

APPENDIX 6E: Systemwide Alternative Analyses



Purpose

This appendix provides additional details for Chapter 6 of the 2050 Facilities Plan (2050 FP) for Milwaukee Metropolitan Sewerage District's (MMSD's) systemwide alternative analyses. This appendix is not a stand-alone document; it should always be used in conjunction with MMSD's 2050 FP, which outlines the overall facilities plan for all of MMSD's asset systems.

6 Alternative Analyses

6.1 PURPOSE

This chapter analyzes alternatives to mitigate the potential risks that may impact multiple asset systems (systemwide risks) that were identified in Chapter 5 and identifies the recommended projects. The potential systemwide risks are all risks to meeting MMSD's 2050 Foundational Goals, which address non-permit requirements and include projects that address Commission policy and rules established by MMSD, projects that help to improve regional water quality and reduce energy usage, and projects that are designed to save MMSD money in the long term. Specifically, the risks addressed by Appendix 6E are all potential risks to meeting the following 2050 Foundational Goals:

- Change the District from an organization that impacts the environment to an organization that benefits the environment. (G1)
- Incorporate new technologies and operational improvements to minimize the District's financial burden on ratepayers. (G2)
- Provide adaptive leadership to climate change and the other drivers. (G5)

Note that some of the recommended projects identified in this appendix may not be included in the final recommendations to address 2050 Foundational Goals (Chapter 8), which presents optimized recommendations that consider *all* recommended projects for *all* asset systems.

For each potential risk identified in Chapter 5, Table 6E-1 shows when the risk is projected to occur and provides a name for the analysis in this chapter that identifies potential alternatives to mitigate the risk.



TABLE 6E-1: SYSTEMWIDE RISKS IDENTIFIED IN CHAPTER 5

Potential Risk Identified in Ch 5	Specific Description of Potential Risk	How Potential Risk was Identified	Estimated Timing of Potential Risk	Type of Potential Risk ¹	Ch 6 Analysis
JIWRF and SSWRF capacity risks	Risk to of increased rates to rate payers if capacity risks are not mitigated in the most effective manner. In order to optimize WRF capacity in the most cost-effective manner, it is important to identify the most effective ways to reutilize various treatment and transportation options at JIWRF, SSWRF, and the Conveyance System Risk of negatively impacting community relationships if changes in customer expectations related to JIWRF odors, noise and nuisance, and recreational opportunities around JIWRF are not addressed Structural risks identified at JIWRF that are due to the construction on wood piles	Systemwide assessment	Varies	Risk to meeting Foundational Goals G1, G2, and G5	SW FG1, JIWRF and SSWRF Reutilization
Lovel of coming viets	Risk of not meeting PI target of 0 SSO events per year	Actual historical performance trends MMSD staff identified as a top priority related to its 2035 Vision	Existing ²	Risk to meeting Foundational Goal G1, G2 and G5	SW FG2, Zero Overflows
Level of service risks	Risk of not meeting PI target of 0 CSO events per year	Actual historical performance trends MMSD staff identified as a top priority related to its 2035 Vision	By 2035 (2035 Vision)	Risk to meeting Foundational Goal G1, G2 and G5	SW FG2, Zero Overflows



Potential Risk Identified in Ch 5	Specific Description of Potential Risk	How Potential Risk was Identified	Estimated Timing of Potential Risk	Type of Potential Risk ¹	Ch 6 Analysis
	Risk of not meeting KPI target of 100% of annual energy from renewable sources	Actual historical performance trends with focus on 2017 baseline energy use MMSD staff identified as a top priority related to its 2035 Vision	By 2035 (2035 Vision)	Risk to meeting Foundational Goal G1, G2 and G5	SW FG3, Energy Plan Additional Alternatives SW FG4, Energy 2035 Vision
	Risk of not meeting KPI target of 80% of annual energy from MMSD- generated renewable sources	Actual historical performance trends with focus on 2017 baseline energy use MMSD staff identified as a top priority related to its 2035 Vision	By 2035 (2035 Vision)	Risk to meeting Foundational Goal G1, G2 and G5	SW FG3, Energy Plan Additional Alternatives SW FG4, Energy 2035 Vision

¹⁾ Foundational Goals: G1: Change the District from an organization that impacts the environment to an organization that benefits the environment, G2: Incorporate new technologies and operational improvements to minimize the District's financial burden on ratepayers, G3: Integrate green infrastructure into all facets of development and redevelopment, G4: Support urban biodiversity activities within the region, and G5: Provide adaptive leadership to climate change and the other drivers

2) Timing is 'existing' since 2019 WDPES permit does not allow SSOs.



6.2 METHODOLOGY

The methodology used to develop each systemwide analysis is described in the Approach section for the analyses in Section 6.4.

In addition, the following energy rate assumptions, which are also noted in Chapter 6, were used in systemwide analyses SW FG3, and SW FG4¹ because they have a significant annual energy use component:

- Annual electrical rates: We Energies electrical rates in effect as of December 23, 2014 [1] were used. While the 2050 FP was being completed, a new We Energies rate structure effective January 1, 2020 was identified that is projected to increase electric rates by an average of 1.3 percent from the December 23, 2014 rates. [2] The impact of this increase in electrical rates was reviewed to determine if it would change recommendations. The review determined that the assumption of a 3 percent annual increase as noted in Chapter 6 (which include annual electrical costs) is more conservative than the 1.3 percent increase anticipated in 2020. Therefore, the recommendations would not change if the 2020 rates were used instead.
- Annual natural gas rate is assumed to be \$5/Dtherm and landfill gas rate is assumed to be \$2.50/Dtherm.²

Because the 2050 FP was developed during a period when a large number of MMSD projects and programs were already underway, the 2050 FP project team also reviewed MMSD's 2020 to 2025 long-range finance plan to determine if any of the existing projects would address the identified risks.

6.3 ANALYSIS OF RISKS TO MEETING REGULATORY GUIDELINES AND PERMIT REQUIREMENTS

There are no systemwide risks to meeting regulatory guidelines and permit requirements.

Note: The risk of not meeting the performance indicator (PI) target of zero sanitary sewer overflows (SSOs) is a systemwide risk that may impact MMSD's ability to meet permit requirements because SSOs are not allowed in the permit. This risk is addressed in the conveyance capacity projects that are recommended to maintain a 5-year level of protection in Appendix 6A, Conveyance Alternative Analyses. Over and above those recommendations, this risk is further addressed as part the SW FG2, Zero Overflows analysis in this appendix, which also includes eliminating combined sewer overflows (CSOs), which is not required in the permit. Because the elimination of CSOs is not a permit requirement, the SW FG2 Zero Overflows analysis is considered an analysis of risks to meeting MMSD's Foundational Goals.

¹ SW FG1 analysis does have a significant energy component but energy costs were not the focus and specific energy rate assumptions were not applied.

² Natural gas rates fluctuate and landfill gas rates are set as a percentage of natural gas rates. Assumptions presented for planning purposes have been simplified based on guidance from MMSD.



6.4 ANALYSIS OF RISKS TO MEETING 2050 FOUNDATIONAL GOALS

This section evaluates potential alternatives to address the identified risks to meeting MMSD's 2050 Foundational Goals, which address non-permit requirements and include projects that address Commission policy and rules established by MMSD, projects that help to improve regional water quality and reduce energy usage, and projects that are designed to save MMSD money in the long term.





SW FG1, JIWRF and SSWRF Reutilization

Purpose

The purpose of this analysis is to evaluate potential options to reutilize the Jones Island Water Reclamation Facility (JIWRF) and South Shore Water Reclamation Facility (SSWRF). The evaluation addresses the following risks:³

- The risk to of increased rates to rate payers if capacity risks are not mitigated in the most effective manner. In order to optimize WRF capacity in the most cost-effective manner, it is important to identify the most effective ways to reutilize various treatment and transportation options at JIWRF, SSWRF, and the Conveyance System. Contributing to this risk is the fact that JIWRF is limited in expansion area.
- The risk of negatively impacting community relationships if changing customer expectations related to JIWRF odors, noise and nuisance, and recreational opportunities around JIWRF are not addressed. Contributing to the risks is the fact that JIWRF is located in an area of the City of Milwaukee that has seen residential growth and is near the Summerfest grounds.
- The structural risks identified at JIWRF that are due to the construction on wood piles.

Appendix 6B, WRFs and Biosolids Alternative Analyses focuses on addressing JIWRF and SSWRF capacity risks by unit process at each WRF. Appendix 6B also presents alternatives to address odor risks at JIWRF, including covering the primary clarifiers. This systemwide analysis considers alternatives to address potential capacity risks from a more holistic, systemwide perspective, including consideration of the potential negative community impacts from the continued operation of JIWRF due to odors and nuisance complaints as well as the structural risks at JIWRF due to the construction on wood piles.

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³ The risk to meeting KPIs related to renewable energy goals would not be reduced under the alternatives identified for this analysis as it is assumed that the transfer of flow from JIWRF to SSWRF would require additional energy above energy baseline conditions established in 2035.



Approach

The baseline WRFs and Biosolids and Conveyance and Storage Asset Systems were reviewed together to determine how they could be reutilized to address the identified risks. Two alternatives were developed:

- 1. Alternative 1 abandon most of JIWRF treatment operations
- 2. Alternative 2 maintain just JIWRF wet weather treatment and transferring the dry weather flows to SSWRF, which would operate under expanded capacity

Alternatives Description

These two alternatives were considered because, as identified in Appendix 6B, SSWRF is projected to need a capacity expansion in the future, which provides the opportunity to consider additional expansion options. In addition, there is interest in moving wastewater treatment facilities away from the increasingly residential Third Ward area, which is where JIWRF is located, due to odors, air emissions, and nuisance complaints. Descriptions and schematics of each alternative are presented below.

Additional Considerations

In both alternatives, the transfer of flows from the JIWRF service area to the SSWRF service area is assumed to be conducted by pumping through a tunnel directly from JIWRF to SSWRF. This approach was selected because the construction would be the least disruptive to MMSD service area stakeholders. A force main option was reviewed, but concerns related to community disruption led to this option being eliminated from the planning-level alternative development. Potential locations throughout the system where flows could be transferred have been identified for use in this effort and are provided in Appendix 6E-1.

Alternative 1 – Diversion of All Flow from JIWRF to SSWRF

This alternative assumes that most of JIWRF is decommissioned and wastewater is transported to SSWRF. The facilities that would remain in service at JIWRF would include MP01, Preliminary Treatment and the Inline Storage System Pump Station (ISS PS) to remove grit and other debris from the wastewater before it is transferred to SSWRF. This alternative requires the liquid and solids processes at SSWRF to be expanded to manage the buildout max day wastewater flow of 790 million gallons per day (MGD).⁴ This alternative addresses the risk of not considering various available treatment and transport reutilization options at JIWRF, SSWRF, and the Conveyance system, by considering transferring all flow to SSWRF for treatment, and addresses the risk of negatively impacting community relationships around JIWRF and structural risks identified at JIWRF that are due to the construction on wood piles by abandoning most treatment processes at the site.

This analysis identifies an approach to achieve treatment at a single facility, including locations and rough sizes of new treatment facilities. Wastewater conveyance assumes the use of a 10 mile 12-foot tunnel from JIWRF and a new deep tunnel pump station at SSWRF sized for 340 MGD and assumes that SSWRF gravity capacity could be increased to 450 MGD (additional details provided in Design Wastewater Conveyance Capacity subsection of this alternative description). Solids processing and disposal facilities are assumed to be at SSWRF, with the installation of new dryers and digestion of all

⁴ This total capacity was identified based on assuming 490 MGD of full treatment at JIWRF to maintain baseline CSO frequency established in Chapter 4 under Buildout Conditions plus 300 design flow at SSWRF.



solids to be sold under the Milorganite® name. The effort to decommission JIWRF is not included in this planning-level analysis since the details regarding how the WRF would be decommissioned depends on how available land at JIWRF site would be redeveloped.

Regulatory Requirements

The effluent from SSWRF is discharged to the near-shore waters of Lake Michigan. Treated effluent quality is regulated by MMSD's Wisconsin Pollutant Discharge Elimination (WPDES) permit, which became effective April 1, 2019. The facility is presently operated under contract with Veolia Water Milwaukee, LLC (Veolia) through 2028. WPDES discharge limits and contractual effluent limits are shown in Table 6E-2.

WPDES discharge limits for biochemical oxygen demand (BOD) and total suspended solids (TSS) satisfy secondary treatment requirements in addition to limits for ammonia and total phosphorus (TP). Current permit requirements are based on sustained flow conditions, such as weekly average or monthly average conditions. However, for purposes of this evaluation, it is assumed that the proposed facilities must consistently achieve compliance with regulatory weekly average limits, even during a 24-hour discharge event. Therefore, the proposed facilities must meet regulatory standards for the assumed daily influent flow and loading condition.

Nitrification is analyzed as part of WRF R3, SSWRF Primary Clarification, Secondary Treatment Capacity Analysis in Appendix 6B. This analysis assumes SSWRF would not be required to provide nitrification to satisfy WPDES ammonia limits, which are higher than the projected wastewater total Kjeldahl nitrogen (TKN) concentrations (see Table 6E-3). Nonetheless, the expanded facility could be designed to allow for nitrification at dry weather flow to satisfy contract conditions. Some relief from the contracted ammonia limit would be required to limit the capital investment required for wet weather conditions.

Phosphorus limits are required for facilities discharging to the Great Lakes. It is assumed that TP removal would continue to be achieved with chemical treatment and can be satisfied at any flow and loading condition.



TABLE 6E-2: SSWRF WPDES PERMIT LIMITS AND VEOLIA OPERATING CONTRACT TREATED EFFLUENT REQUIREMENTS (APRIL 1, 2019 PERMIT)

Parameter	WPDES Permit Limit	Contract Effluent Standard
BOD (mg/L)	45 ¹ , 30 ²	15 ²
TSS (mg/L)	45 ¹ , 30 ²	15 ²
TP (mg/L)	1.0 ² and 0.7 ⁴	0.6 ³ and 0.8 ⁴
Nitrogen Ammonia (mg/L)	27 ^{1,2,5}	5.0 ²
Fecal Coliform (No. /100 ml)	400 ⁶ , 972 ⁷	100 ⁶
E. coli (No./ 100ml) ⁸	126 ⁶ ,410 ⁹	NA
BOD removal (%) ¹⁰	85%	
TSS removal (%) ¹⁰	85%	

Notes:

- 1) Weekly average
- 2) Monthly average
- 3) 24-month rolling average evaluated each month
- 4) 6-month average (May to Oct & Nov to April)
- 5) Daily maximum
- 6) Geometric mean, monthly
- 7) Geometric mean, weekly
- 8) E. coli limits are proposed and not currently in WPDES permit
- 9) No more than 10 percent of results per month exceed
- 10) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period.

Design Wastewater Conveyance Capacity

The design assumes the capacity of SSWRF would increase to 790 MGD. The gravity flow into SSWRF would be increased up to 450 MGD through the metropolitan interceptor sewer (MIS), based on modeling findings presented in Appendix 4A-3, Conveyance Modeling Summary Technical Memorandum. Additionally, 340 MGD of JIWRF flow would be conveyed through a new 12-foot diameter, 10-mile long tunnel from JIWRF to SSWRF. The total flow in the new tunnel would be a combination of up to 330 MGD from the gravity system into JIWRF, which would receive preliminary treatment at JIWRF, and flow from the ISS PS at JIWRF as available. The concept assumes the ISS PS at JIWRF could continue to pump up to 40 MGD to the SSWRF system during wet weather. A new deep tunnel pump station sized to pump the additional 340 MGD of flow out of the new tunnel would be built at SSWRF. Figure 6E-1 presents a schematic of the flow concept to/from JIWRF. Figure 6E-3 shows the flow concept at SSWRF as well as the proposed treatment flow.



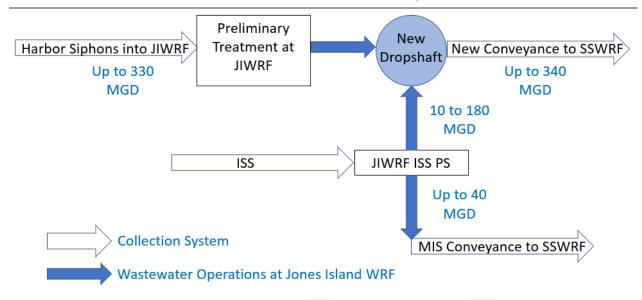


FIGURE 6E-1: FLOW SCHEMATIC FOR ALTERNATIVE 1 FLOW TRANSFER FROM JIWRF TO SSWRF

Design Wastewater Characteristics and Treatment Capacity

Wastewater flows and loads assumed for this analysis are developed based on projected WRF Buildout Conditions calculated for the 2050 FP, shown in Table 6E-3.

The evaluation of treatment capacity assumes maximum day flows and month loading conditions for BOD, TSS, nitrogen (N), and phosphorus (P).

- Maximum day flows are the basis of evaluation for clarifier overflow rate and disinfection hydraulic retention time. If clarifiers and disinfection systems are hydraulically overloaded, MMSD risks failure to meet effluent discharge limits immediately or as a result of a crippling treatment upset condition.
- Maximum month loads are the basis of evaluation for activated sludge BOD loading. Max month
 loads also imply the maximum mixed liquor suspended solids (MLSS) concentration to use for
 secondary clarifiers solids loading rates. Higher short-term loadings on activated sludge systems
 may be compensated by operational changes to aeration, sludge wasting, or sludge
 recirculation.



TABLE 6E-3: DESIGN CONDITIONS WASTEWATER FLOWS AND LOADS FOR SERVICE AREA BUILDOUT CONDITION

Parameter	Average Design Condition	Maximum Design Condition
Flow (MGD)	248.8	790
BOD (lbs./day)	533,000	618,000 ¹
BOD (mg/L)	257	94
TSS (lbs./day)	606,000	783,000 ¹
TSS (mg/L)	292	119
TKN (lbs./day)	51,100	54,750 ¹
TKN (mg/L)	25	8.3
TP (lbs./day)	16,300	20,400 ¹
TP (mg/L)	7.8	3.1

Max month daily loadings are assumed to coincide with the max day flow.

The estimated flow capacity of the existing SSWRF processes based on 10 States Standards is shown in Table 6E-4. The table also shows the parameters from the Chapter 5 capacity assessment for comparison, which is based on WRF Baseline Conditions operations. The estimates confirm that the existing primary and secondary treatment processes are insufficient for wastewater treatment at Buildout Conditions.

- The peak capacity of the existing primary treatment system is 205 MGD.
- The capacity of secondary treatment is 200 MGD max daily flow based on final settling tank solids loading for an assumed MLSS of 3,000 mg/L and a 100 percent return activated sludge (RAS) ratio. Capacity could be increased by utilizing step feed.
- The capacity of secondary treatment is 120 MGD average daily flow based on aeration tank organic loading.



TABLE 6E-4: SSWRF FLOW CAPACITY

Process	Parameter	WRF Capacity Assessment	Design Basis	10 States Standards	Average Design Capacity (MGD)	Maximum Design Capacity (MGD)
Primary Settling	Surface overflow Rate (gal/sqft-d)	2,930	2,240	2,000	113	205
Activated Sludge - Aeration	Volumetric Loading Rate (lbBOD/kcf)	54.5	48	40	120¹	
Activated Sludge - Settling	Surface overflow Rate (gal/sqft-d)	1,210	1,050	1,200	113	300
Activated Sludge - Settling	Solids Loading Rate (Ibs-sqft-d)	61.5	32	40		200²
Disinfection (Chlorine)	Contact Time (min)	24	28	15		483³

- 1) Assumes 30 percent removal of BOD in primary treatment
- 2) Based on WRF Flow and Loadings and 10 States Standards loading
- 3) Based on 10 States Standards

Technologies for treatment intensification can increase the capacity of existing infrastructure. Innovative processes for wastewater treatment intensification have advanced rapidly in recent years. Intensification of the primary treatment process can be achieved with chemically enhanced primary treatment (CEPT), ballasted flocculation, or filtration. Technologies for intensification of secondary treatment include membrane bioreactors, shortcut nitrogen removal, and granular activated sludge (GAS). CEPT and GAS would most easily be retrofitted into existing infrastructure and are selected for more detailed analysis.

Table 6E-5 shows the treatment capacity for primary and secondary treatment based on use of technology for treatment intensification.



TABLE 6E-5: SSWRF FLOW CAPACITY BASED ON TREATMENT INTENSIFICATION

Process	Parameter	Intensified Limits using CEPT or GAS Technologies	Average Capacity (MGD)	Max Capacity (MGD)
Chemically Enhanced Primary Treatment	Surface overflow Rate (gal/sqft-d)	4,000 gpdsf		410
Granular Activated Sludge - Aeration	Volumetric Loading Rate (lbBOD/kcf)	110	586 ¹	
Granular Activated Sludge - Aeration	Hydraulic Retention Time (hrs)	4.0 hr	210	
Granular Activated Sludge - Settling	Solids Loading Rate (lbs- sqft-d)	1,200		300
Granular Activated Sludge - Settling	Solids Loading Rate (lbs- sqft-d)	55	205	

¹⁾ Assumes 50 percent removal of BOD for upstream CEPT

Primary Treatment Intensification

CEPT can be used for full-time treatment or for peak wet weather treatment. There are extensive data on CEPT as a wet-weather treatment strategy with published loading rates in excess of 4,000 gpdsf, which is equivalent to a capacity of 410 MGD for SSWRF. Therefore, CEPT could increase the treatment capacity of the existing primary treatment facilities nearly up to the capacity of the MIS. Additional primary settling tanks would be required for treatment of the buildout max day flow of 790 MGD.

Secondary Treatment Intensification

GAS could be implemented in the existing activated sludge system to increase the loading rate to the aeration tanks and settling tanks. GAS is an extension of conventional activated sludge, except selective pressures are created to form large, dense microbial aggregates with a smooth and nearly round shape and excellent settleability. Typically, the formed granules have effective diameters of 100 to 5,000 µm and sludge volumetric indices (SVIs) below 50 mL/g. Benefits of granular sludge processes include high biomass retention, higher organic load capacity, the ability to achieve nitrogen and phosphorus removal, greater tolerance to toxicity, smaller footprint, and lower energy demands. A major benefit is also related to the higher settling velocities of granular sludge, leading to impacts on final clarifier design and solids-liquid separation assumptions. An image of a granular sludge settleometer test is shown in Figure 6E-2.





FIGURE 6E-2: GRANULAR SLUDGE AFTER 5 MINUTES SETTLING

Assuming a minimum of 50 percent removal of BOD in primary treatment with CEPT, the organic loading rate could be increased to allow the aeration tanks to provide treatment for an average daily flow of up to 586 MGD, although the hydraulic retention time (HRT) would be reduced to less than 2 hours. Applying a standard of 4 hours for HRT, the aeration tank capacity is 210 MGD. A shorter HRT could be employed during transient high flow events. Nitrification may be interrupted at short HRTs.

GAS allows a higher settling tank solids loading rate because of the increased density of settled solids. The allowable solids loading rate is 55 lbs/day/sf based on the experience of other utilities operating GAS to date, which is a 38 percent increase over 10 States Standards (40 lbs/day/sf) and a 15 percent increase over Wisconsin NR 110 (48 lbs/day/sf). The MLSS concentration is also increased from the higher BOD loading rate on the aeration tanks. The net result is that the secondary settling tank solids loading rate would be increased to allow up to approximately 200 MGD of wastewater to be treated through secondary treatment on a daily average basis.

It is estimated that treatment intensification could increase the capacity of the existing SSWRF wastewater treatment processes based on the foregoing analysis.

- Primary treatment capacity with CEPT is a peak flow of 410 MGD and it would increase the removal of BOD, thereby reducing the load on secondary treatment. CEPT could provide treatment for over 90 percent of wastewater from the MIS.
- Secondary treatment capacity of the aeration tanks with GAS is 210 MGD based on HRT. Higher rates of treatment are possible for transient high flow periods.
- Secondary treatment capacity of the final settling tanks with GAS is a maximum daily flow of 205 MGD assuming an allowable solids loading rate of 55 lbs/day/sf, a maximum month MLSS of 4,000 mg/L, and a RAS percent of influent flow of 100 percent. Higher flow rates are possible during transient loading events at wastewater loading conditions less than max month.



Treatment intensification of the existing infrastructure would not be sufficient to provide treatment capacity for Buildout Conditions. Significant new construction would be required at SSWRF in order to allow JIWRF to be decommissioned.

Approach for Increasing Treatment Capacity

The following approach is proposed for increasing treatment capacity, and the corresponding process flow diagram is shown in Figure 6E-3.

Treatment of up to 450 MGD of flow through MIS to SSWRF will be achieved as follows:

- Expansion of existing SSWRF infrastructure to intensify the treatment capabilities as discussed in previous sections
- Installation of a new ballasted clarification system to provide treatment of most of the wet weather flow from the MIS
- Construction of new primary filtration and secondary treatment processes for the remaining wastewater from the MIS

Treatment of up to 340 MGD of flow from JIWRF through the new conveyance tunnel and deep tunnel PS will be achieved as follows:

 New primary filtration and secondary treatment processes noted above would also be sized to treat all wastewater from JIWRF

Wastewater flow will be split between the treatment processes as follows:

- Up to 150 MGD average daily flow from the MIS will receive full treatment through the intensified primary and secondary treatment processes
- 50 to 100 MGD additional flow from the MIS could be treated through the intensified primary and secondary treatment processes depending on BOD load, for a total flow of 200 to 250 MGD
- 100 to 150 MGD of wet weather wastewater could be diverted through a new ballasted clarification process
- 50 to 100 MGD of flow from the MIS could be diverted to the new primary filtration and biological treatment system provided for treatment of wastewater conveyed from JIWRF
- Up to 340 MGD from the new conveyance tunnel from JIWRF will receive full treatment through the new primary filtration and biological treatment system.

In addition, the following improvements are required to increase the capacity of the existing SSWRF processes:

- Expansion of preliminary treatment. The capacity of the existing headworks at SSWRF is 300 MGD. An additional 150 MGD is required to treat the additional wastewater that is conveyed by the MIS to SSWRF.
- New chemical unloading, storage, and feed to support CEPT.
- Reconfiguration of the secondary treatment system for GAS and expansion of air supply and RAS
 pumping systems. Installation of a new ultraviolet (UV) disinfection system in the existing
 chlorine contact tanks as a replacement for chlorine disinfection to reduce the total footprint



required. It is estimated that between 2,000 and 2,500 1,000 W lamps would be required assuming a conservative UV transmittance of 60 percent.

- Installation of a new effluent pumping station. A substantial increase in pumping capacity is required. The new pumping station would be built into the existing chlorine contact tanks.
- Construction of a new outfall. The existing outfall capacity is 300 MGD. A new outfall is proposed, for a combined total conveyance of 790 MGD.
- Expansion of solids treatment facilities. Existing biosolids processing facilities at JIWRF would be
 decommissioned and 100 percent of biosolids would be processed at SSWRF. Production and
 marketing of Milorganite® would be continued at SSWRF so there would be no change in annual
 O&M costs. The project would include increasing digestion and thickening capacity and
 construction of a new dewatering and drying facility.

Wastewater flow from the new conveyance force main from JIWRF will receive full secondary treatment through a new primary filtration and biological treatment system sized to treat from 101 MGD average daily flow up to 340 MGD max daily flow. Another 100 MGD of wet weather flow could be diverted from the MIS to the primary filtration and biological treatment system. It is assumed a preliminary treatment system would be constructed at JIWRF to reduce maintenance on the new conveyance system.





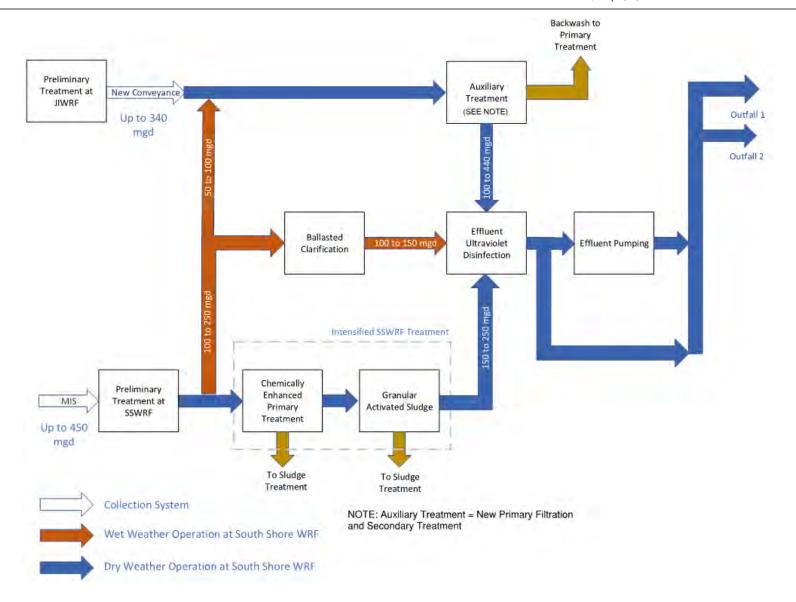


FIGURE 6E-3: PROCESS FLOW DIAGRAM FOR PROPOSAL TO TREAT ALL WASTEWATER FROM THE MMSD SERVICE AREA AT SSWRF



Treated wastewater from both the intensified SSWRF facilities and the primary filtration and biological treatment system would be recombined upstream from disinfection.

A two-stage filtration system is assumed for the new primary filtration and biological treatment process. A diagram of an existing commercial technology is shown in Figure 6E-4. The primary treatment step is a media filter. Screened and de-gritted wastewater is distributed to multiple filter cells where suspended solids and particulate BOD are removed by physical filtration. The filtered wastewater flows vertically through the media and through a strainer block to a biologically active filtration (BAF) secondary treatment stage. Biomass attached to the filter media consumes soluble BOD. The primary treatment and secondary treatment stages are backwashed to remove captured particulates and biological growth. The backwash is discharged to SSWRF primary treatment. Coagulant could be dosed upstream from the primary treatment stage for phosphorus removal. The head loss through the system is 2 meters.

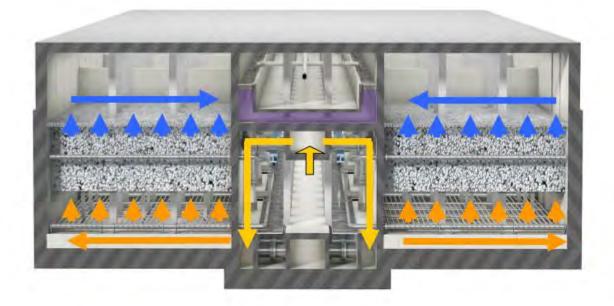


FIGURE 6E-4: SECTION VIEW OF PROPOSED PRIMARY FILTRATION AND BIOLOGICAL TREATMENT SYSTEM SHOWING WASTEWATER FLOW PATH

A vendor proposal provided by Tomorrow Water recommends 64 by 1,600 square foot filter cells. The footprint of the facility is 236 feet by 609 feet, including the filter cells, backwash water storage tank, and electrical and mechanical equipment. The vendor proposal is included as Appendix 6E-2.

The advantages of this technology for this application are as follows:

- Provides both primary treatment by physical filtration in one layer and secondary treatment by BAF in a separate layer.
- Efficient use of limited space. Space requirements are minimized by stacking the physical filtration and BAF layers.



- Modular design provides a very high turn-down capability by varying the number of cells operated in parallel. Cells can be operated in sequence at lower flows. Each cell would provide treatment for up to 7 MGD.
- Enclosed facility, which will control odor complaints.

Figure 6E-5 provides an annotated aerial view of SSWRF that identifies locations of the new and expanded facilities.

The proposed intensified treatment strategy is based on development of presently emerging technologies to achieve high-rate treatment of all wastewater flow at SSWRF. If the cost of the intensified infrastructure and primary filtration and biological treatment facilities proves to be an attractive alternative for MMSD, implementation would require some demonstration testing and applied research to confirm loadings rates and sizing criteria. The potential cost benefit could make a relatively minor applied research investment attractive for MMSD.





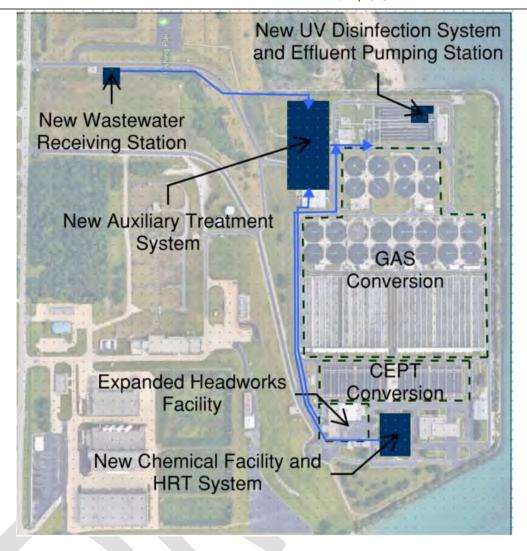


FIGURE 6E-5: AERIAL OF SSWRF SHOWING LOCATIONS OF NEW AND EXPANDED FACILITIES

New primary filtration and biological treatment system identified as "auxiliary"



Alternative 2 - Diversion of Dry Weather Flow from JIWRF to SSWRF

This alternative assumes that JIWRF is only operated as a wet weather treatment facility and all dry weather wastewater is transported to SSWRF. Most of JIWRF would be decommission, similar to Alternative 1. This alternative requires that wet stream and solids stream processes at SSWRF be expanded to manage the additional dry weather wastewater flow of 120 MGD (JIWRF average annual flow projected at Buildout Conditions of 101 MGD plus additional capacity). During wet weather, it is assumed that no flow is pumped to SSWRF and JIWRF handles the 490 MGD identified to maintain baseline CSO frequency established in Chapter 4 under Buildout Conditions. Figure 6E-6 presents a schematic of this concept.

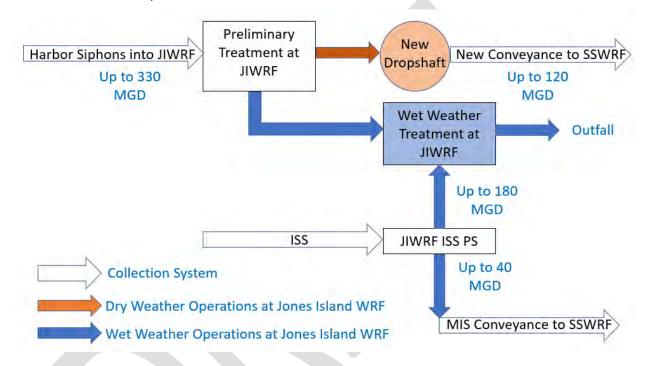


FIGURE 6E-6: FLOW SCHEMATIC FOR ALTERNATIVE 2 FLOW TRANSFER FROM JIWRF TO SSWRF

This alternative addresses the risk of not considering various available treatment and transport reutilization options at JIWRF, SSWRF, and the Conveyance system, by considering transferring dry weather flow to SSWRF for treatment, and addresses the risk of negatively impacting community relationships around JIWRF and structural risks identified at JIWRF that are due to the construction on wood piles by limiting treatment processes at the site. Note that these last two risks are not addressed as fully as in Alternative 1 since wet weather treatment remains at JIWRF.

Wastewater conveyance assumes the use of a 14 mile, 9-foot tunnel from JIWRF and a new deep tunnel PS at SSWRF for conveyance of the 120 MGD dry weather flow. Wet weather treatment operations for the JIWRF service area remain at JIWRF. All pumpout from the ISS PS at JIWRF and gravity wet weather flow goes through new treatment facilities at JIWRF. The new treatment facilities are assumed to be similar to the primary filtration and biological facilities assumed for SSWRF, sized for 490 MGD. This alternative assumes costs would be similar to Alternative 1 in proportion to the capacity of the new facilities. Disinfection and effluent pumping upgrades are assumed to be similar to those developed for WRF FG8, JIWRF Blending Analysis in Appendix 6B. Solids processing and disposal facilities are assumed



to be constructed at SSWRF, similar to Alternative 1, producing solids to be sold under the Milorganite name. The reason for this assumption is that this opens up additional space at JIWRF and eliminates odor complaints related to biosolids processing at JIWRF. The effort to decommission JIWRF is not included in this planning-level analysis since the details regarding how the WRF is decommissioned would depend on how available land at the JIWRF site would be redeveloped.

Alternatives Evaluation

The alternatives were compared to determine if the risks identified in Chapter 5 are addressed and to establish which alternative has the lowest planning-level present worth cost. Capacity risks are eliminated by both alternatives. Negative community impact risks, including those due to odors, and structural risks at JIWRF are significantly reduced in Alternative 1 and less so in Alternative 2 since wet weather treatment still occurs at JIWRF for Alternative 2. The risk of odor complaints is addressed by the new preliminary filtration and secondary treatment facilities, which will be enclosed. As noted, risks to meeting renewable energy goals are not addressed as energy is assumed to increase in both alternatives due to increased pumping energy demands.

The planning-level cost estimates are presented in Table 6E-6. The analysis specific performance factors are presented in Table 6E-7 and the scoring matrix is presented in Table 6E-8. Details for cost estimates are presented in Appendix 6E-3. The annual O&M costs are based on the planning-level assumption that the only additional annual O&M costs would be the new pump station from JIWRF to SSWRF and, in general, the cost to operate the same proposed amount of flow (740 MGD peak wet weather) would the same as reviewed under Appendix 6B, specifically WRF FG8, JIWRF Wet Weather Capacity Analysis.

TABLE 6E-6: SW FG1 PRESENT WORTH PLANNING-LEVEL COST COMPARISON

Planning-level Costs	Alternative 1 – Diversion of All Flow from JIWRF to SSWRF	Alternative 2– Diversion of Dry Weather Flow to SSWRF
Capital Cost	\$3,337,800,000	\$2,027,400,000
Annual O&M Costs	\$11,110,000	\$4,660,000
Present Worth of Annual O&M Costs	\$159,700,000	\$67,000,000
Present Worth of Equipment Replacement Costs	\$0	\$0
Present Worth of Salvage Value	\$0	\$0
Total Present Worth	\$3,497,500,000	\$2,094,400,000



TABLE 6E-7: SW FG1, JIWRF AND SSWRF REUTILIZATION

ANALYSIS-SPECIFIC PERFORMANCE FACTORS

Triple Bottom	Level of Service	
Line Measure	Category	Performance Factor
	Permit Requirements	KPI: Effluent permit violations/year (multiple parameters). The factor considered is the likelihood an alternative will provide the full treatment needed to achieve effluent permit limits under future flows and wasteloads projections through the planning period.
Environmental	Energy	Total energy demand impact of alternative (with minimal impact receiving highest score). The factor considered was the energy for new facilities over and above facilities need to treat same amount of flow.
	Environmental Improvements	Measure of the advantages of a given alternative in terms of improvements to the environment. Specific consideration for this alternative analysis includes compliance with operation and maintenance contract effluent quality limits.
	Fiscal Responsibility	General measure of how well a given alternative reduces identified risk(s) in a cost-effective manner (with most cost-effective receiving highest score). Factors to consider are cost-effectiveness of consolidating operations in one location and total costs.
Economic	Management Effectiveness	Measure of a given alternative's ability to help management achieve the permit and contract goals. Factors to consider include complexity to implement/operate alternative, new technologies or alternative simplifies operations from baseline.
	Safety	Measure of a given alternative's impact on safety. Factors to consider include impact on safety from operating a new technology or increase/decrease in chemical use. The factors to consider are operating new technology and consolidating treatment operations staff.
Social	Customer Service, Communication and Employee Development	Measure of the advantages of a given strategy to reduce potential complaints and notices of violation, improve communication effectiveness, and/or provide employee development opportunities. The factors considered are a given alternative's impact on customer goodwill and additional land for development/reduction of full treatment at JIWRF.



TABLE 6E-8: SW FG1, ALTERNATIVES SCORING MATRIX

Alternative Scoring Matrix SW FG1, JIWRF and SSWRF Reutilization	Alternative 20-yr Present Worth (\$ million) ¹	Permit / Legal Requirements	Energy	Environmental Improvements (non-regulatory, resource recovery)	Fiscal Responsibility	Management and Operational Effectiveness	Safety	Customer Service, Community Economic Development and Organizational Reputation	Total Weighted Score	Value Ratio (Total Weighted Score/ Present Worth)
Weights		26	17	15	17	6	13	6	100	
Alternative 1: Diversion of All Flow from JIWRF	\$3,497.5	5	2	5	1	4	5	5	375	0.11
Alternative 2: Diversion of Dry Weather Flow from JIWRF	\$2,094.4	4	3	4	2	3	3	3	324	0.15
Comments		For Alt 2, a new permit would be needed for JI WW treatment only, TMDL requirements still apply	More energy than baseline with new PS, less energy for smaller pump station for Alt 2	For Alt 2, JI WW treatment TMDL requirements still apply	Both alts are very expensive	New technology but consolidating all to one WRF for the most part for Alt 1	Assumed safer to consolidate treatment at SSWRF in Alt 1, very large wet weather facility at JIWRF	Alt 1 allows for potential redevelopment of most of JIWRF, Alt 2 still has solids processing and wet weather treatment at JIWRF		

¹⁾ The costs to decommission JIWRF for both alternatives is not included in this planning-level analysis since the details regarding how the WRF is decommissioned would depend on how available land at the JIWRF site would be redeveloped.



Recommendations

Alternative 2, Diversion of Dry Weather Flow from JIWRF to SSWRF, has the higher value ratio. The weighted score for Alternative 1, Diversion of All Flow from JIWRF to SSWRF, is higher but the present worth cost for Alternative 1 is almost twice as high as Alternative 1. If Alternative 2 were to be implemented, the recommended upgrades would address, at least in part, the risk of not considering various available treatment and transport reutilization options at JIWRF, SSWRF, and the Conveyance system, by considering transferring dry weather flow to SSWRF for treatment, and addresses the risk of negatively impacting community relationships around JIWRF and structural risks identified at JIWRF that are due to the construction on wood piles by limiting treatment processes at the site. Note that these last two risks are not addressed as fully as in Alternative 1 since wet weather treatment remains at JIWRF.

However, even for Alternative 2, the value ratio is minimal at 0.15, meaning that there is very little value realized for the significant financial impact required. Therefore, the recommendation is to not proceed with preliminary engineering at this time. A change of the baseline operations of full treatment at both JIWRF and SSWRF would be a major undertaking, regardless of the alternative chosen. Instead, this analysis should be used as a resource in the future if the risks identified increase the weighted score and technology improves to reduce the costs such that the value ratio improves significantly enough to justify a project.

The 2050 FP recommends that the feasibility of transferring flow from the JIWRF service area to the SSWRF service area within the conveyance system be determined once the hydraulic model is calibrated, as noted in Appendix 6A, Conveyance and Storage System. The cost for this effort is estimated to be \$100,000 and would assess not only feasibility, but also the costs for upgrades to the conveyance system, including pump stations. If the study determines that a significant amount of flow can be transferred to the SSWRF service area, it is recommended that a pilot study of the primary filtration and biological treatment technology presented in this analysis be conducted at SSWRF to determine the feasibility of its use to provide additional capacity at SSWRF. The estimates capital cost for this pilot study is assumed to be \$8,330,000 to install one module with a treatment capacity of approximately 9 MGD at SSWRF. Both of these cost estimates are presented in Appendix 6E-3.



SW FG2, Zero Overflows

Purpose

The purpose of this analysis is to evaluate potential high-level alternatives to mitigate the risk of not meeting the following level of service targets:

- Key performance indicator (KPI) target of 100 percent of annual overall capture of flow into the MMSD system
- PI target of zero SSOs
- PI target of zero CSOs

For purposes of this analysis, these targets have been grouped together under the umbrella of meeting zero overflows with expectation that if this is achieved, all three targets will be met. These risks were identified as part of the systemwide assessment developed in Chapter 5.

MMSD's actual performance during the 2015 to 2017 performance review time period was as follows:

TABLE 6E-9: ZERO OVERFLOWS ANALYSIS KPI/PI TARGETS

	Level of Service	Actu	Actual Performance		
	Target*	2015	2016	2017	
PI: SSO events/year	0	1	0	1	
PI: CSO events/year	0	1	2	0	

^{*}Level of service targets are internal MMSD goals, which may be more stringent than regulatory requirements.

Green = level of service target achieved

Because increased flows are projected under Conveyance Future and Buildout Conditions, it is anticipated that these targets will be even more difficult to achieve even if recommended projects are implemented for the Conveyance and Storage and WRFs and Biosolids Asset Systems. Achieving zero overflows is predicted to be very expensive, as described in this analysis. Therefore, this analysis is intended to be a roadmap for a phased approach; by developing full-scale alternatives that incorporate treatment and storage options, the most feasible incremental phases can be identified. The base alternative for this analysis assumes that applicable recommended Conveyance, WRF and Green Infrastructure (GI) projects will be implemented as the important first step toward achieving zero overflows.

The analysis presented in Systemwide FG1, JIWRF and SSWRF Reutilization is considered a corollary analysis that addresses JIWRF and SSWRF capacity risks. The planning-level assumption is that the recommendations from FG1 would not reduce the risk of overflows.



Approach

The analysis was developed in multiple steps, starting at a high level to determine the alternatives to eliminate tunnel-related CSOs, then reviewing alternatives to confirm tunnel-related SSOs were also eliminated, and then finally identifying the additional projects that would be needed to eliminate conveyance system-related SSOs and CSOs due to local hydraulic limitations. Note that other approaches could be used in future analyses, such as considering a different period of record for storms or modified future growth projections.

The analysis first focused on tunnel-related CSOs, defined as the CSOs that occur due to limitations of tunnel volume, with the expectation that eliminating tunnel-related CSOs will would eliminate tunnel-related SSOs. A base alternative was developed (Alternative 0) that assumed specific recommendations from the asset system analyses would be implemented to reduce overflows, and then the remaining volume of tunnel-related CSOs based on the annual average was calculated.

Planning-level systemwide alternatives were then developed to address the remaining tunnel-related CSOs that were still predicted to occur after the implementation of the recommended projects in Alternative 0. The following three alternatives were developed that focused on additional treatment and storage:

- Alternative 1: Maximum WRF HRT and CSO HRT. Focuses on just treatment specifically high rate treatment (HRT) systems
- Alternative 2: Maximum tunnel volume. Focuses on just storage specifically additional tunnel storage
- Alternative 3: Maximum WRF HRT capacity plus expanded tunnel volume. Focuses on a combination of treatment and storage

The 2050 FP project team selected these alternatives after reviewing the findings from the State of the Art Report completed as part of the prior 2020 Facilities Plan and determining that these are most cost-effective systemwide solutions. [3] The three alternatives were modeled under Conveyance Future Conditions to determine the treatment and storage needed to achieve zero CSOs. Present worth costs were developed for the three alternatives and the alternatives were scored against established criteria. Based on those findings, a recommended tunnel-related CSO elimination alternative was determined.

The analysis then confirmed the recommended CSO elimination alternative would eliminate the remaining tunnel-related SSOs and compared that to other systemwide options to eliminate SSOs. Two alternatives were identified:

- Alternative 1: Eliminate SSOs with additional tunnel storage and adjustment of the volume reserved for separate sewer inflow (VRSSI). Uses the Conveyance System Model (CSM) to represent the recommended CSO elimination alternative to determine the needed tunnel volume and VRSSI adjustment.
- Alternative 2: Eliminate SSOs by reducing inflow and infiltration (I/I) into the system. Presents
 the findings of business case summary CBC033, originally referenced in CS R9, Combat I/I
 analysis in Appendix 6A, completed under a separate project [4] regarding the costs to
 completely eliminate SSOs.⁵

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⁵ This is over and above the analysis that is presented in Conveyance Analysis CS R9, Combat I/I Impact from Pipe Degradation in Appendix 6A, which identifies the costs to mitigate the projected 14 percent increase in I/I over the planning period, not the costs to completely eliminate SSOs.



The recommendation from these two evaluations is defined as the zero tunnel-related overflow recommended alternative. The final alternative was then simulated in the conveyance model using Buildout Conditions to establish the impacts to tunnel-related overflows.

The remaining conveyance system-related CSOs and SSOs are addressed with recommended conveyance projects. The recommendation to address both tunnel-related overflows and conveyance system-related overflows is defined as the zero overflow recommendation.

Tunnel-Related CSO Elimination Alternatives Description

As stated above, this analysis first focused on eliminating CSOs. The risk was defined as the average annual CSO volume. To determine the tunnel-related CSO volume that needs to be addressed, the base alternative (Alternative 0) was evaluated. To address the risk of the remaining CSO volume, three alternatives were developed. Descriptions and schematics of each alternative are presented below.

Alternative 0 – Base Alternative

Alternative 0 assumes that the following committed projects in the MMSD system will be implemented for the Conveyance and Storage, WRFs and Biosolids, and GI Asset Systems (assumed Watercourse and Flood Management projects will have no impact on overflows):

- Conveyance and Storage (details provided in Appendix 6A):
 - Capacity recommendations made in Conveyance Analyses CS R1 through R8
 - Conveyance Analysis CS R9, Combat I/I Impact from Pipe Degradation recommendation to maintain the Conveyance Baseline Conditions level of I/I
- WRFs and Biosolids (details provided in Appendix 6B):
 - Recommendation in WRF Analysis FG8, JIWRF Wet Weather Capacity to increase blending at JIWRF to 180 MGD
 - Recommendation in WRF Analysis FG9, SSWRF Wet Weather Capacity to increase blending at SSWRF to 75 MGD
- GI (details provided in Appendix 6D): 200 MG of GI in the combined sewer service area (CSSA). Note that there is no alternative developed to increase GI volume past the 200 MG in the CSSA. Review of the modeling results presented in Appendix 6D-5, GI Modeling within the CSSA, indicates that 200 MG is the most effective reasonable volume. Also, GI volume in the separate sewer service area (SSSA) was not incorporated in this alternative because this analysis was focused on CSO elimination, not SSO elimination.

Modeling of Alternative 0 in the Simplified System Model (SSM) determined that even after implementing the above projects, an average annual volume of 406 MG/yr of CSOs is anticipated under Conveyance Future Conditions, with an average of 1.5 CSO events per year. A schematic of Alternative 0 is presented in Figure 6E-7.



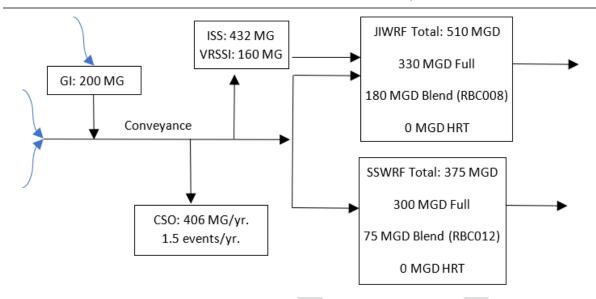


FIGURE 6E-7: ZERO TUNNEL-RELATED CSOS ALTERNATIVE 0 SCHEMATIC

Alternative 1 – Maximum WRF HRT and CSO HRT

Alternative 1 focuses on the maximum HRT needed in the MMSD system to achieve zero CSOs under Conveyance Future Conditions. In Alternative 1, tunnel and GI capacities are assumed to be held at Alternative 0 assumptions and the system was modeled in the SSM to determine how much additional wet weather treatment capacity would be needed. Due to hydraulic limitations in the system, the SSM model indicated that additional treatment capacity at the WRFs is limited to 255 MGD at both JIWRF and SSWRF and that CSOs will still occur. The SSM modeling results also indicated that under these conditions, HRT at JIWRF would be used an average 25.3 events/year (1,900 events over the 75-year period of record [POR]) at JIWRF and 5.3 events/year (403 events over the 75-year POR) at SSWRF. In a phased approach to implementing HRT at the WRFs, HRT at JIWRF is recommended first as modeling shows that an increase in capacity at JIWRF has more of an impact on CSO reduction than an increase in capacity at SSWRF, as discussed in Appendix 4A-3, Conveyance Modeling Summary.

Modeling indicates that with HRT at both JIWRF and SSWRF, CSOs would be reduced to an average of 234 MG per year, with an average 0.9 events per year. Therefore, this alternative also assumes treatment at all remaining CSO sites. It is assumed that treatment would be provided by HRT and UV disinfection at all sites, because they provide the highest treatment capacity at the smallest footprint. A schematic of Alternative 1 is presented in Figure 6E-8. Information provided in red indicates the changes from Alternative 0. The HRT at the WRFs are designed to meet monthly permit requirements, specifically BOD and TSS concentrations less than 30 mg/L, TP less than 1 mg/L, and *E. coli* counts less than 410 #/100 mL (this analysis assumes *E. coli* limits will replace 2019 WPDES effluent fecal coliform limits). CSO HRT design is discussed below.

The CSO treatment permitted in Superior, Wisconsin was reviewed for comparison. [5] According to the Permit Fact Sheet, Superior has three permitted combined sewer treatment plants (CSTPs): CSTP 2 consists of an aerated basin and chlorination/dechlorination disinfection, CSTP 5 and 6 both consist of physical/chemical treatment facilities that each include retention ponds, two stage settling, and coarse and fine screening. [6] The effluent limits from the permit are presented in Table 6E-10.



TARIF 6F-10 ·	SUPFRIOR	WISCONSIN CST	P WPDFS PFRMIT	PILMITS
I WOLL OF IO.	JOF LINION,	WISCONSIN CSI	F VVFDLJ FLIXIVII I	LIIVIII

Parameter	CSTP 2	CSTP 5	CSTP 6
BOD (mg/L)	45 ¹ , 30 ²	45 ¹ , 30 ²	45 ¹ , 30 ²
TSS (mg/L)	60 ²	65¹	65 ¹
TP (mg/L)	1.0 ²	1.0 ²	1.0 ²
Nitrogen Ammonia (mg/L)	39 ^{1,2,3}	NA ⁶	NA ⁶
Fecal Coliform (No. /100 ml)	400 ⁴ , 972 ⁵	NA ⁶	NA ⁶

Notes:

- 1) Weekly average
- 2) Monthly average
- 3) Daily maximum variable based on pH, ranging from > 39 mg/L when pH<7.1 and 1.8 when pH is between 8.9 and 9
- 4) Geometric mean, monthly
- 5) Geometric mean, weekly
- 6) NA values to be reported but does not have a limit

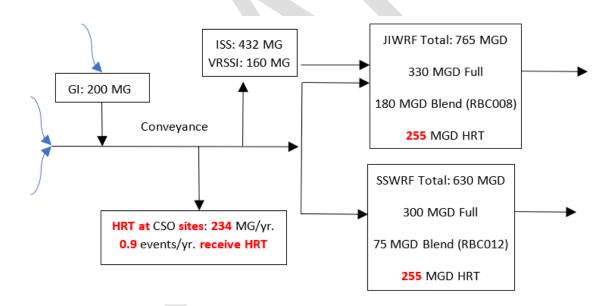


FIGURE 6E-8: ZERO TUNNEL-RELATED CSOS ALTERNATIVE 1 SCHEMATIC

(Items in red are changes from Alternative 0)

HRT at JIWRF

MMSD has been reviewing HRT concepts for a number of years, as documented in the Conceptual Design Report completed in 2007. The HRT at JIWRF for this alternative assumes that a system similar to what was proposed in the Conceptual Design Report would be installed. [7] The Conceptual Design



Report reviewed 50, 100, and 200 MGD DesnaDeg and Actiflo systems. The system closest to the size needed for Alternative 1 is the 200 MGD system, identified in the Conceptual Design Report to be installed on the Harbor Commission property south of JIWRF. Based on those findings, the Alternative 1 analysis assumes a 255 MGD Actiflo system including increasing the size of the systems needed. The system in the Conceptual Design Report included influent piping, preliminary treatment, grit chambers, HRT, chemical feed buildings, UV disinfection, effluent pump station, and gravity thickener, along with influent and effluent piping. In a review of the system, the 2050 FP project team determined that the influent connection to the system needed to be reevaluated. The Conceptual Design Report assumed piping to the preliminary treatment building from the ISS Pumpout conduit and no pump station to pump diverted flow into the HRT system. The Alternative 1 analysis assumes the flow to the HRT system is from the high-level (HL) and low-level (LL) siphons. Therefore, this analysis also includes the cost of a diversion structure from the HL and LL siphons and an influent high flow, low head pump station. The proposed dimensions of each system are presented in Table 6E-11. A layout of the system at the proposed site south of JIWRF is presented in Figure 6E-9.

TABLE 6E-11: JIWRF HRT SYSTEM DIMENSIONS

HRT System Processes	Total Area (rounded, square feet)	Number of Units and Dimensions	
Influent Pump Station	2,700	52 x 52	
Preliminary Treatment	43,700	4 screens (95 x 115)	
Grit Removal	48,600	6 units (180 x 45)	
HRT	93,200	6 units (186 x 83.5)	
Disinfection	1,900	6 units (6 x 8 x 38)	
Effluent Pump Station	2,700	52 x 52	





FIGURE 6E-9: JIWRF HRT SYSTEM LAYOUT

The Conceptual Design Report indicated that over 90 percent removal of TSS was anticipated and effluent TP was anticipated to be 0.4 mg/L. Based on this information, a 255 MGD system at JIWRF is anticipated to generate an additional 55,000 lb/d of TSS and 850 lb/d TP. Depending on the length of a wet weather event, it is anticipated these values will exceed JIWRF TSS and TP mass limits in the 2019 WPDES permit, which are presented in Chapter 4. The limits vary, but TSS weekly average limits range from 51,333 lb/d to 56,832 lb/d, TSS average monthly limits vary from 30,195 lb/d to 33,430 lb/d, and TP average monthly limits range from 664 lb/d to 735 lb/d. This issue is discussed in WRF R6, JIWRF TMDL Management in Appendix 6B. For this analysis, no additional costs have been included to meet the mass limits; instead the assumption is that the proposed HRT effluent limits in the WPDES permit will not include these mass limits.

HRT at SSWRF

The HRT at SSWRF assumes that a system similar to what was proposed as part of the Conceptual Design Report would be installed. [7] The Conceptual Design Report reviewed 50, 100, and 200 MGD DesnaDeg and Actiflo systems. A more current report, the South Shore Process Enhancement Demonstration Project Demonstration Test Report, [8] was also reviewed, but because only one size system (150 MGD)



was developed and most of the costs, except for the HRT system itself, were estimated from the Conceptual Design Report, the costs from the Conceptual Design Report were used to provide a more equitable comparison to the costs established for JIWRF. The Alternative 1 analysis assumes a 255 MGD Actiflo system based on those findings, including increasing the size of the systems needed. The system in the Conceptual Design Report included influent piping, a connection to the MIS flow control structure, preliminary treatment, grit chambers, HRT, chemical feed buildings, UV disinfection, gravity thickener, and influent and effluent piping. In reviewing the proposed 255 MGD system, the 2050 FP project team determined that flow can be discharged from SSWRF by gravity but a second outfall also needs to be included. The proposed dimensions of each system are the same as those presented in Table 6E-11, with the exclusion of the influent and effluent pump stations, which were determined not to be needed at SSWRF. The HRT at SSWRF assumes the same effluent quality as listed for JIWRF HRT above. A layout of the system on the SSWRF site is presented in Figure 6E-10.



FIGURE 6E-10: SSWRF HRT SYSTEM LAYOUT



CSO HRT

For the CSO sites, the SSM model was reviewed to determine where CSOs would still be occurring and what the peak flow would be for each site. The results of the modeling analysis identified 114 sites where CSOs are still occurring, which are presented in Table 6E-12. As noted in the table, two "sites" actually represent 111 individual CSOs; these are along the HL and LL siphons to JIWRF. The locations of the remaining 114 CSO sites in the MMSD service area are presented in Figure 6E-11. The CSO HRT must be designed to the peak CSO rate to treat all CSO flow. As can be seen from the table, peak flow is over 100 MGD at three of the five sites. For CSO56 (which represents 12 individual CSO sites out of the 114 CSO sites), the average peak flow per individual CSO is more than 980 MGD.

