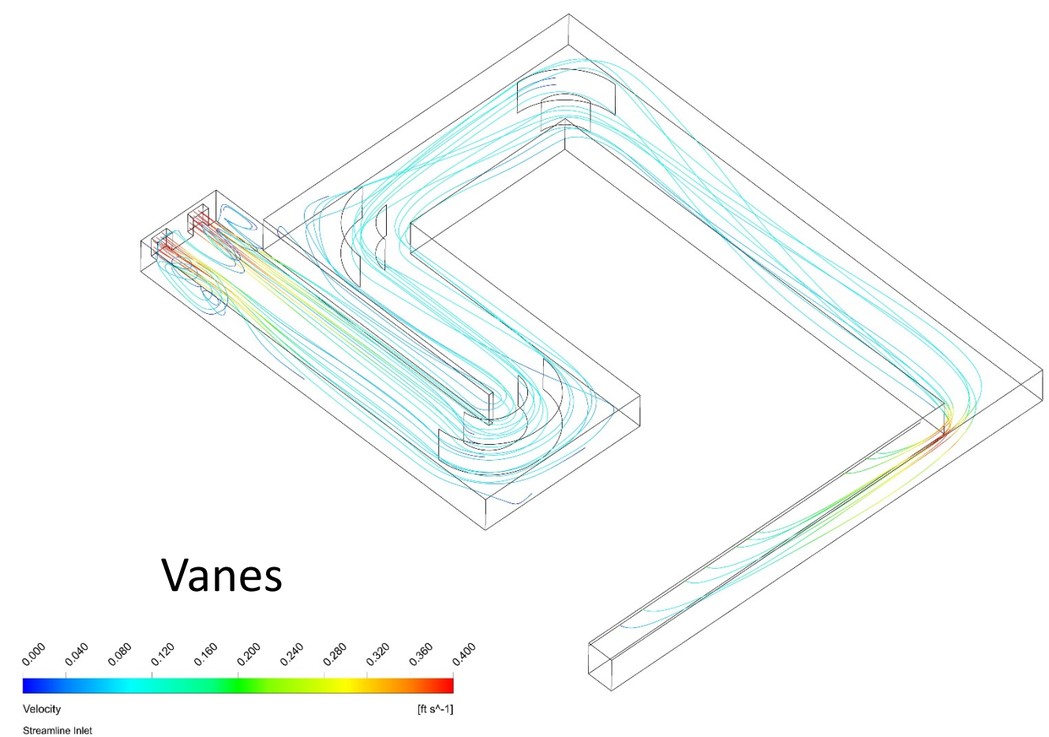
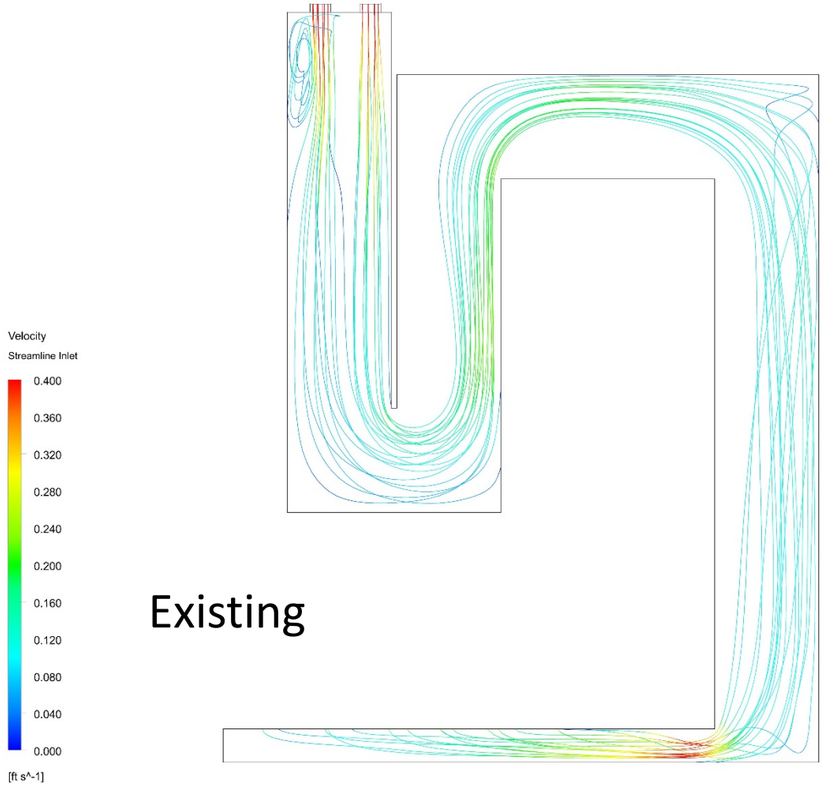
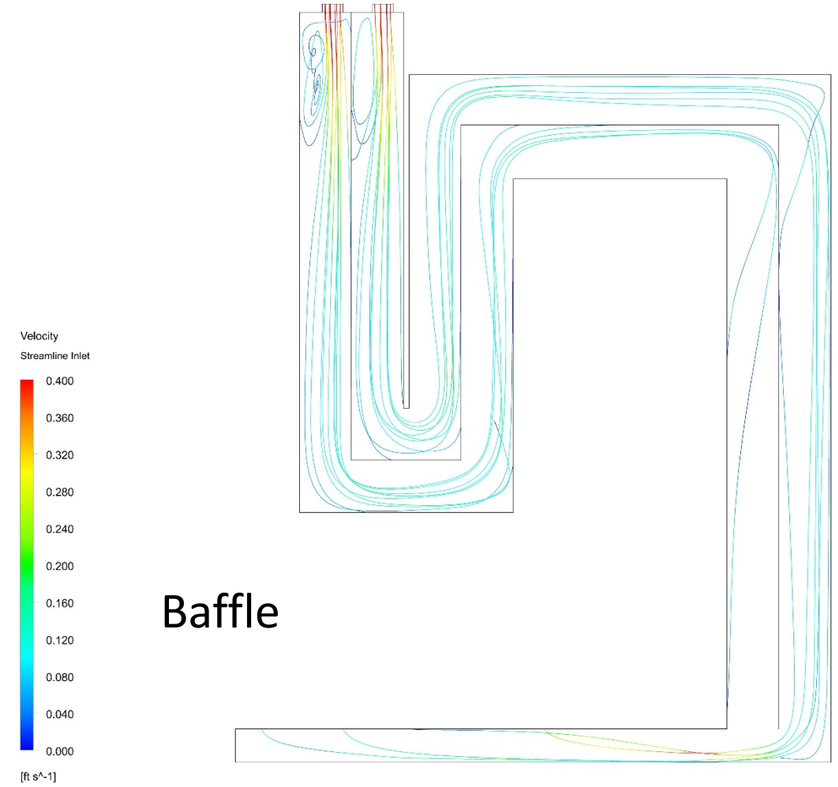
Velocity
[ft s^-1]
Streamline Inlet

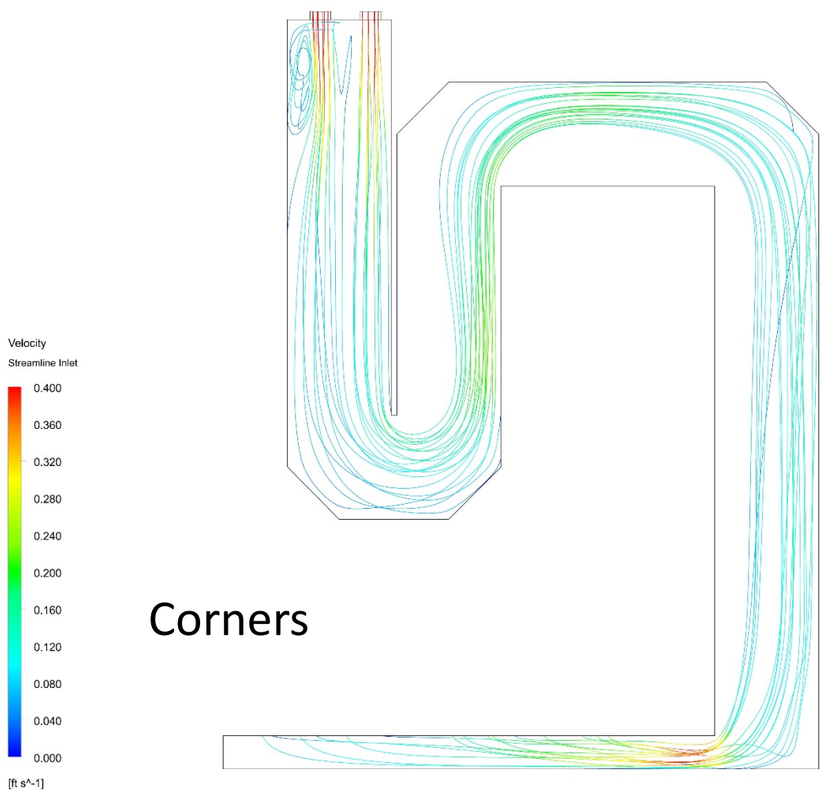

Vanes
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Streamline Inlet



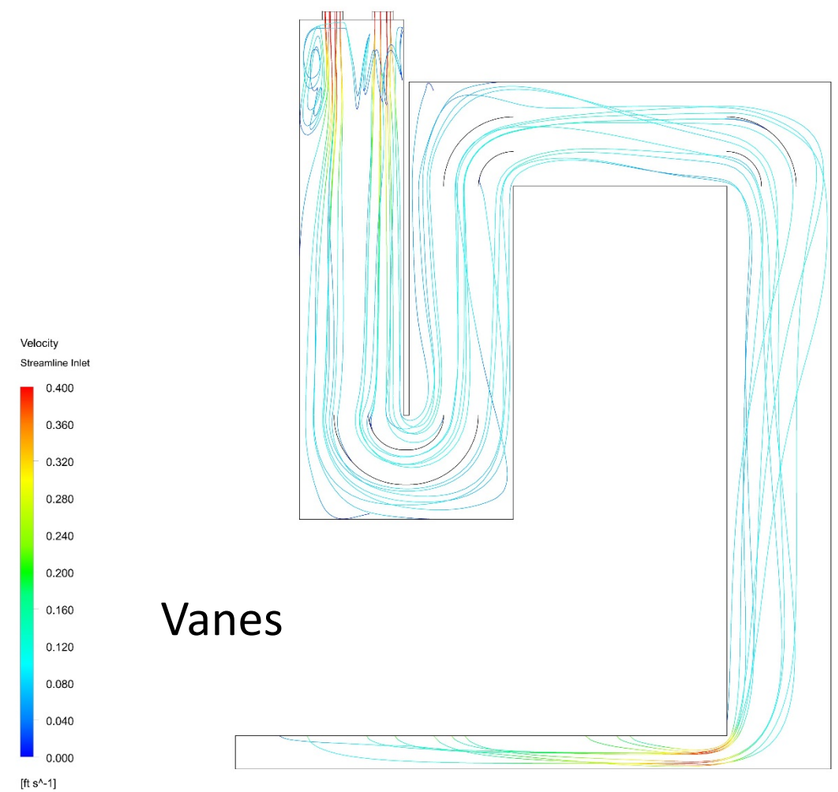
Existing



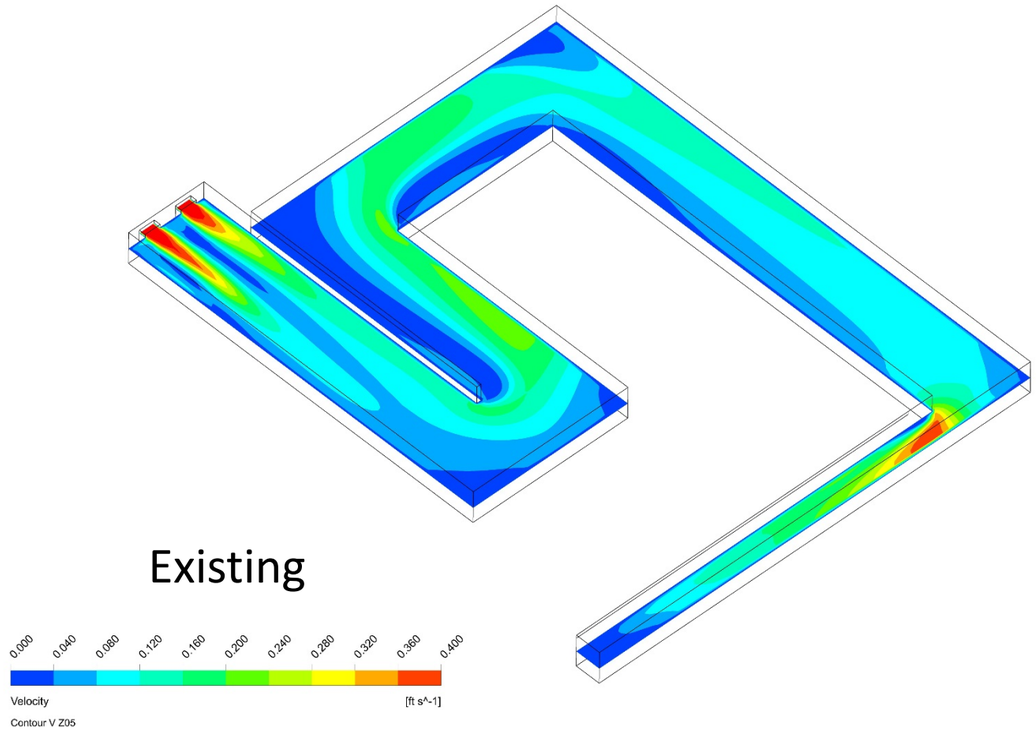
Baffle

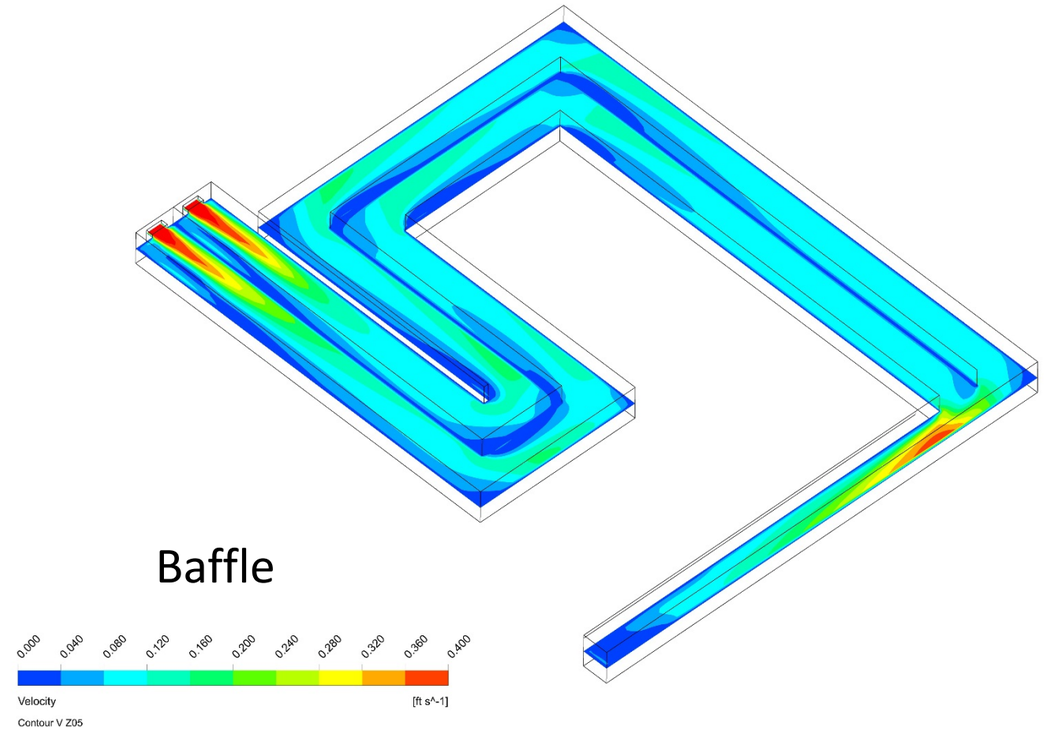


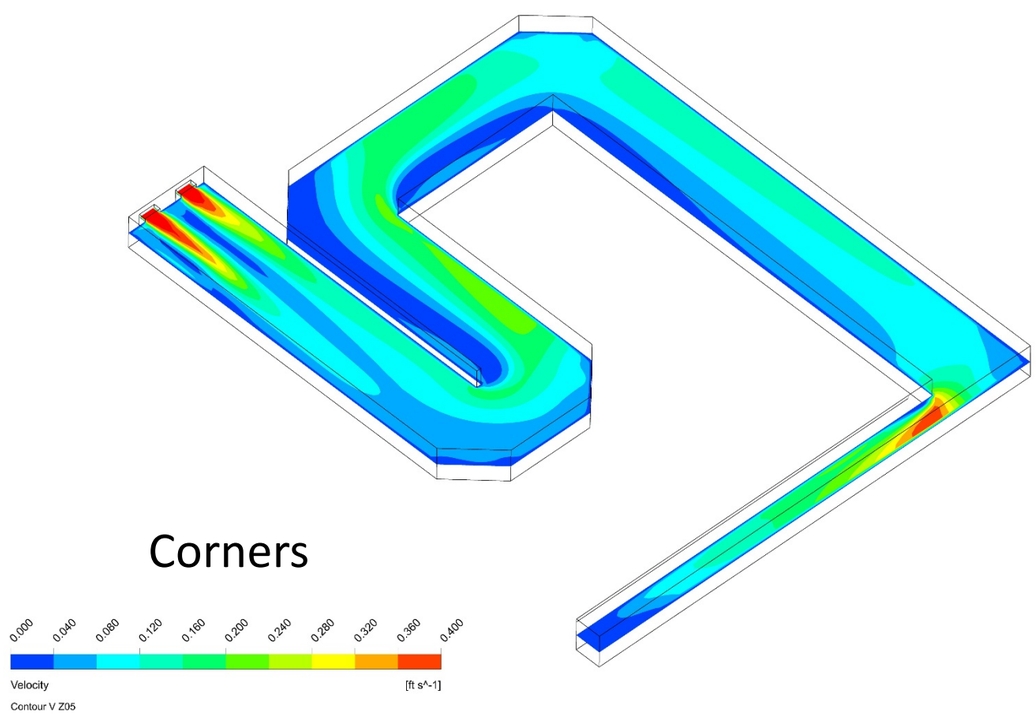
Corners

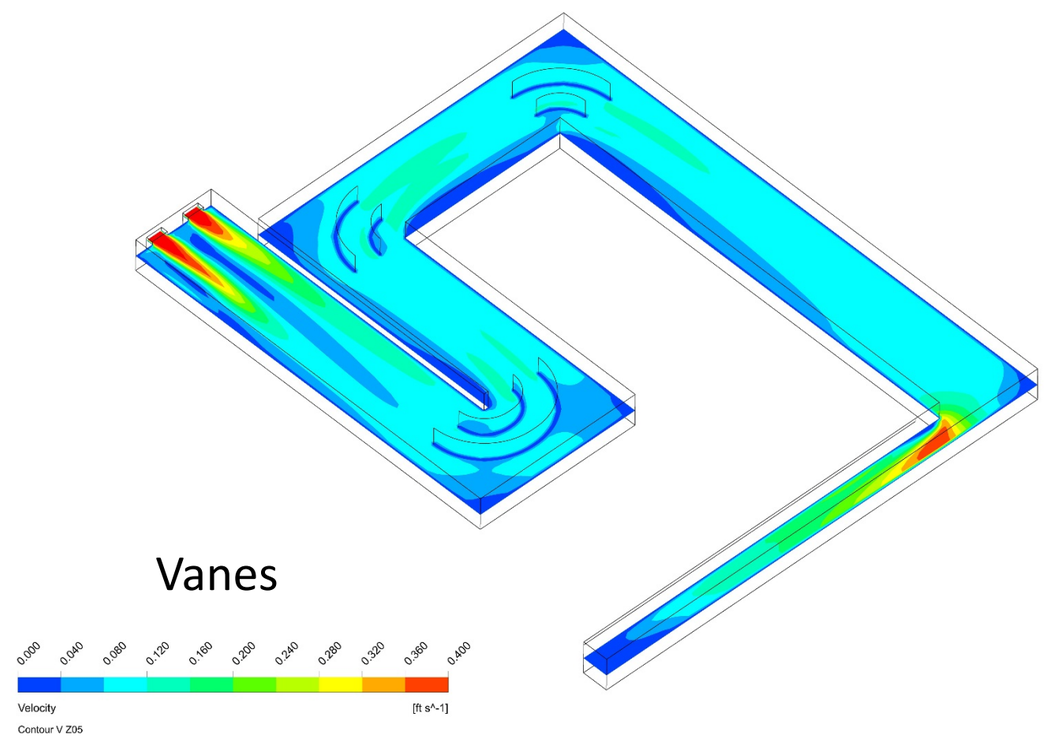


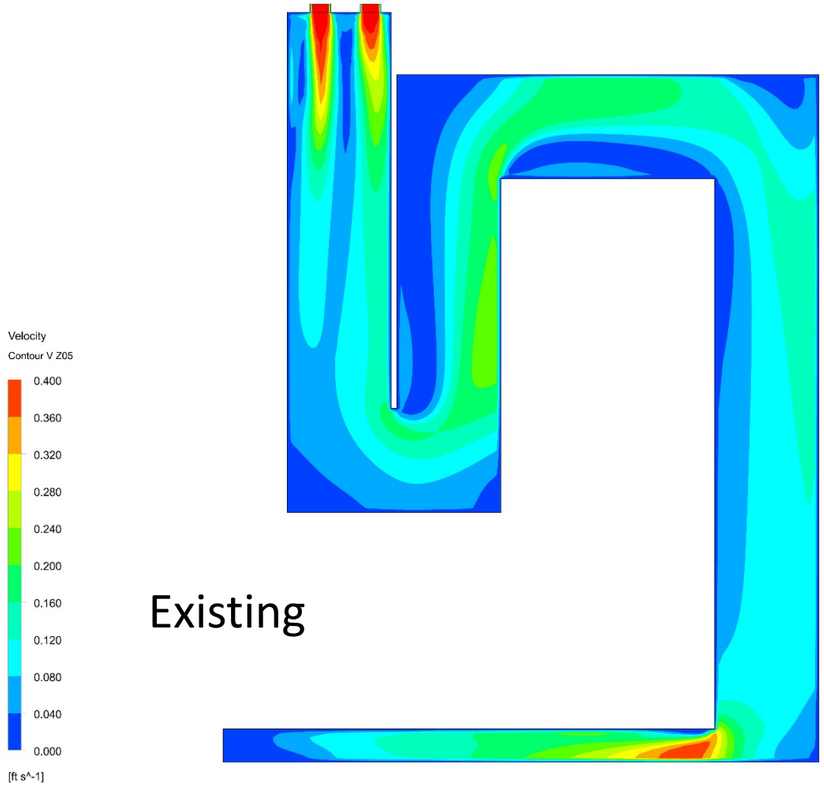
Vanes


Existing
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Contour V Z05


Baffle
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Contour V Z05


Corners
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Contour V Z05


Vanes
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320 0.360 0.400
Velocity
[ft s^-1]
Contour V Z05


Velocity
Contour V Z05
0.400
0.360
0.320
0.280
0.240
0.200
0.160
0.120
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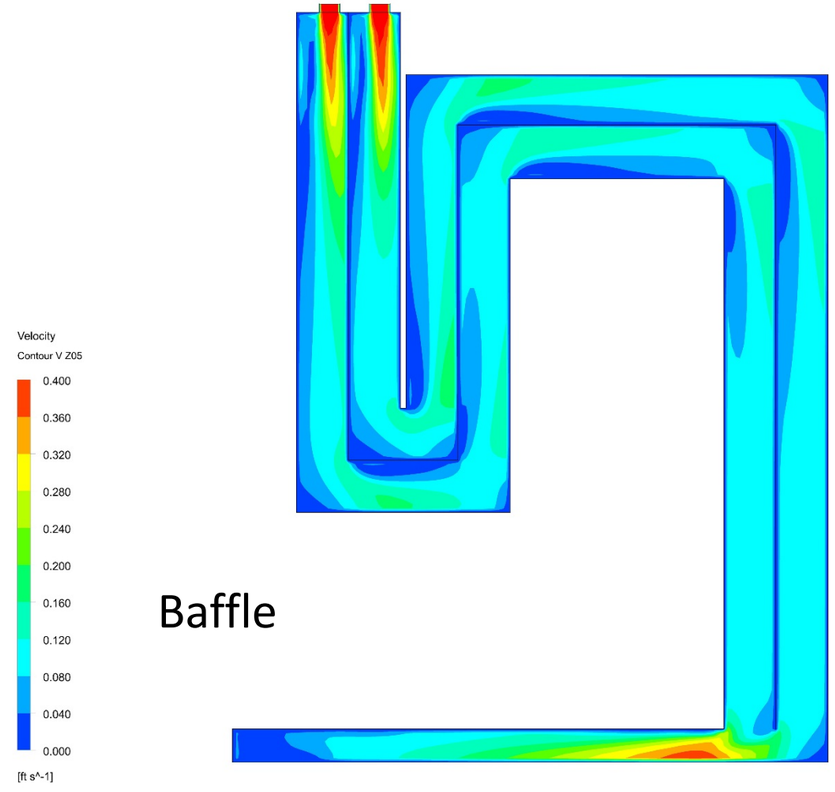
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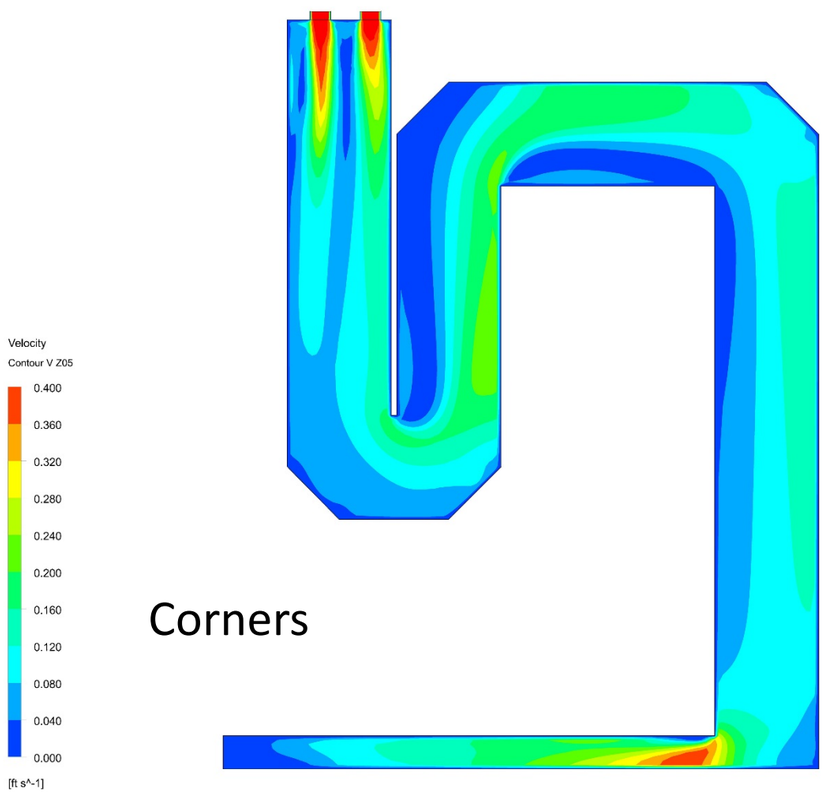
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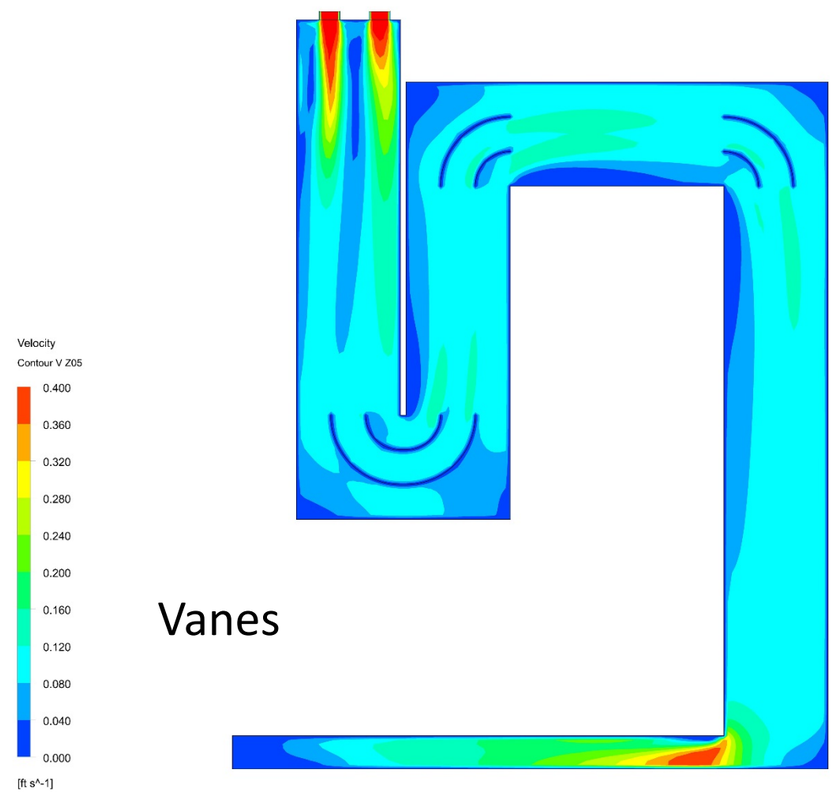
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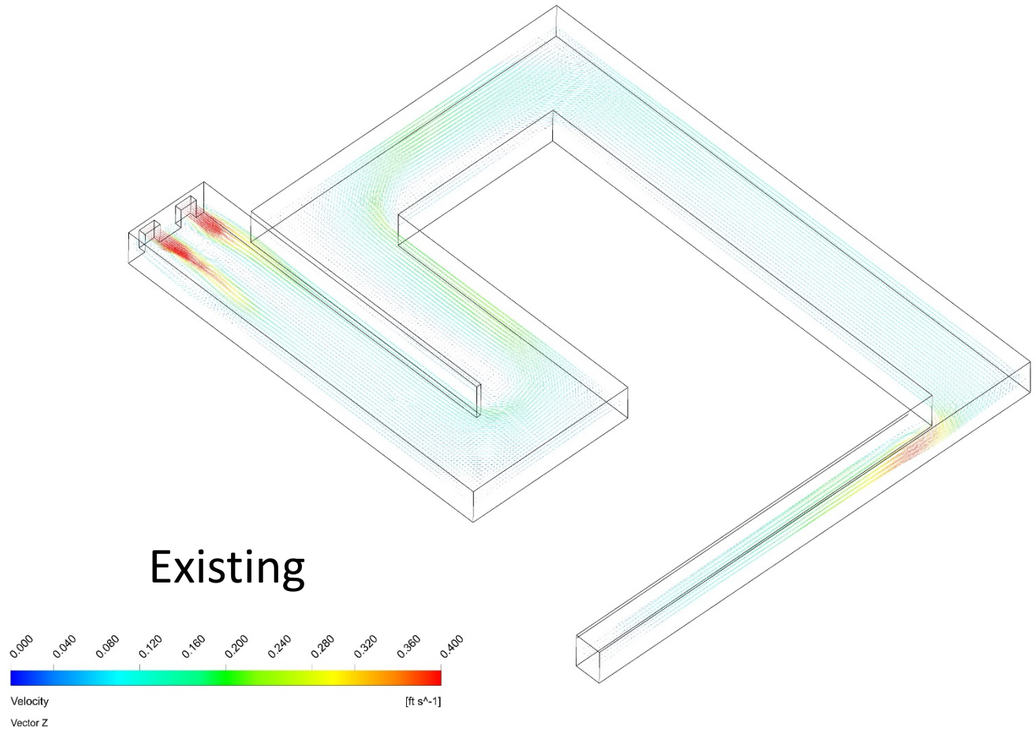
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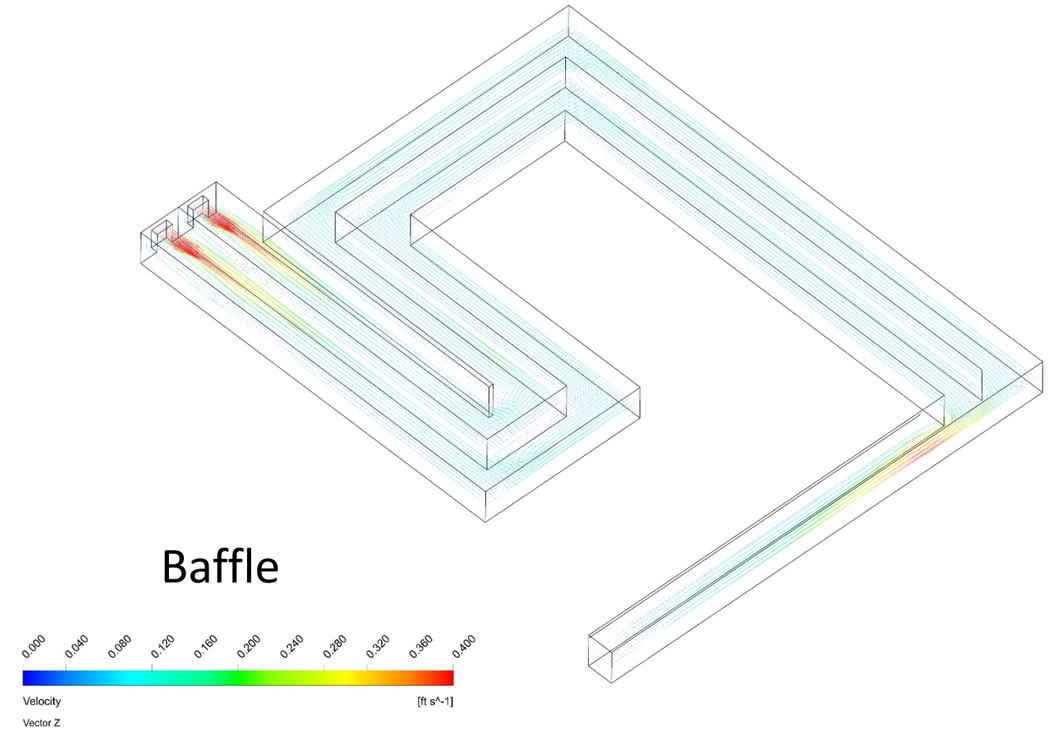
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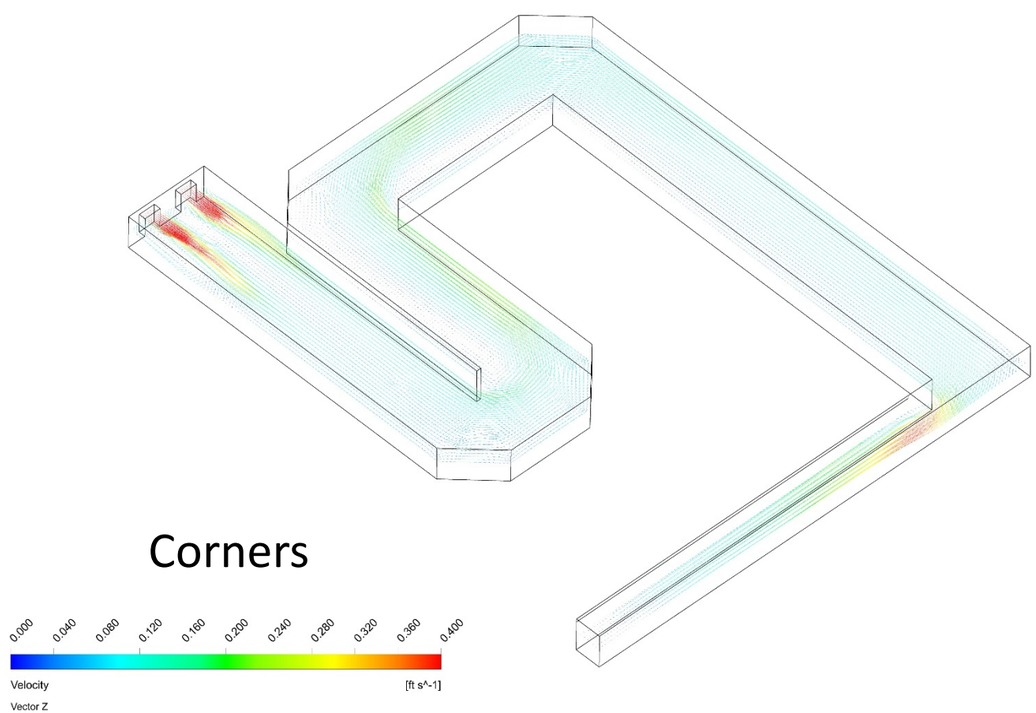
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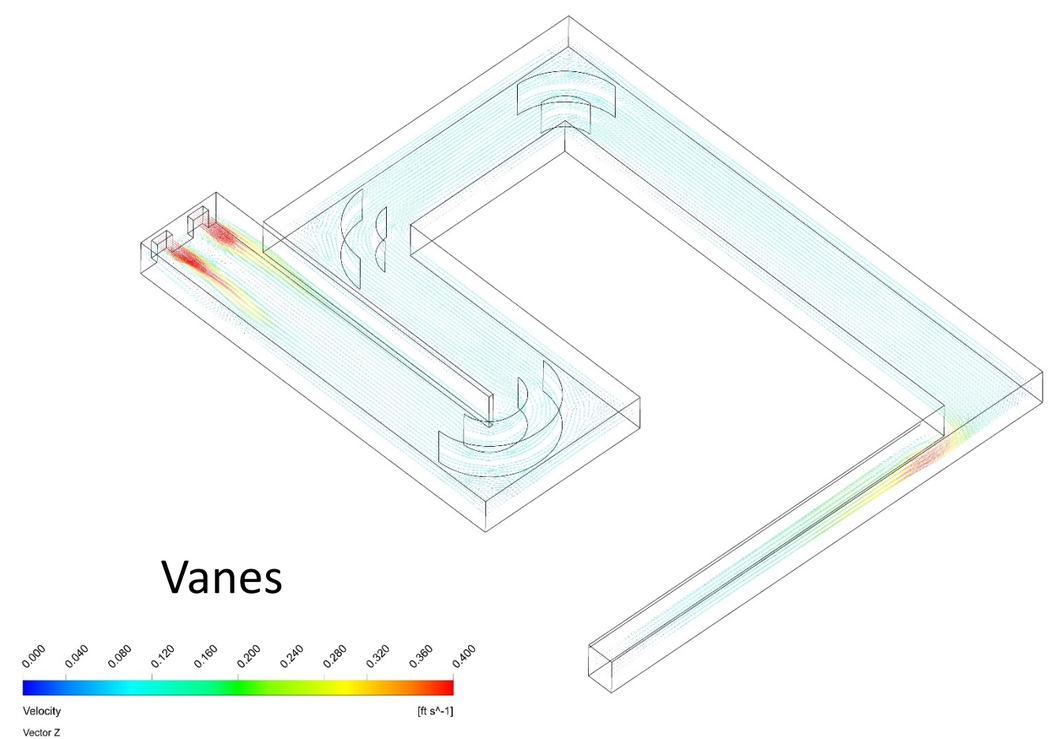
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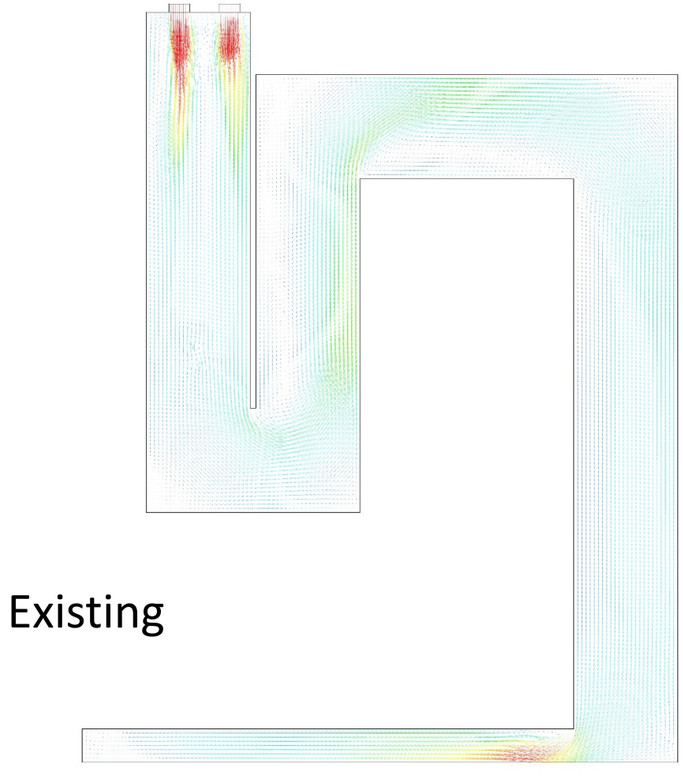
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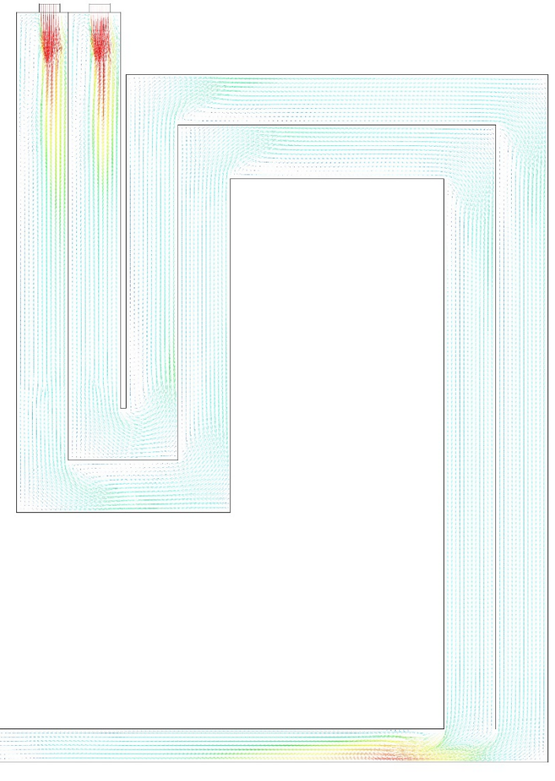
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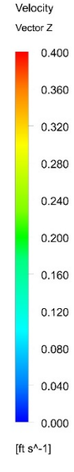
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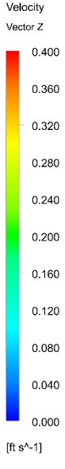
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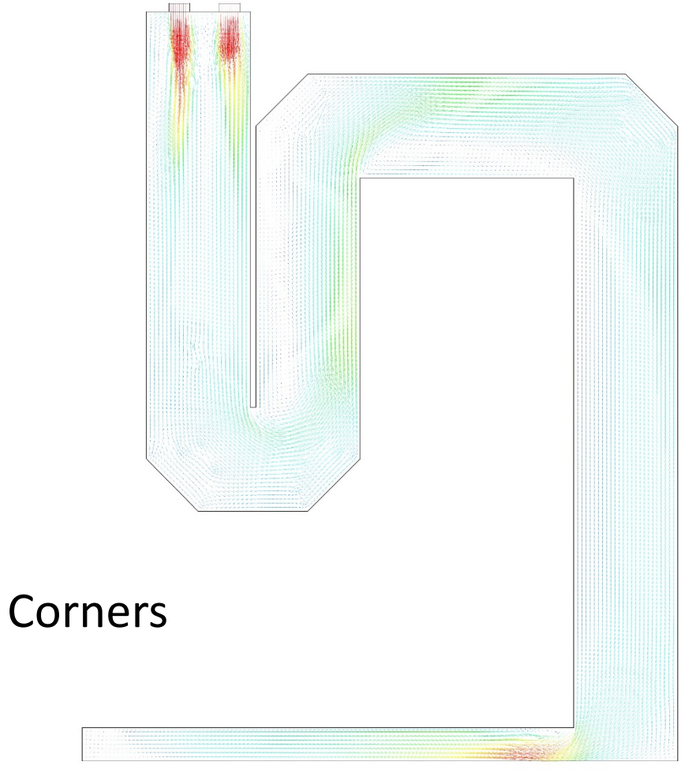
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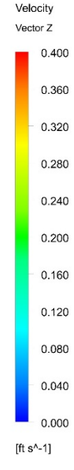
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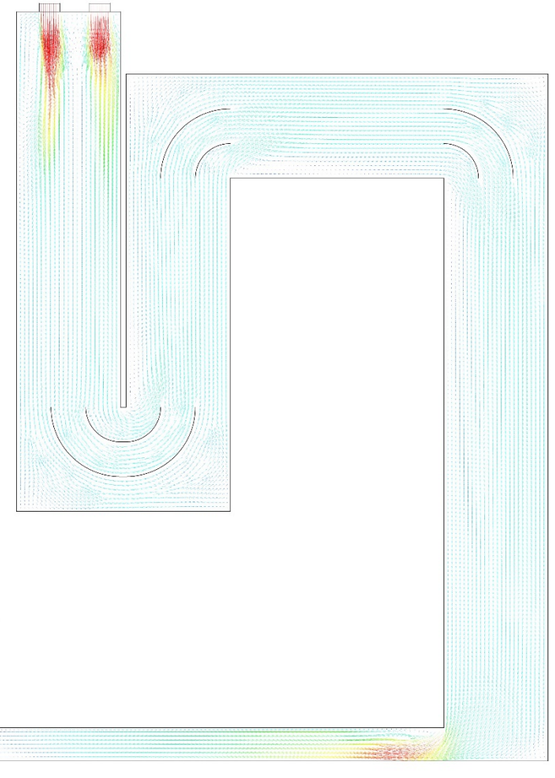
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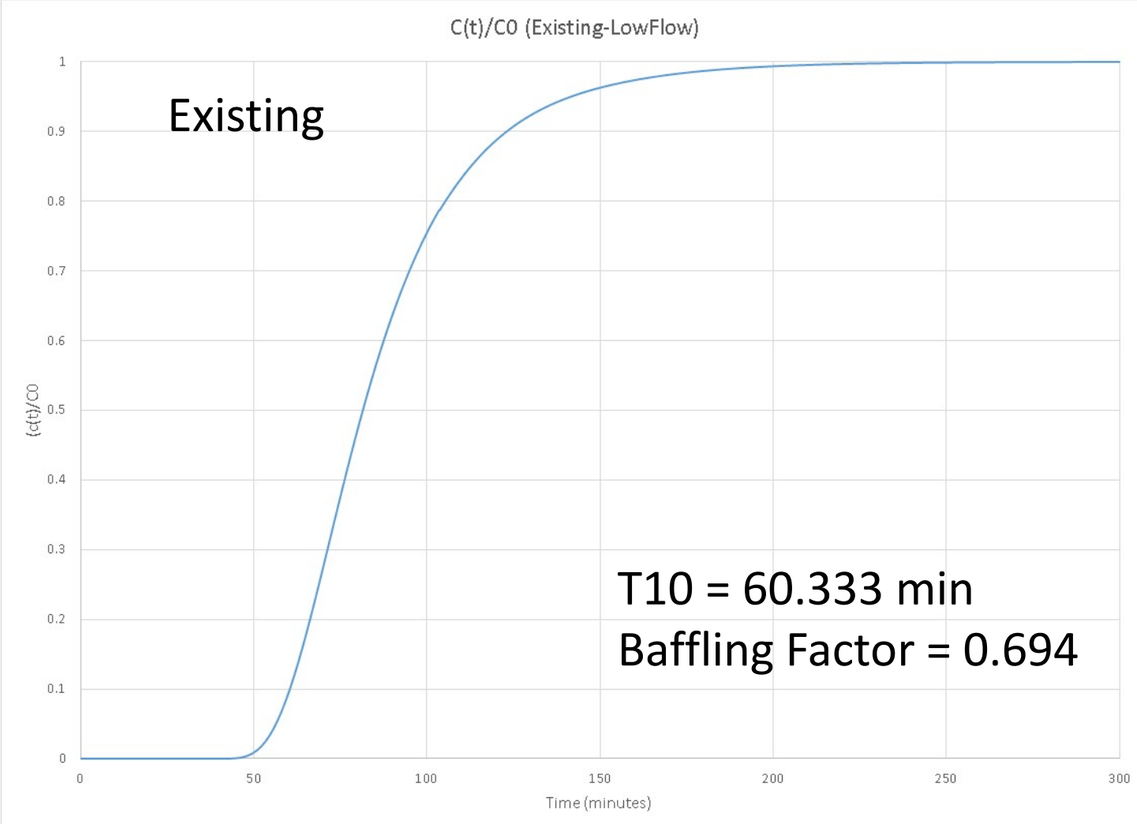
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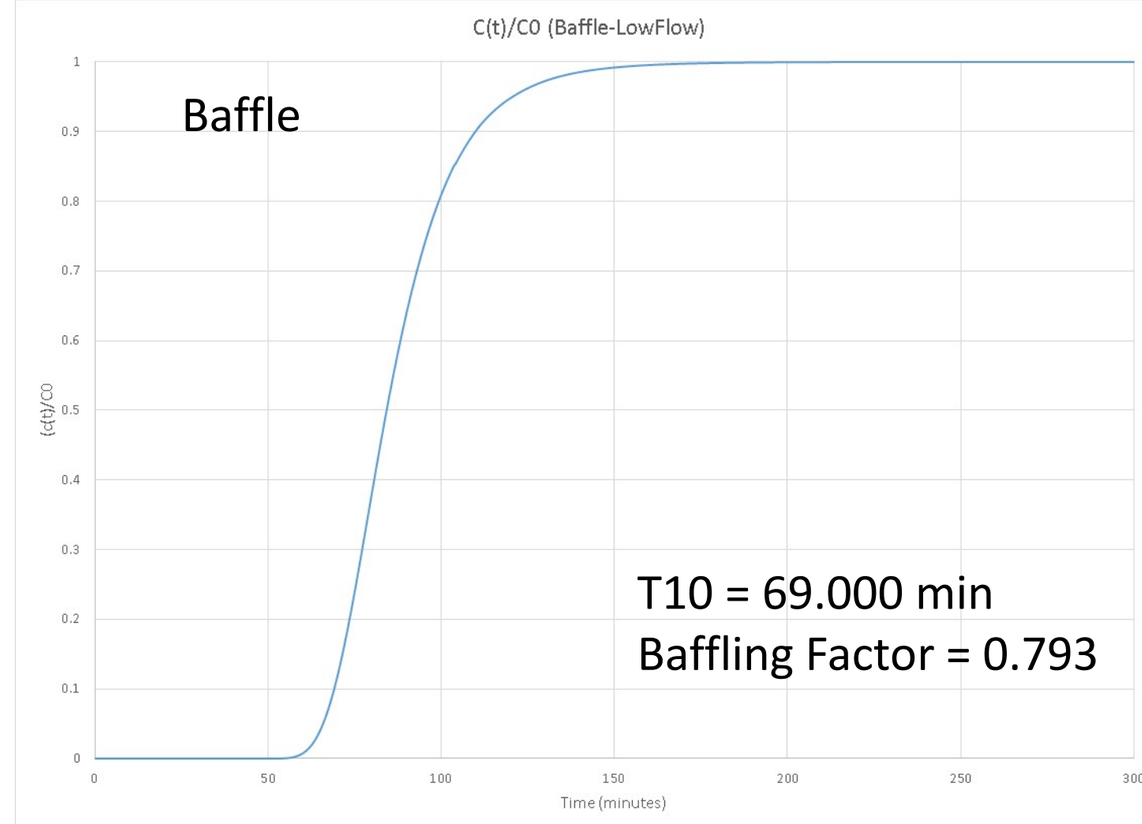
Time (minutes)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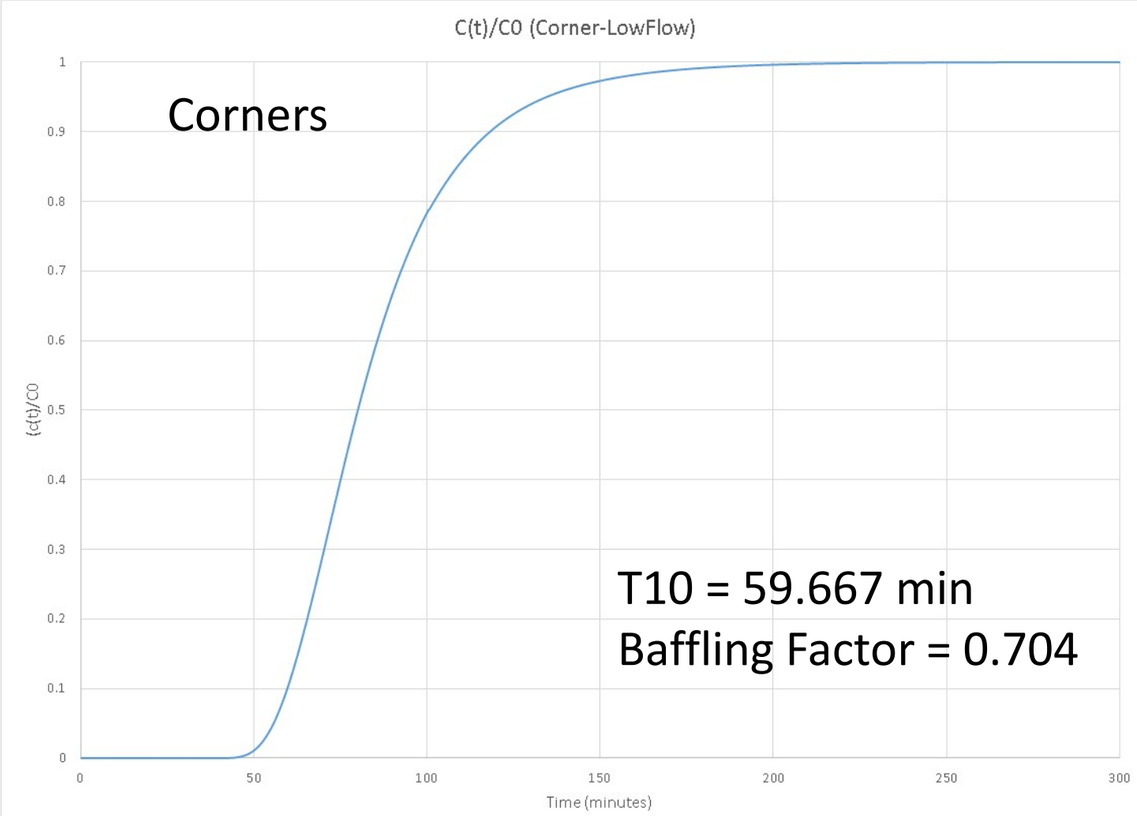
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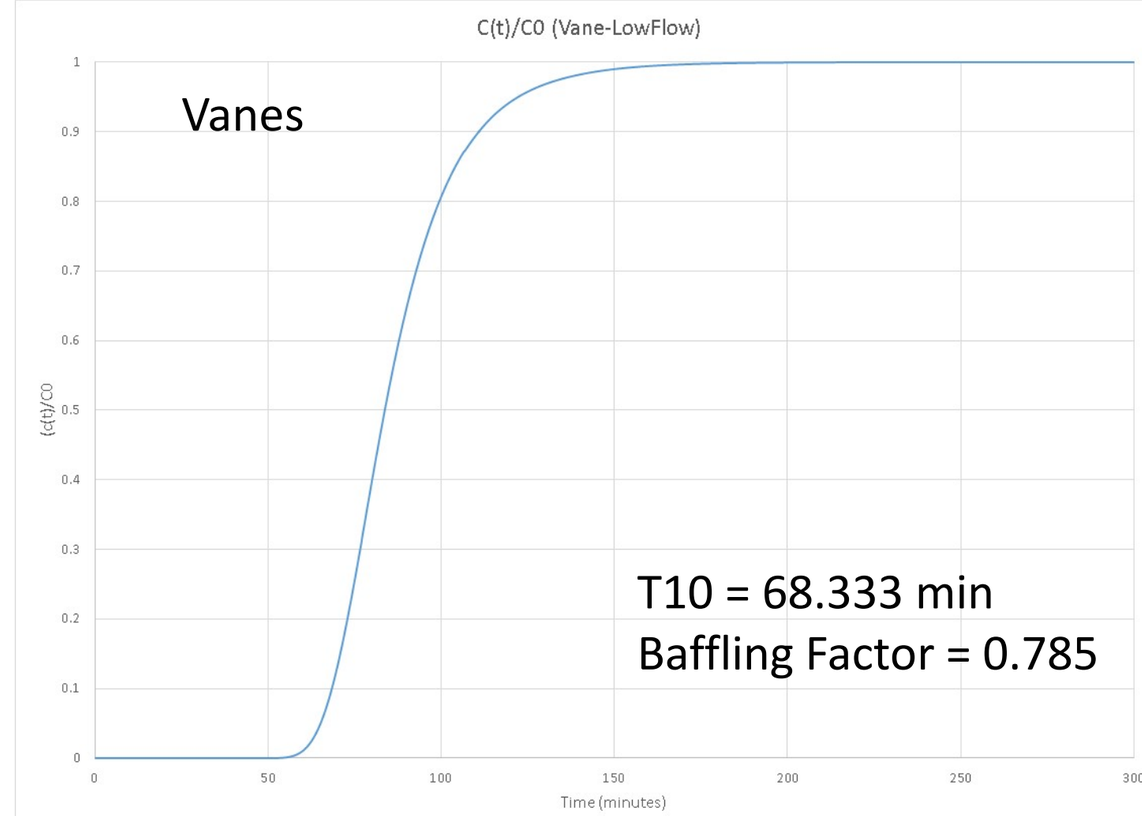
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Technical Memorandum 10.0 Sidestream Treatment Evaluation

10.1 Introduction and Background

Sidestream flows at the HFC AWTP, typically account for 15 to 30 percent of the total influent nitrogen load. This mass of nitrogen can impact the facility's ability to meet ammonia or total nitrogen limits. Treatment of this sidestream can help minimize the impact of the load to the main plant operation. This memo will provide a review of sidestream nitrogen removal options that have been considered and a conceptual design and layout of sidestream treatment facilities for the HFC AWTP.

10.2 Conventional Sidestream Treatment

Sidestream treatment of nitrogen can be accomplished using the conventional approach of two-step nitrification (nitritation and nitratation) and two-step denitrification (denitratation and denitritation) (see **Figure 10.2-1**). In this process, ammonia is oxidized to nitrite and then nitrate by aerobic ammonia oxidizing bacteria (AOB) and aerobic nitrite oxidizing bacteria (NOB) respectively. This nitrate is then denitrified to nitrogen gas using heterotrophic bacteria. The conventional nitrogen removal pathway is the process by which nitrogen is removed at most wastewater treatment plants throughout the United States.

This process theoretically requires 4.57 pounds of oxygen (O_2) per pound of ammonia (NH_3-N) converted to nitrate (NO_3^--N), 7.14 pounds of alkalinity per pound of ammonia nitrified and 2.8 pounds of supplemental carbon (COD) per pound of nitrate removed through heterotrophic denitrification. Note, half of the alkalinity used to nitrify is recovered via the denitrification process. In practice, six pounds of supplemental carbon must be added due to competing carbon sinks in the activated sludge process.

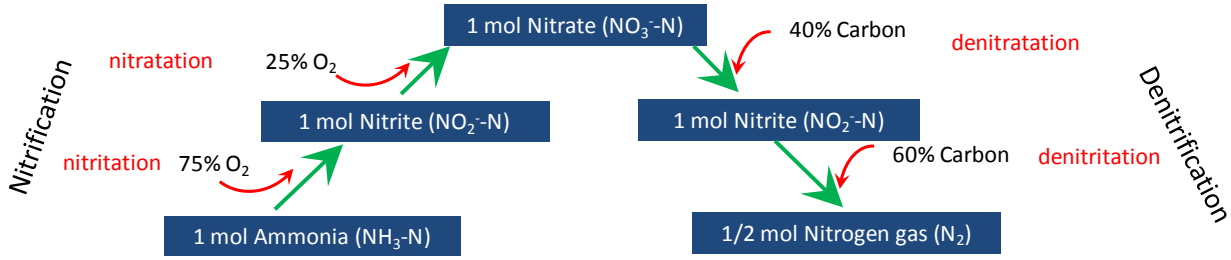

Figure 10.2-1: Nitrification and Denitrification Pathway for Nitrogen Removal

10.3 Deammonification

An alternative approach for removing nitrogen in sidestream flows is the use of the deammonification process (see **Figure 10.3-1**). The deammonification process requires conversion of approximately 50% of the influent ammonia into nitrite by AOB, followed by the simultaneous removal of ammonia and nitrite by anaerobic ammonia oxidizing (AnAOB) bacteria. Under anoxic conditions, AnAOB have the ability to simultaneously reduce nitrite and ammonia to nitrogen gas.

Using this process, a 66.5% savings in aeration, 50% savings in alkalinity, and 100% savings in carbon is realized; resulting in a substantial savings in energy and supplemental chemicals. Supplemental alkalinity is sometimes needed to remove all of the sidestream ammonia load, but these costs are typically minor in comparison to the savings.

Presently, there are nine full-scale sidestream deammonification facilities that are operating in the United States. There are three facilities in startup with several others various phases of design and construction. Given the significant benefit that exists in employing deammonification versus nitrification/denitrification for sidestream nitrogen removal, the deammonification process was considered for implementation at the HFC AWTP.

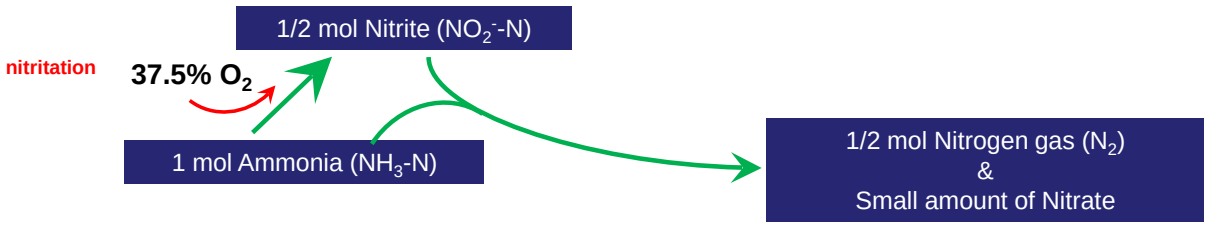

Figure 10.3-1: Deammonification Pathway for Nitrogen Removal

Sidestream Deammonification Technologies

Several sidestream deammonification treatment technologies are currently available, which can be new installations or retrofitted into existing plant tankage/infrastructure. In each of these existing processes, nitrite production is achieved using patented approaches for repressing NOB growth/activity using free ammonia, selective wasting strategies, and dissolved oxygen concentration gradients. AnAOB are retained in the process utilizing patented solids/media separating devices to provide sufficiently long SRTs for AnAOB bacteria growth. In all cases, the technology providers also utilize seed bacteria from elsewhere to startup and maintain the process. A summary of the major deammonification providers and brief description of their technologies is provided in **Table 10.3-1** below:

Table 10.3-1: Overview of Commercially Available Sidestream Deammonification Processes

Parameter	DEMON®		ANITA™ Mox		AnnamoPAQ™
Reactor configuration	SBR[1]	Continuous Flow	MBBR[2]	IFAS[3]	Continuous Flow
Biomass characteristic	Flocs and granules	Flocs and granules	Biofilm	Biofilm and flocs	Granule
Proprietary retention strategy	Hydrocyclone	Rotating Drum Screen and Lamella Clarifier	Plastic carrier and screen	Plastic carrier, screen, and suspended phase wasting	Tilted Plate Settler
North American Vendor	World Water Works	World Water Works	Kruger	Kruger	Ovivo
Number of operating installations in the US (includes facilities in startup) as of January 2018	6	0	6	0	0

1. *Sequencing Batch Reactor*
2. *Moving Bed Biofilm Reactor*
3. *Integrated Fixed-Film Activated Sludge*

10.3.1 DEMON® SBR

The DEMON®, short for DEamMONification, has two different configurations. The first configuration utilizes a SBR configuration with hydrocyclones and operates via recurring react/decant cycles. The DEMON® SBR process reaction cycles include (**Figure 10.3-2**):

- Aeration/Filling and Aeration – Under aerobic conditions, the nitritation process occurs until the low pH setpoint is met (dt1 and dt2 on **Figure 10.3-2**). At that point, the system begins operating in an anoxic mode. The low pH setpoint can range from 6.5 to 6.7 and is dependent on the alkalinity of the system as well as target ammonia removal efficiency.
- Stirring/Filling and Stirring – Nitrite and ammonia are converted under anoxic conditions to nitrogen gas by anammox bacteria (dt3 and dt4 on **Figure 10.3-2**) until a high pH set point is met. This high set point is typically 0.01 to 0.05 pH units higher than the lower setpoint.
- Settle – Solids are settled in the reactor, ensuring that the slow growing anammox are retained.
- Decant – Treated centrate, now low in nitrogen, is discharged.

DEMON® retains the AnAOB bacteria and selectively wastes NOB through the use of mechanical equipment known as hydrocyclones **Figure 10.3-3**. A combination of free ammonia inhibition, tight DO control and selective biomass wasting is used to stimulate nitrite production.

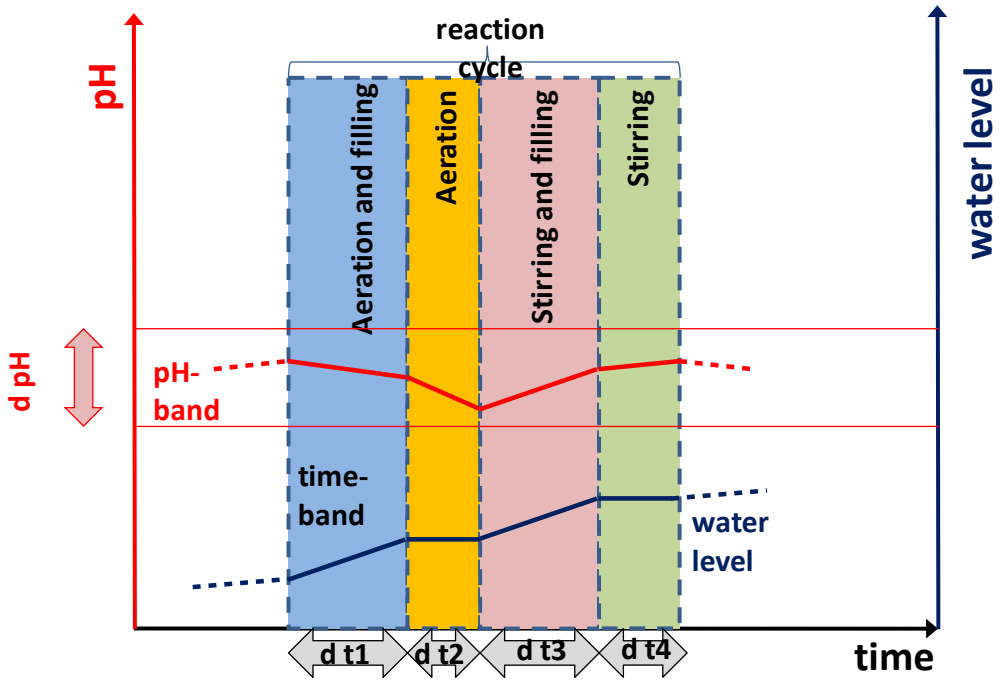

Figure 10.3-2: Process Control Strategy for DEMON® SBR Process (Courtesy of World Water Works)

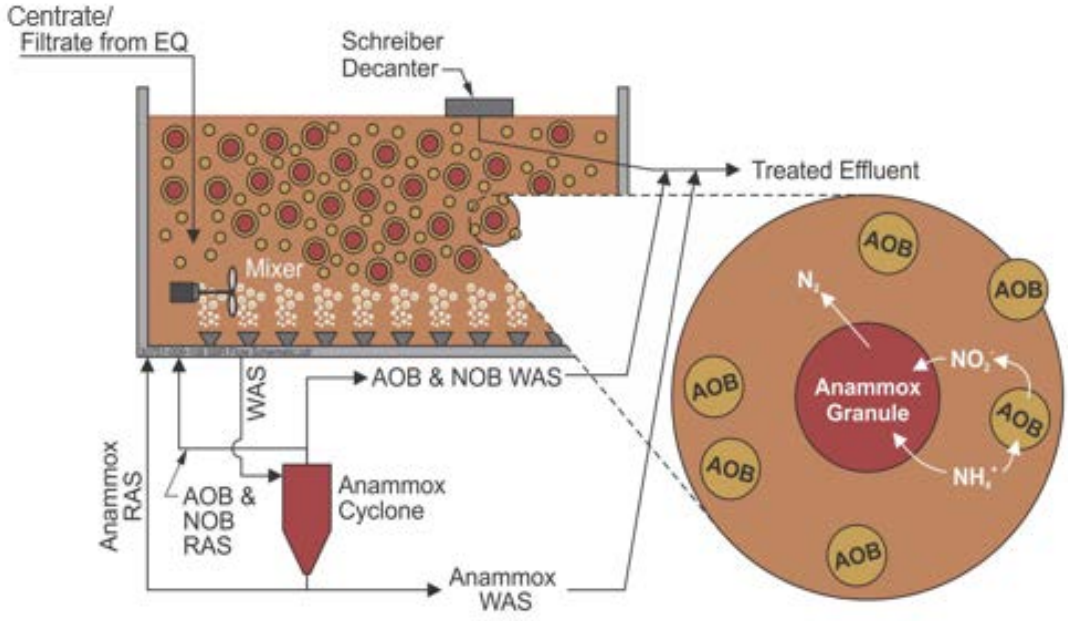

Figure 10.3-3: DEMON® SBR Schematic. Note that Anammox in the figure is used to reference AnAOB.

10.3.2 DEMON® Continuous Flow

The DEMON® continuous flow configuration is shown in **Figure 10.3-4**. In this process, sidestream flow is continually fed through the DEMON® process instead of in different batches. The mixed liquor containing AOB and AnAOB are suspended using a combination of mixers and aeration panels. At the end of the reactor there is a solids separation device, in which the heavier AnAOB granules and MLSS settle out and are returned back to the process, while the clarified effluent leaves the reactor. The solids separation device collects effluent from approximately 15-cm below the water surface to avoid losing any granules or biomass that may float to the surface. The DEMON® continuous flow system is also equipped with a rotating drum screen for selective wasting of NOBs.

Process control of the continuous flow system is similar to the control employed for the SBR in that pH is used to control feed and aeration. A target reactor pH setpoint (constant) will cause adjustment of the DO setpoint (variable) or influent feed rate based on whether the target pH value is met. The blowers will turn off based on a low pH setpoint and the influent feed system will shut off based on a high pH setpoint. The operator has the ability to control selection of the desired organisms by adjusting several process variables, including: pH setpoints, DO setpoints, and the duration of microscreen operation.

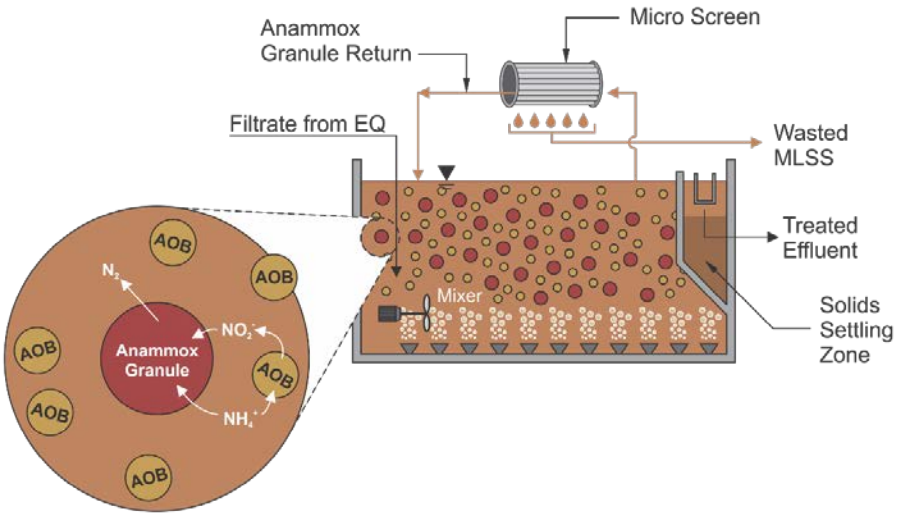

Figure 10.3-4: DEMON® Continuous Flow Schematic. Note that Anammox in the figure is used to reference AnAOB.

10.3.3 ANITA™ Mox Moving Bed Biofilm Reactor (MBBR)

The ANITA™ Mox MBBR configuration utilizes a single stage flow through moving bed bioreactor configuration to perform deammonification. The system is designed to passively retain biomass on carrier media, using of 5/8-inch perforated effluent screens. The media configuration utilizes diffusion gradients to facilitate deammonification in a single stage reactor. Dissolved oxygen diffuses into the biofilm, providing aerobic conditions in the outer layer of the biofilm. Biomass in the inner layer of the media are exposed to anaerobic conditions allowing for the anammox reaction to take place (**Figure 10.3-5**).

Process control consists of limiting the dissolved oxygen concentrations in the system to range between 0.5 and 1.5 mg/L based on pH setpoints. A measured pH below the setpoint will cause the variable DO setpoint to decrease. A measured pH above the setpoint will cause the variable DO setpoint to increase. Any changes in DO setpoint will cause the aeration rate to be adjusted according to the DO mode control method.

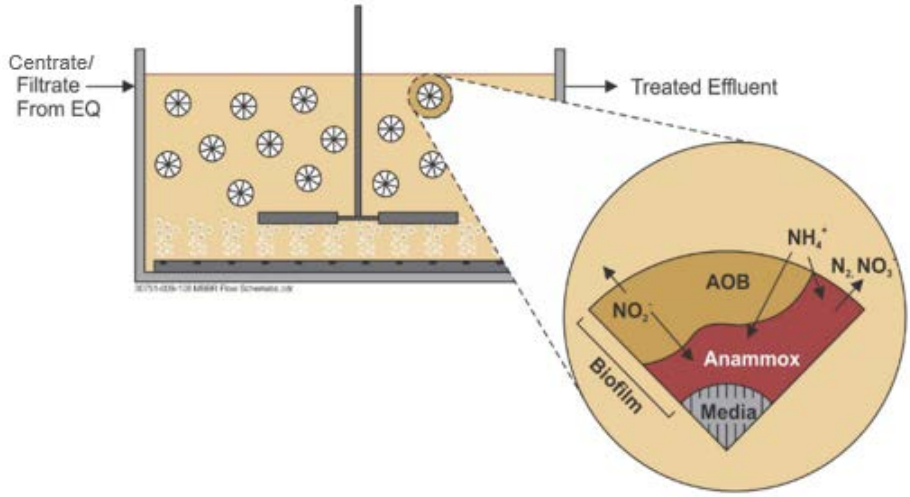

Figure 10.3-5: ANITA™ Mox (MBBR) Biofilm Configuration and Theoretical Diffusion Patterns. Note that Anammox in the figure is used to reference AnAOB.

10.3.4 ANITA™ Mox Integrated Fixed-Film Activated Sludge (IFAS)

ANITA™ Mox IFAS utilizes a flow-through reactor with suspended and attached growth biomass to achieve deammonification. The system is designed to passively retain AnAOB biomass on carrier media, which is kept in the system through the use of 5/8 inch perforated effluent screens. Suspended biomass (AOB/NOB) is retained through use of a dedicated clarifier, which is a key differentiator between IFAS and MBBR technologies. This IFAS configuration utilizes biomass in the suspended phase to perform nitritation. AnAOB biomass on the media is used to achieve deammonification (**Figure 10.3-6**). The operating DO concentration for the IFAS configuration is lower than that associated with the MBBR configuration due to the reduced oxygen diffusion requirements. Though the IFAS process is more complex than the MBBR process, it provides greater control over AOB/NOB selection with separate wasting of the suspended phase, as generally the AOB/NOB populations are thought to be in suspension, while AnAOB bacteria are attached to the media. This control provides the operator with greater flexibility to adjust operations in the event of a process upset.

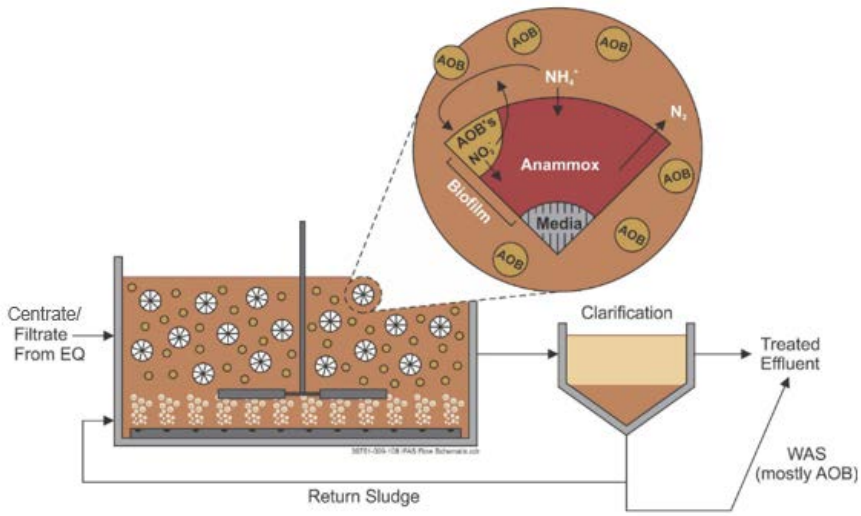

Figure 10.3-6: ANITA™ Mox (IFAS) Biofilm Configuration and Theoretical Diffusion Patterns. Note that Anammox in the figure is used to reference AnAOB.

10.3.5 AnammoPAQ™

The AnammoPAQ™ process uses a continuous flow granular sludge process to achieve deammonification. These systems utilize passive settlers within the reactors to retain heavier granular biomass, like AnAOB, and mechanical pumps to waste excess biomass from the system. AOB are typically present in the outer layer of sludge granules while the AnAOB bacteria are most dominant in the internal fraction of the granule (**Figure 10.3-7**). Process control of the system is achieved by adjusting the target DO concentrations to select for AOB over NOB according to the influent and target effluent concentrations. Even though there are no AnammoPAQ™ processes in the US, there are over 30 installations in Europe and China, deeming this technology mature and viable for consideration.

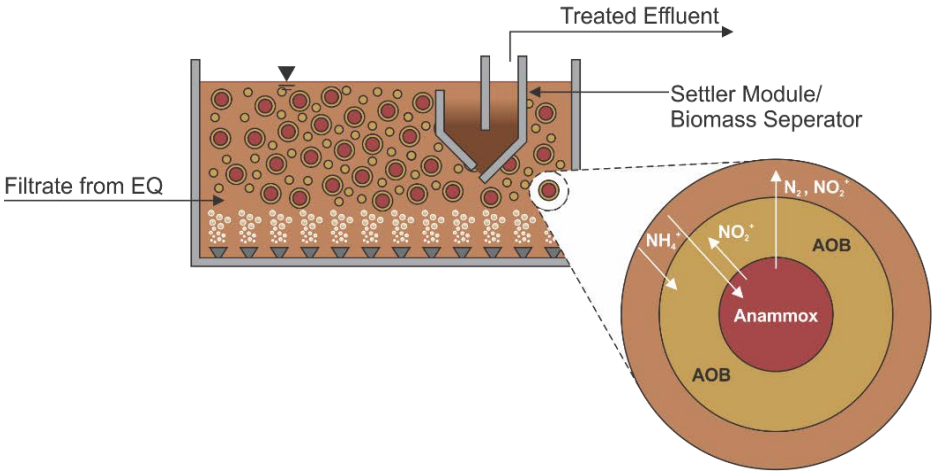

Figure 10.3-7: AnammoPAQ™ Upflow Granular Process and Theoretical Diffusion Patterns

10.4 Sidestream Deammonification Process at HFC AWTP

Regardless of the technology selected, sidestream deammonification processes at the HFC AWTP are expected to remove 80-90% NH_4-N and 70- 80% TIN from the sidestream. The reduction in nitrogen from the sidestream flow translates to a cost savings in the main plant from the reduction of methanol addition at the denitrification filters and a reduction in aeration costs associated with nitrification in the south reactors. Implementation of sidestream deammonification will also result in a reduction of denitrification filters needed in the future. If sidestream deammonification is not implemented, nine (9) additional denitrification filters will be needed within eight (8) years (average annual design flow (AADF) = 68 mgd). If sidestream deammonification is implemented, two (2) additional denitrification filters will be needed within seventeen (17) years (AADF = 77 mgd; see **Table 10.4-1)**.

Table 10.4-1: Denitrification Filters Required Based on NO_x Loading

		With Sidestream Treatment		Without Sidestream Treatment	
Parameter	units	60 MGD MD	80 MGD MD	60 MGD MD	80 MGD MD
Denitrification Filter Influent AA NO_x Load[1]	ppd as N	10,000	17,000	13,000	20,500
Number of New Filters Required within 20 Years[2,3]	#	**0**	**2**	**0**	**9**
Approximate influent AADF when filters are required	mgd	-	77	-	68

[1]*Developed from calibrated process modeling.*
[2]*Required filters are calculated based on the NO_x-N load removed, the filter capacity and the number of existing filters.*
[3]*Existing filters designed for NO_x-N removal of 500 ppd per filter (16,000 ppd NOx load ÷ 32 filters).*

Future sidestream flows and loading were developed from calibrated process modeling. The sidestream loading rates are based on the following assumptions:

- The ratio of Primary Sludge to WAS to the digesters is approximately 50:50.
- HFC AWTP will maintain mesophilic anaerobic digestion with a volatile solids reduction (VSR) of approximately 58% based on historical data and process modeling.

Based on these design conditions, proposals were requested from World Water Works (DEMON®), Kruger (ANITA™ Mox) and Ovivo (AnammoPAQ™) (**Attachment 10-A**). A summary of the equipment costs from each proposal is listed in **Table 10.4-2**.

Table 10.4-2: Sidestream Treatment Equipment Costs

Technology	Equipment Cost
DEMON® (SBR and Continuous)	$2,500,000
ANITA™ Mox MBBR	$3,100,000
AnammoPAQ™	$4,100,000

10.4.1 Design Information

The following section includes a proposed design for a sidestream deammonification process at HFC AWTP. While all of the discussed technologies were evaluated, the ANITA™ Mox MBBR system was used as an example for illustrating implementation of sidestream deammonification at the HFC AWTP because it has the highest TIN removal efficiencies without additional chemical requirements. It is to be noted that the ANITA™ Mox process is just one option suggested for consideration for sidestream treatment at the HFC AWTP.

A conceptual evaluation of the proposed sidestream deammonification process at the HFC AWTP was performed and the ANITA™ Mox system evaluation is presented below. In this assessment, it was determined that sidestream deammonification would require two separate process trains with a total reactor volume of 78,000 gallons. In addition to reactor volume, sidestream equalization (EQ) is recommended to reduce the number of interruptions in flow to the process caused by changes in sludge dewatering. Sidestream EQ will allow the plant to maintain flexibility in their dewatering schedule without interrupting operation of the sidestream treatment process.

The ANITA™ Mox system proposed for this application was based on future sidestream flows and concentrations predicted using the calibrated process model based on dewatering 24 hours/ day, 7 days/ week. The proposed system is also applicable to the current flows as ANITA™ Mox is capable of adapting to changes. Current and future sidestream flow conditions correspond to a current and future plant annual average influent flow of 60 and 80 MGD, respectively. Current loads are based on centrate concentrations observed at the plant (**Appendix B**) based on a week-long sampling event in February 2017. Only centrate flows were considered because it would be cost prohibitive to incorporate sludge drying bed filtrate as the flows and loads are minimal. The design criteria summarized in **Table 10.4-3**, and the design parameters from the ANITA™ Mox Proposal received from Kruger are summarized in **Table 10.4-4**.

Table 10.4-3: Sidestream Deammonification Treatment System Design Criteria

Parameter	Units	60 MGD AADF Influent[1]	80 MGD AADF Influent[2]
Centrate Flow, Design	MGD	0.58	0.8
BOD_5, Design Load	lb/day	300	470
COD, Design Load	lb/day	2,960	4,140
TSS, Design Load	lb/day	2,230	3,140
TKN, Design Load	lb/day	3,490	4,880
NH_3-N, Design Load	lb/day	3,440	4,740
Alkalinity Load	lb/day	12,580	17,350
Design Temperature	°C	30	30

[1] *Current influent values are based on sampling results from the February 2017 sampling campaign.*
[2] *Future influent values are based on the calibrated process model.*

Table 10.4-4: Design Parameters for ANITA™ Mox MBBR[1]

Parameter	Units	Values
Number of Process Trains	-	2
Number of MBBR Reactors per Train	-	1
Dimensions (each)	ft	67L x 33.5W x 23 SWD
Volume (each)	gallons	51,625
Total Volume (all reactors)	gallons	103,250
Recommended Freeboard	ft	2-3
Media Type	-	K5
Fill of Biofilm Carriers, All Reactors	%	42
Media Volume (All Reactors)	ft^3	45,325
Aeration System Type	-	Medium Bubble
Residual DO, Design	mg/L	1.5
Total Process Air Requirement (All Reactors)	SCFM	~3,200
Air Pipe Pressure (Approx. From Top of Drop Pipe)	psi	9.8
Estimated Daily Blower Energy, Annual Avg.	kW-hr/d	1,550
Estimated Daily Influent Feed Pump Energy, Annual Avg.	kW-hr/d	86

[1] *Design parameters are applicable for both current and future sidestream flows.*

10.4.2 Conceptual Layout and Proposed Location

The proposed location for the sidestream treatment reactor is in the re-purposed high purity oxygen (HPO) reactors and the proposed location of the EQ is within the re-purposed final sedimentation tanks (FSTs) (**Figure 10.4-1**). Currently, only three of the six tanks of the HPO reactor are in use. If recommendations for the BNR process made in the *Technical Memorandum 7.0 BNR Process Evaluation* are implemented, four of the six tanks will be in use. This will leave 2 HPO tanks available for other purposes. In this work, it is assumed that the sixth HPO tank will be modified to fit two ANITA™ Mox passes. The ANITA™ Mox MBBR process would require one HPO tank, using approximately 0.78 MG in the HPO reactor. An EQ volume was calculated to provide two days of equalization and storage at the design flow to provide EQ throughout the entire weekend when dewatering is not running. An EQ volume of 2.31 MG is required. The FSTs have available capacity of about 3 MG within the last clarifier and can therefore be considered for use as equalization. The existing mixers will need to be removed from the HPO reactors and the resulting openings will allow for sufficient venting. The use of the HPO reactors and FSTs will save costs by not having to construct new reactors, but if enhanced biological phosphorus removal is implemented in the future, new anaerobic volume will have to be constructed if one of the reactors is used for sidestream treatment. An example plan and profile view of the proposed process are shown in **Figures 10.4-2, and Figure 10.4-3.**

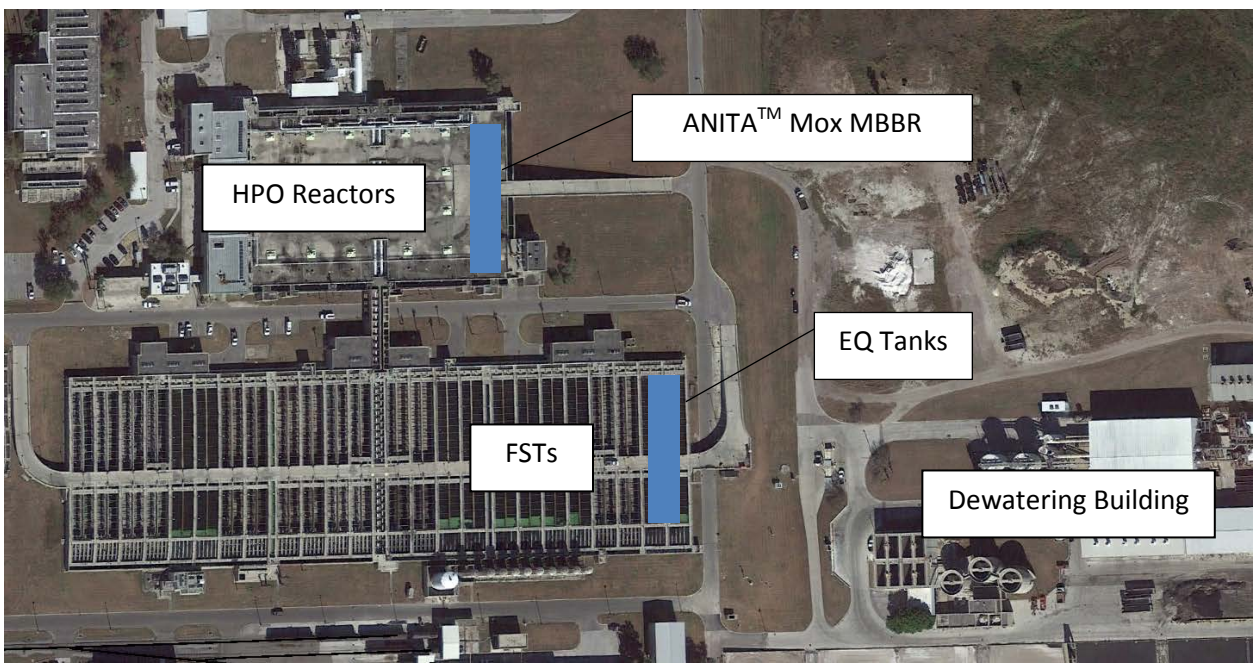

Figure 10.4-1: Proposed Location for ANITA™ Mox MBBR and EQ Tank

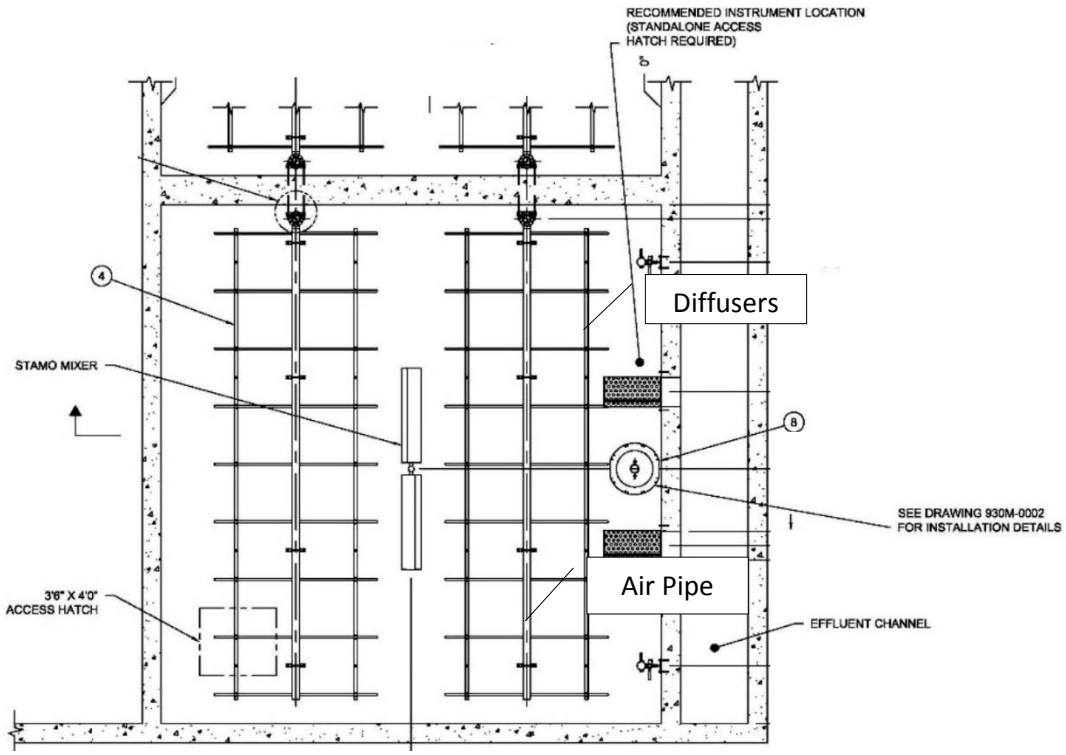

Figure 10.4-2: Plan View of ANITA™ Mox MBBR System

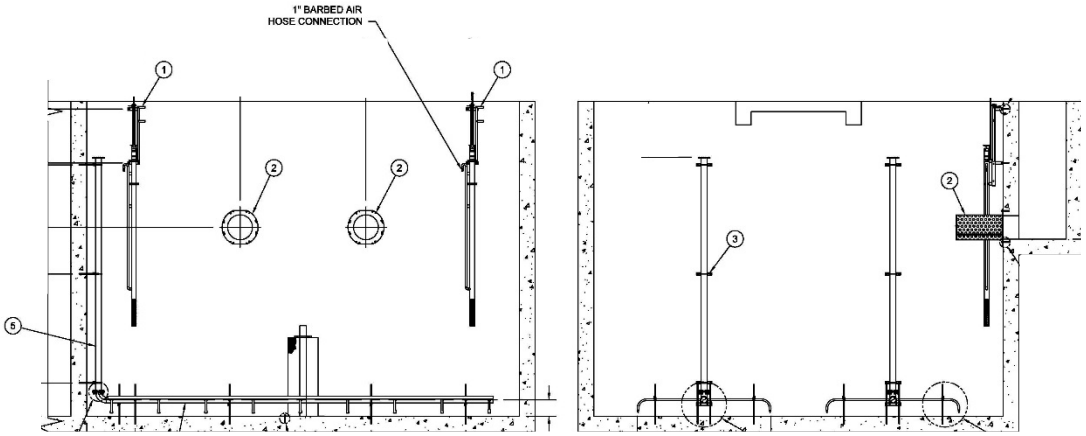

Figure 10.4-3: Profile View of ANITA™ Mox MBBR System

10.4.3 Estimated Capital and Operational Costs

A summary of estimated capital costs for the ANITA™ Mox MBBR system as well as DEMON® and AnammoPAQ™ systems installed at the HFC AWTP is provided in **Table 10.4-5**.

