City of St. Joseph, Missouri

Facilities Plan

Technical Memorandum Nos. TM-CSO-11 and TM-WW-5

Disinfection Facilities

By

BLACK & VEATCH
Building a world of difference.

Work Order No. 09-001
B&V Project 163509

July 31, 2009

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Disinfection Facilities

1.0 Executive Summary

The Missouri Department of Natural Resources' (MDNR) National Pollutant Discharge Elimination System (NPDES) permit for the St. Joseph Water Protection Facility (WPF) requires disinfection of effluent flow by December 31, 2013. Permit requirements mandate disinfection of treated effluent occurs from April 1 through October 31 each year. In addition to flows from the WPF, disinfection will be required for treatment of effluent from a future high rate treatment (HRT) facility to be constructed as part of Phase IA of the Combined Sewer Overflow (CSO) Long Term Control Plan (refer to the CSO Control Facilities Plan for further information). This technical memorandum herein documents the results of disinfection technology screening to narrow the technologies and configurations for further evaluation as well as an economic assessment of the selected alternatives. The following alternatives were considered for disinfection of flows from the WPF and from a future HRT:

- Alternative 1 – Combined ultraviolet (UV) disinfection of WPF and HRT flows (108 mgd)
- Alternative 2 – Combined bulk sodium hypochlorite and sodium bisulfite disinfection of WPF and HRT flows (108 mgd)
- Alternative 3 – Combined on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of WPF and HRT flows (108 mgd)
- Alternative 4 – UV disinfection of WPF flows (54 mgd), bulk sodium hypochlorite and sodium bisulfite disinfection of wet weather flows from HRT (61 mgd)
- Alternative 5 – UV disinfection of WPF flows (54 mgd), on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of wet weather flows from HRT (61 mgd)

Based on an evaluation of each of the alternatives on the criteria of project capital investment, operation and maintenance (O&M) costs, net present worth, and non-economic factors, Alternative 1 – Combined UV disinfection of WPF and HRT flows is recommended for implementation. Table ES-1 presents the results of the project capital, O&M, and net present worth analysis for each of the alternatives.

Table ES-1
Net Present Worth Costs by Alternative [1]

	Alternative 1 108 mgd UV $	Alternative 2 108 mgd Bulk Hypochlorite $	Alternative 3 108 mgd On-site Generation $	Alternative 4 54 mgd UV + 61 mgd Bulk Hypochlorite $	Alternative 5 54 mgd UV + 61 mgd On-site Generation $
Net Project Capital Present Worth [2]	16,933,000	17,942,000	26,295,000	22,461,000	28,701,000
O&M Present Worth [3]	8,340,000	90,400,000	13,480,000	46,110,000	10,700,000
Total Net Present Worth	**25,273,000**	**108,342,000**	**39,775,000**	**68,571,000**	**39,401,000**

1. Costs given in May 2009 dollars. Present worth calculated on a 20-year project life at 5% interest.
2. Net present worth represents the present worth of project costs less the remaining value of facilities at the end of the 20-year project life. A 7% per year escalation rate was applied to capital costs. Service life for determination of replacement frequency and salvage value was estimated as follows: structures – 50 years; equipment, electrical, instrumentation and controls – 20 years.
3. O&M costs were assumed to escalate at 5% per year.

From a project capital cost standpoint, Alternative 1 was found to be approximately equivalent to the next lowest project capital cost alternative (Alternative 2 – 108 mgd bulk sodium hypochlorite). The O&M evaluation demonstrated that the combined UV alternative is the lowest cost alternative on the basis of annual O&M costs. Likewise, the net present worth analysis showed that Alternative 1 is the lowest cost option on the basis of net present worth. The net present worth of the 108 mgd UV alternative ($25 million) is about $14 million less expensive over the 20-year life cycle than the next closest alternative.

On the basis of non-economic criteria, UV disinfection is the highest ranking technology. UV disinfection does not require significant use of hazardous chemicals, is independent of the chemicals market, will not form disinfection byproducts, and is fairly straightforward to operate and maintain after initial training.

It is recommended that the City initiate the design for the 108 mgd combined UV disinfection facility to treat WPF and HRT flows. Figure 11 shows a conceptual layout of the proposed UV disinfection facility. The design should consider phasing of the UV equipment to treat HRT flows, based on the anticipated timing of the HRT construction.

2.0 Purpose of Study

MDNR has established disinfection requirements for wastewater facilities that discharge to the Missouri River. These requirements have been incorporated into the City of St. Joseph's NPDES permit issued by MDNR. In accordance with this requirement, the final permit (effective June 19, 2009) for the St. Joseph WPF mandates the effluent be disinfected by December 31, 2013. Permit requirements mandate disinfection of treated effluent occurs from April 1 through October 31 each year. This memorandum documents the evaluation of disinfection technologies and alternatives for proposed wet and dry weather discharges within the St. Joseph's WPF.

The purpose of this memorandum is to document work performed under the following two phases of the Facilities Plan scope:

- Wastewater Facilities Assessment Phase 330 C – Evaluate Disinfection at Water Protection Facility
- Combined Sewer Overflow Control Facilities Assessment Phase 275 – Wet Weather Disinfection Facilities Assessment

Initially, the Facilities Plan scope envisioned separate memoranda to document the wet and dry weather disinfection facilities; however, as the study progressed, it was decided that it would be more efficient to present both wet and dry weather disinfection alternatives in one document. This technical memorandum will be included in both the Wastewater Facilities Plan as well as the CSO Control Facilities Plan.

The objectives of this assessment include:

- Provision of a brief overview of disinfection technologies selected for further evaluation
- Evaluation of non-economic factors of the disinfection alternatives
- Presentation of the results of alternatives evaluation and life cycle cost comparisons

- Selection of recommended wet and dry weather disinfection configuration(s), technology(ies), and alternative(s).

Evaluations of separate wet and dry weather disinfection facilities as well as combined wet/dry weather disinfection facilities will be considered.

Results of the flow capacity and wet weather analysis will be documented in Technical Memorandum (TM) TM-CSO-10 – Wet Weather Treatment Facilities and serve as the flow basis for the required wet weather and dry weather disinfection capacities. Hydraulic impacts of the recommended improvements and discussion of the resulting effluent pump station will be presented in TM-WW-7 – Hydraulic Analysis and Effluent Pump Station. Results of the previous reports, Wastewater Treatment Plant Disinfection Study – Technical Memorandum No. 1 – Disinfection Alternatives (Black & Veatch, October 2, 2008) and UV Pilot Study Documentation (Black & Veatch, April 23, 2009), will also be referenced throughout this document and are included as Appendices A and B, respectively, of this memorandum.

3.0 Background and Previous Studies

The purpose of this section is to present disinfection regulatory requirements, results of previous studies, and provide a basis for selection of the disinfection alternatives to be considered for further study.

3.1 Disinfection Regulatory Requirements

The WPF has no existing disinfection facilities. MDNR in the final permit has established disinfection requirements for discharges from the WPF. The Escherichia coli (E. coli) limit indicated in the final permit is a monthly average of 206 E. coli colonies per 100 mL with no single sample maximum.

3.2 Technology Overview and Test Results

This section presents the various disinfection technologies evaluated to meet the future disinfection needs of the City of St. Joseph. An initial study, Wastewater Treatment Plant Disinfection Study – Technical Memorandum No. 1 – Disinfection

Alternatives (Black & Veatch, October 2, 2008), evaluated the following technologies for providing disinfection of effluent from the WPF:

- Ultraviolet light
- Bulk sodium hypochlorite and sodium bisulfite
- On-site generation of sodium hypochlorite
- Chlorine and sulfur dioxide gas
- Chlorine dioxide
- Peracetic acid (PAA)
- Hydrogen peroxide
- Ozone
- Ferrate

An initial screening of the suitability of the above disinfection alternatives for the WPF was performed. Screening criteria included simplicity of the system installation, ease of operation and maintenance, and established performance history. As a result of this analysis, the following technologies were selected for detailed evaluation:

- Ultraviolet light
- Bulk sodium hypochlorite and dechlorination with sodium bisulfite
- On-site generation of sodium hypochlorite and dechlorination with sodium bisulfite

The October 2008 Disinfection Alternatives technical memorandum (Appendix A) provides further discussion about the disinfection alternatives selected for further consideration.

3.2.1 Ultraviolet Light

UV light is a physical, not a chemical, disinfectant. UV radiation is electromagnetic energy lying within the spectrum of energy reaching Earth from the Sun, but which is outside the wavelength range of visible light. UV light between the wavelengths of 235 and 270 nanometers (nm) has been found to exhibit biocidal action on bacteria and viruses present in water, wastewater, and process water. This biocidal action is the basis for using UV radiation as a physical disinfectant in the municipal wastewater industry.

Ultraviolet radiation is readily absorbed by deoxyribonucleic acids (DNAs) in certain pathogens found in municipal wastewater. When this energy is absorbed, a pathogen's molecular structure can be altered, resulting in an inability to replicate. While this effect can be reversed (referred to as reactivation) under certain conditions, UV radiation has been proven effective in the disinfection of municipal wastewater.

The October 2008 Disinfection Alternatives technical memorandum (Appendix A) provides further background information on UV disinfection.

3.2.1.1 UV Pilot Test Results. As the design parameters for a UV system must be based on bench- and pilot-scale testing, a UV pilot study was performed. The results of this study are documented in the report, UV Pilot Study Documentation (Black & Veatch, April 23, 2009), which is given in Appendix B of this technical memorandum.

UV demonstration testing began May 21, 2008 with the installation of a Trojan UV 3000Plus unit, which continued to operate for 13 weeks. During the operation of the Trojan pilot system, a fouling study was performed to determine the appropriate safety factor to be used during design. A second demonstration unit, WEDECO TAK 55 HP, was installed on July 8, 2008 and operated for a period of six weeks.

In addition to the pilot testing in the field, a bench-scale UV test was also performed, beginning May 6, 2008. The details of the collimated beam tests are presented in Appendix B. During this period, suspended solids and transmittance were measured for both primary and secondary effluent samples. The average transmittance value of the final effluent during the collimated beam testing (14 total samples) was 57.9 percent with a range from 48.4 to 65.8 percent. In addition to the separate grab samples, an on-line transmittance unit was installed to examine the variability of transmittance throughout the day. This unit had mechanical issues such as programmable logic controller board failure and calibration problems throughout the study. Therefore, data was unable to be collected. Based on the results of the UV transmittance testing, it was recommended that a design value of 55 percent be used for the treated final effluent.

A side by side comparison of Trojan and WEDECO UV systems was carried out beginning July 9, 2008. The results from the side by side operation show that the WEDECO system consistently achieved a comparable E. coli count at approximately two-thirds of the UV dose of the Trojan system.

3.2.1.2 Wet Weather UV Testing. Effluent disinfection testing was conducted as part of the wet weather treatability testing on April 10, 2009. Treatability testing for compressible media filtration (CMF, a type of high-rate filtration), high-rate clarification (HRC), and chemically enhanced primary treatment (CEPT) was conducted on primary clarifier influent during actual wet weather conditions from storms that occurred that morning. A small pilot unit was used for the CMF technology, while jar tests were used for the HRC and CEPT technologies. Bench-scale disinfection tests were then conducted on the effluent from these three different total suspended solids (TSS) removal technologies. The bench-scale disinfection testing consisted of both UV collimated beam and chlorine (hypochlorite) dose response testing.

The data collected from the UV collimated beam testing was used to develop the E. coli dose response curve presented in Figure 1. For CMF, a UV dose as low as 10 mJ/cm^2 was sufficient to decrease E. coli to below the method detection limit of 10 MPN/100 mL. For the HRC effluent, a dose of 40 mJ/cm^2 was required to consistently decrease E. coli below the proposed limit of 206 MPN/100 mL, while the proposed limit was not achieved with the CEPT effluent at doses up to 80 mJ/cm^2.

The UV transmittance value from each of the three technologies measured at or above 54 percent. Based on these results, a transmittance of 50 percent is recommended for the design of the wet weather UV system.

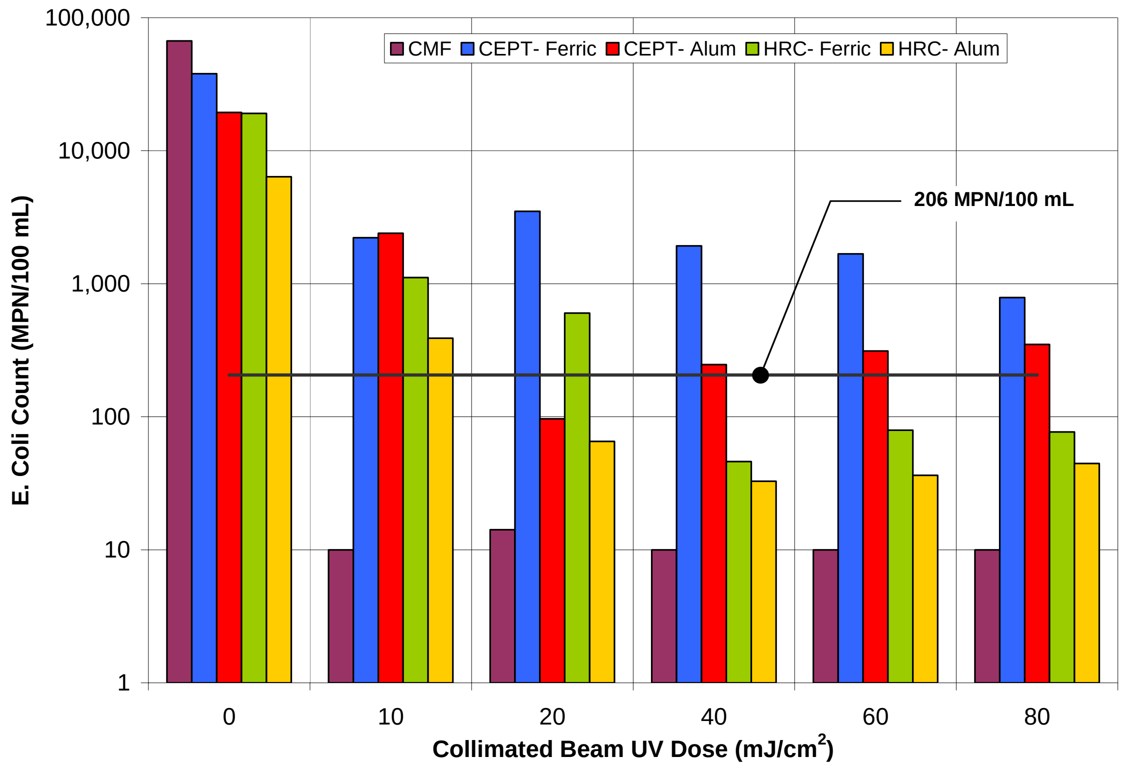


Figure 1 – Wet Weather UV Disinfection Testing Results

3.2.2 Bulk Sodium Hypochlorite and Sodium Bisulfite

Sodium hypochlorite (NaOCl) is a liquid disinfection agent that has proven to be reliable in the inactivation of fecal coliforms, E. coli, and bacterial pathogens. It typically achieves performance levels equal to that of chlorine gas. Its effectiveness can be attributed to the fact that sodium hypochlorite disassociates in solution to form hypochlorous acid, which is the same disinfecting agent formed when chlorine gas is introduced into solution. A drawback is that sodium hypochlorite is a corrosive liquid, so operators must take handling precautions and regularly maintain the feed equipment. With this alternative, bulk sodium bisulfite would be utilized to provide dechlorination.

The main disadvantages of sodium hypochlorite are its relatively high chemical cost and its tendency to degrade over time as a function of product concentration, temperature, and exposure to sunlight. Degradation decreases the strength of the hypochlorite and consequently the effectiveness of disinfection.

The October 2008 Disinfection Alternatives technical memorandum (Appendix A) provides further background information on bulk sodium hypochlorite disinfection and dechlorination with sodium bisulfite.

3.2.2.1 Wet Weather Sodium Hypochlorite Testing. The effluent from the three TSS removal technologies was also tested for hypochlorite disinfection efficacy. The data collected from the hypochlorite testing was used to develop the E. coli dose response curve presented in Figure 2. For all three technologies (CMF, HRC and CEPT), a chlorine dose of 6 mg/L was able to meet the proposed E. coli limit of 206 MPN/100 mL after only 3 minutes of contact time. Furthermore, the E. coli concentration was reduced to below detection limits within 5 minutes of contact time for both CMF and HRC and within 10 minutes of contact time for CEPT. It should be noted that in this dose response testing, the test beaker was rapidly mixed indicating that rapid mixing would be required in the full-scale design to be able to achieve similarly low contact times.

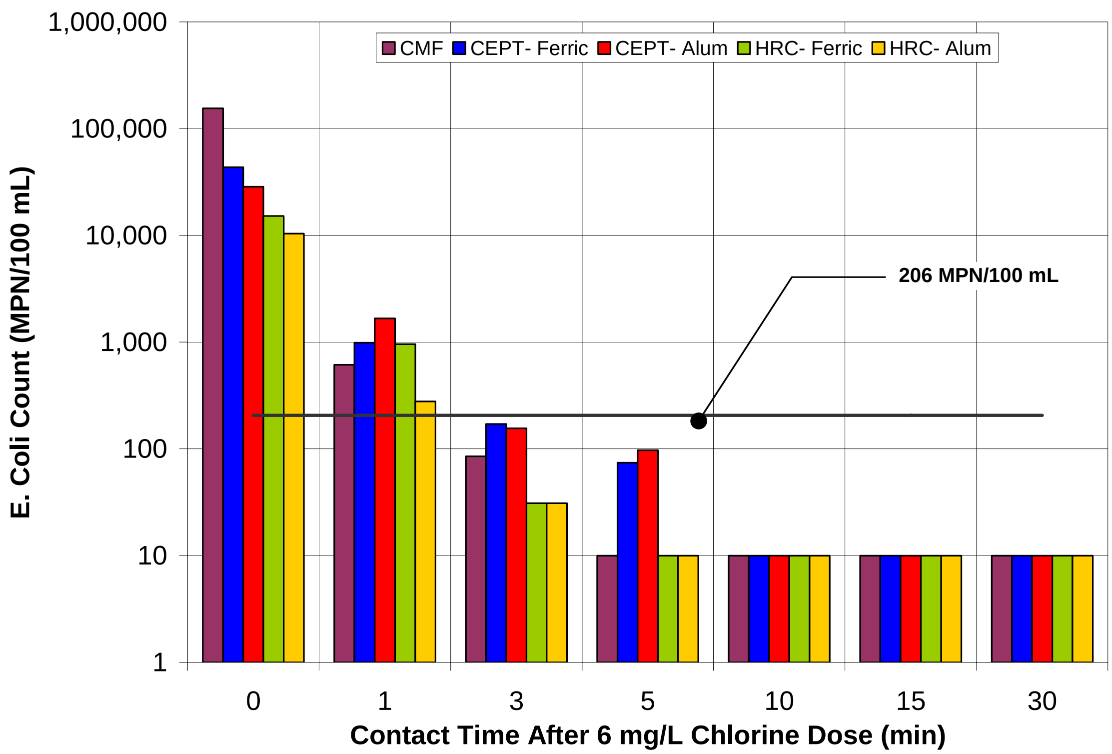


Figure 2 – Wet Weather Sodium Hypochlorite Disinfection Testing Results

3.2.3 On-site Generation of Sodium Hypochlorite and Bulk Sodium Bisulfite

The on-site generation of sodium hypochlorite utilizes electric power to produce chlorine from salt, generating sodium hypochlorite. The generated sodium hypochlorite is then used for liquid chemical disinfection similar to bulk sodium hypochlorite. Similar to the use of bulk sodium hypochlorite, sodium bisulfite would be utilized for dechlorination in the on-site generation alternatives. As with bulk hypochlorite delivered from off-site, on-site generation of hypochlorite requires the use of a contact basin to provide a period of time for the chlorine to react and reduce the E. coli levels below the required limits before discharging to the receiving stream. The on-site generation equipment is fairly complex and would require significant training and attention to operate and maintain.

The October 2008 Disinfection Alternatives technical memorandum (Appendix A) provides further background information on disinfection utilizing on-site generation of sodium hypochlorite and dechlorination with sodium bisulfite.

4.0 Disinfection Facility Capacity

The WPF is rated to treat a maximum flow of 27 mgd through primary treatment. In addition, bacteria (i.e., E. coli) are a pollutant of concern for the ongoing CSO control program. Therefore disinfection facilities at the WPF need to be designed to treat both the maximum WPF capacity and the proposed wet weather high rate treatment (HRT) facilities planned to achieve the objectives of the Phase IA CSO Long Term Control Plan (LTCP) controls. Currently, the proposed Phase IA CSO improvements include the following projects:

- Blacksnake and Whitehead stormwater separation conduits
- Increasing conveyance capacity at the Whitehead Pump Station to 80 mgd (with the option to convey 88 mgd), increasing treatment capacity at the existing WPF headworks to 88 mgd, and providing a 61 mgd HRT with associated disinfection facilities
- Roy’s Branch partial sewer separation (in progress)

The Phase IA improvements are proposed to provide an annual wet weather percent capture of approximately 60 percent by sending a combined 88 mgd through the headworks of the WPF and proposed HRT. A more detailed discussion regarding how the Phase IA improvements will help to achieve the overall CSO control program objectives is included in TM-CSO-3a – Phase IA CSO Control Recommended Improvements Model. Furthermore, a detailed evaluation of the HRT alternatives required to meet the CSO LTCP objectives will be presented in TM-CSO-10 – Wet Weather Treatment Facilities. Grit and screening alternatives required for the WPF and proposed HRT alternatives will be presented in TM-WW-3 – Grit Removal Facilities. This section details the required capacity of the proposed disinfection facilities in order to meet its multifaceted requirements.

As stated previously, it was determined that 88 mgd of combined sewer system (CSS) flow must be treated and disinfected during wet weather events to meet the Phase IA objectives. To convey 88 mgd to the WPF and proposed HRT facilities, it is anticipated that 80 mgd would be conveyed from an improved Whitehead Pump Station and 8 mgd would be conveyed from the existing In-plant Influent Pump Station. However, in situations where the existing In-plant Influent Pump Station is not operational, the City desires the flexibility to have the Whitehead Pump Station convey 88 mgd. Therefore, the flow schematics, presented later within this section, account for this potential situation by presenting both of the aforementioned flow conditions for these two facilities.

Based on the design overflow rate of 800 gallons per day per square foot, 27 mgd of inflow from the Whitehead and the In-plant Influent Pump Stations will be sent through the primary clarifiers for treatment by the WPF. The remainder of the 88 mgd (i.e., 61 mgd) will be sent through the proposed wet weather HRT facility. Downstream of the primary clarifiers, three pretreated industrial waste streams (South St. Joseph Industrial Sewer District (SSJISD), National Beef Leathers, and Triumph Foods) enter the WPF to receive secondary treatment and are anticipated to account for 20 mgd of secondary treatment capacity under peak flow conditions. Therefore, the total effluent flow from the WPF is 47 mgd (i.e., 27 mgd entering primary clarification and 20 mgd of additional industrial flows directly entering secondary treatment facilities) while the effluent from the proposed HRT remains at 61 mgd. Since the disinfection facilities will be placed downstream of the WPF and HRT facilities, the proposed capacity of the disinfection facilities is 108 mgd (47 mgd plus 61 mgd). The sections that follow provide two possible disinfection facility configurations (i.e., combined or separate facilities) and corresponding alternatives required to treat a peak flow of 108 mgd.

4.1 Combined Disinfection Facility

Several combined disinfection facility configurations are evaluated in this technical memorandum. Figure 3 presents a combined disinfection facility alternative utilizing a single treatment configuration for the disinfection of WPF and HRT flows. With maximum design flows of 47 and 61 mgd from the WPF and HRT, respectively, the combined disinfection facility would have a maximum design capacity of 108 mgd.