TABLE 6E-12: CSO SITES STILL EXPERIENCING TUNNEL-RELATED OVERFLOWS IN ALTERNATIVE 1

CSO Sites	QCSO 5fh (BS0502A)	QCSO56	QCSO7	QCSO DC0103	QCSO BS0405
Average CSO Volume (MG)	0.42	127.56	132.56	0.15	5.71
Max CSO Volume (MG)	8.17	1,133.97	918	7.67	112.37
Average CSO Rate (mgd)	2.16	1,664.68	1,510.49	3.68	15.1
Average time of CSO event (hrs)	4.7	1.8	2.1	1.0	9.1
Peak CSO Rate (mgd)	36.82	11,802.71	9,532.63	184.12	244.54
Max CSO Event	Sep-41	Aug-86	Aug-86	Aug-86	Mar-60
# of individual CSO	1	12	99	1	1
Peak flow per individual CSO (mgd)	37	984	96	184	245
CSO Frequency (events/year)	0.09	0.93	1	0.03	0.11
Total CSO event in POR	7	70	75	2	8



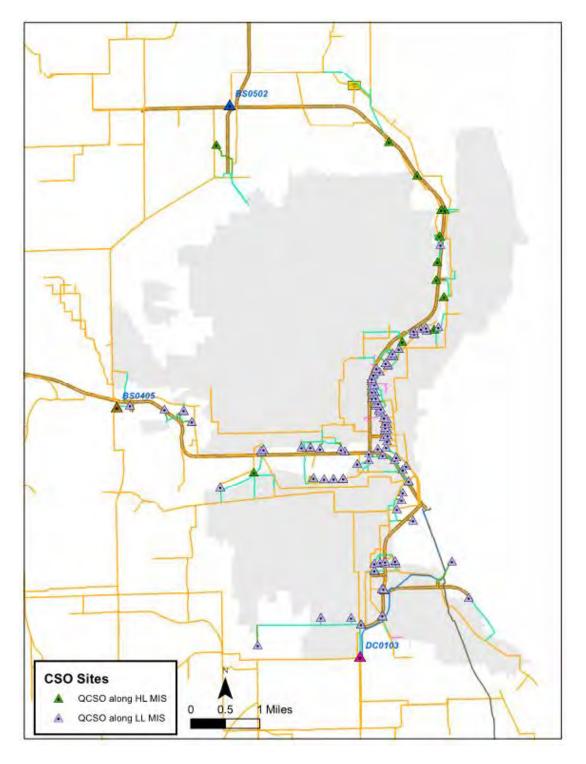


FIGURE 6E-11: CSO LOCATIONS WHERE HRT ASSUMED TO BE IMPLEMENTED IN MMSD SERVICE AREA



Alternative 1 assumes that each CSO site has its own HRT system, including diversion structure, screening, HRT, UV disinfection, waste and chemical storage, and piping and that land can be acquired for all sites based on planning completed as part of the Port Washington Road Relief Sewer (PWRS) project (also known as N 27th St ISS Extension project). [9] Alternative 1 also assumes that the cost savings realized by consolidating sites would be offset by the cost to divert flow to the consolidated HRT location. For CSO treatment, the HRT is assumed to use cloth media filter technology rather than Actiflo based on projects in design as of 2019, including a 256 MGD system in Hammond, Indiana using the AquaStormTM technology developed by Aqua-Aerobic Systems, Inc. [10] The system performance is anticipated to be similar to the Actiflo system, providing 90 percent removal of influent TSS to achieve greater than 30 mg/L effluent TSS concentration and 70 percent removal of TP with 3 mg/L addition of Alum. [11] UV disinfection is designed to achieve *E. coli* counts of less than 410 #/100 mL for the duration of the event. At the April 22, 2019 Commission meeting, MMSD approved Project M03091P10 to pilot an HRT system that incorporates chemically enhanced primary treatment and advanced oxidative disinfection processes. [12] The assumptions included in this analysis should be reviewed again at the end of that pilot study, scheduled for spring 2021.

The total land requirements are assumed to be the same as developed for the PWRS project. Figure 6E-12 presents an estimate of the space needed for the layout of an example system at the BS0405 CSO location at approximately North Hawley Road and West State Street, which is projected to need over 7 acres of land for all processes.



FIGURE 6E-12: EXAMPLE CSO HRT SYSTEM SPACE LAYOUT AT BS0405



Alternative 2 - Maximum Tunnel Volume

Alternative 2 focuses on the maximum tunnel volume needed in the MMSD system to achieve zero CSOs under Conveyance Future Conditions. In Alternative 2, WRF and GI capacities are assumed to be held at Alternative 0 assumptions and the system was modeled in the SSM to determine how much additional tunnel volume would be needed. From SSM simulations, it was determined that over 2,600 MG of storage capacity would be needed, which is six times the 2019 capacity of 432 MG, with 2,178 MG of additional storage volume needed. The SSM applies Conveyance Future Conditions to the storms from the 75-year POR; therefore, it is assumed this volume takes into account back-to-back storm events similar to what has happened in the past.

A total volume of 2,610 MG for tunnel storage is quite large, which leads to concerns about creating void space by tunneling a significant area under the MMSD service area, which could cause settling and compromise structures. Assuming a 30-foot diameter tunnel, an additional 78 linear miles of tunnel would be needed, which equates to around 285 acres, which represents 0.04 percent of Milwaukee County land area. A schematic of Alternative 2 is presented in Figure 6E-13.

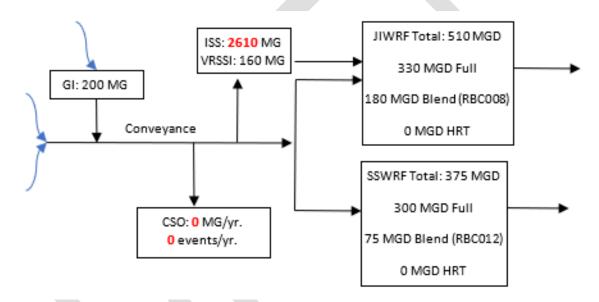


FIGURE 6E-13: ZERO TUNNEL-RELATED CSOS ALTERNATIVE 2 SCHEMATIC

(Items in red are changes from Alternative 0)

Alternative 2 – Initial Tunnel Volume Considerations

As part of the alternative, any existing tunnel volume not currently being utilized should be considered before constructing additional storage tunnels. In 2015, MMSD reviewed the feasibility of rehabilitating the existing 6 MG Kinnickinnic (KK) River Flushing Tunnel into CSO storage in the Kinnickinnic River Flushing Tunnel CSO Storage Facility Feasibility Study (KK River CSO Storage Study). [13] This tunnel is an approximately 7,200 foot-long, 12-foot inside diameter, 18-inch thick brick pipeline, with associated pump station and outlet structure. Put into service in 1907, the tunnel had originally been used to pull water from Lake Michigan to flush the KK River, the use of which was discontinued in 2008. The KK River CSO Storage Study determined that the KK River Flushing Tunnel could be repurposed as CSO storage,



recommending the following elements: inspection of the tunnel, installation of gravity diversion facilities in the KK River Flushing Tunnel at outfall no. 196-Lake Michigan South (LM-S) dropshaft site, gravity drainage facilities from the KK River Flushing Tunnel to Kinnickinnic/Lake Michigan Tunnel System, KK-2 dropshaft and ancillary facilities site (KK-2), and PVC lining of the brick structure. Lining of the tunnel would reduce the volume to 5.59 MG of available storage.

Alternative 2A – Maximum Tunnel Volume plus CSO HRT at Select Locations

Alternative 2A focuses on the maximum tunnel volume needed in the MMSD system to achieve zero CSOs under Conveyance Future Conditions if CSO HRT is provided at select locations. Alternative 2A also assumes WRF and GI capacities are held at Alternative 0 assumptions. Select CSO locations were chosen for HRT based on the assumption that CSO locations along the HL and LL siphons are located in highly-developed areas with minimal land immediately available for siting HRT systems; therefore, the three distinct CSO locations identified in Table 6E-12 were chosen: BSO502A, DC0103, and BS0405 for HRT systems. The system was then represented in the SSM to determine how much additional tunnel volume would be needed to capture the CSO flow from the remaining HL and LL CSOs (CSO56 and CSO7 from Table 6E-12). Using results from the SSM simulation, it was determined that providing CSO HRT at the three locations would reduce the tunnel volume needed for Alternative 2 by 74 MG from 2610 MG to 2,536 MG, which is 5.8 times the 2019 capacity of 432 MG, resulting in an additional 2,104 MG of tunnel volume needed. The SSM applies Conveyance Future Conditions to the storms from the 75-year POR; therefore, it is assumed this volume takes into account back-to-back storm events similar to those that have happened in the past.

A volume of 2,536 MG of tunnel storage is quite large, which leads to concerns about creating void space by tunneling a significant area under the MMSD service area, which could cause settling and compromise structures. Assuming a 30-foot diameter tunnel, the additional linear miles of tunnel would drop from 78 miles to 75 miles and the square acreage needed for additional tunnels is only reduced by 10 acres, to about 275 acres, which still represents 0.04 percent of Milwaukee County land area. A schematic of Alternative 2A is presented in Figure 6E-14.



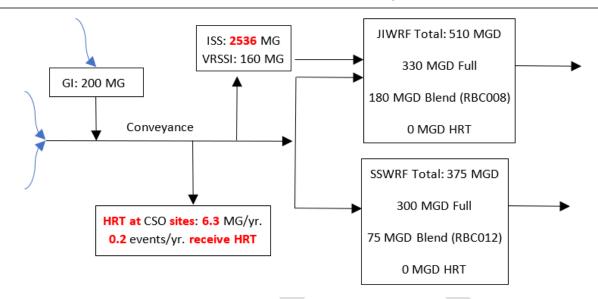


FIGURE 6E-14: ZERO TUNNEL-RELATED CSOS ALTERNATIVE 2A SCHEMATIC

(Items in red are changes from Alternative 0)

Alternative 3 – Maximum WRF HRT Capacity plus Expanded Tunnel Volume

Alternative 3 takes the findings from Alternatives 1 and 2 to develop a combined alternative to achieve zero CSOs under Conveyance Future Conditions. In Alternative 3, GI capacities are assumed to be held at Alternative 0 assumptions, WRF capacities are held at the maximum capacities determined in Alternative 1 (255 MGD at each WRF), and the system was modeled in the SSM to determine how much additional tunnel volume would be needed. In this alternative, no HRT is provided at individual CSO locations. Using SSM model results, it was determined that 2,303 MG of storage tunnel would be needed, which is more than five times the 2019 capacity of 432 MG, with 1,871 MG of additional tunnel volume needed. This volume is very close to the volume projected for Alternative 2. This is because of the significant peak flows during events. As shown in Table 6E-12, although the average modeling results indicate that the CSOs only last from 1 to just under 10 hours, the peak flow at the CSOs can range from 37 to 11,800 MGD. The duration of peak flows can be short, but every time peak flow exceeds the 510 MGD of HRT at the WRFs, that flow would need to be captured by the tunnel until the WRFs have capacity.

As stated previously, the very large tunnel volume leads to concerns about creating void space by tunneling a significant area under the MMSD service area, which could cause settling and compromise structures. Assuming a 30-foot diameter tunnel, the square acreage needed for additional tunnels is around 245 acres, which represents 0.03 percent of Milwaukee County land area. A schematic of Alternative 3 is presented in Figure 6E-15.



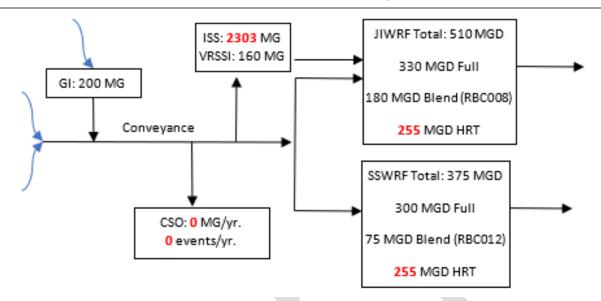


FIGURE 6E-15: ZERO TUNNEL-RELATED CSOS ALTERNATIVE 3 SCHEMATIC

(Items in red are changes from Alternative 0)

Alternatives 3A and 3B – Maximum WRF HRT Capacity plus Expanded Tunnel Volume with Expanded ISS Pump Station

Alternatives 3A and 3B take the findings from Alternative 3 and include an expanded ISS Pump Station to determine if increasing the ISS pumpout would reduce the tunnel volume required, which in Alternative 3 is still significant at over 2,300 MG. Alternative 3A assumes the ISS Pump Station would increase by 120 MGD to a total capacity of 260 MGD and Alternative 3B assumes the ISS Pump Station would double in size to 360 MGD. Using SSM modeling results, it was determined that even doubling the size of the ISS Pump Station had little impact on the tunnel volume needed, reducing tunnel volume from 2,303 MG as presented in Alternative 3 to 2,300 MG. This is because JIWRF often reaches the peak full treatment capacity during the peak hours of events and thus ISS pumping is restricted to 180 MGD, which is the capacity available for blending. Therefore, no costs were developed for these alternatives and they are not evaluated further.

Tunnel-Related CSO Elimination Alternatives Evaluation

The modeling input assumptions for the CSO elimination alternatives are presented in Table 6E-13. Parameters that are changed for each alternative in comparison to the parameters established for Alternative 0 are identified in red.



TABLE 6E-13: SW FG2, PRESENT WORTH PLANNING-LEVEL COST COMPARISON

	Conveyance Future Flows ¹						
Modeling Parameters	Alt. 0	Alt. 1	Alt. 2	Alt. 2A	Alt. 3	Alt. 3A	Alt. 3B
Inputs:							
SSWRF Disinfection Capacity (MGD)	375	630	375	375	630	630	630
Maximum Blending Capacity at SSWRF(MGD)	75	75	75	75	75	75	75
JIWRF Capacity (MGD)	330	585	330	330	585	585	585
Maximum Blending Capacity at JIWRF(MGD)	180	180	180	180	180	180	180
JIWRF Disinfection Capacity (MGD)	510	765	510	510	765	765	765
Low Level Influent Pump Capacity (MGD)	130	355	130	130	355	355	355
VRSSI (MG)	160	160	160	160	160	160	160
ISS Pumping Rate to JIWRF (MGD)	140	140	140	140	140	260	320
ISS Pumping Rate to SSWRF (MGD)	40	40	40	40	40	40	40
ISS Pumping Rate to JIWRF (MGD) when pumping to SS is not occurring	180	180	180	180	180	300	360
Maximum ISS Volume (MG)	432	432	2,610	2,536	2,303	2,300	2,300
Additional ISS Volume (compared to Alternative 0)	0	0	2,178	2,104	1,871	1,868	1,868
Total GI Volume (MG)	200	200	200	200	200	200	200
CSO HRT Peak Flow (MGD)	0	See Table 6E-12	0	See Note ²	0	0	0
Outputs:							
Average Annual CSO volume (MG/yr)	406	234	0	0	0	0	0
CSO Frequency (Events/yr)	1.5	0.9	0	0	0	0	0

Notes:

- 1) Values in red represent values that are adjusted from those established for Alternative 0 for a specific alternative.
- 2) See peak flow for CSO locations BS0502A, DC0103, BS0405 in Table 6E-12.



Each alternative was evaluated as follows:

- Compare the advantages and disadvantages (Table 6E-14)
- Determine its planning-level present worth cost (Table 6E-15)

Alternatives 2, 2A and 3 tunneling costs were developed from information available from MMSD's most recent tunnel project, the North 27th Street ISS Expansion (2007), along with more recent tunnel costs from Cleveland, Ohio and Indianapolis, Indiana (2017), all of which include costs for lining the tunnel. [14] [15] [16] The alternatives that include tunneling also assume minor tunnel annual maintenance costs based on experience MMSD has with the tunnel system in place. The alternative does include additional ISS pumping costs, which appear to be minor. Over the 75-year POR simulated in the SSM, additional ISS pumping required an average of 35 hours over 61 events, with the longest additional ISS pump being active for almost 12 days. Because it was assumed that demand charges would already be factored into energy bills based on the peak of 180 MGD ISS Pump Station capacity, only on-peak and off-peak hourly charges were considered, which were determined to be about \$2,200 a year.

Unit costs in terms of \$ per gallon of storage for tunnels can vary greatly depending on the specific circumstances – for instance, the tunnel present worth unit cost at 2,178 MG of additional tunnel volume (Alternative 2) is \$2.07/gal of tunnel, whereas the present worth cost for the KK River Flushing Tunnel is calculated to be \$4.07/gal of tunnel. However, this unit cost does not accurately compare alternatives against each other as HRT is typically considered on a unit flow basis (\$/MGD, for instance). Therefore, Table 6E-16 presents a range of unit costs for each CSO reduction system by dividing the present worth costs against the projected annual average CSO reduction.

Details for the tunnel-related CSO elimination alternative cost estimates are presented in Appendix 6E-4.

The alternatives were also scored to see how well each one addresses specific level of service performance factors, as guided by the advantages and disadvantages developed in Table 6E-14. The analysis-specific performance factors are presented in Table 6E-17. The scoring matrix is presented in Table 6E-18. The scoring matrix table also includes a value ratio, calculated by dividing the total weighted score by the present worth cost, which indicates the overall value that each alternative provides per billion dollars spent.

Findings

The comparison of the advantages and disadvantages presented in Table 6E-14 indicate that alternatives that treat the wet weather flow to reduce CSOs are more advantageous than the expanded tunnel volume alternatives against the risk of back-to-back storms not captured in the modeling. Alternative 3, which uses a combination of WRF HRT and additional tunnels, is the most advantageous because it combines the advantages of both Alternatives 1 and 2. Alternative 2A does reduce the amount of tunnel volume required, but CSO HRT costs are significantly higher than WRF HRT costs due to additional solids handling process and land acquisition along with higher annual O&M costs.

As Table 6E-15 indicates, if MMSD commits to eliminating all CSOs, the cost is in the billions of dollars, regardless of the alternative. Alternative 2 has the lowest present worth, but Alternative 3 is within 7 percent, while Alternative 2A is higher than both Alternative 2 and Alternative 3. Alternatives 2, 2A and 3 include the salvage value for the tunnel whereas Alternatives 1, 2A and 3 assume that at 20 years there would be no salvage value remaining for the HRT equipment systems. As a comparison of costs, the portion of the total capital costs in Alternative 1 related to HRT costs at JIWRF and SSWRF are projected to be \$413,750,000 (1.5 percent of total capital cost) and \$355,800,000 (1.3 percent of total



capital cost) respectively. The percent of the total capital cost for JIWRF and SSWRF HRT rises to 4.7 percent and 4 percent, respectively, of the total capital cost in Alternative 3.

Table 6E-16 indicates that HRT at the WRFs has the lowest unit cost per gallon of CSO volume removed. CSO HRT has the highest unit cost and varies significantly by CSO location because peak flows required for HRT capacity can vary significantly from annual CSO volume based on hydraulics in the Conveyance and Storage Asset System. Unit costs are more than 5 times higher for 25 MG of storage tunnel than for 2,178 MG of additional tunnel due to the initial set up cost of tunnel boring equipment that is inherent to any tunnel project. The costs to rehabilitate the KK River Flushing Tunnel (5.6 MG) are approximately the same as about 100 MG of new tunnel.

Table 6E-17 indicates that the focus of this analysis is the KPI and PI targets established by MMSD under the Environmental Improvements level of service category, which are more stringent than permit requirements. Although these targets are the main focus of the scoring, the other six level of service categories are also of importance.

Table 6E-15 indicates that due to the expense of all of the alternatives, the value ratio is very low for all of them. Due to the cost of CSO HRT, Alternative 1 is much more expensive than Alternatives 2, 2A, and 3; therefore, in in Table 6E-18, the value ratio is approximately one-tenth that of the other alternatives. Although Alternative 3 is more expensive than Alternative 2, the weighted score presented in Table 6E-18 is higher, resulting in a higher value ratio for Alternative 3. This alternative takes advantage of WRF HRT, which has the lowest unit cost per gallon of CSO removed, and tunnel volume to capture peak storm flows. Therefore, Alternative 3 was the CSO elimination alternative that was used for analysis in the subsequent tunnel-related SSO elimination evaluation.



TABLE 6E-14: RISK REDUCTION COMPARISON

How well each alternative addresses the risk of not meeting the following KPI and PIs:

- KPI: 100% of annual overall capture of flow into the MMSD system
- PI: 0 Combined Sewer Overflows (CSOs)

Alternative	Advantages	Disadvantages
Alternative 1: Maximum WRF HRT and CSO HRT	By using flow capacity rather than static volume, no risk of secondary storms occurring while emptying out storage	Numerous CSOs in the heart of the downtown Milwaukee area, land acquisition might not be feasible Uses technology MMSD operations staff is unfamiliar with WPDES permit will need to allow an exception at JIWRF of mass effluent limits on TSS and P for HRT
Alternative 2: Maximum Tunnel Volume	No discharge at CSO locations Uses system with which MMSD is already familiar	Static system – if have back to back extreme events not captured in the 75-yr period of record (longer or wetter), than could still have CSO
Alternative 2A: Maximum Tunnel Volume plus Select CSO HRT	By using flow capacity along with static volume, reduces risk of secondary storms occurring while emptying out storage	Doesn't reduce volume of tunnel significantly (only 74 MG from 2610 MG in Alternative 2) but adds expense of CSO HRT
Alternative 3: Maximum WRF HRT Capacity plus Expanded Tunnel Volume	No discharge at CSO locations By using flow capacity as well as static volume, reduce risk of secondary storms occurring while emptying out storage	Tunnel volume is not significantly less than what is needed in Alternative 2



TABLE 6E-15: SW FG2, PRESENT WORTH PLANNING-LEVEL COST COMPARISON

	Alternative 1	Alterntive2	Alterntive2A	Alternative 3
Planning-level Costs	Maximum WRF HRT Capacity plus CSO HRT	Expanded Tunnel Volume	Expanded Tunnel Volume Plus Select CSO HRT	Maximum WRF HRT Capacity plus Expanded Tunnel Volume
Capital Cost	\$27,359,500,000	\$7,678,800,000	\$8,220,400,000	\$7,418,800,000
Annual O&M Costs	\$271,300,000	\$73,000	\$6,290,000	\$8,210,000
Present Value of Annual O&M Costs	\$3,899,800,000	\$1,000,000	\$90,400,000	\$118,000,000
Present Worth of Replacement Costs	\$0	\$0	\$0	\$0
Salvage Value	\$0	(\$3,162,800,000)	(\$3,079,800,000)	(\$2,738,700,000)
Total Present Value	\$31,259,300,000	\$4,517,000,000	\$5,231,000,000	\$4,798,100,000



TABLE 6E-16: UNIT PRESENT WORTH PLANNING-LEVEL COST COMPARISON

Facility	Average Annual CSO Volume Reduced (MG)	Unit Present Worth (\$/gal) ¹	Comments
WRF HRT	172	1.57	CSO volume is the reduction between Alternative 0 and Alternative 1
CSO HRT			
BS0502 A	0.04	3,225	Annual CSO reduction is the average
DC0103	0.01	76,689	modeled volume at specific CSO location multiplied by the annual
BS0405	0.63	696	frequency
Tunnels ¹			
KK River Flushing Tunnel	0.87	22.00	Rehabilitation of existing tunnel
25 MG	3.89	58.09	
75 MG	11.7	26.40	CSO volume presented represents
200 MG	31.1	16.52	incremental decreases in annual CSO volume where 2610 MG achieves full CSO reduction from
1000 MG	156	11.77	Alternative 0
2610 MG	406	11.13	

¹⁾ Unit costs per tunnel volume are also presented in Appendix 6E-4, and range from \$2.07 per gal of tunnel volume to \$10.83 per gal of tunnel volume



TABLE 6E-17: SW FG2, ZERO OVERFLOWS

ANALYSIS-SPECIFIC PERFORMANCE FACTORS CONSIDERED IN ALTERNATIVE SCORING

Triple Bottom Line Measure	Level of Service Category	Performance Factor			
	Permit Requirements	Measure of a given alternative's likelihood to meet permit requirements. Note that the MMSD has established targets for KPI and PIs related to permit requirements (capture into MMSD system, CSO events/year) that are more stringent than permit requirements as noted below under Environmental Improvements. Specific considerations made to meeting effluent limits.			
Environmental	Energy	Total energy demand impact of alternative (with minimal impact receiving highest score). Specific considerations given to energy use from proposed facilities.			
	Environmental Improvements	Measure of the advantages of a given alternative in terms of improvements to the environment. Specific considerations for this alternative analysis are the ability to eliminate overflows, including meeting the 100 percent capture of annual flow into MMSD system KPI target, and the 0 CSO events/year PI target.			
	Fiscal Responsibility	General measure, separate from PW analysis, of how well a given alternative reduces identified risk(s) in a cost-effective manner (with most cost-effective receiving highest score) and/or the potential financial impact an alternative might have to other programs. Specific considerations given to the ISS Pump Station and number of additional facilities to maintain.			
Economic	Management Effectiveness	Measure of a given alternative's ability to help management achieve the permit and contract goals. Factors to consider include complexity to implement/operate alternative, new technologies or alternative simplifies operations from baseline. Specific considerations given to the number of additional facilities to maintain.			
	Safety	Measure of a given alternative's ability to minimize safety risks to employees, contractors, and the general public. Specific considerations given to employees, and the general public, especially for alternatives with new facilities in the system.			
Social	Customer Service, Communication and Employee Development	Measure of the advantages of a given alternative to reduce potential complaints and notices of violation, improve communication effectiveness, and/or provide employee development opportunities. Specific considerations given to stakeholder concerns regarding overflows in the system.			



TABLE 6E-18: SW FG2, ALTERNATIVE SCORING MATRIX

Alternative Scoring Matrix SW FG2, Zero Overflows	Alternative 20-yr Present Worth (\$ million)	Permit / Legal Requirements	Energy	Environmental Improvements (non-regulatory, resource recovery)	Fiscal Responsibility	Management and Operational Effectiveness	Safety	Customer Service, Community Economic Development and Organizational Reputation	Total Weighted Score	Value Ratio (Total Weighted Score/ Present Worth)
Weights		28	18	18	19	5	7	5	100	
Alternative 1: Maximum WRF HRT Capacity plus CSO HRT	\$31,259.3	3	2	5	1	2	2	5	272	0.009
Alternative 2: Expanded Tunnel Volume	\$4,517.0	4	2	5	2	3	3	5	334	0.074
Alternative 2A: Expanded Tunnel Volume Plus Select CSO HRT	\$5,231.0	3	2	5	2	3	3	5	308	0.059
Alternative 3: Maximum WRF HRT Capacity plus Expanded Tunnel Volume	\$4,798.1	4	3	5	2	3	4	5	364	0.076
Comments specific to LOS category scoring decisions as applicable		Permitting over 100 CSOs and TMDL concerns reduced score for Alternative 1 and 2A	Alt 1, 2A: CSO HRT energy demand assumed to be high with so many sites Alts 2, 2A - ISS Pumping extended by 14 days but Alt 3 12 days	All alternatives assumed to meet targets	All alternatives are very expensive, financial impact of ISS pumpout in Alts 2, 2A, and 3 determined not to be significant when compared to capital costs	Alt 1: Numerous HRT sites with new technology to maintain Alts 2, 2A, 3: Anticipated increased maintenance	Alt 1: Numerous systems to maintain increases risk of injury	All alternatives assumed to meet customer satisfaction in eliminating CSOs		



Tunnel-Related SSO Elimination Alternatives Description

The elimination of SSOs is first priority for MMSD as the permit does not allow any SSOs. However, as stated above, the alternatives were first developed in the SSM, focusing on eliminating tunnel-related CSOs. This is because analysis modifications are easier to manage in the SSM and refinements then can be made in the CSM. Therefore, the next step was to use the CSM to confirm the CSO reduction findings for the recommended alternative and modify as needed to eliminate the tunnel-related SSOs. The risk was defined as average annual SSO volume. To address the risk, two alternatives were developed. Descriptions of each alternative are presented below.

Alternative 1 – Additional Tunnel Storage and VRSSI Adjustment

This alternative modeled the recommended tunnel-related CSO Elimination Alternative 3 in the CSM under multiple storm events to determine the needed additional tunnel volume and VRSSI adjustment to achieve zero SSOs.

Alternative 2 – I/I Reduction into System

This alternative presents the findings of business case evaluation CBC033 completed under a separate project [4] regarding the costs to implement even more aggressive I/I reduction than what is presented in Conveyance Analysis CS R9 - Combat I/I Impact from Pipe Degradation in Appendix 6A. At the time of publication of the 2050 FP, CBC033 was still in draft form.

Two of the strategies identified in CBC033 were specifically related to eliminating SSOs:

- 1. (Strategy 3) Improve the enforcement capability of the Wet Weather Peak Flow Management Program (WWPFMP) to achieve a higher level of control. These targets would focus on the leakiest sewersheds. Only administrative costs would be incurred by MMSD under this strategy.
- 2. (Strategy 5) Focus municipal I/I reduction work as well as private property inflow and infiltration (PPI/I) to eliminate SSOs. Programmatic costs for this strategy assume that the PPI/I program grows in kind with the WWPFMP program.

The analysis performed in CBC033 did not explicitly represent the 540 MG of additional GI in the SSSA as recommended in Appendix 6D-6, GI Modeling within the SSSA; however, it is assumed that GI in the SSSA could be a part of I/I reduction strategies.

Tunnel-Related SSO Elimination Alternatives Evaluation

For Alternative 1, the CSM modeling determined that no additional tunnel volume over and above the 2,303 MG identified in Alternative 3 was required, and the VRSSI should be adjusted from 160 MG to 10 MG. Therefore, no additional cost was calculated for this alternative.

For Alternative 2, Strategies 3 and 5 presented in CBC033 are very similar to those described in Conveyance Analysis CS R9, only more aggressive. CBC033 projected that the additional annual O&M cost for the aggressive I/I reduction over and above the annual O&M costs presented in Conveyance Analysis CS R9 to be \$79.8 million. It should be noted that this evaluation does not include reduction in flow provided by GI; therefore, the annual O&M costs can be anticipated to be less than presented. As documented in Appendix 6D, MMSD is committed to installing 540 MG of GI in the SSSA over and above the 200 MG assumed in the CSO elimination Alternative 0 to be installed in the CSSA.

Each alternative was evaluated as follows:



- Compare the advantages and disadvantages (Table 6E-19)
- Determine its planning-level present worth cost (Table 6E-20)

Because no additional facilities—and therefore no costs—were determined to be necessary to achieve 0 SSOs for SSO Elimination Alternative 1, while SSO Elimination Alternative 2 is projected to have a total present worth of over \$1 billion, no analysis-specific performance factors or scoring matrix were developed for this evaluation.

Details for tunnel-related SSO elimination alternative cost estimates are presented in Appendix 6E-4.

TABLE 6E-19: SW FG2, RISK REDUCTION COMPARISON

How well each alternative addresses the risk of not meeting the following KPI and PIs:

- KPI: 100% of annual overall capture of flow into the MMSD system
- PI: 0 Separate Sewer Overflows (SSOs)

Alternative	Advantages	Disadvantages
Alternative 1: Additional tunnel storage and VRSSI adjustment	CSO elimination Alternative 3 already includes tunnel expansion No discharge of SSOs into the system	Reactive solution rather than proactive
Alternative 2: I/I Reduction into the System	Proactive solution – eliminates I/I before gets into the system and needs to be managed	Static system – if have back to back extreme events not captured in the 75-yr period of record (longer or wetter), then could still have CSO

TABLE 6E-20: SW FG2, PRESENT WORTH PLANNING-LEVEL COST COMPARISON

	Alternative 1	Alternative 2
Planning-level Costs	Additional tunnel storage and VRSSI adjustment	I/I Reduction into the System
Capital Cost	\$0	\$0
Annual O&M Costs	\$0	\$79,800,000
Present Value of Annual O&M Costs	\$0	\$1,147,100,000
Present Worth of Replacement Costs	\$0	\$0
Salvage Value	\$0	\$0
Total Present Value	\$0	\$1,147,100,000



Zero Tunnel-Related Overflows Recommended Alternative

Based on the findings, tunnel-related CSO elimination Alternative 3, Maximum WRF HRT plus Expanded Tunnel Volume is the recommended alternative to achieve zero tunnel-related CSOs and SSOs under Conveyance Future Conditions. This alternative, which includes 255 MGD of HRT at both JIWRF and SSWRF plus a total of 2,303 MG of tunnel and a reduction of the VRSSI from 160 MG to 10 MG, takes advantage of WRF HRT, which has the lowest unit cost per gallon of CSO removed, and tunnel volume to capture peak storm flows.

This alternative was run through the SSM and the SSM under Buildout Conditions to determine if SSOs and CSOs are projected to occur. Modeling in the SSM indicated that for the zero tunnel-related overflow recommended alternative under Buildout Conditions, CSOs occur in only two events (August 1986 and June 2008). The average annual CSO volume and frequency is 13 MG and 0.03 event/year respectively. Modeling in the CSM indicates that SSOs only occur in one event (June 2008). The details of the modeling results are presented in Appendix 4A-3, Conveyance Modeling Summary.

Zero Conveyance-Related Overflows Additional Projects

Even after implementing the recommendation under tunnel-related CSO elimination Alternative 3, Maximum WRF HRT plus Expanded Tunnel Volume, modeling in the CSM indicated that for the 75-year POR six SSOs are still projected to occur, presented in Table 6E-21, and 11 CSOs are still projected to occur, presented in Table 6E-22. The overflows are referred to as conveyance-related overflows because they are caused by localized hydraulic limitations and therefore cannot be eliminated by additional tunnel volume. As indicated in the tables, two of the SSOs would be addressed under recommended projects detailed in Appendix 6A. Additional projects are needed for the remaining four SSOs and 11 CSOs. For this planning-level analysis, the overflows were all assumed to be addressed by relief sewers, using costs developed in Appendix 6A to address Conveyance and Storage Asset System capacity risks. The planning-level details for each of the projects, including descriptions, maps, and costs, are included in Appendix 6E-5, SW FG2 Conveyance-Related Overflow Elimination Project Details.

Total present worth costs are presented in Table 6E-23. The relief sewers for each of the SSOs were developed in enough detail to develop total present worth costs. For the CSOs, two CSOs were selected as representative projects: CSO 104 and CSO 260. Total present worth costs were developed for relief sewers to the Near Surface Collector (NSC) for each and the average total present worth cost of \$7,040,000 was assumed to apply to each of the 11 CSO locations. As presented in Table 6E-23, an additional \$108,500,000 for projects would be required to achieve zero overflows throughout the system.

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⁶ Model represents CSO 145 as two separate CSO locations.



TABLE 6E-21: REMAINING CONVEYANCE-RELATED SSOS

SSO Still Occurring	Volume (MG)	Peak Flow Rate (cfs)	Comments
	3.28	29.25	Addressed in Appendix 6A for a 5-year LOP
	1.25	22.28	Not addressed in Appendix 6A
	0.20	22.22	Not addressed in Appendix 6A
	0.32	11.24	Not addressed in Appendix 6A
	1.49	23.15	Addressed by recommendation in CS R11, CBC0101, SSOs at BS0603
	0.02	2.95	Addressed by Additional Project Mill Road Relief Sewer – Project No. C04010

TABLE 6E-22: REMAINING CONVEYANCE-RELATED CSOS

CSO STILL OCCURRING	VOLUME (MG)	PEAK FLOW RATE (CFS)	Comments
CSO 017	0.31	8.58	
CSO 102	20.13	255.28	
CSO 104	4.76	56.47	
CSO 116	0.16	2.23	
CSO 117	0.02	3.20	
CSO 144	0.20	4.02	Not addressed in Conveyance projects identified in Appendix 6A
CSO 145	0.02	0.051	dentined in Appendix oa
CSO 151	0.06	2.49	
CSO 155	1.66	32.33	
CSO 188	0.01	0.53	
CS0 260	0.11	11.49	



SSO Still Occurring	Capital Cost	Present Worth of Annual O&M Costs	Total Present Worth Cost	Description
BS0101	\$14,210,000	\$60,000	\$14,270,000	30-inch & 42-inch Diameter Relief Sewers from BS0101 to DC0102
BS0303	\$3,430,000	\$10,000	\$3,440,000	30-inch Diameter Relief Sewer from BS0303 Pump Discharge to Existing MH 16416
BS0601	\$1,210,000	\$0 ¹	\$1,210,000	30-inch Diameter Relief Sewer from BS0601 Pump Discharge to Existing MH 31704
BS0602	\$12,000,000	\$40,000	\$12,040,000	30-inch Diameter Relief Sewer from BS0602 to 48" MIS at S. Clement Ave.
11 CSOs	\$77,000,000	\$330,000	\$77,330,000	Average costs per CSO based on relief sewers at CSO 104 and CSO 260
TOTAL	\$107,850,000	\$440,000	\$108,290,000	

TABLE 6E-23: REMAINING CONVEYANCE-RELATED SSOS – PRESENT WORTH COSTS

Zero Overflow Recommendation

As presented in this analysis, the achievement of zero overflows should be accomplished in multiple steps. The findings of this analysis indicate the effort to achieve zero overflows in the system is complicated and very expensive, resulting in value ratios of less than 0.1 for all alternatives – meaning that there is very little value realized for the significant financial impact required. The present worth cost to implement the recommended tunnel-related CSO and SSO elimination Alternative 3, Maximum WRF HRT plus Expanded Tunnel Volume is projected to be \$4,798,100,000. The present worth cost to implement projects to eliminate the remaining conveyance-related CSOs and SSOs is \$107,850,000, for a total present worth cost of \$4,905,950,000. As noted in the Purpose section, this analysis is not intended to recommend immediate full implementation of the zero overflow recommended alternative. Instead, this analysis provides a roadmap for a phased approach to achieving zero overflows, as outlined below:

Phase 1

Implement all recommended projects assumed in CSO Elimination Alternative 0, starting in the year 2020 and completed by the year 2040, including the following:

 Recommended projects in Conveyance Analyses CS R1 through R8 to address capacity issues in the Conveyance and Storage Asset System

¹⁾ Annual O&M costs are only \$170, which is so minimal that present worth was calculated as \$0 when rounded to nearest \$10,000



- Conveyance Analysis CS R9 recommendation to combat I/I impact from pipe degradation in the system to maintain the Conveyance Baseline Conditions level of I/I
- Recommendation in WRF Analysis FG8, JIWRF Wet Weather Capacity to increase blending at JIWRF to 180 MGD
- Recommendation in WRF Analysis FG9, SSWRF Wet Weather Capacity to increase blending at SSWRF to 75 MGD
- Recommendation in GI Analysis R1 to install 200 MG of GI (specifically, as recommended in Appendix 6D-5, GI Modeling within CSSA, GI installation should be focused in the CSSA) and FG3 to install the remaining 540 MG of GI (specifically, as recommended in Appendix 6D-6, GI Modeling within SSSA, remaining GI installation should be focused in the SSSA).

Total capital costs for the recommendations in phase 1 are already included in Appendix 6A for Conveyance Analyses CS R1 through R9, Appendix 6B for WRF Analyses FG8 and FG9, and Appendix 6D for GI Analyses R1 and FG3.

Phase 2/Ongoing efforts

Throughout the implementation of phase 1, continuously assess the impacts of these projects on the annual average CSOs through hydraulic modeling. Based on the impact of these projects and impacts due to climate change, reassess the capacity of HRT at JIWRF and SSWRF identified in this analysis (255 MGD at each WRF) and the conveyance-related overflow locations and costs to confirm the projected recommendations do not need to be adjusted. This effort is assumed to start after enough data is collected on the performance of phase 1 projects, and therefore is assumed to be an ongoing effort that begins in 2026 and goes through the year 2050.

There is a cost associated with assessing the impacts of the projects to be implemented as part of Phase 1. Because of the timing and the need to assess the impacts of all of the asset systems, it is assumed that this effort would be a continual effort up to year 2050; therefore, it is assumed to have an annual capital cost of \$400,000 per year from 2026 to 2050, representing a total capital cost of \$10,000,000.

Phase 3

Assuming zero overflows have not been achieved and the phase 2 assessment does not recommend a change in the needed HRT capacity at the WRFs, implement 255 MGD of HRT at JIWRF (\$413,750,000 in December 2019 dollars) by the year 2040. HRT at JIWRF is recommended first as modeling showed that an increase in capacity at JIWRF has more of an impact on CSO reduction than an increase in capacity at SSWRF, as discussed in Appendix 4A-3, Conveyance Modeling Summary. This recommendation assumes that the wasteload allocation limits in the WPDES permit will not be applied to the proposed HRT. The KPI/PIs identified as the risk for this analysis should be tracked to determine if and when JIWRF HRT upgrades should be implemented as follows: one or both of the targets listed below have not been met in any year after 10 years of performance (2021–2030).

- KPI 100% of annual overall capture of flow into MMSD system
- PI 0 CSO events/year

In addition, implement the recommended projects necessary to eliminate the remaining conveyance-related CSOs and SSOs. Assuming the capacity needs and costs are not adjusted in phase 2, the capital cost is projected to be \$107,850,000. The following PIs identified as the risk for this analysis should be tracked to determine if and when conveyance-related CSO and SSO upgrades should be implemented as follows: one or both of the targets listed below have not been met in any year after 10 years of performance (2021–2030).

- 0 CSO events/year
- 0 SSO events/ year



Finally, as part of phase 3, implement select CSO HRT projects to address a portion of the tunnel-related CSO. Based on the findings from the modeling completed under this analysis, the details of which are presented as a part of Alternative 1, Maximum WRF and CSO HRT, in Appendix 6E-4, SW FG2 Tunnel-Related Overflows Cost Estimates, the CSO sites that should be considered are BS0502A - \$105,000,000 (peak capacity needed is less than DC0103, but the average annual CSO volume is higher, at 0.42 MG versus 0.15 MG for DC0103) and BS0405 - \$355,800,000 (average annual CSO volume of 5.7 MG).

In addition, monitor the viability of improvements in GI, CSO HRT and other technologies that would eliminate untreated overflows to determine if the recommendations presented in this analysis should be revisited. Preliminary engineering should also analyze feasibility of including tunnel expansion and incorporate the findings from MMSD HRT pilot study project M03091P10, which is anticipated to be completed in spring 2021.

The total capital cost for the recommendations in phase 3 is \$982,400,000.

Phase 4

Assuming zero overflows have not been achieved, implement 255 MGD of HRT at SSWRF (\$355,800,000 in December 2019 dollars) after the year 2050.

Summary

The goal of achieving zero overflow will not be fully achieved by following this phased approach, but allows for a controlled implementation to allow MMSD to close the gap while also measuring the impacts of recommended projects and reassessing the recommendations with new information in the future. The total capital costs of recommended projects under this phased approach over and above the projects already assumed that MMSD is committed to in phase 1 would be \$992,400,000 through the regulatory planning period (2020 to 2040) plus an additional \$355,800,000 after the year 2050 (all in December 2019 dollars).

Note that other approaches could be used in future analyses, such as considering a different period of record for storms or modified future growth projections



SW FG3, Energy Plan Additional Alternatives

Purpose

The purpose of this analysis is to address the risk identified in Chapter 5 of MMSD not meeting its long-term goal to meet 80 percent of its energy needs with internal, renewable sources. To help achieve that goal, MMSD has implemented several energy saving projects and continues to assess other opportunities as documented in Systemwide Analysis FG4, 2035 Vision Goals Analysis of this appendix and WRF R2, Alternative Biosolids Processing and Disposal, WRF FG4, Increase SSWRF Renewable Energy Use, WRF FG5, JIWRF and SSWRF Interplant Energy Connection, and WRF FG6, Reduction of SSWRF Energy Use in Appendix 6B, WRFs and Biosolids Alternative Analyses.

This analysis documents the review of three additional energy alternatives that were identified in MMSD's Final Energy Plan (Energy Plan): [17]

- JIWRF Channel Mixing (adapted from Alternative 34 of Energy Plan)
- Heat Recovery from Effluent (adapted from Alternative 31 of Energy Plan)
- Power Generation with SSWRF Influent (adapted from Alternative 78 of Energy Plan)

Note that this analysis specifically focuses on whether the alternatives meet the Energy Plan's fiscal goal of producing a long-term, positive impact on MMSD's budget. Therefore, the typical scoring matrix used for other analyses was not used.

Background

MMSD established the 2035 Vision in 2011 to document objectives and goals to achieve by the year 2035. [18] In the 2035 Vision, MMSD identified several energy goals. To better define how to meet these energy goals, MMSD developed the Energy Plan to identify potential energy reduction alternatives. The following energy goals were presented in the Energy Plan:

- Meet a net 100 percent of MMSD's energy needs with renewable energy sources (defined as internallygenerated renewable energy minus purchased/external energy = net equivalent total energy used at all MMSD facilities annually)
- Meet 80 percent of MMSD's energy needs with internal, renewable sources
- Produce a long-term, positive impact on MMSD's budget
- Provide a foundation for MMSD's 2050 FP, the development of which began in 2014

The Energy Plan generated and developed initial analyses on numerous energy alternatives that both increased usage of renewable energy sources and decreased energy usage in the MMSD system.

In 2017, JIWRF had an average day electrical usage of about 10 MW, which can increase to about 23 MW when the ISS PS is running during wet weather. SSWRF had an average day electrical usage of about 4.5 MW, which can increase to almost 6 MW during wet weather events.

The Energy Plan presented all energy usage in million British thermal units per year (MMBTU/yr) to standardize the energy comparison between different energy usage. The Energy Plan established the total energy usage at both JIWRF and SSWRF using 2013 data as shown in Table 6E-24. This information was compared to proposed energy reductions in the alternatives reviewed in this analysis.



TABLE 6E-24: YEAR 2013 TOTAL ENERGY USAGE AT JIWRF AND SSWRF FROM ENERGY PLAN¹

Sources of Energy Used (all in MMBTU/yr)	JIWRF ³	SSWRF
Electricity Total Used	294,500	133,700
Purchased	129,700	83,500
Generated ²	164,800	50,100
Natural Gas ²	554,700	29,600
Waste Heat Generated ²	568,700	44,900
Digester Gas Generated ²	NA	44,600
Fuel Oil	300	NA
Total Energy Used	1,418,200	252,700
Percent Renewable Energy Used	39%	49%

Notes:

- Information based on data provided in Tables 4 and 5 in the Energy Baseline Technical Memorandum in the Energy Plan.
- 2) Gas (natural, landfill, and digester) used to generate electricity and waste heat is documented under energy generated, and not included in the standalone gas line items.
- 3) Total energy usage at JIWRF in the Energy Plan was calculated based on total energy purchased minus the losses calculated in the turbines. To present data in the same manner as SSWRF in the table above, the natural gas usage was reduced, since natural gas accounts for most of the energy used to operate the turbines.

Since 2013, MMSD has implemented several energy-related projects that reduce energy consumption and increase renewable energy use, which have reduced purchased energy and increased renewable energy usage. Major projects include:

- Installation of three turbines, which can be fueled by landfill gas, to generate electricity at JIWRF
- Installation of four high efficiency blowers at SSWRF
- Installation of on-line dissolved oxygen and ammonia monitoring in the aeration basins at SSWRF
- Upgrading the air flow control valves to the aeration basins at SSWRF to better control the air supply
- Installation of a high efficiency blower at JIWRF
- Installation of on-line dissolved oxygen monitoring in the aeration basins at JIWRF
- Upgrading the air flow control valves to the aerated channels at JIWRF to eliminate over-aeration
- Installation of variable frequency drives (VFDs) on additional large motors to optimize energy usage
- Upgrading digester mixing systems to increase renewable energy production

Many of the energy reduction alternatives identified in the evaluations presented in the Energy Plan, along with several additional alternatives, were selected to be analyzed in more detail as part of the 2050 FP. Twenty-four of the Energy Plan alternatives were reviewed at a March 9, 2015 meeting between MMSD 2050 FP project team and consultant energy task leads, as discussed in Appendix 5E, Energy Reduction Alternatives for 2050 FP Review. As shown in Appendix 5E, it was determined that most of the 24 energy reduction alternatives identified in the Energy Plan did not warrant analysis because they were determined to no longer be viable.



Of the remaining seven Energy Plan alternatives, four were selected to be analyzed as part of Appendix 6B, WRFs and Biosolids Alternative Analyses. The remaining three energy alternatives were selected to be addressed as part of this analysis, as noted below:

- JIWRF Channel Mixing (adapted from Alternative 34 of Energy Plan)
- Heat Recovery from Effluent (adapted from Alternative 31 of Energy Plan)
- Power Generation with SSWRF Influent (adapted from Alternative 78 of Energy Plan)

The findings on these three alternatives are documented below. For the analyses, the electrical rates were those in place as of 2016. The analyses assume that demand charges, which are impacted by peak electrical usage, would not be impacted and instead focus on impacts to average annual electrical usage. Specific assumptions are included in the appendices provided for each individual analysis.

Alternative Evaluation

Alternative 1: JIWRF Channel Mixing

The channel mixing alternative in this analysis is the most developed alternative. This alternative, which is adapted from Alternative 34, Change Channel Mixing to Large Bubble Mixers in the Energy Plan, reviews the feasibility of replacing the existing channel mixing system with a more energy efficient large bubble mixing system. The detailed evaluation performed for this analysis is provided in Appendix 6E-6, JIWRF Channel Mixing. A summary of the analysis is provided below.

Existing System

A number of treatment channels at JIWRF are mixed with air from the secondary treatment air system, provided by the blowers in the Process Air Compressor (PAC) Building. With the exception of the Flow Control Structure, all secondary treatment channels are equipped with the same type of ceramic plate air diffusers as found in most of the aeration basins (excluding the six aeration basins converted to membrane diffusers to allow for solids storage). The diffusers are set within concrete containers sitting on the channel bottom, with air piping from the air system. Coarse bubble air diffusers are used in the Flow Control Structure to mix primary effluent with RAS and recycle flows from sludge thickening and dewatering/drying facilities. The aeration system keeps the solids in suspension and supports biological activities as the flow moves from one unit process to another.

Alternative Description and Required Modifications

This energy reduction alternative would use a large bubble air mixing system in the Flow Control Structure, Mixed Liquor Channels, Aerated Effluent Channels, and RAS channels instead of air from the aeration system (taking into consideration that this may impact the biological phosphorous removal that is occurring). Two different types of large bubble mixing systems were reviewed:

- 1. A compressed air mixing system would completely disconnect the mixing from the existing air system. The system would use compressors to provide high pressure air to nozzles within the channel. The EnviroMix compressed air mixing system was selected for this analysis based on previous experience in the wastewater industry.
- 2. A low-pressure air mixing system would utilize the existing low-pressure air headers into the channels. New membrane diffusers would be connected to the existing air headers and the mixers would be installed on top of the membrane diffusers. With this system, air builds within the bubble mixer until pressure forces a large bubble out into the channel. The StarBurst low pressure air mixing system was



selected for this analysis as it was the only low-pressure air mixing system on the market at the time of the analysis and was piloted in the SSWRF aeration tanks.

Both systems would require removal of the existing air mixing systems in the channels and installation of new systems, with select concrete slab demolition and hatch installation to access the mixers.

Estimate of Energy Reduction and Present Worth Cost Estimate

Existing Energy Usage

The existing channel air mixing system was determined to require approximately 21,500 cfm of air. The total average daily air flow demand at JIWRF is estimated to be 85,600 scfm, with the channel mixing comprising 25 percent of the total air needs. The air usage in the channels was determined as part of an air optimization task completed under the 2015 JIWRF Aeration System Upgrades project. [19] MMSD's analysis of the Siemens blower installed in 2014, which was presented in the Jones Island Power Load Profiling PowerPoint developed in 2015, indicated that the Siemens blower requires 26.3 kW for every 1,000 scfm of air generated. [20] Therefore, the current channel mixing system requires approximately 565 kW of power to operate. The amount of power required to operate the channel mixing system equates to 16,900 MMBTU/yr out of the 294,500 MMBTU/yr of electricity and 1,418,200 MMBTU/yr used at JIWRF.

Alternatives

The compressed air mixing system (EnviroMix alternative) would eliminate the use of air for mixing in the channels. This system is anticipated to use 236 kW of power, which is a reduction in power requirements of 329 kW per hour or 9,800 MMBTU/yr, representing a 58 percent reduction in channel mixing power and a 3 percent reduction in electricity used at JIWRF.

The low-pressure air mixing system (StarBurst alternative) alternative would reduce air usage for channel mixing to 1,300 cfm. This system is anticipated to use 34 kW of power. This is a reduction in power requirements of 531 kW per hour or 15,900 MMBTU/yr, representing a 94 percent reduction in channel mixing power and a 5 percent reduction in electricity used at JIWRF.

For both alternatives, the total energy required at JIWRF would be reduced by about 1 percent. The total air usage for the secondary system would be reduced to a possible minimum air requirement of 64,100 cfm with the EnviroMix system and 65,400 cfm with the StarBurst system. The Siemens blower is designed to provide a minimum 50,000 cfm of air. The air required is still above the minimum operation point for the blower, but is something that would be of concern if other air reducing operation strategies were implemented for secondary treatment.

The present worth cost for these alternatives is provided in Table 6E-25, with details provided in Appendix 6E-6-A.



TABLE 6E-25: JIWRF CHANNEL MIXING ALTERNATIVE COST REVIEW

Item	Compressed Air Mixing System	Low Pressure Air Mixing System	
Capital Cost	\$27,900,000	\$27,400,000	
Existing System Annual O&M Eliminated	(\$248,000)	(\$248,000)	
New System Annual O&M Added	\$110,000	\$20,000	
Annual O&M Savings	(\$138,000)	(\$228,000)	
Present Worth of Annual O&M Cost Savings	(\$2,000,000)	(\$3,300,000)	
TOTAL PRESENT WORTH	\$25,900,000	\$24,100,000	

To justify installing either of these systems, the present worth of 20 years of annual O&M cost savings needs to be more than the capital cost so that the total present worth is a negative value, indicating a cost savings. Based on the costs developed, the present worth of 20 years of annual O&M cost savings is substantially less that the capital costs for both of the alternatives, meaning that there is no total present worth savings. The electrical demand of the existing air mixing system has been lowered significantly since the air mixing demand was optimized in the summer of 2015. Therefore, even for the low-pressure air mixing system, the energy cost savings do not make enough of an impact to justify the large capital cost.

Alternative 1 Conclusions and Recommendations

The two systems reviewed would both reduce the total JIWRF electrical load from the current 294,500 MMBTU/yr as follows:

- The EnviroMix system would reduce the JIWRF electrical load to 284,700 MMBTU/yr
- The StarBurst system would reduce the JIWRF electrical load to 278,600 MMBTU/yr

However, the present worth savings analysis indicates that neither system is economically feasible; therefore, the Energy Plan goal to produce a long-term, positive impact on MMSD's budget is not met. Optimization of the existing system has reduced the existing electrical demand of the channel mixing to the point where a new system is not financially advisable. Therefore, the recommendation is to continue with the existing diffuser airmixing system. If the existing system performance drops significantly enough in the future to warrant replacement, these mixing alternatives should be revisited. But any reduction in air requirements should also consider blower operation limitations.

Alternative 2: Heat Recovery from Effluent

MMSD has been reviewing the potential for heat recovery from its sewer system for a few years. The Sewage Heat Technology Assessment project, Contract No. M03029P11, provided an assessment of technologies and their applicability to MMSD's system. [21] The study provided cost information, identified potential heat recovery locations, and recommended that an additional review be conducted. The WRFs were both identified as potential locations. The heat recovery location considered was the WRF effluent because the wastewater is very clean, thereby eliminating the need for additional treatment prior to heat recovery.

The Energy Plan identified heat recovery from effluent as Alternative 31, Large-Scale Effluent Heat Recovery Using Heat Pumps and reviewed the available technology. [17] The alternative analysis reviewed a general



concept of installing a heat pump at the site. Currently, the building heat at JIWRF and SSWRF is provided from natural gas boilers. The alternative evaluated the natural gas energy used in existing boilers to the energy (electricity) needed to operate the effluent water source heat pump, which would then provide the heat for these facilities instead. The Energy Plan found that the heat pumps would not be as cost effective as natural gas on a cost per MMBTU basis. The detailed analysis of Energy Plan Alternative 31 is included as in Appendix 6E-7.

The Energy Plan did not document that, although the heat pump was not economically feasible at the thencurrent natural gas and electrical unit costs, this alternative would provide potential additional energy to use at JIWRF and would be more energy efficient than the existing boiler.

WRFs typically have more energy available than what is taken advantage of. For instance, in theory, the amount of energy available by increasing or decreasing the temperature of an effluent wastewater at a flow of 150 MGD just 2 degrees is almost 1 million MMBTU/yr.

Using the specific data for the heat pump selected for the evaluation in the Energy Plan (details provided in Exhibit 31-2 in Appendix 6E-7), more than 15,500 MMBTU of additional thermal energy could be produced per year. When comparing the amount of energy required to produce 1 MMBTU of heat to the existing building heat system for each system, the natural gas boiler requires 1.28 MMBTU of natural gas to produce 1 MMBTU of heat, while the heat pump requires 0.76 MMBTU of electricity to transfer 1 MMBTU of heat from the effluent to the building heat system. Therefore, the heat pump would reduce the amount of energy required to heat the buildings by more than 40 percent. The calculations for this analysis are provided in Appendix 6E-7.

Natural gas and electrical unit costs have not changed enough to make the heat pump economically feasible as of December 2019.

Alternative 2 Conclusions and Recommendations

Based on natural gas and electrical unit costs as of December 2019, installation of a heat pump at SSWRF is not recommended at this time. Based on the data reviewed, it is recommended that this alternative be deferred for the near future. The assumptions used to develop this alternative can be reviewed again in the future to see if any should be revised. This alternative may have potential to meet the MMSD goal established in the Energy Plan to produce a long-term, positive impact on MMSD's budget if the following conditions are met:

- Natural gas cost increases have outpaced electric cost increases
- Heat pump technology becomes efficient enough to more cost effectively utilize available energy

Alternative 3: Power Generation with SSWRF Influent

MMSD identified large-scale hydrokinetic turbines/micro-hydropower as Alternative 78 in the in the Energy Plan. [17] This alternative focused on hydropower from the wastewater effluent but also identified power generation from SSWRF influent as a variation. This analysis uses the information from the Energy Plan and includes additional information researched as part of the development of the 2050 FP.

The alternative analysis in the Energy Plan noted that the head drop between the grit chambers and primary clarifiers is about 4.4 feet. At an assumed average annual flow of 90 MGD and full-time operation of the turbines, the annual power savings were calculated at about \$20,700 at a rate of \$0.07/kWh based on the installation of a Verterra Energy Inc. turbine. However, the additional O&M labor and parts to maintain the turbines was calculated at \$31,500, resulting in an increase in total annual O&M costs. Therefore, the Energy Plan did not recommend this alternative for further study. The detailed analysis of Alternative 78 from the Energy Plan is included as part of Appendix 6E-8.



For the 2050 FP, additional research was performed for this alternative. First, it should be noted that the head drop between the grit system and the primary clarifiers is due to hydraulic losses and is not available head. Major modifications to the system would have to be made to eliminate the hydraulic losses so the head drop could be utilized for energy generation. Based on initial data developed for this analysis, the maximum theoretical head drop available between the grit effluent and the primary clarifiers is higher than noted in the Energy Plan, at 9.2 ft. Additional hydropower technologies identified in the Renewable Energy Fact Sheet: Low-Head Hydropower from Wastewater, published by the U. S. EPA in August 2013 were researched in more detail. [22] Limited information gathered on 11 identified manufacturers is provided in Appendix 6E-8. Three turbine technologies were identified as viable based on SSWRF conditions:

- Toshiba International Hydro-eKIDS
- Natel hydroEngine
- Verterra Energy Inc. Hydrokinetic

Since the Energy Plan included a review the Hydrokinetic turbine, only the Hydro-eKIDS and hydroEngine turbines are reviewed in this analysis to determine rough capital and operating costs.

Estimate of Energy Reduction and Present Worth Cost Estimate

The Hydro-eKIDS system is anticipated to produce 20 kW of power or 600 MMBTU/yr, assuming the peak head drop is available all year, even during high flow conditions. The hydroEngine system is anticipated to produce 15 kW of power or 400 MMBTU/yr. For the Hydro-eKIDS system, the total electrical purchase required at SSWRF would be reduced by 0.7 percent. For the hydroEngine system, the total electrical purchase required at SSWRF would be reduced 0.5 percent.

The present worth cost review is provided in Table 6E-26, with the detailed cost analysis in Appendix 6E-8. The annual O&M costs only review the change in annual usage, with the assumption that demand charges will not be impacted.

TABLE 6E-26: POWER GENERATION WITH SSWRF INFLUENT ALTERNATIVE COST REVIEW

Item	Hydro-eKIDS	hydroEngine	
Capital Cost	\$700,000	\$400,000	
Power Generation Cost Savings	(\$14,000)	(\$10,000)	
Additional Operational Labor Costs	\$6,000	\$3,000	
Additional Equipment Maintenance Costs	\$1,000	\$1,000	
Annual O&M Savings	(\$7,000)	(\$7,000)	
Present Worth of Annual O&M Cost Savings	(\$100,000)	(\$100,000)	
TOTAL PRESENT WORTH	\$600,000	\$300,000	

To justify installing either of the two systems, the present worth of 20 years of annual O&M cost savings needs to be more than the capital cost so that the total present worth is a negative value. Based on the costs developed, the present worth of 20 years of annual O&M cost savings are less that the capital costs for both of



the alternatives, meaning that there is no total present worth savings. Neither system generates enough additional power to make an impact to justify the capital cost.

Alternative 3 Conclusions and Recommendations

The two systems reviewed would both reduce the total electrical purchase required at SSWRF. However, the reduction is minimal and the present worth savings analysis indicates that neither system is economically feasible. Therefore, the Energy Plan goal to produce a long-term, positive impact on MMSD's budget is not met for this alternative at this time. If turbine technology improves such that the turbines generate more power or are cheaper to install, this alternative may be economically feasible in the future.

Recommendations

This analysis documents the review of three energy alternatives identified in the Energy Plan. Of the three alternatives, only the JIWRF Channel Mixing alternative was analyzed in depth. The other two alternatives—Heat Recovery from Effluent and Power Generation with SSWRF Influent—include an initial review and updated information using 2050 FP energy assumptions. The conclusions of the reviews for all three alternatives indicate that none of them meets the energy goal established in the Energy Plan to produce a long-term, positive impact on MMSD's energy consumption and energy costs. Therefore, none of these alternatives should proceed at this time.

MMSD does have a long-term goal to meet 80 percent of MMSD's energy needs with internal, renewable sources. As noted in the Background section, MMSD has implemented a number of other energy-saving projects and continues to assess other opportunities as documented in Systemwide Analysis FG4, 2035 Vision Goals Analysis of this appendix and in several analyses in Appendix 6B, WRFs and Biosolids Alternative Analyses. All of these alternatives may be viable in the future if energy costs vary significantly from projections and equipment costs decrease significantly, so it is recommended that MMSD consider including these alternatives in any future energy system assessments.