Table 10.4-5: Capital Cost Estimate for Sidestream Treatment

Description	ANITA™ Mox MBBR[3]	DEMON®[4]	AnnamoPAQ™[5]
System	$3,100,000	$2,500,000	$4,100,000
Building for Blowers and Pumps	$600,000	$600,000	$600,000
HPO Reactor Retrofit[6]	$200,000	$200,000	$200,000
HPO Reactor Retrofit for EQ[6]	$600,000	$600,000	$600,000
10" Pipe from Dewatering to FSTs and HPO Reactor	$100,000	$100,000	$100,000
Sum of Bare Construction Costs	$4,600,000	$4,000,000	$5,600,000
25% Electrical and I&C	$1,200,000	$1,000,000	$1,400,000
30% Contingencies	$1,700,000	$1,500,000	$2,100,000
Bare Construction Cost	$7,500,000	$6,500,000	$9,100,000
20% OH&P & GCs	$1,500,000	$1,300,000	$1,800,000
Total Construction Cost	$9,000,000	$7,800,000	$10,900,000
20% Management and Engineering[2]	$1,800,000	$1,600,000	$2,200,000
Total Capital Cost[1]	**$10,800,000**	**$9,400,000**	**$13,100,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of 50% to +100% of actual costs.*

[2]*Includes COT management, legal and administrative costs*

[3]*Includes AnoxKaldenes K5 media, cylindrical screen assemblies, medium bubble aeration system, specifically designed mechanical mixers, airlift pump, positive displacement blowers, PLC control panel, high level float switch, DO probe, pH meter, thermal mass flow meter, magnetic flow meter.*

[4]*Includes SS decanter model 350, 14" flow control valves, Messner aeration panels, SS304L drop pipe, DEMON Biomass separation systems, submersible pumps, pressure sensor, radar type level control, influent feed pumps, positive displacement blowers, side mounted mixers, seed sludge, control panel, pH and DO probes with controller, conductivity probes with controller, air flow insertion meter, water flow magnetic meters, inspection, start up, training, and remote monitoring.*

[5]*Includes Type 33 settler and support construction, fine bubble aeration system with aerostrip diffusers, basin piping for c/w drop legs, flanged diffuser pipes, mounting brackets, connection fasteners, piping for aeration, influent, effluent and biomass sampling, process air blowers for AnammoPAQ with VFD, Anammox granular biomass, controls and instrumentation, O&M manuals, detailed shop drawings and service days to inspect, install, test and start up system.*

[6]*Retrofit includes: demolition, new piping, EQ mixers and pumps*

The benefits of sidestream deammonification at the HFC AWTP were quantified by assessing the savings in methanol and aeration due to the reduction in sidestream nitrogen loading to the plant and by assessing the cost of additional denitrification filters required if sidestream were not implemented. Results indicate that implementing sidestream deammonification could reduce methanol and aeration costs by $16.3 million and $1.3 million over the 20-year period respectively. The operating costs were generated by accounting for the electrical costs,

equipment maintenance costs, and operator and maintenance personnel costs. All costs were projected over a 20- year period. The following assumptions were used to generate costs:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over a 20-year period. This cost was used to determine power consumption costs for major pieces of equipment. The kWh usage per year was calculated based on information provided by the manufacturer.
- Half time equivalent operators and maintenances personnel were projected year-round. Average operator and maintenance labor rates costs for direct salary ($40/hr) were used, with a 3% inflation rate added for the 20-year period.
- Consumables, which include equipment maintenance costs associated with lubrication, minor replacement components, bearings, mechanical seals, or other necessary replacement parts, were also considered. Consumables were considered at 0.5% of the capital cost with an inflation rate of 3% each year.
- Blower electrical savings were based on reduction of nitrogen loading to the south reactors as a result of sidestream treatment. An assumption is made that new blowers will be installed that have turndown capabilities.
- Methanol savings were based on a typical pounds of methanol to pound of nitrate ratio of 3.4:1. Historical unit price for bulk methanol costs was also determined by evaluating yearly average price from 1994 through 2017 to project potential future escalated costs. The future cost projection for 10 years into the 20-year period was used ($1.41 / gal). Operating costs also included pumping power costs, maintenance and labor costs.
- The denitrification filters capital cost offset savings is based on the total capital costs for the seven denitrification filters no longer required as a result of sidestream treatment. Unit costs of $2,500/ SF and 1,050 SF/ filter are used based on engineer's prior experience and marked up to a total cost of $34,420,0000 to account for contingency (30%), OH&P & GCs (20%), management and engineering costs (20%). The capital cost offset for the seven additional denitrification filters is calculated using an annual uniform series with the assumption that all the required filters will be designed and constructed starting in year 6 and completed by the end of year 8.

The 20-year life cycle costs for electrical, labor, and consumables to operate the sidestream treatment system are listed in **Table 10.4-6**, along with the capital cost offset of additional denitrification filters. The aeration savings and methanol savings were based on the difference between a system without sidestream treatment and with sidestream treatment and the costs of treating the additional nitrogen loading in a system without sidestream treatment. A negative net present worth value in the table corresponds to a savings as compared to operating the plant without sidestream treatment.

Table 10.4-6: O&M Cost Estimate for Sidestream Treatment

	ANITA™ Mox MBBR	DEMON	AnnamoPAQ™
	Future	Future	Future
Electrical Power Consumption	$1,200,000	$1,730,000	$1,390,000
O&M Labor	$1,120,000	$1,120,000	$1,120,000
Consumables	$1,300,000	$1,300,000	$1,300,000
Denitrification Filter Offset Savings	($34,420,000)	($34,420,000)	($34,420,000)
Aeration Savings	($1,350,000)	($1,350,000)	($1,350,000)
Methanol Addition Savings	($16,120,000)	($16,120,000)	($16,120,000)
Total O&M 20- Year Cost	($48,270,000)	($47,740,000)	($48,080,000)
Total O&M 20- Year Cost Present Value	($26,730,000)	($26,440,000)	($26,630,000)

10.5 Recommendations

Based on a capital cost in **Table 10.4-5,** the O&M costs and savings and the denitrification filter capital cost offset in **Table 10.4-6**, a payback on all sidestream deammonification systems could be seen by year seven as shown in **Figure 10.5-1**.

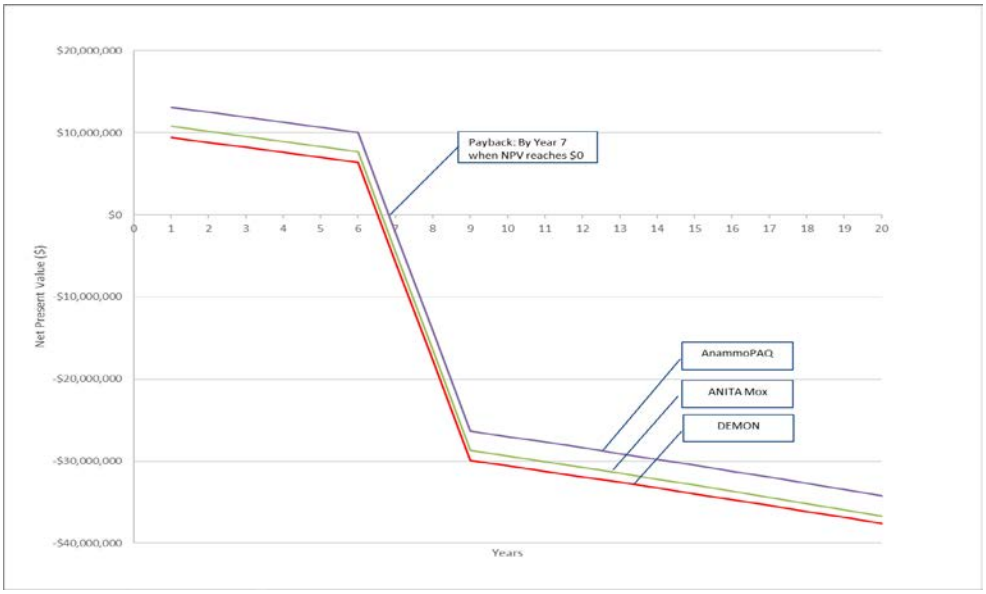

Figure 10.5-1: Sidestream Treatment Payback Period

Regardless of cost and payback period, the benefit of sidestream treatment includes the ability to operate to design capacity through the denitrification filters which can prevent TN permit exceedances. Sidestream treatment is also a more cost-effective option than the addition of denitrification filters to meet TN permit limits due to operating costs. Piloting sidestream treatment could help increase the design removal efficiency of nitrogen in sidestream treatment, but these are known technologies and piloting is not necessary or recommended by the manufacturer. The capital cost, 20-year costs and payback period for each technology are summarized in **Table 10.5-1**. Each of the technologies discussed have potential for savings at HFC AWTP and should be considered and a more detailed design analysis should be completed before selection of a technology for design and implementation.

Table 10.5-1: Summary of Capital Costs, Life Cycle Costs and Payback Period for Sidestream Treatment

Technology	Capital Cost	Total O&M 20- Year Cost Present Value	Payback (Years)
DEMON® (SBR and Continuous)	$9,400,000	($26,440,000)	7
ANITA™ Mox MBBR	$10,800,000	($26,730,000)	7
AnammoPAQ™	$13,100,000	($26,630,000)	7

Attachment 10-A: Proposals for Sidestream Treatment

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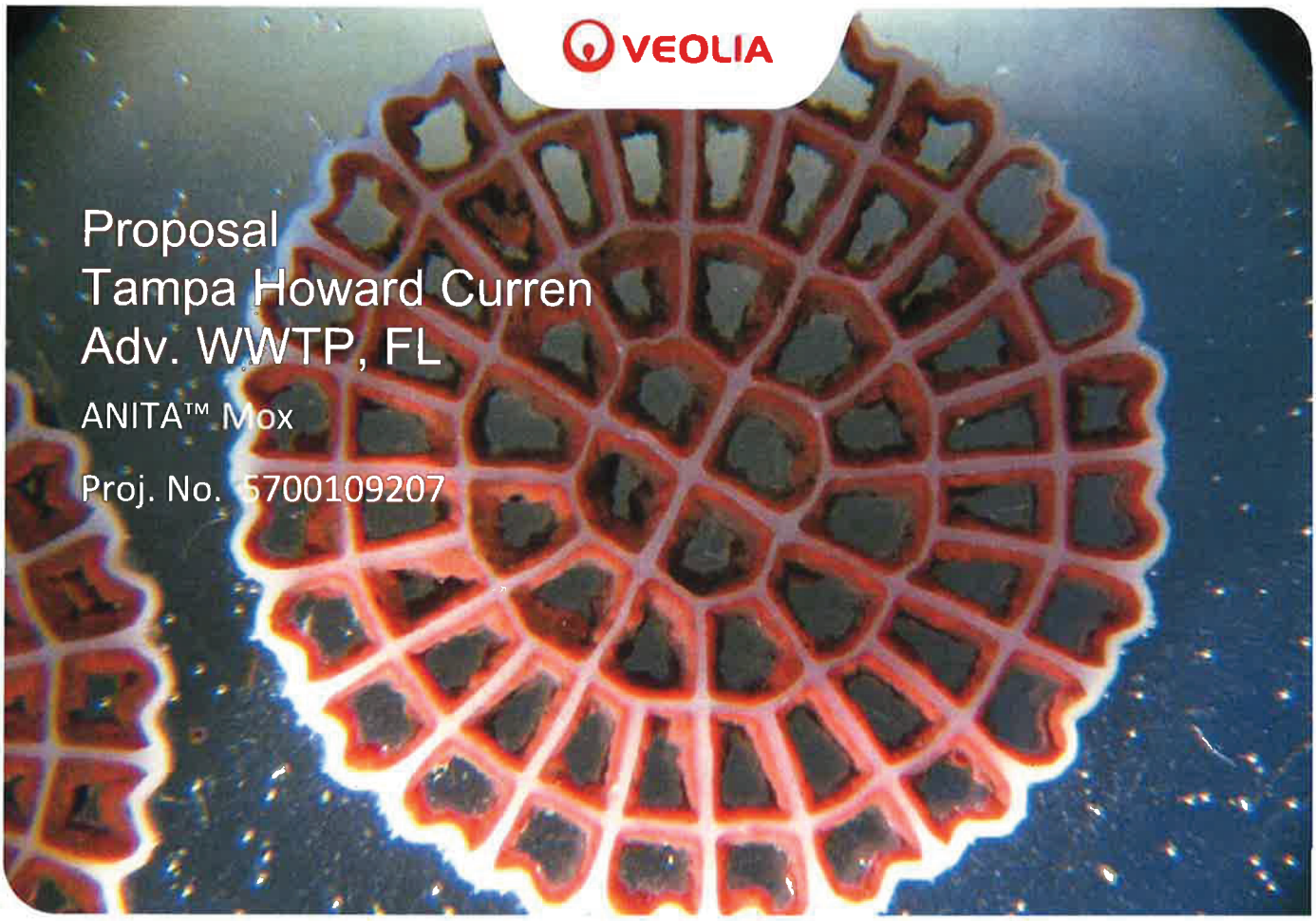


Proposal
Tampa Howard Curren Adv. WWTP, FL

ANITA™ Mox

Proj. No. 5700109207

Submitted to: Ann Sager
Hazen and Sawyer

Submitted by: Daniel Hurt
Application Engineer

Date: 1/19/2018

This document is confidential and may contain proprietary information.
It is not to be disclosed to a third party without the written consent of Veolia Water Technologies.

Veolia Water Technologies Inc. (dba Kruger)
4001 Weston Parkway
Cary, NC 27513
tel. +1 919-677-8310 • fax +1 919-677-0082
www.veoliawatertech.com

Water Technologies

Introduction

Kruger (a subsidiary of Veolia Water Technologies) is pleased to present this budgetary proposal for our ANITA™ Mox process for deammonification of the anaerobic digester rejection water in Tampa Howard Curren Adv. WWTP, FL. This design is based upon the information we have received from you. The influent design criteria are summarized in Table 1.

In order to achieve the expected removals as summarized in Table 2, we recommend two (2) ANITA Mox process trains. The tank dimensions along with other important process parameters are summarized in Table 3. The proposed tank dimensions are preliminary and can be adjusted to optimize for other design constraints.

The total ANITA Mox tank volume requirement is 0.78 MG at 1.0 MGD design flow. The remaining available volume is 2.31 MG which can be utilized as equalization. This volume is capable of providing the design flow without additional input from dewatering for 55 hours. In order to provide EQ volume sufficient to maintain the design flow through the weekend (64 hours), an additional 0.36 MG is recommended. At 0.8 MGD flow rate, the remaining available EQ tank volume of 2.31 MG is sufficient for maintaining design flow through the weekend.

It is important that each reactor have the capability for independent control of influent feed and aeration. This can be accomplished through dedicated pumps and blowers or by using high performance modulating valves. We have included one (1) dedicated blower per train as part of Kruger's Scope to meet this need for aeration control. Kruger may supply influent equipment upon request. Kruger recommends the use of an equalization tank upstream of the ANITA Mox process to reduce the number of interruptions in flow to the process caused by the plant's dewatering schedule. Kruger also recommends covering the basins to minimize heat loss if significant loss is possible given the site layout. Particularly in warm climates, heat dissipation is also an important design consideration.

We appreciate the opportunity to provide this proposal to you. If you have any questions or need further information, please contact our local Representative, Bob Bierhorst of MTS, or our Regional Sales Manager, Daniel Hurt at (919) 653-4586 (daniel.hurt@veolia.com).

cc: EG, DRH, GAT, ZSL, project file (Kruger)
Bob Bierhorst (MTS)

Revision	Date	Process Eng.	Comments
0	11/03/2017	ZSL	Initial, budgetary proposal.
1	01/15/2018	ZSL	Budgetary revised retrofit ANITA Mox proposal.

We Know Water

Kruger is a water and wastewater solutions provider specializing in advanced and differentiating technologies. Kruger provides complete processes and systems ranging from biological nutrient removal to mobile surface water treatment. The ACTIFLO® Microsand Ballasted Clarifier, BioCon® Dryer, BIOSTYR® Biological Aerated Filter (BAF) and NEOSEP™ **MBR are just a few of the innovative technologies offered by Kruger.**

Kruger is a Veolia Water Solutions & Technologies' (VWS) company providing innovative water and wastewater treatment solutions for the U.S. municipal market. As a global company with 135 Business Units in 57 countries, **Veolia Water** with nearly 10,000 employees worldwide and with over 250 proprietary technologies is the world leader in water and wastewater treatment.

Kruger delivers unequalled **S**ervice to our customers delivering and creating **V**alue while being environmentally **R**esponsible with a focus on safety. Since 1986, Kruger has been providing leading edge technologies for biological wastewater treatment, High Rate Clarification for phosphorus removal and water treatment, filtration for TSS removal, water reuse and drinking water and Biosolids processing. Based in Cary, North Carolina, Kruger's 120 plus professionals are dedicated to providing the most technically sound solution to meet our customers' needs while following our principles of **SVR.**

Energy Focus

Kruger, along with Veolia Water Solutions & Technologies (VWS) is dedicated to delivering sustainable and innovative technologies and solutions. We offer our customers integrated solutions which include resource-efficient technology to improve operations, reduce costs, achieve sustainability goals, decrease dependency on limited resources, and comply with current and anticipated regulations.

Veolia's investments in R&D outpace that of our competition. Our focus is on delivering

- neutral or positive energy solutions
- migration towards green chemicals or zero chemical consumption
- water-footprint-efficient technologies with high recovery rates

Our carbon footprint reduction program drives innovation, accelerates adoption and development of clean technologies, and offers our customers sustainable solutions.
Kruger is benchmarking its technologies and solutions by working with our customers and performing total carbon cost analysis over the lifetime of the installation.
By committing to the innovative development of clean and sustainable technologies and solutions worldwide, Kruger and VWS will continue to maximize the financial benefits for every customer.

Process Description

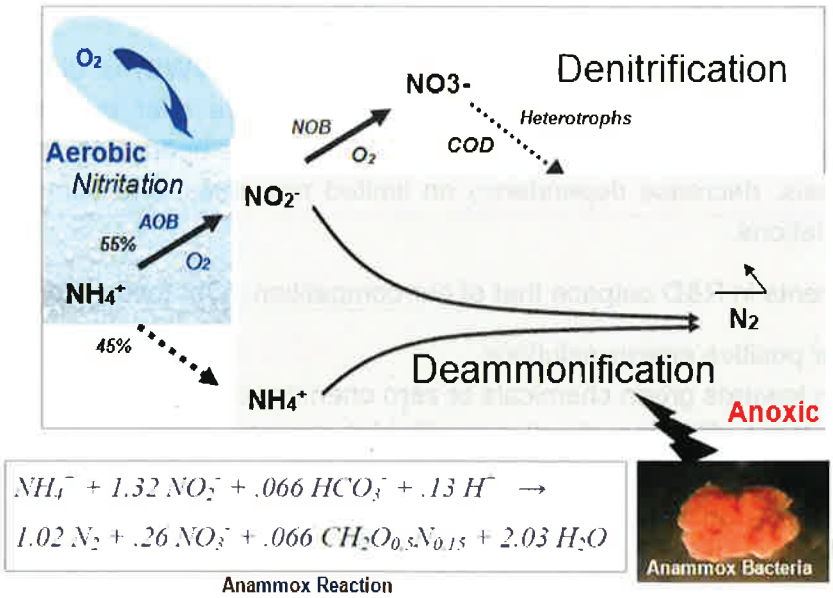
AnoxKaldnes MBBR

The MBBR process is a continuous-flow, non-clogging biofilm reactor containing moving "carrier elements" or media. The media flows with the water currents in the reactor and does not require backwashing or cleaning.

The biomass that treats the wastewater is attached to the surfaces of the media. The media is designed to provide a large protected surface area for the biofilm and optimal conditions for biological activity when suspended in water. AnoxKaldnes media is made from polyethylene and has a density slightly less then water.

The ANITA™ Mox process is a single-stage nitrogen removal process based on the MBBR platform. The process is specifically designed for treatment of waste streams with high ammonia concentrations. The system can achieve ammonia removals of up to 80-90% and total nitrogen removals of up to 75-85%. The treatment method uses only 40% of the oxygen demand of conventional nitrification, and it requires no external carbon source.

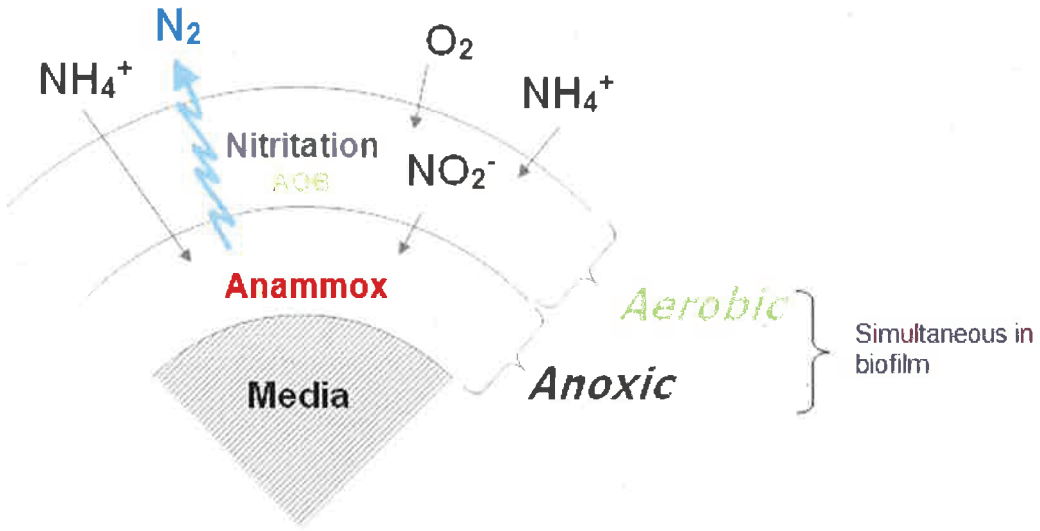
Nitrogen removal with ANITA™ Mox



$$NH_4^+ + 1.32\,NO_2^- + .066\,HCO_3^- + .13\,H^+ \rightarrow 1.02\,N_2 + .26\,NO_3^- + .066\,CH_2O_{0.5}N_{0.15} + 2.03\,H_2O$$

Anammox Reaction

The ANITA Mox process consists of an aerobic nitritation reaction and an anoxic ammonia oxidation (anammox) reaction. The two steps take place simultaneously in different layers of the biofilm. Nitritation occurs in the outer layer of the biofilm. Approximately 55% of the influent ammonia is oxidized to nitrite (NO_2^-). Anammox activity occurs in the inner layer. In this step, the nitrite produced and the remaining ammonia are utilized by the anammox bacteria and converted to nitrogen gas (N_2) and a small amount of nitrate (NO_3^-).

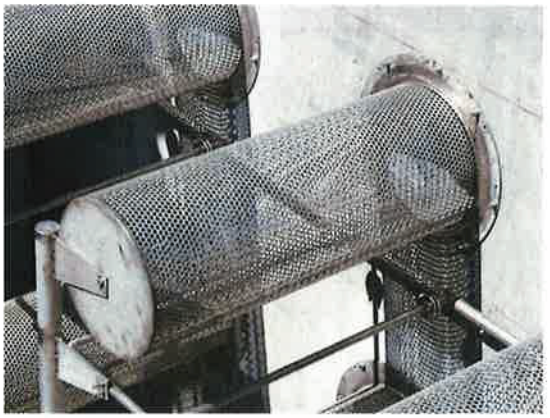


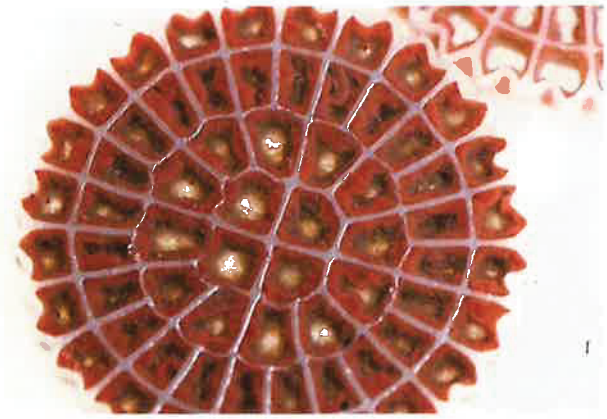
The aerobic and anoxic reactions occur in a single MBBR reactor. The combined biomass grows attached to the AnoxKaldnes media and is retained in the reactor by media screens. This biomass retention is an important characteristic of the system, since the anammox bacteria growth rate is very slow when compared to conventional wastewater bacteria growth rates.

AnoxKaldnes ANITA™ Mox System Configuration

Kruger proposes the ANITA™ Mox process for deammonification of centrate at the Tampa Howard Curren Advanced WWTP in Florida. We recommend two (2) ANITA Mox MBBR process trains using our K5 media.

Kruger's design and scope include the AnoxKaldnes media, screen assemblies (to keep media in each reactor), medium bubble aeration grids, and mixers. In cases where they are needed, Kruger also provides the blowers, instrumentation and controls, SCADA, and field instruments (dissolved oxygen, nitrate, ammonia, etc.) for single-source responsibility.





Design Summary

The design assumes that the side stream entering into the proposed ANITA Mox system contains no toxic compounds and has sufficient alkalinity and that none of the equipment provided would be used in a classified area (e.g. Class 1, Division 1 or Class 1, Division 2).

The ANITA Mox influent design basis is summarized in Table 1. The target effluent criteria for the ANITA Mox system are listed in Table 2. The process design is summarized in Table 3.

Table 1: Influent Design Basis

Parameter	Units	Influent
Flow, Design	MGD	1.0
BOD_5, Design Flow	mg/L	125
COD, Design Flow	mg/L	630
TSS, Design Flow[a,b]	mg/L	480
TKN, Design Flow	mg/L	700
NH_4-N, Design Flow	mg/L	680
Alkalinity, Design Flow[a]	mg/L	2,800
Elevation[a]	ft	100
Design Temperature[a]	°C	30

[a] **Assumed values.**

[b] **If TSS above 1,000 mg/L is sustained, pretreatment of centrate is recommended.**

Table 2: Expected Removals (30-day average)

Parameter	Units	Expected % Removal*
NH4-N (mg/L)	%	85-90
Total Inorganic Nitrogen (mg/L)	%	80-85

*Expected performance, not process guarantee values.

Table 3: Process Design Summary

Parameter	Units	Values
Number of Process Trains	-	2
Number of MBBR Reactors per Train	-	1
Dimensions (Each)	ft	67 L × 33.5 W × 23 SWD
Volume (Each)	ft^3	51,625
Total Volume (All Reactors)	ft^3	103,250
Recommended Freeboard for all reactors	ft	2 - 3
Media Type:	-	K5
Fill of Biofilm Carriers, All Reactors	%	42
Media Volume (All Reactors)	ft^3	43,325
Aeration System Type	-	Medium Bubble
Residual DO, Max. Month	mg/L	1.5
Total Process Air Requirement (All Reactors)	SCFM	~3,200
Air Pipe Pressure (From Top of Drop Pipe)	psi	9.8

Scope of Supply

Kruger is pleased to present our scope of supply which includes process engineering design, equipment procurement, and field services required for the proposed treatment system, as related to the equipment specified. The work will be performed to Kruger's high standards under the direction of a Project Manager. All matters related to the design, installation, or performance of the system shall be communicated through the Kruger representative giving the Engineer and Owner ready access to Kruger's extensive capabilities.

Process and Design Engineering

Kruger will provide process engineering and design support for the system as follows:

- Process Engineering consisting of aeration system sizing and configuration, sieve and outlet design.
- Review and approval of P&I Diagram for the AnoxKaldnes ANITA Mox portion of the process. Preliminary General Arrangement Drawings and review and approval of final General Arrangement Drawings for the process. Review of reactor drawings with respect to penetrations and dimensions, excluding structural design.
- Equipment installation instructions for all equipment supplied by Kruger.

Field Services

Kruger will furnish a Service Engineer to perform the following tasks:

- Inspect installation of key pieces of equipment during construction.
- Inspect the completed system prior to startup.
- Assist the Contractor with initial startup of the system.
- Train the Owner's staff in the proper operation and maintenance of the AnoxKaldnes ANITA Mox system.
- Test and start any Kruger-supplied control equipment, including PLC programming and SCADA systems.

AnoxKaldnes ANITA™ Mox System Equipment

Mechanical Equipment Items	Qty	Description
AnoxKaldnes K5 Media, (ft^3)	43,325	Carrier elements are made of high density polyethylene. The total media quantity will include a minimum volume of ~5% seeded media.
Cylindrical Screen Assemblies	8	Four (4) per reactor. 304L SS. 23"ø perforated plate pipes terminated in ANSI flanges for mounting directly to the tank wall.
Medium Bubble Aeration System	2 Lot	One (1) air grid system per reactor. 304L SS including header, lateral piping, and hardware (excluding concrete anchor bolts).
Specially Designed Mechanical Mixers	4	Two (2) per ANITA Mox Reactor. Includes VFD.
Airlift Pump	6	Three (3) airlift pump per ANITA Mox reactor for foam suppression.
Positive Displacement Blowers	2 + 1	Two (2) duty plus one (1) standby. Each blower will be rated for 1,600 SCFM and 125 NPHP. Includes VFD.

Instrumentation and Controls Equipment Items	Qty	Description
PLC Control Panel	1	NEMA 12 Freestanding or Wall Mount Control Panel (For Indoor Use). ControlLogix PLC; Panelview HMI; 120V Feed
pH-based Control Logic	1	For control of aeration.
High Level Float Switch	2	One (1) for each media zone.
DO Probe (LDO)	2	One (1) for each Aerobic zone. Aerobic Zone DO Monitoring
pH meter	2	One (1) pH meter for each ANITA Mox reactor.
Thermal Mass Flowmeter	2	One (1) for each ANITA Mox reactor for air flow control
Magnetic Flowmeter	2	One (1) magnetic flow meter per reactor to measure influent flow.

Notes Regarding System Design and Installation

- A note on concrete specifications: For any MBBR or IFAS system, regardless of manufacturer, it is sound practice to require good, quality concrete work for the process reactors. The Consulting Engineer's standard concrete specification section is typically adequate to eliminate large holes, excessive form marks, large pockets, and excessively rough areas. It is particularly important to eliminate the potential for annular space around media retention screens.
- A note on construction sequencing: It is important, particularly for IFAS installations, to have level detection and level communication systems in place and operational prior to the filling of process tanks with water and media.

Scope of Supply BY INSTALLER/PURCHASER

The scope of supply by others for the AnoxKaldnes ANITA™ Mox system should include, but is not limited to, the following items:

- All civil/site and electrical work.
- A concrete foundation for the tanks.
- Reactors to house the MBBR treatment equipment.
- All provisions for interconnecting piping.
- Unloading, storage and installation of equipment.
- Install and test all level floats, level transmitters, level alarms, and alarm communication devices prior to filling a process tank with media and water
- Centrate equalization tanks
- Cover for reactor tanks
- Temporary provisions for screened primary or secondary effluent during startup.
- Temporary reactor heating during startup.
- Mixer bridges and other structural modifications for the reactors.
- Video recording of any training activities.

Design Options

In addition to the proposed system as detailed herein, Kruger is able to further incorporate our process and controls expertise into wastewater treatment plants, allowing municipalities to meet stringent effluent requirements and future plant upgrades. Kruger is also able to offer our instrumentation and controls expertise to build upon the proposed system by providing a **customized plant-wide SCADA system** or designing a **Motor Control Center (MCC)**, providing clients a single source responsibility for plant controls. Please contact Kruger if the options above are of interest or to be included in the current proposed system or future upgrades. ***Please note that the design options listed above are not included in the pricing noted herein.*

Schedule

- Shop drawings will be submitted within 6-8 weeks of receipt of an executed contract by all parties.
- All equipment will be delivered within 18-20 weeks after receipt of written approval of the shop drawings.
- Installation manuals will be furnished upon delivery of equipment.
- Operation and Maintenance Manuals will be submitted within 90 days after receipt of approved shop drawings.

Pricing

The price for the AnoxKaldnes ANITA™ Mox system, as defined herein, including process and design engineering, field services, and equipment supply is: **$3,100,000.**

Pricing is FOB shipping point, with freight allowed to the job site. This pricing does not include any sales or use taxes. In addition, pricing is valid for ninety (90) days from the date of issue.

Please note that the above pricing is expressly contingent upon the items in this proposal and are subject to Kruger's Standard Terms of Sale detailed herein.

Kruger Standard Terms of Payment

The terms of payment are as follows:

- 10% on receipt of fully executed contract
- 15% on submittal of shop drawings
- 75% on the delivery of equipment to the site

Payment shall not be contingent upon receipt of funds by the Contractor from the Owner. There shall be no retention in payments due to Kruger. All other terms per our Standard Terms of Sale are attached.

All payment terms are net 30 days from the date of invoice. Final payment not to exceed 120 days from delivery of equipment.

Kruger Standard Terms of Sale

1. Applicable Terms. These terms govern the purchase and sale of the equipment and related services, if any (collectively, "Equipment"), referred to in Seller's purchase order, quotation, proposal or acknowledgment, as the case may be ("Seller's Documentation"). Whether these terms are included in an offer or an acceptance by Seller, such offer or acceptance is conditioned on Buyer's assent to these terms. Seller rejects all additional or different terms in any of Buyer's forms or documents.

2. Payment. Buyer shall pay Seller the full purchase price as set forth in Seller's Documentation. Unless Seller's Documentation provides otherwise, freight, storage, insurance and all taxes, duties or other governmental charges relating to the Equipment shall be paid by Buyer. If Seller is required to pay any such charges, Buyer shall immediately reimburse Seller. All payments are due within 30 days after receipt of invoice. Buyer shall be charged the lower of 1 ½% interest per month or the maximum legal rate on all amounts not received by the due date and shall pay all of Seller's reasonable costs (including attorneys' fees) of collecting amounts due but unpaid. All orders are subject to credit approval.

3. Delivery. Delivery of the Equipment shall be in material compliance with the schedule in Seller's Documentation. Unless Seller's Documentation provides otherwise, Delivery terms are F.O.B. Seller's facility.

4. Ownership of Materials. All devices, designs (including drawings, plans and specifications), estimates, prices, notes, electronic data and other documents or information disclosed by Seller or prepared solely by Seller or Buyer or jointly by Seller and Buyer in connection with this Agreement, and all intellectual property rights therein, shall be and remain the confidential and proprietary property of Seller, whether or not patented by Seller ("Work Product"). Buyer hereby irrevocably assigns all rights in any Work Product to Seller. Seller grants Buyer a non-exclusive, non-transferable (except to a successor-in interest to the ownership of the Equipment), paid-up license to use the Work Product solely in connection with Buyer's use, operation, repair and maintenance of the Equipment at the Jobsite defined in this Agreement. Buyer may not disclose, share, transfer, or sell any such Work Product to third parties without Seller's prior written consent and such consent may be arbitrarily withheld. Buyer agrees not to resell, transfer or give any of the biologically colonized media or bacteria from the system to any party other than Seller or any of Seller's affiliates without the prior written consent of Seller for a period of fifteen (15) years from the effective date of this Agreement. Buyer shall not cultivate bacteria or use biomass carriers retrieved from the ANITA Mox system for any research or non-research purposes without prior written consent of the Seller. Any new developments, discoveries or inventions resulting from the operation of the ANITA Mox system in which the ANITA Mox process is a component or is in any way incorporated in whole or in part shall be owned solely by the Seller.

5. Changes. Seller shall not implement any changes in the scope of work described in Seller's Documentation unless Buyer and Seller agree in writing to the details of the change and any resulting price, schedule or other contractual modifications. This includes any changes necessitated by a change in applicable law occurring after the effective date of any contract including these terms.

6. Warranty. Subject to the following sentence, Seller warrants to Buyer that the Equipment shall materially conform to the description in Seller's Documentation and shall be free from defects in material and workmanship. The foregoing warranty shall not apply to any Equipment that is specified or otherwise demanded by Buyer and is not manufactured or selected by Seller, as to which (i) Seller hereby assigns to Buyer, to the extent assignable, any warranties made to Seller and (ii) Seller shall have no other liability to Buyer under warranty, tort or any other legal theory. If Buyer gives Seller prompt written notice of breach of this warranty within 18 months from delivery or 1 year from beneficial use, whichever occurs first (the "Warranty Period"), Seller shall, at its sole option and as Buyer's sole remedy, repair or replace the subject parts or refund the purchase price therefore. If Seller determines that any claimed breach is not, in fact, covered by this warranty, Buyer shall pay Seller its then customary charges for any repair or replacement made by Seller. Seller's warranty is conditioned on Buyer's (a) operating and maintaining the Equipment in accordance with Seller's instructions, (b) not making any unauthorized repairs or alterations, and (c) not being in default of any payment obligation to Seller. Seller's warranty does not cover damage caused by chemical action or abrasive material, misuse or improper installation (unless installed by Seller). THE WARRANTIES SET FORTH IN THIS SECTION ARE SELLER'S SOLE AND EXCLUSIVE WARRANTIES AND ARE SUBJECT TO SECTION 10 BELOW. SELLER MAKES NO OTHER WARRANTIES OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR PURPOSE.

7. Indemnity. Seller shall indemnify, defend and hold Buyer harmless from any claim, cause of action or liability incurred by Buyer as a result of third party claims for personal injury, death or damage to tangible property, to the extent caused by Seller's negligence. Seller shall have the sole authority to direct the defense of and settle any indemnified claim. Seller's indemnification is conditioned on Buyer (a) promptly, within the Warranty Period, notifying Seller of any claim, and (b) providing reasonable cooperation in the defense of any claim.

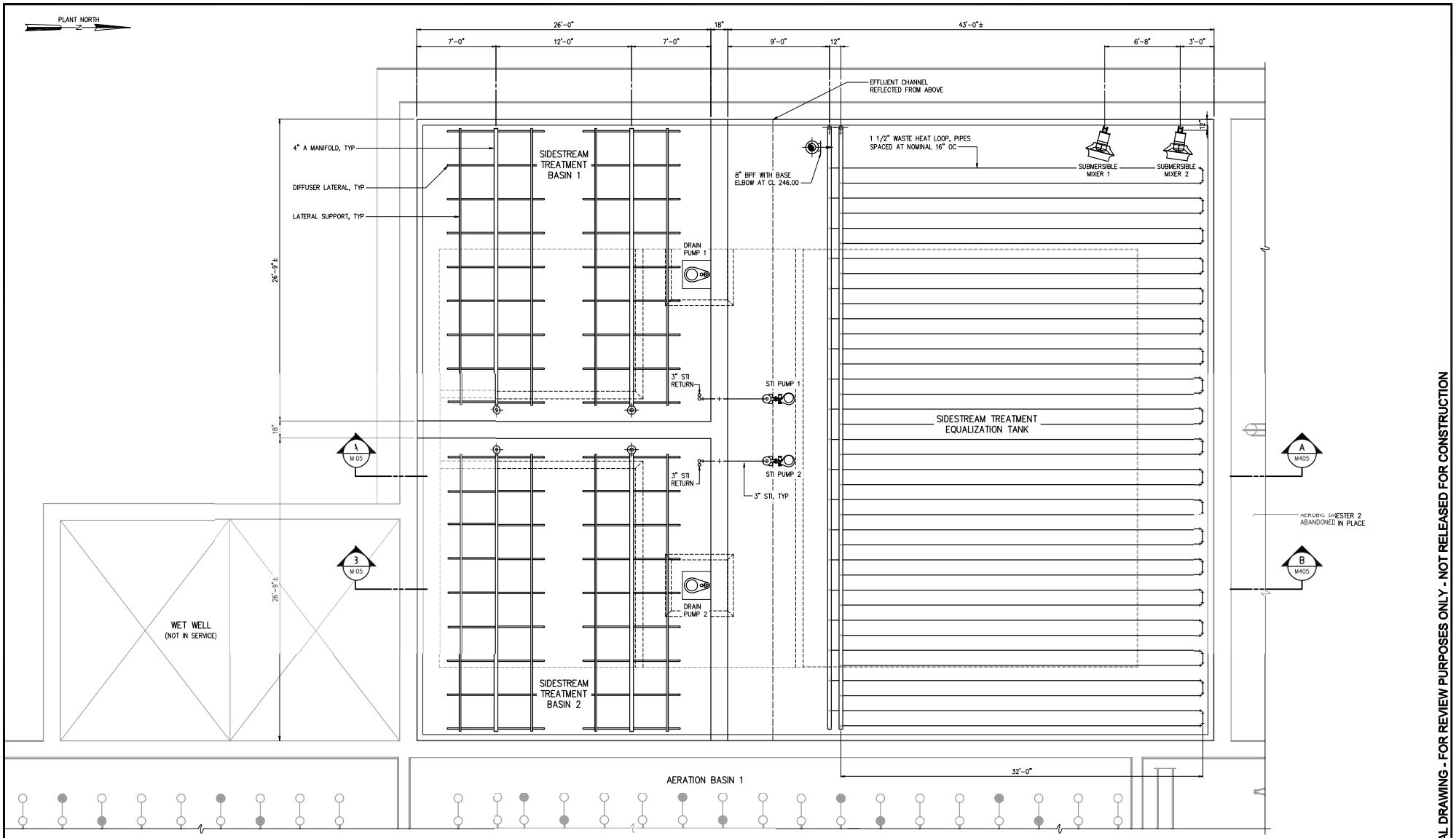
8. Force Majeure. Neither Seller nor Buyer shall have any liability for any breach (except for breach of payment obligations) caused by extreme weather or other act of God, strike or other labor shortage or disturbance, fire, accident, war or civil disturbance, delay of carriers, failure of normal sources of supply, act of government or any other cause beyond such party's reasonable control.

9. Cancellation. If Buyer cancels or suspends its order for any reason other than Seller's breach, Buyer shall promptly pay Seller for work performed prior to cancellation or suspension and any other direct costs incurred by Seller as a result of such cancellation or suspension.

10. LIMITATION OF LIABILITY. NOTWITHSTANDING ANYTHING ELSE TO THE CONTRARY, SELLER SHALL NOT BE LIABLE FOR ANY CONSEQUENTIAL, INCIDENTAL, SPECIAL, PUNITIVE OR OTHER INDIRECT DAMAGES, AND SELLER'S TOTAL LIABILITY ARISING AT ANY TIME FROM THE SALE OR USE OF THE EQUIPMENT SHALL NOT EXCEED THE PURCHASE PRICE PAID FOR THE EQUIPMENT. THESE LIMITATIONS APPLY WHETHER THE LIABILITY IS BASED ON CONTRACT, TORT, STRICT LIABILITY OR ANY OTHER THEORY.

Miscellaneous. If these terms are issued in connection with a government contract, they shall be deemed to include those federal acquisition regulations that are required by law to be included. These terms, together with any quotation, purchase order or acknowledgement issued or

signed by the Seller, comprise the complete and exclusive statement of the agreement between the parties (the "Agreement") and supersede any terms contained in Buyer's documents, unless separately signed by Seller. No part of the Agreement may be changed or cancelled except by a written document signed by Seller and Buyer. No course of dealing or performance, usage of trade or failure to enforce any term shall be used to modify the Agreement. If any of these terms is unenforceable, such term shall be limited only to the extent necessary to make it enforceable, and all other terms shall remain in full force and effect. Buyer may not assign or permit any other transfer of the Agreement without Seller's prior written consent. The Agreement shall be governed by the laws of the State of North Carolina without regard to its conflict of laws provisions.



BOTTCM PLAN
1/4" = 1'-0"

FINAL DRAWING - FOR REVIEW PURPOSES ONLY - NOT RELEASED FOR CONSTRUCTION

REV.	ISSUED FOR	DATE	BY
1	REGULATORY APPROVAL	XX/XX	AAA

DESIGNED AR
DRAWN AKG
CHECKED
PROJ.ENGR. RLT
APPROVED

NORTH CAROLINA PROFESSIONAL SEAL 14176 ENGINEER RONALD L. TAYLOR

NORTH CAROLINA PROFESSIONAL SEAL 038541 ENGINEER PATRICIA DRUMMEY STIEGEL

HAZEN AND SAWYER
Environmental Engineers & Scientists
4011 WestChase Boulevard, Suite 500
Raleigh, North Carolina 27607
License No. : C-0381

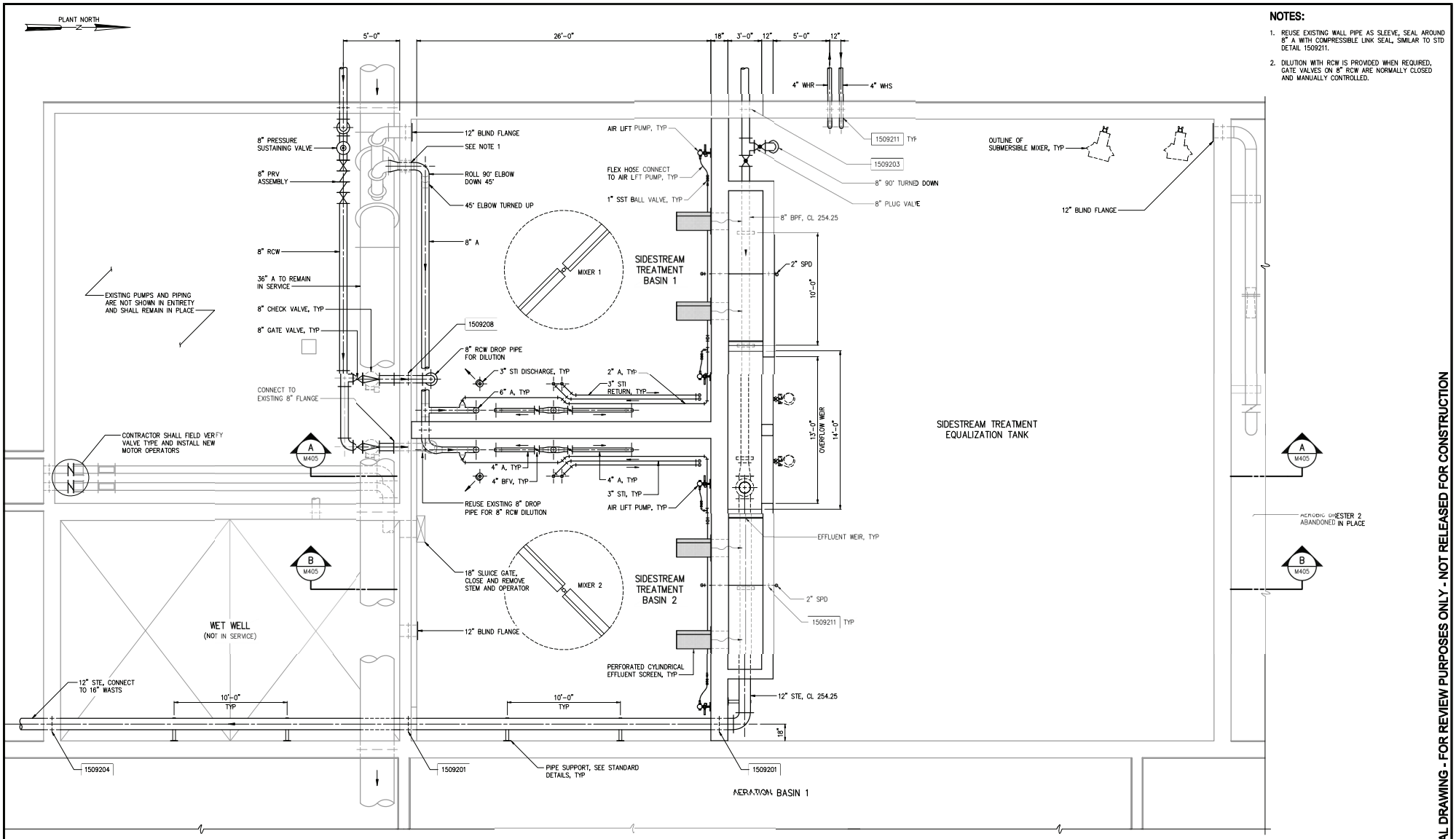
CITY OF DURHAM, NORTH CAROLINA
DEPARTMENT OF WATER MANAGEMENT

SOUTH DURHAM WATER RECLAMATION FACILITY
CHEMICAL SYSTEMS AND NUTRIENT RELATED IMPROVEMENTS

SIDESTREAM TREATMENT
MECHANICAL
BOTTOM PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2013
H & S JOB NUMBER 30751-007
CONTRACT NUMBER 3
DRAWING NUMBER M402



INTERMEDIATE PLAN

1/4" = 1'-0"

NOTES:

1. REUSE EXISTING WALL PIPE AS SLEEVE, SEAL AROUND 8" A WITH COMPRESSIBLE LINK SEAL, SIMILAR TO STD DETAIL 1509211.
2. DILUTION WITH RCW IS PROVIDED WHEN REQUIRED, GATE VALVES ON 8" RCW ARE NORMALLY CLOSED AND MANUALLY CONTROLLED.

FINAL DRAWING - FOR REVIEW PURPOSES ONLY - NOT RELEASED FOR CONSTRUCTION

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1	REGULATORY APPROVAL	XX/XX	AAA

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SIDESTREAM TREATMENT
MECHANICAL
INTERMEDIATE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2013
H & S JOB NUMBER 30751-007
CONTRACT NUMBER 3
DRAWING NUMBER M403

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PLOT DATE 8/23/2013 2:02 PM BY: JLAUGE
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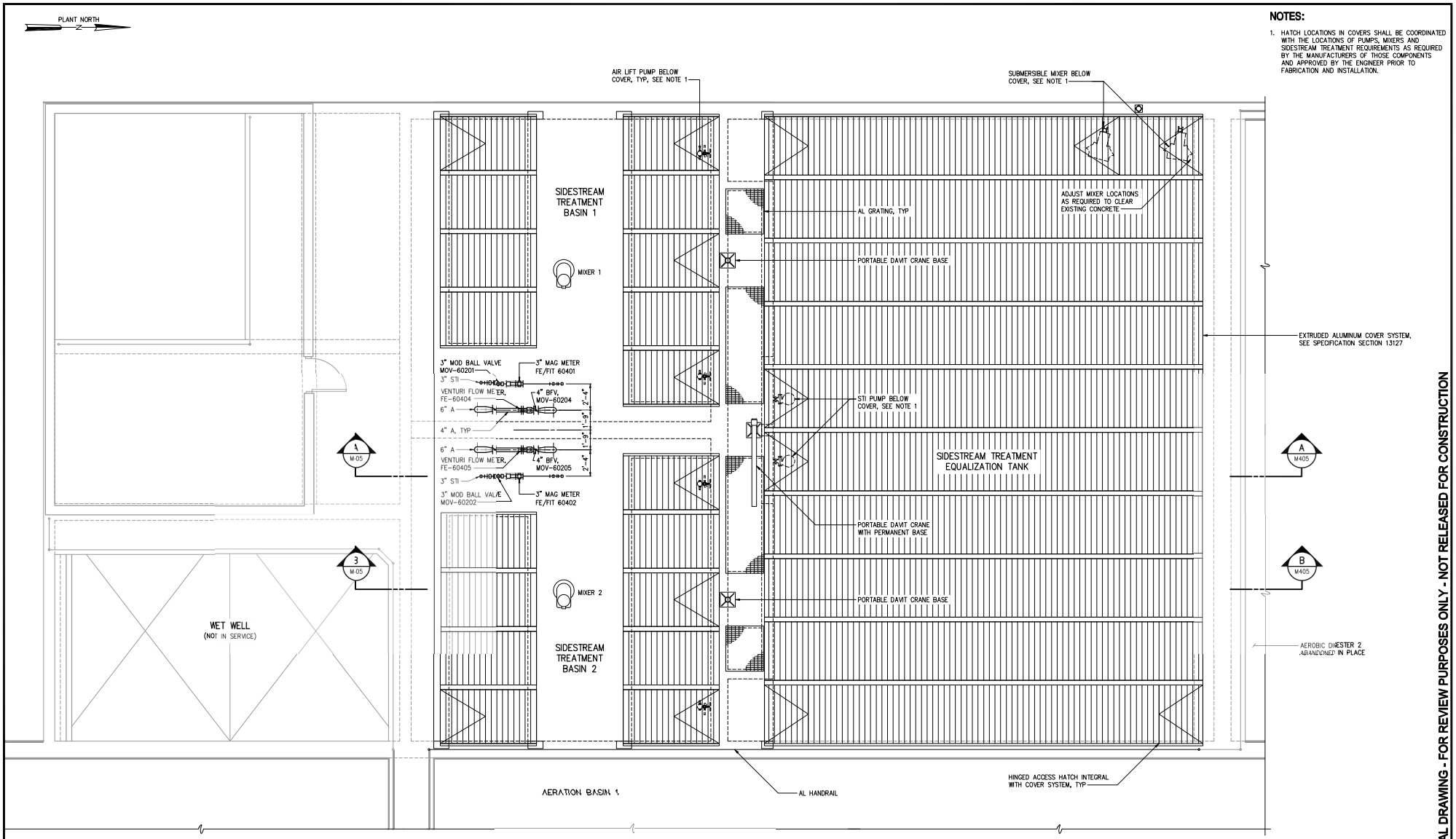

TOP PLAN
1/4" = 1'-0"

NOTES:

1. HATCH LOCATIONS IN COVERS SHALL BE COORDINATED WITH THE LOCATIONS OF PUMPS, MIXERS AND SIDESTREAM TREATMENT REQUIREMENTS AS REQUIRED BY THE MANUFACTURERS OF THOSE COMPONENTS AND APPROVED BY THE ENGINEER PRIOR TO FABRICATION AND INSTALLATION.

FINAL DRAWING - FOR REVIEW PURPOSES ONLY - NOT RELEASED FOR CONSTRUCTION

REV.	ISSUED FOR	DATE	BY
1	REGULATORY APPROVAL	XX/XX	AAA

DESIGNED AR
DRAWN AKG
CHECKED
PROJ.ENGR. RLT
APPROVED

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DEPARTMENT OF WATER MANAGEMENT

SOUTH DURHAM WATER RECLAMATION FACILITY
CHEMICAL SYSTEMS AND NUTRIENT RELATED IMPROVEMENTS

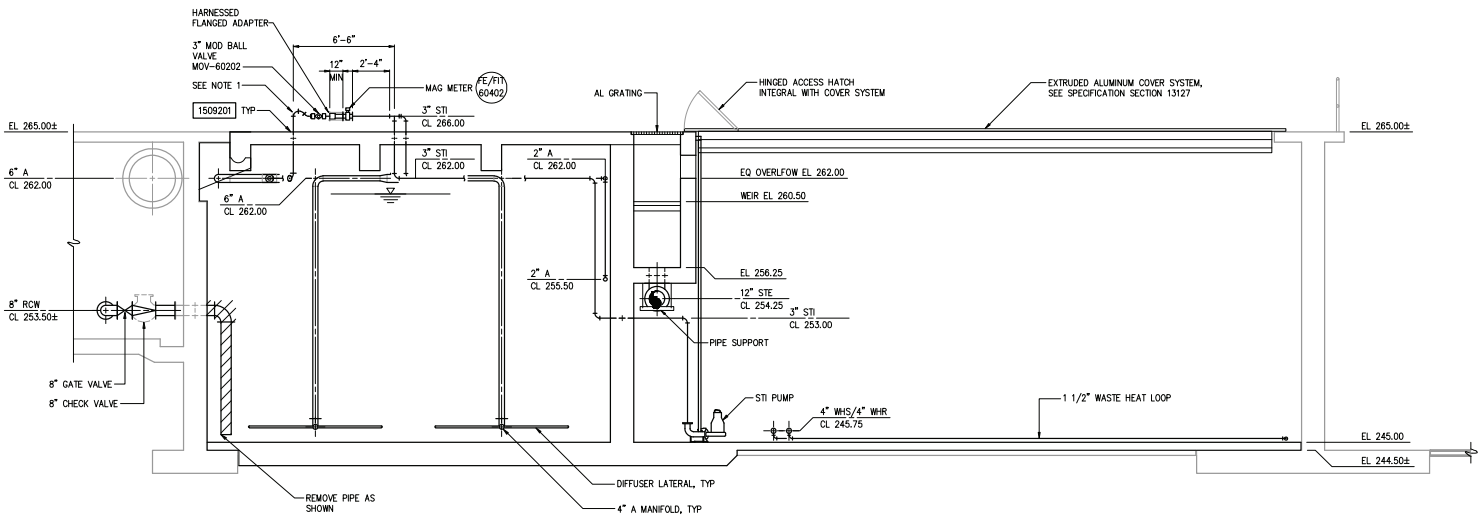
SIDESTREAM TREATMENT
MECHANICAL
TOP PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

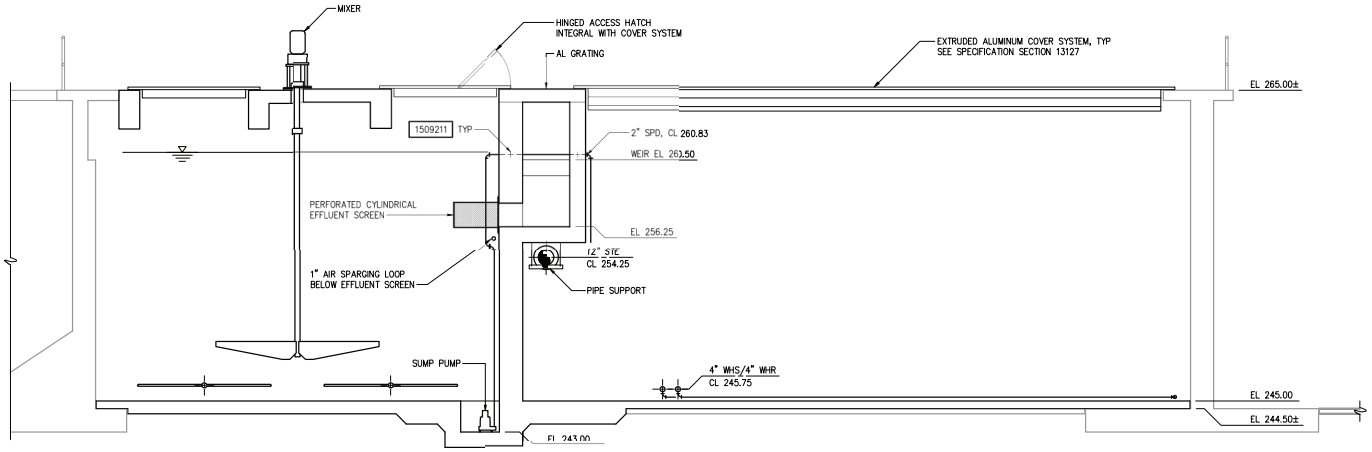
DATE AUGUST 2013
H & S JOB NUMBER 30751-007
CONTRACT NUMBER 3
DRAWING NUMBER M404

NOTES:

1. PROVIDE ELBOWS ORIENTED AS SHOWN TO GUARANTEE A FULL, FLOODED FLOW IN THE MAGNETIC FLOW METER.



SECTION A / M405
1/4" = 1'-0"



SECTION B / M405
1/4" = 1'-0"

FINAL DRAWING - FOR REVIEW PURPOSES ONLY - NOT RELEASED FOR CONSTRUCTION

REV.	ISSUED FOR	DATE	BY
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DEPARTMENT OF WATER MANAGEMENT

SOUTH DURHAM WATER RECLAMATION FACILITY
CHEMICAL SYSTEMS AND NUTRIENT RELATED IMPROVEMENTS

SIDESTREAM TREATMENT
MECHANICAL
SECTIONS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2013
H & S JOB NUMBER 30751-007
CONTRACT NUMBER 3
DRAWING NUMBER M405

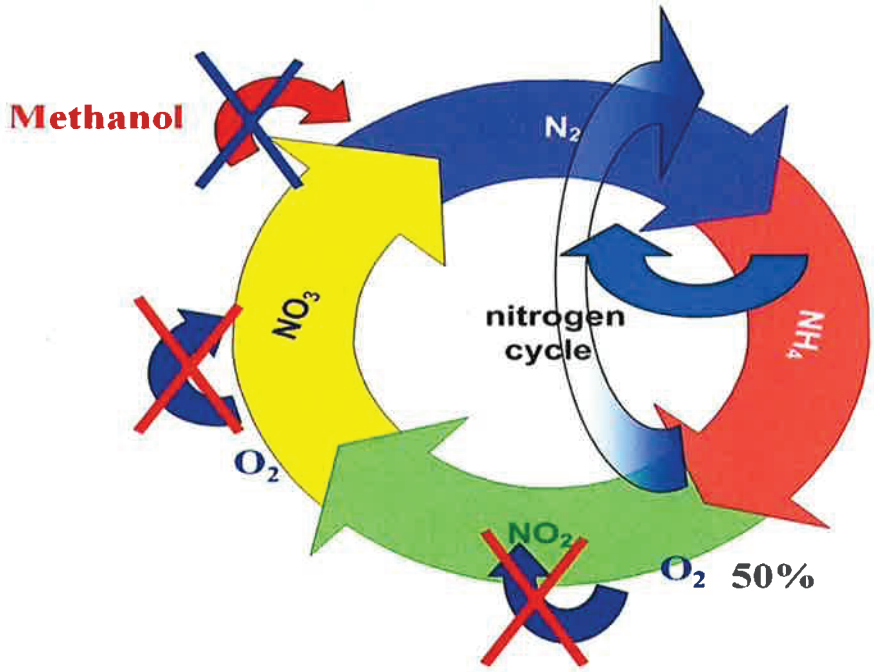
World water works
Clean Water and Energy from Wastewater

DATE: 5 January, 2018
TO: **Annie Sager, Hazen and Sawyer**
FROM: Chandler Johnson – World Water Works (WWW)
CC: Wendell Khunjar, Hazen and Sawyer
Greg Parks, WWW
Hal Midkiff, Hydra Service
RE: Information on DEMON® Process – City of Tampa – Rev0

Per your request for design and sizing for both an SBR based and a Continuous Demon® treatment system based on the **design criteria provided**, please find below our design summary based on the information provided. Below are some graphs showing the typical cycle of a DEMON® treatment system.

1. DEMON® TREATMENT PROCESS

Deammonification represents a short-cut in the N-metabolism pathway and comprises of 2 steps. About half the amount of ammonia is oxidized to nitrite and then residual ammonia and nitrite is anaerobically transformed to elementary nitrogen. See this shortcut in the diagram below. By using this process there is no excess oxygen required or external carbon source to achieve nitrogen removal.



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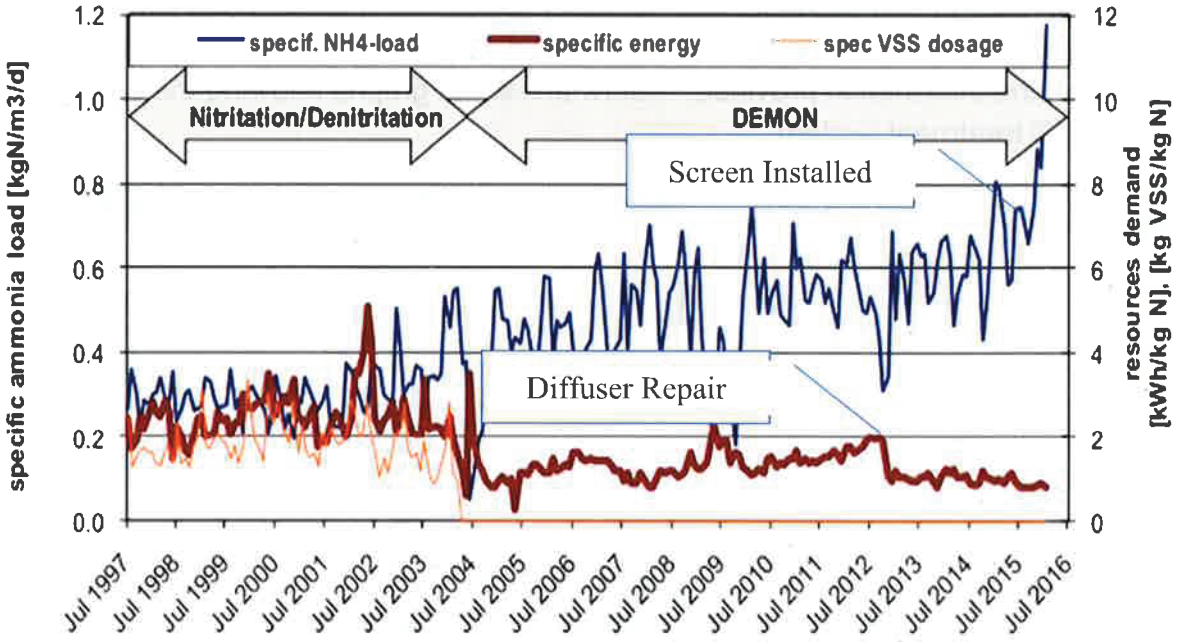
Implementation of the University of Innsbruck pH controlled strategy for the DEMON® process for deammonification of reject water in a single sludge system is what this design is proposed around. The **specific energy demand of the side stream process results in 1.4 kWh per kg ammonia nitrogen removed comparing to about 6.5 kWh of mainstream treatment.** This process is achieving results of greater than 90% at the Strass WWTP (see data presented below). Biomass enrichment and Demon® -start up is key for this process to achieve its results in a short period of time and this proposal provides the seed sludge and start up assistance to ensure achieving the goal of efficient nitrogen removal.

Life cycle of the SBR based system design has larger influent feed pumps and larger installed HP blowers due to having to treat the water in only a 20 hour active cycle vs the continuous system which as 24 hours of operation and a constant feed.



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Design Concept

The overall design concept for is to retro-fit the existing No. 6 Settling tank with EQ, Demon reactors and in the SBR concept Post EQ tank for equalization of the effluent discharge. Two (2) reactors will be required for the DEMON® treatment system and EQ tank for the design conditions provided.

SBR Concept:
EQ Tank: 85 ft long x 33.5 ft wide x 21 ft SWD
Demon SBR #1 & SBR #2: 65 ft long x 33.5 ft wide x 22 ft SWD (each)
Post SBR EQ Effluent Tank: 25 ft long x 33.5 ft wide x 15 ft SWD (max)

Continuous Concept:
EQ Tank: 115 ft long x 33.5 ft wide x 21 ft SWD
Demon #1 & #2: 60 ft long x 33.5 ft wide x 21 ft SWD (each)
Anammox Harvesting Tank: 12 ft long x 33.5 ft wide x 21 ft SWD (max)

New mixers and aeration system will be placed in each reactor for providing the mixing energy for re-suspension of the granules, proper mixing distribution of the influent feed flow and provide the necessary aeration for nitritation. For the Continuous DEMON design, an internal settling zone will be used to settle out the MLSS / Anammox biomass and allow the treated wastewater to be discharged. A single control panel will be provided to control process.

The Strass WWTP has been operating with a new Anammox retention system, which has proven to be very successful and will allow for the Continuous Demon® process to a continuous process vs. the SBR mode. We see many advantages in this upgrade to the Anammox process as it will allow for a lower installed HP for the blowers, not require the Decanter and operate continuously with higher Anammox biomass retention which allows for higher operating loading rates.

We have designed the system based on having removal efficiencies of 90% for ammonia and 80% for TIN however the aeration system is sized based on 95% ammonia removal. We have also assumed minimum operating temperature of 30C.

Based on the influent alkalinity value of 2,600 mg/L (AM) and 2,470 mg/L (MM), sodium bicarbonate will be required in the range of 2,300 lb/day under max month conditions to achieve 90% ammonia removal. Should the system be acceptable to achieve 85% removal, then no external alkalinity source will be required.

Under design loads with influent ammonia load of 4,540 lb/day, the estimated effluent ammonia using two (2) reactors will be <455 lb/day and total nitrogen will be < 905 lb/day.

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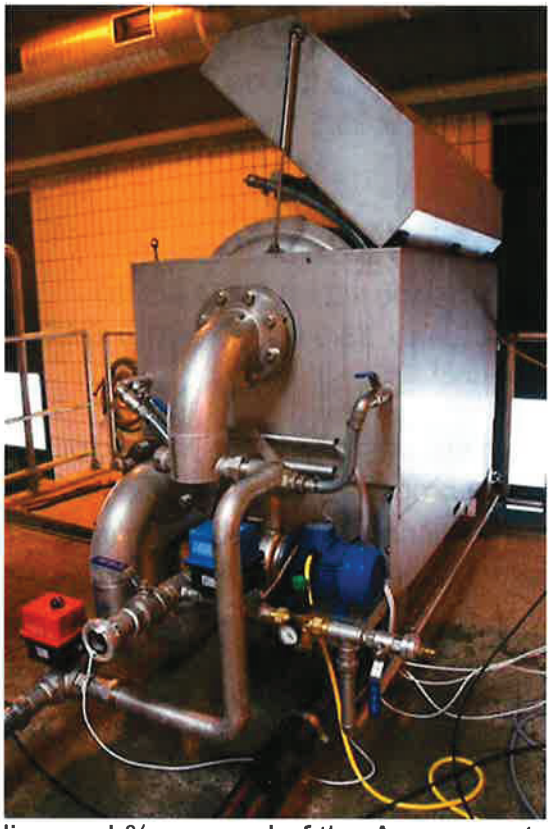
DEMON® TANK COMPONENTS

a) **Biomass Separation System** – A micro-screen will be used for this project and will have submerged pumps feeding it for a period time to waste out the AOB and NOB bacteria. The waste sludge of AOB and NOB bacteria will be discharged from the system while the underflow (Anammox bacteria) will be returned to the reactor.



Below are graphs of the loading and % removal of the Anammox treatment system at Strass WWTP in Austria using the microscreen since fall 2015. In February 2016, The specific load was increased to over 1.4 kg/m3-day while still maintaining greater than 90% removal of Ammonia-nitrogen.

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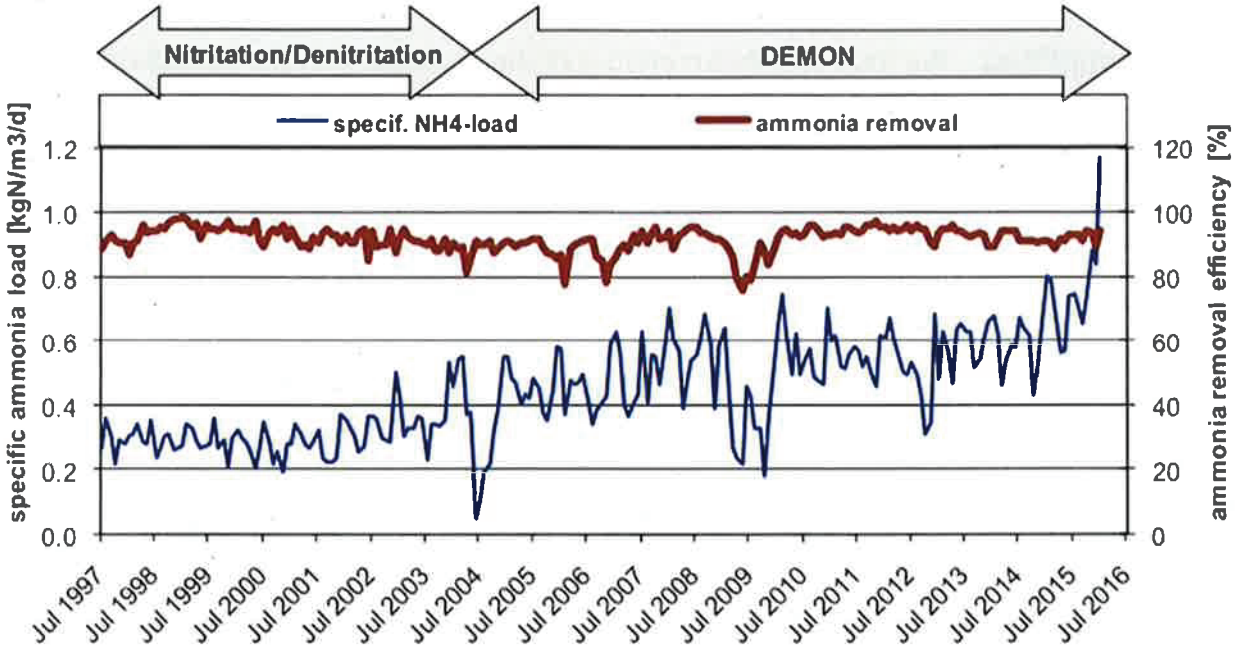

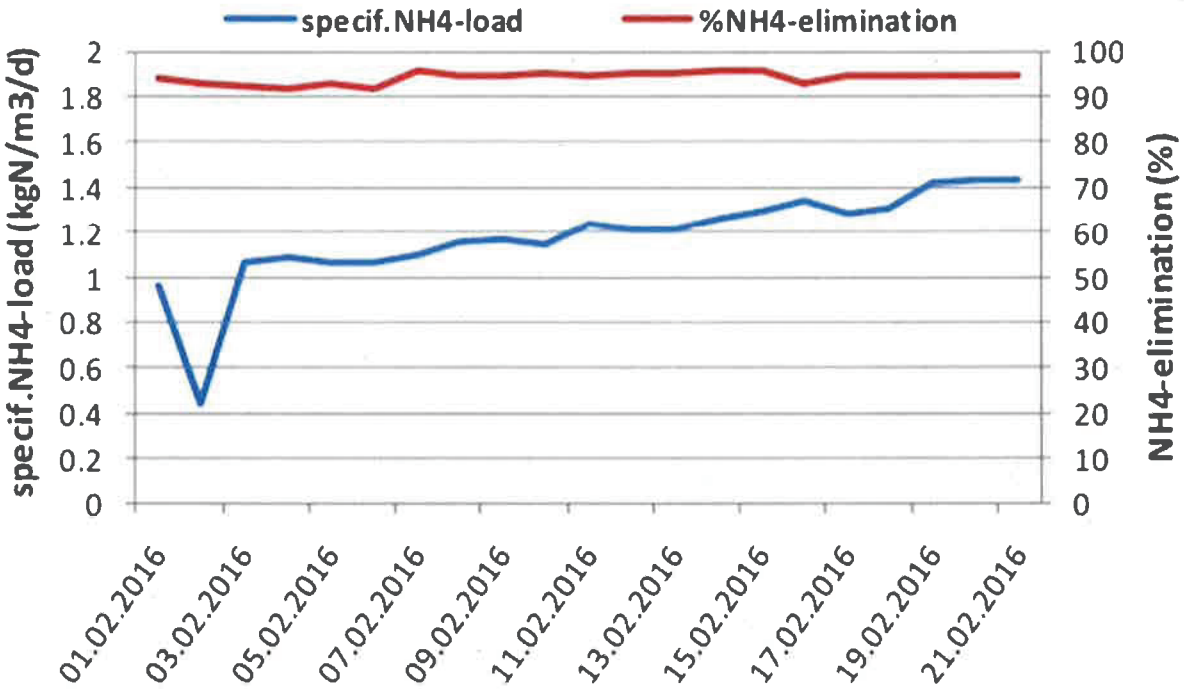

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b) **Instrument Float** – the instruments for control of the process will be installed on a float system which will float with the level of the system. One (1) pH probe & one (1) DO probe for control of the overall operation of the process will be provided. A dedicated controller for the DO and pH is our recommendation. The conductivity probe is also to be provided with its own controller. Spare instrument locations will be provided in the instrument float for adding additional analyzers over time.

c) **Seed Sludge** – for the quick start up of the DEMON® treatment process, an adequate amount of seed sludge will be supplied. The seed sludge will be shipped in as dry content possible based on the harvesting technique used and will be added to the systems as they are started up.

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d) **<u>Aeration System</u>** – The Messner aeration system will be supplied in each tank. The amount of panels is provided in the scope of supply section and is subject to final design.

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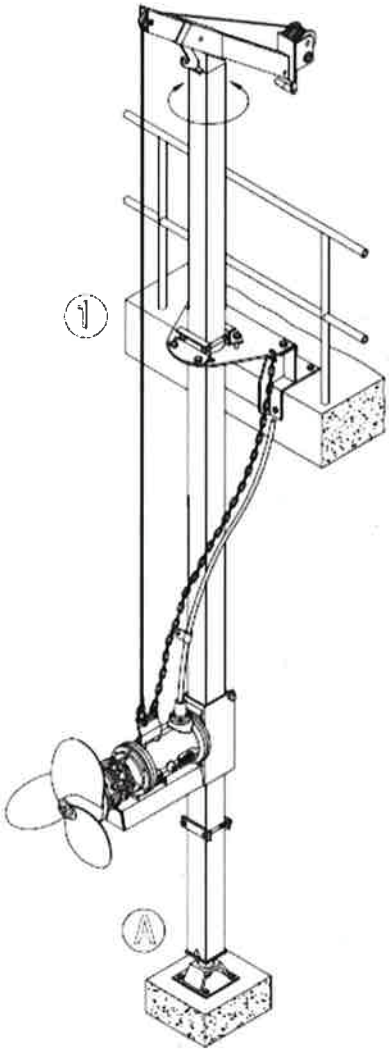
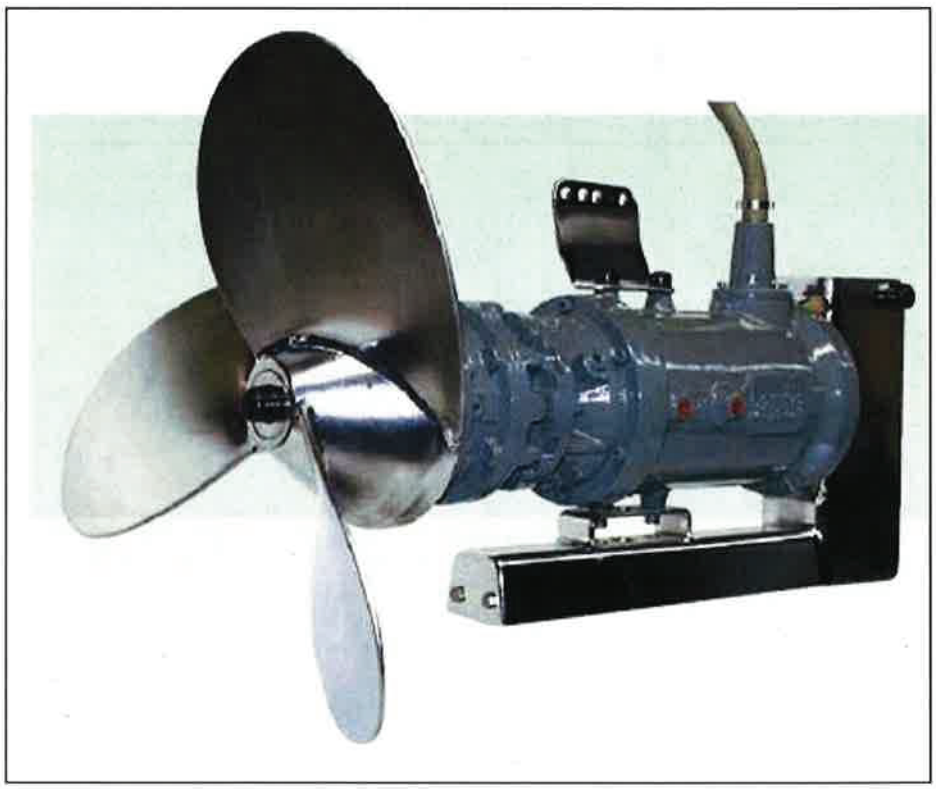
e) **Side Mounted Mixers** – Landia side mounted mixers will be used to maintain mixing energy within each reactor. The mixers will help re-suspend the "reds" during the start up phase of each cycle. VFD's will be provided to allow the mixers to be turned down and save on energy during the overall operation of the cycle.





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f) **SBR Based Design - Decanter** – The decanter is a specially designed decanter and is very effective for use with the Demon process and is made from very durable stainless steel. One (1) Decanter will be provided for each reactor provided.

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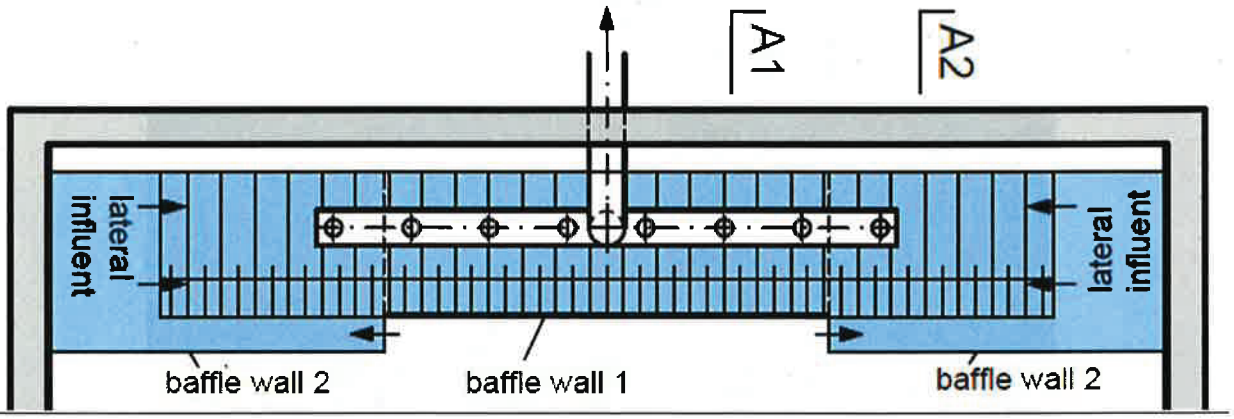
g) **Continuous Based Design - Internal Settling Zone** – An internal settling zone will be provided to allow for a continuous operation of the Anammox treatment system. Clarified effluent will be discharged back into the main process while the settled MLSS will be returned to the Anammox reactor. The waste stream enters the vessel and immediately the velocity is reduced to enhance particle separation. The vessel is polypropylene, so the operating pH has no affect on the systems longevity. The "clean" liquid is continuously removed from the top of the settling area and passes through holes into an effluent collection piping system. From the effluent collection piping system, the wastewater gravity feeds out of the system. Heavy solids settle into the bottom where they fall back into the main DEMON® process tank on a automatic basis. The system is compact, robust, cleanable, and does not have moving parts. The settling zone will be located on the long wall of the reactor to allow for passing the Max Month flows of 400,000 gpd per reactor.



View of the Top of the DEMON Reactor

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h) **Blowers** – Positive displacement blowers capable of providing the necessary turndown for operation of the DEMON® system are to be provided.

SBR - Design Case	Model	Air Flow	Est. HP	Est. bHP
2 duty + 1 standby per Process train	GM 25S	670 SCFM	50 HP	36.4 bHP
Continuous - Design Case	**Model**	**Air Flow**	**Est. HP**	**Est. bHP**
2 duty + 1 standby per Process train	GM 25S	435 SCFM	40 HP	29.3 bHP

This blower design will allow the most flexibility in allowing the system have efficient use of blower capacity during start up and low load periods of time. The blowers will each have its own sound enclosure to maintain < 75 db sound rating. Each blower will also be equipped with a variable frequency drive unit to allow efficient turndown of the blower while maintaining the proper dissolved oxygen concentration in the Continuous DEMON® reactor.

i) **Documentation / Design / License** – All necessary documentation and design information will be provided as well as a license for treating the Maximum Month Loads.

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2. CONTROLS

World Water Works provides pre-wired control panels to optimally control all equipment provided within the scope of this proposal. World Water Works includes an Ethernet connection with the control panel to allow remote access to the program and to assist in troubleshooting.

INSTRUMENTATION

Electrical Enclosure	**Hoffman, NEMA 4**
PLC	**Allen Bradley**
Software	**Allen Bradley**
Touchscreen	**15 inch Color Touch Screen**
Motor Starters	**Cutler Hammer or equiv**
Indicator & Stack Lights	**Cutler Hammer or equiv, Nema 4**
Control Buttons	**Cutler Hammer or equiv, Nema 4**
Local Disconnect	**Hubbell, NEMA 4**
Air Solenoids	**SMC**
Phase Protector	**SYMCON**

ADDITIONAL OPTIONS PROVIDED

Remote Operation Capability

UL Listed Panel

PLC Panel – The PLC panel and control program is the heart of the Continuous DEMON® process and its integral to our scope of supply. The PLC program will have each reactor created as a separate reactor. The reactor will have independent feed of raw centrate, aeration and mixing time. A touch panel with remote access is standard for allowing WWW access to the system and provides operational oversight.

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SBR - DESIGN FOR 30C – Average Month Flows & Loads

Basic process figures	Design		Design	
Water temperature in DEMON®-tank	30	°C	86	F
Load and concentration				
Daily water flow	2,196	m^3/d	0.580	MGD
NH4-N-load	1,559	kg/d	3,437	lb/day
NH4-N-concentration	710	mg/L	710	mg/L
COD soluble, degradable (estimate)	300	mg/L	300	mg/L
Suspended solids	460	mg/L	460	mg/L
COD soluble, degradable load	659	kg/d	1,452	lbday
Suspended solids load	1,010	kg/d	2,227	lb/day
Alkalinity Concentration	2,600	mg/L	2,600	mg/L
Alkalinity Load	5,708	kg/d	12,585	lbday
SBR-cycle				
Active time	7.0	h	7.0	h
Sedimentation	0.5	h	0.5	h
Decant	0.5	h	0.5	h
Total cycle	8.0	h	8.0	h
DEMON-tanks				
Number of tanks	2	in parallel	2	in parallel
Max. water depth	6.71	m	22.0	ft
Total volume per Demon® Reactor	1356	m^3	47,880	m^3
Length of Each Demon® Reactor	19.8	m	65.0	ft
Width of Each Demon® Reactor	10.2	m	33.5	ft
Total Treatment Volume Provided	2,712	m^3	95,760	ft^3
Min. water level	4.90	m	16.06	ft
Inlet				
Feeding pump per tank	310	m^3/h	1365	gpm
Design of aeration system				
Oxygen consumption				
Daily oxygen consumption, operating conditions	3,232	kg O2/d	7,124	lb O2/d
Oxygen consumption per hour and DEMON® tank, operating conditions	110	kg O2/h	242	lb O2/h
Fine bubble aeration				
Design air flow (per DEMON®-tank)	1,599	Nm^3/h	941	SCFM
Design air flow (per ALL TANKS)	3,199	Nm^3/h	1,883	SCFM

Air flows are based on 22 ft operating water level and discharge pressure of 11 psig

Rough Footprint would be two (2) basins at 33.5 ft wide x 65 ft long x 22 ft SWD.

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SBR - DESIGN FOR 30C – Maximum Month Flows & Loads

Basic process figures	Design		Design	
Water temperature in DEMON®-tank	30	°C	86	F
Load and concentration				
Daily water flow	3,028	m^3/d	0.800	MGD
NH4-N-load	2,059	kg/d	4,540	lb/day
NH4-N-concentration	680	mg/L	680	mg/L
COD soluble, degradable (estimate)	300	mg/L	300	mg/L
Suspended solids	480	mg/L	480	mg/L
COD soluble, degradable load	909	kg/d	2,003	lbday
Suspended solids load	1,454	kg/d	3,205	lb/day
Alkalinity Concentration	2,470	mg/L	2,470	mg/L
Alkalinity Load	7,480	kg/d	16,490	lbday
SBR-cycle				
Active time	5.0	h	5.0	h
Sedimentation	0.5	h	0.5	h
Decant	0.5	h	0.5	h
Total cycle	6.0	h	6.0	h
DEMON-tanks				
Number of tanks	2	in parallel	2	in parallel
Max. water depth	6.71	m	22.0	ft
Total volume per Demon® Reactor	1356	m^3	47,880	m^3
Length of Each Demon® Reactor	19.8	m	65.0	ft
Width of Each Demon® Reactor	10.2	m	33.5	ft
Total Treatment Volume Provided	2,712	m^3	95,760	ft^3
Min. water level	4.83	m	15.86	ft
Inlet				
Feeding pump per tank	310	m^3/h	1365	gpm
Design of aeration system				
Oxygen consumption				
Daily oxygen consumption, operating conditions	4,307	kg O2/d	9,496	lb O2/d
Oxygen consumption per hour and DEMON® tank, operating conditions	154	kg O2/h	339	lb O2/h
Fine bubble aeration				
Design air flow (per DEMON®-tank)	2,321	Nm^3/h	1,366	SCFM
Design air flow (per ALL TANKS)	4,643	Nm^3/h	2,732	SCFM

Air flows are based on 22 ft operating water level and discharge pressure of 11.0 psig

Rough Footprint would be two (2) basins at 33.5 ft wide x 65 ft long x 22 ft SWD.

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Continuous - DESIGN FOR 30C – Average Month Flows & Loads

Influent Flow and Wastewater Characteristics	Design		Design	
Wastewater temperature in DEMON® Anammox-tank	30	°C	86	F
Daily water flow	2,196	m^3/d	0.580	MGD
Ammonia (NH4-N) Load	1,559	kg/d	3,437	lb/day
Ammonia (NH4-N) Concentration	710	mg/L	710	mg/L
Soluble COD, degradable (estimate)	300	mg/L	300	mg/L
Suspended Solids Concentration (TSS)	460	mg/L	460	mg/L
Soluble COD, degradable Load	659	kg/d	1,452	lbday
Suspended Solids Load (TSS)	1,010	kg/d	2,227	lb/day
Alkalinity Concentration	2,600	mg/L	2,600	mg/L
Alkalinity Load	5,708	kg/d	12,585	lbday
DEMON® Anammox Tank Information				
Number of tanks	2	in parallel	2	in parallel
Max. water depth	6.40	m	21.0	ft
Total volume per DEMON® Anammox Reactor	1196	m^3	42,241	m^3
Length of Each DEMON® Anammox Treatment Reactor	18.3	m	60.0	ft
Width of Each DEMON® Anammox Treatment Reactor	10.2	m	33.5	ft
Total Treatment Volume Provided	2,393	m^3	84,482	ft^3
Influent Feeding Design				
Feeding pump per tank	93	m^3/h	407	gpm
Design of aeration system				
Biological Oxygen Requirements System Design				
Actual Oxygen Requirements (AOR), operating conditions	3,232	kg O2/d	7,124	lb O2/d
Actual Oxygen Required (AOR) in DEMON® Anammox tank	96	kg O2/h	212	lb O2/h
Aeration System & Blower Design Air Flow Requirements				
Design Air Flow (per DEMON® Anammox-tank)	1,103	Nm^3/h	649	SCFM
Design Air Flow (per ALL TANKS)	2,206	Nm^3/h	1,298	SCFM

Air flows are based on 21 ft operating water level and discharge pressure of 10.5 psig

Rough Footprint would be two (2) basins at 33.5 ft wide x 60 ft long x 21 ft SWD.

Continuous - DESIGN FOR 30C – Maximum Month Flows & Loads

Influent Flow and Wastewater Characteristics	Design		Design	
Wastewater temperature in DEMON® Anammox-tank	30	°C	86	F
Daily water flow	3,028	m^3/d	0.800	MGD
Ammonia (NH4-N) Load	2,059	kg/d	4,540	lb/day
Ammonia (NH4-N) Concentration	680	mg/L	680	mg/L
Soluble COD, degradable (estimate)	300	mg/L	300	mg/L
Suspended Solids Concentration (TSS)	480	mg/L	480	mg/L
Soluble COD, degradable Load	909	kg/d	2,003	lbday
Suspended Solids Load (TSS)	1,454	kg/d	3,205	lb/day
Alkalinity Concentration	2,470	mg/L	2,470	mg/L
Alkalinity Load	7,480	kg/d	16,490	lbday
DEMON® Anammox Tank Information				
Number of tanks	2	in parallel	2	in parallel
Max. water depth	6.40	m	21.0	ft
Total volume per DEMON® Anammox Reactor	1196	m^3	42,241	m^3
Length of Each DEMON® Anammox Treatment Reactor	18.3	m	60.0	ft
Width of Each DEMON® Anammox Treatment Reactor	10.2	m	33.5	ft
Total Treatment Volume Provided	2,393	m^3	84,482	ft^3
Influent Feeding Design				
Feeding pump per tank	93	m^3/h	407	gpm
Design of aeration system				
Biological Oxygen Requirements System Design				
Actual Oxygen Requirements (AOR), operating conditions	4,307	kg O2/d	9,496	lb O2/d
Actual Oxygen Required (AOR) in DEMON® Anammox tank	128	kg O2/h	283	lb O2/h
Aeration System & Blower Design Air Flow Requirements				
Design Air Flow (per DEMON® Anammox-tank)	1,470	Nm^3/h	865	SCFM
Design Air Flow (per ALL TANKS)	2,940	Nm^3/h	1,730	SCFM

Air flows are based on 21 ft operating water level and discharge pressure of 10.5 psig

Rough Footprint would be two (2) basins at 33.5 ft wide x 60 ft long x 21 ft SWD.