An advantage of the combined disinfection alternative is that the peak WPF and HRT flows are disinfected in the same facility. Therefore, the combined configuration provides greater flexibility to handle variations in flow rates from either the WPF or HRT if required during operation. In addition, this approach is the easiest to operate (same technology) and maintain (similar equipment). A possible disadvantage of this alternative is that the same disinfection technology must be applied for both the WPF and HRT flows, but this should not be considered a major disadvantage since the effluent from the HRT processes being considered (high rate clarification using aluminum-based coagulants and high rate filtration) are anticipated to be equally amenable to disinfection as the effluent from the WPF.

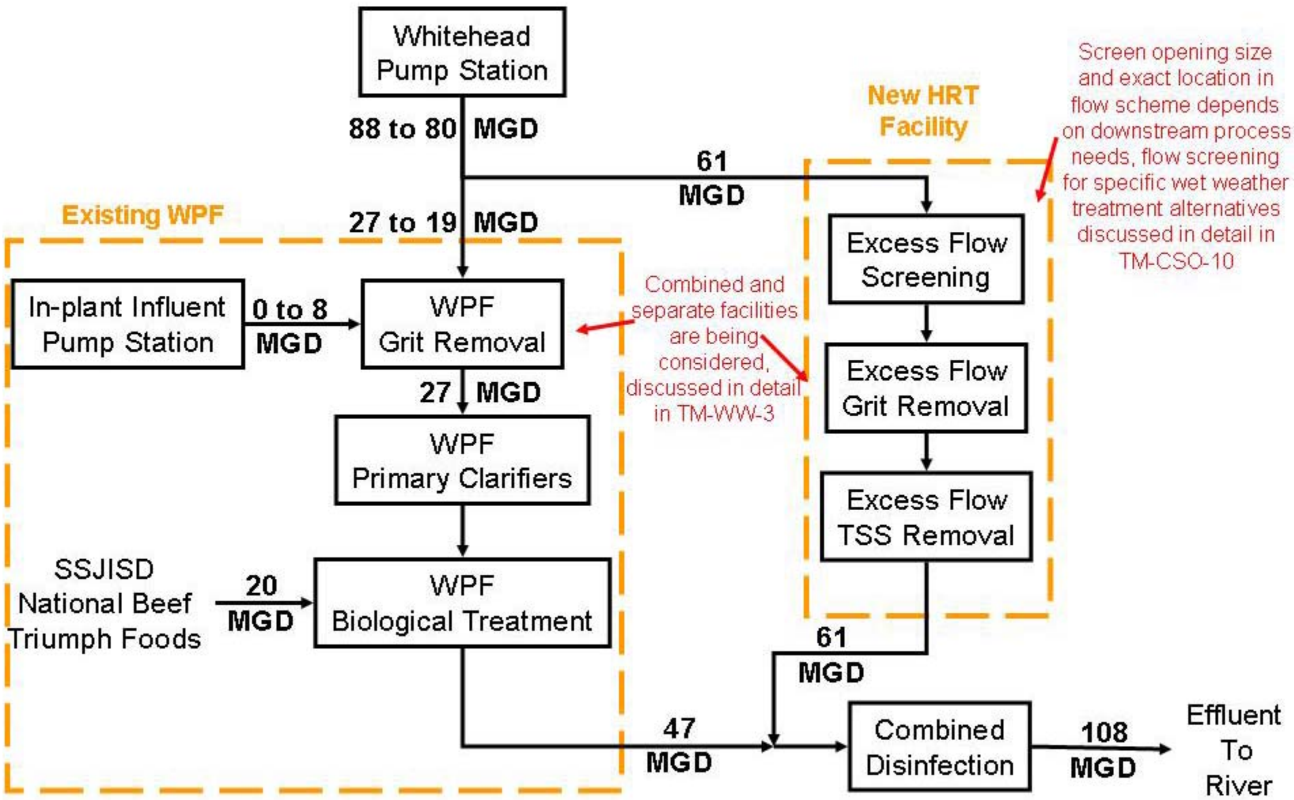
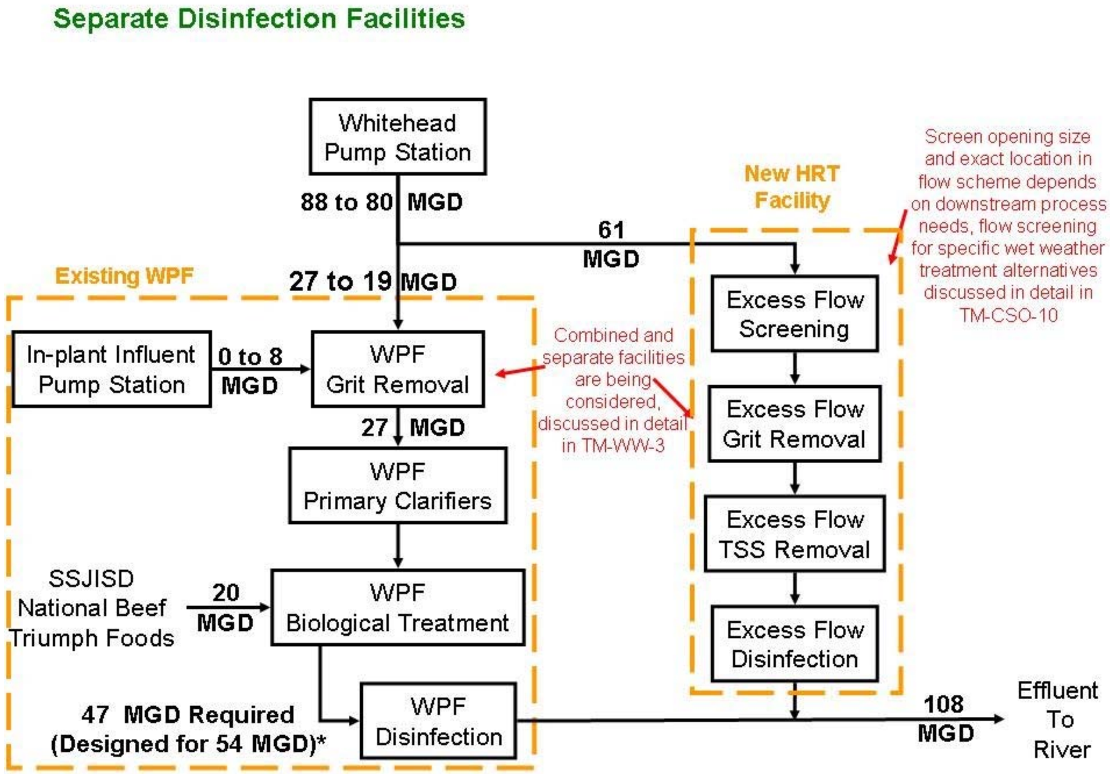


Figure 3 – Combined Disinfection Facility Alternative

4.2 Separate Disinfection Facilities

Figure 4 provides a schematic for a separate WPF and HRT disinfection facility alternative. In this configuration, the WPF and the HRT facilities each have their own dedicated disinfection facility, independent from one another. A possible advantage of the separate WPF and HRT disinfection alternative is that it allows different disinfection technologies to be applied to the WPF and HRT effluent flows, respectively.

A disadvantage of this alternative is that additional redundancy must be added for WPF disinfection to provide the same amount of redundancy as in the combined disinfection alternative (i.e., a combined disinfection facility allows flows to be modulated between the WPF and HRT to achieve a maximum disinfection capacity of 108 mgd, the separate disinfection facility does not). To address the reduced flexibility for this alternative, the WPF disinfection facility was sized for 54 mgd instead of 47 mgd to add flexibility back to the system. Figure 4 reflects this condition at the WPF disinfection facility.



***Note: The WPF disinfection facility is being oversized to provide flexibility lost due to the disinfection facilities being kept as separate facilities.**

Figure 4 – Separate Disinfection Facility Alternative

5.0 Alternative Development

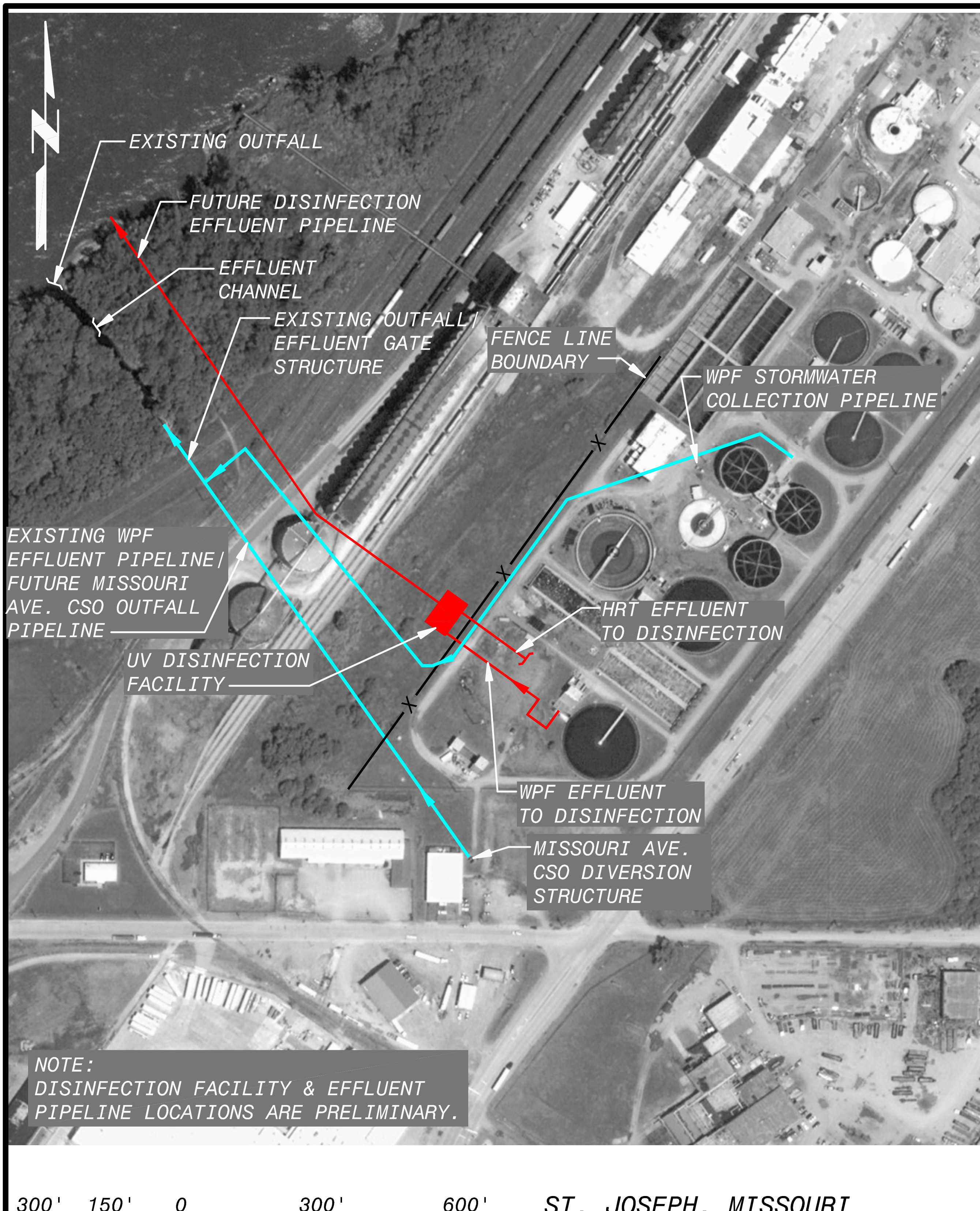
In order to develop alternatives for further study and cost development, several permutations of preferred technologies and configurations were considered. Wet weather bench-scale testing demonstrated that UV would not be effective at disinfecting the wet weather flow through certain HRT technologies initially considered (CEPT). Therefore, UV was eliminated from consideration for treatment of HRT flows within the separate disinfection facility configurations. A dedicated contact basin constructed to treat flows solely from the WPF, as required for the bulk sodium hypochlorite and on-site generation technologies, would be a large capital investment for a comparatively small flow rate and would not be economically attractive relative to the other alternatives. Therefore, neither bulk sodium hypochlorite nor on-site generation of sodium hypochlorite were considered for separate treatment of the WPF flows.

The following disinfection alternatives were considered for further development and costing for this technical memorandum:

- Alternative 1 – Combined UV disinfection of WPF and HRT flows (108 mgd)
- Alternative 2 – Combined bulk sodium hypochlorite and sodium bisulfite disinfection of WPF and HRT flows (108 mgd)
- Alternative 3 – Combined on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of WPF and HRT flows (108 mgd)
- Alternative 4 – UV disinfection of WPF flows (54 mgd), bulk sodium hypochlorite and sodium bisulfite disinfection of wet weather flows from HRT (61 mgd)
- Alternative 5 – UV disinfection of WPF flows (54 mgd), on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of wet weather flows from HRT (61 mgd)

5.1 Alternative 1 – Combined UV Disinfection of WPF and HRT Flows (108 mgd)

Alternative 1 utilizes a single UV disinfection facility sized to treat peak flows from the WPF (47 mgd) and from the HRT (61 mgd) as described in Section 4.1. Figure 5 provides a simplified footprint layout of the proposed facility. The location of the proposed facility shown in Figure 5 should not be considered definite. A final location of the disinfection facility will be determined once land acquisition needs for all recommended alternatives for the Facilities Plan have been finalized. The final location of facilities will also depend on land availability, cost, and other related factors.



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PN 163509
ALTERNATIVE 1
UV DISINFECTION (108 MGD)

JULY 2009

FIGURE 5

CYGNET ID: 163509-1000-WWTUP-C-N00018KJJ

AFIGBORD
FAFIGBORD

5.1.1 Design Criteria

Table 1 summarizes the preliminary design conditions for the proposed combined UV disinfection alternative. Peak and average flows are based on the design capacities of the WPF and the future HRT as described in Section 4.1. A design value for transmittance of WPF flows was determined to be 55 percent from previous pilot-scale testing; a design transmittance of wet weather flows was determined to be 50 percent from previous bench-scale testing. Based on these results, a design transmittance of 50 percent will be applied for the composite system. The TSS criterion is based on MDNR permit requirements for the WPF of 30 mg/L. The maximum average particle size of 30 to 40 microns is based on typical values for wastewater treatment facilities utilizing an activated sludge secondary treatment process.

Table 1
Alternative 1 – Design Criteria

Peak Flow, mgd	108
Average Flow, mgd	17
Minimum Flow, mgd	10
UV Transmittance, percent	50
Total Suspended Solids, mg/L	30
Maximum Average Particle Size, microns	30-40

5.1.2 Facility Sizing

The WEDECO TAK 55 system was selected as the basis of design for this alternative based on its performance in the summer 2008 pilot test at the WPF. This horizontal low pressure/high intensity (LP-HI) system is installed in an open-channel arrangement. Table 2 summarizes the proposed system design for the WPF.

Table 2
Alternative 1 – UV Equipment Sizing

Number of Channels	4
Number of Banks per Channel	2
Total Number of Banks	8
Number of Lamps per Module	18
Total Number of UV Lamps	1,872
Approximate Power Consumption at Peak Flow, kW	674

5.1.3 Proposed Improvements

The WPF does not have existing disinfection facilities. The proposed UV system would be constructed in a new building, with all equipment located indoors and the ballast area air conditioned. The UV system would be installed in four channels with each pair treating 54 mgd flow at designed water quality conditions. Controls for the UV system would also be located within this building. It is estimated the UV building would need to be approximately 4,000 square feet (sq ft) to house all necessary equipment (UV equipment and ballasts).

5.2 Alternative 2 – Combined Bulk Sodium Hypochlorite and Sodium Bisulfite Disinfection of WPF and HRT Flows (108 mgd)

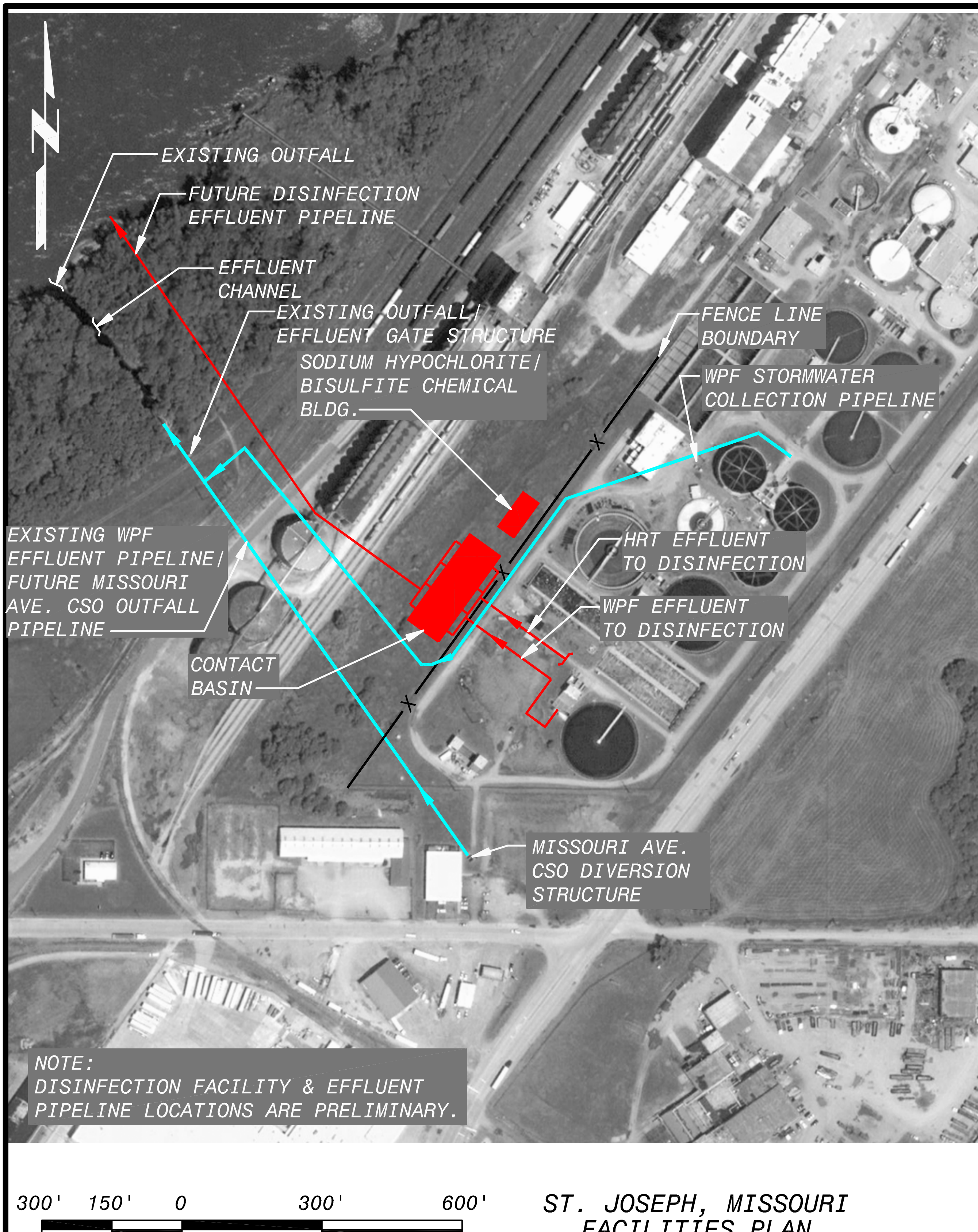
Alternative 2 would utilize a single bulk sodium hypochlorite and sodium bisulfite disinfection facility sized to treat peak flows from the WPF (47 mgd) and from the HRT (61 mgd) as described in Section 4.1. Figure 6 provides a simplified footprint layout of the proposed facility. As previously mentioned, the location of the proposed facility shown in Figure 6 should not be considered definite. A final location of the disinfection facility will be determined once land acquisition needs for all recommended alternatives for the Facilities Plan have been finalized. The final location of facilities will also depend on land availability, cost, and other related factors.

5.2.1 Design Criteria

Table 3 summarizes the design criteria used for the proposed combined bulk sodium hypochlorite and sodium bisulfite systems.

Table 3
Alternative 2 – Design Criteria

	Flow, mgd	Chlorine Dose, mg/L	Chlorine Residual, mg/L	12.5% Sodium Hypochlorite Dose, mg/L	12.5% Sodium Hypochlorite Use, gpd	38% Sodium Bisulfite Dose, mg/L	38% Sodium Bisulfite Use, gpd
Peak/Maximum	108	6	3	6.3	5,460	4.8	700
Average	17	6	2	6.3	860	3.2	110
Minimum	10	4	1	4.2	510	1.6	35



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ALTERNATIVE 2
SODIUM HYPOCHLORITE / BISULFITE DISINFECTION (108 MGD)

JULY 2009

FIGURE 6

CYGNET ID: 163509-1000-WWTUP-C-N00018KJK

AFIGBORD
FAFIGBORD

5.2.2 Facility Sizing

Disinfection by sodium hypochlorite is comprised of two primary components: chlorine dose and contact time. Ten State Standards have established design parameters for each component. Ten State Standards require a minimum of 15 minutes of retention time at peak flow. Black & Veatch typically uses 15 days of storage at average flow for the disinfection chemical to minimize degradation of the chemical from extended storage. Chemical storage at peak flow conditions should also be considered, especially for a facility that will be handling CSO flows on a frequent basis. Therefore, storage was based on providing a minimum of four days of storage at peak flow or 15 days at average conditions. A chlorine dose of 6.0 mg/L would be required to achieve the desired degree of disinfection. Table 4 summarizes the storage requirements for the alternative as well as the contact basin capacity.

Table 4
Alternative 2 – Facility Sizing

Design Flowrates	
Average Flow, mgd	17
Peak Flow, mgd	108
Sodium Hypochlorite System	
Sodium Hypochlorite Solution Strength, %	12.5
Sodium Hypochlorite Dose (Storage), mg/L	6.3
Daily Storage Requirements (Average), gpd	860
Daily Storage Requirements (Peak), gpd	5,460
Storage Tanks	
Number of Storage Tanks	6
Total Storage Volume, gallons	28,200
Days of Storage (Average)	32
Days of Storage (Peak)	5
Sodium Bisulfite System	
Sodium Bisulfite Solution Strength, %	38
Daily Storage Requirements (Average), gpd	110
Daily Storage Requirements (Peak), gpd	700
Storage Tanks	
Number of Storage Tanks	2
Total Storage Volume, gallons	4,500
Days of Storage (Average)	40
Days of Storage (Peak)	6

Table 4 Alternative 2 – Facility Sizing	
Contact Basin	
Number of Cells	4
Sidewater Depth, ft	10
Number of Passes per Cell	5
Width of Each Pass, ft	10
Length of Each Pass, ft	80
Volume of Each Cell, cu ft (gallons)	40,000 (299,200)
Total Contact Basin Volume, cu ft (gallons)	160,000 (1,196,900)
Contact Time at Peak Flow, min	16.0
Contact Time at Average Flow, min	101.3

5.2.3 Proposed Improvements

5.2.3.1 Sodium Hypochlorite/Bisulfite Chemical Storage and Feed Building. Both sodium hypochlorite and sodium bisulfite would be stored indoors in a conditioned room space to minimize degradation from high temperature and sunlight exposure. A single, approximately 3,600 sq ft building would be provided to allow one location for bulk chemical delivery. The sodium hypochlorite and sodium bisulfite tanks would be isolated from each other to minimize the potential of chemical interaction, which could result in adverse chemical reactions and the formation of chlorine gas. Hypochlorite and bisulfite feed pumps would also be housed in this building.

5.2.3.2 Contact Basin. The WPF does not have existing contact basins. Based on Ten States Standards and MDNR regulations, a contact time of 15 minutes was provided in the basins. The contact basin would be designed with multiple passes to minimize short-circuiting. The contact basin footprint, based on the process volume required, is approximately 200 feet long by 80 feet wide. The design parameters of the basin are provided in Table 4.