SW FG4, 2035 Vision Energy Goals Analysis

Purpose

The purpose of this analysis is to provide guidance to MMSD regarding the systemwide level of service risks identified in Chapter 5 to meeting KPI targets related to energy, which have been grouped together in this analysis. The performance targets for the two energy-related KPIs were identified in MMSD's 2035 Vision: [23]

- Meet a net 100 percent of MMSD's energy needs with renewable energy sources
- Meet 80 percent of MMSD's energy needs with internal renewable sources

This analysis incorporates specific recommendations for the WRFs and Biosolids Asset System into a systemwide review of projected energy needs and renewable energy sources to:

- 1. Determine how close MMSD will be to achieving projected renewable energy performance targets if the recommended projects are implemented
- 2. Determine the additional costs needed to achieve renewable energy performance targets
- 3. Review alternative methods to achieve renewable energy targets

The intent of this analysis is to provide guidance on how MMSD could achieve 2035 Vision energy goals and what MMSD could consider in the future to reach renewable energy performance targets. The analysis is predicated on the assumption that MMSD will update the Energy Plan that was completed in 2015.

For purposes of this analysis, it is assumed that the following recommended WRFs and Biosolids Asset System projects are implemented:

- Produce Milorganite with new drying systems at JIWRF D&D Facility as recommended the WRF FG2,
 Alternative Biosolids Processing and Disposal Systems Analysis in Appendix 6B
- Implement 3.2 MW Solar Grid with Battery Storage as recommended in the WRF FG4, Increase SSWRF Renewable Energy Use Analysis in Appendix 6B

Carbon footprint is another component of the 2035 Vision goals. Although it is not specifically tied to the energy goal, energy use has a significant impact on carbon emissions. Therefore, this analysis also considers the impact on MMSD's carbon footprint.

Approach

The analysis defines needs and energy sources as follows:

Needs

Energy needs include the measured energy consumption values at the WRFs and non-process (e.g., conveyance) facilities plus fleet vehicle fuel. Energy needs do not encompass broader energy impacts such as manufacturing and delivery of chemicals, MMSD construction contractor energy consumption, and other supplies, commuting costs, etc.

Energy needs are identified in three categories:

- 1. Heat
- 2. Electricity
- 3. Vehicle fuel



Sources

Currently, internal renewable energy sources include digester gas, landfill gas, and small rooftop solar panel installations. Potential new sources of internal renewable energy include solar, wind, and geothermal/hydrothermal heat extraction. Additionally, MMSD considers waste heat recovered from both natural gas and landfill gas combustion to be an internal renewable source. Natural gas currently has no purchased renewable offset.

External renewable blocks of electricity can be purchased from We Energies. The renewable energy from external sources will be comprised of purchased renewable electricity.

Additional considerations regarding what is considered a renewable energy source:

- Renewable energy generated internally by MMSD is considered a renewable energy credit even if it does not directly offset WRF needs. For example, peak solar generation could be used to meet the renewable goal even if the power were exported to the grid (which is not currently possible with equipment and policies in place as of 2019). Alternatively, JIWRF and SSWRF could be connected by an interplant electrical transmission line (or even a gas transmission line) to distribute renewable energy between the facilities, but this approach would not offset the other non-process facilities so was not included in this analysis.
- Digester gas or landfill gas can be upgraded to renewable natural gas (RNG) for pipeline injection either to We Energies or the interstate pipeline (owned by ANR Pipeline Co.) to allow internal renewable energy sources to be used by the non-process facilities and JIWRF. Historically, We Energies has not allowed injection of RNG into the local service network that it owns and operates. Going forward, it may be possible to access the local pipeline as rules change. The ANR Pipeline Co. owns an interstate pipeline with a gate station in Racine that appears to be the closest potential interconnection site. Injecting RNG into the pipeline system allows offtake of an equivalent amount of natural gas by an end user while retaining the renewable attributes of the RNG. The RNG approach for MMSD is to use the renewable value of the digester gas to offset heating needs at the non-process facilities, provide compressed natural gas (CNG) vehicle fuel, and potentially offtake additional RNG at JIWRF.

Energy Baseline and 2035 Projections

Energy Baseline and 2035 Projections are presented in Chapter 5, Assessment of Existing Facilities, based on existing biosolids facilities as of 2017.

Optimizing Internal Sources of Renewable Energy

LFG and digester gas (DG) are fuels that can be used at each WRF to offset purchased natural gas. The value of DG and LFG as internal sources of renewable energy is maximized when used for heat production because the energy conversion to heat is the most efficient.

MMSD analyzed opportunities to use additional landfill gas as part of the Potential Uses of Additional Landfill Gas Technical Memorandum, finalized in 2015. [24] The evaluation determined that the most cost-effective use of additional LFG is in the dryer burners. Therefore, Project J06061, Dryer Conversion for Additional LFG, is going into construction, with completion anticipated in 2022, to convert the dryer burners to burn both natural gas and LFG. [25]

To determine the impact on renewable energy use from the use of additional LFG with implementation of the dryer burner conversion project, the 2017 Baseline was evaluated using all internal renewable sources for heat production, which resulted in an increase in MMSD's percent renewable use from 33 percent to 36 percent. A



second scenario evaluated digesting all the solids production to produce more digester gas and reduce drying energy needs, which increased the percent renewable use to 50 percent. Adding purchased renewable electricity pushed the percentage to 70 percent. These findings are summarized in Figure 6E-16. The details of the evaluation used to develop the figure is presented in Appendix 6E-9, SW FG4 Energy Balance Calculations for years 2017 and 2035.

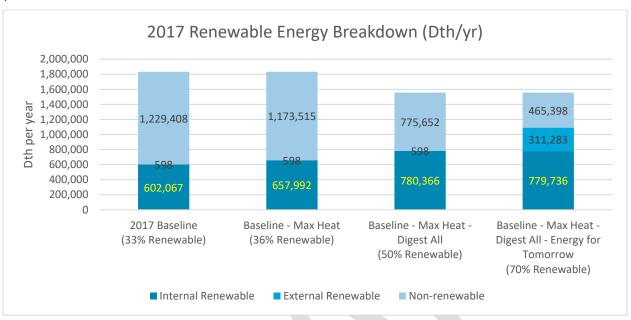


FIGURE 6E-16: COMPARISON OF 2017 BASELINE RENEWABLES

Alternatives Description

Ninety-three percent of JIWRF heating needs shown in the 2017 Baseline (Table 6E-27) are for sludge drying. The table does not delineate that 70,000 Dth per year goes to building heat while 995,000 Dth goes to sludge drying. Therefore, over 50 percent of MMSD's total energy use of 1.8 million Dth in 2017 Baseline, presented in Figure 6E-17, went to drying solids to make Milorganite.



TABLE 6E-27: 2017 BASELINE MILORGANITE WITH EXISTING DRYERS

2035 Energy Balance Annual Totals		Total Baseline	Renewable	Difference		
JIWRF Heat Demand	Dth/yr	1,065,559	297,542	768,017		
JIWRF Electricity Demand	Dth/yr	342,789	141,776	201,013		
SSWRF Heat Demand	Dth/yr	127,733	98,282	29,451		
SSWRF Electricity Demand	Dth/yr	138,727	63,828	74,899		
Non-process (NP) Heat Demand	Dth/yr	136,627	0	136,627		
Non-process (NP) Electricity Demand	Dth/yr	18,119	639	17,480		
Fleet Vehicles	Dth/yr	1,921	0	1,921		
Totals	Dth/yr	1,831,475	602,067	1,229,408		
% renewables	NA	33%	NA	NA		
Landfill Gas Purchased	Dth/yr	380,423	NA	NA		
Digester Gas Produced	Dth/yr	284,706	NA	NA		
Solar Panels JI	Dth/yr	73	NA	NA		
Solar Panels HQ	Dth/yr	41	NA	NA		

Source: MMSD 2017 energy demand data

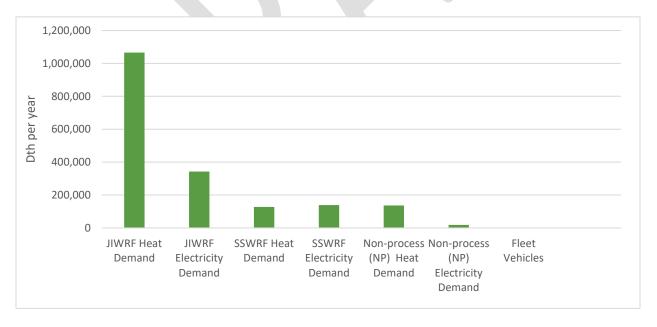


FIGURE 6E-17: 2017 BASELINE BREAKDOWN OF ENERGY USAGE



Solids processing alternatives offer the greatest potential to meet the 100 percent renewable energy goal. While processes such as aeration represent large energy needs, the incremental nature of improvements to the various treatment processes would not offer enough energy savings on their own to meet the renewable energy goal. Producing drier cake would reduce the energy requirement under each alternative; however, drier cake could impact Milorganite quality. A more detailed analysis could provide sensitivities based on other process improvements.

Alternative analysis WRF FG2, Alternative Biosolids Processing and Disposal Systems in Appendix 6B presents the solids processing alternatives that were considered using a new dryer technology that evaporates water more efficiently than the current dryers. All 2035 sludge drying alternatives used the new rotary drum drying technology. Based upon the evaluation of the 2017 energy needs and sources, the following assumptions and goals were used to develop alternatives for the 2035 Vision Energy analysis:

- 1. Prioritize the use of LFG and DG to meet heating needs
- 2. Convert excess SSWRF DG. After heating needs are met, excess DG is converted to RNG, which is exported to meet non-process and vehicle fuel needs and JIWRF heat loads or electricity generation.
- 3. No electricity is generated from DG at SSWRF
- 4. Include a 5.2 MW solar grid for SSWRF
- 5. Purchase renewable electricity to meet the balance of electrical needs at SSWRF
- 6. Purchase renewable electricity for all non-process needs
- 7. Use RNG from SSWRF to meet all non-process heat (NG) loads
- 8. Use CNG for fleet vehicle fuel, offset by RNG from SSWRF (needs future review, including consideration SSWRF fueling station and commitment by MMSD to CNG vehicles)

A base alternative was developed assuming 2017 dryer facilities plus available external renewable energy resources are utilized. Four alternatives were then developed to evaluate different end use options for the solids residuals:

- Alternative 0: Baseline Milorganite with existing dryers
- Alternative 1: Baseline Milorganite with new dryers
- Alternative 2: Milorganite with new dryers- all digested
- Alternative 3: Class B Land Application of biosolids (lowest energy input)⁷
- Alternative 4: Incineration of digested biosolids (highest energy recovery)

The net acquisition of renewable sources to meet the 100 percent goal was estimated as the amount of additional LFG to be purchased. The base amount of additional LFG to be purchased was determined using information on LFG available from an additional source provided in the Potential Uses of Additional Landfill Gas

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⁷ This evaluation considers only Class B biosolids as a biosolids alternative to Milorganite. It should be noted that MMSD is currently evaluating other biosolids products. Because drying is a major energy user, other alternatives that do not involve drying may also fit with MMSD's energy goals.



Technical Memorandum, finalized in 2015, which provided LFG projections to 2032. [24] The 2035 LFG estimate was extrapolated from this memorandum.

Other renewable sources could be added to the mix, which would reduce the amount of LFG purchased. Each project, such as co-digestion or development of offsite renewables, can be evaluated on its own merits. LFG gas may require treatment, but the costs are unknown at this time. LFG cost-effectively replaces natural gas for either heat or electricity production.

Alternative 0 – Baseline Milorganite with existing dryers

This alternative assumes the same amount of energy use as the renewable energy conditions presented in Chapter 5, Assessment of Existing Facilities. The alternative assumes upgrades to the existing dryers as recommended in WRF FG2, Alternative Biosolids Processing and Disposal Systems in Appendix 6B and additional solar arrays added to achieve 5.2 MW of solar energy over and above the 3.2 MW recommended in WRF FG4, Increase SSWRF Renewable Energy Use in Appendix 6B. In addition, the alternative assumes external renewable blocks of electricity can be purchased from We Energies.

Alternative 1– Baseline Milorganite with new dryers

This scenario is similar to Alternative 2 in alternative analysis WRF FG2, Alternative Biosolids Processing and Disposal Systems in Appendix 6B in that all solids will go to Milorganite production using the same waste activated sludge (WAS) to digested sludge (DSD) blend ratio as Baseline Conditions. Solids are dewatered and dried at JIWRF with new higher efficiency rotary drum dryers. After the completion of the WRF FG2 analysis, the 2050 FP project team learned that waste heat from the solar turbines can be used with the new drying technology by pre-heating combustion air.

Alternative 2 – Digest all Milorganite with new dryers

In this alternative, all of the primary sludge (PSD) and WAS are digested at SSWRF and the resultant DSD is dewatered and dried at JIWRF into a Milorganite product. New dryers can form a stable pellet with 100 percent digested sludge and the mass balance developed for alternative analysis WRF FG2 (Appendix 6B) indicates that the digested sludge product contains 4.9 percent nitrogen by weight. This alternative does not consider the marketability of the 100 percent digested sludge product.

Alternative 3 – Class B land application of biosolids

Drying biosolids for Milorganite production currently represents over 50 percent of the energy needs for MMSD. MMSD previously had a Class B land application program for liquid sludge (Agri-Life®). This alternative proposes land application of dewatered digested sludge. In the previous liquid program, approximately 0.5 dry tons of solids could be transported in a 5,000-gallon tanker. When hauling dewatered cake, approximately 4 tons of dry solids can be transported in a 30 cubic yard dump trailer. Overall, it would be possible to manage all of the Class B biosolids with fewer trucks than the Agri-Life program.

Land application is a beneficial use of the biosolids with carbon sequestration benefits. Challenges include finding and permitting the land required, identifying sludge storage areas, and managing the program as anecdotal information as of 2019 indicates regional facilities are having difficulties reliably land applying biosolids. This alternative only looks at the energy balance and the costs to expand SSWRF biosolids processing and disposal facilities, with the assumption that JIWRF drying facilities would be abandoned. It is assumed that all of the LFG is available for electricity generation with the solar turbines. For this alternative, the solar gas turbines would be retrofitted to operate as combined-cycle systems in which the turbine exhaust generates



steam for electricity generation in a steam turbine. Under these assumptions, the turbine efficiency increases to 49 percent conversion of input LFG to electricity.

There is enough digester gas as RNG to offset the JIWRF building heat demands.

Alternative 4 – Incineration of digested biosolids

Incineration is employed by many large wastewater facilities, including NEW Water's Green Bay facility in Wisconsin and the Metro Plant in St. Paul, Minnesota. Incineration greatly reduces the mass and volume of solids for ultimate end use and offers the greatest potential energy recovery from solids residuals. However, the nitrogen value of the biosolids is lost. Central Contra Costa Sanitary District in California offers their incinerator ash to fertilizer blender for its P content. However, in general, incineration is not considered to be a beneficial use of biosolids. In the context of meeting renewable energy goals, incineration represents the highest energy recovery potential and provides a frame for reference for MMSD. For purposes of this evaluation, the incineration process would be installed at SSWRF.

The incineration process envisions a fluidized-bed incinerator preceded by scalping dryers to remove sufficient moisture from the dewatered digested sludge to create the conditions for autogenous combustion. "Autogenous" means that the incinerator requires no supplemental fuel. A scalping dryer refers to a drying process in which the solids are only partially dried. Paddle dryers or disc dryers have been employed for this purpose. The heat recovered from the incinerator is sufficient to partially dry the incoming biosolids and offset digester heating needs. The net heat recovery is after any demand from the emissions control system. The incinerator system, including emissions control, has a significant electrical demand.

For this alternative, the solar gas turbines at JIWRF are retrofitted to operate as combined-cycle systems in which the turbine exhaust generates steam for electricity generation in a steam turbine. All LFG would go to the turbines for a net efficiency of 49 percent conversion of input electricity to electricity. Incinerator ash residuals would be hauled to landfill.

Evaluation

Energy Balance Comparison

The alternatives were developed specifically to address the 2035 Vision energy goals. In this context, the alternative providing the best renewable energy profile may not be the lowest cost alternative and may not be the most environmentally favorable pathway.

Figure 6E-18 presents the energy balance in bar chart format, with each column representing the total energy needs of each alternative and how the 100 percent renewable energy goal would be achieved. Tables 6E-28 thru 6E-32 show the energy balance for each alternative. The details of the evaluation used to develop the figure and tables are presented in Appendix 6E-9, SW FG4 Energy Balance Calculations for years 2017 and 2035.

The energy sources in Figure 6E-18 are broken down into three categories: Internal Renewable, External Renewable, and LFG Required for 100% Renewable. The Internal Renewable includes the current contracted value for LFG, which also is represented as a percent. The External Renewable represents We Energies Energy for Tomorrow electricity purchase at the maximum allowable 20 percent of total energy needs. The LFG Required for 100% Renewable is the additional amount of LFG required to be purchased from an available source to attain the 100 percent renewable goal. The "% renewable" indicated under each alternative name on Figure 6E-18 is the percentage of renewable energy achieved without purchasing more LFG than the contracted value represented by the LFG Required for 100% Renewable value. While there may be energy sources other than LFG that can provide the required renewable energy, the purpose of this presentation is to simplify the



evaluation based on the documented projections from an additional available source. As shown on Figure 6E-18, there is no alternative where 100 percent renewable is achieved without the purchase of additional LFG from an available source, though Alternative 3, Class B land application, is the closest at 92 percent. In addition, there is no alternative where the internal renewable percent goal of 80 percent is achieved. Alternative 3, Class B land application of biosolids, has the highest percent at 67 percent.

Alternative 0, Baseline Milorganite, existing dryers, requires 1,412,000 MMBTU/yr LFG input, which is greater than the total LFG available from an additional source documented in the Potential Uses of Additional Landfill Gas TM; therefore, the goal of achieving 100 percent renewable cannot be achieved under the baseline conditions presented. [24]

Alternatives 1 and 2, which maintain Milorganite production, can meet the 100 percent renewable energy goal with additional LFG assuming the 1,364,000 MMBTU/yr projection for total LFG is attainable. As with the other Milorganite alternatives, the amount of LFG that could be acquired in 2035 needs to be verified. If the additional LFG needed to get to the 100 percent renewable energy goal were not available, Alternative 1 is projected to achieve 60 percent renewable energy, and Alternative 2 is projected to achieve 76 percent renewable energy as a percent of total energy demand. The high energy requirement for drying cannot be avoided. However, the new dryers would be 16 percent more energy efficient than the existing dryers based on heat demand. Digesting all of the solids reduces the amount of purchased LFG required to meet the 100 percent renewable energy goal. In addition, digestion of all of the solids decreases the dryer heat demand by 35 percent and increases digester production by 84 percent, which results in a 17 percent increase in overall internal renewable energy as a percent of the total energy demand.

Alternative 3, Class B biosolids requires 962,000 Dth per year, which is 49 percent of the total energy needed under Alternative 0, which maintains Milorganite with the existing dryers. The net RNG available from the digester gas meets the JIWRF building heating needs and the solar turbines with a steam generator retrofit achieve the highest electrical efficiency.

Alternative 4 has a similar energy profile to the class B biosolids alternative because the solids processing itself does not require energy inputs, but the incineration process requires additional electrical energy to operate, which is reflected in the SSWRF energy needs.

Sensitivities

The alternatives are structured around biosolids processing. To illustrate why biosolid holds the key to meeting the renewable energy goal, two sensitivity cases were considered:

- 1. Reduce energy consumption by 10 percent
- 2. Produce 25 percent cake

Considering the 2017 baseline presented in Table 6E-27:

The percent renewables increases from 33 percent to 34 percent with the reduced electrical consumption.

If 25 percent cake were produced and could be successfully processed into Milorganite, the renewable energy percentage increases from 33 percent to 42 percent and the dryer heat load is reduced by 40 percent. Each of the alternatives is sensitive to the cake solids because of the avoided need to process additional water. Even though the Class B alternative does not involve evaporation of water, the energy required for transportation is reduced. Energy savings is highly sensitive to the energy required for solids processing and that is the reason to structure the alternatives around solids processing alternatives.





FIGURE 6E-18: COMPARISON OF 2035 ENERGY BALANCE FOR ALTERNATIVES



TABLE 6E-28: ALTERNATIVE 0, BASELINE MILORGANITE WITH EXISTING DRYERS

IIWRF Heat Demand IIWRF Electricity Demand IIWRF Purchased Renewable SSWRF Heat Demand SSWRF Electricity Demand SSWRF Purchased Renewable Elec	Dth/yr Dth/yr Dth/yr Dth/yr	1,081,768 400,397 NA	409,047 0 230,340	672,721
IIWRF Purchased Renewable SSWRF Heat Demand SSWRF Electricity Demand	Dth/yr Dth/yr	NA		
SSWRF Heat Demand SSWRF Electricity Demand	Dth/yr		230 340	
SSWRF Electricity Demand	·		230,340	169,984
·		145,990	145,990	0
SSWRF Purchased Renewable Elec	Dth/yr	174,920	31,390	NA
	Dth/yr	NA	143,530	NA
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,119	41	
NP Purchased Renewable	Dth/yr	NA	18,078	0
Fleet Vehicles	Dth/yr	1,921	1,921	0
Totals	Dth/yr	1,959,742	1,116,964	842,705
% renewables	NA NA	57%	NA	NA
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	282,802	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA
Net DG to RNG	Dth/yr	129,972	NA	NA
Net DG after NP and Vehicles	Dth/yr	-8,576	NA	NA
Solar Panels SS (5.2 MW project)	Dth/yr	31,390	NA	NA
Purchased Renewables	Dth/yr	NA	391,948	NA
Additional LFG or DG for 100% renewable	Dth/yr	994,312	NA	NA
Total LFG Purchase (Note 1)	Dth/yr	1,411,935	NA	NA

Source: Appendix 6E-9 – SW FG4 Energy Balance Calculations, Years 2017 and 2035



TABLE 6E-29: ALTERNATIVE 1, BASELINE MILORGANITE WITH NEW DRYERS

2035 Energy Balance Annual Totals		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	913,421	409,047	504,374
JIWRF Electricity Demand	Dth/yr	383,004	0	
JIWRF Purchased Renewable	Dth/yr	NA	197,661	185,270
SSWRF Heat Demand	Dth/yr	145,990	145,990	0
SSWRF Electricity Demand	Dth/yr	169,334	31,390	NA
SSWRF Purchased Renewable Elec	Dth/yr	NA	137,944	NA
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,119	41	NA
NP Purchased Renewable	Dth/yr	NA	18,078	0
Fleet Vehicles	Dth/yr	1,921	1,921	0
Totals	Dth/yr	1,768,415	1,078,698	689,644
% renewables	NA	61%	NA	NA
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	282,802	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA
Net DG to RNG	Dth/yr	129,972	NA	NA
Net DG after NP and Vehicles	Dth/yr	-8,576	NA	NA
Solar Panels SS (5.2 MW project)	Dth/yr	31,390	NA	NA
Purchased Renewables	Dth/yr	NA	353,683	NA
Additional LFG or DG for 100% renewable	Dth /vr	854,884	NA	NA
	Dth/yr		NA NA	NA NA
Total LFG Purchase	Dth/yr	1,272,507	IVA	IVA
Baseline Milo. Solids production= 62,780 DT/	yr			

Source: Appendix 6E-9 – SW FG4 Energy Balance Calculations, Years 2017 and 2035



TABLE 6E-30: ALTERNATIVE 2, DIGEST ALL MILORGANITE WITH NEW DRYERS

2035 Energy Balance Annual Totals		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	699,182	491,282	207,900
JIWRF Electricity Demand	Dth/yr	378,215	64,000	207,300
JIWRF Purchased Renewable	Dth/yr	NA	133,142	181,000
SSWRF Heat Demand	Dth/yr	169,900	169,900	0
SSWRF Electricity Demand	Dth/yr	200,771	31,390	NA NA
SSWRF Purchase renewables	Dth/yr	NA	169,381	NA NA
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,551	41	NA
NP Purchased Renewable	Dth/yr	NA NA	18,510	0
Fleet Vehicles	Dth/yr	1,921	1,921	0
Treet venicies	Diliyyi	1,321	1,521	J
Totals	Dth/yr	1,605,167	1,216,194	388,900
% renewables	NA	76%	NA	NA
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	520,729	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA
Solar Panels SS (5.2 MW project)	Dth/yr	31,390	NA	NA
Net DG to RNG	Dth/yr	333,288	NA	NA
Net DG after NP and Vehicles	Dth/yr	194,740	NA	NA
Purchased Renewables	Dth/yr	NA	321,033	NA
			NA	NA
Additional LFG or DG for 100% renewable	Dth/yr	550,333		

Source: Appendix 6E-9 – SW FG4 Energy Balance Calculations, Years 2017 and 2035



TABLE 6E-31: ALTERNATIVE 3, CLASS B LAND APPLICATION OF BIOSOLIDS

2035 Energy Balance Annual Totals		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	70,069	70,069	0
JIWRF Electricity Demand	Dth/yr	320,215	244,222	75,993
SSWRF Heat Demand	Dth/yr	169,900	169,900	0
SSWRF Electricity Demand	Dth/yr	200,771	31,390	NA
SSWRF Purchased Renewable	Dth/yr	NA	169,381	0
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,551	41	NA
NP purchased renewable	Dth/yr	NA	18,510	0
Fleet Vehicles	Dth/yr	45,951	45,951	0
Totals	Dth/yr	962,084	886,091	75,993
% renewables	NA	92%	NA	NA
				Γ
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	520,729	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA
Solar Panels SS (5.2 MW project)	Dth/yr	31,390	NA	NA
Net DG to RNG	Dth/yr	333,288	NA	NA
Net DG after NP and Vehicles	Dth/yr	150,710	NA	NA
Purchased Renewables	Dth/yr	NA	187,891	NA
	T	T	T	T
Additional LFG or DG for 100% renewable	Dth/yr	155,087	NA	NA
Total LFG Purchase	Dth/yr	572,710	NA	NA

Source: Appendix 6E-9 – SW FG4 Energy Balance Calculations, Years 2017 and 2035



TABLE 6E-32: ALTERNATIVE 4, INCINERATION OF DIGESTED BIOSOLIDS

2035 Energy Balance Annual Totals		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	70,069	0	70,069
JIWRF Electricity Demand	Dth/yr	320,215	345,249	-25,033
SSWRF Heat Demand	Dth/yr	169,900	169,900	0
SSWRF Electricity Demand	Dth/yr	257,521	31,390	NA
SSWRF Purchased Renewable	Dth/yr	NA	180,061	46,070
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,551	41	NA
NP purchased renewable	Dth/yr	NA	18,510	0
Fleet Vehicles	Dth/yr	19,973	19,973	0
Totals	Dth/yr	992,856	901,750	91,105
% renewables	NA	91%	NA	NA
				-
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	520,729	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA
Solar Panels SS (5.2 MW project)	Dth/yr	31,390	NA	NA
Net DG to RNG	Dth/yr	443,566	NA	NA
Net DG after NP and Vehicles	Dth/yr	286,966	NA	NA
Purchased Renewables	Dth/yr	NA	198,571	NA
	1	1		
Additional LFG or DG for 100% renewable	Dth/yr	185,929	NA	NA
Total LFG Purchase	Dth/yr	603,552	NA	NA
Digest all solid production= 46,720 DT/yr				

Source: Appendix 6E-9 – SW FG4 Energy Balance Calculations, Years 2017 and 2035



All alternatives propose upgrading digester gas at SSWRF to RNG with pipeline injection to meet the renewable heat requirements for the non-process facilities and contribute to offsets at JIWRF. Gas treatment currently installed at SSWRF provides a pre-treatment base that lends itself to further treatment for a full upgrade to RNG. Gas storage can continue to be utilized.

In estimating the amount of additional energy required to meet the 100 percent renewable, it was apparent that there was a direct trade-off between purchasing renewable electricity from We Energies or purchasing additional LFG and generating more electricity at JIWRF. Purchased renewable energy costs MMSD an additional \$0.018 per kWh and presumably would also contribute to the monthly peak demand charges and yearly customer demand charges. The net effect is that the purchased, external renewable energy is costly. In order to make full use of the LFG for electrical generation, a fourth solar gas combustion turbine should be considered to ensure capacity and to provide redundancy. If LFG is used for drying, there would not be enough LFG available for a fourth gas combustion turbine.

Carbon Footprint Evaluation

Carbon footprint is another component of the 2035 Vision goals. Although not specifically tied to the energy goal, energy use has a significant impact on carbon emissions. While carbon dioxide (CO_2) is the primary component of greenhouse gases (GHG), the emissions were estimated as CO_2 equivalent, which encompasses other greenhouse gases. MMSD compiled a greenhouse gas inventory in 2010. [26] The estimates included in this analysis follow similar protocols. In the 2010 report, a distinction is made between biogenic and non-biogenic emissions. Biogenic emissions are considered to be carbon neutral in terms of contributing GHG to the atmosphere. CO_2 emissions from combustion of LFG and digester gas are biogenic. Non-biogenic emissions are methane and nitrous oxide emitted during combustion and sludge drying. As seen in Table 6E-33, only a small portion of the estimated emissions are non-biogenic.

Table 6E-33 summaries the GHG data for the four alternatives and Figure 6E-19 displays these data in a bar chart format. GHG was not estimated for the Baseline Milorganite case using the existing drying technology since it was not possible to project that this case could meet the 100 percent renewable goal. The details of the evaluation used to develop the table and figure is presented in Appendix 6E-10, SW FG4 Milwaukee GHG Analysis.



TABLE 6E-33: GREENHOUSE GAS EMISSIONS

Milwaukee Metropolitan Sewerage District

Renewable Energy Alternatives - Carbon Footprint Analysis

1 DTh = 1 mmBtu

CO2 115 lb/mmBtu

CH₄ 7.05E-03 lb/mmBtu N_2O 1.39E-03 lb/mmBtu

CO2[2 42%

Oxidation Factor^[3] 100% Stoichiometric carbon equivalence 12/44

CH₄ 7.05E-02 lb/mmBtu N_2O 9.26E-03 lb/mmBtu

CO

25 CH₄

-0.25 MT CO2/MT dry biosolids

Alternative GHG Emissions Attributable to Biogas/Biosolids Combustion under 2035 Conditions

Digester Gas Combusted	282 802	mmBtu/yr
Landfill Gas Combusted		. ,
	1,274,499	
Total Biogas	1,557,301	mmBtu/yr
GHG Associated with Biogas Co	ombustion	
CO ₂	89,385	tons/year
CH ₄	5.49	tons/year
N ₂ O	1.08	tons/year
GHG on CO ₂ e Basis ^[6]		
CO ₂	89,385	tons/year
CH ₄	137.3	tons/year
N ₂ O	322	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year

Alternative 2 - Digest all Milor	ganite with ne	ew dryers
Digester Gas Combusted	520,729	mmBtu/yr
Landfill Gas Combusted	700,433	mmBtu/yr
Total Biogas	1,221,162	mmBtu/yr
GHG Associated with Biogas Coml	bustion	
CO ₂	70,091	tons/year
CH ₄	4.31	tons/year
N ₂ O	0.848	tons/year
GHG on CO ₂ e Basis ^[6]		
CO ₂	70,091	tons/year
CH ₄	107.7	tons/year
N ₂ O	253	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year
Total GHG on CO ₂ e Basis	70,446	tons/year

Alternative 3 - Class B land	application of b	iosolids
Digester Gas Combusted	520,729	mmBtu/yr
Landfill Gas Combusted	565,691	mmBtu/yr
Total Biogas Combusted	1,086,420	mmBtu/yr
GHG Associated with Biogas Co	mbustion	
CO ₂	62,358	tons/year
CH ₄	3.83	tons/year
N ₂ O	0.754	tons/year
GHG on CO₂e Basis [6]		
CO ₂	62,357.64	tons/year
CH ₄	95.8	tons/year
N ₂ O	225	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year
Total GHG on CO ₂ e Basis	62,672	tons/year

Alternative 4 - Incineration	•	
Digester Gas Combusted	520,729	mmBtu/yr
Landfill Gas Combusted	571,188	mmBtu/yr
Total Biogas	1,091,917	mmBtu/yr
Total Sludge Incineration ^[7]	918,982	mmBtu/yr
GHG Associated with Biogas Com	bustion	
CO ₂	62,673	tons/year
CH ₄	3.9	tons/year
N ₂ O	0.76	tons/year
GHG Associated with Sewage Slu	dge Incineratio	n
CO ₂ ^[7]	71,255.80	tons/year
CH ₄	32.4	tons/year
N ₂ O	4.25	tons/year
GHG on CO₂e Basis ^[6]		
CO ₂	133,929	tons/year
CH ₄	906.7	tons/year
N ₂ O	1,494	tons/year
Total GHG on CO₂e Basis	136,329	tons/year

- Notes []:

 1. Emission Factors obtained from 40 CFR §98, Subpart C, Tables C-1 and C-2. Emission factors are for gaseous biomass fuels.
- 2. Carbon content of domestic sludge from Tchobanoglous 1979
- 3. Oxidation factor from 2006 IPCC Guidelines. Vol 5 Ch. 5
- 4. Global Warming Potentials obtained from 40 CFR §98, Subpart A, Table A-1.
- 5. Biosolids Emissions Assessment Model developed by the Canadian Council of Ministers of the Environment (Version 1.1, 2011)
- 6. CO₂ equivalent (CO₂e) is each GHG constituents mass emission rate multiplied by the respective global warming potential.
- 7. Based on 46,270 dry tons per year of sewage sludge and an assumed heat content of 9,835 Btu/lb. Assumed heat content was obtained from published value measured at Green Bay, WI.



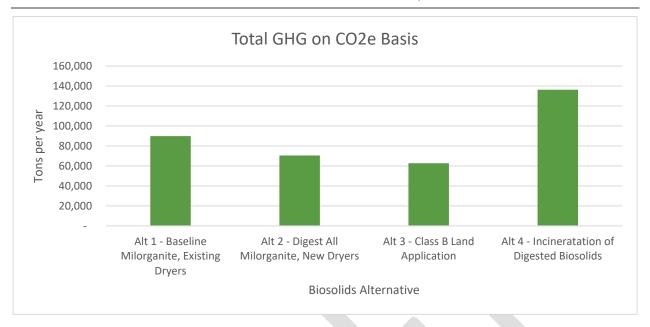


FIGURE 6E-19: COMPARISON OF 2035 GHG EMISSIONS FOR ALTERNATIVES





Alternative Comparison

The alternatives presented involve differing solids processing scenarios. As noted above, these alternatives were selected to provide a range of solids processes for which the 100 percent renewable goal can be achieved. As shown previously in Figure 6E-18, none of the alternatives achieved the goal of 80 percent renewable from internal sources. Alternative 0 could not achieve the 100 percent renewable goal within the projected amount of additional available LFG for purchase from an additional source;⁸ therefore, because it cannot meet the 100 percent renewable goal, it was excluded from the alternative comparison.

Advantages and disadvantages of each alternative are presented in Table 6E-34. Planning-level cost estimates are presented in Table 6E-35. Details for cost estimates are presented in Appendix 6E-11. Analysis-specific performance factors are developed in Table 6E-36. These performance factors were used to rate the alternatives against each other and then a total weighted score was calculated for each alternative. For each alternative, the total weighted score was divided by the alternative's present worth to determine its value ratio (the value that the alternative provides per million spent), which is presented in Table 6E-37.

The Milorganite alternatives (Alternatives 1 and 2) are based on the related alternatives and costs developed in alternative analysis WRF FG2 (Appendix 6B), in which dewatering and drying would continue to occur at JIWRF. Alternative 3, Class B Land Application, includes new dewatering at SSWRF. Alternative 4, Incineration of Digested Biosolids is based on all solids dewatering at SSWRF with the addition of new facilities for drying and incineration, also at SSWRF.

Alternative 1, Baseline Milorganite with new dryers, has the highest present worth cost. Alternative 4, Incineration has the highest capital cost. Alternative 3, Class B Biosolids has the lowest present worth due to lower capital costs but has the highest annual O&M costs due to trucking costs.

Appendix 6E-11 also includes an estimated cost for an update to the Energy Plan completed in 2015 that would further analyze findings presented in this analysis. This evaluation, which is assumed to also include advanced planning efforts such as testing, contracting recommendations, and preliminary design as appropriate, is estimated to cost \$1.6 million.

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⁸ The projected amount of additional LFG to be purchased was determined using information on LFG available from an additional source provided in the Potential Uses of Additional Landfill Gas Technical Memorandum, finalized in 2015, which provided LFG projections to 2032.



TABLE 6E-34: SW FG4, ADVANTAGES AND DISADVANTAGES

Alternative No.	Advantages	Disadvantages	Comments
Baseline Milorganite with new dryers	 Successful product with known revenue 	 High Energy Consumption Reliant on significant LFG availability to achieve 100% 	 Alternative includes new dryers
2. Digest all Milorganite with new dryers	 Lower energy consumption; increases energy production 	 All-digested product market potential and performance not known 	 Alternative include new dryers
3. Class B land application of biosolids	 Lowest energy consumption 	 May not fit with MMSD image and product goals Program management required 	 Dewatering facility and truck loading at SSWRF
4. Incineration of digested biosolids	Highest energy recovery	No resource recovery	 New facility at SSWRF

TABLE 6E-35: SW FG4, PRESENT WORTH PLANNING-LEVEL COST COMPARISON

Planning-level Costs	Alternative 1 - Baseline Milorganite with New Dryers	Alternative 2 – Digest all Milorganite with New Dryers	Alternative 3 – Class B land application	Alternative 4 – Incineration of digested biosolids
Capital Cost	\$179,700,000	\$ 179,100,000	\$ 82,400,000	\$ 204,500,000
Annual O&M Costs	\$14,000,000	\$11,000,000	\$14,100,000	\$12,400,000
Present Value of Annual O&M Costs	\$ 171,100,000	\$134,000,000	\$ 172,600,000	\$ 151,300,000
Present Worth of Equipment Replacement Costs	\$ 3,000,000	\$3,900,000	\$ 1,800,000	\$1,800,000
Present Worth of Salvage Value	(\$1,500,000)	(\$5,400,000)	(\$ 12,700,000)	(\$11,100,000)
Total Present Worth	\$ 352,300,000	\$ 311,600,000	\$244,100,000	\$ 346,500,000



TABLE 6E-36: SSW FG4, 2035 VISION ENERGY GOALS ANALYSIS

ANALYSIS-SPECIFIC PERFORMANCE FACTOR

Triple Bottom Line Measure	Level of Service Category	Performance Factor
	Permit Requirements	Measure of a given alternative's likelihood to meet permit requirements. This factor considered air permit requirements, which were assumed to be met for all alternatives.
Environmental	Energy	A measure of a given alternative's relative impact to baseline energy usage. The considerations were the KPIs related to renewable energy: 100 percent renewable energy used, with 80 percent generated by MMSD.
	Environmental Improvements	Measure of the advantages of a given alternative in terms of improvements to the environment. The factor considered was the beneficial reuse of biosolids.
	Fiscal Responsibility	General measure, separate from PW analysis, of how well a given alternative reduces identified risk(s) in a cost-effective manner (with most cost-effective receiving highest score). The factor considered was the impact from sale of biosolids.
	Management Effectiveness	Measure of a given alternative's ability to help management achieve the permit and contract goals. Factors that were considered included whether an alternative would simplify operations compared to Alternative 0 and whether new technology is part of the alternative.
	Safety	Measure of a given alternative's ability to minimize safety risks to employees, contractors, and the general public. Factors considered were safety to employees compared to existing and new technology.
Social	Customer Service, Communication and Employee Development	Measure of the advantages of a given alternative to reduce potential complaints and notices of violation, improve communication effectiveness, and/or provide employee development opportunities. This factor considered the community impacts from not producing Milorganite as well as the community impacts (trucking/odors) related to biosolids disposal.



TABLE 6E-37: SW FG4, ALTERNATIVES SCORING MATRIX

Alternative Scoring Matrix SW FG4, 2035 Vision Energy Goals	Alternative 20-yr Present Worth (\$ million)	Permit / Legal Requirements	Energy	Environmental Improvements (non-regulatory, resource recovery)	Fiscal Resp.	Management and Operational Effectiveness	Safety	Cust. Service, Community Economic Development and Organizational Reputation	Total Weighted Score	Value Ratio (Total Weighted Score / Present Worth
Weights		26	17	15	17	6	13	6	100	
Alternative 1: Baseline Milorganite with new dryers	\$352.3	5	2	5	2	3	3	5	377	1.07
Alternative 2: Digest all Milorganite with new dryers	\$311.6	5	3	5	3	4	3	4	394	1.26
Alternative 3: Class B land application	\$244.1	5	5	5	4	2	3	1	370	1.52
Alternative 4: Incineration of digested biosolids	\$346.5	5	5	1	2	2	3	2	327	0.94



Recommendations

The recommendation of this analysis is a phased process, where the first phase is to proceed with other WRFs and Biosolids Asset System Recommendations as made in Appendix 6B, which include new dryers as recommended in WRF FG2 and 3.2 MW solar array as recommended in WRF FG4. After these projects are implemented, renewable energy is projected to increase from 33 percent under Baseline Conditions to 60 percent as a percent of total energy demand, as presented for Alternative 1 in Figure 6E-18, assuming MMSD continues with Baseline Conditions biosolids processing and no additional LFG is purchased. The Biosolids Advanced Facility Plan project should confirm the recommendations from WRF FG2, Alternative Biosolids Processing and Disposal Systems to install new dryers and this analysis regarding the recommended biosolids system.

While those recommendations are being implemented, a detailed evaluation should be developed as an update to the Energy Plan completed in 2015 to confirm the feasibility of the following recommendations of this evaluation to achieve the renewable energy goals from the 2035 Vision, including project capital costs and projected annual O&M costs:

- 1. Produce RNG at SSWRF to meet renewable energy needs at remote facilities and provide vehicle fuel
- 4. Expand the 3.2 MW solar array at SSWRF as recommended in WRF FG4, Increase SSWRF Renewable Energy Use to achieve 5.2MW of solar power generation
- 5. Acquire as much LFG as is available
- 6. Purchase electricity at the renewable energy rate from We Energies
- 7. Research other renewable energy sources to supplement LFG sources

The update to the Energy Plan, projected to cost \$1.6 million, is assumed to include advanced planning efforts such as testing, contracting recommendations, and preliminary design as appropriate.

Other items to consider:

- This energy analysis illustrates that the biosolids processing and disposal system is the largest contributor to total energy demand.
 - Milorganite production is an energy-intensive pathway as shown in Figure 6E-18 (Alternatives 0-2), though digesting all the solids reduces the amount of purchased renewable energy in the form of LFG and renewable electricity as show on in Alternative 2. Based on the scoring, Alternative 3, Class B land application of biosolids, has the highest total weighted score and the best value ratio. In addition, this alternative is projected to require the least amount of LFG to achieve 100 percent renewable energy. However, processing biosolids as Class B product has reliable disposal concerns at the magnitude of biosolids that MMSD generates, along with a negative impact on public relations and product image with the loss of Milorganite.
 - o Focusing on alternatives that maintain Milorganite, Alternative 2, Digest all Milorganite with new dryers, had the next highest value ratio, and is projected to increase the renewable energy percent without purchase of additional LFG to 76 percent. However, to achieve renewable energy goals, Alternative 2 is estimated to have \$11.0 million in additional annual O&M costs over and above WRF Baseline Conditions.
 - Because incineration does not represent a resource recovery pathway; it was scored lower for environmental attributes. It was the lowest scoring alternative and is a new process that does



not present a compelling economic case; therefore, incineration is not recommended for further consideration.

- Renewable electricity is especially costly. All alternatives show a significant increase in annual O&M costs over and above WRF Baseline Conditions, ranging from \$11.0 million to over \$14.0 million per year.
- Additional LFG beyond the contracted values was required for all of the alternatives to meet the
 renewable energy goal. The additional LFG could be replaced in part with increased digester gas
 production through co-digestion if additional high strength waste streams could be identified, as
 presented in Alternative 3 of WRF FG4, Increase SSWRF Renewable Energy Use in Appendix 6B. Research
 is recommended to determine if energy sources other than LFG can provide the required renewable
 energy; the purpose of this presentation is to simplify the evaluation based on a known, available
 source.
- Reduction in energy usage can be achieved under the alternatives reviewed in this analysis. In addition, MMSD is already committed to other energy reduction projects identified in the Energy Plan. [17]
 Though WRF FG6, Reduction of SSWRF Energy Use Analysis, presented in Appendix 6B, and SW FG3, Energy Plan Additional Alternatives indicate that the additional energy reduction alternatives reviewed in the 2050 FP would not provide a significant reduction in energy usage compared to the total energy needs in the MMSD system, energy reduction technologies should be revisited as part of the detailed evaluation.





6.5 RECOMMENDED SYSTEMWIDE PROJECTS

This section presents a summary of the recommended systemwide projects.

- There were no systemwide risks related to meeting regulatory guidelines and permit requirements; therefore, there are no recommended projects.
- Table 6E-38 summarizes the recommended systemwide projects to meet 2050 Foundational Goals.





TABLE 6E-38: SUMMARY OF RECOMMENDED SYSTEMWIDE PROJECTS TO MEET 2050 FOUNDATIONAL GOALS

				More Research			Annual O&M	
				Recommended Prior	Recommended	Capital Costs	Costs	Present Worth
Ch 6 Analysis	Specific Risk Description	How Potential Risk was Identified	Name of Recommended Project	to Project? (Y/N) ¹	Timeframe of Project	(Millions)	(Millions)	Cost (Millions)
SW FG1, JIWRF and SSWRF Reutilization	Risk to of increased rates to rate payers if capacity risks are not mitigated in the most effective manner. In order to optimize WRF capacity in the most costeffective manner, it is important to identify the most effective ways to reutilize various treatment and transportation options at JIWRF, SSWRF, and the Conveyance System	JIWRF and SSWRF capacity risks identified in Systemwide Assessment MMSD staff identified as a top priority related to its 2035 Vision	Assessment of Conveyance system – diversion of flow from JIWRF service area to SSWRF service area	N – recommendation includes research	2020 – 2024	\$0.1	\$0	\$0.1
	Risk of negatively impacting community relationships if changes in customer expectations related to JIWRF odors, noise and nuisance, and recreational opportunities around JIWRF are not addressed							
	Structural risks identified at JIWRF that are due to the construction on wood piles							
SW FG 2, Zero Overflows	Risk of not meeting PI target of 0 SSO events per year Risk of not meeting PI target of 0 CSO events per year	Actual historical performance trends MMSD staff identified as a top priority related to its 2035 Vision	Phase 1: See recommended projects in Appendices 6A, 6B, 6D: - CS R1 through R8, Capacity - CS R9, Combat I/I Impact from Pipe Degradation - WRF FG8, JIWRF Wet Weather Capacity - WRF FG9, SSWRF Wet Weather Capacity - GI projects to get to 740 MG	N recommendation	2020 – 2025	\$0	\$0	\$0
			Phase 2: Assessment of system through modeling	N - recommendation includes research	2026 – 2050	\$10.0	\$0	\$10.0
			Phase 3: JIWRF HRT, Conveyance- Related Overflow projects, select CSO HRT	Y - Phase 2 assessment	2030 – 2039	\$982.4	\$0	\$982.4
			Phase 4: SSWRF HRT	Y - Phase 2 assessment	After 2050	\$355.8	\$0	\$355.8



Ch 6 Analysis	Specific Risk Description	How Potential Risk was Identified	Name of Recommended Project	More Research Recommended Prior to Project? (Y/N) ¹	Recommended Timeframe of Project	Capital Costs (Millions)	Annual O&M Costs (Millions)	Present Worth Cost (Millions)
SW FG3, Energy Plan Additional Alternatives	Risk of not meeting KPI target of 100% of annual energy from renewable sources Risk of not meeting KPI target of 80% of annual energy from MMSD-generated renewable sources	Actual historical performance trends using information from Energy Plan MMSD staff identified as a top priority related to its 2035 Vision	No additional projects over and above those already committed to in the Energy Plan	N/A	N/A	\$0	\$0	\$0
SW FG4, Energy 2035 Vision	Risk of not meeting KPI target of 100% of annual energy from renewable sources Risk of not meeting KPI target of 80% of annual energy from MMSD-generated renewable sources	Actual historical performance trends with focus on 2017 baseline energy use MMSD staff identified as a top priority related to its 2035 Vision	Update Energy Plan completed in 2015 Include projected impact from recommended projects in Appendix 6B: - WRF FG2, Alternative Biosolids Processing and Disposal Systems - WRF FG4, Increase SSWRF Renewable Energy Use	N – recommendation is research	2020-2024	\$1.6	\$0	\$1.6

¹⁾ Where applicable, additional research opportunities are identified in Chapter 9.





6.6 APPENDICES

Information used to develop this appendix may be found in the following documents:

- Appendix 6E-1 Locations in Conveyance System where Flow can be transferred from JIWRF to SSWRF
- Appendix 6E-2 Tomorrow Water Vendor Proposal
- Appendix 6E-3 SW FG1 JIWRF/SSWRF Reutilization Cost Estimate Details
- Appendix 6E-4 SW FG2 Tunnel-Related Overflows Cost Estimates
- Appendix 6E-5 SW FG2 Conveyance-Related Overflow Elimination Project Details
- Appendix 6E-6 SW FG3 JIWRF Channel Mixing
 - o Appendix 6E-6-A: SW FG3 JIWRF Channel Mixing Backup
- Appendix 6E-7 SW FG3 Effluent Heat Recovery Backup
- Appendix 6E-8 SSWRF Influent Power Generation Backup
- Appendix 6E-9 SW FG4 Energy Balance Calculations, Years 2017 and 2035
- Appendix 6E-10 SW FG4 Milwaukee GHG Analysis
- Appendix 6E-11 SW FG4 SW FG4 Project Conceptual Costs



6.7 REFERENCES

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APPENDIX 6E-1: Conveyance System Flow Transfer Locations -





APPENDIX 6E-1

LOCATIONS IN CONVEYANCE SYSTEM WHERE FLOW CAN BE TRANSFERRED FROM JIWRF TO SSWRF

LEAD ENGINEER: P. CHIANG/OTIE

DATE: 1/15/19

1. PURPOSE

The SW FG1, JIWRF and SSWRF Reutilization analysis in Appendix 6E assumes the transfer of flows from the JIWRF service area to the SSWRF service area is to be conducted by pumping through a tunnel directly from JIWRF to SSWRF. This was selected because the construction would be the least disruptive to MMSD service area stakeholders. However, the costs for this approach are anticipated to be very high (see analysis in Appendix 6E). Another approach would be to transfer flows within the conveyance system once the conveyance model has been calibrated. The costs for this second approach have not been developed because more information needs to be evaluated to confirm its feasibility. The purpose of this document is to identify potential locations throughout the conveyance system where flows could be transferred and the modifications required in the system for use in managing the conveyance system.

2. BACKGROUND

In Conveyance Baseline Conditions, Subsystems 2, 3, and 4 discharge into Subsystem 1 and then Subsystem 1 delivers the wastewater to the SSWRF. Similarly, under normal conditions, Subsystems 5, 6, and 7 directly route wastewater into the JIWRF.

Five diversion chambers (referred to with "DC" designation) and four pump stations ("PS" designation) automatically divert flow from one MIS subsystem to another. They are presented in Table 1:



DRAFT

TABLE 1: LOCATIONS OF AUTOMATIC DIVERSIONS FROM ONE MIS SUBSYSTEM TO ANOTHER

Structure ID	Diversion Chamber Location or Pump Station Name	Subsystem Diversion		
DC0505	51st Street and Hampton Avenue	Subsystem 5 to 4		
DC0603	6th Street and Oklahoma Avenue	Subsystem 6 to 1		
DC0604	35th and Manitoba Streets	Subsystem 6 to 1		
DC0605	6th Street and Warnimont Avenue	Subsystem 6 to 1		
DC0606	Kinnickinnic and Lunham Avenues	Subsystem 6 to 1		
PS0301	Greenfield Park Pump Station	Subsystem 3 to 2		
PS0302	Underwood Creek Pump Station	from one portion of Subsystem 3 to another		
PS0502	Green Tree Road Pump Station	Subsystem 5 to 4		
PS0703	Brady Street Pump Station	Subsystem 7 to 5		

In addition to these automated diversions, there are 15 diversion chambers with gates that can be operated remotely through the Central Control System (CCS) in a manual mode to cause additional MIS-to-MIS diversions, which is typically done during maintenance operations. Manual diversion chambers are presented in Table 2:



DRAFT

TABLE 2: LOCATIONS FOR MANUAL DIVERSIONS FROM ONE MIS SUBSYSTEM TO ANOTHER

Chamber		
ID	Diversion Chamber Location	Subsystem Diversion
DC0101	27th Street and Howard Avenue	Subsystem 1 to 6
DC0102	Howell and Layton Avenues	Subsystem 1 to 6
DC0301	84th and Walker Streets	Subsystem 3 to 4 through DC0302 and BS0301
DC0302	84th and Adler Streets	Subsystem 3 to 4
DC0303	84th Street and Wisconsin Avenue	Subsystem 3 to 4
DC0305	Menomonee River Parkway and Keefe Avenue	Subsystem 3 to 4
DC0401	Hawley Road and Schlinger Avenue	Subsystem 4 to 6
DC0403	58th and State Streets	Subsystem 4 to 5
DC0404	58th Street and Roosevelt Drive	Subsystem 4 to 5
DC0406	Green Tree Road and 1-43	Subsystem 4 to 5
DC0407	Dean Road and Teutonia Avenue	Subsystem 4 to 5
DC0408	Fairy Chasm Road and Green Bay Avenue	Subsystem 4 to 5
DC0409	Mill Road and Sidney Place	Subsystem 4 to 5; passive diversion, gate in
		outlet to Subsystem 5 is normally open. It is closed only for maintenance purposes.
DC0901	Erie Street	Subsystem 5 to 7
DC0902	Bruce Street	Subsystem 7 to or from 6

3. APPROACH

The two alternatives identified in the SW FG1, JIWRF and SSWRF Reutilization analysis in Appendix 6E were reviewed to determine where in the conveyance system flows could be diverted. The two alternatives are as follows:

- SW FG1 Alternative 1: Diversion of All Flow from JIWRF to SSWRF
- SW FG1 Alternative 2: Diversion of Dry Weather Flow from JIWRF to SSWRF

This evaluation looks at SW FG1 Alternative 2 first because it only requires a partial transfer of flows in the system and therefore would be less expensive to implement and then expands to look at SW FG1 Alternative 1. For each alternative, the diversion chambers identified in the Background section are reviewed and are feasible transfer locations are identified. Flows are then established for each location and issues identified.



4. EVALUATION

SW FG1 Alternative 2: Diversion of Dry Weather Flow from JIWRF to SSWRF

Under the current conditions, dry weather flow (DWF) from Subsystems 1, 2, 3 is treated at SSWRF. For Subsystem 4, the majority of DWF is treated at SSWRF, with the exception of five sewersheds: FP4005, FP4006, FP4008, GL4032, and GL4052 (sewershed details are provided in Appendix 4A-2, Flow Generation TM)—). For purposes of this analysis, DWF from these sewersheds is diverted to Subsystem 5 through DC0406 and would continue flow to the JIWRF.

Under the current conditions, DWF from Subsystems 5, 6 and 7 is routed to JIWRF through the Harbor Siphons. Subsystems 5 and 6 contain both separate and combined sewer sewersheds and Subsystem 7 contains only combined sewer sewersheds. The separate sewer parts of Subsystems 5 and 6 flow in the combined sewer portions of Subsystems 5 and 6 (high-level MIS) through several diversion chambers. The diversion chambers route flow to JIWRF in dry weather and can automatically divert flows to SSWRF in wet weather. Under SW FG1 Alternative2, the operations of these diversion chambers would need to be changed and surrounding structures may need to be modified to route DWF to SSWRF (as listed in Table 1). The diversion chambers for the separate sewer portion of Subsystem 5 are DC0505 and DC 70509. The separate sewer parts of Subsystems 5 flow in the high-level MIS into the combined sewer service area. The combined flow is conveyed to the JIWRF through High Level Erie Siphons (one 60-inch and two 78-inch siphons). The flow will need to be pumped to the SSWRF through force mains.

The diversion chambers for the separate sewer portion of Subsystem 6 are DC0603, DC604, DC0605, and DC0606. The combined DWF from the separate sewer parts of Subsystems 6 flow in the high-level MIS into the combined sewer service area. The combined flow is conveyed to the JIWRF through High Level 48-inch DWF Barclay Siphons. The flow will need to be pumped to the SSWRF through force mains.

The DWF from Subsystem 7 is conveyed to the JIWRF through several low-level siphons (Bruce, Erie and Scott Siphons). The flow will need to be pumped to the SSWRF through force mains.

Table 3 lists the dry and wet weather flow destination WRFs for each subsystem and the diversion chambers where operation can be modified to route DWF to the SSWRF, along with the divertible area from each diversion location. Pipe segments from the MMSD GIS system are also identified by the 5-digit pipe segment identification number for reference where applicable, referred to in this document as "Pipe Segment XXXXXX." The DWF peak flows listed in the table are based on the Comprehensive System Model (CSM) model results for the February 2014 event in the Conveyance Buildout Conditions. For the combined sewer parts of Subsystems 5 and 6, the additional DWF diverted to the SSWRF were reported as subsystem totals rather than the combined sewershed flows only because separate sewer flows discharge into the combined sewer service area.

The additional flows diverted to the SSWRF are 77, 24, and 56 MGD for Subsystems 5, 6, and 7, for a total of 156.8 MGD additional DWF that will be pumped and treated at the SSWRF. This is more dry weather flow than is assumed can be transferred, which was established as 120 MGD in the SW FG1 Alternative 2 analysis. Because the purpose of this alternative is to evaluate routing DWF to the SSWRF and DWF is small compared to the sewer capacity, no diversion chamber or sewer capacity evaluations were conducted.



TABLE 3: SUBSYSTEM FLOW TREATMENT DESTINATION AND THE POTENTIAL APPROACH FOR SW FG1 ALTERNATIVE 2

	Separate/	Current (Conditions	Alte	rnative 2				
Subsystem	Combined Sewers	DWF	WWF	DWF	WWF	Diversion chamber	Comments / Status / Potential Approach	Resulting Total Flow Routed to SSWRF (MGD)	Total Tributary Area Diverted (acres)
1	SS	SSWRF	SSWRF	SSWRF	SSWRF		No changes	0	
2	SS	SSWRF	SSWRF	SSWRF	SSWRF		No changes	0	
3	SS	SSWRF	SSWRF	SSWRF	SSWRF		No changes	0	
4	SS	JI/SSWRF	JI/SSWRF	SSWRF	JI/SSWRF	DC0406	Change the operations of DC0406 to route DWF to the 36" Pipe Segment 70406.	0.8	847
5	SS	JIWRF	JI/SSWRF	SSWRF	JI/SSWRF	DC0505 DC 70509	Change the operations of DC0505 to route DWF to the 48" Pipe Segment 70505. Change the operations of DC 70509 to pump DWF to the 30" Pipe Segment 90502.	DC0505-2.7 DC70509-1.6	DC0505-1,601 DC 70509-3,852
5	CS	JIWRF	JIWRF	SSWRF	JIWRF		Currently DWF (combined with DWF from SS sewersheds) is conveyed to JIWRF through High Level Erie Siphons (one 60-inch and two 78-inch siphons). Need to pump DWF from JIWRF to SSWRF.	77.1	System 5 total-23,243
6	SS	JIWRF	JI/SSWRF	SSWRF	JI/SSWRF	DC0603 DC0604 DC0605 DC0606	Change the operations of DC0603, DC0604, and DC0606 to allow DWF being routed to SSWRF. Structural modifications to DC0605 including constructing a new weir to divert WWF to the 36" Pipe of DC0605 (now to JIWRF) and removing weir on the 90" Pipe Segment 70605 to allow DWF being routed to SSWRF.	DC0603-14.2 (cumulative) DC0604-2.9 DC0605-6.6 DC0606-4.6	DC0603-4,202 DC0604-1,452 DC0605-0 DC0606-2,361
6	CS	JIWRF	JIWRF	SSWRF	JIWRF		Currently DWF (combined with DWF from SS sewersheds) is conveyed to JIWRF through High Level 48" DWF B Siphons. Need to pump DWF from JIWRF to SSWRF.	24.0	System 6 total- 9,897
7	CS	JIWRF	JIWRF	SSWRF	JIWRF		Currently DWF from Leg V discharges to JIWRF through the low level 42" A Siphon. Legs SB and XB discharge to low level 54"Erie Siphon. Leg W discharges to low level Bruce siphons. Flows from Erie and Bruce Siphons are combined through a series of valves into 90" and 72" low level siphons. Need to pump DWF from JIWRF to SSWRF.	56.0	10,711



SW FG1 Alternative 1: Diversion of All Flow from JIWRF to SSWRF

Similar to Alternative 2, this alternative focuses on changing the destination WRF for Subsystems 4, 5, 6, and 7. Under the current conditions, flow from Subsystems 4 is treated at SSWRF, except DWF diverted through DC0406 and wet weather flow (WWF) through DC0409. Subsystems 5, 6, and 7 directly route wastewater into the JIWRF, except a portion of Subsystems 5 and 6 can be diverted to SSWRF in wet weather. As stated in Alternative 2, Subsystems 5 and 6 contain both separate and combined sewer sewersheds and Subsystem 7 contains only combined sewer sewersheds. The separate sewer parts of Subsystems 5 and 6 flow in the combined sewer portions of Subsystems 5 and 6 (high-level MIS) through several diversion chambers. The diversion chambers route flow to JIWRF in dry weather and can divert flow to SSWRF in wet weather. Under this alternative, the operations of these diversion chambers would need to be changed and surrounding structures may need to be modified to route both dry and wet weather flows to SSWRF (as listed in Table 4). The diversion chambers for the separate sewer portion of Subsystem 5 are DC0505 and DC 70509. The diversion chambers for the separate sewer portion of Subsystem 6 are DC0603, DC604, DC0605 and DC0606. The combined dry and wet weather flows from Subsystems 5, 6, and 7 would continue to flow to JIWRF and be pumped to the SSWRF through force mains.