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CONSUMABLES OF CONVENTIONAL VS. CONTINUOUS DEMON® TREATMENT SYSTEM - DESIGN CONDITIONS

Nitrogen-Load	3,437	lb/day
Energy costs	$0.070	USD $ /kWh
Specific energy costs	0.2268	kWh/lb O2
Methanol	$0.219	USD $ /lb
Sludge	$367	USD $ /US ton

Conventional Nitrification / Denitrification			**Specific Costs (USD $ / lb N)**	**Costs per Year**	
Oxygen	4.3 lb/lb N		0.0685	$	85,876
Methanol	2.3 lb/lb N		0.5028	$	630,704
Sludge	0.35 lb/lb N		0.0643	$	80,653
		TOTAL	**0.6356**	**$**	**797,233**

DEMON Anammox Treatment System			**Specific Costs (USD $ / lb N)**	**Costs per Year**	
Oxygen	1.6125 lb/lb N		0.0257	$	32,204
Methanol	0 lb/lb N		0.0000	$	-
Sludge	0.03 lb/lb N		0.0055	$	6,913
		TOTAL	**0.0312**	**$**	**39,117**

Savings per year on aeration	**$**	**53,673**
Savings per year on Methanol	**$**	**630,704**
Savings per year on Sludge disposal	**$**	**73,740**
Total Operational Savings per year	**$**	**758,116**

WWW Scope of Supply – SBR Design Concept

- Design & Engineering for System
- Two (2) SS Decanter Model 350 with 14 inch flange connection
- Two (2) 14 inch flow control values for decant control of system
- One hundred sixteen (116) Messner Aeration panels for the reactors (58 per reactor)
- Four (4) SS 304L Drop pipe with manifold to feed Messner panels
- Two (2) DEMON® Biomass Separation Systems
- Three (3) submersible pumps (two duty + one standby) rated at 50 gpm and 5 HP motor with VFD's on each pump (operated 8 hrs per day)
- Two (2) Pressure sensor with 4-20 mA output for monitoring of DEMON® Biomass Separation system
- Four (4) Radar type level control for each DEMON® Tank, EQ Tank and Post SBR Tank
- Three (3) influent feed pumps to the DEMON® reactor each rated for 1,365 gpm with VFD's on each pump. (operated 6 hrs per day) (2 duty + 1 standby)
- Six (6) Positive Displacement blowers (670 SCFM each) with VFD's on each blower (50 HP motors) (operated 14 hrs per day at design load) – (1 Duty + 1 Standby)
- Four (4) – 12.2 HP side mounted mixers with VFD's for each mixer (operated 6 hr/day)
- Seed Sludge for start up of system delivered to the site
- DEMON® Control program with panel with VFD's for blowers, submersible pump and mixers
- Two (2) pH and DO probe with two (2) SC1000 controller
- Two (2) Conductivity probe with two (2) SC200 controller
- Two (2) Air flow insertion meter and two (2) water flow magnetic meters
- Inspection, start up and training services (5 trips / 20 days)
- 3-4 months of off-site / remote monitoring services
- **Estimated Price for above scope of supply: $2,500,000 USD**

Items not included:

Conversion of Tankage for EQ Tank, DEMON® tanks and Post SBR Tank
Unloading, storage, installation of equipment
Electrical connections and interconnecting piping

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WWW Scope of Supply – Continuous Design Concept

- Design & Engineering for System
- Two (2) Polypropylene Internal Settling Zone Baffle walls
- Eighty (80) Messner Aeration panels for the reactor
- Two (2) SS 304L Drop pipe with manifold to feed Messner panels
- Two (2) DEMON® Biomass Separation System
- Three (3) submersible pumps (one duty + one standby) rated at 50 gpm and 5 HP motor with VFD's on each pump (operated 8 hrs per day)
- Two (2) Pressure sensor with 4-20 mA output for monitoring of DEMON® Biomass Separation system
- Three (3) Radar type level control for each DEMON® Tank & EQ Tank
- Three (3) influent feed pumps to the DEMON® reactor each rated for 410 gpm with VFD's on each pump. (operated 12 - 24 hrs per day) (1 duty + 1 standby)
- Six (6) Positive Displacement blowers (435 SCFM each) with VFD's on each blower (40 HP motors) (operated 14 hrs per day at design load) – (1 Duty + 1 Standby)
- Four (4) – 12.2 HP side mounted mixers with VFD's for each mixer (operated 6 hr/day)
- Seed Sludge for start up of system delivered to the site
- DEMON® Control program with panel with VFD's for blowers, submersible pump and mixers
- Two (2) pH and DO probe with two (2) SC1000 controller
- Two (2) Conductivity probe with two (2) SC200 controller
- Two (2) Air flow insertion meter and two (2) water flow magnetic meters
- Inspection, start up and training services (5 trips / 20 days)
- 3-4 months of off-site / remote monitoring services
- **Estimated Price for above scope of supply: $2,500,000 USD**

Items not included:

Conversion of Tankage for EQ Tank, DEMON® tanks
Unloading, storage, installation of equipment
Electrical connections and interconnecting piping

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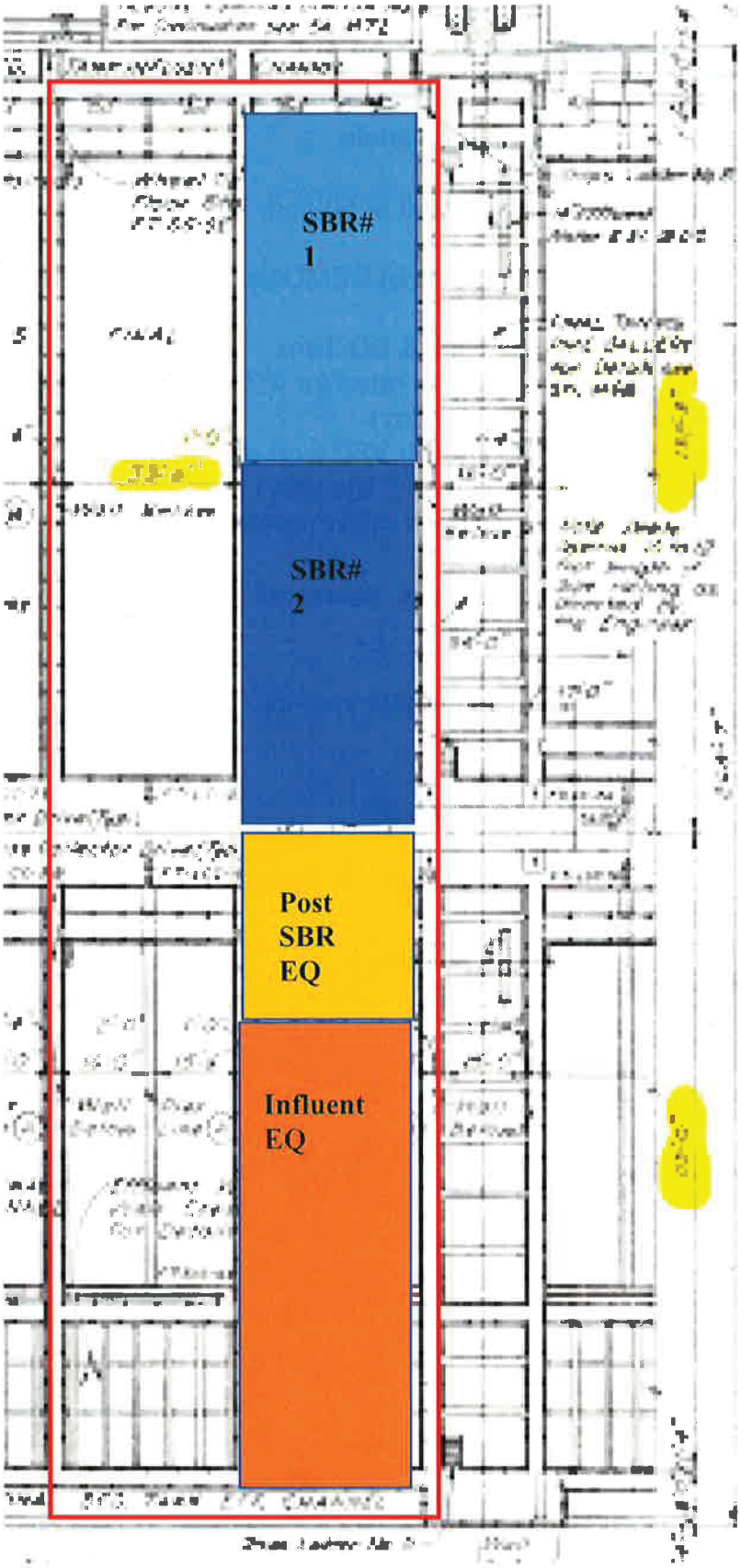

SBR Design Concept:
2 – SBR's: 65 ft long x 33.5 ft wide x 22 ft SWD

EQ Tank: 85 ft x 33.5 ft x 22 ft SWD

Post SBR Effluent: Tank: 25 ft x 33.5 ft x 15 ft SWD

SBR Decant at MM Flows: 100,400 gallons in 30 minutes (3,333 gpm)

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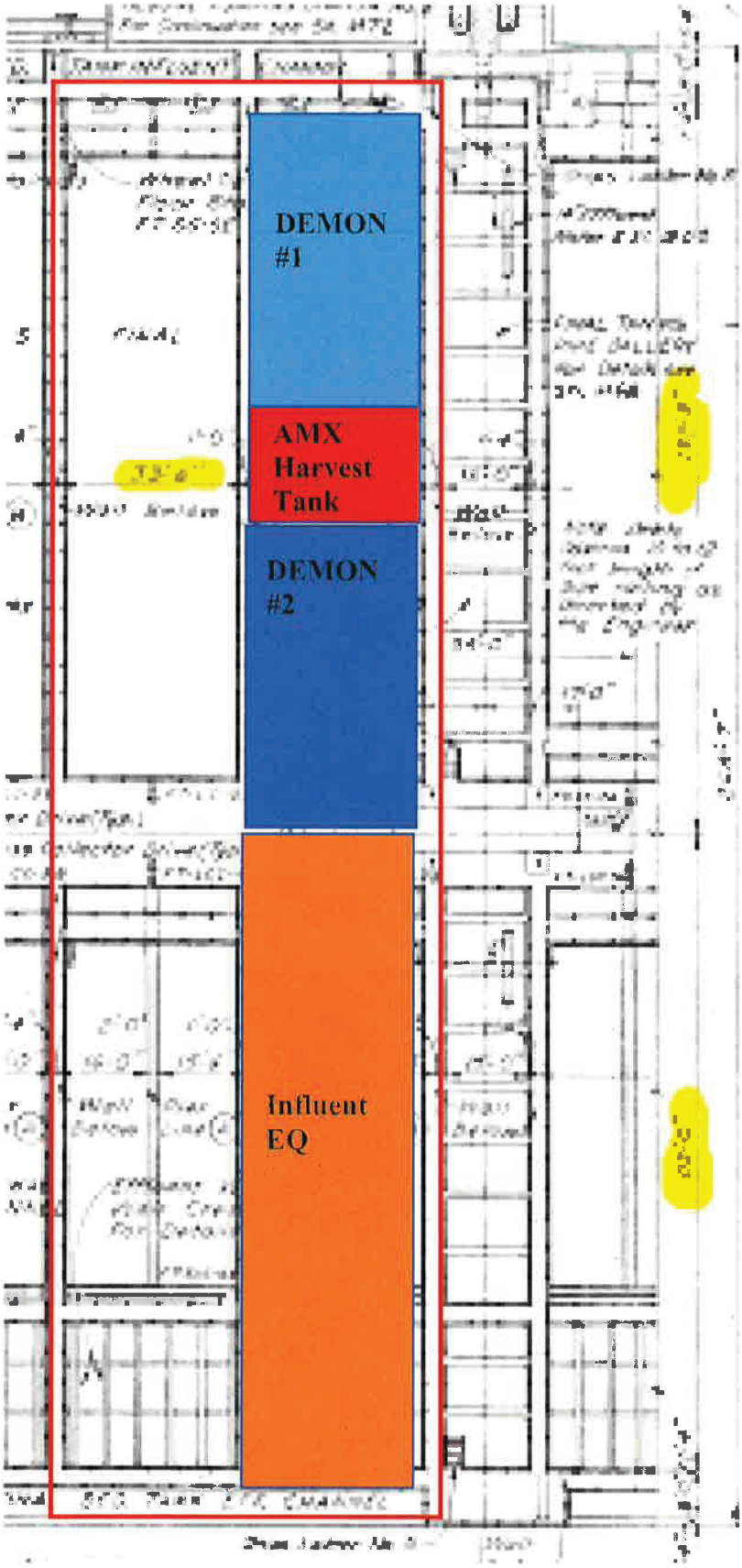

Continuous Design Concept:
2 – DEMON Reactors: 60 ft long x 33.5 ft wide x 21 ft SWD

Anammox Harvesting Tank: 33.5 ft x 12 ft x 21 ft SWD

EQ Tank: 115 ft x 33.5 ft x 21 ft SWD

OVIVO Worldwide Experts in Water Treatment

PROPOSAL LETTER

PROPOSAL # 01102018-1-MG-R0

JANUARY 10, 2017

CITY OF TAMPA - HOWARD F. CURREN AWTP, FL

AnammoPAQ™ System

PREPARED FOR

Hazen & Sawyer, Inc.
Ann Sager
asager@hazenandsawyer.com

AREA REPRESENTATIVE

TSC Jacobs, Inc.
Todd Rubens
todd@tscjacobs.com

PREPARED BY

Mudit Gangal
Phone: (512)-834-6042
mudit.gangal@ovivowater.com

Ovivo USA, LLC
2404 Rutland Drive
Austin, Texas, 78758, USA

January 10, 2018

Attn: Ms. Ann Sager
Hazen & Sawyer, Inc.

Re: City of Tampa – Howard F. Curren AWTP, FL
Ovivo AnammoPAQ™ System
Proposal No. 011018-1-MG-R0

Dear Ms. Sager,

With regard to your recent request for the City of Tampa Howard F. Curren AWTP, FL, Ovivo USA, LLC is pleased to submit this preliminary proposal for its AnammoPAQ™ system. The system design is based on the influent high nitrogen stream at the HFC AWTP having a design (Future MM) flow of 0.8 MGD to achieve 80% Ammonia-N removal at a design temperature of 30 °C.

It is assumed that the dewatering will occur 24 hours a day and 7 days a week with AnammoPAQ™ system operation 7 days a week. However, if dewatering frequency was reduced to 5 days per week, then a larger equalization tank (2-3 days HRT is recommended). It is also assumed enough equalization in either case will be provided (by others) and all equipment in the equalization tank including feed pumps will be by others.

We have endeavored to provide complete information in this proposal. However, if you have any questions or need additional information, please feel free to contact Todd, our regional sales representative, or me directly.

Sincerely,

Mudit Gangal
Product Manager - AnammoPAQ™

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TABLE OF CONTENTS

1. APPLICATION ..... **Error! Bookmark not defined.**
2. TREATMENT APPROACH ..... **Error! Bookmark not defined.**
3. SCOPE ..... **Error! Bookmark not defined.**
4. BUDGET PRICE ..... **Error! Bookmark not defined.**
5. BROCHURE ..... **Error! Bookmark not defined.**

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INTRODUCTION

The Howard F. Curren AWTP, FL is in the process of evaluating technologies for treatment of its high Nitrogen content side-stream to reduce the Ammonia-N load to help meet its effluent permits in an efficient manner. The design flows and loads required to be treated by using the AnammoPAQ™ treatment process to reduce the Ammonia-N concentration in the effluent stream being discharged to more acceptable limits are provided in Table 1 below.

BASIS OF DESIGN

The AnammoPAQ™ system design and performance is based on the design information provided by Hazen & Sawyer, Inc. Table 1 summarizes the parameters used for developing the proposed solution.

Table 1: Design Parameters

Treatment Parameter	Units	Influent	Treated Effluent
Equalized Design Flow	MGD	0.8	
Design Temperature	°C	30	
BOD	mg/l	< 80	
COD	mg/l	< 630	
TSS	mg/l	< 480	
NH_3-N	mg/l	< 680	< 136
TKN	mg/l	< 700	
Alkalinity	mg/l	> 2,470	
OP	mg/l	< 50	

The design is based on the following assumption(s):

- The influent flows are produced seven (7) days a week, twenty four (24) hours a day.

The HFC AWTP, FL AnammoPAQ™ system was designed using extensive modeling and experience from Ovivo's pilot and full-scale installations. The modeling assists in process selection and determining the optimal volumes for treatment and the overall process operating parameters.

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OVIVO-PAQUES ANAMMOPAQ™ EXPERIENCE

The Ovivo-Paques AnammoPAQ™ system currently has over 50 operating nitrogen removal deammonification systems worldwide. Further, Ovivo's AnammoPAQ™ installation base cumulatively treats globally Nitrogen loads in excess of 250,000 lbs N/d, which is second to none. This is estimated to be around 80% of all Ammonia-N load currently treated in engineered systems utilizing anammox bacteria worldwide.

Figure:1 Modular AnammoPAQ™ setup at Rendac, The Netherland (13,000 lds N/day)

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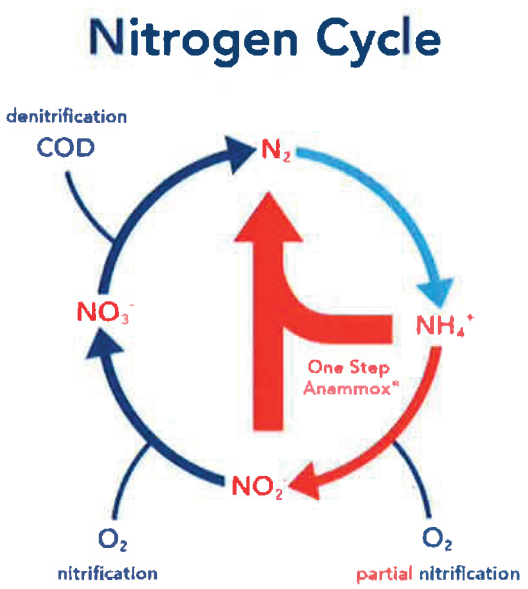
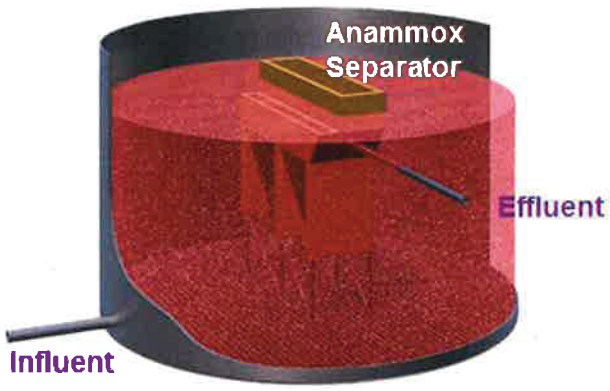
TREAMENT APPROACH

In the AnammoPAQ™ reactor, ammonium is converted to nitrogen gas. The reaction is executed by two different bacteria, which coexist in the reactor. Ammonium oxidizing bacteria (AOB) oxidize about half of the ammonium to nitrite. Anammox bacteria then convert the remaining ammonium and nitrite, into nitrogen gas. The overall reaction of the one step AnammoPAQ™ reactor is:

$$NH_4^+ + 0.85O_2 \rightarrow 0.45N_2 + 0.1NO_3^- + 1.1H^+$$

The deammonification conversion thus is an elegant shortcut in the natural nitrogen cycle. A key feature of the AnammoPAQ™ system is that ammonium is removed from the reject water stream in one treatment step without the use of external carbon sources and with minimal energy input.





The AnammoPAQ™ reactor is a continuously fed and aerated tank, equipped with Ovivo's patented biomass retention system. The aeration provides for rapid mixing of the influent with the reactor content, intense contact with the biomass and oxygen supply to drive the conversion. This process is based on granular biomass. The aeration is controlled in order to selectively convert ammonium to nitrogen gas. Around 10% of the ammonium is converted into nitrate. The treated wastewater leaves the reactor via the biomass retention system at the top of the reactor.

The granular biomass is separated from the cleaned wastewater, assuring high biomass content in the reactor. Together with the dense conversion properties typical for granular biomass, the high biomass content provides for high loading/conversion rates and therefore a small reactor volume.

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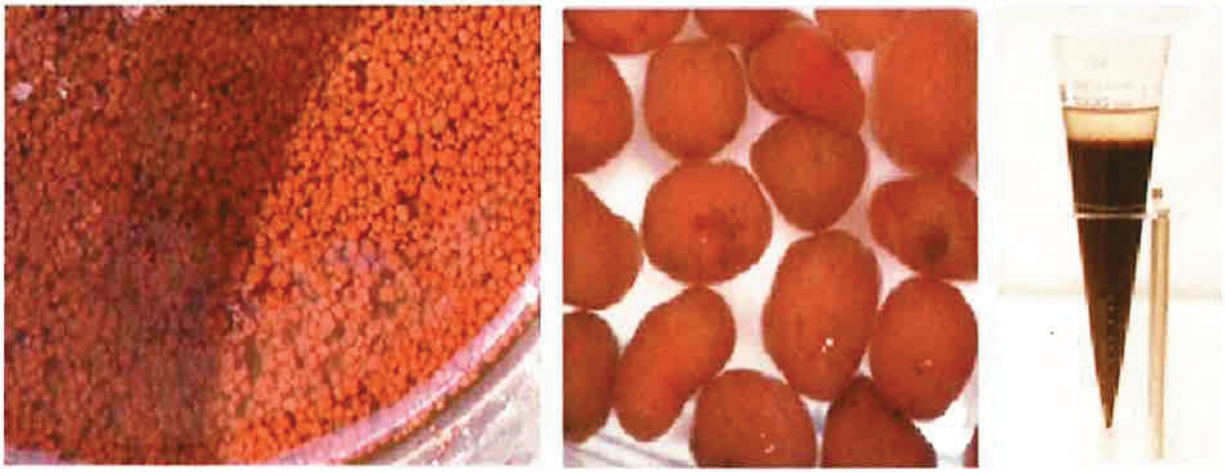
AnammoPAQ™ PROCESS ADVANTAGES

Main benefits of implementing the AnammoPAQ™ system for Nitrogen removal are the significant savings on operational costs and environmental impact compared to conventional and alternative deammonification systems. These include:

- Aeration Energy Savings (over 60%)
- Elimination of external Carbon source (100% saving)
- Reduction in sludge production (up to 90%)
- Compact footprint
- High Loading Rates
- Reduction in CO2 emission
- Limited chemical consumption
- Fast start up due to inoculation with granular biomass
- Robust process: Tolerant to presence of toxic chemicals
- Ability to handle high suspended solids in influent



Anammox Granular Biomass

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AnammoPAQ™ PROCESS DESIGN

The system for the HFC AWTP, FL has been designed using proprietary models to perform process selection and to determine essential operating parameters.

A summary of the AnammoPAQ™ system design is provided in Table 2. This table demonstrates the volumes required to achieve desired effluent Ammonia-N reduction, and provides associated process design details.

Table 2. Design Summary

Treatment Parameter	Unit	Value
Equalized Design Flow	MGD	0.8
Total No. of AnammoPAQ™ Reactors	#	1
Volume of AnammoPAQ™ Reactors (each)	Gallons	295,000
AnammoPAQ™ Reactor Length	ft	44.5
AnammoPAQ™ Reactor Width	ft	44.5
AnammoPAQ™ Reactor SWD	ft	20
Air Flow	scfm	2,550

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SCOPE

SCOPE OF SUPPLY

The following table outlines the Ovivo AnammoPAQ™ system scope of supply for the proposed project.

Scope of Supply		
Item	Qty	Description
1	1	AnammoPAQ™ reactor internals (suitable for a 0.295 MGal tank – tank by others) • 2 x Type 33 Settler and support construction • Fine Bubble aeration system with Aerostrip® diffusers, basin piping for c/w drop legs, flanged diffuser pipes, mounting brackets and connection fasteners (Capacity: 2,550 scfm) • Piping for aeration, influent, effluent, biomass sampling
2	3 (2+1)	Process Air Blowers for AnammoPAQ™ with VFD; Capacity: 1,275 scfm each
3	Lot	Anammox granular biomass
4	Lot	Controls and Instrumentation ($NH4^+$, $NO3^-$, $NO2^-$, DO, pH, T)
5	2	Sets of O&M Manuals
6	2	Sets of Detailed Shop Drawings
7	20	Service Days, to inspect equipment installation, test all supplied components, assist in start-up and train plant personnel.

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ITEMS BY OTHER

The following items are specifically not by Ovivo. They may or may not be required.

Items Not Included	
Air Main Piping and all accessories including valves, bolts gaskets and connectors for attaching to drop pipes	Liquid sampling and analytical work
Chemical Feed Systems for alkalinity correction, nutrients, methanol and defoamer	Motor Control Center (MCC)
Chemicals for operation: Including methanol, nutrients, alkaline solution, defoamer	Non-potable water supply
Cleanouts	Overflow structures including baffles and weir plates
Concrete	Power
Drains	Sludge handling and disposal
Engines/Generators	Sludge Pumps
Equalization Tank equipment	Support Platforms
Foam control	Transformers
Hoses /Bibs	Ventilation
Influent/Feed Pumps	Walkways/Roofing/Stairs/Gratings/Handrails
Laboratory	Wireways/Wiring
Ladders	Yard Hydrants
Lighting	Yard Piping

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ADDITIONAL ITEMS BY INSTALLING CONRACTOER

1 Obtain necessary construction permits and licenses, construction drawings (including interconnecting piping drawings) field office space, telephone service, and temporary electrical service.

2 All site preparation, grading, locating foundation placement, excavation for foundation, underground piping, conduits and drains.

3 Demolition and/or removal of any existing structures, equipment or facilities required for construction and installation of the AnammoPAQ™ system.

4 Installation of all foundation - supply and installation of all embedded or underground piping, conduits and drains.

5 All backfill, compaction, finish grading, earthwork and final paving.

6 Receiving (preparation of receiving reports), unloading, storage, maintenance preservation and protection of all equipment and materials supplied by Ovivo.

7 Installation of all equipment and materials supplied by Ovivo.

8 Supply, fabrication, installation, cleaning, pickling and/or passivation of all interconnecting steel piping components.

9 Provide and install all embedded pipe sections and valves for tank drains and reactor inlets and elbows.

10 All cutting, welding, fitting and finishing for all field fabricated piping.

11 Supply and installation of all flange gaskets and bolts for all piping components.

12 Supply and installation of all pipe supports and wall penetrations.

13 Install and provide all motor control centers, motor starters, panels, field wiring, wireways, supports and transformers.

14 Install all control panels and instrumentation as supplied by Ovivo, as applicable.

15 Supply and install all electrical power and control wiring and conduit to the equipment served plus interconnection between the Ovivo equipment as required, including wire, cable, junction boxes, fittings, conduit, cable trays, safety disconnect switches, circuit breakers, etc.

16 Supply and install all insulation, supports, drains, gauges, hold down clamps, condensate drain systems, flanges, flex pipe joints, expansion joints, boots, gaskets, adhesives, fasteners, safety signs, and any specialty items such as traps.

17 All labor, materials, supplies and utilities as required for start-up including laboratory facilities and analytical work.

18 Provide all chemicals required for plant operation and all chemicals, lubricants, glycol, oils or grease and other supplies thereafter.

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19 Install all anchor bolts and mounting hardware supplied by Ovivo; and supply and install all anchor bolts and mounting hardware not specifically supplied by Ovivo.

20 Provide all nameplates, safety signs and labels.

21 Provide all additional support beams and/or slabs.

22 Provide and install all manual valves.

23 Provide and install all piping required to interconnect to the Ovivo's equipment.

24 The Contractor shall coordinate the installation and timing of interface points such as piping and electrical with the Ovivo Supplier.

All other necessary equipment and services not otherwise listed as specifically supplied by Ovivo.

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BUDGET PRICE

Our current budget estimate price for the AnammoPAQ™ system, as described in this proposal is:

Description	Price
AnammoPAQ™ system as described above	**As Advised by Rep**

NOTES –

1. Our Price and Payment Terms are based on Ovivo's standard terms and conditions, which can be provided upon request.
2. This price will be valid for thirty (30) days.
3. All prices are excluding Florida state sales and use taxes and any federal taxes which shall be the sole responsibility of the Client. No additional duties will have to be paid for the equipment supplied by Ovivo.
4. Pricing is subject to the London Metal exchange index for stainless steel rolled coil calculated from the original proposal date and is in accordance with the Scope of Supply and terms of this proposal and any changes may require the price to be adjusted.

Shipping Terms
FOB Shipping Point, Full Freight Allowed

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BROCHURE

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OVIVO **Worldwide Experts** in **Water Treatment**

Municipal **BIOSOLIDS MANAGEMENT**

OVIVO-PAQUES

AnammoPAQ™ PROCESS

SUSTAINABLE NITROGEN REMOVAL

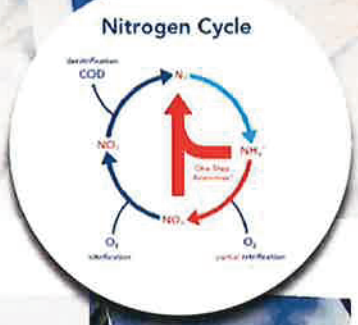
HOW WE CREATE VALUE

Cost-effective nitrogen removal from digester sidestreams (with or without THP) using Anammox

Compared to conventional nitrification and denitrification:

- 60% energy savings compared
- 100% reduction in supplemental organic carbon
- 90% reduction in sludge production
- 90% reduction in footprint
- 85% reduction in CO_2 emissions

Quick startup time with potential for full process optimization within 3 weeks



THE CHALLENGE

- Despite representing 1% to 3% of the flow to the mainstream, typical anaerobic digester sidestream contains 10% to 30% of the nitrogen load, with concentrations often in excess of 1,000 mg/L ammonia-N
- Sludge pre-treatment with THP can double the ammonia-N concentrations in the sidestream
- Stringent BNR limits on main stream
- Conventional nitrification and denitrification requires significant aeration energy and supplemental carbon

THE OVIVO SOLUTION

The AnammoPAQ™ process is an elegant shortcut in the natural nitrogen cycle. The process utilizes Anammox bacteria which directly convert ammonium (NH_4^+) and nitrite (NO_2^-) into nitrogen gas. Paques developed the original process for commercial purposes in cooperation with Delft University of Technology and the University of Nijmegen. Since the first full-scale plant started up in 2002 (treatment of sidestream from sludge digestion), many other plants have been installed and are running successfully.

The AnammoPAQ™ ADVANTAGE

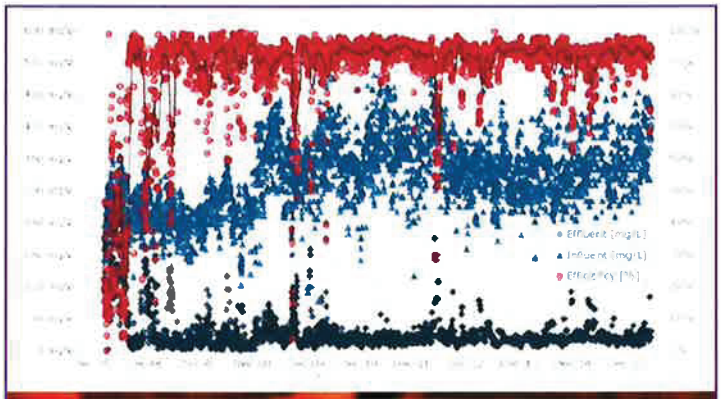
- Proven technology with 15+ years operational experience
- 35+ AnammoPAQ™ references worldwide
- Largest single unit can handle 10 metric tons of nitrogen/day (equivalent to sidestream from a 250 MGD municipal plant)!
- Robust system, handling high loading variations
- Up to 60% saving on operational costs
- Savings on excess sludge production
- No addition of organic carbon source (methanol) required
- Production of valuable Anammox biomass
- High loading rates leading to compact footprint
- Lowest O&M amongst competing systems

OPERATING PRINCIPLE

AnammoPAQ™ is a continuos flow reactor system in which nitritation and anammox conversion occur simultaneously in a single process unit. Anammox (anaerobic ammonium oxidation) conversion is an elegant short-cut in the natural nitrogen cycle where ammonium and nitrite are converted to nitrogen gas. As the Anammox process involves removal of ammonium over nitrite (NO_2^-) rather than nitrate (NO_3^-), 63% less oxygen (O_2) is required while eliminating the need for an external carbon source altogether. Optimal process control ensures retention of AOBs and Anammox bacteria while eliminating NOBs, leading to stable & robust operation.

$$NH_4^+ + 1\tfrac{1}{2}\,O_2 \rightarrow NO_2^- + H_2O + 2H^+$$

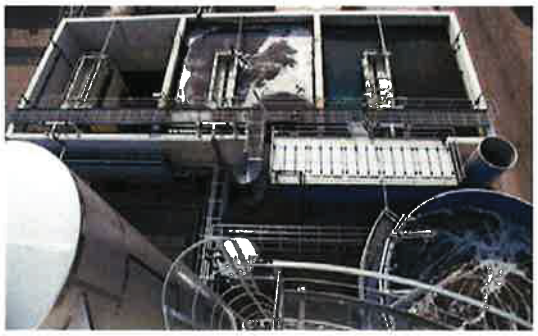
$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

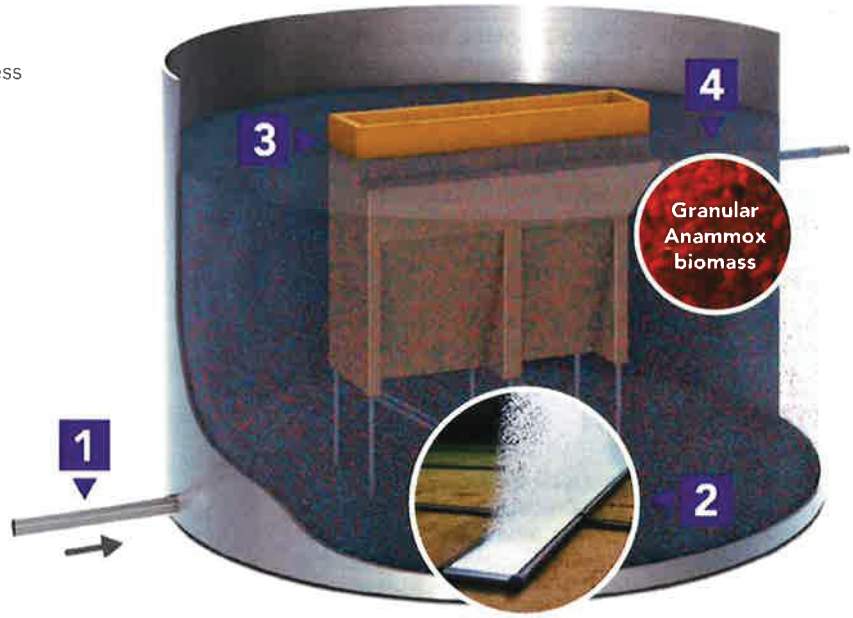


The Olburgen WWTP in Netherlands, with the Ovivo AnammoPAQ® process has reached stable & continuous 92% ammonium and 85% total nitrogen removal average for over 10 years

HOW IT WORKS

1. Ammonia-rich influent
2. Aerators for mixing and ammonia removal process
3. AnammoPAQ™ separator for biomass retention
4. Effluent exits the reactor





CONTACT
1-855-GO-OVIVO
info@ovivowater.com
www.ovivowater.com

Technical Memorandum 11.0 Biosolids System Alternatives Evaluation

11.1 Purpose and Background

This report describes the Biosolids System Alternatives Evaluation for the HFC AWTP. This work was completed under the Phase 2 Master Plan Contract by Hazen and Sawyer as a subconsultant to McKim & Creed.

The Phase 1 Biosolids Workshop established alternatives to be included in the biosolids system evaluation. The purpose of this technical memorandum is to provide a 20 year life cycle costs/revenue analysis of the biosolids system alternatives.

11.1.1 Existing Biosolids System Overview

The existing biosolids treatment system at the HFC AWTP processes the solids produced from the primary clarification and secondary clarification processes, as shown in **Figure 11.1-1**. Secondary waste activated sludge (WAS) is sent from the high purity oxygen system to gravity thickeners to be thickened prior to being pumped to the mixed sludge pump station where it is blended with the primary sludge. From the mixed sludge tank the biosolids are sent to anaerobic digestion tanks. Following digestion, the sludge is stored in holding tanks and then dewatered. After dewatering, the biosolids are either hauled away for land application or further processed in the heat drying facility. If the biosolids are sent to the heat dryer, a pelletized product is produced and then sold.

The Florida Department of Environmental Protection (FDEP) regulates the beneficial use and disposal of biosolids generated by domestic wastewater facilities through Chapter 62-640 of the Florida Administrative Code (F.A.C.). The FAC incorporates 40 CFR Part 503 Subpart D for pathogen reduction processes. Federal regulations, contained in 40 CFR Part 503, have been in place since 1993 and primarily set pathogen control criteria and limit the attraction of biosolids to disease-carrying organisms (vectors). These rules contain numerical limits for nine metals in biosolids, pathogen reduction standards, requirements for vector attraction reduction, site restrictions, crop harvesting restrictions and monitoring requirements, record keeping and reporting requirements for land applied biosolids, as well as similar requirements for biosolids that are surfaced disposed or incinerated.

The pathogen reduction mandates are divided into two categories: Class A and Class B. Class A biosolids are of the highest quality and can be spread on sites having unrestricted access while Class B biosolids are limited to areas having restricted public access. As discussed in the Phase 1 report (Appendix A), the digestion upgrade/enhancement alternative to be evaluated with the ability to produce Class A biosolids is thermal hydrolysis pretreatment (THP). FAC Rule 62-640 was amended in the year 2010, including requirements for site specific Nutrient Management Plans (NMP). However, based on recent discussions with the City's current biosolids hauler Synagro, it was noted that the available land application sites and costs associated with hauling and disposal of Class B biosolids have stabilized significantly. More stringent requirements in the future may create additional value associated with upgrading the treatment process to produce a Class A biosolids as related to limitations to land application of Class B biosolids.

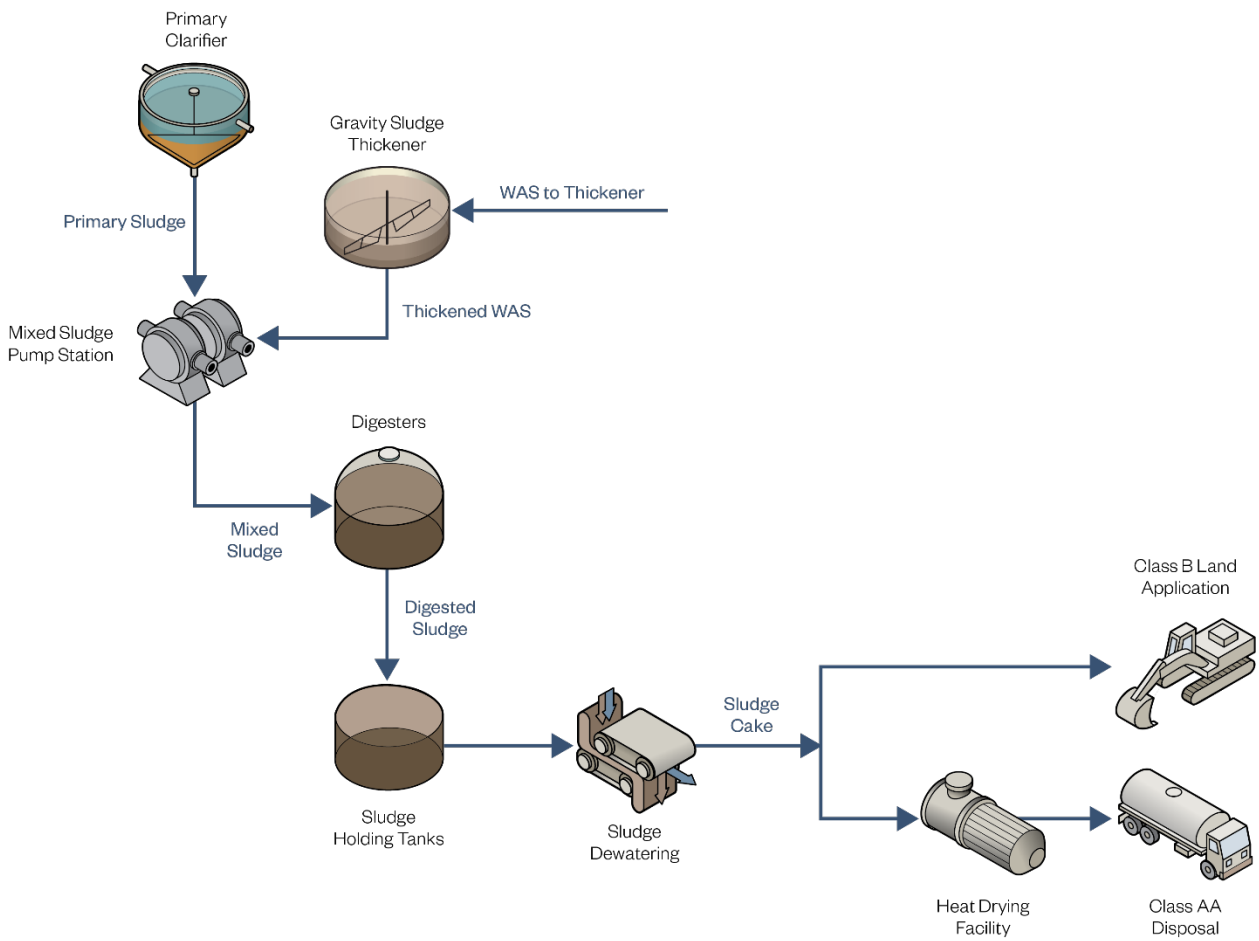


Figure 11.1-1: Existing HFC AWTP Process Schematic

11.2 Sludge Conditioning and Thickening

As discussed in the Existing Systems Technical Memorandum of Findings (Phase 1 of the Master Plan) completed in November 2016, the gravity thickening equipment was recently replaced and is reported to be functioning well. The older switchgear, MCCs, and cabling to the respective equipment are scheduled to be replaced this fiscal year (2018). It is recommended that no additional improvements be made to the existing gravity thickening mechanisms and thickened WAS (TWAS) pumps. However, the Phase 1 Technical Memorandum noted that the thickeners are being overloaded with respect to hydraulics and solids loading, and a third equally sized thickener train (consisting of a new tank, two TWAS pumps, and associated appurtenances) is recommended to provide redundancy and improve loading rates. The estimated capital cost for a third equally sized thickener train is summarized in **Table 11.2-1**.

Table 11.2-1: Capital Cost Estimate Third Thickener Train

Parameter	Cost[1] ($)
Civil and Site Work	$635,000
Structural/Architectural	$410,000
Equipment	$513,000
Piping, Valves	$213,000
Electrical	$210,000
Instrumentation	$140,000
Sum of Bare Construction Costs	**$2,121,000**
30% Contingencies	$636,000
Bare Construction Cost	$2,757,000
20% OH&P & GCs	$551,000
Total Construction Cost	**$3,308,000**
20% Management and Engineering[2]	$662,000
Total Capital Cost[1,2]	**$3,970,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of 50% to +100% of actual costs.*

[2]*Includes COT management, legal and administrative costs.*

Polymer is added to the gravity thickeners to improve performance. The current system includes bulk neat emulsion polymer storage tanks, and a batch mixing and aging system. This system appears to be functioning well but needs repairs, and it is suspected that it is less efficient than newer designs. Historically, the City has paid close to $7/gallon for neat polymer (~$1.81/lb active), and based on the plant's polymer usage (about 42 lb active/DT assuming 45% activity) for thickening and dewatering the resulting yearly polymer cost is around $1 million. It is anticipated that a new polymer activation system can lower the polymer dose by around 10-15% to around 35-38 lb active/DT. Therefore, there is a potential for significant operational cost savings from less polymer usage. It is recommended that the polymer system be replaced with a more efficient system as part of the project to add a third gravity thickener and additional TWAS pumps. The recommended new polymer system will consist of bulk storage tanks for neat emulsion polymer, two liquid polymer activation systems (such as the Velodyne Veloblend or UGSI Chemical Feed Polyblend automated polymer feed technologies), two aging tanks, and activated polymer feed pumps dedicated to each gravity thickener. Capital costs to upgrade to a new polymer system are summarized in **Table 11.2-2**. A similar new polymer system is recommended to replace the existing bed polymer system located by the sludge storage tanks which is 30 years old and in fairly poor condition.

Table 11.2-2: Capital Cost Estimate Gravity Thickener Polymer System

Parameter	Cost[1] ($)
Replacement Polymer System	$397,000
Sum of Bare Construction Costs	**$397,000**
30% Contingencies	$119,000
Bare Construction Cost	$516,000
20% OH&P & GCs	$103,000
Total Construction Cost	**$619,000**
20% Management and Engineering[2]	$124,000
Total Capital Cost[1,2]	**$743,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of 50% to +100% of actual costs.*

[2]*Includes COT management, legal and administrative costs.*

As demonstrated in **Figure 11.2-1**, the potential operational cost savings from less polymer use which is estimated to be between 10 to 15% indicates a 5 to 7-year payback period for the associated capital investment of the more efficient replacement polymer system.

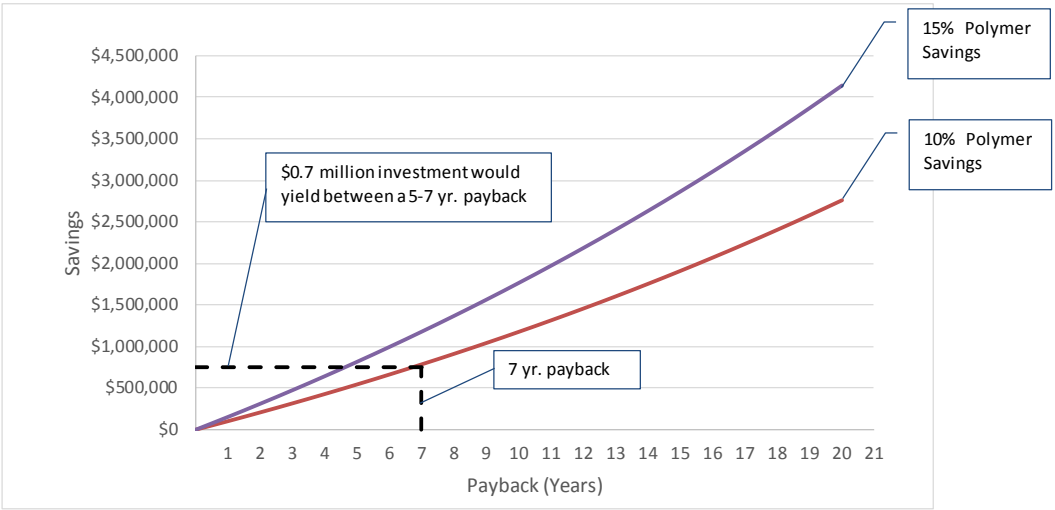


Figure 11.2-1: Polymer System Payback Period

11.3 Digestion

At the HFC AWTP, a blend of thickened primary sludge and thickened waste activated (TWAS+PS) sludge is typically pumped from the Mixed Sludge Pumping Station to the anaerobic digesters. The purposes of the anaerobic digesters are to produce stabilized biosolids, reduce pathogens, reduce biosolids mass by volatile solids destruction, and generate biogas as a usable by-product. Residual solids in the digesters are designed to be heated to a mesophilic (95°F to 100°F) range (utilizing an external heat source) with a minimum solids retention time (SRT) of 15 days to maintain a high rate of biological activity in the tanks. The tanks are constantly mixed to promote digestion by maintaining a uniform sludge mixture and heat distribution within the digesters. The digested solids are then pumped to holding tanks prior to the belt press dewatering facilities. The volatile content of the feed sludge is relatively high; the high volatile fraction can be attributed to the primary sludge component and low mean cell residence time (MCRT) of the activated sludge process.

The HFC AWTP anaerobic digestion process includes the following systems:

- Anaerobic Digesters
- Digester Gas Mixing Systems
- Digester Sludge Heating Systems
- Sludge Transfer Pumping Systems
- Waste Gas (Biogas) Handling System

The existing anaerobic digestion facilities at the HFC AWTP consist of seven (7) digesters (aggregate volume of 9.2 MG) and three (3) digester control buildings (A, B and C). Digester control buildings house heated sludge recirculation pumps, digested sludge transfer pumps, back-up boilers, sludge to hot water heat exchangers, and process piping and appurtenances.

Each digester is served by a dedicated sludge heating/recirculation pump and a paired heat exchanger (HEX) to maintain the digester contents at or above 95° F. Sludge is drawn from each digester, discharged through a dedicated HEX unit and the heated sludge is returned to the digester. Five (5) two-pass HEX units serve the HFC AWTP, with two located in Digester Control Building A to serve Digesters 1 through 4; one (1) located in Digester Control Building B to serve Digester 5; and two (2) located in Digester Control Building C to serve Digesters 6 and 7. Waste heat from the biogas combined heat and power (CHP) system is conveyed to the water-side of the existing heat exchangers. Backup boilers located in the digester control buildings provide hot water to the heat exchangers in the event the CHP system is not operating. However, due to limitations on the use of the CHP engines, the boilers are used on a regular basis.

Digester Nos. 1, 2, 3 and 4 have floating gasholder type covers. Digester Nos. 5, 6 and 7 have floating (not gasholder) covers. Digester gas is compressed, pre-treated and used as fuel at the combined heat and power system to generate electrical power and heat water for the digested sludge heating system. Excess digester gas is flared through waste gas burners.

The existing anaerobic digestion system physical size data are summarized in **Table 11.3-1**.

Table 11.3-1: Existing HFC AWTP Anaerobic Digesters

Parameter	Units	Digesters 1-4	Digester 5	Digesters 6-7	Total
Diameter, ea.	**ft**	75	95	110	
Max. Side Water Depth, ea.	**ft**	22.5	25.5	34.5	
Max. Active Digester Volume[1], ea.	**gallons**	743,528	1,352,010	2,452,432	9,230,987
Largest Unit Out of Service	**gallons**				6,778,555
Working[2] Side Water Depth, ea.	**ft**	19.7	23.7	28.5	
Max. Working Active Digester Volume[1], ea.	**gallons**	651,000	1,256,574	2,025,922	7,912,420

Notes:
[1] *Volume does not include bottom cone.*
[2] *City presently operates digesters at reduced side water depth because of foaming.*

The HFC AWTP GPS-X® process model was updated and expanded under previous Task 2. The GPS-X® process model was used to predict solids production for the liquid stream alternatives discussed in the BNR Process Evaluation memorandum at: current annual average, future annual average and future max month flow. **Table 11.3-2** summarizes the projected long-term organic loading to the digesters for the selected liquid stream alternative, Alternative 1: Optimize Existing.

Table 11.3-2: Projected HFC AWTP Anaerobic Digester Long-Term Organic Loads

Parameter	Current Annual Average	Future Annual Average	Future Max. Month
Plant Influent, mgd	60.0	80.0	112.9
Primary Sedimentation Tanks			
Primary TSS Removal	60%	60%	60%
TWAS+PS (Digester Feed)			
Total Solids, ppd	106,000	147,000	185,000
Volatile content, %	85%	85%	86%
Volatile solids, ppd	90,700	126,000	158,000
Flow, mgd	0.324	0.446	0.560

Table 11.3-3 presents GPS-X® process modeling results of predicted digestion performance based on the sludge production rates and long-term BNR process changes. Under these baseline conditions, annual average volatile solids destruction is expected to approximate 58%, which historically has ranged from 45 to 60 percent (**Appendix A**).

Table 11.3-3: Projected HFC AWTP Anaerobic Digester Performance

Parameter	Current Annual Average	Future Annual Average	Future Max. Month
Plant Influent, mgd	60.0	80.0	112.9
Primary digesters in service	7	7	6
Hydraulic retention time[1] (@design SWD)	28.5	20.7	12.1[2]
Minimum Volume to meet HRT[3], MG	4.860	6.479	9.144
Volatile solids reduction (VSR), %	58%	58%	55%
Biogas flow total, cfm	615	832	993
Total CH4 gas flow, cfm	367	500	605
Dewatered cake TS load, ppd	46,500	65,100	86,000

Notes:

1 *Volume does not include bottom cone.*
2 *With largest tank out of service.*
3 *HRT = 15 days.*

11.3.1 Evaluation Framework

The overall goal of the digestion evaluation is to identify and evaluate alternatives for achieving efficient and reliable volatile solids destruction and biogas production and better control of foaming in the future, with consideration for future implementation to achieve Class A biosolids. A framework was developed to identify process alternatives for the digestion process evaluation. The following key project goals were identified for the digestion process evaluation:

- Life Cycle Operational Costs
- Capital Costs
- Ease of Operation
- Required Maintenance
- Future Flexibility

The following alternatives selected in the Phase 1 Biosolids Workshop were evaluated for improving anaerobic digestion performance by increasing volatile solids reduction and digester gas production:

- Conversion from a conventional mesophilic anaerobic digestion process to a temperature-phased (thermophilic-mesophilic) anaerobic digestion process
- Conversion from a conventional mesophilic anaerobic digestion process to an acid-gas phased anaerobic digestion process
- Addition of Thermal Hydrolysis Pretreatment

Each of the technology options listed above will be evaluated against the existing anaerobic digestion process (baseline). The performance, capital and life cycle cost projections are based on relative differences between the alternatives. The life cycle cost projections in this evaluation include cogeneration equipment for estimating power production ($/MMBTU). Alternatives for the utilization of the generated biogas are further evaluated in the Biogas Process Evaluation memorandum.

Four anaerobic digestion process alternatives were identified for the digestion evaluation **Table 11.3-4**.

Table 11.3-4: Digestion Process Alternatives

Alt #	Abbreviation	Description
1	Baseline	Maintain/upgrade mesophilic anaerobic digestion process
2	TPAD	Conversion from a conventional mesophilic anaerobic digestion process to a temperature-phased (thermophilic-mesophilic) anaerobic digestion process
3	AGMD	Conversion from a conventional mesophilic anaerobic digestion process to an acid-gas phased anaerobic digestion process

4	THP	Addition of Thermal Hydrolysis Pretreatment

Prediction of anaerobic digestion performance is currently limited to conventional mesophilic processes in the GPS-X® process model. Digestion limitations in GPS-X include:

- Temperature dependency of kinetics in the thermophilic range is currently being developed by Hydromantis.
- The impacts of low pH (Acid Phase) on VSR or gas production is not incorporated into the digestion model.
- THP can be incorporated into the model but will be based on empiric assumptions about conversion of inert organics to biodegradable.

Therefore, to evaluate the biosolids process alternatives for achieving more efficient and reliable volatile solids destruction and biogas production over mesophilic digestion, industry standards and engineering experience were used.

11.3.2 Alternative 1: Baseline Maintain/Upgrade Mesophilic Anaerobic Digestion Process

In the baseline condition, existing digesters would continue to operate in a conventional mesophilic mode with operating temperatures of 95˚F to 100˚F. The baseline condition of the HFC AWTP digestion process is shown schematically in **Figure 11.3-1**.

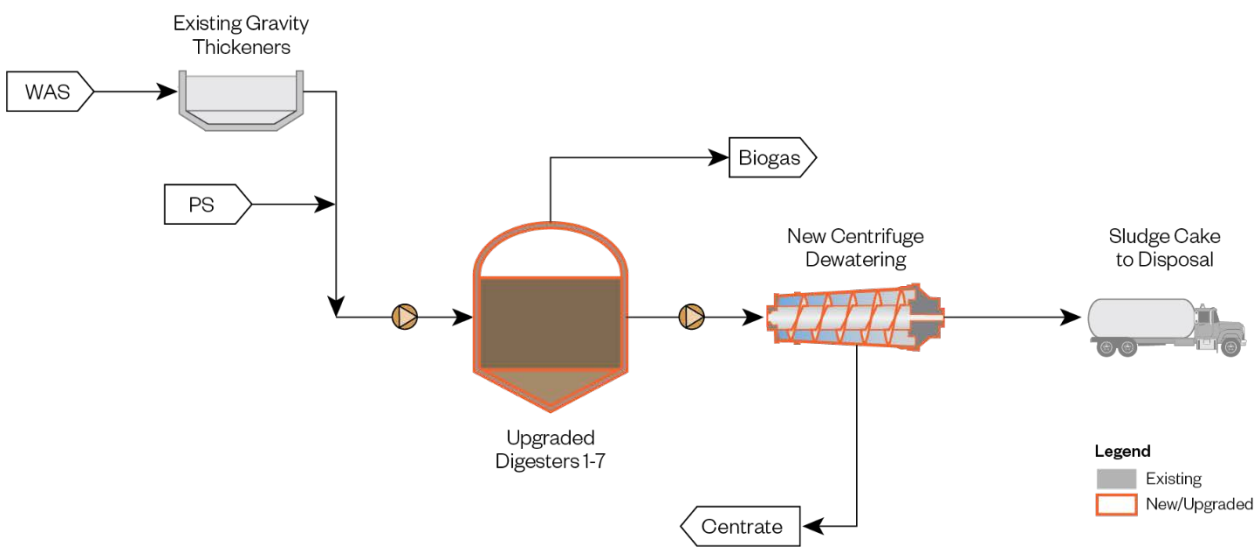


Figure 11.3-1: Solids Process Flow Schematic – Baseline Mesophilic Anaerobic Digestion

Near and long-term capital improvements are needed for the existing digester tanks, process control buildings, and process equipment. The concrete tank structures for Digesters 1 through 5 are between 45 and 65 years old. The physical structural testing, including petrographic analysis of core samples and Windsor Probe tests, to estimate the remaining useful service life of Digester Tanks 1 through 5 determined the concrete walls are in relatively good condition for their age (see **Attachment 11-A**). While vertical cracks were present throughout the structure, no other indications of a failure or distress of the concrete or the steel reinforcement were

detected during testing. Therefore, with a suitable coating to the interior and exterior walls the useful service life of the concrete can be extended. Coating the interior and exterior walls of the existing concrete tanks covers are programmed in the next 5 years of the City's capital improvements plan. In addition, replacement of Digester covers 1, 2, 4, 5 and 7 with gas holding covers are programmed in the next 5 years of the City's capital improvements plan. The Digester 6 cover was replaced in 2012 with a non-gas holding cover. However, with the replacement of covers 5 and 7 with gas-holding, there is adequate gas storage capacity as detailed in **Table 11.3-5**. The typically recommended gas holding time is between 2 to 3 hours which is met even during future maximum month flow.

Table 11.3-5: Upgraded Digestion Gas Storage Capacity

Digester #	Gas Storage Capacity, ft^3	Gas Holding Time, hours		
		Current AA	Future AA	Future Max. Month
1	22,089			
2	22,089			
3	22,089			
4	22,089			
5	35,441			
6	0			
7	47,517			
Total	171,315	4.0	2.9	2.4

The sludge heat exchangers, boilers and heated sludge recirculation pumps in all three digestion process control buildings (A, B and C) are in "poor" condition and have a remaining useful service life of less than 5 years. In addition, the building structure for buildings A and B is also in "poor" condition. Based on the condition assessment, the remaining useful life of all pumps, gas compressors, boilers and heat exchangers is less than 5 years. Rehabilitation of pumps, heat exchangers, boilers and building structures are programmed in the next 5 years of the City's capital improvements plan. The City has a desire to create a centralized heating system building with hot water loop to each of the process buildings. The cost for the centralized heating system

is included in Section 11.4 below, as an enhancement. Therefore, the replacement boilers are not included in the alternatives cost analyses.

Given a master planning horizon of 20 years, it is recommended that the following assumptions be used in evaluating upgrades and /or enhancements to digestion facilities:

1. Concrete tanks, digester covers and process equipment for Digesters 1 through 4 should be rehabilitated as needed or replaced with new infrastructure to be selected based on evaluation of potential digestion upgrades and/or enhancements.
2. Digesters 5, 6 and 7 should be retained to operate throughout the planning period.
3. Digesters 5 and 7 covers should be replaced and process equipment for Digesters 5, 6 and 7 should be rehabilitated or replaced.

For the maintain/upgrade mesophilic digestion alternative, the necessary improvements include:

- Coating of both interior and exterior of Digesters 1 through 7.
- Replacement of tank covers with gas holding covers Digesters 1, 2, 4, 5 and 7.
- Rehabilitation of gas safety equipment Digesters 1 through 7
- Replacement of mixing system Digesters 1 through 7
- Rehabilitation of structure of Digester Buildings A and B.
- Replacement of Digester Buildings A, B and C pumps, heat exchangers, condensate tanks, safety equipment, waste gas burners, and piping (sludge, gas, water and fuel).
- Replacement of mixed sludge transfer pumps
- Replacement of generator building digester gas compressor and drying system.

The recommended digestion rehabilitation and replacement phasing is detailed below:

1. The centralized heating system building, including the replacement of all the heat exchangers within Building A, B and C completed concurrently with the rehabilitation of Digester 7 and all its parts in Building C.
2. Digesters 1-4 can be rehabilitated concurrently in the dry season and meet 15-day HRT, if Digesters 5, 6 and 7 are operational. Therefore, the second project is recommended to include improvements to Digesters 1-4 while performing Building A improvements.
3. Digester 5 and Building B improvements.
4. Digester 6 and Building C improvements.

Figure 11.3-2 is a partial site plan of the solids processing facilities summarizing the maintain/upgrade mesophilic digestion alternative improvements.

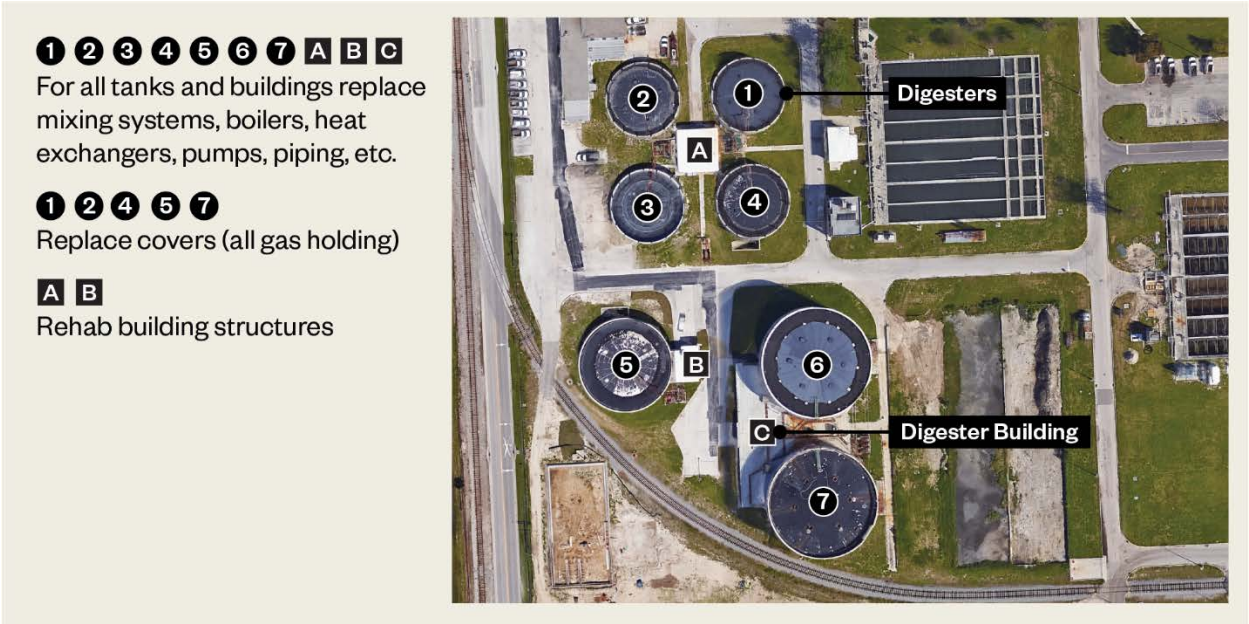


Figure 11.3-2: Site Plan – Existing HFC AWTP Solids Processing Facilities Improvements

Capital costs to maintain/upgrade baseline mesophilic anaerobic digestion are summarized in **Table 11.3-6**.

Table 11.3-6: Capital Cost Estimate Baseline Anaerobic Digestion

Parameter	Cost[1] ($)
Rehabilitation of Existing Digester Tanks	$7,879,000
Rehabilitation of Existing Digester Process Buildings	$7,120,000
Rehabilitation of Existing Mixed Sludge Pump Station	$312,000
Sum of Bare Construction Costs	**$15,311,000**
30% Contingencies	$4,593,000
Bare Construction Cost	$19,904,000
20% OH&P & GCs	$3,981,000
Total Construction Cost	**$23,885,000**
20% Management and Engineering[2]	$4,777,000
Total Capital Cost[1,2]	**$28,662,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.*
[2]*Includes COT management, legal and administrative costs.*

Operating costs for Alternative 1 were generated by accounting for major pieces of equipment electrical costs, equipment maintenance costs, and full time equivalent operator and maintenance personnel costs. All costs were projected over a 20-year period, and a yearly inflation cost of 3.0% was allocated unless otherwise specified below. For Alternative 1, the following assumptions were used to generate costs:

- Electrical cost of $0.081 per kWh with an inflation rate of 2% was projected over the 20-year period. This cost was used to determine power consumption costs for major pieces of equipment including the digester mixing system and post dewatering equipment (centrifuges). From the power demand calculations, kWh needs were determined and used to forecast power costs.
- Equipment maintenance costs associated with the digester process and post dewatering equipment were determined. A monetary cost per hourly run time was used in generating this cost.
- Post dewatering polymer consumption was determined for the projected sludge production rates. A unit cost of $2.40 per lb polymer was used in generating the post dewatering conditioning chemical cost.
- Full time equivalent operators and maintenance personnel were projected for full time operation. Average operator and maintenance labor rates for direct salary were used at $40 per hour. Two full time equivalent operators were assumed for the digestion and post dewatering operation assuming 24-hours per day, 7 days a week. An additional two full time equivalent maintenance technicians were assumed for both systems using a 40-hour work week.
- Cogeneration equipment was assumed to be used for estimating power production ($/MMBTU).
- Yearly estimates of sludge projections and the associated wet tons of cake were used to determine land application hauling and disposal costs. The current contract cost of $27.60 per wet ton was used in generating hauling and disposal costs.

Life-cycle costs of the baseline anaerobic digestion process are summarized below in **Table 11.3-7**.

Table 11.3-7: O&M Cost Estimate Baseline Anaerobic Digestion

Unit Process	Life Cycle Cost[1,2] ($)
Anaerobic Digestion Cost	$11,630,000
Post Dewatering Cost	$34,351,000
Hauling and Disposal Cost	$37,901,000
O&M Labor Cost	$24,002,000
CHP Savings[3]	($23,012,000)
Total O&M 20-Year Cost	**$84,872,000**
Total O&M 20-Year Cost Present Value	**$46,992,000**

Notes:
1. *20-year planning period*
2. *Annual general inflation rate of 3%*
3. *Based on calculations from the Biogas Utilization Evaluation*

Net operating costs (NOC), which includes both the total capital costs and total O&M costs, for the baseline option are summarized in **Table 11.3-8**. The net operating costs presented below represent the baseline against which potential long-term technology enhancements to the digestion process will be evaluated in the following sections of this TM.

Table 11.3-8: Net Operating Costs Baseline Anaerobic Digestion

	20-Year Present Value NOC ($)
Total 20-Year Net Operating Costs Present Value	**$75,654,000**

Notes:
1. *Costs are based on relative differences between digestion alternatives only.*

11.3.3 Alternative 2: Conversion to Temperature-Phased Anaerobic Digestion

In the baseline condition, existing digesters would continue to operate in a conventional mesophilic mode with operating temperatures of 95°F to 100°F. This section evaluates converting the conventional mesophilic anaerobic digestion process into a temperature-phased anaerobic digestion configuration. Temperature-phased anaerobic digestion (TPAD) consists of thermophilic digestion (131°F to 140°F) followed in series by mesophilic digestion (95°F to 100°F). The potential conversion of the HFC AWTP's digestion process to TPAD configuration is shown schematically in **Figure 11.3-3**.

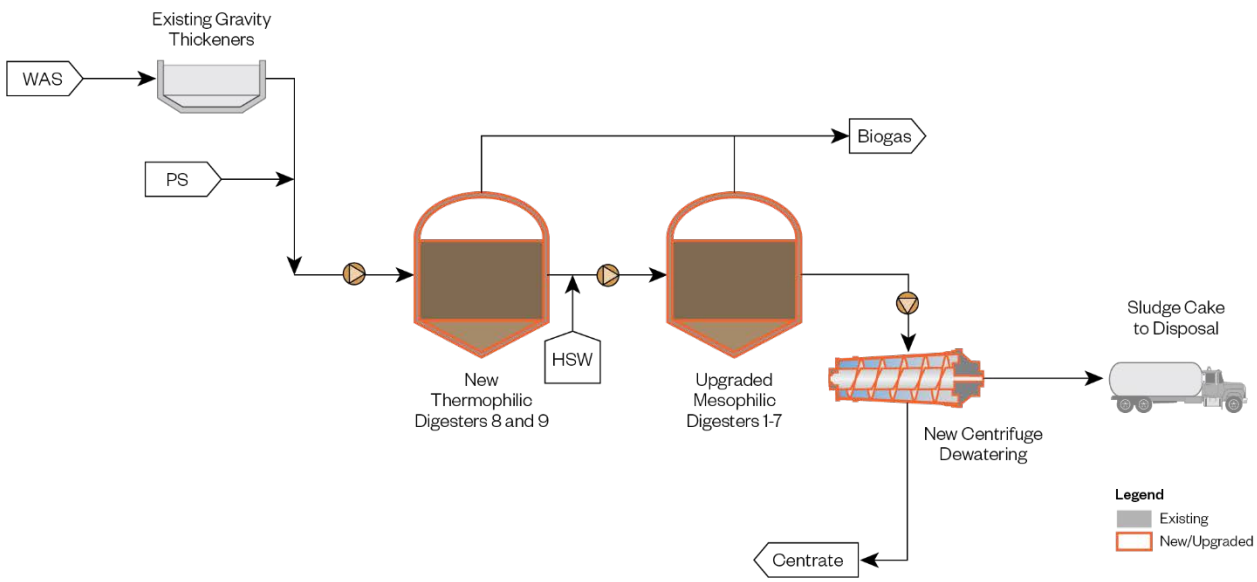


Figure 11.3-3: Solids Process Flow Schematic – Temperature-Phased Anaerobic Digestion

In temperature-phased mode, TWAS+PS would be fed to the thermophilic digesters. Partially digested sludge from the thermophilic digesters would be transferred to the mesophilic digesters. Raw fats, oils and grease (FOG) stream would be routed directly to the second-phase mesophilic digesters. Digested sludge from the anaerobic digestion complex would be transferred to the dewatering facility.

When implemented in other facilities, temperature-phased operation has increased the degradable fraction of volatile solids and has also increased digestion reactions rates. **Table 11.3-9** summarizes the differences in volatile solids reduction between mesophilic and thermophilic anaerobic digesters.

Table 11.3-9: Anaerobic Digester Volatile Solids Reduction Parameters

Criteria	Mesophilic	Thermophilic
Operating Temperature, °F/°C	95.0 / 35.0	131.0 / 55.0
Waste Activated Sludge VRS_{MAX}	58%	60% (+3%)
Methane Production, cfm	367	378 (+3%)

These parameters indicate that thermophilic conditions promote faster and more complete degradation than mesophilic conditions, resulting in an increase in both volatile solids reduction and digester gas production.

Minimum digester hydraulic retention times (HRT) required for temperature-phased operation are presented in **Table 11.3-10**.

Table 11.3-10: Minimum HRT for Temperature-Phased Anaerobic Digestion

	Average Annual Loading	Maximum Month Loading	Maximum Week Loading	
Thermophilic Minimum HRT, All in Service, days	10.0	7.5	5.0	
Mesophilic Minimum HRT, All in Service, days	20.0	15.0	10.0	
All Digesters (T + M), Minimum HRT, days	30.0	22.5	15.0	

Based on these HRT criteria, a minimum of two operating thermophilic digesters and six existing operating mesophilic digesters would be required to meet future organic loading conditions (80-MGD sludge production). In addition to the eight operating digesters, a standby digester would be required for "N+1" reliability. Therefore, conversion to a TPAD configuration would require a total of nine digesters, including the seven existing digesters and construction of two new thermophilic digesters (minimum total volume of 6.1 million gallons). Key design criteria for the new thermophilic digesters include:

- Cast-in-place concrete construction (to meet structural and temperature insulation criteria)
- Fixed digester covers (for odor control)
- Gas mixing systems (similar to existing digesters)

A new thermophilic digestion process equipment building would also be constructed to house thermophilic-to-mesophilic transfer pumps, heated sludge recirculation pumps, heat exchanger units and a sludge heat recovery system. Proposed TPAD facilities are shown in **Figure 11.3-4**.

Figure 11.3-4: Site Plan – Proposed TPAD Facilities

The combination of existing and new digester tanks would result in hydraulic residence times at future design conditions as presented in **Table 11.3-11**.

Table 11.3-11: Proposed HRT for TPAD Configuration

	Current Annual Average	Future Annual Average	Future Max. Month
All Reactors in Service			
Thermophilic Reactor HRT, days	19	14	10
Mesophilic Reactor HRT, days	28	21	15
Total HRT, days	47	35	25
One Thermophilic Reactor out of Service			
Thermophilic Reactor HRT, days	9	7	5
Mesophilic Reactor HRT, days	28	21	15
Total HRT, days	38	28	20
One Mesophilic Reactor out of Service			
Thermophilic Reactor HRT, days	19	14	10
Mesophilic Reactor HRT, days	21	16	11
Total HRT, days	40	30	21

For maximum month loading conditions, with one of the two thermophilic digesters out of service, thermophilic residence time meets the minimum recommended HRT of 5.0 days. Similarly with one of the largest mesophilic digesters out of service, mesophilic residence time meets the minimum recommended HRT of 10 days.

A sludge heat recovery system (sludge-to-sludge heat exchangers) would be provided in the thermophilic digester control building to transfer (recover) excess heat from the thermophilic sludge to “pre-heat” TWAS+PS feed to the thermophilic digesters; and cool thermophilic sludge before it enters the second-stage mesophilic digesters.

Table 11.3-12 presents a comparison of TPAD digestion and baseline digestion based on 80-MGD sludge production rates. Through implementation of TPAD, annual average VSR would increase from 58% (in baseline digestion mode) to 60% (in TPAD mode); biogas energy production would increase by 3%; and dewatered biosolids disposal quantities would decrease by 3%.

Table 11.3-12: Projected Digestion Performance with Temperature-Phased Anaerobic Digestion

Unit Process	Baseline Digestion Future AA	Temperature-Phased Digestion Future AA
Total number of digesters required	7	9
Volatile solids loading (VS %)	85%	85%
Volatile solids reduction (VSR)	58%	60%
Digester gas production, scfm	500	515
Dewatered cake solids (TS %)	22%	22%
Dewatered biosolids, wet tons/day	160	155

For the temperature-phased anaerobic digestion alternative, the necessary improvements in addition to those included for the baseline digestion facilities include:

- (2) new temperature-phased Digesters 8 and 9 including gas-holding covers, gas safety equipment, mixing systems, electrical and I&C
- (1) new Digester Building D including thermophilic sludge transfer pumps, heat exchanger equipment, heating pumps, waste gas burners, gas safety equipment, piping (sludge, gas, water and fuel), electrical and I&C

Capital costs for the conversion of the baseline digestion facilities to a temperature-phased anaerobic digestion (TPAD) process are summarized in **Table 11.3-13**.

Table 11.3-13: Capital Cost Estimate Temperature-Phased Anaerobic Digestion

Parameter	Cost[1] ($)
Rehabilitation of Existing Digester Tanks	$7,879,000
Rehabilitation of Existing Digester Process Buildings	$7,120,000
Rehabilitation of Existing Mixed Sludge Pump Station	$312,000
New Thermophilic Digester Tanks	$9,258,000
New Digester Process Building	$5,209,000
Sum of Bare Construction Costs	**$29,778,000**
30% Contingencies	$8,933,000
Bare Construction Cost	$38,711,000
20% OH&P & GCs	$7,742,000
Total Construction Cost	**$46,453,000**
20% Management and Engineering[2]	$9,291,000
Total Capital Cost[1,2]	**$55,744,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.*

[2]*Includes COT management, legal and administrative costs.*

Life-cycle costs for Alternative 2 were generated using the same methodology and assumptions as Alternative 1 accounting for two additional thermophilic digesters. O&M costs for the TPAD facilities are summarized in **Table 11.3-14**.

Table 11.3-14: O&M Cost Estimate Temperature-Phased Anaerobic Digestion

Unit Process	Life Cycle Cost[1,2] ($)
Anaerobic Digestion Cost	$15,176,000
Post Dewatering Cost	$33,345,000
Hauling and Disposal Cost	$36,619,000
O&M Labor Cost	$24,002,000
CHP Savings[3]	($23,494,000)
Total O&M 20-Year Cost	**$85,648,000**
Total O&M 20-Year Cost Present Value	**$47,422,000**

Notes:
1. *20-year planning period*
2. *Annual general inflation rate of 3%*
3. *Based on calculations from the Biogas Utilization Evaluation*

Net operating costs (total capital costs plus total O&M costs) for Alternative 2 are summarized in **Table 11.3-15**.

Table 11.3-15: Net Present Total Costs Temperature-Phased Anaerobic Digestion

	20-Year Present Value NOC ($)
Net Operating Costs, TPAD	**$103,166,000**
Baseline Anaerobic Digestion	$75,654,000
Cost Differential[1]	**$27,512,000**

Notes:
1. *Costs are based on relative differences between digestion alternatives only.*

Based on projected process performance and life-cycle costs, the following conclusions can be drawn:

- TPAD is predicted to increase average VSR from 58% to 60%.
- With the addition of two new thermophilic digesters, TPAD would not reduce 20-year net present life cycle costs even with the increased volatile solids reduction and increased biogas energy production.
- O&M cost savings for digestion, dewatering and hauling/disposal partially offset the new O&M costs for TPAD.
- New TPAD facilities require capital costs of approximately $55.7 million. Therefore, TPAD results in a net increase of approximately $27.5 million in projected 20-year present value of life cycle costs to implement TPAD.

- It is highly unlikely that increased biogas energy production and tipping fees for high strength wastes would offset the net increase of $27.5 million in projected operating costs to implement TPAD.
- Implementation of temperature-phased anaerobic digestion is not recommended.

11.3.4 Alternative 3: Conversion to Acid-Gas Phased Anaerobic Digestion

This section evaluates converting the conventional mesophilic anaerobic digestion process into an acid-gas phased anaerobic digestion configuration. Acid-gas phased anaerobic digestion (AGMD) consists of acid phase digestion, where shorter detention times favor the proliferation of acidogenic organisms producing volatile fatty acids while suppressing methanogenic growth (pH remains in weakly acidic range 5.0 to 6.0) followed in series by gas-phase digestion where longer detention times allow the methanogenic organisms to grow. The potential conversion of the HFC AWTP's digestion process to AGMD configuration is shown schematically in **Figure 11.3-5**.

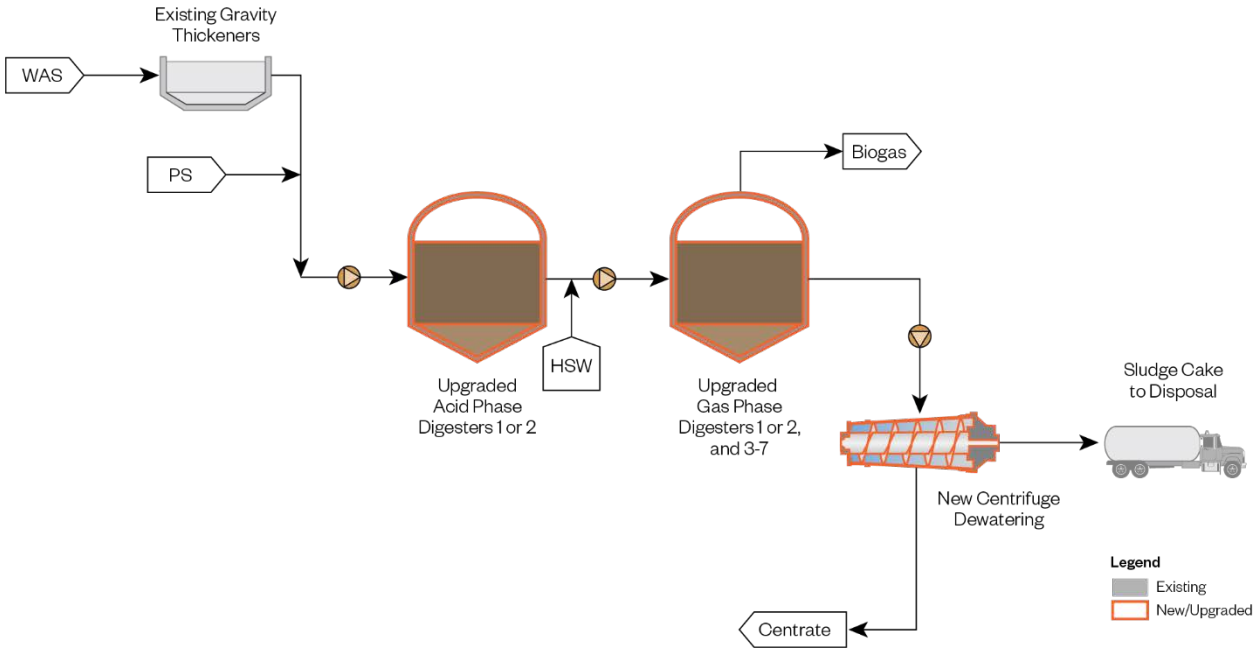


Figure 11.3-5: Solids Process Flow Schematic – Proposed AGMD Facilities

In acid-gas phased mode of operation, TWAS+PS would be fed to the acid-phase digester. Partially digested sludge from the acid-phase digester would be transferred to the gas-phase digesters. Raw fats, oils and grease (FOG) stream would be routed directly to the gas-phase mesophilic digesters. Digested sludge from the anaerobic digestion complex would be transferred to the dewatering facility.

When implemented in other facilities, acid-gas phased operation has increased the degradable fraction of volatile solids and has also increased digestion reaction rates. **Table 11.3-16**

summarizes the differences in volatile solids reduction between mesophilic and acid-gas phase anaerobic digesters.

Table 11.3-16: Anaerobic Digester Volatile Solids Reduction Parameters

Criteria	Mesophilic	Acid-Gas Phased
Waste Activated Sludge VSR_{MAX}	58%	60% (+3%)
Methane Production, cfm	367	378 (+3%)

The two-phase acid-gas digestion process was developed to provide ideal growth conditions for acid and gas producing organisms. Separation of acid and gas phases was found to improve volatile solids reduction while reducing retention time requirements. Minimum digester hydraulic retention times (HRT) required for acid-gas phased operation are presented in **Table 11.3-17.**

Table 11.3-17: Minimum HRT for Acid-Gas Phased Anaerobic Digestion

	Average Annual Loading	Maximum Month Loading	Maximum Week Loading
Acid-Phase Maximum HRT, All in Service, days	2.0	2.0	2.0
All Digesters (Acid + Gas Phase), Minimum HRT, days	20.0	15.0	10.0

Based on these HRT criteria, a minimum of one operating acid-phase digester and five existing operating mesophilic digesters would be required to meet future organic loading conditions (80-MGD sludge production). In addition to the operating digesters, a standby digester would be required for "N+1" reliability.

Digesters 1 and 2 would be configured to operate as either an acid or a gas reactor. Therefore, one of the two would be in acid-phase service to meet 2-day acid-phase HRT and the other would be in gas-phase service, being interchangeable for "N+1" acid reactor reliability. The size of the smaller existing digesters is ideal for use as acid reactors to meet the short 2-day HRT. Therefore, conversion to AGMD configuration would not require additional digesters but rehabilitation of the seven existing digesters and construction of a new interstage pump station in building A. Proposed AGMD facilities are shown in **Figure 11.3-6**.

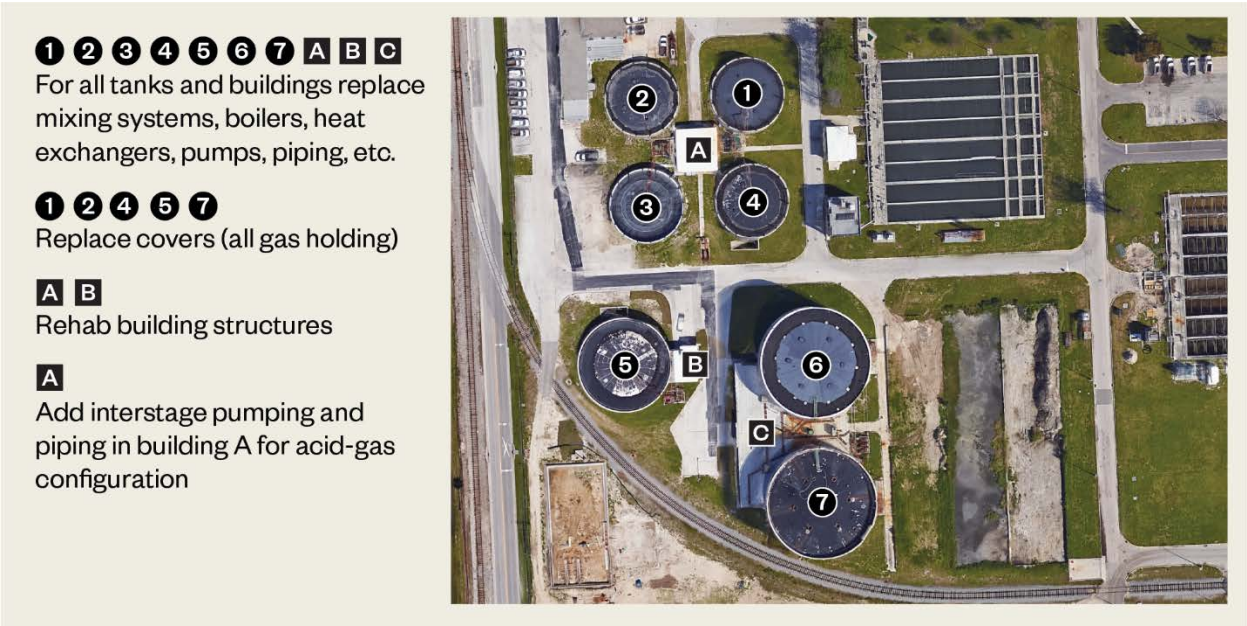


Figure 11.3-6: Site Plan – Proposed AGMD Facilities

The combination of existing tanks would result in hydraulic residence times at future design conditions as presented in **Table 11.3-18**.

Table 11.3-18: Proposed HRT for AGMD Configuration

	Current Annual Average	Future Annual Average	Future Max. Month
All Reactors in Service			
Acid Reactor HRT, days	2.3	1.7	1.2
Gas Reactor HRT, days	26	20	14
Total HRT, days	28	21	15
One Gas Reactor out of Service			
Acid Reactor HRT, days	2.3	1.7	1.2
Gas Reactor HRT, days	19	14	10
Total HRT, days	21	16	11

For future maximum month loading conditions, with one of the six gas-phase digesters out of service, residence time falls below the minimum recommended HRT of 15.0 days. Under these conditions, operations should limit maintenance activities requiring one reactor to be taken out of service.

Table 11.3-19 presents a comparison of AGMD digestion and baseline digestion based on 80-MGD sludge production rates. Through implementation of AGMD, annual average VSR would increase from 58% (in baseline digestion mode) to 60% (in AGMD mode); biogas energy production would increase by 3%; and dewatered biosolids disposal quantities would decrease by 3%.

Table 11.3-19: Projected Digestion Performance with Acid-Gas Phased Anaerobic Digestion

Unit Process	Baseline Digestion Future AA	Acid-Gas Phased Digestion Future AA
Total number of digesters required	7	7
Volatile solids loading (VS %)	85%	85%
Volatile solids reduction (VSR)	58%	60%
Digester gas production, scfm	500	515
Dewatered cake solids (TS %)	22%	22%
Dewatered biosolids, wet tons/day	160	155

For the acid-gas phased anaerobic digestion alternative, the necessary improvements in addition to those included for the baseline digestion facilities include:

- New acid-phase transfer pumps (from acid to gas phase digesters), electrical and I&C

Capital costs for the conversion of the baseline digestion facilities to acid-gas phased anaerobic digestion (AGMD) process are summarized in **Table 11.3-20**.

Table 11.3-20: Capital Cost Estimate Acid-Gas Phased Anaerobic Digestion

Parameter	Cost[1] ($)
Rehabilitation of Existing Digester Tanks	$7,879,000
Rehabilitation of Existing Digester Process Buildings	$7,120,000
Rehabilitation of Existing Mixed Sludge Pump Station	$312,000
New Interstage Pumping	$208,000
Sum of Bare Construction Costs	**$15,519,000**
30% Contingencies	$4,656,000
Bare Construction Cost	$20,175,000
20% OH&P & GCs	$4,035,000
Total Construction Cost	**$24,210,000**
20% Management and Engineering[2]	$4,842,000
Total Capital Cost[1,2]	**$29,052,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.*

[2]*Includes COT management, legal and administrative costs.*

Life-cycle costs for Alternative 3 were generated using the same methodology and assumptions as Alternative 1 accounting for interstage pumping. O&M costs for the AGMD facilities are summarized in **Table 11.3-21**.

Table 11.3-21: O&M Cost Estimate Acid-Gas Phased Anaerobic Digestion

Unit Process	Life Cycle Cost[1,2] ($)
Anaerobic Digestion Cost	$11,236,000
Post Dewatering Cost	$33,345,000
Hauling and Disposal Cost	$36,619,000
O&M Labor Cost	$24,002,000
CHP Savings[3]	($23,494,000)
Total O&M 20-Year Cost	**$81,708,000**
Total O&M 20-Year Cost Present Value	**$45,240,000**

Notes:
1. 20-year planning period
2. Annual general inflation rate of 3%
3. Based on calculations from the Biogas Utilization Evaluation
3. Based on calculations from the Biogas Utilization Evaluation

Net operating costs (total capital costs plus total O&M costs) for Alternative 3 are summarized in **Table 11.3-22**.

Table 11.3-22: Net Operating Costs Acid-Gas Phased Anaerobic Digestion

	20-Year Present Value NOC ($)
Net Operating Costs, AGMD	**$74,292,000**
Baseline Anaerobic Digestion	$75,654,000
Cost Differential[1]	**($1,362,000)**

Notes:1. Costs are based on relative differences between digestion alternatives only.

Based on projected process performance and life-cycle costs, the following conclusions can be drawn:

- AGMD is predicted to increase average VSR from 58% to 60%.
- Through increased volatile solids reduction, increased biogas energy production and reduced dewatered cake to haul, AGMD would reduce 20-year present value costs by approximately $1.36 million.
- Capital costs of approximately $0.4 million to construct the new interstage pump station in building A for acid-phase does not exceed the projected O&M savings.
- The City should weigh the short payback period for investment in new infrastructure when considering whether or not to convert from baseline anaerobic digestion to acid-gas phased anaerobic digestion.

11.3.5 Alternative 4: Addition of Thermal Hydrolysis Pretreatment to Baseline Anaerobic Digestion

This section evaluates the addition of thermal hydrolysis pretreatment (THP) to the conventional mesophilic anaerobic digestion process configuration. THP could be added prior to anaerobic digestion at the HFC AWTP. The process would significantly increase volatile solids reduction across the digesters, reduce post digested sludge mass, and improve post digested sludge dewaterability resulting in much lower hauling costs. Because THP reduces WAS viscosity, it is expected that the anaerobic digesters could be operated with a feed concentration of 8-10% TS. Increasing the digester feed sludge concentration could potentially allow anaerobic digestion to be consolidated to three mesophilic digesters. Thermal hydrolysis pretreatment facilities proposed under this scenario would be preceded by a new sludge screenings process to remove small trash/debris and a new pre-dewatering process to concentrate the feed sludge. The pre-dewatering facility would consist of centrifuges, cake pumps and polymer storage and feed facilities. The cake pumps would transfer pre-dewatered WAS to a sludge hopper prior to introduction to the pulper tank. The polymer storage and feed facilities would consist of polymer make up units, polymer aging tanks, recirculation pumps and diluted polymer feed pumps.

The potential conversion of the HFC AWTP's digestion process to THP configuration is shown schematically in **Figure 11.3-7**.

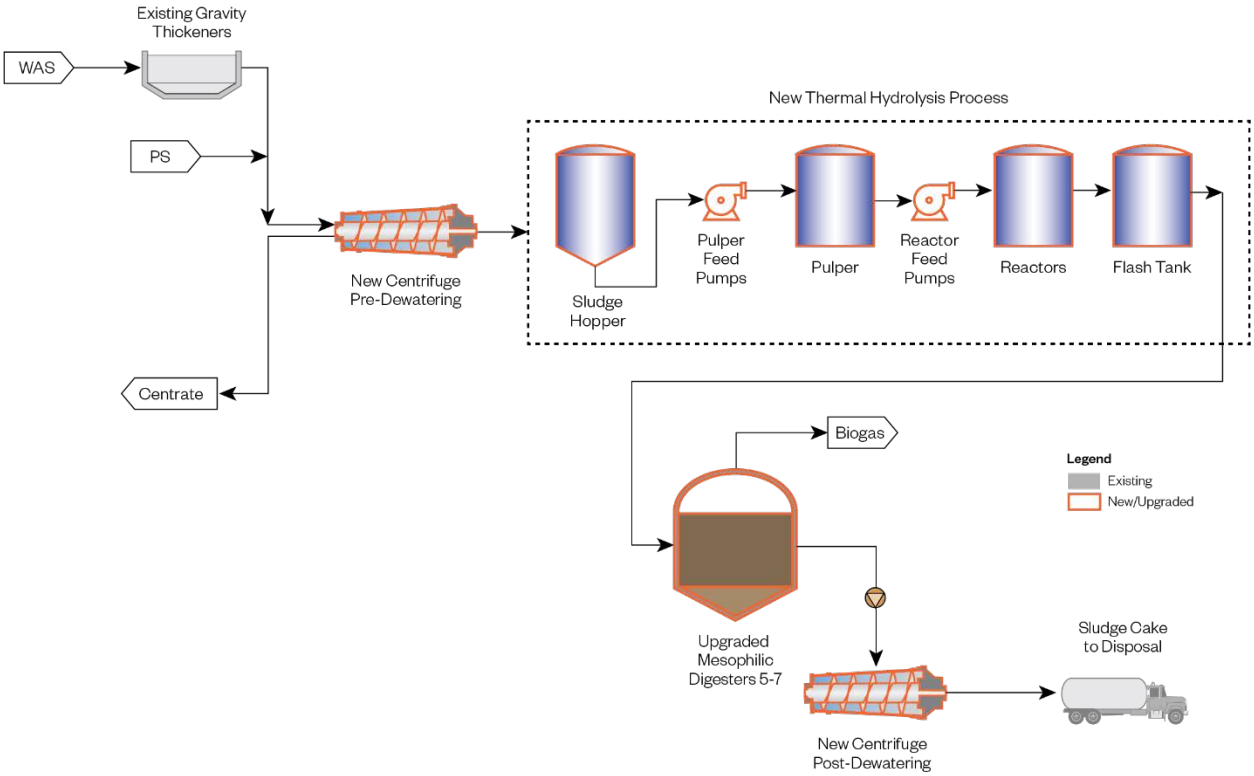


Figure 11.3-7: Solids Process Flow Schematic – Proposed THP Anaerobic Digestion Facilities

Thermal hydrolysis processes generally expose partially dewatered biological wastewater treatment residuals to a combination of high temperature and high pressure for a fixed time period such that the cellular wall structure in the residuals is fractured and soluble organic material contained within the cells is made bio-available as a substrate in downstream digestion unit treatment processes. There are several THP system providers. The CAMBI® thermal hydrolysis process has the largest installation base and was assumed for this evaluation. The graphic below **Figure 11.3-8** shows the main process components and the results of CAMBI® thermal hydrolysis process.

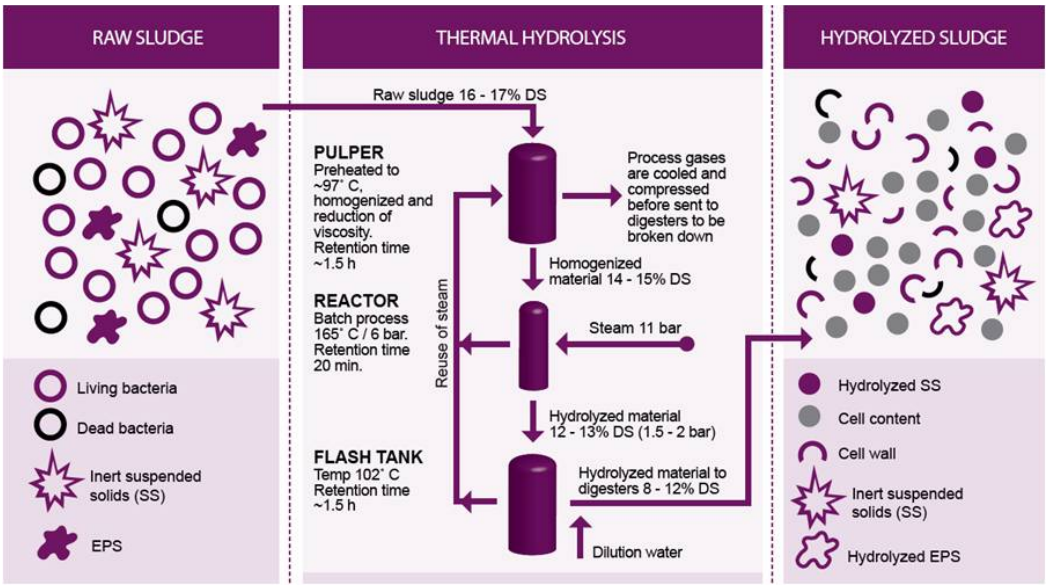


Figure 11.3-8: CAMBI's Thermal Hydrolysis Process (www.cambi.no)

The CAMBI® thermal hydrolysis portion of the process includes the following components:

- Pulper tank to pre-heat the incoming sludge using recycled steam which also serves to decrease the viscosity of the sludge
- Pulper recirculation and reactor feed pumps to ensure a homogenous mixture in the pulper and consistent feed to the reactor tanks
- Dual-fired (digester gas and natural gas) boiler to produce the steam for the hydrolysis process
- Reactor tanks where the incoming sludge is pressurized and heated further using more steam to provide the batch holding time to lyse the cells
- Flash tank where pressure of the hydrolyzed sludge is relieved and the steam is recycled to pre-heat the incoming sludge
- Digester feed pumps transfer the hydrolyzed sludge to the sludge to water heat exchangers at the digestion process for cooling or heating as required
- Foul gas from the pulper tank is treated and routed to the digester for inclusion with the digester gas

- Process water is supplied for dilution as necessary in the pulper tank or prior to the digester feed pumps. It is also supplied for the foul gas treatment

The CAMBI® system proposed for this application was based on the design criteria summarized in **Table 11.3-23**.