5.3 Alternative 3 – Combined On-site Generation of Sodium Hypochlorite and Bulk Sodium Bisulfite for Disinfection of WPF and HRT Flows (108 mgd)

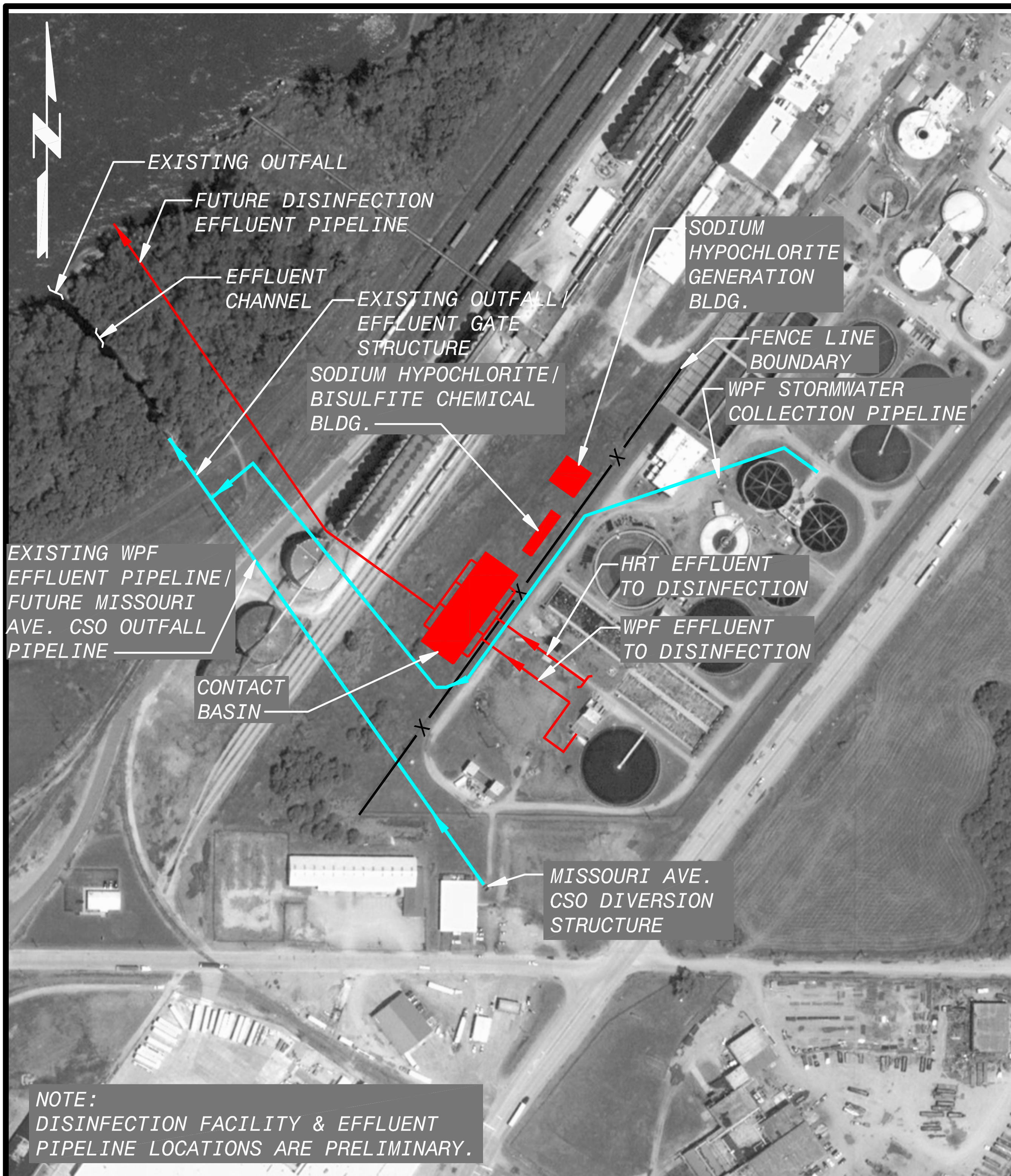
This alternative utilizes a single sodium hypochlorite and sodium bisulfite facility sized to treat peak flows from the WPF (47 mgd) and from the HRT (61 mgd) as described in Section 4.1. Figure 7 provides a simplified footprint layout of the proposed facility. As previously mentioned, the location of the proposed facility shown in Figure 7 should not be considered definite. A final location of the disinfection facility will be determined once land acquisition needs for all recommended alternatives for the Facilities Plan have been finalized. The final location of facilities will also depend on land availability, cost, and other related factors.

5.3.1 Design Criteria

Dosage requirements for the on-site generation alternatives are the same as those for the bulk sodium hypochlorite alternatives. The difference between the alternatives is related to the source of the sodium hypochlorite – the on-site generation system produces the sodium hypochlorite on-site instead of requiring bulk chemical deliveries. Table 5 summarizes the design criteria utilized for the proposed on-site sodium hypochlorite generation and bulk sodium bisulfite systems. On-site sodium hypochlorite systems are sized using chlorine equivalency, with chemical concentrations based on the criteria presented in the following table.

Table 5
Alternative 3 – Design Criteria

	Flow, mgd	Chlorine Dose, mg/L	Chlorine Residual, mg/L	12.5% Sodium Hypochlorite Dose, mg/L	12.5% Sodium Hypochlorite Use, gpd	38% Sodium Bisulfite Dose, mg/L	38% Sodium Bisulfite Use, gpd
Peak/Maximum	108	6	3	6.3	5,460	4.8	700
Average	17	6	2	6.3	860	3.2	110
Minimum	10	4	1	4.2	330	1.6	35



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ALTERNATIVE 3
ON-SITE SODIUM HYPOCHLORITE GENERATION/
BULK SODIUM BISULFITE DISINFECTION (108 MGD)

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FIGURE 7

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On-site generation systems producing 0.8 and 12.5 percent solutions of sodium hypochlorite are the most viable at wastewater treatment facilities, with various systems available capable of producing sodium hypochlorite solution at either strength. One 0.8 percent system is manufactured by Severn Trent Water Purification, Inc. under the name ClorTec. Electrolytic Technologies Corporation manufactures the most common 12.5 percent generation system under the name Klorigen. Both systems include electrolyzers, rectifiers, water chillers, brine makers, hydrogen dilution blowers, and the ability to receive bulk sodium hypochlorite. The 12.5 percent system has additional ancillary equipment required for operation such as hypochloric acid, caustic, and sodium bisulfite systems.

For on-site generation of sodium hypochlorite at the WPF the Electrolytic Technologies design of 12.5 percent was utilized as the design basis. This system would require a larger footprint for the equipment when compared to the 0.8 percent system. However, the increased equipment space requirements for this system versus the 0.8 percent system are offset by drastically reduced storage volumes for the higher solution concentration. Storage volumes are significantly different as one gallon of a 12.5 percent sodium hypochlorite solution has the equivalent chlorinating potential of approximately 15 gallons of a 0.8 percent solution. The equipment cost of the 0.8 percent system is approximately one-third less than that of the 12.5 percent system, but the latter is a more viable alternative due to the significant difference in storage requirements. In addition, the 0.8 percent system has very limited experience at facilities of this size. Operation and maintenance costs should be comparable between the systems.

5.3.2 Facility Sizing

The design criteria for the bulk sodium hypochlorite and sodium bisulfite system are applicable for this alternative. A chlorine dose of 6.0 mg/L would be used to size the storage facilities for the raw materials (salt, hydrochloric acid, sodium bisulfite, and caustic) used in the generation of sodium hypochlorite and in establishing minimum feed system requirements. A minimum of 30 days of raw materials would be provided to meet storage requirements and provide for a monthly delivery frequency. A minimum of 7.5 days of storage of generated hypochlorite solution would be provided at the average flow, and two days at the peak flow would be provided. Reduced hypochlorite storage can be provided for the on-site generation alternative when compared to the bulk sodium hypochlorite alternative because the facility is not dependent on a third party to provide the disinfection chemical. Multiple on-site generation units would be specified to allow the continual on-site production of sodium hypochlorite when one unit is out of service for maintenance or repairs. Additionally, the ability to accept bulk sodium hypochlorite at the storage tanks would be provided.

Table 6 summarizes the storage requirements for the disinfection chemicals as well as the contact basin capacity. As it is based on the required contact time, sizing of the contact basin is identical to that provided for Alternative 2. Feed systems for each chemical would be designed to operate over the flow ranges presented in Section 5.3.1.

Table 6
Alternative 3 – Facility Sizing

Design Flowrates	
Average Flow, mgd	17
Peak Flow, mgd	108
Sodium Hypochlorite System	
Sodium Hypochlorite Solution Strength, %	12.5
Equivalent Chlorine Dose (Storage), mg/L	6.3
Daily Storage Requirements (Average), ppd	860
Daily Storage Requirements (Peak), ppd	5,460
Storage Tanks	
Number of Storage Tanks	6
Total Storage Volume, gallons	14,100
Days of Storage (Average)	15
Days of Storage (Peak)	2.5
Sodium Bisulfite System	
Sodium Bisulfite Solution Strength, %	38
Daily Storage Requirements (Average), gpd	110
Daily Storage Requirements (Peak), gpd	700
Storage Tanks	
Number of Storage Tanks	2
Total Storage Volume, gallons	4,500
Days of Storage	40
Days of Storage	6

Table 6 **Alternative 3 – Facility Sizing**	
Contact Basin	
Number of Cells	4
Sidewater Depth, ft	10
Number of Passes per Cell	5
Width of Each Pass, ft	10
Length of Each Pass, ft	80
Volume of Each Cell, cu ft (gallons)	40,000 (299,200)
Total Contact Basin Volume, cu ft (gallons)	160,000 (1,196,800)
Contact Time at Peak Flow, min	16.0
Contact Time at Average Flow, min	101.3

5.3.3 Proposed Improvements

5.3.3.1 On-site Sodium Hypochlorite Generation Building. The sodium hypochlorite generation process requires several pieces of equipment as described in Table 7.

Table 7
On-site Generation Sodium Hypochlorite
Equipment System Requirements

Item	Quantity/Capacity
Electrolyzers per Module	8
Electrolyzer Modules	3
Hydrogen Gas Blower Modules	2
Brine Softener Modules	1
Chlorine Stripper Module	1
Sodium Hypochlorite Conversion Module	1
Transformer/Rectifier	6
Master Control Panel	1
Motor Control Center	1
Brine Dissolver/Storage Tank, tons	2-72
Finished Brine Storage Vessel, gallons	2,000
Hydrochloric Acid Tank, gallons	1,500
Sodium Bisulfite Tank, gallons	500
50% Caustic Storage Tank, gallons	1,000
15% Caustic Receiver Module	1
Water Chiller	1

The on-site generation equipment should be housed in an indoor, ventilated space. The equipment for on-site generation would require the construction of a new building, approximately 3,600 sq ft. The conceptual design basis assumes the on-site generation equipment would be housed in a dedicated building. If this alternative is carried forward, a future study should determine if the on-site generation building could be combined with the chemical storage facility. Hypochlorite feed pumps would also be housed in this building.

5.3.3.2 Sodium Hypochlorite/Bisulfite Chemical Storage and Feed Building. As previously discussed for Alternative 2, sodium hypochlorite and sodium bisulfite would be stored in a dedicated chemical storage building. However, the building size is reduced, based on the reduced storage requirements for on-site generation. The proposed building footprint is approximately 2,000 sq ft.

5.3.3.3 Contact Basin. The contact basin construction would be identical to that proposed in Alternative 2. The basin footprint, based on the process volume required, would be approximately 200 feet long by 80 feet wide. The details of the contact basin sizes are summarized in Table 6.

5.4 Alternative 4 – UV Disinfection of WPF Flows (54 mgd), Bulk Sodium Hypochlorite and Sodium Bisulfite Disinfection of Wet Weather Flows from HRT (61 mgd)

This alternative utilizes a dedicated UV disinfection facility sized to treat peak flows from the WPF (54 mgd) as described in Section 4.2. Flows from the HRT (61 mgd) are disinfected in a separate bulk sodium hypochlorite and sodium bisulfite system. Figure 8 provides a simplified footprint layout of the proposed facilities. The locations of the proposed facilities shown in Figure 8 should not be considered definite. The final locations of the disinfection facilities will be determined once land acquisition needs for all recommended alternatives for the Facilities Plan have been finalized. The final locations of facilities will also depend on land availability, cost, and other related factors.

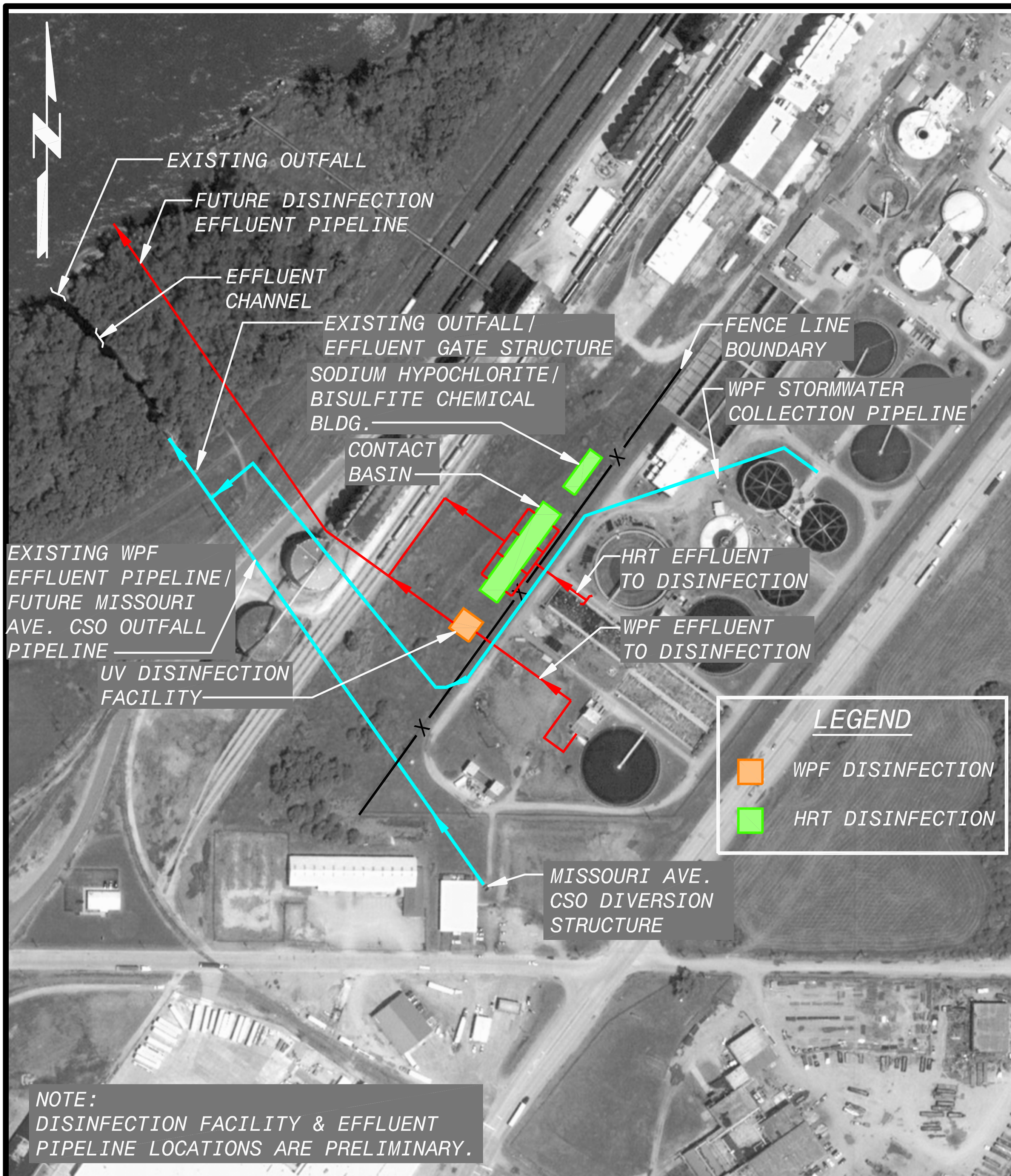

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FIGURE 8

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5.4.1 Design Criteria

Table 8 summarizes the design peak, average, and wet weather flows used in this alternative. The other design criteria for the proposed UV design are the same as described in Table 1; the design criteria for the proposed sodium hypochlorite design are summarized in Table 3.

Table 8
Alternative 4 – Design Flows

Peak WPF Flow, mgd	54
Average WPF Flow, mgd	17
Minimum WPF Flow, mgd	6
Flow Through HRT, mgd	61

5.4.2 UV Disinfection of Water Protection Facility Flows

5.4.2.1 Facility Sizing. Similar to the combined disinfection alternative (Alternative 1), the WEDECO TAK 55 system was selected as the basis of design for this alternative as a result of previous pilot study work. This horizontal LP-HI system is installed in an open-channel arrangement. Table 9 summarizes the proposed system design for the WPF.

Table 9
Alternative 4 – UV Equipment Sizing

Number of Channels	2
Number of Banks per Channel	2
Total Number of Banks	4
Number of Lamps per Module	18
Total Number of UV Lamps	936
Approximate Power Consumption at Peak Flow, kW	337

5.4.2.2 Proposed Improvements. The proposed UV system would be constructed in a new building, with all equipment located indoors and the ballast area air conditioned. The controls for the UV system would also be located within this building. It is estimated the UV building would need to be approximately 2,500 sq ft to house all necessary equipment and structures.

5.4.3 Bulk Sodium Hypochlorite Disinfection of High Rate Treatment Flows

5.4.3.1 Facility Sizing. Similar to the combined bulk hypochlorite disinfection alternative (Alternative 2), storage facilities were designed for a minimum of 15 days at average flow and four days at peak flow. The contact basin volume was based on a minimum of 15 minutes of retention time at peak flow. Table 10 summarizes the storage requirements for the alternative as well as the contact basin capacity.

Table 10
Alternative 4 – Facility Sizing

Design Flowrates	
Peak Flow, mgd	61
Sodium Hypochlorite System	
Sodium Hypochlorite Solution Strength, %	12.5
Sodium Hypochlorite Dose (Storage), mg/L	6.3
Daily Storage Requirements (Peak), gpd	3,080
Storage Tanks	
Number of Storage Tanks	5
Total Volume of Storage, gallons	15,000
Days of Storage (Peak)	4
Sodium Bisulfite System	
Sodium Bisulfite Solution Strength, %	38
Daily Storage Requirements (Peak), gpd	400
Storage Tanks	
Number of Storage Tanks	2
Total Volume of Storage, gallons	2,500
Days of Storage (Peak)	6
Contact Basin	
Number of Cells	4
Sidewater Depth, ft	10
Number of Passes per Cell	5
Width of Each Pass, ft	10
Length of Each Pass, ft	43
Volume of Each Cell, cu ft (gallons)	21,500 (160,820)
Total Contact Basin Volume, cu ft (gallons)	86,000 (643,280)
Contact Time at Peak Flow, min	15.2

5.4.3.2 Proposed Improvements

5.4.3.2.1 Sodium Hypochlorite/Bisulfite Chemical Storage and Feed Building. As described for Alternative 2, both sodium hypochlorite and sodium bisulfite would be stored indoors in a conditioned room space to minimize the degradation from high temperature and sunlight exposure. A single, approximately 2,500 sq ft building would be provided to allow one location for bulk chemical delivery. Hypochlorite and bisulfite feed pumps would also be housed in this building.

5.4.3.2.2 Contact Basin. The contact basin construction would be similar to that proposed in Alternatives 2 and 3, except with a smaller footprint due to the reduced flow rate through the facility in this alternative. The basin footprint, based on the process volume required, would be approximately 200 feet long by 45 feet wide. The details of the contact basin sizes are summarized in Table 10.

5.5 Alternative 5 – UV Disinfection of WPF Flows (54 mgd), On-site Generation of Sodium Hypochlorite and Bulk Sodium Bisulfite for Disinfection of Wet Weather Flows from HRT (61 mgd)

This alternative utilizes a dedicated UV disinfection facility sized to treat peak flows from the WPF (54 mgd) as described in Section 4.2. Flows from the HRT (61 mgd) are disinfected with sodium hypochlorite which is generated on-site. Figure 9 provides a simplified footprint layout of the proposed facilities. The locations of the proposed facilities shown in Figure 9 should not be considered definite. The final locations of the disinfection facilities will be determined once land acquisition needs for all recommended alternatives for the Facilities Plan have been finalized. The final locations of facilities will also depend on land availability, cost, and other related factors.

5.5.1 UV Disinfection of Water Protection Facility Flows

The design conditions and facility sizing for this alternative would be identical to those proposed in Alternative 4 as described in Section 5.4.2.1.

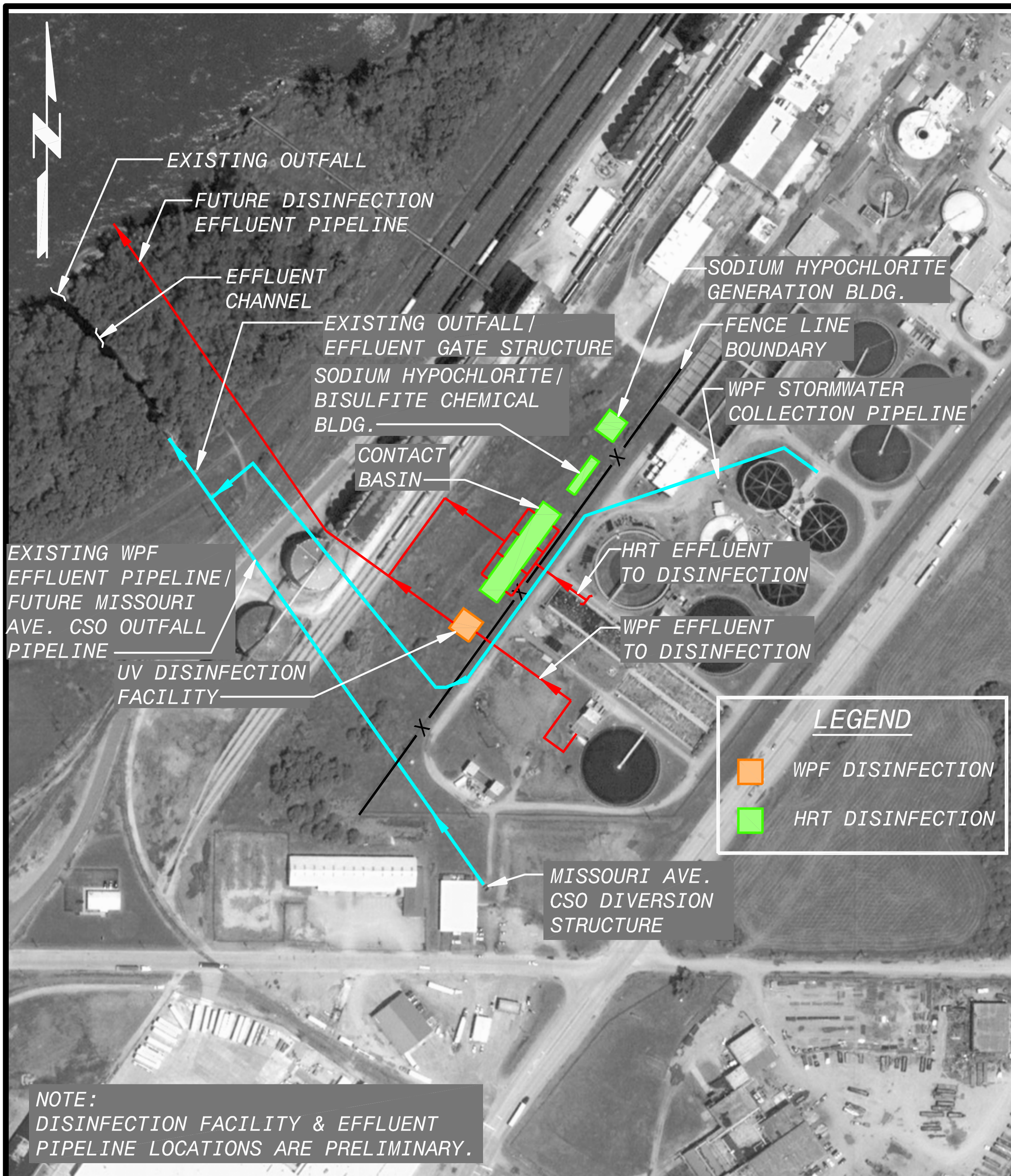

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FIGURE 9

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5.5.2 On-Site Generation of Sodium Hypochlorite Disinfection of High Rate Treatment Flows

5.5.2.1 Design Criteria. The design flow for HRT is identical to that given in Table 8, 61 mgd, and the design conditions for this alternative are similar to those presented in Table 5. As previously described, the Electrolytic Technologies 12.5 percent sodium hypochlorite generation system was utilized as the design basis for this alternative.