Table 4 lists the dry and wet weather flow destination WRFs for each subsystem and the diversion chambers that can be changed to route both the dry and wet weather flows to SSWRF. Pipe segments from the MMSD GIS system are also identified by the 5-digit pipe segment identification number for reference where applicable, referred to in this document as "Pipe Segment XXXXX." The peak flows listed in the table are based on the CSM model results for the August 1986 event in the Conveyance Buildout Conditions, which is the event that resulted in the highest peak flow at the WRFs. To estimate the allowable flow and the divertible tributary area in each of the subsystems that can be routed to SSWRF, the operation of the diversion chamber was reviewed and the total peak flow tributary to the diversion chamber was compared to the capacity of the immediate downstream sewer of the structure routing to SSWRF. If a sewer that is downstream of a diversion chamber is identified to divert flow to SSWRF and it does not have adequate capacity, only the portion of the flow that currently discharges to JIWRF will be diverted to SSWRF. The remaining flow will continue the original conveyance route to the next downstream diversion chamber. The flow will be combined with the flow needed to be routed to SSWRF at this downstream diversion chamber and the total will be evaluated against the capacity of the sewer to the SSWRF. The process will continue downstream to JIWRF. The remaining flow that is routed to JIWRF will be pumped to SSWRF. The above flow additions and subtractions are based on a simple math calculation and are not intended to include flow attenuation and storage.

For the two diversion chambers in Subsystem 4, the sewer downstream of DC0406 that flows to SSWRF has an adequate capacity (Pipe Segment 70406, with a capacity of 9.8 MGD, column 2 of Table 4) to accommodate the additional DWF of 0.8 MGD (column 1 of Table 4). The total flow discharges to Pipe 70406 is 5.5 MGD (column 3 of Table 4). Thus, the total tributary area to DC0406 can be diverted to SSWRF (column 4 of Table 4). The flow currently diverted to JIWRF through DC0409 is 86.3 MGD, which is much larger than the capacity of the downstream pipe to SSWRF (Pipe Segment 33801, with a capacity of 26.3 MGD). Thus, the WWF needs to discharge to the ISS Extension and be pumped out of the ISS to the JIWRF or the SSWRF.





The diversion chamber for the separate sewer portion of Subsystem 5 are DC0505 and DC 70509. For both diversion chambers, the downstream sewer pipes and pump station to SSWRF (Pipe Segment 70505 for DC0505, Pump PS0502 and Pipe Segment 90502 for DC 70509) all have adequate capacities to accommodate the additional DWF originally routed to the JIWRF. The total tributary area can be diverted through the structures, which are 1,602 acres for DC0505 and 3,852 acres for DC 70509.

The separate sewer parts of Subsystems 5 flow in the high-level MIS into the combined sewer service area. The combined flow is conveyed to the JIWRF through High-Level Erie Siphons (one 60-inch and two 78-inch siphons). The flow will need to be pumped to the SSWRF through force mains. The combined flow through High-Level Erie Siphons is 146.2 MGD without the upstream diversions to SSWRF through DC0505 and DC 70509. After the diversions, the flow through High-Level Erie Siphons will be approximately 138.4 MGD. The total tributary routed to the SSWRF from Subsystem 5 is 23,243 acres.

For the flow from the separate sewer portion of Subsystem 6, three out of four diversion chambers have adequate capacity to convey the additional flow currently treated at JIWRF (DC0604, DC0605 and DC0606). For DC0603, the pipe capacity of the immediate downstream pipe to SSWRF (Pipe Segment 70603A, with a design capacity of 55.6 MGD) is less than the total combined flow currently diverted to JIWRF and SSWRF (100.4 MGD). However, DC0604, DC0605, and DC0606 are located at upstream of DC0603 and the JIWRF portion of flows are diverted through DC0603 in the current operation. JIWRF portion of DC0606 flow discharges into DC0605 and the combined JIWRF flow through DC0605 (11.7 MGD) and DC0604 (27.8 MGD) discharges to DC0603. Under this alternative, the actual total flow that is routed to SSWRF through DC0603 would be much smaller and was assumed to be at or slightly above the downstream pipe capacity. The total tributary areas diverted through the diversion chambers are 4,202 acres, 1,452 acres, 0 acres and 2,361 acres for DC0603, DC0604, DC0605 and DC0606, respectively.

The combined JIWRF portion of flows from the separate sewer parts of Subsystem 6 flows in the high-level MIS into the combined sewer service area. The combined flow is conveyed to JIWRF through high-level B Siphons. The flow will need to be pumped to SSWRF through force mains. The combined flow through High-Level Barclay Siphons is 65.5 MGD without the upstream diversions to SSWRF through DC0603, DC0604, DC0605, and DC0606. After the diversions, the flow through High-Level B Siphons will be approximately 40.6 MGD (subtracting 24.9 MGD from the DC0603 JIWRF portion of flow). The total tributary routed to SSWRF from Subsystem 6 is 9,897 acres.

The DWF from Subsystem 7 is conveyed to the JIWRF through several low-level siphons (Scott/Barclay, Bruce and Erie Siphons) and the combined flow from the low-level siphons is 121.7 MGD. The flow will need to be pumped to SSWRF through force mains. The total tributary routed to the SSWRF from Subsystem 7 is 10,711 acres.



TABLE 4: SUBSYSTEM FLOW TREATMENT DESTINATION AND THE POTENTIAL APPROACH FOR ALTERNATIVE 1

	Current Conditions		Current Conditions Alternative 1		rnative 1		Alternative 1	Capacity of DC Pipe	Resulting Total Flow	
Subsystem	CS/SS	DWF	WWF	DWF	WWF	Comments / Status / Potential Approach	Additional flow routed to SSWRF (MGD)	to SSWRF (MGD)	Routed to SSWRF (MGD)	Total Tributary Area Diverted (acres)
1	SS	SSWRF	SSWRF	SSWRF	SSWRF	No changes	0			
2	SS	SSWRF	SSWRF	SSWRF	SSWRF	No changes	0			
3	SS	SSWRF	SSWRF	SSWRF	SSWRF	No changes	0			
4	SS	JI/SSWRF	JI/SSWRF	SSWRF	SSWRF	Change the operations of DC0406 to route DWF to the 36" Pipe Segment 70406. DC0409-72" Pipe Segment 33803 no capacity, route WWF to the ISS extension and pump the flow from JIWRF to SSWRF.	DC0406-0.8 DC0409-86.3	Pipe Segment 70406-9.8 Pipe Segment 33801-26.3	Pipe Segment 70406-5.5 86.3 to ISS Extension	DC0406-847 DC0409-0
5	SS	JIWRF	JI/SSWRF	SSWRF	SSWRF	Change the operations of DC0505 to route DWF to the 48" Pipe Segment 70505. Change the operations of DC 70509 to pump DWF to the 30" Pipe Segment 90502.	DC0505-4.7 DC 70509-3.1	Pipe Segment 70505- 208.0 Pipe Segment 90502-47.1	Pipe Segment 70505-18.4 Pipe Segment 90502-19.0	DC0505-1,601 DC 70509-3,852
5	CS	JIWRF	JIWRF	SSWRF	SSWRF	Currently flow (combined with DWF from SS sewersheds) is conveyed to JIWRF through High Level Erie Siphons (one 60-inch and two 78-inch siphons). Need to pump flow from JIWRF to SSWRF.	146.2	Pump to SSWRF		System 5 total-23,243
6	SS	JIWRF	JI/SSWRF	SSWRF	SSWRF	Change the operations of DC0603, DC0604, and DC0606 to allow DWF being routed to SSWRF. Structural modifications to DC0605 including abandoning the 36" Pipe of DC0605 (now to JIWRF) and removing weir on the 90" Pipe Segment 70605 to allow DWF being routed to SSWRF.	DC0603-24.9 (cumulative) DC0604-27.8 DC0605-11.7 DC0606-17.3	Pipe Segment 70603A- 55.6 Pipe Segment 70604- 130.5 Pipe Segment 70605- 100.7 Pipe Segment 30911-28.0	Pipe Segment 70603A- 100.4 (cumulative) Pipe Segment 70604- 132.1 Pipe Segment 70605-74.3 Pipe Segment 30911-63.0	DC0603-4,202 DC0604-1,452 DC0605-0 DC0606-2,361
6	CS	JIWRF	JIWRF	SSWRF	SSWRF	Flow Currently is route to JIWRF through high level Scott/Barclay and Erie Siphons. Need to pump flows from JIWRF to SSWRF.	65.5	Pump to SSWRF		System 6 total-9,897
7	cs	JIWRF	JIWRF	SSWRF	SSWRF	Flow Currently is routed to JIWRF through low level Scott/Barclay and Erie Siphons. Need to pump DWF from JIWRF to SSWRF.	121.7	Pump to SSWRF		10,711



5. RECOMMENDATIONS

The review of the conveyance system indicates that there are opportunities to transfer flow from the JIWRF service area to the SSWRF service area rather than transfer flow from JIWRF through a tunnel and pump station as is assumed for the alternatives in SW FG1 analysis. These opportunities should be analyzed in more detail once the hydraulic model is updated, including developing costs as applicable for the modifications to the system recommended.





APPENDIX 6E-2: SW FG1 Tomorrow Water Vendor Proposal -



South Shore WRF Peak Flow Design

Milwaukee, WI

CONFIDENTIAL

Prepared For: Rob Smith Black & Veatch



Option 1:

Dry Weather Average: 101 MGD

Wet Weather Peak Flow: 450 MGD

BOD & TSS Control Only



Influent Water Quality

	14 0	Influ	uent	□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □	Unit
	Item	Daily Average	WWF	Effluent	Unit
	Flow Rate	101.3	450	100.3	MGD
Q	Trow Rate	383,421	1,703,435	379,677	m ³ /d
	P.F	-	4.4	-	-
	Concentration	264*	95*	20	mg/L
DOD	Lood	101,233	161,809	7,592	Kg/d
BOD	Load	223,197	356,788	16,741	lb/d
	P.F		1.6		
	Concentration	292*	120*	20	mg/L
TSS	Load	111,959	204,390	7,592	Kg/d
	Load	246,869	450,680	16,741	lb/d
	Peaking Factor		1.8		

^{*}New influent BOD/TSS concentrations provided in email 10/25/19

Design Goals: Option 1



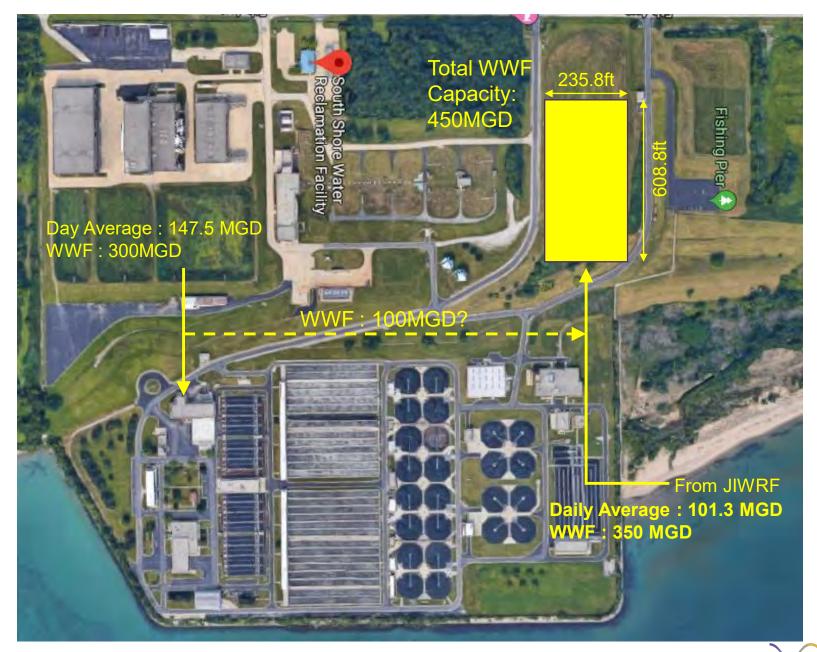
- 1. Maximum flow variation capacity (101-450 MGD)
- 2. Minimum footprint
- 3. Secondary treatment (incl. BOD, TSS) for 101.3 MGD in dry weather
- 4. Meet BOD & TSS permit targets AND provide Biological Treatment @ 450 MGD
- 5. Immediate startup in wet weather, no chemicals, easy O&M and low OPEX

Proteus Design

Item	Cell Size	Cell Number	Total Area	LV (m/hr)		EBCT ²⁾ (min)	
itom	(ft ²)	(Ea)	(ft ²)	Dry Flow	Wet Flow	Dry Flow	Wet Flow
	1,583 (47.5ftX33.3ft)	64	143,555 ¹⁾	1.7	7.5	106.2	23.9

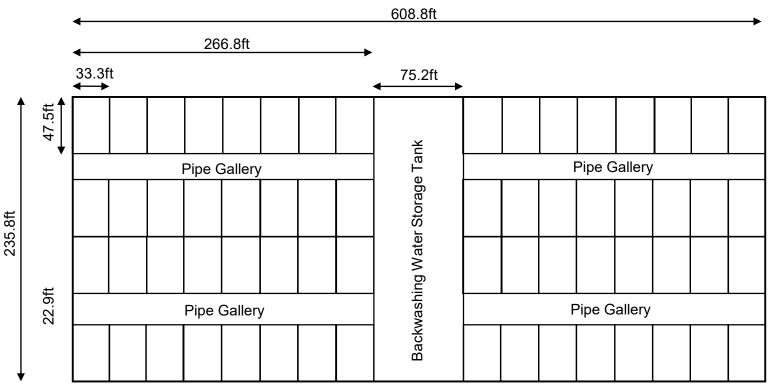
1) BBF Cells+ Pipe Galley + Backwashing Water Storage Tank + Electric Room + Backwash Treatment

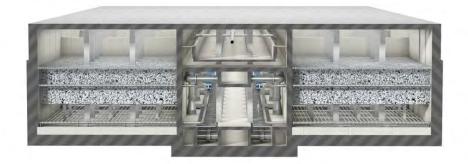
2) OxigotableT



System Layout (Approximate)







Effluent Water Quality



	Inf	fluent	Efflue	ent	
ltem	Dry	Dry Weather Flows Dry Season WWF		WWF	Unit
BOD	264	95	10	20	mg/L
SS	292	120	10	20	mg/L



Cost Estimates (Does not include civil works)



CAPEX

Item	Tomorrow Water Scope	General Equipment	Total
USD	\$77,000,000	100,000,000	\$177,000,000

OPEX

	kWh/d	kWh/year	Remarks
Item	54,512	18,896,960	- Except Influent pump



Option 2:

Dry Weather Average: 50 MGD

Wet Weather Peak Flow: 590 MGD

BOD, TSS & Ammonia Control

(Nitrification Stage Included)



Influent Water Quality

lte	em	Daily Average WWF		Unit
Q		50	590	MGD
(Flo	ow)	189,270	2,233,393	m³/d
P	.F		11.8,	
		313*	75.6*	mg/L
ВС	OD	59,159	168.903	Kg/d
		130,455	372,430	lb/d
		345*	83.4*	mg/L
TS	SS	65,209	186,177	Kg/d
		143,786	143,786	lb/d
		26*	9.2	mg/L
	Influent	4,991	20,627	Kg/d
Nitrogen		11,005	42,285	lb/d
Millogen		17.4	-	mg/L
	Nitrified	3,278	-	Kg/d
		7,249	-	lb/d

^{*}Monthly max concentrations used



Design Goals



- 1. Maximum flow variation capacity (50-590 MGD)
- 2. Minimum footprint
- 3. Full treatment (incl. BOD, TSS, NH₄ control) for 50 MGD in dry weather
- 4. Meet all permit targets AND provide Biological Treatment at 590 MGD peak flow
- 5. Immediate startup in wet weather, no chemicals, easy O&M and low OPEX

Proteus Design

Item	Cell Size	Cell Number	Total Area		V /hr)		CT ²⁾ nin)		Remarks
II.OIII	(ft ²)	(Ea)	(ft ²)	Dry Flow	Wet Flow	Dry Flow	Wet Flow		romano
	1,614 (49.2ftX32.	52	114,210 ¹⁾	1.0	12.0	180	15	•	Daily Average(50MGD)
	8ft)							•	WWF(590MGD)

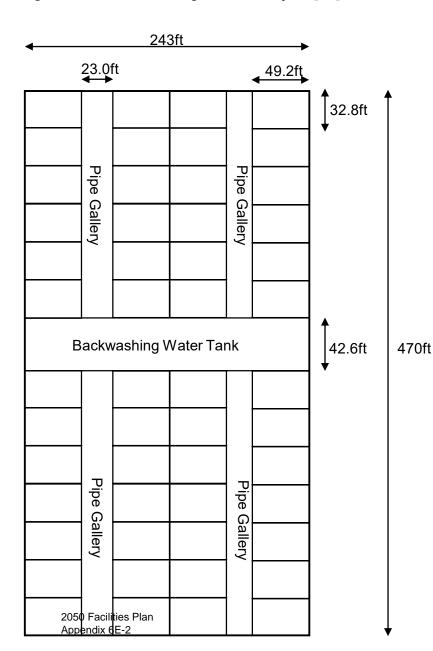
1) BBF Cells+ Pipe Galley + B.W Tank

2) Oxigo EBCT

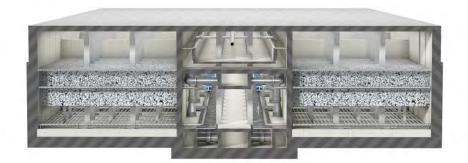


System Layout (Approximate)





- Footprint includes:
 - Filter Cells
 - Pipe Galleries
 - Backwash Storage
 - Mechanical & E&IC Rooms
 - Service Access
- Total Constructed Depth = 7m



Effluent Water Quality



	Inf	fluent	Efflue	ent	
ltem	Dry	Wet Weather Flows	Dry Season	WWF	Unit
BOD	313	75.6	10	20	mg/L
SS	345	84.3	3 10 20		mg/L
Nitrogen	26	9.2	9.0	9.0	mg/L



Cost Estimates (Does not include civil works)



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CAPEX

Item	Tomorrow Water Scope	General Equipment	Total
USD	\$63,730,000	82,844,000	\$146,574,000

Estimated Concrete Volume (for civil estimation): 25,291 m³ (391,387 ft³)

<u>Tomorrow Water Scope of Supply:</u>

Concrete-Type:

- Media
- Strainer Block & Nozzles
- Aeration Grid
- Process Design, License & Control Philosophy

Exclusions:

Civil Work (& Const. Materials), Gen Equipment (Influent Pump, Blower, Valves, Controls hipping, Electrical, Shipping SW FG1 Tomorrow Water Vendor Proposal

OPEX Estimates



Electric Power List

Item	Quantity		Power (kw)	Operating Time (hr/d)	Demand factor	kWh/d	
	Duty	Standby	Total				
■ Proteus Biofilter							
Air compressors system	4	0	4	3.7	3	1	44
Drainage pump	4	4	8	1.5	0	1	
Hanging crane	4	0	4	1.5	0	1	
Process air blower	8	2	10	225	24	1	43,200
Backwash air blower	4	2	6	75	1	1	300
■ Backwashing sludge storage							
Mixer for sludge storage tank	4	0	4	7.5	3	1	90
Backwash Sludge Transfer Pump	4	2	6	15	24	1	1,440
Sum							45,074

Labor Required (Estimate):

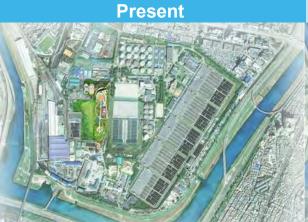
- 2 Operators/Shift
- + Mechanic, Pipe Fitter, Electrician, Sensor Tech, Maintenance Tech, etc.

Selected Reference: Jungnang WRC



Modernization Plan of Jungnang WRC





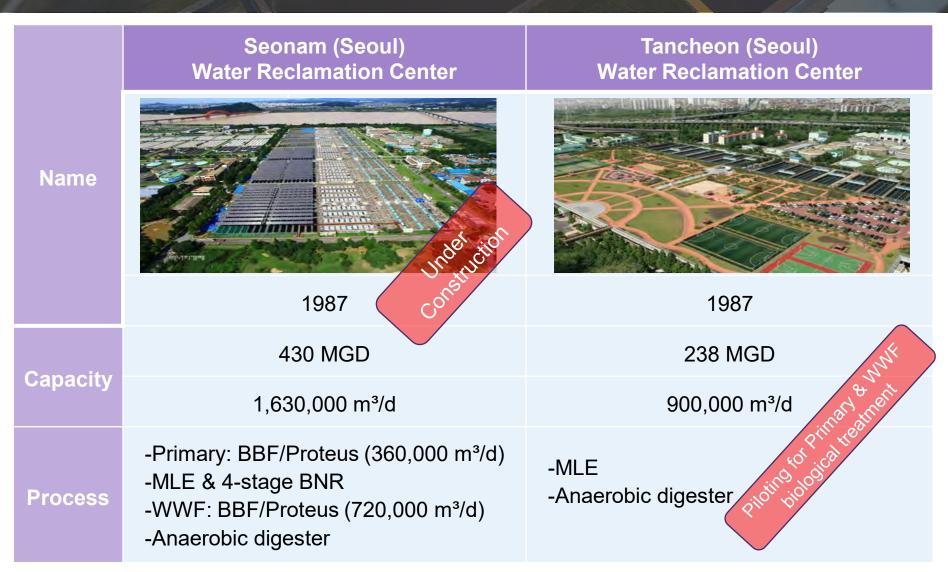


- Activated sludge process 1,130,000 m³/d
- 4-stage BNR 460,000 m³/d
- The first modernization on existing footprint and fully underground of part of the treatment plant with BBF/Proteus (250,000 m³/d)
- Includes WWF treatment 500,000 m3/d (132 MGD)

- Modernization and putting fully underground the entire treatment plant
- Include WWF treatment 3,460,000m3/d (914 MGD)

Additional References





BBF & Proteus References

Primary treatment Jungrang WWTP 250,000 66 Primary treatment Seonam WWTP 360,000 95 Wet Weather Flows Seonam WWTP 720,000 190 Wet Weather Flows Jungrang WWTP 500,000 132 Wet Weather Flows Hwado WWTP 63,000 16.6 Secondary w/BNR Jungrang WWTP 250,000 66 Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary <th>APPLICATION</th> <th>CLIENT</th> <th>CAPACITY (m³/d)</th> <th>CAPACITY (MGD)</th>	APPLICATION	CLIENT	CAPACITY (m³/d)	CAPACITY (MGD)
Primary treatment Seonam WWTP 360,000 95 Wet Weather Flows Seonam WWTP 720,000 190 Wet Weather Flows Jungrang WWTP 500,000 132 Wet Weather Flows Hwado WWTP 63,000 16.6 Secondary w/BNR Jungrang WWTP 250,000 66 Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 45,000 11.9 Tertiary	Primary treatment	Jungrang WWTP	· /	
Wet Weather Flows Seonam WWTP 720,000 190 Wet Weather Flows Jungrang WWTP 500,000 132 Wet Weather Flows Hwado WWTP 63,000 16.6 Secondary w/BNR Jungrang WWTP 250,000 66 Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan	-		· · · · · · · · · · · · · · · · · · ·	
Wet Weather Flows Jungrang WWTP 500,000 132 Wet Weather Flows Hwado WWTP 63,000 16.6 Secondary w/BNR Jungrang WWTP 250,000 66 Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	•		•	
Wet Weather Flows Hwado WWTP 63,000 16.6 Secondary w/BNR Jungrang WWTP 250,000 66 Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15		Jungrang WWTP	· ·	132
Secondary w/BNR Geomdan WWTP 40,000 10.6 Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Wet Weather Flows	5 5	· · · · · · · · · · · · · · · · · · ·	16.6
Secondary w/BNR Okjung WWTP 22,000 5.8 Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Jungrang WWTP	250,000	66
Secondary w/BNR Yangbeol WWTP 20,000 5.3 Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Geomdan WWTP	40,000	10.6
Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Okjung WWTP	22,000	5.8
Secondary w/BNR Samri WWTP 5,000 1.3 Secondary w/BNR Julpo WWTP 1,600 0.4 Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Yangbeol WWTP	20,000	5.3
Secondary w/BNR Gumi WWTP 14,300 3.8 Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	<u> </u>	5,000	1.3
Secondary w/BNR Jingun WWTP 25,000 6.6 Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Julpo WWTP	1,600	0.4
Tertiary Deajuk WWTP 12,000 3.2 Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Gumi WWTP	14,300	3.8
Tertiary Pocheon WWTP 24,000 6.3 Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Secondary w/BNR	Jingun WWTP	25,000	6.6
Tertiary Chungbuk WWTP 15,200 4 Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Tertiary	Deajuk WWTP	12,000	3.2
Tertiary BukhangWWTP 35,000 9.2 Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Tertiary	Pocheon WWTP	24,000	6.3
Tertiary UnyangWWTP 45,000 11.9 Tertiary Osan WWTP 57,000 15	Tertiary	Chungbuk WWTP	15,200	4
Tertiary Osan WWTP 57,000 15	Tertiary	BukhangWWTP	35,000	9.2
,	Tertiary	UnyangWWTP	45,000	11.9
T45	Tertiary	Osan WWTP	57,000	15
Tertiary Munmak WWTP 200 -	Tertiary	Munmak WWTP	200	-
Tertiary Pyeongchang WWTP 200 -	Tertiary	Pyeongchang WWTP	200	_
Tertiary Boryung WWTP 30,000 7.9	Tertiary	Boryung WWTP	30,000	7.9
Tertiary Gwangju WWTP 25,000 6.6	Tertiary	Gwangju WWTP	25,000	6.6
Tertiary Ohpo WWTP 14,000 3.7	Tertiary	Ohpo WWTP	14,000	3.7
Tertiary Docheok WWTP 4,000 1.1	Tertiary	Docheok WWTP	4,000	1.1
Tertiary Jeungpyung WWTP 25,000 6.6	Tertiary	Jeungpyung WWTP	25,000	6.6
Tertiary (Water reuse) Qufu WWTP (China) 40,000 10.6	Tertiary (Water reus	e) Qufu WWTP (China)	40,000	10.6
Tertiary (Water reuse) Dangjin WWTP 30,000 7.9	Tertiary (Water reus	e) Dangjin WWTP	30,000	7.9
Tertiary (Water reuse) Seonam magok WRP 20,000 5.3	Tertiary (Water reus	e) Seonam magok WRP	20,000	5.3
Tertiary (Water reuse) Songdo WRP 20,000 5.3	Tertiary (Water reus		20,000	5.3
R/O brine treatment Pohang WWTP 9,000 2.4	R/O brine treatment	Plan Pohang WWTP	9,000	2.4
R/O brine type attract Paju WWTP 17,000 4.5	R/O brine type attorneent	Paju WWTP	17,000	4.5

62 References in Korea:

38 municipal, 27 systems for livestock waste

One in California (groundwater treatment)

One in China (tertiary)

52 Operational5 in Construction5 in design/commissioning

Proteus

3 Refs from 17 - 190 MGD

BBF

25 Refs from 1–66 MGD







APPENDIX 6E-3: SW FG1 JIWRF/SSWRF Reutilization Cost Estimate Details -



MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 1 Diversion of All Flow from JIWRF

General Description:

All wastewater flow to be treated at SSWRF. Wastewater flow in JIWRF service are directed to JIWRF and then transferred to SSWRF with pump station and force main. ISS assumed to operate in same manner with flow directed to new pump station along with flow through high and low level siphons. JIWRF operations reduced to preliminary treatment, with transfer of flows to JIWRF after grit removal. SSWRF expanded to handle 790 MGD of flow, which equals projected 490 MGD of flow to JIWRF necessary to maintain baseline CSO frequency plus baseline SSWRF capacity of 300 MGD.

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%
Discount Rate 3.375%
Number of Years 20

	Capital Costs	
	Life	Capital Cost
ITEM	Years	 (\$)
Diversion structure at JIWRF	100	\$ 5,830,000
Tunnel from JIWRF to SSWRF (340 MGD)	100	\$ 611,100,000
ISS Pump Station at SSWRF (340 MGD)	20	\$ 1,051,650,000
Capital Cost to Divert Flow from JIWRF	20	\$ 1,668,580,000
Site Work	20	\$ 8,610,000
Yard Piping	20	\$ 6,550,000
Preliminary Treatment Facility	20	\$ 75,220,000
CES Facility	20	\$ 52,510,000
Primary Filtration and Biological Treatment Facility	20	\$ 601,440,000
Aeration Tank Modifications	20	\$ 24,540,000
UV Disinfection System	20	\$ 551,250,000
Effluent Pumping	20	\$ 22,610,000
Outfall Construction	20	\$ 58,030,000
Solids Treatment	20	\$ 268,450,000
Capital Cost at SSWRF		\$ 1,669,210,000
Total (Capital Cost	\$ 3,337,790,000

		Unit Cost		
Units	Quantity	(\$)	А	nnual Cost (\$)
			\$	-
LS	1	\$10,520,000.00	\$	10,520,000
LS	1	\$592,051	\$	592,000
14.375				
			\$	159,730,000
	LS LS	LS 1 LS 1	LS 1 \$10,520,000.00 LS 1 \$592,051	LS 1 \$10,520,000.00 \$ LS 1 \$592,051 \$

Equipment Replacement	nt Costs				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
				\$	-
Present Worth of Equipment Replacement Costs (Note 2)				\$	-

Salvage Val	ue				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
	LS	1			
	LS	1			
	LS	1			
Present Worth of Salvage Value				\$	

TOTAL PRESENT WORTH	
Capital Costs	\$ 3,337,790,000
Present Worth of O&M Costs	\$ 159,730,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 3,497,520,000

Notes

¹⁾ See additional sheets attached for details for additional capital cost breakdown.

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide FG1 Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 1

Alternative # 1 Diversion of All Flow from JIWRF

General Description:

All wastewater flow to be treated at SSWRF. Wastewater flow in JIWRF service are directed to JIWRF and then transferred to SSWRF with pump station and force main. ISS assumed to operate in same manner with flow directed to new pump station along with flwo through high and low level siphons. JIWRF operations reduced to preliminary treatment, with transfer of flows to JIWRF after grit removal. SSWRF expanded to handle 790 MGD of flow, which equals projected 490 MGD of flow to JIWRF necessary to maintain baseline CSO frequency plus baseline SSWRF capacity of 300 MGD.

						Capital Costs	s							Danima		
	Life			Unit Cost SUBTOTAL 1 U			Undesigned			SUBTOTAL 2	Constr. Overhead	C	ONSTR. COST	Design, Bidding, Const.	CA	APITAL COST
ITEM	Years	Units	Quantity	(\$)	(\$)		-	Contingency		(\$)	& Profit		(\$)	Oversight	_	(\$)
Diversion structure at JIWRF	100	LF	1	3,325,000	\$	3,325,000	20%	20%	\$	4,660,000	25%	\$	5,830,000	0%	\$	5,830,000
Tunnel from JIWRF to SSWRF (340 MGD)	100	LF	1	291,000,000	\$	291,000,000	20%	20%	\$	407,400,000	25%	\$	509,250,000	20%	\$	611,100,000
ISS Pump Station at SSWRF (340 MGD)	20	LS	1	429,240,000	\$	429,240,000	20%	20%	\$	600,940,000	25%	\$	751,180,000	40%	\$ '	1,051,650,000
Capital Cost to Divert Flow from JIWRF															\$ 1	1,668,580,000
Site Work	20	LS	1	3.516.868	\$	3,516,868	20%	20%	\$	4,920,000	25%	\$	6,150,000	40%	\$	8,610,000
Yard Piping	20	LS	1	2.672.819	\$	2,672,819	20%	20%	\$	3,740,000	25%	\$	4,680,000	40%	\$	6,550,000
Preliminary Treatment Facility	20	LS	1	30,702,254	\$	30,702,254	20%	20%	\$	42,980,000	25%	\$	53,730,000	40%	\$	75,220,000
CES Facility	20	LS	1	21,435,308	\$	21,435,308	20%	20%	\$	30,010,000	25%	\$	37,510,000	40%	\$	52,510,000
Primary Filtration and Biological Treatment Facility	20	LS	1	245,484,750	\$	245,484,750	20%	20%	\$	343,680,000	25%	\$	429,600,000	40%	\$	601,440,000
Aeration Tank Modifications	20	LS	1	10,015,293	\$	10,015,293	20%	20%	\$	14,020,000	25%	\$	17,530,000	40%	\$	24,540,000
UV Disinfection System	20	LS	1	225,000,000	\$	225,000,000	20%	20%	\$	315,000,000	25%	\$	393,750,000	40%	\$	551,250,000
Effluent Pumping	20	LS	1	9,231,777	\$	9,231,777	20%	20%	\$	12,920,000	25%	\$	16,150,000	40%	\$	22,610,000
Outfall Construction	20	LS	1	23,686,103	\$	23,686,103	20%	20%	\$	33,160,000	25%	\$	41,450,000	40%	\$	58,030,000
Solids Treatment	20	LS	1	109,568,912	\$	109,568,912	20%	20%	\$	153,400,000	25%	\$	191,750,000	40%	\$	268,450,000
Capital Cost at SSWRF															\$ 1	1,669,210,000
													Total	Capital Cost	\$:	3,337,790,000

Notes:

1) Definitions:

LS - lump sum

2) See additional cost worksheets for additional information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 2 Diversion of Dry Weather Flow from JIWRF

General Description:

All dry weather flow to be treated at SSWRF. Up to 120 MGD of dry weather wastewater flow in JIWRF service are directed to JIWRF and then transferred to SSWRF with pump station and force main. JIWRF to handle 490 MGD during wet weather. ISS assumed to operate in same manner.

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate
Number of Years 20

	Capital Costs	
	Life	Capital Cost
ITEM	Years	 (\$)
Diversion structure at JIWRF	100	\$ 5,830,000
Tunnel from JIWRF to SSWRF (120 MGD)	100	\$ 533,400,000
ISS Pump Station at SSWRF (120 MGD)	20	\$ 421,390,000
Capital Cost to Divert Flow from JIWRF		\$ 960,620,000
JIWRF Wet Weather Treatment		
Site Work	20	\$ 3,710,000
Primary Filtration and Biological Treatment Facility	20	\$ 443,170,000
Disinfection and Effluent Pump System	20	\$ 1,570,000
Capital Cost to Upgrade JIWRF Wet Weather Treatment		\$ 448,450,000
SSWRF Expansion		
Site Work	20	\$ 1,320,000
Yard Piping	20	\$ 5,240,000
Preliminary Treatment Facility	20	\$ 60,190,000
Primary Filtration and Biological Treatment Facility	20	\$ 108,540,000
Aeration Tank Modifications	20	\$ 14,710,000
UV Disinfection System	20	\$ 83,730,000
Effluent Pumping	20	\$ 18,100,000
Outfall Construction	20	\$ 58,030,000
Solids Treatment	20	\$ 268,450,000
Capital Cost at SSWRF		\$ 618,310,000
Total C	capital Cost	\$ 2,027,380,000

Operation and Mainte	enance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	A	nnual Cost (\$)
Added annual assumed to be 1% of PS capital cost	LS	1	\$4,210,000	\$	4,210,000
SS PS at SSWRF	LS	1	\$452,559	\$	453,000
Life Cycle Analysis					
Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	67,030,000

Equipment Re	eplacement Costs				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
				\$	-
Present Worth of Equipment Replacement Costs (Note 2)				\$	_

Salvage Value					
			Unit Value	Value	
ITEM	Units	Quantity	(\$)	(\$)	
	LS	1			
	LS	1			
	LS	1			
Present Worth of Salvage Value				\$	

TOTAL PRESENT WORTH	
Capital Costs	\$ 2,027,380,000
Present Worth of O&M Costs	\$ 67,030,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 2,094,410,000

Notes:

1) See additional sheets attached for details for additional capital cost breakdown.

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide FG1 Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

Alternative # 2 Diversion of Dry Weather Flow from JIWRF

General Description:

All dry weather flow to be treated at SSWRF. Up to 120 MGD of dry weather wastewater flow in JIWRF service are directed to JIWRF and then transferred to SSWRF with pump station and force main. JIWRF to handle 490 MGD during wet weather. ISS assumed to operate in same manner.

						Capital Costs	s							Danian		
	Life			Unit Cost	5	SUBTOTAL 1	Undesigned		S	SUBTOTAL 2	Constr. Overhead	CC	ONSTR. COST	Design, Bidding, Const.	C.	APITAL COST
ITEM	Years	Units	Quantity	(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
Diversion structure at JIWRF	100	LF	1	3,325,000	\$	3,325,000	20%	20%	\$	4,660,000	25%	\$	5,830,000	0%	\$	5,830,000
Tunnel from JIWRF to SSWRF (120 MGD)	100	LF	1	254,000,000	\$	254,000,000	20%	20%	\$	355,600,000	25%	\$	444,500,000	20%	\$	533,400,000
ISS Pump Station at SSWRF (120 MGD)	20	LS	1	171,990,000	\$	171,990,000	20%	20%	\$	240,790,000	25%	\$	300,990,000	40%	\$	421,390,000
Capital Cost to Divert Flow from JIWRF															\$	960,620,000
JIWRF Wet Weather Treatment																
Site Work	20	LS	1	1,513,589	\$	1,513,589	20%	20%	\$	2,120,000	25%	\$	2,650,000	40%	\$	3,710,000
Primary Filtration and Biological Treatment Facility	20	LS	1	180,883,500	\$	180,883,500	20%	20%	\$	253,240,000	25%	\$	316,550,000	40%	\$	443,170,000
Disinfection and Effluent Pump System	20	LS	1	1,570,300	\$	1,570,300	0%	0%	\$	1,570,000	0%	\$	1,570,000	0%	\$	1,570,000
Capital Cost to Upgrade JIWRF Wet Weather Treatment															\$	446,880,000
SSWRF Expansion																
Site Work	20	LS	1	534,208	\$	534,208	20%	20%	\$	750,000	25%	\$	940,000	40%	\$	1,320,000
Yard Piping	20	LS	1	2,138,256	\$	2,138,256	20%	20%	\$	2,990,000	25%	\$	3,740,000	40%	\$	5,240,000
Preliminary Treatment Facility	20	LS	1	24,561,803	\$	24,561,803	20%	20%	\$	34,390,000	25%	\$	42,990,000	40%	\$	60,190,000
Primary Filtration and Biological Treatment Facility	20	LS	1	44,298,000	\$	44,298,000	20%	20%	\$	62,020,000	25%	\$	77,530,000	40%	\$	108,540,000
Aeration Tank Modifications	20	LS	1	6,009,176	\$	6,009,176	20%	20%	\$	8,410,000	25%	\$	10,510,000	40%	\$	14,710,000
UV Disinfection System	20	LS	1	34,177,215	\$	34,177,215	20%	20%	\$	47,850,000	25%	\$	59,810,000	40%	\$	83,730,000
Effluent Pumping	20	LS	1	7,385,422	\$	7,385,422	20%	20%	\$	10,340,000	25%	\$	12,930,000	40%	\$	18,100,000
Outfall Construction	20	LS	1	23,686,103	\$	23,686,103	20%	20%	\$	33,160,000	25%	\$	41,450,000	40%	\$	58,030,000
Solids Treatment	20	LS	1	109,568,912	\$	109,568,912	20%	20%	\$	153,400,000	25%	\$	191,750,000	40%	\$	268,450,000
Solids Treatment																618,310,000

Notes:

- 1) Definitions:
 - LS lump sum
- 2) See additional cost worksheets for additional information
- 3) JIWRF site works and treatment facility costs based on the unit cost per MGD developed in Liquid Cost Table spreadsheet, assuming 490 MGD wet weather flow
- 4) Disinfection and Effluent Pump costs are the total capital costs developed for WRF FG8, JIWRF Blending Capacity, so no additional markups added
- 4) SSWRF costs based on the unit cost per MGD developed in the Liquid Cost Table spreadsheet, assuming expansion to provide additional 120 MGD of dry weather flow

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide FG1 Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

Pilot Cost

Auxiliary Treatment Facility Module

General Description:

Capital costs:

Conveyance System Evaluation: cost to study feasibility of transfering flow from JIWRF to SSWRF service areas within conveyance system.

SSWRF Pilot Study: capital costs to purchase and install one Auxiliary Treatment Facility Module for pilot study at SSWRF.

							Capital Cost	s							Design,		
	Life			Uni	it Cost	SI	JBTOTAL 1	Undesigned		SL	JBTOTAL 2	Constr. Overhead	COI	NSTR. COST	Bidding, Const.	CAF	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
Conveyance System Evaluation																	
Evaluation - PM	NA	hrs	80	\$	250	\$	20,000	20%	20%	\$	30,000	0%	\$	30,000	0%	\$	30,000
Evaluation - Engineer	NA	hrs	320	\$	150	\$	48,000	20%	20%	\$	70,000	0%	\$	70,000	0%	\$	70,000
														Total	Capital Cost	\$	100,000
SSWRF Pilot Study Primary Filtration and Biological Treatment Facility	20	LS	1	3,4	103,102	\$	3,403,102	20%	20%	\$	4,760,000	25%	\$	5,950,000	40%	\$	8,330,000
														Total	Capital Cost	\$	8,330,000

Notes:

- 1) Definitions:
 - LS lump sum
- 2) See additional cost worksheets for additional information
- 3) JIWRF costs based on the unit cost per MGD developed in Liquid Cost Table spreadsheet, assuming 490 MGD wet weather flow
- 4) SSWRF costs based on the unit cost per MGD developed in the Liquid Cost Table spreadsheet, assuming expansion to provide additional 120 MGD of dry weather flow

RS Means location factor for

			10%		5% sub	total 1		7% subt	total 2		0%			C	Current ENR	CCI: 1132		or for waukee								F	Report (Costs	102.3	
																				eans Locatio										
Capital Cost Item 1 Demolition	Cost	<u>Elec</u>	<u>trical</u>	<u>1&C</u>			Mobilizatio	<u>on</u>	C	ontingencies	Cons	struction cos	st	Y	Year	ENR	2019	9 Cost	facto	r	2019	Location Cost	\$ / MG	i Capac	city					
2 Excavation Site Work and Lake 3 Fill	\$	2,500,000 ş	250,000	ş 1	125,000 ş	2,875,000	ş 20)1,250 ş	3,076,250	, -	· \$	3,076,2	50 ş	3,076,250		2014	\$	3,5:	16,868		\$	3,516,868	\$	4,452	790 r	mgd	\$	B&V MMSD HRT demonstration study biological contact 3,516,868 alternative		1,714,848 Site Work
Wastewater 4 Pumping Station													\$	62,000,000		9,907 2005 7,446	\$	94,3	807,279		\$	105,669,602	ş 10	06,737	990 r	mgd		Columbus Southerly Raw Sewage Pump Building		T
5 Yard Piping	\$	6,250,000 ş	625,000	\$ 3	312,500 \$	7,187,500	\$ 50	3,125 ş	7,690,625		\$	7,690,6	25 ş	2,337,950		2014 9,907	\$	2,6	72,819 102.3		\$	2,672,819	\$ 1	17,819	150 r	mgd :	\$	B&V MMSD HRT demonstration study biological contact 2,672,819 alternative		7,145,200 Yard Piping
Preliminary 6 Treatment Facility													\$	110,000,000		2005	\$	167,31	91.3 19,366		\$	187,478,326	\$ 18	89,372	r	ngd		columbus southerly headworks project includes pumping	station	
Preliminary	ć	17 400 000	1 746 000		272 000	20.070.000	. 140	NE E20 .	24 404 520			24.404.5	20 .	26.055.662		7,446		20.7	102.3			20 702 254	. 20	990				30,702,254 B&V MMSD HRT demonstration study		Preliminary 19,960,832 Treatment Facility
7 Treatment Facility	,	17,460,000 Ş	1,746,000	\$ °	575,000 Ş	20,079,000	Ş 1,40	,530 Ş	21,484,530 Ş		Ş	21,484,5	30 Ş	26,855,663		2014 9,907	\$	30,71	702,254 91.3		\$	30,702,254	Ş 20	04,682 150	r	ngd \$	5	50,702,234 B&V MINISD RKI GEIHOUSTRATION STUDY		High Rate
		13,281,000 12,190,000 \$	1,219,000	\$ 6	509,500 s	14,018,500	\$ 98	31,295 s	14,999,795	; .	· \$	14,999,7	95 \$	18,749,744		2014 9,907	\$	21,4	35,308 102.3		\$	21,435,308	\$ 14		r	ngd \$	5 :	21,435,308 B&V MMSD HRT demonstration study		15,183,265 Treatment System 13,935,999 CES Facility
	\$	22,500,000 \$	2,250,000	\$ 1,1	125,000 \$	25,875,000	\$ 1,81	11,250 \$	27,686,250		\$	27,686,2		7,686,250		2019 9,907 11,326	\$	27,6	886,250		\$	27,686,250	\$ 4	46,926 150	590 r			TW concrete quantity estimate		İ
Primary Filtration and Biological													-	.7,000,230					102.3											Auxiliary Treatment
10 Treatment System Aeration Tank	\$ 1	.77,000,000 Ş	17,700,000	\$ 8,8	850,000 ş	203,550,000	\$ 14,24	18,500 ş	217,798,500 §	•	\$	217,798,50	00 \$	217,798,500		2019 11,326	\$	217,79	98,500 102.3		\$	217,798,500	\$ 36	69,150	590 r	ngd	\$ 24	5,484,750 Tomorrow Water	1	164,574,000 Facility Aeration Tank
11 Modifications Final Clarifier 12 Modifications	\$	8,400,000 \$	840,000	\$ 4	120,000 ş	9,660,000	\$ 67	'6,200 \$	10,336,200 န	•	\$	10,336,2	00 ş	10,336,200		2014 9,907	\$	11,8	102.3		\$	10,015,293	\$ 5	50,076	200 r	ngd :	\$:	10,015,293 allowance of \$250,000 per tank before factors		9,603,149 Modifications
UV disinfection 13 system													\$	260,530,000		2008	\$	355,08	85,774 120.7		\$	300,955,051	ş 20	08,997	r	ngd		Chicago Stickney WRP		
UV disinfection 14 system	\$ 1	.82,852,499 ş	18,285,249.90	ş 9,142,	,624.95 ş	210,280,374	\$ 14,71	19,626 ş	225,000,000 §		\$	225,000,00	00 ş	225,000,000		8,310 2019 11,326	\$	225,00	00,000		\$	225,000,000	\$ 28	84,810 1,440	r	mgd	\$ 22	5,000,000 Gary Hunter estimate		UV Disinfection 73,141,000 System
Chlorine																			120.7					790						
15 disinfection system 16 Effluent Pumping	\$	5,250,000 ş	525,000	\$ 2	262,500 ş	6,037,500	\$ 42	2,625 \$	6,460,125		\$	6,460,125	\$	9,413,325 8,075,156		2014 2014 8,310 9,907	\$ \$		329,762 31,777 102.3		\$ \$	12,829,762 9,231,777		85,532 61,545		ngd ngd	\$	9,231,777 B&V MMSD HRT demonstration study		6,001,968 Effluent Pumping Outfall
17 Outfall Construction Solids Handling	\$	13,470,000 ş	1,347,000	\$ 6	573,500 ş	15,490,500	\$ 1,08	34,335 ş	16,574,835 ફ		\$	16,574,8	35 \$	20,718,544		2014 9,907	\$	23,6	586,103 102.3		\$	23,686,103	\$ 15	150 57,907 150	r	mgd :	\$:	23,686,103 B&V MMSD HRT demonstration study		15,399,336 Construction
18 Improvements																			102.3					150						Solids Treatment
			9 costs																102.3											
		2,500,000 \$ 6,250,000 \$	2,858,080 7,145,200																											
Preliminary 7 Treatment Facility	\$:	17,460,000 ş	19,960,832																											
		13,281,000 \$ 12,190,000 \$	15,183,265 13,935,999																											
Primary Filtration and Biological																														
Treatment Facility Aeration Tank	\$ 1	99,500,000 \$	199,500,000																											
UV Disinfection		8,400,000 \$	9,603,149																											
14 System 16 Effluent Pumping		91,426,249 \$ 5,250,000 \$	91,426,249 6,001,968																											
17 Outfall Construction	\$	13,470,000 \$	15,399,336																											
2 - ment																														
Auxiliary Treatment																								50.450	4			0000500 T		Auxiliary Treatment
10 System																							\$ 36	69,150	490 r	ngd :	\$ 18	0,883,500 Tomorrow Water	1	164,574,000 Facility
Auxiliary Treatment																														
10 System																							\$ 36	69,150	9 r	ngd :	\$ 3,4	03,101.56 Tomorrow Water, one module		

STRATEGY NO. 3 - All biosolids digested, 43,000 dtpy, no Milo, new dewatering & drying at SSWRF SSWRF CAPITAL IMPROVEMENTS INITIAL COST ESTIMATE

General Description.

Transfer all biosolids processing to the SSWRF, maintain Milorganite® production and marketing but for all digested product. This alternative includes increaseed anaerobic digestion capacity, increaseed thickening capacity, new dewatering and drying with dried biosolids beneficial reuse sold to fertilizer blender market.

ITEM	Units	Quantity	Unit Cost (\$)	Initial Cost (\$)	1
Digester 9, and 11 Inspection and Repairs	each	Quantity 2	92,950	185,900	
Digester 9, and 11 Dispection and Repairs	each	2	357.500	715,000	П
Digester 9, 11, 13, 14 Linear Motion Mixer	each	4	653,400	2,613,600	П
Digester 13, 14 Heat Exchanger	each	2	82.875	165,750	П
Digester 13, 14 Recirc Pump	each	2	32,500	65,000	П
Digester 13, 14 Heating Pump	each	2	32,500	65,000	П
Co-thickening GBTs	each	11	227,639	2,504,030	П
Odor Hoods	each	11	23,808	261,890	П
Thickened Sludge Pumps	each	5	25,492	127,459	П
IPS Receiving Wet Well Mixing	each	3	57,850	173,550	
Centrifuges	each	5	692,510	3,462,550	П
Polymer System	each	1	500,500	500,500	
Air Compressor	each	2	26,000	52,000	
Centrifuge Feed Piping Modifications	LS	1	100,000	100,000	
Rotary Drum Drying System	LS	5	11,000,000	55,000,000	
Major Equipment Subtotal				65,992,229	
Digesters Architectural/Structural	Soo Work-h-	ot for Dotalls - C	ort Brookdown	2 000 000	74
Digesters Earthwork Digesters Concrete	See Workshe	et for Detailed C et for Detailed C	ost Breakdown	3,000,000 5.000.000	74
Digesters Concrete Metals:		et for Detailed C et for Detailed C		5,000,000	1
Metals: Digesters Buildings		et for Detailed C et for Detailed C		5.088	1
Digesters Buildings Digesters Demolition		et for Detailed C et for Detailed C		750,000	1
-	see Workshe	er ioi petalled C	ost predkdOWN	/50,000	1
Drying/Storage Architectural/Structural				_	1
Drying/Storage Earthwork		et for Detailed C		0	1
Drying/Storage Concrete Metals:		et for Detailed C		7,800,000	26
		et for Detailed C		0	1
Drying/Storage Buildings Drying/Storage Demolition		et for Detailed C et for Detailed C		0	
Thickening/Dewatering Architectural/Structural					
Thickening/Dewatering Earthwork		et for Detailed C		0	1
Thickening/Dewatering Concrete		et for Detailed C		459,000	2
Metals:		et for Detailed C		0	1
Thickening/Dewatering Buildings		et for Detailed C		99,960	1
Thickening/Dewatering Demotition	See Workshe	et for Detailed C	ost Breakdown	851,824	
Digesters Building Costs Architectural	%	5%		540,541	
Electrical	%	5%		540,541	
I&C	%	5%		540,541	1
Process Piping & Valves	%	8%		864,865	1
HVAC & Plumbing	%	3%		324,324	
Drying/Storage Building Costs					1
Civil (Earthwork)	%	8%		2,400,000	1
Architectural	%	12%		3,600,000	1
Electrical	%	14%		4,200,000	1
1&C	%	10%		3,000,000	1
Process Piping & Valves	%	15%		4,500,000	1
HVAC & Plumbing	%	15%		4,500,000	1
Thickening/Dewatering Building Costs					
Civil (Earthwork)	LS	1	0		-
Architectural	LS	1	50,000	50,000	c
Electrical	LS	1	100,000	100,000	c
I&C	LS	1	150,000	150,000	c
Process Piping & Valves	LS	1	150,000	150,000	c
HVAC & Plumbing	LS	1	150,000	150,000	С
HVAC & Plumbing	LS	1	150,000	150,000	
Subtotal 1				109,568,912	
Undesigned Details Contingency			30% 20%	32,870,673 21,913,782	l
Subtotal 2				164,353,367	I
Contractor Overhead & Profit			25%	41,088,342	
Total Construction Cost				205,441,709	
Total Initial Cost				205 441 709	
rocar miniar COST				205,441,709	-1

			2050 Facilities Plan Milwaukee, WI					
STRATEGY NO. 3 - All biosolids digested, 43,000 dtpy, no Milo, new dewatering & drying at SSWRF ANNUAL DAM COST ESTIMATE FOR SSWRF IMPROVEMENTS								
		ANNUAL O&M COST	ESTIMATE FOR SSV Cun			ture		
		Unit Cost	Annual	Annual Cost	Annual	Annual Cost	Cost Differential	
ITEM	Units	(\$)	Quantity	(\$)	Quantity	(\$)	(\$)	
O&M.								
DAF Thickening O&M Labor	hours	50	3,359	167,950	0	0	-167,950	
Digesters O&M Labor	hours	50	9,594	479,700	14,391	719,550	239,850	
GBT Thickening O&M Labor	hours	50	3,024	151,200	16,640	832,000	680,800	
Agrilife Storage O&M Labor	hours	50	2,924	146,200	3,000	150,000	3,800	
Dewatering O&M Labor	hours	50	10,921	546,050	41,600	2,080,000	1,533,950	
Drying O&M Labor	hours	50	0	0	41,600	2,080,000	2,080,000	87,
Solids Processing Equipment Maintenance	%	2%	4,640,000	92,800	65,992,229	1,319,845	1,227,045	
Electricity								
DAF Thickening Electricity	kwh	0.06	1,086,240	65,392	438,000	26,368	-39,024	Information only, not in
Digesters Electricity	kwh	0.06	3,171,120	190,901	6,105,720	367,564	176,663	Information only, not in
GBT Thickening Electricity	kwh	0.06	438,000	26,368	10,503,240	632,295	605,927	Information only, not in
Agrilife Storage Electricity	kwh	0.06	385,440	23,203	385,440	23,203	0	Information only, not in
Dewatering Electricity	kwh	0.06	438,000	26,368	12,062,520	726,164	699,796	Information only, not in
Drying Electricity	kwh	0.06	0	0	9,075,360	546,337	546,337	Information only, not in
Generated Electricity	kwh	0.06	-13,323,960	-802,102	-41,364,720	-2,490,156	-1,688,054	Information or ######
Purchased Electricity	kwh	0.06	26,744,280	1,610,006	17,905,440	1,077,907	-532,098	-8,838
Natural Gas								
Digester heating and Generators	MMBtu	3.0	68,255	204,765	54,750	164,250	-40,515	-13
Dryer operation	MMBtu	3.0	0	0	375,585	1,126,755	1,126,755	375,
<u>Chemicals</u>								
Polymer (GBTs)	lb	1.10	16,425	18,068	679,995	747,995	729,927	663,
Polymer (P&F Presses)	lb	1.10	3,285	3,614	0	0	-3,614	-3
Polymer (Centrifuges)	lb	1.10		0	404,055	444,461	444,461	404
Biosolids								
Biosolids Disposal	dry ton	120	0	0	0	0	0	
Biosolids Revenue	dry ton	-45			42,705	-1,921,725	-1,921,725	
Biosolids Management	LS				1	300,000	300,000	
							Cost Differential	
Total Annual Cost				3.420.352		9.121.037	5.700.685	l

solids processing equipment	num !	Unit Cost	Total
GBTs	3	200,000	600,00
Pumps	12	40,000	480,00
Thickening Ancillary	1	540,000	540,00
P&F Presses	1	1,512,000	1,512,00
Pumps	1	500,000	500,00
Dewatering Ancillary	1	1,006,000	1,006,00
TOTAL			4.638.00

Equipment	Status	% of Current Operation	% of Current Labor
DAF Thickening	Demolished	0%	0%
GBT	3 GBTs demolished, replaced with 9	0%	150%
Digestion	Mixers for 4 digesters	100%	133%
Agri-life	Unused	100%	100%
P&F Presses	Demolish, replace w/ centrifuges	0%	133%

		Labor:	\$ 50.00	/hr	
			2016 Labor Costs from	n Veolia	
Equipment	Avg Energy Use (kW)	Labor Cost	Labor Hours	Other	Total
DAF Thickening	133.3	-167,950	-3,359	-95,080	-263,030
GBTs	34.7	-151,186	-3,024	-138,328	-289,514
Digestion	503.6	-479,684	-9,594	-90,716	-570,400
Agri-life	44.2	-146,198	-2,924	-15,750	-161,948
P&F Presses	47.6	-546,036	-10,921	-85,514	-631,550

DAFs Equipment	kW
DAFT Building	26.6
Pressurized Recycle Pumps	84.2
TAS Pumps	14.0
DAF Bottom Collectors	0.6
DAF Top Scrapers	2.2
Air Compressor	5.7

GBT Equipment	kW	
Centrifuge Building	22.8	
Grinder (10 hp)	0.6	
Mix Pump (20 hp)	1.1	
Feed Pump (20 hp)	1.1	
GBT Feed Pumps	3.4	
Gravity Belt Thickeners	0.9	
Bulk Polymer Pumps	0.3	
Polymer Feed Pumps	0.3	
Thickened Sludge Pumps	4.3	
Sludge Transfer Tank Mixers	0.0	

Digestion Equipment	kW	
Digesters and Digester Gallery	76.0	
Digesters 6 & 8 Mechanical Mixers	45.4	
Digesters 9 Gas Mix Compressors	16.8	
Digesters 11 Gas Mix Compressors	16.8	
Digester 10 Linear Motion Mixer	25.5	
Digester 12 Pump and NozzleMixer	113.4	
Digester Heating Pumps	42.5	
Digester Hot Water Pumps	21.3	
Digested Sludge Transfer Pumps	14.0	
Digested Sludge IPS Pumps	5.7	
Sphere Gas Compressor	35.4	
Llanar Sita W3 Pussar	90.7	

Agri-life Equipment	kW
Agri-Life Transfer Pump	34.0
Operational Storage Tank Mixers	3.4
Operation Storage Tank Pumps	6.8

P&F Press Equipment	kW	
Plate and Frame Bld.	0.0	
Abel Pumps	17.0	
Plate and Frame Preses	0.0	
Sludge transfer tank mixers	3.4	
Sludge Transfer Pump	20.4	
Bulk Polymer Pumps	0.3	
Polymer Feed Pumps	0.1	
Compressed Air Systems	6.4	

STRATEGY NO. 3 - All biosolids digested, 43,000 dtpy, no Milo, new dewatering & drying at SSWRF

Biosolids, cu yd/day Storage, days Storage, cu yd Existing Building Lengt Existing Building Depth Cake Storage Height, fi Existing Storage, cu yd Additional Storage, cu yd

ITEM	Units	Quantity	Unit Cost (\$)	Initial Cost (\$)	Additional Storage, cu yu Additional Storage, cu Building extension len Building extension dep
Excavation: Digester Earthwork Digesters Earthwork	lump sum	1	3,000,000	3,000,000	.
Excavation: Thickening/Dewatering Earthwork Thickening/Dewatering Earthwork					-
Excavation: Drying/Storage Earthwork Drying/Storage Earthwork					-
Concrete: Digester Concrete Digesters Concrete	LS	1	5,000,000	5,000,000	-
Concrete: DAF Conversion Concrete: Base Slab Concrete: DAF Conversion Floor Slabs Concrete: Plate and Frame Press Cutout Slab Thickening/Dewatering Concrete	cu yds cu yds cu yds	3 3 270	25,000 20,000 1,200	75,000 60,000 324,000 459,000	Fill three Sx18x1yd cutouts
Concrete: Concrete Silos Concrete: Drying Building Concrete with CMU infill Drying/Storage Concrete	each LS	6	300,000 6,000,000		26 ft diameter, 78 ft tall 280 ft x 140 ft x 25 ft tall concrete frame building with CMU infill, \$150 ft x 140 ft x 25 ft tall concrete frame building with CMU infill, \$150 ft x 150
Metals:					
Buildings: Misc Equipment Pads - Digesters Digesters Buildings	cu yds	4	1,272	5,088 5,088	Estimate: 2 heat exchangers, 2 recirc pumps, each 1 cu yd
Buildings: Misc Equipment Pads - Thickening/Dewaterin Buildings: Centrifuge Equipment Pads Buildings: DAF Conversion GBT Equipment Pads Thickening/Dewatering Buildings	g cu yds cu yds sq ft	5 50 6	1,272 1,272 5,000		Estimate: 5 thickened sludge pumps, each 1 cu yd Estimate: 5 centrifuges needed, includes labor -
Buildings: Drying/Storage Drying/Storage Buildings					-
Demolition: Digester 9, 11 Mixing Demolition: DAF Demolition Demolition: Line and Flyash systems Digesters Demolition	each each LS	2 6 1	80,000 15,000 500,000	160,000 90,000 500,000 750,000	
Demolition: Selective Concrete Removal Demolition: Plate and Frame Feed Pumps Demolition: Plate and Frame Presses Demolition: Vash Pumps Demolition: Air Compressors Demolition: Air Compressors	cu ft each each each each	432 8 5 2 3	32 75,000 8,000 12,000 8,000 30,000	13,824 600,000 40,000 24,000 24,000 150,000	Bidg 358 GBT Discharge
Thickening/Dewatering Demolition Demolition: Drying/Storage Drying/Storage Demolition		-		851,824	_

Additional Process-Mechanical Work
Modification to Building 358 GBT feed piping
P5 Receiving Well mixing piping
Digister No. 13 and 14 Feed Piping
Digister No. 13 and 14 Windrawal Piping
Digister No. 13 and 14 Gas Piping
Digister No. 13 and 14 Gas Piping
Digister No. 13 and 14 Gas Piping
Digister No. 13 and 14 Healing/recirculation piping
Digister No. 13 and 14 Healing/recirculation piping
Digister No. 13 and 14 Healing infrastructure
Modify Thickened Studge Well No. 9 Infrastructure

Piping to convert HSW receiving back to thickened sludge well BFP feed piping Piping to transfer DSD from GBT feed pumps to sludge transfer wells

Additional Electrical Work
Demo DAF power
Install GBT power
Install receiving wet well mixing power

Additional Controls Work
Demo DAF controls invoids
Install GBT controls
Install GBT controls
Install Centrifuge controls
Install centrifuge controls
Additional Plumbing Work
BFP Washwater
BFP Drains
Compressed air for BFP

Demolition:	People	-	Hour Wage		Total Demolition/unit	
P&F Presses		10	150	50	75,000	
Wash Pumps		4	40	50	8,000	
Air Compressors		4	60	50	12,000	
Feed Pumps		4	40	50	8,000	

Analysis of transfer of flow from JIWRF to SSWRF

Created by: KMZ 12/12/2019 Updated: 12/19/2019

Checked by: JK 12/12/2019

Capacity Needed for Alternative 1 - Diversion of All Flow from JIWRF

First reviewed the use of a forcemain with pump station at JIWRF

Assumption: 790 MGD total, with 450 MGD through MIS based on modeling documented in App 4A-3 340 MGD 526.1 cfs Distance 14 miles Estimated - 10 miles between JIWRF and SSWRF, use easement for ISP pipes for part of the route

73920 ft

Velocity (fps) 7 Diameter, forcemain (ft) 12 11 10 Cross-sectional area (sf) 113 95 79 Head needed due friction loss (ft) 29.98 45.79 72.84 $h_L = ((4.73L)/(d^{4.87}))*((Q_t/C)^{1.852})$

where C = 120

Recommend no more than 5 fps velocity which then requires 12 ft diameter of equivalent pipe or tunnel. Review if should be force main or tunnel:

Forcemain Review: 2-6 ft diameter pipes

To be protect against pipe failure, assume a split of 2-6 ft diameter pipes, with one backup

Use forcemain information developed in Appendix 9B, Section 9B.1, of Conveyance Report completed as part of 2020 Facilities Plan:

Table 9B-1, MIS - Tunnel Construction

Unit cost for 72" MIS Open Cut, approximately 25' deep

\$1,500 per LF

20% based on an assumed mix of residential and commercial/industrial along alignment Markup for utility conflicts:

Total cost from 2020 FP \$1.800 10.000 June 2007 ENR from 2020 FP

Adjusted to Projected Dec 2019 ENR \$2,600.00

TOTAL COST, before markup \$ 384,380,000 2-6 ft pipes for full length

Tunnel Review: 12 ft diameter tunnel

Assumed the tunnel costs developed for SW FG2, Zero Overflows analysis since based on total volume

Assume distance dropped 10 miles - distance form JIWRF to SSWRF.