Table 11.3-23: Thermal Hydrolysis System Design Criteria

Parameter	Current Annual Average	Future Annual Average	Future Max. Month
Solids Loading, dT/D	50	70	88
Feed Sludge Solids Concentration	16%	16%	16%
Feed Volume, gpd	75,600	104,555	131,520
Number of Reactors	3	3	3
Hydrolyzed Sludge Solids Concentration (After dilution)	8.8%	8.8%	8.8%

Notes dT/d = dry tons per day; gpd = gallons per day

When implemented in other facilities, the addition of thermal hydrolysis pretreatment has increased the degradable fraction of volatile solids and has also increased digestion reactions rates. **Table 11.3-24** summarizes the differences in volatile solids reduction between mesophilic and THP anaerobic digestion facilities.

Table 11.3-24: Anaerobic Digester Volatile Solids Reduction Parameters

Criteria	Mesophilic	THP + Mesophilic
Waste Activated Sludge VRS_{MAX}	58%	63% (+8%)
Methane Production, cfm	367	400 (+9%)

Based on the HRT criteria, a minimum of two existing operating mesophilic digesters would be required to meet future organic loading conditions (80-MGD sludge production). In addition to the operating digesters, a standby digester would be required for “N+1” reliability.

Therefore, conversion to THP configuration would not require additional digesters but rehabilitation of three existing digesters (5, 6 and 7) and construction of new thermal hydrolysis pretreatment and pre-dewatering facilities. Proposed THP facilities are shown in **Figure 11.3-9**.

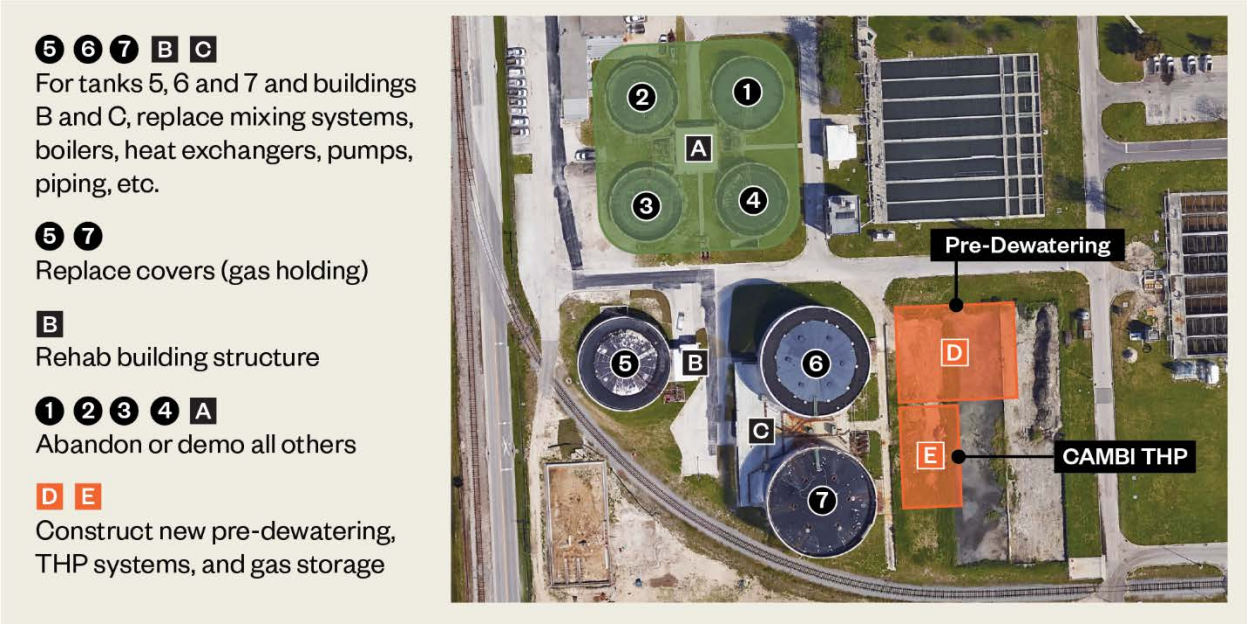


Figure 11.3-9: Site Plan – Proposed THP Facilities

The combination of existing and new digester tanks would result in hydraulic residence times at future design conditions as presented in **Table 11.3-25**.

Table 11.3-25: Proposed HRT for THP Configuration

	Current Annual Average	Future Annual Average	Future Max. Month
All Reactors in Service			
Total HRT, days	43	32	23
One Reactor out of Service			
Total HRT, days	26	20	14

For future maximum month loading conditions, with one of the three digesters out of service, residence time falls below the minimum recommended HRT of 15.0 days. Under these conditions, operations should limit maintenance activities requiring one reactor to be taken out of service.

Table 11.3-26 presents a comparison of THP digestion and baseline digestion based on 80-MGD sludge production rates. Through implementation of THP, annual average VSR would increase from 58% (in baseline digestion mode) to 63% (in THP mode); biogas energy production would increase by 9%; and dewatered biosolids disposal quantities would decrease by 36%.

Table 11.3-26: Projected Digestion Performance with THP Anaerobic Digestion

Unit Process	Baseline Digestion	THP Digestion
Total number of digesters required	7	3
Volatile solids loading (VS %)	85%	85%
Volatile solids reduction (VSR)	58%	63%
Digester gas production, scfm	500	545
Dewatered cake solids (TS %)	22%	30%
Dewatered biosolids, wet tons/day	160	108

For the thermal hydrolysis pretreatment aneraboic digestion (THP) alternative, the necessary improvements include:

- Coating of Digesters 5, 6 and 7 interior and exterior.
- Replacement of tank covers with gas holding covers Digesters 5 and 7.
- Rehabilitation of gas safety equipment Digesters 5, 6 and 7.
- Replacement of mixing system Digesters 5, 6 and 7.
- Rehabilitation of structure of Digester Building B.
- Replacement of Digester Buildings B and C pumps, heat exchangers, condensate tanks, safety equipment, waste gas burners, and piping (sludge, gas, water and fuel), electrical and I&C.
- Replacement of mixed sludge transfer pumps.
- Replacement of generator building digester gas compressor and drying system.
- New Pre-Screening and Pre-Dewatering Building including dewatering centrifuges, polymer feed system, feed pumps, cake pumps, cake discharge hopper with outlet conveyor, and truck loading conveyor, screening feed well, feed pumps, press screens, discharge well, transfer pumps, screenings room, equipment building, piping, HVAC, electrical and I&C.
- New THP equipment (CAMBI B6-3 reactor system), post-CAMBI heat exchanger, concrete slab for THP equipment and Steam Generation Building, piping, HVAC electrical and I&C.

Capital costs for the conversion of the baseline digestion facilities to the THP anaerobic digestion process are summarized in **Table 11.3-27**.

Table 11.3-27: Capital Cost Estimate THP Anaerobic Digestion

Parameter	Cost[1] ($)
Rehabilitation of Existing Digester Tanks	$4,155,000
Rehabilitation of Existing Digester Process Buildings	$5,539,000
Rehabilitation of Existing Mixed Sludge Pump Station	$312,000
New Screening and Pre-Dewatering Facility	$18,174,000
New THP Facility	$16,864,000
Sum of Bare Construction Costs	**$45,044,000**
30% Contingencies	$13,513,000
Bare Construction Cost	$58,557,000
20% OH&P & GCs	$11,711,000
Total Construction Cost	**$70,268,000**
20% Management and Engineering[2]	$14,054,000
Total Capital Cost[1,2]	**$84,322,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

Life cycle costs for Alternative 4 were generated using the same methodology and assumptions as Alternative 1 accounting for additional pre-screening, pre-dewatering, THP and sludge transfer pumps. The full time equivalent operators were increased to 2.3 to account for the additional pre-dewatering and THP process oversight. O&M costs for THP anaerobic digestion are summarized in **Table 11.3-28**.

Table 11.3-28: Net Present Costs of Annual O&M Costs THP Anaerobic Digestion

Unit Process	Life Cycle Cost[1,2] ($)
Pre-Dewatering	$25,633,000
Thermal Hydrolysis Pretreatment	$8,922,000
Anaerobic Digestion Cost[3]	$9,294,000
Post Dewatering Cost[3]	$27,680,000
Hauling and Disposal Cost	$24,171,000
O&M Labor Cost	$26,911,000
CHP Savings[3]	($25,086,000)
Total O&M 20-Year Cost	**$97,525,000**
Total O&M 20-Year Cost Present Value	**$53,998,000**

Notes:1. 20-year planning period
2. Annual general inflation rate of 3%
3. Based on calculations from the Biogas Utilization Evaluation

Net operating costs (total capital costs plus total O&M costs) for Alternative 4 are summarized in **Table 11.3-29**.

Table 11.3-29: Net Operating Costs THP Anaerobic Digestion

	20-Year Present Value NOC ($)
Net Operating Costs, THP	**$138,320,000**
Baseline Anaerobic Digestion	$75,654,000
Cost Differential[1]	**$62,666,000**

Notes:1. Costs are based on relative differences between digestion alternatives only.

Based on projected process performance and life-cycle costs, the following conclusions can be drawn:

- THP is predicted to increase average VSR from 58% to 63%.
- THP reduces the required number of operating digesters from seven to three while significantly improving volatile solids reduction and dewatered cake solids content. As such THP significantly reduces digestion, dewatering and hauling costs.
- O&M cost savings for digestion, dewatering and hauling/disposal do not offset new O&M costs for pre-dewatering/THP facilities.
- New pre-dewatering and THP facilities require capital costs of approximately $84.3 million. THP results in a net increase of approximately $62.7 million in net operating costs.

- It is highly unlikely that increased biogas energy production and tipping fees for high strength wastes would offset the net increase in net operating costs to implement THP.
- Implementation of thermal hydrolysis pretreatment is not recommended.

11.3.6 Summary of Digestion Alternatives Costs

The net operating cost for the alternatives evaluated for improving anaerobic digestion performance over a 20-year planning period ranged from $76.5 million to $139.5 million as summarized in **Table 11.3-30**.

Table 11.3-30: Summary of Anaerobic Digestion Alternatives Present Value

Digestion Alternative	Alternative 1: Upgraded Mesophilic	Alternative 2: TPAD	Alternative 3: Acid-Gas Phased	Alternative 4: THP + Meso
Total Capital Cost ($)	$28,662,000	$55,744,000	$29,052,000	$84,322,000
Total O&M 20-Year Cost Present Value	$46,992,000	$47,422,000	$45,240,000	$53,998,000
Total 20-Year Cost Present Value	$75,654,000	$103,166,000	$74,292,000	$138,320,000

11.3.7 Alternatives Evaluation

Scoring Alternatives

At the onset of the project, several goals were identified. These included the following:

- Life Cycle Operational Costs
- Capital Costs
- Ease of Operation
- Required Maintenance
- Future Flexibility

It is imperative that each of these goals are considered when selecting between viable alternatives. Some of these goals / criteria can be readily quantified. Others are more qualitative and subjective in nature. One method for evaluating quantitative and qualitative criteria is to use a comparison matrix with weighted decision factors. Multiple discussions with City staff resulted in the development of a decision matrix. **Table 11.3-31** is the matrix with weighting of decision factors and scoring for each alternative. The scoring system is based on a scale of 1 to 10 with 10 being the most preferred option. Life cycle operational costs includes all energy usage.

Table 11.3-31: Digestion Alternatives Decision Matrix

Digestion Process Alternative	Alternative #		Preliminary Ranking of Alternatives for Screening					
		Weight %	25%	25%	20%	20%	10%	100%
		Factors	Life Cycle Operational Costs	Capital Cost	Ease of Operation	Required Maintenance	Future Flexibility	Total Score
Upgraded Meso	**1**	Scores	9.5	10.0	10	10	6	7.5
TPAD	**2**		9.5	5.4	8	8	8	6.1
Acid-Gas	**3**		10.0	10.0	9	9	6	7.4
THP + Meso	**4**		8.2	3.6	5	4	10	4.8

As can be seen from the matrix, Alternatives 2 and 4 are the lowest ranked alternatives, and were removed from further consideration. Alternative 3 (Acid-Gas) and Alternative 1 (Upgraded Meso) had the highest and very similar scores of 7.4 and 7.5, respectively. As a result, either option is a good fit for the City. If the Acid-Gas alternative is chosen, it is recommended that the design include consideration for infrastructure to easily convert back to Upgraded Mesophilic (baseline).

11.4 Centralized Heating System Enhancement

An enhancement to the biosolids system is a centralized heating system located in a new boiler Building D. The centralized heating system will be used to heat all digesters and includes new boilers, air separator, expansion tank, primary hot water loop pumps, feed tank, new heat exchangers with the ability to use natural gas or digester gas (located within Buildings A, B and C), hot water pipeline to Buildings A, B and C, and a new natural gas pipeline connection. The boiler building enhancement cost estimate is summarized in **Table 11.4-1**.

Table 11.4-1: Capital Cost Estimate Centralized Digester Heating System

Parameter	Cost[1] ($)
Centralized Digester Heating System	$2,313,000
Sum of Bare Construction Costs	**$2,313,000**
30% Contingencies	$694,000
Bare Construction Cost	$3,007,000
20% OH&P & GCs	$601,000
Total Construction Cost	**$3,608,000**
20% Management and Engineering[2]	$722,000
Total Capital Cost[1,2]	**$4,330,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of 50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.

11.5 Dewatering Facility

The Phase 1 Technical Memorandum noted that an assessment of the dewatering system has previously been completed, and a new dewatering project has been recommended. The 2013 Biosolids Dewatering Pilot Testing Summary Report provided the recommendation to install a new dewatering system based on the use of centrifuges and to continue to dispose of biosolids through Class B land application due to the significant cost savings as compared with other disposal options. Short interruptions in availability of land application sites can be handled by one repaired train of the heat drying system. The associated cost estimate provided is summarized in **Table 11.5-1** which includes centrifuges, grinders, feed pumps, conveyors, piping, polymer system, electrical and I&C.

Table 11.5-1: Construction Cost Estimate Biosolids Dewatering Facility

Parameter	Cost[1] ($)
Dewatering Facility Building (including centrifuges, grinders, feed pumps, conveyors, piping, polymer system, electrical and I&C)	$6,923,000[3]
Sum of Bare Construction Costs	**$6,923,000**
30% Contingencies	$2,077,000
Bare Construction Cost	$9,000,000
20% OH&P & GCs	$1,800,000
Total Construction Cost	**$10,800,000**
20% Management and Engineering[2]	$2,160,000
Total Capital Cost[1,2]	**$12,960,000**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.
[2]Includes COT management, legal and administrative costs.
[3]Escalated at a 3% interest rate from Biosolids Dewatering Pilot Testing Summary and Comparison of Performance Report, 2013

The Phase 1 Technical Memorandum recommended that location options be explored for the new dewatering building based on the findings of the Phase 2 Master Plan efforts. The Upgraded Mesophilic or Acid-Gas Phased Digestion alternatives will have little impact on the overall downstream biosolids processing. Therefore, it is recommended to locate the new dewatering building near the existing dewatering building. This will simplify maintenance of plant operations during construction of the new facility, allows for continued use of the existing sludge holding tanks and sludge drying beds, is in close proximity to the heat dryers if brought back online, and limits traffic within the plant site.

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Attachment 11-A: Digester Structural Testing

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Report of

Structural Testing Program

Digester 2

H.F. Curren Advanced Waste Water Treatment Plant

Tampa, Florida

May 1, 2017

Ardaman Project No. 17-54-9482

Ardaman & Associates, Inc.

Geotechnical, Environmental and Materials Consultants

3925 Coconut Palm Drive, Suite 115, Tampa, FL 33619 (813) 620-3389

Ardaman & Associates, Inc.

Geotechnical, Environmental and
Materials Consultants

May 1, 2017
Ardaman Project No. 17-54-9482

McKim & Creed
1365 Hamlet Avenue
Clearwater, FL 33756

Attention: Mr. Mitchel Chiavaroli

Subject: Report of Structural Testing Program
Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Tampa, Florida

Dear Mr. Chiavaroli:

Ardaman and Associates, Inc. has completed the requested concrete testing for the above mentioned tank structure. These services were completed in general accordance with our Proposal No. 16-p242.

Project Information

Project information was provided via email correspondence between July 2016 and February 2017. We understand that Digester 2 of the wastewater treatment plant is approximately 80 feet in diameter, and was constructed of concrete in the early 1970s. The wastewater treatment plant is presently undergoing the development of a Master Plan for future work at the facility. As part of the Master Plan development, the structural testing program of Digester 2 was requested to ascertain the condition of the existing concrete and to obtain an idea as to the remaining useful life of the concrete structure.

Scope of Services

Ardaman was requested to perform a series of tests that included both destructive and non-destructive testing of the tank wall. The testing program included the following services:

1. Extraction of five core samples from the concrete tank walls. The nominal 4 inch diameter cores were taken from the inside face of the tank and drilled 8 to 10 inches into the wall. The core samples were utilized for the following:

    a. Three cores were tested for compressive strength in general accordance with *ASTM C42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*.
    b. A portion of the fourth core (the core was cut in half longitudinally) was utilized for testing in accordance with *ASTM C642, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*.
    c. The remaining portion of the fourth core was sliced into approximate 1-½ inch thick wafers, starting from the surface of the core. The wafers were submitted to TEC Services in Lawrenceville, Georgia for chloride testing and pH determination. Chloride testing was performed with the Germann Instruments Rapid Chloride Test, Water and Acid Soluble Methods.
    d. The fifth core was evaluated with petrographic methods in general accordance with *ASTM C856, Standard Practice for Petrographic Examination of Hardened Concrete*.

2. Half-cell potential testing was performed about the inside circumference of the exposed tank wall. Testing was conducted in general accordance with *ASTM C876 – Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete.*

3. Non-destructive rebound hammer testing was performed at various points about the perimeter of the tank. The testing was performed in general accordance with *ASTM C805, Standard Test Method for Rebound Number of Hardened Concrete.*

Field Services

To perform the field services, treatment plant personnel had lowered the floating cover of the digester to its lowest point, thus exposing 8 to 10 feet of the inside face of the wall from the top of the cover. All testing was performed on this exposed portion of the walls. The field services consisted of both destructive and non-destructive testing. Prior to the commencement of testing, Ground Penetrating Radar (GPR) scans were made of the areas where cores were to be extracted from, as well as the location for the grounding of the half-cell potential system. The GPR scans at the coring locations were used to indicate the locations of the steel reinforcement to maximize the chance that no reinforcing steel would be cut during the coring process (Photo 1). The location where the reinforcement was exposed for grounding of the half-cell system is shown in Photo 2. The core locations and the area where the reinforcing steel was exposed to provide a grounding point for the half-cell potential testing were patched with a non-shrink cementitious grout, SikaGrout 212.

Non-Destructive Testing

Half-Cell Potential Testing

Half-cell potential testing was performed along the entire perimeter of the interior tank wall. Prior to testing, the walls of the tank had to be scraped of all the build-up to allow contact between the reference cell and the concrete (Photo 3). A grid was then made along the interior of the tank with the test locations separated at 4 ft. intervals vertically, and 2.5 ft. intervals horizontally.

The half-cell potential data obtained during testing were interpolated using the computer program Surfer 8, which generated an equipotential contour map of the surface of the concrete. The equipotential contour map is presented in attached Figure 1. Please note that the areas marked in red are locations where the half-cell potential values were positive. These areas corresponded to locations where lighting and electrical wires were mounted to the walls of the tank, and the resulting positive values are likely due to stray currents being present at these locations.

Rebound Hammer Testing

A total of eight areas were tested using the rebound hammer. The areas chosen were the north, northeast, east, southeast, south, southwest, west, and northwest points on the tank relative to the magnetic north of a compass, and testing was performed with the hammer. The results of the rebound hammer testing may be found in Table 1 below.

Table 1. Digester 2 Rebound Numbers.

Zone	North	North-east	East	South-east	South	South-west	West	North-west
Rebound Number	53	52	56	55	54	54	51	55

The rebound hammer method covers the determination of a rebound number of hardened concrete using a spring-driven steel pin. The test method is applicable to assess the in-place uniformity of concrete, to delineate regions in a structure of poor quality or deteriorated concrete, and to estimate in-place strength development.

Destructive Testing

Concrete Coring

A total of five nominal 4-inch diameter cores were extracted from the tank walls, using the hydraulic core machine shown in Photo 4. The cores were cut to a nominal length of 8+ inches to prevent penetrating the entire thickness of the tank walls. One core was extracted from the west and east walls of the tank, while three cores were extracted from the southern portion of the tank. The cores were used for laboratory testing of the concrete comprising the tank walls.

Visual Inspection

A visual inspection/sounding was performed on the walls of the tank during the testing program. No areas were present along the tank walls where rust was observed weeping through cracks in the concrete, nor were any areas present where spalling has occurred or appears imminent of occurring. The steel exposed for half-cell potential testing (Photo 2) appeared to be free from any significant corrosion. Despite the lack of visible distress to the tank walls from corrosion, numerous vertical cracks were observed in the tank walls that appear to penetrate to the tank exterior in some area. Photos 5 through 26 show some of the vertical cracking that was observed on both sides of the tank walls. This vertical cracking was noted to generally be located near the top of the tank walls and extended down only a portion of the walls before no longer being visible. The wider portion of the cracks such as that seen in Photos 6, 9, 12 and 15 were at the top of tank wall. Crack widths ranged from hairline to 0.05 inches in width.

Laboratory Testing

At the conclusion of the field activities, the core samples were returned to our laboratory where they were assigned to various tests.

Core Carbonation

Carbonation occurs in concrete when the calcium hydroxide found in concrete reacts with carbon dioxide which is normally found in the air to form calcium carbonate. Normal carbonation results in a decrease in porosity, making carbonated paste stronger. Carbonation can be considered an advantage to

non-reinforced concrete. However, fresh cement paste typically has a pH of at least 12.5 and that of fully carbonated paste on the order of 7. With the drop in pH, carbonation changes the beneficial properties of reinforced concrete. As the pH drops, the normal passive protection provided to the reinforcing steel by the high alkaline environment is lost, making is susceptible to corrosion. Carbonation can also cause surface crazing and cracking.

A phenolphthalein indicator solution was used to evaluate all of the cores to indicate areas where the pH value is greater than 10 by dying the object purple. The testing concluded that the depth of carbonation of the cores was less than $^1/_8$ inch (surficial) in all cases. A summary of the carbonation depths of the core may be found in Table 2 below.

Table 2. Depth of Carbonation.

Core	Carbonation Depth (in)
C-01	$^1/_8$
C-02	Negligible
C-03	Negligible
C-04	$^1/_8$
C-05	$^1/_8$

Compressive Strength Testing

Three of the concrete cores were placed in sealed bags and returned to the office to allow the moisture content of the samples to come to equilibrium ("Moisture Conditioning"). The samples were then trimmed and capped for testing. The average compressive strength of the extracted cores was 6,040 psi. The results of the compressive strength testing may be found in Table 3 below, with the complete results presented in the appendix.

Table 3. Concrete Core Compressive Strength Results

Core	Compressive Strength (psi)
C-01	5,260
C-02	6,140
C-03	6,710

Chloride and pH Testing

A portion of Core C-04 was sliced into two 1 ½ inch wafers and tested for chloride content and pH value. The results of the chloride and pH testing may be found in Table 4 below.

Table 4. Chloride and pH Results

Core No.	Depth (in)	Water Soluble Chlorides (%)	Acid Soluble Chlorides (%)	pH
4	0 to 1 ½	0.003	0.003	12.46
	1 ½ to 3	0.002	0.002	12.54

Density, Absorption, and Voids

The other portion of Core C-04 was used for the determination of the Density, Absorption, and Voids of the concrete. The results of this testing may be found in Table 5 below.

Table 5. Density, Absorption and Voids Summary for the Concrete Cores

Core	Absorption After Immersion	Absorption After Immersion & Boiling	Dry Bulk Density (pcf)	Bulk Density After Immersion (pcf)	Bulk Density After Immersion & Boiling (pcf)	Apparent Density (pcf)	Volume of Permeable Pore Space
C-04	5.4%	5.3%	139.7	147.3	147.1	158.3	11.8

Petrographic Testing

One core, C-05, was subjected to petrographic analyses. The core was cut longitudinally in half and the cut surface was polished. The sample was then observed with a stereo microscope under magnifications ranging from 7x to 45x. A summary of the petrographic testing may be found below, with the full results presented in the appendix of this report.

<u>Core C-05</u>

- Nominal maximum particle size is ¾ inch graded down to ¼ inch
- Volume of coarse aggregate appears reasonable
- Coarse aggregate is relatively well distributed
- Aggregate-paste bond is good
- Fine aggregate particle size is ⅛ inch graded down to fine sand sizes
- No measureable carbonation was observed in the concrete.
- Air voids estimated to be at 0.5 to 1%
- Some minor surface erosion was noted, along with some staining of the surface from the sludge (Struvite formation) that penetrated the concrete at some locations up to ½ inch.

In summary the concrete in Core C05 was judged to be of relatively good quality. No cracking or other distress was observed in the sample. There was only one indication of an adverse reaction in the coarse aggregates utilized in the concrete. This reaction was considered slight and was deep in the concrete section, with the concrete having no adverse effects from the reaction. The presence and slight penetration of the struvite crystals has not adversely affected the concrete in the sample observed. The concrete was estimated to have a low to moderate water cement ratio.

Discussion

Half-Cell Potential Testing

During the half-cell potential testing a total of 279 readings were taken. ASTM C879 states that "If potentials over an area are more positive than -0.20 V CSE, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement." The ASTM also states that "If potentials over an area are in the range of -0.20 to -0.35V CSE, corrosion activity of the reinforcing steel in that area is uncertain." and "If potentials over an area are more negative than -0.35 V CSE, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement."

Of all the areas tested, only 22 locations were more negative than -0.20 V CSE, representing 8% of the tested area, and no recorded value was less than -0.35 V CSE. The results of the half-cell potential testing suggest that no significant steel corrosion is occurring within the tank walls within the area tested.

Rebound Hammer Testing

The eight rebound hammer tests ranged in value from a low of 51 to a high 56, with an average value of 54 and a standard deviation of 1.7. Six of the eight tests were essentially within one standard deviation of the average value. The rebound hammer testing suggests that the concrete walls of the tank are composed of concrete with uniform properties.

Visual Inspection

The visual inspection/sounding did not indicate any signs of distress to the tank walls such as spalling or discoloration that might indicate corrosion occurring in the embedded reinforcing steel. A significant number of vertical cracks were present in the tank walls. The cause of the cracking is not apparent, however based on the uniformity of it about the circumference of the tank it may be a result of shrinkage within the concrete. While the cracks are abundant, they do not appear as yet, to be accelerating the rate of corrosion of the steel reinforcement, nor have they yet to cause any significant leaking of the tank.

Core Carbonation

The carbonation testing performed on the extracted cores yielded a carbonation depth of $^1/_8$ inch or less from the surface of the cores. Given the age of the tank, carbonation of the concrete is not likely to be an issue in the foreseeable future.

Compressive Strength Testing

The compressive strength values of the extracted cores varied from 5,260 psi to 6,710 psi, with an average strength of 6,040 psi. No cracking or spalling was observed in the concrete cores used for compressive strength testing, indicating that the concrete is of sound quality.

Density, Absorption, and Voids

The density, absorption and voids testing of the concrete concluded that the properties of the tank walls fall within the expected range for normal weight concrete. The volume of permeable pore space (voids) in the concrete of 11.8 percent is relatively low for concrete comprised of local aggregates and is an indicator of a low water-cement ratio of the concrete.

Chloride and pH Testing

An indicator of a concrete material's ability to protect the reinforcing steel embedded in the concrete is to look at the chloride ion to hydroxyl ion ratio (Cl^-/OH^-). A $Cl^-/OH^- \geq 0.6$ indicates that the concrete has lost its naturally occurring protection for corrosion of reinforcing steel as referenced in ACI Publication SP-49, "Corrosion of Metal in Concrete". It should be noted that a ratio greater than or

equal to 0.6 does not mean that the steel is corroding; however the concrete has lost its ability to protect the reinforcing steel. As can be seen in the Table 6, the chloride to hydroxyl ion ratios indicate that the concrete is still providing its naturally occurring protection for corrosion of reinforcing steel.

Table 6 – Chloride Ion to Hydroxyl Ion Ratio

Core No.	Depth From Surface, in.	pH	Cl^- (%)	Cl^-/OH
C-04	0 to 1 ½	12.46	0.003	0.03
C-04	½ to 3	12.54	0.002	0.02

FDOT Standard Specification for Road and Bridge Construction, 2010 Edition indicates the maximum allowable chloride content in reinforced concrete is as follows:

Slightly Aggressive Environment ----------0.70 lb/cuyd
Moderately or Extremely Aggressive Environment ----------0.40 lb/cuyd

Based on the average dry bulk specific gravity as determined in the ASTM C642 testing, this would indicate a chloride content as shown in Table 7.

Table 7 – Chloride Content (DENSITY TESTING STILL IN PROGRESS)

Core	Depth in Core Sample, in.	Dry Bulk Density (pcf)	Chloride Content, %	Chloride Content, lb/cuyd
C-05	0 to 1 ½	139.7	0.003	0.113
	1 ½ to 3		0.002	0.075

As shown in Table 7, the samples are well below the maximum allowable chloride content for reinforced concrete exposed to a moderate or extremely aggressive environments

Petrographic Testing

The petrographic testing did not reveal any issues within the concrete sample observed, and further concluded that the concrete is of relatively good quality given the age.

Conclusion

Based on our observations at the site and the data obtained during testing, it is our opinion that Digester 2 concrete walls are in relatively good condition for their age. While vertical cracks are present throughout the structure, no other indications of a failure or distress of the concrete or the steel reinforcement were detected during testing. It is our opinion that with the addition of some protective systems, the useful service life of the concrete walls can be extended. These systems would include the following:

- The interior walls should be lined with a suitable coating that is able to bridge and seal the noted cracks (up to 0.05 inches). The coating should be able to resist the harsh environment of the digester and prevent aggressive compounds from within the sludge from penetrating the concrete.

- It was noted that the exterior of the tank had been painted in the past, however some cracks are showing through the existing coating system. We believe the exterior of the tank should prepared and recoated with an appropriate system to seal the exterior surface of the tank and seal the noted cracking.

We appreciate the opportunity to be of service to you on this project. Should you have any questions regarding this information or if we may be of additional service to you please contact our Tampa office.

Sincerely,

ARDAMAN AND ASSOCIATES, INC.
Florida Certificate of Authorization No. 5950

Julio Aguilar, Ph.D., P.E
Project Engineer
Licensed Florida 79412

William R. Goodson, PE
Senior Materials Engineer
Licensed Florida 37935

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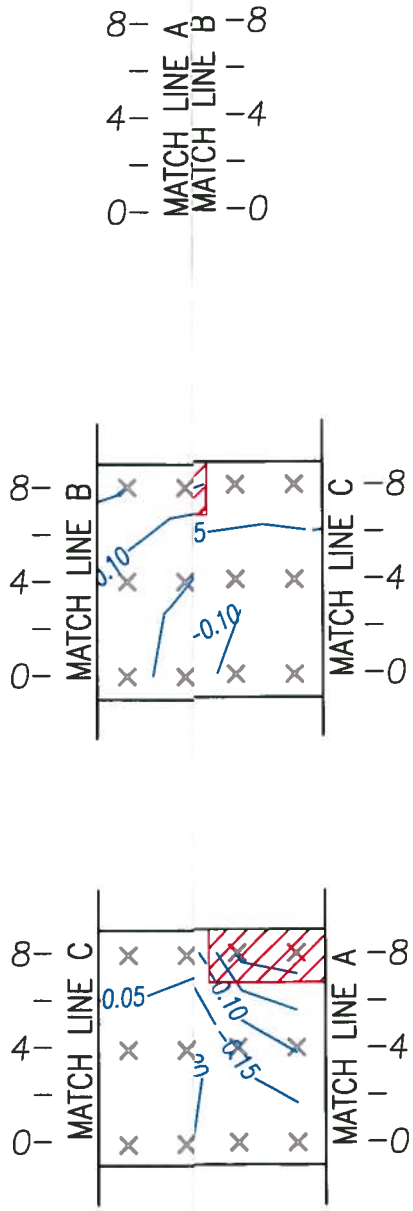
Attachments: Figure 1 Equipotential Contour Map
Photos 1 to 26
Compressive Strength Results
Petrographic Report

Distribution: Addressee
File

ATTACHMENTS

Ardaman & Associates, Inc.



0 10 20

APPROXIMATE SCALE: 1"=20'

EQUIPOTENTIAL CONTOUR MAP

Ardaman & Associates, Inc.
Geotechnical, Environmental and Materials Consultants

HF CURREN AWTP
2700 MARITIME BLVD
TAMPA, FLORIDA

DRAWN BY:	CHECKED BY:	DATE:
ajl	JIA	3/30/17
FILE NO. 17-54-9482	APPROVED BY: WRG	FIGURE: 1

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Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

Photo 1 *– Reinforcement trace based on GPR scans.*

Photo 2 *– Exposed steel for half-cell potential testing.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

***Photo 3** – Scraping the walls prior to half-cell testing.*

***Photo 4** – Hydraulic core machine mounted on the wall.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

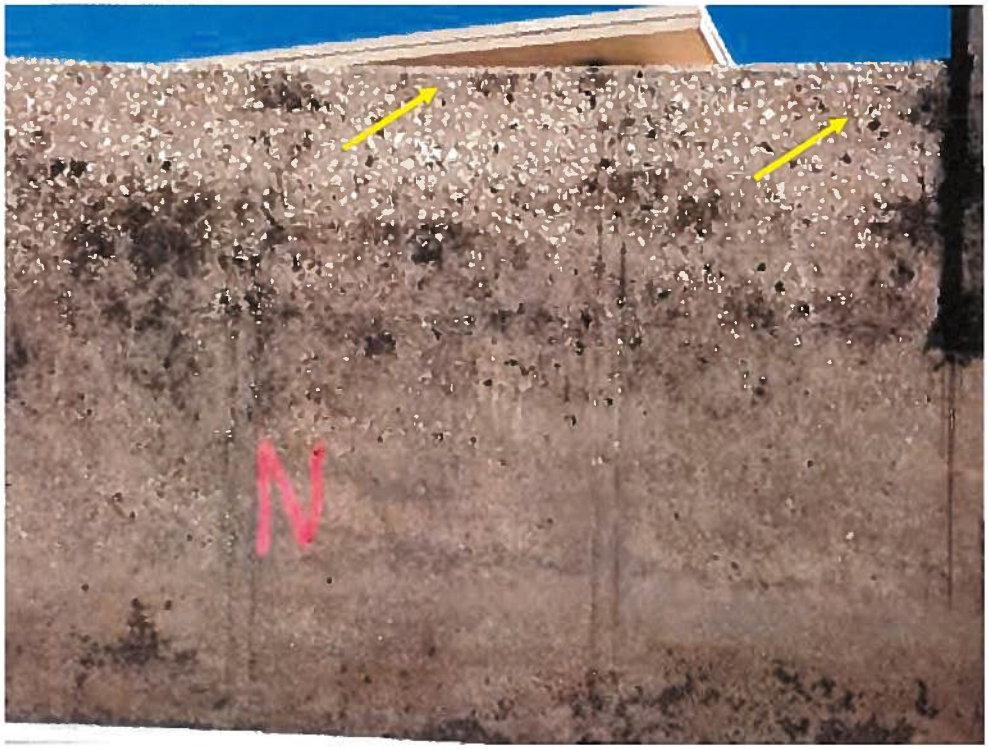


Photo 5 *– North face with vertical cracks.*

Photo 6 *– Close-up of area shown in Photo 5.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

Photo 7 *– Northeast face with vertical cracks.*

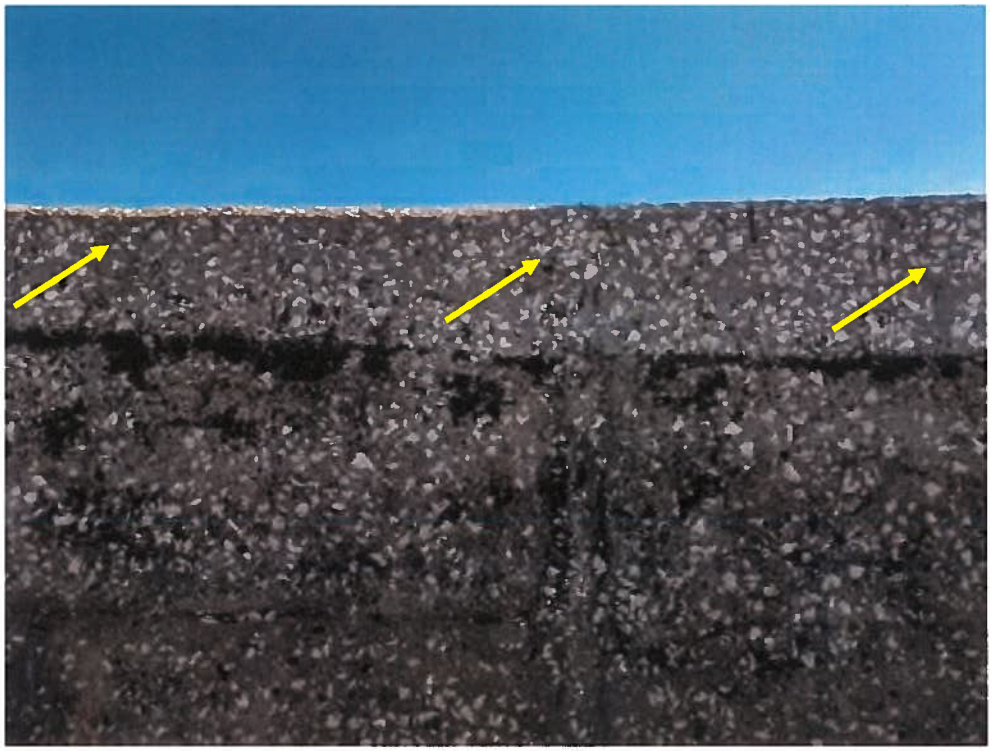


Photo 8 *– Close-up of area shown in Photo 7.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

***Photo 9** – East wall of tank with vertical cracks.*

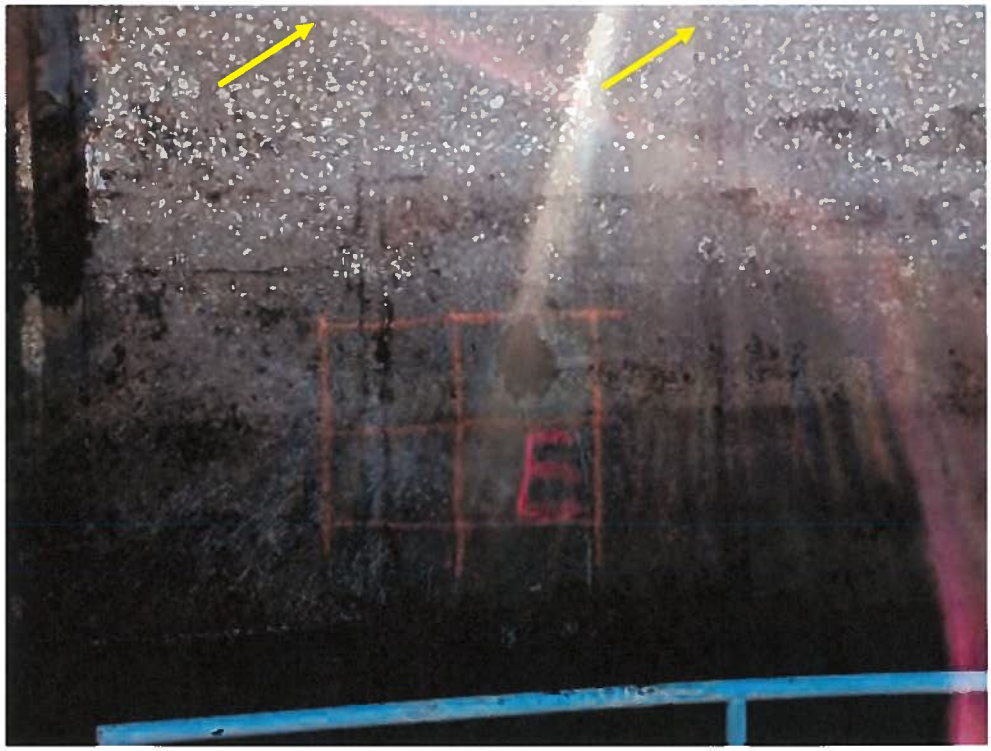


***Photo 10** – East wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

Photo 11 *– East wall of tank with vertical cracks.*

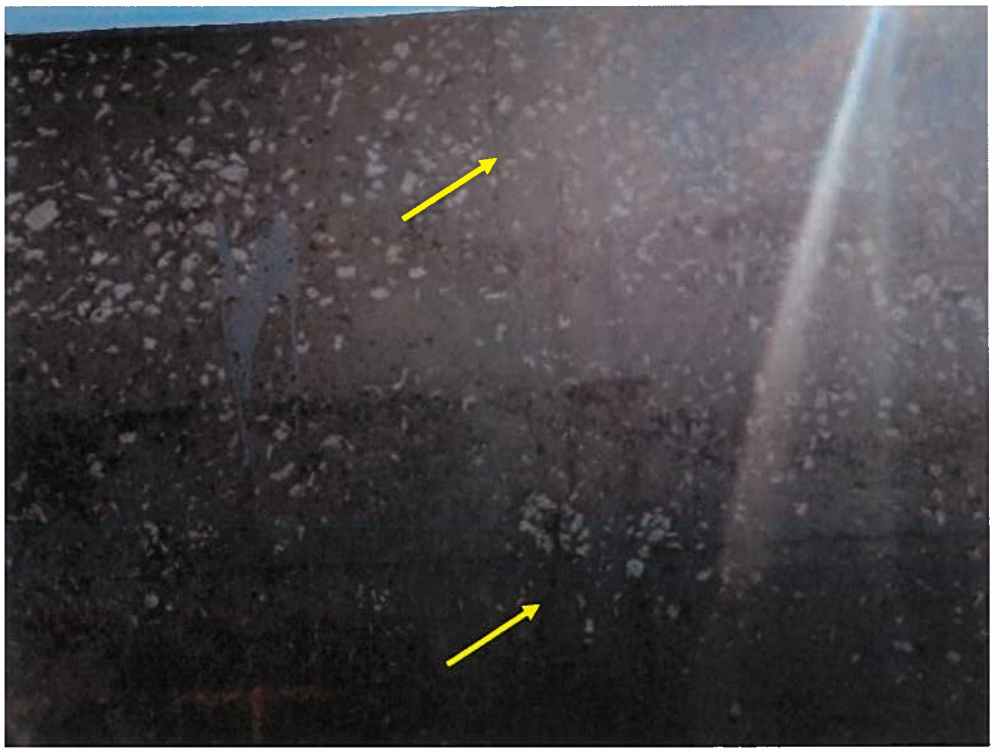


Photo 12 *– East wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

***Photo 13** – Southeast wall of tank with vertical cracks.*

***Photo 14** – Southeast wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

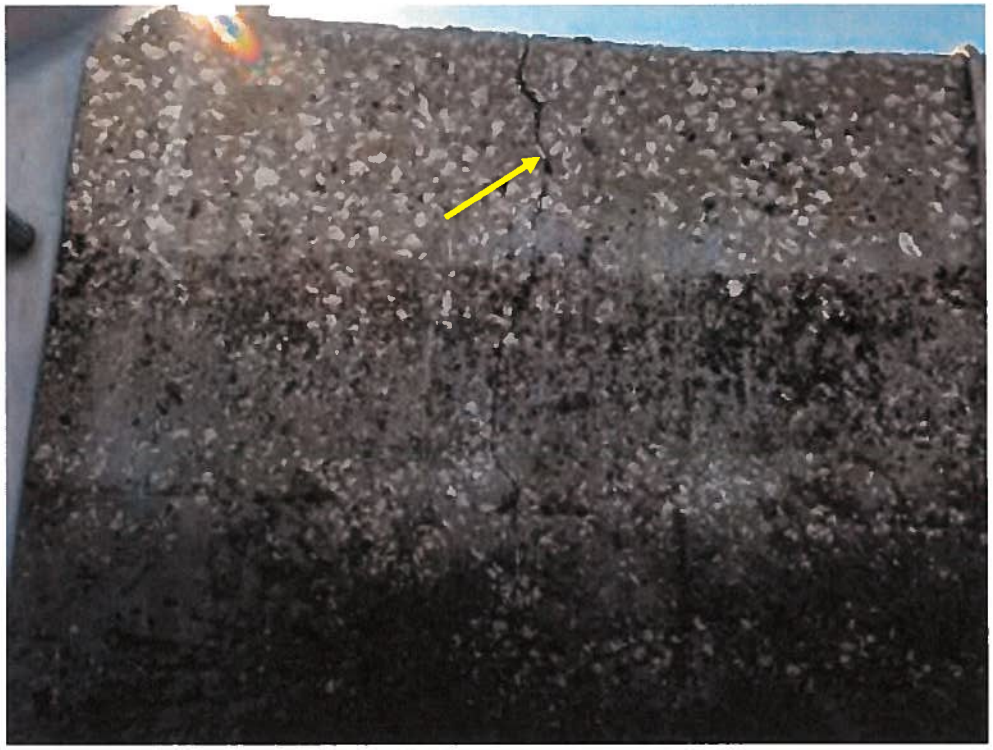


Photo 15 *– South wall of tank with vertical cracks.*

Photo 16 *– South wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

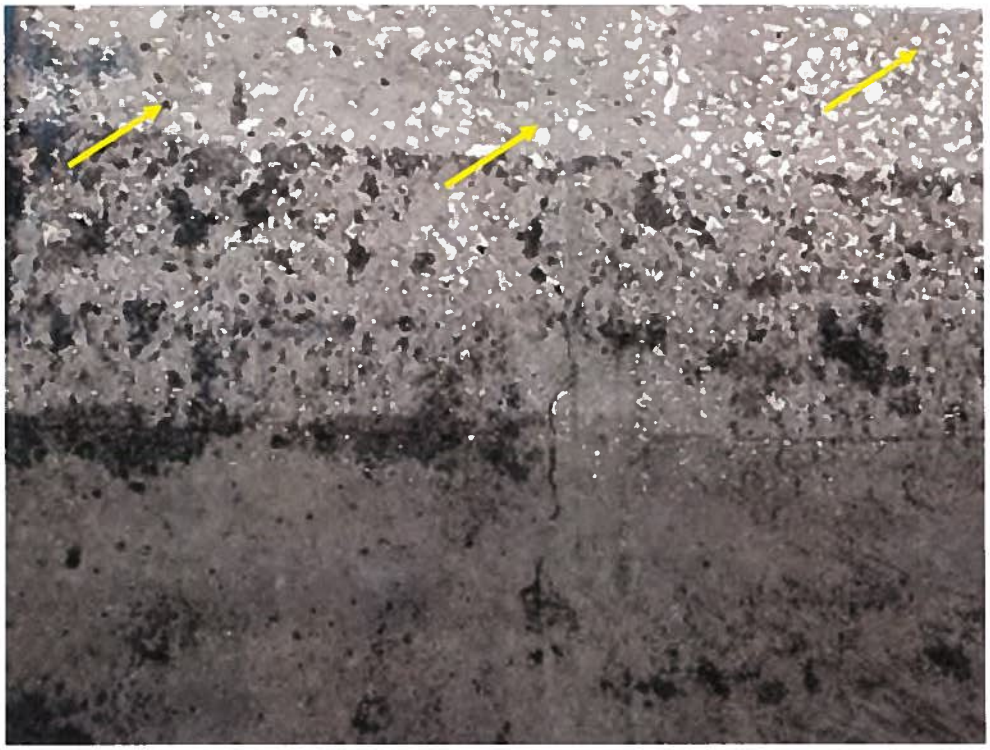


Photo 17 *– Southwest wall of tank with vertical cracks.*

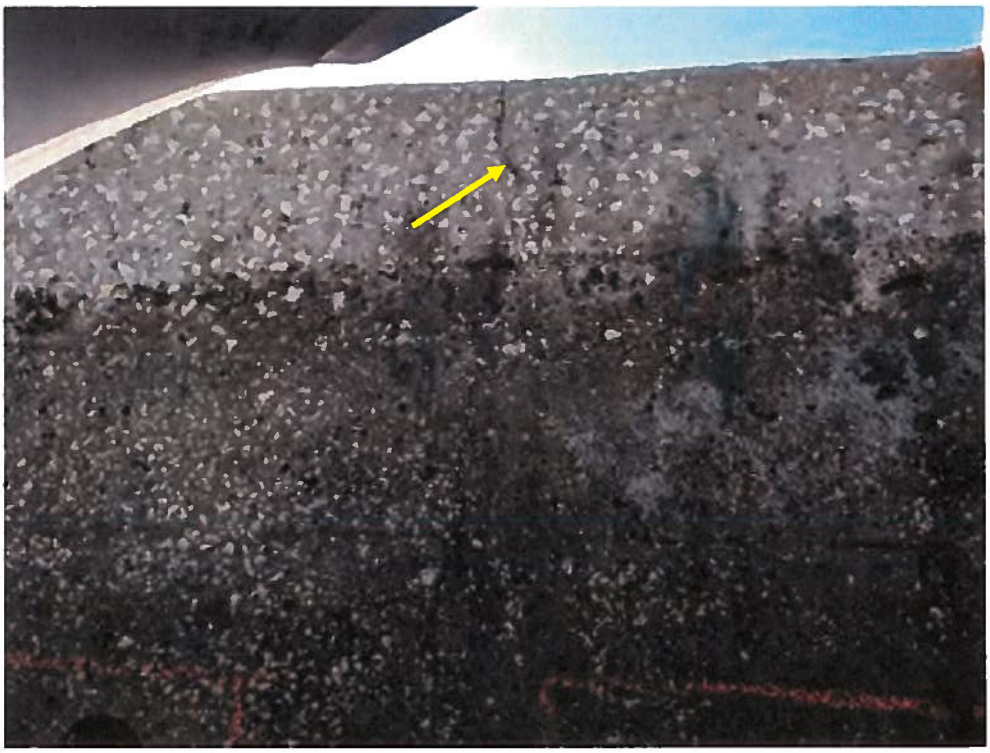


Photo 18 *– West wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

***Photo 19** – West wall of tank with vertical cracks.*

***Photo 20** – Northwest wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

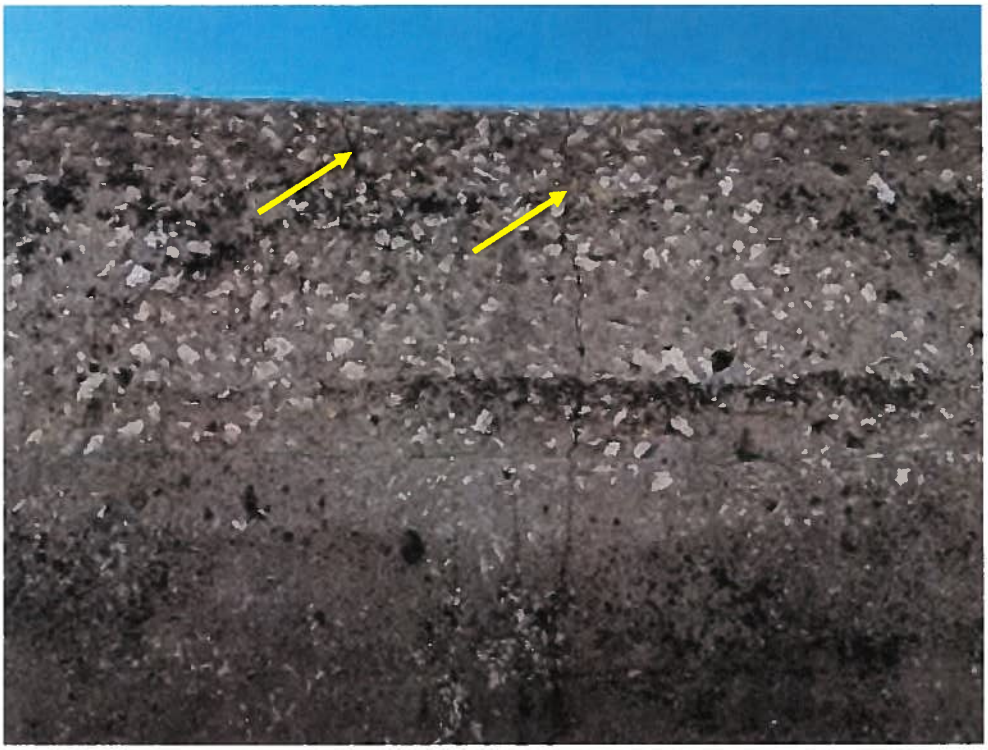


Photo 21 *– Northwest wall of tank with vertical cracks.*

Photo 22 *– Northwest wall of tank with vertical cracks.*

Digester 2
Howard F. Curren Advanced Wastewater Treatment Plant
Port Tampa Bay, Florida

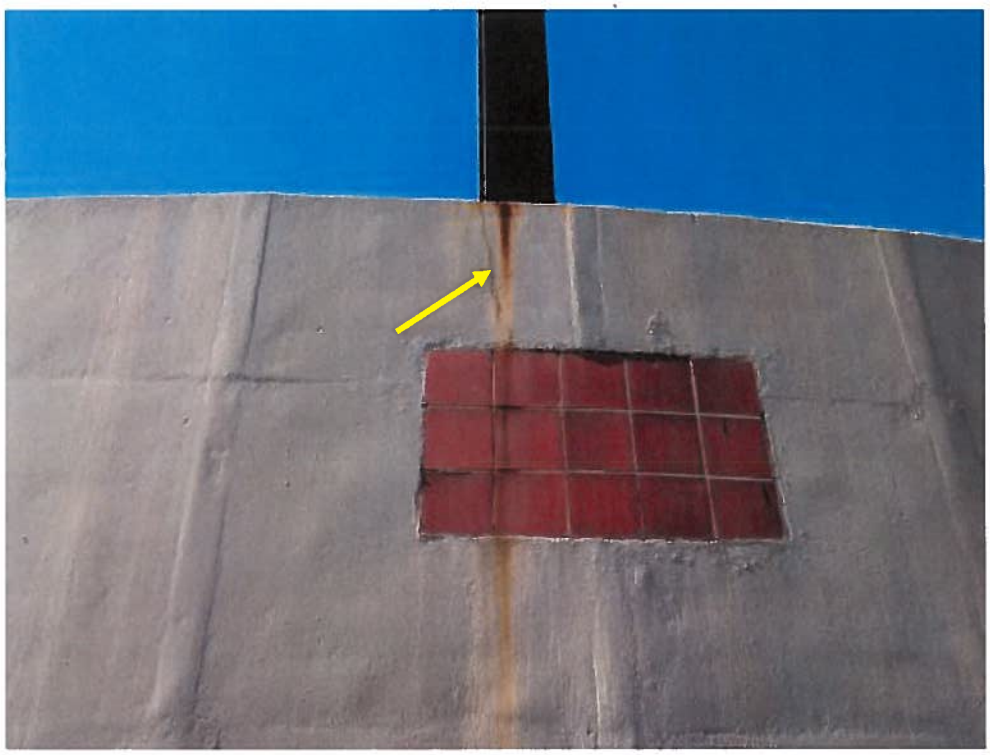


Photo 23 *– North external wall of tank with vertical cracks.*

Photo 24 *– East external wall of tank with vertical cracks.*

***Photo 25** – South external wall of tank with vertical cracks.*

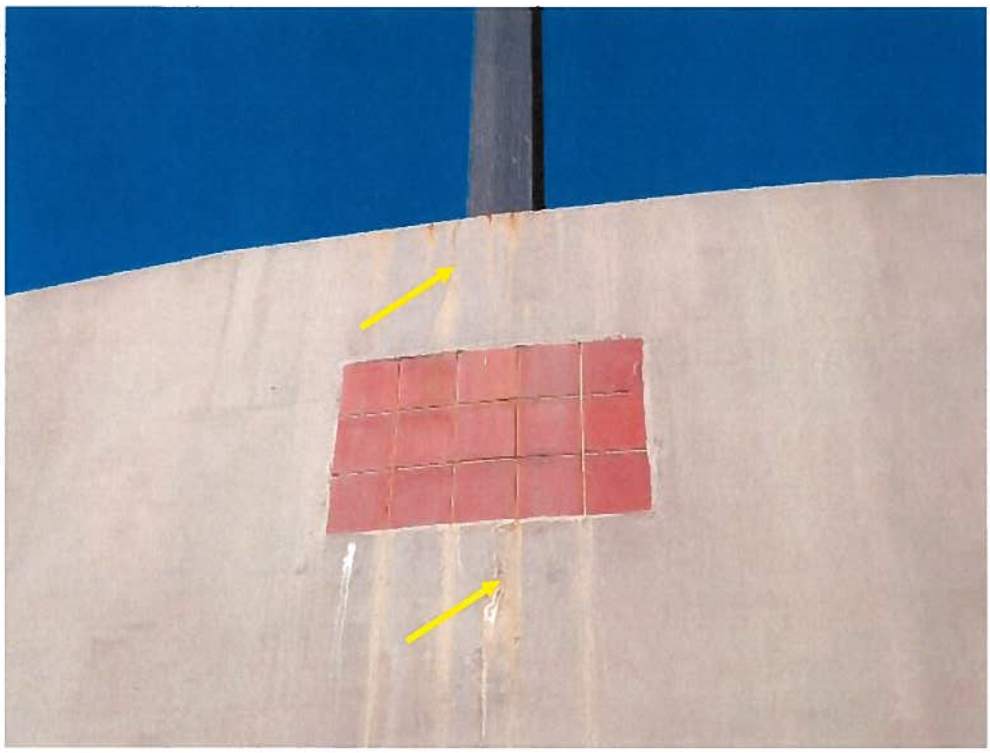


***Photo 26** – West external wall of tank with vertical cracks.*

ARDAMAN & ASSOCIATES, INC.
3925 COCONUT PALM DRIVE, SUITE 115
TAMPA, FLORIDA 33619
(813) 620-3389, FAX (813) 628-4008

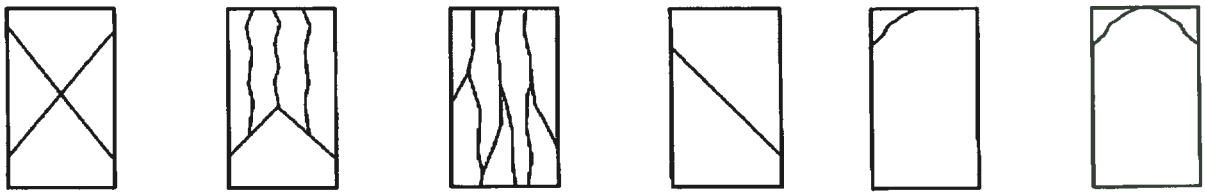
COMPRESSIVE STRENGTH OF CONCRETE CORES

PROJECT NAME:	HF Curren AWTP - Digester 2	REPORT DATE:	4/21/2017
PROJECT LOCATION:	Tampa, Florida	FILE NUMBER:	17-54-9482
PROJECT CLIENT:	McKim & Creed	DATE CORED:	3/21/2017

CORE ID	C-01	C-02	C-03			
ITEM CORED	West Tank Wall	East Tank Wall	South Tank Wall			
CORED LENGTH (in)	8.5	8.7	8.7			
NOMINAL MAX. SIZE OF AGGREGATE (in)	3/4"	3/4"	3/4"			
REINFORCEMENT STEEL DISTANCE FROM TOP/OUTSIDE EDGE (in)	YES / [NO]	YES / [NO]	YES / [NO]	YES / NO	YES / NO	YES / NO
CORE PREPARATION CURING TIME (days)	WET / [DRY] 6	WET / [DRY] 6	WET / [DRY] 6	WET / DRY	WET / DRY	WET / DRY
DATE TESTED	3/27/2017	3/27/2017	3/27/2017			
TRIMMED LENGTH (in)	7.2	6.8	7.0			
TRIMMED WEIGHT (grams)	2854.0	2750.0	2822.0			
UNIT WEIGHT (lbs/ft^3)	140.9	143.0	143.1			
CAPPED LENGTH (in)	7.5	7.1	7.3			
AVERAGE CORE DIAMETER (in)	3.69	3.70	3.70			
CROSS-SECTIONAL AREA (in^2)	10.72	10.76	10.73			
TOTAL APPLIED LOAD (lbs)	56,342	66,069	71,970			
DIRECTION OF APPLIED LOAD	Perpendicular	Perpendicular	Perpendicular			
TEST STRENGTH (psi)	5,260	6,140	6,710			
L/D COEFFICIENT	2.02	1.92	1.98			
L/D CORRECTION FACTOR	1.000	1.000	1.000			
CORRECTED COMPRESSIVE STRENGTH (psi)	**5,260**	**6,140**	**6,710**			
TYPE OF FRACTURE	3	3	3			
COMMENTS		average strength= 6,040 psi				

REMARKS: CONCRETE CORES WERE PREPARED AND TESTED IN GENERAL ACCORDANCE WITH ASTM C-42 and C-39.
Core C-04 was used for Density and Air Void testing in accordance with ASTM C642, along with Chloride Content and pH Testing.
Core C-05 was used for petrographic testing.

FRACTURE TYPES



TYPE 1 TYPE 2 TYPE 3 TYPE 4 TYPE 5 TYPE 6

By: _____
Julio I. Aguilar, P.E.

Florida License No.: 79412

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Ardaman & Associates, Inc.
Geotechnical, Environmental and
Materials Consultants

Report of Petrographic Examination of Concrete
ASTM C-856

Project:	Digester 2 HF Curren AWTP	**Date:**	April 17, 2017
Location:	Tampa, Florida	**Project No.**	17-54-9482
Client:	McKim & Creed		

Sample No. C-05 **Sample Size:** 3 ¾ in. wide, 10± in. long

Photo 1 – Sample C-05 (sample cut to allow insertion into saw for longitudinal cut)

Coarse Aggregate

- White to tan to light brown crushed fossiliferous limestone and siliceous limestone.
- Nominal maximum particle size is ¾ inch graded down to ⅛ inch.
- The particles are equidimensional with a sub-rounded to sub-angular texture.
- Volume of coarse aggregate appears reasonable.
- Coarse aggregate relatively well distributed.
- Two pieces of aggregate were noted to have a partial halo or ring about them indicating possible alkali reaction.
- Aggregate paste bond is good.

Fine Aggregate

- Natural sand, gray, white and clear quartz.
- Maximum particle size ⅛ inch, graded down to fine sand sizes.
- Particles have sub-rounded texture.
- No indications of cement-aggregate reactions were noted within the concrete.

Matrix (cement paste)

- Paste is medium gray to dark gray in color.
- Paste was noted to be hard when scratched with steel point.
- Paste to aggregate bond appears good.
- No measurable carbonation was observed at the concrete surface.
- The paste is estimated to have a low to moderate water cement ratio.

Air Voids

- Concrete is not air-entrained, but does have some entrapped air and/or water gain voids.
- Air voids are spherical to irregular in shape and are not well distributed, visually estimated at 0.5 to 1.0 percent.
- Several water gain voids were observed under coarse aggregate pieces.

Surface

- The outer surface of the sample is a formed surface, however some minor surface erosion was noted.
- The surface of the sample was noted to be stained (brown color) from the sludge. This brown staining is believed to be Struvite crystals, which is a magnesium ammonium phosphate hexahydrate, which is known to form in post-digestion areas of treatment plants employing anaerobic digestion. At several locations the brown staining had penetrated the surface up to ½ inch.

Cracking

- No cracking was observed in the sample.

Embedded Items

- There were no embed items such as reinforcing steel observed in the sample.

Conclusions: Concrete is not air entrained with entrapped air estimated at between 0.5 and 1.0 percent. There is an indication of some minor reactive coarse aggregates in the concrete. The pieces were noted deep in the concrete section with no detrimental effects observed as a result of the reaction. The paste is hard when scratched with a steel point. The coating of the surface of the core and the penetration in select areas by the Struvite crystals has not adversely affected the concrete. The concrete was noted to be of relatively good quality for its age.

William R. Goodson, PE
Senior Materials Engineer

Ardaman & Associates, Inc.

Photo 2 – Sample split for examination.

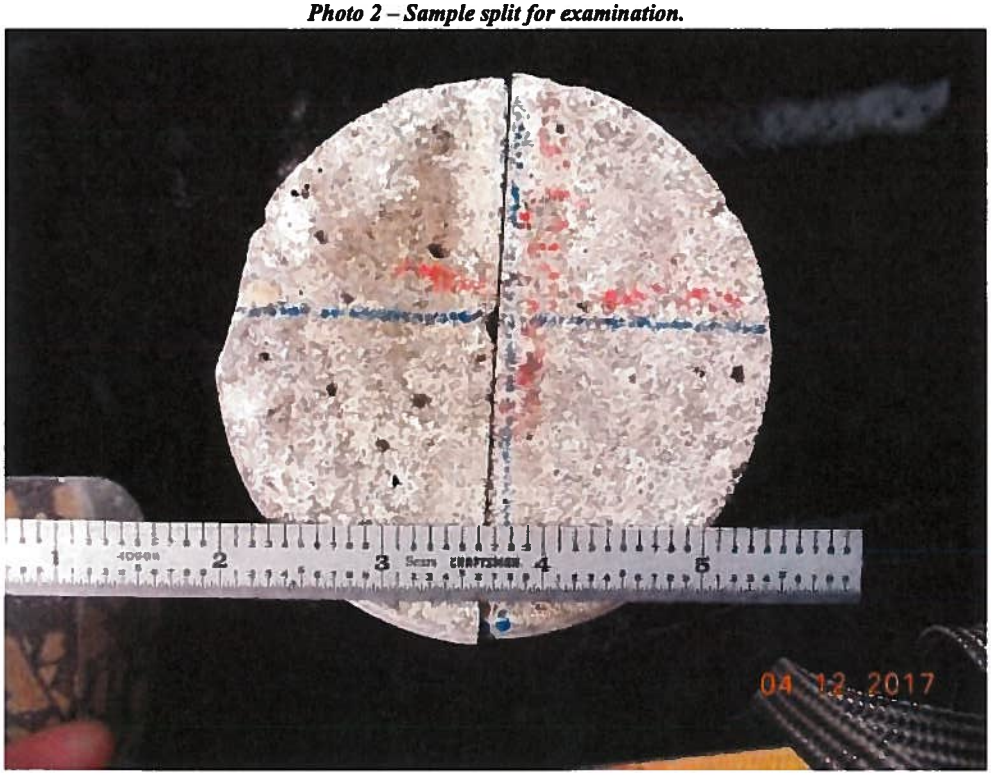

Photo 3 – Outer surface of core sample.

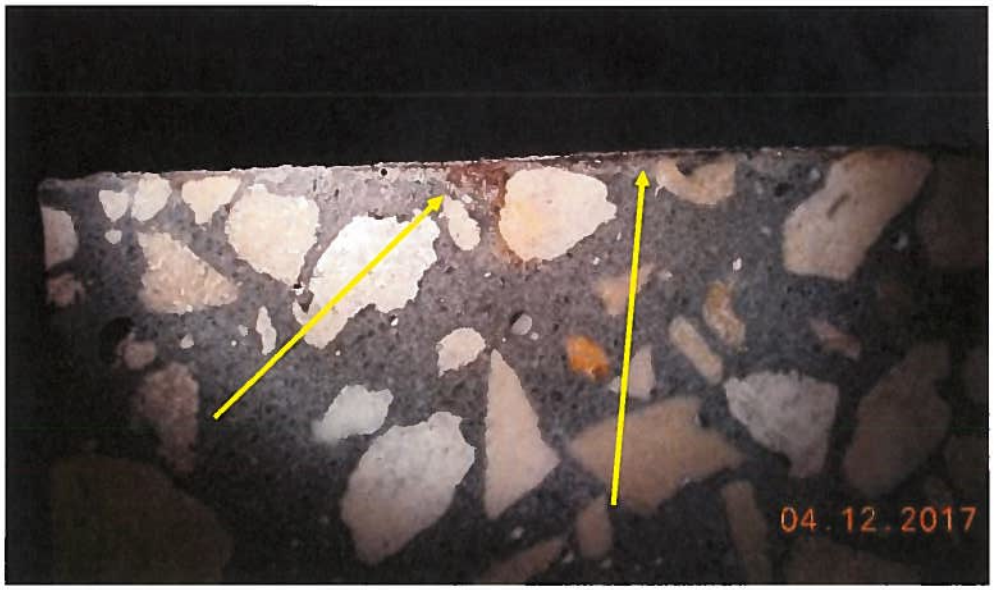

Photo 4 – Cross-sectional view of core surface. Note brown stained layer (Struvite crystals) at surface and deeper inclusion of stain.

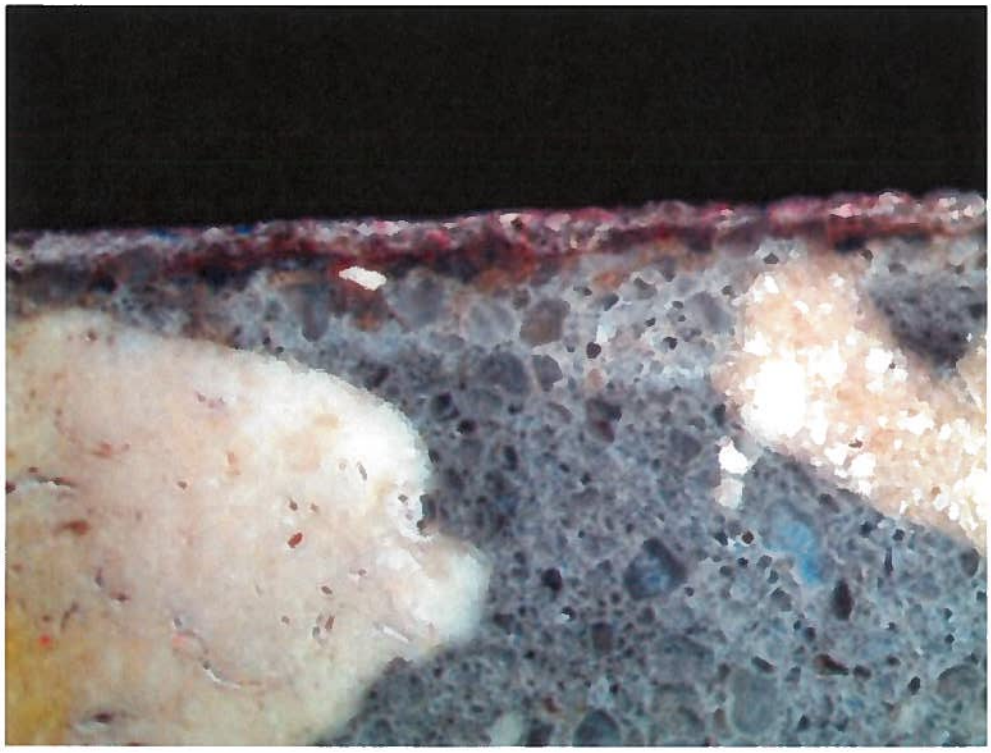

Photo 5 – Magnified view of stain layer (Struvite crystals) at concrete surface.

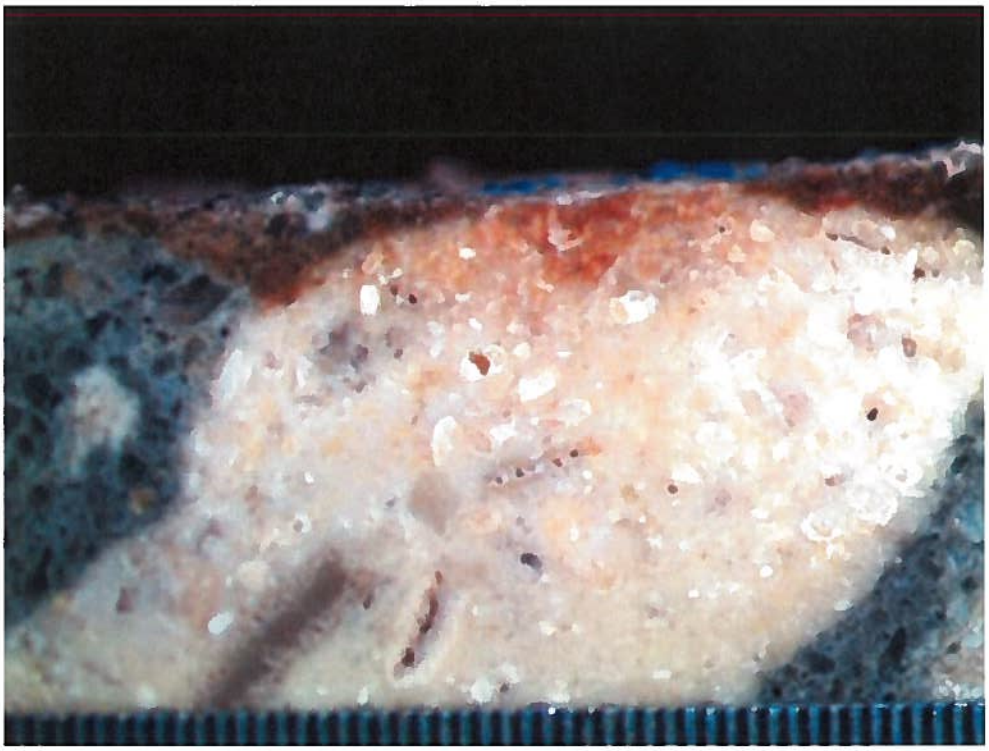

Photo 6 – Magnified view of stain inclusion (Struvite) getting deeper at coarse aggregate piece. Scale = 0.01 inches

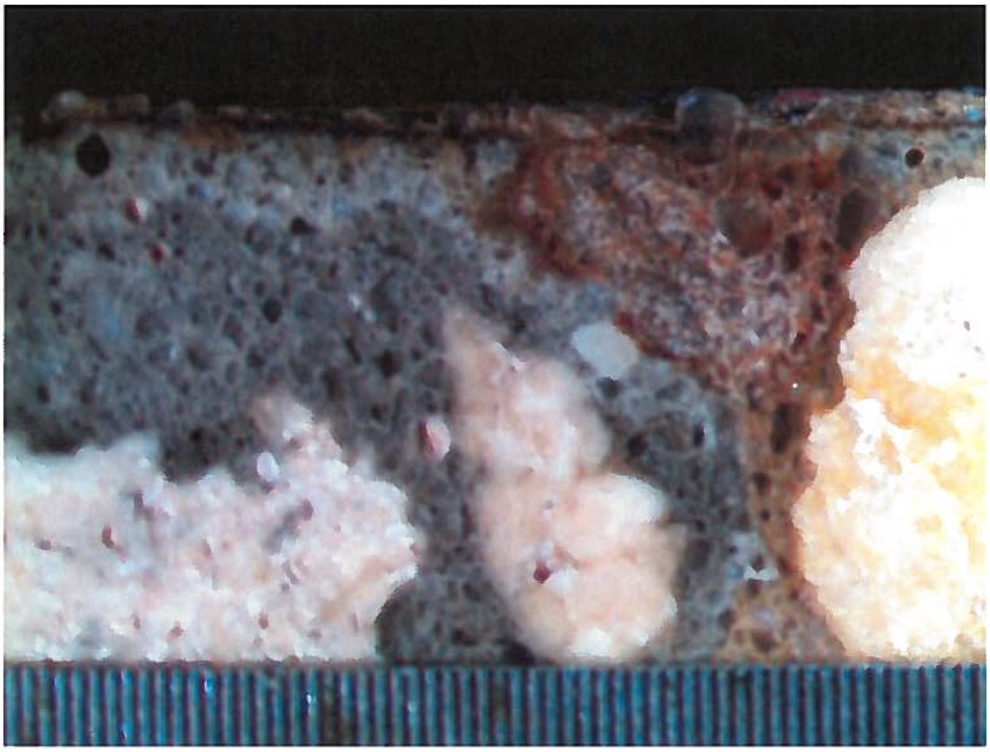

Photo 7 – Close-up view of larger stain inclusion (Struvite crytals) at surface. Scale = 0.01 inches

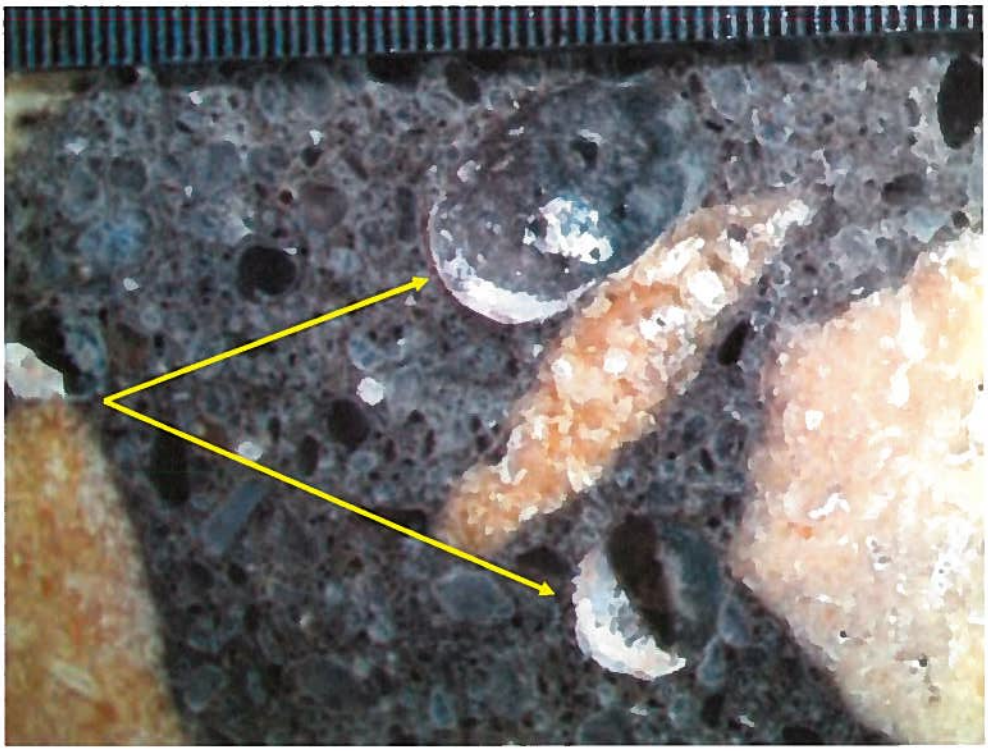

Photo 8 – Magnified view of entrapped air void. Scale = 0.01 inches

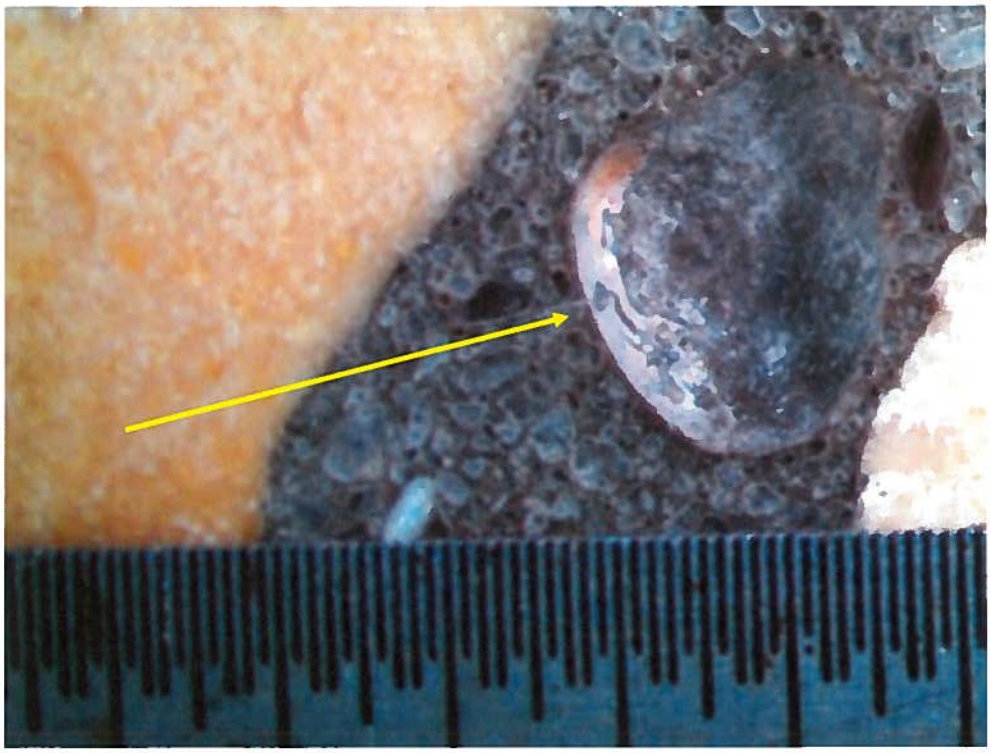

Photo 9 – Magnified view of entrapped air void. Scale = 0.01 inches

Photo 10 – Chert piece observed in core sample.

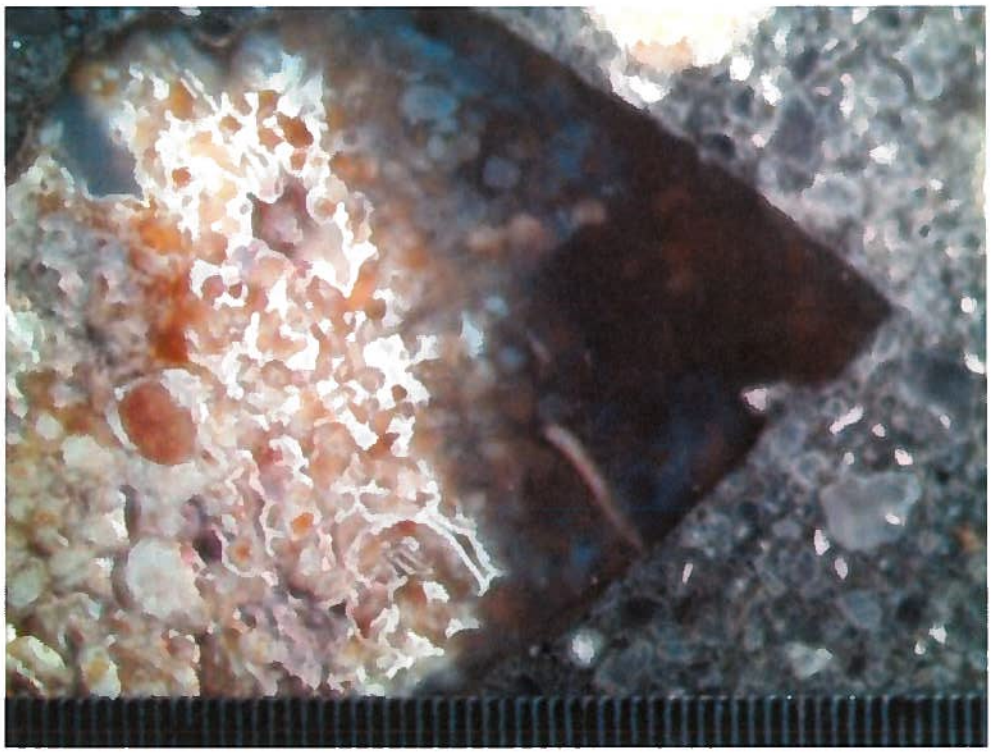

Photo 11 – Magnified view of chert found in sample. Scale = 0.01 inches

Photo 12 – Piece of coarse aggregate with partial ring/halo around it.

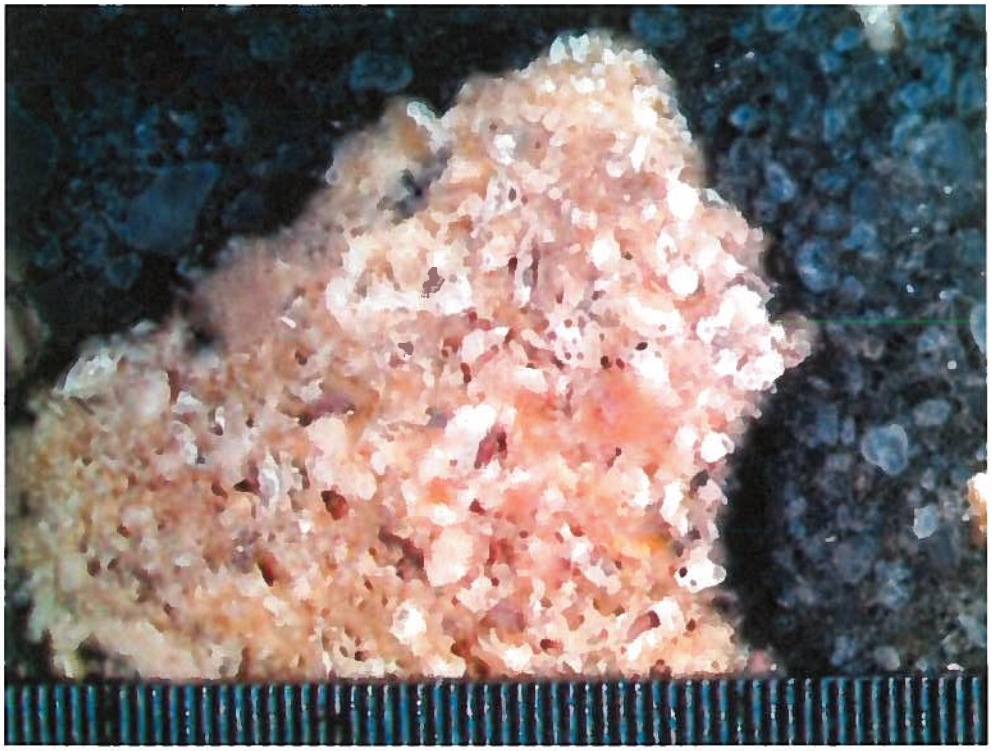

Photo 12 – Magnified view of aggregate piece with partial ring/halo indicating possible aggregate reaction. Scale = 0.01 inches

Technical Memorandum 12.0 Biogas Utilization Evaluation

12.1 Purpose and Background

This report describes the Biogas Utilization Alternatives evaluation for the HFC AWTP. This work was completed under the Phase 2 Master Plan Contract by Hazen and Sawyer as a subconsultant to McKim & Creed. The data presented in this technical memorandum builds on the original Phase 1 Master Plan (**Appendix A**).

The HFC AWTP currently flares all biogas generated by the anaerobic digesters. Prior to March 2017, the biogas was utilized by fueling a combined heat and power (CHP) system using reciprocating internal combustion engines (RICE) to offset the plant's energy demands. As a part of this biosolids master plan, an evaluation was performed to determine how the City could best utilize this valuable resource. This study evaluates the 20-year life cycle cost/benefits of multiple biogas utilization alternatives to identify the most economically feasible alternatives.

Biosolids and liquid stream treatment alternative evaluations are also part of the Phase 2 Master Plan. Biogas production and utilization were evaluated as a part of the treatment alternatives selection process. **Section 12.3** of this technical memorandum covers the biogas production and utilization of these treatment alternatives in further detail.

12.2 Existing Conditions and Current Biogas Utilization

12.2.1 Existing Conditions

As noted in the Phase 1 Master Plan, biogas production and heating requirements were estimated for current and future digester loadings by using:

- SCADA data;
- Laboratory monthly reports;
- Daily monitoring reports;
- Process reports; and
- Design criteria obtained from as-built information.

The collected data was averaged to obtain monthly statistical measures. Future growth was accounted for in the estimates by incorporating flow and load projections presented in the Updated Capacity Analysis Report, dated May 2015, which was provided by the City and produced to estimate HFC AWTP's future capacity needs.

Desktop modeling estimated the biogas production by first calculating theoretical secondary and primary sludge production prior to digestion, which was then calibrated to fit the existing sludge SCADA data from 2015 monthly averages. Biogas production was then estimated by using the modeled sludge production, historical sludge characteristics from 2015 (monthly averages), and industry standard gas production rates to generate a low and high estimated range of digester gas production. If the current treatment continues to be used, the estimates projected gas production from 2019 to 2039 is summarized in **Table 12.2-1**.

Table 12.2-1: Projected Biogas Production

Year	Low (SCFM)	High (SCFM)	Average (SCFM)
2019	637.5	637.5	637.5
2020	646.4	647.7	647.1
2021	655.5	658.1	656.8
2022	664.7	668.6	666.6
2023	674.0	679.3	676.6
2024	683.4	690.2	686.8
2025	693.0	701.2	697.1
2026	702.7	712.4	707.5
2027	712.5	723.8	718.1
2028	722.5	735.4	728.9
2029	732.6	747.2	739.8
2030	742.8	759.1	750.9
2031	753.2	771.3	762.2
2032	763.8	783.6	773.6
2033	774.5	796.1	785.2
2034	785.3	808.9	797.0
2035	796.3	821.8	809.0
2036	807.5	835.0	821.1
2037	818.8	848.3	833.4
2038	830.2	861.9	845.9
2039	841.9	875.7	858.6

Biogas production is expected to increase ~1.5% per year. It is important to note that historical sludge production was used to calibrate the desktop model because the City did not measure gas production until August 2017; and back calculation of the gas produced from engine consumption rates may be misleading due to flaring and system inefficiencies.

Digester heating requirements were estimated using desktop modeling. Heat losses were calculated by using standard heat transfer coefficients and digester characteristics that were identified in as-built information and collected during a site visit. Summer, winter, and extreme winter heating requirements were calculated with annual average and maximum month loadings to estimate a range for energy demand. The estimated seasonal heating demands for the current conditions are shown in **Figure 12.2-1**.

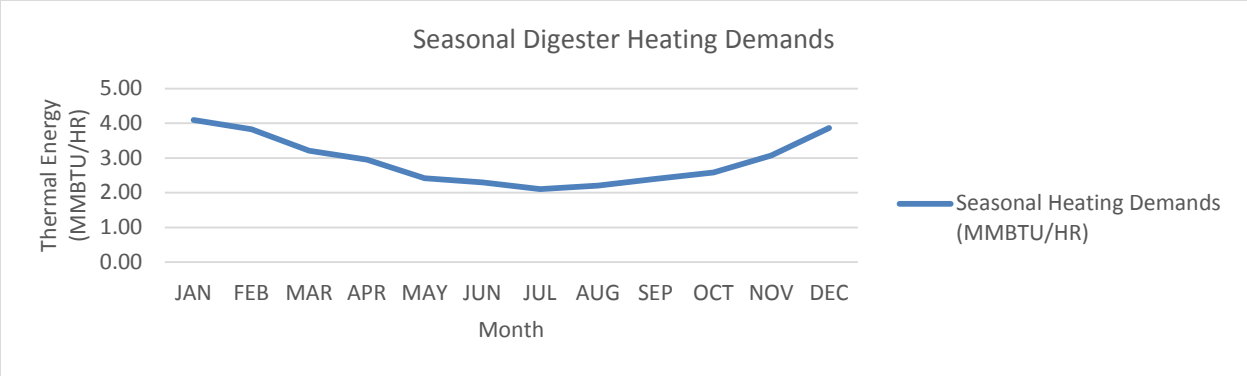

Figure 12.2-1: Seasonal Digester Heating Demands

12.2.2 Current Biogas Utilization

A condition assessment was performed to determine the remaining useful life of the existing biogas utilization equipment and infrastructure. The condition assessment was based on a combination of field observations performed by Hazen, discussions with the plant staff, and the results from previous condition assessments performed under the previous biogas utilization study.

Biogas Fueled Engines – Prior to March 2017, the HFC AWTP utilized biogas to fuel five (5) 500kW internal combustion engines in a CHP configuration to produce electric and thermal energy. The electric energy was used to offset the plant purchased energy and thermal energy was recovered from the engine cooling system to provide digester heating. Based on reports from the plant staff, engines No. 3 and No.5 were the only engines in service the past three (3) years. Engines No. 1 and No. 4 are inoperable and engine No.2 was in some state of repair. Repair costs are likely to exceed the value of the existing units. Existing engines Nos. 1 through 3 were installed in 1984 and are 900 RPM Model L7042GU manufactured by Waukesha. The remaining engines (No.4 and No.5) were installed in 1988. Since all engines are in need of refurbishment and repairs, the plant staff began using rented diesel boilers to heat the digesters and flare all biogas in March 2017.

Biogas Handling and Pre-Treatment – Prior to March 2017, biogas was pressurized by five (5) positive displacement compressors which pumped biogas to the digester mixing system and to the existing gas conditioning equipment. The HFC AWTP treated the biogas to remove sulfur compounds using cellulosic fiber based filters. Moisture and sediment were removed via condensate/sediment removal traps. Additional biogas moisture was removed, immediately upstream of the engines, by pressurized condensate units. A condition assessment performed by Hazen and under previous biogas utilization studies noted multiple leaks around pipe joints and concluded that much of the biogas handling system was in need of repairs. The plant staff noted that the existing gas cleaning was ineffective and excessive siloxane buildup and corrosion had been observed on the internal components of the engines. The majority of the biogas handling and treatment equipment is in poor condition and should be replaced or refurbished as a part of the biosolids process expansion.

Heat Recovery Equipment – Prior to March 2017, heat was recovered from the engine jacket cooling system to provide heat to the digesters. Each engine is furnished with a shell-in-tube heat exchanger, which transferred heat from the engine to a hot water digester heating recovery loop. The heat recovery loop configuration includes two loops. One loop provides heat to digesters 1 and 5 from engines 1 and 2, while the other provides heat to digesters 6 and 7 from engines 3-5. During a site visit on 12/18/15, the plant staff noted that the two heat recovery loops do have a cross connection, however, digester temperature control is difficult when the cross connection is open. The heat recovery pumps, heat exchangers, and piping should be refurbished or replaced as a part of the biosolids process expansion.

Boilers – The existing HFCWTP boilers are at the end of their useful life and are no longer being utilized. Currently, temporary diesel boilers provide thermal energy as needed for the digestion process. Since March 2017, the temporary boilers have been the sole source of thermal energy for digester heating and all biogas is being flared.

12.3 Treatment Alternatives Analysis

The liquid and biosolids treatment alternatives were modeled using Hazen's Energy Balance Analysis Tool (EBAT) for the CHP and RNG biogas utilization alternatives. **Figure 12.3-1** through **Figure 12.3-3** below show the expected annual digester gas production for the liquid and biosolids alternatives. In the figures in this section, Alt 1 represents optimizing the existing liquid stream, and Alts 2a and 2b represent different parallel liquid feed options. Alts 1, 2a, and 2b liquid stream treatment options are described in detail in the *BNR Process Evaluation* technical memorandum. They are also summarized below.

Liquid Stream Alternatives:

- Alt 1 – Optimize Existing
- Alt 2a – Two MLE in Series
- Alt 2b – Two MLE in Parallel

The liquid stream treatment alternatives were found to have the largest impact on biogas production as well as the annualized cost/benefit. The biosolids treatment alternatives did not have a large impact on the biogas gas production. See the *BNR Process Evaluation* and the *Biosolids System – Alternatives Evaluation* technical memorandums for further details. The biogas production contributed to the selection of the biosolids and liquid stream treatment alternatives, as shown in the figures below. From the figures, it is clear that optimizing the existing liquid stream produces the most biogas, which can be utilized in the most beneficial way possible.