5.5.2.2 Facility Sizing. The design criteria for the 61 mgd bulk sodium hypochlorite and sodium bisulfite system presented for Alternative 4 are applicable for this alternative. A minimum of 30 days of raw materials storage would be provided to meet storage requirements and provide for a monthly delivery frequency. As previously discussed for Alternative 3, a minimum of 7.5 days of storage of generated hypochlorite solution would be provided at the average flow rate, and two days at the peak flow would be provided.

Table 11 summarizes the storage requirements for the disinfection chemicals as well as the contact basin capacity. As it is based on the required contact time, sizing of the contact basin is identical to that provided for Alternative 4.

Table 11
Alternative 5 – Facility Sizing

Design Flowrates	
Peak Flow, mgd	61
Sodium Hypochlorite System	
Sodium Hypochlorite Solution Strength, %	12.5
Equivalent Chlorine Dose (Storage), mg/L	6.3
Daily Storage Requirements (Peak), ppd	3,080
Storage Tanks	
Number of Storage Tanks	2
Total Storage Volume, gallons	8,600
Days of Storage (Peak)	2.8
Sodium Bisulfite System	
Sodium Bisulfite Solution Strength, %	38
Daily Storage Requirements (Peak), gpd	400

Table 11 Alternative 5 – Facility Sizing	
Storage Tanks	
Number of Storage Tanks	2
Size of Storage Tanks, gallons	2,500
Days of Storage (Peak)	6
Contact Basin	
Number of Cells	4
Sidewater Depth, ft	10
Number of Passes per Cell	5
Width of Each Pass, ft	10
Length of Each Pass, ft	43
Volume of Each Cell, cu ft (gallons)	21,500 (160,820)
Total Contact Basin Volume, cu ft (gallons)	86,000 (643,280)
Contact Time at Peak Flow, min	15.2

5.5.2.3 Proposed Improvements

5.5.2.3.1 On-site Sodium Hypochlorite Generation Building. The on-site sodium hypochlorite generation process requires the equipment described in Table 12.

Table 12
On-site Generation Sodium Hypochlorite
Equipment System Requirements

Item	Quantity/Capacity
Electrolyzers per Module	8
Electrolyzer Modules	2
Hydrogen Gas Blower Modules	1
Brine Softener Modules	1
Chlorine Stripper Module	1
Sodium Hypochlorite Conversion Module	1
Transformer/Rectifier	4
Master Control Panel	1
Motor Control Center	1
Brine Dissolver/Storage Tank, tons	2-72
Finished Brine Storage Vessel, gallons	1,060
Hydrochloric Acid Tank, gallons	780
Sodium Bisulfite Tank, gallons	270
50% Caustic Storage Tank, gallons	530
15% Caustic Receiver Module	1
Water Chiller	1

The on-site generation equipment should be housed in an indoor, ventilated space. The equipment for on-site generation would require the construction of a new, 2,300 sq ft building. The conceptual design basis assumes the on-site generation equipment would be housed in a dedicated building. If this alternative is carried forward, a future study should determine if the on-site generation building could be combined with the chemical storage facility.

5.5.2.3.2 Sodium Hypochlorite/Bisulfite Chemical Storage and Feed Building. As previously discussed for Alternative 4, sodium hypochlorite and sodium bisulfite would be stored in a dedicated chemical storage building. However, the building size is reduced, based on the reduced storage requirements for on-site generation. The proposed building footprint is approximately 1,700 sq ft.

5.5.2.3.3 Contact Basins. The chlorine contact basin construction would be identical to that proposed in Alternative 4. The details of the contact basin sizes are summarized in Table 11.

6.0 Evaluation of Alternatives

The combined and separate disinfection facilities alternatives described in Section 5.0 were evaluated based on economic and non-economic criteria.

6.1 Economic Evaluation

The economic evaluation of the five disinfection alternatives was based on life cycle costs using a 20-year present worth basis. The following sections present the capital and operations and maintenance (O&M) costs developed for each alternative.

6.1.1 Opinion of Probable Project Costs

A conceptual cost estimating methodology was employed to develop capital project costs for the alternatives considered. All project costs are given in May 2009 dollars (Engineering News Record (ENR) Building Cost Index (BCI) equal to 4773).

Building areas required for the various treatment alternatives were estimated based on the facilities needed to provide the required treatment dosages and previous Black & Veatch project experience. Building costs were determined assuming brick and block wall construction. Contact basin costs were based upon Black & Veatch project experience and unit prices appropriate for use in St. Joseph. Consistent with construction history at the WPF, it was assumed that all buildings and basins would need to be constructed on piles. Piles were assumed to be 70 feet deep based on the 2004 DRG/CDM Wastewater Treatment Plant Expansion, R-32 project drawings and the 1973 Geotechnical Report by L. Robert Kimball.

Equipment costs for the UV systems in Alternatives 1, 4 and 5 were based on quotations provided by ITT/WEDECO. Equipment costs for alternatives including on-site generation, storage tanks, and feed systems were developed based on previous Black & Veatch experience for similarly sized units. Equipment installation was estimated at 40 percent of the equipment cost for all equipment except for package systems such as tanks and UV equipment; for these systems, installation was estimated as 20 percent of the equipment cost. Table 13 provides a summary of the opinion of the probable project costs for each of the alternatives.

A cost for the influent line to convey WPF flow to the new disinfection facilities is included in Table 13. This cost is based on an assumed location for these facilities; the cost for the WPF disinfection influent will need to be confirmed once the final site location is determined. Cost for the influent line from the HRT to the new disinfection facilities will be included in the opinion of probable project cost for the wet weather treatment facilities given in TM-CSO-10 – Wet Weather Treatment Facilities. The facilities location and costs associated with effluent conveyance from the recommended disinfection facilities will be presented with the effluent pumping station in TM-WW-7 – Hydraulic Analysis and Effluent Pump Station.

In addition to building, structure, and equipment costs estimated directly, other construction costs were estimated by applying a percentage to appropriate project costs as indicated in Footnotes 3 and 4 of Table 13. The cost for electrical, instrumentation, and controls (E, I&C) was estimated as 25 percent of the cost of equipment, installation, and structures. This E, I&C cost does not include any new or back-up power feeds; these facilities will be evaluated in TM-WW-9 – Site Considerations, Utility Improvements, and Ancillary Facilities. An allowance of 10 percent was applied for project sitework. Contractor general requirements were estimated at 12 percent and contingency was set at 25 percent. Costs related to engineering, legal, and administration are reflected in a 20 percent multiplier applied to all construction costs.

Additional site related costs are also reflected in the capital costs given in Table 13. The costs reflected in the table are shown as placeholders as the final site location of the disinfection facilities must be known in order to provide a more accurate estimate of the site associated costs. Site area for each alternative was estimated as the footprint of any building or structures required for the alternative plus a 50-foot buffer around the facility. The flood protection line item estimates the amount of fill soil required to bring the future disinfection facility site(s) up to the approximate elevation of the WPF (approximate El 816). It was estimated that five feet of fill would be required. As most of the potential locations for siting the disinfection facilities are located on industrial land with unknown environmental history, a placeholder for site remediation was also included. A unit cost of $150 per cubic yard of soil removed, considering a five foot depth over the area of the site. In addition, five foot of fill dirt would be utilized to replace the five feet of contaminated soil removed. This number should be considered as only a placeholder as site remediation costs are very specific to the site location and type of contamination encountered. Likewise, land acquisition costs were estimated at $1.33 per sq ft based on preliminary guidance from the City; this value was based on the purchase price of the property located to the south of the WPF. Actual land costs may vary significantly based on the site chosen. Determination of site related costs must be revisited once the actual site selection(s) have been finalized.

Appendix C presents additional details of the development of the conceptual capital costs.

Table 13
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1 108 mgd UV $	Alternative 2 108 mgd Bulk Hypochlorite $	Alternative 3 108 mgd On-site Generation $	Alternative 4 54 mgd UV + 61 mgd Bulk Hypochlorite $	Alternative 5 54 mgd UV + 61 mgd On-site Generation $
Disinfection Influent Pipeline for WPF Flow (54 mgd)	246,000	246,000	246,000	246,000	246,000
UV Building	2,032,000			1,195,000	1,195,000
UV Equipment	4,560,000			2,280,000	2,280,000
Contact Basins		4,017,000	4,017,000	3,085,000	3,085,000
Chemical Storage Building		2,065,000	1,363,000	1,550,000	1,166,000
On-site Generation Building			1,311,000		890,000
On-site Generation Equipment			2,678,000		2,040,000
Flood Protection/Fill (placeholder) [2]	250,000	725,000	875,000	683,000	765,000
Site Remediation (placeholder) [2]	750,000	2,175,000	2,625,000	2,055,000	2,295,000
Subtotal	*7,838,000*	*9,228,000*	*13,115,000*	*11,094,000*	*13,962,000*
E, I&C, Sitework, Contractor General Requirements [3]	3,693,000	3,417,000	5,193,000	4,512,000	5,887,000
Subtotal	*11,531,000*	*12,645,000*	*18,308,000*	*15,606,000*	*19,849,000*
Contingency [4]	2,883,000	3,161,000	4,577,000	3,902,000	4,962,000
Land Acquisition (placeholder) [2, 5]	36,000	104,000	126,000	98,000	109,000
Opinion of Probable Construction Cost	**14,450,000**	**15,910,000**	**23,011,000**	**19,606,000**	**24,920,000**
Engineering, Legal, and Administration [6]	2,890,000	3,182,000	4,602,000	3,921,000	4,983,000
Opinion of Total Project Cost	**17,340,000**	**19,092,000**	**27,613,000**	**23,527,000**	**29,903,000**

Table 13
Summary of Opinion of Probable Project Costs [1]

Item	Alternative 1 108 mgd UV $	Alternative 2 108 mgd Bulk Hypochlorite $	Alternative 3 108 mgd On-site Generation $	Alternative 4 54 mgd UV + 61 mgd Bulk Hypochlorite $	Alternative 5 54 mgd UV + 61 mgd On-site Generation $

1. All costs presented in May 2009 dollars (ENR BCI = 4773).
2. Site related costs are placeholders and must be revised following final siting of the facilities. Site related costs are provided for the site area required for the disinfection facilities.
3. Electrical, instrumentation, and controls (E, I&C) estimated at 25% of the total of all equipment and structure costs. The E, I&C cost does not include any new or back-up power feeds; these facilities will be evaluated in TM-WW-9 – Site Considerations, Utility Improvements, and Ancillary Facilities. Sitework estimated at 10% of the total of equipment, structures, and E, I&C costs. Contractor general requirements estimated at 12% of the total of equipment, structures, E, I&C, and sitework costs.
4. Project contingency is estimated at 25% of the total of all equipment, structures, E, I&C, sitework, contractor general requirements, flood protection/fill, and site remediation costs.
5. Land acquisition cost based on an estimate provided by the City for the site area required for the disinfection facilities.
6. Engineering, legal, and administration (ELA) costs are estimated at 20% of the total of all equipment, structures, E, I&C, sitework, contractor general requirements, flood protection/fill, site remediation costs, contingency, and land acquisition.

As shown in Table 13, Alternative 1 (108 mgd UV) and Alternative 2 (108 mgd bulk sodium hypochlorite) have the lowest associated project costs. As the project costs of these two alternatives are within approximately 10 percent of each other, they are considered equivalent on a project cost basis for the purpose of this study.

6.1.2 Opinion of Probable Operations and Maintenance Costs

Estimates of operations and maintenance (O&M) costs were determined for each alternative. O&M costs associated with disinfection are dependent upon the extent of time the disinfection facilities are in operation each year. The final NPDES permit (effective June 19, 2009) requires disinfection during the Missouri Recreation Season, which extends from April 1 to October 31 of each year. Therefore, O&M cost estimates for each alternative were based on providing seven months of disinfection.

In addition to the duration of disinfection periods, the flow rates through the disinfection facilities also impact O&M costs. The average flow for disinfection of WPF flows during dry weather conditions was set at 17 mgd based on historical records and future projections.

During wet weather conditions, both the WPF and HRT facilities would operate at peak capacity. As a result, the entire disinfection facility, whether in a separate or combined configuration, would also run at peak capacity. In order to determine the wet weather contribution to O&M costs, an estimate of the number of rainy days during the seven month recreation season was calculated by reviewing WPF inflow data, rainfall data, and LTCP CSO typical year modeling results. Based on this analysis, approximately 52 wet days were projected to occur during the recreation season. For the purposes of developing wet weather O&M costs, the disinfection facilities were estimated to run at peak capacity (108 mgd) for each of those 52 rainy days.

The true number and duration of rain events occurring during the disinfection season will vary widely depending on the year. As a result, the estimated annual disinfection volume used to compare O&M costs between alternatives is unlikely to represent the actual number for any given year. O&M costs for each alternative increase with increasing flow more or less proportionately; as long as a consistent flow basis is utilized in the comparison of all alternatives, the alternative ranking results of the O&M

present worth analysis will hold under conditions of various flows. Based on the overall present worth results, a sensitivity analysis was conducted on the most cost effective disinfection alternative to demonstrate the impact of increasing and decreasing the number of wet weather days on the annual O&M costs. Further detail regarding the development of the wet weather treatment volumes can be found in TM-CSO-10 – Wet Weather Treatment Facilities.

Table 14 presents the unit costs employed for O&M cost development. Unit costs shown in Table 14 for power, labor, and process water were provided by the City. The remaining unit costs are based on Black & Veatch experience with similar operating facilities. Annual O&M costs for each alternative calculated were determined by multiplying the unit costs in Table 14 by the quantities of each of the items required to operate and maintain the facilities to achieve the desired level of disinfection over the course of an annual disinfection period (seven months per year). The annual O&M costs for each alternative, separated into the dry and wet weather contribution, are given in Table 15. Major O&M costs for UV include power, labor (unit maintenance and cleaning of channels), and the material costs for replacement of consumables such as bulbs, ballasts, sleeves, and wipers. The cost of purchasing bulk sodium hypochlorite is the single largest contributor to the O&M costs for the bulk hypochlorite alternatives; other costs include purchase of sodium bisulfite and labor costs. Costs for on-site generation of sodium hypochlorite include power, the salt feedstock, and hydrochloric acid for unit cleaning.

Table 14
O&M Unit Costs [1]

General	
Power [2]	$0.10/kW-hr
Labor (including benefits and overhead) [2]	$32.78/hr
UV	
Bulb Replacement	$200 each
Ballast Replacement	$350 each
Sleeve Replacement	$180 each
Wiper Replacement	$12 each
Cleaning Chemicals	Lump Sum

Table 14 O&M Unit Costs [1]	
Bulk Hypochlorite	
12.5% Bulk Sodium Hypochlorite	$1.40/gal
38% Sodium Bisulfite	$1.50/gal
On-site Generation	
Salt	$0.12/lb
Water [2]	$0.001/lb
38% Sodium Bilsulfite	$1.50/gal
50% Sodium Hydroxide	$1.40/gal
32% Hydrochloric Acid	$3.31/gal

1. All costs provided in May 2009 dollars. Except for those indicated as City provided, all unit costs based on Black & Veatch project experience.
2. Units costs based on data provided by the City. City provided water unit cost of 0.05 cents per pound was doubled to account for the unknown customer charge.

Table 15
Annual [1] O&M Costs by Alternative

	Alternative 1 108 mgd UV $	Alternative 2 108 mgd Bulk Hypochlorite $	Alternative 3 108 mgd On-site Generation $	Alternative 4 54 mgd UV + 61 mgd Bulk Hypochlorite $	Alternative 5 54 mgd UV + 61 mgd On-site Generation $
Dry Weather	283,000	1,640,000	386,000	283,000	283,000
Wet Weather	134,000	2,880,000	288,000	2,022,500	252,000
Total	417,000	4,520,000	674,000	2,305,500	535,000

1. Annual costs reflect disinfection during the Missouri Recreation Season, which extends seven months per year.

As shown in Table 15, the annual O&M cost of Alternative 1 (108 mgd UV) is the lowest of the five alternatives examined as part of this study. The next closest alternative is Alternative 5 (54 mgd UV and 61 mgd on-site generation of hypochlorite). The O&M cost differential between these alternatives is greater than the 10 percent criteria for the two alternatives to be considered equivalent; therefore, the combined UV facility emerges as the lowest cost alternative on the basis of annual O&M costs. Appendix D provides additional detail on the development of the O&M costs.

Table 15 demonstrates that the annual O&M costs for any alternative utilizing bulk sodium hypochlorite are at least triple that of the other alternatives considered. The

O&M cost evaluation is extremely sensitive to the purchase price of bulk sodium hypochlorite. The analysis presented in Table 15 utilizes a conservative sodium hypochlorite unit price of $1.40/gal. Based on Black & Veatch project experience, sodium hypochlorite costs have increased significantly in recent years. Using a conservative price basis is also prudent as sodium hypochlorite costs are tied to fuel costs which fluctuate greatly; in addition, St. Joseph would be a new customer for any chemical provider and would not receive a discount in price that might be extended to an existing customer.

While it is believed the conservative cost basis of $1.40/gal sodium hypochlorite is reasonable, a sensitivity analysis was conducted to bracket the impact of reducing sodium hypochlorite costs. The annual O&M costs were determined at a sodium hypochlorite cost of $1.00/gal, which lies below what would be considered a reasonable planning basis cost. The annualized O&M costs with this lower pricing basis for Alternative 2 (108 mgd bulk hypochlorite) and Alternative 4 (54 mgd UV and 61 mgd bulk sodium hypochlorite) are $3.3 million and $1.8 million, respectively. While the reduction in sodium hypochlorite unit price reduces the O&M for the associated alternatives by more than 20 percent, the annualized O&M costs are still at least two and a half times greater than any of the other alternatives considered. Regardless of the price basis employed, the contribution of the sodium hypochlorite costs to the overall present worth is significant as demonstrated in the following section.

6.1.3 Opinion of Probable Net Present Worth Costs

The project capital and O&M costs presented previously were utilized to develop the life cycle costs of each alternative on a present worth basis. The present worth provides the equivalent amount of money that must be invested at a given interest rate at the start of the project in order to provide all funds necessary to construct, operate, and maintain the facilities and equipment throughout the design life of the project. The net present worth of an alternative is the sum of the present worth of the project capital and O&M costs less any remaining value of facilities at the end of the project’s design life. By capturing both project capital and O&M expenses associated with the project, the net present worth method allows the City to understand the full life cycle costs associated with each of the alternatives.

Table 16 presents a summary of the estimated net present worth costs developed for each alternative. A 20-year design life was utilized in the present worth calculations; 2009 was assumed as "Year 0" for consistency of present worth calculations throughout the Facilities Plan. Consistent with the City's Capital Improvements Plan (CIP), project capital and O&M expenditures were escalated at a rate of seven and five percent, respectively, per year. A five percent interest rate was applied. Service life for determination of replacement frequency and salvage value was estimated as follows: structures – 50 years and equipment, electrical, instrumentation and controls – 20 years.

Table 16
Net Present Worth Costs by Alternative [1]

	Alternative 1 108 mgd UV $	Alternative 2 108 mgd Bulk Hypochlorite $	Alternative 3 108 mgd On-site Generation $	Alternative 4 54 mgd UV + 61 mgd Bulk Hypochlorite $	Alternative 5 54 mgd UV + 61 mgd On-site Generation $
Net Project Capital Present Worth [2]	16,933,000	17,942,000	26,295,000	22,461,000	28,701,000
O&M Present Worth [3]	8,340,000	90,400,000	13,480,000	46,110,000	10,700,000
Total Net Present Worth	**25,273,000**	**108,342,000**	**39,775,000**	**68,571,000**	**39,401,000**

1. Costs given in May 2009 dollars. Present worth calculated on a 20-year project life at 5% interest.
2. Net present worth represents the present worth of project costs less the remaining value of facilities at the end of the 20-year project life. A 7% per year escalation rate was applied to capital costs. Service life for determination of replacement frequency and salvage value was estimated as follows: structures – 50 years; equipment, electrical, instrumentation and controls – 20 years.
3. O&M costs were assumed to escalate at 5% per year.

From Table 16, it can be seen that Alternative 1, the combined 108 mgd UV facility, offers the lowest overall present worth; the net present worth value is more than 30 percent less than that of the next lowest cost alternative. As presented in Section 6.1.1, the project capital costs for this alternative and the 108 mgd bulk sodium hypochlorite alternative are considered equivalent within the level of cost information provided. As presented in Section 6.1.2, the annualized O&M costs for the bulk sodium hypochlorite alternatives were at least triple those of the other alternatives considered. When the annual O&M costs are presented on a present worth basis as shown in Table

16, the full impact of these greater costs over the 20-year project life are apparent. Though Alternatives 1 and 2 have capital costs that can be considered equivalent at this level of study, incorporation of the O&M cost impacts clearly discourage the selection of a bulk sodium hypochlorite option.

On a present worth basis, the two alternatives utilizing on-site generation are nearly equivalent and are the next most economical options after Alternative 1. The net present worth cost differential between the on-site alternatives and Alternative 1 is greater than the 10 percent criteria for the alternatives to be considered equivalent; therefore, the combined UV facility emerges as the lowest cost alternative on the basis of net present worth costs. Appendix E provides additional detail on the calculation of the net present worth for each alternative.

As previously described, the net present worth given in Table 16 reflects all disinfection capital expenditures occurring in 2009 (Year 0). O&M costs associated with disinfecting WPF and HRT flows are shown in 2010 (Year 1). The construction of the disinfection facility to treat WPF flows must occur immediately due to the upcoming regulatory compliance deadline. The future timing of the HRT construction will be determined throughout the course of the CSO Facilities Plan; therefore, it is unlikely that HRT-associated disinfection costs will occur simultaneously with those for the WPF flow. An alternate present worth analysis was conducted assuming that the HRT-related disinfection facilities are deferred 10 years after the construction of the WPF-related facilities. The intent of this analysis was to confirm that deferring a portion of the capital and O&M expenses to a later year does not change the lowest cost alternative recommendation for a combined UV facility. For the combined alternatives, estimates of the phasing of equipment and structure installation and construction were determined. For the separate alternatives, the HRT-associated portion of the project was delayed in its entirety. For all alternatives, O&M associated with disinfection of the HRT flows was deferred. The results of this analysis show that even with the deferred investments for the HRT disinfection component, the 108 mgd combined UV facility is still the lowest cost alternative, with a net present worth more than 25 percent less of the next lowest cost alternative. This analysis confirms that the selection of a combined UV disinfection system is the best alternative considering any type of phasing schedule for the facilities.