Assume flow will enter tunnel through drop shaft at JIWRF and pumped out at SSWRF via PS similar to ISS PS (Cost calculated sepatately).

Volume of 10 mile long, 12 ft diameter tunnel \$ 291,000,000 TOTAL COST, before markup

Recommendation:

Due to disruption, soil conditions and need to maintain ISP while construction underway, recommend deep tunnel

Capacity Needed for Alternative 2 - Diversion of Dry Weather Flow from JIWRF

Assuming a forcemain with pump station at JIWRF

120 MGD 185.7 cfs

Same distance assumption as Alternative 1

Velocity (fps) 3 9 7 Diameter, forcemain (ft) 6 Cross-sectional area (sf) 64 38 28 Head needed due friction loss (ft) 17.68 60.13 127.39

 $h_L = ((4.73 \, L)/(d^{4.87}))*((Q_t/C)^{1.852})$

where C = 120

Due to headloss over varying velocities, recommend a 9' diamter pipe

Forcemain Review: 2-4.5 ft diameter pipes

To be protect against pipe failure, assume a split of 2-4.5 ft diameter pipes, with one backup

Use forcemain information developed in Appendix 9B, Section 9B.1, of Conveyance Report completed as part of 2020 Facilities Plan:

Table 9B-1, MIS - Tunnel Construction

Unit cost for 54" MIS Open Cut, approximately 25' deep \$1.200 per LF

20% based on an assumed mix of residential and commercial/industrial along alignment Markup for utility conflicts:

Total cost from 2020 FP \$1.440 10,000 June 2007 ENR from 2020 FP

Adjusted to Projected Dec 2019 ENR \$2,100.00

TOTAL COST, before markup \$ 310,460,000 2-4.5 ft pipes for full length

Assumed the tunnel costs developed for SW FG2, Zero Overflows analysis since based on total volume

Assume pump station located at SSWRF instead of at JIWRF

Volume of 10 mile long, 9 ft diameter tunnel 25 MG \$ 254,000,000 TOTAL COST, before markup

Recommendation:

Due to disruption, soil conditions and need to maintain ISP, recommend deep tunnel

Alternative 3A - 'Maximum WRF HRT Capacity plus Expanded Tunnel Volume PLUS ISS PS Expansion Backup Capital Cost Estimate

Note: Data for 100 MGD and 120 MGD is from following source:

From 2020 Facilities Plan, Treatment Report

Appendix 9-A: Treatment Recommended Plan Alternatives - Cost Estimates

Table 9-A-1: ISS Pumping Recommendation: 100 MGD and 120 MGD

		See Note		Se	See Note		lculated
			100		120		180
			MGD		MGD		MGD
ISS Pump Station		\$	63,590,000	\$	69,107,000	\$	85,703,000
Channel		\$	330,000	\$	380,000	\$	530,000
			\$64,000,000)	\$69,500,000		\$86,300,000
Subtiotaincies	25%	\$	16,000,000	\$	17,000,000	\$	22,000,000
TOTAL ESTIMATED CONSTR	UCTION COST	\$	80,000,000	\$	87,000,000	\$	108,000,000
Non-Construction Cost	35%	\$	28,000,000	\$	30,000,000	\$	38,000,000
CAPITAL COSTS		\$	108,000,000	\$	117,000,000	\$	146,000,000

NOTES:

1) ISS Pump Station expansion would mostly be to existing ISS Pump Station rock cavern.

Therefore assume no need to purchase land; possibly a tunnel easement from the Harbor Commission

2) The above are June 2007 costs. The ENR CCI for estimated Milwaukee for June 2007 equal to 10000.

Annual O&M (at June 2007, ENR 10,000)

Energy		\$ 126,000	\$ 150,000	\$ 220,000
Labor		\$ 10,000	\$ 10,000	\$ 10,000
Equipment Maintenance		\$ 795,000	\$ 864,000	\$ 1,072,000
Percent of Project Cost	1.00%			
Contingecy	25%			
Total Annual Costs		\$ 931 000	\$ 1 024 000	\$ 1 302 000

TOTAL PRESENT WORTH COSTS - June 2007

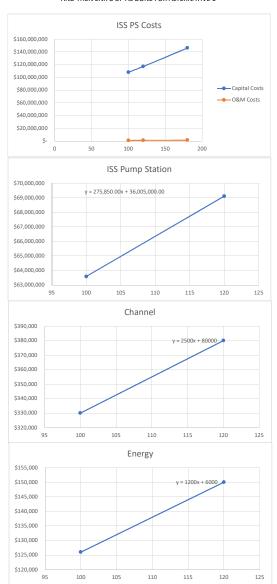
Basis:	
Old June 2007 Milw EN	IR: 9900
Revised June 2007 Milw EN	IR: 10000
Annual discount ra	ate: 5.125%
Planning period (yea	rs): 20

Present Worth of O & M Costs:

Year 2007 1 Total P.W. of O & M	Present Worth of \$931,000 \$11,000,000	0 & M \$1,024,000 \$13,000,000	\$1,302,000 \$16,000,000
Capital Costs	\$108,000,000	\$117,000,000	\$146,000,000
2. Total Present Worth Costs	\$119,000,000	\$130,000,000	\$162,000,000
Design Average Daily Flow, MGD	100	120	180
UNIT COST (\$/gal of ave flow)	\$1.19	\$1.08	\$0.90
salvage value @ 8.1%	\$8,748,000	\$9,477,000	\$11,826,000
net present worth	\$110,252,000	\$120,523,000	\$150,174,000

NOTES:

-ALTERNATIVE 1: ASSUMED DOUBLE THE 180 MGD ESTIMATES AND THEN ENR'd UP TO DECEMBER 2019 IN CAPITAL/SUMMARY -ALTERNATIVE 2: USED 120 MGD ESTIMATES AND THEN ENR'd UP AS DONE FOR ALTERNATIVE 1



New ISS PS at SSWRF Energy Assumptions

1) Existing ISS PS Power is 3 MW/Hr to run 180 MGD full capacity - this is simplied, based on Energy model developed for Potential Uses of Additional Landfill Gas Technical Memorandum, approved October 16, 2015

2) Cost assumed as Electricity Costs

3) Energy use assumptions included:

5/ Energy use assumptions included:						
	Days	On Peak Days	Off Peak Days			
	31	20	11	Jan		
	28	20	8	Feb		
	31	23	8	Mar		
	30	22	8	Apr		
	31	20	11	May		
	30	22	8	Jun		
	31	22	9	Jul		
	31	22	9	Aug		
	30	21	9	Sep		
	31	21	10	Oct		
	30	21	9	Nov		
	31	22	9	Dec		

	Dry demand from			No. days per	Wet demand from
	Dry Flow (MGD)	ISS PS (MW)	Wet (MGD)	month	ISS PS (MW)
Alternative 1	100	0.83	340	3	2.83
Alternative 2	100	0.83	0	0	0.00

- 4) Electricity costs are assumed based on event occuring on a Monday morning: On-Peak for first 12 hours of additional time, then switch 12 hours Off-Peak/12 hrs On-Peak during the week
- 5) No facilities charge, assumed to already included in electrical costs to operate system. New customer demand charge and On-Peak energy charge included are included, just for SSWRF ISS PS.
- 6) Electrical rate charges are as of 2019 from We Energies, Rate Schedule Cp 1, for Medium Voltage (grreater than 12,470 volts and less than 138,000 volts), issued 12-23-14:

On-Peak, kWh: \$ 0.07415 Off-Peak, kWh: \$ 0.05281 On-Peak Demand Charge, kW: \$ 13.51900 Customer Demand Charge, KW \$ 1.38000

SUMMARY OF FINDINGS

	On Peak hours	Off-Peak Hours			On Peak hours	Off-Peak Hours		Off-Peak kWh	Cutomer Demand	
	Dry	Dry	On Peak kWh Dry	Off-Peak kWh Dry	Wet	Wet	On Peak kWh Wet	Wet	KW	Total Annual cost
Alternative 1	2640	5256	2,200,000	4,380,000	432	432	1,224,000	1,224,000	2,833	\$ 592,051
Alternative 2	3072	5688	2,560,000	4,740,000	0	0	-	-	833	\$ 452,559

South Shore

Preliminary Treatment

Course Screens Grit Removal 4 ea 4 ea

PRELIMINARY TREATMENT

Primary Sedimentation

	A Train	B Train	Total	
Number of tanks	8	8	16	ea
Length	160	160	-	ft
Width	40	40	-	ft
SWD	10	10	-	ft
Surface Area per Tank	6,400	6,400	-	ft ²
Surface Area Total	51,200	51,200	102,400	ft ²
Volume per Tank	64,000	64,000	-	ft ³
Volume Total	512,000	512,000	1,024,000	ft ³
Volume Total	3,830,026	3,830,026	7,660,052	gal
Volume Total	3.83	3.83	7.66	MG

Aeration Basins

	A Train	B Train	Total	
Number of tanks	14	14	28	ea
Length	370	370	-	ft
Width	30	30	-	ft
SWD	15	15	-	ft
Surface Area per Tank	11,100	11,100	-	ft ²
Surface Area Total	155,400	155,400	310,800	ft ²
Volume per Tank	166,500	166,500	-	ft ³
Volume Total	2,331,000	2,331,000	4,662,000	ft ³
Volume Total	17,437,091	17,437,091	34,874,182	gal
Volume Total	17.44	17.44	34.87	MG

Secondary Sedimentation

	A Train	B Train	Total
Number of tanks	12	12	24 ea
Diameter	112	112	- ft
SWD	14	14	- ft
Surface Area per Tank	10,392	10,392	- ft ²
Surface Area Total	124,704	124,704	249,408 ft ²
Volume per Tank	145,488	145,488	- ft ³
Volume Total	1,745,856	1,745,856	3,491,712 ft ³
Volume Total	13,059,910	13,059,910	26,119,820 gal
Volume Total	13.06	13.06	26.12 MG
Weir Length per Tank	352	352	
Weir Length Total	4,222	4,222	8,445

8.23 MG

Disinfection

Disinfection	
Number of tanks	2 ea
Nominal Length	300 ft
Number of Passes	5 ea
Nominal Width	17 ft
Depth	13 ft
Surface Area per Tank	25,875 ft ²
Surface Area Total	51,750 ft ²
Volume per Tank	336,375 ft ³
Volume Total	672,750 ft ³
Volume Total	5,032,519 gal
Volume Total	5.03 MG

Required for 15 minutes HRT

2050 Facilities Plan Appendix 6E-3

Flow Capacity (MGD)					
Process	Avg	Peak	Basis		
Primary Settling		205	SOR = 2,000 gpdsf at Peak Flow		
Aeration	105		Organic Loading Rate = 40 ppd/1,000 ft^3 at design average flow		
Secondary Settling	100		SLR = 40 ppdsf at max day flow		
Disinfection		483	15 minutes minimum detention time		

Average Flow				
10 States CEPT	Primary Settling	Aeration	Secondary Settling	Disinfection
Peak Flow 10 States	Primary Settling	Aeration	Secondary Settling	Disinfection
Standards CEPT				

	Average Daily Flow		Max D	aily Flow	Peak Flow		
	Standard	Intensified	Standard	Intensified	Standard	Intensified	
	Capacity	Capacity	Capacity	Capacity	Capacity	Capacity	
Process	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	(MGD)	
Primary Settling Surface Overflow Rate					205		256
Secondary Aeration Organic Loading Rate	104	586					
Secondary Settling Surface Overflow Rate					299		
Secondary Settling Solids Loading Rate*			199	206			
Disinfection					483		
* - Assumes MLSS = 4,000 mg/L at Intensified	Freatment Rate						

	Setting	
Primary Settling		
SWD	10 ft	
Total Surface Area	102,400 ft ²	
Firm Surface area	96,000 ft ²	
Surface Overflow (Avg.)	1,000 gpd/ft ²	
Surface Overflow (Peak)	2,000 gpd/ft ²	
CEPT	2,500 gpd/ft ²	Peak Flow
Average Flow at Capacity	102 MGD	
Peak Flow at Capacity	205 MGD	
Firm Avg Capacity	96 MGD	Based on SOR
Firm Peak Capacity	192 MGD	Based on SOR
CEPT Capacity	256 MGD	Intensified Treament
Secondary Treatment Settling - Surface Overflow (SOR)		
SWD	14 ft	
Surface Area	249,408 ft ²	
	·	
Firm Surface area	239,016 ft ²	
Surface Overflow (Peak)	1,200 gpd/ft ²	10 States Standards at PHF
Peak Flow at Capacity	299 MGD	Per surface overflow
Firm Peak Capacity	287 MGD	Per surface overflow
Secondary Treatment Settling - Solids Loading Rate (SLR)		
Solids Loading Rate (Peak)	40 lb/day/ft²	
Allowable Solids Loading Rate	9,976,320 lbs./day	
MLSS	3,000 mg/L	Assumed
Total Flow	399 MGD	
QRAS	100%	
Qww	199 MGD	per SLR
Qras	199 MGD	Existing RAS capacity is 125 MGD
Solids Loading Rate	55 ppdsf	Intensified treatment
Allowable Solids Loading Rate	13,717,440 lbs./day	
MLSS	4,000 mg/L	Intensified Treament
Total Flow	411 MGD	
QRAS	100%	
Qww	206 MGD	per SLR
Qras	206 MGD	Existing RAS capacity is 125 MGD
		, ,
Wier Length	8,445 ft	
Weir Overflow Rate	30,000 gpd/ft	
Peak Flow at Capacity	267 MGD	Per Wier Overflow
,		
Secondary Treatment Aeration		
Organic Loading	40 lbs ROD ₊ /d/1000 ft ³	Ten States Standards
Organic Loading	40 lbs BOD ₅ /d/1000 ft ³	Ten States Standards
Maximum BOD load	186,480 lbs./day	Ten States Standards
Maximum BOD load Flow	186,480 lbs./day 104.5 Average flow	Ten States Standards Ten States Standards
Maximum BOD load Flow F/M ratio	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD ₅ /d/lb MLVSS	Ten States Standards Ten States Standards Ten States Standards
Maximum BOD load Flow F/M ratio MLSS (calculated)	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _S /d/lb MLVSS 2,850 mg/L	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M
Maximum BOD load Flow F/M ratio	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD ₅ /d/lb MLVSS	Ten States Standards Ten States Standards Ten States Standards
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance)	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified
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Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading HRT Design HRT	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _S /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified Intensified Intensified
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Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD:BOD5 in PE BOD ₅ COD MLVSS MLVSS	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75%	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₆ COD MLVSS MLVSS MLYSS MLSS	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD / day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified
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Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD:BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLVSS MLSS Volume	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLSS MLSS MLSS MLSS MLSS MLSS Volume Flow	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m^3/day 112.2 lbs. BOD / mool fra/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD:BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLVSS MLSS Volume	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLSS MLSS MLSS MLSS MLSS MLSS Volume Flow	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m^3/day 112.2 lbs. BOD / mool fra/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLSS MLSS MLSS MLSS MLSS MLSS MLS	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD / day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD.BOD5 in PE BOD ₅ COD MLVSS MLSS MLSS MLSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww PT BOD removal efficiency	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / moy VSS / day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD.BOD5 in PE BOD ₅ COD MLVSS MLSS MLSS MLSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww PT BOD removal efficiency	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / moy VSS / day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD:BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww PT BOD removal efficiency Max BOD load to secondary	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / moy VSS / day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD-BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww PT BOD removal efficiency Max BOD load to secondary	186,480 lbs./day 104.5 Average flow 0.30 lbs BODs/d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / 1,000 ft^3/day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft³ MGD 4,495,500 cu. Ft. 522,989 lbs./day 50% 1,045,978 lbs./day	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified
Maximum BOD load Flow F/M ratio MLSS (calculated) MLSS (mass balance) Organic Loading Organic Loading Organic Loading Flow HRT Design HRT Flow SUR (granular AS) MLSS (intensified) BOD ₅ COD:BOD5 in PE BOD ₅ COD MLVSS MLVSS MLVSS MLVSS MLSS Volume Flow Aeration Tank Volume Maximum BOD load in ww PT BOD removal efficiency Max BOD load to secondary	186,480 lbs./day 104.5 Average flow 0.30 lbs BOD _s /d/lb MLVSS 2,850 mg/L 2,860 mg/L 3.6 kg COD / m^3/day 4.0 lbs BOD / m^3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / m/3/day 112.2 lbs. BOD / moy VSS / day 586 Average Flow 1.43 hrs. 4.00 hrs. 209 mgd 3 mg COD / mg VSS / day 1.5 mg BOD /day/mg MLVSS 1,598 mg/L 214 mg/L 2.0 186,480 lbs/d 1,045,978 lbs./day 348,659 lbs. VSS 75% 464,879 lbs. MLSS 1,598 mg/L 4,662,000 ft ³ MGD 4,495,500 cu. Ft.	Ten States Standards Ten States Standards Ten States Standards Calculated based on F:M Standard Flow Intensified Intensified Intensified What is minimum HRT? Intensified Intensified Intensified Intensified

BOD lbs PT rem eff BOD conc 250 723000 50% 173.3813 TSS lbs 1016000 70% 146.1871

CES Wastewater Treated: 847 MG

CY

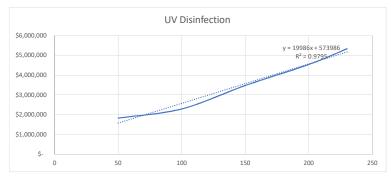
Concrete

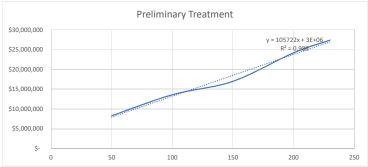
Unit cost Total cost

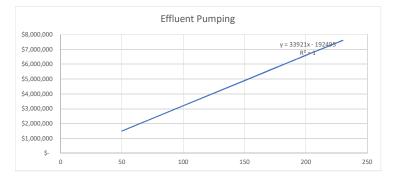
15,000 \$ 1,200 \$ 18,000,000 TW proposal for 243 x 470 footprint

18,750 \$ 1,200 \$ 22,500,000 TW proposal for 235 x 470 footprint scaled up 25% for 243 x 609 footprint

	UV DI	construction costs	Pre	liminary Treatment	Eff	luent Pumpin	g
50	\$	1,825,000	\$	8,300,000	\$	1,500,000	
100	\$	2,291,000	\$	13,600,000	\$	3,200,000	
150	\$	3,475,000	\$	17,000,000	\$	4,900,000	
200	\$	4,540,000	\$	24,200,000	\$	6,600,000	
230	\$	5,329,000	\$	27,400,000	\$	7,600,000	
340	\$	7,369,226	\$	38,945,480	\$	11,340,642	JIWRF
450	\$	9,567,686	\$	50,574,900	\$	15,071,952	SSWRF
790	\$	16,362,926	\$	86,520,380	\$	26,605,092	Combined







Capital Item	Cost	:	
Site Work	\$	2,858,080	
Yard Piping	\$	7,145,200	
Preliminary Treatment Facility	\$	19,960,832	
Actiflo	\$	15,183,265	
CES Facility	\$	13,935,999	
Primary Filtration and Biological Treatment Fac	\$	199,500,000	
Aeration Tank Modifications	\$	9,603,149	
UV Disinfection System	\$	91,426,249	
Effluent Pumping	\$	6,001,968	
Outfall Construction	\$	15,399,336	
SUBTOTAL 1	\$	381,014,079	
Electrical (10%)	\$	38,101,408	10%
I&C (5%)	\$	19,050,704	5%
SUBTOTAL 2	\$	438,166,191	
Mobilization/Demobilization (7%)	\$	30,671,633	7%
SUBTOTAL PROBABLE CONSTRUCTION COST	\$	468,837,824	
Contingencies (25%)	\$	117,209,456	25%
TOTAL PROBABLE CONSTRUCTION COST	\$	586,047,280	

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN BUSINESS CASE EVALUATIONS Assumptions

General

00110101			Milwaukee ENR is the average between Chicago and Minneapolis
			Construction Cost Index values published monthly by ENR. Milwaukee ENR
			December 2019 is a projected value from May 2019 based on average
			historical monthly increase in value from 2007 (2020 Facilities Plan published
Miller III FND December 2010	44.700	Historia ENDualuse 4074 2040 OF MCA KMZDEV ulau	
Milwaukee ENR December 2019	14,700	Historic_ENRvalues 1974-2019-05_MCA_KMZREV.xlsx	June 2007) to May 2019.
Annual increase in costs	0%	Discussions with MMSD	
		Email from Andrew Dutcher, WDNR to Troy Deibert,	
Discount Rate	3.375% 3.37500% net for PW	HNTB on 6/5/19	Facility planning is using the value established by the WDNR.
Life Cycle - number years	20		
2035 No. years	16		
Capital Costs			
Un-designed Details Allowance - Varies, see below	N	Allowance varies at engineer's discretion based on o	definitions provided for each %
all major components have documented installed unit	10%		
costs		K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
costs missing for some components, but other costs	20%		
are for installed facilities and well documented			
(connections to existing systems, etc.)		K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
(commodative to existing eyetems, etc.)	30%	The Elimination B. Thin on Ord, TT, Committee of Co. To.	
Alternative development is still conceptual	30 /0	K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
Contingency Allowance - Set %		R. Ziillo emaii to B. Riill on 0/0/17, comilined on 0/19/17	
Planning Level Contingency	20%	2050 FP Team - WRF discussion on 1/30/17	
Contractor Overhead & Profit - Varies, see below	2070	2000 FF Team - WRF discussion on 1/50/17	
	0.507	0050 FD T WDF !!	
Equipment costs are from manufacturers	25%	2050 FP Team - WRF discussion on 1/30/17	
Costs are from previous project, unit costs already			
include OH&P	0%	2050 FP Team - cost estimate discussion on 5/20/19	
Design, Bidding, & MMSD Oversight			
Total Percent, Conveyance	20%		g, For FP Use only. This is incorporated into AMP BCE template already.
Total Percent, WRFs	40%	Design, Construction (exc. Contractor Cost) and	Varies for each asset system
Total Percent, Watercourse	20%	Post Construction in the BCE	
Total Percent, GI	15%		
Cost Escalation Factor 2035	0.588		
Annual Cost Gradient Present Worth Factor incl esc	12.20844		
Power assumptions		SOURCE	Comments
Gas	2018		Comments
	Current Rates		
	our on rates	K. Ziino email sent 4/20/17 called "2050 - WRF TBC	
turbine fuel, LFG	\$2.500 /Dtherm	Energy Cost Assumptions" for assumptions	
turbine ruei, Li G	\$2.500 /Dillettii	K. Ziino email sent 4/20/17 called "2050 - WRF TBC	
turking fuel NO	&E 000 /D4h		
turbine fuel, NG	\$5.000 /Dtherm	Energy Cost Assumptions" for assumptions	
Plantalant			
Electrical			
		1/""	
		Kziino email sent 4/20/17 called "2050 - WRF TBC	
Electrical Rates, JI/SS	Varies	Energy Cost Assumptions" for assumptions	Detailed assumptions need to be included in backup on a case by case basis
Labor assumptions			
Veolia Labor	\$50 per hour	Included in BCE assumptions	
Contractor Labor	\$70 per hour	To be included in capital costs	
		•	

Source

Comments



APPENDIX 6E-4: SW FG2 Tunnel-Related Overflows Cost Estimates -



MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



TUNNEL-RELATED CSO ELIMINATION COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

General Description:

Over and above the recommended Conveyance, WRF and GI projects recommended in the 2050 FP, this analysis reviews the additional treatment and/or tunnel capacity required to meet zero overflow under Future Conditions. The treatment capacity is assumed to be high rate treatment (HRT), at both JIWRF and SSWRF and at CSOs.

TOTAL PRESENT WORTH Alternative 1 - Maximum WRF HRT Capacity plus CSO HRT	\$ 31,259,300,000
Alternative 2 - Expanded Tunnel Volume	\$ 4,517,040,00
Alternative 2A - Expanded Tunnel Volume plus Select CSO HRT	\$ 5,230,990,000
Alternative 3 - Maximum WRF HRT Capacity plus Expanded Tunnel Volume	\$ 4,798,070,00

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 1 Maximum WRF HRT Capacity plus CSO HRT

General Description:

Maximum WRF capacity expansion achievable using HRT along with additional influent pumping, preliminary treatment, disinfection and outfalls as applicable. Note that this Alternative does NOT achieve zero CSOs due to limitations in the conveyance system. Therefore this Alternative also includes in-system HRT treatment at remaining CSOs, including land acquisition, influent pumping, preliminary treatment, and disinfection.

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%
Discount Rate 3.375%

Number of Years 20

Capital Costs (Note 1)						
	Life		Capital Cost			
ITEM	Years		(\$)			
Item 1 - JIWRF HRT expansion	20	\$	413,750,000			
Item 2 - SSWRF HRT expansion	20	\$	355,820,000			
Item 3 - CSO HRT	20	\$	26,589,930,000			
Tota	al Capital Cost	\$	27,359,500,000			

Operation and Mainte	Operation and Maintenance Costs (Note 2)								
			Unit Cost (\$)			Annual Cost			
ITEM	Units	Quantity			(\$)		(\$)		
Item 1 - O&M - JIWRF	LS	1	\$	4,110,000	\$	4,110,000			
Item 2 - O&M - SSWRF	LS	1	\$	4,030,000	\$	4,030,000			
Item 3 - O&M - CSO HRT	LS	1	\$	263,160,000	\$	263,160,000			
Annual Operation and Maintenance Total					\$	271,300,000			
<u>Life Cycle Analysis</u>									
Present Worth Factor (including annual increase)	14.375								
Present Worth of Operation and Maintenance Costs					\$	3,899,800,000			

Equipment Replacement Costs (Note 3)						
ITEM	Units	Quantity	Unit Value (\$)	Val (\$		
Present Worth of Equipment Replacement Costs (Note 2)				\$	-	

Salvage V	/alue (Note 4)				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
Present Worth of Equipment Replacement Costs (Note 2)				\$	

TOTAL PRESENT WORTH	
Capital Costs	\$ 27,359,500,000
Present Worth of O&M Costs	\$ 3,899,800,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 31,259,300,000

Notes

- ${\bf 1)} \ See \ Capital \ Cost \ Details, \ WRF \ HRT \ Cost \ and \ CSO \ HRT \ Cost \ for \ additional \ capital \ cost \ breakdown.$
- 2) Annual O&M for CSO HRT may be conservative depending on the system installed.
- 3) Assumed all equipment has a 20 year life so no replacement within 20-year life cycle.
- 4) Assumed no salvage value for HRT systems. These are largely mechanical systems with no value at end of service life.

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 2 Expanded Tunnel Volume

General Description:

Maximum additional tunnel volume needed to achieve zero CSOs: 2,610 MG of total tunnel volume which equates to 2,178 MG of additional tunnel

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%
Discount Rate 3.375%

Number of Years 20

	ITEM	Capital Costs (Note 1) Life Years	Capital Cost (\$)
Item 1 - Tunnel		100	\$ 7,678,800,000
	Tot	al Capital Cost	\$ 7,678,800,000

Quantity	Unit Cost (\$)	Ar	nnual Cost (\$)
Quantity	(\$)		(\$)
· · · · · · · · · · · · · · · · · · ·			
		\$	70,000
		\$	3,000
		\$	1,050,000
			\$ \$

Equipment Replace	ement Costs (Note	3)			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	•
Present Worth of Equipment Replacement Costs (Note 3)				\$	_

Salvage V	alue (Note 4)			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
Item 1 - Tunnel	LS	1	\$ 3,162,808,461	\$ (3,162,810,000)
Present Worth of Equipment Replacement Costs (Note 4)				\$ (3,162,810,000)

TOTAL PRESENT WORTH	
Capital Costs	\$ 7,678,800,000
Present Worth of O&M Costs	\$ 1,050,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ (3,162,810,000)
Total Present Worth	\$ 4,517,040,000

Notes:

- 1) See Capital Cost Details and Tunnel Cost for additional capital cost breakdown.
- 2) Based on modeling, additional tunnel volume needed, not additional connections from MMSD into tunnels. ISS appears to be self cleaning based on past inspections documented in the press. Thefore assumed minimal additional annual costs.
- 3) Assumed all equipment has a 20 year life so no replacement within 20-year life cycle.
- 4) Assumed salvage only for tunnel. Tunnel assets are assumed to have residual value at end of service life.

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 2A

Expanded Tunnel Volume plus Select CSO HRT

General Description:

Maximum additional tunnel volume needed to achieve zero CSOs if HRT provided at 3 select CSOs: total tunnel volume reduced from 2610 MG in Alternative 2 to 2,536 MG, which equates to additional tunnel volume needed reduced from 2,178 MG in Alternative 2 to 2,104 MG

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0% Discount Rate 3.375%

Number of Years

	Capital Costs (Note 1)	
	Life	Capital Cost
ITEM	Years	 (\$)
Item 1 - Tunnel	100	\$ 7,477,240,000
Item 2 - BS0502A CSO	20	\$ 105,030,000
Item 3 - DC0103 CSO	20	\$ 282,270,000
Item 4 - BS00405 CSO		\$ 355,820,000
	Total Capital Cost	\$ 8,220,360,000

Operation and Maintena	ance Costs (Note	2)			
			Unit Cost	Α	nnual Cost
ITEM	Units	Quantity	(\$)		(\$)
Item 1 - Tunnel Annual Maintenance	<u>-</u>	·		\$	70,000
Item 2 - BS0502A CSO				\$	650,000
Item 3 - DC0103 CSO				\$	2,420,000
Item 4 - BS00405 CSO				\$	3,150,000
Annual Operation and Maintenance Total				\$	6,290,000
Life Cycle Analysis					
Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	90,420,000

Equipment Replacer	ment Costs (Note 3)			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
Present Worth of Equipment Replacement Costs				\$	

Salvage \	/alue (Note 4)			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
Item 1 - Tunnel	LS	1	\$ 3,079,788,240	\$ (3,079,790,000)
Present Worth of Salvage Value				\$ (3,079,790,000)

TOTAL PRESENT WORTH	
Capital Costs	\$ 8,220,360,000
Present Worth of O&M Costs	\$ 90,420,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ (3,079,790,000)
Total Present Worth	\$ 5,230,990,000

- 1) See Capital Cost Details, and Tunnel Cost for additional capital cost breakdown along with Alternative 1 Capital Costs for CSOs
- 2) Based on modeling, additional tunnel volume needed, not additional connections from MMSD into tunnels. ISS appears to be self cleaning based on past inspections documented in the press. Therefore assumed minimal additional annual costs. For WRF HRT, assume same costs as Alternative 1.
- 3) Assumed all equipment has a 20 year life so no replacement within 20-year life cycle.
- 4) Assumed salvage only for tunnel. Tunnel assets are assumed to have residual value at end of service life.

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 3

Maximum WRF HRT Capacity plus Expanded Tunnel Volume

General Description:

Maximum WRF capacity expansion achievable using HRT along with additional influent pumping, preliminary treatment, disinfection and outfalls as applicable. Note that maximum WRF capacity does NOT achieve zero CSOs due to limitations in the conveyance system. Therefore, remaining CSOs captured by additional tunnel capacity (2,303 MG of additional volume).

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

A 14 1	
realiser of Fours	20
Number of Years	20
Discount Rate	3.375%
Ailliadi Illorcasc III 003ts -	0.070

	Capital Costs (Note 1)	
	Life	Capital Cost
ITEM	Years	 (\$)
Item 1 - Tunnel	100	\$ 6,649,200,000
Item 2 - JIWRF HRT Expansion (Alternative 1)	20	\$ 413,750,000
Item 3 - SSWRF HRT Expansion (Alternative 1)	20	\$ 355,820,000
Total Ca	pital Cost	\$ 7,418,770,000

Operation and Mainten	ance Costs (Not	e 2)			
			Unit Cost	Δ	nnual Cost
ITEM	Units	Quantity	(\$)		(\$)
Item 1 - Tunnel Annual Maintenance				\$	70,000
Item 1a - ISS PS Pumpout Annual Energy Cost				\$	1,000
Item 2 - JIWRF HRT Expansion (Alternative 1)				\$	4,110,000
Item 3 - SSWRF HRT Expansion (Alternative 1)				\$	4,030,000
Annual Operation and Maintenance Total				\$	8,211,000
Life Cycle Analysis					
Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	118,030,000

Equipment Replacen	nent Costs (Note 3	3)			
ITEM	Units	Quantity	Unit Value (\$)	Valu (\$)	e
Present Worth of Equipment Replacement Costs				\$	-

Salvage Value (Note 4)					
ITEM	Units	Quantity	Unit Value (\$)		Value (\$)
Item 1 - Tunnel	LS	1	\$ 2,738,728,190	\$	(2,738,730,000)
Present Worth of Salvage Value				\$	(2,738,730,000)

TOTAL PRESENT WORTH	
Capital Costs	\$ 7,418,770,000
Present Worth of O&M Costs	\$ 118,030,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ (2,738,730,000)
Total Present Worth	\$ 4,798,070,000

Notes:

- 1) See Capital Cost Details, WRF HRT Cost and Tunnel Cost for additional capital cost breakdown.
- 2) Based on modeling, additional tunnel volume needed, not additional connections from MMSD into tunnels. ISS appears to be self cleaning based on past inspections documented in the press. Therefore assumed minimal additional annual costs. For WRF HRT, assume same costs as Alternative 1.
- 3) Assumed all equipment has a 20 year life so no replacement within 20-year life cycle.
- 4) Assumed salvage only for tunnel. Tunnel assets are assumed to have residual value at end of service life.

2050 FP

Zero Overflows Analysis

WRF HRT, CSO HRT and Tunnel Varying Unit Present Worth Costs Plus PW Costs to Achieve 0 SSOs

Unit Present Worth Costs per Gallon of CSO Reduced for systems reviewed in Tunnel-Related CSO analysis

W	R	F	Н	R ⁻	Г

Average Annual PW Unit Cost
CSO Volume (\$/gal of CSO
PW Cost Reduced (MG) reduced)

CSO volume reduced based on the difference between CSO volume of 406 MG/yr CSOs

Notes

WRF HRT \$ 269,890,000 172 \$ 1.57 in Alternative 0 and 234 MG/yr of (treated) CSOs in Alternative 1

CSO HRT

Average Annual PW Unit Cost CSO Volume (\$/gal of CSO

CSO PW Cost Reduced (MG) reduced) Peak Flow (MGD) BS0502 A Ś 114,370,000 0.038 \$ 3.026 37 Average annual CSO volume reduced determined by multiplying 317,060,000 0.005 \$ 70,458 DC0103 \$ 184 average CSO volume by annual frequency - assumed reduction

BS0405 \$ 401,100,000 0.628 \$ 638.59 245 because CSO now treated

Tunnel

PW Unit Cost Average Annual CSO Volume (\$/gal of CSO PW Unit Cost (\$/gal Reduced (MG) Volume PW Cost reduced) tunnel volume) Notes 5.6 MG 22,970,000 1.04 \$ 22.00 \$ 4.11 KK River Flushing Tunnel - see note below 25 MG 269,890,000 4.66 \$ 57.91 \$ 10.80 Average Annual CSO Volume assumes a straight-line between 0 \$ 368,340,000 14.0 \$ 26.35 \$ 4.91 additional tunnel and total CSO removal (406 MG from Alt 0) 75 MG \$ 614,990,000 37.3 \$ 16.50 \$ 200 MG 3.07 just for comparison purposes, no modeling was done. PW unit 11.77 \$ 2.19 cost of CSO reduction was compared to PW unit cost of gal of 1000 MG \$ 2,193,370,000 186 S 2178 MG \$ 4,517,000,000 406 \$ 11.13 \$ 2.07 tunnel volume

Costs and volume developed in Kinnickinnic River Flushing Tunnel CSO Storage Facility Feasibility Study (M01007P01)

Separate Analysis: Alternatives to Achieve 0 SSOs

I/I Reduction to Achieve 0 SSOs

Annual Cost PW Cost

I/I to Maintain \$ 12,500,000 \$ 179,700,000 CBC 033 Strategy 2 and Strategy 4 cost already included as part of Alternative 0 I/I for 0 SSOs \$ 92,300,000 \$ 1,326,800,000 CBC 033 Strategy 3 and 5 costs

Incremental Inc \$ 79,800,000 \$ 1,147,100,000 Additional cost to achieve 0 SSOs

Tunnel Volume to Achieve 0 SSOs

PW Unit Cost

Volume PW Cost (\$/gal) 0 MG \$ - \$

Based on modeling, email to Kate Ziino from Pat Chiang on 10/8/19, subject: RE: 0 Overflows Scenario 2A, 3A and 3B

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF and Biosolids Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 1 Maximum WRF HRT Capacity plus CSO HRT

General Description:

Alternative 1 represents the total additional HRT needed to achieve 0 overflows under Conveyance Future Conditions. Most HRT is assumed to be located at the WRFs. However, due to system constructions, not all CSOs can be eliminated - 234 MGD average annual COS volume remaining out of the 406 MG calculated for Alternative 0. Remaining CSOs as identified in the model are assumed to receive HRT at the CSO location.

				 	 	Capital Cos	its	 				Design,		
	Life			Unit Cost	SUBTOTAL 1	Undesigned		SUBTOTAL 2	Constr. Overhead	c	CONSTR. COST	Bidding, Const.	c	CAPITAL COST
ITEM	Years	Units	Quantity	 (\$)	 (\$)	Details	Contingency	 (\$)	& Profit		(\$)	Oversight		(\$)
JIWRF HRT														
Item 1 - Diversion Structure	100	LS	1	\$ 3,320,000	\$ 3,320,000	30%	20%	\$ 4,980,000	0%	\$	4,980,000	40%	\$	6,970,000
Item 2 -Influent PS	20	LS	1	\$ 24,390,000	\$ 24,390,000	10%	0%	\$ 26,830,000	0%	\$	26,830,000	0%	\$	26,830,000
Item 3 - HRT System	20	LS	1	\$ 246,720,000	\$ 246,720,000	10%	0%	\$ 271,390,000	0%	\$	271,390,000	40%	\$	379,950,000
SSWRF HRT														
Item 1 - HRT System	20	LS	1	\$ 210,830,000	\$ 210,830,000	10%	0%	\$ 231,910,000	0%	\$	231,910,000	40%	\$	324,670,000
Item 2- Outfall	100	LS	1	\$ 14,830,000	\$ 14,830,000	30%	20%	\$ 22,250,000	0%	\$	22,250,000	40%	\$	31,150,000
CSO HRTs														
Item 1 - BS0502A	20	LS	1	\$ 57,704,998	\$ 57,704,998	30%	0%	\$ 75,020,000	0%	\$	75,020,000	40%	\$	105,030,000
Item 2 - CSO56	20	LS	1	\$ 7,852,714,708	\$ 7,852,714,708	30%	0%	\$ 10,208,530,000	0%	\$	10,208,530,000	40%	\$	14,291,940,000
Item 3 - CSO7	20	LS	1	\$ 6,348,833,011	\$ 6,348,833,011	30%	0%	\$ 8,253,480,000	0%	\$	8,253,480,000	40%	\$	11,554,870,000
Item 4 - DC0103	20	LS	1	\$ 155,092,932	\$ 155,092,932	30%	0%	\$ 201,620,000	0%	\$	201,620,000	40%	\$	282,270,000
Item 5 - BS0405	20	LS	1	\$ 195,505,612	\$ 195,505,612	30%	0%	\$ 254,160,000	0%	\$	254,160,000	40%	\$	355,820,000
											Total	Capital Cost	\$	27,359,500,000

Notes:

1) Definitions:

LS = lump sum

²⁾ See Cost Table Backup for additional information, with details provided in WRF HRT Cost and CSO HRT Cost spreadsheets.

³⁾ Undesigned details: JIWRF Item 1 - Diversion Structure, and CSO Item 1 - HRT System are set at 30%. The diversion structure has 30% undesigned details because costs were taken from other projects out in the MMSD system, not on the JIWRF site built on piles. The CSO HRT system has 30% undesigned details because of the number of CSOs and the inclusion of cloth media HRT, which is a newer technology.

⁴⁾ Contingency: Back up costs already included contingency so did not include it in this table, except for JIWRF Item 1 - Diversion Structure connecting to Harbor Siphons which are built on piles and SSWRF Item 2 - Outfall since costs were from 2020 Facilities Plan. Influent PS cost also already had Design, Bidding and Construction Oversight costs so did not include.



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 2

Expanded Tunnel Volume

General Description:

Alternative 2 represents the total additional tunnel volume needed to achieve 0 overflows under Conveyance Future Conditions. Modeling indicated that total tunnel volume would need to be increased from 432 MG to 2610 MG, which equals

Ī							Capital C	osts					Design,		
		Life			Un	it Cost	SUBTOTAL 1	Undesigned		SUBTOTAL 2	Constr. Overhead	CONSTR. COST	Bidding, Const.	C	APITAL COST
	ITEM	Years	Units	Quantity		(\$)	(\$)		Contingency	(\$)	& Profit	(\$)	Oversight		(\$)
	Item 1 - Tunnel	100	Gal	2,178,000,000	\$	1.96	\$ 4,266,000,000	30%	20%	\$ 6,399,000,000	0%	\$ 6,399,000,000	20%	\$	7,678,800,000
												Total	Capital Cost	\$	7,678,800,000

Notes:

1) Definitions:

Gal = gallon

2) Straight-line but not \$X for X gallons, assumes diminishing unit cost as volume goes up. See Tunnel Cost for additional information



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

Alternative 3

Expanded Tunnel Volume plus Select CSO HRT

General Description:

Alternative 3 represents the total additional WRF capacity that can be achieved within the existing conveyance system plus the additional tunnel volume needed to achieve 0 overflows under Conveyance Future Conditions.

						Capital C	osts					Design,		
	Life			Uni	it Cost	SUBTOTAL 1	Undesigned		SUBTOTAL 2	Constr. Overhead	CONSTR. COST	Bidding, Const.	C	APITAL COST
ITEM	Years	Units	Quantity		(\$)	(\$)	Details	Contingency	(\$)	& Profit	(\$)	Oversight		(\$)
Item 1 - Tunnel (Note 2)	100	Gal	2,104,000,000	\$	1.97	\$ 4,154,022,448	30%	20%	\$ 6,231,030,000	0%	\$ 6,231,030,000	20%	\$	7,477,240,000
Item 2 - BS0502A CSO (Note 3)	20	LS	1										\$	105,030,000
Item 3 - DC0103 CSO (Note 3)	20	LS	1										\$	282,270,000
Item 4 - BS00405 CSO (Note 3)	20	LS	1										\$	355,820,000
											Total	Capital Cost	\$	8,220,360,000

Notes:

1) Definitions:

Gal = gallon

LS = lump sum

3) Capital Cost for Items 2-4 is the same as presented in Alternative 1, see Alternative 1 for total capital cost assumptions. In addition, see Cost Table Backup for additional information, with details provided in WRF HRT Cost and CSO HRT Cost spreadsheets.

²⁾ Straight-line but not \$X for X gallons, assumes diminishing unit cost as volume goes up. See Tunnel Cost for additional information



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

Alternative 3

Maximum WRF HRT Capacity plus Expanded Tunnel Volume

General Description:

Alternative 3 represents the total additional WRF capacity that can be achieved within the existing conveyance system plus the additional tunnel volume needed to achieve 0 overflows under Conveyance Future Conditions. For this alternative, total tunnel needed is 2,303 MG of tunnel, which equates to 1,871 MG of additional tunnel.

						Capital C	osts					Design,		
	Life			Un	it Cost	SUBTOTAL 1	Undesigned		SUBTOTAL 2	Constr. Overhead	CONSTR. COST	Bidding, Const.	С	APITAL COST
ITEM	Years	Units	Quantity		(\$)	(\$)	•	Contingency	(\$)	& Profit	(\$)	Oversight		(\$)
Item 1 - Tunnel	100	Gal	1,871,000,000	\$	1.97	\$ 3,694,000,000	30%	20%	\$ 5,541,000,000	0%	\$ 5,541,000,000	20%	\$	6,649,200,000
Item 2 - JIWRF HRT Expansion (See Note 3)	20	LS	1										\$	413,750,000
Item 3 - SSWRF HRT Expansion (See Note 3)	20	LS	1										\$	355,820,000
											Total	Capital Cost	\$	7,418,770,000

Notes:

1) Definitions:

Gal = gallon

LS = lump sum

3) Capital Cost for Items 2-3 is the same as presented in Alternative 1, see Alternative 1 for total capital cost assumptions. See Cost Table Backup for additional information, with details provided in WRF HRT Cost and CSO HRT Cost spreadsheets.

²⁾ Straight-line but not \$X for X gallons, assumes diminishing unit cost as volume goes up. See Tunnel Cost for additional information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



COST TABLE BACKUP
OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS
Alternative 1
Maximum WRF HRT Capacity plus CSO HRT

Capital Costs

Undesigned Detail: Chose 30% for all Alternatives since design is still conceptual Contruction Overhead & Profit: 0% - costs are from previous projects in which C O&P already included

WRF HRT Costs - ENR'd up from original data to Dec-2019

255 MGD at each of the WRFs

Original Cost Mo-Year ENR Multiplier Updated cost

ADDITIONAL WR	F CAPACITY:	JIWRF			See WRF HRT Cost for details
\$1,700,000	11-2001	7525	1.95	\$3,320,000	Diversion Structure Contract No. C03003C01, November 2001
\$19,728,076	05-2012	11888	1.24	\$24,390,000	
					Influent PS Contract No. C04006C01, May 2012
\$164,731,521	06-2007	9815	1.50	\$246,720,000	
					Capital: Conceptual Design Report, Contract No.
					M03022P01, February 2007 (Note: costs to June 2007)
ADDITIONAL WR	F CAPACITY:	SSWRF			
\$140,768,515	06-2007	9815	1.50	\$210,830,000	Capital Same as above
\$9,905,000	06-2007	9815	1.50	\$14,830,000	
					Treatment Report from 2020 Facilities Plan, June 2007
Assume no addit	ional land ne	eded			
KK River Flushing	Tunnel Stud	У			
\$20,600,000	06-2015	13183	1.12	\$22,970,000	
					Kinnickinnic River Flushing Tunnel CSO Storage Facility Feasibility Study, June 15, 2015

All ENR values from: Historic_ENRvalues 1974 to 2019-05_MCA_KMZREV.xlsx updated 6/6/19

O&M Costs

ADDITIONAL WR	F CAPACITY: J	IIWRF			
\$2,741,871	06-2007	9815	1.50	\$4,110,000	O&M: same as above
ADDITIONAL WR	F CAPACITY: S	SSWRF			
\$2,690,650	06-2007	9815	1.50	\$4,030,000	O&M: same as above
TOTAL CSO HRT	CAPACITY				
\$160,617,486	09-2004	8972	1.64	\$263,160,000	
					O&M: Port Washington Road Relief Sewer Project
					Alternatives Analysis Memo published in 2007 as part of
					N 27th St ISS Extension project. Costs were established
					in report as of 9/1/2004
SELECT CSO HRT	BS0502A, DC	0103, BS04	05		
\$398,388	09-2004	8972	1.64	\$650,000	BS0502A O&M: same as above
\$1,477,074	09-2004	8972	1.64	\$2,420,000	DC0103 O&M: same as above
\$1,924,692	09-2004	8972	1.64	\$3,150,000	BS0405 O&M: same as above

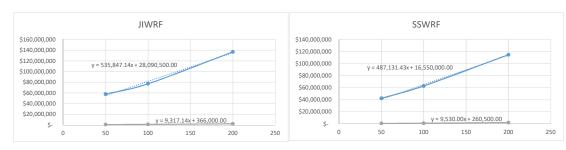
Equipment Replacement Costs

2050 FF

Zero Overflows Alternative Analysis - Alternative 1 WRF HRT Costs Backup

A) HRT costs from from Conceptual Design Report, Contract No. M03022P01, February 2007

JIWRF MAX TREATMENT 100 200 255 MGD MGD MGD Capital \$ 57,891,000 \$ 77,163,000 \$ 136,764,000 \$ 164,731,521 Annual O&M 875,000 \$ 1,233,000 \$ 2,251,000 \$ 2,741,871 SSWRF MAX TREATMENT 50 100 200 255 MGD MGD MGD



Influent PS 30 45 52 52 x 52 Preliminary/grit 7225 8875 13800 16137 6 units (180 x 45), 4 screens (95 x 115) HRT 3419 5177 10354 12822 6 units (186 x 83.5) Disinfection 304 608 1216 1550 6 units (6 x 8 x 38) Effluent PS 25 30 45 52 52 x 52 HRT System Details Total Square footage (SF)

100

200

Influent PS 2704

Grit

HRT

43700

48600

93186

1824

2704

Preliminary

Disinfection

Effluent PS

50

NOTES:

Capital

Annual O&M

0) The costs above appear to be missing some costs as listed in Item B below.

1) Conceptual Report looked at both ACTIFLO and DesnaDeg - found the cost of the technologies to be relatively the same

750,000 \$ 1,194,000 \$ 2,173,000 \$ 2,690,650

\$ 42,408,000 \$ 63,011,000 \$ 114,727,000 \$ 140,768,515

Actiflo - ballasted flocculation HRT technology - falls under Chemically Enhanced Sedimentation or Suspended Growth Biological Contact technologies in Demo Test Repor

DensaDeg - Solida Contact/Recirculation listed under Chemically Enhanced Sedimentation technologies in Demo Test Report

2) JIWRF costs include influent and effluent piping, expansions of effluent pump stations, more extensive demolition, cramped site conditions, land costs for Harbour Commission site and tight sheet or ground support for facility excavatio

24% Other Project Costs - multiplier on Construction Costs

- 3) JIWRF costs assumed piping to HRT would connect to ISS pumpout conduit at preliminary treatment.
- Updated assumption: Piping would come from High Level and Low Level Siphons to influent pump station into HRT. Need to add costs for MH connection to harbor siphons (1 each for High Level and Low Level) and high flow/low head influent pump station at Harbour Commission situ
- 4) JI Disinfection is UV, based on space availability, put in parking lot for 50 MGD and on Harbor Commission site for 100 and 200 MGI
- 5) SSWRF costs include expansion of effluent pump station, additional outfall, assume land available for all additional facilities
- 6) SSWRF Disinfection cost is for UV as well; though costs are higher, assume want to conserve space on site.
- 8) Did not use SSWRF costs from Demonstration Testing Report, July 2014 2007 report as it only sized for one capacity, 150 MGD, and only updated HRT costs, with other facility costs interpolated from previous studies
- 9) SSWRF system can discharge by gravity but another outfall is necessary, not included in the Conceptual Design Report cost.

B) Missing costs at JIWRF

Background: Conceptual Design Report appears to have assumed piping from preliminary treatment downstream of existing screw pumps - but existing screw pumps do not have enough capacity

Proposed solution: Pick up flow from harbor siphons, send by gravity to high flow, low level pump station at HRT Harbor Commission site

Connection to HL and LL siphons

Need cost for connection - assumed diversion structure in yard between Jones Island Dropshaft and Influent Pumping.

Low Level siphon piping is 72" at I.E. -26.5

High Level Siphon piping is 90" at I.E. -12

NWSRS Diversion Structure (C03003C01), bid date 11/2001 - provided as part of a group of miscellaneous pump station and structure cost information

1) on existing 108", 40' deep \$ 350,000 2) on existing 96", 26' deep \$ 270,000

3) DC0308, on existing 72" 42" deep, 1 gate \$ 1,700,000 USE THIS TO BE CONSERVATIVE, WORK ON JIWRF DIFFICULT

Assume bid price

Pump Station

Need cost for high flow, low head pump station upstream of HRT

59th & State (C04006C01), install date 05/2012 - date provided from AssetView data, total project cost provided by Kevin Jankowski to Kate Ziino in email 7/12/201:

 Total Project Cost (TPC)
 \$ 16,865,571

 Construction Cost
 \$ 13,629,187

59 th /State has 6 x 30,300 gpm, 310 HP submersible centrifugal pumps. (from Joel Marshall on 7/12/19)

Firm Capacity: 218 MGD

Calculated

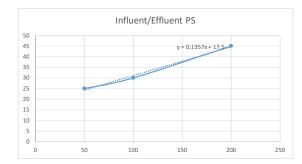
Pump Station Needed, Firm Capacity: 255 MGD

TPC of PS needed, assuming straightline increase in flow \$ 19,728,076

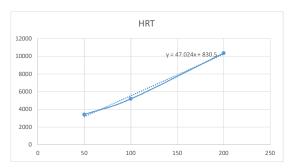
C) Missing costs at SSWRF - Outfall

The outfall costs are from Table 9A-2 of the Treatment Report from the 2020 Facilities Plan, June 2007. The outfall was sized to 300 MGD

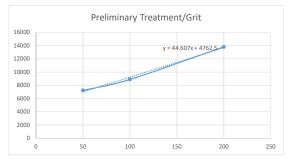
SSWRF Outfall Cost: \$ 9,905,000

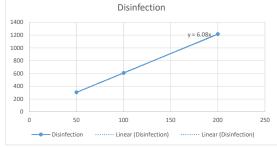


255 MGD



255 Dimensions for 255 MGD (ft)



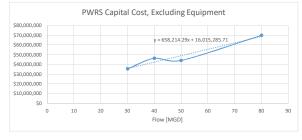


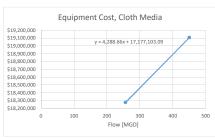
2050 FP

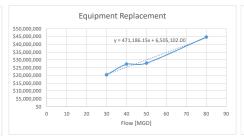
Zero Overflows Alternative Analysis - Alternative 1 CSO HRT Costs Backup

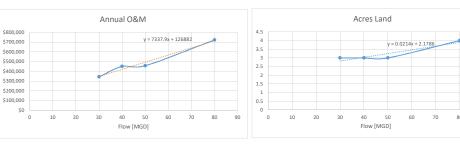
Dec 2019 ENR 14700 Port Washington Road Relief Sewer Project Alternatives Analysis Cloth Media HRT Equipment QCSO5fh

Memo done as part of N 27th St ISS Extension project (Note 1) (Note 2) Peak Flow HRT Equipment Cost (Installed cost) \$8,640,000 \$11,520,000 \$14,400,000 \$23,040,000 \$17,933,000 \$18,750,000 Month-Year of Original Cost Sep-04 May-19* Sep-04 Sep-04 Sep-04 May-19 8972 8972 8972 \$14,425 \$14,425 \$18,875,000 \$23,593,000 \$37,749,000 \$18,275,000 ENR'd Equipment Cost to Dec-2019 (Note 0) \$19,107,000 \$67,796,157 \$14,156,000 Capital Costs, excluding equipment \$35,464,000 \$46,316,000 \$44,126,000 \$69,798,000 8972 8972 8972 8972 \$14,425 \$14,425 \$30,925,000 \$38,655,000 \$61,849,000 ENR'd Capital Costs, excluding equipment to Dec-2019 \$18,623,000 \$19,471,000 Total Capital Cost, original year \$44.104.000 \$57.836.000 \$58.526.000 \$92.838.000 \$57,704,998 \$7,852,714,708 \$6,348,833,011 \$195,505,612 \$14,609,851,260 Annual O&M \$344,000 \$451,000 \$458,000 \$722,100 Equipment Replacen \$20,422,269 \$27,227,769 \$27,928,144 \$44,679,456 \$23.938.984 \$5.567.913.460 \$4,498,321,240 \$93,203,326 \$121.945.672 **\$10.305.322.682** #DIV/0 Acres Land









0) CSO HRT costs have been developed based on already available information. The focus was going to be on the CSO HRT analysis done as part of the Port Washington Road Relief Sewer (PWRS) /N 27th St ISS Extension project

for the MMSD. However, other technologies have become more mainstream that appear to be less expensive. Therefore, the planning level costs have been developed by using all of the assumptions from the PWRS project (Note 1) but replacing the HRT equipment with cloth media equipment (Note 2).

Because of this effort, capital costs have been "ENR'd" to Dec-2019 in this worksheet. Annual O&M used for PW costs are assumed to be similar to PWRS even with cloth media. 1) Information for data for PWRS CSO HRT costs:

a) Source: Port Washington Road Relief Sewer Project Alternatives Analysis Memo published in 2007 as part of N 27th St ISS Extension project. Costs were established in report as of 9/1/2004.
b) Costs were developed for the capacity need at 2 sites to meet a 5 year Level of Protection and a 10 year Level p of Protection (4 costs - 30 MGD and 50 MGD at one site, 30 MGD and 80 MGD at another).

c) Costs for all alternatives included the following facilities. Also note contingency included in these costs so no additional contingency included in the Scenario 1 capital cost table.

Inflow Piping

Pumping Station

Fine Screens (3 units)

HRT, Actiflo - when compared to cloth media costs from 2019, these are signficantly higher

Disinfection (3 units) Waste to Landfill Storage container

Waste Sludge Storage

Outflow Piping from Sludge Storage to MIS

MH Structure Polymer Storage

Coagulant Storage

Sand Storage

Outflow Piping to Milw River

Land Acquisition

Contingencies

d) Included equipment replacement in this worksheet because information available but did not include in Scenario 1 since assumed replacement would not occur within 20 year PW analysis. e) Assumptions for CSO HRT costs in Scenario 1 - used PWRS Annual Costs, even polymer/coagulant and land acquisition costs, assuming all needed to be conservative.