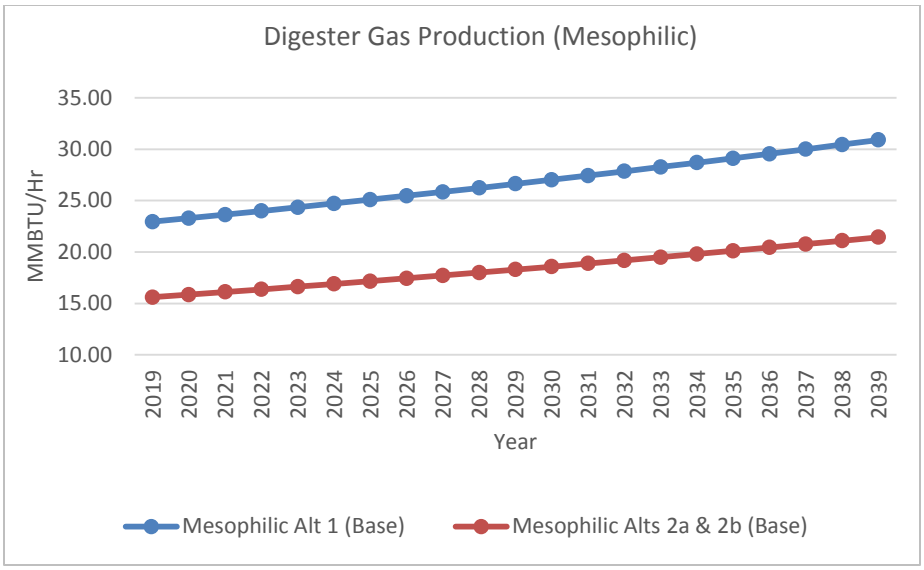

Figure 12.3-1: Mesophilic Biosolids Treatment Digester Gas Production

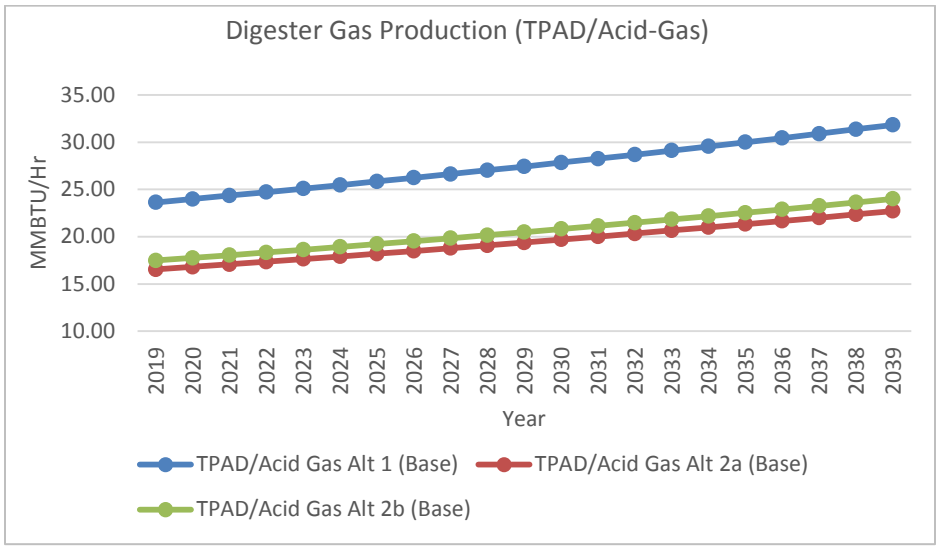

Figure 12.3-2: TPAD/Acid Gas Biosolids Treatment Digester Gas Production

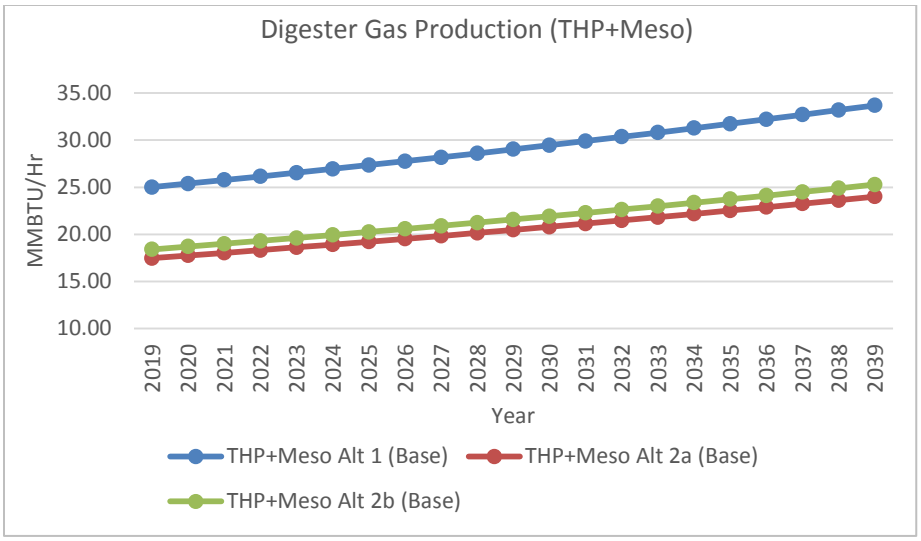

Figure 12.3-3: THP+Meso Biosolids Treatment Digester Gas Production

Using the biogas production information in shown **Figures 12.3-1 through 12.3-3** above, the EBAT model was used to calculate the annualized net revenue cost/benefit for CHP (with new engines) and RNG (renewable natural gas). The annualized net revenue cost/benefit for CHP and RNG are explained in further detail in **Section 12.4** of this technical memorandum. **Figure 12.3-4** summarizes the annualized net revenue cost/benefit for all evaluated treatment alternatives for both the CHP (with new engines) and RNG biogas utilization alternatives. In addition to producing more biogas, as shown above, **Figure 12.3-4** clearly shows that optimizing the existing liquid stream treatment has the potential to produce the most revenue for the plant. Additional details regarding the CHP and RNG alternatives are provided in the remainder of **Technical Memorandum 12.0**.

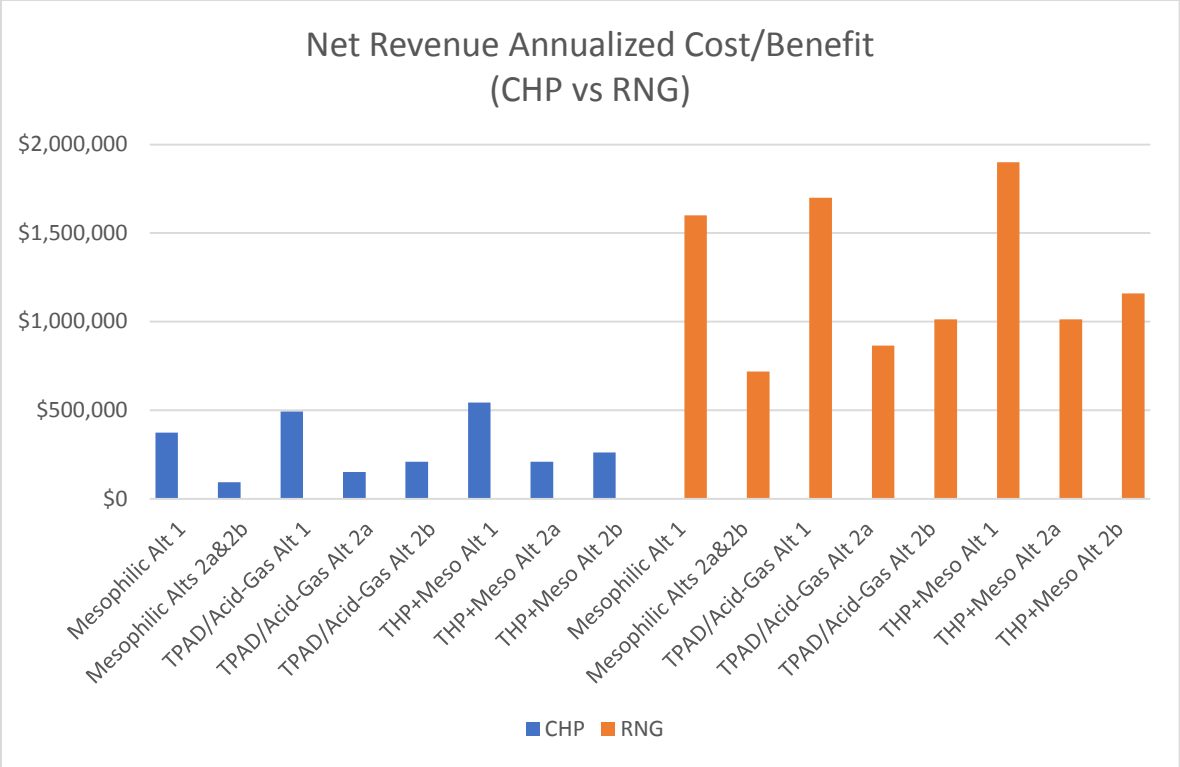

Figure 12.3-4: Net Revenue Annualized Cost/Benefit

After a workshop on October 3, 2017, the City expressed interest in optimizing the existing liquid stream treatment alternative and the acid-gas biosolids treatment alternative. The combination of optimizing the existing liquid stream alternative and the acid-gas biosolids treatment alternative are expected to produce ~3% more biogas than shown in **Table 12.2-1**. The remainder of this technical memorandum focuses on the biogas production and utilization for those treatment alternatives. Additional economic analysis for this treatment alternative is provided in **Section 12.5** of this document.

12.4 Biogas Alternatives Description

After the review of the existing biogas utilization study and discussions with the City, the following biogas utilization alternatives are included in this study:

- **Alternative 0 – Flare all Biogas** – All biogas is flared and natural gas is purchased to provide digester heating.
- **Alternative 1 – Biogas Fueled Boilers** – Utilize digester gas to provide digester heating by using boilers and flare all unused gas.
- **Alternative 2 – Combined Heat and Power (CHP)** – Utilize biogas fueled engines to generate electric and thermal energy to offset the plant's energy demands
    - **Alternative 2a – Refurbish Existing Engines** – This alternative makes use of existing infrastructure by refurbishing the existing five (5) 500 kW Waukesha CHP engines for re-use in lieu of purchasing new engines.
    - **Alternative 2b – New CHP System Engines and Building** – Remove the existing Waukesha engines and heat recovery equipment and install new engines furnished with engine jacket heat recovery in a new building.
    - **Alternative 2c – New CHP System Engines in Existing Building** – Remove the existing Waukesha engines and heat recovery equipment and install new engines furnished with engine jacket heat recovery in the existing building.
- **Alternative 3 – Biogas to RNG for Vehicle Fueling** – Recover and condition/compress biogas to be used in the City's CNG capable vehicles.

12.4.1 Alternative 0 – Flare all Biogas

Alternative 0 assumes all biogas is flared and natural gas is purchased to provide digester heating. The purpose of evaluating this alternative is to establish a "zero resource recovery" baseline to compare the revenue generation of the other biogas utilization alternatives. This alternative will eliminate the existing capital costs and O&M costs associated with biogas fueled engines and is the lowest capital cost scenario. The advantages, disadvantages and summary are described in **Table 12.4-1**.

Table 12.4-1: Alternative 0 Summary

Summary	Advantages
• Remove all existing biogas fueled engines and appurtenances. • Remove existing gas treatment equipment. • Flare all biogas produced. • Purchase natural gas to meet heating demands.	• Lowest capital cost scenario • Lowest O&M cost scenario
	Disadvantages
	• No economic benefit from biogas energy recovery (all biogas flared)

12.4.2 Alternative 1 – Biogas Fueled Boilers

This alternative makes beneficial utilization of the biogas by fueling new boilers to provide digester heating. All unused biogas would be flared. This alternative eliminates the capital costs and O&M costs associated with biogas fueled engines. To prolong the life of the boiler, this scenario includes new biogas conditioning systems to remove sulfur compounds (H_2S) and moisture. The advantages, disadvantages and summary are described in **Table 12.4-2** below.

Table 12.4-2: Alternative 1 Summary

Summary	Advantages
• Remove all existing biogas fueled engines and appurtenances. • Replace existing gas treatment equipment. • All digester heating demands provided by biogas fueled boilers with natural gas backup. • Digester heating offsets = ~$215,000/year in purchased natural gas savings.	• Low capital costs • Low O&M costs • No purchased natural gas for digester heating • Less gas treatment required
	Disadvantages
	• Partial utilization of the biogas resource (majority of gas will be flared) • Moderate biogas treatment O&M costs for gas treatment equipment

12.4.3 Alternative 2 – Combined Heat and Power (CHP)

The CHP alternative explores technologies and strategies that utilize digester gas to produce electric energy to offset purchased energy and thermal energy that can be recovered for digester heating. The electric energy is used to offset the purchased utility power at the current retail rate. Thermal energy is recovered from the exhaust and engine cooling system to provide the digester/building heating demands. New CHP systems convert 35% of their energy input to electricity and 40% to heat, making them nearly 75% efficient.

With seasonal digester heating demands, any surplus thermal energy created by the CHP system can be released into the atmosphere. During periods of high digester seasonal heating demands, additional thermal energy can be added to the thermal energy created by the CHP system through the use of boilers. Boilers can be fueled by biogas and/or purchased natural gas.

Reciprocating internal combustion engines (RICE) are assumed in this study for the CHP alternative. The City has a large installed base of natural gas and digester gas fueled reciprocating internal combustion engines at the treatment plants and pumping stations. The City also has well developed engine maintenance and operations team that will enable them to effectively operate and maintain a biogas fueled CHP system. A concern to using reciprocating internal combustion engines to utilize digester gas is they will require costly digester gas pre-treatment systems and emission post-treatment. A typical CHP process diagram is shown below in **Figure 12.4-1**.

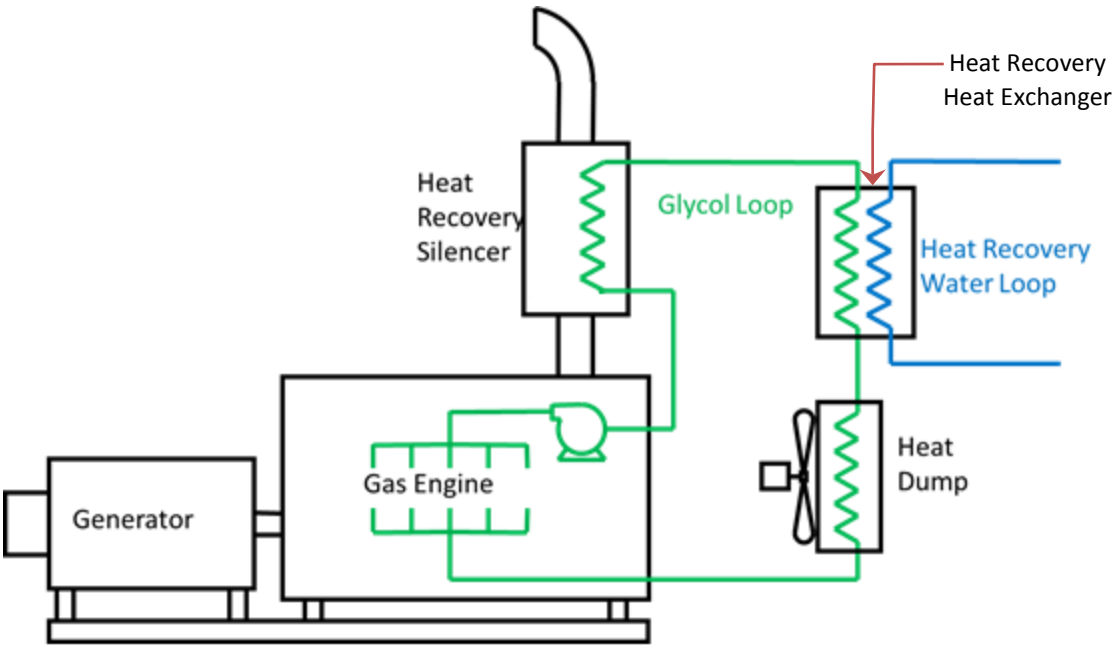

Figure 12.4-1: CHP Process Diagram

The three (3) CHP system alternatives include:

- Alternative 2a – Refurbish the existing biogas fueled engines and heat recovery equipment
- Alternative 2b – Replace existing engines and heat recovery equipment in a new building.
- Alternative 2c – Replace existing engines and heat recovery equipment in the existing building.

Digester gas pretreatment equipment to remove hydrogen sulfide, moisture, and siloxanes will be included for all CHP alternatives examined in the analysis. The digester gas pretreatment equipment includes an iron-oxide based hydrogen sulfide removal system, chillers and condensate traps for moisture removal, and a fixed bed carbon media system to remove siloxanes compounds. Capital costs for the pretreatment system was the same for all CHP Alternatives and is estimated to be approximately $1,125,000, including materials and labor. A detailed cost estimate is provided in **Attachment 12-B**. Digester gas pretreatment equipment O&M costs are included in the CHP system analysis. O&M costs include the time, labor, and materials for daily and media change-out operations and maintenance.

For this study, it was assumed that the benefit gained from offsetting the purchased electric energy under the retail rate would be from the energy usage component of the total utility bill, only to account for the loss of demand offset from CHP system downtime. It was determined the annual average electric energy offset benefit would be approximately $0.07/kWh for the CHP alternative.

A summary of the assumptions used in the CHP benefit evaluations are included in **Table 12.4-3.**

Table 12.4-3: CHP Benefit Evaluation Assumptions

Item	Description
Electric Energy Offset Benefit	$0.070/kWh
O&M Costs	$0.025/kWh of electric energy generated
Thermal Efficiency	40%
Electrical Efficiency	35%
CHP System Average Uptime	90% (10% Downtime)
Digester Gas Pre-Treatment Requirements	Moisture, hydrogen sulfide, and siloxane treatment systems required
Electrical Interconnection	Continuous parallel operation with plant electrical distribution system.
System Construction	"Containerized" system with weather proof enclosure
Thermal Energy Recovery	Heat recovery from engine cooling jacket and exhaust system. Heat is rejected to plant's existing hot water loop
Engine Parameters	1800 or 1200 RPM rich burn with three-way catalyst

Alternative 2a – Refurbish Existing Engines

This alternative refurbishes the existing five (5) 500 kW Waukesha CHP engines to like new condition. Refurbishing the existing engines will have lower capital costs, however the older engine technology is less efficient than modern engines. Each engine would be evaluated to determine the extent of repairs needed. If the damage is too extensive to rebuild, the unit would need to be replaced. Ancillary equipment associated with the existing engine system including heat recovery loop (pumps, heat exchangers, piping), digester gas trains, load sharing controls, and instrumentation and controls is assumed to all need replacement for the next phase of refurbished engine operations.

Based upon the existing average biogas production of ~650 SCFM and an electrical efficiency of 30%, it is estimated that the existing engines would generate an average of 2000kW, which would require four (4) of the CHP units to operate at ~100% capacity. The fifth engine will be a standby unit for use while another engine is down to maintain production.

The existing CHP system recovers thermal energy for digester heating from the engine's cooling water jacket only. Based on the results of a digester heating evaluation, the thermal energy production from the engine cooling water jacket only should be sufficient to supply 100% of the digester heating demands during the warm weather months. A more detailed evaluation is recommended during the design phase to determine if additional heat recovery is needed from the engine exhaust system to provide additional thermal energy to meet the digester heating demands.

The costs of emissions treatment are included in this alternative if the cost of the engine re-builds exceeds 50% of the engine value per the EPA, Subpart JJJJ and Subpart ZZZZ. The existing generator control switchgear is obsolete and will be upgraded with new generator control and load sharing control devices. The advantages, disadvantages and summary are described in **Table 12.4-4** below.

The total estimated cost for refurbishing the existing CHP system is approximately $9,844,689. A detailed cost estimate is provided in **Attachment 12-B**. It includes the following system components and existing infrastructure modifications:

- Refurbishing Existing Engine/Generator Systems
- Exhaust Emissions Controls
- Heat Recovery Heat Exchanger
- Gas Pre-treatment Skid (Includes H_2S, Moisture, and Siloxane treatment)
- Hot Water Recirculation Pump
- Existing Instrumentation and Control Modifications

Table 12.4-4: Alternative 2a Summary

Summary	Advantages
• Refurbish all existing biogas fueled engines and heat recovery equipment. • Replace existing gas treatment equipment and generator control switchgear. • Replace existing boilers and other gas handling equipment near the end of its useful life. New boilers will have biogas and natural gas fueling capabilities. • Replace existing gas treatment equipment to remove siloxanes, sulfur compounds, and moisture. • Initially generate ~14.8M kWh/year of electric energy, resulting in ~$1M/year in electric energy savings. • Digester heating offsets = ~$155,000/year in purchased natural gas savings	• Lower capital cost compared to new engines • Plant staff already trained to perform engine repairs and troubleshooting on existing engines. • Existing engines do not utilize proprietary engine controls. • Established Technology
	Disadvantages
	• High level of biogas treatment to remove siloxanes, sulfur compounds, and moisture • Higher O&M costs compared to Alternatives 0 and 1. • Lower electrical efficiency compared to newer engines (30% vs. 35%). • Potential requirements for exhaust after treatment to meet EPA emission requirements for stationary internal combustion engines.

<u>Alternative 2b – New CHP System Engines in New Building</u>

This alternative removes the existing Waukesha engines and heat recovery equipment and installs new engines and heat recovery equipment in a new building. The City requested a new building for the new CHP system engines during Phase 1 meetings. The new building would be located in close proximity to or would replace to the existing structure. The new engines will operate at a higher electrical efficiency (~35%) than the existing engines (~30%), increasing the electric energy offset benefit.

Ancillary equipment associated with the existing engine system, including heat recovery loop (pumps, heat exchangers, piping), digester gas trains, electrical generators, and instrumentation and controls is all assumed to need replacement.

Preliminary CHP system sizing calculation were performed using the current and projected gas production. To run properly, CHP systems must be utilized to at least 75% of their rating. Biogas production of ~650 SCFM and an electrical efficiency of 35%, would provide ~2423kW of electric power generation. This could support the installation of 2-1500kW units or 3-1000kW rated engine/generator units, staying above the 75% system rating. In the event that the biogas production is below the 75% system rating, natural gas can be blended with the biogas to reach the 75% system rating. For the purposes of this evaluation, 2-1500kW engines are assumed. The evaluation assumes a new generator building will be built and the CHP system ratings will remain constant over the 20-year planning horizon.

As the CHP system reaches it rated output and during periods of CHP system downtime, any digester gas not utilized by the CHP system will be flared. **Figure 12.4-2** shows the overall balance between the digester gas utilized by the CHP system and the gas flared for optimizing the existing liquid stream treatment and the acid-gas biosolids treatment alternatives. As expected, the amount of digester gas flared will increase over the 20-year planning period as gas production exceeds the fuel demand. It is anticipated that the CHP system can meet the heating demands without any additional thermal energy required and explains why no biogas is shown going to the boiler in **Figure 12.4-2**. The boiler will be a backup source of thermal energy as needed.

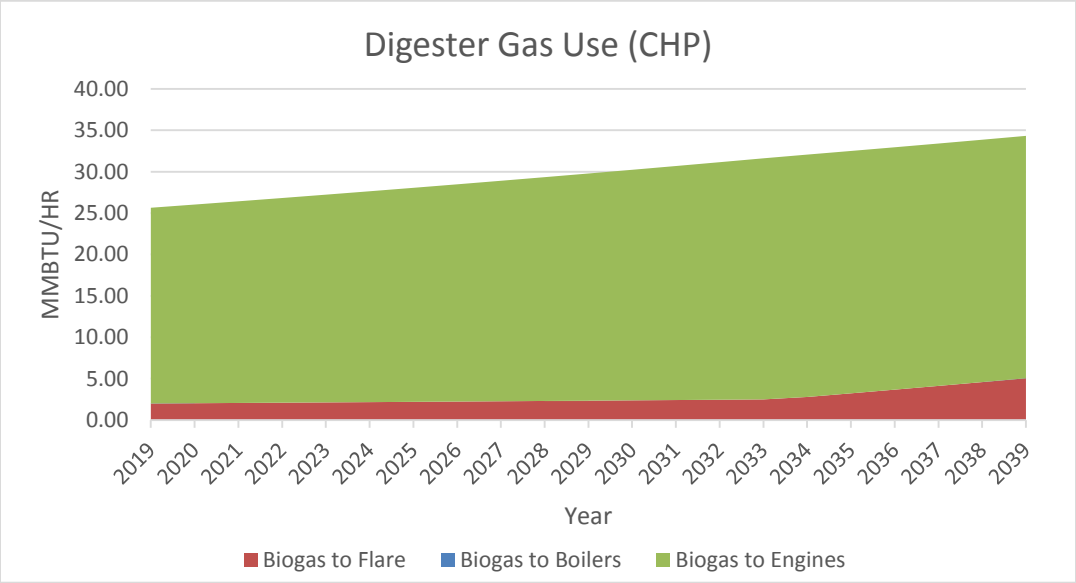

Figure 12.4-2: CHP Digester Gas Utilization (Optimize Existing Liquid Stream, Acid Gas Biosolids)

Figure 12.4-3 shows the 20 year heating demands vs production for optimizing the existing liquid stream treatment and the acid-gas biosolids treatment alternatives. The heat production shown includes both exhaust and water jacket heat recovery systems. The figure indicates that the CHP system creates more heat than required by the digesters.

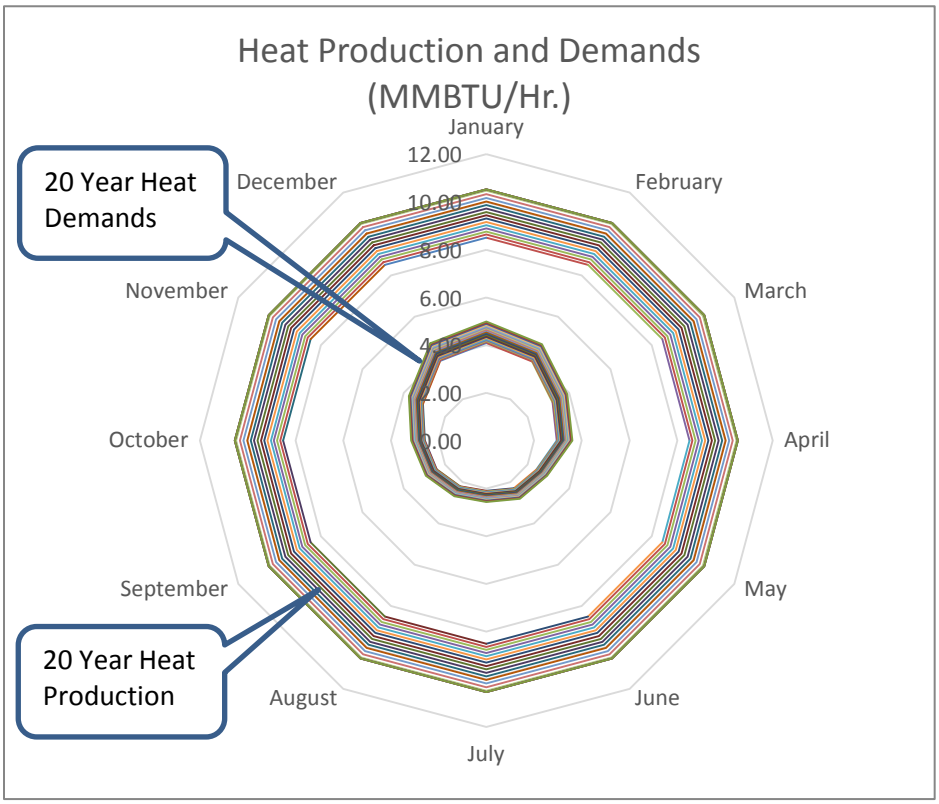

Figure 12.4-3: CHP Heating Demands and Production (Optimize Existing Liquid Stream, (Acid Gas Biosolids)

Engines purchased after 2006 are required to meet the EPA's New Source Performance Standards (NSPS) emission requirements for the criteria pollutants such as carbon monoxide (CO), oxides of nitrogen (NOx) and oxides of sulfur (SOx). To meet the NSPS standards, new modern engines utilize turbo charging and intercooling as well as complex and proprietary engine control systems, which require the engine supplier's certified technicians to troubleshoot and repair. This reliance on the engine supplier's support has the potential to increase the O&M costs and engine downtime between repairs when compared to the City's ability to utilize plant staff to repair the existing engines. The advantages, disadvantages, and summary are described in **Table 12.4-5** below.

The total estimated cost for a new CHP system in a new building as described is approximately $13,173,816. A detailed cost estimate is provided in **Attachment 12-B**. It includes the following system components and existing infrastructure modifications:

- Packaged Engine/Generator with gas blending and engine controls
- Exhaust Emissions Controls
- Continuous Emissions Monitoring Systems (CEMS) for engines over 1,000 bhp (brake horsepower)
- Heat Recovery Heat Exchanger
- Gas Pre-treatment Skid (Includes H_2S, Moisture, and Siloxane treatment)
- Hot Water Recirculation Pump
- Existing Electrical Distribution Modifications

- Existing Piping Modifications
- Site Work/Modifications
- Existing Instrumentation and Control Modifications
- New generator building

Table 12.4-5: Alternative 2b Summary

Summary	Advantages
• Replace existing engines with new units. • Replace existing gas treatment equipment and generator control switchgear. • Replace existing gas treatment equipment to remove siloxanes, sulfur compounds, and moisture. • Replace existing boilers and other gas handling equipment near the end of its useful life. New boilers will have biogas and natural gas fueling capabilities. • Initially generate ~20M kWh/year of electric energy, resulting in ~$1.34M/year in electric energy savings. • Digester heating offsets = ~$155,000/year in purchased natural gas savings	• Higher electrical efficiency compared to the existing engines (35% vs. 30%). • New engines will meet the EPA's emission requirements for stationary internal combustion engines. • Established Technology **Disadvantages** • High level of biogas treatment to remove siloxanes, sulfur compounds, and moisture • Higher O&M costs compared to Alternatives 0 and 1. • Proprietary engine controls require specialized manufacturer training and certifications to troubleshoot and repair engine problems. • EPA emission requirements results in more complex engine systems (i.e. turbo charging and intercooling, advanced engine controls).

<u>Alternative 2c – New CHP System Engines in Existing Building</u>

This alternative removes the existing Waukesha engines and heat recovery equipment and installs new engines and heat recovery equipment in the existing building. The City requested a new building for the new CHP system engines during Phase 1 meetings; however, this alternative is worth consideration due to the capital cost savings of using the existing building. Ultimately, this decreases the payback period of the CHP investment. The new engines are smaller than the existing engines and will operate at a higher electrical efficiency (~35%) than the existing engines (~30%), increasing the electric energy offset benefit.

Ancillary equipment associated with the existing engine system, including heat recovery loop (pumps, heat exchangers, piping), digester gas trains, electrical generators, and instrumentation and controls is all assumed to need replacement.

Preliminary CHP system sizing calculations are the same as Alternative 2b. For the purposes of this evaluation, 3-1000kW engines are assumed. The evaluation assumes the existing generator building will be used and the CHP system ratings will remain constant over the 20-year planning horizon. Preliminary designs after reviewing existing generator building record drawings indicate that three (3) CHP engines such as the GE Jenbacher Model 320 1062kW systems would fit in the existing building where CHP Engine Nos. 3, 4, and 5 are currently located.

Digester gas utilization, heating production, and emissions treatment remain the same in this alternative as described for Alternative 2b. **Figure 12.4-2** shows the overall balance between the digester gas utilized by the CHP system and the gas flared for optimizing the existing liquid

stream treatment and the acid-gas biosolids treatment alternatives. **Figure 12.4-3** shows the 20-year heating demands vs production for optimizing the existing liquid stream treatment and the acid-gas biosolids treatment alternatives. The advantages, disadvantages, and summary are described in **Table 12.4-6** below.

The total estimated cost for a new CHP system in the existing building as described is approximately $9,102,216. A detailed cost estimate is provided in **Attachment 12-B**. It includes the following system components and existing infrastructure modifications:

- Packaged Engine/Generator with gas blending and engine controls
- Exhaust Emissions Controls
- Continuous Emissions Monitoring Systems (CEMS) for engines over 1,000 bhp (brake horsepower)
- Heat Recovery Heat Exchanger
- Gas Pre-treatment Skid (Includes H_2S, Moisture, and Siloxane treatment)
- Hot Water Recirculation Pump
- Existing Electrical Distribution Modifications
- Existing Piping Modifications
- Site Work/Modifications
- Existing Instrumentation and Control Modifications
- Building Rehabilitation/Modifications

Table 12.4-6: Alternative 2c Summary

Summary	Advantages
• Replace existing engines with new units. • Replace existing gas treatment equipment and generator control switchgear. • Replace existing gas treatment equipment to remove siloxanes, sulfur compounds, and moisture. • Replace existing boilers and other gas handling equipment near the end of its useful life. New boilers will have biogas and natural gas fueling capabilities. • Initially generate ~20M kWh/year of electric energy, resulting in ~$1.34M/year in electric energy savings. • Digester heating offsets = ~$155,000/year in purchased natural gas savings	• Higher electrical efficiency compared to the existing engines (35% vs. 30%). • New engines will meet the EPA's emission requirements for stationary internal combustion engines. • Established Technology • Utilize existing building
	Disadvantages
	• High level of biogas treatment to remove siloxanes, sulfur compounds, and moisture • Higher O&M costs compared to Alternatives 0 and 1. • Proprietary engine controls require specialized manufacturer training and certifications to troubleshoot and repair engine problems. • EPA emission requirements results in more complex engine systems (i.e. turbo charging and intercooling, advanced engine controls).

12.4.4 Alternative 3 – Biogas to RNG for Vehicle Fueling

For this alternative, digester gas is treated (or "upgraded") to natural gas pipeline quality (RNG) and will be used as a transportation fuel to gain the benefit from the RIN commodity market. The pathway to the transportation fuels market can be accomplished by the following two pathways:

- Pathway 1 – Direct Vehicle Fueling. RNG would be compressed and stored for onsite vehicle fueling. The RNG could be used to fuel the City's CNG capable vehicle fleet such as refuse trucks to offset purchased liquid fuels (i.e. diesel and gasoline). The RNG could also be sold to other agencies with CNG vehicles (such as the Hillsborough Area Regional Transient (HART) busses and vans) at the retail CNG prices.
- Pathway 2 – Pipeline Injection. RNG would be injected into TECO's pipeline and "wheeled" through TECO's distribution system to transportation fuel customers. The RNG will generate revenue through methane sales to TECO and through the generation of renewable energy commodities that can be traded/sold to parties obligated to meet the renewable energy requirements under the EPA Renewable Fuel Standards (RFS2). Based on discussions with various third party RNG marketing companies, RNG can also be sold as a renewable material to corporations who manufacturer goods from natural gas such as plastics and chemicals.
- Combination of Pathways 1 and 2

Direct vehicle fueling is the simplest and most direct pathway to the fuels market. However, there are some barriers associated with this alternative:

- There could be logistical challenges with fueling the vehicles given the location of the CNG fleet and the plant sites. A study of the City's current and projected CNG vehicle fleet will be required to fully understand the logistics involved with meeting the fleet fueling needs.
- Fueling the vehicles directly would be an intermittent use of the RNG produced. Since digester gas is produced continuously, compressed RNG storage would be required during periods when the fleet vehicles are fully fueled or not in use (i.e. nights, weekends, holidays).

Pipeline injection overcomes many of the direct vehicle fueling logistical and production barriers. For example, RNG can be injected into the pipeline continuously, allowing around the clock production. In addition, the RNG production quantity and schedule would not be limited to the City's fleet demands and operations. Pipeline injection also enables the RNG produced to reach a wide network of RNG customers. Pipeline injection does however pose a few barriers that must be considered:

- A pipeline extension from the RNG facility to a connection point approved by TECO could be a significant cost
- To establish the pathway to the transportation fuel market, a contractual agreement must be established with an end use customer that demonstrates the fuel produced is used as a transportation fuel. This will be explained in further detail below.
- A high level of gas monitoring, metering, and reporting must be installed to ensure the RNG meets TECO's gas quality requirements.

For the purposes of this alternative, it is assumed that all biogas will be treated to natural gas pipeline quality standards and injected into the natural gas pipeline. The CNG will be "wheeled" through TECO's natural gas pipeline network out to a wide network of customers, including the City's CNG fueling stations. Between the City's existing 60 refuse trucks and Hillsborough Area Regional Transit Authority's (HART) 60 CNG busses, it is anticipated that approximately 1.1M GGE of RNG per year will be consumed, the majority of RNG produced.

CO2 Removal Technologies

Upgrading raw digester gas to natural gas standards requires the removal of carbon dioxide (CO_2), which makes up approximately 40% of the digester gas by volume. Other contaminants such as moisture, sulfides of hydrogen (H_2S), and silica compounds (Siloxanes) must also be removed. The commonly available technologies for CO_2 removal are:

- Pressure Swing Adsorption (PSA)
- Selective Membranes
- Water Scrubbing
- Chemical Scrubbing (Amine)

Pressure Swing Adsorption (PSA)

Pressure swing adsorption (PSA) systems pass raw digester gas through multiple vessels containing adsorbent media. The PSA system media adsorbs specific gas constituents (i.e. CO_2) under high pressure. These constituents are released from the media during the decompression stage (blowdown) of the PSA cycle. Typical adsorbent media include activated carbon, natural and synthetic zeolites, and molecular sieves. These adsorbents can be used to remove CO_2, H_2S, and volatile organic carbons (VOCs), including siloxanes. **Figure 12.4-4** shows the basic components of a typical PSA system.

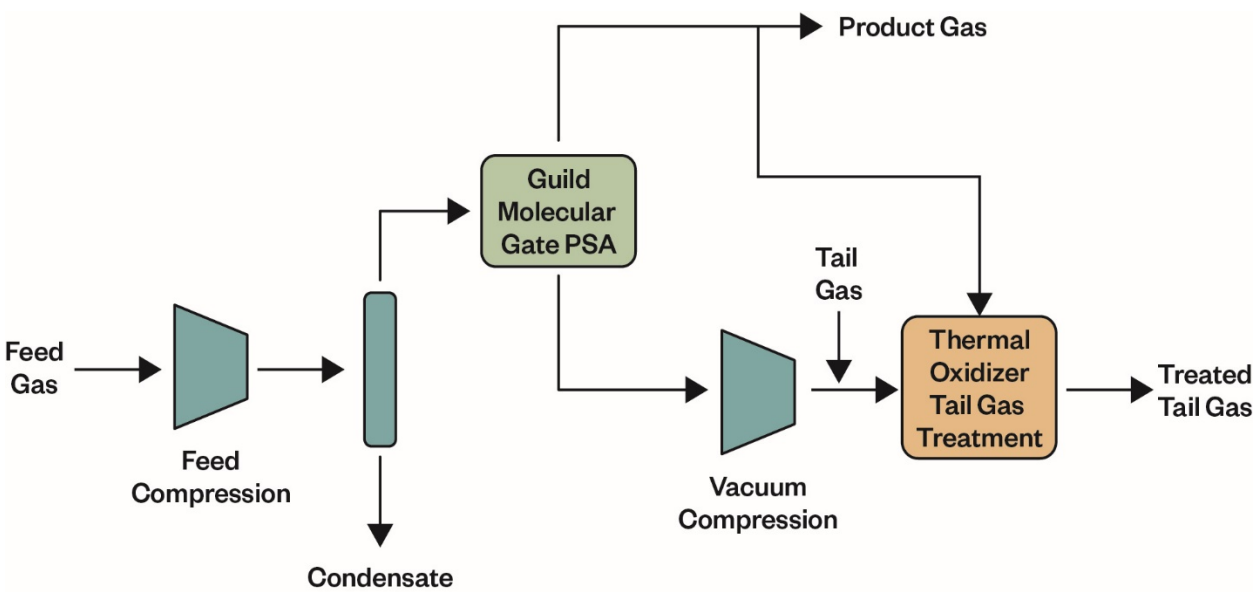

Figure 12.4-4: Typical PSA Process Flow Diagram (Guild Associates Molecular Gate™ Example)

Common manufacturers of PSA systems include:

- Guild Associates
- Greenlane
- Carbotech
- Xebc

The basic operating principal is the same for these manufactures. However, it should be noted that different adsorbents are used depending on the manufacturer most of which are proprietary to the system manufacturer. For example, Guild Associates offers a molecular sieve type media that removes H_2S, siloxanes, and CO_2 in a single unit; reducing the level of gas pre-treatment required. Other manufacturers use activated carbon or similar adsorbing media which may require an additional treatment step to remove H_2S and siloxanes. The typical PSA cycle is as follows:

- Digester gas is pretreated to remove contaminants (i.e. moisture, H_2S, siloxanes, etc.) as required by the specific PSA process.
- Pretreated gas is compressed (typically around 100psi using liquid ring compressors) and chilled to remove water vapor and other condensable contaminants. Some manufacturers may treat for H_2S and siloxane during this step also.
- Compressed gas is fed to the PSA unit where contaminants (i.e. CO_2) are adsorbed by the adsorptive media. The treated gas exits the process at a slightly lower pressure (typically around 90psi). Some manufacturers require the gas to be preheated prior to this step.
- After a determined operating period, the contaminants are desorbed by depressurizing the PSA vessel and then purging with treated gas. The purged material is known as “tail gas”.
- The tail gas is oxidized in a thermal oxidizer.

Thermal oxidation is a method of air pollution control, which decomposes hazardous gases at a high temperature and releases them to the atmosphere. Thermal oxidation is typically used to destroy hazardous air pollutants (HAPs) and VOCs by thermal combustion to form CO_2 and H_2O.

The number and size of PSA and pretreatment vessels depend on the digester gas quantity and contaminants and will vary with each manufacturer.

Selective Membranes

Selective membranes create a semi-permeable barrier to separate methane and CO_2. Compressed digester gas (typically around 200psi) travels through the membranes, allowing CO_2, O_2, H_2O and H_2S to permeate at a high rate while methane molecules permeates at a slower rate. The faster permeation of the undesirable constituents, along with the slower permeation of methane results in a product leaving the membrane module, which is rich in methane, but with low concentrations of the other gases. Pre-treatment is typically used before the membranes to remove moisture, H_2S, siloxanes, and other undesirable contaminants. **Figure 12.4-5** shows the basic components of a typical selective membrane system.

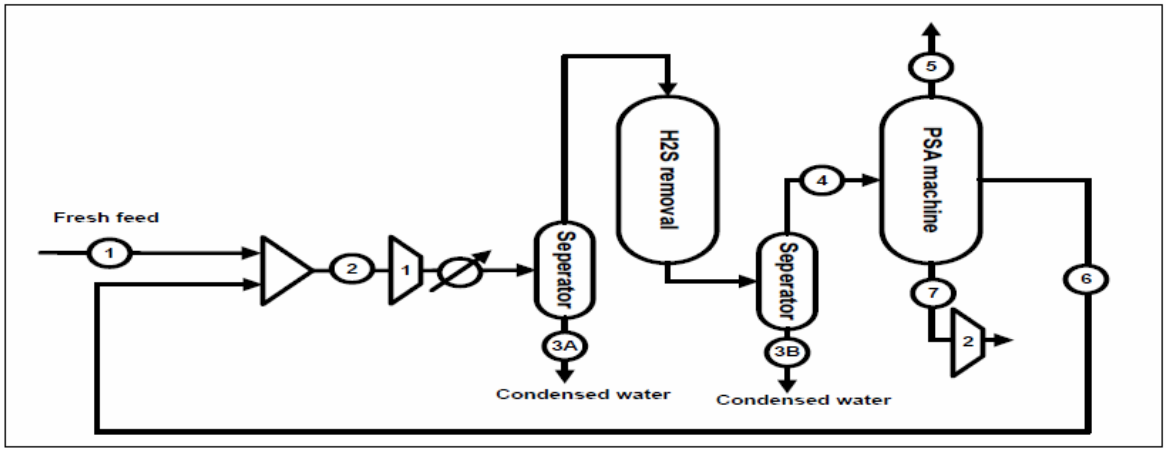

Figure 12.4-5: Typical Membrane Process Flow Diagram (Courtesy of Xebec)

Common manufacturers of selective membrane systems include:

- Xebec
- Hitachi Zosen Inova (HZI)
- DMT

The basic operating principal is the same for these manufactures with the primary difference being the type of membrane and the level of pre-treatment used before the membranes. The typical membrane treatment cycle is described below:

- Digester gas undergoes pre-treatment to remove H_2S, VOCs, siloxanes, and other undesirable containments.
- Pre-treated gas is compressed (typically around 200 – 350psi) and chilled to remove water vapor and other condensable contaminants. Some manufacturers may provide additional H_2S and siloxane treatment during this step.
- For some manufacturers, gas undergoes a catalytic oxygen removal step before the membranes
- Gas is fed through the membranes for CO_2 and other gas constituent removal.
- Treated gas is provided around 200 – 350psi.
- The membrane treatment by-product (tail gas, or sometimes referred to as "lean gas" for membrane systems) is typically oxidized in a thermal oxidizer.

<u>Water Scrubbing</u>

Water scrubbing systems use water to absorb CO_2 and H_2S by taking advantage of the fact that methane is much less soluble in water than CO_2 and H_2S. Gas is compressed to around 100 to 150 psig (to increase the amount of CO_2 that can be dissolved in the water) and enters an absorption column. CO_2, in addition to a very small proportion of methane, is dissolved in water within the column. The CO_2 laden water is sent to a desorption column, where air (at atmospheric pressure), is added to strip CO_2 from the water. Both columns are filled with packing material to maximize contact between the gas and the water. Because water leaving the absorption column contains some methane, a flash column is used, which operates at low

pressure to remove methane from the water. The methane is then returned to the raw gas feed. **Figure 12.4-6** shows the basic components of a typical water scrubbing system.

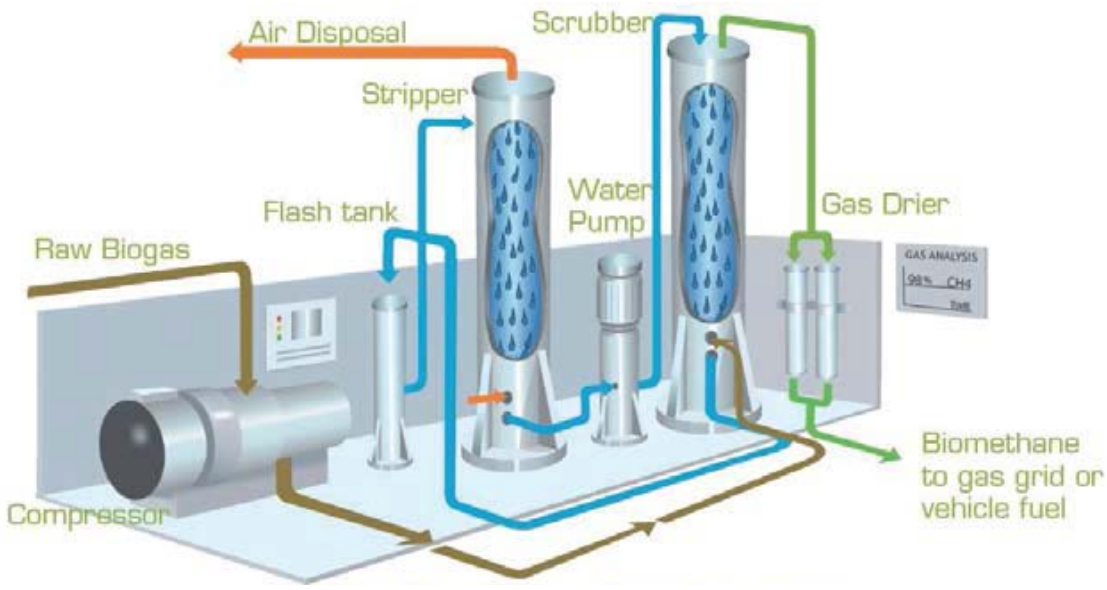

Figure 12.4-6: Typical Water Scrubbing Process Flow Diagram (Courtesy of Greenlane)

Common manufacturers of water scrubbing systems include:

- Greenlane

Water scrubbing systems are relatively tolerant of gas contaminants and biogas can often be processed without prior removal of moisture, H_2S, and VOCs. Air leaving these systems will, however, contain H_2S and other gas contaminants and often the air stream may require treatment to avoid environmental issues (e.g. using adsorptive media in an adsorption vessel or using a thermal oxidizer).

<u>Chemical Scrubbing (Amine)</u>

Chemical scrubbing works on a similar principle to water scrubbing, except that the solvent used to remove CO_2 is a water-based solution of methyldiethanolamine (MDEA). The amine reacts with CO_2 dissolved in the water, which increases the rate at which CO_2 is removed. Chemical scrubbing improves the removal efficiency as compared to water scrubbing. Common manufacturers of chemical scrubbing systems include:

- Purac Puregas

As with water scrubbing, it is not necessary to remove H_2S prior to amine scrubbing for the process to function. However, H_2S removal is often utilized anyway for environmental reasons. While amine scrubbing is very efficient, its use is much less common than other technologies discussed, due primarily to higher life cycle cost.

Technology Comparison

Table 12.4-7 provides a summary of the digester gas upgrading technologies described.

Table 12.4-7: Digester Gas Upgrading Technology Summary

Digester Gas Upgrading Technology	Treatment Method	Pre-treatment Requirements	Consumables	Comments
PSA	Adsorption media	Varies with Manufacturer	Pretreatment media and some adsorption media (i.e. activated carbon).	Most common technology. Large footprint and high noise
Selective Membranes	Molecular Permeation	Yes	Pretreatment media	Small footprint, simple operations
Water Scrubbing	Water Solvent	No	Make up water	No consumables except water. Not able to absorb some containments.
Chemical Scrubbing	Water and Amine Solvent	No	Make up water and chemicals	Highly effective CO2 removal. Chemical consumption

For this evaluation, a PSA system is used as the basis of the RNG evaluations since PSA is one of the most common technologies used for biogas upgrading. Even though some RNG system manufacturers do not require gas pre-treatment, it is assumed that upstream H_2S and siloxane removal will be required and the waste gas would be burned in a thermal oxidizer. It should be noted that it is not the intent of this study to identify the most beneficial RNG production technology but to evaluate the overall feasibility of RNG production. It is recommended that a detailed technology study should be performed if the City decides to pursue RNG production as a long-term digester gas utilization strategy.

An example Microgate PSA RNG system installed at an existing treatment plant is shown in **Figure 12.4-7**.

Figure 12.4-7: Example Microgate PSA RNG System (75 SCFM)

RINs

Using RNG as a transportation fuel qualifies it to generate renewable transportation fuel credits, known as "Renewable Identification Numbers" (RINs). RINs are tradable renewable fuel commodities that are used to for compliance with the EPA's "Renewable Fuel Standards" (RFS2). RNG produced from municipal anaerobic digester gas qualifies as an "advanced cellulosic biofuel" or "D3" RIN, which can be sold to obligated parties, who are required to comply with the renewable volume obligations (RVOs) under the RFS2 requirements. The RFS2 sets a target volume of 36 billion gallons of renewable fuels to be blended in the United States transportation fuel market by 2022. As shown in **Figure 12.4-8** below, the RVOs are comprised of different fuel types, which are formed from different feed stocks.

Cellulosic biofuels (D3) must be produced from feed stocks that produce a fuel that has a 60% overall lifecycle GHG reduction compared to non-renewable fuels. The EPA has developed a pathway (Pathway Q) that establishes municipal wastewater digester gas as a cellulosic biofuel that would generate a D3 RIN if used in the transportation fuels market. It should be noted that the EPA recognizes biogas generated from waste digesters (i.e. food waste, HSW, FOG, etc.) as an "advanced biofuel" that qualifies to generate a D5 RIN. This segregation of municipal sludge/digester and waste digester could cause concern when identifying the RIN code for gas produced from co-digesting waste products, such as food waste and fats oils and grease with municipal sludge.

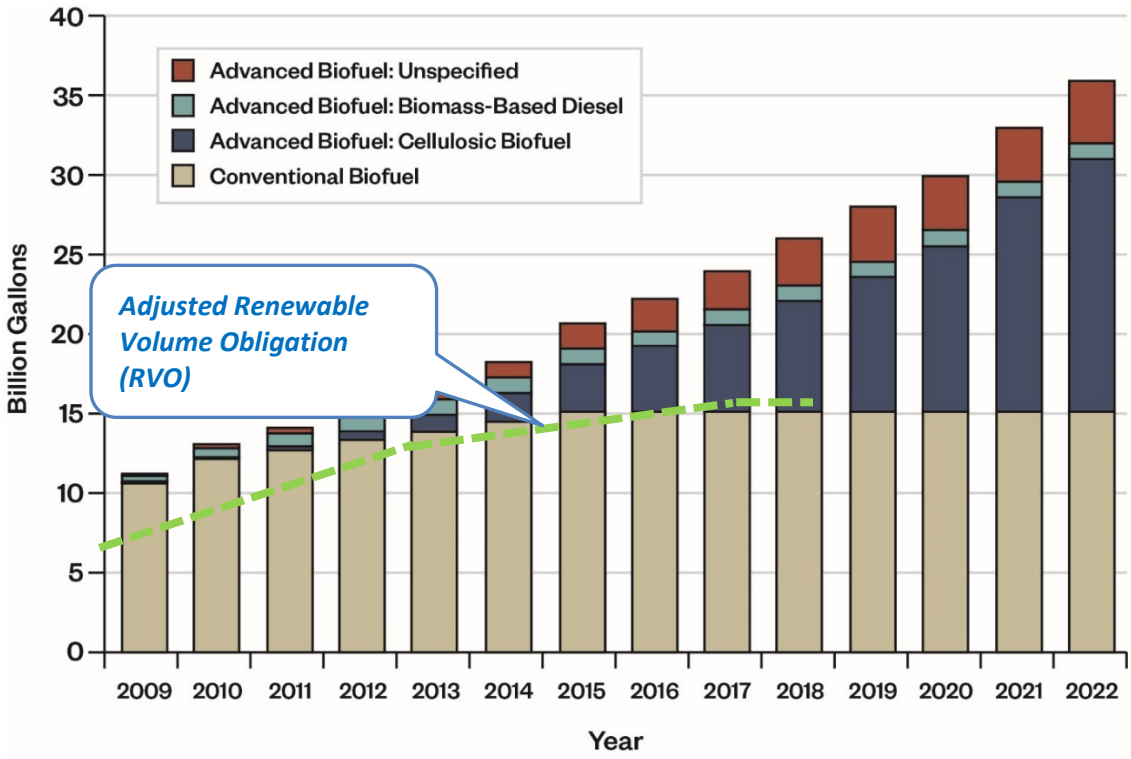

Figure 12.4-8: RFS2 Renewable Fuel Target

The historical trading prices for D3 and D5 RINs are shown in **Figure 12.4-9**.

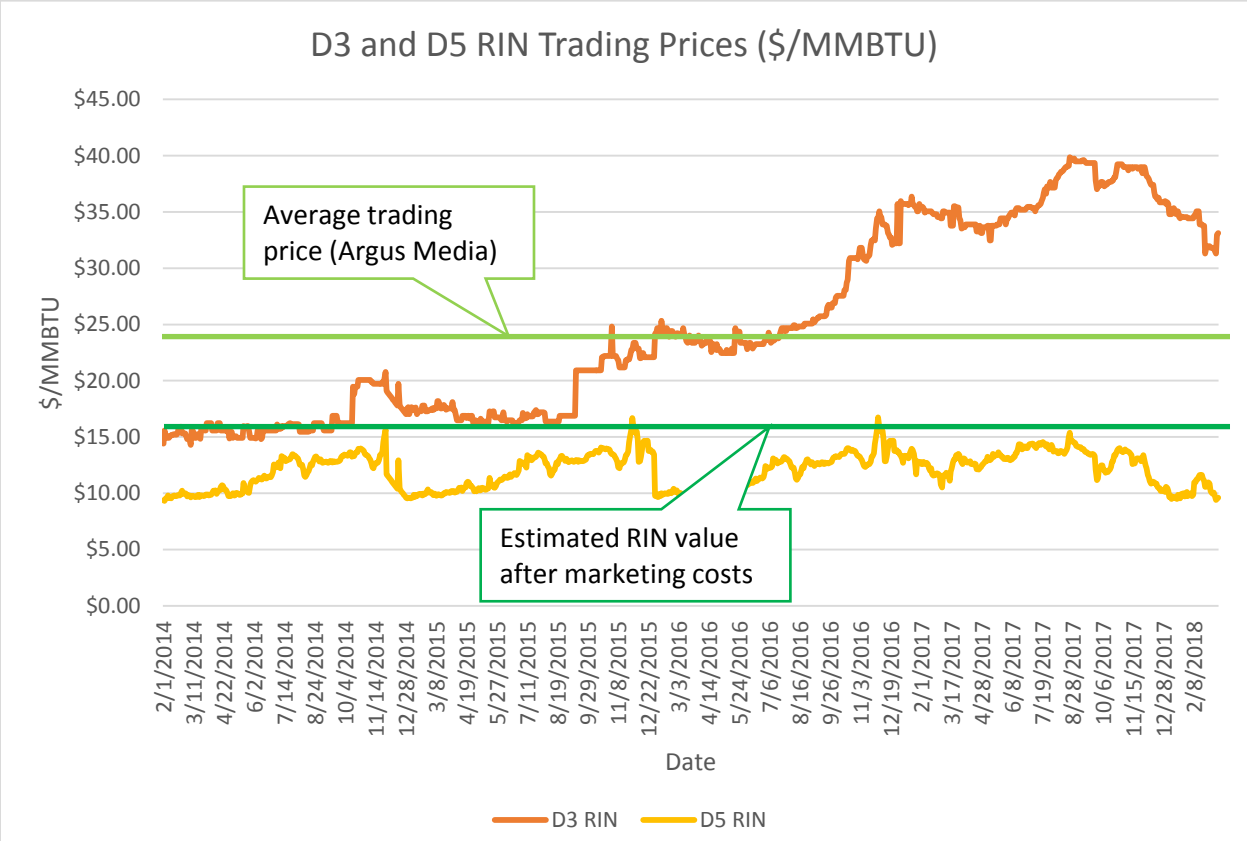

Figure 12.4-9: Historical D3 and D5 RIN Prices

For the purposes of this study, it is assumed that RNG produced would meet the requirements of a cellulosic biofuel that would qualify for the production of D3 RINS. For the time period covered in the Figure above, the average D3 RIN trading price is over $23/MMBTU. For this evaluation, the projected base RIN values are assumed to be $16.00/MMBTU, after marketing costs have been removed.

The demand for cellulosic biofuels is anticipated to continue to grow until the renewable volume for the cellulosic biofuels is met. The EPA calculates and modifies the RVO for each renewable fuel category each year based on the fuel availability and growth demands. To date, the annual compliance RVOs for cellulosic biofuels has been reduced below the standard projections due to the low availability of qualifying fuels. **Figure 12.4-8** shows the adjusted RVO through 2018. As shown in **Figure 12.4-8**, the renewable volume obligations set by the EPA for years 2014 to 2017 have fallen behind the RVOs projected in the standard. If this trend continues, it would delay the final RVO objectives well beyond the 2022 goal.

The value of the RNG production is summarized in **Figure 12.4-10** and compared to the value of electric energy generation. For the purposes of this study, it is assumed that 30% of the RIN carbon offset value would be consumed as marketing expenses such as the cost of a 3rd party marketer. It should be noted that the values show in **Figure 12.4-10** are adjusted for the energy

conversion efficiencies of the CHP and RNG technologies. For example, the $16/MMBTU RIN Credit at 80% conversion efficiency is $12.80/MMBTU as shown in **Figure 12.4-10**.

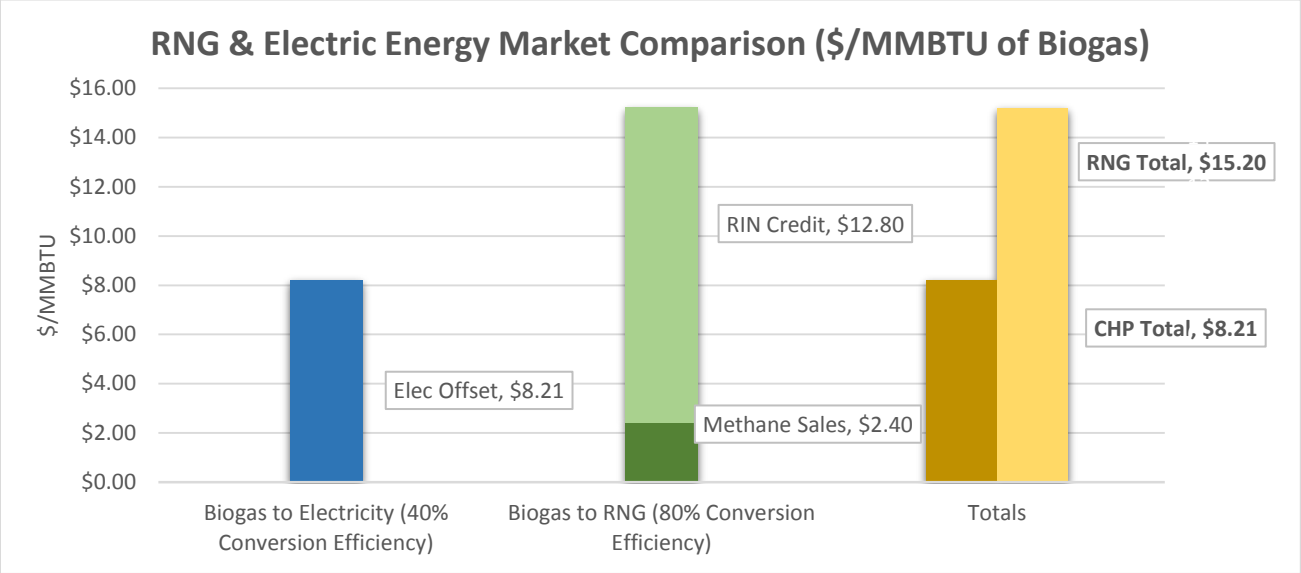

Figure 12.4-10: RNG and Electric Energy Market Comparison

Pipeline Extension and Interconnection Requirements

The detailed pipeline interconnection includes two primary components:

- The point in the TECO owned pipeline facilities where the RNG can be injected ("point of receipt")
- The pipeline extension from the HFC AWTP plant site to the point of injection.

The pipeline network injection point must have the capacity to accept the maximum supply of RNG produced by the plant. The connection point distance from the plant can have a significant impact on the RNG project capital costs. A preliminary interconnection study has indicated that RNG cannot be injected into the pipeline on the port peninsula. The injection point will have to be at the transmission main near the Selmon Expressway, approximately 2.5 miles from the plant. A detailed interconnection study must be performed by TECO to confirm the nearest suitable injection point. The interconnection study includes the following general steps:

- High level utility pipeline assessment – Identifies the nearest likely connection point to TECO's pipeline networks and length of gas interconnection pipeline.
- Interconnection Capacity Study – Determines TECO's gas acceptance capacity and cost estimate for extension pipeline. The study would be funded by the City.
- Interconnection Engineering Studies – More detailed study which includes cost estimate for Gas Quality Monitoring and Measurement Facilities. Describes all costs of construction, develop complete engineering construction drawings, and prepare all permit applications.
- TECO Interconnection Authorization and Construction

During preliminary discussions with TECO, TECO estimates that ~$1.8/MMBTU (18cents/therm) of RNG produced would cover the interconnection installation, gas monitoring and metering

under an RNG system contract between the City and TECO. This would not cover injection of propane if required.

It should be noted that only a preliminary interconnection study has been done at the time of this study. A map of the natural gas distribution network in the area is found in **Figure 12.4-11**.

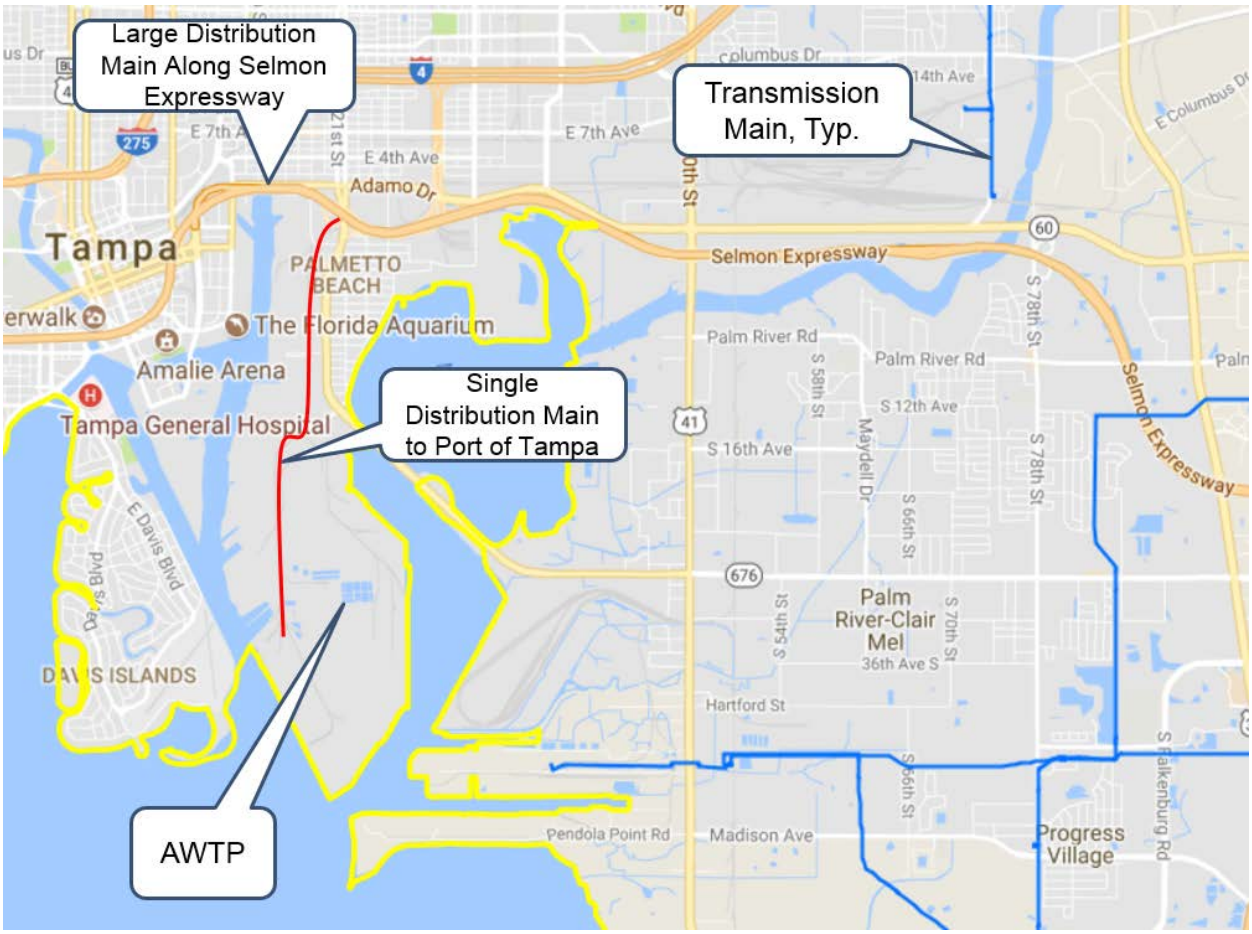

Figure 12.4-11: Existing Natural Gas Pipeline

Preliminary Sizing Calculations

The evaluation of this alternative assumes all biogas will be used for RNG production for pipeline injection and natural gas will be purchased to meet heating demands. This option provides the greatest financial benefit as the RIN prices exceed the cost of natural gas. The available biogas will be sufficient to produce approximately 1.44M gasoline gallon equivalents (GGE) of RNG per year for pipeline injection.

RNG systems are sized based upon the feed flow. For HFC AWTP, a feed flow of 800 SCFM is suggested. Expected annual output in gasoline gallon equivalents (GGE) for the current biogas production is ~1.44M GGE/Yr initially, using the existing liquid stream optimization and acid gas treatment alternatives. The projected GGE production rate is shown in **Figure 12.4-12**. As the biogas production reaches the RNG system rating, any biogas not utilized by the RNG system would be flared.

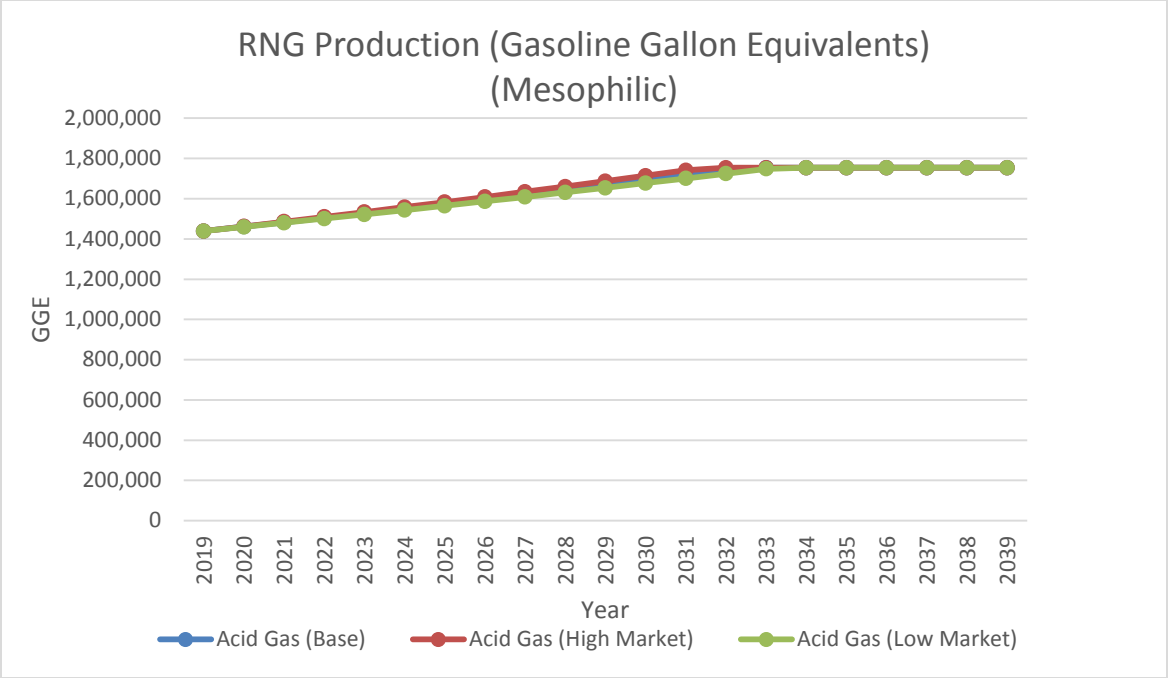

Figure 12.4-12: Estimated Annual RNG Production

The advantages, disadvantages and summary are described in **Table 12.4-8** below.

The total estimated cost for a new RNG system as described is approximately $19,456,632. A detailed cost estimate is provided in **Attachment 12-B**. It includes the following system components and existing infrastructure modifications:

- PSA Treatment System
- Thermal Oxidizer
- Gas Monitoring with sulfur analyzer
- Gas Piping
- Condensate Drain Piping
- Electrical and Mechanical Distribution Modifications
- Existing Piping Modifications
- Site Work/Modifications
- Pipeline Interconnect
- Odorize System
- Existing Instrumentation and Control Modifications

Table 12.4-8: Alternative 3 Summary

Summary	Advantages
• Remove all biogas fueled engines and heat recovery equipment • Install new biogas to RNG treatment, compression, storage, transport, and dispensing equipment • Use natural gas to provide digester heating. • Biogas converted to RNG for pipeline injection. • Replace existing boilers and other gas handling equipment near the end of its useful life. New boilers will have biogas and natural gas fueling capabilities. • Sales of ~158,000 MMBTU/Yr of CNG = ~$475,000/Yr in revenue • RIN sales at $16.00/MMBTU = ~$2.5M/Yr in revenue (includes RNG marketing costs)	• Higher benefit potential by offsetting purchased liquid fuels and by generating RIN credits. • City already has CNG capable vehicles and CNG dispensing • Vehicle fuel is used off-site and does not contribute to the plant's emissions inventory
	Disadvantages
	• Emerging technology • Long term benefit dependent on strength and stability of the RIN market

12.5 High Strength Waste

Receiving high strength organic waste (HSW) provides an additional source of readily biodegradable material that can increase biogas production. Current research indicates that HSW loading to digesters should range between 30 and 50% of the total volatile solids. A preliminary evaluation of the current digester loadings concluded that co-digesting HSW has the potential to increase digester gas production by approximately 25%. Based on Hazen's experience on previous HSW receiving projects, the acceptance of HSW would require a capital investment of $1,000,000 for a new HSW receiving facility and would increase the digester heating demands by ~15%. However, there are few facilities that can provide the HSW to the plant as discussed at the October 3, 2017 workshop. As noted earlier, the amount of HSW added to the treatment process can affect the RIN classification and the resulting trading price. Calculations performed in the Phase 1 Master Plan and workshops indicate that a 15-20 year payback is expected for HSW. With the long payback period and the uncertainty around getting HSW to the plant, the City is not interested in pursuing HSW further and HSW is not considered in calculations in this technical memorandum.

12.6 Project Delivery Alternatives

The biogas utilization recommendations herein are based on a biogas utilization system that is owned and operated by the City of Tampa. The City of Tampa can explore other project delivery alternatives that may bring value to the City. Project delivery alternatives include city owned and operated systems as well as 3rd party ownership and operations alternatives. The project delivery alternative should be based on the City's risk tolerance, project costs, and O&M capacity. At a minimum, it is recommended the City explore the risks/benefits from a 3rd party delivery alternative for the RNG alternative to understand if a 3rd party involvement can bring value to the project by taking the ownership and/or operations of the RNG system. Third parties include TECO gas and other private energy project developers. It is recommended that the City of Tampa coordinate with their procurement department to understand the procurement requirements for all project delivery alternatives.

12.7 Biogas Alternatives Analysis

The biogas utilization feasibility evaluations were performed using Hazen's Energy Balance & Analysis Tool (EBAT). EBAT is an energy analysis and modeling tool that models the complex relationship between energy production, energy demands and energy costs to provide accurate long-term cost/benefit assessments for multiple biogas utilization alternatives. The EBAT model was used to generate a 20-year Life Cycle Cost/Benefit Analysis (LCA) for each of the biosolids and liquid stream alternatives and the impact on the biogas production and utilization alternatives. The 20-year LCA incorporates capital cost debt service, the energy savings, and the O&M costs to calculate the true 20-year life cycle cost/benefit for each alternative. The EBAT model calculates 20-year life cycle costs for current market conditions as well as high and low market conditions so the full range of economic outcomes for the biogas utilization alternatives can be understood.

The EBAT model calculates all costs/revenues for the year the cost was incurred (nominal dollars) over the 20 year life cycle. To simplify the 20 year lifecycle costs and to be consistent with previous studies, the revenue and cost data shown herein are shown in terms of "annualized" costs. The annualized costs represent the net present value of the 20 year lifecycle costs as an annual cost expressed in present day dollars (net present value) over a 20 year amortization period.

The assumptions used for the life cycle cost/benefit analysis are summarized in **Attachment 12-A**.

12.7.1 Estimated Capital Costs

Conceptual level capital cost estimates were developed for each alternative. The cost estimates include the costs for the major equipment and the supporting equipment and infrastructure. The capital costs include 30% contingencies, 20% overhead and profit and general conditions, and 20% for management and engineering. **Table 12.7-1** below shows the conceptual capital cost estimates for each alternative evaluated. A break-down of the capital costs are provided in **Attachment 12-B** of this report.

Table 12.7-1: Estimated Capital Costs

Alternative	Capital Costs[1]
Alt 0 (Flare all Biogas)	$0
Alt 1 (Biogas to Boilers)	$0
Alt 2a (CHP w/ Refurbished Engines)	$9,844,689
Alt 2b (CHP w/ New Engines, New Bldg.)	$13,173,816
Alt 2c (CHP w/ New Engines, Exist. Bldg.)	$9,102,216
Alt 3 (RNG)	$19,456,632

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

12.7.2 Operational and Maintenance (O&M) Costs

The operation and maintenance costs for each alternative include the labor, materials, and energy costs. The O&M costs were calculated using typical costs per unit of energy produced or consumed for the major equipment used in each alternative. The O&M costs are based on typical industry accepted costs as well as data provided by the City and data collected by Hazen

for similar systems on other projects. The assumed O&M costs are summarized in **Attachment 12-A**.

O&M costs for the current CHP system operation for years 2014 and 2015 was provided by City and was evaluated to confirm the existing CHP system O&M costs did not exceed the O&M costs included in the study. The data provided by the City shows an average CHP system O&M costs of $0.018/KWH which did not include the O&M for the gas treatment facilities.

The O&M costs were escalated over the 20 year life cycle at the rate of inflation to account for increases in labor rates, cost of materials and cost of energy. The O&M costs for each alternative are summarized in **Table 12.7-2** below.

Table 12.7-2: Estimated O&M Costs (Base Conditions)

Alternative	20-Year Present Value
Alt 0 (Flare all Biogas)	$490,000
Alt 1 (Biogas to Boilers)	$672,000
Alt 2a (CHP w/ Refurbished Engines)	$9,298,000
Alt 2b (CHP w/ New Engines, New Bldg.)	$18,890,000
Alt 2c (CHP w/ New Engines, Exist. Bldg.)	$18,890,000
Alt 3 (RNG)	$15,585,000

12.7.3 Net Operating Costs

The Net Operating Costs (NOC) accounts for the actual operating costs or "cash flow" for each alternative. The NOC includes the capital cost debt service, purchased energy costs, energy production revenue, and O&M costs over a 20 year life cycle. The NOC for each alternative are summarized in **Table 12.7-3** below.

Table 12.7-3: Net Operating Costs (Base Conditions)

Alternative	20-Year Present Value
Alt 0 (Flare all Biogas)	$3,577,000
Alt 1 (Biogas to Boilers)	$389,000
Alt 2a (CHP w/ Refurbished Engines)	($3,102,000)
Alt 2b (CHP w/ New Engines, New Bldg.)	($3,125,000)
Alt 2c (CHP w/ New Engines, Exist. Bldg.)	($7,053,000)
Alt 3 (RNG)	($27,113,000)

Figure 12.7-1 shows the NOC Present Value for all alternatives. The study results show that Alternatives 2 (CHP) and 3 (Vehicle Fueling/RNG) are the only two alternatives with a negative net operating cost and could produce revenue for the plant.

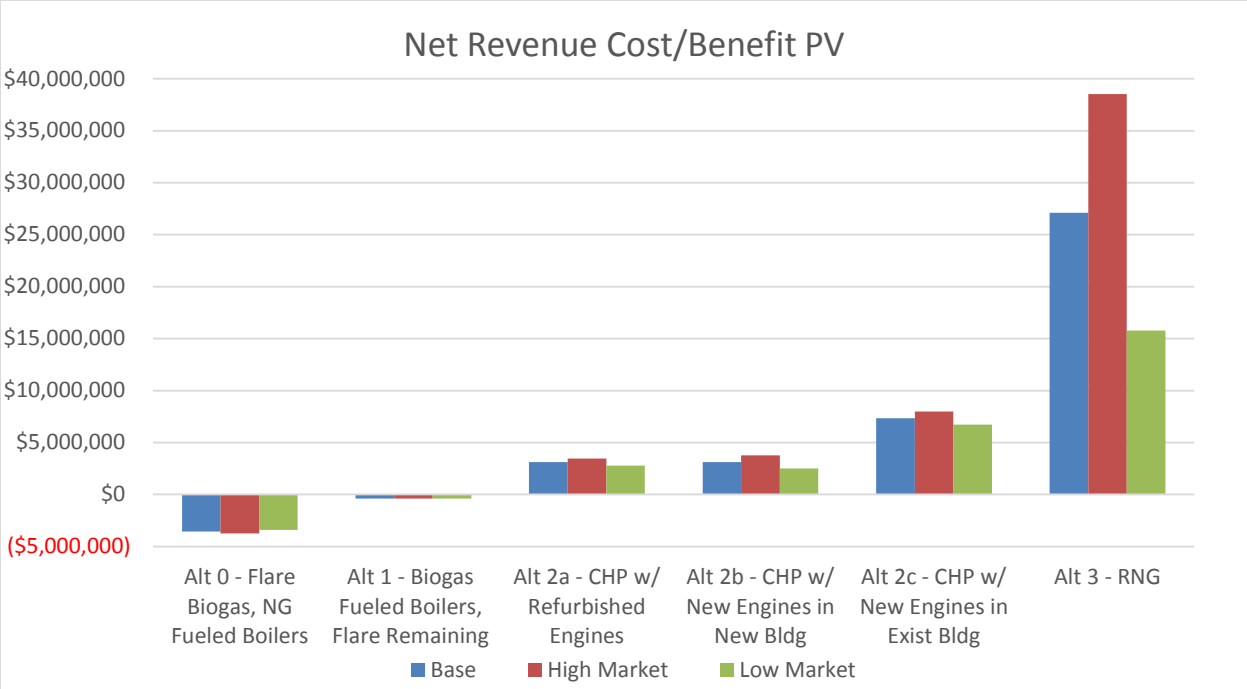

Figure 12.7-1: Net Revenue Cost/Benefit

Alternative 0

Alternative 0 returns a net 20 year lifecycle loss, primarily due to the biogas resource not being recovered to offset the purchased natural gas, which is used for heating.

Alternative 1

Alternative 1 improves the net operating cost by eliminating purchasing natural gas for digester heating. The capital costs include modifications to the gas handling infrastructure and gas treatment to remove compounds of sulfur (H_2S) and moisture.

Alternative 2

Refurbishing the existing engines will likely mean lower overall capital costs and may result in a mostly positive annual revenue. However, all engines are already out of service and it is unknown how much longer the existing equipment can function, even if it is refurbished. The existing engines are less efficient and the heat recovery equipment may not be sufficient to provide all heating demands.

The net operating costs for Alternatives 2b and 2c provide positive annual cash flow and should be investigated further. New engines will have a higher electrical efficiency resulting in more energy production. New engines are required to meet the requirements of the EPA New Source Performance Standards (NSPS) for Stationary Internal Combustion Engines (Subpart JJJJ). To meet these requirements, modern engines use "lean burn" technology, turbocharging, and higher speed operation (i.e. 1800RPM vs 900RPM) to reduce the emissions and increase efficiency. While modern engines are 5%-10% more efficient, the mandated reduction in emissions requires complex and proprietary engine controls that operate the engine to very

tight operating parameters. The combination or higher engine speed, higher pressures from turbocharging, and tight engine operation parameters results in a very low tolerance to changes in biogas quality and/or minor buildup of siloxane in the combustion chambers compared to the existing "rich burn" engines. Based on Hazen's experience and discussions with stationary engine manufacturers, the O&M costs for modern lean burn, EPA rated engines will likely be higher than the older technology for the following reasons:

- Lean burn engines require more frequent calibration to meet emission limits.
- Engine calibrations require changes to proprietary engine controls which have to be performed by a factory trained technician.
- Complexities from turbocharging and charge air intercooling add to the O&M costs.
- Modern engines are very susceptible to fuel pre-ignition or "knock" due to the higher engine pressures and speed. This results in more frequent engine internal cleaning costs and downtime.

The O&M costs for the new engines and gas cleaning system in Alternative 2a, 2b, and 2c described herein are assumed to be $0.025/kWh. This O&M cost is based on historical O&M costs from wastewater utilities who own and operate modern "lean burn" EPA rated biogas fueled engines and data from engine manufacturers. Based on the O&M data provided by the City and the data in the MWH report, the historical O&M costs for the existing engines is approximately $0.018/kWh.

<u>Alternative 3</u>

Alternative 3 has the highest benefit potential of all the alternatives included in the study. The primary reason for this is the combination of offsetting liquid fuels and CNG results in a higher value energy source than offsetting electric energy and natural gas. In addition, producing vehicle fuels decouples the digester heating process and energy production process allowing for a more efficient utilization of the biogas resource.

The production of RIN credits further enhances the revenue generated by Alternative 3. At the time of this report, the expected long-term value for the RINs is $16.00/MMBTU for the base case and $19.00/MMBTU and $13.00/MMBTU for high and low market conditions, respectively. It should be noted that the RIN and liquid fuels markets has historically shown a higher level of volatility than other energy sources.

12.8 Recommendations

This technical memorandum concludes that the CHP (Alternatives 2b and 2c) and RNG (Alternative 3) biogas utilization strategies have the highest potential to produce revenue for the plant. The other biogas utilization alternatives investigated produce a negative revenue.

As shown in **Figure 12.5-1**, the RNG alternative could produce greater revenue than the CHP alternative under the market conditions at the time of this report. It is important to note that the RNG alternative can have a higher revenue potential will have a higher level of volatility due to the uncertainly on the long-term health of the RIN market.

It is recommended that the RNG alternative be investigated further with TECO. It is recommended that the following next steps be taken:

- Initiate a detailed utility pipeline assessment with TECO. This will determine if there is a nearby injection point for the plant or if a pipeline extension would be required.
- If the first step is viable, an interconnection capacity study can be initiated to determine if there is capacity in the pipeline for the additional natural gas.

To supplement the recommendation, a Digester Gas Value Evaluation Tool was also developed to show the relationship between capital costs, revenue generation, and payback period for the RNG and CHP utilization alternatives. This tool is intended to be used to identify the approximate payback period for each alternative given the specific value of the digester gas (based on market conditions) and the project capital costs. The Digester Gas Value Evaluation Tool is included in **Attachment 12-C.**

12.8.1 Considerations with Solid Waste Division

A discussion was held between the City's wastewater and solid waste departments on February 16th, 2018 to discuss opportunities to supply RNG directly to the City refuse trucks from the HFC AWTP. Representatives from the City's solid waste department, wastewater department, Hazen and Sawyer, and Integral Energy were in attendance. A summary of the meeting is below:

- The solid waste department (SWD) is in the process of converting their 140 refuse truck fleet to CNG. It is estimated that 112 of the actual fleet will be converted to CNG by 2021.
- The SWD stated that they supply ~500,000 diesel gallon equivalents per year of CNG to their refuse fleet. This equates to approximately 570,000 gasoline gallon equivalents (GGE) per year. This number is based on the current CNG fleet (~35 trucks). It is estimated that SWD will have ~112 CNG trucks by 2021 with a CNG demand of ~1,100,000 GGE/Year.
- The SWD is considering moving the refuse truck fleet to the McKay Bay facility which is about 2.5 miles from the HFC AWTP.
- Integral Energy stated that they are installing a CNG station near the Port of Tampa which could be a consideration in the RNG feasibility evaluation.
- The possibility of fueling the refuse trucks at the HFC AWTP site was discussed. It was concluded that this was not feasible due to the logistics with accessing the port to reach the plant site.
- The possibility of an RNG pipeline from the HFC AWTP was discussed. The City stated that there is a 16" pipeline from the plant site to the McKay Bay solid waste facility that could be used as a "conduit" for an RNG gas pipe.

- SWD stated that their fast fill CNG stations cannot fill the truck CNG tanks to 100%. They typically see 75% fill with their fast fill CNG stations.
- SWD operates a trash incinerator located at the McKay Bay facility. The estimated natural gas demand for the incinerator is ~80,000 therms per year. Natural gas is primarily used to start the incinerator. The incinerator typically can operate without an external fuel source to supplement the incineration process.

A feasibility evaluation was performed on providing a dedicated RNG pipeline from the HFC AWTP to the McKay Bay solid waste facility to fuel the CNG trucks directly from RNG produced at the HFC AWTP. Based on an annual RNG demand of ~1,100,000 gasoline gallon equivalents, the refuse truck fleet will use approximately 121,000 MMBTUs/Yr of RNG. The RNG production potential from the HFC AWTP exceeds the SWD's CNG demand by 13,000 MMBTUs/Yr resulting in 17,500 MMBTUs/Yr of biogas being unused/flared.

This alternative has the following limitations:

- In order to fully use the RNG in the City's refuse trucks, RNG storage will be required during times when trucks are offsite and during holidays in weekends resulting in lower utilization of RNG.
- The 2.5 mile pipeline and RNG storage is estimated to add approximately $2,000,000 to the project costs.
- Direct fueling does not afford access to the national RNG markets possible with pipeline injection.
- While direct fueling will qualify for a RIN credit, the value of the RNG cannot be enhanced by selling in into other regional markets such as the California Low Carbon Fuels market.

For the reasons listed above, it is recommended the City focus on injecting RNG into the natural gas network and consider direct fueling only if there if pipeline injection is deemed not feasible. It should be noted that the RNG can still be "wheeled" through TECOs pipeline to the City's CNG fueling stations which would allow the City to use the RNG credits without the limitations of the truck fueling schedule.

Attachment 12-A: Assumptions of Life Cycle Costs Benefit Analysis

Description	Base Conditions	High Market	Low Market	Units
Energy Costs				
Purchased Energy Costs (Annual Average)	$0.081	$0.081	$0.081	$/KWH
Purchased Energy Costs (Annual Average)	$23.74	$23.74	$23.74	$/MMBTU
Recovered Elec Energy Benefit (Annual Average)	$0.070	$0.070	$0.070	$/KWH
Recovered Elec Energy Benefit (Annual Average)	$20.52	$20.52	$20.52	$/MMBTU
Electricity Cost Escalation (Nominal)	2.0%	2.2%	1.8%	
Natural Gas Costs	$4.80	$4.80	$4.80	$/MMBTU
Natural Gas Cost Escalation (Nominal)	2.5%	3.0%	2.0%	
Renewable Energy Credit Benefit	$0.00	$0.00	$0.00	$/KWH
RIN Benefit	$16.00	$19.00	$13.00	$/MMBTU
Methane Credit	$3.00	$3.00	$3.00	$/MMBTU
Vehicle Fuel Offset	$10.00	$10.00	$10.00	$/MMBTU
Retail CNG (GGE Equivalent)	$0.99	$1.05	$0.94	$/Gal
Fuel Costs (Gas and Diesel)	$19.00	$19.00	$19.00	$/MMBTU
Fuel Costs (Gas and Diesel)	$2.09	$2.09	$2.09	$/Gal
Fuel Cost Escalation (Nominal)	1.0%	1.5%	0.5%	
Digester Gas Production				
Digester Gas Production	656.625	656.625	656.625	SCFM
Digester Gas Production Escalation	1.5%	1.6%	1.4%	
Digester Gas BTU Content	600	600	600	BTU/SCF
Boilers				
Boiler Efficiency	80%	80%	80%	
Boiler and Gas Treatment O&M	$0.50	$0.50	$0.50	$/MMBTU
CHP				
CHP Electrical Generation Efficiency (new engines)	35%	35%	35%	
CHP Electrical Generation Efficiency (existing engines)	30%	30%	30%	
CHP O&M	$0.025	$0.025	$0.025	$/KWH
CHP O&M	$2.50	$2.50	$2.50	$/MMBTU
CHP Unit Availability	90%	90%	90%	
CHP Engine Size	3000	3000	3000	kW
CHP Minimum Operating %	75%	75%	75%	
RNG				
CNG Conversion Efficiency	85%	85%	85%	
CNG O&M	$2.50	$2.50	$2.50	$/MMBTU
CNG Vehicle Fuel Demand Escalation	2%	3%	1%	
Parasitic Electrical Load (CNG)	10%	10%	10%	
RNG System Rating	800	800	800	CFM
RNG Minimum Operating %	25%	25%	25%	
Financials				
General Inflation	3%	3%	3%	
Cost of Capital (Interest Rate)	3%	3%	3%	

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Attachment 12-B: Estimated Capital Costs

Table 12.B-1: Alt 2a (CHP w/ Existing Engines) Cost Estimate

Item	Units	Quantity	Materials	Labor	Construction Total
Refurbish existing engines	EA	5	$250,000	$0	$1,250,000
Heat Recovery	EA	5	$100,000	$50,000	$750,000
New Engine	EA	1	$500,000	$250,000	$750,000
4" Water Piping	LF	50	$100	$50	$7,500
Gas Cleaning Skid (Siloxane and H_2S)	EA	1	$750,000	$375,000	$1,125,000
Hot Water Recirculation Pump	EA	3	$10,000	$5,000	$45,000
Electrical Switchgear	LS	1	$356,000	$178,000	$534,000
Mechanical/Elec Misc (10%)	LS	1	$111,610	$85,805	$197,415
Emissions Controls	EA	4	$100,000	$50,000	$600,000
			Sum of Bare Construction Costs		$5,258,915
			Contingencies (30%)		$1,577,675
			Bare Construction Cost		$6,836,590
			20% OH&P & GCs		$1,367,318
			Total Construction Cost		$8,203,907
			20% Management and Engineering[2]		$1,640,781
			Total		**$9,844,689**[1]

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal, and administrative costs.

Table 12.B-2: Alt 2b (CHP w/ New Engines & New Bldg) Cost Estimate

Item	Units	Quantity	Materials	Labor	Construction Total
Packaged Engine/Generator (~1500KW)	EA	2	$1,000,000	$500,000	$3,000,000
4" Water Piping	LF	100	$150	$75	$22,500
4" Biogas Piping	LF	200	$150	$75	$45,000
Shell in Tube Heat Exchanger	EA	2	$15,000	$7,500	$45,000
Heat Recovery Piping Modifications	LS	1	$15,000	$7,500	$22,500
Gas Cleaning Skid (Siloxane and H_2S)	EA	1	$750,000	$375,000	$1,125,000
Exhaust Piping	LS	1	$25,000	$12,500	$37,500
Hot Water Recirculation Pump	EA	3	$10,000	$5,000	$45,000
Electrical Switchgear	LS	1	$150,000	$75,000	$225,000
New Generator Building	Sqft	6000	$250	$125	$2,250,000
Concrete Pad & Site Prep	LS	1	$100,000	$50,000	$150,000
Mechanical/Elec Misc (10%)	LS	1	$196,530	$98,265	$294,795
			Sum of Bare Construction Costs		$7,037,295
			Contingencies (30%)		$2,111,189
			Bare Construction Cost		$9,148,484
			20% OH&P & GCs		$1,829,697
			Total Construction Cost		$10,978,180
			20% Management and Engineering[2]		$2,195,636
			Total		**$13,173,816**[1]

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal, and administrative costs.

Table 12.B-3: Alt 2c (CHP w/ New Engines in Ex. Bldg) Cost Estimate

Item	Units	Quantity	Materials	Labor	Construction Total
Packaged Engine/Generator (~1500KW)	EA	2	$1,000,000	$500,000	$3,000,000
4" Water Piping	LF	100	$150	$75	$22,500
4" Biogas Piping	LF	200	$150	$75	$45,000
Shell in Tube Heat Exchanger	EA	2	$15,000	$7,500	$45,000
Heat Recovery Piping Modifications	LS	1	$15,000	$7,500	$22,500
Gas Cleaning Skid (Siloxane and H_2S)	EA	1	$750,000	$375,000	$1,125,000
Exhaust Piping	LS	1	$25,000	$12,500	$37,500
Hot Water Recirculation Pump	EA	3	$10,000	$5,000	$45,000
Electrical Switchgear	LS	1	$150,000	$75,000	$225,000
Mechanical/Elec Misc (10%)	LS	1	$196,530	$98,265	$294,795
			Sum of Bare Construction Costs		$4,862,295
			Contingencies (30%)		$1,458,689
			Bare Construction Cost		$6,320,984
			20% OH&P & GCs		$1,264,197
			Total Construction Cost		$7,585,180
			20% Management and Engineering[2]		$1,517,036
			Total		**$9,102,216**[1]

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal, and administrative costs.