6.1.4 Sensitivity to Wet Weather Flow Volumes

The annual O&M costs for a disinfection facility are highly sensitive to the volume of flow treated. It is impossible to accurately predict the frequency and duration of wet weather events. As a result, a sensitivity study was conducted to determine the impact of varying wet weather conditions on the projected annual O&M costs for the lowest cost alternative, the combined UV facility. Figure 10 demonstrates the relationship of wet weather flows and annualized O&M costs, assuming the UV facility operates at peak capacity (108 mgd) on each wet day. The basis of the present worth presented in the previous section assumes 52 wet days occur during the disinfection season. If, for example, 150 wet days actually occur, the annual O&M cost for the UV system would increase from approximately $417,000/year for 52 wet days to $604,000/year for 150 wet days.

The annualized and present worth O&M values discussed in Sections 6.1.2 and 6.1.3 are provided for comparison among alternatives and to provide the City with an idea of the range of annual O&M costs to expect from future facilities. As demonstrated by Figure 10, the actual O&M costs associated with an operating facility are highly dependent upon the flow rate to the facility and cannot be predicted with a high degree of certainty due to the flow variability inherent within the CSO system.

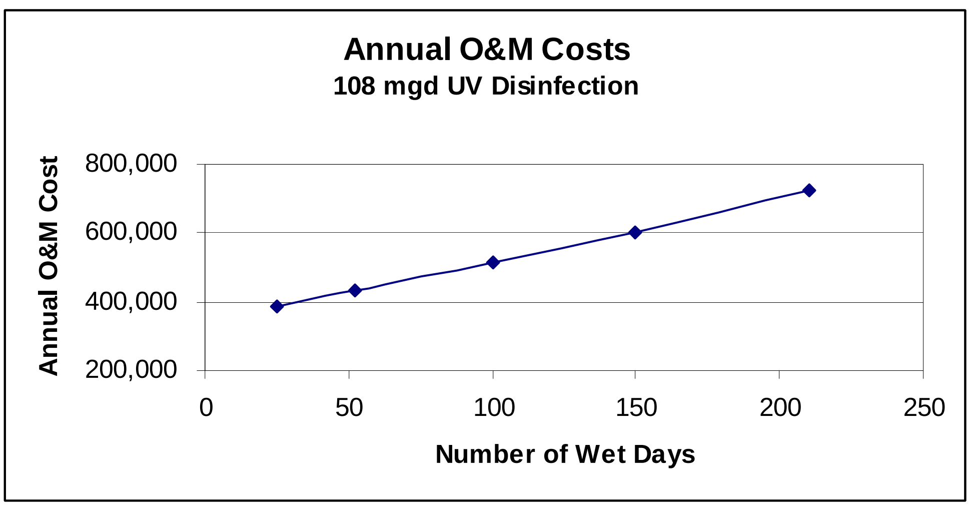


Figure 10 – Annual UV O&M Costs as a Function of the Number of Wet Days

6.2 Non-Economic Considerations

6.2.1 Non-Economic Criteria

Many important factors beyond cost affect a facility planning decision. A discussion of several non-economic criteria for the various alternatives is provided in the following sections. A summary of the non-economic advantages and disadvantages of the disinfection technology alternatives is also provided.

6.2.1.1 Safety. The safety of the surrounding community and plant personnel is one of the paramount factors to consider when selecting a disinfection technology. The following sections present safety considerations of disinfection technologies.

6.2.1.1.1 Risk to Public. The most common means for a disinfection technology to introduce risk to the public is through the regular transportation of chemicals through the community. The disinfection facilities will be located in the general vicinity of the existing WPF; though not located in a major residential or population center, the risk associated with an accidental spill or release should still be considered. In addition, the risk associated with a technology also plays an important role in its overall public acceptance. Sodium hypochlorite is a corrosive liquid. The bulk sodium hypochlorite alternatives would require the regular transportation of chemicals through the community. While the consequences associated with the spill of a liquid chemical are less than for a gas, the risks associated with bulk sodium hypochlorite transportation should still be considered. While still requiring regular deliveries of salt, the alternatives utilizing on-site generation of sodium hypochlorite mitigate the transportation risk of a hazardous chemical. On-site generation releases hydrogen, a potentially explosive gas, but it is unlikely to impact public areas. UV disinfection introduces essentially no risk as it does not require regular transportation of chemicals.

6.2.1.1.2 Operator Safety. Operator safety is also an important consideration. Sodium hypochlorite is a corrosive chemical that requires safe-handling procedures. On-site sodium hypochlorite generation releases hydrogen gas as a byproduct, which is potentially explosive. While eye exposure to UV light must be addressed through training and personal protective equipment, UV poses the least risk to operators since chemical handling is minimal.

6.2.1.1.3 Security. Security of facilities and transported chemicals is a current national focus area. None of the alternative technologies under consideration introduce significant risks associated with security of the facility or the surrounding community.

6.2.1.2 Impacts on Environment. The major purpose of a disinfection system is to protect public health and the environment. The following section present environmental considerations of disinfection technologies.

6.2.1.2.1 System Reliability. The disinfection process should be assessed by its ability to consistently meet the level of treatment required to meet permit conditions. System reliability is of particular importance to the effectiveness of disinfection achieved within St. Joseph due to the potentially high volumes of flow that will be received during wet weather events. Each of the technologies evaluated has been proven in the wastewater treatment industry and will be able to meet the applicable permit requirements.

6.2.1.2.2 Disinfection Byproduct Formation. While current regulations do not limit the release of disinfection byproducts, such as trihalomethanes (THMs), these chemicals may be limited by future water quality regulations. The use of sodium hypochlorite for disinfection as in the bulk sodium hypochlorite or on-site generation alternatives has the potential to form disinfection byproducts. Disinfection byproducts can be removed once formed, but removal involves constructing an additional treatment step after disinfection such as activated carbon adsorption. UV disinfection does not form any byproducts and therefore offers the greatest protection against potential future disinfection byproduct regulations.

6.2.1.2.3 Environmental Compatibility. Disinfection approaches need to support the use-designation and downstream uses of the receiving stream. Bacteria disinfected with UV light can go through photoreactivation. In photoreactivation, bacteria disinfected by UV can repair the dimers in their DNA strand when exposed to higher wavelengths of UV light such as sunlight. To minimize the impact of photoreactivation, UV doses should be within recommended ranges and all structures downstream of the UV system should be covered before the compliance/sampling point. Chemical disinfection with the sodium hypochlorite alternatives actually oxidizes the bacteria, and regrowth should be minimal if chlorine is applied with adequate contact time.

6.2.1.3 Operability and Maintenance. The ease with which the facilities may be operated and maintained is a significant factor for consideration. Plant personnel desire a facility that is straightforward to operate and requires minimal routine maintenance. The following sections present operability and maintenance considerations of disinfection technologies.

6.2.1.3.1 Ease of Operation and Maintenance. When comparing the overall complexity of operating a process, day-to-day operator activities must be considered as well as the need for any additional training. As the WPF does not currently have a disinfection unit, any technology chosen will require additional training for WPF personnel. LP-HI UV systems require very little maintenance, since lamp cleaning is now typically automated. Lamp life ranges from 12,000 to 18,000 hours depending on the manufacturer, so operators do not have to change lamps frequently. Operating and maintaining a bulk sodium hypochlorite system is relatively simple as the system consists of metering pumps and storage tanks, system components with which operations and maintenance personnel are already familiar. The on-site sodium hypochlorite generation system is quite complex and contains several ancillary systems. More in-depth training would be required for the on-site generation system.

6.2.1.3.2 Familiarity of Equipment. Although the WPF does not have existing disinfection facilities, operations and maintenance personnel would be most familiar with the fundamentals of operating the bulk sodium hypochlorite system as it mainly consists of familiar systems, tanks and metering pumps. On-site sodium hypochlorite generation and UV would be completely new systems to plant staff; thus requiring more extensive training. UV disinfection systems are more established in the municipal wastewater market than on-site generation systems; therefore more resources for reference in operating the UV system would be available to assist WPF personnel. The on-site generation system is a higher level of complexity than a UV system.

6.2.1.4 Viability. Long-term stability and supply of disinfection supplies should be considered when selecting a disinfection technology. The following sections present viability considerations of disinfection technologies.

6.2.1.4.1 Availability of Chemical. Use of a chemical treatment system such as bulk sodium hypochlorite introduces the risk that chemical supply could become limited for a number of reasons including market demand, a shortage of production materials, or a natural disaster. As UV treatment does not require chemicals, UV has a clear advantage when measured against this criterion. A smaller volume of chemicals is required for generating sodium hypochlorite on-site as compared to purchasing bulk liquid shipments, reducing the associated risk. However, on-site generation would require monthly deliveries of high purity salt, sodium hydroxide, and hydrochloric acid. Therefore, UV is the only technology that is entirely independent of the chemical market.

6.2.1.4.2 Shelf Life of Chemical. Sodium hypochlorite naturally degrades with time and has a limited shelf life based on the temperature of the stored chemical. Chemical degradation increases with temperature and is amplified at higher solution strengths. Shelf life is less of a concern with on-site generation of sodium hypochlorite, since chemicals can be generated as needed. Shelf life is not an issue with UV disinfection as there is no chemical utilized that can degrade. Indoor storage facilities would be provided for all disinfection chemicals utilized for St. Joseph, minimizing the impact of degradation. The use of indoor storage as well as the likelihood that chemicals will not be stored for long periods of time due to the CSO nature of the system suggests this criterion will not have a major impact. That said, the UV technology will not be susceptible to degradation issues while the other technologies considered could be.

6.2.1.4.3 Cost Stability. Recent trends have indicated that the cost for bulk sodium hypochlorite can increase quite rapidly due to market demands. This is a function of the cost to manufacture the chemical (costs associated with sodium hydroxide and hydrochloric acid which are used in the production of PVC) and transportation fuel costs. Other chemicals delivered to the site, such as sodium bisulfite and salt would also be impacted by fuel prices.

UV operating costs are highly dependent upon power costs. Nationwide, power costs are quite stable, primarily because power rate increases are regulated by state boards. The one exception is that during times of deregulation, power costs typically increase rapidly. However, it appears that after deregulation occurs, the rate of increase returns to pre-deregulation periods. Thus, it is anticipated that increases in power costs, while they will occur, will be less frequent and more stable than increases in chemical costs. As a result, UV likely provides the highest level of O&M cost stability of the technologies considered.

6.2.2 Non-Economic Evaluation

Table 17 presents a summary of select advantages and disadvantages used for comparison of the disinfection technologies.

Table 17
Advantages/Disadvantages of Disinfection Technologies

Disinfection Method	Advantages	Disadvantages
UV Disinfection	• Minimal public/operator safety threat • Lower space compared to other alternatives • Dechlorination not required • No chemical hazards • No potential for disinfection byproduct formation • Independent of chemical supply market	• Chemical disinfectants may still be needed for process control/non-potable water system • Lamps require regular cleaning and replacement (although cleaning is often automated) • Potential for photoreactivation of effluent

Table 17
Advantages/Disadvantages of Disinfection Technologies

Disinfection Method	Advantages	Disadvantages
Bulk Sodium Hypochlorite	• Minimal public safety threat • Additional uses such as process control and chlorine residual for non-potable water system • Easy to operate and maintain • Familiar equipment technology	• Moderately corrosive • Safety risks with transportation, storage and handling • Requires OSHA safety program • Disinfection byproduct formation possible • Dechlorination required • Solution strength degrades with time • Instability of chemical price
On-site Generation of Sodium Hypochlorite	• Minimal public safety threat • Flexibility (produce when it is needed) • Additional uses such as process control and chlorine residual for non-potable water system	• Limited operating experience • Moderately corrosive • Requires additional chemical for cleaning • Disinfection byproduct formation possible • Dechlorination required • Relatively complex system

7.0 Conclusions and Recommendations

MDNR's final NPDES permit for the St. Joseph WPF requires implementation of disinfection of effluent flow by December 31, 2013. The following alternatives were considered for disinfection of flows from the WPF and from a future HRT:

- Alternative 1 – Combined UV disinfection of WPF and HRT flows (108 mgd)
- Alternative 2 – Combined bulk sodium hypochlorite and sodium bisulfite disinfection of WPF and HRT flows (108 mgd)
- Alternative 3 – Combined on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of WPF and HRT flows (108 mgd)
- Alternative 4 – UV disinfection of WPF flows (54 mgd), bulk sodium hypochlorite and sodium bisulfite disinfection of wet weather flows from HRT (61 mgd)
- Alternative 5 – UV disinfection of WPF flows (54 mgd), on-site generation of sodium hypochlorite and bulk sodium bisulfite for disinfection of wet weather flows from HRT (61 mgd)

Based on an evaluation of each of the alternatives on the criteria of project capital investment, O&M costs, net present worth, and non-economic factors, combined UV disinfection (Alternative 1) is recommended for implementation.

From a project capital cost standpoint, the combined UV facility was found to be approximately equivalent to the next lowest project capital cost alternative (Alternative 2 – 108 mgd bulk hypochlorite). The O&M evaluation demonstrated that the combined UV alternative is the lowest cost alternative on the basis of annual O&M costs. Likewise, the net present worth analysis showed that Alternative 1 is the lowest cost option on the basis of net present worth. The net present worth of the 108 mgd UV alternative is about $14 million less expensive, over the 20-year life cycle, than the next closest alternative.

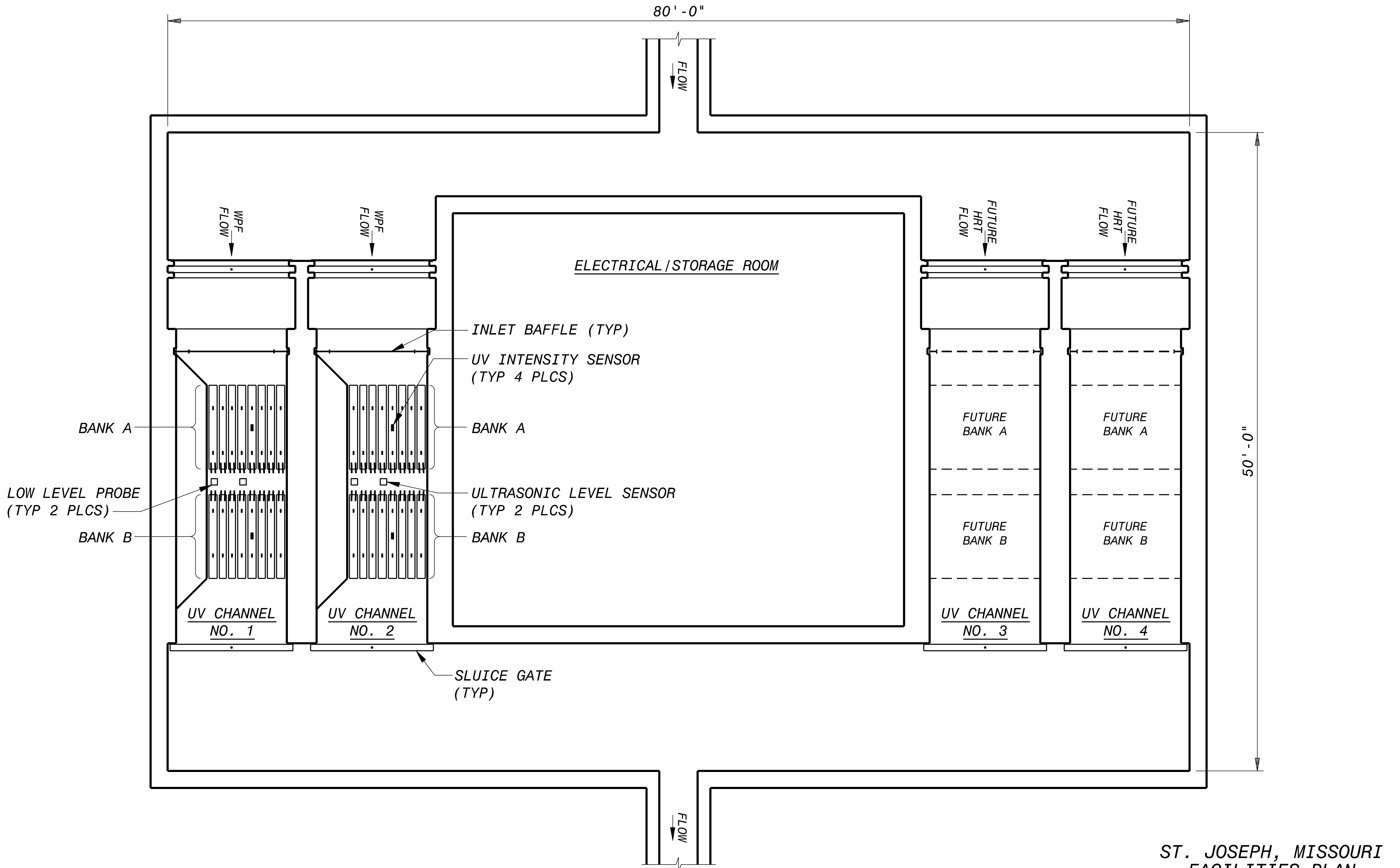
On the basis of non-economic criteria, UV is the highest ranking technology. UV disinfection does not require significant use of hazardous chemicals, is independent of the chemicals market, will not form disinfection byproducts, and is fairly straightforward to operate and maintain after initial training.

It is recommended that the City initiate the design for the 108 mgd combined UV disinfection facility to treat WPF and HRT flows. Figure 11 shows a conceptual layout of the proposed UV disinfection facility. The design should consider phasing of the UV equipment to treat HRT flows, based on the anticipated timing of the HRT construction.

8.0 References

The following references were utilized in the preparation of this memorandum:

- Wastewater Treatment Plant Disinfection Study, Technical Memorandum No. 1, Disinfection Alternatives (Black & Veatch, October 2, 2008).
- UV Pilot Study Documentation (Black & Veatch, April 23, 2009).
- Wastewater Treatment Plant Expansion, R-32 drawings (DRG/CDM, July 21, 2004).
- Geotechnical Engineering Report (L. Robert Kimball, 1973).



PLAN
1/8" = 1'-0"

ST. JOSEPH, MISSOURI
FACILITIES PLAN
PN 163509
ALTERNATIVE 1
UV DISINFECTION BUILDING
JULY 2009

FIGURE 11

BLACK & VEATCH
Building a world of difference.

BFIGBORD
FBFIGBORD

Appendix A

Disinfection Alternatives Memorandum

Black & Veatch Corporation

TECHNICAL MEMORANDUM

City of St. Joseph, Missouri	B&V Project 161799
Wastewater Treatment Plant Disinfection Study	B&V File B-1.1
Technical Memorandum No. 1 – Disinfection Alternatives	October 2, 2008

To: Bruce Woody, Andy Clements, Roger Sparks, Don Gilpin

From: Gary Hunter

cc: Matt Schultze, Larry Chapple, Dianne Honomichl

This memorandum presents the findings from the work performed for Task 1 – Prepare Technology Assessment and Bench Scale Testing Protocol for the Disinfection System Conceptual Study. This task is the first of several tasks to assist the City of St. Joseph in determining appropriate disinfection technologies to apply at the City's Wastewater Treatment Plant (WWTP). The St. Joseph WWTP currently has no existing disinfection facilities. The Missouri Department of Natural Resources (MDNR) will require dischargers to disinfect plant effluent prior to discharge by 2013. A draft National Pollutant Discharge Elimination System (NPDES) permit was forwarded to the City for review, which contains disinfection requirements based on fecal coliforms. However, it is anticipated that E. coli may become a basis for establishing disinfection levels with a 30 day mean expected to range from 126 to 1,134 E. coli colonies per 100 mL. MDNR has indicated that the City should plan on the development of a disinfection system that achieves a 30 day geometric mean of 126 E. coli colonies per 100 mL.

This technical memorandum provides a screening level discussion of the possible disinfection technologies and their applicability to the St. Joseph WWTP. For those alternatives that are deemed to be a potential fit, further high-level screening regarding space requirements as well as capital and operations and maintenance (O&M) costs will be conducted as part of subsequent tasks in the upcoming WWTP Facilities Plan being performed by Black & Veatch.

The following technologies were evaluated for providing disinfection to the plant effluent at the St. Joseph WWTP:

- Ultraviolet light
- Bulk sodium hypochlorite and sodium bisulfite
- On-site generation of sodium hypochlorite
- Chlorine and sulfur dioxide gas

- Chlorine dioxide
- Peracetic acid (PAA)
- Hydrogen peroxide
- Ozone
- Ferrate

For this assessment, it has been assumed that plant flows requiring disinfection are as follows:

- Average Day – 18 mgd
- Peak Capacity – 50 mgd

The following sections provide a screening level discussion of disinfection technologies that were considered for the St. Joseph WWTP.

1.0 Ultraviolet Light

Ultraviolet (UV) disinfection differs from chlorine disinfection in that it is a physical, not a chemical, disinfectant. UV radiation is electromagnetic energy lying within the spectrum of energy reaching Earth from the Sun, but which is outside the wavelength range of visible light. UV light between the wavelengths of 235 and 270 nanometers (nm) has been found to exhibit biocidal action on bacteria and viruses present in water, wastewater, and process water. This biocidal action is the basis for using UV radiation as a physical disinfectant in the municipal wastewater industry.

Ultraviolet radiation is readily absorbed by deoxyribonucleic acids (DNAs) in certain pathogens found in municipal wastewater. When this energy is absorbed, a pathogen's molecular structure can be altered, resulting in an inability to replicate. While this effect can be reversed (referred to as reactivation) under certain conditions, UV radiation has been proven effective in the disinfection of municipal wastewater.

Over the past several years, UV disinfection systems have gained in popularity resulting in the industry continually researching new applications of state-of-the-art technology. Since 1990, more sophisticated and reliable UV systems that operate much more cost effectively have been marketed to the municipal wastewater industry and have been installed in many plants, as effluent chlorine residual limits become tighter. There are many viable UV systems available on the market today, with new systems and changes in the technology occurring almost on a daily basis as the market responds to user demands. The systems may be broken down into the four major classifications described in the following paragraphs and shown on Figure 1.

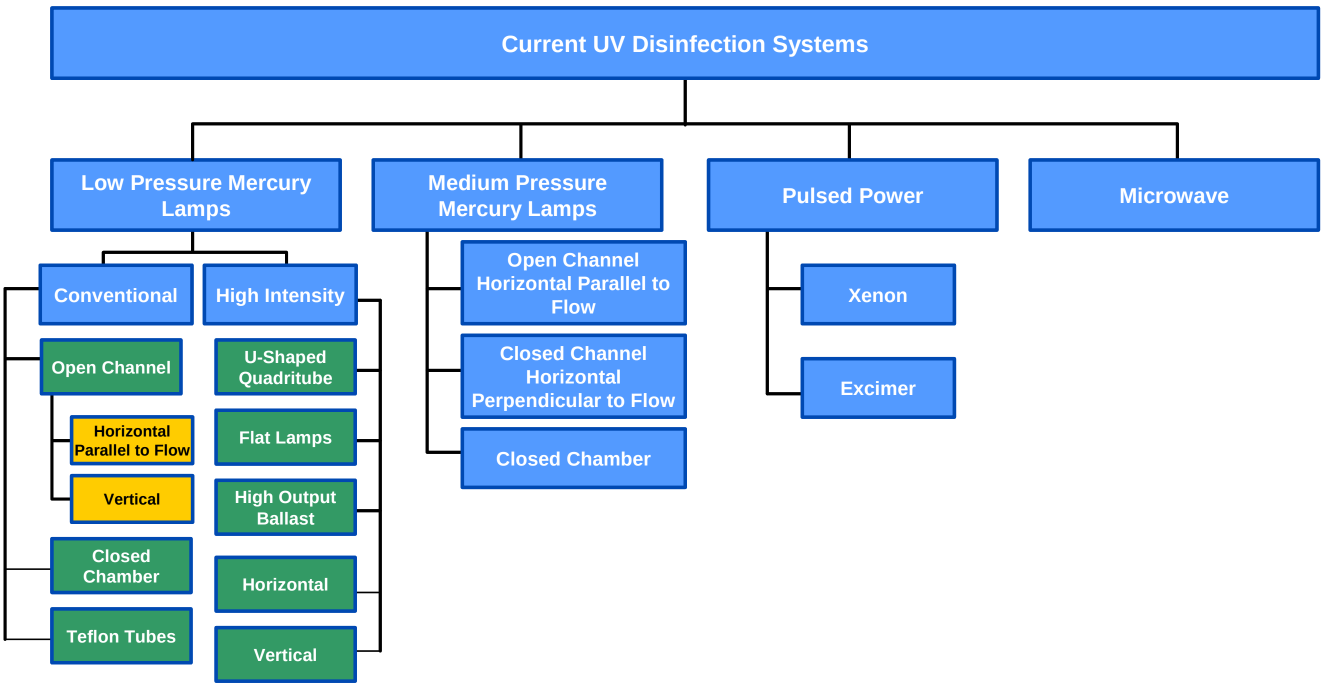


Figure 1 Current UV Disinfection Systems

Low Pressure Conventional Lamps

The oldest technology is the low pressure lamp, which is commonly available from several manufacturers in horizontal and vertical bulb configurations. Low pressure systems have been available for over 20 years. These systems can be provided in the horizontal alignment by Capital Controls and Fisher & Porter. Fisher & Porter was the first UV vendor to advance the use of the electronic ballast. They however were sued and ultimately have ceased from being a major player in the market. Of the major vendors of horizontal UV equipment, Trojan Technologies has indicated that they will not support research and development activities on the low pressure product. While they will continue to provide replacement parts, it will not be emphasized and may not be manufactured for systems the size of the St. Joseph WWTP. Several larger facilities with design capacities greater than 100 mgd that currently use this technology are converting to low pressure, high intensity lamp systems. Therefore, low pressure conventional technology was not considered as part of this study.