2) Cloth Media HRT costs

a) The following costs were used in replacement of the Actiflow system assumed in are HRT costs in replacement for the original HRT costs in the PWRS total capital costs

Equipment Only Cost (Installed) Cost Capacity (MGD) Source:

Hammond HRT \$ 11,955,000 \$ 17,933,000

Chicago HRT \$ 12,500,000 \$ 18,750,000 450 Email from Jay Kemp to K. Ziino and D. Dineen on 7/10/19, assumed ENR for May-2019 since did not state year b) Only the HRT equipment costs were substituted - in review, it was determined that original costs that may not be needed such as chemicals (cloth media appears to require chemicals for P removal, though not for TSS removal),

waste management and storage may not be needed but cloth media needs backwash pumps and other waste management facilties, included as part of the undesigned detail. c) Cloth media is anticipated to need replacement every 10 years but costs were anticipated to be negligible - email from D. Dineen to K. Ziino on 8/21/19

3) Modeling using the Simplified System Model (SSM) over 75 year period of record (POR) indicates that even with HRT at JIWRF and SSWRF under Alternative 1, there would still be CSOs as follows:

CSO Frequency (Events/yr)

0.90 This equates to

67.5 CSOs per year

3) Sites where modeling for Scenario 1 indicated CSOs still occurred even with WRF capacity maximized, along with CSO volume and peak flow information, (from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and from email from Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and From Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19 and From Pat Chiang to Kate Ziino and Troy Deibert on 7/11/19
| CSO Sites | QCSO
5fh (BS0502A) | QCSO56* | QCSO7* | QCSO
DC0103 | QCSO
BS0405 | Select sites | * QCSO56 and QCSO7 represent multiple small CSOs along the HL and LL siphons - model has 111 sites: difficult to break down but majority go TOTAL to CSO7 with remaining to CSO56, split between those on HL and LL siphons is not clear. |
|------------------------------------|-----------------------|-----------|----------|----------------|----------------|--------------|--|
| Average CSO Volume (MG) | 0.42 | 127.56 | 132.56 | 0.15 | 5.71 | 6.28 | 266.4 NOTE: Total shown does not exactly equal average annual CSO volume above because different CSOs occurred during different storms. |
| Max CSO Volume (MG) | 8.17 | 1,133.97 | 918 | 7.67 | 112.37 | | 2180.18 |
| Average CSO Rate (mgd) | 2.16 | 1,664.68 | 1,510.49 | 3.68 | 15.1 | | |
| Average time of CSO event (hrs) | 4.7 | 1.8 | 2.1 | 1.0 | 9.1 | | |
| Peak CSO Rate (mgd) | 36.82 | 11,802.71 | 9,532.63 | 184.12 | 244.54 | | |
| Max CSO Event | Sep-41 | Aug-86 | Aug-86 | Aug-86 | Mar-60 | | |
| # of individual CSO | 1 | 12 | 99 | 1 | 1 | | |
| Peak flow per individual CSO (mgd) | 37 | 984 | 96 | 184 | 245 | | |
| CSO Frequency (events/year) | 0.09 | 0.93 | 1 | 0.03 | 0.11 | 0.2 | 2.2 NOTE: Total shown does not equal CSO frequency above because total CSO frequency counts CSOs at multple locations during the same event as 1 CSO event. |
| Total CSO event in POR | 7 | 70 | 75 | 2 | 8 | 15 | 162 |

Source Data (9/1/2004)

2050 FP

Zero Overflows Analysis HRT Performance

Actiflow, from Conceptual Design Report

Effluent TSS 90% removal of TSS

Effluent TP 0.4 mg/L

Cloth media, from email correspondence provided by Dennis Dineen, Donohue & Associates on 8/21/19 to Kate Ziino

Effluent TSS 90% removal of TSS

Effluent TP 70% removal of P with 3 mg/L Alum addition

Projected Influent TSS and P at JIWRF and SSWRF (assumed average day, HRT handling flow after first flush)

JIWRF

Future Conditions

 Flow
 101 MGD

 TSS
 Influent Load
 217,000 lb/d

 Concentration
 258 mg/L

Effluent load at 255 MGD 851 lb/d

SSWRF

Future Conditions

 Flow
 120 MGD

 TSS
 Influent Load
 273,000 lb/d

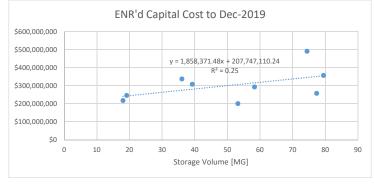
 Concentration
 273 mg/L

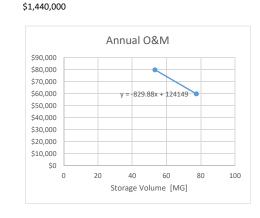
 Effluent from HRT
 27 mg/L

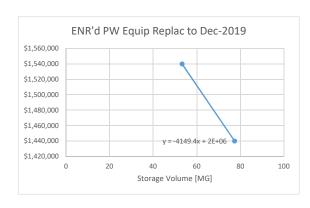
 Effluent load at 255 MGD
 58,013 lb/d

Backup tunnel costs

Dec 2019 ENR	14700				Indianapolis Tunnel Sy	stem - rom each tun	nel system in 2017	7 Long Term Control I	Plan			
See Note 1 for letters	A B		С	D	E1	E2	E3	E4	E5	E6	E7	E - Don't use
	Milwaukee River Storage Relief Dee; 27th S	treet Storage Relief Deep	Doan Valley Tunnel	Westerly Tunnel	Fall Creek	Pogues Run	Pleasant Run	Eagle Creek	White River	Deep Rock Connector	DRTC PS	
	53.2	77.3	18	36	39	19	74	17	58	79		250
	MG	MG	MG	MG	MG	MG	MG	MG	MG	MG		MG
Original Capital Cost	\$131,000,000	\$168,000,000	\$142,000,000	\$220,000,000	\$ 201,300,000	\$ 160,600,000	\$ 319,800,000	55,100,000	\$ 191,400,00	00 \$ 232,800,000	0 \$ 100,700,000	\$1,600,000,000
Month-Year of Original Cost	Jun-06	Jun-06	Jul-17	May-19	2016	2016	201	.6 201	6 20	16 201	.6 201	5 2016
ENR	9564	9564	14425	14425	13532	13532	1353	1353	2 135	32 1353	32	
ENR'd Capital Cost to Dec-2019	\$201,000,000	\$258,000,000	\$218,000,000	\$338,000,000	\$309,000,000	\$247,000,000	\$492,000,00	90,000,00	\$294,000,0	00 \$358,000,00	0	
Unit capital cost (\$/gal)	\$3.78	\$3.34	\$12.11	\$9.39	\$7.88	\$12.94	\$6.6	52	\$5.	04 \$4.5	1	\$6.40
Annual O&M	\$50,000	\$40,000)									
ENR'd Annual O&M to Dec-2019	\$80,000	\$60,000)									







Notes

1) Source data details:

A&B Source Data (6/1/2006)

PW Equipment Replacement ENR'd PW Equip Replac to Dec-2019

Memo PWAlternativesAnalysis 10.11.04 ALL.doc

\$1,000,000

\$1,540,000

C Source Data (7/2017 for costs)

\\Indw00\289PROJECTS\61129 MMSD 2050 FP\FP\0 Overflows\KK RE _2050 FP - 0 CSOs tunnel costs.msg https://www.stantec.com/en/projects/united-states-projects/w/westerly-tunnel-pump-station-project.

\$940,000

D Source Data (5/2019 for costs) E Source Data (2017 report, Table 7.1,

use annual 2016 for costs)

 $\underline{http://www.citizensenergygroup.com/pdf/LongTermControlPlan/Citizens%20LTCP%20Report%20and%20Appendices%20-%20November%202017%20Update.pdf}$

E Source Data (for volume) https://www.citizensenergygroup.com/Our-Company/Our-Projects/Dig-Indy/The-Solution/Tunnel-System-Map

2) Tunnel volumes used for the calculated unit costs are from Zero CSO Alternatives modeling as follows:

a) Alternative 2 determined the total tunnel needed to eliminate overflows through modeling

b) Alternative 3 determined the total tunnel needed after maximizing WRF hydraulic capacity through modeling

c) Alternative 2A - additionall tunnel needed if HRT installed at select CSOs

	Alternatives with Tunnel Capacity (s			Incremental Increas	ses in Tunneling			
	Alt 2 - MAX TUNNEL	Alt 3 - MAX WRF PLUS TUNNEL	Alt 2A - Tunnel plus sele	ect CSOs				Comparied to GI
Volume (MG)	2178	1871	2104	25	75	200	1000	740
ENR'd Capital Cost to Dec-2019	\$4,266,000,000	\$3,694,000,000	\$4,129,000,000	\$254,000,000	\$347,000,000	\$580,000,000	\$2,071,000,000	\$1,587,000,000
Unit capital cost (\$/gal)	\$1.96	\$1.97	\$1.96	\$10.16	\$4.63	\$2.90	\$2.07	\$2.14
ENR'd Annual O&M to Dec-2019	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$70,000	\$0 Assumed does not go up with tunnel volume, took average
ENR'd PW Equip Replac to Dec-2019	\$1,500,000	\$1,500,000	\$1,500,000					Assumed does not go up with tunnel volume, took average
								PW cost
ISS Pumpout (days)	12.1	10.4	11.7					\$1,588,050,000
Additional tunnel (MG)	1746	1439	1672					Unit cost (\$/gal)
Assumed tunnel diameter (ft)	30	30	30					\$2.15
Tunnel cross-sectional area (sf)	707	707	707					
Length of additional tunnel (ft)	330,225	272,162	316,229					
Length of additional tunnel (mi)	63	52	59.89					
Additional area of tunnels (acres)	227	187	217.79					
% of Milwauke County area	0.03%	0.02%	0.03%					

Backup tunnel costs

Milwaukee County acreage (sq mi) Milwaukee County acreage (acres)

KK River Flushing Tunnel Study, June 2015 Volume of tunnel after recommendations 5.59 MG

1189

760960

Recommendations	Cost (millions)	
Inspection of the tunnel		\$2.70
Gravity diversion at oufall 196		\$3.60
Gravity drain to KK-2 drops shaft		\$2.60
PVC lining		\$11.70
TOTAL		\$20.60

ISS PS Energy costs - cost to pump additional flow in larger tunnel

Information provided by P. Chiange to K. Ziino on 8/21/19 - only events where flow was above the tunnel capacity as of 2019 (432 MG) were provided Note: Peak ISS Volume presented below is less than total Tunnel Volume presented for Scenarios 2 and 3 because pulled from specific note rather than overall output. 2035, 0CSO Sc2 2035GI, JI=330+180, SS=300+75, VRSSI=160

MMSD Simplified System Model Repres

2035, OCSO Sc3 2035GI, JI=585+180, SS=630+75,VRSSI=160

MMSD Simplified System Model Representation of Statistics - Node ISS Depth

MIMSD Simplified System Model Representation of
Statistics - Node ISS Depth

Rank		vent Event uration Peak lours) (ft)	Yı	ear	Event			Time to pump out additional volume using 180 MGD pumps (days)	out additional volume using 180 MGD pumps (hours)	On-Peak Hours (hours)	Off-peak hours (hours)	Ran	C	Ouration F	Event Peak (ft)	Year	Event	Peak ISS Volume (MG)	Additional volume pumped out after event complete (MG)	Time to pump out additional volume using 180 MGD pumps (days)	out additional volume using 180 MGD	On-Peak Hours(Off-peak hours (hours)
Ave Max						2516	2084	1.5 11.6	35.4 277.8									2152	1720	9.6	229.4		
	5 6/22/1940	232 401.0			1	1733	1301	7.23	173	63	111		5 6/22/1940	164		1940	1	1229	797	4.43	106	53	53
	4 9/8/1941 59 12/27/1942	236 418.3 12 104.1		941 942	1	1807 450	1375 18	7.64 0.10	183 2	68 2	116 0		4 9/8/1941 14 6/13/1950	170 44	306.677 160.423	1941 1942	1 0	1325 0	893 0	4.96 0.00	119 0	60 0	60 0
	60 9/5/1947	8 104.0	52 19	943	0	0	0	0.00	0	0	0		25 7/19/1950	50	130.111	1943	0	0	0	0.00	0	0	0
	53 9/21/1947 51 5/10/1948	14 106.0 17 107.7		944 945	0	0	0	0.00	0	0	0		29 7/18/1952 11 8/1/1953	23 100	111.92 175.802	1944 1945	0	0	0	0.00	0	0	0
	23 6/13/1950	53 175.6		946	0	0	0	0.00	0	0	0		10 7/18/1959	87	200.497	1946	0	0	0	0.00	0	0	0
	15 7/19/1950	101 210.6		947	2	458	26	0.15	3	3	0		9 3/30/1960	120	213.079	1947	0	0	0	0.00	0	0	0
	31 7/18/1952 11 8/1/1953	50 149.0 141 235.7		948 949	1 0	466 0	34 0	0.19 0.00	4	4 0	0		12 8/3/1960 33 9/14/1961	61 12	171.602 102.728	1948 1949	0	0	0	0.00	0	0	0
	26 6/3/1954	65 162.4		950	2	910	478	2.66	64	32	32		31 9/22/1961	6	103.961	1950	2	693	261	1.45	35	17	17
	43 7/6/1954 61 10/9/1958	27 118.9 4 100.6		951 952	0 1	0 644	0 212	0.00 1.18	0 28	0 14	0 14		13 7/18/1964 32 6/29/1969	55 7	164.087 103.625	1951 1952	0 1	0 483	0 51	0.00 0.29	0 7	0 7	0
	9 7/18/1959	126 265.	74 19	953	1	1018	586	3.26	78	39	39		17 4/21/1973	54	141	1953	1	759	327	1.82	44	22	22
	6 3/29/1960 18 8/3/1960	196 336. 77 197.8		954 955	2 0	702 0	270 0	1.50 0.00	36 0	18 0	18 0		21 4/24/1976 23 7/18/1977	56 42	135.148 133.585	1954 1955	0	0	0	0.00	0	0	0
	34 9/13/1961	46 143.9		956	0	0	0	0.00	0	0	0		16 5/13/1978	58	148.749	1956	0	0	0	0.00	0	0	0
	45 9/22/1961 16 7/18/1964	15 115.9 83 209.7		957 958	0	0 435	0	0.00 0.02	0	0	0		19 8/17/1983	33 254	137.624 498.223	1957 1958	0	0	0	0.00	0	0	0
	49 6/11/1967	13 108.9		959	1	1148	716	3.98	95	48	48		1 8/6/1986 18 8/16/1987	54	139.227	1959	1	866	434	2.41	58	29	29
	37 6/26/1968	46 133.8		960	2	1453	1021	5.67	136	60	76		28 5/10/1990	35	116.115	1960	2	921	489	2.71	65	33	33
	41 6/29/1969 22 4/21/1973	23 120.4 81 183.7		961 962	2 0	622 0	190 0	1.05 0.00	25 0	13 0	13 0		26 8/18/1990 30 5/22/1991	22 5	121.166 104.072	1961 1962	2 0	449 0	17 0	0.10 0.00	2	2	0
	12 4/24/1976	110 221.		963	0	0	0	0.00	0	0	0		7 6/21/1997	122		1963	0	0	0	0.00	0	0	0
	56 5/5/1976 19 7/18/1977	10 104.9 82 196.1		964 965	1 0	906 0	474 0	2.63 0.00	63 0	32 0	32 0		8 8/5/1998 24 6/13/1999	86 41	218.502 132.731	1964 1965	1 0	709 0	277 0	1.54 0.00	37 0	18 0	18 0
	13 5/13/1978	101 214.9	53 19	966	0	0	0	0.00	0	0	0		6 7/2/2000	121	284.402	1966	0	0	0	0.00	0	0	0
	38 9/13/1978 44 3/4/1979	33 128.5 24 116.		967 968	1 1	471 578	39 146	0.22 0.81	5 20	5 10	0 10		22 7/9/2006 2 6/7/2008	23 314	134.848 487.892	1967 1968	0	0	0	0.00	0	0	0
	50 4/26/1979	19 108.1		969	1	521	89	0.49	12	12	0		15 6/19/2009	64	158.791	1969	1	448	16	0.09	2	2	0
	52 6/6/1980 35 4/2/1983	41 107.2 64 141.2		970 971	0	0	0	0.00	0	0	0		27 7/15/2010	17 202	119.316 359.729	1970 1971	0	0	0	0.00	0	0	0
	25 8/17/1983	48 162.5		972	0	0	0	0.00	0	0	0		3 7/22/2010 20 5/6/2012		136.565	1971	0	0	0	0.00	0	0	0
	57 6/27/1986	9 104.4		973	1	794	362	2.01	48	24	24					1973	1	609	177	0.98	24	12	12
	2 8/6/1986 42 9/11/1986	276 541.0 29 119.5		974 975	0	0	0	0.00	0	0	0					1974 1975	0	0	0	0.00	0	0	0
	14 8/15/1987	115 212.		976	2	957	525	2.92	70	35	35					1976	1	584	152	0.84	20	10	10
	39 7/19/1989 17 5/10/1990	36 127.2 92 199.6		977 978	1 2	847 929	415 497	2.31 2.76	55 66	28 33	28 33					1977 1978	1	577 643	145 211	0.81 1.17	19 28	10 14	10 14
	29 8/18/1990	45 151.8	92 19	979	2	505	73	0.41	10	10	0					1979	0	0	0	0.00	0	0	0
	46 5/22/1991 27 4/19/1993	13 115.6 72 160.5		980 981	1 0	463 0	31 0	0.17 0.00	4	4	0					1980 1981	0	0	0	0.00	0	0	0
	7 6/21/1997	152 321.9	07 19	982	0	0	0	0.00	Ō	0	0					1982	0	0	0	0.00	0	0	0
	48 6/30/1997 10 8/5/1998	53 109.4 100 237.3		983 984	2 0	702 0	270 0	1.50 0.00	36 0	18 0	18 0					1983 1984	1 0	595 0	163 0	0.90 0.00	22 0	11 0	11 0
	33 4/23/1999	52 146.2		985	0	0	0	0.00	0	0	0					1985	0	0	0	0.00	0	0	0
	21 6/13/1999 58 7/21/1999	75 185.9 11 104.4		986 987	3 1	2337 919	1905 487	10.59 2.71	254 65	103 32	151 32					1986 1987	1	2152 601	1720 169	9.56 0.94	229 23	91 11	139 11
	55 9/28/1999	11 104.4		988	0	0	0	0.00	0	0	0					1988	0	0	0	0.00	0	0	0
	24 5/18/2000	74 168.2		989	1	550 863	118	0.65	16 57	8 29	8					1989 1990	0	0	0 91	0.00	0 12	0	0 6
	8 7/2/2000 40 9/11/2000	149 310.8 30 126.2		990 991	2 1	500	431 68	2.39 0.38	9	9	29 0					1991	1	523 450	18	0.51 0.10	2	2	0
	47 2/9/2001	20 115.3		992	0	0	0	0.00	0	0	0					1992	0	0	0	0.00	0	0	0
	32 7/9/2006 1 6/7/2008	31 148.3 386 582.3		993 994	1 0	694 0	262 0	1.45 0.00	35 0	17 0	17 0					1993 1994	0	0	0	0.00	0	0	0
	20 6/19/2009	84 189.		995	0	0	0	0.00	0	0	0					1995	0	0	0	0.00	0	0	0
	36 7/15/2010 3 7/22/2010	28 137.7 250 432.4		996 997	0 2	0 1391	0 959	0.00 5.33	0 128	0 60	0 68					1996 1997	0 1	0 1178	0 746	0.00 4.14	0 99	0 50	0 50
	30 5/6/2012	40 151.0	39 19	998	1	1025	593	3.30	79	40	40					1998	1	944	512	2.84	68	34	34
	54 4/11/2013 28 4/18/2013	21 106.0 68 157.8		999 000	4 3	803 1343	371 911	2.06 5.06	50 121	25 60	25 61					1999 2000	1	573 1229	141 797	0.79 4.43	19 106	9 53	9 53
	20 1/10/2013	00 137.0		001	1	498	66	0.37	9	9	0					2001	0	0	0	0.00	0	0	0
				002	0	0	0	0.00	0	0	0					2002	0	0	0	0.00	0	0	0
				003 004	0	0	0	0.00	0	0	0					2003 2004	0	0	0	0.00	0	0	0
				005	0	0	0	0.00	0	0	0					2005	0	0	0	0.00	0	0	0
				006 007	1 0	641 0	209 0	1.16 0.00	28 0	14 0	14 0					2006 2007	1 0	583 0	151 0	0.84	20 0	10 0	10 0
			20	800	1	2516	2084	11.58	278	115	163					2008	1	2108	1676	9.31	223	88	136
				009 010	1 2	819 1868	387 1436	2.15 7.98	52 191	26 72	26 120					2009 2010	1 2	686 1554	254 1122	1.41 6.23	34 150	17 60	17 90
			20	011	0	0	0	0.00	0	0	0					2011	0	0	0	0.00	0	0	0
				012 013	1 2	652 682	220 250	1.22 1.39	29 33	15 17	15 17					2012 2013	1 0	590 0	158 0	0.88	21 0	11 0	11 0
				014	0	0	0	0.00	0	0	0					2014	0	0	0	0.00	0	0	0
			Co	ount	61																		

ISS PS Energy Assumptions

1) ISS PS Power is 3 MW/Hr to run 180 MGD full capacity - this is simplied, based on Energy model developed for Potential Uses of Additional Landfill Gas Technical Memorandum, approved October 16, 2015

2) Cost assumed as Electricity Costs, not NG/LFG costs from turbine operation - turbines have enough capacity to operate WRF during average day flow conditions, power needed for ISS PS needs is over and above turbine capacity

3) Energy costs included are just those over and above the costs to pump out 432 MGD - how much more time do 180 MGD pumps need to operate to empty tunnel?

4) Electricity costs are assumed based on event occurring on a Monday morning: On-Peak for first 12 hours of additional time, then switch 12 hours off-Peak/12 hrs On-Peak during the weel

5) No facilities charge, customer demand charrge or On-Peak energy charge included, assumed to already included in electrical costs to operate system.

6) On-Peak, kWh: \$ 0.07324

Off-Peak, kWh: \$ 0.05118

SUMMARY OF FINDINGS

Total Off-

	Total On-			Total Off-		
	Peak	Total Off-	Total On-	Peak		
	Hours	Peak Hours	Peak MWh	MWh	Total cost	
	over 75-yr					
	period of	Average				
	record	record	record	record	record	Annual cost
Scenario 2	1224	1430	3672	4290	\$ 162,851.59	\$ 2,171.35
Scenario 3	742	854	2225	2561	\$ 37,956.51	\$ 506.09

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN BUSINESS CASE EVALUATIONS Assumptions

General

Milwaukee ENR December 2019 Annual increase in costs	14,700 0%	
Discount Rate Life Cycle - number years	3.375% 20	
<u>Capital Costs</u> <u>Un-designed Details Allowance - Varies, see below</u> all major components have documented installed unit	10%	
costs costs missing for some components, but other costs are for installed facilities and well documented (connections to existing systems, etc.)	20%	
Alternative development is still conceptual	30%	
Contingency Allowance - Set % Planning Level Contingency Contractor Overhead & Profit - Varies, see below	20%	
Equipment costs are from manufacturers Costs are from previous project, unit costs already	25%	
include OH&P	0%	
Design, Bidding, & MMSD Oversight Total Percent, Conveyance	20%	
Total Percent, WRFs	40%	
Total Percent, Watercourse	20%	
Total Percent, GI	15%	
Power assumptions		
Gas	2018 Current Ra	
turbine fuel, LFG	\$2.500	/Dtherm
turbine fuel, NG	\$5.000	/Dtherm
Electrical		
Electrical Rates, JI/SS	Varies	
<u>Labor assumptions</u>		
Veolia Labor Contractor Labor		per hour
Contractor Edbor	ΨΙΟ	poi noui

Source	Comments
Historic_ENRvalues 1974-2019-05_MCA_KMZREV.xlsx Discussions with MMSD Email from Andrew Dutcher, WDNR to Troy Deibert, HNTB on 6/5/19	Milwaukee ENR is the average between Chicago and Minneapolis Construction Cost Index values published monthly by ENR. Milwaukee ENR December 2019 is a projected value from May 2019 based on average historical monthly increase in value from 2007 (2020 Facilities Plan published June 2007) to May 2019. Facility planning is using the value established by the WDNR.
Allowance varies at engineer's discretion based on de	finitions provided for each %
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
2050 FP Team - WRF discussion on 1/30/17	
2050 FP Team - WRF discussion on 1/30/17	
2050 FP Team - cost estimate discussion on 5/20/19	
Total Percent used for Planning, Preliminary Engineering, Design, Construction (exc. Contractor Cost) and Post Construction in the BCE	For FP Use only. This is incorporated into AMP BCE template already. Varies for each asset system
SOURCE	Comments
K. Ziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions K. Ziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions	
Kziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions	Detailed assumptions need to be included in backup on a case by case basis
Included in BCE assumptions To be included in capital costs	



APPENDIX 6E-5: SW FG2 Conveyance-Related Overflow Elimination Project Details -



MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Zero Overflows Alternatives Analysis



CONVEYANCE-RELATED OVERFLOW ELIMINATION COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

General Description:

This table summarizes the present worth costs for the remaining conveyance-related overflows identified in the CSM model even after if the Tunnel-Related Overflows Recommended Alternative recommendations are implemented, which included 2303 MG of tunnel and 255 MGD of HRT each at JIWRF and SSWRF.

	то	TAL PR	ESENT WORTH					
SSO I	Location	(Capital Cost	_	Annual Costs	o	sent Worth f Annual Costs	Total Present Worth
	BS0101	\$	14,210,000	\$	4,000	\$	60,000	\$ 14,270,000
	BS0303	\$	3,430,000	\$	1,000	\$	10,000	\$ 3,440,000
	BS0601	\$	1,210,000	\$	170	\$	-	\$ 1,210,000
	BS0602	\$	12,000,000	\$	3,000	\$	40,000	\$ 12,040,000
	11 CSOs	\$	77,000,000	\$	16,500	\$	330,000	\$ 77,330,000
	TOTAL COSTS	\$	107,850,000	\$	24,670	\$	440,000	\$ 108,290,000



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0101 - S. Howell Ave. 30-inch & 42-inch Diameter Relief Sewers from BS0101 to DC0102

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate 3.375% Number of Years 20

	Capital Costs				•		•
ITEM	Haita	Overatity.	Uı	nit Cost	 onstruction	С	apital Cost
ITEM	Units	Quantity		(\$)	 Cost (\$)		(\$)
Item 1 - Mob/Demob	LS	1	\$ 1	,000,000	\$ 1,000,000	\$	1,200,000
Item 2 - 30" Relief Sewer, Ex MH 17611 to MH 17604	LF	3,800	\$	1,224	\$ 6,510,000	\$	7,810,000
Item 3 - 42" Relief Sewer, Ex MH 17604 to DC0102	LF	1,421	\$	1,599	\$ 3,180,000	\$	3,820,000
Item 4 - Std. MHs: 3800'/500' = 8 @ 15'	EA	8	\$	50,000	\$ 560,000	\$	670,000
Item 5 - Std. MHs: 1420'/500' = 3 @ 25'	EA	3	\$	130,000	\$ 550,000	\$	660,000
Item 6 - New Opening on Existing MH (DC0102)	LS	1	\$	15,000	\$ 20,000	\$	20,000
Item 7 - Abandon 254 LF 24" Existing Overflow Pipe	CY	30	\$	500	\$ 20,000	\$	20,000
Item 8 - Abandon 1 MH along Existing Overflow Pipe	EA	1	\$	5,000	\$ 10,000	\$	10,000
Total Construction	n Cost				\$ 10,690,000		
Total Capita	l Cost					\$	14,210,000

Operation and Mainte	nance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	Anr	nual Cost (\$)
Operation and Maintenance Labor	LF	5,221	0.75	\$	4,000
Life Cycle Analysis	44.075				
Present Worth Factor (including annual increase) Present Worth of Operation and Maintenance Costs	14.375			\$	60,000

Equipment Replacer	nent Costs			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
		_		
Present Worth of Equipment Replacement Costs				\$ -

Salvage Value)			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
Present Worth of Equipment Replacement Costs				\$

TOTAL PRESENT WORTH	
Capital Costs	\$ 14,210,000
Present Worth of O&M Costs	\$ 60,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 14,270,000

Notes

1) See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0101 - S. Howell Ave.

30-inch & 42-inch Diameter Relief Sewers from BS0101 to DC0102

					C	apital	Costs									
ITEM	Life Years	Units	Quantity	Ur	nit Cost	s	UBTOTAL 1	Undesigned Details	Contingency	SI	JBTOTAL 2 (\$)	CO	NSTR. COST	Design, Bidding, Const. Oversight	CA	PITAL COST
Item 1 - Mob/Demob		LS	1	\$ 1	1.000.000	\$	1,000,000	-	_		_	\$	1,000,000	20%	\$	1,200,000
Item 2 - 30" Relief Sewer, Ex MH 17611 to MH 17604		LF	3,800	\$	1,224	\$	4,651,200	20%	20%	\$	6,510,000	\$	6,510,000	20%	\$	7,810,000
Item 3 - 42" Relief Sewer, Ex MH 17604 to DC0102		LF	1,421	\$	1,599	\$	2,272,179	20%	20%	\$	3,180,000	\$	3,180,000	20%	\$	3,820,000
Item 4 - Std. MHs: 3800'/500' = 8 @ 15'		EA	8	\$	50,000	\$	400,000	20%	20%	\$	560,000	\$	560,000	20%	\$	670,000
Item 5 - Std. MHs: 1420'/500' = 3 @ 25'		EA	3	\$	130,000	\$	390,000	20%	20%	\$	550,000	\$	550,000	20%	\$	660,000
Item 6 - New Opening on Existing MH (DC0102)		LS	1	\$	15,000	\$	15,000	20%	20%	\$	20,000	\$	20,000	20%	\$	20,000
Item 7 - Abandon 254 LF 24" Existing Overflow Pipe		CY	29.5	\$	500	\$	14,770	20%	20%	\$	20,000	\$	20,000	20%	\$	20,000
Item 8 - Abandon 1 MH along Existing Overflow Pipe		EA	1	\$	5,000	\$	5,000	20%	20%	\$	10,000	\$	10,000	20%	\$	10,000
													Total	Capital Cost	\$	14,210,000

Notes:

1) Definitions:

LS - lump sum

LF/VF/SF/CF - linear foot, vertical foot, square feet, cubic feet

2) Pipe cost from ASSETVIEW

3) Mob/Demob cost is estimated at \$1M for projects ranging from \$10-\$25 million.



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0303 - W. Oklahoma Ave. 30-inch Diameter Relief Sewer from BS0303 Pump Discharge to Existing MH 16416

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate 3.375% Number of Years 20

Capit	al Costs						
ITEM	Units	Quantity	U	Init Cost (\$)	 onstruction Cost (\$)	C	apital Cost (\$)
Item 1 - Mob/Demob	LS	1	\$	500,000	\$ 500,000	\$	600,000
Item 2 - 30" Relief Sewer - P.S. Disch. to Ex. MH 16416	LF	1,020	\$	1,224	\$ 1,750,000	\$	2,100,000
Item 3 - Std. MHs: 1020'/500' = 2 +1 at stream, 25' deep	EA	3	\$	130,000	\$ 550,000	\$	660,000
Item 4 - New Opening on Existing MH	LS	1	\$	15,000	\$ 20,000	\$	20,000
Item 5 - Modify Force Main Discharge	LS	1	\$	30,000	\$ 40,000	\$	50,000
Total Construction Cost					\$ 2,860,000		
Total Capital Cost						\$	3,430,000

Operation and Mainter	nance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	Anr	nual Cost (\$)
Operation and Maintenance Labor	LF	1,020	0.75	\$	1,000
<u>Life Cycle Analysis</u> Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	10,000

Equipment Replacem	nent Costs				
ITEM	Units	Quantity	Unit Value (\$)	Val	lue \$)
Present Worth of Equipment Replacement Costs				\$	-

Salvage Value					
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
Present Worth of Equipment Replacement Costs				\$	_

TOTAL PRESENT WORTH	
Capital Costs	\$ 3,430,000
Present Worth of O&M Costs	\$ 10,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 3,440,000

Notes:

1) See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0303 - W. Oklahoma Ave. 30-inch Diameter Relief Sewer from BS0303 Pump Discharge to Existing MH 16416

						Capit	al Costs							Daniss		
	Life			U	nit Cost	s	UBTOTAL 1	Undesigned		SL	IBTOTAL 2	СО	NSTR. COST	Design, Bidding, Const.	CAI	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)		(\$)	Oversight		(\$)
Item 1 - Mob/Demob		LS	1	\$	500,000	\$	500,000	-	-		-	\$	500,000	20%	\$	600,000
Item 2 - 30" Relief Sewer - P.S. Disch. to Ex. MH 16416		LF	1,020	\$	1,224	\$	1,248,480	20%	20%	\$	1,750,000	\$	1,750,000	20%	\$	2,100,000
Item 3 - Std. MHs: 1020'/500' = 2 +1 at stream, 25' deep		EA	3	\$	130,000	\$	390,000	20%	20%	\$	550,000	\$	550,000	20%	\$	660,000
Item 4 - New Opening on Existing MH		LS	1	\$	15,000	\$	15,000	20%	20%	\$	20,000	\$	20,000	20%	\$	20,000
Item 5 - Modify Force Main Discharge		LS	1	\$	30,000	\$	25,000	20%	20%	\$	40,000	\$	40,000	20%	\$	50,000
													Total	Capital Cost	\$	3,430,000

Notes:

1) Definitions:

LS - lump sum

²⁾ Pipe cost from ASSETVIEW

³⁾ Mob/Demob cost is estimated at \$500k for projects ranging from \$0-\$5 million.



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0601 30-inch Diameter Relief Sewer from BS0601 Pump Discharge to Existing MH 31704

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate 3.375% Number of Years 20

Сар	ital Costs								
			U	nit Cost	Co	nstruction	C	apital Cost	
ITEM	Units	Quantity		(\$)	(Cost (\$)	(\$)		
tem 1 - Mob/Demob	LS	1	\$	500,000	\$	500,000	\$	600,000	
tem 2 - 30" Relief Sewer - BS0601 to Ex MH 31704	LF	220	\$	1,224	\$	380,000	\$	460,000	
tem 3 - Std. MH - Assume 1 for P.S. Force Main, 10-15' deep	EA	1	\$	50,000	\$	70,000	\$	80,000	
tem 3 - New Opening on Existing MH	LS	1	\$	15,000	\$	20,000	\$	20,000	
tem 4 - Modify Force Main Discharge	LS	1	\$	25,000	\$	40,000	\$	50,000	
Total Construction Cost					\$	970,000			
Total Capital Cost							\$	1,210,000	

Operation and Mainter	nance Costs			
ITEM	Units	Quantity	Unit Cost (\$)	ıal Cost (\$)
Operation and Maintenance Labor	LF	220	0.75	\$ 170
<u>Life Cycle Analysis</u> Present Worth Factor (including annual increase)	14.375			
Present Worth of Operation and Maintenance Costs				\$ -

Equipment Replace	ment Costs				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
	-				
Present Worth of Equipment Replacement Costs				\$	

Salvage Value					
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
Present Worth of Equipment Replacement Costs				\$	-

TOTAL PRESENT WORTH							
Capital Costs	\$	1,210,000					
Present Worth of O&M Costs	\$	-					
Present Worth of Equipment Replacement	\$	-					
Present Worth of Salvage Value	\$	-					
Total Present Worth	\$	1,210,000					

Notes:

1) See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - BS 0601

30-inch Diameter Relief Sewer from BS0601 Pump Discharge to Existing MH 31704

					C	apital	l Costs									
	Life			U	Init Cost	s	UBTOTAL 1	Undesigned		SL	IBTOTAL 2	CO	NSTR. COST	Design, Bidding, Const.	CAP	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)		(\$)	Oversight		(\$)
Item 1 - Mob/Demob		LS	1	\$	500,000	\$	500,000	-	-		-	\$	500,000	20%	\$	600,000
Item 2 - 30" Relief Sewer - BS0601 to Ex MH 31704		LF	220	\$	1,224	\$	269,280	20%	20%	\$	380,000	\$	380,000	20%	\$	460,000
Item 3 - Std. MH - Assume 1 for P.S. Force Main, 10-15' deep		EA	1	\$	50,000	\$	50,000	20%	20%	\$	70,000	\$	70,000	20%	\$	80,000
Item 3 - New Opening on Existing MH		LS	1	\$	15,000	\$	15,000	20%	20%	\$	20,000	\$	20,000	20%	\$	20,000
Item 4 - Modify Force Main Discharge		LS	1	\$	25,000	\$	25,000	20%	20%	\$	40,000	\$	40,000	20%	\$	50,000
													Total	Capital Cost	\$	1,210,000

Notes:

1) Definitions:

LS - lump sum

LF/VF/SF/CF - linear foot, vertical foot, square feet, cubic feet

2) Pipe cost from ASSETVIEW

3) Mob/Demob cost is estimated at \$500k for projects ranging from \$0-\$5 million.



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows - SSO BS0602 - E. Warnimont Ave. 30-inch Diameter Relief Sewer from BS0602 to 48" MIS at S. Clement Ave.

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate 3.375% Number of Years 20

Capit	al Costs								
ITEM		Quantity	U	Init Cost (\$)	C	onstruction Cost (\$)	Capital Cost (\$)		
Item 1 - Mob/Demob	LS	1	\$ 1	1,000,000	\$	1,000,000	\$	1,200,000	
Item 2 - 30" Relief Sewer to Ex 48" MIS	LF	4,200	\$	1,224	\$	7,200,000	\$	8,640,000	
Item 3 - Std. MHs: 4,200'/500' = 8.4, say 9. Ave. Depth 25'	LF	9	\$	130,000	\$	1,640,000	\$	1,970,000	
Item 4 - New Opening on Existing MH on 48" MIS	LS	1	\$	15,000	\$	20,000	\$	20,000	
Item 5 - Abandon 707 LF 36" Existing Overflow Pipe	CY	185	\$	500	\$	130,000	\$	160,000	
Item 6 - Abandon 2 MHs along Existing Overflow Pipe	EA	2	\$	5,000	\$	10,000	\$	10,000	
Total Construction Cost					\$	10,000,000			
Total Capital Cost							\$	12,000,000	

Operation and Mainter	nance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	Ann	ual Cost (\$)
Operation and Maintenance Labor	LF	4,200	0.75	\$	3,000
<u>Life Cycle Analysis</u> Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	40,000

Equipment Replace				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
Present Worth of Equipment Replacement Costs				\$ -

Salva	ige Value					
				Unit Value	Va	alue
ITEM	_	Units	Quantity	(\$)	((\$)
Present Worth of Equipment Replacement Costs					\$	-

TOTAL PRESENT WORTH	
Capital Costs	\$ 12,000,000
Present Worth of O&M Costs	\$ 40,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 12,000,000

Notes

¹⁾ See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows - SSO BS0602 - E. Warnimont Ave. 30-inch Diameter Relief Sewer from BS0602 to 48" MIS at S. Clement Ave.

	Capital Costs												Daniem			
	Life			Un	it Cost	SI	JBTOTAL 1	Undesigned		SI	IBTOTAL 2	со	NSTR. COST	Design, Bidding, Const.	CA	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)		(\$)	Oversight		(\$)
Item 1 - Mob/Demob		LS	1	\$ 1	,000,000	\$	1,000,000	-	-		-	\$	1,000,000	20%	\$	1,200,000
Item 2 - 30" Relief Sewer to Ex 48" MIS		LF	4,200	\$	1,224	\$	5,140,800	20%	20%	\$	7,200,000	\$	7,200,000	20%	\$	8,640,000
Item 3 - Std. MHs: 4,200'/500' = 8.4, say 9. Ave. Depth 25'		LF	9	\$	130,000	\$	1,170,000	20%	20%	\$	1,640,000	\$	1,640,000	20%	\$	1,970,000
Item 4 - New Opening on Existing MH on 48" MIS		LS	1	\$	15,000	\$	15,000	20%	20%	\$	20,000	\$	20,000	20%	\$	20,000
Item 5 - Abandon 707 LF 36" Existing Overflow Pipe		CY	185.0	\$	500	\$	92,499	20%	20%	\$	130,000	\$	130,000	20%	\$	160,000
Item 6 - Abandon 2 MHs along Existing Overflow Pipe		EA	2	\$	5,000	\$	10,000	20%	20%	\$	10,000	\$	10,000	20%	\$	10,000
													Total	Capital Cost	\$	12,000,000

Notes:

1) Definitions:

LS - lump sum

LF/VF/SF/CF - linear foot, vertical foot, square feet, cubic feet

2) Pipe cost from ASSETVIEW

3) Mob/Demob cost is estimated at \$1M for projects ranging from \$10-\$25 million.



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - CSO 104 - 1872 N. Commerce St. 42-inch Diameter NSC Relief Sewer from CSO 104 to NS 7 Drop Shaft System

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%

Discount Rate 3.375% Number of Years 20

(Capital Costs								
ITEM	Units	Units Quantity		nit Cost (\$)		onstruction Cost (\$)	Capital Cost (\$)		
Item 1 - Mob/Demob	LS	1	\$	750,000	0 \$	750,000	\$	900,000	
Item 2 - 42" Relief NSC Sewer, Ex MH to MH	LF	1,300	\$	1,599	\$	2,910,000	\$	3,490,000	
Item 3 - Std. MHs: 1300'/500' = 3 + 2 Addt'l, up to 25' Deep	EA	5	\$	130,000	\$	910,000	\$	1,090,000	
Item 4 - Flow Control System Mods at NS7 - Assumption	EA	1	\$	150,000	\$	210,000	\$	250,000	
Item 5 - Modify Structure at Diversion Structure - Assumption	LS	1	\$	150,000	\$	210,000	\$	250,000	
Item 6 - Modify Structure at NS7 - Assumption	LS	1	\$	150,000	\$	210,000	\$	250,000	
Item 7 - Abandon CSO - Assumption	EA	1	\$	50,000	\$	70,000	\$	80,000	
Total Construction Co	ost				\$	4,570,000			
Total Capital Co	st						\$	6,310,000	

Operation and Mainter	nance Costs				
			Unit Cost	Anı	nual Cost
ITEM	Units	Quantity	(\$)		(\$)
Operation and Maintenance Labor	LF	1,300	0.75	\$	1,000
Life Cycle Analysis					
Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	14,000
				•	

Equipment Replacement	ent Costs				
		-	Unit Value	Valu	е
ITEM	Units	Quantity	(\$)	(\$)	
					ļ
Present Worth of Equipment Replacement Costs				\$	-

Salvage Value	Э			
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)
_				
Present Worth of Equipment Replacement Costs				\$

TOTAL PRESENT WORTH	
Capital Costs	\$ 6,310,000
Present Worth of O&M Costs	\$ 14,000
Present Worth of Equipment Replacement	\$ -
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 6,320,000

Notes:

1) See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - CSO 104 - 1872 N. Commerce St. 42-inch Diameter NSC Relief Sewer from CSO 104 to NS 7 Drop Shaft System

					C	apital	Costs									
ITEM	Life Years Units		Unit Cost SUBTOTAL 1 Undesigned Units Quantity (\$) (\$) Details						Contingency	SUBTOTAL 2		CONSTR. COST		Design, Bidding, Const. Oversight	CAI	PITAL COST
I I EWI	Tears	Ullits	Quantity		(Ψ)		(Φ)	Details	Contingency		(Φ)		(Ψ)	Oversignt		(4)
Item 1 - Mob/Demob		LS	1	\$	750,000	\$	750,000	-	-		-	\$	750,000	20%	\$	900,000
Item 2 - 42" Relief NSC Sewer, Ex MH to MH		LF	1,300	\$	1,599	\$	2,078,700	20%	20%	\$	2,910,000	\$	2,910,000	20%	\$	3,490,000
Item 3 - Std. MHs: 1300'/500' = 3 + 2 Addt'l, up to 25' Deep		EA	5	\$	130,000	\$	650,000	20%	20%	\$	910,000	\$	910,000	20%	\$	1,090,000
Item 4 - Flow Control System Mods at NS7 - Assumption		EA	1	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 5 - Modify Structure at Diversion Structure - Assumption		LS	1	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 6 - Modify Structure at NS7 - Assumption		LS	1.0	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 7 - Abandon CSO - Assumption		EA	1	\$	50,000	\$	50,000	20%	20%	\$	70,000	\$	70,000	20%	\$	80,000
													Total	Capital Cost	\$	6,310,000

Notes:

1) Definitions:

LS - lump sum

LF/VF/SF/CF - linear foot, vertical foot, square feet, cubic feet

2) Pipe cost from ASSETVIEW

3) Mob/Demob cost is estimated at \$750K for projects ranging from \$5-\$10 million.



COST TABLE SUMMARY

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - CSO 260 - S. 6th St. & W. Oklahoma Ave. 21-inch Diameter NSC Relief Sewer from CSO 260 at DC0103 to KK1 Drop Shaft

ENR Index = 14700 (projected to December 2019)

Annual Increase in Costs = 0.0%
Discount Rate 3.375%

Number of Years 20

Quantity 1 2,400	\$ \$	(\$) 750,000		Cost (\$)		apital Cost (\$)
1 2,400	-	,	\$	750 000	Φ.	
2,400	\$	0.4.4		1 30,000	\$	900,000
_	Ψ	944	\$	3,170,000	\$	3,800,000
7	\$	130,000	\$	1,270,000	\$	1,520,000
1	\$	150,000	\$	210,000	\$	250,000
1	\$	150,000	\$	210,000	\$	250,000
1	\$	150,000	\$	210,000	\$	250,000
1	\$	50,000	\$	70,000	\$	80,000
			\$	5,190,000	•	7,050,000
	1 1 1	1 \$ 1 \$	1 \$ 150,000 1 \$ 150,000	1 \$ 150,000 \$ 1 \$ 150,000 \$ 1 \$ 50,000 \$	1 \$ 150,000 \$ 210,000 1 \$ 150,000 \$ 210,000 1 \$ 50,000 \$ 70,000	1 \$ 150,000 \$ 210,000 \$ 1 \$ 150,000 \$ 210,000 \$ 1 \$ 50,000 \$ 70,000 \$

Operation and Mainte	nance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	Anr	nual Cost (\$)
Operation and Maintenance Labor	LF	2,400	0.75	\$	2,000
<u>Life Cycle Analysis</u> Present Worth Factor (including annual increase)	14.375				
Present Worth of Operation and Maintenance Costs				\$	29,000

Equipment Replacement Costs									
ITEM	Units	Quantity	Unit Value (\$)		lue \$)				
Present Worth of Equipment Replacement Costs				\$	-				

Salvage Value)				
ITEM	Units	Quantity	Unit Value (\$)	Value (\$)	
_					
Present Worth of Equipment Replacement Costs				\$	

TOTAL PRESENT WORTH						
Capital Costs	\$	7,050,000				
Present Worth of O&M Costs	\$	29,000				
Present Worth of Equipment Replacement	\$	-				
Present Worth of Salvage Value	\$	-				
Total Present Worth	\$	7,080,000				

Notes:

1) See Capital Cost Details for additional capital cost breakdown.



CAPITAL COST DETAILS

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS

SW FG2 - Zero Overflows Project - CSO 260 - S. 6th St. & W. Oklahoma Ave.

21-inch Diameter NSC Relief Sewer from CSO 260 at DC0103 to KK1 Drop Shaft

					C	apital	Costs									
	Life			u	nit Cost	S	UBTOTAL 1	Undesigned		SI	JBTOTAL 2	CO	NSTR. COST	Design, Bidding, Const.	CAF	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)		(\$)	Oversight		(\$)
Item 1 - Mob/Demob		LS	1	\$	750,000	\$	750,000	-	-		_	\$	750,000	20%	\$	900,000
Item 2 - 21" Relief NSC Sewer, Ex MH 17611 to MH 17604		LF	2,400	\$	944	\$	2,265,600	20%	20%	\$	3,170,000	\$	3,170,000	20%	\$	3,800,000
Item 3 - Std. MHs: 2350'/500' = 5 + 2 Addt'l, up to 25' Deep		EA	7	\$	130,000	\$	910,000	20%	20%	\$	1,270,000	\$	1,270,000	20%	\$	1,520,000
Item 4 - Flow Control System Mods at KK1 - Assumption		EA	1	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 5 - Modify Structure at DC0103 - Assumption		LS	1	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 6 - Modify Structure at KK1 - Assumption		LS	1.0	\$	150,000	\$	150,000	20%	20%	\$	210,000	\$	210,000	20%	\$	250,000
Item 7 - Abandon CSO - Assumption		EA	1	\$	50,000	\$	50,000	20%	20%	\$	70,000	\$	70,000	20%	\$	80,000
													Total	Capital Cost	\$	7,050,000

Notes:

1) Definitions:

LS - lump sum

LF/VF/SF/CF - linear foot, vertical foot, square feet, cubic feet

3) Mob/Demob cost is estimated at \$750K for projects ranging from \$5-\$10 million.

²⁾ Pipe cost from ASSETVIEW

2035 0 Overflows Simulation -June2008 Conveyance-Related SSOs

18

Overflow Structure	Node ID	Volume (MG)
BS0101	BS0101l1	3.28
BS0302	BS32l1	0
BS0303	BS33WWp1	0.92
	BS33WWp2	0.32
BS0304	BS0304l1	0
BS0401	BS0401p1	0
	BS0401p2	0
BS0403	BS0403l1	0
BS0505	BS55p1	0
	BS55p2	0
BS0506	BS56p1	0
BS0507	BS57l1	0
BS0511	BS0511L1	0
BS0513	BS0513l1	0
BS0514	BS0514l1	0
BS0515 & BS0516	2140w1	0
	2141w1	0
BS0601	BS61WWp1	0.20
	BS61WWp2	0
BS0602	BS62SOI1	0.32
BS0603	BS0603I1	1.49
MS0409	MS0409l1	0.02
ISS-Related SSOs		
BS0404	34004w1	0
	34003w1	0
BS0503	BS53WWp1	0
	BS53WWp2	0

QC (# of structrues)

7

Total SSOs 6.57 **ISS-related SSOs** 0

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN BUSINESS CASE EVALUATIONS Assumptions

General

Milwaukee ENR December 2019 Annual increase in costs	14,700 0%	
Discount Rate Life Cycle - number years	3.375% 20	
Capital Costs Un-designed Details Allowance - Varies, see below all major components have documented installed unit costs	10%	
costs missing for some components, but other costs are for installed facilities and well documented (connections to existing systems, etc.)	20%	
Alternative development is still conceptual Contingency Allowance - Set %	30%	
Planning Level Contingency	20%	
Contractor Overhead & Profit - Varies, see below Equipment costs are from manufacturers Costs are from previous project, unit costs already	25%	
include OH&P	0%	
Design, Bidding, & MMSD Oversight Total Percent, Conveyance Total Percent, WRFs Total Percent, Watercourse Total Percent, GI	20% 40% 20% 15%	
Power assumptions		
Gas	2018 Current Ra	
turbine fuel, LFG	\$2.500	/Dtherm
turbine fuel, NG	\$5.000	/Dtherm
Electrical		
Electrical Rates, JI/SS	Varies	
Labor assumptions Veolia Labor Contractor Labor		per hour per hour

Course	Commonio
Historic_ENRvalues 1974-2019-05_MCA_KMZREV.xlsx Discussions with MMSD Email from Andrew Dutcher, WDNR to Troy Deibert, HNTB on 6/5/19	Milwaukee ENR is the average between Chicago and Minneapolis Construction Cost Index values published monthly by ENR. Milwaukee ENR December 2019 is a projected value from May 2019 based on average historical monthly increase in value from 2007 (2020 Facilities Plan published June 2007) to May 2019. Facility planning is using the value established by the WDNR.
Allowance varies at engineer's discretion based on de	ofinitions provided for each %
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	
2050 FP Team - WRF discussion on 1/30/17	
2050 FP Team - WRF discussion on 1/30/17	
2050 FP Team - cost estimate discussion on 5/20/19	
Total Percent used for Planning, Preliminary Engineering, Design, Construction (exc. Contractor Cost) and Post Construction in the BCE	For FP Use only. This is incorporated into AMP BCE template already. Varies for each asset system
SOURCE	Comments
K. Ziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions K. Ziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions	
Kziino email sent 4/20/17 called "2050 - WRF TBC Energy Cost Assumptions" for assumptions	y Detailed assumptions need to be included in backup on a case by case basis
Included in BCE assumptions To be included in capital costs	

Comments

Source







APPENDIX 6E 6

JIWRF CHANNEL MIXING

Description

This energy alternative reviewed the feasibility of replacing the existing channel mixing system with a more energy efficient mixing system. The alternative focuses on large bubble mixing.

Existing System

A number of treatment channels at JIWRF are mixed with air from the secondary treatment air system, provided by the blowers in the Process Air Compressor (PAC) Building.

Secondary treatment facilities that are currently air-mixed include the following:

- Facility 209/210, Flow Control Structure and Mix Channel
- Facility 213, West Plant Mixed Liquor Channels
- Facility 214, East Plant Mixed Liquor Channels
- Facility 220, East Plant and West Plant Aerated Effluent Channels
- Facility 233, East Plant and West Plan RAS Channels
- Facilities 234/235, RAS/WAS Pump Stations

Although the following channels can also be air-mixed, preliminary information indicates that due to lack of air pressure or for other reasons, they are currently receiving essentially no air supply from the existing compressors:

- Facility 203, Preliminary Treatment/Grit Channels (including influent wet well and grit chamber)
- Facility 205, Primary Treatment Channels (primary clarifier influent channel and dilute scum tank)
- Facility 247, Effluent Pump Station

With the exception of the Flow Control Structure, all secondary treatment channels are equipped with the same type of ceramic plate air diffusers as found in most of the aeration basins (excluding the six aeration basins converted to membrane diffusers to allow for solids storage). The diffusers are set within concrete containers sitting on the channel bottom, with air piping from the air system. Coarse bubble air diffusers are used in the Flow Control Structure to mix primary effluent with return activated sludge and recycle flows from sludge thickening and dewatering/drying facilities. The aeration system keeps the solids in suspension and supports biological activities as the flow moves from one unit process to another. Figures 1 and 2 indicate the general layout of the existing system in the channels. Most of these channels are covered that are outside of galleries running the length of the aeration basins.



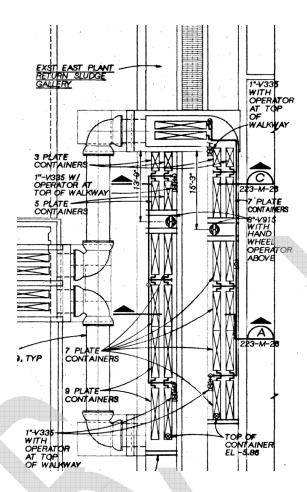


Figure 1: Channel Diffuser System Plan View

Source: MMSD Project J42G11, West Plant Rehab/New East Plant Clarifiers, Sheet M32

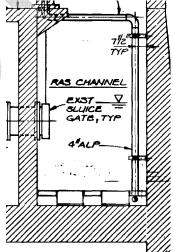


Figure 2: Channel Diffuser System Section View of Containers Source: MMSD Project J42G11, West Plant Rehab/New East Plant Clarifiers, Sheet M26



Alternative Description and Modifications Required

As part of the Energy Plan, MMSD Contract No. M03072P01, an energy reduction alternative was identified that would use large bubble air mixing as an alternative mixing system in the Flow Control Structure, Mixed Liquor Channels and Aerated Effluent Channels instead of air from the aeration system (taking into consideration that this may impact the biological phosphorous removal which is occurring). The alternative reviewed in this report has been expanded to also include the RAS channels. In reviewing the facilities currently aerated, the RAS/WAS pump station was excluded as being too difficult to implement.

The manufacturers contacted for this analysis include EnviroMix, Pulsair and SunBurst. Enviromix and Pulsair have similar systems that mix the wastewater using intermittent bursts of compressed air through units (nozzles or plates) set at the bottom of the channels. The bursts of air form large bubbles that minimize oxygen transfer to the liquid. The system is designed with multiple compressors and piping to the compressed air units within the channels, with the system programed to provide compressed air to units in an organized intermittent fashion. SunBurst utilizes the existing aeration system but requires less air – air is supplied to mixing chambers where the air accumulates to a maximum set point and then is released in large bubbles. For this analysis, the compressed air system provided by EnviroMix and the low pressure air system provided by SunBurst are compared to the existing system.

Compressed Air Mixing System

The modifications to the existing system would include demolishing and removing the existing diffuser containers in the channels and removing the existing air piping, along with selective top slab demolition to access the channels. The new system would be set on the bottom of the channels with the valve control panels and compressors set within the galleries throughout the secondary system. Hatches would be installed where applicable to access the equipment. Construction sequencing would need to be reviewing during design to maintain the existing system while installing the new system. Figure 3 shows standard layouts for the new EnviroMix system in similar installations.





Figure 3: Standard Layouts for Large Bubble Compressed Air Mixing System
Source: Budgetary Proposal – BioMix System, Enviromix Proposal dated 10/9/15

Low Pressure Air Mixing System

The modifications to the existing system would include demolishing and removing the existing diffuser containers in the channels and removing the existing air piping, along with selective top slab demolition to access the mixers being installed in the channels. A new membrane diffuser system would be installed along the center of each channel, connected to each existing air header into the channel with the new mixers set on the top of each of the membrane diffusers. Hatches would be installed where applicable to access the mixers. The system would be connected to the existing low pressure air piping in each channel. Construction sequencing would need to be reviewing during design to maintain the existing system while installing the new system. Figure 4 shows standard layouts for the StarBurst system in the South Shore Water Reclamation Facility pilot study performed in 2015. The proposed layout in each channel at JIWRF would only include a new air header and one diffuser per mixer.



Figure 4: Standard Layout for Large Bubble Low Pressure Air Mixing System in Aeration Basin



Source: BioP Mixing Demonstration Study at MMSD — South Shore Wastewater Treatment Facility Presentation dated 11/8/15

Estimate of Energy Reduction

As part of the final completion of the JI Aeration System Upgrades Project, J02008C03, an air optimization study was completed that reduced air flows to all of the channels from a constant air flow of approximately 30,900 standard cubic feet per minute (scfm) to 21,500 scfm¹. The reduced air flow was set in an attempt to meet a mixing air requirement of approximately 0.12 cfm per square foot (sf). The reduction in channel air demand reduced the total average daily air flow from 95,000 scfm² to 85,600 scfm, with the channel mixing making up 25% of the total air needs.

The JI Aeration System Upgrades Project replaced one of the four Process Air Compressors (PACs) with a new 100,000 cfm Siemens single-stage centrifugal blower. The initial analysis included in this report assumes that the air needed for mixing is provided by the new Siemens blower since the older PACs are only used as backup. The new blower is more efficient than the remaining three PACs, requiring an average of 26.3 kilowatt (kW) of power to provide kscfm of air³. Based on this ratio, the channel air mixing requires approximately 565 kW of power to operate. The blower curve was not reviewed for this initial analysis - actual power demand will be higher at the lower air demand but more detailed blower curve information is not anticipated to change the results of this analysis. The amount of power required to operate the channel mixing system equates to 16,900 Million British Thermal Units per year (MMBTU/yr) out of the 294,500 MMBTU/yr of electricity and 1,418,000 MMBTU/yr used at JIWRF.

The proposed EnviroMix system would eliminate the use of air for mixing in channels. This system is anticipated to use 236 kW of power⁴, which is a reduction in power requirements of 329 kW per hour or 9,800 MMBTU/yr, a 58% reduction in channel mixing power and a 3% reduction in electricity used at JIWRF. The proposed StarBurst system would reduce air usage for channel mixing to 1,300 cfm. This system is anticipated to use 34 kW of power⁵, which is a reduction in power requirements of 531 kW per hour or 15,900 MMBTU/yr, a 94% reduction in channel mixing power and a 5% reduction in electricity used at the plant. For either alternative, the total energy required at JIWRF would be reduced about 1%.

The total air usage for the secondary system would be reduced to a possible minimum air requirement of 64,100 cfm with the EnviroMix system and 65,400 cfm with the StarBurst system. The Siemens blower is designed to provide a minimum 50,000 cfm of air. The air required is still above the minimum operation point for the blower but is something that would be of concern if other air reducing operation strategies were implemented for secondary treatment.

2050 Facilities Plan
Page 5 -

¹ Air flow based on information provided by Alan Scrivner in an email to Bill Farmer and Dave Woznicki, MMSD, on 8/6/15 as part of the J02008, JIWRF Aeration Systems Upgrade Project

² Total airflow prior to channel mixing optimization provided in Jones Island Power Load Profiling PowerPoint developed by Sidharta (Sid) Arora, P.E. attached to email from Bill Krill, dated 5/11/15, subject: JI Power Load Profiling.pptx

³ Ibid

⁴ Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-

⁵ Based on 1.5 CFM/20' channel per telephone conversation between Kate Ziino, HNTB, and Ken Neu, Environmental/Health Products & Service, on 2-5-16



Present Worth Cost Estimate

Table 1 presents the capital costs and annual operation and maintenance (O&M) savings of the proposed EnviroMix and StarBurst systems. The capital cost of the proposed EnviroMix system includes the demolition of the existing system – including existing air piping, and installation of a new large bubble compressed air mixing system. The capital cost of the proposed StarBurst system includes the demolition of the existing system – in the channels only, and installation of a new large bubble low pressure air mixing system using the existing air system. The existing O&M costs include electrical costs as well as costs incurred maintaining the existing system, including inspection and periodic diffuser replacement. The new system O&M costs include reduced electrical costs along with costs associated with maintaining the new system. The present worth of the annual cost savings is based on a 20-year life cycle. The cost details are provided in Attachment A to this appendix.