Table 12.B-4: Alt 3 (RNG) Cost Estimate

Item	Units	Quantity	Materials	Labor	Construction Total
PSA Treatment System	EA	1	$6,000,000	$1,500,000	$7,500,000
Concrete	CY	200	$65,000	$32,500	$97,500
Site Work	EA	1	$499,500	$249,750	$749,250
Connection Piping	LF	1000	$175,000	$87,500	$262,500
Electrical/I&C	EA	1	$499,500	$249,750	$749,250
Thermal Oxidizer	EA	1	$450,000	$225,000	$675,000
Odorize System	EA	1	$8,000	$4,000	$12,000
Gas Analyzer	EA	1	$150,000	$75,000	$225,000
Sulfur Analyzer	EA	1	$82,000	$41,000	$123,000
			Sum of Bare Construction Costs		$10,393,500
			Contingencies (30%)		$3,118,050
			Bare Construction Cost		$13,511,550
			20% OH&P & GCs		$2,702,310
			Total Construction Cost		$16,213,860
			20% Management and Engineering[2]		$3,242,772
			Total		**$19,456,632**[1]

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal, and administrative costs.

Attachment 12-C: Digester Gas Value Evaluation Tool

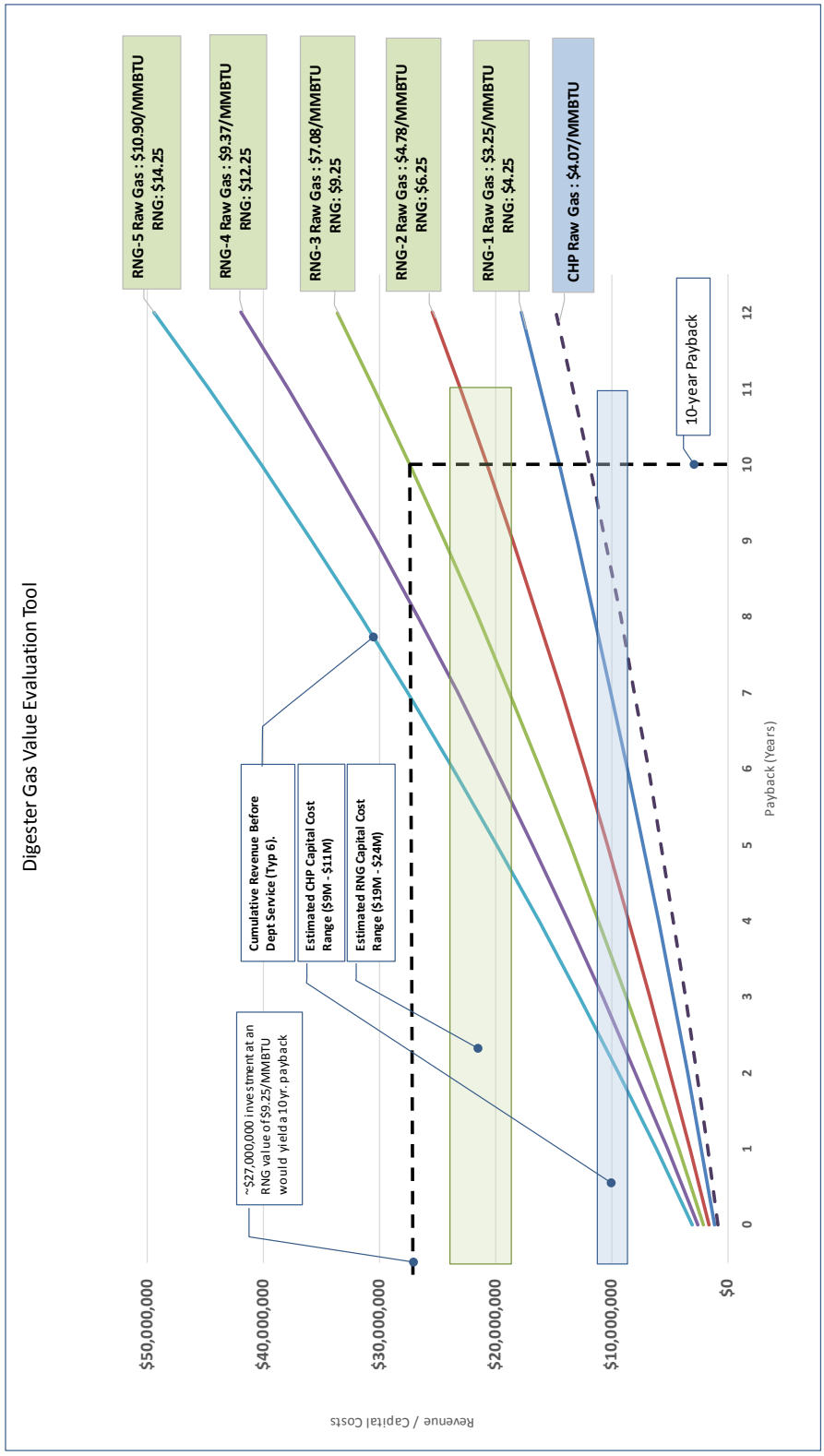
The Digester Gas Value Evaluation Tool shows the relationship between capital costs, revenue generation, and payback period for the RNG and CHP (with new engines) utilization alternatives. It is intended to be used to identify the approximate payback period for each alternative given a specific value of the digester gas, based on market conditions and capital costs.

Using the market conditions shown on the line marked "Example" in **Figure 12.C-1** below, it is estimated that the RNG value of the gas is $9.25/MMBTU. This line is represented by the cumulative revenue graph line labeled RNG-3. When parasitic losses and downtime are taken into account, it is estimated that the value of the raw, unprocessed digester gas is $7.08/MMBTU. If arrangements can be made with a third party to purchase the raw digester gas at a value higher than $7.08/MMBTU, that is a better option than the given set of market conditions and would be a favorable approach to utilize the digester gas.

It is anticipated that the RNG system capital cost will be $19M-$24M. The break-even point is where the line representing a given set of market conditions rises above the anticipated capital cost estimate. Using a 10-year payback as the maximum, a capital cost of up to ~$27M will meet a 10-year payback requirement. However, using the example market conditions above and the capital cost estimate, it is expected that the break-even point is between years 7 and 9.

If the market conditions are more favorable, using the line marked "High Mkt", the value of the gas increases, resulting in a faster payback period. Using the associated "RNG-5" cumulative revenue line and the same RNG cost estimate, the break-even point is between years 4 and 6.

A similar analysis can be performed for the CHP alternative and is shown on the the same axis for comparison.



	RIN Mkt		Methane Credit		Marketing Costs		O&M & Parasitic Loads		RNG Value
Example	$16/MMBTU	+	$3/MMBTU	-	$6/MMBTU	-	$3.75/MMBTU	=	$9.25/MMBTU
	Range: $10-30/MMBTU		Range: ~$3/MMBTU		Range: $5-7/MMBTU		Range: ~$3.75/MMBTU		
High Mkt	$22/MMBTU	+	$3/MMBTU	-	$7/MMBTU	-	$3.75/MMBTU	=	$14.25/MMBTU
Base	$16/MMBTU	+	$3/MMBTU	-	$6/MMBTU	-	$3.75/MMBTU	=	$9.25/MMBTU
Low Mkt	$10/MMBTU	+	$3/MMBTU	-	$5/MMBTU	-	$3.75/MMBTU	=	$4.25/MMBTU

The purpose of this tool is to show the approximate revenue generation potential and payback period for various capital costs and market conditions. This tool is intended to provide general guidance on the economic value of the digester gas to compare various digester gas utilization strategies under various market conditions.

Scenario	Electric Energy Production ($/MMBTU)			
	Electric Energy Offset	O&M**	Raw Gas	Electric Energy Value
CHP	$20.52	-$7.33	$4.08	$13.19

** - Value based on KWH produced @ 40% conversion efficiency

Figure 12.C-1: Digester Gas Value Evaluation Tool

Technical Memorandum 13.0 High Strength Waste Evaluation

13.1 Purpose and Background

High strength waste (HSW) contains fats, oils and grease (FOG), other organic components not usually found in residential wastewater or certain chemicals. Any or all of these compounds can interfere with the normal biological process at a wastewater treatment plant. FOG primarily comes from food preparation establishments, such as restaurants and grocery stores. FOG creates a problem in wastewater collection systems as it cools, solidifies and deposits inside the collecting piping. These deposits decrease the capacity of the collection system, increase maintenance costs and sometimes leads to blockages and sewer overflows. To reduce FOG in the collection system, many city or county ordinances require the installation of grease traps or interceptors downstream of kitchen sinks to collect FOG and regularly clean and maintain these traps. These traps must be cleaned to remove accumulations and generally includes pumping of the contents to tanker trucks for disposal at a treatment facility.

Hazen was tasked with evaluating and summarizing the regional HSW market in the Tampa, FL area. This included contacting major vendors to determine available supply, surplus quantities and anticipated quality. It also included considering alternative regional disposal options and the tipping fees associated to determine the cost/ benefit analysis of the addition of a new receiving facility with the ability to receive HSW.

The main objective of the receiving station study is the payback analysis to determine the estimated years for the savings in power production to pay for the capital and operations and maintenance costs for accepting HSW. A secondary benefit of the receiving station would be to provide the community with an additional facility to unload HSW.

13.2 Available Supply

To determine the available supply of HSW in the area, Hazen contacted haulers who are registered on the City of Tampa Grease Haulers list and hauled to a Hillsborough County approved land application site or to the Howard F. Curren Advanced Wastewater Treatment Plant (HFC AWTP) in the last year. A majority of the haulers do not currently haul HSW because they do not have a convenient disposal location. Next, breweries, food processing and beverage companies were contacted to determine additional sources and quantities of HSW, but did not provide helpful information. Lastly, a list of existing receiving facilities in the vicinity of HFC AWTP **Table 13.2-1** was created. An attempt at determining the quantity HSW they receive was unsuccessful, but helpful in determining competition in the market.

Table 13.2-1: Receiving Facilities in Hillsborough, Pinellas and Polk County Areas

Site	Type	Gallons/ year[1]	Accept FOG?	Distance from HFC AWTP	Listed as Approved by COT?
Averett Septic			Yes	40 miles	Y
Grease Depot	Preliminary Treatment		Yes	21 miles	Y
Howard F. Curren AWTP	WWTP	25,724,000	No	0 miles	N
South Cross Bayou WRF	WWTP		Yes, but only from FCS[2]	28 miles	N
City of Clearwater NEWWTP	WWTP		Yes, but frequently closed	28 miles	N
City of Dunedin WWTP	WWTP		Yes	29 miles	N
Bingham- Hobbs	Land Application	689,000	No		Y
Bryan Site	Land Application		Unknown	14 miles	Y
Butts Site	Land Application	7,000	Unknown	19 miles	Y
Carlton- Ranch	Land Application		Unknown	22 miles	Y
Carlton- 675	Land Application		Unknown	15 miles	Y
Griffin- Mango	Land Application		Yes	11 miles	Y
Hartford	Land Application	29,440,000	Unknown	4.5 miles	Y
Laminksi Grove	Land Application		Unknown		Y
Lawton Grove	Land Application		Unknown	21 miles	Y
Powell	Land Application	825,000	Unknown	19 miles	Y
Thompson Property	Land Application	631,000	Unknown	21 miles	Y

[1]*Volume reported to FDOH-Hillsborough in 2016*
[2]*FCS, Inc. is an approved Hillsborough County hauler*

FCS, Inc. (FCS) hauls FOG from Hillsborough and Pinellas counties and thickens it at their facility, Grease Depot. Averett Septic Tank Company noted that they do not typically receive waste from Hillsborough County because Grease Depot is a closer disposal site. FCS is the most likely source of HSW supply to the HFC AWTP. Once processed at their facility, it is either disposed of at the South Cross Bayou WRF or through other means. FCS has shown interest in directing about 10,000 gpd of thickened FOG to the HFC AWTP if a receiving facility were to be constructed.

Available supply also potentially includes 4,000 gpd Tampa Fisheries currently disposes of at the current septage receiving station which could be diverted directly to the digesters as a source of HSW. This would first require testing to verify the strength of the waste to determine how beneficial it would be for gas production.

13.3 Alternative Regional Disposal Options

Alternative regional disposal sites approved for disposal by Florida Department of Health (FDOH) prior to July 1, 2017 are shown in **Figure 13.3-1**. This figure was created from a list of Hillsborough County Approved Grease Hauler Disposal sites and a list from the Florida Water Environment Association of Wastewater Facilities Potentially Accepting Septage. Only sites in Pinellas, Polk and Hillsborough Counties were added since other sites were considered too far of a drive for haulers to be considered alternatives to HFC AWTP.

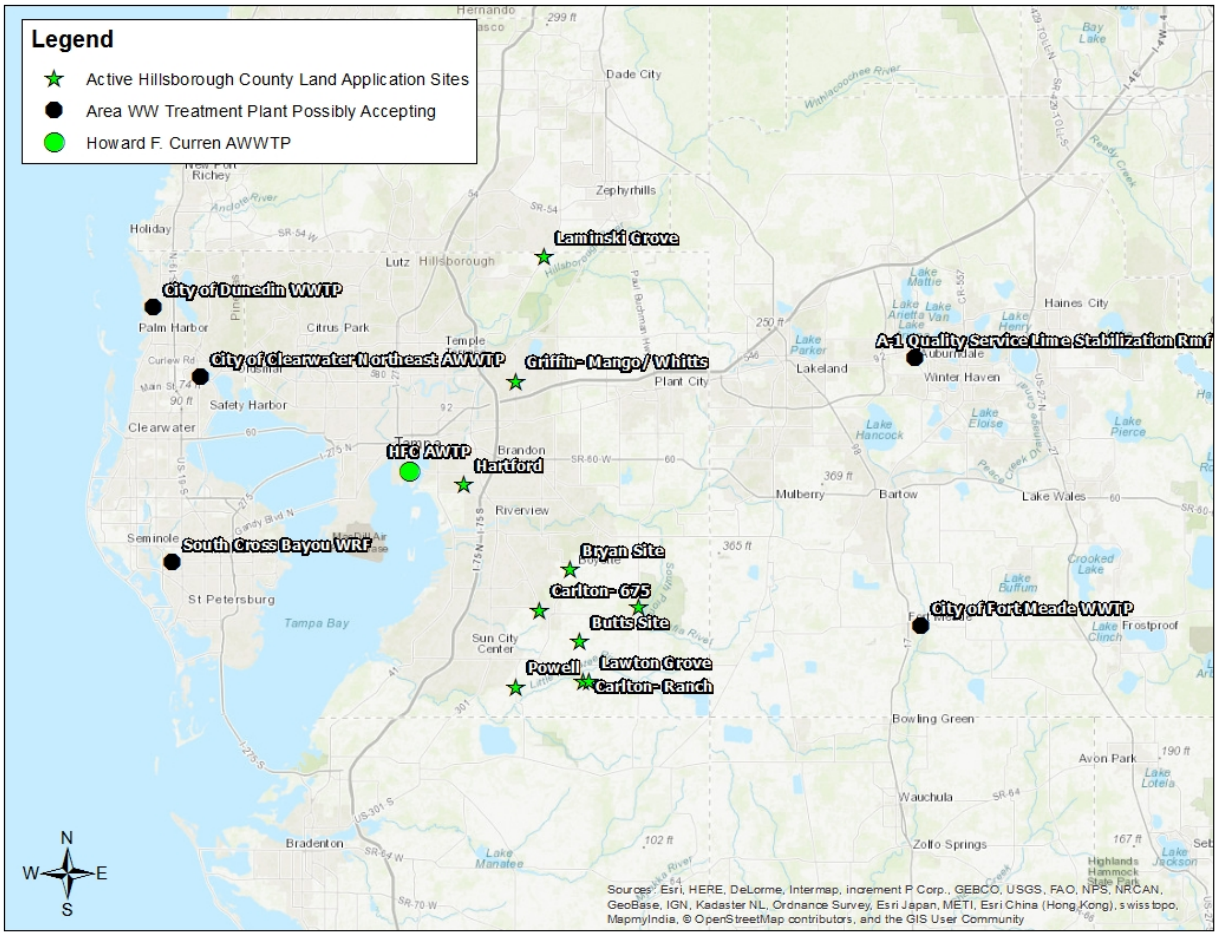


Figure 13.3-1: Alternative Regional Disposal Sites prior to July 1, 2017

As of June 30, 2016, under Section 381.0065(6), F.S., the prohibition of land application became effective, but under Chapter 62-640, F.A.C, variances were granted to allow sites to continue to operate through July 1, 2017 and apply for permits through Florida Department of Environmental Protection (FDEP). These sites are no longer overseen by the FDOH after June 30, 2016. This change now requires land disposal sites have a nutrient management plan and they must meet site requirements set by FDEP

such as slope, storage, seasonal high groundwater table, setbacks, signage, cumulative application limits, public access and harvesting restrictions. As of July 14, 2017, only two land application sites have been approved to operate by FDEP and 16 applications are pending. Sites in environmentally sensitive areas will not be granted a permit. The two locations currently permitted include Southeastern Septic (Permit # FLA 943606) in Polk County and 579WTF (previously Griffin- Mango) (Permit # FLA 931381) in Hillsborough County. 579WTF is currently under construction and will be open to the public and permitted to accept 0.04 MGD. Of the two land application sites permitted in this area, only one is in Hillsborough County. Currently, South Cross Bayou only accepts thickened FOG from FCS and no other haulers. Powell is a land application site that is privately owned and only accepts waste from their own haulers for disposal, though they are not currently permitted as of July 1, 2017 by FDEP. The City of Clearwater is currently permitted to accept HSW, but according to haulers it is frequently closed. Within 25 miles of HFC AWTP, this leaves Grease Depot in Pinellas County and 579WTF in Hillsborough County as alternative regional disposal options. **Figure 13.3-2** shows these two locations in relation to HFC AWTP.

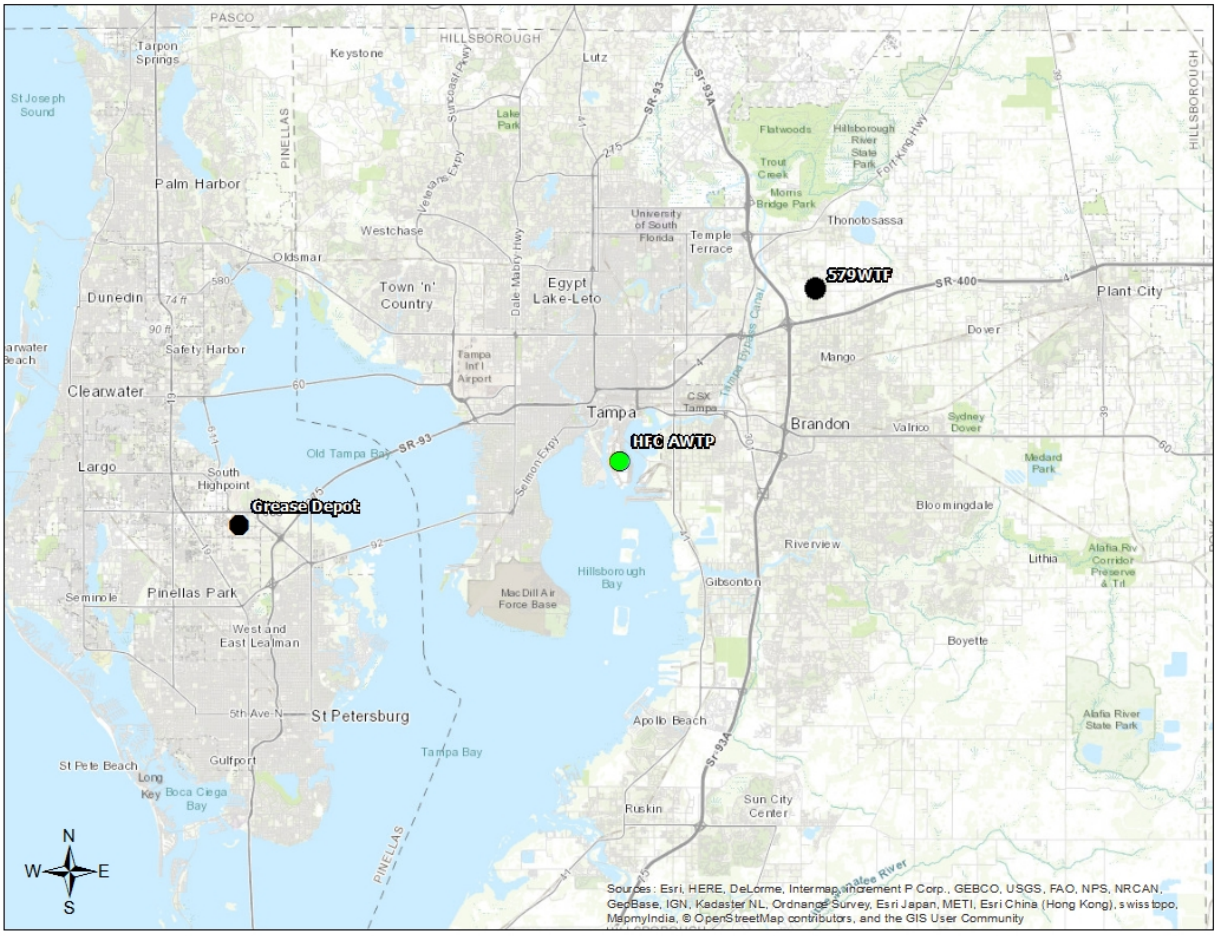


Figure 13.3-2: Updated Alternative Regional Disposal Sites as of July 1, 2017

13.4 Anticipated Quality

Based on assumptions made in the Phase 1 report dated June 2016, *Existing Systems Technical Memorandum of Findings*, with a current volatile solids (VS) loading to the digesters of approximately 107,000 lbs VS/day, the HSW capacity at 30% of total VS loading will be about 46,000 lbs VS/day. However, the additional volume for HSW will cause the hydraulic retention time (HRT) to drop below 15 days which is required for Class B biosolids during a maximum month of primary and thickened waste activated sludge (TWAS) influent flow. If all seven digesters are online, there will be sufficient operating volume for up to about 10,000 gpd of HSW while maintaining the 15 days HRT.

A sample of thickened FOG from FCS was taken on August 22, 2017 and the results are shown in **Table 13.4-1**. As expected, the thickened FOG has a much higher total and volatile solids content which is beneficial for gas production and would require a smaller volume to yield similar results to FOG that has not been thickened. This gas could be used for energy production through combined heat and power (CHP), renewable natural gas (RNG) or another technology to convert methane to energy.

Table 13.4-1: Results from August 22, 2017 sample of Grease Depot's thickened grease

Sample Date		Total Solids (mg/ kg)	Ammonia (N) (mg/kg)	Total Volatile Solids (mg/kg)	pH	Percent Solids (%)	Percent Moisture (%)
8/22/17		420,000	740	340,000	7.38	42.3	58

FCS receives their FOG from various locations such as restaurants and grocery stores, therefore, it is difficult to know what the grease traps contain prior to pump out. The risk of receiving toxic substances in the grease trap is a possibility which is dangerous for the microorganisms in the digesters and could cause a decrease in gas production. Receiving FOG of this strength has a higher production of gas when added to the digesters, but at the additional cost of requiring constant heating and mixing. The thickened FOG comes in a near solid state which if not heated and mixed properly could cause an increase in struvite production and has a higher chance of clogging the pipes. This would require more attention to operation and maintenance. If the City choses to move forward with this option, it would be important to test more samples of the thickened grease for the parameters listed in **Table 13.4-1** and for toxicity.

13.5 Typical Tipping Fees

Table 13.5-1 shows tipping fees for septage from other nearby facilities and recommended HSW tipping fees from interviews conducted with haulers. However, as there is likely only one HSW supplier, the tipping fees will be more of a direct negotiation, and then potentially applied to other suppliers in the future.

Table 13.5-1: Nearby Tipping Fees

Municipality or Hauler	Current Cost or Suggested Cost by Hauler	Source
Broward County	$0.045[1] / gallon and based on truck capacity (septage)	Interview
City of Tampa	$0.07/ gallon (septage)	2016 HFC AWWTP Hauler Records
Miller Septic[2]	$0.07/ gallon (septage)	Interview
Quality Septic	$0.065/ gallon (septage)	Interview
Nuckles[3]	$0.08/ gallon (FOG)	Interview

[1] *2010 cost*
[2] *Currently dispose of septage at HFC AWTP*
[3] *As of Spring 2017, disposes of septage at HFC AWTP; FOG at Grease Depot and Griffin*

13.6 Potential Receiving Facility Design

FCS can provide 10,000 gpd of thickened FOG, which is the additional capacity of HSW the digesters can accept. Since they are the main source of HSW hauling in the area, the facility should be designed to accept 10,000 gpd. Each aspect of the receiving station facility design is discussed in more detail below.

13.6.1 HSW Receiving Station

The receiving station will include two unloading stations, each with a quick release pinch valve to allow two trucks to unload at once and a flow meter on each will allow for volumes to be recorded for billing purposes. Two stations would still be necessary even if FCS is the sole hauler for redundancy. A pull through station will allow trucks to easily enter and leave without having to back up, a request some of the haulers made when interviewed. The HSW unloading area will be gated separately from the AWTP to allow the haulers to continue to unload 24/7. The HSW equipment for treatment will be located next to the receiving station but within the gate of the treatment plant to allow easy access for operators.

The HSW receiving station will be similar to the septage receiving station, but rock traps and grinders should be installed for potentially damaging debris. The trucks will also be unloading on a containment pad to prevent the spread of spills if they occur.

13.6.2 Unloading and Mixing Pumps

Two unloading pumps will be located downstream of the rock trap and the grinder and will be sized to unload the truck in less than 15 minutes. The mixing pumps will be sized to keep the receiving tank and the blending tank completely mixed and to provide tank turnover and help the waste from stratifying.

13.6.3 Receiving Tank

The HSW will be pumped from the trucks to a 30,000 gallon holding tank that will allow a 3-day supply to be stored if needed. This will allow a steady flow of HSW to flow to a blending tank and then on to the digesters. A continual flow will prevent a buildup on the pipes and allow a continual feed of HSW to enter the digesters. Additionally, this tank will be heated with a heat exchanger to prevent the HSW from building up in the pipes. The proposed tank will be constructed of Type 304 Stainless Steel.

13.6.4 Blending Tank

A 3,000 gallon blending tank is proposed to mix HSW with digested sludge to allow a steady load of HSW to be fed into the digesters. Microorganisms within the digesters require time to acclimate to the increase loading rate from the HSW. Overdosing can lead to the accumulation of long-fatty acid chains which can cause a drop in pH and inhibit methane formation. By blending the HSW with digested sludge, the microorganisms can adapt and support a higher HSW loading and ultimately maximizing biogas production. Pumping from this tank, through the mixed sludge pump station, will allow each of the anaerobic digesters through the mixed sludge pump station to receive HSW at a controlled and constant rate. This tank is required to allow the acclimation of the microorganisms which would not be possible if mixing only occurred in a pipe prior to the digesters.

13.6.5 Feed Pumps

The blending tank will have feed pumps for transferring the HSW from the receiving tank to the blending tank and to the mixed sludge pump station. The feed pump will be sized to pump the total volume of the blending tank to the mixed sludge pump station with a 24- hour period. Here the HSW can be mixed and distributed evenly between the seven digesters.

13.6.6 Odor Control

HSW is a source of many odors so, odor control will be required to collect air from the receiving tank and blending tank for treatment.

13.6.7 Receiving Station Schematic

A schematic of the potential receiving station is shown in **Figure 13.6-1**.

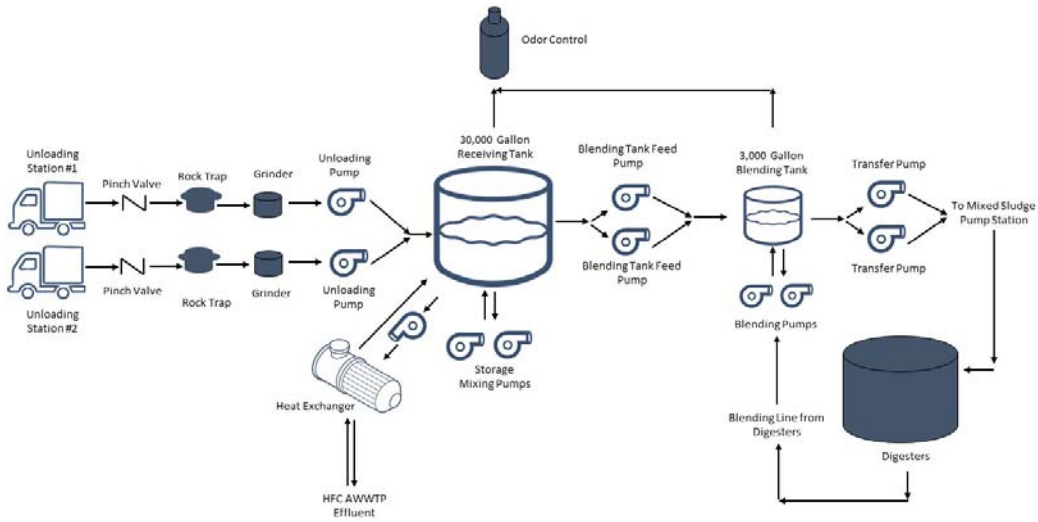


Figure 13.6-1: Potential Schematic of HSW Receiving Station

13.6.8 Proposed Receiving Station Location and Layout

The proposed location for the HSW receiving station is on the old drying beds next to the septage receiving station, shown in **Figure 13.6-2**. This location was chosen because of the proximity to the digesters, requiring less pumping and piping to the mixed sludge pump station. This location is on the west side of the plant, south of the existing digesters. The unloading area will be outside the plant fence to allow drivers the ability to deliver even when the plant gate is closed and the equipment will be inside the plant gates to allow easy access for operators. The unloading area layout can be seen in the *Preliminary Treatment Technical Memorandum*. During conversations with FCS, they expressed reservations with entering the Port of Tampa and the hassle of dealing with security prior to unloading at the receiving station. They expressed concern over the extra time it adds to each delivery and the City would really need to make it worthwhile for them to deliver to HFC AWTP. Additional negotiations between FCS and the City would need to be addressed to work out logistical issues. The proposed layout of the receiving station is show in **Figure 13.6-3**.

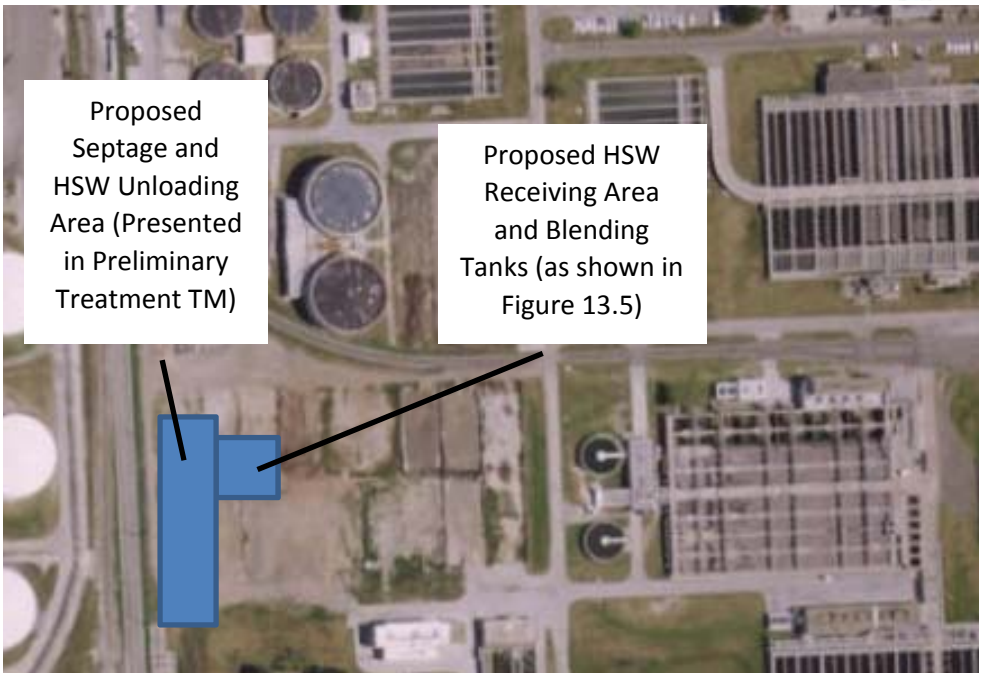


Figure 13.6-2: Proposed Location of the HSW Unloading Area and Receiving Station

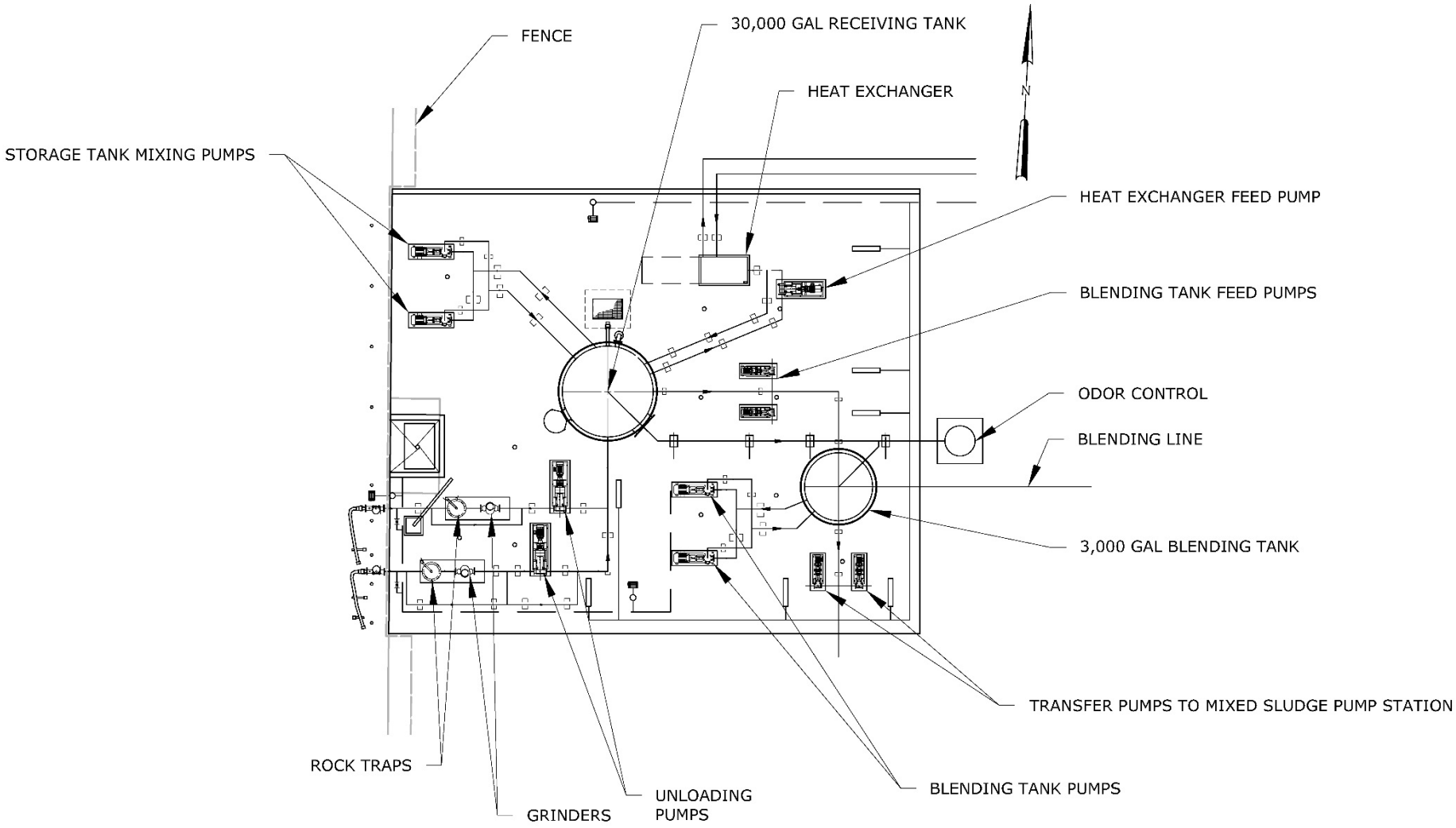


Figure 13.6-3: Potential Layout of HSW Receiving Station

13.7 Cost Summary for HSW Receiving Station

13.7.1 Capital Cost Estimate

This section of the evaluation provides a breakdown of the conceptual level opinion of probable construction costs, as summarized in **Table 13.7-1**, which include the elements of the receiving station discussed above.

Table 13.7-1: Conceptual Opinion of Probable Construction Cost for HSW Receiving Facility

Description	Cost
Site Prep	$10,000
Unloading Pumps	$14,000
Grinders	$20,000
Rock Traps	$6,000
Heat Exchanger Feed Pump	$13,000
Storage Tank Mixing Pumps	$66,000
Blending Tank Feed Pumps	$18,000
Blending Pumps	$18,000
Transfer Pumps	$18,000
Heat Exchanger	$30,000
Odor Control	$60,000
30,000 gallon Receiving Tank	$113,000
3,000 gallon Blending Tank	$34,000
Misc. Mechanical	$100,000
Misc. Structural	$62,000
HVAC	$30,000
Misc. Electrical and I & C	$42,000
Sum of Bare Construction Costs	**$654,000**
30% Contingencies	$196,200
Bare Construction Cost	$850,200
20% OH&P & GCs	$170,040
Total Construction Cost	**$1,020,000**
20% Management and Engineering[2]	$204,000
Total Capital Cost[1, 2]	**$1,224,000**

[1]*Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of 50% to +100% of actual costs.*
[2]*Includes COT management, legal and administrative costs.*

13.7.2 Cost/ Benefit

The benefits of a HSW facility at HFC AWTP were quantified by assessing the energy savings from an increased methane production in the digesters due to the addition of HSW. All costs were projected over a 20- year period with a yearly inflation rate of 3%, unless otherwise specified below. The following assumptions were used to generate costs:

- One operator was projected for 20 hours/week, year-round. Average operator and maintenance labor rates costs of $40/hr for direct salary were used, with a 3% inflation rate added for the 20-year period.
- Consumables, which include equipment maintenance costs associated with lubrication, minor replacement components, bearings, mechanical seals, or other necessary replacement parts, were also considered. These consumables were considered at 1% of the capital cost per year with an inflation rate of 3% each year.
- Additional methane production was calculated using a methane gas yield of 10 cf/lbVS destroyed, a solids destruction of 60% and based on a HSW loading rate of 22,000 pounds VS/day. This resulted in a 24% increase in methane production. This was converted into electricity savings based on an electrical cost of $0.081 per kWh with an inflation rate of 2%, projected over a 20-year period. Solids hauling costs were calculated based on a 60% volatile solids destruction rate. Yearly estimates for wet tons of cake were used to determine land application hauling costs at a rate of $27.60 and inflation rate of 3%.

The 20-year costs for labor, consumables, hauling and energy are listed in **Table 13.7-2**.

Table 13.7-2: 20-year Life Cycle Cost for the HSW Facility

	Life Cycle Cost[1,2] ($)
Consumables 20-Year Cost[3]	$339,000
Hauling and Disposal 20-Year Cost	$1,949,000
O&M Labor 20-Year Cost Cost[4]	$1,152,000
CHP Savings 20-Year Cost[3, 5]	-$4,890,000
Total 20-Year Operating Cost[5]	-$1,452,000
Total 20-Year Operating Cost Present Value[5]	$-804,000

Notes:
1. 20-year planning period starting with year 2017 dollars.
2. Annual inflation rate of 3%.
3. Based on calculations from Biogas Utilization Evaluation
4. Operations/ Maintenance labor cost of $40/hr.
5. A negative cost indicates a savings.

A summary of total estimated conceptual costs associated with the HSW facility is provided in **Table 13.7-3.**

Table 13.7-3: Total Net Operating Costs

	20- Year Present Value ($)
Total Capital Cost[1]	$1,224,000
Total 20-Year Operating Cost Present Value[2]	-$804,000
Total 20-Year Net Operating Costs Present Value	$420,000

Notes:

1. *Assumes no residual value after 20 years and capital cost occurs in the year it is constructed.*
2. *A negative cost indicates a savings.*

Based on a capital cost of approximately $1.2 million and an increase in methane production of 24%, the payback will occur within year 15. This is calculated by taking the cumulative future value costs and savings each year and noting where it intersects with the capital cost, shown in **Figure 13.7-1**. This indicates within what year an expected payback will occur. The payback period is sensitive to the quality and quantity of HSW received and the operator and maintenance personnel hours required. The additional methane production is driving the savings for a payback period. This system is not being recommended due to the long payback period and the high risk associated with relying heavily on one main supplier with port access concerns.

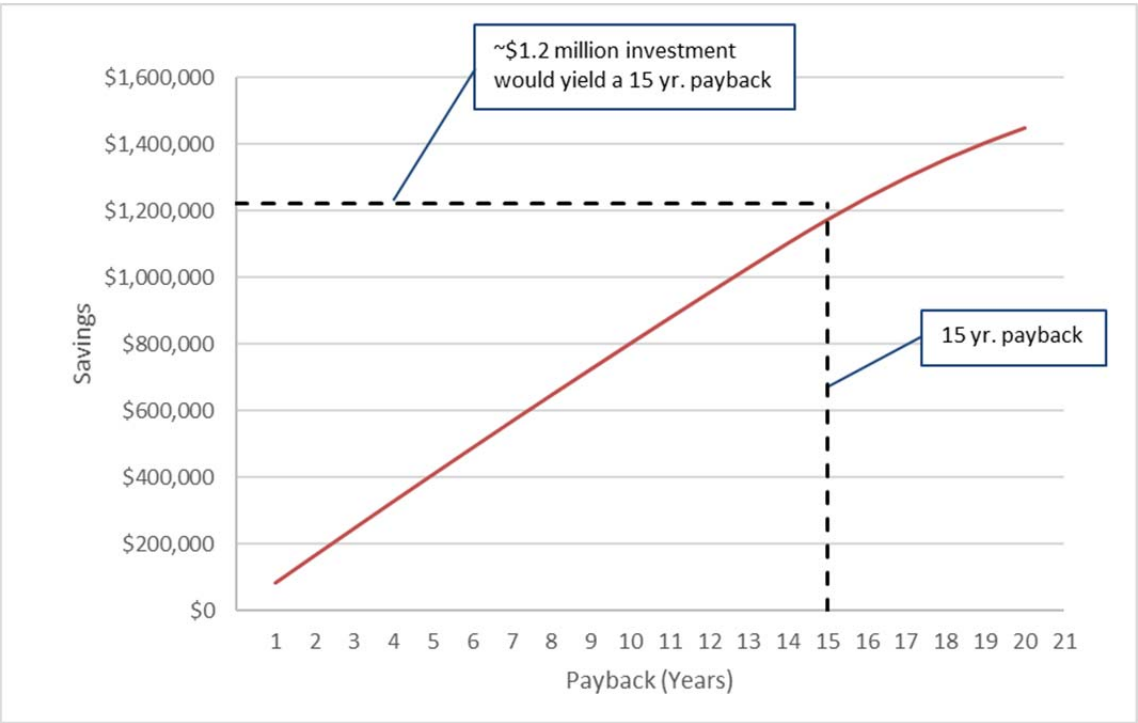


Figure 13.7-1: High Strength Waste Receiving Station Payback Period

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Technical Memorandum 14.0 Partial Discharge Testing

14.1 Purpose and Background

As part of the development of the Wastewater Treatment Plant master plan, partial discharge (PD) testing was performed to determine the condition of the HFC AWTP's medium voltage (MV) switchgear and cable systems. The purpose for the testing is to detect and characterize PD activity occurring in the MV cable distribution circuits at plant. PD's cause deterioration and erosion of electrical insulation systems of medium voltage cables, switchgear, transformers and other electrical apparatus. If not detected and corrected, PD will result in insulation failure, unplanned power outages, and/or personnel injury. Analysis of PD activity can assist the City with prioritizing maintenance and equipment replacements.

In accordance with the scope of services, the PD testing of the medium voltage system was performed by C.E. Testing, Inc., a NETA certified testing company with planning and oversight provided by McKim & Creed.

On-site data acquisition was performed by C.E. Testing, Inc. on February 7, 2017 through February 10, 2017. A total of 102 Points of Attachment (POA) were analyzed at the plant. The test data was gathered from temporary sensors affixed to each of the POA test locations. Results of the PD testing are provided in the December 18, 2017 *Online Partial Discharge Testing Report* prepared by C.E. Testing, Inc., a copy of which is included as **Appendix C**. Observations and recommended actions for specific POA's are listed in Chapter 5 of the Online Partial Discharge Testing Report and summarized below.

Based on the magnitude of the detected PD pulse and the manner in which the pulses occurred, each POA was assigned a classification category, Red, Orange, Yellow or Green. Each classification represents a different criticality level.

- Green – No action required, re-test in 3 years
- Yellow – No action required, re-test in 12-18 months
- Orange – Action recommended, re-test within 6 months
- Red – Prioritize immediate corrective action, re-test to confirm and establish new baseline.

Seven (7) POA's were found with significant partial discharge activities requiring immediate attention. Twenty-five (25) POA's were found with partial discharge activities classified as "Orange" recommended for follow-up testing within 6 months. Seventy (70) POA's were found with partial discharge activities classified as "Green.

As the specific cables and subsequently the length of cables that need to be replaced will depend on the results of the re-testing noted above, it is recommended the City's CIP include an allowance for cable replacement, with the understanding that the amount of cable to be replaced will vary from year to year.

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15.0 Standby Generator Capacity Analysis

15.1 Purpose and Background

As part of the Master Plan, McKim & Creed is to provide an analysis of the existing standby generation capacity to meet the current and future electrical loading of the HFC AWTP. Per the Phase 2 scope, the review of the standby generation capacity focuses only on the required standby power system capacity and not on equipment condition and reliability. An assessment of the standby power generators was performed in Phase 1. In this initial phase, it was reported that the existing generators are regularly tested for reliability and maintenance and that the generators are in good condition with a remaining useful life of 10-15 years. The use of N+1 redundancy will be a topic as well as different options for engine driven power generation.

Included in this review is a review of EPA emissions requirements for permanent standby power systems for any new generation system that may be recommended as a result of this memorandum. Solar or wind generation options, were not considered for this report.

15.1.1 Existing Power System

The HFC AWTP's electrical systems were designed with reliability and redundancy should failures of electrical equipment occur. Both the normal and standby power electrical systems were designed to supply power to the plant under peak flow conditions to meet Class 1 reliability.

Tampa Electric Company (TECO) supplies normal utility power to the facility using two separate high voltage feeders from different substations transformers. These feeders and transformers are understood to be redundant with each having the capacity to supply power to the entire plant.

As mentioned above, the plant facility is powered from two separate power feeds from Tampa TECO called Line 1 and Line 2. They in turn, feed the West 13.2kV outdoor switch gear and the East 13.2kV switchgear, respectively. There is also a normally open tie breaker (3-52-Tie) between the two, providing the capability to connect them, in order to supply power from either side. If there is a loss of power from one of the TECO feeds, the breaker for the failing feeder will open, and the tie breaker closed, suppling power to the side in need.

The standby power system is a "split bus" system with two generators connected to power to the East Outdoor Switchgear and two generators connected to the West Outdoor Switchgear. The two separate switchgear buses are then paralleled when the standby system is called to run.

Four 2,000 kW Caterpillar diesel generators comprise the current standby power generating system. The generators are housed in the Standby Generation Building #78 for a total of 8MW of connected standby power. For standby rating, Caterpillar recommends, "The average load factor of a standby rated generator set should be no more than 70% of the nameplate rating with varying loads. A standby generator set can run for a maximum of 500 hours per year with varying loads. Typical peak demand allowance is 100% of the rating; for

maximum of 5% of the operating time." ("Understanding Generator Ratings" Caterpillar© 2013). This is the recommendation of the generator manufacturer to maintain reliability and to maximize the lifespan of the units.

The AWTP also has (5) 500 kW Waukesha biogas fueled, "Base Load" generators that, when operating, can supply up to 2,000 kW. "Base load" is defined as the generator continually running at a nominal load, while supplying power at a constant rate. The biogas fueled generators are meant to run in parallel with the Power Utility (i.e. TECO) and to operate at all times, supplementing normal power from the Power Utility, thus reducing the plant's total power costs. While not considered as part of the standby power supply, the biogas generators could be used as a supplement during times when utility power is lost as they can be separated from the power grid on loss of power. Once utility power is restored, the biogas generators are returned to normal service supplementing utility power. During a power outage, the biogas generators could remain online suppling power to raw sewage pump station MCC-60 and equipment connected to it. Currently the generators are off-line and are being evaluated as part of this Master Plan in the Biogas Utilization Technical Memorandum.

15.1.2 Current Power Usage

Based on 2016 TECO billing information supplied by the City, average monthly demand power usage for the treatment plant ranged between 6MW and 8.5MW during a two-year period from 2016 through 2018. This energy usage is based on a 30-minute average interval recorded by the TECO power meters. It is also substantiated by the City's onsite monitoring equipment which is set at 15-minute intervals. The TECO method of monitoring captures the peak power demands of a system and is the method used to charge a facility for peak demand charges.

The City's TECO billing rate is "Time-Of-Day Firm Standby and Supplemental Service" (SBFT). It is for "self-generating customers whose generating capacity (exclusive of emergency generating equipment) exceeds 20% of their site load in kilowatts…" It has a "Time-of-Use" component that charges more at certain times of the day, and these times change for different times of the year. These are called the "Peak and Off-Peak" charges. TECO refers to this as "Supplemental Billing" and these charges are based on the "Peak and Off-Peak" times.

The rate structure agreement also states that upon notification by Tampa Electric Company, electric service to all or a portion of the customer's load; could be asked to be transferred by the customer to a standby generator(s) for plant power service. Because of this option, a monthly credit is given for average transferable demand of a customer's load. It is also because of this option that customers with this rate must adhere to Environmental Protection Agency Reciprocating Internal Combustion Engine (EPA RICE) standards discussed later in this document.

Peak monthly power demands between peak and off-peak times, on average, varied by only 210 kW during a particular month for the entire year. It can be inferred that demand power is relatively steady during the month and shows the plant energy usage is generally evenly split between peak and off-peak times as shown in **Figure 15.1-1**.

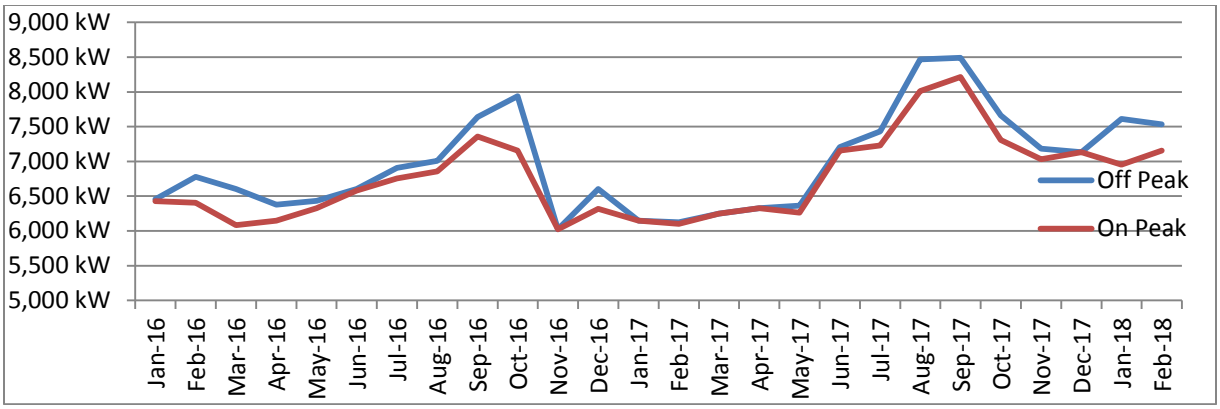


Figure 15.1-1: Utility Billing Information January 2016 through January 2018

15.1.3 Electrical System Power Loading

Starting large motors, or systems with large loads, will affect the ability of a power system to recover from the subsequent voltage or frequency dips caused by these loads being brought online. Large loads can subject the power system to supply electrical currents to as much as 6 to 10 times the normal full load current of the motor during startup. This is called “inrush”, and a power system must be robust enough to handle several of these at any moment and will be numerous throughout the day.

Utility power systems, because of their large size and ability to draw from multiple sources, are not as adversely affected by multiple large loads starting. However, standby generation systems are affected because of their much smaller capacity compared to the load served. Designs of generator and plant control systems generally have a power recovery sequence, after a power outage, which staggers the electrical system loading, adding life safety systems first, followed by the larger process motors or systems next, with the remaining processes added in order of priority. This review did not look at the SCADA control, of system recovery, after a power outage.

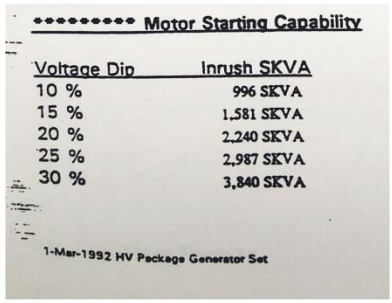
15.1.4 Generator Load Capability

The standby power system consists of (4) 2,000 kW (2,500 kVA) generators that when paralleled, can provide a total of 8,000 kW (8MW) or 10,000 kVA (10MVA) of standby power. Per manufactures literature, this maximum power can be sustained for short durations “5% of the operating time”. If also using the manufactures recommended load percentage of 70% for a maximum of 500 hours per year for standby operation. Each generator will be able handle 1,400 kW over the time period with no de-rating needed from its nameplate. This average running condition changes the system operating potential, by manufactures recommendation, to 5,600 kW (7,000 kVA). It must be added, this is a recommendation only to keep the average life of the engine (typically 20 to 40 years) and will depend on how close or far from the recommended average run time one is, for the expected useful life.

15.1.5 Generator Starting Capability

From the plant’s Operation & Maintenance Manual (O&M) information for the existing standby generators supplied by the City, the following discussion is for the Starting kilo-Volt

Amps (SkVA), or motor starting capacity, as a percentage of voltage drop for each generator as shown in **Figure 15.1-2.**



********* Motor Starting Capability

Voltage Dip	Inrush SKVA
10 %	996 SKVA
15 %	1,581 SKVA
20 %	2,240 SKVA
25 %	2,987 SKVA
30 %	3,840 SKVA

1-Mar-1992 HV Package Generator Set

Figure 15.1-2: SkVA

This table shows each generator has a momentary maximum starting capability of 3,840 SkVA @ 30% voltage dip, motor starting ability under no additional load conditions, with a combined a total of 15,360 SkVA using all four generators. This is under ideal conditions and assumes that any load connected will remain connected and running under a 30% voltage dip, usually 2 to 5 seconds, but that will depend on the type of motor controller and load connected. The generators are designed to fully recover under these conditions.

Assuming the plants electrical equipment can sustain this momentary voltage dip, the generators should be able to recover and plant operations continue. A more conservative estimate would be a 25% voltage dip for equipment to remain online, but for this example 30% will be used as it will be somewhere in between.

If generator system is already loaded, say at 6MW (7,500 kVA), the total available starting capability would be reduced to approximately 7,860 SkVA, (15,360 to 7,500) starting capacity. It should be noted, that this is a dynamic system and, in addition to motors, transformers have magnetic resonance and act like a “shock absorber” during the initial voltage dip but will experience “in-rush” currents as the system voltage recovers, that will subtract from the available starting current.

The High Purity Oxygen (HPO) system is the largest motor needing to be started while on standby power, and could be required to start, while the standby system is experiencing heavy operational loads. This motor is a premium efficiency 1,500 hp, 4160V, Code – E electric motor, using a reduced voltage starter. The lock-rotor or starting current for this motor is between 4.5 ≤ kVA/hp ≤ 5.0 based on NEMA MG-1 Motor tables.

This equates to the steady state motor “in-rush” current, that is seen by the system, and assumes a Full Voltage starting method or “Across the line” starter, which can be from 2 to 5 seconds depending on the “slip” of the motor. It is this momentary current draw that must be built into a standby system in order to start the motor.

To calculate the current required by the motor to start, using the starting method employed by the HPO system, is to first calculate the full load in-rush current.

A Code – E motor has between 4.5 ≤ kVA/hp ≤ 5.0 lock rotor current. The expected lock-rotor current using the apparent power equation:

$$kVA/hp \times hp \times 1000 = 1.732 \times V_{line} \times I_{line}$$

Thus;

The upper limit: $5 \times 1{,}500 \times 1{,}000 = 1.732 \times 4160 \times I_{line} = 1{,}040A \approx 7{,}500$ SkVA
The lower limit: $4.5 \times 1{,}500 \times 1{,}000 = 1.732 \times 4160 \times I_{line} = 937A \approx 6{,}750$ SkVA

As stated above, this lock rotor in-rush current is based on a full voltage motor starter. Having a different method of starting the motor, such as an auto-transformer, or reduced voltage starter or variable frequency drive, will significantly reduce the motor starting current load as seen by the electrical system. Additionally, once started the nominal full load amperage (FLA) for this motor is 186A @ 4160V (1,340 kVA) which is the normal operational load for this motor.

The motor starting auto transformer method employed to start the HPO motor, reduces the in-rush current to approximately 400**%** of the rated motor FLA, which is (186A x 4) = 744A @ 4160V or approximately 5,360 SkVA. ((744 x 4160 x 1.732) ÷ 1,000).

Using the aforementioned assumptions of total generator SkVA capacity (15,360 SkVA) and plant power consumption at a lower level (approximately 6MW or 7,500 kVA) it should be possible to start the HPO 1,500 hp motor. But more than likely, a reduction in plant loading to something less than 6MW (7,500 kVA) will be needed to achieve this due to the voltage drop percentage effect on the other plant systems.

To understand the true standby power system starting ability under load, a standby power test was performed on July 13, 2017 and was completed under real-time load conditions. The calculated points above were used to provide a starting point for testing the ability to start the HPO system while under generator power. The generators were brought online and the plant loads transferred without the 1,500 hp HPO system motor. A plant load of 5.85MW was maintained, and the 1,500 hp motor was started. Initially the plant load spiked to 7.5MW for about 3 to 5 seconds, it then settled back to 6.6MW. The test was successful and showed the generators starting capacity was sufficient to start the HPO system as long as the remaining plant load is 6MW or less. The City added an interlock starting function for the HPO system to disable attempted starting above a 6MW plant power loading threshold while on standby.

15.1.6 Future Power Requirements

For the most part according to the process technical memorandums, the plant power needs will essentially remain the same with these exceptions.

15.1.7 Return Activated Pumps Station (RAS) No.6

Process changes of additional clarifier(s) have dictated the need for an additional RAS pump station. This station will house five (5) 75 hp pumps that will be connected to variable

frequency drives (VFD). These pumps will function in a duty/standby (4/5) configuration. It should be noted that during high flow events the need for RAS is lessened, and therefore less power is used. The additional 300 hp (375 kVA) will be considered in the capacity study.

15.1.8 Diffused Air Reactors (DAR) Blowers

This change will eliminate mechanical mixers and replace them with a fine bubble diffused air system that will be more efficient. By removing mechanical mixers and replacing with blowers; the net change is anticipated to be negligible on the electrical system. No additional power capacity will be added for this system.

15.1.9 Dewatering System

The existing dewatering system comprising of eight (8) belt filter presses at 25 hp each are to be replaced by five (5) centrifuges at 100 hp each. Because of the increased throughput of centrifuges; the run times compared to belt filter press will be significantly less. Though a possible savings in electrical costs; the additional power requirements of 300 hp (375 kVA) for the system will need to be factored into the standby capacity needs.

15.1.10 Miscellaneous Ancillary Loads

As there will be additions to chemical facilities, primary and final sedimentation tanks, odor control equipment, side stream treatment, and other small loads throughout the plant; an approximation of 400 hp (500 kVA) will be used for future loading.

15.1.11 Capacity Recommendations

From the billing information provided by the City; the operating electrical demands at HFC AWTP, range between 6MW and 8.5MW. The 8.5MW was a peak load seen by the plant without any existing biogas generators supplementing power; as they have been off line for some time. The current standby power generation load capacity is 8.0 MW under ideal conditions at full capacity. This additional power needed for peak loads plus the future plant loads will be factored into the capacity requirements.

In addition, if during normal operations, the plant experienced a utility power outage coupled with the failure of one standby generator, the plant would need to load shed enough load to be under the 6MW limit of the remaining available standby power. This would limit the plants ability to treat at some of the higher flows.

To avoid load shedding under generator failure and provide for future loading, the standby power capacity should be extended to cover a 2MW standby generator failure at a minimum. This would raise the standby capacity to 10MW, which would cover most of the current upper power loads seen by the AWTP and could provide recovery of a failure, at less than peak load, of one 2MW standby generator giving an N+1 capability.

Table 15.1-1 shows options to provide standby power for the current peak loading demands without the assistance of the biogas power generation system. It shows power requirement options to add N+1 reliability to the standby power system (Option 1), cover future loads (Option 2), and to start the HPO under peak conditions and future loads (Option 3).

Table 15.1-1: Capacity Recommendations

	Option 1 Current Peak Load w/ N+1 and No Future loads.	**Option 2** Current Peak load, plus N+1 and future loads	**Option 3** Current Peak load, plus using N+1 capacity for HPO starting at peak loads.
Peak loads w/ HPO plant running load	8,500 kW	8,500 kW	7,250 kW[1]
Future	0	1,000 kW	1,000 kW
HPO Starting	0	0	1,500kW
N+1 Capability	2,000 kW	2,000 kW	2,000 kW
Subtotal	10,500 kW	11,500 kW	11,750 kW
Existing Capacity	(8,000) kW	(8,000) kW	(8,000) kW
Additional Standby	**2,500 kW**	**3,500 kW**	**3,750 kW**

[1] HPO generation plant not running

For the long term, provisions for permanently installed multiple standby generators should be planned with a priority to install N+1 ability as soon as possible. The addition of capacity for future loads and HPO starting ability can be added as funding becomes available. It should be noted that additional standby power from a single source is not recommended for reliability and flexibility and would not give true N+1. Multiple individual sources will be necessary with at least one at 2MW capacity.

Generators can be installed in a separate walk-in enclosure that is hurricane rated. Separate fuel tanks, or tanks incorporated into the enclosure can be used, to add to the total fuel capacity of the standby system or additional above ground tanks can also be installed.

In addition, the option to install the generators in the existing, and now empty, TECO generator building could be evaluated at a later date. The reason is the available structure has a natural gas pipeline installed in the building, which could be an option for a natural gas standby generator(s) to help meet EPA emission standards.

15.1.12 Natural Gas Engines

During the progress meeting on February 6, 2018, the City asked that the Standby Generator Capacity Analysis Report include a discussion of using a Natural Gas or Combined Heat and Power (CHP) engine for standby conditions. Though not directly related to the actual power capacity needed, the following is provided.

This type of engine is in wide use where piped in, or bio-fuel produced, natural gas is available. These engines can use both fossil fuel or bio-fuel produced Methane (Natural Gas) (CH_4) in compressed form, Compressed Natural Gas (CNG) or liquid, Liquefied Natural Gas (LNG), that when burned emits low Carbon Monoxide (CO), Nitrogen Oxides (NO_X), and Ozone (O_3) gases into the atmosphere.

The Environmental Protection Agency (EPA) recognizes these lower emissions from these types of fuels and allows this fuel type for continuous non-emergency use. This gives this engine the advantage to provide both standby and non-emergency power, for plants or usage on the power grid without the air permit restrictions.

Because of advances in the ground extraction method of natural gas, available supplies of this fuel has grown enough to compete with oil and coal for large power generator systems. The abundance and price has made it more affordable to run generators and have the added benefits of lower exhaust emissions. A drawback is the higher initial capital costs than an equivalent emissions "Tiered" diesel engine, and lower power density or the weight per kilowatt.

Some average fuel energies calculated in British Thermal Units (Btu) per pound (lb).

- LNG: 21,240 Btu/lb
- CNG: 20,160 Btu/lb
- Propane: 91,333 Btu/gal - 1gal =4.2lbs. = 20,059 Btu/lb
- Bio-Gas : 9,834 Btu/lb (Methane % dependent)
- Diesel 138,500 Btu/gal - 1gal = 7lbs = 19,785 Btu/lb
- From: (https://www.eia.gov)

Advantages of natural gas engines include:

- Best fuel efficiency;
- Lowest owning and operating costs (Especially in high hour applications);
- Lower emissions capabilities;
- Better suited for variable load applications;
- No local fuel storage requirement;
- Accepts a wide range of gaseous fuels;
- High BTU fuels; and
- Low BTU fuels.

However, compared to the cost of additional systems needed to meet exhaust emissions requirements, it typically is much less. These engines can be designed to "block loaded" which is to have the ability to instantly handle 75% of the rated load once at rated speed (1,800 rpm in < 30 sec).

15.1.13 Combined Heat and Power Generators

A subset of natural gas generators is the Combined Heat and Power (CHP) that uses both the electricity generated and the heat recovered to increase its efficiency. The HFC AWTP produces biogas that has methane component. It has been used for many years to generate electricity using CHP generators. These engines are similar to natural gas engines. However, to use them in a standby mode only, would not be the most cost-effective solution for this type of system.

This is because in standby mode, the system does not reap the benefits of producing continuous electric power and heat recovery utilization due to the shorter duration of standby power needs over a yearly period when factoring in the capital and maintenance costs.

When this type of generator system runs continuously, it supplements power to the plant, and the heat is captured to fuel other systems requiring heat. CHP systems routinely achieve

efficiencies between 60 to 80%.[1] Whereas; "typically, the combined efficiency of diesel generator sets varies between 30 to 55% while stand-alone efficiency of diesel engine and alternator ranges between 35 to 60% and 85 to 95%, respectively".[2]

An option from an overall power and fuel usage perspective, is to install a CHP engine that would reduce the base load at the plant at all times, similar to what has been done in the past at the plant. By supplementing the power being used by the plant "behind the meter"; would not only lower the electricity usage from the Utility, but in an emergency situation, be able to supplement the standby system. The efficiency of the CHP system could be fully utilized by using the heat recovery portion to supplement digester heat. The overall plant energy cost could be reduced when the self-generated power is used in an efficient manner such as the use of a CHP system.

Further discussion of the existing bio-fueled generation system along with other options is continued in the Biogas Utilization Technical Memorandum of this Master Plan.

15.2 EPA Requirements for Installation of Generator Reciprocating Internal Combustion Engine

As previously stated, the TECO tariff rate for the facility is "Time-Of-Day Firm Standby and Supplemental Service" (SBFT) with the option of interruptible service requiring the standby generators at the plant to serve TECO's power needs by powering the power grid.

In addition, the City has been able to obtain an Air Permit that not only allows the existing four diesel generators to produce standby emergency power for the plant in the event of a TECO power outage at no restriction, but "provide supplemental power generation to the electric power grid for Tampa Electric Company (for non-emergency operation) being the maximum fuel usage 400,000 gallons per 12-consecutive month period."[3]

At the current fuel consumption rate of 625 gallons per hour with four engines running; this would allow for about 27 days of runtime per year for non-emergency use. However, it is unknown how many days per year the plant has been required by TECO to run the standby system in this non-emergency mode.

The existing older generators (pre-2006) were required, by EPA standards starting in 2010, to be outfitted with catalytic exhausts to obtain a 70% reduction in emissions, or be replaced with upgraded engines (Tier 2, 3, or 4) depending on when upgrades were to be performed. The EPA requires all new diesel engines incorporate new engine technologies dependent on their use (emergency vs. non-emergency), which meet or exceed the EPA standards for emissions.

Under the current TECO tariff rate schedule, air permit, and EPA emission standards, the City may be required to install generators that have engines meeting the Tier 4 regulations in order for the City to continue at the current electric rate schedule. For diesel fuel, the current technology meeting this requirement of exhaust emissions uses a system that injects Urea into the exhaust stream. It is a very

[1] https://www.epa.gov/chp
[2] ICF analysis based on typical fuel consumption of diesel generators available at www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx
[3] Refer to the AWTP Air Permit

complex, expensive and maintenance intensive system. If this route is chosen, a comprehensive design will need to be done to incorporate this new type of generator.

Another option per the regulations is to use "a stationary Reciprocating Internal Combustion Engine (RICE) for standby emergency purposes only, as defined by 40 CFR Part 63 Subpart ZZZZ Section 63.6675, and complies with the operational requirements of Section 63.6640, and **is <u>not</u> part of an "Interruptible Rate" program where the City receives compensation.** [4] This may require the City to give up the interruptible rate incentives they have enjoyed over the years, but the City would be able to use Tier 2 diesel powered generators for emergency standby.[5]

This option assumes no special air permit has been issued for the generator system as is in the City's case. It is not known whether the current air permit can be modified to add additional Tier 2 diesel engines, even if they have less emissions than the current existing generator engines. This should be researched further to assess this option's viability.

If the City air permit were able to be modified, the new diesel generator may be able to be built to Tier 2 specifications. However, the same restrictions would apply for the total non-emergency run time (@ 400,000 gal/year) per the current plants' air permit, unless that too could be renegotiated.

An additional option is to use a renewable fuel (i.e. biogas) produced by the plant; or a low emission fossil fuel such as CNG, LNG, or Propane which is available from TECO Peoples Gas. It should be noted that CNG and LNG can be produced from a renewable or as a fossil fuel. The merits and uses of these fuels are further discussed in the Biogas Utilization Technical Memorandum in this Master Plan. The uses as far as power generation using Biogas, has been discussed for Combined Heat Power Engines. Use of these types of fuels will allow for the generator to meet the EPA Tier 4 emissions requirements without the need for additional diesel exhaust purifying systems, such as Urea.

15.2.1 Generator Capital Costs

2MW EPA Tier 2 Diesel Generator – A new 2MW diesel generator with walk-in enclosure, is one of the proposed solutions for maintaining standby system reliability. The following items were budget priced as summarized in **Table 15.2-1**.

[4] EPA CFR Part 63
[5] Per 40 CFR Part 89 "Control of Emissions from New and In-Use Non-road Compression-Ignition Engines"

Table 15.2-1: 2MW EPA Tier 2 Diesel Generator Capital Costs

Item Description (For each generator)[1]	**Cost**
Generator -	$600,000
Walk-in Enclosure -	$150,000
Electrical -	$200,000
Miscellaneous piping -	$10,000
Concrete slab for generator -	$50,000
I&C integration and Programming -	$50,000
Sum of Bare Construction Costs	$1,060,000
30% Contingencies	$318,000
Bare Construction Cost	$1,378,000
20% OH&P & GCs	$275,600
Total Construction Cost	**$1,653,600**
20% Management and Engineering[2]	$330,720
Total Capital Cost[3]	**$1,984,320**

[1]Bulk Fuel Storage discussed later in this Technical Memorandum
[2]Includes COT management, legal and administrative costs
[3]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

2MW EPA Tier 4 Diesel Engine – Similar as above except with Urea system to lower exhaust emissions per EPA guidelines as summarized in **Table 15.2-2** (Same footnotes apply).

Table 15.2-2: 2MW EPA Tier 4 Diesel Engine Capital Costs

Item Description (For each generator)[1]	**Cost**
Generator -	$1,000,000
Walk-in Enclosure -	$150,000
Electrical -	$200,000
Miscellaneous piping -	$10,000
Concrete slab for generator -	$50,000
I&C integration and Programming -	$50,000
Sum of Bare Construction Costs	$1,460,000
30% Contingencies	$438,000
Bare Construction Cost	$1,898,000
20% OH&P & GCs	$379,600
Total Construction Cost	**$2,277,600**
20% Management and Engineering[2]	$455,520
Total Capital Cost[3]	**$2,733,120**

2MW Standby Natural Gas Generator - New 2MW natural gas fueled generator for standby use. Similar to Tier 2 diesel engine described above but with the ability because of the fuel to be used in non-emergency requests from Utility. Assumes natural gas source easily obtained and nearby as summarized in **Table 15.2-3** (Same footnotes apply).

Table 15.2-3: 2MW Standby Natural Gas Generator Capital Costs

Item Description (For each generator)[1]	**Cost**
Generator -	$750,000
Walk-in Enclosure -	$150,000
Electrical -	$200,000
Miscellaneous piping -	$10,000
Concrete slab for generator -	$70,000
I&C integration and Programming -	$50,000
Sum of Bare Construction Costs	$1,060,000
30% Contingencies	$318,000
Bare Construction Cost	$1,378,000
20% OH&P & GCs	$275,600
Total Construction Cost	**$1,653,600**
20% Management and Engineering[2]	$330,720
Total Capital Cost[3]	**$1,984,320**

2MW CHP Generator – A new CHP generator that would use digester Bio-Gas, CNG, LNG recoup much of these costs over the life of the system using the generated electricity and heat recovery, making the system over 80% efficient. The generator location would need to be close to the heat recovery client (boilers) for efficiency.

These are budgetary capital costs with no cost-benefit analysis performed. The fuel filtering and compression system was assumed to already be in place for other methane uses. This generator will operate over 80% of the time during the life of the system as summarized in **Table 15.2-4** (Footnotes 2 & 3 still apply).

Table 15.2-4: Budgetary CHP Capital Costs

Item Description (For each generator)	**Cost**
Generator -	$850,000
Walk-in Enclosure -	$200,000
Electrical -	$400,000
Heat Exchanger Miscellaneous Piping -	$150,000
Concrete slab for generator -	$75,000
I&C integration and Programming -	$75,000
Sum of Bare Construction Costs	$1,750,000
30% Contingencies	$525,000
Bare Construction Cost	$2,275,000
20% OH&P & GCs	$455,000
Total Construction Cost	**$2,730,000**
20% Management and Engineering[2]	$546,000
Total Capital Cost[3]	**$3,276,000**

15.2.2 TECO TARIFF RATE COMPARISON

A rate comparison between the existing SBFT rate and a new TECO tariff rate was performed without formal discussions with TECO, and is provided as a worst-case estimation. It is also based on the published TECO tariff schedule updated in 2014. The tariff rate compared is Time of Day General Service - Demand (GSDT) and is based on the TECO GSDT definition sheet 6.330. It is assumed the "Standby Charges" for the redundant TECO feeder No. 2 will remain per the current tariff, as well as the "Standby Rider" Rider (GSSG-1) TECO sheet 3.200 for the interruption agreement with the Utility requesting the plant go to standby power generation, at the current tariff schedule. This will have to be renegotiated if changes are made.

Bills supplied by the City were compared between the current SBFT rate and the 2017 TECO tariff for Time of Day General Service (GSDT) and are summarized in **Table 15.2-5**. The Fuel Charges are the same for both tariffs.

Table 15.2-5: Rate Comparison SBFT vs. GSDT

Monthly Rate	SBFT	GSDT	Remarks
Basic Service Charge			
Secondary Meter Charge	$60.93	$33.24	N/A
Primary Meter Charge	$171.72	$144.03	
Sub-transmission Meter Charge	$1,124.52	$1,096.82	N/A
Demand Charge			
Billing Demand	$3.46 kW	$3.46 kW	
Peak Demand	$6.79 kW	$6.79 kW	
Energy Charge			
Peak	$.03211/Supplemental kWh	$.03211/ kWh	
Off-Peak	$.01159/ Supplemental kWh	$.01159/ kWh	
Standby Service (Methane Gas)			
Local Facilities Reservation Charge	$2.15 kW/month		
Power Supply Reservation Charge	$1.71 kW/month		
Power Supply Demand Charge	$.68 kW/month		
Energy Charge	$.01012 /standby kWh		
Standby Rider (Standby Generators)	$5.35 kW/month	$5.35 kW/month	

The main cost difference between the two rate schedules is the use or non-use of the methane generators. All things being equal at an average 1,000 kW of methane generator production a rough cost savings of 11% (see **Table 15.2-6**) could be realized with the SBTF rate schedule due to the decrease in energy usage, and therefore Energy Charge. This does not however take into account the heat use benefits of the engines to supplement boiler heat for the digesters, the cost of maintenance, or cost of fuel. It also does not account for

the sale of methane fuel on the open market. The Biogas Utilization Evaluation Technical Memorandum discusses this further and will ascertain the cost benefits of the fuel system approaches.

Table 15.2-6: Based TECO Feb 2017 SBFT Billing

CHARGE	SBFT VALUE	SBFT COST	GSDT VALUE	GSDT COST
BASIC CUST. CHARGE (PRIMARY)	-	$ 171.72	-	$ 144.03
SUPPL BILLING DEMAND	6,125 kW	$ 21,192.50	7,107 kW	$ 24,590.22
SUPPL PEAK BILLING DEMAND	6,099 kW	$ 41,412.21	7,081 kW	$ 48,079.99
LOCAL FAC. RESERV	982 kW	$ 2,111.30		$ -
POWER SUPPLY DEMAND	11,522 kWd	$ 7,834.96		$ -
STANDBY ON-PEAK	51,069 kWh	$ 516.82		$ -
STANDBY OFF-PEAK	158,280 kWh	$ 1,601.79		$ -
SUPPL ON-PEAK	955,306 kWh	$ 30,674.88	1,242,055 kWh *	$ 39,882.39
SUPPL OFF-PEAK	3,115,553 kWh	$ 36,109.26	3,745,193 kWh **	$ 43,406.79
DELIVERY VOLTAGE CREDIT	-	$ (5,761.33)	-	$ (5,761.33)
RELAY POWER CHARGE	-	$ 4,690.62	-	$ 4,690.62
METER VOLTAGE ADJUSTMENT	-	$ (1,403.83)	-	$ (1,403.83)
STANDBY GENERATOR CREDIT	5,284 kW	$ (25,099.00)	5,284 kW	$ (25,099.00)
ON-PEAK FUEL ADJ CHARGE	1,006,375 kWh	$ 31,539.79	1,242,055 kWh *	$ 38,926.00
OFF-PEAK FUEL ADJ CHARGE	3,273,833 kWh	$ 92,845.90	3,745,193 kWh **	$ 106,213.67
SUPPLEMENTAL	6,125 kW	$ 1,653.75	7,107 kW	$ 1,918.89
STANDBY	548 kW	$ 147.96		$ -
SUPPLEMENTAL	6,125 kW	$ 4,655.00	7,107 kW	$ 5,401.32
ENVIRONMENTAL COST RECOVERY	4,280,208 kWh	$ 16,350.39	4,987,248 kWh **	$ 19,051.29
	Monthly Bill	$ 261,244.70		$ 300,041.05
	Dollars per KW Hour	$ 0.0610 / kWh		$ 0.0602 / kWh
	Dollars per KW Demand	$ 42.6522 / kW		$ 42.2177 / kW

Total monthly bill increase: 14.85%
Assuming 8 hours/day o loc.fac.reserv. Additional loading due to loss of methane generators to GSDT kWh, on peak
Assuming 16 hour/day of loc.fac.reserv. Additional loading due to loss of methane generators to GSDT kWh, off-peak.

15.3 Standby Power Capacity Analysis – Fuel Storage Capacity

15.3.1 Background

The City asked McKim & Creed to provide an analysis of improvements needed to increase fuel storage for the standby power generator system to 5 days at the HFC AWTP. This request comes out of the need to increase bulk fuel storage from the current two-day bulk fuel capacity and the possibility of standby power generation being added.

This supplemental memorandum will identify the fuel capacity needs for 5-day standby generator operation based on the existing standby power generators, as well as give fuel requirements for incremental bulk storage demands needed, if additional standby power generators are installed.

15.3.2 Existing Conditions

The City has four Model 3615, 2,000 KW 2,500 kVA Caterpillar engines which are supplied by two 12,000-gallon underground storage tanks located near the standby power generation facility. These tanks are connected to a day tank pumping system that draws from the underground bulk storage tanks. This serves as a fuel reservoir for the standby power generators.

In addition to the consumption rate; recirculation rate must also be looked at when designing a generator fuel system. The recirculation rate is to control the temperature of the fuel entering the engine. High fuel temperature will effect engine performance and cause deration of engine output. Fuel recirculation rates are typically 3 times consumption. The day tank also serves as a reservoir to recirculate fuel through the engine for keeping the fuel temperature from exceeding limits. This is why the existing day tank system includes fuel radiators, see **Figure 15.3-1**, to help keep the day tank fuel temperature within range.

Manufacturers published fuel consumption of each of these existing generators was 135.7 gph at full load, but with age and the addition of emission controls the consumption has increased.

The City reported that their observed fuel consumption was about 15,000 gpd or 625 gph. It is assumed this rate is at or near full load. This works out to approximately 156 gallons per engine per hour. These consumption rates will be used to determine the necessary storage capacity to run the plant for 5 days using the current generators. In addition, the published rate for a new 2MW Tier 2 Emissions generator is 138 gal/hr at full load, which will also be used in the calculation.

Figure 15.3-1 – Day Tank Fuel System and Fuel Radiators

The City also informed McKim & Creed that there are two existing 12,000-gallon underground fuel storage tanks west of the Main Pump Station that were used for the old turbine generators. They are approximately 600 feet away from the standby power facility. These fiberglass tanks were installed in 1991. The leak detection and "VeederRoot" fuel usage monitoring system are inspected yearly. As these tanks are underground, the integrity of the tanks was not inspected, and only inferred through the leak detection system.

The two 12,000-gallon underground fuel storage tanks west of the Main Pump Station are not connected to a day tank system but has the ability to be used to fuel City vehicles in an emergency. In the past, fuel has also been transferred via truck to the underground standby generator storage tanks for supplementing fuel usage.

15.3.3 Fuel Consumption Demands

From the technical data sheet for the Model 3615 Caterpillar engine, the consumption rate is stated to be 135.7 gph at 100% full load. The difference in manufacturer rating and observed consumption can be attributed to the ages and runtimes of the engines (from circa 1992). In addition, emission control were installed that will add to fuel consumption. All of these observations are based on the generators being at, or near 100% full load as fuel consumption varies with load.

For the purpose of this memorandum, the fuel consumption information provided by the City was used in lieu of the consumption rate from the manufacturer's data sheet, and is shown in **Table 15.3-1**.

Note that the two 12,000-gallon fiberglass fuel storage tanks at the Main Pump Station were not entered into the equation, as they are not connected to the standby generator system. However, their future possible usage will be discussed further in the report.

Table 15.3-1: Fuel Storage Requirements

	Existing Fuel System	Proposed Fuel System Addition w/ Existing Generators	Required Fuel for the Addition of 2MW Tier 2 Generator
Percent Load	100%	100%	100%
Fuel consumption rate (gph) per engine	156.25	156.25	138
Number of Engines Running	4	4	1
Fuel consumption (gph) all engines running	625	625	763
Per day fuel demand (gal)	15,000	15,000	18,312
Days of Fuel Capacity @ Full Load	< 2	5	5
Additional Storage Capacity Required (gal)	**-**	**51,000**	**17,000**
Total Fuel Storage (gal)	24,000	75,000 (includes existing)	92,000 (includes existing and proposed)

With the existing two onsite 12,000-gallon underground tanks located at the standby power facility, the fuel storage capacity is less than two days with the generators operating at, or near, full load of the standby system. As power consumption varies throughout the day, it is possible to have more runtime, though not much more than two days because the plants' systems run at near full standby capacity (6MW to 8.5MW).

Factoring in the additional non-connected fuel storage of the old turbine generators' fiberglass tanks, the available fuel storage capacity increases to 48,000-gallons and the time extends to approximately 3.2 days with the consumption rates discussed.

Due to the unknown long-term condition of the existing old turbine generators' fuel storage tanks and the distance between them and the standby power facility, for the scope of this report, they are not considered other than from a capacity availability stand point. However, if they were deemed usable through inspection, a transfer pumping system and leak detection piping would need to be installed for the 600± feet distance to the standby power day tank system. The approximate cost to run two 1.5-inch x 600-feet double walled fuel lines with leak detection system for the existing unconnected tanks is approximately $60,000. If return lines are necessary, the cost will nearly double. In addition; the cost of a new transfer pump system for these tanks is approximately $25,000. This retrofit will only gain the City an additional 1.6 days.

15.4 Recommendations

With the existing two on-site underground 12,000-gallon fuel storage tanks, at the calculated consumption rate, with no increase in generator capacity, for 5-days the existing standby generator system requires an additional bulk fuel storage of approximately 51,000 gallons. This assumes the generator used for N+1 reliability as it not used until one generator fails. This would bring the total storage to 75,000 gallons. Using standard tank sizes to achieve 51,000 gallons, this can be attained using five (5) 10,000-gallon storage tanks, or three (3) 20,000-gallon storage tanks, or two (2) 25,000-gallon tanks. The recommendation for this configuration is using two 25,000 gallon tanks.

With the addition of each 2 MW generator, not including ”+1”, the additional fuel storage capacity for 5-days is approximately 17,000 gallons, bringing the total to an additional fuel storage capacity needed to 68,000 gallons for the existing generators and one additional “In Service” 2MW generator. As with the previous option above, this fuel storage capacity is on top of the existing 24,000 gallon fuel storage currently available, for a total of 92,000 gallons of needed fuel storage. This 68,000 gallons increase in storage capacity can be accomplished with the addition of (2) 35,000 gallon steel tanks.

It is the recommendation of this report to use an above ground tank system with the choice of material to be discussed further. This said, if the facility decides to add diesel generators for standby use; two 35,000 gallon tanks will cover the needed tankage for the existing generators (including N+1) and one additional 2MW diesel standby. For each additional 2MW generator the City would need to provide an additional 17,000 gallons of fuel storage in order to meet the five day requirement, with the location shown in **Figure 15.4-1**.

Figure 15.4-1: Footprint of Aboveground Fuel Storage Tanks

[1]25,000 gallon aboveground fuel storage tanks are shown in red

[2]35,000 gallon aboveground fuel storage tanks are shown in blue

When adding additional fuel storage tanks, keeping the footprint and associated piping to a minimum is a consideration for maintenance and points of failures. In addition, the determination of using above or below ground tanks is matter of aesthetics, maintenance and security. Below ground tankage will cost more because of installation and permitting. Maintenance is easier for above ground tanks because of access. Security is a concern for both below and above ground, but more so with above ground. For above ground tanks, the use of double walled steel or concrete are good options to address security concerns, with concrete being stronger for projectiles.

New skid mounted above ground fuel tanks include submersible fuel transfer pumps, fill suction and return piping within the tank, along with visual level indication. Piping is additional and assumes the use of the day tank system. However, additional 2MW generator(s) will require expansion of the day tank system. The existing day tank system appears to be in good condition; and aside from routine maintenance and repair, should last for at least 10 years.

The Standby Generator Capacity Analysis section discusses the need for an approximate of available standby power to meet the peak demands during standby power conditions. The range given in the report is between 2.0 MW and 4.0 MW, dependent on usage requirements. In addition, the report discusses the type of generator with options between a CHP and the traditional diesel engine; with the latter system, needing the additional gallons of diesel fuel in 2 MW increments.

This being the case, this Fuel Storage Capacity section and the costs presented in **Table 15.4-1** are centered on the need to provide 5 days diesel fuel storage for the minimum of a 2MW generator increase over the existing generator capacity for a total required increase of 68,000 gallons of fuel storage.

Table 15.4-1: Conceptual Cost Estimate for Diesel Fuel Storage Improvements

Item Description	**Cost**
Two Above ground double walled fuel storage tanks with submersible transfer pumps (2) 35,000 gallon tanks	$ 270,000
Two Concrete pads	$ 70,000
Fuel piping system	$ 15,000
One New 500 gallon Day Tank System for each 2MW generator	$ 60,000
Two Fuel Fill and polishing system	$ 80,000
Instrumentation & Control	$ 25,000
Electrical	$ 40,000
Sum of Bare Construction Costs	$ 560,000
30% Contingencies	$ 168,000
Bare Construction Cost	$ 728,000
20% OH&P & GCs	$ 145,600
Total Construction Cost	**$ 873,600**
20% Management and Engineering[2]	$ 174,720
Total Capital Cost[1]	**$1,048,320**

[1]Estimates of probable costs are planning level (AACE Class 5) estimates as defined by the Association for the Advancement of Cost Engineering. These cost estimates are defined to be accurate within a range of -50% to +100% of actual costs.

[2]Includes COT management, legal and administrative costs.

15.4.1 Additional Discussion Items

The existing day tank system piping will need to be modified to accommodate the additional above ground tanks.

Because of the increased fuel storage volume, a tank fill station is recommended to off load fuel trucks quickly. It is also recommended that a fuel maintenance and polishing system be installed to continuously clean and dewater the fuel, in order to extend fuel life. For this size of fuel storage, the filling and filtering system will cost approximately $80,000 with design and installation.

16.0 Instrumentation and Controls, SCADA Automation Evaluation

16.1 Purpose and Background

As part of the Phase I Master Plan for the HFC AWTP, the plant SCADA system was reviewed and evaluated to determine its overall ability to provide reliable and effective monitoring and control of the plant operations. This technical memorandum expands the initial evaluation and provides recommendations on modifications and expansions to meet the requirements of the plant process modifications.

16.2 Current SCADA System

The HFC AWTP SCADA system provides monitoring and some control capability for in-plant equipment and instrumentation as well as off-site facilities such as master pump stations and sewer lift stations. The following Sections describe the SCADA hardware and HMI software systems utilized at the plant for both in-plant and off-site remote control and monitoring, in addition to the existing plant PLCs and communications network systems.

16.2.2 SCADA System Software

The Administration Building serves as the central point of the SCADA system. A server rack located in the Administration Building, shown in **Figure 16.2-1**, includes servers for both in-plant and off-site remote stations control and monitoring.

The City uses HSQ Technologies Miser software as the in-plant SCADA platform. The software is installed on five HP servers where each server has the HSQ SCADA software and an operating system (HSQ MISER 6.08, OS: Open VMS 8.3-1H1) installed, with the exception of one server which has an older version of the operating system (OS: VMS 7.3-2) to support older applications. The four other servers in this rack are client, development and two application servers, where one application server is redundant to the other.

Off-site facilities are monitored and controlled through Trihedral, Inc. VTScada software (v.9.1.20), which is installed on two servers, with one server providing redundancy to the other. The software runs on a standard Windows Server operating system, in this case v. 2008 R2, SP1. The current version of the VTScada software is 11.2, which is compatible with the latest Windows Server 2012, R2 operating systems.

Additional SCADA HMI computers are located inside various buildings throughout the plant to provide remote monitoring and control of the plant processes. Each computer has the HSQ MISER 6.08 SCADA software installed on it with a Windows 7 Professional 64 bit operating system.

Figure 16.2-1: Administration Building Network Rack

16.2.3 Programmable Logic Controllers

A distributed system of programmable logic controllers (PLCs) is located throughout the plant. These systems are mostly manufactured by General Electric (GE). Exceptions include an Automation Direct unit used for the Chemscan PLC and Motorola MOSCAD PLCs used for interface to the remote site control systems. GE PLC equipment life status is categorized in three different stages, which are defined in **Figure 16.2-2**.

Figure 16.2-2: GE PLC Life Status Stage Definition

The majority of GE PLC control systems model type is the PAC Systems RX3i, which has an active life cycle status, where both hardware and software are currently supported by the manufacturer. The remaining installation of GE PLCs are either the model 90-30, 90-70 or Genius I/O, where these have limited or no support and their hardware production has been discontinued or will be in the near future. An inventory of PLC type and life cycle status is included at the end of this memorandum as **Attachment 16-A**.

The older PLCs are utilized in a few areas of the plant as a stand-alone PLC system, with or without remote I/O, or as remote I/O to the newer PLC platform, PAC Systems RX3i PLCs. **Figure 16.2-3** and **Figure 16.2-4** show a couple of typical PLC panel installations with remote I/O utilizing these older PLC platforms.

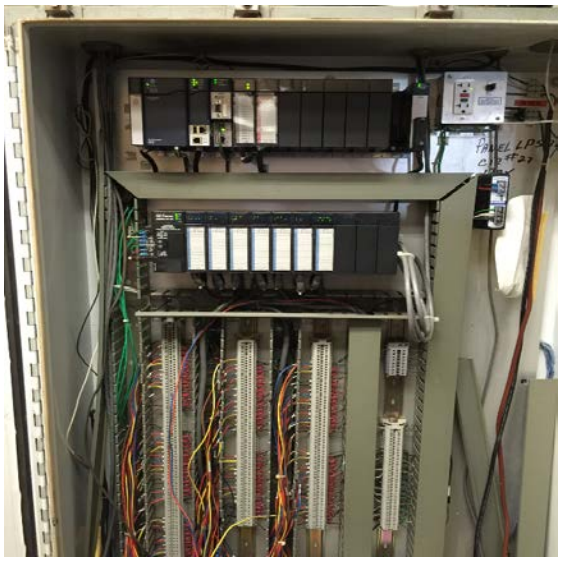


Figure 16.2-3: PLC-15 GE PACSystems RX3i PLC with GE 90-30 Remote I/O

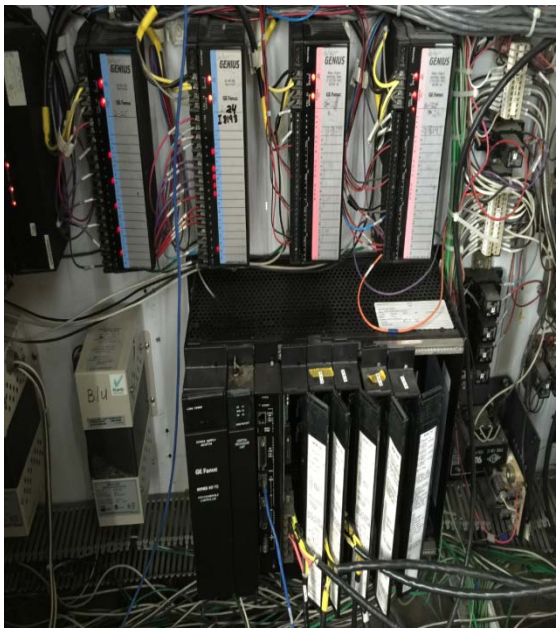


Figure 16.2-4: PLC-5:33 GE 90-70 PLC with GE Genius I/O

16.2.4 Communications System Network

The in-plant communications system is an Ethernet-based network and consists of servers, network switches, hubs, fiber optic cable, patch panels and Category 5e network cable, distributed through the plant. Network switches are located inside the Administration Building network rack, shown in **Figure 16.2-1**, and throughout the plant in other buildings. These provide for fiber optic communication network connections to the in-plant SCADA system and the City's off-site remote stations, via internet connection.

The topology of the fiber optic network is a multi-level star-type configuration, where a direct connection is provided between the network switch and area hubs or to remote-mounted PLCs. The area hubs have a direct hardwired connection to local PLCs. **Figure 16.2-5** shows the current in-plant and off-site SCADA communications network diagram with the exception of some missing information for equipment recently added to the network. Note, off-site systems utilize the VTScada software, located on servers designated as DCRSCADA1 and DCRSCADA2 and communicating through the network switch designated as DCR Switch. The balance of indicated servers and communications equipment supports the in-plant HSQ SCADA software.

The in-plant network speed is one gigabit between the servers and area hubs and 100 mb/s between the area hubs and PLCs.