At least two of the UV vendors offer the vertical alignment in the low pressure system including Ozonia and UltraTech. A number of Black & Veatch clients have selected vertical low pressure technology over the past few years. One major disadvantage of the traditional low pressure vertical system is the large number of lamps that have to be cleaned and maintained. Other issues include shortened lamp life and availability of replacement parts. A typical low pressure system is shown in Figure 2.

Figure 2 Conventional Low Pressure UV System

One of the more interesting developments of the low pressure technology is the re-emergence of the Teflon tube systems as a player in the UV market. In this system, water flows through a Teflon tube enclosed in a UV chamber where UV light is emitted as wastewater flows through, inactivating the incoming bacteria. The manufacturer indicates that the advantage of this system is that it eliminates the need for cleaning of quartz sleeves. However, discussions with operation staff of surveyed facilities using this equipment indicate that daily (at least weekly) cleaning of the inside of the Teflon tubes is required. A recent survey conducted by Black & Veatch indicated that there are six operating facilities in the United States utilizing this technology. Figure 3 shows a typical Teflon tube UV system.

Figure 3 Teflon Tube UV Systems

Low Pressure, High Intensity Lamps

A newer technology which has become popular is the low pressure, high intensity (LP-HI) lamp introduced by three manufacturers in the last decade. This lamp configuration bridges the gap between low and medium pressure systems, requiring about one-third the number of bulbs compared with conventional low pressure systems, but three times as many as medium pressure systems. Self-cleaning features are available on these systems.

All the major vendors (Trojan Technologies, Wedeco, and Ozonia) supply low pressure, high intensity systems. In addition, Trojan Technologies, Wedeco, and Aquionics can supply an enclosed reactor system using low-pressure, high intensity technology. A low pressure, high intensity system is shown in Figure 4. This UV technology is one that is typically used at plants the size of the City of St. Joseph, and it is recommended that piloting be conducted to assess being able to implement it at the treatment plant.

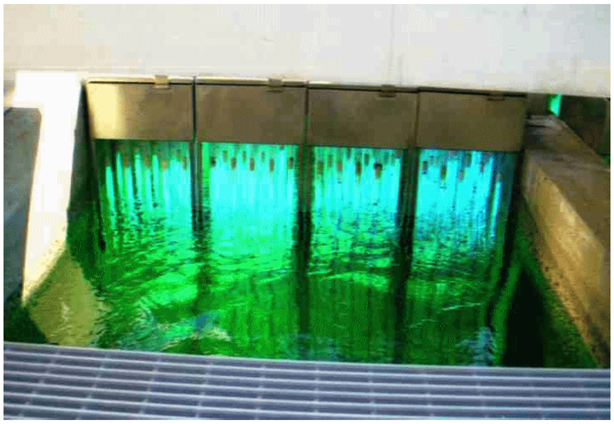


Figure 4 LP-HI UV System

Medium Pressure Lamps

Another UV technology is the medium pressure system. While some of the early installations have been subject to problems with ballasts and electrical components, many of these first generation problems have been resolved, and medium pressure systems are proving to be successful. These lamps operate at a higher power and UV output. A significant advantage to these systems is that about one-tenth of the number of bulbs are required compared to low pressure systems. Automatic cleaning systems are necessary on these systems because the bulb operates at a higher temperature, causing material to coat the quartz sleeves that protect the bulbs. Medium pressure systems are available in open channel and closed pipe applications from three different manufacturers. A medium pressure system is shown in Figure 5.

Figure 5 Medium Pressure UV Lamps

Pulsed Power Lamps

Pulsed power UV technology is emerging as an effective, economical method for water treatment facilities for inactivating cryptosporidium. Currently there are no full-scale demonstration facilities and, as a result, this system should not be considered further.

Microwave UV

Microwave UV is another technology that is emerging as an effective, economical UV system for wastewater treatment facilities. Currently no full-scale systems are in use at wastewater facilities; however the vendor has expressed some interest in piloting at the St. Joseph WWTP. Given the results of the piloting that has just been completed at the plant, it may not be practical to complete a microwave UV pilot.

2.0 Bulk Sodium Hypochlorite and Sodium Bisulfite

Sodium hypochlorite (NaOCl) is a liquid disinfection agent that has proven to be reliable in the inactivation of fecal coliforms, E. coli, and bacterial pathogens. It typically achieves performance levels equal to that of chlorine gas. Its effectiveness can be attributed to the fact that sodium hypochlorite disassociates in solution to form hypochlorous acid, which is the same disinfecting agent formed when chlorine gas is introduced into solution. A drawback is that sodium hypochlorite is a corrosive liquid, so operators must take handling precautions and regularly maintain the feed equipment.

Sodium hypochlorite can be delivered in bulk quantities at a concentration of 10 to 15 percent by weight, although 12.5 percent is most common. A 12.5 percent solution contains 1 pound of chlorine per gallon of solution. Liquid sodium hypochlorite will cause a slight increase in the pH of the finished water. The feed system consists of bulk and day storage tanks, metering pumps, and a calibration column used to pace the metering pumps. Contact tanks are sized to provide adequate retention time for disinfection once the proper dose of sodium hypochlorite has been added. The St. Joseph WWTP does not have any existing disinfection infrastructure. Therefore, the plant would need to construct costly, large footprint chlorine contact basins in order to implement this disinfection technology.

The main drawback of sodium hypochlorite is its relatively high chemical cost compared with the cost of chlorine gas and its tendency to degrade over time as a function of product concentration, temperature, and exposure to sunlight. Degradation decreases the strength of the hypochlorite and consequently the effectiveness of disinfection.

Because its solution strength degrades over time, bulk quantities should not be stored for periods longer than 60 days. Storage tanks are typically sized to provide 15 to 30 days of storage for average flow conditions. Containment around the storage tanks is required in the event of a spill or leak. Storage in an air-conditioned environment and additional monitoring of the stored product is recommended to maintain product quality and proper dosing. Dilution of the delivered product reduces the rate of degradation and is typically recommended if storage time will exceed 15 to 30 days, depending on the temperature. However, dilution water requires a water softening system.

There are a number of issues associated with the use of sodium hypochlorite, one of which is crystallization. This can occur if the temperature of the storage tanks is not regulated. To minimize the formation of crystals, sodium hypochlorite tanks can be installed indoors.

Dechlorination with sodium bisulfite ($NaHSO_3$) is required for this technology. This chemical is typically delivered by tanker truck and stored in bulk tanks as a concentrated aqueous solution. Common delivery concentration is 38 percent sodium bisulfite. This concentrated solution is either diluted in mixing tanks and then fed to the system with metering pumps or fed directly with metering pumps. Since sodium bisulfite is a liquid solution, it is safer than sulfur dioxide, and the storage and feed systems are relatively simple. However, sodium bisulfite is still classified as a hazardous material and must meet design requirements such as secondary containment as listed in the codes. Sodium bisulfite is also prone to freezing during cold weather (approximately

40º F) and requires heat tracing or insulated tanks and pipes where exposed to the weather.

Use of bulk sodium hypochlorite is widely accepted as a safer disinfection alternative to chlorine gas. While the sodium hypochlorite chemical costs are high in comparison to chlorine gas, operational costs associated with Risk Management Plans (RMPs) and Process Safety Management (PSM) rule compliance required for chlorine gas are eliminated for a bulk sodium hypochlorite system. Sodium hypochlorite is a corrosive liquid; however, chlorine in gaseous form is toxic and has a high tendency for dispersion, posing much greater safety risks to facility operators and the surrounding public.

Capital costs for the sodium hypochlorite system will be highly influenced by the cost to construct the necessary contact basins. Sodium hypochlorite chemical costs are higher than other systems such as chlorine gas and will be sensitive to rising fuel prices. Even considering these costs, sodium hypochlorite systems have been deemed cost competitive with other disinfection alternatives in evaluations completed by Black & Veatch. It is recommended that bulk sodium hypochlorite be carried forward as a disinfection alternative for further study. Wastewater treatment plant staff are currently conducting bench scale testing to determine chlorine dose requirements.

3.0 On-site Generation of Sodium Hypochlorite

This process involves the application of electric power to produce chlorine from salt or brine. If salt is used, it is dissolved into brine which is diluted and passed across electrodes powered by low voltage current. Typical on-site generation processes produce a 0.8 percent hypochlorite solution. A new technology developed by Electrolytic Technologies can produce up to 12 percent hypochlorite solution, which makes this technology feasible. On-site generation involves the use of a brine tank, a rectifier, electrolytic cells, a product tank, metering pumps, and controls. Generation of sodium hypochlorite is illustrated on Figure 6.

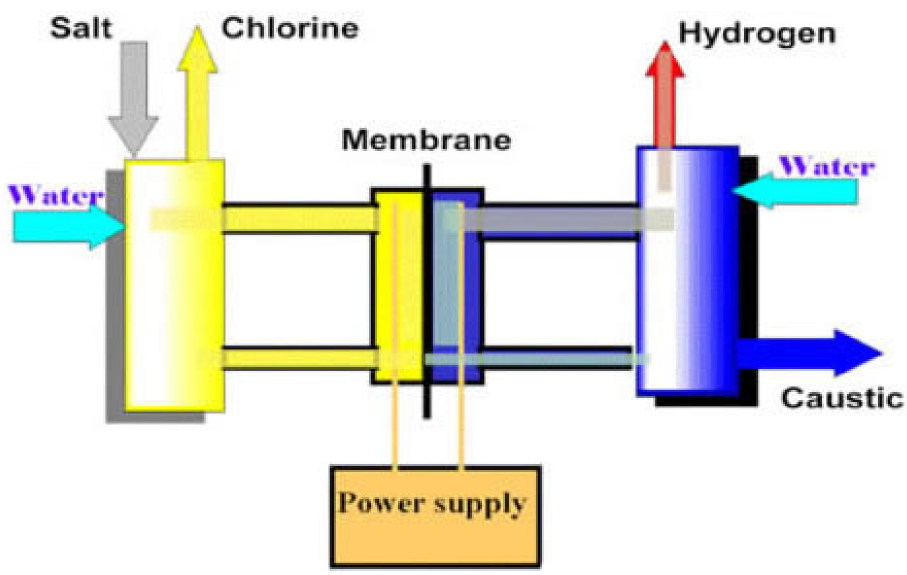


Figure 6 On-Site Sodium Hypochlorite Generation System
(http://www.electrolytictech.com)

A brine system operation begins with the water supply flowing through the water softener where its hardness is reduced. A portion of the softened water flows to the salt dissolver to produce a concentrated brine of approximately 300 grams/liter. The concentrated salt brine is then mixed with the main stream of softened water to produce a final brine with an approximately 3 percent (30 grams/liter) salt concentration. This brine is then pumped through the electrolyzer cell to produce the sodium hypochlorite solution.

The sodium hypochlorite solution is forced by the incoming water pressure to the storage tank and used as the supply for dosing pumps. The pumps are either controlled by residual analysis or by a flow-pacing signal to supply sodium hypochlorite to the point of application.

On-site generation systems are typically designed to provide one to three days storage of the maximum generation capacity of sodium hypochlorite to ensure that disinfection capacity is always available to the end user in the event of generation interruptions. Once the hypochlorite is generated, it is used in the same manner as bulk hypochlorite.

A number of items affect the overall operations of an on-site generation system including the following:

- Water Temperature. The 2006 Water Environment Federation (WEF) Wastewater Disinfection Manual indicates that water temperature is a very critical item. If water temperatures fall below 15° C, then the water temperature must be raised using a heat exchanger. This heat exchanger needs to be cleaned on a periodic basis.
- Electrolyzer Cell. The electrolyzer cell cleaning frequency varies from one to six months. The cell for the 12.5 percent system is cleaned using either dilute hydrochloric or sulfamic acid at a concentration ranging from 5 to 10 percent. Additional cleaning acid storage facilities need to be provided, and these chemical systems need to be maintained on a regular basis.
- Cathode. In order to avoid monthly cathode cleaning, the hardness of the feed water needs to be less than 50 mg/L. If the hardness were above 50 mg/L, a softening system is needed as part of the on-site system increasing maintenance costs. Therefore, both the cathode and softening systems need to be maintained on a periodic basis. Exact maintenance activities are based on the supplier of the on-site generation system as well as the softening system.
- Salt Tanks. The salt transfer lines can become plugged with obstructions and must be checked on a monthly basis.
- Power. Over time, the electrodes in the system need to be replaced. If the DC current to the cell is maintained at a higher level than recommended by the manufacturer, then the operating life of the system may decrease. This results in an increased frequency of maintenance for the electrodes.

Similar to the use of bulk sodium hypochlorite, a dechlorination agent is needed to neutralize the residual chlorine in the wastewater before discharging to the receiving stream. A sodium bisulfite system would therefore need to be included in the on-site generation alternatives in this study.

As with bulk hypochlorite delivered from off site, on-site generation of hypochlorite requires the use of a contact basin to provide a period of time for the chlorine to react and reduce the fecal coliform level below the required limits before discharging to the receiving stream. The St. Joseph WWTP does not have any existing disinfection infrastructure. Therefore, the plant would need to construct costly, large footprint chlorine contact basins in order to implement this disinfection technology. In addition, the generation equipment is fairly complex and would require significant training and attention to operate and maintain.

The combination of the large footprint required, costly capital investment, and addition of another level of complexity to the hypochlorite facility are reasons on-site hypochlorite generation will be eliminated from further consideration for the St. Joseph WWTP.

4.0 Chlorine and Sulfur Dioxide Gas

The most common means of disinfection in United States utilizes chlorine gas (Cl_2) for disinfection and sulfur dioxide gas ($S0_2$) for dechlorination. Since it is so frequently used, the design parameters and dosing requirements for disinfection by chlorine gas are well established. The equipment is fairly reliable and easy to operate. Typical gaseous chlorine facilities are comprised of a chlorine cylinder storage area equipped with storage cradles, scales, chlorine gas detectors, and an overhead crane or hoist. Chlorine feeders transfer the chlorine from the cylinders and disperse a dose of chemical into a stream of water. An emergency scrubber is generally installed to capture and neutralize any chlorine gas leaks.

Chlorine is a gas at room temperature and atmospheric pressure; however, the gas liquefies when it is cooled or pressurized. To maximize the amount of chlorine that can be transported and stored, chlorine is delivered in a liquefied state in containers, tank trucks, or railroad cars specifically designed to hold pressurized chlorine.

Chlorine reacts with water to become hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-). These chlorine compounds are strong oxidizing agents (i.e. react with other substances by gaining electrons) and are damaging to viruses, bacteria, and other organisms found in wastewater. In order for chlorine to kill bacteria and other harmful pathogens, it must have time to react. Therefore, chlorine is fed to the inlet side of chlorine contact tanks. This provides a period of time for the chlorine to react and reduce the fecal coliform level below the required limits before discharging to the receiving stream. The St. Joseph WWTP does not have any existing disinfection infrastructure. Therefore, the plant would need to construct costly, large footprint chlorine contact basins in order to implement this disinfection technology.

Chlorine is relatively inexpensive compared to most other disinfection processes and is highly effective. Perhaps the most substantial drawback associated with the use of chlorine gas is the safety risk. Chlorine is a toxic gas that can be harmful or fatal if inhaled. It is heavier than air, and if leaks occur, vapors can accumulate to high concentrations within the building. Many WWTPs which were originally located in remote areas are now surrounded by development. The closer people in the community are to stored and transported chlorine gas, the greater the risk to the public in the event of an accidental release. The hazard to WWTP operations staff is also a significant concern.

As a result of these concerns, the Uniform Fire Code (UFC) regulations have required, since 1988, some form of treatment or containment for gas chlorination systems using and/or storing more than 150 pounds of chlorine at a given time (at manned facilities). Options for addressing the requirements include chlorine scrubbers and cylinder containment vessels. The facility must also have a Risk Management Plan (RMP) in place, as required by the United States Environmental Protection Agency (USEPA).

In 1992, the Occupational Safety and Health Administration (OSHA) put forth the requirements of the Process Safety Management (PSM) rule (29 CFR 1910.119). Utilities that operate gas chlorine systems are required to comply with this regulation, given the threshold quantities (TQs) of chlorine used and stored on-site. The TQs are 1,500 pounds for chlorine and 1,000 pounds for sulfur dioxide. The rule contains compliance requirements for thirteen PSM plan elements that apply to the facilities. Compliance with the rule requires the development of written policies, procedures, and records for each of these plan elements. The impacts of PSM and UFC will need to be evaluated carefully as part of the selection of a disinfection technology.

While chlorine gas is typically delivered on-site in pressurized tanks, there are newer systems that are capable of on-site generation. These systems can simultaneously generate chlorine gas, sodium hydroxide, and high strength sodium hypochlorite (up to 12 percent). This onsite generation option would not be beneficial for the St. Joseph WWTP because the facility does not currently require production of sodium hydroxide. According to experience and manufacturers of the technology, on-site generation of chlorine gas is not financially beneficial if sodium hydroxide is not being used at the plant.

Sulfur dioxide is used with chlorine gas disinfection as the dechlorination agent. Sulfur dioxide is a toxic gas which is delivered, stored, and kept under pressure in a liquefied form in bulk storage tanks or one-ton cylinders. The feed system components and application process are nearly identical to chlorine. When sulfur dioxide is added to water containing chlorine compounds, it reacts quickly with residual chlorine to form inert chloride (Cl^-). The hazards and regulations associated with the storage and use of chlorine apply equally to sulfur dioxide.

Due to the significant safety risks and associated compliance costs related to operating a chlorine/sulfur dioxide gas disinfection system, many facilities are choosing to replace their existing chlorine gas systems with newer technologies. Therefore, Black & Veatch did not proceed any further with the investigation into this technology.

5.0 Chlorine Dioxide

Chlorine dioxide is an effective wastewater disinfectant and is considered to be an emerging technology in the field. It is an unstable, greenish-yellow gas with an odor similar to that of chlorine. Because of its unstable nature, it must be generated on-site. Water and wastewater facilities usually produce and use it in its aqueous form. When produced and handled properly, chlorine dioxide is an effective and powerful biocide, disinfecting agent, and oxidizer. It penetrates the biological cell wall more effectively than chlorine and reacts with vital amino acids of the cell to kill microorganisms present in wastewater. Therefore, it is a much stronger disinfectant than traditional chlorine. The chemistry of chlorine dioxide is much different from that of chlorine; chlorine dioxide oxidizes natural organic matter constitutes in a different manner. Therefore, it does not generate any trihalomethanes (THMs) or haloacetic acids (HAAs). Its only disinfection by-product is the chlorite ion.

There are several ways to generate chlorine dioxide; the two most common methods use sodium chlorate or sodium chlorite. The chlorine dioxide oxidation reaction is very quick and typically requires minimal contact time. Dosage is very site specific, but typical doses are up to five times less than chlorine. This technology is relatively new and has been mostly used at paper mills and water treatment plants. Chlorine dioxide has just recently been suggested for use at WWTPs. As chlorine dioxide is a newer technology with relatively limited wastewater treatment plant installations, operating requirements and costs can not be developed. Therefore, it is recommended that this technology not be evaluated further for the St Joseph WWTP.

6.0 Peracetic Acid (PAA)

Recent publications have indicated the use of peracetic acid (PAA) for disinfection of wastewaters. Results of these studies have been typically on physical/chemical treated wastewaters and have shown a high degree of success. Literature indicates that peracetic acid is most generally used for discharges to marine waters. Peracetic acid offers the advantage that it can achieve disinfection objectives (1,000 fecal coliforms) without forming disinfection by-products or requiring a de-chlorination step. Black & Veatch is currently part of a team investigating the use of peracetic acid for disinfecting storm flows from two facilities in California (one with an average design flow of 100 mgd and the other with a design flow of 200 mgd). In addition, PAA is being used with other disinfectants to reduce endocrine disrupting compounds (EDCs) and nitrosodiumethylamine (NDMA) compounds. This technology is still in the early stages of development concerning the disinfection of wastewater; therefore, no operational requirements and costs are available. It has not been evaluated further for application at the St. Joseph WWTP.

7.0 Hydrogen Peroxide

Literature indicates that hydrogen peroxide could be used for disinfection; however, no full scale facilities have been built utilizing this type of disinfection alternative. Typically when hydrogen peroxide is used it is combined with another disinfection alternative such as UV or ozone. This combination of disinfectants is being examined as a method for removal of EDC and NDMA type compounds. This technology is still in the development stage with no full scale facilities in operation; therefore, no operational requirements and costs can be developed. It has not been evaluated further for application at the St. Joseph WWTP.

8.0 Ozone

The application of ozone to wastewater effluent is another means of chemical disinfection which presents less of an environmental hazard than the use of chlorine gas. Ozone is formed when oxygen is passed through an electrically charged reactor. The ozone is then fed as a gas to the wastewater. Major system components include a high purity oxygen source (preferred), ozone generator and feed system, a well-baffled ozone contact chamber, and ozone destruction units.

Ozone is a more powerful disinfectant than chlorine gas and reacts rapidly in wastewater. Additionally, ozone breaks down into oxygen during its reaction which adds dissolved oxygen to the water. Ozone has been found to form bromated by-products. Ozone is also very unstable and must be generated on-site from air or a pure oxygen supply which is very expensive. The interest in the use of ozone has increased due to its ability to oxidize contaminants of emerging concern such as EDC and NDMA compounds.

Due to the high cost associated with generation or provision of a pure oxygen supply and high operation and maintenance costs, this alternative has been eliminated from further consideration.

9.0 Ferrate

Ferrate is a highly oxidized valence of iron (+6), found in the form of FeO_4^{2-}. Logistical roadblocks have prevented its implementation in wastewater treatment as ferrate is difficult to produce and store. Ferrate can be produced by three methods: dry oxidation, electrochemical oxidation, and wet synthesis. Since ferrate has not been actively used to achieve disinfection, it is anticipated that determining the most cost effective dose will be one of the challenges.