Table 1: Alternative Cost Review

Item	Compressed	Low Pressure
	Air Mixing	Air Mixing
	System	System
Capital Cost	\$27,900,000	\$27,400,000
Existing System Annual O&M Eliminated	(\$248,000)	(\$248,000)
New System Annual O&M Added	\$110,000	\$20,000
Annual O&M Savings	(\$138,000)	(\$228,000)
Present Worth of Annual O&M Cost Savings	(\$3,600,000)	(\$5,900,000)
TOTAL PRESENT WORTH	\$24,300,000	\$21,500,000

To justify installing either of the two systems, the present worth of 20 years of annual cost savings needs to be more than the capital cost such that the total present worth is a negative value representing cost savings. Based on the costs developed, the present worth of 20 years of annual cost savings are substantially less that the capital costs for both of the alternatives such that there is no total present worth savings. The electrical demand of the existing air mixing system has been lowered significantly since the air mixing demand was optimized in the summer of 2015. Therefore, even for the low pressure air mixing system, the energy cost savings do not make enough of an impact to justify the large capital cost.

Therefore, the present worth cost analysis indicates that changing the existing system is not advised.

Conclusions and Recommendations

The two systems reviewed would both reduce the total JIWRF electrical load from 294,500 MMBTU/yr – the EnviroMix system would reduce the JIWRF electrical load to 284,700 MMBTU/yr and the StarBurst system would reduce the JIWRF electrical load to 278,600 MMBTU/yr. However, the present worth savings analysis indicates that neither system is economically feasible. Optimization of the existing





system has reduced the existing electrical demand of the channel mixing to the point where a new system is not financially advisable. In addition, the reduction in air required to meet new mixing goals would drop the total air demand to 64,000-65,000 scfm. This drop in the air flow may push the blower operation off the design set point enough to affect the efficiency of the blower. Therefore, the recommendation is to continue with the existing diffuser air-mixing system.





APPENDIX 6E-6 -

Attachment A: SW FG3 Channel Mixing Cost Estimates -



MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN **ENERGY ALTERNATIVE EVALUATIONS: Large Bubble Mixing for JIWRF Channels**

COST TABLE OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Compressed Air Mixing System

General Description

Provide channel mixing through large bubble compressed air system, rather than through Secondary Aeration System. New large bubble compressed air system installed ML, AE and RAS channels and FCS. Existing systems removed, including all air piping.

Construc	tion Costs					
	U	nit Cost	C	onst. Cost		
ITEM	Units	System Quantity		(\$)		(\$)
Demolition - diffuser containers	SY	18,000	\$	50.00	\$	900,000
Demolition - air piping around channels only	LF	26,200	\$	14.00	\$	366,800
Selective Top Slab Demolition	SY	240	\$	90.00	\$	21,600
Aluminum Hatches	EACH	231	\$	3,300.00	\$	762,30
Compressed air mixing system (including installation)	LS	1	\$ 5,692,000.00		\$	5,692,000
Compressed air piping from compressors to valve panels	LF	17,500	\$	200.00	\$	3,500,000
Subtotal Material Co					\$	11,242,70
Subtotal Labor Co				/	\$	-
Contingend				20%	\$	2,248,50
Undesigned Deta				40%	\$	4,497,10
Subto Contractor Overhead & Pro				15%	\$	17,988,30 2,698,20
				15% 40%	\$	7,195,30
Design, Bidding and MMSD Oversig				40%	\$	
Total Construction Co	ost				\$	27,881,8

Operation and Maint	tenance Cos	ts					
ITEM	Units Quantity		Unit Cost (\$)	Annual Cost (\$)			
Existing Diffuser Mixing System Annual Costs - Eliminated	LS	1	248,000	\$	(248,000)		
Compressed Air Mixing System Annual Costs - Added	LS	1	110,000	\$	110,000		
Net Estimated Annual Operation and Maintenance Cost Savings				\$	(138,000)		
Life Cycle Analysis							
Annual Increase in Costs	0.00%						
Discount Rate	3.375%						
Number of Years	20						
Present Worth Factor	14.375						
Present Worth of Operation and Maintenance Costs Savings				\$	(1,984,000)		

Salvage Values								
ITEM	Units	Quantity	Unit Value (\$)		Value (\$)			
No salvage value for this option	Each	0	0					
Total Salvage Value				\$	-			

TOTAL PRESENT WORTH	
Capital Costs	\$ 27,900,000
Present Worth of O&M Costs	\$ (2,000,000)
Present Worth of Salvage Value	\$ - 1
Total Present Worth	\$ 25,900,000

ENR Construction Cost Index, MKE area projected to December 2019 (14700)



MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Large Bubble Mixing for JIWRF Channels

COST TABLE OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Low Pressure Air Mixing System

General Description

Provide channel mixing through large bubble low pressure air system, utilizing Secondary Aeration System. New large bubble low pressure air system installed ML, AE and RAS channels and FCS. Existing systems removed, but all air piping to remain.

Construction	n Costs					
		Unit Cost	Const. Cost			
ITEM	Units	System Quantity		(\$)		(\$)
Demolition - diffuser containers	SY	18,000	\$	50.00	\$	900,000
Selective Top Slab Demolition	SY	240	\$	90.00	\$	21,600
Aluminum Hatches	EACH	870	\$	3,300.00	\$	2,871,160
Low Pressure air mixing system - equipment only	EACH	870	\$	7,000.00	\$	6,090,340
Install equipment	HR	1,740	\$	70.00	\$	121,807
Modification of existing 4"drop leg piping	LF	5,220	\$	200.00	\$	1,044,058
9" Membrane Diffusers Installed every 20'	EACH	870	\$	6.00	\$	5,220
Installation of piping modification and membrane diffusers	HR	1,740	\$	70.00	\$	121,807
Subtotal Material Cost					\$	11,054,200
Subtotal Labor Cost					\$	-
Contingency				20%	\$	2,210,800
Undesigned Details	Undesigned Details					
Subtotal					\$	17,686,700
Contractor Overhead & Profit				15%	\$	2,653,000
Design, Bidding and MMSD Oversight				40%	\$	7,074,700
Total Construction Cost					\$	27,414,400

Operation and Main	tenance Cos	its					
ITEM		Quantity	Unit Cost (\$)	Annual Cos (\$)			
Existing Diffuser Mixing System Annual Costs - Eliminated	LS	1	248,000	\$	(248,000)		
Low Pressure Air Mixing System Annual Costs - Added	LS	1	20,000	\$	20,000		
Net Estimated Annual Operation and Maintenance Cost Savings				\$	(228,000)		
Life Cycle Analysis							
Annual Increase in Costs	0.00%						
Discount Rate	3.375%						
Number of Years	20						
Present Worth Factor	14.375						
Present Worth of Operation and Maintenance Costs Savings				\$	(3,278,000		

Salvage Values								
ITEM	Units	Quantity	Unit Value (\$)		/alue (\$)			
No salvage value for this option	Each	0	0					
Total Salvage Value				\$	-			

TOTAL PRESENT WORTH	
Capital Costs	\$ 27,400,000
Present Worth of O&M Costs	\$ (3,300,000)
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 24,100,000

ENR Construction Cost Index, MKE area projected to December 2019 (14700)

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN ENERGY ALTERNATIVE EVALUATIONS: Large Bubble Mixing for JIWRF Channels Alternative Capital Cost Backup Information

	Actual Unit Cost		COS Cost		JSTMENT Adjustment	ADJUSTED UNIT COST		
Compressed Air Alternative	(\$)	Units	Year	Index	Factor	(\$)	SOURCE	COMMENTS
Demolition - diffuser containers	\$34	SY	2013	12218	1.20	\$50	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Used unit cost for sidewalk removal, concrete, mesh reinforced, 6" thick, in a congested area
Demolition - air piping around channels only	\$11	LF	2013	12218	1.20	\$14	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Used unit cost for pipe removal, sewer/water, no excavation, 12" diameter, assumed lengths just for channels and increased by 50% for lengths between channels
Selective Top Slab Demolition	\$68	SY	2013	12218	1.20	\$90	Demo \$ - RS Means Building Construction Cost Data 2013, Facility Dimensions Tab; No. of headers - Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-15	Top slab demo'd to install mixers and provide access, assumed double the unit cost of diffuser container demolition; assume 3'x3' for 231 headers
Aluminum Hatches	\$3,000	EA	2016	13397	1.10	\$3,300	Hatches - Typical wastewater treatment plant project costs; No. of headers - Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-15	Heavy duty (driveable) access hatch needed for each mixer
Compressed air mixing system (including installation)	\$5,106,000	LS	2015	13187	1.11	\$5,692,000	Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-15	Included installation estimate included in ROI evaluation in EnviroMix proposal (though not in scope of supply), startup is included in EnviroMix scope of supply; Undesigned details increased to 20% to cover electrical connection to compressors, control wiring and onsite application engineering
Compressed air piping from compressors to valve panels	\$166	LF	2013	12218	1.20	\$200	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Used unit cost for Sched 40, Type 304, 4" diameter SS to be conservative (Enviromix will call for 3"), estimated length using length of channels - may be less depending on compressor and valve panel locations Note: Pulsair indicated PVC could be used - would drop the cost by over \$4M but ROI would still be significant
Low Pressure Air Alternative								
Demolition - diffuser containers	\$34	SY	2013	12218	1.20	\$50	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Used unit cost for sidewalk removal, concrete, mesh reinforced, 6" thick, in a congested area
Selective Top Slab Demolition	\$68	SY	2013	12218	1.20	\$90	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Top slab demo'd to install mixers and provide access, assumed double the unit cost of diffuser container demolition
Aluminum Hatches	\$3,000	EA	2016	13397	1.10	\$3,300	Typical wastewater treatment plant project costs	Heavy duty (driveable) access hatch needed for each mixer, no. of mixers calculated - 1 mixer every 20' per Starburst Pricing Original quote did not include installation or shipping & handling -
Low Pressure air mixing system - equipment only	\$6.027	EACH	2016	13380	1.10	\$7.000	Preliminary Budget Pricing - StarBurst Mixer System dated 1-21-16, sent to Kate Ziino from Ken Neu, Environmental/Health Products & Service on 1-22-16	actual cost includes 5% markup on shipping and handling, plus additional for anchoring equipment; no. of mixers calculated - 1 mixer every 20' per Starburst Pricing
Install equipment	\$70	HR	2016	14700	1.00	\$70	BCE Cost Estimates	Assumed 2 hours per mixer to install
Modification of existing 4"drop leg piping	\$166	LF	2013	12218	1.20	\$200	RS Means Building Construction Cost Data 2013, Facility Dimensions Tab	Used unit cost for Sched 40, Type 304, 4" diameter SS, estimated length assuming 8' for each drop leg (~ ave half of width of channels plus added length for additional fittings)
9" Membrane Diffusers Installed every 20'	\$4	EACH	2011	11477	1.28	\$6	JI Aeration Upgrade PER, Technical Memorandum 1, Dated February 28, 2011, Appendix 1C	
Installation of piping modification and membrane diffusers	\$70	HR	2016	14700	1.00	\$70	BCE Cost Estimates	Assumed 2 hours per drop leg for modifications and diffuser installation

Milwaukee Metropolitan Sewerage District

2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Large Bubble Mixing for JIWRF Channels

Alternative Annual Operating and Maintenance Cost Backup Information

Compressed Air Alternative

Jones Island Existing Annual Operating and Maintenance Costs

COMMENTS

			SUBTOTAL	\$248,000 Did not include blower maintenance since will still be operational so no savings in maintenance costs
5-Yr Inspection	32 hr/yr	\$50.00	per hr	\$2,000 Assume 80 hours of inspection every 5 years for 2 people
Maintenance	1 hr/week	\$50.00	per hr	\$3,000 Assumed minimal maintenance to piping and air valves to channel mixing, no diffuser maintenance
Diffuser Replacement Air Piping and Valves Operation and	150 per year	\$220.00	per diffuser	Possibly over-estimated since field information indicates minimal replacement occurring, costs increased by 10 since number \$33,000 replaced is 0.5% of total included in bid
Electricity - Blower Air for Channel Mixing	21,500 scfm	565	kW	\$210,000 the J02008, JIWRF Aeration Systems Upgrade Project

Compressed Air Mixing System Annual Operating & Maintenance Costs

			s	UBTOTAL	\$110,000
System Operation and Maintenance					\$20,000 Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-15
Mixing	317	HP	236	kW	\$90,000 Budgetary Proposal - BioMix System - Process Channels sent to Kate Ziino from Tyler Kunz, EnviroMix, dated 10-9-15
Electricity - Compressed Air for Channel					

MMBTU/yr Channel Mixing Reduction

16,900 NA

Low Pressure Air Mixing System An	nual Opera	ting & Mair	ntenance	Costs	
Electricity - Low Pressure Air for Channel					1.5 CFM/20' channel per telephone conversation between Kate Ziino, HNTB, and Ken Neu, Environmental/Health Products &
Mixing	1,305	scfm	34	kW	\$10,000 Service, on 2-5-16
System Operation and Maintenance					\$10,000 Estimated, assume more maintenance but not as much as compressed air system with compressor
				SUBTOTAL	\$20,000

Power Usage Reduction Review

Power Usage

Existing System

Compressed Air Mixing System	236	7,100	9,800	58.0%
Low Pressure Air Mixing System	34	1,000	15,900	94.1%
JIWRF Total Power Requirement	MMBTU/yr	Total Plant Energy Reduction	MMBTU/yr	Total Plant Energy Reduction
Existing System	1,418,200		294,500	
With Compressed Air Mixing System	1,408,400	0.7%	284,700	3.3%
With Low Pressure Air Mixing System	1.402.300	1.1%	278.600	5.4%

kW

565

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN ENERGY ALTERNATIVE EVALUATIONS: Assumptions Large Bubble Mixing for JIWRF Channels

<u>General</u>		Source	Comments
_		ENR Construction Cost Index, MKE area Projected	
ENR CCI	14700	December 2019	MKE Area is the average between Chicago and Minneapolis ENRs
Useful Life			
Land	Permanent		
Sewer & Force Mains	50 years	2020 FP: Amy Hagner (Symbiont)	
Structures, Piping, & Valves	40 years	2020 FP: Amy Hagner (Symbiont)	
Process Equipment, Electrical, I&C	20 years	2020 FP: Amy Hagner (Symbiont)	
Undesigned Details Allowance			
all inclusive firm bid price	0%	2020 FP: Bill Krill (HNTB), phone conference 11.16.06	
all major components have documented installed unit	10%		
costs		2020 FP: Amy Hagner (Symbiont)	
costs missing for some components, but other costs are			
for installed facilities and well documented (connections			
to existing systems, etc.)		2020 FP: Amy Hagner (Symbiont)	
installed costs for major components are not well	40%		
documented (e.g Installation cost is estimated)		2020 FP: Amy Hagner (Symbiont)	
Contingency			
all inclusive firm bid price	0%	2020 FP: Bill Krill (HNTB), phone conference 11.16.06	
everything else	20%	WRF BCE Cost Estimate Template	
Design, Bidding, & MMSD Oversight			
Total Percent	40%	Total Percent used for Planning, Preliminary Engineering and Post Construction in the BCE	ng, Design, Construction (exc. Contractor Cost)
Power assumptions		SOURCE	Comments
Gas			Commonto
	Future Rates		
			MMSD developed analysis of JI Energy costs that was used for unit costs in the
turbine fuel, LFG	\$2.500 /Dtherm	Assumed rates from "JI Electrical Unit.xlsx" file	2050 FP.
turbine fuel, NG	\$5.000 /Dtherm		
Electrical			
Averaged Energy Charge (Notes 1 and 2)	\$0.0420 /kWh	MMSD in "JI Electrical Unit Cost.xlsx" file	Assumed blended rate based on purchased and generated electrical power.
Averaged Energy Charge (Notes 1 and 2) Assumption:	\$0.0420 /KVVII	MINISD IT STELECTRICAL UTIL COSLXISX THE	Assumed blended rate based on purchased and generated electrical power.
	e in average day electrical demand results in a minimal ch	gange in the neak demand costs	
1) Demand charges are not be included since the charg	e in average day electrical demand results in a minimal ci	lange in the peak demand costs	
New Centrifugal Blower PAC 1 Energy Usage		SOURCE	Comments
		Jones Island Power Load Profiling PowerPoint	
		developed by Sidharta(Sid) Arora, P.E. attached to	
		email from Bill Krill, dated 5/11/15, subject: JI Power	
Electrical Usage	26.3 kW/kscfm	Load Profiling.pptx	
	_0.0	·-·····9·FF	
Existing System Maintenance		SOURCE	Comments
Difference Development			
<u>Diffuser Replacement</u>	COOT AD HIGTMENT AD HIGH		
Actual	COST ADJUSTMENT ADJUSTED		
Unit Cost	Cost ENR AdjustmentUNIT COST		
(\$)	Year Index Factor (\$)	Did no active d 4/0/40 are 100000004 from \$1	This was based on 28,875 plates being replaced. The project was halted and this
\$17	7 Apr-12 11877 1.24 \$22	Bid received 4/2/12 on J02008C01 from Ahern, lowest	
		bid	work removed from the installation contract J02008C03.
		File: Channel Diffuser plate count 102710, developed	
Total number of diffusers	15136		
Total linear feet of channel	17.401	as part of J02008, JI Aeration Upgrades Project Facility Dimensions information	
Diffusers/LF	0.87	i acinty dimensions information	
Diffusers/LF Assuming	100 year life		
•	150 diffusers a year		
Need to replace	150 ulliusers a year		

FACILITY DIMENSIONS

Facility Number	Chan	nel Description	Length (ft)	Width (ft)	Surface Area per Channel (ft²)	Number of Channels	Total Surface Area (ft²)	Water Depth (ft)	Typical distance between drop legs (ft)**
209/210/ 211	Secondary Flow Control Structure Channels	Front Pass	297	17.5	5,197	1	5,197	~13-15	20
		Return Pass (2)	265	12.0	3,183	2	6,366		18
	TOTAL		827				11,563		
213	West Plant Mixed Liquor Channels (2)	From Flow Control Structure to Basin 1 From Basin 1 to 12	360 630	8.3 12.0	2,970 7,560	2 2	5,940 15,120	~12-13	32-40
	TOTAL		1,980		1,000		21,060		
214	East Plant Mixed Liquor Channels (2)	North/South Run East/West + Diagonal Runs	849 378	14.0 12.0	11,879 4,533	2 2	23,758 9,066	~14	42 42
	TOTAL	-	2,453				32,824		İ
	Aerated Effluent Channels	East Plant North/South Run (2) East Plant East/West + Diagonal	957	12.0	11,486	2	22,971		65-80
220		Runs (2) East Plant Channel Around	449	8.0	3,594	2	7,188	~8-9	60
220		Clarifiers West Plant Channels Around	1,530	8.0	12,237	1	12,237	-	
		Clarifiers (2) West Plant Channel Around	1,596	8.0	8.0 12,767 2 25,5		25,533		
		Clarifiers	283	8.0	2,264	1	2,264		
	TOTAL	T	7,817				70,193	•	1
233	RAS Channels	East Plant RAS Channels West Plant RAS Channels	1,503 659	6.0 6.0	9,018 3,954	2 2	18,036 7,908	~5-6	
	TOTAL		4,324				25,944		
205 205 234/235	Additional Channels*								
247	TOTAL	Effluent Pump Station	17,401				161,584		

^{*} Additional channels do receive minimal process air, but modifications are difficult to achieve so not included in channel mixing alternative evaluation.

Source: Data developed from available record drawings and estimated for remaining channels as part of the J02008, JIWRF Aeration System Upgrades Project

^{**} Drop leg information needs to be verified in the field



APPENDIX 6E-7: SW FG3 Effluent Heat Recovery Backup -



ALTERNATIVE 31

Large-Scale Effluent Heat Recovery Using Heat Pumps

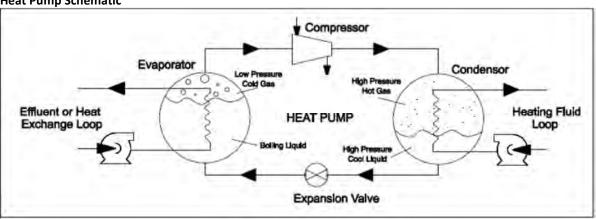
Alternative Description

Alternative 31 evaluates recovering heat from the plant effluent using heat pumps. Treated final effluent from a wastewater treatment plant offers a convenient and reliable source of heat at a relatively high temperature (compared to surface or ground waters). The heat pump withdrawal would take the water from the effluent channel after the chlorine contact tank and heat a circulating water loop. The heated water can then be used in another part of the treatment plant through the plant's heat loop. Effluent temperatures at the Jones Island and South Shore WRFs are above 50 degrees Fahrenheit throughout the year, presenting adequate temperatures for heat pump operation. Exhibit 31-1 shows a schematic of a water-to-water heat pump.

Hot water heating system temperatures often operate between 160 and 199 degrees to provide adequate temperatures for process heating. One issue with integrating effluent heat pumps into an existing plant heating system is that the temperature of the hot water produced is limited to a value of about 110 degrees greater than the effluent water temperature. In addition, the efficiency of the process decreases as the hot water temperature set point is increased. If the plant heating system is designed and operated at 190 degrees, some heating system components might not have sufficient heat transfer area or flow capacity with lower temperature water on very cold days.

EXHIBIT 31-1

Heat Pump Schematic



Description of Modifications Required

The heat pump would be installed at the final effluent conduit. One example water source heat pump model, which is suitable for producing 170-degree heated water, is capable of recovering 1.7 million Btu/hr of thermal energy. This heat pump was chosen because of its ability to heat water to 170 degrees and to handle the flow from the final effluent. If the plant requires more heat, two or more heat pumps can be placed in parallel to get the desired heat output.

A water pump to circulate the water taken from the final effluent conduit will be needed, along with insulated pipe to convey the hot water to a connection to the existing hot water system connection or another desired location.

Estimate of Energy Reduction or Recovery

The thermal energy recovered from the heat pumps can either be placed back into the plant's existing heat loop to help reduce heating cost during the winter months or the hot water from the heat pump could be used for other uses such as heating the sludge or polymer dilution water to increase cake solids as described in Alternative 16.

Exhibit 31-1 summarizes the potential energy that could be recovered from the treated effluent. The actual energy recovered will vary depending on the system design and configuration. There is much more heat in the effluent than could ever be used in the plant and the system size could be increased to cover all plant heating needs.

Cost Estimate

This alternative is estimated to have a capital cost of roughly \$905,000 for the example heat pump size described in Exhibit 31-3.

The heat generated by the heat pump may not be needed when buildings do not require heat. However, a chiller air conditioning system could be installed to use the energy. Exhibit 31-3 compares the cost to generate heat for the effluent heat pump system to other available sources of energy. In addition to the electrical cost to run the heat

EXHIBIT 31-2
Potential Energy Recovery from the Jones
Island and South Shore WRFs Effluent Using
Heat Pumps

Average flow rate: Jones Island WRF and South Shore WRF, mgd	97
Hot water produced temperature, °F	170
Coefficient of performance, COP	2.3
Effluent temperature, °F	50.6 to 67
Thermal energy output, MMBtu/hr	1.77
Operating power, kW	222
Effluent flow rate, gpm	424

Note: Data are for a multistack model #MS105AN

pump, there is a small energy requirement to pump the final effluent through the heat pump. This does not include the cost of capital to install the heat pump system and if that were included it would make the cost of generating heat with the heat pump higher. This shows that at current natural gas prices, a heat pump system would be more costly than heat generated by a natural gas boiler. As natural gas prices rise due to inflation, the gap between the cost to generate energy using a heat pump system and natural gas would narrow. Exhibit 31-4 is the complete cost estimate.

EXHIBIT 31-3

Comparison of Effluent Heat Pump System to Other Purchased Energy Sources

Cost to produce 1,000,000 Btu

Energy Source	Equipment	Efficiency or COP	Heat Value	Cost of Source ^a	Cost per MMBtu
Fuel oil	Boiler	80%	140,000 Btu/gal	\$3.09/gal	\$27.59
Natural gas	Boiler	78%	100,000 Btu/therm	\$0.60/therm	\$7.69
Electric	Water source heat pump	2.3	3413 Btu/kW	\$0.07 kWh	\$8.91

^a Approximate MMSD cost to purchase.

EXHIBIT 31-4

Cost Estimate for Alternative 31

Capital Costs		
Heat pumps		\$200,000
Water pumps	2	\$60,000
10-inch ductile iron pipe (300 ft)		\$47,670
12-inch ductile iron pipe (100 ft)		\$20,010
Installation (30% of equipment)		\$98,304
Subtotal—Project Cost		\$425,984
Markups		
Site, piping, electrical, I&C, demolition, etc.	20%	\$85,197
Subtotal		\$511,181
Contingency	25%	\$127,795
Subtotal		\$638,976
Contractor mobilization, bonds, and insurance	20%	\$127,795
Subtotal		\$766,771
Subtotal with markups		\$766,771
Total Construction Cost		\$766,771
Non-Construction Costs		
Engineering/administration	18%	\$138,019
Subtotal—Non-Construction Costs		\$904,790
Total Capital Cost (2014 dollars)		\$904,790
O&M Costs (using 2014 average loads)		Annual Cost
Power cost		-\$36,986
Additional O&M Labor (1% of new construction)		\$7,500
Additional maintenance—parts (1% of new equipment)		\$4,000
Natural gas fuel savings		-\$77,110
Total O&M Costs (2014)		-\$28,624

Milwaukee Metropolitan Sewerage District

2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Heat Recovery from Effluent

Available Energy from SSWRF Effluent

Theoretical Energy Available from SSWRF Effluent

Assumed Flow 150 MGD, or 104,167 gpm

Assumed Temperature Change 2 degrees (either increase or decrease)

Calculated energy available by transfering heat from or to effluent: 912,135 MMBTU/yr

Amount of available energy from the SSWRF effluent using a heat pump:

Using the heat pump recommended by the Final Energy Plan, Contract No. M03072P01 in January 2015 (Energy Plan):

Average flow rate: South Shore WRF, mgd 97
Hot water produced temperature, °F 170
Coefficient of performance, COP 2.3
Effluent temperature, °F 50.6 to 67
Thermal energy output, MMBtu/hr 1.77
Operating power, kW 222
Effluent flow rate, gpm 424

Annual thermal energy that could be produced: 15,505 MMBtu, at 1.77 MMBtu/hr

Comparing energy required to operate existing natural gas (NG) boiler to heat pump, using information from Energy Plan NG Boiler with 78% efficiency requires 1.28 MMBTU to produce 1 MMBTU of thermal energy for heating

Selected Heat Pump requires 0.43 MMBtu to produce 1 MMBtu of thermal energy for heating

Reduction in energy from boiler to heat pump: -66.09%

SSWRF Total Power Requirement	Existing	Proposed	Change
	MMBTU/yr	MMBTU/yr	%
Electricity Purchased	83,500	90,100	8%
NG Purchased for facility heating	25,700	8,700	-66%
Other Energy Purchased/Generated	266,100	266,100	0%
Total Energy Purchased/Generated	375,300	364,900	-3%

Existing data is 2013 data from Table 5 in Energy Plan, TM2 - Energy Baseline

Milwaukee Metropolitan Sewerage District

2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Heat Recovery from Effluent

Effluent Temperature Review

	PE Temp	Min	Max		Ave
Jan	50-56		50	56	53
Feb	50-55		50	55	52.5
Mar	48-55		48	55	51.5
Apr	50-55		50	55	52.5
May	51-56		51	56	53.5
Jun	54-58		54	58	56
Jul	55-60		55	60	57.5
Aug	55-60		55	60	57.5
Sep	55-60		55	60	57.5
Oct	55-60		55	60	57.5
Nov	53-58		53	58	55.5
Dec	52-58		52	58	55
		Annual	Annua	I	Annual
		Min	Max		Average
			48	60	54.95833

Data in email to Kate Ziino by Dennis Dineen, Donohue & Associates, on 12/7/16, from forwarded email from Marty Dierker, Veolia, on 12/11/2009
Assume degrees are in Fahrenheit



APPENDIX 6E-8: SSWRF Influent Power Generation Backup -

ALTERNATIVE 78

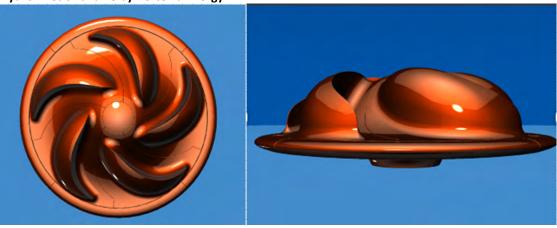
Large-Scale Hydrokinetic Turbines/Micro-Hydropower

Alternative Description

This alternative involves recovery of the hydraulic energy captured from plant effluent flow by means of a hydrokinetic turbine. A hydrokinetic turbine has a rotating element or runner that is attached to a power generator. The assembly typically is either in a floating arrangement, anchored to the floor of an effluent channel (see Exhibit 78-1), or contained in a pipe. The hydroturbine is operated by the flow from the treated effluent water before it is discharged to Lake Michigan. The effluent would be diverted from the outfall pipeline to pass through a turbine-generator unit before flowing into the lake. An in-pipe turbine, which has been used in potable water systems, could also be used.

EXHIBIT 78-1

Hydrokinetic Turbine by Verterra Energy

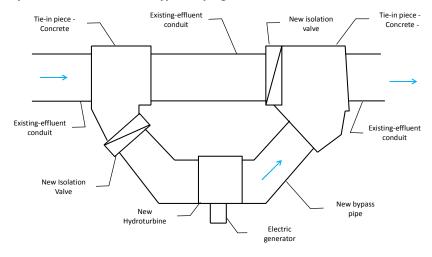


Description of Modifications Required

The hydrokinetic turbine would be operated roughly 7 months of the year. The remainder of the year, the effluent head would not be enough to justify operating the turbine because of high lake levels. Piping at least 72 inches in diameter and about 40 feet long would be installed parallel to the effluent channel to house the turbine. Effluent would bypass the turbine when it is not operational or during periods of high lake levels. Isolation valves could operate automatically based on lake level. If this alternative were to be refined further, other locations for

EXHIBIT 78-2

Hydrokinetic Turbine and Bypass Piping



capturing hydro energy could be evaluated. -

Exhibit 78-2 shows the possible location of the hydrokinetic turbine and the bypass piping. -

Estimate of Energy Reduction or Recovery

Exhibit 78-3 shows the amount of electrical energy that could be produced by the hydroturbine, based on the available head between effluent water level and the Lake Michigan surface elevation. The estimate is based on the water level of Lake Michigan and the effluent flow in a typical year. The power output would vary, but average about 13 kW.

EXHIBIT 78-3 **Hydrokinetic Energy Recovery**

Available Head (ft)	Hours per year	Plant Flow (cfs)	Power Output (kW)	Electric Output (kWh)	Electric Value (kWh)	Electric Value
2.00	8.76	123.78	14.68	129	\$0.09	\$12
1.99	867.24	124.81	14.72	12,770	\$0.09	\$1,149
1.95	876	173.80	20.06	17,571	\$0.09	\$1,581
1.94	876	143.12	16.49	14,444	\$0.09	\$1,300
1.86	876	99.02	10.90	9,548	\$0.09	\$859
1.60	876	202.68	19.18	16,804	\$0.09	\$1,512
1.59	876	123.00	11.57	10,134	\$0.09	\$912
1.35	701	107.53	8.62	6,046	\$0.11	\$665
1.33	701	130.74	10.33	7,242	\$0.11	\$797
1.16	701	153.17	10.50	7,360	\$0.11	\$810
1.13	701	129.19	8.68	6,082	\$0.11	\$669
1.07	701	115.27	7.31	5,123	\$0.11	\$564
	8,761			113,251		\$10,830

Cost Estimate

Exhibit 78-4 presents the estimated cost to implement the alternative.

EXHIBIT 78-4

Cost Estimate for Alternative 78

Capital Costs		
Hydrokinetic turbine		\$250,000
Generator		\$10,000
Concrete work		\$200,000
72-inch reinforced concrete pipe	40 ft	\$12,840
72-inch 45° bend	2 each	\$15,000
Isolation valve	1 each	\$25,000
Temporary bypass		\$250,000
Electrical conduit, cables, etc.		\$200,000
Installation (30% of equipment)		\$141,852
Subtotal—Project Cost		\$1,104,692
Markups		
Site, piping, electrical, I&C, demolition, etc.	23%	\$254,079
Subtotal		\$1,358,771
Contingency	25%	\$339,693
Subtotal		\$1,698,464
Contractor mobilization, bonds, and insurance	20%	\$339,693
Subtotal		\$2,038,157
Subtotal with Markups		\$2,038,157
Total Construction Cost		\$2,038,157
Non-Construction Costs		
Engineering/administration	18%	\$366,868
Subtotal—Non-Construction Costs		\$2,405,025
Total Capital Cost (2014 dollars)		\$2,405,025
O&M Costs (using 2014 average loads)		Annual Cost
Power savings		-\$10,830
Additional O&M labor (1% of new construction)		\$20,500
Additional maintenance—Parts (1% of new equipment)		\$11,000
Total O&M (2014)		\$20,670

Alternative Variation—Utilize Head between South Shore WRF Grit Chambers and Primary Clarifiers

A variation of this alternative would be to install a turbine or bank of turbines to capture energy from the head drop between the grit chambers and primary clarifiers at the South Shore WRF. Under average flow conditions, the head drop is about 4.4 ft. Assuming an average annual flow of 90 mgd and full time operation of the turbines, the annual power savings would be about \$20,700 at a rate of \$0.07/KWH. The capital cost of installation and annual O&M cost for the turbine facility would be at least as high at that estimated in Exhibit 78-4 for a facility to recovery energy from the effluent line. With an energy savings of \$20,700, there would be a net additional O&M cost for the turbine installation.

Milwaukee Metropolitan Sewerage District 2050 FACILITIES PLAN ENERGY ALTERNATIVE EVALUATIONS:

Power Generation with SSWRF Influent

MANUFACTURER REVIEW

Viable Manufa	cturers for SSW	RF Conditions	Non-viab	le Manufacture	ers for SSWRF Co	nditions	No info	rmation was g	athered
Toshiba International Hydro-eKIDs	Natel hydroEngine	Verterra Energy Inc Hydrokinetic	LucidPipe Power System	Rentricity SEMS	Canyon Hydro- Kaplan Turbine	12" Hydrocoil Unit	Hydrovolts C- 12 Canal Turbine	SLUICE Micro Hydropower Turbine Sluice Gate	Turbiwatt Lion Turbine
5 kW to 200 kW	Eric Thompson	Ted Christopher	_	5 to 30 kW	30 to 50 ft of head	7.2 MGD			
In pipe installation	8 ft head, 15 kW rated capacity, 61 MWh annually	Pilot project in	24"-96" pipes	20 psi+	100 to 400 cfs	In pipe			
6 to 49 ft head	\$75k for equipment plus almost \$75k to install	Open channel installation	11 to 100 ft head		turndown: 35% of design flow	8 to 10 kW			
		In-pipe is better, except for clogging issue				10 to 100 ft head			
\$7,000 to \$30,000 per unit		Power generation estimate later in July, 10-20 kW? Min 20%							
		efficiency Small depth, high velocity is ideal							

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Power Generation with SSWRF Influent

COST TABLE

OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Toshiba International Hydro-eKIDS Turbine

General Description

Install the Hydro-eKIDS turbine in the 36" pipes from the grit unit process to the primary clarifiers. For this assumption, did not assume turbines installed in bypass lines but directly into SSWRF system piping.

Construction					
	Unit Cost	С	onst. Cost		
ITEM	Units	System Quantity	 (\$)		(\$)
Turbines	Each	4	\$ 13,500.00	\$	54,000
Generator	LS	1	\$ 15,000.00	\$	15,000
Temporary Bypass	LS	1	\$ 70,000.00	\$	70,000
Electric conduits, cables, etc.	LS	1	\$ 100,000.00	\$	100,000
Unknowns - site, piping, electrical, I&C, demolition, etc.	LS	1	\$ 60,000.00	\$	60,000
Subtotal Material Cost				\$	299,000
Subtotal Labor Cost				\$	-
Contingency			20%	\$	60,000
Undesigned Details			40%	\$	120,000
Subtotal				\$	479,000
Contractor Overhead & Profit			15%	\$	72,000
Design, Bidding and MMSD Oversight			40%	\$	192,000
Total Construction Cost				\$	743,000

Operation and Maintenance Costs									
			Unit Cost	An	nnual Cost				
ITEM		Quantity		(\$)		(\$)			
Power Savings	LS	1	\$	(14,000.00)	\$	(14,000)			
Additional Operational Labor Costs	1	\$	6,000.00	\$	6,000				
Additional Equipment Maintenance Costs	LS	1	\$	1,000.00	\$	1,000			
Net Estimated Annual Operation and Maintenance Cost Savings					\$	(7,000)			
Life Cycle Analysis									
Annual Increase in Costs	0.00%								
Discount Rate	3.375%								
Number of Years	20								
Present Worth Factor	14.375								
Present Worth of Operation and Maintenance Costs Savings					\$	(101,000)			

Salvag	e Values				
ITEM	Units	Quantity	Unit Value (\$)	Val	
No salvage value for this option	Each	0	0		
Total Salvage Val	ue			\$	-

Capital Costs Present Worth of O&M Costs	\$ 700.000
	700,000
Dresent Worth of Column Volum	\$ (100,000)
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 600,000

ENR Construction Cost Index, MKE area projected to December 2019 (14700)

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Power Generation with SSWRF Influent

COST TABLE OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Natel hydroEngine Turbine

General Description

Install the hydroEngine turbine in the 36" pipes from the grit unit process to the primary clarifiers. For this assumption, did not assume turbines installed in bypass lines but directly into SSWRF system piping.

	Construction Costs						
				-	Unit Cost	С	onst. Cost
	ITEM	Units	System Quantity		(\$)		(\$)
Turbines and Generator Cost		LS	1	\$	75,000.00	\$	75,000
Installation Cost		LS	1	\$	75,000.00	\$	75,000
	Subtotal Material Cost					\$	150,000
	Subtotal Labor Cost					\$	-
	Contingency				20%	\$	30,000
	Undesigned Details				40%	\$	60,000
	Subtotal					\$	240,000
	Contractor Overhead & Profit				15%	\$	36,000
	Design, Bidding and MMSD Oversight				40%	\$	96,000
	Total Construction Cost					\$	372.000

Operation and Maintenance Costs									
			Unit Cost		Annual Cost				
ITEM		Quantity		(\$)		(\$)			
Power Savings	LS	1	\$	(11,000.00)	\$	(11,000)			
Additional Operational Labor Costs	1	\$	3,000.00	\$	3,000				
Additional Equipment Maintenance Costs	LS	1	\$	1,000.00	\$	1,000			
Net Estimated Annual Operation and Maintenance Cost Savings					\$	(7,000)			
Life Cycle Analysis									
Annual Increase in Costs	0.00%								
Discount Rate	3.375%								
Number of Years	20								
Present Worth Factor	14.375								
Present Worth of Operation and Maintenance Costs Savings					\$	(101,000)			

Salvag	je Values				
ITEM	Units	Quantity	Unit Value (\$)	Valu (\$)	ie
No salvage value for this option	Each	0	0		
Total Salvage Val	lue			\$	-

TOTAL PRESENT WORTH	
Capital Costs	\$ 400,000
Present Worth of O&M Costs	\$ (100,000)
Present Worth of Salvage Value	\$ -
Total Present Worth	\$ 300,000

ENR Construction Cost Index, MKE area projected to December 2019 (14700)

Milwaukee Metropolitan Sewerage District

2050 FACILITIES PLAN

ENERGY ALTERNATIVE EVALUATIONS: Power Generation with SSWRF Influent

ASSUMPTIONS

Theorectical Available HeadlossAveragePeakHeadworks Headloss (ft)4.49.2

This assumes that the piping between the grit and primary clarifier systems could be modified so that all of the existing headloss

could be eliminated.

Hydro-eKIDS Turbine Cost Assumptions

Cost and power information

49 \$30,000 200

SSWRF Conditions - assumed turbine cost and power based on head available

Head Equipment

Available Cost Power (kW)
4.4 \$7,000 5
9.2 \$9,000 20

Capital Cost Assumptions:

Installed cost: \$13,500 Assume installation is 50% of equipment

General Assumptions based on review of cost estimate from Alternative 78 in 2015 Energy Plan:

Need an generator: \$15,000 Installation included

Don't need isolation valves or vaults - assume installation space is near existing meters

Temporary bypass for only 1/4 flow is needed, so 1/4 cost: \$70,000

Electric conduit, cables, etc is half as much: \$100,000

Unknowns - site, piping, electrical, I&C, demolition, etc. - assume 25% of subtotal

Operating Cost Assumptions:

Purchased Energy Charge \$0.0764 /kWh over the year

Rate Source: MMSD calculated SSWRF Purchased 2016 Electrical Rate - only used purchased rate since turbine power will replace

purchased electricity

Based on being able to only reduce the headloss under average day flow conditions.

Annual Power Cost Savings: \$4,000 based on 5 kW average annual power generation

Based on being able to reduce the headloss under peak flow conditions.

Annual Power Cost Savings: \$14,000 based on 20 kW average power generation

Additional Operating Costs due to additional equipment to operate and maintain:

Additional Operating Labor: 1% construction cost
Additional Parts Cost: 1% of equipment

Natel Turbine Cost Assumptions

Capital Cost Assumptions:

Equipment \$75,000 Install \$75,000

Operating Cost Assumptions:

Power Cost Savings: \$11,000 based on 15 kW average annual power generation

Same electric unit cost assumption as Hydro-eKIDS

Same additional operational cost assumption as Hydro-eKIDS

Power Usage Reduction Review

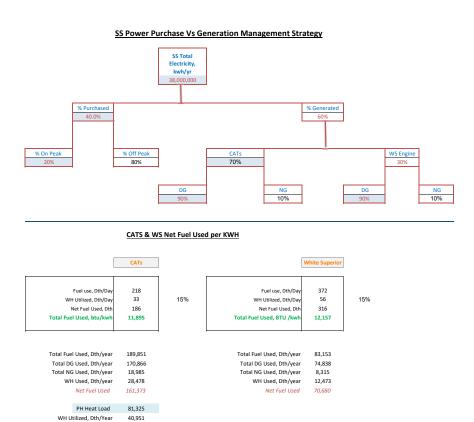
Power UsagekWMMBTU/yrHydro-eKIDS Turbine20600Natel Turbine15400

SSWRF Total Power Requirement MMBTU/yr Total Plant Electrical Purchase Reduction

Existing System, Electricity Used 83,500

 Hydro-eKIDS Turbine
 600
 0.7%

 Natel Turbine
 400
 0.5%



	South Shore Electricity Unit Co	<u>st</u>		
South Shore Annual Electricity Used	38,000,000 kwh/year	4.3 MW		
% Purchased	15,200,000 kwh/year	1.7 MW		
% Generated	22,800,000 kwh/year	2.6 MW		
Generated Power Cost				
Generated by CATS	15,960,000 kwh/year		Unit Cost of DG	\$0.00
Generated by WS	6,840,000 kwh/year		Unit Cost of NG	\$5.0
Cost to Generate Power by CATS			DG Utilization Summary	
Fuel Used, btu/kwh	11,895 btu/kwh		Total DG Used Engines, Dth	245,704
Total Fuel Used	189,851 Dth		Total NG Used Engines, Dth	27,300
Net DG Used, Dth	170,866 Dth	\$0		
Net NG Used, Dth	18,985 Dth	\$94,925	DG Used Sludge Heat/Bldg Heat, Dth	38,356
Cost to Generate Power by CATS		\$94,925	NG Used Other, Dth	2,019
Maintenance & Supervsion Costs	\$0.0240 2.4 cents/kwh	\$383,040		
Cost to Generate Power by WS			Total DG Used, Dth	284,059
Net Fuel Used, btu/kwh	12,157 btu/kwh		DG Flared, Dth	7,247
Total Fuel Used	83,153 Dth			
Net DG Used, Dth	74,838 Dth	\$0	DG Total (Used+ Flared), Dth	291,307
Net NG Used, Dth	8,315 Dth	\$41,576	DG Total, CF/day	1.388
Cost to Generate Power by WS		\$41,576	•	
Maintenance & Supervsion Costs	\$0.0240 2.4 cents/kwh	\$164,160		
Total Cost to Generate Power		\$683,702		\$0.030
Purchased Power Cost				
Purchased On Peak	3,040,000 kwh/year		ON Peak Electric Rate	\$ 0.07724
Purchased Off Peak	12,160,000 kwh/year		OFF Peak Electric Rate	\$ 0.05279
			Facilities Charge (\$/day)	\$17.26027
On Peak Demand, MW	1.5		Demand (\$/kw)	\$12.861
Fixed Cost of Purchased Power, per year	r	\$284,815	Customer Demand (\$/kw)	\$1.306
(Facility Charge+Coustomer Demand+On Pea	ak Demand)		customer demand load Actual (kw)	3,000
On Peak Costs		\$234,810		٦
Off Peak Costs		\$641,926		
Total Purchased Power Cost		\$1,161,551		0.076
Total Power Cost				
Total	38,000,000 kwh/year	\$1,845,253		\$0.049

Hydrokinetic	c Energy R	ecover					
Available Head Plant Flow			Power Outp	out	Electric Ou	Electric Va	ılue
(ft) I	Hours per y	(cfs)	(kW)		(kWh)	(kWh)	Electric Value
2	8.76	123.78	14.68	8.43188	129	\$0.09	\$12
1.99	867.24	124.81	14.72	8.47894	12766	\$0.09	\$1,149
1.95	876	173.8	20.06	8.664008	17573	\$0.09	\$1,582
1.94	876	143.12	16.49	8.6792	14445	\$0.09	\$1,300
1.86	876	99.02	10.9	9.084404	9548	\$0.09	\$859
1.6	876	202.68	19.18	10.56726	16802	\$0.09	\$1,512
1.59	876	123	11.57	10.63094	10135	\$0.09	\$912
1.35	701	107.53	8.62	12.47448	6043	\$0.11	\$665
1.33	701	130.74	10.33	12.65634	7241	\$0.11	\$797
1.16	701	153.17	10.5	14.58762	7361	\$0.11	\$810
1.13	701	129.19	8.68	14.88364	6085	\$0.11	\$669
1.07	701	115.27	7.31	15.76881	5124	\$0.11	\$564
	8,761				113,252		\$10,830

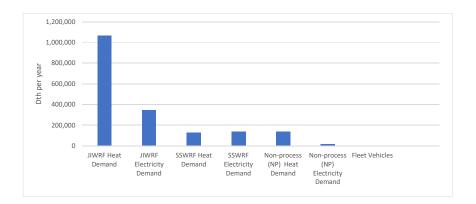


APPENDIX 6E-9: SW FG4 Energy Balance Calculations, Years 2017 and 2035 -



Existing Conditions

		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	1,065,559	297,542	768,017
JIWRF Electricity Demand	Dth/yr	342,789	141,776	201,013
SSWRF Heat Demand	Dth/yr	127,733	98,282	29,451
SSWRF Electricity Demand	Dth/yr	138,727	63,828	74,899
Non-process (NP) Heat Demand	Dth/yr	136,627	0	136,627
Non-process (NP) Electricity Demand	Dth/yr	18,119	639	17,480
Fleet Vehicles	Dth/yr	1,921	0	1,921
Totals	Dth/yr	1,831,475	602,067	1,229,408
% renewables		33%		
Landfill Gas Purchased	Dth/yr	380,423		
Digester Gas Produced	Dth/yr	284,706		
Solar Panels JI	Dth/yr	73		
Solar Panels HQ	Dth/yr	41		



Baseline Solids production= 56,980 DT/yr

Chapter 5: 2035 Energy Balance Annual Totals

REMOVE WE ENERGIES ENERGY FOR TOMORROW SINCE NOT USING RIGHT NOW

2000 Energy Balance / limital Fotals		Total Baseline	Renewable	Difference	Notes	Emissions Sources
JIWRF Heat Demand	Dth/yr	1,081,768	409,047	672,721		Dryers; Building Heat
JIWRF Electricity Demand	Dth/yr	400,397	0	400,397		No generation
JIWRF Purchased Renewable	Dth/yr					We Energies Energies Energy for Tomorrow
SSWRF Heat Demand	Dth/yr	145,990	145,990	0		Hot Water Boilers-DG
SSWRF Electricity Demand	Dth/yr	174,920	31,390	143,530		Solar Panels
SSWRF Purchased Renewable Elec						We Energies Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0		Building heat -SS RNG
Non-process (NP) Electricity Demand	Dth/yr	18,119	41	18,078		Solar Panels
NP Purchased Renewable	Dth/yr					We Energies Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	1,921	1,921	0		SS RNG
Totals	Dth/yr	1,959,742	725,015	1,234,726		
% renewables	.,	37%	,	, ,		
Landfill Gas Purchased	Dth/yr	417,623				
Digester Gas Produced	Dth/yr	· · · · · · · · · · · · · · · · · · ·				
Solar Panels JI	Dth/yr	•				
Solar Panels HQ	Dth/yr					
Net DG to RNG	Dth/yr	129,972				
Net DG to KNG Net DG after NP and Vehicles	Dth/yr	· · · · · · · · · · · · · · · · · · ·				
Solar Panels SS (5.2 MW project)	Dth/yr	31,390				
Soldi Tallels 33 (3.2 WW project)	Daily yi	31,330				
						REMOVE WE ENERGIES ENERGY FOR
Purchased Renewables	Dth/yr		0		0% Purchased Renewable	TOMORROW SINCE NOT USING RIGHT NOW
Add'nl LFG or DG for 100% renewable	Dth/yr	672,721				Gas Combustion Turbines; Dryers
Total LFG Purchase	Dth/yr	,		AD+ 2,5	560 scfm	Exceeds LFG projection

Baseline Milo. Solids production= 62,780 DT/yr

Chapter 5

Data

Baseline Conditions

(33% WRF Future Conditions

Renewable) (37% Renewable)

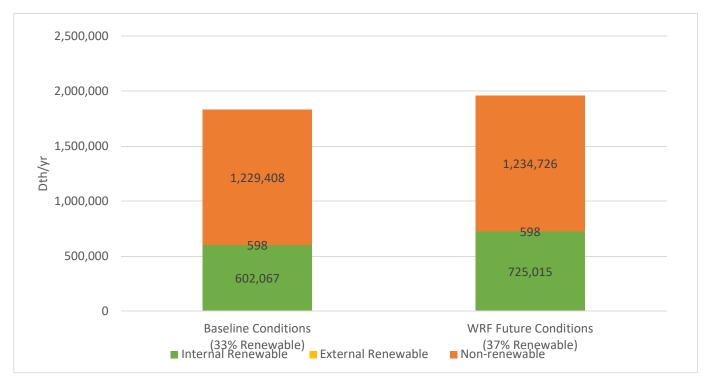
 Non-renewable
 1,229,408
 1,234,726

 External Renewable
 598
 598

 Internal Renewable
 602,067
 725,015

 0.328952504
 0.370146777

Graph



All LFG and DG to heat offsets

Existing Conditions

		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	1,065,559	529,547	536,012
JIWRF Electricity Demand	Dth/yr	342,789	41	342,748
SSWRF Heat Demand	Dth/yr	127,733	127,733	0
SSWRF Electricity Demand	Dth/yr	138,727	0	138,727
Non-process (NP) Heat Demand	Dth/yr	136,627	0	136,627
Non-process (NP) Electricity Demand	Dth/yr	18,151	671	17,480
Fleet Vehicles	Dth/yr	1,921	0	1,921
Totals	Dth/yr	1,831,507	657,992	1,173,515
% renewables		36%		
Landfill Gas Purchased	Dth/yr	380,423		
Digester Gas Produced	Dth/yr	284,706		
Solar Panels JI	Dth/yr	73		
Solar Panels HQ	Dth/yr	41		
Net DG to RNG*	Dth/yr	149,124		
*RNG offsets JI Heat Demand				

Baseline Solids Production=56,980 DT/yr

Existing Conditions

		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	790,069	651,962	138,108
JIWRF Electricity Demand	Dth/yr	342,789	0	342,789
SSWRF Heat Demand	Dth/yr	127,733	127,733	0
SSWRF Electricity Demand	Dth/yr	138,727	0	138,727
Non-process (NP) Heat Demand	Dth/yr	136,627	0	136,627
Non-process (NP) Electricity Demand	Dth/yr	18,151	671	17,480
Fleet Vehicles	Dth/yr	1,921	0	1,921
Totals	Dth/yr	1,556,017	780,366	775,652
% renewables		50%		
Landfill Gas Purchased	Dth/yr	380,423		
		•		
Digester Gas Produced	Dth/yr	413,563		
Solar Panels JI	Dth/yr	73		
Solar Panels HQ	Dth/yr	41		
Net DG to RNG	Dth/yr	271,539		

Digest all solid production= 41,245 DT/yr

Existing Conditions

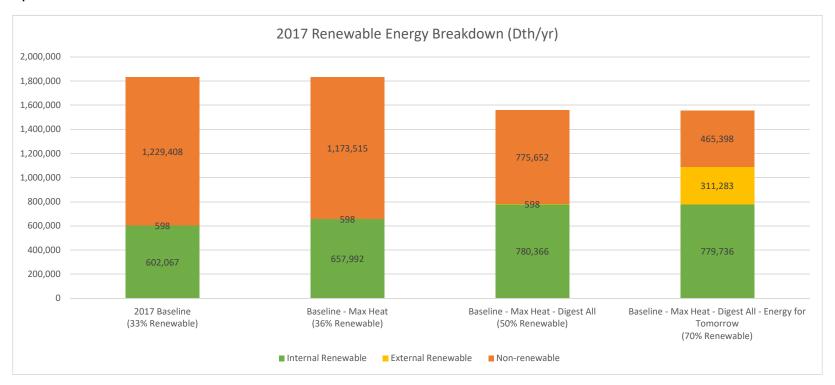
		Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	790,069	513,414	276,656
JIWRF Electricity Demand	Dth/yr	342,789	154,046	188,743
SSWRF Heat Demand	Dth/yr	127,733	127,733	0
SSWRF Electricity Demand	Dth/yr	138,727	138,727	0
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,551	41	
NP Purchased renewables			18,510	0
Fleet Vehicles	Dth/yr	1,921	1,921	0
Totals	Dth/yr	1,556,417	1,091,019	465,398
% renewables		70%		
Landfill Gas Purchased	Dth/yr	380,423		
Digester Gas Produced	Dth/yr	413,563		
Solar Panels JI	Dth/yr	73		
Solar Panels HQ	Dth/yr	41		
Net DG to RNG	Dth/yr	271,539		
Net DG after NP and Vehicles	Dth/yr	132,991		
Purchased Renewables	Dth/yr		311,283	
Add'nl LFG or DG for 100% renewable	Dth/yr	786,771		
Total LFG purchase		1,167,194		

Digest all solid production= 41,245 DT/yr

Data

	2017 Baseline						
	(33% Baseline - Max Heat		Baseline - Max Heat - Digest All	E	Baseline - Max Heat - Digest All - Energy for Tomorrow		
	Renewable)	(36% Renewable)	(50% Renewable)	(70% Renewable)		
Non-renewable	1,229,408	1,173,515	7	75,652	465,398	8	
External Renewable	598	598		598	311,283	3	
Internal Renewable	602,067	657,992	7	780,366	779,730	6	
Chapter 6							

Graph



Chapter 6 2035 Renewable Energy Breakdown (Dth per year)

ı	D	а	t	а

	Alt 0 - Baseline Milorganite, Existing Dryers (57% Renewable)	Milorganite, New	Alt 2 - Digest All Milorganite, New Dryers (76% Renewable)	Alt 3 - Class B Land Application (92% Renewable)	Alt 4 - Incineration of Digested Biosolids (91% Renewable)
LFG Required for 100% Renewable	994,312	854,884	550,333	155,087	185,929
External Renewable	391,948	353,683	321,033	187,891	198,571
Internal Renewable	725,015	725,015	895,160	698,200	703,179
Internal + Added LFG Renewable Perce	81%	82%	82%	82%	82%
TOTAL	2,111,276	1,933,583	1,766,527	1,041,179	1,087,680
% reduction in total energy from Alt 0		8%	16%	51%	48%
% increase in internal renewable from Alt 0		0%	23%	-4%	-3%
Granh					





Chap 6 - Alt 0 - Baseline milorganite with existing dryers 2035 Energy Balance Annual Totals

0,							
		Total Baseline	Renewable	Difference		Notes	Emissions Sources
JIWRF Heat Demand	Dth/yr	1,081,768	,	672,721			Dryers; Building Heat
JIWRF Electricity Demand	Dth/yr	400,397	0				No generation
JIWRF Purchased Renewable	Dth/yr		230,340	•			We Energies Energies Energy for Tomorrow
SSWRF Heat Demand	Dth/yr	145,990	145,990	0			Hot Water Boilers-DG
SSWRF Electricity Demand	Dth/yr	174,920	31,390	1			Solar Panels
SSWRF Purchased Renewable Elec			143,530)			We Energies Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0			Building heat -SS RNG
Non-process (NP) Electricity Demand	Dth/yr	18,119	41				Solar Panels
NP Purchased Renewable	Dth/yr		18,078	0			We Energies Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	1,921	1,921	. 0			SS RNG
Totals	Dth/yr	1,959,742	1,116,964	842,705			
% renewables		57%					
Landfill Gas Purchased	Dth/yr	417,623					
Digester Gas Produced	Dth/yr	282,802					
Solar Panels JI	Dth/yr	73					
Solar Panels HQ	Dth/yr	41					
Net DG to RNG	Dth/yr	129,972					
Net DG after NP and Vehicles	Dth/yr	-8,576					
Solar Panels SS (5.2 MW project)	Dth/yr	31,390					
Purchased Renewables	Dth/yr		391,948	1	20	0% Purchased Renewables	
	-						
Add'nl LFG or DG for 100% renewable	Dth/yr	994,312					Gas Combustion Turbines; Dryers
Total LFG Purchase	Dth/yr	1,411,935			AD+ 3,784	scfm	Exceeds LFG projection

Baseline Milo. Solids production= 62,780 DT/yr

Chap 6 - Alt 1 - Baseline milorganite with new dryers 2035 Energy Balance Annual Totals

		Total Baseline	Renewable	Difference		Notes	Emissions Sources
JIWRF Heat Demand	Dth/yr	913,421	409,047	504,374	-16%		Dryers; Building Heat
JIWRF Electricity Demand	Dth/yr	383,004	· .)			No generation
JIWRF Purchased Renewable	Dth/yr		197,661	•			We Energies Energies Energy for Tomorrow
SSWRF Heat Demand	Dth/yr	•	145,990	0			Hot Water Boilers-DG
SSWRF Electricity Demand	Dth/yr	169,334	31,390)			Solar Panels
SSWRF Purchased Renewable Elec			137,944	1			We Energies Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	7 0			Building heat -SS RNG
Non-process (NP) Electricity Demand	Dth/yr	18,119	41	L			Solar Panels
NP Purchased Renewable	Dth/yr		18,078	0			We Energies Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	1,921	1,921	L 0			SS RNG
Totals	Dth/yr	1,768,415	1,078,698	689,644			
% renewables		61%	•				
Landfill Gas Purchased	Dth/yr	417,623	}				
Digester Gas Produced	Dth/yr	282,802	!				
Solar Panels JI	Dth/yr	73	1				
Solar Panels HQ	Dth/yr	41	•				
Net DG to RNG	Dth/yr	129,972	!				
Net DG after NP and Vehicles	Dth/yr	-8,576	i				
Solar Panels SS (5.2 MW project)	Dth/yr	31,390)				
Purchased Renewables	Dth/yr		353,683	3		20% Purchased Renewables	
	•						
Add'nl LFG or DG for 100% renewable	Dth/yr	854,884	ļ				Gas Combustion Turbines; Dryers
Total LFG Purchase	Dth/yr	1,272,507	,	AD+ 3	3,253 scfm	n	

Baseline Milo. Solids production= 62,780 DT/yr

Chap 6 - Alt 2 - Digest all milorganite with new dryers 2035 Energy Balance Annual Totals

-		Total Baseline	Renewable	Difference		Notes	Emission Sources
JIWRF Heat Demand	Dth/yr	699,182	491,282	207,900	-35%		Dryers; building heat-LFG/SS RNG
JIWRF Electricity Demand	Dth/yr	378,215	64,000				Gas Combustion turbines, solar panels LFG/SS RNG
JIWRF Purchased Renewable			133,142	181,000		Credit for JI solar panels taken in difference	We Energies Energy for Tomorrow
SSWRF Heat Demand	Dth/yr	169,900	169,900	0		Boiler Eff= 80%	Hot Water Boilers- DG
SSWRF Electricity Demand	Dth/yr	200,771	31,390				Solar Panels
SSWRF Purchase renewables	Dth/yr		169,381				We Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0			Building heat
Non-process (NP) Electricity Demand	Dth/yr	18,551	. 41				Solar Panels
NP Purchased Renewable	Dth/yr		18,510	0			We Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	1,921	1,921	0			SS RNG
Totals	Dth/yr	1,605,167		388,900			
% renewables		76%	•				
Landfill Gas Purchased	Dth/yr	417,623	,				
Digester Gas Produced	Dth/yr	520,729			84%	Increase in digester production	
Solar Panels JI	Dth/yr	73			0470	increase in digester production	
Solar Panels HQ	Dth/yr	41					
Solar Panels SS (5.2 MW project)	Dth/yr	31,390					
Net DG to RNG	Dth/yr	333,288					
Net DG to KNG Net DG after NP and Vehicles	Dth/yr	194,740					
Net Do after NF and Vehicles	Dtil/yi	194,740	,				
Purchased Renewables	Dth/yr		321,033			20% Purchased Renewables	
Add'nl LFG or DG for 100% renewable	Dth/yr	550,333	ı				Dryers; Gas Combustion Turbines
Total LFG Purchase	Dth/yr	967,956		VD+ 3	2,094 scf	fm	Di yers, Gas Combustion Turbines
TOTAL EL O FUI CHASE	Daily yi	307,330	,	ADT 2	±,034 SCI	IIII	