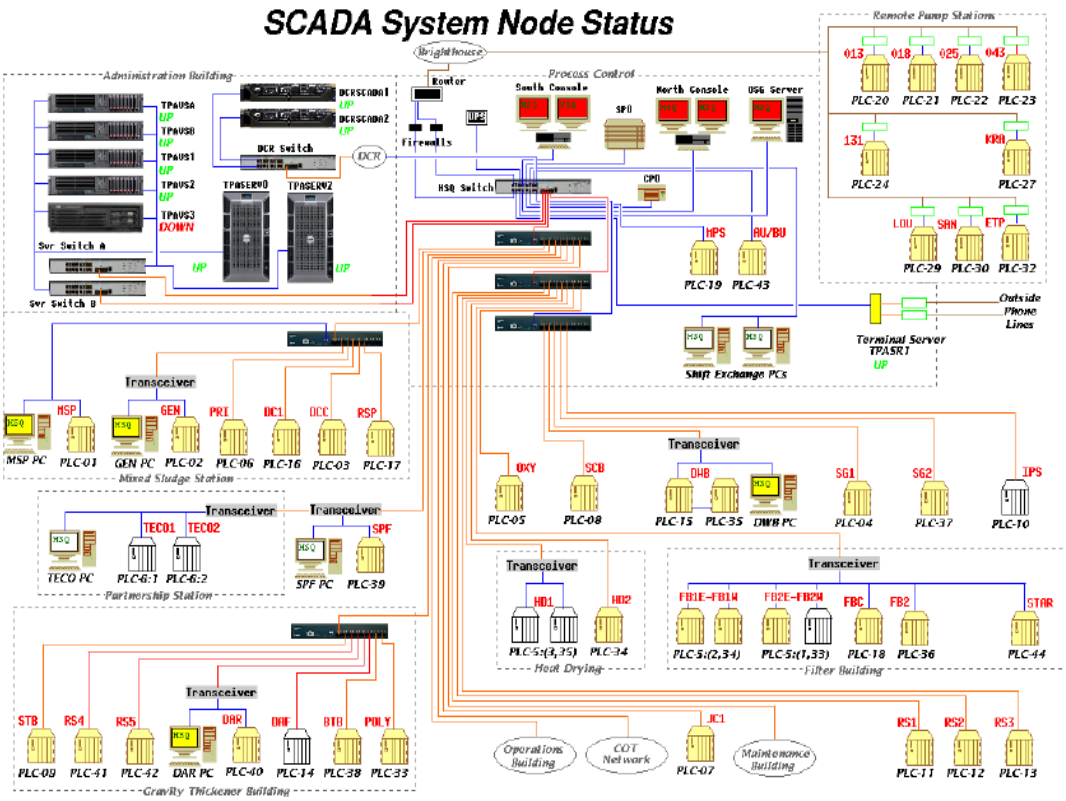


Figure 16.2-5: HFC AWTP Fiber Optic & Off-Site Communications Network

16.2.5 General

The City provided an Asset List inventory spreadsheet of the equipment and instruments installed at HFC AWTP. The spreadsheet does not include any of the noted SCADA hardware or software documented during the site visit and described here. Other documentation provided, such as control panel layout and wiring diagrams as well as fiber optic cable drawings, the City staff indicated are approximately 75% accurate, which plant maintenance staff are aware of and know where these deficiencies are located.

16.3 SCADA System Status

16.3.1 SCADA Software

During the plant site visits, City personnel indicated that the HSQ SCADA system stability is excellent, in that the VMS operating system does not require nuisance reboots caused by the computer locking up or crashing. Since the City's experience has been positive, they are hesitant to move to a different system software or standard operating system. However, HSQ software has a limited nationwide installed base and the plant's existing HSQ software version is out of date. The limited installed base may impact the future ability of the manufacturer to maintain system technology levels. Software updates will require a maintenance visit from the manufacturer to upgrade the software to the latest version (HSQ MISER 6.14). This version includes several improvements to the software within the last 10 years and also allows operation on some Windows platforms. Moving to a Windows based operating system would allow the City to implement a program of regular security and system updates to maintain the protection and performance of the system.

The City also indicated that the current VTScada HMI software system has been unstable, causing the need to reboot, synchronize the servers and address communications issues related to the current software and telemetry system hardware. However, the software version in use is several revision levels out of date and missing several levels of updates and modifications. A project is in progress to upgrade the VTScada software application and telemetry system hardware to current technology levels, and it is expected these upgrades will improve the system performance.

If the VTScada system performance improves with these upgrades to the City's expectations then the City will consider moving the in-plant processes over to the VTScada system. Combining the two SCADA systems to operate uniformly on one SCADA system software platform will eliminate the requirement for utilizing separate servers dedicated to the HSQ SCADA system and also allow the City to view and operate both off-site and in-plant processes on the same computer system.

16.3.2 Mobile SCADA

Mobility throughout the plant is required for the plant operators, such that they can perform testing and maintenance on field equipment and instruments, while having the capability to monitor and control the plant remote from the Process Control Building SCADA computers. The current operation method utilizes secondary HSQ computer stations, located in several electrical rooms around the plant. The City is testing a few industrial tablets to control and monitor the plant remotely, via a cellular 4G air card. The City stated that the industrial tablets will function as portable HMI computers eliminating the requirement to install additional operator interface terminals or maintain the HSQ computer stations in the future. The use of industrial tablets for mobile plant operations has been increasing due to SCADA system software updates that allow graphic screens to automatically resize to match the tablet and the ability to support cellular and/or WIFI data connections.

The City indicated some limited in-plant Wi-Fi communication has been implemented, although not documented on site plans and network diagrams. Expansion of wireless communications across the plant has the potential to support plant operations, process alarming, video monitoring, telephone communications, etc. including the ability to support the industrial tablets as a SCADA system device.

Use of cellular technology can provide operational benefits to the City and make use of infrastructure the City does not have to maintain. Service availability in the plant area is dependent on the service provider area coverage and the cost of data service plans to the City. Cellular technology is beginning to gain widespread use for SCADA systems, and service providers, in general, have improved their security offerings for these applications. However, it does expose plant SCADA system communications to networks not controlled by the City and requires the tablets use outside access to the City SCADA and administration networks. This access must be actively managed and typically requires Information Technology personnel to maintain.

Use of the cellular technology should be contrasted with in-plant, internally managed Wi-Fi technology for costs and benefits to determine the acceptable level of implementation risk moving forward. Wi-Fi requires considerably more upfront cost and planning by the City to provide full coverage of the plant. This coverage needs to be balanced with limiting the exposure of communications to outside of the facility perimeter. Wi-Fi also requires active management of the communications system security and requires that all maintenance and repairs be performed by City resources.

Decisions for the preferred technology to use are typically made based on the user's ability to plan and maintain the systems along with the acceptance of the security risk/protection level and area coverage available from a service provider.

16.3.3 Programmable Controller Hardware

The City has an ongoing program for upgrading and replacing PLC systems to achieve current technology levels. As part of the field investigations and equipment inventory, PLC equipment was identified for life cycle stage. Equipment that has been identified as obsolete or discontinued should be in an active process for replacement. Equipment that has been identified as mature should be in a planning process for eventual, near-term replacement.

In addition to technology level replacement, consideration should also be given to future monitoring and control needs. The installation of PLC controller hardware is adequate for current operation, however, as new instrumentation and/or equipment is added to the plant processes, it may become necessary to expand the capability of the PLC equipment to monitor and/or control the equipment. In other cases, the level of automation or monitoring available may not be adequate for desired improvements in plant operation. In these cases, it will be necessary to add modules and expand the PLCs to control the equipment or monitor the status. This needs to be a consideration for implementation on each recommendation on process improvement.

16.3.4 Documentation

As plant maintenance personnel move out of their current positions - either through retirement, promotion or resignation - it is critical that the SCADA and control system knowledge they possess is not lost. The cost of updating documentation or developing disaster recovery plans now is far less than the cost of tracing out control panel wiring or developing software applications from scratch. Review of plant documentation, noted above, indicated that this information is not up to date and plant personnel are aware of deficiencies. It should be a high priority to implement a program for updating this documentation, both to make it current and to capture modifications in the future. This includes control panel bills of material and electrical schematics, plant SCADA network diagrams, fiber optic cable installation routing and application software functionality descriptors.

Similarly, a program of software version control, backups and planned system recovery for unplanned events can assist in maintaining reliable plant operations. The replacement of computer or PLC hardware requires the installation of operating system and multiple application level software programs. Installation of outdated application software, unsupported operating systems or incompatible equipment firmware can have consequences as critical as the failure of the original equipment. Considerations would include development of disaster recovery plans for each computer, server, PLC and managed network device. The plans should include use of software asset management programs or regularly scheduled backups of PLC application software along with a log of PLC hardware firmware levels to provide the resource for controller failure recovery. Images of computer hard drives will provide tools for recovery of SCADA computers and servers while regularly scheduled backups of historical data will ensure reporting and compliance with operational data. These recovery procedures should be developed and then tested for validation for each device.

16.4 Plant Control Network Review

As part of each of the projects identified in the master plan, improvements will also include recommendations for process control automation as well as enhancements to monitoring through process instrumentation and control devices. To maximize the advantages of these improvements, and to provide a high level of system reliability, will require a robust SCADA system control network capable of high speed communications and timely interaction between control components.

The existing plant SCADA control system network is a multi-level Ethernet star configuration with connection to a distribution of PLC control panels and SCADA computers using a combination of fiber optic and copper cable. The hub of the star is the communications room in the Process Control Building and then connection to the server room in the Administration Building. The control system network is separated into four segments that generally divide the plant into sectors. Each sector provides that area of the plant with an independent connection to the Process Control Building. Where multiple control panels and/or computers are located in proximity to each other, they are grouped to a local network switch, which limits the number of fiber cables routed to the communications room. Review of the SCADA network and interview with plant technicians indicated a high level of performance of the network, albeit with some limited concerns. These include the use of some non-industrial rated network components in industrial areas, the lack of standardized network components immediately

available to minimize down time during equipment failure, the aging of installed fiber optic cable and occasional limited network outages.

A review of the SCADA network was performed to investigate the possibility of improving the reliability and performance of the control system network through implementation of a redundant path fault tolerant fiber optic ring. A fiber ring implementation can provide a level of fault tolerance by providing an alternate network path to any location by communicating either clockwise or counterclockwise through the network ring. A redundant path fault tolerant fiber optic ring requires switch components that can provide this type of operation, such as rapid spanning tree or vendor proprietary protocols, to support managed directional communications. It also requires alternate fiber optic paths arranged sequentially through the distributed control panels to form a ring through the control locations. However, the benefits of the network ring configuration are limited if the failure occurs within a control panel, as the site is then not reachable from either direction. Also, if a true alternate path is not provided, such as a shared duct bank, any event that interrupts the cable would likely interrupt both directional paths.

Fault tolerant fiber optic ring implementations can be costly to install in an existing facility as it effectively doubles the amount of network cable and conduit, with significant new installations required, and requires the replacement or reconfiguration of much of the plant network components when they are unable to support two directional communications. In an installation as large as the HFC AWTP, with nearly thirty control locations, this can be a significant consideration and the cost of installation must be balanced with the risks of network failure. A review of the current network star arrangement did not indicate a method to easily rearrange the network in a circular pattern, with true alternative paths without a complete rework of the existing network and installation of new conduit paths between control panel or computer locations.

Implementation of a fault tolerant fiber optic ring could also be considered in terms of the plant sectors instead of the entire plant control system. With the Process Control Building generally centered in the plant infrastructure, each sector could be configured as a ring for that area of the plant, starting and ending at the Process Control Building. While this would still require the significant installation of new conduit paths, it would be easier to develop within the existing infrastructure.

A network star configuration can also provide a high level of reliability as independent paths to the hub typically limit the impact of a failure to a single network path. In the case of the Curren plant, most communication cable is installed in conduit as part of duct banks, providing a high level of protection to the infrastructure. However, the network does not include all independent paths and loss of some paths or network equipment could have an impact on multiple locations. The areas of greatest vulnerability would include the filter building, the mixed sludge station and the gravity thickener building. As an alternate to the installation of a fault tolerant fiber optic ring, the City may want to consider other methods to mitigate the impact of equipment failure through a program of standardized networking equipment and shelf spare components.

The control system network operates in a harsh, industrial environment and all equipment utilized should be capable of withstanding these conditions. A review of several control panels indicated cases where general consumer level network switches were in use. Plant technicians indicated these were used primarily as a temporary measure to return network links to service during an outage. However, in some instances, use of the switches has continued as local suppliers do not always maintain the needed

stock or the desired equipment to replace the temporary. The recommendation would be to evaluate and select a standard industrial fiber optic managed and unmanaged switch and work with local distributors to maintain a desired level of stock for use. A smaller level of plant stock should also be maintained for immediate replacement during an unplanned outage.

Much of the fiber optic cable used in the control system network dates back to at least the original documentation of 1995. This cable has mostly been installed in conduits within duct banks and has therefore been well protected from damage. While officially there is no stated lifespan for fiber optic cable, some of the cable has been installed for about twenty-five years. Most cable is made from a high quality plastic but even this can be affected by exposure to gases and other conditions that can cause a haze on the surface that could affect the performance or make the unprotected strand sections brittle and potentially break at the connector. Because of the reliance of the control system on this cable, it is recommended to implement a program of routine testing, per ANSI/TIA-526, to determine how well the cable is lasting. Use of a light source and receiver measurement kit over a cable segment can determine the performance of the cable against the original manufacturing specification and to a calculated fiber optic link signal budget that accounts for connectors, splices and patch cords in the link. Performance of the cable to significantly below the original specification could then be scheduled for replacement as a preventive maintenance task whereas performance within the original specification tolerance can be used as a benchmark measurement for future performance.

16.5 Plant Process Modifications

16.5.1 Screening and Grit Removal

As part of upgrades to the Screening and Grit Removal systems, replacement process equipment will be provided with local control panels for operation of the equipment. The controls will provide continuous automated sequential operation and require little interaction from operations personnel after initial configuration. The equipment will be monitored through the plant SCADA system to provide status and alarm information for monitoring purposes.

16.5.2 Primary Settling Tanks

Expansion of the Primary Settling Tanks will eliminate the hydraulic limitation that currently exist with this process under high flow conditions as well as provide flexibility to rotate equipment in operation. The settling tank equipment maintains continuous operation once placed in service and the ability to initiate or remove from operation will be provided through the plant SCADA system. Status and alarm information will also be provided for monitoring purposes, including improved sludge blanket monitoring. Primary sludge and scum system pumping will maintain and extend the existing controls with status and alarm information provided to the SCADA system for monitoring purposes.

16.5.3 Main Pumping Station

Upgrades proposed to the Main Pump Station include replacement of pumps and VFDs only. No changes are recommended for the pump control or SCADA system monitoring.

16.5.4 HPO Reactor Mixers

Upgrades proposed in the HPO Reactors include replacement of existing surface aerators in stages 2-4 and the use of submerged mixers in stage 1 (anoxic zone). Dissolved oxygen monitoring and control is required to control the speed of the submerged mixers and surface aerators. This would also include monitoring of run status and alarms as well as the ability to start and stop mixers, individually.

16.5.5 Biological Nutrient Removal (BNR)

Modifications to the BNR process will provide the most benefit when the control is automated to account for changes in flow patterns, weather conditions and water makeup. Use of process analyzers, air flow meters and motor operated valves with remote control can provide the data and adjustability for automated control of the process. Data collected by the SCADA system can be analyzed over varying process conditions and used to optimize the process operation. Depending on the project design decisions made for process equipment and operation, control system improvements and modifications can be accommodated using the existing control panels and PLC equipment, expanded to incorporate new equipment.

16.5.6 Final Settling Tanks

Expansion of the South Final Settling Tanks is proposed to reduce the surface overflow rate under wet weather flows. The settling tank equipment maintains continuous operation once placed in service and the ability to initiate or remove from operation will be provided through the plant SCADA system. Status and alarm information will also be provided for monitoring purposes. New RAS pumping with variable speed control and flow monitoring will be provided for automated control of the return, based on the number of settling tanks in operation and the plant influent flow rate. Status and alarm information will be provided to the SCADA system for monitoring purposes while manual and automated control parameters will be accessible to operators.

16.5.7 Sidestream Treatment

Treatment of the sidestream process will utilize vendor provided equipment and control panels for operation. The panels will be connected to the plant SCADA network for monitoring from the Process Control Building. Status and alarm information will be provided for monitoring purposes while some parameters for automated operation will be accessible for adjustment. Balance of treatment operation equipment such as instrumentation, pumping equipment or motor operated valves for enabling and disabling the process will be connected to existing plant control panels, expanded to meet the new requirement. Status and alarm information will be provided to the plant SCADA system along with manual and automatic adjustable controls.

16.5.8 Denitrification Filters

Modifications recommended for the Denitrification Filters include replacement and upgrades to existing process equipment, including valve and gate actuators, flow meters and blowers. Future changes will also include the eventual addition of two new filters. Operational changes recommended include adjusting air/water wash times, the frequency of nitrogen release cycles

and the frequency of backwashes. These operational changes can be programmed into the filter controls.

16.5.9 Sludge Digestion and Dewatering

With the changes recommended for the digesters and dewatering system, it is more expedient to replace the controls for the existing systems with new area controls for monitoring and operation of these systems. Dewatering units will include individual local control panels, connected to the plant SCADA network for integrated local control and additional monitoring from the plant SCADA system. A local SCADA computer node will provide the ability to operate the unit controls in automatic mode as well as provide full process monitoring capability.

Local digester control panels will provide a connection point for instrumentation and equipment controls to the SCADA system for remote monitoring. Motor operated valves and remote pump controls as well as boiler and heat exchanger operations will be available locally and also provide the capability to maintain digester operations remotely. The local control panels will be connected to the plant SCADA network for remote monitoring and to provide a more complete view of system operation.

16.5.10 Septage Receiving

Implementation of a new Septage Receiving Station will include a local control system that will allow and process discharges of waste along with a security system overlay. While the system will be self-contained, a communications link to the plant SCADA system will be needed to monitor the station, collect data for billing purposes and support security camera monitoring for unauthorized dumping or vandalism. The SCADA network fiber optic cable will be extended to the station, along with the installation of the discharge pipeline. The plant SCADA system will monitor the equipment operation and alarm status as well as the waste discharge flow.

16.6 Recommendations

The City has begun the process of upgrading and testing the remote site SCADA system VTScada software. As the City gains confidence in the performance of the software, it is recommended to migrate away from the HSQ software and Open VMS operating system in favor of VTScada software and Microsoft Windows operating system for in-plant systems.

The plant control system includes an installation of GE PLCs for control of plant processes. While many of these PLCs are at active technology level, some are still at the mature or discontinued level. It is recommended the City move forward with replacement of remaining discontinued level devices and implement planning for replacement of mature level devices as a priority program.

Documentation and drawings for plant control panels, network configurations, fiber optic cable routing and application software have not been maintained to reflect system modifications and upgrades performed over time. It is recommended the City implement a program to verify and update documentation to have it reflect current conditions and maintain the documentation into the future.

SCADA system disaster event recovery should be planned for in advance with procedures, documentation and software backups. It is recommended the City implement and test a system of

disaster recovery procedures for the SCADA system including individual servers, computers, programmable controllers and managed network devices.

The City is considering the use of industrial tablets for use in plant operations. The intent is to utilize cellular communications for connection to City networks, which has some concerns for security and connectivity. The City has also installed limited Wi-Fi connectivity in the plant for network extensions, which have similar concerns. It is recommended that the City perform a comprehensive evaluation of both cellular and Wi-Fi technology for use with industrial tablets and other devices for SCADA system operation and other networking needs.

The plant SCADA system network is implemented as a tiered modified star configuration. Review of the existing fiber optic cable routing indicates implementation of plant wide or sectional fault tolerant fiber optic rings would not provide improved reliability without a complete reconstruction of the network paths and replacement of most network hardware. The most effective and cost effective method to improve and maintain network reliability is to standardize on industrial network components and develop availability of shelf and vendor spares to support plant operations.

The plant SCADA system communicates using fiber optic cable with some segments as old as twenty-five years. To ensure the cable is still performing to original manufacturer specifications and within calculated fiber optic link budgets, the City should implement a program for fiber optic cable testing as a baseline and with the intent to replace cable that does not perform within specification.

Improvements to existing or new process specific instrumentation, control panel modifications and/or additions and software updates for monitoring and control shall be included as part of the considerations in each CIP project.

Attachment 16-A: PLC Hardware Inventory and Lifecycle Status

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Appendix 16-A
PLC Hardware Inventory and Lifecycle Status

ITEM	LOCATION/PROCESS BUILDING	PLC/RIO TAG	MANUFACTURER & MODEL	LIFE CYCLE STATUS	COMMENTS
1	Mixed Sludge Bldg. 31	PLC 1	GE PACSystems RX3i	ACTIVE	
2	Generator Bldg. 80	PLC 2	GE PACSystems RX3i	ACTIVE	
3	Generator Bldg. 80	PLC 17	GE PACSystems RX3i	ACTIVE	With Remote Rack
4	Generator Bldg. 80	PLC 17 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
5	Digester Control Area C Bldg. 74	PLC 3	GE PACSystems RX3i	ACTIVE	
6	Bldg. 41	PLC 5	GE PACSystems RX3i	ACTIVE	With Remote Rack
7	Bldg. 41	PLC 5 RIO	GE 90-30	Mature Date:10/1/2015	
8	Junction Chamber #1 Bldg. 2	PLC 7	GE PACSystems RX3i	ACTIVE	Serial comms to Maple OIT mounted in door; HMI5056N
9	Filter Bldg. 2	PLC 44	GE 90-30	Mature Date:10/1/2015	Wireless I/O to Compressors
10	Filter Bldg.15	PLC 36	GE 90-30	Mature Date:10/1/2015	For Filter Building 2 process
11	Filter Bldg.15	PLC 5:1	GE 90-70	Processor End of Life, Discontinued Date:3/31/2011	For Filter Building 2 process. Inside same enclosure & Redundant to 5:33
12	Filter Bldg.15	PLC 5:1 RIO	GE Genius	Mature Date:1/1/2011 (May be discontinued)	Genius RIO located inside PLC 5:1 enclosure.
13	Filter Bldg.15	PLC 5:33	GE 90-70	Processor End of Life, Discontinued Date:3/31/2011	For Filter Building 2 process. Out of Service. Inside same enclosure & Redundant to 5:1
14	Filter Bldg.15	PLC 5:33 RIO	GE Genius	Mature Date:1/1/2011 (May be discontinued)	Genius RIO located inside PLC 5:33 enclosure.
15	Filter Bldg.15	PLC 49	GE PACSystems RX3i	ACTIVE	For Filter Building 1 process
16	Filter Bldg.15	PLC 5:2	GE PACSystems RX3i	ACTIVE	For Filter Building 1 process. Genius I/O Rack in front of cabinet. Redundant to 5:34
17	Filter Bldg.15	PLC 5:34	GE PACSystems RX3i	ACTIVE	For Filter Building 1 process. Genius I/O Rack in front of cabinet. Redundant to 5:2
18	Filter Bldg.15	PLC 18	GE PACSystems RX3i	ACTIVE	Remote rack next to panel. Another remote rack in SO2 building
19	Filter Bldg.15	PLC 18 RIO-1	GE 90-30	Mature Date:10/1/2015	
20	SO2 Bldg.	PLC 18 RIO-2	GE 90-30	Mature Date:10/1/2015	
21	Sludge Heat Drying Bldg. 35	PLC 5:3	GE 90-70	Processor End of Life, Discontinued Date:3/31/2011	Out of Service. Remote racks on other side of wall. Redundant to 5:35
22	Sludge Heat Drying Bldg. 35	PLC 5:35	GE 90-70	Processor End of Life, Discontinued Date:3/31/2011	Out of Service. Remote racks on other side of wall. Redundant to 5:3

ITEM	LOCATION/PROCESS BUILDING	PLC/RIO TAG	MANUFACTURER & MODEL	LIFE CYCLE STATUS	COMMENTS
23	Sludge Heat Drying Bldg. 35	PLC 34	GE 90-30	Mature Date:10/1/2015	With Remote Rack
24	Raw Sludge Station Bldg. 83	PLC 6	GE PACSystems RX3i	ACTIVE	Serial comms to Maple OIT mounted in door; HMI507OTH
25	Sludge Control Bldg. 54	PLC 8	GE PACSystems RX3i	ACTIVE	With Remote Rack
26	Sludge Control Bldg. 54	PLC 8 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
27	Sludge Treatment Bldg. 30	PLC 9	GE PACSystems RX3i	ACTIVE	Serial comms to Maple OIT mounted in door; HMI507OTH
28	Intermediate Pump Station	PLC 10	GE PACSystems RX3i	ACTIVE	Out of Service
29	Return Sludge Bldg. #4	PLC 41	GE PACSystems RX3i	ACTIVE	Return Sludge Building 4
30	Return Sludge Bldg. 4	PLC 41 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
31	Return Sludge PS #1 Bldg. 21	PLC 11	GE PACSystems RX3i	ACTIVE	Remote Rack Downstairs
32	Return Sludge PS #1 Bldg. 21	PLC 11 RIO	GE 90-30	Mature Date:10/1/2015	
33	Return Sludge PS #2 Bldg. 23	PLC 12	GE PACSystems RX3i	ACTIVE	Remote Rack Downstairs
34	Return Sludge PS #2 Bldg. 23	PLC 12 RIO	GE 90-30	Mature Date:10/1/2015	
35	Return Sludge PS #3 Bldg. 24	PLC 13	GE PACSystems RX3i	ACTIVE	Remote Rack Downstairs
36	Return Sludge PS #3 Bldg. 24	PLC 13 RIO	GE 90-30	Mature Date:10/1/2015	
37	DAF Thickening Bldg. 70	PLC 14	GE PACSystems RX3i	ACTIVE	Not in Service
38	Dewatering Bldg. 32	PLC 15	GE PACSystems RX3i	ACTIVE	Remote rack in other enclosure
39	Dewatering Bldg. 32	PLC 15 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
40	Dewatering Bldg. 32	PLC 15 RIO	GE 90-30	Mature Date:10/1/2015	Remote rack in other enclosure
41	Digester Control Areas A&B Bldg. 28	PLC 16	GE PACSystems RX3i	ACTIVE	With Remote Rack
42	Digester Control Areas A&B Bldg. 28	PLC 16 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
43	Bldg. 10	PLC 19	GE PACSystems RX3i	ACTIVE	Processing
44	Bldg. 10	PLC 19 RIOs	GE 90-30 (Typ. of 2)	Mature Date:10/1/2015	Both located inside same enclosure as PACSystems RX3i.

ITEM	LOCATION/PROCESS BUILDING	PLC/RIO TAG	MANUFACTURER & MODEL	LIFE CYCLE STATUS	COMMENTS
45	Bldg. 10	PLC 19 RIO-1	GE 90-30	Mature Date:10/1/2015	
46	Bldg. 10	PLC 19 RIO-2	GE 90-30	Mature Date:10/1/2015	
47	Bldg. 10	PLC 43	GE 90-30	Mature Date:10/1/2015	Remote Rack behind Control Panel
48	Methanol Station	PLC 35	NA		Not installed yet. Identified as for Methanol station on HMI screen
49	Screen & Grit #1 Bldg. 5	PLC 4	GE PACSystems RX3i	ACTIVE	Has remote rack on door for test
50	Screen & Grit Bldg. 59	PLC 37	GE PACSystems RX3i	ACTIVE	Remote Rack
51	Screen & Grit Bldg. 59	PLC 37 RIO	GE 90-30	Mature Date:10/1/2015	Located inside same enclosure as PACSysystems RX3i
52	Belt Thickener Bldg.	PLC 38	GE PACSystems RX3i	ACTIVE	
53	Bldg. 78	PLC 39	GE PACSystems RX3i	ACTIVE	
54	Polymer Bldg. 30	PLC 33	GE PACSystems RX3i	ACTIVE	Poly PLC
55	DAR Bldg. 25	PLC 40	GE PACSystems RX3i	ACTIVE	Modbus serial to Alkalinity PLC. Serial comms to Maple OIT mounted in door; HMI507OTH
56	DAR Bldg. 25	PLC 40 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
57	DAR Bldg. 25	Alkalinity PLC	GE PACSystems RX3i	ACTIVE	
58	DAR Bldg. 25	Chemscan PLC	Automation Direct		Communicates to Chemscan. Analog signals split between this PLC and Alkalinity PLC
59	Mixed Sludge Bldg. 63	PLC 42	GE PACSystems RX3i	ACTIVE	
60	Mixed Sludge Bldg. No. 63	PLC 42 RIO	GE 90-30	Mature Date:10/1/2015	Located Inside same enclosure as PACSystems RX3i
61	Maintenance Bldg. 40	PLC 99	GE PACSystems RX3i	ACTIVE	Monitors A/C System
62	Administration Bldg.	ADM	GE PACSystems RX3i	ACTIVE	Monitors AC in Admin Bldg
63	Bldg. 10	Large cabinet	Motorolla		Upgrading this year to ACE

Technical Memorandum 17.0 Regionalization Evaluation

17.1 Purpose and Background

Regionalization consists of aggregating resources between municipalities/utilities to serve a mutual interest by optimizing systems to be more efficient, economically beneficial, and better serving to its customers. As part of the master planning effort, regionalization of select equipment and systems were evaluated to determine if there is a feasible and beneficial regionalization opportunity for the City and surrounding municipalities and industries. The following categories were evaluated for regionalization:

1. Equipment acquisition from other municipalities;
2. Receiving/transmitting raw wastewater from/to other municipal or industrial sources;
3. Receiving/transmitting septage;
4. Receiving/transmitting fats, oils, and greases (FOG); and
5. Receiving/transmitting sludge/biosolids.

Each one of the categories for regionalization impact a specific plant process discussed in the Phase 1 Technical Memorandum of Findings (**Appendix A**) and the previous technical memoranda of this document. Within these technical memoranda, alternatives are presented for rehabilitating and/or modifying each plant process evaluated. In cases where regionalization impacts a unit process's capacity and level of treatment required, further consideration needs to be made to the alternatives presented in the technical memorandum with respect to additional equipment, tankage, and associated costs. Furthermore, there is potential for regionalization to create revenue through disposal and treatment fees that will offset a portion of the capital and operation and maintenance costs required.

17.2 Equipment Acquisition

Based on recommendations of the Phase 1 report for equipment rehabilitation and/or replacement, there are limited opportunities for major equipment acquisition from other municipalities. Most of the equipment recommended for replacement or refurbishment is not practical for a regionalization approach due to its size and relatively low costs. However, Hillsborough County's Northwest Regional Water Reclamation Facility (NWWRF) is currently undergoing an expansion and plans to demolish its biosolids dryer facility including two lightly used rotary drum dryers. The dryers at the NWWRF, shown in **Figure 17.2-1**, are Andritz DD50 units, which are rated for approximately 5,500 kilograms (kg) (12,100 lbs) of evaporation of water per hour each. These units could meet the biosolids processing needs of the City based on the dryers' operational schedule.

Figure 17.2-1: Existing 2 (Two) Andritz DD50 Rotary Drum Dryers at Hillsborough County's NWWRF

Table 17.2-1 presents the operating schedule of either one or two Andritz DD50 dryers operating continuously to process HFC AWTP's average biosolids production.

Table 17.2-1: Dryer Operation Summary[1]

Processing Capacity (DTPD)	%TS Pellet	No. of Units Operating	Hours Per Day	Days per week
29.5	90	1	24	7
		2	24	3.6

[1]Operation summary of (2) Andritz DD50 rotary drum dryers processing HFC AWTP biosolids

From a physical-fit perspective, the dryer equipment at HFC AWTP has a larger footprint (approximately 120-feet x 92-feet) than the dryer equipment at NWWRF (approximately 90-feet x 82-feet); however, the height of the equipment at NWWRF is approximately 11-feet higher than that at HFC AWTP. The added height of the dryer equipment at NWWRF is due to locating the exhaust separation cyclone and recycle bin high to minimize conveyance equipment to the following processes. To reduce the height of the equipment to fit within the HFC AWTP dryer building, the cyclone and recycle bin would be lowered and additional conveyance equipment required. From a preliminary evaluation and discussion with the manufacturer, it is feasible the NWWRF dryer system would fit within the HFC AWTP dryer building.

A planning level cost estimate was performed for the removal, relocation, and installation of these dryers at HFC AWTP. The planning level cost for this work is approximately $18M. A more detailed breakdown of the costs are presented in **Attachment 17-A**. This cost estimate is magnitude of scale for

evaluation purposes only. Actual costs to procure the dryer from Hillsborough County and a more detailed assessment of the actual improvements required at HFC AWTP for retrofitting would have to be performed to refine the costs. While this initial cost is approximately $9M higher than the projected costs of refurbishing the existing dryer system, it would provide the City the benefit of having a relatively unused dryer system with updated control systems, hot air recycle, and likely a longer service life. Costs for refurbishing the existing drying system from the 2012 Biosolids Processing Assessment Report are presented in **Attachment 17-B**.

17.3 Raw Wastewater

The HFC AWTP has available capacity with respect to base flows; however, hydraulic capacity is diminished by infiltration and inflow. The availability of additional base flow allows for near-term potential for regionalization of accepting additional raw wastewater without major capital improvements to the plant. Hydraulic bottleneck improvements may need to be addressed as recommended in Phase 1, as well as collection and transmission system improvements depending on the magnitude of additional flows introduced. Growth within City limits is expected to continue mainly in the northern residential and commercial areas of New Tampa, Tampa Palms, and Hunter's Green shown in **Figure 17.3-1.** Growth outside of City limits, but within the existing wastewater service area boundary, is limited either due to these areas already at or approaching build-out or areas that are excluded from development including parks, wetlands, nature preserves. It is improbable that these areas will be developed in the foreseeable future.

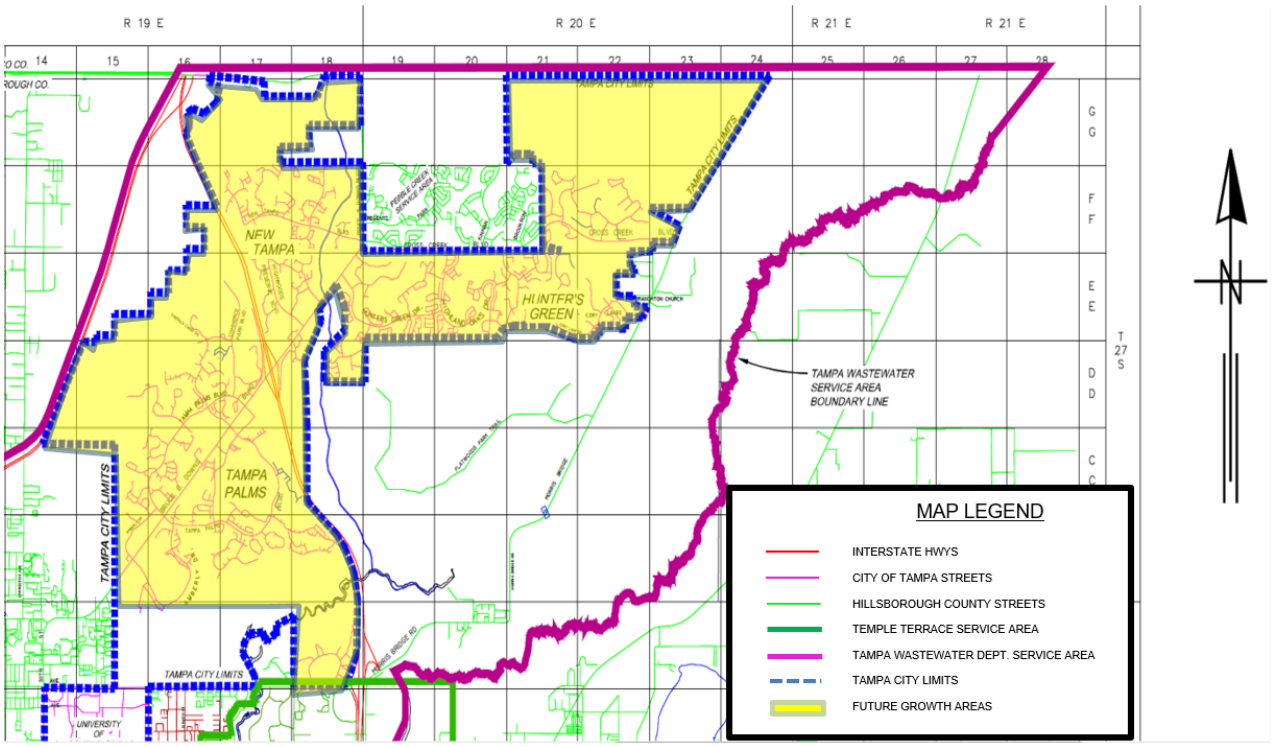

Figure 17.3-1: Expected Growth Areas (Northern Wastewater Service Area)

The City's current wastewater service extends beyond the City of Tampa corporate limits show in **Attachement 17-C**; indicating that the City has already undergone significant regionalization with its wastewater utility mainly by accepting wastewater flows from Temple Terrace through a bulk service

agreement and interconnections to the City's collection system. Temple Terrace is still experiencing growth at a forecasted rate of approximately 370 people per year. Applying a wastewater flow rate of 110 gallons/person/day, there will be a potential need to increase flows from Temple Terrace to the City's system at a rate of 40,700 gallons per day per year.

Other wastewater utilities that are directly adjacent to the HFC AWTP wastewater service area are owned by Hillsborough and Pasco Counties. The City's wastewater service area currently extends outside the City boundary into Hillsborough County west of US Highway 301 and north of Madison Avenue. The City has an agreement with Hillsborough County to use an interconnection located at Falkenburg Road and Adamo Drive to accept up to 2.48 MGD. Currently, the County is not utilizing the connection; however, this connection can be used and potentially increased with appropriate improvements made downstream of the connection. Additionally, there has been recent discussions with Hillsborough County to potentially accept additional flows through the Brandon Meter in the next few years. Hillsborough County has recently expanded its South County Regional AWTF and is currently undergoing regionalization within the northwestern portions of the County with the Northwest Hillsborough Wastewater Consolidation Program. Hillsborough County is expecting continual high growth rates both in the northwestern and southern portions of the County. Hillsborough County growth areas are in closer proximity to the City's wastewater service area, creating the potential for flow diversion to be more economically feasible than other wastewater utilities that would require extensive wastewater pumping and transmission to get raw wastewater to the City's collection system. Main areas adjacent to the City's service area boundary include a portion of Hillsborough County west of I-75 and north of the Alafia River. These areas are serviced by the Falkenburg AWTF. Being directly adjacent to the City's wastewater collection system would likely reduce the capital costs required for raw wastewater transmission and potential improvements to increase collection system capacity. Hillsborough County is also seeing major growth along the I-75 corridor south of the Alafia River. These areas are serviced by the South County Regional AWTF, which was recently expanded. There is potential to divert flow north from this area, but it would require significant infrastructure for transmission to the north side of the Alafia River and through several miles of Hillsborough County's service area before entering the City's collection system. Additional flows from the southern portion of Hillsborough County are seen as less feasible due to the likely increased infrastructure required for transmission.

Adjacent to the northern boundary of the City of Tampa's wastewater service area is Pasco County, specifically the Wesley Chapel area. This area continues to see high growth rates and the County is in the early planning phases of additional wastewater treatment expansion in this area. Due to the distance to HFC AWTP, accepting a significant portion of the Pasco County's wastewater service area is not likely to be cost effective and favorable due to the long distances for transmission and potential need for collection and pumping capacity to get additional wastewater flows south to HFC AWTP.

17.4 Septage

Septage is a waste usually produced from rural homes and deposited into a septic tank. This waste is typically removed by and received at the HFC AWTP in small tanker trucks. As indicated in the Phase 1 report, because of recent FDEP regulations, septage land application will be significantly reduced in the near future, resulting in additional septage haulers to turn to other locations for disposal including wastewater treatment facilities. Septage, although low in volume compared to influent flows, is typically a high strength waste. Limitations on additional septage flows able to be accepted will need to be evaluated and balanced with biological process capacity. Currently, the HFC AWTP is receiving

approximately 6,000 gallons of septage a day. The septage is received at the Sewage Receiving Station adjacent to the Raw Sewage Pump Station. Although not currently an issue at the HFC AWTP, septage, depending on the source, can be laden with trash, debris, rocks, etc. Septage treatment including a rock trap to provide heavy, large debris settling and a material screening and grinding, similar to what is described in Technical Memoranda 5.0 and 13.0 for pretreatment, may be warranted in the future with increasing septage quantities and septage received from new haulers and/or sources. Revenue from increases in septage disposal quantities could offset a portion of the capital and operation and maintenance expenditures for increased septage treatment. The City currently accepts septage at a rate of $0.067 per gallon. **Table 17.4-1** lists disposal rates for septage from various regional utilities that would potentially be in competition with the City for the business of these septage haulers.

Table 17.4-1: Septage Disposal Rates by Nearby Municipalities and Haulers

Municipality or Hauler	Septage Disposal Rate
Pinellas County- South Cross Bayou	$0.035/ gallon
Pasco County	$0.082/ gallon
Hernando County	$0.058/ gallon

17.5 Fats, Oils, and Grease

An evaluation of the City receiving and processing fats, oils and grease (FOG) for co-digestion has been previously presented in the HSW Technical Memorandum 13. As discussed, the HFC AWTP has the capacity to accept approximately 10,000 gpd of thickened FOG for use in co-digestion. FCS Inc.'s Grease Depot, a local FOG collection business, has expressed interest in potentially directing up to 10,000 gpd to HFC AWTP. Additionally, up to 4,000 gpd currently disposed by Tampa Fisheries into the HFC AWTP, could also be diverted directly to the digesters. **Table 17.5-1** lists disposal rates for FOG from various utilities and haulers and provide an idea of the potential rate the City could receive for additional FOG disposal at HFC AWTP. Using disposal rates of $0.012/gallon (lower rate charged by Pinellas County) and $0.082/gallon (higher rate charge by Pasco County), the City could potentially receive a range of $44,000 to $299,300 in disposal revenue annually.

Table 17.5-1: FOG Disposal Rates by Nearby Municipalities and Haulers

Municipality or Hauler	FOG Disposal Rates
Pinellas County- South Cross Bayou	$0.012/ gallon
Pasco County	$0.082/ gallon
Nuckles Septic Tank Services	$0.080/ gallon

17.6 Sludge and Biosolids

Dewatered, anaerobically digested Class B biosolids produced at the HFC AWTP are currently hauled off for land application. When the thermal dryers are in operation, the biosolids are further processed to a Class AA quality dried pellet which are sold. Because of more strict regulations for land application of biosolids and the diminishing capacity at landfills, there is a significant potential for the City to accept additional biosolids for processing. The HFC AWTP has the advantage of being able to produce multiple biosolids end-products. Should land application or landfilling of Class B biosolids continue to become

increasingly difficult and expensive due to land application site restrictions and diminishing landfill capacity, the City can rehabilitate and recommission the thermal dryers to create a product of significantly less volume than dewatered biosolids and can create revenue from disposal.

With the anaerobic digestion system and dewatering system rehabilitated to process the rated future biosolids production, the City would have approximately 250,000 gallons per day of excess liquid sludge capacity pre-digestion. Since most municipalities typically dewater sludge to minimize volume and the number of truckloads for economic reasons, this amount of liquid sludge is likely not feasible for receiving at the HFC AWTP. Municipalities who do have liquid sludge hauled either have very small volumes (e.g., small package plants) or typically do so temporarily if their solids processing system is out of service for repairs, maintenance, or construction. Regardless, liquid sludge receiving is feasible and the City would receive additional revenue through disposal fees and benefit from increased biogas production. Sludge could also be received by the City in the form of dewatered cake. Since the HFC AWTP's current sludge production could be handled with one dryer train, the other dryer train could be utilized to dry up to 29.5 dry tons per day (184 wet tons per day or approximately 15 dump truck loads) of additional dewatered sludge. This option requires the dryers to be rehabilitated. Additionally, receiving and handling of dewatered sludge cake for dryer feed would likely require additional storage and conveyance equipment.

The biosolids treatment option the City chooses for future operations will result in various regionalization options for sludge and biosolids. As discussed in Technical Memorandum 11.0, the existing anaerobic digesters, CHP engines, and thermal dryer all require capital expenditures for rehabilitation and replacement. Should the City consider accepting additional sludge and/or biosolids from outside sources/municipalities, an assessment would need to be performed on what additional tankage, equipment, and labor is required to handle and process the additional sludge quantities. **Table 17.6-1** lists disposal rates for sludge from various utilities and are potential rates the City could receive.

Table 17.6-1: Sludge Disposal Rates for Nearby Municipalities

Municipality	Sludge Disposal Rates
Pasco County	$0.134/ gallon
Hernando County	$0.060/ gallon

17.7 Conclusions and Recommendations

The potential to acquire a relatively new direct dryer system that has adequate processing capacity may suit the City's need in lieu of rehabilitating the existing system. As with any retrofit, a detailed assessment of compatibility, ancillary equipment needs, and limits of demolition/replacement will need to be further evaluated. Additionally, contractual and warranty terms should be considered. It is important to note that the NWWRF dryer facility is currently under contract to be disassembled and removed from the facility. It is recommended that the City enter discussions with Hillsborough County and/or their Contractor in the immediate future if there is an interest in this option.

For raw wastewater, the City has already undergone some regionalization as its wastewater service area extends beyond the corporate limits of the City to Temple Terrace and Hillsborough County. The wastewater service area is nearly built out and adjacent counties and municipalities have already began to expand their collection and treatment systems in response to current needs and to meet estimated

future growth. Increases in raw wastewater flow from outside City limits is seen to be limited to existing or new interconnections with Temple Terrace and Hillsborough County because of economic feasibility through minimizing infrastructure improvements for raw wastewater transmission and conveyance. Additional wastewater flow from Temple Terrace, based on anticipated growth, is a small percentage increase to the City's influent flow rate. As the annual increase in wastewater flow from Temple Terrace is minimal, major infrastructure improvements are not likely required; however, should be periodically evaluated as flows increase with growth. Increase in wastewater flow from Hillsborough County is likely to be on a larger magnitude than that of Temple Terrace. It is recommended that the City evaluate infrastructure improvements necessary to convey and treat additional flows and set limitations on flow rates from Hillsborough County accordingly.

An opportunity to treat additional septage and FOG from regional haulers for treatment exists. Because of the expected more stringent requirements for the disposal of septage in the future, there will likely be an increased demand for disposal sites that can accept this waste. The City is in a unique position to supply a needed regional service and benefit and has the potential for increased revenue from disposal fees. FOG appears to be the most advantageous, as the City can not only obtain additional revenue through disposal fees, but also increase methane production which can be used on-site by unit processes or be converted to electricity by using the City's CHP system. However, a HSW receiving facility will be needed for this option, and as presented in Technical Memorandum 13.0, the benefit of the additional biogas produced does not offset the cost to construct, operate, and maintain a FOG receiving facility and is therefore, not recommended.

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Attachment 17-A:
Conceptual Level Cost Estimate Dryer Relocation and Installation

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Conceptual Level Capital Cost Estimates

Dryer Relocation and Installation Costs

Item	Units	Quantity	Materials	Labor (50%)	Construction Cost	Comments
(2) Andritz DD50 Dryer Systems, Odor Control, Silos	LS	1	$ 5,000,000	$ 2,500,000	$ 7,500,000	This cost estimate is magnitude of scale for evaluation purposes only. Actual costs to procure dryer from Hillsborough County and a more detailed assessment of the actual improvements required at HFC AWTP for retrofitting would have to be performed to refine costs. Materials cost for Dryer is a conceptual-level estimate for diassembling the dryer in a manner that is appropriate from reassembly (not demo), and delivery to HFC AWTP. Assosciated Dryer labor includes offloading and reassembly at HFC AWTP.
Misc. Equipment, Parts, Piping, Hardware, etc.	LS	1	$ 1,500,000	$ 750,000	$ 2,250,000	
Electrical Misc.	LS	1	$ 500,000	$ 250,000	$ 750,000	

Subtotal Estimate Cost	$ 10,500,000
Contingency (50%)	$ 5,250,000
Total Construction Cost	**$ 15,750,000**
Engineering (15%)	$ 2,362,500
Total Project Cost	**$ 18,112,500**

Attachment 17-B:
Cost Estimate for Refurbishing the Existing Dryer System

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placed. Depending on the usage of the repaired heat drying system, it is anticipated that the remaining useful life will be less than 10 years.

Table 5.6
Baseline Project – Drying System
Estimated Costs for Repairing Individual Components of the Heat Drying System

Component	Repairs Needed	Opinion of Costs
Dryer Train 2 Components		
Wet Sludge Storage Bins	Replace one influent belt conveyor with a screwconveyor Redesign and replace stairway	$150,000
Pugmill Mixers	Replace mixer for Train 2	$280,000
Drum Dryers	Repair Train 2 burner's internal wear and refractory work	$100,000
Settling Chambers	Replace Train 2's ceramic tile and screw	$100,000
Cyclones	Replace cyclones and exhaust piping for Train 2	$200,000
Vibrating Screens	Replace Train 2's K conveyor and screen	$300,000
Crushers	Train 2 – Add automatic lubrication capability	$10,000
Recycle Bins	Replace bin for Train 2 Repair inlet and outlet conveyor for Train 2 and replace liner	$200,000
Venturi Scrubbers	Replace Train 2's ID fan base and balance fan	$20,000
Total		**$1,360,000**
Elements Common to Both Trains		
Afterburners	Replace dampers with slide gate valves Replace exhaust fans	$100,000
Product Storage Silos (three of six silos)	Install inert interior liner Replace tops and inlet chutes Install temperature probes to detect hot spots Install carbon monoxide analyzers to detect combustion Install rubberized rotary valves and aspirators on discharges	$1,000,000
Odor Control System	Repair bleach system and spray nozzles Repair fan	$50,000
Dust Control System	Perform dust control system maintenance	$20,000
Truck Loading Conveyors	Replace liner for Conveyor SHD-TLSC-1A Repair electrical issues for Conveyor SHD-TLSC-1B	$50,000
Pellet Cooling System	Control system needs maintenance	$20,000
Building	Replace siding on building with vinyl siding	$50,000
Electrical	Replace corroded motors, actuators, and instruments	$50,000
Overhead & Profit	Approximately 20% of total cost	$540,000

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Table 5.6
Baseline Project – Drying System
Estimated Costs for Repairing Individual Components of the Heat Drying System

Component	Repairs Needed	Opinion of Costs
Mgmt. & Engineering	Approximately 30% of total cost plus O&P	$972,000
Total		**$2,852,000**

5.3.2 Additional Dryer System Improvements

Beyond the baseline dryer system improvements described above, there were some additional improvements identified that required evaluation. These include:

1. Conversion of the dryer train(s) to include an exhaust recycle system

2. Decision to repair Train 3, install a new dryer train in place of Train 3, or limit the dryer system improvements to repair of Train 2 only (base line)

3. System to deliver dewatered cake to the dryer train(s) in coordination with improvements made to the dewatering system

Each of these additional improvements are presented herein below with a life cycle cost analysis to estimate the possible savings and capital investment return if implemented. The evaluations of these additional improvements are not inter-dependent and any or all three of the improvements can be made without altering the conclusions given for each evaluation.

5.3.2.1 Conversion to an Exhaust Recycle System

The benefits and description of modifying the existing dryer trains to incorporate an exhaust recycle system are described in Section 4.1. The capital costs to convert an existing dryer train to include an exhaust recycle system are presented in Table 5.7, along with the potential yearly savings that could be expected from making such a conversion.

Table 5.7
Estimated Dryer Exhaust Recycle Costs

Capital Costs[1]	$750,000
Yearly Operational Savings[2]	up to $480,000 (if all cake is dried)

[1] *Assumes RTO system remains as is operating at lower capacity*

[2] *Assumes a $42/DT savings (approximately 20 percent of thermal energy costs) on drying cost for plant biosolids production (up to 11,500 DT/year of dewatered biosolids) with current dewatering to 17 percent*

41077-001R1

is that the system can be designed with equipment spacing that allows for more conventional conveyor slopes and greater access to equipment for maintenance and repair.

The estimated cost of to repair existing Train 3 is presented in Table 5.9 and also includes refurbishment of the dryer train to include an exhaust recycle stream in order to compare the costs to a comparable new dryer train.

Table 5.9
Estimated Costs for Repairing Individual Components Train 3 Dryer

Component	Repairs Needed	Opinion of Costs
Wet Sludge Storage Bins	Replace influent belt conveyor with a screw conveyor Redesign and replace stairway	$150,000
Pugmil Mixers	Replace mixer for Train 3	$280,000
Drum Dryers	Replace Train 3 drum and burner	$400,000
Settling Chambers	Replace covers on Train 3 C conveyor and repair to prevent jamming, replace ceramic tile	$150,000
Exhaust Recycle System	Refurbish Train 3 with exhaust recycle system	$750,000
Vibrating Screens	Replace Train 3 screen	$250,000
Crushers	Rebuild Train 3 unit, replace K conveyor, add automatic lubrication capability	$100,000
Recycle Bins	Replace bins for Train 3 Repair inlet and outlet conveyors Train 3 and replace liner	$400,000
Pellet Cooling System	Control system needs maintenance	$20,000
Electrical	Replace corroded motors, actuators, and instruments	$50,000
Overhead & Profit	Approximately 20% of total cost	$510,000
Mgmt & Engineering	Approximately 30% of total cost plus O&P	$918,000
Total		**$3,978,000**

As the operational cost of either repairing Train 3 or construction of a new dryer train will be insignificantly different, the repair of Train 3 is substantially cheaper than constructing a new dryer train. In the event that the existing co-generation system at the digesters is abandoned and excess methane gas becomes available to fuel the dryers, it would still be far less capital costs required to pipe the methane gas across the plant to the dryers than constructing a dryer system at the digesters. Repair of Train 3 is the most economical approach if a second dryer train is considered necessary in the future.

Attachment 17-C:
City of Tampa Wastewater Department Service Area

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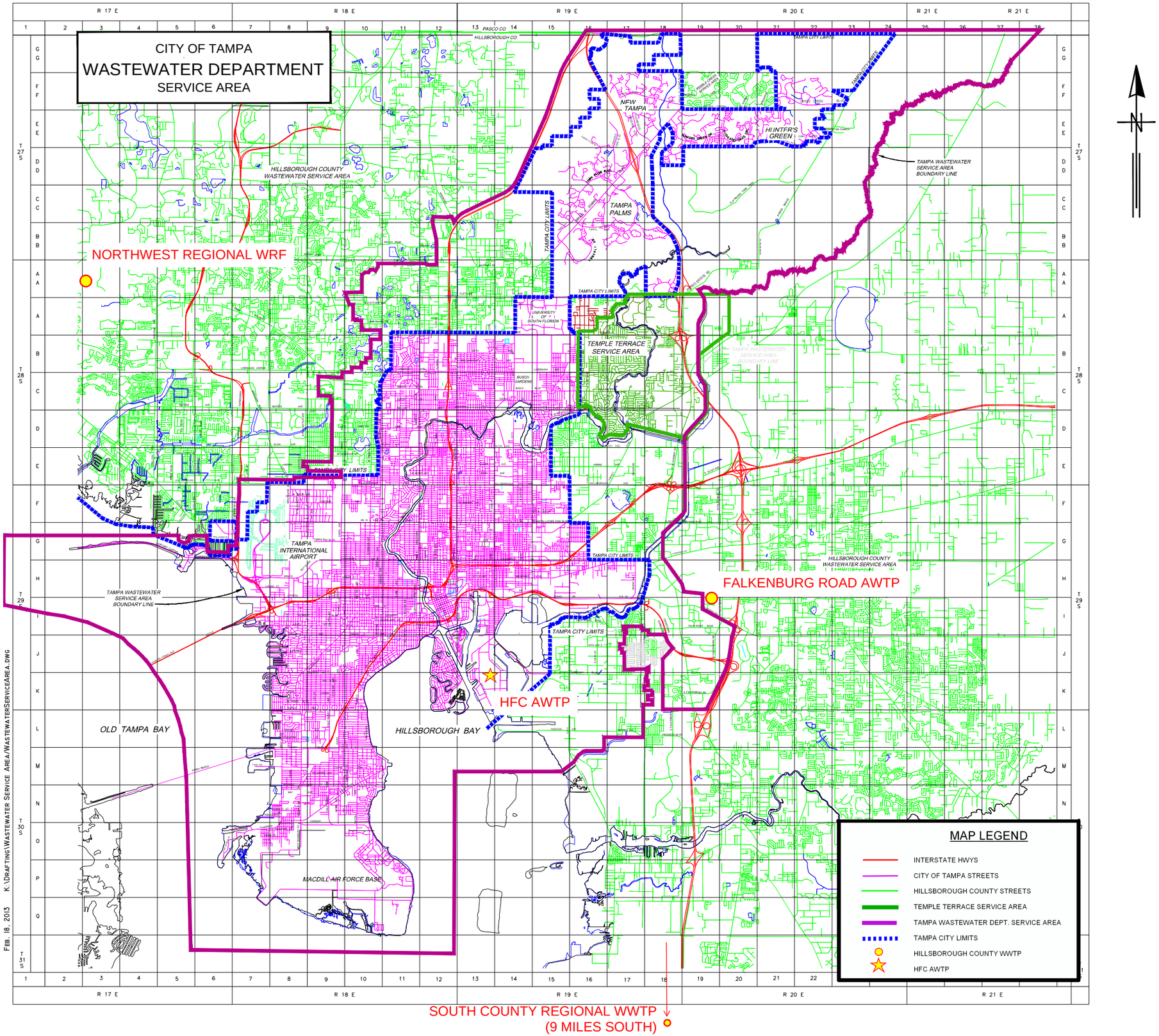
CITY OF TAMPA
WASTEWATER DEPARTMENT
SERVICE AREA
NORTHWEST REGIONAL WRF
FALKENBURG ROAD AWTP
HFC AWTP
SOUTH COUNTY REGIONAL WWTP
(9 MILES SOUTH)
HILLSBOROUGH COUNTY
WASTEWATER SERVICE AREA
TAMPA WASTEWATER
SERVICE AREA
BOUNDARY LINE
TAMPA CITY LIMITS
TEMPLE TERRACE
SERVICE AREA
TAMPA
INTERNATIONAL
AIRPORT
OLD TAMPA BAY
HILLSBOROUGH BAY
MACDILL AIR FORCE BASE
NEW
TAMPA
HUNTER'S
GREEN
TAMPA
PALMS
UNIVERSITY
OF
SOUTH FLORIDA
BUSCH
GARDENS
PASCO CO.
HILLSBOROUGH CO.
R 17 E
R 18 E
R 19 E
R 20 E
R 21 E
T 27 S
T 28 S
T 29 S
T 30 S
T 31 S
MAP LEGEND
INTERSTATE HWYS
CITY OF TAMPA STREETS
HILLSBOROUGH COUNTY STREETS
TEMPLE TERRACE SERVICE AREA
TAMPA WASTEWATER DEPT. SERVICE AREA
TAMPA CITY LIMITS
HILLSBOROUGH COUNTY WWTP
HFC AWTP
FEB. 18, 2013 K:\DRAFTING\WASTEWATER SERVICE AREA/WASTEWATERSERVICEAREA.DWG

Section 18.0 Overall Process Selection and Summary of Recommendations

Evaluations were conducted for each area of the HFC AWTP based on the existing condition assessments in the Phase 1 Technical Memorandum (**Appendix A**). Recommended improvements throughout the facility based on the Phase 2 evaluations are summarized in this section. Additional replacement and rehabilitation projects identified in Phase 1, as well as those identified by the City are listed in Section 19.0 Capital Improvements Plan and Project Costs.

18.1 Preliminary Treatment

Replacement of the diffused aeration system and a new hybrid odor control system, consisting of biotrickling filters followed by chemical scrubbers for polishing, is recommended for Junction Chamber No. 1. Additional supply and exhaust fans are recommended in the Screen & Grit Building No. 2 to improve ventilation and reduce the potential for corrosion in this facility. New grit conditioning systems are recommended to replace existing systems in both screen and grit buildings. New grit removal systems and pump stations are recommended if the new grit conditioning systems do not solve the sugar sand problem to the City's satisfaction. A new sewage receiving station is recommended to be located outside of the security fence along Maritime Boulevard.

18.2 Primary Treatment

Four additional primary sedimentation tanks are recommended and could be located in an open area south of the existing Primary Sedimentation Tank Nos. 5-8. Additional recommended improvements for primary treatment include equipment replacement, the addition of a dewatering pump station for Primary Sedimentation Tank Nos. 1-4, and sludge blanket monitors.

18.3 Biological Nutrient Removal

The results of the secondary process evaluation concluded that optimizing the existing two-stage activated sludge process is preferred over the other process modifications evaluated. Recommended improvements to the North (HPO) reactors include the following:

- Adding anaerobic selectors,
- Larger aerators with variable frequency drives,
- Rehabilitating/replacing Oxygen Generation Plant No. 1,
- Evaluating the option to replacing one cryogenic system (Oxygen Generation Plant No. 1) with an alternative technology, such as a vacuum pressure swing adsorption (VPSA) system.

Recommended improvements to the South (DAR) reactors include the following:

- Optimization of the spike line,
- Modifications in Reactors 2-4 to reflect the MLE configuration similar to the recent Reactor 1 upgrades. These modifications include new anoxic zone mixers, IMLR pumps, new fine bubble diffusers, new blowers, implementation of the ammonia-based aeration control, and four new final sedimentation tanks with corresponding increase in RAS pumping. Note that the recommended

improvements to Reactors 2-4 include disc-type membrane diffusers in lieu of the panel diffusers installed in Reactor 1. The recommended improvements also include separate IMLR piping, nitrate measurement, and flow measurement be installed for each reactor to allow for more flexibility and control of the IMLR flow.

New sidestream treatment is recommended to meet the denitrification filter loading criteria and reduce the number of new filters recommended as the AADF increases towards 80 MGD. A deammonification process is recommended in the eastern portion of the HPO reactors currently not in use with equalization tanks in two existing HPO final settling tank trains.

18.4 Tertiary Treatment

Recommended improvements to the existing denitrification filters include operational changes including nitrogen release cycle and backwash frequency and duration changes, equipment replacement, and new methanol controller. The filters will be hydraulically limited if influent nitrate + nitrite loading exceeds estimated 16,000 lb/day. As annual average flows approach 80 MGD two additional filters are recommended (nine additional filters if sidestream treatment is not added).

18.5 Disinfection

A new sodium hypochlorite and sodium bisulfite disinfection system is recommended to replace the chlorine gas and sulfur dioxide gas system. New center baffle walls in the chlorine contact tanks and relocating the post aerations system is also recommended. New motorized gates and control system in the overflow structure and possible second 96-inch pipe to the overflow structure are recommended.

18.6 Biosolids

Improvements to biosolids thickening include a third WAS gravity thickener train and a more efficient polymer feed system. Recommended improvements to the anaerobic digestors include conversion to an acid-gas phased process with design considerations to facilitate operating in the current conventional mesophilic mode as well. An enhancement to the digestion system is a centralized heating system located in a new boiler Building D. The centralized heating system will be used to heat all digesters and includes new boilers with the ability to use natural gas or digester gas, air separator, expansion tank, primary hot water loop pumps, feed tank, new heat exchangers (located within Control Buildings A, B and C), hot water pipeline to Control Buildings A, B and C, and a new natural gas pipeline connection.

The previously recommended centrifuge dewatering improvements located near the existing dewatering building are included in the Master Plan. These improvements include a new dewatering building to house centrifuges, grinders, feed pumps, conveyors, piping, polymer system, and associated electrical and I&C systems.

18.7 Biogas Utilization

The evaluation of biogas use alternatives concluded that the RNG alternative could produce greater revenue than the CHP alternative under the market conditions at the time of this report. It is important to note that the RNG alternative can have a higher revenue potential, but this potential has a high level of volatility due to the uncertainly on the long-term health of the Renewable Identification Number

(RIN) market. Therefore, it is recommended that the RNG alternative be investigated further with TECO. It is recommended that the following next steps be taken:

- Initiate a detailed utility pipeline assessment with TECO. This will determine if there is a nearby injection point for the plant or if a pipeline extension would be required.
- If the first step is viable, an interconnection capacity study can be initiated to determine if there is capacity in the pipeline for the additional natural gas.

18.8 Standby Power Systems

Recommended improvements to the standby power capacity include the addition of a 2MW generator as soon as possible to provide N+1 reliability for existing loads, plus the addition of 2 MW of future generator capacity to meet future loads while maintaining N+1 reliability. Fuel storage improvements to meet 5 days of fuel storage capacity include the addition of 68,000 gallons of diesel fuel storage capacity, 17,000 gallons of which is for the future 2MW diesel generator, if the City elects to go with diesel. Recommendations also include expansion of day tank capacity and a tank fill station.

18.9 Plant Automation

Recommended improvements to facility instrumentation and controls and SCADA automation include migrating away from the HSQ software and Open VMS operating system in favor of VTScada software and Microsoft Windows operating system for in-plant systems, replace remaining discontinued level PLCs and implement planning for replacement of mature level PLCs as a priority program, evaluate cellular and Wi-Fi technology for use with industrial tablets and other devices for SCADA system operation and other networking needs. Upgrades to specific process area instrumentation and controls should be incorporated in the various projects/project designs identified for each process area.

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Section 19.0 Capital Improvements Plan and Project Costs

19.1 Purpose and Background

As part of the development of the Wastewater Treatment Plant Master Plan, a capital improvements projects (CIP) list was developed. The CIP list includes repair and replacement (R&R) projects identified during the Phase 1 existing equipment inventory and useful life assessment, evaluation of the existing facility, recommended improvements to various process areas identified in the Phase 2 evaluations, as well as projects identified by City staff. The CIP list identifies projects by "Building No.". In addition, there are several plant-wide projects, for example "Plant Roof Repairs".

The CIP list was prepared using an Excel spreadsheet and includes the aforementioned "Building No.", "Project Name", "Project Description", "Fiscal Year", "Estimated Cost", "Total Project Cost" which includes an additional seven percent (7%) of the construction cost to cover the City's costs associated with the administration of contracts, inspection, and other related costs, and "Total Project Cost with Inflation"; the latter added to account for inflation for projects programmed for greater than one year out. A three percent (3%) annual inflation factor was applied, starting in Year 2 for the projects programmed in Year 2 and later.

Working with the City, the projects were prioritized and scheduled over the 20-year planning period. The priority and schedule are based on several factors, including criticality, expected remaining equipment and facility life/condition, plant operations and need to maintain continued plant operation and capacity, ability to meet regulatory requirements, correlation with other impacted process improvements, and the need to distribute costs over the planning period. For the majority of the capital improvement projects listed with an estimated total capital cost over two million dollars, a "design project" is identified in Year N with the associated "construction project" in Year N+1. There is also the potential to group several projects into larger projects, related by either process and/or physical location, should the City elect to do so.

Many listed projects have been discussed in greater detail in the Technical Memorandums and previous sections of this Master Plan. Several of these projects have been expanded in the CIP list to include replacement of ancillary equipment and facility repairs, primarily due to age or remaining useful life. As a result, the project cost estimates presented in the various technical memorandums of the Master Plan may be less than the cost included in the CIP list. For example, Technical Memorandum 7 discusses the recommended improvements to the HPO Reactors and presents an estimated capital cost of approximately $5,460,000 for the construction of these improvements. The CIP list shows a total project cost, without adjusting for inflation, of $11,770,000 for the construction of the HPO Reactor Improvements. The CIP list project includes more than just process modifications. It includes cleaning and lining the reactor influent and effluent channels, replacement of the aeration equipment in these channels, and the bypass pumping required to perform the work in the channels. The HPO Reactor Improvements project on the CIP list also includes replacement of various gates, valves and associated actuators.

19.2 Summary

The CIP list, arranged by fiscal year, is included as **Attachment 19-A**. Year 1 corresponds to the City's FY 2020. Note that there are seven (7) projects listed under Year 0. These projects were included in the FY 2019 budget. The CIP list, arranged by "Building No.", is included as **Attachment 19-B**.

There are a total of 210 projects identified. Again, many of the capital projects have a "design project" in Year N and a "construction project" in Year N+1.

The distribution of the projects by year are shown in **Table 19.2-1**.

Table 19.2-1: Distribution of Capital Improvement Projects

Year	FY	Number of Projects	Total Estimated Project Cost[1]
0	FY 2019	7	$7,543,500
1	FY 2020	18	$21,603,300
2	FY 2021	27	$69,940,000
3	FY 2022	26	$79,870,000
4	FY 2023	19	$72,090,000
5	FY 2024	10	$27,500,000
6	FY 2025	15	$33,730,000
7	FY 2026	12	$34,520,000
8	FY 2027	10	$34,340,000
9	FY 2028	8	$14,900,000
10	FY 2029	7	$8,650,000
11	FY 2030	4	$7,350,000
12	FY 2031	5	$10,250,000
13	FY 2032	5	$10,560,000
14	FY 2033	5	$8,670,000
15	FY 2034	7	$19,240,000
16	FY 2035	6	$16,530,000
17	FY 2036	5	$17,700,000
18	FY 2037	5	$12,590,000
19	FY 2038	5	$39,920,000
20	FY 2039	4	$9,580,000
Total		**210**	**$557,076,800**

[1] The total project cost includes an additional seven percent (7%) of the construction to cover the costs associated with administration of the contracts, inspection, and other related costs. Costs shown are in future inflated dollars based on the planning year for which each project is programmed. Estimated costs developed in the CIP were generated in 2018 dollars with a 3% annual increase starting in year 2.

As can be expected, the number of projects and subsequently the total cost of the projects by year are skewed towards the first ten years of the planning period. This is due to both the need to make

immediate improvements to enhance/maintain process performance and since there is a significant amount of equipment that has reached, or will reach the end of its useful life in the near future.

It is also possible to group the various projects by process area as summarized in **Table 19.2-2**.

Table 19.2-2: Capital Improvement Projects by Process Area

Process Area	Number of Projects	Total Estimated Project Cost [1]
Preliminary Treatment Improvements	19	$66,124,000
Primary Treatment Improvements	11	$30,502,000
BNR Process Improvements	29	$160,473,000
Tertiary Treatment Improvements	9	$27,426,000
Disinfection and Discharge Improvements	7	$19,160,000
Biosolids Systems Improvements	39	$92,260,550
Electrical Systems Improvements	18	$15,573,250
I&C and SCADA Improvements	3	$4,300,000
Plant-Wide Improvements	75	$141,258,000
Total	**210**	**$557,076,800**

[1] The total project cost includes an additional seven percent (7%) of the construction to cover the costs associated with administration of the contracts, inspection, and other related costs. Costs shown are in future inflated dollars based on the planning year for which each project is programmed. Estimated costs developed in the CIP were generated in 2018 dollars with a 3% annual increase starting in year 2.

It should be noted that several of the plant-wide projects, such as Plant Roof Repairs, repeat every year to account for general maintenance needs and unforeseen equipment failures.

19.3 Sequencing

It has already been mentioned that there is the potential to group several projects into larger projects, related by either process and/or physical location. The benefits from doing this include:

- Reduced total project cost by reducing contractor overhead, ability to obtain materials and equipment at a lower cost, and reduced schedule;
- Greater control for both the City and the contractor – fewer parties and contracts to manage and coordinate; and
- Improved ability to utilize alternative project delivery methods such as design-build delivery.

Grouping project by process area as shown in **Table 19.2-2** is one possibility; however, consolidating all 210 projects into a handful of very large projects may not be feasible or acceptable to the City. Still, consolidating similar projects, such as the improvements to all seven digesters and the associated digester control buildings, or the improvements to the HPO Reactors with the rehabilitation of Oxygen Generation Plant No. 2, or the improvements to Denitrification Filters 1-20 with the improvements to Denitrification Filters 21-36, is an option that the City should consider.

When grouping projects into larger projects, maintaining plant operation and performance needs to be considered. In doing so, it is common to include a maintenance of plant operation (MOPO), or

construction sequencing plan in the contract documents. The MOPO plan should identify the limitations that will be imposed on the construction, for example, the minimum number of tanks that must remain in service throughout the construction or the time of the year when certain components must be on line.

As previously discussed, the CIP list includes capital projects with design in Year N and construction in Year N+1. Dependent on the number, type and size of the grouped projects, it is possible that both the design and the construction periods will be greater than one year. However, the overall schedule for a grouped project will most likely be less, and in some cases significantly less, since the procurement period of both design and construction services for a single large project will be less than several smaller projects.

Attachment 19-A:

CIP List arranged by Fiscal Year

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Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
21	Digester No. 4 Rehabilitation - Design & Construction	0	$1,600,000	$1,712,000	$1,712,000	Rehab of Digester No. 4, including tank cleaning, recoat tank interior and exterior, replace gas holder and associated piping, new sludge mixing system, cover level transmitter, add gas meter.
33	Waste Gas Burners for Digester Tanks No. 1 - No. 7 Rehabilitation	0	$900,000	$963,000	$963,000	Project includes the replacement of pressure relief and flame trap assemblies, drip trap manual operation, flame check, waste gas burner and ignition systems, plug valves and stainless steel pipes.
59	Screen & Grit Building No. 1 - MCC 29 Replacement	0	$400,000	$428,000	$428,000	Replace MCC 29
59	Grit Washer Replacement, Phase II - Construction	0	$2,700,000	$2,889,000	$2,889,000	Construction - Grit washers for both Screen & Grit facilities have reached the end of their useful life. This equipment will be replaced through 2 phases. Phase II will be to replace the grit washers for Building No 1 - NEW screen & grit.
78	Standby Power System Improvements - Design	0	$400,000	$428,000	$428,000	Design - To avoid load shedding under generator failure, the standby power capacity should be extended to cover a 2MW standby generator failure. This will raise the standby capacity to 10MW, giving a N+1 capability. One 2MW (Tier 4) generator can be installed in a separate walk-in enclosure that is hurricane rated. Additional fuel storage tanks (68,000 gals total) are required to bring the total fuel storage capacity of the standby system to 5 days, while also allowing for an additional future generator.
Plantwide	Plant Concrete Repairs	0	$300,000	$321,000	$321,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Treatment Plant improvements	0	$750,000	$802,500	$802,500	Includes miscellaneous improvements and repairs throughout the plant.
2	Junction Chamber No. 1 Improvements - Design	1	$100,000	$107,000	$107,000	Design - Misc. improvements to Junction Chamber No. 1 include replacing the influent sampling station, 4 overhead doors, 3 wet well exhaustr fans, wet well hatch covers, lighting and lighting panels (2), bubbler tube system, supply fan, PRVs, misc. electrical systems, and miscellaneous concrete repairs.
5	Screen & Grit Building No. 2 – Improved Ventilation - Design	1	$150,000	$160,500	$160,500	Design - Improvements to the ventilation system include replacement of existing exhaust fans and installation of new exhaust and supply fans in the open grit and screening areas to increase the rated air flow capacity and the air changes per hour in Screen & Grit Building No. 2 to be similar those currently in Screen & Grit Building No. 1.
10	Main Pump Station Discharge Channel Rehabilitation - Design	1	$600,000	$642,000	$642,000	Design - Discharge aeration improvements. Channel to be cleaned. Concrete rehabilitation and lining of the discharge channel and replacement of air process piping with SS pipe, (1) gate and actuator for 66" spike line to be replaced, inspection and rehabilitation of the 66-inch spike line. Design should include bypass pumping system for construction work in channel and inspection/rehab of spike line.
12	Final Sedimentation Tanks No.1 - No. 12 Improvements - Phase III	1	$2,300,000	$2,461,000	$2,461,000	Perform remaining work at FSTs 1-6 that was not completed during previous project phases. Work includes replacing process air piping for tanks 1-6, baffle walls in tanks 1-6, (48) influent sluice gates and actuators; influent stop log grooves, stems for the (2) manual sluice gates used for scum manhole, (12) scum sludge gates and acuators, and (4) sluice gates in influent channel used to drain the channel. Scum tilting weirs to be removed/demolished. Concrete repairs. Handrail repair.
30	Sludge Treatment Building Miscellaneous Repairs - Design	1	$130,000	$139,100	$139,100	Design - Recommended improvements also include replacement of the existing polymer feed system with a new polymer feed system consisting of bulk storage tanks, liquid polymer activation systems, aging tanks, and activated polymer feed pumps dedicated to each gravity thickener. Remove dewatering pumps.
32	Sludge Dewatering Facility Rehabilitation - Design	1	$2,700,000	$2,889,000	$2,889,000	Design - Recommended improvements identified in Hazen and Sawyer study performed in FY 11. Scope of work includes a new building, polymer activation system, centrifuge technology, and all associated piping, sludge handling, pumping, and electrical equipment.
36	Junction Chamber No. 1 Odor Control Replacement - Design	1	$850,000	$909,500	$909,500	Design - Odor control system replacement consist of hybrid system utilizing biotrickling filters followed by chemical scrubbers for polishing. The system would include a 15,000 cfm air handling fan, parallel biological towers, one multi-stage chemical scrubber, recirculation pumps for each tower, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, blowdown pump station, ductwork, and other associated equipment, as well as misc. concrete repairs. Design should include performance testing by the manufacturer(s) to confirm expected hydrogen sulfide removal.
55	Sludge Drying Bed Rehabilitation, Phase II	1	$900,000	$963,000	$963,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
71	Mixed Sludge Pumping Station Improvements	1	$520,000	$556,400	$556,400	Replace sludge transfer pumps. Replace exhaust fan and repair duct work
72	Digester No. 7 Rehabilitation - Design	1	$640,000	$684,800	$684,800	Design - Gas holder cover to replace existing floating cover, roof, stainless gas mixing/piping to replace existing pipe, and components; repair hole in the tank sidewall; recoat tank interior; repair/replace digested sludge pumps, gas mixing comp, recirculation pumps, and water heater feed pumps. Perform concrete repairs.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
78	Standby Power System Improvements - Construction	1	$3,200,000	$3,424,000	$3,424,000	Construction - To avoid load shedding under generator failure, the standby power capacity should be extended to cover a 2MW standby generator failure. This will raise the standby capacity to 10MW, giving a N+1 capability. One 2MW (Tier 4) generator can be installed in a separate walk-in enclosure that is hurricane rated. Additional fuel storage tanks (68,000 gals total) are required to bring the total fuel storage capacity of the standby system to 5 days, while also allowing for an additional future generator.
80	Biogas Use Improvements - Design	1	$3,250,000	$3,477,500	$3,477,500	Design - Cost is based on the election to pursue RNG biogas utilization. The RNG alternative includes the removal of existing biogas fueled engines and heat recovery equipment; installation of new biogas to RNG treatment, compression, storage, transport, and dispensing equipment; the use natural gas to provide digester heating; instrumentation, electrical, and safety systems upgrades.
14, 15	Denitrification Filter Improvements - Filters No. 1 thru No. 20 - Design	1	$800,000	$856,000	$856,000	Design - Replace control BFVs w/ pneumatic actuators, replace air piping. BFVs include (20) backwash drain valves, (40) backwash water valves, (20) influent valves, (40) effluent valves. Replace (20) influent gate actuators. Replace (3) backwash, (2) effluent water pumps, and (3) sump pumps. Replace (2) blowers. Replace supply and exhaust fans, 5 ton hoist, (2) flow meters. Misc. ancillary equipment and facility repairs including concrete rehabilitation and expansion joint repair, pipe replacement, paint backwash piping on outside over filters, Control Room ceiling; door and window replacement. Removal of polymer equipment from the pump room (no longer in use). Replace (2) sampler stations. Replace MCC 57, MCC 58-A . Repair/replace the level control system, control console.
New Facility	Digester Heating System Replacement Design	1	$725,000	$775,750	$775,750	Design includes new centralized heating system Building D, new heat exchangers, new boilers, air separator, expansion tank, primary hot water loop pumps, feed tank, hot water pipeline to Buildings A and C, and new natural gas pipeline connection.
New Facility	New Primary Sedimentation Tanks - Design	1	$2,600,000	$2,782,000	$2,782,000	Addition of four (4) new primary sedimentation tanks . The new primary sedimentation tanks would be rectangular in shape and of similar size (length, width, depth) to the existing PSTs 5-8. The new primary sedimentation tanks would be located south of PSTs 5-8. A 96-inch pipe would be installed from Junction Chamber No. 2 to the new primary sedimentation tanks and a new 66-inch pipe from the effluent channel of the primary sedimentation tanks to the Main Pump Station. Stress testing and computational fluid dynamics (CFD) modeling of the existing primary sedimentation tanks is recommended prior to initiation of the design to evaluate the TSS removal efficiencies at higher SORs to confirm the timing and number of new primary sedimentation tanks required. Other improvements include replacing supply fans, sump pump at Meter Vault Nos. 1 and 2 and perform miscellaneous concrete repairs in JC No.2 and Meter Vault No. 2.
Plantwide	Medium Voltage Cables Upgrade, Phase I - Design	1	$75,000	$80,250	$80,250	Design - Medium Voltage Cables Upgrade, Phase I
Plantwide	Fire Alarm System Upgrades - Design	1	$350,000	$374,500	$374,500	Design - Replacement of fire alarm systems and deteriorated fire line piping
Plantwide	Arc Flash Improvements	1	$300,000	$321,000	$321,000	Implement Arc Flash improvements as identified in FY15 study
2	Junction Chamber No. 1 Improvements - Construction	2	$500,000	$535,000	$560,000	Construction - Misc. improvements to Junction Chamber No. 1 include replacing the influent sampling station, 4 overhead doors, 3 wet well exhaustr fans, wet well hatch covers, lighting and lighting panels (2), bubbler tube system, supply fan, PRVs, misc. electrical systems, and miscellaneous concrete repairs.
5	Screen & Grit Building No. 2 Improvements - Design	2	$900,000	$963,000	$1,000,000	Design - Project includes equipment and pipe, electrical systems, concrete repairs and facility improvements. More specifically,replacement of backflow preventer, piping and tubing for all four grit tanks, (5) influent gate actuators, (8) grit pump and piping, sump pump and piping, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, switchgear 20 and MCC-21, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Additional building repairs include replacement of windows and doors and concrete repair.
5	Screen & Grit Building No. 2 – Improved Ventilation - Construction	2	$750,000	$802,500	$830,000	Construction - Improvements to the ventilation system include replacement of existing exhaust fans and installation of new exhaust and supply fans in the open grit and screening areas to increase the rated air flow capacity and the air changes per hour in Screen & Grit Building No. 2 to be similar those currently in Screen & Grit Building No. 1.
8	Junction Chamber No. 3 Miscellaneous Repairs	2	$360,000	$385,200	$400,000	Repair or replace mixers 1 and 2, sluice gate actuator, concrete repairs. Remove DAF scum and overflow pipe.
10	Main Pump Station Discharge Channel Rehabilitation - Construction	2	$4,000,000	$4,280,000	$4,410,000	Construction - Discharge aeration improvements. Channel to be cleaned. Concrete rehabilitation and lining of the discharge channel and replacement of air process piping with SS pipe, (1) gate and actuator for 66" spike line to be replaced, inspection and rehabilitation of the 66-inch spike line. Construction will require bypass pumping system for work in channel and inspection/rehab of spike line.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
10	Main Pump Station Rehabilitation - Design	2	$2,000,000	$2,140,000	$2,210,000	Design - Replace pumps (7) and other equipment that is unreliable and no longer cost effective to maintain. Replace eddy current couplings with VFD's (3). Provide VFD's on constant speed pumps (2). Replace check valves and 11 ton hoist. Replacement of MCC's (5) , circuit breakers (5), emergency battery bank, dry transformers, lighting panel. Clean and inspect the main drain. Replace sluice gates and operators for Main Pump Station Influent Channel (7) and Main Drain. Replacement of spent cooling water pumps, flow recorder/totalizer, chilled water pumps motors (2), level controllers (2), condensing unit 1, backflow preventer, computer system hardware, oxygen dissolution control panel, deep bed scrubber, electric heat coils, water pressure tank, containment area waste dumping pit, Halon fire extinguisher system in computer room, fire hydrants, fuel oil storage tank, fire and sprinkler system, life line motor wet well, multigas detectors, base-7 radio unit, roof exhaust fans, overhead doors (2), security alarm system, return sludge control system, sampler station, sump pump (2), UPS radio system, water cooler & heater process, water break tank, sluice gate MPS-SG-10. Replace blowers (3) that are unreliable and no longer cost effective to maintain. Replace (1) dewatering pump. Demo existing scum pumps (2). Window replacement. Misc. concrete repairs
18	Overflow Structure Improvements	2	$300,000	$321,000	$340,000	Design and construction of improvements which include replacement of the existing 4 manual sluice gates at Overflow Structure with motor operated gates tied to SCADA and operated based on either level or flow. Replace the sample pump. Replace existing 5 kVA transformer. Misc concrete repair to Overflow Structure.
21	Digester Nos. 1-3 Rehabilitation - Design	2	$750,000	$802,500	$830,000	Design - Rehab of Digester Nos. 1 through 3, including tank cleaning, recoat tank interior and exterior, replace gas holder and associated piping and replace flame trap assembly (Digester Nos. 1 and 2 only), new sludge mixing system, pressure relief valves, cover level transmitter, add gas meter. Design should consider issuing a single construction contract for the improvements to Digester Nos. 1 through 3, but allow the construction to be phased if preferred by the City.
25	DARs Upgrades - Design	2	$1,900,000	$2,033,000	$2,100,000	Design - Improvements to the DARs Nos. 2-4 include demolition and cleaning of the existing equipment/tanks; new fine bubble diffused aeration, anoxic mixers, internal mixed liquor recycle pumps; miscellaneous concrete and handrail repair, pads and pedestals for new equipment and pipe; process pipe; and instrumentation including O2 meters. Replace influent and effluent gate actuators (16). It is recommended that changes to the aeration equipment be re-evaluated under this design (as described in the BNR Memo).
28	Digester Control Building A Improvements - Design	2	$900,000	$963,000	$1,000,000	Design - Restore building and replace process equipment, piping, and electrical components. Replacement includes sludge flow mag meter, gas condensate tanks, digested sludge pumps No. 1 & 2, gas condensate collectors, sludge gas mixing compressors (6), recirculation pumps, acid-phase transfer pump & grinder; sludge, gas, secondary water and fuel piping and valves, MCC-62B.
30	Sludge Treatment Building Miscellaneous Repairs - Construction	2	$625,000	$668,750	$690,000	Construction - Recommended improvements also include replacement of the existing polymer feed system with a new polymer feed system consisting of bulk storage tanks, liquid polymer activation systems, aging tanks, and activated polymer feed pumps dedicated to each gravity thickener. Remove dewatering pumps.
32	Sludge Dewatering Facility Rehabilitation - Construction	2	$13,500,000	$14,445,000	$14,880,000	Construction - Recommended improvements identified in Hazen and Sawyer study performed in FY 11. Scope of work includes a new building, polymer activation system, centrifuge technology, and all associated piping, sludge handling, pumping, and electrical equipment.
36	Junction Chamber No. 1 Odor Control Replacement - Construction	2	$4,250,000	$4,547,500	$4,690,000	Construction - Odor control system replacement consist of hybrid system utilizing biotrickling filters followed by chemical scrubbers for polishing. The system would include a 15,000 cfm air handling fan, parallel biological towers, one multi-stage chemical scrubber, recirculation pumps for each tower, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, blowdown pump station, ductwork, and other associated equipment; misc. concrete repairs.
47	Filter Building No. 2 Improvements - Design	2	$460,000	$492,200	$510,000	Design - Improvements to Filter Building No. 2 include replacing backwash pumps (3) and blowers (3); influent channel gate, pipe, replacing one 72" and one 48" mag meters, MCC 85 and MCC 86 replacement, roof repairs, skylight replacement, concrete repairs.
48	Denite Filters No. 21 thru No. 26 and No. 31 thru No. 36 Improvements - Design	2	$760,000	$813,200	$840,000	Design - Replace valves and actuators. Valves include (12) backwash water valves, (12) effluent valves, (12) backwash drain valves, (12) influent valves, (2) backwash flow regulating valves. Replace (12) influent gate actuators. Air piping and dressers need to be painted. Replace pumps including (2) filter drain pumps, (2) sump pumps need to be replaced, (3) backwash pumps. Replace two 18" mag meters. Paint backwash piping on outside over filters. Misc. concrete repairs.
54	Dried Sludge Control Building Improvements	2	$1,500,000	$1,605,000	$1,660,000	Replace bed polymer storage tanks and piping, water line and blended polymer pipe, pipes that feed sludge in the tanks, sump pump. Replace MCC-501, MCC-501A & MCC-501B.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
55	Sludge Drying Bed Rehabilitation, Phase III	2	$900,000	$963,000	$1,000,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
72	Digester No. 7 Rehabilitation - Construction	2	$3,250,000	$3,477,500	$3,590,000	Construction - Gas holder cover to replace existing floating cover, roof, stainless gas mixing/piping to replace existing pipe, and components; repair hole in the tank sidewall; recoat tank interior and exterior; repair/replace digested sludge pumps, gas mixing comp, recirculation pumps, and water heater feed pumps. Perform concrete repairs.
80	75 KVA Dry Transformer T Replacement	2	$15,000	$16,050	$20,000	Repair/replace 75 KVA Dry Transformer T
85	Switchgear No. 60 Generator Monitoring Panel Replacement	2	$500,000	$535,000	$560,000	Replace Switchgear No. 60 Generator Monitoring Panel
14, 15	Denitrification Filter Improvements - Filters No. 1 thru No. 20 - Construction	2	$6,600,000	$7,062,000	$7,280,000	Construction - Replace control BFVs w/ pneumatic actuators, replace air piping. BFVs include (20) backwash drain valves, (40) backwash water valves, (20) influent valves, (40) effluent valves. Replace (20) influent gate actuators. Replace (3) backwash, (2) effluent water pumps, and (3) sump pumps. Replace (2) blowers. Replace supply and exhaust fans, 5 ton hoist, (2) flow meters. Misc. ancillary equipment and facility repairs including concrete rehabilitation and expansion joint repair, pipe replacement, paint backwash piping on outside over filters, Control Room ceiling; door and window replacement. Removal of polymer equipment from the pump room (no longer in use). Replace (2) sampler stations. Replace MCC 57, MCC 58-A. Repair/replace the level control system, control console.
New Facility	Digester Heating System Replacement Improvements- Construction	2	$3,600,000	$3,852,000	$3,970,000	Construction includes new centralized heating system Building D, new heat exchangers, new boilers, air separator, expansion tank, primary hot water loop pumps, feed tank, hot water pipeline to Buildings A and C, and new natural gas pipeline connection.
New Facility	New Primary Sedimentation Tanks - Construction	2	$13,000,000	$13,910,000	$14,330,000	Addition of four (4) new primary sedimentation tanks with provisions for a fourth future tank. The new primary sedimentation tanks would be rectangular in shape and of similar size (length, width, depth) to the existing PSTs 5-8. The new primary sedimentation tanks would be located south of PSTs 5-8. A 96-inch pipe would be installed from Junction Chamber No. 2 to the new primary sedimentation tanks and a new 66-inch pipe from the effluent channel of the primary sedimentation tanks to the Main Pump Station. Other improvements include replacing supply fans, sump pump at Meter Vault Nos. 1 and 2 and perform miscellaneous concrete repairs in JC No.2 and Meter Vault No. 2.
Plantwide	Medium Voltage Cables Upgrade, Phase I - Construction	2	$500,000	$535,000	$560,000	Construction - Medium Voltage Cables Upgrade, Phase I
Plantwide	Fire Alarm System Upgrades - Construction	2	$1,000,000	$1,070,000	$1,110,000	Construction - Replacement of fire alarm systems and deteriorated fire line piping
Plantwide	AWT SCADA - Master Plan and Design	2	$200,000	$214,000	$230,000	Evaluate current system and develop a master plan to improve the AWT SCADA system. Design AWT SCADA improvements as identified in the SCADA Master Plan.
Plantwide	Effluent Water System Improvements - Design	2	$300,000	$321,000	$340,000	Design - Replacing deteriorated effluent water system piping and construct new effluent water pipe loop to improve effluent water system at the plant. New system will Include additional capacity for a new odor control unit at JC No. 1 and improved pressure at screen and grit.
5	Screen & Grit Building No. 2 Improvements - Construction	3	$4,500,000	$4,815,000	$5,110,000	Construction - Project includes equipment and pipe, electrical systems, concrete repairs and facility improvements. More specifically,replacement of backflow preventer, piping and tubing for all four grit tanks, (5) influent gate actuators, (8) grit pump and piping, sump pump and piping, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, switchgear 20 and MCC-21, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Additional building repairs include replacement of windows and doors and concrete repair.
9	Primary Sedimentation Tanks No. 1 - No. 4 Improvements -Design	3	$700,000	$749,000	$800,000	Design - Improvements to the PSTs No. 1 - No. 4 including replacement of chain and flights, gearboxes and motors for influent sluice gate actuators (4), replacement of manual backflush sluice gates with motor operated gates (8); replacement of sludge blanket detector, rehab of scum pit; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Line deck on effluent side of tanks. Scum and gravity thickener overlfow pipe and valves to be replaced. 14" and 8" DAF scum and overflow pipes to be removed from ground up.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
10	Main Pump Station Rehabilitation - Construction	3	$14,000,000	$14,980,000	$15,900,000	Construction - Replace pumps (7) and other equipment that is unreliable and no longer cost effective to maintain. Replace eddy current couplings with VFD's (3). Provide VFD's on constant speed pumps (2). Replace check valves and 11 ton hoist. Replacement of MCC's (5) , circuit breakers (5), emergency battery bank, dry transformers, lighting panel. Clean and inspect the main drain. Replace sluice gates and operators for Main Pump Station Influent Channel (7) and Main Drain. Replacement of spent cooling water pumps, flow recorder/totalizer, chilled water pumps motors (2), level controllers (2), condensing unit 1, backflow preventer, computer system hardware, oxygen dissolution control panel, deep bed scrubber, electric heat coils, water pressure tank, containment area waste dumping pit, Halon fire extinguisher system in computer room, fire hydrants, fuel oil storage tank, fire and sprinkler system, life line motor wet well, multigas detectors, base-7 radio unit, roof exhaust fans, overhead doors (2), security alarm system, return sludge control system, sampler station, sump pump (2), UPS radio system, water cooler & heater process, water break tank, sluice gate MPS-SG-10. Replace blowers (3) that are unreliable and no longer cost effective to maintain. Replace (1) dewatering pump. Demo existing scum pumps (2). Window replacement. Misc. concrete repairs
11	HPO Reactor Improvements - Design	3	$1,700,000	$1,819,000	$1,930,000	Design - Improvements in the HPO Reactors consist of improvements to the influent and effluent channels which include cleaning, concrete repair and channel lining, new SS aeration system, replacement of 12 gates and actuators (4 reactor influent, 2 swing reactor, 3 reactor NIT influent, 2 side spike line, and 1 carb inf to reactor), meters, and sampling equipment. Improvements to the reactors consist of cleaning of the existing tanks, structural rehabilitation of the tanks (repair to concrete surfaces above the normal water line), replacing the existing surface aerators with larger mechanical aerators in stages 2-4 (3 reactors), replacing existing instrumentation and electrical systems upgrades. The aerator in the first mixing zone will be replaced with a submerged mixer, the areators in stages 2-4 are larger to accomodate higher oxygen transfer. Additional improvements include replacing the dewatering main drain sluice gate and actuator, upgrade butterfly valves to electric butterfly valves, removal of alum pipe on reactor deck, replacing influent and effluent stop logs and actuators, replacing instrumentation including rate controllers, gas monitoring, air meters, step-feed meters, high water alarm, replacing MLSS sample pumps, and painting process air piping and spike line in influent channel. Design shall include identifying bypass pumping requirements. Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs.
16	Post Aeration Chlorination Improvements - Design	3	$250,000	$267,500	$290,000	Design - Improvements include relocating the post aeration system from the head of the chlorine contact tanks to the effluent channel. Misc. process equipment improvements including replacing post aeration tank gearboxes, post aeration spent cooling water mag meter and pipe, sample pumps, meters, temperature indicator, process air piping and a post aeration tank dewatering pump.
21	Digester No. 2 Rehabilitation - Construction	3	$1,600,000	$1,712,000	$1,820,000	Construction - Rehab of digester, including tank cleaning, recoat tank interior (compatable with acid-gas phase digestion) and exterior, replace gas holder and associated piping, new sludge mixing system, replace flame trap assembly on cover, pressure relief valve, cover level transmitter, add gas meter.
21	Digester No. 5 Rehabilitation - Design	3	$480,000	$513,600	$550,000	Design - Rehab of Digester No. 5, including tank cleaning; recoat tank interior and exterior; replace cover with gas holder and associated piping (sludge piping may be plugged to struvite); new sludge mixing system; replace flame trap assembly, pressure relief valves, cover level transmitter; add gas meter.
21	Digester No. 1 Rehabilitation	3	$600,000	$642,000	$690,000	Construction - Rehab of digester, including tank cleaning, recoat tank interior (compatable with acid-gas phase digestion) and exterior, new sludge mixing system, replace flame trap assembly, pressure relief valves, cover level transmitter, add gas meter. Consider single construction contract for the improvements to Digester Nos. 1 through 4.
21	Digester No. 3 Rehabilitation	3	$620,000	$663,400	$710,000	Construction includes cleaning and tank interior and exterior recoating, new sludge mixing system. (Note - sludge piping was replaced in 2013.)
25	DAR Train #1 Internal Recycle Magnetic Flow Meter Installation	3	$60,000	$64,200	$70,000	Install a magnetic flow meter on the internal recycle conduit of Train #1 to monitor and control internal recycle.
25	DARs Upgrades - Construction	3	$9,500,000	$10,165,000	$10,790,000	Construction - Improvements to the DARs Nos. 2-4 include demolition and cleaning of the existing equipment/tanks; new fine bubble diffused aeration, anoxic mixers, internal mixed liquor recycle pumps; miscellaneous concrete and handrail repair, pads and pedestals for new equipment and pipe; process pipe; and instrumentation including O2 meters. Replace influent and effluent gate actuators (16). It is recommended that changes to the aeration equipment be re-evaluated under this design (as described in the BNR Memo). Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
28	Digester Control Building A Improvements - Construction	3	$4,500,000	$4,815,000	$5,110,000	Construction - Restore building and replace process equipment, piping, and electrical components. Replacement includes sludge flow mag meter, gas condensate tanks, digested sludge pumps No. 1 & 2, gas condensate collectors, sludge gas mixing compressors (6), recirculation pumps, acid-phase transfer pump & grinder; sludge, gas, secondary water and fuel piping and valves, MCC-62B.
29	Digester Control Building B Improvements - Design	3	$400,000	$428,000	$460,000	Design - Restore building and replace process equipment, piping, and electrical components. Air compressor; sludge, gas, water and fuel piping and valves
47	Filter Building No. 2 Improvements - Construction	3	$2,300,000	$2,461,000	$2,620,000	Construction - Improvements to Filter Building No. 2 include replacing backwash pumps (3) and blowers (3); influent channel gate, pipe, replacing one 72" and one 48" mag meters, MCC 85 and MCC 86 replacement, roof repairs, skylight replacement, concrete repairs.
48	Denite Filters No. 21 thru No. 26 and No. 31 thru No. 36 Improvements - Construction	3	$3,800,000	$4,066,000	$4,320,000	Construction - Replace valves and actuators. Valves include (12) backwash water valves, (12) effluent valves, (12) backwash drain valves, (12) influent valves, (2) backwash flow regulating valves. Replace (12) influent gate actuators. Air piping and dressers need to be painted. Replace pumps including (2) filter drain pumps, (2) sump pumps need to be replaced, (3) backwash pumps. Replace two 18" mag meters. Paint backwash piping on outside over filters. Misc. concrete repairs.
55	Sludge Drying Bed Rehabilitation, Phase IV	3	$900,000	$963,000	$1,030,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
57	Nitrification Pump Station Improvements - Design	3	$450,000	$481,500	$520,000	Design - Station needs to be rehabilitated; all pumps replaced (7) and design improvements made to prevent repeated pump failures
59	Screen & Grit Building No. 1 Improvements - Design	3	$800,000	$856,000	$910,000	Design - Project includes equipment and pipe, electrical systems, ventilation improvements, concrete repairs and facility improvements. More specifically, replacing washer compactors, (6) influent gate actuators, (8) grit pumps, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Ceiling pipe penetration needs to be repaired. Grit pumps piping needs to be replaced. Influent and effluent gate actuators to be replaced.
80	Biogas Use Improvements - Construction	3	$16,200,000	$17,334,000	$18,390,000	Construction - Cost is based on the election to pursue RNG biogas utilization. The RNG alternative includes the removal of existing biogas fueled engines and heat recovery equipment; installation of new biogas to RNG treatment, compression, storage, transport, and dispensing equipment; the use natural gas to provide digester heating; instrumentation, electrical, and safety systems upgrades.
80	Digester gas compressor and drying system	3	$310,000	$331,700	$360,000	Gas compressor and drying systems includes electric motors, motor starters, steel bases, expansion joints, check valves, butterfly valves, bypass throttling valves with actuators, multi-stage centrifugal gas compressors, heat exchangers, coalescers, chillers, interconnecting piping, wiring, electrical conduit and related supports, structural steel supports for each component, control panels, gas temperature and pressure gauges.
New Facility	Additional Final Sedimentation Tanks (No. 21 - 24) and Return Station No. 6 - Design	3	$3,600,000	$3,852,000	$4,090,000	Design - Add 4 more nitrification final tanks and another return station. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods.
Plantwide	Medium Voltage Cables Upgrade, Phase II - Design	3	$75,000	$80,250	$90,000	Design - Medium Voltage Cables Upgrade, Phase II
Plantwide	Treatment Plant Office and Building Improvements - Design	3	$700,000	$749,000	$800,000	Design - This project will include demo of existing buildings (carpenter shop, old screen and grit building, tech building), potential construction of new administration office building, improvements to O&M building, and relocation of carpenter shop.
Plantwide	AWT SCADA - Construction	3	$1,000,000	$1,070,000	$1,140,000	Construction of Improvements for SCADA system
Plantwide	Effluent Water System Improvements - Construction	3	$1,000,000	$1,070,000	$1,140,000	Construction - Replacement effluent water system piping and new effluent water pipe loop to improve effluent water system at the plant. New system will Include additional capacity for a new odor control unit at JC No. 1 and improved pressure at screen and grit facilities.
Plantwide	Treatment Plant Security and Emergency Responses Improvements - Design	3	$200,000	$214,000	$230,000	Design - Improvements to treatment plant's security and emergency response systems. Department is currently evaluating emergency response, safety, and security needs at the treatment plant. This project will provide funding for identified improvements which may include new access/entry gate systems and perimeter fencing.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
9	Primary Sedimentation Tanks No. 1 - No. 4 Improvements - Construction	4	$3,600,000	$3,852,000	$4,210,000	Construction - Improvements to the PSTs No. 1 - No. 4 including replacement of chain and flights, gearboxes and motors for influent sluice gate actuators (4), replacement of manual backflush sluice gates with motor operated gates (8); replacement of sludge blanket detector, rehab of scum pit; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Line deck on effluent side of tanks. Scum and gravity thickener overlfow pipe and valves to be replaced. 14" and 8" DAF scum and overflow pipes to be removed from ground up.
11	HPO Reactor Improvements - Construction	4	$11,000,000	$11,770,000	$12,870,000	Construction - Improvements in the HPO Reactors consist of improvements to the influent and effluent channels which include cleaning, concrete repair and channel lining, new SS aeration system, replacement of 12 gates and actuators (4 reactor influent, 2 swing reactor, 3 reactor NIT influent, 2 side spike line, and 1 carb inf to reactor), meters, and sampling equipment. Improvements to the reactors consist of cleaning of the existing tanks, structural rehabilitation of the tanks (repair to concrete surfaces above the normal water line), replacing the existing surface aerators with larger mechanical aerators in stages 2-4 (3 reactors), replacing existing instrumentation and electrical systems upgrades. The aerator in the first mixing zone will be replaced with a submerged mixer, the aerators in stages 2-4 are larger to accomodate higher oxygen transfer. Additional improvements include replacing the dewatering main drain sluice gate and actuator, upgrade butterfly valves to electric butterfly valves, removal of alum pipe on reactor deck, replacing influent and effluent stop logs and actuators, replacing instrumentation including rate controllers, gas monitoring, air meters, step-feed meters, high water alarm, replacing MLSS sample pumps, and painting process air piping and spike line in influent channel. Construction work within influent and effluent channel will require bypass pumping. Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs.
16	Post Aeration Chlorination Improvements - Construction	4	$1,750,000	$1,872,500	$2,050,000	Construction - Improvements include relocating the post aeration system from the head of the chlorine contact tanks to the effluent channel. Misc. process equipment improvements including replacing post aeration tank gearboxes, post aeration spent cooling water mag meter and pipe, sample pumps, meters, temperature indicator, process air piping and a post aeration tank dewatering pump.
20	Primary Sludge Pump Station No. 1 Improvements	4	$500,000	$535,000	$590,000	Replace dry-pit pumps (2), valves, (1) scum gate and actuator, (1) dewatering gate and actuator, misc. pipe, and instrumentation upgrades. Misc. building upgrades including new windows and doors.
21	Digester No. 5 Rehabilitation - Construction	4	$2,400,000	$2,568,000	$2,810,000	Construction - Rehab of Digester No. 5, including tank cleaning; recoat tank interior and exterior; replace cover with gas holder and associated piping (sludge piping may be plugged to struvite); new sludge mixing system; replace flame trap assembly, pressure relief valves, cover level transmitter; add gas meter.
29	Digester Control Building B Improvements - Construction	4	$1,900,000	$2,033,000	$2,230,000	Construction - Restore building and replace process equipment, piping, and electrical components. Air compressor; sludge, gas, water and fuel piping and valves
44	Switch Gear Facility Rehabilitation - Design	4	$500,000	$535,000	$590,000	Design -Facility is generally in poor condition and will need to be replaced. Construction includes 24 new switchgear and 5000 sf building.
55	Sludge Drying Bed Rehabilitation, Phase V	4	$900,000	$963,000	$1,060,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
57	Nitrification Pump Station Improvements - Construction	4	$4,500,000	$4,815,000	$5,270,000	Construction -Replaced submersible pumps (7), repair or replace valves, upgrade instrumentation an electrical systems
58	DAR Blowers Replacement - Design	4	$600,000	$642,000	$710,000	Design - Blowers are constant speed; should be replaced with blowers that match air demands associated with DARS improvements and are adjustable. Replace transformers T-8A & 8B.
59	Screen & Grit Building No. 1 Improvements - Construction	4	$4,000,000	$4,280,000	$4,680,000	Construction - Project includes equipment and pipe, electrical systems, ventilation improvements, concrete repairs and facility improvements. More specifically, replacing washer compactors, (6) influent gate actuators, (8) grit pumps, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Ceiling pipe penetration needs to be repaired. Grit pumps piping needs to be replaced. Influent and effluent gate actuators to be replaced.
72	Digester No. 6 Rehabilitation - Design	4	$260,000	$278,200	$310,000	Design - Includes cleaning and recoating tank interior and exterior, and misc. improvements. Digester 6 already has stainless gas mixing/piping from the 2012 rehab .
74	Digester Control Building C Improvements - Design	4	$800,000	$856,000	$940,000	Replace sludge pump, recirculation pumps, misc. pipe repairs and hot water pumps; sludge, gas, water and fuel piping and valves; building improvements