The efficacy of ferrate as an oxidant has been well proven in the published literature. The chemical contaminants treatable by ferrate are in the categories of endocrine disrupting chemicals, pharmaceutical personal care products, odiferous compounds, various aldehydes, amines, anilines, mercaptans, chlorinated aliphatic, amino acids, phenols and polyaromatic hydrocarbons (PAHs). Ferrate is an excellent disinfecting agent and is effective in inactivating bacteria, viruses, bacterial spores, and algae. Its application for wastewater disinfection is currently being developed to prove it is economical and technically feasible to produce ferrate at a lower cost for large-scale applications. Recent laboratory investigations indicate that ferrate may be more effective than other disinfectants when applied to low quality effluent. Currently, there are no operating wastewater treatment facilities using ferrate. Therefore, no operation and maintenance costs or requirements can be developed. It is not recommended that ferrate be examined as part of this study.

10.0 Recommendations

Based on the screenings level evaluation, it is recommended that the following technologies should be considered for further higher level evaluation:

- Bulk Sodium Hypochlorite and Sodium Bisulfite
- UV Low Pressure – High Intensity

A chlorination study is recommended for the St. Joseph WWTP to confirm the accepted standard doses (6 - 8 mg/L for trickling filter treated effluent) in order to further develop the evaluation of this alternative.

Most current UV designs use either medium pressure or LP-HI systems. These systems have incorporated energy saving controls and have greatly reduced operation and maintenance costs. LP-HI systems have consistently proven to be the better choice for small to medium size treatment plants and have therefore been selected as the UV technology for the evaluations in this study.

Several manufacturers now supply LP-HI systems. Two variations of this technology are available and are categorized by the lamp orientation: horizontal systems that install the bulbs parallel to the direction of flow and vertical systems that install the lamps perpendicular to the flow. Trojan Technologies, Wedeco/Ideal Horizons, and Calgon Corporation are manufacturers of horizontal systems with Trojan and Wedeco having the most experience in the market. Ozonia/IDI and Sunlight Systems are manufacturers of vertical LP-HI systems with IDI having more experience. All of these systems offer automated cleaning of the equipment to minimize operation and maintenance costs. For the UV evaluations in this study, the Trojan 3000Plus and WEDECO TAK 55 were selected for piloting.

New LP-HI systems have automated pacing to decrease operating costs. Systems now have flow and dose basing capabilities. Channels and banks are brought online as required to treat the incoming flow. Power to the lamps is variable based on influent conditions, primarily flow and transmittance, to always provide the minimum dose. Transmittance values can be input into the system based on assumed values, manual monitoring, or on-line transmittance monitors integrated into the system controls. An on-line transmittance unit was provided by Trojan to use on their pilot unit. Data from the Trojan unit was used to establish the control set points for the WEDECO pilot unit.

11.0 Next Steps

The findings of this technology assessment have been discussed with City staff in a workshop, and the City concurs that further evaluation of bulk sodium hypochlorite and UV LP-HI systems be conducted. As discussed previously in this memorandum, the Trojan 3000Plus and WEDECO TAK 55 were selected for UV pilot testing which has recently been completed. City staff have also completed the chlorine demand testing. A report will be prepared by Black & Veatch that summarizes findings of the chlorine and UV pilot testing. In addition, the effluent from industrial users will be examined to determine if modifications can be made to improve the overall transmittance and decrease the cost of the disinfection system. In the WWTP Facilities Plan, UV pilot testing results will be used to size equipment and develop costs (O&M and capital) allowing a comparison against the use of sodium hypochlorite. An assessment of hypochlorite disinfection and UV systems will also be conducted for wet weather flows in the Combined Sewer Overflow (CSO) Facilities Plan.

Appendix B

UV Pilot Study Documentation

City of St. Joseph, Missouri

Facilities Plan

UV Pilot Study Documentation

By

BLACK & VEATCH

Building a world of difference.

Work Order No. 09-001
B&V Project 163509

April 23, 2009

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UV Pilot Study Documentation

1.0 Executive Summary

The St. Joseph Water Protection Facility (WPF) currently has no existing disinfection facilities. The Missouri Department of Natural Resources (MDNR) is moving towards requiring all National Pollutant Discharge Elimination System (NPDES) permit holders to disinfect plant effluent. The Escherichia coli (E. coli) limit indicated in a draft permit received by the City on February 25, 2009 is a monthly average of 206 E. coli colonies per 100 mL with no single sample maximum.

To allow further development of disinfection alternatives at the WPF, bench scale and demonstration testing were conducted for ultraviolet (UV) light (low pressure – high intensity) and bulk sodium hypochlorite. Additional water quality data was also collected during the testing to help establish the design parameters for the UV systems. The UV demonstration study was conducted comparing the Trojan 3000Plus and WEDECO TAK 55 pilot units from May 21 to August 31, 2008. The results of the UV pilot testing indicate that the disinfection limits proposed by MDNR could be achieved with the piloted units.

A chlorination study was conducted during September 2009 to examine chlorine residual and formation of disinfection byproducts. The results of this study were inconclusive and will need to be repeated during the examination of disinfection alternatives for the Facilities Plan.

2.0 Background

The St. Joseph WPF currently has no existing disinfection facilities. MDNR is moving towards requiring all NPDES permit holders to disinfect plant effluent. The E. coli limit indicated in a draft permit received by the City on February 25, 2009 is a monthly average of 206 E. coli colonies per 100 mL with no single sample maximum. During 2008, the City of St. Joseph contracted with Black & Veatch to examine various disinfection alternatives and the applicability of these technologies at the WPF. The study findings indicated that the best disinfection alternatives for the WPF were chlorine and UV with the recommendation to conduct additional bench scale and demonstration testing. In addition, it was recommended that UV facilities be visited by City staff to gain a better understanding of the operational and maintenance requirements.

3.0 Data Collection

A multiple phased testing program was established to confirm the design parameters for the proposed disinfection facilities at the St. Joseph WPF. The following tests were conducted as part of this program:

- Water quality testing for UV transmittance
- Bench scale UV testing using collimated beam
- UV system demonstration testing
- Chlorine bench scale testing

Transmittance data were collected beginning May 6, 2008 and continued through the end of the UV demonstration testing on September 31, 2008. City laboratory staff conducted the transmittance testing. Water samples were collected for collimated beam testing starting on May 6, 2008. Samples were collected twice a week for eight weeks on both the primary and secondary effluent and transported to Black & Veatch in Kansas City for analysis. Bacterial analysis was conducted by the Johnson County Wastewater Laboratory.

UV demonstration testing began May 21, 2008 with the installation of a Trojan UV 3000Plus unit and continued to operate for 13 weeks. During the operation of the Trojan pilot system, a fouling study was performed to determine the appropriate safety factor to be used during design. A second demonstration unit, WEDECO TAK 55, was installed on July 8, 2008 and continued to operate for six weeks.

Bench scale testing using chlorine was conducted during October 2008. The purpose of this testing was to determine the design chlorine dose and contact time to achieve the 206 E. coli discharge limit. At the same time, samples were to be collected to determine the formation of disinfection byproducts. The disinfection byproduct formation data was collected to determine if the State of Missouri water quality standards for those compounds would be exceeded if chlorine was selected as the disinfection alternative at the plant.

3.1 Bench Scale Transmittance Test

In order to confirm the design water quality parameters for the proposed disinfection facilities, both suspended solids and transmittance data were collected and analyzed for both the primary and secondary effluent samples. Transmittance data was collected at the plant as well as during the collimated beam testing. Figure 1 shows the distribution of the transmittance data collected at the plant.

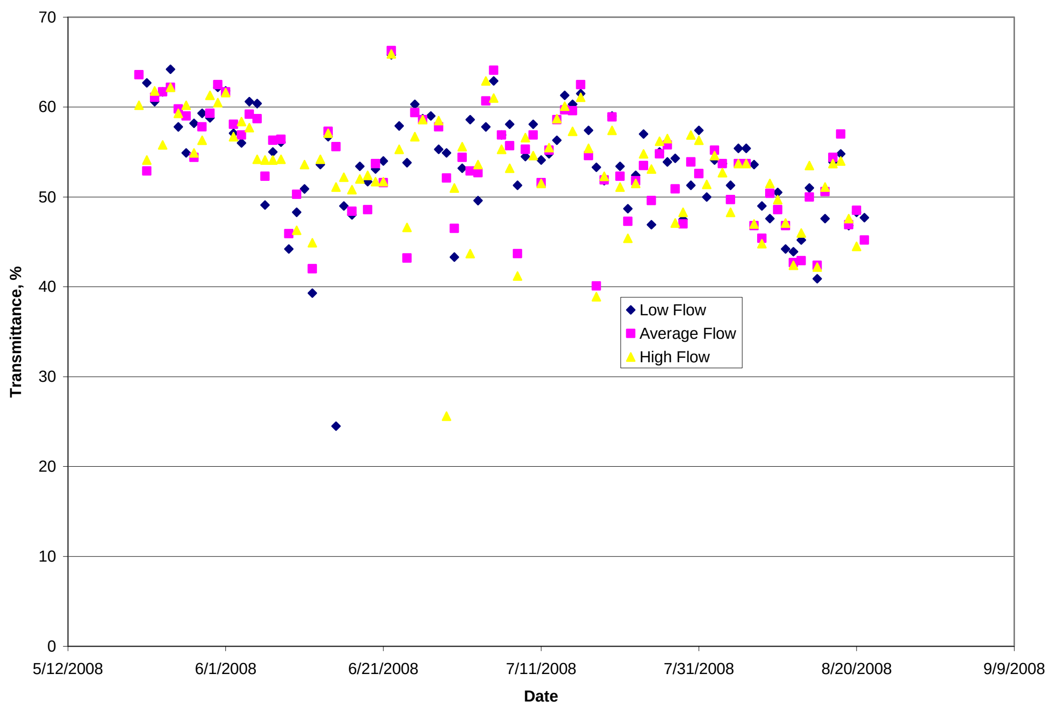

Figure 1 Effluent Transmittance Collected at Plant

The average transmittance value of the final effluent during the collimated beam testing (14 total samples) was 57.9 percent with a range from 48.4 to 65.8 percent. Therefore, the data collected at the WPF and during the collimated beam testing were comparable. In addition to the separate grab samples, an on-line transmittance unit was installed to examine the variability of transmittance throughout the day. This unit had mechanical issues such as programmable logic controller board failure and calibration problems throughout the study. Therefore, data was unable to be collected.

Since the focus of the plant testing was the final effluent, primary clarifier transmittance was collected during the collimated beam testing to simulate wet weather diverted flow water quality. Samples were blended as the primary treated effluent would be combined with secondary effluent for disinfection. The average transmittance value of the blended primary and secondary effluent collected during the collimated beam testing (14 total samples) was 39.3 percent with a range from 27.2 to 53.5 percent.

Based on the results of both transmittance tests, it is recommended that a design value of 47 percent be used for the blended effluent condition and a design value of 55 percent be used for treatment of just the final effluent.

Figure 2 shows the UV transmittance with respect to total suspended solids (TSS). The UV transmittance decreased as the TSS increased. During the pilot testing, the transmittance ranged from 25 to 66 percent, with an average value of approximately 53 percent. The results show that a UV transmittance of 50 percent and higher was achieved when TSS was less than 30 mg/L.

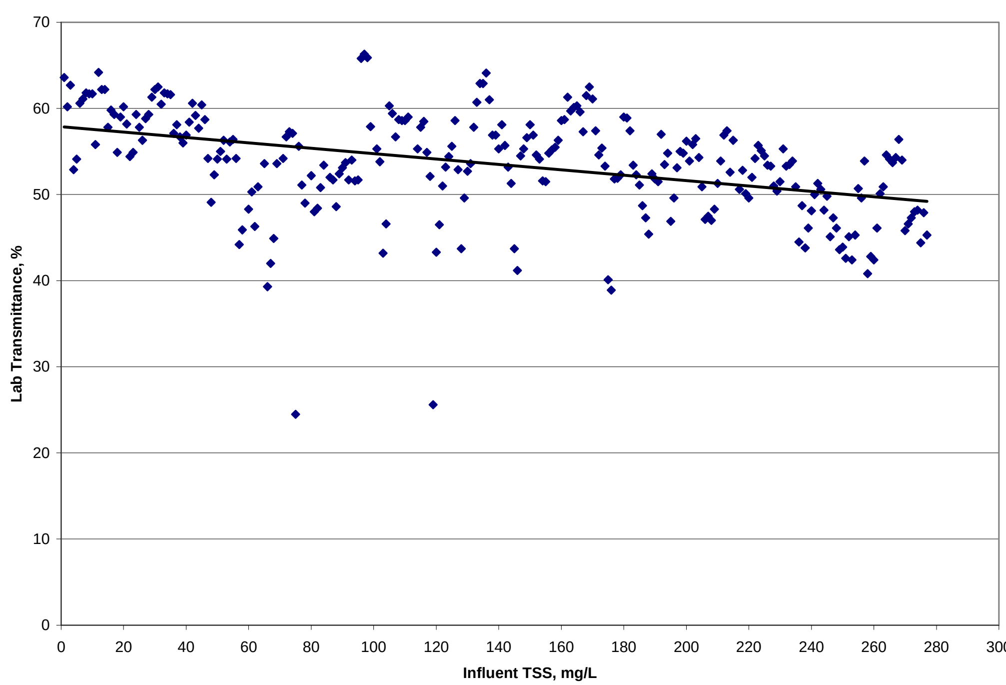

Figure 2 Trojan Pilot UV Transmittance versus Influent TSS

Figure 3 shows the cumulative distribution of UV transmittance collected at the WPF. The results show that 95 percent of the samples had a UV transmittance of less than 62 percent.

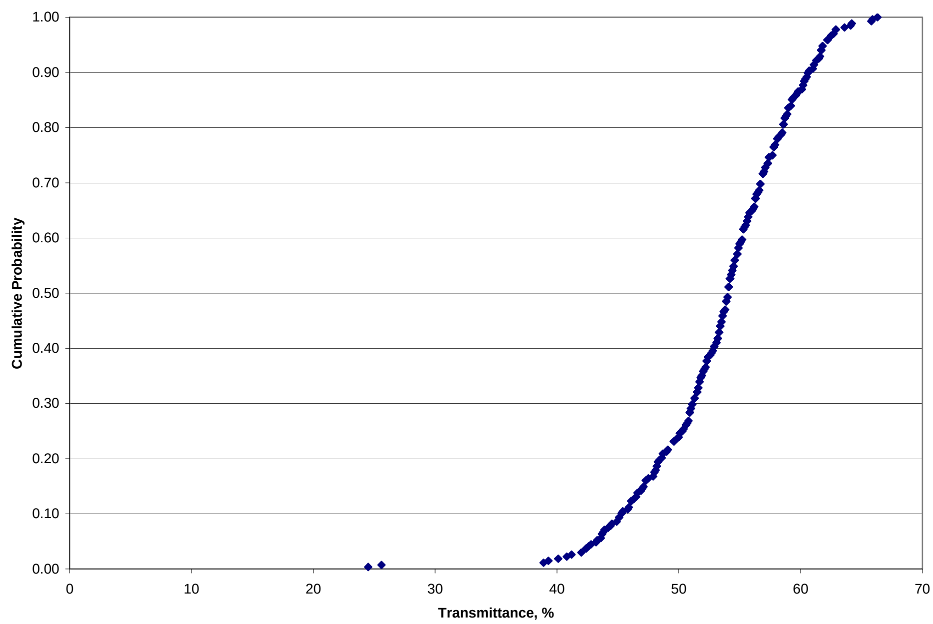

Figure 3 Pilot UV Transmittance Cumulative Distribution

3.2 Bench Scale Collimated Beam Tests

Collimated beam tests were completed over an eight week period beginning May 6, 2008 to confirm the design dose that would be established for the UV system. Samples were collected by St Joseph WPF staff and delivered to Kansas City for analysis by Black & Veatch staff. Both primary effluent and secondary effluent samples were collected. To simulate the future need for blending under wet weather conditions, the primary effluent samples were combined with secondary effluent samples before undergoing the collimated beam tests. Figure 4 shows the dose response curve of the secondary effluent samples, and Figure 5 shows the dose response curve of the blended primary effluent samples.

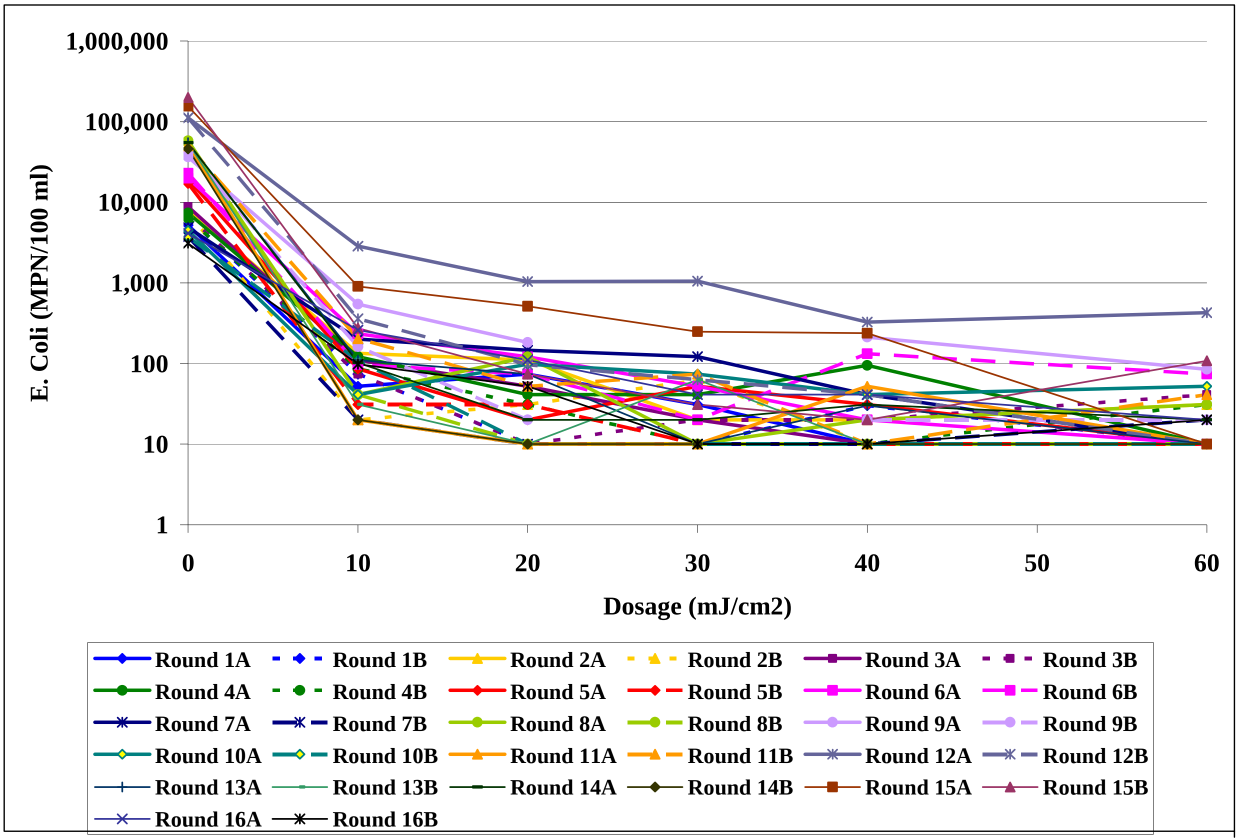

Figure 4 Secondary Effluent Dose Response Curve

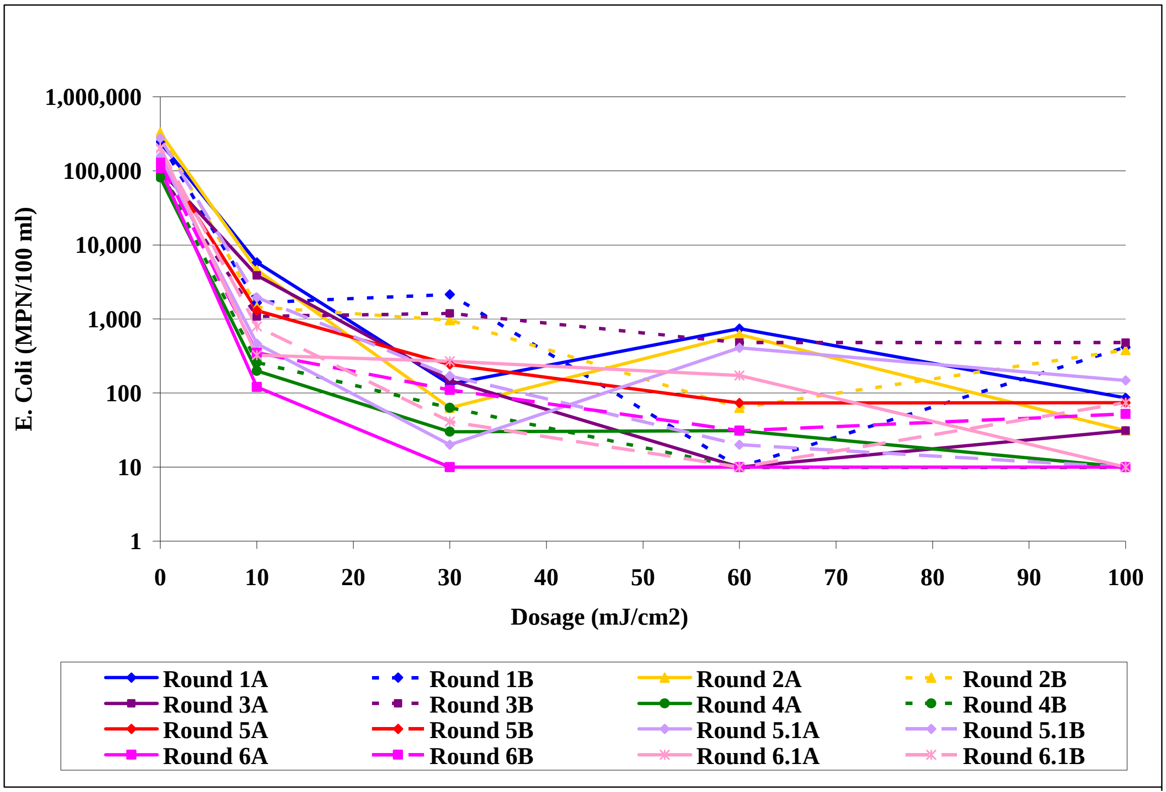

Figure 5 Blended Primary Effluent Dose Response Curve

The developed dose response curves indicate that after a dose of 30 mJ/cm2, the fecal coliform density is below the anticipated permit limit of 206 E. coli per 100 mL for secondary effluent. Based on the results, it is recommended that a design dose of 80 mJ/cm2 be established for primary effluent if UV were to be used in this application.

3.3 Full Scale Demonstration – Pilot Tests

Two low pressure high output demonstration units, one from WEDECO and the other from Trojan (Figure 6), were set up side by side to draw effluent from the final clarifiers at the St. Joseph WPF. Samples were collected upstream and downstream of the pilot units and tested for transmittance and E. coli counts.

Figure 6 Side-by-Side Operation of Trojan and WEDECO UV Systems

3.3.1 Trojan Pilot Test

A Trojan 3000Plus unit with 12 lamps (Figure 7) was set up at the site and operated for a period of 13 weeks starting in May 2008 to study the performance of the UV system. Each module contained four lamps with 250 watts each.

Figure 7 Trojan 3000Plus UV Pilot Unit

3.3.1.1 Fouling Study. The purpose of the fouling study was to determine how fast the quartz sleeves would foul after the cleaning system was turned off and then determine what length of time the cleaning system would need to recover to pre-fouled conditions.

The transmittance of the quartz sleeves was determined by measuring double layer UV transmittance through the sleeve using a UV/Visible Spectrophotometer and converting to single layer UV transmittance (Figure 8). This method does not give an absolute measurement due to the curvature of the sleeve, but was used as a relative measure to compare sleeves or to compare changes in fouling on a sleeve under controlled test conditions. A Varian Cary 50 UV/Visible Spectrophotometer was set up with a holder that holds the sleeve stationary and level such that the beam passes through the center of both sides of the sleeve and into the detector.