Digest All Solids production= 46,720 DT/yr

		Total Baseline	Renewable	Difference	Notes	Emission Sources
JIWRF Heat Demand	Dth/yr	70,069	70,069	0	Heat demand met by SS RNG	Building heat-not known if boilers or direct/indirect fired heaters
JIWRF Electricity Demand	Dth/yr	320,215	244,222	75,993		Gas Combustion turbines- LFG/ RNG; solar panels
SSWRF Heat Demand	Dth/yr	169,900	169,900	0	Boiler eff 80% for digester heating	Hot water boilers-DG
SSWRF Electricity Demand	Dth/yr	200,771	1 31,390			Solar panels
SSWRF Purchased Renewable	Dth/yr		169,381	. 0		WE Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	7 136,627	0	SS RNG	Building heat-not known if boilers or direct/indirect fired heaters
Non-process (NP) Electricity Demand	Dth/yr	18,551	L 41			Solar panels
NP purchased renewable			18,510	0		WE Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	45,951	L 45,951	. 0		SS RNG
Totals	Dth/yr	962,084	886,091	75,993		
% renewables		92%	6			
Landfill Gas Purchased	Dth/yr	417,623				
Digester Gas Produced	Dth/yr	520,729				
Solar Panels JI	Dth/yr	73				
Solar Panels HQ	Dth/yr	41	L			
Solar Panels SS (5.2 MW project)	Dth/yr	31,390				
Net DG to RNG	Dth/yr	333,288				
Net DG after NP and Vehicles	Dth/yr	150,710)			
Purchased Renewables	Dth/yr		187,891		20% Purchased renewables	
Addled LEC as DC for 400% see small.	Dale 6	455.00	,			
Add'nl LFG or DG for 100% renewable	Dth/yr	155,087		40.	500 f	Con Combustion Turkings
Total LFG Purchase	Dth/yr	572,710	J	AD+	590 scfm	Gas Combustion Turbines

Digest all solid production= 46,720 DT/yr

2035 Energy Balance Annual Totals							
		Total Baseline	Renewable	Difference		Notes	Emissions Sources
JIWRF Heat Demand	Dth/yr	70,069) (70,069			
JIWRF Electricity Demand	Dth/yr	320,215	345,249	-25,033			Gas Combustion Turbines LFG/RNG
SSWRF Heat Demand	Dth/yr	169,900	169,900	0			Hot Water Boilers. Incinerator Heat Recovery
SSWRF Electricity Demand	Dth/yr	257,521	. 31,390)			Solar Panels
SSWRF Purchased Renewable	Dth/yr		180,061	46,070		Difference met by generation at JIWRF	We Energies Energy for Tomorrow
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	7 0			SS RNG
Non-process (NP) Electricity Demand	Dth/yr	18,551	. 41	L			Solar Panels
NP purchased renewable			18,510	0			We Energies Energy for Tomorrow
Fleet Vehicles	Dth/yr	19,973	19,973	3 0			SS RNG
Totals	Dth/yr	992,856	901,750	91,105			
% renewables		91%	Ď				
Landfill Gas Purchased	Dth/yr	417,623	1				
Digester Gas Produced	Dth/yr	520,729)				
Solar Panels JI	Dth/yr	73	1				
Solar Panels HQ	Dth/yr	41					
Solar Panels SS (5.2 MW project)	Dth/yr	31,390)				
Net DG to RNG	Dth/yr	443,566	i				
Net DG after NP and Vehicles	Dth/yr	286,966	i				
Purchased Renewables	Dth/yr		198,571	L		20% Purchased renewable electricity	
Addled LEC as DC for 4000/ same 11	Dul. /	405.000				In the March of the character for the first of the character for t	Can Carehouting Turkings
Add'nl LFG or DG for 100% renewable	Dth/yr	185,929			707 (Incin Waste heat meets building heat load	Gas Compustion Turbines
Total LFG Purchase	Dth/yr	603,552	!	AD+	707 scfm		

Digest all solid production= 46,720 DT/yr

		Total Baseline	Renewable	Difference		Notes
JIWRF Heat Demand	Dth/yr	70,069	70,069	0		Heat demand met by SS RNG
JIWRF Electricity Demand	Dth/yr	316,776	248,536	68,239		
SSWRF Heat Demand	Dth/yr	169,900	169,900	0		Boiler eff 80% for digester heating
SSWRF Electricity Demand	Dth/yr	204,081	31,390)		
SSWRF Purchased Renewable	Dth/yr		172,120	571		Difference met by generation at JIWRF
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0		
Non-process (NP) Electricity Demand	Dth/yr	18,551	41	_		
NP purchased renewable			18,510	0		
Fleet Vehicles	Dth/yr	37,147	37,147	0		
Totals	Dth/yr	953,151	884,340	68,811		
% renewables	, , .	93%				
Landfill Gas Purchased	Dth/yr	417,623				
Digester Gas Produced	Dth/yr	520,729				
Solar Panels JI	Dth/yr	73				
Solar Panels HQ	Dth/yr	41				
Solar Panels SS (5.2 MW project)	Dth/yr	31,390				
Net DG to RNG	Dth/yr	333,288				
Net DG to MVG Net DG after NP and Vehicles	Dth/yr	159,514				
Net bu after Mr and venicles	Dillyyl	133,314	•			
Purchased Renewables	Dth/yr		190,630)		
						Includes unmet SS electric demand- net
Add'nl LFG or DG for 100% renewable	Dth/yr	140,430	1			from JI generation
Total LFG Purchase	Dth/yr	558,053		AD+	534 scfm	3
	.,	,				

Digest all solid production= 46,720 DT/yr

Existing Conditions

		Total Baseline	Renewable	Difference	
JIWRF Heat Demand	Dth/yr	670,561	513,414	157,148	
JIWRF Electricity Demand	Dth/yr	342,789	148,614	194,175	
SSWRF Heat Demand	Dth/yr	127,733	127,733	0	
SSWRF Electricity Demand	Dth/yr	138,727	138,727	0	
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0	
Non-process (NP) Electricity Demand	Dth/yr	18,551	41		
NP Purchased Renewable	Dth/yr		18,510	0	
Fleet Vehicles	Dth/yr	1,921	1,921	0	
Totals	Dth/yr	1,436,909	1,085,586	351,323	
% renewables	, , .	76%	•		
Landfill Gas Purchased	Dth/yr	380,423			
Digester Gas Produced	Dth/yr	413,563			
Solar Panels JI	Dth/yr	73			
Solar Panels HQ	Dth/yr	41			
Net DG to RNG	Dth/yr	271,539			
Net DG after NP and Vehicles	Dth/yr	132,991			
Purchased Renewables	Dth/yr		287,382		
Add'nl LFG or DG for 100% renewable	Dth/yr	681,945			
Total LFG Purchase	Dth/yr	1,062,368		AD+36	00

Digest all solid production= 41,245 DT/yr

2000 Elicity Balance Allitual Totals					
		Total Baseline	Renewable	Difference	
JIWRF Heat Demand	Dth/yr	480,754	183,709	297,045	
JIWRF Electricity Demand	Dth/yr	374,776	226,574	ļ	
JIWRF Purchased Renewable	Dth/yr		54,731	93,398	Credit for JI solar panels taken in difference
SSWRF Heat Demand	Dth/yr	169,900	169,900	0	
SSWRF Electricity Demand	Dth/yr	204,081	204,081	. 0	
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	' 0	
Non-process (NP) Electricity Demand	Dth/yr	18,551	. 41	•	
NP Purchased Renewable	Dth/yr		18,510	0	
Fleet Vehicles	Dth/yr	1,921	1,921	. 0	
Totals	Dth/yr	1,386,610	996,094	390,443	
% renewables	.,	72%	•	,	
Landfill Gas Purchased	Dth/yr	417,623	.		
Digester Gas Produced	Dth/yr	520,729)		
Solar Panels JI	Dth/yr	73	}		
Solar Panels HQ	Dth/yr	41	L		
Net DG to RNG	Dth/yr	333,288	3		
Net DG after NP and Vehicles	Dth/yr	194,740)		
Purchased Renewables	Dth/yr		277,322	!	20% Purchased Renewables
Add'nl LFG or DG for 100% renewable	Dth/yr	473,743	}		
Total LFG Purchase	Dth/yr	891,366	5	AD+	1,803 scfm

Digest All Solids production= 46,720 DT/yr

2035 Energy Balance Annual Totals					
		Total Baseline	Renewable	Difference	Notes Emissions Sources
					Incinerator net heat recovery meets JI
JIWRF Heat Demand	Dth/yr	70,069	70,069	0	heat demand Incinerator
					Incinerator electricity demand taken as
JIWRF Electricity Demand	Dth/yr	378,215	344,021	1 34,194	the same as projected dryer electric load Gas Combustion Turbine LFG/RNG; incinerator steam
SSWRF Heat Demand	Dth/yr	169,900		,	
SSWRF Electricity Demand	Dth/yr	200,771			
SSWRF Purchased Renewable	Dth/yr		169,381		Difference met by generation at JIWRF
Non-process (NP) Heat Demand	Dth/yr	136,627			
Non-process (NP) Electricity Demand	Dth/yr	18,551			
NP purchased renewable	,	-,	18,510	0	
Fleet Vehicles	Dth/yr	3,000			
Totals	Dth/yr	977,133	942,939	34,194	
% renewables		97%	•		
Landfill Gas Purchased	Dth/yr	417,623			
Digester Gas Produced	Dth/yr	520,729			
Solar Panels JI	Dth/yr	73			
Solar Panels HQ	Dth/yr	41			
Solar Panels SS (5.2 MW project)	Dth/yr	31,390			
Net DG to RNG	Dth/yr	333,288			
Net DG after NP and Vehicles	Dth/yr	193,661			
	. , ,	,			
Purchased Renewables	Dth/yr		187,891	L	19% Purchased renewable electricity
Add'nl LFG or DG for 100% renewable	Dth/yr	69,783			Incin Waste heat meets building heat load
Total LFG Purchase	Dth/yr	487,406	i	AD+	266 scfm

Digest all solid production= 46,270 DT/yr

<u>.</u>		Total Baseline	Renewable	Difference	
JIWRF Heat Demand	Dth/yr	620,609	409,047	211,562	
JIWRF Electricity Demand	Dth/yr	383,004	0		
JIWRF Purchased Renewable	Dth/yr		138,046	244,885	
SSWRF Heat Demand	Dth/yr	145,990	120,780	25,210	
SSWRF Electricity Demand	Dth/yr	170,649	31,390		
SSWRF Purchased Renewable Elec			139,259		
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0	
Non-process (NP) Electricity Demand	Dth/yr	18,119	41		
NP Purchased Renewable	Dth/yr		18,078	0	
Fleet Vehicles	Dth/yr	1,921	1,921	0	
Totals	Dth/yr	1,476,919	995,190	481,656	
% renewables		67%			
Landfill Gas Purchased	Dth/yr	417,623			
Digester Gas Produced	Dth/yr	282,802			
Solar Panels JI	Dth/yr	73			
Solar Panels HQ	Dth/yr	41			
Net DG to RNG	Dth/yr	129,972			
Net DG after NP and Vehicles	Dth/yr	-8,576			
Solar Panels SS (5.2 MW project)	Dth/yr	31,390			
Purchased Renewables	Dth/yr		295,384	209	% Purchased Renewables
Add'nl LFG or DG for 100% renewable	Dth/yr	674,858			
Total LFG Purchase	Dth/yr	1,092,481		AD+ 2,568 scfm	

Baseline Milo. Solids production= 62,780 DT/yr

New Dryer Evaporation	Btu/lb H2O	1,500
Old Dryer Evaporation	Btu/lb H2O	1,800
Scalping dryer	Btu/lb H2O	1,500
Solids Energy Content	Btu/lb DS	9,800
Digester gas	Btu/scf	550 LHV
Cake Solids 2017 Baseline		17%
Cake Solids 2035 dryer		18%
Cake Solids 2035 haul		20%
Cake Haul Energy	MMBtu/WT	0.19 Based on 20% solids cake, 120 mile round trip. 3.4 MPG (DGE)
Solar Turbine Electric Eff		37%
Solar Turbine Heat Rec.		30%
		Based on 40% steam turbine efficiency, 30% of turbine input converted to
Solar Turbine Comb Cycle		49% steam.
Boiler Eff.		80%

Existing Conditions

-		Total Baseline	Notes/Source	Renewable	Difference
JIWRF Heat Demand	Dth/yr	699,182	AZ21 + building heat from 2017 plant data	297,542	401,640
JIWRF Electricity Demand	Dth/yr	374,776	BD24	141,776	233,000
SSWRF Heat Demand	Dth/yr	139,908	BA8 + building heat from 2017 plant data	98,282	41,626
SSWRF Electricity Demand	Dth/yr	204,081	BD16	63,828	140,253
Non-process (NP) Heat Demand	Dth/yr	136,627	no change	C	136,627
Non-process (NP) Electricity Demand	Dth/yr	18,119	no change	639	17,480
Fleet Vehicles	Dth/yr	1,921	no change	C	1,921
	5.1.7	. ==		500.05	
Totals	Dth/yr	1,574,614		602,067	972,547
% renewables		38%			
Landell Can Burshamad	Duly /	447.622			
Landfill Gas Purchased	Dth/yr	417,623			
Digester Gas Produced	Dth/yr	520,709	X81*365/10		
Solar Panels JI	Dth/yr	73			
Solar Panels HQ	Dth/yr	41			

Baseline Solids production= 46,720 DT/yr





Basis

1 DTh = 1 mmBtu

GHG Emission Factors for Biogas Combustion

 ${\rm CO_2}$ 115 lb/mmBtu ${\rm CH_4}$ 7.05E-03 lb/mmBtu ${\rm N_2O}$ 1.39E-03 lb/mmBtu

GHG Emission Factors for Sewage Sludge Incineration

CO₂^[2] 42%
Oxidation Factor^[3] 100%
Stoichiometric carbon
equivalence
CH₄ 7.05E-02 lb/mmBtu
N₂O 9.26E-03 lb/mmBtu

Global Warming Potentials CO₂

CH₄ 25 N₂O 298

Carbon sequesteration credits

Biosolids Application^[5]

-0.25 MT CO2/MT dry biosolids

Alternative GHG Emissions Attributable to Biogas/Biosolids Combustion under 2035 Conditions

Alternative 1 - Baseline N	lilo with new d	ryers
Digester Gas Combusted	282,802	mmBtu/yr
Landfill Gas Combusted	1,274,499	mmBtu/yr
Total Biogas	1,557,301	mmBtu/yr
GHG Associated with Biogas Comb	ustion	
CO ₂	89,385	tons/year
CH ₄	5.49	tons/year
N ₂ O	1.08	tons/year
GHG on CO ₂ e Basis ^[6]		
CO ₂	89,385	tons/year
CH ₄	137.3	tons/year
N ₂ O	322	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year
Total GHG on CO₂e Basis	89,839	tons/year

Alternative 3 - Class B land ap	plication of bi	osolids
Digester Gas Combusted	520,729	mmBtu/yr
Landfill Gas Combusted	565,691	mmBtu/yr
Total Biogas Combusted	1,086,420	mmBtu/yr
GHG Associated with Biogas Combust	tion	
CO ₂	62,358	tons/year
CH₄	3.83	tons/year
N ₂ O	0.754	tons/year
GHG on CO₂e Basis ^[6]		
_	62.257.64	*****
CO ₂	62,357.64	. ,
CH₄	95.8	tons/year
N ₂ O	225	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year
Total GHG on CO₂e Basis	62,672	tons/year

Alternative 2 - Digest all N	lilorganite with ne	w dryers
Digester Gas Combusted	520,729	mmBtu/yr
Landfill Gas Combusted	700,433	mmBtu/yr
Total Biogas	1,221,162	mmBtu/yr
GHG Associated with Biogas Cor	nbustion	
CO ₂	70,091	tons/year
CH ₄	4.31	tons/year
N ₂ O	0.848	tons/year
GHG on CO ₂ e Basis ^[6]		
CO ₂	70,091	tons/year
CH ₄	107.7	tons/year
N ₂ O	253	tons/year
Carbon Sequestration		
CO ₂	-5.78	tons/year
Total GHG on CO₂e Basis	70,446	tons/year

Alternative 4 - Incineration	on of digested biosolids
Digester Gas Combusted	520,729 mmBtu/yr
Landfill Gas Combusted	571,188 mmBtu/yr
Total Biogas	1,091,917 mmBtu/yr
Total Sludge Incineration [7]	918,982 mmBtu/yr
GHG Associated with Biogas Com	bustion
CO ₂	62,673 tons/year
CH ₄	3.9 tons/year
N ₂ O	0.76 tons/year
GHG Associated with Sewage Slu	dge Incineration
CO ₂ ^[7]	71,255.80 tons/year
CH ₄	32.4 tons/year
N ₂ O	4.25 tons/year
GHG on CO ₂ e Basis ^[6]	
CO ₂	133,929 tons/year
CH ₄	906.7 tons/year
N ₂ O	1,494 tons/year
Total GHG on CO₂e Basis	136,329 tons/year

Notes []:

- 1. Emission Factors obtained from 40 CFR §98, Subpart C, Tables C-1 and C-2. Emission factors are for gaseous biomass fuels.
- 2. Carbon content of domestic sludge from Tchobanoglous 1979
- 3. Oxidation factor from 2006 IPCC Guidelines. Vol 5 Ch. 5 $\,$
- 4. Global Warming Potentials obtained from 40 CFR $\S98$, Subpart A, Table A-1.
- 5. Biosolids Emissions Assessment Model developed by the Canadian Council of Ministers of the Environment (Version 1.1, 2011)
- 6. CO₂ equivalent (CO₂e) is each GHG constituents mass emission rate multiplied by the respective global warming potential.
- 7. Based on 46,270 dry tons per year of sewage sludge and an assumed heat content of 9,835 Btu/lb. Assumed heat content was obtained from published value measured at Green Bay, WI.



APPENDIX 6E-11: SW FG4 Project Conceptual Costs -

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 1, Baseline Milorganite with New Dryers SW FG4, Vision 2035 Energy Analysis

General Description:

Update to the 2015 Energy Plan using the recommendations from the SW FG4 evaluation:

- 1. Produce RNG at SSWRF to meet renewable energy needs at remote facilities and provide vehicle fuel.

 2. Expand the 3.2 MW solar array at SSWRF recommended in WRF FG4, Increase SSWRF Renewable Energy Use, to achieve 5.2 MW of solar power generation.
- 3.Acquire as much LFG as is available.
- 4. Purchase electricity at the renewable energy rate from We Energies
- 5.Research other renewable energy sources to supplement LFG sources.

	Capital Costs											Design,					
	Life			Un	it Cost	SUI	BTOTAL 1	Undesigned		SU	BTOTAL 2	Constr. Overhead	COI	NSTR. COST	Bidding, Const.	CAI	PITAL COST
ITEM	Years	Units	Quantity		(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
Evaluation - PM	NA	hrs	520	\$	250	\$	130,000	20%	20%	\$	180,000	0%	\$	180,000	0%	\$	180,000
Evaluation - Engineer	NA	hrs	3120	\$	150	\$	468,000	20%	20%	\$	660,000	0%	\$	660,000	0%	\$	660,000
Technical Expert	NA	hrs	400	\$	300	\$	120,000	20%	20%	\$	170,000	0%	\$	170,000	0%	\$	170,000
Project Engineer	NA	hrs	2080	\$	175	\$	364,000	20%	20%	\$	510,000	0%	\$	510,000	0%	\$	510,000
Expenses																\$	50,000
														Total	Capital Cost	\$	1,570,000

Notes:

1) Definitions:

Hrs - hours of time

- 2) Estimate includes advanced planning efforts including testing, contracting recommendations, preliminary design as appropriate
- 3) PM time meetings, oversight of evaluation and development of alternatives, review of reports, QC 2 years, 5 hrs per week
- 4) Engineer report development, investigation, testing as appropriate, Technical Expert multiple experts for RNG, LFG contracting, other renewable energy sources, Project Engineer oversight of report development and associated tasks
- 5) Only cost for evaluation includeds, no capital costs of potential recommendations

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 1 Baseline Milorganite - New Dryers

General Description:
Milorganite made at JIWRF with new dryers. All solids to Milorganite. Primary Sludge digested at SSWRF. Milo. Blend= WAS + digested sludge. No electrical generatic at SSWRF. DG above heating needs at SSWRF converted to RNG.

ENR Index = 14700 (projected to December 2019)
Annual Increase in Costs = 0.0%
Discount Rate
Number of Years 20

	Capital Costs				
	Life		Unmarked up	Capital Cost	
ITEM	Years	Units	Quantity	Unit cost	 (\$)
SSWRF Costs					
Architectural/Structural	0	0	0	0	\$ -
Earthwork	0	0	0	0	\$ -
Concrete	0	0	0	0	\$ -
Metals	0	0	0	0	\$ -
Buildings	40	LS	1	751,272	\$ 1,075,97
Demolition	0	LS	1	160,000	\$ 229,30
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$ 270,46
Digester 9, and 11 Cleaning	10	each	2	357,500	\$ 1,028,93
Digester 9, 11 Mixing	10	each	2	653,400	\$ 1,887,36
Thickened Sludge Pumps	10	each	3	25,492	\$ 117,59
Electrical - Dig 9 & 11 Mixing	20	LS	2	50,000	\$ 146,99
I&C - Dig 9 & 11 Mixing	20	LS	2	50,000	\$ 146,99
Digester Gas Treatment	20	Each	1	7,000,000	\$ 10,083,60
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$ 3,645,38
JIWRF Costs					
Architectural/Structural/Civil	0	0	0	0	\$ -
Sitework	0	LS	1	400,000	\$ 576,2
Demolition	0	LS	1	3,000,000	\$ 4,321,54
Buildings - D&D structural modifications	40	LS	1	3,000,000	\$ 4,321,54
Dryer Equipment & Installation (6 DDS 80s)	20	LS	1	79,200,000	\$ 114,088,77
Belt Filter Press Rehabilitation	20	LS	1	3,482,000	\$ 5,015,34
Solids Conveyance	10	LS	1	2,000,000	\$ 2,881,0
Process Piping	20	LS	1	4,000,000	\$ 5,762,0
Non-potable Water System	20	LS	1	3,000,000	\$ 4,321,5
Electrical	20	LS	1	9,681,840	\$ 13,946,5
I&C	20	LS	1	4,034,100	\$ 5,809,0

Operatio	n and Maintenance Costs				
ITEM	Units	Quantity	Unit Cost (\$)	,	Annual Cost (\$)
Chemical Costs	LS	1	\$1,120,185	\$	1,120,000
Electricity Costs - Purchased Renewables	MMBtu	353,683	\$35.45	\$	12,538,000
Contracted LFG Costs	MMBtu	417,623	\$2.50	\$	1,044,000
Additional LFG Costs to meet 80% MMSD Renewable	MMBtu	854,884	\$2.50	\$	2,137,000
Equipment Maintenance Costs	LS	1	\$1,900,000	\$	1,900,000
ladi da a sa a sa a sa a sa a sa a sa a s			(444	_	

Total Capital Cost

Total Annual O & M Costs Life Cycle Analysis
Present Worth (A/P) Factor to Year 2035
Present Worth of Operation and Maintenance Costs

\$ 171,137,882

2,939,278

179,676,292

	Equipment Replacement	Costs				
				Unit Value		Value
ITEM		Units	Quantity	(\$)		(\$)
Digester 9, and 11 Cleaning	20	each	2	357,500	\$	368,125
Thickened Sludge Pumps	10	LS	3	25,500	\$	54,892
Electrical - Dig 9 & 11 Mixing	10	LS	2	50,000	\$	71,754
I&C - Dig 9 & 11 Mixing	10	LS	2	50,000	\$	71,754
Solids Conveyance	10	LS	1	2,000,000	\$	1,435,076
Digester 9, 11 Mixing	10	each	2	653,400	\$	937,678
					S	-

12.208

Present Worth of Equipment Replacement Costs (Note 2)

Salvage V	alue				
			U	nit Value	Value
ITEM	Units	Quantity		(\$)	(\$)
RF Buildings	LS	1	\$	193,400	\$ (190,000)
F Building	LS	1	\$	772,291	\$ (770,000)
Array	LS	1	\$	532,022	\$ (530,000)
Present Worth of Salvage Value					\$ (1,490,000)

ITEM	Units	Quantity	(\$)	(\$)
SSWRF Buildings	LS	1	\$ 193,400	\$ (190,000)
JIWRF Building	LS	1	\$ 772,291	\$ (770,000)
Solar Array	LS	1	\$ 532,022	\$ (530,000)
Present Worth of Salvage Value				\$ (1,490,000)
TOTAL PRESENT WO	RTH			
Capital Costs				\$ 179,676,292
Present Worth of O&M Costs				\$ 171,137,882
Present Worth of Equipment Replacement				\$ 2,939,278
Present Worth of Salvage Value				\$ (1,490,000)
Total Present Worth				\$ 352,263,452

Notes: 1) See Capital Cost Details for additional capital cost breakdown. 3) See Cost Table Backup for additional detailed information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 1, Baseline Milorganite with New Dryers SW FG4, Vision 2035 Energy Analysis

General Description:

Insert description

						Capital Cost	ts							Desima		
	Life			Unit Cost	SI	UBTOTAL 1	Undesigned		SI	UBTOTAL 2	Constr. Overhead	со	ONSTR. COST	Design, Bidding, Const.	CA	PITAL COST
ITEM	Years	Units	Quantity	(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
SSWRF Costs																
Architectural/Structural				0	\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Earthwork				0	\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Concrete				0	\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Metals				0	\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Buildings	40	LS	1	751,272	\$	751,272	20%	20%	\$	1,050,000	25%	\$	1,310,000	40%	\$	1,830,000
Demolition		LS	1	160,000	\$	160,000	20%	20%	\$	220,000	25%	\$	280,000	40%	\$	390,000
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$	185,900	20%	20%	\$	260,000	25%	\$	330,000	40%	\$	460,000
Digester 9, and 11 Cleaning	20	each	2	357,500	\$	715,000	20%	20%	\$	1,000,000	25%	\$	1,250,000	40%	\$	1,750,000
Digester 9, 11 Mixing	10	each	2	653,400	\$	1,306,800	20%	20%	\$	1,830,000	25%	\$	2,290,000	40%	\$	3,210,000
Thickened Sludge Pumps	10	each	3	25,492	\$	76,475	20%	20%	\$	110,000	25%	\$	140,000	40%	\$	200,000
Electrical - Dig 9 & 11 Mixing	20	LS	2	50,000	\$	100,000	20%	20%	\$	140,000	25%	\$	180,000	40%	\$	250,000
I&C - Dig 9 & 11 Mixing	20	LS	2	50,000	\$	100,000	20%	20%	\$	140,000	25%	\$	180,000	40%	\$	250,000
Digester Gas Treatment	20	Each	1	7,000,000	\$	7,000,000	20%	20%	\$	9,800,000	25%	\$	12,250,000	40%	\$	17,150,000
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$	3,100,000	10%	20%	\$	4,030,000	10%	\$	4,430,000	40%	\$	6,200,000
JIWRF Costs																
Architectural/Structural/Civil					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Sitework		LS	1	400,000	\$	400,000	20%	20%	\$	560,000	25%	\$	700,000	40%	\$	980,000
Demolition		LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
Buildings - D&D structural modifications	40	LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
Dryer Equipment & Installation (6 DDS 80s)	20	LS	1	79,200,000	\$	79,200,000	20%	20%	\$	110,880,000	25%	\$	138,600,000	40%	\$	194,040,000
Belt Filter Press Rehabilitation	20	LS	1	3,482,000	\$	3,482,000	20%	20%	\$	4,870,000	25%	\$	6,090,000	40%	\$	8,530,000
Solids Conveyance	10	LS	1	2,000,000	\$	2,000,000	20%	20%	\$	2,800,000	25%	\$	3,500,000	40%	\$	4,900,000
Process Piping	20	LS	1	4,000,000	\$	4,000,000	20%	20%	\$	5,600,000	25%	\$	7,000,000	40%	\$	9,800,000
Non-potable Water System	20	LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
Electrical	10	LS	1	9,681,840	\$	9,681,840	20%	20%	\$	13,550,000	25%	\$	16,940,000	40%	\$	23,720,000
I&C	10	LS	1	4,034,100	\$	4,034,100	20%	20%	\$	5,650,000	25%	\$	7,060,000	40%	\$	9,880,000

Notes:

1) Definitions:

LS - lump sum

2) See Cost Table Backup for additional information

Total Capital Cost \$ 305,590,000

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide Project Alternatives Analysis



COST TABLE BACKUP
OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS
Alternative 1
Baseline Milorganite - New Dryers

Capital Costs

Unit cost for 3.2 SW solar array from WRF FG4 \$5,110,000
Unit cost for 5.2 MW solar array from WRF FG5 \$8,210,000

O&M Costs

Equipment Replacement Costs

Salvage Value

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 2 2035 Milorganite Digest All

General Description: Milorganite made from all digested sludge
All solids are digested at SSWRF. Milorganite made at JIWRF with new dryers. No electrical generation at SSWRF. DG above heating needs at SSWRF converted to RNG.

ENR Index = 14700 (projected to December 2019)
Annual Increase in Costs = 0.0%
Discount Rate 3.375%
Number of Years 20

	Capital Costs					
	Life			Unmarked up		Capital Cost
ITEM	Years	Units	Quantity	Unit cost		(\$)
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$	270,46
Digester 9, and 11 Cleaning	10	each	2	357,500	\$	1,028,93
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$	3,768,85
Digester 13, 14 Heat Exchanger	20	each	2	82,875	\$	241,06
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$	88,19
Digester 13, 14 Heating Pump	10	each	2	32,500	\$	88,19
Co-thickening GBTs	20	each	11	227,639	\$	3,615,98
Odor Hoods	20	each	11	23,808	\$	376,29
Thickened Sludge Pumps	20	each	5	25,492	\$	188,14
IPS Receiving Wet Well Mixing	20	each	3	57,850	\$	246,94
Digester Gas Treatment	20	each	1	7,000,000	\$	10,083,60
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$	3,645,38
SSWRF Architectural/ Structural/Building Cost	40	LS	1	12,001,083	\$	17,286,17
JIWRF Costs					\$	-
Architectural/Structural/Civil					\$	-
Sitework	20	LS	1	400,000	\$	576,20
Demolition	20	LS	1	3,000,000	\$	4,321,54
Buildings - D&D structural modifications	40	LS	1	3,000,000	\$	4,321,54
-					\$	-
Dryer Equipment & Installation (6 DDS 80s)	20	LS	1	66,000,000	\$	95,073,97
Belt Filter Press Rehabilitation	20	LS	1	3,115,080	\$	4,486,17
Solids Conveyance	10	LS	1	2,000,000	\$	2,881,03
Process Piping	40	LS	1	4,000,000	\$	5,762,05
Non-potable Water System	20	LS	1	3,000,000	\$	4,321,54
					s	_
Electrical	20	LS	1	8,054,000	\$	11,606,43
1&C	20	LS	1	3,356,000	\$	4,838,95
Tota	I Capital Cost				\$	179,117,72

Operation and Maint	enance Costs			
			Unit Cost	Annual Cost
ITEM	Units	Quantity	(\$)	(\$)
				\$ -
Electrical Costs (purchased renewable)	MMBTU	320,346	\$35.45	\$ 11,356,000
LFG costs	MMBtu	701,685	\$2.50	\$ 1,754,000
Equipment Maintenance	LS	1	\$1,500,000	\$ 1,500,000
Chemicals	LS	1	\$800,000	\$ 800,000
Residuals Management (Milo Revenue)	DT	46,270	(\$95.80)	\$ (4,433,000
Life Cycle Analysis				
Annual Escalation Factor to Year 2035	12.208			
Present Worth of Operation and Maintenance Costs				\$ 134,012,022

Equipment Rep	acement	Costs			
ITEM		Units	Quantity	Unit Value (\$)	Value (\$)
Digester 9, and 11 Cleaning	10	each	2	357,500	\$ 513,040
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$ 1,875,357
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$ 46,640
Digester 13, 14 Heating Pump	10	each	2	32,500	\$ 46,640
Solids Conveyance	10	LS	1	2,000,000	\$ 1,435,076
Present Worth of Equipment Replacement Costs					\$ 3,916,752

Salvage Value)				
			ι	Jnit Value	Value
ITEM	Units	Quantity		(\$)	 (\$)
SSWRF Buildings	LS	1	\$	3,089,442	\$ (3,090,000)
JIWRF Building	LS	1	\$	772,291	\$ (770,000)
Process piping	LS	1	\$	1,029,721	\$ (1,030,000)
Solar Array	LS	1	\$	532,022	\$ (530,000)
Present Worth of Salvage Value					\$ (5,420,000)

TOTAL PRESENT WORTH	
Capital Costs	\$ 179,117,725
Present Worth of O&M Costs	\$ 134,012,022
Present Worth of Equipment Replacement	\$ 3,916,752
Present Worth of Salvage Value	\$ (5,420,000)
Total Present Worth	\$ 311,626,499

Notes:
1) See Capital Cost Details for additional capital cost breakdown.
3) See Cost Table Backup for additional detailed information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN Systemwide Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 2, Milorganite Digest All, New Dryers SW FG4, Vision 2035 Energy Analysis

General Description: Digest all solids at SSWRF and make Milorganite at JIWRF
All solids are digested at SSWRF. Milorganite made at JIWRF with new dryers. No electrical generation at SSWRF. DG above heating needs at SSWRF converted to RNG

						Capital Cos	ts							Design,		
	Life			Unit Cost	s	UBTOTAL 1	Undesigned		S	UBTOTAL 2	Constr. Overhead	C	ONSTR. COST	Bidding, Const.	CA	PITAL COST
ITEM	Years	Units	Quantity	(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
SSWRF Costs																
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$	185,900	20%	20%	\$	260,000	25%	\$	330,000	40%	\$	460,000
Digester 9, and 11 Cleaning	10	each	2	357,500	\$	715,000	20%	20%	\$	1,000,000	25%	\$	1,250,000	40%	\$	1,750,000
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$	2,613,600	20%	20%	\$	3,660,000	25%	\$	4,580,000	40%	\$	6,410,000
Digester 13, 14 Heat Exchanger	20	each	2	82,875	\$	165,750	20%	20%	\$	230,000	25%	\$	290,000	40%	\$	410,000
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
Digester 13, 14 Heating Pump	10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
Co-thickening GBTs	20	each	11	227,639	\$	2,504,030	20%	20%	\$	3,510,000	25%	\$	4,390,000	40%	\$	6,150,000
Odor Hoods	20	each	11	23,808	\$	261,890	20%	20%	\$	370,000	25%	\$	460,000	40%	\$	640,000
Thickened Sludge Pumps	20	each	5	25,492	\$	127,459	20%	20%	\$	180,000	25%	\$	230,000	40%	\$	320,000
IPS Receiving Wet Well Mixing	20	each	3	57,850	\$	173,550	20%	20%	\$	240,000	25%	\$	300,000	40%	\$	420,000
Digester Gas Treatment	20	Each	1	7,000,000	\$	7,000,000	20%	20%	\$	9,800,000	25%	\$	12,250,000	40%	\$	17,150,000
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$	3,100,000	10%	20%	\$	4,030,000	10%	\$	4,430,000	40%	\$	6,200,000
SSWRF Architectural/ Structural/Building Cost	40	LS	1	12,001,083	\$	12,001,083	20%	20%	\$	16,800,000	25%	\$	21,000,000	40%	\$	29,400,000
JIWRF Costs					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
Architectural/Structural/Civil							20%	20%	\$	-	25%	\$	-	40%	\$	-
Sitework	20	LS	1	400,000	\$	400,000	20%	20%	\$	560,000	25%	\$	700,000	40%	\$	980,000
Demolition	20	LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
Buildings - D&D structural modifications	40	LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
					\$	-	20%	20%	\$	_	25%	\$	-	40%	\$	_
Dryer Equipment & Installation (6 DDS 80s)	20	LS	1	66,000,000	\$	66,000,000	20%	20%	\$	92,400,000	25%	\$	115,500,000	40%	\$	161,700,000
Belt Filter Press Rehabilitation	20	LS	1	3,115,080	\$	3,115,080	20%	20%	\$	4,360,000	25%	\$	5,450,000	40%	\$	7,630,000
Solids Conveyance	10	LS	1	2,000,000	\$	2,000,000	20%	20%	\$	2,800,000	25%	\$	3,500,000	40%	\$	4,900,000
Process Piping	40	LS	1	4,000,000	\$	4,000,000	20%	20%	\$	5,600,000	25%	\$	7,000,000	40%	\$	9,800,000
Non-potable Water System	20	LS	1	3,000,000	\$	3,000,000	20%	20%	\$	4,200,000	25%	\$	5,250,000	40%	\$	7,350,000
•					\$	-	20%	20%	\$	· · · · -	25%	\$	-	40%	\$	· · · · -
Electrical	20	LS	1	8,054,000	\$	8,054,000	20%	20%	\$	11,280,000	25%	\$	14,100,000	40%	\$	19,740,000
I&C	20	LS	1	3,356,000	\$	3,356,000	20%	20%	\$	4,700,000	25%	\$	5,880,000	40%	\$	8,230,000
					\$	-										
					\$	-										
					\$	-										
					¢								Total	Capital Cost	¢	304,640,000

Notes:

1) Definitions:

2) See Cost Table Backup for additional information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE BACKUP
OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS
Alternative 2
2035 Milorganite Digest All

Capital Costs

Unit cost for 3.2 SW solar array from WRF FG4 \$5,110,000
Unit cost for 5.2 MW solar array from WRF FG5 \$8,210,000

O&M Costs

Equipment Replacement Costs

Salvage Value

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 3 Class B Cake

General Description:

All solids are digested at SSWRF. Class B cake product made at SSWRF. No electrical generation at SSWRF. DG above heating needs at SSWRF converted to RNG.

ENR Index = 14700 (projected to December 2019)
Annual Increase in Costs = 0.0%
Discount Rate 3.375%
Number of Years 20

	Capital Costs				
	Life		0	Unmarked up	Capital Cost
ITEM	Years	Units	Quantity	Unit cost	 (\$)
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$ 270,464
Digester 9, and 11 Cleaning	10	each	2	357,500	\$ 1,028,939
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$ 3,768,857
Digester 13, 14 Heat Exchanger	20	each	2	82,875	\$ 241,066
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$ 88,19
Digester 13, 14 Heating Pump	10	each	2	32,500	\$ 88,19
Co-thickening GBTs	20	each	11	227,639	\$ 3,615,986
Odor Hoods	20	each	11	23,808	\$ 376,298
Thickened Sludge Pumps	20	each	5	25,492	\$ 188,149
IPS Receiving Wet Well Mixing	20	each	3	57,850	\$ 246,945
Centrifuges	20	each	5	692,510	\$ 4,985,945
Polymer System	20	each	1	500,500	\$ 723,197
Air Compressor	20	each	2	26,000	\$ 76,435
Centrifuge Feed Piping Modifications	20	LS	1	100,000	\$ 146,99
Digester Gas Treatment	20	each	1	7,000,000	\$ 10,083,604
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$ 3,645,384
					\$ -
Building costs	40	LS	1	42,676,683	\$ 52,805,157
					\$ -
					\$ -
					\$ -
					\$ -
					\$ -
					\$ -
					\$ -
Total	Capital Cost				\$ 82,379,80

Operation and Main	tenance Costs				
			Unit Cost	-	Annual Cost
ITEM	Units	Quantity	(\$)		(\$)
	·		-	\$	-
Electrical Costs (purchased renewable	MMBTU	187,891	\$35.45	\$	6,661,000
LFG costs	MMBtu	565,691	\$2.50	\$	1,414,000
Equipment Maintenance	LS	1	\$1,960,000	\$	1,960,000
Chemicals	LS	1	\$1,200,000	\$	1,200,000
Residual;s Management (trucking)	miles	1,160,000	\$2.50	\$	2,900,000
Life Cycle Analysis					
Annual Escalation Factor to Year 2035	12.208				
Present Worth of Operation and Maintenance Costs				\$	172,566,269

	Equipment Replacement	Costs			
ITEM		UnitsC			Value (\$)
Digester 9, and 11 Cleaning	10	each	2	357,500	\$ 368,125
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$ 1,345,639
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$ 33,466
Digester 13, 14 Heating Pump	10	each	2	32,500	\$ 33,466
					\$ -

Present Worth of Equipment Replacement Costs (Note 2)				\$ 1,780,696
Salvage Value				
			Unit Value	Value
ITFM	Units	Quantity	(S)	(\$)

alue			Unit Value		Value	
Units	Quantity		(\$)	(\$)		
LS	1	\$	10,986,268	\$	(10,990,000)	
LS	0	\$	-			
LS	1	\$	1,162,298	\$	(1,160,000)	
LS	1	\$	532,022	\$	(530,000)	
				\$	(12,680,000)	
	Units LS LS LS	Units Quantity LS 1 LS 0 LS 1	Units Quantity LS 1 LS 0 LS 1	Units Quantity Unit Value (\$) LS 1 \$ 10,986,268 LS 0 \$ - LS 1 \$ 1,162,298	Units Quantity Unit Value (\$) LS 1 \$ 10,986,268 \$ LS 0 \$ - LS 1 \$ 1,162,298 \$	

TOTAL PRESENT WORTH	
Capital Costs	\$ 82,379,807
Present Worth of O&M Costs	\$ 172,566,269
Present Worth of Equipment Replacement	\$ 1,780,696
Present Worth of Salvage Value	\$ (12,680,000)
Total Present Worth	\$ 244,046,773

Notes:

1) See Capital Cost Details for additional capital cost breakdown.

3) See Cost Table Backup for additional detailed information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF and Biosolids Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 3, Class B Biosolids SW FG4, Vision 2035 Energy Analysis

General Description: Produce a Class B cake product from digested sludge at SSWRF Insert description

					Capital Cost	ts							Danima		
Life			Unit Cost	s	UBTOTAL 1	Undesigned		SI	JBTOTAL 2	Constr. Overhead	со	NSTR. COST	Bidding, Const.	CA	PITAL COST
Years	Units	Quantity	(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
20	each	2	92,950	\$	185,900	20%	20%	\$	260,000	25%	\$	330,000	40%	\$	460,000
10	each	2	357,500	\$	715,000			\$			\$			\$	1,750,000
10	each	4	653,400	\$	2,613,600	20%	20%	\$	3,660,000	25%	\$	4,580,000	40%	\$	6,410,000
20	each	2	82,875	\$	165,750	20%	20%	\$	230,000	25%	\$	290,000	40%	\$	410,000
10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
20	each	11	227,639	\$	2,504,030	20%	20%	\$	3,510,000	25%	\$	4,390,000	40%	\$	6,150,000
20	each	11	23,808	\$	261,890	20%	20%	\$	370,000	25%	\$	460,000	40%	\$	640,000
20	each	5	25,492	\$	127,459	20%	20%	\$	180,000	25%	\$	230,000	40%	\$	320,000
20	each	3	57,850	\$	173,550	20%	20%	\$	240,000	25%	\$	300,000	40%	\$	420,000
20	each	5	692,510	\$	3,462,550	20%	20%	\$	4,850,000	25%	\$	6,060,000	40%	\$	8,480,000
20	each	1	500,500	\$	500,500	20%	20%	\$	700,000	25%	\$	880,000	40%	\$	1,230,000
20	each	2	26,000	\$	52,000	20%	20%	\$	70,000	25%	\$	90,000	40%	\$	130,000
20	LS	1	100,000	\$	100,000	20%	20%	\$	140,000	25%	\$	180,000	40%	\$	250,000
20	each	1	7,000,000	\$	7,000,000	20%	20%	\$	9,800,000	25%	\$	12,250,000	40%	\$	17,150,000
30	each	1	3,100,000	\$	3,100,000	10%	20%	\$	4,030,000	10%	\$	4,430,000	40%	\$	6,200,000
40	LS	1	36,653,606	\$	36,653,606	20%	20%	\$	51,320,000	25%	\$	64,150,000	40%	\$	89,810,000
				\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
				\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
				\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
				\$	-	20%	20%	\$	-	25%	\$	_	40%	\$	-
				\$	-	20%	20%	\$	_	25%	\$	_	40%	\$	_
				\$	-	20%	20%	\$	_	25%	\$	_		\$	_
				\$	_	20%	20%	\$	-		\$	_		\$	_
				\$	_			•						•	
				\$	_										
				\$	_										
				\$	_							Total	Canital Cost	\$	140.110.000
	20 10 10 20 10 20 10 20 20 20 20 20 20 20 20 20 20 30	Years Units 20 each 10 each 10 each 20 each 10 each 20 each	Years Units Quantity 20 each 2 10 each 2 10 each 4 20 each 2 10 each 2 20 each 11 20 each 11 20 each 5 20 each 3 20 each 1 20 each 1	Years Units Quantity (\$) 20 each 2 92,950 10 each 2 357,500 10 each 4 653,400 20 each 2 82,875 10 each 2 32,500 20 each 2 32,500 20 each 11 227,639 20 each 11 23,808 20 each 5 25,492 20 each 3 67,850 20 each 3 67,850 20 each 1 500,500 20 each 1 500,500 20 each 2 26,000 20 LS 1 100,000 20 each 1 7,000,000 30 each 1 3,100,000	Years Units Quantity (\$) 20 each 2 92,950 \$ 10 each 2 357,500 \$ 10 each 4 653,400 \$ 20 each 2 82,875 \$ 10 each 2 32,500 \$ 20 each 2 32,500 \$ 20 each 11 227,639 \$ 20 each 11 23,808 \$ 20 each 1 23,808 \$ 20 each 3 57,850 \$ 20 each 3 57,850 \$ 20 each 5 692,510 \$ 20 each 1 500,500 \$ 20 each 2 26,000 \$ 20 Each 1 7,000,000 \$ 20 each 1	Life Units Quantity (\$) SUBTOTAL 1 20 each 2 92,950 \$ 185,900 10 each 2 357,500 \$ 715,000 10 each 4 653,400 \$ 2,613,600 20 each 2 82,875 \$ 165,750 10 each 2 32,500 \$ 65,000 10 each 2 32,500 \$ 65,000 20 each 11 227,639 \$ 2,504,030 20 each 11 23,808 \$ 261,890 20 each 11 23,808 \$ 261,890 20 each 3 57,880 \$ 173,550 20 each 3 57,880 \$ 173,550 20 each 3 500,500 \$ 500,500 20 each 1 500,500 \$ 500,500 20 each 1 500,500 \$ 500,500 20 each <	Years Units Quantity (\$) Undesigned Details 20 each 2 92,950 \$ 185,900 20% 10 each 2 357,500 \$ 715,000 20% 10 each 4 653,400 \$ 2,613,600 20% 20 each 2 82,875 \$ 165,750 20% 10 each 2 32,500 \$ 65,000 20% 20 each 11 227,639 \$ 2,504,030 20% 20 each 11 23,808 \$ 261,890 20% 20 each 5 25,492 \$ 127,459 20% 20 each 5 52,492 \$ 173,550 20% 20 each 5 692,510 \$ 3,462,550 20% 20 each 1 500,500 \$ 500,500 20% 20 each 1 500,500 \$ 500,500 20% 20 each	Life Units Quantity (\$) SUBTOTAL 1 (\$) Undesigned Details Contingency 20 each 2 92,950 \$ 185,900 20% 20% 10 each 2 357,500 \$ 715,000 20% 20% 10 each 4 653,400 \$ 2,613,600 20% 20% 20 each 2 32,500 \$ 65,000 20% 20% 10 each 2 32,500 \$ 65,000 20% 20% 20 each 11 227,639 \$ 2,504,030 20% 20% 20 each 11 23,808 \$ 261,890 20% 20% 20 each 11 23,808 \$ 261,890 20% 20% 20 each 5 25,492 \$ 127,459 20% 20% 20 each 5 692,510 \$ 3,462,550 20% 20% 20 each 1 500,500	Life Vears Units Quantity (\$) SUBTOTAL 1 Undesigned Details Contingency	Life Units Quantity (\$) SUBTOTAL 1 Undesigned Details Contingency Cont	Life Years Units Quantity (\$) SUBTOTAL 1 (\$) Undesigned Details Contingency SUBTOTAL 2 (\$) Constr. Overhead & Profit 20 each 2 92,950 \$ 185,900 20% 20% \$ 260,000 25% 10 each 2 357,500 \$ 715,000 20% 20% \$ 1,000,000 25% 10 each 4 653,400 \$ 2,613,600 20% 20% \$ 3,660,000 25% 20 each 2 82,875 \$ 165,750 20% 20% \$ 230,000 25% 10 each 2 32,500 \$ 65,000 20% 20% \$ 90,000 25% 10 each 2 32,500 \$ 65,000 20% 20% \$ 90,000 25% 20 each 11 227,639 \$ 2,540,030 20% 20% \$ 370,000 25% 20 each 5 25,492 \$ 127,459 20% 20% \$ 370,000 <t< td=""><td> Life Vears Units Quantity (\$) SUBTOTAL 1 Undesigned Details Contingency Contingency Constr. Overhead & Profit </td><td> Life Units Press Unit Cost Subtotal 1 Undesigned Details Contingency Subtotal 2 Constr. Overhead & Profit (\$) (\$) </td><td> Life Units Units Unit Cost Unit Cost (\$) Undesigned Contingency Cont</td><td> Life Units Unit Cost SUBTOTAL Undesigned Contingency SUBTOTAL Constr. Constr</td></t<>	Life Vears Units Quantity (\$) SUBTOTAL 1 Undesigned Details Contingency Contingency Constr. Overhead & Profit	Life Units Press Unit Cost Subtotal 1 Undesigned Details Contingency Subtotal 2 Constr. Overhead & Profit (\$) (\$)	Life Units Units Unit Cost Unit Cost (\$) Undesigned Contingency Cont	Life Units Unit Cost SUBTOTAL Undesigned Contingency SUBTOTAL Constr. Constr

Notes:

1) Definitions:

LS - lump sum

2) See Cost Table Backup for additional information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE BACKUP
OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS
Alternative 3
Class B Cake

Capital Costs

Unit cost for 3.2 SW solar array from WRF FG4 \$5,110,000
Unit cost for 5.2 MW solar array from WRF FG5 \$8,210,000

O&M Costs

Equipment Replacement Costs

Salvage Value

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE SUMMARY OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative 4 2035 Incineration

General Description:
All solids are digested at SSWRF. Dewatering and incineration at SSWRF. No electrical generation at SSWRF. DG above heating needs at SSWRF converted to RNG.

ENR Index = 14700 (projected to December 2019)
Annual Increase in Costs = 0.0%
Discount Rate 3.375%
Number of Years 20

	Capital Costs					
	Life				(Capital Cost
ITEM	Years	Units	Quantity	Unit cost		(\$)
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$	270,46
Digester 9, and 11 Cleaning	10	each	2	357,500	\$	1,028,93
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$	3,768,85
Digester 13, 14 Heat Exchanger	20	each	2	82,875	\$	241,06
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$	88,19
Digester 13, 14 Heating Pump	10	each	2	32,500	\$	88,19
Co-thickening GBTs	20	each	11	227,639	\$	3,615,98
Odor Hoods	20	each	11	23,808	\$	376,29
Thickened Sludge Pumps	20	each	5	25,492	\$	188,14
PS Receiving Wet Well Mixing	20	each	3	57,850	\$	246,94
Centrifuges	20	each	5	692,510	\$	4,985,9
Polymer System	20	each	1	500,500	\$	723,1
Air Compressor	20	each	2	26,000	\$	76,4
Centrifuge Feed Piping Modifications	20	LS	1	100,000	\$	146,9
calping Drying System	20	Each	3	11,000,000	\$	47,536,9
Fluid Bed Incinerators	20	each	3	18,000,000	\$	77,787,7
Digester Gas Treatment	20	each	1	7,000,000	\$	3,645,3
ncremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$	6,934,8
Building costs	40	LS	1	36,653,606	\$	52,805,1
					\$	-
					\$	-
					\$	-
					\$	-
					\$	-
					\$	
					\$	-
Total Cap	ital Cost				\$	204,555,8

Operation and Mainte	enance Costs				
			Unit Cost	-	Annual Cost
ITEM	Units	Quantity	(\$)		(\$)
				\$	-
Electrical Costs (purchased renewable)	MMBTU	187,891	\$35.45	\$	6,661,000
LFG costs	MMBtu	574,288	\$2.50	\$	1,436,000
Equipment Maintenance	LS	1	\$1,960,000	\$	1,960,000
Chemicals	LS	1	\$1,200,000	\$	1,200,000
Residual;s Management	DT	18,971	\$60	\$	1,138,000
<u>Life Cycle Analysis</u> Annual Escalation Factor to Year 2035	12.208				
Present Worth of Operation and Maintenance Costs				\$	151,323,587

	Equipment Replacement	Costs			
ITEM		Units	Quantity	Unit Value (\$)	Value (\$)
Digester 9, and 11 Cleaning	10	each	2	357,500	\$ 368,125
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$ 1,345,639
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$ 33,466
Digester 13, 14 Heating Pump	10	each	2	32,500	\$ 33,466
1					\$ -

1,780,696 Present Worth of Equipment Replacement Costs (Note 2)

Salvage Valu	ıe				
ITEM	Units	Quantity	ι	Jnit Value (\$)	Value (\$)
SSWRF Buildings	LS	1	\$	9,435,746	\$ (9,440,000)
JIWRF Building	LS	0	\$	-	
Process piping	LS	1	\$	1,162,298	\$ (1,160,000)
Solar Array	LS	1	\$	532,022	\$ (530,000)
Present Worth of Salvage Value					\$ (11,130,000)

TOTAL PRESENT WORTH	
Capital Costs	\$ 204,555,801
Present Worth of O&M Costs	\$ 151,323,587
Present Worth of Equipment Replacement	\$ 1,780,696
Present Worth of Salvage Value	\$ (11,130,000)
Total Present Worth	\$ 346,530,085

See Capital Cost Details for additional capital cost breakdown.
 See Cost Table Backup for additional detailed information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF and Biosolids Project Alternatives Analysis



CAPITAL COST DETAILS OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS Alternative # 4, Incineration SW FG4, Vision 2035 Energy Analysis

General Description: Incinerate all digested solids at SSWRF Insert description

						Capital Cos	ts							Desima		
	Life			Unit Cost	s	UBTOTAL 1	Undesigned		S	UBTOTAL 2	Constr. Overhead	со	NSTR. COST	Design, Bidding, Const.	CA	PITAL COS
ITEM	Years	Units	Quantity	(\$)		(\$)	Details	Contingency		(\$)	& Profit		(\$)	Oversight		(\$)
SSWRF Costs																
Digester 9, and 11 Inspection and Repairs	20	each	2	92,950	\$	185,900	20%	20%	\$	260,000	25%	\$	330,000	40%	\$	460,000
Digester 9, and 11 Cleaning	10	each	2	357,500	\$	715,000	20%	20%	\$	1,000,000	25%	\$	1,250,000	40%	\$	1,750,000
Digester 9, 11, 13, 14 Linear Motion Mixer	10	each	4	653,400	\$	2,613,600	20%	20%	\$	3,660,000	25%	\$	4,580,000	40%	\$	6,410,000
Digester 13, 14 Heat Exchanger	20	each	2	82,875	\$	165,750	20%	20%	\$	230,000	25%	\$	290,000	40%	\$	410,000
Digester 13, 14 Recirc Pump	10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
Digester 13, 14 Heating Pump	10	each	2	32,500	\$	65,000	20%	20%	\$	90,000	25%	\$	110,000	40%	\$	150,000
Co-thickening GBTs	20	each	11	227,639	\$	2,504,030	20%	20%	\$	3,510,000	25%	\$	4,390,000	40%	\$	6,150,000
Odor Hoods	20	each	11	23,808	\$	261,890	20%	20%	\$	370,000	25%	\$	460,000	40%	\$	640,000
Thickened Sludge Pumps	20	each	5	25,492	\$	127,459	20%	20%	\$	180,000	25%	\$	230,000	40%	\$	320,000
IPS Receiving Wet Well Mixing	20	each	3	57,850	\$	173,550	20%	20%	\$	240,000	25%	\$	300,000	40%	\$	420,000
Centrifuges	20	each	5	692,510	\$	3,462,550	20%	20%	\$	4,850,000	25%	\$	6,060,000	40%	\$	8,480,000
Polymer System	20	each	1	500,500	\$	500,500	20%	20%	\$	700,000	25%	\$	880,000	40%	\$	1,230,000
Air Compressor	20	each	2	26,000	\$	52,000	20%	20%	\$	70,000	25%	\$	90,000	40%	\$	130,000
Centrifuge Feed Piping Modifications	20	LS	1	100,000	\$	100,000	20%	20%	\$	140,000	25%	\$	180,000	40%	\$	250,000
Scalping Drying System	20	Each	3	11,000,000	\$	33,000,000	20%	20%	\$	46,200,000	25%	\$	57,750,000	40%	\$	80,850,000
Fluid Bed Incinerators	20	each	3	18,000,000	\$	54,000,000	20%	20%	\$	75,600,000	25%	\$	94,500,000	40%	\$	132,300,000
Digester Gas Treatment	20	each	1	7,000,000	\$	7,000,000	20%	20%	\$	9,800,000	25%	\$	12,250,000	40%	\$	17,150,000
Incremental Increase to go from 3.2 MW to 5.2 MW solar array	30	Each	1	3,100,000	\$	3,100,000	10%	20%	\$	4,030,000	10%	\$	4,430,000	40%	\$	6,200,000
Builiding costs	40	LS	1	36,653,606	\$	36,653,606	20%	20%	\$	51,320,000	25%	\$	64,150,000	40%	\$	89,810,000
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-	20%	20%	\$	-	25%	\$	-	40%	\$	-
					\$	-										
					\$	-										
					\$	-										
					\$	-							Total	Capital Cost	\$	353,260,000

Notes:

1) Definitions:

LS - lump sum

2) See Cost Table Backup for additional information

MILWAUKEE METROPOLITAN SEWAGE DISTRICT 2050 FACILITIES PLAN WRF Project Alternatives Analysis



COST TABLE BACKUP
OPINION OF BUDGETARY PROBABLE CONSTRUCTION COSTS
Alternative 4
2035 Incineration

Capital Costs

Unit cost for 3.2 SW solar array from WRF FG4 \$5,110,000
Unit cost for 5.2 MW solar array from WRF FG5 \$8,210,000

O&M Costs

Equipment Replacement Costs

Salvage Value

<u>General</u>		Source	Comments
			Milwaukee ENR is the average between Chicago and Minneapolis Construction Cost Index values published monthly by ENR. Milwaukee ENR
			December 2019 is a projected value from May 2019 based on average
			historical monthly increase in value from 2007 (2020 Facilities Plan published
Milwaukee ENR December 2019	14,700	Historic_ENRvalues 1974-2019-05_MCA_KMZREV.xls:	x June 2007) to May 2019.
Annual increase in costs	0%	Discussions with MMSD Email from Andrew Dutcher, WDNR to Troy Deibert,	
Discount Rate	3.375% 3.37500% net for PW	HNTB on 6/5/19	Facility planning is using the value established by the WDNR.
Life Cycle - number years 2035 No. years	20 16		
Capital Costs	10		
Un-designed Details Allowance - Varies, see belo	w	Allowance varies at engineer's discretion based on	definitions provided for each %
all major components have documented installed uni	t 10%		
costs		K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	,
costs missing for some components, but other costs are for installed facilities and well documented	20%		
(connections to existing systems, etc.)		K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	,
(connections to existing systems, etc.)	30%	14. Zimo oman to B. 14iii on 0/0/17, commined on 0/10/17	
Alternative development is still conceptual Contingency Allowance - Set %		K. Ziino email to B. Krill on 6/8/17, confirmed on 6/19/17	,
Planning Level Contingency	20%	2050 FP Team - WRF discussion on 1/30/17	
Contractor Overhead & Profit - Varies, see below			
Equipment costs are from manufacturers Costs are from previous project, unit costs already	25%	2050 FP Team - WRF discussion on 1/30/17	
include OH&P	0%	2050 FP Team - cost estimate discussion on 5/20/19	
module of the	070	2000 11 104111 0001 004111410 41004001011 011	
Design, Bidding, & MMSD Oversight			
Total Percent, Conveyance	20%		g, For FP Use only. This is incorporated into AMP BCE template already.
Total Percent, WRFs	40%	Design, Construction (exc. Contractor Cost) and	Varies for each asset system
Total Percent, Watercourse Total Percent. GI	20% 15%	Post Construction in the BCE	
Total Percent, Gr	1376		
Cost Escalation Factor 2035	0.588		
Annual Present Worth Factor (A/P)	12.20844		
Power assumptions	22.42	SOURCE	Comments
Gas	2018 Current Rates		
	Our rates	K. Ziino email sent 4/20/17 called "2050 - WRF TBC	
turbine fuel, LFG	\$2.500 /Dtherm	Energy Cost Assumptions" for assumptions K. Ziino email sent 4/20/17 called "2050 - WRF TBC	
turbine fuel, NG	\$5.000 /Dtherm	Energy Cost Assumptions" for assumptions	
Electrical			
		Kziino email sent 4/20/17 called "2050 - WRF TBC	
Electrical Rates, JI/SS	Varies	Energy Cost Assumptions" for assumptions	Detailed assumptions need to be included in backup on a case by case basis
<u>Labor assumptions</u>	#50	to de de de POE	
Veolia Labor Contractor Labor	\$50 per hour \$70 per hour	Included in BCE assumptions To be included in capital costs	
CONTRACTOR LADOR	ψτο per riour	To be included in capital costs	