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
83	Primary Sludge Pump Station No. 2 Improvements	4	$620,000	$663,400	$730,000	Replace pumps (2), sluice gates and actuators (3), and instrumentation upgrades. Replace Existing MCC-48 & MCC-49. Concrete repairs
New Facility	Automated Septage Receiving Facility - Design	4	$540,000	$577,800	$640,000	Design - A new septage receiving facility would be constructed near the southwest corner of the plant property. The septage receiving facility would consist of four standalone, automated sewage receiving stations that discharge to a new duplex submersible pump station. This new pump station would be connected via a new force main to either the Raw Sewage Pump Station or the Junction Chamber No. 1. The site work for the new septage receiving facility would include a new entrance and exit off Maritime Blvd., security fencing and access gate. While located on plant property, the security fencing would separate this site from the rest of the treatment plant
New Facility	Additional Final Sedimentation Tanks (No. 21 - 22) and Return Station No. 6 - Construction	4	$19,500,000	$20,865,000	$22,800,000	Construction - Add 2 more nitrification final tanks and another return station, with provisions for adding 2 more tanks in the future. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods.
Plantwide	Medium Voltage Cables Upgrade, Phase II - Construction	4	$500,000	$535,000	$590,000	Construction - Medium Voltage Cables Upgrade, Phase II
Plantwide	Treatment Plant Office and Building Improvements - Construction	4	$6,700,000	$7,169,000	$7,840,000	Construction - This project will include demo of existing buildings (carpenter shop, old screen and grit building, tech building), potential construction of new administration office building, improvements to O&M building, and relocation of carpenter shop.
Plantwide	Treatment Plant Security and Emergency Response Improvements - Construction	4	$1,000,000	$1,070,000	$1,170,000	Construction -Improvements to treatment plant's security and emergency response systems. Department is currently evaluating emergency response, safety, and security needs at the treatment plant. This project will provide funding for identified improvements which may include new access/entry gate systems and perimeter fencing.
44	Switch Gear Facility Rehabilitation - Construction	5	$5,000,000	$5,350,000	$6,030,000	Construction - Facility is generally in poor condition and will need to be replaced. Construction includes 24 new switchgear and 5000 sf building.
50	Junction Chamber No. 5 Improvements	5	$1,130,000	$1,209,100	$1,370,000	Install a flow meter in the Junction Chamber No. 5 to be able to have a constant primary effluent feeding to the Nitrification Pump Station. Repair/replace mag meter JC-5 FE-301, two spike line valves, five actuators, exhaust fan. Concrete repairs.
55	Sludge Drying Bed Rehabilitation, Phase VI	5	$900,000	$963,000	$1,090,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
58	DAR Blowers Replacement - Construction	5	$5,800,000	$6,206,000	$6,990,000	Construction - Blowers are constant speed; should be replaced with blowers that match air demands associated with DARS improvements and are adjustable. Replace transformers T-8A & 8B.
61	Final Sedimentation Tanks Improvements No. 13 thru No. 20 Improvements - Design	5	$600,000	$642,000	$730,000	Design - Project provides for replacement of chains and drive system for final sedimentation tanks 13-20. Also replace end-of-life motors, sluice gates (68), and gears. Mitigate any corrosion or leaks. Perform concrete repairs. Evaluate alternatives for automatic sludge blanket monitoring. Replace the rate controller equipment in the secondary effluent control channel including the secondary control weir, motor operated gear boxes, and gate operator motors. Instrumentation upgrades include automatic sludge blanket monitors, return sludge and waste sludge flow indicating transmitters, pump speed indication, and return sludge solids concentration monitoring. Design should evaluate options to automate return sludge pumping including SCADA integration with HPO and DAR MLSS monitoring equipment. .
72	Digester No. 6 Rehabilitation - Construction	5	$1,300,000	$1,391,000	$1,570,000	Construction - Includes cleaning and recoating tank interior and exterior, and misc. improvements. Digester 6 already has stainless gas mixing/piping from the 2012 rehab.
74	Digester Control Building C Improvements - Construction	5	$4,000,000	$4,280,000	$4,820,000	Replace sludge pump, recirculation pumps, misc. pipe repairs and hot water pumps; sludge, gas, water and fuel piping and valves; building improvements
22, 23, 24	Return Sludge Pumping Stations No. 1, No. 2 and No. 3 Rehabilitation - Design	5	$1,200,000	$1,284,000	$1,450,000	Design - Replace piping, (12 per PS) valves and actuators, supply fans, (3) 2-ton Hoist, sump pumps, (5 per PS) sludge pumps, gates, (2) 24" return sludge meters, (2) 10" waste sludge flowmeters, SWGR-40, and MCC-43, MCC-45, (5 per PS) VFD's, lighting panels and misc. electrical components, roof repairs, in Return Sludge Pump Stations No. 1, No. 2, and No. 3. Miscellaneous concrete repairs.
New Facility	Automated Septage Receiving Facility - Construction	5	$2,700,000	$2,889,000	$3,260,000	Construction - A new septage receiving facility would be constructed near the southwest corner of the plant property. The septage receiving facility would consist of four standalone, automated sewage receiving stations that discharge to a new duplex submersible pump station. This new pump station would be connected via a new force main to either the Raw Sewage Pump Station or the Junction Chamber No. 1. The site work for the new septage receiving facility would include a new entrance and exit off Maritime Blvd., security fencing and access gate. While located on plant property, the security fencing would separate this site from the rest of the treatment plant
Plantwide	Medium Voltage Cables Upgrade, Phase III - Design	5	$150,000	$160,500	$190,000	Design - Medium Voltage Cables Upgrade, Phase III

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
26	3rd Gravity Thickener - Design	6	$660,000	$706,200	$820,000	Design- A new sludge thickener train consisting of a new gravity thickener tank, two thickened waste activated sludge pumps, and associated appurtenances is recommended to provide redundancy and improve loading rates. The new sludge thickener train would be sized equal to the existing gravity thickeners and pumps. Replacement of the existing polymer feed system to be performed as a separate project, however this project will include a new polymer feed pump dedicated to the new gravity thickener.
31	Side Stream Treatment - Design	6	$1,800,000	$1,926,000	$2,240,000	Design - Improvements recommended consist of the addition of a sidestream deammonification process to remove approximately 80-85% NH4-N and 70-75% TKN from the sidestream. Improvements include retrofitting two (2) of the existing twelve north final settling tanks, one as a sidestream equalization basin and the other as a biofilm reactor basin (e.g. ANITA™ Mox MBBR); building to house the blowers and pumps associated with the reactor; process pipe; instrumentation and controls.
41	O2 Plant No. 1 Rehabilitation - Design and GMP Development	6	$900,000	$963,000	$1,120,000	Design -Improvements to the High Purity Oxygen Generation System No. 1 should be similar to the recently completed rehabilitation of the High Purity Oxygen Generation System No. 2 and includes replacement of process pipe, valves, and valve actuators; repairs to the cold box; replacement of the compressor; and new instrumentation and electrical components.
49	Junction Chamber No. 6 Miscellaneous Repairs	6	$300,000	$321,000	$380,000	Repair or replace sluice gates (4).
55	Sludge Drying Bed Rehabilitation, Phase VII	6	$900,000	$963,000	$1,120,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
61	Final Sedimentation Tanks Improvements No. 13 thru No. 20 Improvements - Construction	6	$6,000,000	$6,420,000	$7,450,000	Construction -Project provides for replacement of chains and drive system for final sedimentation tanks 13-20. Also replace end-of-life motors, sluice gates (68), and gears. Mitigate any corrosion or leaks. Perform concrete repairs. Provide for automatic sludge blanket monitoring. Replace the rate controller equipment in the secondary effluent control channel including the secondary control weir, motor operated gear boxes, and gate operator motors. Instrumentation upgrades include automatic sludge blanket monitors, return sludge and waste sludge flow indicating transmitters, pump speed indication, and return sludge solids concentration monitoring.
82	Primary Sedimentation Tank No. 5 thru No. 8 Improvements - Design	6	$700,000	$749,000	$870,000	Design of improvements include replacement of chain and flights, gearboxes and motors for influent sluice gates (4), replacement of manual backflush sluice gates with motor operated gates (8); provide sludge blanket level monitors to improve operations, rehab of scum pit; rehab of baffles; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Paint scum discharge piping from FSTs 13-20. Replace dewatering line from DARs (16") and nit waste line (6"). Replace Scum Valves.
22, 23, 24	Return Sludge Pumping Stations No. 1, No. 2 and No. 3 Rehabilitation - Construction	6	$6,000,000	$6,420,000	$7,450,000	Construction - Replace piping, (12 per PS) valves and actuators, supply fans, (3) 2-ton Hoist, sump pumps, (5 per PS) sludge pumps, gates, (2) 24" return sludge meters, (2) 10" waste sludge flowmeters, SWGR-40, and MCC-43, MCC-45, (5 per PS) VFD's, lighting panels and misc. electrical components, roof repairs, in Return Sludge Pump Stations No. 1, No. 2, and No. 3. Miscellaneous concrete repairs.
9, 82	Reroute residuals recycle flow ahead of screening and grit removal	6	$2,900,000	$3,103,000	$3,600,000	Rerouting the filter backwash, FST 13-20 WAS, and gravity thickener overflow (GTO) recycle streams ahead of screening and grit removal. This will require re-directing these flows to a new submersible PS and force main to either JC 1 or the 72" pipe into Screen and Grit Building No. 2. Several submersible PS's may be required if the various recycle streams cannot gravity flow to a central pump station site.
Plantwide	Medium Voltage Cables Upgrade, Phase III - Construction	6	$500,000	$535,000	$630,000	Construction - Medium Voltage Cables Upgrade, Phase III
Plantwide	Plant Roof Repairs	6	$250,000	$267,500	$320,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	6	$250,000	$267,500	$320,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	6	$600,000	$642,000	$750,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Plant Full Automation - Construction	6	$2,360,000	$2,525,200	$2,930,000	Construction - Each system at the treatment plant will be automated (if possible). Includes the monitoring devices and control devices needed for the automation.
Plantwide	Miscellaneous Plant Equipment Repairs	6	$3,000,000	$3,210,000	$3,730,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
1	Raw Sewage PS Miscellaneous Repairs and Improvements	7	$840,000	$898,800	$1,080,000	Repair general air leaks, replace duct axial supply fan, scum pit sluice gate, lighting panel, transformer, and MCC-64 and MCC-65.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
2	Junction Chamber No. 1 Aeration Improvements - Design	7	$600,000	$642,000	$770,000	Design - Aeration and mixing improvements consist of replacing the existing diffused air system which is reaching the end of its remaining useful life. Four new PD blowers, two 3600 cfm and two 4320 cfm, to replace the existing blowers, along with exposed air piping. New MCC's (3). (Note the second 4320 cfm blower is currently identified as a standby blower. As this blower is a considerably newer than the other blowers, it is recommended that the condition of this blower be evaluated during the design to confirm its replacement is necessary.) Additional improvements to Junction Chamber No. 1 include replacing sluice gates (17) and actuators (9).
9	PST Nos 1-4 Dewatering Pump Station - Design	7	$150,000	$160,500	$200,000	Design - The addition of a dewatering pump station, similar to that associated with PSTs 5-8. The pump station layout would be similar to that of PSTs 5-8, including a wet well with two (2) submersible pumps and a valve box. Piping modifications would consist of cutting in a tee to the existing drain line(s), and extending a new pipe from the branch of the tee to the new pumps station. Valves would be added to the existing and proposed lines and would be used to switch between gravity and pump dewatering.
26	3rd Gravity Thickener - Construction	7	$3,300,000	$3,531,000	$4,220,000	Construction- A new sludge thickener train consisting of a new gravity thickener tank, two thickened waste activated sludge pumps, and associated appurtenances is recommended to provide redundancy and improve loading rates. The new sludge thickener train would be sized equal to the existing gravity thickeners and pumps. Replacement of the existing polymer feed system to be performed as a separate project, however this project will include a new polymer feed pump dedicated to the new gravity thickener.
31	Side Stream Treatment - Construction	7	$9,000,000	$9,630,000	$11,500,000	Construction - Improvements consist of the addition of a sidestream deammonification process to remove approximately 80-85% NH4-N and 70-75% TKN from the sidestream. Improvements include retrofitting two (2) of the existing twelve north final settling tanks, one as a sidestream equalization basin and the other as a biofilm reactor basin (e.g. ANITA™ Mox MBBR); building to house the blowers and pumps associated with the reactor; process pipe; instrumentation and controls.
41	O2 Plant No. 1 Rehabilitation - Construction	7	$4,500,000	$4,815,000	$5,750,000	Construction -Improvements to the High Purity Oxygen Generation System No. 1 should be similar to the recently completed rehabilitation of the High Purity Oxygen Generation System No. 2 and includes replacement of process pipe, valves, and valve actuators; repairs to the cold box; replacement of the compressor; and new instrumentation and electrical components.
55	Sludge Drying Bed Rehabilitation, Phase VIII	7	$900,000	$963,000	$1,150,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
82	Primary Sedimentation Tank No. 5 thru No. 8 Improvements - Construction	7	$3,600,000	$3,852,000	$4,600,000	Construction of improvements include replacement of chain and flights, gearboxes and motors for influent sluice gates (4), replacement of manual backflush sluice gates with motor operated gates (8); provide sludge blanket level monitors to improve operations, rehab of scum pit; rehab of baffles; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Paint scum discharge piping from FSTs 13-20. Replace dewatering line from DARs (16") and nit waste line (6"). Replace Scum Valves.
Plantwide	Plant Roof Repairs	7	$250,000	$267,500	$320,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	7	$250,000	$267,500	$320,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	7	$600,000	$642,000	$770,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	7	$3,000,000	$3,210,000	$3,840,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
2	Junction Chamber No. 1 Aeration Improvements - Construction	8	$3,000,000	$3,210,000	$3,950,000	Construction - Aeration and mixing improvements consist of replacing the existing diffused air system which is reaching the end of its remaining useful life. Four new PD blowers, two 3600 cfm and two 4320 cfm, to replace the existing blowers, along with exposed air piping. New MCC's (3). (Note the second 4320 cfm blower is currently identified as a standby blower. As this blower is a considerably newer than the other blowers, it is recommended that the condition of this blower be evaluated during the design to confirm its replacement is necessary.) Additional improvements to Junction Chamber No. 1 include replacing sluice gates (17) and actuators (9).
9	PST Nos 1-4 Dewatering Pump Station - Construction	8	$750,000	$802,500	$990,000	Construction - The addition of a dewatering pump station, similar to that associated with PSTs 5-8. The pump station layout would be similar to that of PSTs 5-8, including a wet well with two (2) submersible pumps and a valve box. Piping modifications would consist of cutting in a tee to the existing drain line(s), and extending a new pipe from the branch of the tee to the new pumps station. Valves would be added to the existing and proposed lines and would be used to switch between gravity and pump dewatering.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
16	Disinfection Improvements - Design	8	$1,200,000	$1,284,000	$1,580,000	Design - Disinfection facility improvements consist of replacing the existing chlorine gas disinfection system with a new sodium hypochlorite disinfection system. The sodium hypochlorite disinfection system includes liquid chemical storage, chemical transfer pumps, chemical feed pumps, process pipe, instrumentation and controls. Improvements would include demolition of the existing chlorine gas and sodium dioxide feed equipment. Additional disinfection facilities improvements include installation of baffle walls to improve disinfection performance. Perform misc. concrete repairs within the contact tank.
40	Operations and Maintenance Building MCC Replacement	8	$350,000	$374,500	$470,000	Replace MCC-26, MCC-27, MCC-28.
New Facility	Additional Final Sedimentation Tanks (No. 23 - 24) - Construction	8	$16,600,000	$17,762,000	$21,850,000	Construction - Add 2 more nitrification final tanks. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods. Two tanks and areturn pump station will be constructed in a prior year. This project completes the expansion of the tanks.
Plantwide	Plant Roof Repairs	8	$250,000	$267,500	$330,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	8	$250,000	$267,500	$330,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	8	$600,000	$642,000	$790,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	8	$3,000,000	$3,210,000	$3,950,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Medium Voltage Cables Upgrade, Phase IV - Design	8	$75,000	$80,250	$100,000	Design - Medium Voltage Cables Upgrade, Phase IV
16	Disinfection Improvements - Construction	9	$5,400,000	$5,778,000	$7,320,000	Construction - Disinfection facility improvements consist of replacing the existing chlorine gas disinfection system with a new sodium hypochlorite disinfection system. The sodium hypochlorite disinfection system includes liquid chemical storage, chemical transfer pumps, chemical feed pumps, process pipe, instrumentation and controls. Improvements would include demolition of the existing chlorine gas and sodium dioxide feed equipment. Additional disinfection facilities improvements include installation of baffle walls to improve disinfection performance. Perform misc. concrete repairs within the contact tank.
55	Sludge Drying Bed Rehabilitation, Phase IX	9	$900,000	$963,000	$1,220,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
Plantwide	Plant Roof Repairs	9	$250,000	$267,500	$340,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	9	$250,000	$267,500	$340,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	9	$600,000	$642,000	$820,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	9	$3,000,000	$3,210,000	$4,070,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Medium Voltage Cables Upgrade, Phase IV - Construction	9	$500,000	$535,000	$680,000	Construction - Medium Voltage Cables Upgrade, Phase IV
Plantwide	Medium Voltage Cables Upgrade, Phase V - Design	9	$75,000	$80,250	$110,000	Design - Medium Voltage Cables Upgrade, Phase V
43	Chemical Storage Tanks Demolition	10	$300,000	$321,000	$420,000	(9) Alum Storage Tanks and (1) Brewery Waste Tank need to be removed.
43	Methanol Storage Tank Replacement	10	$280,000	$299,600	$400,000	Replace existing 100,000 gal. steel methanol storage tank No. 1 with two 50,000 gal. tanks to povide redundancy to the process.
Plantwide	Plant Roof Repairs	10	$250,000	$267,500	$350,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	10	$250,000	$267,500	$350,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	10	$600,000	$642,000	$840,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	10	$4,000,000	$4,280,000	$5,590,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Medium Voltage Cables Upgrade, Phase V - Construction	10	$500,000	$535,000	$700,000	Construction - Medium Voltage Cables Upgrade, Phase V
Plantwide	Plant Roof Repairs	11	$250,000	$267,500	$360,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	11	$250,000	$267,500	$360,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	11	$600,000	$642,000	$870,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	11	$4,000,000	$4,280,000	$5,760,000	Includes miscellaneous plant equipment repairs throughout the plant.
62	Return Sludge Pumping Station No. 4 Rehabilitation	12	$1,800,000	$1,926,000	$2,670,000	Rehabilitate return station No. 4. Replace 5 sludge pumps and VFDs. Replace valves and actuators (12). Replace MCC. Mitigate any corrosion or leaks. Miscellaneous pipe and concrete repairs
Plantwide	Plant Roof Repairs	12	$250,000	$267,500	$380,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	12	$250,000	$267,500	$380,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	12	$600,000	$642,000	$890,000	Includes miscellaneous concrete repairs throughout the plant.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
Plantwide	Miscellaneous Plant Equipment Repairs	12	$4,000,000	$4,280,000	$5,930,000	Includes miscellaneous plant equipment repairs throughout the plant.
63	Return Sludge Pumping Station No. 5 Rehabilitation	13	$1,800,000	$1,926,000	$2,750,000	Rehabilitate return station No. 5. Replace 5 sludge pumps and VFDs. Replace valves and actuators (12). Replace MCC. Mitigate any corrosion or leaks. Miscellaneous pipe and concrete repairs
Plantwide	Plant Roof Repairs	13	$250,000	$267,500	$390,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	13	$250,000	$267,500	$390,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	13	$600,000	$642,000	$920,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	13	$4,000,000	$4,280,000	$6,110,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	14	$250,000	$267,500	$400,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	14	$250,000	$267,500	$400,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	14	$600,000	$642,000	$950,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Emergency Plant Bypass - Design	14	$400,000	$428,000	$630,000	Design - Install a passive by-pass with disinfectant dosage from the southwest corner of JC1 to the existing 84" pipe that continues to the outfall structure at the SW corner of the plant site to be used in case of an emergency. Approximate length of new pipe required is 500 lf.
Plantwide	Miscellaneous Plant Equipment Repairs	14	$4,000,000	$4,280,000	$6,290,000	Includes miscellaneous plant equipment repairs throughout the plant.
17	JC 4 to Overflow Structure - 96-inch pipe - Design	15	$760,000	$813,200	$1,240,000	Design - Improvements consist of the installation of a second 96-inch pipe between JC 4 and the Overflow Structure.
Plantwide	Plantwide Paving Improvements	15	$4,000,000	$4,280,000	$6,480,000	Plantwide Paving Improvements
Plantwide	Plant Roof Repairs	15	$250,000	$267,500	$410,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	15	$250,000	$267,500	$410,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	15	$600,000	$642,000	$980,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	15	$4,000,000	$4,280,000	$6,480,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Emergency Plant Bypass - Construction	15	$2,000,000	$2,140,000	$3,240,000	Install a passive by-pass with disinfectant dosage from the southwest corner of JC1 to the existing 84" pipe that continues to the outfall structure at the SW corner of the plant site to be used in case of an emergency. Approximate length of new pipe required is 500 lf.
17	JC 4 to Overflow Structure - 96-inch pipe - Constrcution	16	$3,800,000	$4,066,000	$6,340,000	Construction - Improvements consist of the installation of a second 96-inch pipe between JC 4 and the Overflow Structure.
New Facility	Additional Denite Filters - Design	16	$1,000,000	$1,070,000	$1,670,000	Design - Addition of two denitrification filters. With the addition of sidestream treatment, additional filters are required as AADF exceeds 77 mgd.
Plantwide	Plant Roof Repairs	16	$250,000	$267,500	$420,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	16	$250,000	$267,500	$420,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	16	$600,000	$642,000	$1,010,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	16	$4,000,000	$4,280,000	$6,670,000	Includes miscellaneous plant equipment repairs throughout the plant.
New Facility	Additional Denite Filters - Construction	17	$5,200,000	$5,564,000	$8,930,000	Construction - Addition of two denitrification filters. With the addition of sidestream treatment, additional filters are required as AADF exceeds 77 mgd.
Plantwide	Plant Roof Repairs	17	$250,000	$267,500	$430,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	17	$250,000	$267,500	$430,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	17	$600,000	$642,000	$1,040,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	17	$4,000,000	$4,280,000	$6,870,000	Includes miscellaneous plant equipment repairs throughout the plant.
59	Screen and Grit Building No.1 New Grit Tanks - Design	18	$2,000,000	$2,140,000	$3,540,000	Design - Construct new more efficient grit tanks. Possible tecnology is the Eutek Headcell. Design will need ot include grit classification study and hydraulic model to determine extent of pumping required.
Plantwide	Plant Roof Repairs	18	$250,000	$267,500	$450,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	18	$250,000	$267,500	$450,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	18	$600,000	$642,000	$1,070,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	18	$4,000,000	$4,280,000	$7,080,000	Includes miscellaneous plant equipment repairs throughout the plant.
59	Screen and Grit Building No.1 New Grit Tanks - Construction	19	$16,800,000	$17,976,000	$30,610,000	Construction - Construct new more efficient grit tanks. Possible tecnology is the Eutek Headcell. Design will need ot include grit classification study and hydraulic model to determine extent of pumping required.
Plantwide	Plant Roof Repairs	19	$250,000	$267,500	$460,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	19	$250,000	$267,500	$460,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	19	$600,000	$642,000	$1,100,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	19	$4,000,000	$4,280,000	$7,290,000	Includes miscellaneous plant equipment repairs throughout the plant.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
Plantwide	Plant Roof Repairs	20	$250,000	$267,500	$470,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	20	$250,000	$267,500	$470,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	20	$600,000	$642,000	$1,130,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	20	$4,000,000	$4,280,000	$7,510,000	Includes miscellaneous plant equipment repairs throughout the plant.

The number of projects and cost shown for Year 0 were based on preliminary budget information provided by the City. These numbers may change depending on the final approval of the FY2019 CIP budget.

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Attachment 19-B:

CIP List arranged by Building Number

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Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
1	Raw Sewage PS Miscellaneous Repairs and Improvements	7	$840,000	$898,800	$1,080,000	Repair general air leaks, replace duct axial supply fan, scum pit sluice gate, lighting panel, transformer, and MCC-64 and MCC-65.
2	Junction Chamber No. 1 Improvements - Design	1	$100,000	$107,000	$107,000	Design - Misc. improvements to Junction Chamber No. 1 include replacing the influent sampling station, 4 overhead doors, 3 wet well exhaustr fans, wet well hatch covers, lighting and lighting panels (2), bubbler tube system, supply fan, PRVs, misc. electrical systems, and miscellaneous concrete repairs.
2	Junction Chamber No. 1 Improvements - Construction	2	$500,000	$535,000	$560,000	Construction - Misc. improvements to Junction Chamber No. 1 include replacing the influent sampling station, 4 overhead doors, 3 wet well exhaustr fans, wet well hatch covers, lighting and lighting panels (2), bubbler tube system, supply fan, PRVs, misc. electrical systems, and miscellaneous concrete repairs.
2	Junction Chamber No. 1 Aeration Improvements - Design	7	$600,000	$642,000	$770,000	Design - Aeration and mixing improvements consist of replacing the existing diffused air system which is reaching the end of its remaining useful life. Four new PD blowers, two 3600 cfm and two 4320 cfm, to replace the existing blowers, along with exposed air piping. New MCC's (3). (Note the second 4320 cfm blower is currently identified as a standby blower. As this blower is a considerably newer than the other blowers, it is recommended that the condition of this blower be evaluated during the design to confirm its replacement is necessary.) Additional improvements to Junction Chamber No. 1 include replacing sluice gates (17) and actuators (9).
2	Junction Chamber No. 1 Aeration Improvements - Construction	8	$3,000,000	$3,210,000	$3,950,000	Construction - Aeration and mixing improvements consist of replacing the existing diffused air system which is reaching the end of its remaining useful life. Four new PD blowers, two 3600 cfm and two 4320 cfm, to replace the existing blowers, along with exposed air piping. New MCC's (3). (Note the second 4320 cfm blower is currently identified as a standby blower. As this blower is a considerably newer than the other blowers, it is recommended that the condition of this blower be evaluated during the design to confirm its replacement is necessary.) Additional improvements to Junction Chamber No. 1 include replacing sluice gates (17) and actuators (9).
5	Screen & Grit Building No. 2 – Improved Ventilation - Design	1	$150,000	$160,500	$160,500	Design - Improvements to the ventilation system include replacement of existing exhaust fans and installation of new exhaust and supply fans in the open grit and screening areas to increase the rated air flow capacity and the air changes per hour in Screen & Grit Building No. 2 to be similar those currently in Screen & Grit Building No. 1.
5	Screen & Grit Building No. 2 Improvements - Design	2	$900,000	$963,000	$1,000,000	Design - Project includes equipment and pipe, electrical systems, concrete repairs and facility improvements. More specifically,replacement of backflow preventer, piping and tubing for all four grit tanks, (5) influent gate actuators, (8) grit pump and piping, sump pump and piping, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, switchgear 20 and MCC-21, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Additional building repairs include replacement of windows and doors and concrete repair.
5	Screen & Grit Building No. 2 – Improved Ventilation - Construction	2	$750,000	$802,500	$830,000	Construction - Improvements to the ventilation system include replacement of existing exhaust fans and installation of new exhaust and supply fans in the open grit and screening areas to increase the rated air flow capacity and the air changes per hour in Screen & Grit Building No. 2 to be similar those currently in Screen & Grit Building No. 1.
5	Screen & Grit Building No. 2 Improvements - Construction	3	$4,500,000	$4,815,000	$5,110,000	Construction - Project includes equipment and pipe, electrical systems, concrete repairs and facility improvements. More specifically,replacement of backflow preventer, piping and tubing for all four grit tanks, (5) influent gate actuators, (8) grit pump and piping, sump pump and piping, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, switchgear 20 and MCC-21, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Additional building repairs include replacement of windows and doors and concrete repair.
8	Junction Chamber No. 3 Miscellaneous Repairs	2	$360,000	$385,200	$400,000	Repair or replace mixers 1 and 2, sluice gate actuator, concrete repairs. Remove DAF scum and overflow pipe.
9	Primary Sedimentation Tanks No. 1 - No. 4 Improvements -Design	3	$700,000	$749,000	$800,000	Design - Improvements to the PSTs No. 1 - No. 4 including replacement of chain and flights, gearboxes and motors for influent sluice gate actuators (4), replacement of manual backflush sluice gates with motor operated gates (8); replacement of sludge blanket detector, rehab of scum pit; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Line deck on effluent side of tanks. Scum and gravity thickener overlfow pipe and valves to be replaced. 14" and 8" DAF scum and overflow pipes to be removed from ground up.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
9	Primary Sedimentation Tanks No. 1 - No. 4 Improvements - Construction	4	$3,600,000	$3,852,000	$4,210,000	Construction - Improvements to the PSTs No. 1 - No. 4 including replacement of chain and flights, gearboxes and motors for influent sluice gate actuators (4), replacement of manual backflush sluice gates with motor operated gates (8); replacement of sludge blanket detector, rehab of scum pit; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Line deck on effluent side of tanks. Scum and gravity thickener overlfow pipe and valves to be replaced. 14" and 8" DAF scum and overflow pipes to be removed from ground up.
9	PST Nos 1-4 Dewatering Pump Station - Design	7	$150,000	$160,500	$200,000	Design - The addition of a dewatering pump station, similar to that associated with PSTs 5-8. The pump station layout would be similar to that of PSTs 5-8, including a wet well with two (2) submersible pumps and a valve box. Piping modifications would consist of cutting in a tee to the existing drain line(s), and extending a new pipe from the branch of the tee to the new pumps station. Valves would be added to the existing and proposed lines and would be used to switch between gravity and pump dewatering.
9	PST Nos 1-4 Dewatering Pump Station - Construction	8	$750,000	$802,500	$990,000	Construction - The addition of a dewatering pump station, similar to that associated with PSTs 5-8. The pump station layout would be similar to that of PSTs 5-8, including a wet well with two (2) submersible pumps and a valve box. Piping modifications would consist of cutting in a tee to the existing drain line(s), and extending a new pipe from the branch of the tee to the new pumps station. Valves would be added to the existing and proposed lines and would be used to switch between gravity and pump dewatering.
10	Main Pump Station Discharge Channel Rehabilitation - Design	1	$600,000	$642,000	$642,000	Design - Discharge aeration improvements. Channel to be cleaned. Concrete rehabilitation and lining of the discharge channel and replacement of air process piping with SS pipe, (1) gate and actuator for 66" spike line to be replaced, inspection and rehabilitation of the 66-inch spike line. Design should include bypass pumping system for construction work in channel and inspection/rehab of spike line.
10	Main Pump Station Discharge Channel Rehabilitation - Construction	2	$4,000,000	$4,280,000	$4,410,000	Construction - Discharge aeration improvements. Channel to be cleaned. Concrete rehabilitation and lining of the discharge channel and replacement of air process piping with SS pipe, (1) gate and actuator for 66" spike line to be replaced, inspection and rehabilitation of the 66-inch spike line. Construction will require bypass pumping system for work in channel and inspection/rehab of spike line.
10	Main Pump Station Rehabilitation - Design	2	$2,000,000	$2,140,000	$2,210,000	Design - Replace pumps (7) and other equipment that is unreliable and no longer cost effective to maintain. Replace eddy current couplings with VFD's (3). Provide VFD's on constant speed pumps (2). Replace check valves and 11 ton hoist. Replacement of MCC's (5) , circuit breakers (5), emergency battery bank, dry transformers, lighting panel. Clean and inspect the main drain. Replace sluice gates and operators for Main Pump Station Influent Channel (7) and Main Drain. Replacement of spent cooling water pumps, flow recorder/totalizer, chilled water pumps motors (2), level controllers (2), condensing unit 1, backflow preventer, computer system hardware, oxygen dissolution control panel, deep bed scrubber, electric heat coils, water pressure tank, containment area waste dumping pit, Halon fire extinguisher system in computer room, fire hydrants, fuel oil storage tank, fire and sprinkler system, life line motor wet well, multigas detectors, base-7 radio unit, roof exhaust fans, overhead doors (2), security alarm system, return sludge control system, sampler station, sump pump (2), UPS radio system, water cooler & heater process, water break tank, sluice gate MPS-SG-10. Replace blowers (3) that are unreliable and no longer cost effective to maintain. Replace (1) dewatering pump. Demo existing scum pumps (2). Window replacement. Misc. concrete repairs
10	Main Pump Station Rehabilitation - Construction	3	$14,000,000	$14,980,000	$15,900,000	Construction - Replace pumps (7) and other equipment that is unreliable and no longer cost effective to maintain. Replace eddy current couplings with VFD's (3). Provide VFD's on constant speed pumps (2). Replace check valves and 11 ton hoist. Replacement of MCC's (5) , circuit breakers (5), emergency battery bank, dry transformers, lighting panel. Clean and inspect the main drain. Replace sluice gates and operators for Main Pump Station Influent Channel (7) and Main Drain. Replacement of spent cooling water pumps, flow recorder/totalizer, chilled water pumps motors (2), level controllers (2), condensing unit 1, backflow preventer, computer system hardware, oxygen dissolution control panel, deep bed scrubber, electric heat coils, water pressure tank, containment area waste dumping pit, Halon fire extinguisher system in computer room, fire hydrants, fuel oil storage tank, fire and sprinkler system, life line motor wet well, multigas detectors, base-7 radio unit, roof exhaust fans, overhead doors (2), security alarm system, return sludge control system, sampler station, sump pump (2), UPS radio system, water cooler & heater process, water break tank, sluice gate MPS-SG-10. Replace blowers (3) that are unreliable and no longer cost effective to maintain. Replace (1) dewatering pump. Demo existing scum pumps (2). Window replacement. Misc. concrete repairs

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
11	HPO Reactor Improvements - Design	3	$1,700,000	$1,819,000	$1,930,000	Design - Improvements in the HPO Reactors consist of improvements to the influent and effluent channels which include cleaning, concrete repair and channel lining, new SS aeration system, replacement of 12 gates and actuators (4 reactor influent, 2 swing reactor, 3 reactor NIT influent, 2 side spike line, and 1 carb inf to reactor), meters, and sampling equipment. Improvements to the reactors consist of cleaning of the existing tanks, structural rehabilitation of the tanks (repair to concrete surfaces above the normal water line), replacing the existing surface aerators with larger mechanical aerators in stages 2-4 (3 reactors), replacing existing instrumentation and electrical systems upgrades. The aerator in the first mixing zone will be replaced with a submerged mixer, the areators in stages 2-4 are larger to accomodate higher oxygen transfer. Additional improvements include replacing the dewatering main drain sluice gate and actuator, upgrade butterfly valves to electric butterfly valves, removal of alum pipe on reactor deck, replacing influent and effluent stop logs and actuators, replacing instrumentation including rate controllers, gas monitoring, air meters, step-feed meters, high water alarm, replacing MLSS sample pumps, and painting process air piping and spike line in influent channel. Design shall include identifying bypass pumping requirements. Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs.
11	HPO Reactor Improvements - Construction	4	$11,000,000	$11,770,000	$12,870,000	Construction - Improvements in the HPO Reactors consist of improvements to the influent and effluent channels which include cleaning, concrete repair and channel lining, new SS aeration system, replacement of 12 gates and actuators (4 reactor influent, 2 swing reactor, 3 reactor NIT influent, 2 side spike line, and 1 carb inf to reactor), meters, and sampling equipment. Improvements to the reactors consist of cleaning of the existing tanks, structural rehabilitation of the tanks (repair to concrete surfaces above the normal water line), replacing the existing surface aerators with larger mechanical aerators in stages 2-4 (3 reactors), replacing existing instrumentation and electrical systems upgrades. The aerator in the first mixing zone will be replaced with a submerged mixer, the aerators in stages 2-4 are larger to accomodate higher oxygen transfer. Additional improvements include replacing the dewatering main drain sluice gate and actuator, upgrade butterfly valves to electric butterfly valves, removal of alum pipe on reactor deck, replacing influent and effluent stop logs and actuators, replacing instrumentation including rate controllers, gas monitoring, air meters, step-feed meters, high water alarm, replacing MLSS sample pumps, and painting process air piping and spike line in influent channel. Construction work within influent and effluent channel will require bypass pumping. Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs.
12	Final Sedimentation Tanks No.1 - No. 12 Improvements - Phase III	1	$2,300,000	$2,461,000	$2,461,000	Perform remaining work at FSTs 1-6 that was not completed during previous project phases. Work includes replacing process air piping for tanks 1-6, baffle walls in tanks 1-6, (48) influent sluice gates and actuators; influent stop log grooves, stems for the (2) manual sluice gates used for scum manhole, (12) scum sludge gates and acuators, and (4) sluice gates in influent channel used to drain the channel. Scum tilting weirs to be removed/demolished. Concrete repairs. Handrail repair.
16	Post Aeration Chlorination Improvements - Design	3	$250,000	$267,500	$290,000	Design - Improvements include relocating the post aeration system from the head of the chlorine contact tanks to the effluent channel. Misc. process equipment improvements including replacing post aeration tank gearboxes, post aeration spent cooling water mag meter and pipe, sample pumps, meters, temperature indicator, process air piping and a post aeration tank dewatering pump.
16	Post Aeration Chlorination Improvements - Construction	4	$1,750,000	$1,872,500	$2,050,000	Construction - Improvements include relocating the post aeration system from the head of the chlorine contact tanks to the effluent channel. Misc. process equipment improvements including replacing post aeration tank gearboxes, post aeration spent cooling water mag meter and pipe, sample pumps, meters, temperature indicator, process air piping and a post aeration tank dewatering pump.
16	Disinfection Improvements - Design	8	$1,200,000	$1,284,000	$1,580,000	Design - Disinfection facility improvements consist of replacing the existing chlorine gas disinfection system with a new sodium hypochlorite disinfection system. The sodium hypochlorite disinfection system includes liquid chemical storage, chemical transfer pumps, chemical feed pumps, process pipe, instrumentation and controls. Improvements would include demolition of the existing chlorine gas and sodium dioxide feed equipment. Additional disinfection facilities improvements include installation of baffle walls to improve disinfection performance. Perform misc. concrete repairs within the contact tank.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
16	Disinfection Improvements - Construction	9	$5,400,000	$5,778,000	$7,320,000	Construction - Disinfection facility improvements consist of replacing the existing chlorine gas disinfection system with a new sodium hypochlorite disinfection system. The sodium hypochlorite disinfection system includes liquid chemical storage, chemical transfer pumps, chemical feed pumps, process pipe, instrumentation and controls. Improvements would include demolition of the existing chlorine gas and sodium dioxide feed equipment. Additional disinfection facilities improvements include installation of baffle walls to improve disinfection performance. Perform misc. concrete repairs within the contact tank.
17	JC 4 to Overflow Structure - 96-inch pipe - Design	15	$760,000	$813,200	$1,240,000	Design - Improvements consist of the installation of a second 96-inch pipe between JC 4 and the Overflow Structure.
17	JC 4 to Overflow Structure - 96-inch pipe - Constrcution	16	$3,800,000	$4,066,000	$6,340,000	Construction - Improvements consist of the installation of a second 96-inch pipe between JC 4 and the Overflow Structure.
18	Overflow Structure Improvements	2	$300,000	$321,000	$340,000	Design and construction of improvements which include replacement of the existing 4 manual sluice gates at Overflow Structure with motor operated gates tied to SCADA and operated based on either level or flow. Replace the sample pump. Replace existing 5 kVA transformer. Misc concrete repair to Overflow Structure.
20	Primary Sludge Pump Station No. 1 Improvements	4	$500,000	$535,000	$590,000	Replace dry-pit pumps (2), valves, (1) scum gate and actuator, (1) dewatering gate and actuator, misc. pipe, and instrumentation upgrades. Misc. building upgrades including new windows and doors.
21	Digester No. 4 Rehabilitation - Design & Construction	0	$1,600,000	$1,712,000	$1,712,000	Rehab of Digester No. 4, including tank cleaning, recoat tank interior and exterior, replace gas holder and associated piping, new sludge mixing system, cover level transmitter, add gas meter.
21	Digester Nos. 1-3 Rehabilitation - Design	2	$750,000	$802,500	$830,000	Design - Rehab of Digester Nos. 1 through 3, including tank cleaning, recoat tank interior and exterior, replace gas holder and associated piping and replace flame trap assembly (Digester Nos. 1 and 2 only), new sludge mixing system, pressure relief valves, cover level transmitter, add gas meter. Design should consider issuing a single construction contract for the improvements to Digester Nos. 1 through 3, but allow the construction to be phased if preferred by the City.
21	Digester No. 2 Rehabilitation - Construction	3	$1,600,000	$1,712,000	$1,820,000	Construction - Rehab of digester, including tank cleaning, recoat tank interior (compatable with acid-gas phase digestion) and exterior, replace gas holder and associated piping, new sludge mixing system, replace flame trap assembly on cover, pressure relief valve, cover level transmitter, add gas meter.
21	Digester No. 5 Rehabilitation - Design	3	$480,000	$513,600	$550,000	Design - Rehab of Digester No. 5, including tank cleaning; recoat tank interior and exterior; replace cover with gas holder and associated piping (sludge piping may be plugged to struvite); new sludge mixing system; replace flame trap assembly, pressure relief valves, cover level transmitter; add gas meter.
21	Digester No. 1 Rehabilitation	3	$600,000	$642,000	$690,000	Construction - Rehab of digester, including tank cleaning, recoat tank interior (compatable with acid-gas phase digestion) and exterior, new sludge mixing system, replace flame trap assembly, pressure relief valves, cover level transmitter, add gas meter. Consider single construction contract for the improvements to Digester Nos. 1 through 4.
21	Digester No. 3 Rehabilitation	3	$620,000	$663,400	$710,000	Construction includes cleaning and tank interior and exterior recoating, new sludge mixing system. (Note - sludge piping was replaced in 2013.)
21	Digester No. 5 Rehabilitation - Construction	4	$2,400,000	$2,568,000	$2,810,000	Construction - Rehab of Digester No. 5, including tank cleaning; recoat tank interior and exterior; replace cover with gas holder and associated piping (sludge piping may be plugged to struvite); new sludge mixing system; replace flame trap assembly, pressure relief valves, cover level transmitter; add gas meter.
25	DARs Upgrades - Design	2	$1,900,000	$2,033,000	$2,100,000	Design - Improvements to the DARs Nos. 2-4 include demolition and cleaning of the existing equipment/tanks; new fine bubble diffused aeration, anoxic mixers, internal mixed liquor recycle pumps; miscellaneous concrete and handrail repair, pads and pedestals for new equipment and pipe; process pipe; and instrumentation including O2 meters. Replace influent and effluent gate actuators (16). It is recommended that changes to the aeration equipment be re-evaluated under this design (as described in the BNR Memo).
25	DAR Train #1 Internal Recycle Magnetic Flow Meter Installation	3	$60,000	$64,200	$70,000	Install a magnetic flow meter on the internal recycle conduit of Train #1 to monitor and control internal recycle.
25	DARs Upgrades - Construction	3	$9,500,000	$10,165,000	$10,790,000	Construction - Improvements to the DARs Nos. 2-4 include demolition and cleaning of the existing equipment/tanks; new fine bubble diffused aeration, anoxic mixers, internal mixed liquor recycle pumps; miscellaneous concrete and handrail repair, pads and pedestals for new equipment and pipe; process pipe; and instrumentation including O2 meters. Replace influent and effluent gate actuators (16). It is recommended that changes to the aeration equipment be re-evaluated under this design (as described in the BNR Memo). Note that project cost listed differs from that in the Tech Memo as the CIP includes additional work/equipment replacement identified by the COT staff and in the asset inventory, whereas the Tech Memo focused on process modification costs

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
26	3rd Gravity Thickener - Design	6	$660,000	$706,200	$820,000	Design- A new sludge thickener train consisting of a new gravity thickener tank, two thickened waste activated sludge pumps, and associated appurtenances is recommended to provide redundancy and improve loading rates. The new sludge thickener train would be sized equal to the existing gravity thickeners and pumps. Replacement of the existing polymer feed system to be performed as a separate project, however this project will include a new polymer feed pump dedicated to the new gravity thickener.
26	3rd Gravity Thickener - Construction	7	$3,300,000	$3,531,000	$4,220,000	Construction- A new sludge thickener train consisting of a new gravity thickener tank, two thickened waste activated sludge pumps, and associated appurtenances is recommended to provide redundancy and improve loading rates. The new sludge thickener train would be sized equal to the existing gravity thickeners and pumps. Replacement of the existing polymer feed system to be performed as a separate project, however this project will include a new polymer feed pump dedicated to the new gravity thickener.
28	Digester Control Building A Improvements - Design	2	$900,000	$963,000	$1,000,000	Design - Restore building and replace process equipment, piping, and electrical components. Replacement includes sludge flow mag meter, gas condensate tanks, digested sludge pumps No. 1 & 2, gas condensate collectors, sludge gas mixing compressors (6), recirculation pumps, acid-phase transfer pump & grinder; sludge, gas, secondary water and fuel piping and valves, MCC-62B.
28	Digester Control Building A Improvements - Construction	3	$4,500,000	$4,815,000	$5,110,000	Construction - Restore building and replace process equipment, piping, and electrical components. Replacement includes sludge flow mag meter, gas condensate tanks, digested sludge pumps No. 1 & 2, gas condensate collectors, sludge gas mixing compressors (6), recirculation pumps, acid-phase transfer pump & grinder; sludge, gas, secondary water and fuel piping and valves, MCC-62B.
29	Digester Control Building B Improvements - Design	3	$400,000	$428,000	$460,000	Design - Restore building and replace process equipment, piping, and electrical components. Air compressor; sludge, gas, water and fuel piping and valves
29	Digester Control Building B Improvements - Construction	4	$1,900,000	$2,033,000	$2,230,000	Construction - Restore building and replace process equipment, piping, and electrical components. Air compressor; sludge, gas, water and fuel piping and valves
30	Sludge Treatment Building Miscellaneous Repairs - Design	1	$130,000	$139,100	$139,100	Design - Recommended improvements also include replacement of the existing polymer feed system with a new polymer feed system consisting of bulk storage tanks, liquid polymer activation systems, aging tanks, and activated polymer feed pumps dedicated to each gravity thickener. Remove dewatering pumps.
30	Sludge Treatment Building Miscellaneous Repairs - Construction	2	$625,000	$668,750	$690,000	Construction - Recommended improvements also include replacement of the existing polymer feed system with a new polymer feed system consisting of bulk storage tanks, liquid polymer activation systems, aging tanks, and activated polymer feed pumps dedicated to each gravity thickener. Remove dewatering pumps.
31	Side Stream Treatment - Design	6	$1,800,000	$1,926,000	$2,240,000	Design - Improvements recommended consist of the addition of a sidestream deammonification process to remove approximately 80-85% NH4-N and 70-75% TKN from the sidestream. Improvements include retrofitting two (2) of the existing twelve north final settling tanks, one as a sidestream equalization basin and the other as a biofilm reactor basin (e.g. ANITA™ Mox MBBR); building to house the blowers and pumps associated with the reactor; process pipe; instrumentation and controls.
31	Side Stream Treatment - Construction	7	$9,000,000	$9,630,000	$11,500,000	Construction - Improvements consist of the addition of a sidestream deammonification process to remove approximately 80-85% NH4-N and 70-75% TKN from the sidestream. Improvements include retrofitting two (2) of the existing twelve north final settling tanks, one as a sidestream equalization basin and the other as a biofilm reactor basin (e.g. ANITA™ Mox MBBR); building to house the blowers and pumps associated with the reactor; process pipe; instrumentation and controls.
32	Sludge Dewatering Facility Rehabilitation - Design	1	$2,700,000	$2,889,000	$2,889,000	Design - Recommended improvements identified in Hazen and Sawyer study performed in FY 11. Scope of work includes a new building, polymer activation system, centrifuge technology, and all associated piping, sludge handling, pumping, and electrical equipment.
32	Sludge Dewatering Facility Rehabilitation - Construction	2	$13,500,000	$14,445,000	$14,880,000	Construction - Recommended improvements identified in Hazen and Sawyer study performed in FY 11. Scope of work includes a new building, polymer activation system, centrifuge technology, and all associated piping, sludge handling, pumping, and electrical equipment.
33	Waste Gas Burners for Digester Tanks No. 1 - No. 7 Rehabilitation	0	$900,000	$963,000	$963,000	Project includes the replacement of pressure relief and flame trap assemblies, drip trap manual operation, flame check, waste gas burner and ignition systems, plug valves and stainless steel pipes.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
36	Junction Chamber No. 1 Odor Control Replacement - Design	1	$850,000	$909,500	$909,500	Design - Odor control system replacement consist of hybrid system utilizing biotrickling filters followed by chemical scrubbers for polishing. The system would include a 15,000 cfm air handling fan, parallel biological towers, one multi-stage chemical scrubber, recirculation pumps for each tower, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, blowdown pump station, ductwork, and other associated equipment, as well as misc. concrete repairs. Design should include performance testing by the manufacturer(s) to confirm expected hydrogen sulfide removal.
36	Junction Chamber No. 1 Odor Control Replacement - Construction	2	$4,250,000	$4,547,500	$4,690,000	Construction - Odor control system replacement consist of hybrid system utilizing biotrickling filters followed by chemical scrubbers for polishing. The system would include a 15,000 cfm air handling fan, parallel biological towers, one multi-stage chemical scrubber, recirculation pumps for each tower, chemical storage tanks, chemical containment, chemical feed pumps, wash water connection, blowdown pump station, ductwork, and other associated equipment; misc. concrete repairs.
40	Operations and Maintenance Building MCC Replacement	8	$350,000	$374,500	$470,000	Replace MCC-26, MCC-27, MCC-28.
41	O2 Plant No. 1 Rehabilitation - Design and GMP Development	6	$900,000	$963,000	$1,120,000	Design -Improvements to the High Purity Oxygen Generation System No. 1 should be similar to the recently completed rehabilitation of the High Purity Oxygen Generation System No. 2 and includes replacement of process pipe, valves, and valve actuators; repairs to the cold box; replacement of the compressor; and new instrumentation and electrical components.
41	O2 Plant No. 1 Rehabilitation - Construction	7	$4,500,000	$4,815,000	$5,750,000	Construction -Improvements to the High Purity Oxygen Generation System No. 1 should be similar to the recently completed rehabilitation of the High Purity Oxygen Generation System No. 2 and includes replacement of process pipe, valves, and valve actuators; repairs to the cold box; replacement of the compressor; and new instrumentation and electrical components.
43	Chemical Storage Tanks Demolition	10	$300,000	$321,000	$420,000	(9) Alum Storage Tanks and (1) Brewery Waste Tank need to be removed.
43	Methanol Storage Tank Replacement	10	$280,000	$299,600	$400,000	Replace existing 100,000 gal. steel methanol storage tank No. 1 with two 50,000 gal. tanks to povide redundancy to the process.
44	Switch Gear Facility Rehabilitation - Design	4	$500,000	$535,000	$590,000	Design -Facility is generally in poor condition and will need to be replaced. Construction includes 24 new switchgear and 5000 sf building.
44	Switch Gear Facility Rehabilitation - Construction	5	$5,000,000	$5,350,000	$6,030,000	Construction - Facility is generally in poor condition and will need to be replaced. Construction includes 24 new switchgear and 5000 sf building.
47	Filter Building No. 2 Improvements - Design	2	$460,000	$492,200	$510,000	Design - Improvements to Filter Building No. 2 include replacing backwash pumps (3) and blowers (3); influent channel gate, pipe, replacing one 72" and one 48" mag meters, MCC 85 and MCC 86 replacement, roof repairs, skylight replacement, concrete repairs.
47	Filter Building No. 2 Improvements - Construction	3	$2,300,000	$2,461,000	$2,620,000	Construction - Improvements to Filter Building No. 2 include replacing backwash pumps (3) and blowers (3); influent channel gate, pipe, replacing one 72" and one 48" mag meters, MCC 85 and MCC 86 replacement, roof repairs, skylight replacement, concrete repairs.
48	Denite Filters No. 21 thru No. 26 and No. 31 thru No. 36 Improvements - Design	2	$760,000	$813,200	$840,000	Design - Replace valves and actuators. Valves include (12) backwash water valves, (12) effluent valves, (12) backwash drain valves, (12) influent valves, (2) backwash flow regulating valves. Replace (12) influent gate actuators. Air piping and dressers need to be painted. Replace pumps including (2) filter drain pumps, (2) sump pumps need to be replaced, (3) backwash pumps. Replace two 18" mag meters. Paint backwash piping on outside over filters. Misc. concrete repairs.
48	Denite Filters No. 21 thru No. 26 and No. 31 thru No. 36 Improvements - Construction	3	$3,800,000	$4,066,000	$4,320,000	Construction - Replace valves and actuators. Valves include (12) backwash water valves, (12) effluent valves, (12) backwash drain valves, (12) influent valves, (2) backwash flow regulating valves. Replace (12) influent gate actuators. Air piping and dressers need to be painted. Replace pumps including (2) filter drain pumps, (2) sump pumps need to be replaced, (3) backwash pumps. Replace two 18" mag meters. Paint backwash piping on outside over filters. Misc. concrete repairs.
49	Junction Chamber No. 6 Miscellaneous Repairs	6	$300,000	$321,000	$380,000	Repair or replace sluice gates (4).
50	Junction Chamber No. 5 Improvements	5	$1,130,000	$1,209,100	$1,370,000	Install a flow meter in the Junction Chamber No. 5 to be able to have a constant primary effluent feeding to the Nitrification Pump Station. Repair/replace mag meter JC-5 FE-301, two spike line valves, five actuators, exhaust fan. Concrete repairs.
54	Dried Sludge Control Building Improvements	2	$1,500,000	$1,605,000	$1,660,000	Replace bed polymer storage tanks and piping, water line and blended polymer pipe, pipes that feed sludge in the tanks, sump pump. Replace MCC-501, MCC-501A & MCC-501B.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
55	Sludge Drying Bed Rehabilitation, Phase II	1	$900,000	$963,000	$963,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase III	2	$900,000	$963,000	$1,000,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase IV	3	$900,000	$963,000	$1,030,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase V	4	$900,000	$963,000	$1,060,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase VI	5	$900,000	$963,000	$1,090,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase VII	6	$900,000	$963,000	$1,120,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase VIII	7	$900,000	$963,000	$1,150,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
55	Sludge Drying Bed Rehabilitation, Phase IX	9	$900,000	$963,000	$1,220,000	This project provides for the rehabilitation of four (4) sludge drying beds per year. The filter media within several of the drying beds is clogged reducing efficiency of the sludge dewatering process. The rehabilitation of the sludge drying beds will be completed over several fiscal years and each phase will address the drying beds that are in most severe need of rehabilitation.
57	Nitrification Pump Station Improvements - Design	3	$450,000	$481,500	$520,000	Design - Station needs to be rehabilitated; all pumps replaced (7) and design improvements made to prevent repeated pump failures
57	Nitrification Pump Station Improvements - Construction	4	$4,500,000	$4,815,000	$5,270,000	Construction -Replaced submersible pumps (7), repair or replace valves, upgrade instrumentation an electrical systems
58	DAR Blowers Replacement - Design	4	$600,000	$642,000	$710,000	Design - Blowers are constant speed; should be replaced with blowers that match air demands associated with DARS improvements and are adjustable. Replace transformers T-8A & 8B.
58	DAR Blowers Replacement - Construction	5	$5,800,000	$6,206,000	$6,990,000	Construction - Blowers are constant speed; should be replaced with blowers that match air demands associated with DARS improvements and are adjustable. Replace transformers T-8A & 8B.
59	Screen & Grit Building No. 1 - MCC 29 Replacement	0	$400,000	$428,000	$428,000	Replace MCC 29
59	Grit Washer Replacement, Phase II - Construction	0	$2,700,000	$2,889,000	$2,889,000	Construction - Grit washers for both Screen & Grit facilities have reached the end of their useful life. This equipment will be replaced through 2 phases. Phase II will be to replace the grit washers for Building No 1 - NEW screen & grit.
59	Screen & Grit Building No. 1 Improvements - Design	3	$800,000	$856,000	$910,000	Design - Project includes equipment and pipe, electrical systems, ventilation improvements, concrete repairs and facility improvements. More specifically, replacing washer compactors, (6) influent gate actuators, (8) grit pumps, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Ceiling pipe penetration needs to be repaired. Grit pumps piping needs to be replaced. Influent and effluent gate actuators to be replaced.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
59	Screen & Grit Building No. 1 Improvements - Construction	4	$4,000,000	$4,280,000	$4,680,000	Construction - Project includes equipment and pipe, electrical systems, ventilation improvements, concrete repairs and facility improvements. More specifically, replacing washer compactors, (6) influent gate actuators, (8) grit pumps, (4) overhead doors, cranes, grit tank rakes and drivers, collectors, baffles and guides, organic return flow pipe, air piping and valves, drain gate and intermediate gate including acuators in the influent channel, and downlegs of the air process piping at the effluent channel. Replace roof drain/ vent pipe, effluent water pipe. Lighting features need to be replaced. Rake support beams to be sand blasted and painted. Electrical conduits need to be replaced. Ceiling pipe penetration needs to be repaired. Grit pumps piping needs to be replaced. Influent and effluent gate actuators to be replaced.
59	Screen and Grit Building No.1 New Grit Tanks - Design	18	$2,000,000	$2,140,000	$3,540,000	Design - Construct new more efficient grit tanks. Possible tecnology is the Eutek Headcell. Design will need ot include grit classification study and hydraulic model to determine extent of pumping required.
59	Screen and Grit Building No.1 New Grit Tanks - Construction	19	$16,800,000	$17,976,000	$30,610,000	Construction - Construct new more efficient grit tanks. Possible tecnology is the Eutek Headcell. Design will need ot include grit classification study and hydraulic model to determine extent of pumping required.
61	Final Sedimentation Tanks Improvements No. 13 thru No. 20 Improvements - Design	5	$600,000	$642,000	$730,000	Design - Project provides for replacement of chains and drive system for final sedimentation tanks 13-20. Also replace end-of-life motors, sluice gates (68), and gears. Mitigate any corrosion or leaks. Perform concrete repairs. Evaluate alternatives for automatic sludge blanket monitoring. Replace the rate controller equipment in the secondary effluent control channel including the secondary control weir, motor operated gear boxes, and gate operator motors. Instrumentation upgrades include automatic sludge blanket monitors, return sludge and waste sludge flow indicating transmitters, pump speed indication, and return sludge solids concentration monitoring. Design should evaluate options to automate return sludge pumping including SCADA integration with HPO and DAR MLSS monitoring equipment. .
61	Final Sedimentation Tanks Improvements No. 13 thru No. 20 Improvements - Construction	6	$6,000,000	$6,420,000	$7,450,000	Construction -Project provides for replacement of chains and drive system for final sedimentation tanks 13-20. Also replace end-of-life motors, sluice gates (68), and gears. Mitigate any corrosion or leaks. Perform concrete repairs. Provide for automatic sludge blanket monitoring. Replace the rate controller equipment in the secondary effluent control channel including the secondary control weir, motor operated gear boxes, and gate operator motors. Instrumentation upgrades include automatic sludge blanket monitors, return sludge and waste sludge flow indicating transmitters, pump speed indication, and return sludge solids concentration monitoring.
62	Return Sludge Pumping Station No. 4 Rehabilitation	12	$1,800,000	$1,926,000	$2,670,000	Rehabilitate return station No. 4. Replace 5 sludge pumps and VFDs. Replace valves and actuators (12). Replace MCC. Mitigate any corrosion or leaks. Miscellaneous pipe and concrete repairs
63	Return Sludge Pumping Station No. 5 Rehabilitation	13	$1,800,000	$1,926,000	$2,750,000	Rehabilitate return station No. 5. Replace 5 sludge pumps and VFDs. Replace valves and actuators (12). Replace MCC. Mitigate any corrosion or leaks. Miscellaneous pipe and concrete repairs
71	Mixed Sludge Pumping Station Improvements	1	$520,000	$556,400	$556,400	Replace sludge transfer pumps. Replace exhaust fan and repair duct work
72	Digester No. 7 Rehabilitation - Design	1	$640,000	$684,800	$684,800	Design - Gas holder cover to replace existing floating cover, roof, stainless gas mixing/piping to replace existing pipe, and components; repair hole in the tank sidewall; recoat tank interior; repair/replace digested sludge pumps, gas mixing comp, recirculation pumps, and water heater feed pumps. Perform concrete repairs.
72	Digester No. 7 Rehabilitation - Construction	2	$3,250,000	$3,477,500	$3,590,000	Construction - Gas holder cover to replace existing floating cover, roof, stainless gas mixing/piping to replace existing pipe, and components; repair hole in the tank sidewall; recoat tank interior and exterior; repair/replace digested sludge pumps, gas mixing comp, recirculation pumps, and water heater feed pumps. Perform concrete repairs.
72	Digester No. 6 Rehabilitation - Design	4	$260,000	$278,200	$310,000	Design - Includes cleaning and recoating tank interior and exterior, and misc. improvements. Digester 6 already has stainless gas mixing/piping from the 2012 rehab .
72	Digester No. 6 Rehabilitation - Construction	5	$1,300,000	$1,391,000	$1,570,000	Construction - Includes cleaning and recoating tank interior and exterior, and misc. improvements. Digester 6 already has stainless gas mixing/piping from the 2012 rehab.
74	Digester Control Building C Improvements - Design	4	$800,000	$856,000	$940,000	Replace sludge pump, recirculation pumps, misc. pipe repairs and hot water pumps; sludge, gas, water and fuel piping and valves; building improvements
74	Digester Control Building C Improvements - Construction	5	$4,000,000	$4,280,000	$4,820,000	Replace sludge pump, recirculation pumps, misc. pipe repairs and hot water pumps; sludge, gas, water and fuel piping and valves; building improvements
78	Standby Power System Improvements - Design	0	$400,000	$428,000	$428,000	Design - To avoid load shedding under generator failure, the standby power capacity should be extended to cover a 2MW standby generator failure. This will raise the standby capacity to 10MW, giving a N+1 capability. One 2MW (Tier 4) generator can be installed in a separate walk-in enclosure that is hurricane rated. Additional fuel storage tanks (68,000 gals total) are required to bring the total fuel storage capacity of the standby system to 5 days, while also allowing for an additional future generator.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
78	Standby Power System Improvements - Construction	1	$3,200,000	$3,424,000	$3,424,000	Construction - To avoid load shedding under generator failure, the standby power capacity should be extended to cover a 2MW standby generator failure. This will raise the standby capacity to 10MW, giving a N+1 capability. One 2MW (Tier 4) generator can be installed in a separate walk-in enclosure that is hurricane rated. Additional fuel storage tanks (68,000 gals total) are required to bring the total fuel storage capacity of the standby system to 5 days, while also allowing for an additional future generator.
80	Biogas Use Improvements - Design	1	$3,250,000	$3,477,500	$3,477,500	Design - Cost is based on the election to pursue RNG biogas utilization. The RNG alternative includes the removal of existing biogas fueled engines and heat recovery equipment; installation of new biogas to RNG treatment, compression, storage, transport, and dispensing equipment; the use natural gas to provide digester heating; instrumentation, electrical, and safety systems upgrades.
80	75 KVA Dry Transformer T Replacement	2	$15,000	$16,050	$20,000	Repair/replace 75 KVA Dry Transformer T
80	Biogas Use Improvements - Construction	3	$16,200,000	$17,334,000	$18,390,000	Construction - Cost is based on the election to pursue RNG biogas utilization. The RNG alternative includes the removal of existing biogas fueled engines and heat recovery equipment; installation of new biogas to RNG treatment, compression, storage, transport, and dispensing equipment; the use natural gas to provide digester heating; instrumentation, electrical, and safety systems upgrades.
80	Digester gas compressor and drying system	3	$310,000	$331,700	$360,000	Gas compressor and drying systems includes electric motors, motor starters, steel bases, expansion joints, check valves, butterfly valves, bypass throttling valves with actuators, multi-stage centrifugal gas compressors, heat exchangers, coalescers, chillers, interconnecting piping, wiring, electrical conduit and related supports, structural steel supports for each component, control panels, gas temperature and pressure gauges.
82	Primary Sedimentation Tank No. 5 thru No. 8 Improvements - Design	6	$700,000	$749,000	$870,000	Design of improvements include replacement of chain and flights, gearboxes and motors for influent sluice gates (4), replacement of manual backflush sluice gates with motor operated gates (8); provide sludge blanket level monitors to improve operations, rehab of scum pit; rehab of baffles; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Paint scum discharge piping from FSTs 13-20. Replace dewatering line from DARs (16") and nit waste line (6"). Replace Scum Valves.
82	Primary Sedimentation Tank No. 5 thru No. 8 Improvements - Construction	7	$3,600,000	$3,852,000	$4,600,000	Construction of improvements include replacement of chain and flights, gearboxes and motors for influent sluice gates (4), replacement of manual backflush sluice gates with motor operated gates (8); provide sludge blanket level monitors to improve operations, rehab of scum pit; rehab of baffles; misc. concrete repairs to the tanks with coating. Effluent weirs and trough to be replaced. Paint scum discharge piping from FSTs 13-20. Replace dewatering line from DARs (16") and nit waste line (6"). Replace Scum Valves.
83	Primary Sludge Pump Station No. 2 Improvements	4	$620,000	$663,400	$730,000	Replace pumps (2), sluice gates and actuators (3), and instrumentation upgrades. Replace Existing MCC-48 & MCC-49. Concrete repairs
85	Switchgear No. 60 Generator Monitoring Panel Replacement	2	$500,000	$535,000	$560,000	Replace Switchgear No. 60 Generator Monitoring Panel
14, 15	Denitrification Filter Improvements - Filters No. 1 thru No. 20 - Design	1	$800,000	$856,000	$856,000	Design - Replace control BFVs w/ pneumatic actuators, replace air piping. BFVs include (20) backwash drain valves, (40) backwash water valves, (20) influent valves, (40) effluent valves. Replace (20) influent gate actuators. Replace (3) backwash, (2) effluent water pumps, and (3) sump pumps. Replace (2) blowers. Replace supply and exhaust fans, 5 ton hoist, (2) flow meters. Misc. ancillary equipment and facility repairs including concrete rehabilitation and expansion joint repair, pipe replacement, paint backwash piping on outside over filters, Control Room ceiling; door and window replacement. Removal of polymer equipment from the pump room (no longer in use). Replace (2) sampler stations. Replace MCC 57, MCC 58-A . Repair/replace the level control system, control console.
14, 15	Denitrification Filter Improvements - Filters No. 1 thru No. 20 - Construction	2	$6,600,000	$7,062,000	$7,280,000	Construction - Replace control BFVs w/ pneumatic actuators, replace air piping. BFVs include (20) backwash drain valves, (40) backwash water valves, (20) influent valves, (40) effluent valves. Replace (20) influent gate actuators. Replace (3) backwash, (2) effluent water pumps, and (3) sump pumps. Replace (2) blowers. Replace supply and exhaust fans, 5 ton hoist, (2) flow meters. Misc. ancillary equipment and facility repairs including concrete rehabilitation and expansion joint repair, pipe replacement, paint backwash piping on outside over filters, Control Room ceiling; door and window replacement. Removal of polymer equipment from the pump room (no longer in use). Replace (2) sampler stations. Replace MCC 57, MCC 58-A. Repair/replace the level control system, control console.
22, 23, 24	Return Sludge Pumping Stations No. 1, No. 2 and No. 3 Rehabilitation - Design	5	$1,200,000	$1,284,000	$1,450,000	Design - Replace piping, (12 per PS) valves and actuators, supply fans, (3) 2-ton Hoist, sump pumps, (5 per PS) sludge pumps, gates, (2) 24" return sludge meters, (2) 10" waste sludge flowmeters, SWGR-40, and MCC-43, MCC-45, (5 per PS) VFD's, lighting panels and misc. electrical components, roof repairs, in Return Sludge Pump Stations No. 1, No. 2, and No. 3. Miscellaneous concrete repairs.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
22, 23, 24	Return Sludge Pumping Stations No. 1, No. 2 and No. 3 Rehabilitation - Construction	6	$6,000,000	$6,420,000	$7,450,000	Construction - Replace piping, (12 per PS) valves and actuators, supply fans, (3) 2-ton Hoist, sump pumps, (5 per PS) sludge pumps, gates, (2) 24" return sludge meters, (2) 10" waste sludge flowmeters, SWGR-40, and MCC-43, MCC-45, (5 per PS) VFD's, lighting panels and misc. electrical components, roof repairs, in Return Sludge Pump Stations No. 1, No. 2, and No. 3. Miscellaneous concrete repairs.
9, 82	Reroute residuals recycle flow ahead of screening and grit removal	6	$2,900,000	$3,103,000	$3,600,000	Rerouting the filter backwash, FST 13-20 WAS, and gravity thickener overflow (GTO) recycle streams ahead of screening and grit removal. This will require re-directing these flows to a new submersible PS and force main to either JC 1 or the 72" pipe into Screen and Grit Building No. 2. Several submersible PS's may be required if the various recycle streams cannot gravity flow to a central pump station site.
New Facility	Digester Heating System Replacement Design	1	$725,000	$775,750	$775,750	Design includes new centralized heating system Building D, new heat exchangers, new boilers, air separator, expansion tank, primary hot water loop pumps, feed tank, hot water pipeline to Buildings A and C, and new natural gas pipeline connection.
New Facility	New Primary Sedimentation Tanks - Design	1	$2,600,000	$2,782,000	$2,782,000	Addition of four (4) new primary sedimentation tanks . The new primary sedimentation tanks would be rectangular in shape and of similar size (length, width, depth) to the existing PSTs 5-8. The new primary sedimentation tanks would be located south of PSTs 5-8. A 96-inch pipe would be installed from Junction Chamber No. 2 to the new primary sedimentation tanks and a new 66-inch pipe from the effluent channel of the primary sedimentation tanks to the Main Pump Station. Stress testing and computational fluid dynamics (CFD) modeling of the existing primary sedimentation tanks is recommended prior to initiation of the design to evaluate the TSS removal efficiencies at higher SORs to confirm the timing and number of new primary sedimentation tanks required. Other improvements include replacing supply fans, sump pump at Meter Vault Nos. 1 and 2 and perform miscellaneous concrete repairs in JC No.2 and Meter Vault No. 2.
New Facility	Digester Heating System Replacement Improvements- Construction	2	$3,600,000	$3,852,000	$3,970,000	Construction includes new centralized heating system Building D, new heat exchangers, new boilers, air separator, expansion tank, primary hot water loop pumps, feed tank, hot water pipeline to Buildings A and C, and new natural gas pipeline connection.
New Facility	New Primary Sedimentation Tanks - Construction	2	$13,000,000	$13,910,000	$14,330,000	Addition of four (4) new primary sedimentation tanks with provisions for a fourth future tank. The new primary sedimentation tanks would be rectangular in shape and of similar size (length, width, depth) to the existing PSTs 5-8. The new primary sedimentation tanks would be located south of PSTs 5-8. A 96-inch pipe would be installed from Junction Chamber No. 2 to the new primary sedimentation tanks and a new 66-inch pipe from the effluent channel of the primary sedimentation tanks to the Main Pump Station. Other improvements include replacing supply fans, sump pump at Meter Vault Nos. 1 and 2 and perform miscellaneous concrete repairs in JC No.2 and Meter Vault No. 2.
New Facility	Additional Final Sedimentation Tanks (No. 21 - 24) and Return Station No. 6 - Design	3	$3,600,000	$3,852,000	$4,090,000	Design - Add 4 more nitrification final tanks and another return station. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods.
New Facility	Automated Septage Receiving Facility - Design	4	$540,000	$577,800	$640,000	Design - A new septage receiving facility would be constructed near the southwest corner of the plant property. The septage receiving facility would consist of four standalone, automated sewage receiving stations that discharge to a new duplex submersible pump station. This new pump station would be connected via a new force main to either the Raw Sewage Pump Station or the Junction Chamber No. 1. The site work for the new septage receiving facility would include a new entrance and exit off Maritime Blvd., security fencing and access gate. While located on plant property, the security fencing would separate this site from the rest of the treatment plant
New Facility	Additional Final Sedimentation Tanks (No. 21 - 22) and Return Station No. 6 - Construction	4	$19,500,000	$20,865,000	$22,800,000	Construction - Add 2 more nitrification final tanks and another return station, with provisions for adding 2 more tanks in the future. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods.
New Facility	Automated Septage Receiving Facility - Construction	5	$2,700,000	$2,889,000	$3,260,000	Construction - A new septage receiving facility would be constructed near the southwest corner of the plant property. The septage receiving facility would consist of four standalone, automated sewage receiving stations that discharge to a new duplex submersible pump station. This new pump station would be connected via a new force main to either the Raw Sewage Pump Station or the Junction Chamber No. 1. The site work for the new septage receiving facility would include a new entrance and exit off Maritime Blvd., security fencing and access gate. While located on plant property, the security fencing would separate this site from the rest of the treatment plant
New Facility	Additional Final Sedimentation Tanks (No. 23 - 24) - Construction	8	$16,600,000	$17,762,000	$21,850,000	Construction - Add 2 more nitrification final tanks. The current final tanks are not fully adequate for solids settling and the additional tanks would allow for less solids to clog the denitrification filters during high flow periods. Two tanks and areturn pump station will be constructed in a prior year. This project completes the expansion of the tanks.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
New Facility	Additional Denite Filters - Design	16	$1,000,000	$1,070,000	$1,670,000	Design - Addition of two denitrification filters. With the addition of sidestream treatment, additional filters are required as AADF exceeds 77 mgd.
New Facility	Additional Denite Filters - Construction	17	$5,200,000	$5,564,000	$8,930,000	Construction - Addition of two denitrification filters. With the addition of sidestream treatment, additional filters are required as AADF exceeds 77 mgd.
Plantwide	Plant Concrete Repairs	0	$300,000	$321,000	$321,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Treatment Plant improvements	0	$750,000	$802,500	$802,500	Includes miscellaneous improvements and repairs throughout the plant.
Plantwide	Medium Voltage Cables Upgrade, Phase I - Design	1	$75,000	$80,250	$80,250	Design - Medium Voltage Cables Upgrade, Phase I
Plantwide	Fire Alarm System Upgrades - Design	1	$350,000	$374,500	$374,500	Design - Replacement of fire alarm systems and deteriorated fire line piping
Plantwide	Arc Flash Improvements	1	$300,000	$321,000	$321,000	Implement Arc Flash improvements as identified in FY15 study
Plantwide	Medium Voltage Cables Upgrade, Phase I - Construction	2	$500,000	$535,000	$560,000	Construction - Medium Voltage Cables Upgrade, Phase I
Plantwide	Fire Alarm System Upgrades - Construction	2	$1,000,000	$1,070,000	$1,110,000	Construction - Replacement of fire alarm systems and deteriorated fire line piping
Plantwide	AWT SCADA - Master Plan and Design	2	$200,000	$214,000	$230,000	Evaluate current system and develop a master plan to improve the AWT SCADA system. Design AWT SCADA improvements as identified in the SCADA Master Plan.
Plantwide	Effluent Water System Improvements - Design	2	$300,000	$321,000	$340,000	Design - Replacing deteriorated effluent water system piping and construct new effluent water pipe loop to improve effluent water system at the plant. New system will Include additional capacity for a new odor control unit at JC No. 1 and improved pressure at screen and grit.
Plantwide	Medium Voltage Cables Upgrade, Phase II - Design	3	$75,000	$80,250	$90,000	Design - Medium Voltage Cables Upgrade, Phase II
Plantwide	Treatment Plant Office and Building Improvements - Design	3	$700,000	$749,000	$800,000	Design - This project will include demo of existing buildings (carpenter shop, old screen and grit building, tech building), potential construction of new administration office building, improvements to O&M building, and relocation of carpenter shop.
Plantwide	AWT SCADA - Construction	3	$1,000,000	$1,070,000	$1,140,000	Construction of Improvements for SCADA system
Plantwide	Effluent Water System Improvements - Construction	3	$1,000,000	$1,070,000	$1,140,000	Construction - Replacement effluent water system piping and new effluent water pipe loop to improve effluent water system at the plant. New system will Include additional capacity for a new odor control unit at JC No. 1 and improved pressure at screen and grit facilities.
Plantwide	Treatment Plant Security and Emergency Responses Improvements - Design	3	$200,000	$214,000	$230,000	Design - Improvements to treatment plant's security and emergency response systems. Department is currently evaluating emergency response, safety, and security needs at the treatment plant. This project will provide funding for identified improvements which may include new access/entry gate systems and perimeter fencing.
Plantwide	Medium Voltage Cables Upgrade, Phase II - Construction	4	$500,000	$535,000	$590,000	Construction - Medium Voltage Cables Upgrade, Phase II
Plantwide	Treatment Plant Office and Building Improvements - Construction	4	$6,700,000	$7,169,000	$7,840,000	Construction - This project will include demo of existing buildings (carpenter shop, old screen and grit building, tech building), potential construction of new administration office building, improvements to O&M building, and relocation of carpenter shop.
Plantwide	Treatment Plant Security and Emergency Response Improvements - Construction	4	$1,000,000	$1,070,000	$1,170,000	Construction -Improvements to treatment plant's security and emergency response systems. Department is currently evaluating emergency response, safety, and security needs at the treatment plant. This project will provide funding for identified improvements which may include new access/entry gate systems and perimeter fencing.
Plantwide	Medium Voltage Cables Upgrade, Phase III - Design	5	$150,000	$160,500	$190,000	Design - Medium Voltage Cables Upgrade, Phase III
Plantwide	Medium Voltage Cables Upgrade, Phase III - Construction	6	$500,000	$535,000	$630,000	Construction - Medium Voltage Cables Upgrade, Phase III
Plantwide	Plant Roof Repairs	6	$250,000	$267,500	$320,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	6	$250,000	$267,500	$320,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	6	$600,000	$642,000	$750,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Plant Full Automation - Construction	6	$2,360,000	$2,525,200	$2,930,000	Construction - Each system at the treatment plant will be automated (if possible). Includes the monitoring devices and control devices needed for the automation.
Plantwide	Miscellaneous Plant Equipment Repairs	6	$3,000,000	$3,210,000	$3,730,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Plant Roof Repairs	7	$250,000	$267,500	$320,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	7	$250,000	$267,500	$320,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	7	$600,000	$642,000	$770,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	7	$3,000,000	$3,210,000	$3,840,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Plant Roof Repairs	8	$250,000	$267,500	$330,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	8	$250,000	$267,500	$330,000	Includes miscellaneous painting throughout the plant.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
Plantwide	Plant Concrete Repairs	8	$600,000	$642,000	$790,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	8	$3,000,000	$3,210,000	$3,950,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Medium Voltage Cables Upgrade, Phase IV - Design	8	$75,000	$80,250	$100,000	Design - Medium Voltage Cables Upgrade, Phase IV
Plantwide	Plant Roof Repairs	9	$250,000	$267,500	$340,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	9	$250,000	$267,500	$340,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	9	$600,000	$642,000	$820,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	9	$3,000,000	$3,210,000	$4,070,000	Includes miscellaneous plant equipment repairs throughout the plant, including the rehabilitation/replacement of one (1) of the existing standby generators.
Plantwide	Medium Voltage Cables Upgrade, Phase IV - Construction	9	$500,000	$535,000	$680,000	Construction - Medium Voltage Cables Upgrade, Phase IV
Plantwide	Medium Voltage Cables Upgrade, Phase V - Design	9	$75,000	$80,250	$110,000	Design - Medium Voltage Cables Upgrade, Phase V
Plantwide	Plant Roof Repairs	10	$250,000	$267,500	$350,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	10	$250,000	$267,500	$350,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	10	$600,000	$642,000	$840,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	10	$4,000,000	$4,280,000	$5,590,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Medium Voltage Cables Upgrade, Phase V - Construction	10	$500,000	$535,000	$700,000	Construction - Medium Voltage Cables Upgrade, Phase V
Plantwide	Plant Roof Repairs	11	$250,000	$267,500	$360,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	11	$250,000	$267,500	$360,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	11	$600,000	$642,000	$870,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	11	$4,000,000	$4,280,000	$5,760,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	12	$250,000	$267,500	$380,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	12	$250,000	$267,500	$380,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	12	$600,000	$642,000	$890,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	12	$4,000,000	$4,280,000	$5,930,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	13	$250,000	$267,500	$390,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	13	$250,000	$267,500	$390,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	13	$600,000	$642,000	$920,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	13	$4,000,000	$4,280,000	$6,110,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	14	$250,000	$267,500	$400,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	14	$250,000	$267,500	$400,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	14	$600,000	$642,000	$950,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Emergency Plant Bypass - Design	14	$400,000	$428,000	$630,000	Design - Install a passive by-pass with disinfectant dosage from the southwest corner of JC1 to the existing 84" pipe that continues to the outfall structure at the SW corner of the plant site to be used in case of an emergency. Approximate length of new pipe required is 500 lf.
Plantwide	Miscellaneous Plant Equipment Repairs	14	$4,000,000	$4,280,000	$6,290,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plantwide Paving Improvements	15	$4,000,000	$4,280,000	$6,480,000	Plantwide Paving Improvements
Plantwide	Plant Roof Repairs	15	$250,000	$267,500	$410,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	15	$250,000	$267,500	$410,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	15	$600,000	$642,000	$980,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	15	$4,000,000	$4,280,000	$6,480,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Emergency Plant Bypass - Construction	15	$2,000,000	$2,140,000	$3,240,000	Install a passive by-pass with disinfectant dosage from the southwest corner of JC1 to the existing 84" pipe that continues to the outfall structure at the SW corner of the plant site to be used in case of an emergency. Approximate length of new pipe required is 500 lf.
Plantwide	Plant Roof Repairs	16	$250,000	$267,500	$420,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	16	$250,000	$267,500	$420,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	16	$600,000	$642,000	$1,010,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	16	$4,000,000	$4,280,000	$6,670,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	17	$250,000	$267,500	$430,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	17	$250,000	$267,500	$430,000	Includes miscellaneous painting throughout the plant.

Howard F. Curren AWTP Capital Improvement Projects List

Building No.	Project Name	Fiscal Year	Estimated Cost	Total Project Cost	Total Project Cost with Inflation	Project Description
Plantwide	Plant Concrete Repairs	17	$600,000	$642,000	$1,040,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	17	$4,000,000	$4,280,000	$6,870,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	18	$250,000	$267,500	$450,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	18	$250,000	$267,500	$450,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	18	$600,000	$642,000	$1,070,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	18	$4,000,000	$4,280,000	$7,080,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	19	$250,000	$267,500	$460,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	19	$250,000	$267,500	$460,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	19	$600,000	$642,000	$1,100,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	19	$4,000,000	$4,280,000	$7,290,000	Includes miscellaneous plant equipment repairs throughout the plant.
Plantwide	Plant Roof Repairs	20	$250,000	$267,500	$470,000	Includes miscellaneous roof repairs throughout the plant.
Plantwide	Plant Painting Repairs	20	$250,000	$267,500	$470,000	Includes miscellaneous painting throughout the plant.
Plantwide	Plant Concrete Repairs	20	$600,000	$642,000	$1,130,000	Includes miscellaneous concrete repairs throughout the plant.
Plantwide	Miscellaneous Plant Equipment Repairs	20	$4,000,000	$4,280,000	$7,510,000	Includes miscellaneous plant equipment repairs throughout the plant.

The number of projects and cost shown for Year 0 were based on preliminary budget information provided by the City. These numbers may change depending on the final approval of the FY2019 CIP budget.

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SUBMITTED BY:
MCKIM & CREED | CLEARWATER, FL
727.442.7196 | MCKIMCREED.COM

SUBMITTED BY:
HAZEN AND SAWYER | TAMPA, FL
813.630.4498 | HAZENANDSAWYER.COM