Figure 8 Sleeve Measured for UVT in Varian Cary 50 UV/Visible Spectrophotometer

Figure 9 shows the results from the fouling study conducted with the Trojan system. As the fouling increased by turning off the cleaning system, the sleeve transmittance kept decreasing and the effluent fecal coliform started to increase. The sleeve transmittance decreased at a rate of about 6.2 percent per day.

Figure 10 shows the increase in effluent E. coli concentration as the sleeves were allowed to foul by turning off the cleaning systems on June 9, 2008 followed by a decrease in effluent E. coli concentrations once the cleaning system was turned back on June 23, 2008. The E. coli counts eventually returned to pre-fouling conditions in about two days following the start of the cleaning system.

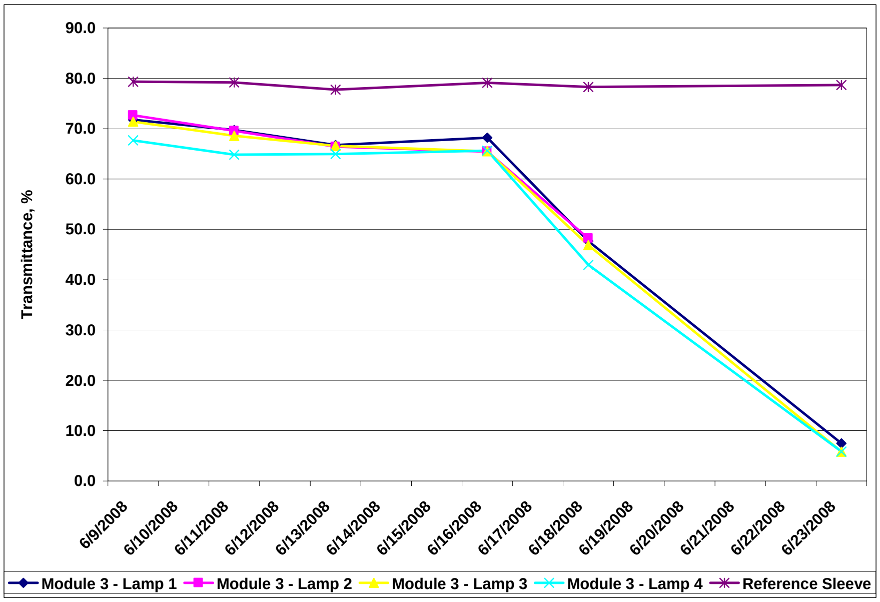

Figure 9 Results of Fouling Test

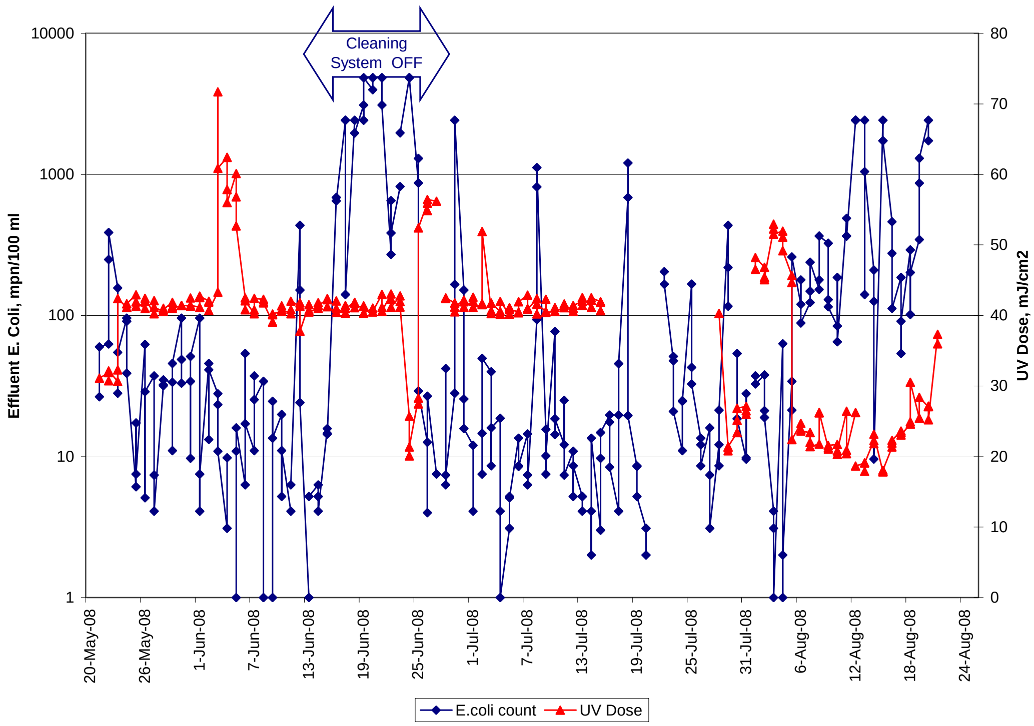

Figure 10 Trojan Pilot Effluent E. coli Counts

3.3.1.2 Performance Study. An initial performance study was conducted to confirm the performance of the Trojan 3000Plus unit (May 21 through July 8, 2008). A second performance study was completed after installation of the WEDECO unit to compare the performance between the two pilot units (July 8 through August 21, 2008). This section presents the results of the first and second performance studies from May 21 through August 21, 2008.

As demonstrated in Figure 10, the E. coli density for the Trojan system was below 100 mpn/100 mL under a normal UV lamp cleaning cycle and a UV dose of 50 mJ/cm2 and higher. Figure 11 presents the UV dose response curves for Trojan, and the results show that the E. coli count was below 100 mpn/100 mL at a UV dose of 50 mJ/cm2 and higher.

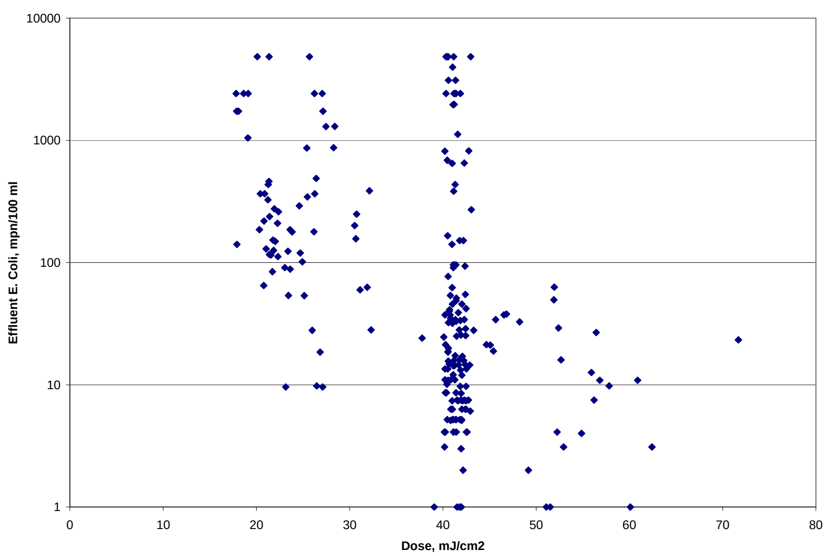

Figure 11 Trojan Pilot Effluent E. coli Counts versus UV Dose

3.3.2 WEDECO Pilot Test

A WEDECO pilot unit (Figure 12) was set up on July 9, 2008 and operated for six weeks to study the performance of the system in comparison with the Trojan 3000Plus UV system.

Figure 12 WEDECO UV Pilot Unit

Figure 13 demonstrates the WEDECO pilot effluent E. coli count with the data indicating that the E. coli density was less than 100 mpn/100 mL for a UV dose of 30 mJ/cm2 and higher. Figure 14 shows the UV dose versus the E. coli count from the WEDECO pilot. The E. coli count was less than 100 mpn/100 mL at a UV dose of 30 mJ/cm2 and higher.

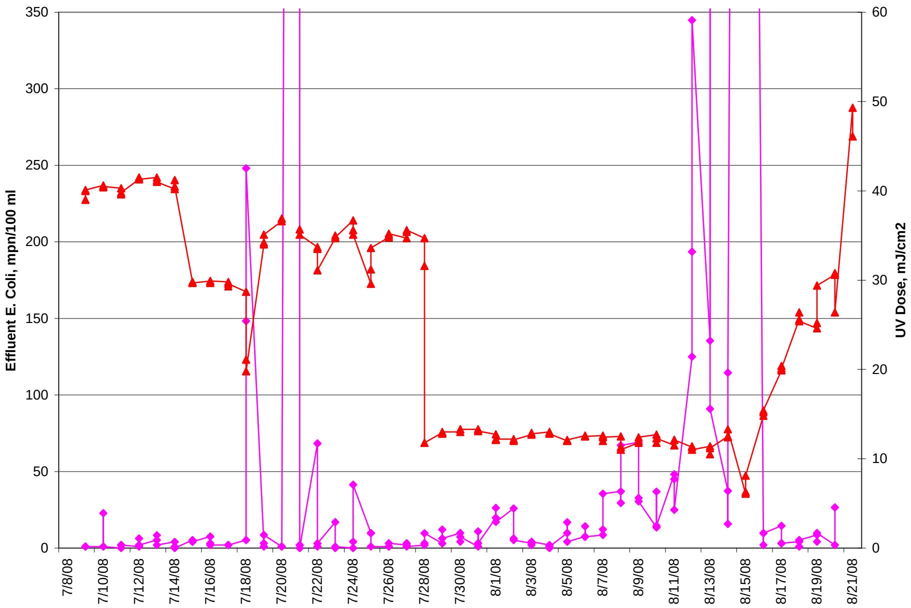

Figure 13 WEDECO Pilot Effluent E. coli Counts

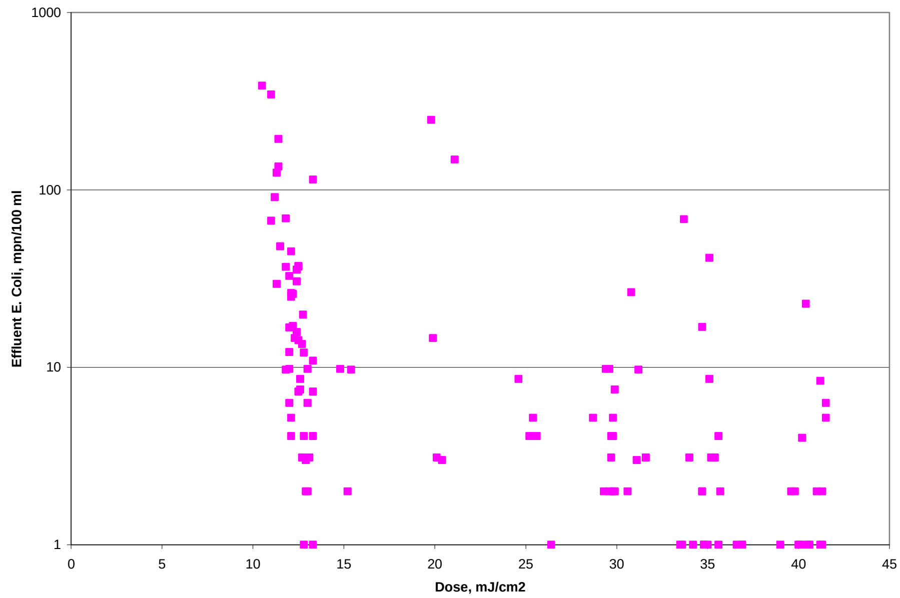

Figure 14 WEDECO Pilot Effluent E. coli Counts versus UV Dose

3.3.3 Pilot System Comparison

In order to compare the performance of the Trojan and WEDECO UV systems, a side by side pilot study was conducted for a period of six weeks starting on July 9, 2008. Figures 15 and 16 compare the E. coli counts and UV dose applied for the side-by-side operation of the Trojan and the WEDECO systems. The results show that the WEDECO system consistently achieved a lower E. coli count at a lower UV dose during the six weeks of operation.

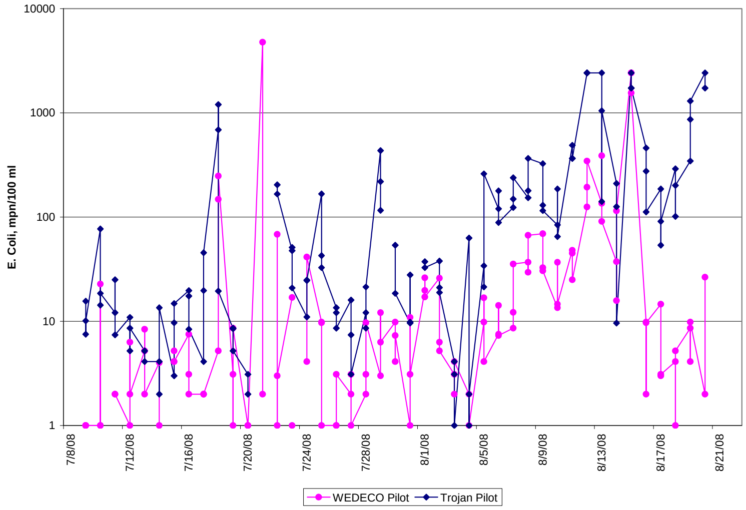

Figure 15 Pilot Comparison of Trojan and WEDECO Effluent E. coli Counts

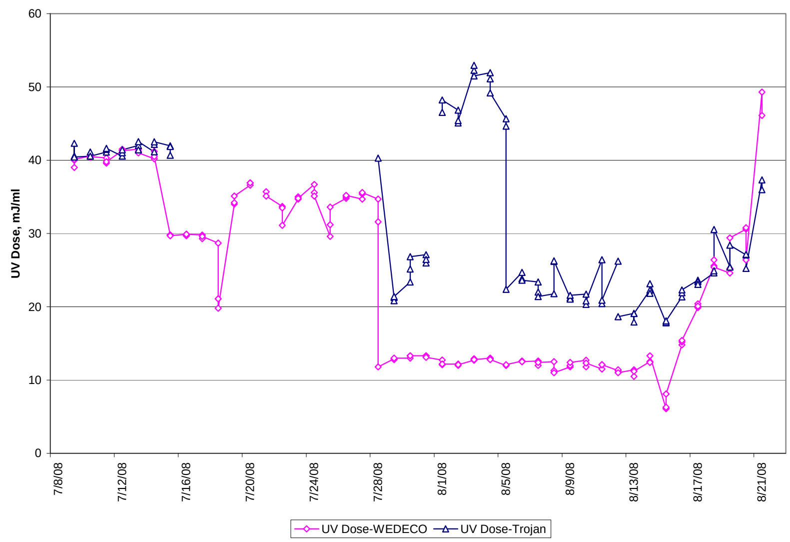

Figure 16 Pilot Comparison of Trojan and WEDECO UV Dose

Figure 17 compares the E. coli count for the Trojan and WEDECO systems at different UV doses. For the Trojan system, the E. coli count was less than 100 mpn/100 mL at a UV dose of >50 mJ/cm2 while for WEDECO, a lower UV dose of >30 mJ/cm2 was sufficient for an E. coli count of less than 100 mpn/100 mL.

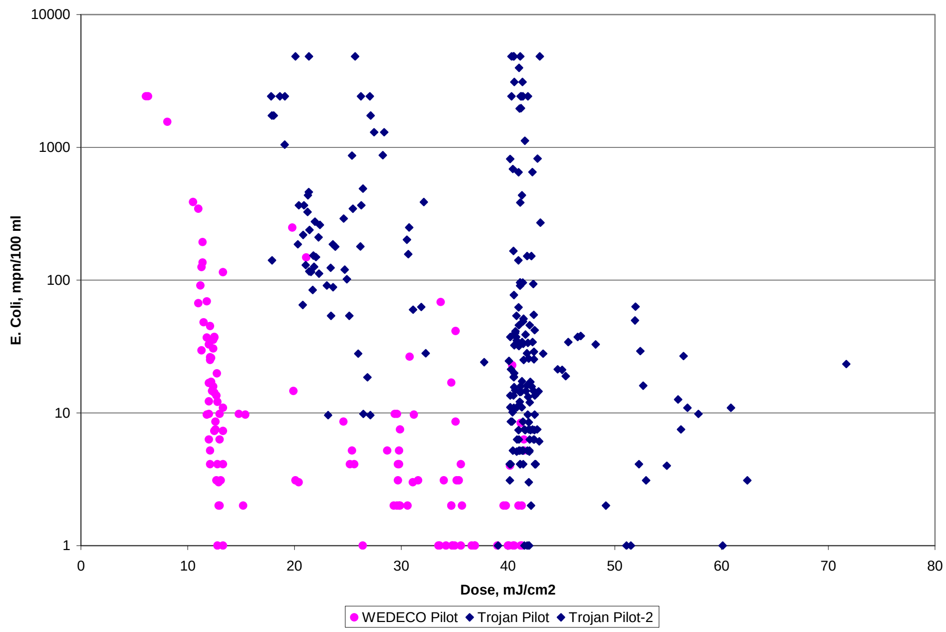

Figure 17 Pilot Comparison of Effluent E. coli Count versus UV Dose

3.4 Chlorination Study

A chlorination study was performed with an initial dose of chlorine. Results of the study were inconclusive, and additional testing will need to be completed during the Facilities Plan to verify the chlorine dose.

4.0 Conclusions

The results of the UV pilot testing indicate that the disinfection limits proposed by MDNR could be achieved with the piloted units. Therefore, UV disinfection will be further evaluated as a disinfection alternative in the Facilities Plan. Results of the chlorination study were inconclusive, and additional testing should be conducted during the Facilities Plan to verify the chlorine dose for the use of sodium hypochlorite as a disinfectant.

Appendix C

Capital Cost Backup

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 1 - Ultraviolet Light (108 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Disinfection Influent Pipeline for WPF Flow (54 mgd)				
	lin ft	600.00	410	246,000
WPF Disinfection Influent Pipeline Subtotal				*246,000*
UV Building				
Building Superstructure and Slab	sq ft	180.00	4,000	720,000
Earthwork				
Structural Excavation	cu yd	20.00	1,385	27,704
Compacted Fill	cu yd	25.00	346	8,657
Granular Fill	cu yd	35.00	173	6,060
Concrete				
Slab on Grade/Footings	cu yd	530.00	30	15,704
Walls	cu yd	850.00	322	273,889
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			7,037
HVAC	sq ft	35.00	4,000	140,000
Plumbing	sq ft	10.00	4,000	40,000
Fire Protection	sq ft	3.50	4,000	14,000
Piles	each	4,550.00	80	364,000
Bridge Crane	LS			62,313
Sluice Gates (60 inch)	each	40,000.00	7	280,000
UV Channel Grating	sq ft	55.00	1,320	72,600
UV Building Subtotal				*2,032,000*
UV Equipment				
Phase 1 (54 mgd) (WEDECO as basis)	LS			2,280,000
Phase 2 (54 mgd) (WEDECO as basis)	LS			2,280,000
UV Equipment Subtotal				*4,560,000*
Alternative Subtotal				*6,838,000*
Electrical, Instrumentation, & Controls	LS	25%		1,710,000
Subtotal				*8,548,000*
Sitework	LS	10%		855,000
Subtotal				*9,403,000*
General Requirements	LS	12%		1,128,000
Flood Protection/Fill (placeholder)	cu yd	25.00	10,000	250,000
Site Remediation (placeholder)	cu yd	150.00	5,000	750,000
Subtotal				*11,531,000*
Contingency	LS	25%		2,883,000
Land Acquistion (placeholder)	sq ft	1.33	27,000	36,000
Opinion of Probable Construction Cost				***14,450,000***
Engineering, Legal, & Administration	LS	20%		2,890,000
Opinion of Probable Project Cost				**17,340,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 2 - Bulk Sodium Hypochlorite/Bisulfite (108 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Disinfection Influent Pipeline for WPF Flow (54 mgd)				
	lin ft	600.00	410	246,000
WPF Disinfection Influent Pipeline Subtotal				*246,000*
Contact Basins				
Basins (230 ft long by 80 ft wide by 12 ft depth, 4 cells)				
Earthwork				
Structural Excavation	cu yd	20.00	9,413	188,259
Compacted Fill	cu yd	25.00	1,448	36,204
Granular Fill	cu yd	35.00	724	25,343
Concrete				
Slab on Grade/Footings	cu yd	530.00	1,425	755,250
Walls	cu yd	850.00	1,347	1,144,667
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			55,433
Piles	each	4,550.00	276	1,255,800
Sluice Gates (60 inch)	each	40,000.00	8	320,000
Rotating Scum Weirs (18 in diameter, 10 ft long)	each	9,000.00	4	36,000
Mixers	each	50,000.00	4	200,000
Contact Basins Subtotal				*4,017,000*
Chemical Storage Building				
Building Superstructure and Slab	sq ft	183.00	3,600	658,800
Earthwork				
Structural Excavation	cu yd	20.00	317	6,333
Compacted Fill	cu yd	25.00	387	9,676
Granular Fill	cu yd	35.00	158	5,542
Concrete				
Slab on Grade/Footings	cu ft	530.00	-	-
Pump and Tank Pads	cu ft	630.00	37	23,461
Walls	cu ft	850.00	44	37,778
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded Accessories	LS			1,634
HVAC	sq ft	35.00	3,600	126,000
Plumbing	sq ft	10.00	3,600	36,000
Fire Protection	sq ft	3.50	3,600	12,600
Protective Coating for Chemical Storage Floors	sq ft	35.00	3,600	126,000
Piles	each	4,550.00	73	332,150
Sodium Hypochlorite				
FRP Storage Tanks	gallons	6.60	28,200	186,120
Level Transmitter	each	3,500.00	6	21,000
Level Gauge	each	2,100.00	6	12,600
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	3,000	60,000
2" PVC Piping around Tanks	lin ft	25.00	600	15,000
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			79,544
Sodium Bisultfite				
FRP Storage Tanks	gallons	6.60	4,512	29,779
Level Transmitter	each	3,500.00	2	7,000
Level Gauge	each	2,100.00	2	4,200
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,000	20,000
2" PVC Piping around Tanks	lin ft	25.00	500	12,500
Piping Devices	LS/pump	3,500.00	5	17,500

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 2 - Bulk Sodium Hypochlorite/Bisulfite (108 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			35,296
Chemical Storage Subtotal				*2,065,000*
Alternative Subtotal				*6,328,000*
Electrical, Instrumentation, & Controls	LS	25%		1,582,000
Subtotal				*7,910,000*
Sitework	LS	10%		791,000
Subtotal				*8,701,000*
General Requirements	LS	12%		1,044,000
Flood Protection/Fill (placeholder)	cu yd	25.00	29,000	725,000
Site Remediation (placeholder)	cu yd	150.00	14,500	2,175,000
Subtotal				*12,645,000*
Contingency	LS	25%		3,161,000
Land Acquistion (placeholder)	sq ft	1.33	78,300	104,000
Opinion of Probable Construction Cost				***15,910,000***
Engineering, Legal, & Administration	LS	20%		3,182,000
Opinion of Probable Project Cost				**19,092,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 3 - On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (108 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Disinfection Influent Pipeline for WPF Flow (54 mgd)				
	lin ft	600.00	410	246,000
WPF Disinfection Influent Pipeline Subtotal				*246,000*
Contact Basins				
Basins (230 ft long by 80 ft wide by 12 ft depth, 4 cells)				
Earthwork				
Structural Excavation	cu yd	20.00	9,413	188,259
Compacted Fill	cu yd	25.00	1,448	36,204
Granular Fill	cu yd	35.00	724	25,343
Concrete				
Slab on Grade/Footings	cu yd	530.00	1,425	755,250
Walls	cu yd	850.00	1,347	1,144,667
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			55,433
Piles	each	4,550.00	276	1,255,800
Sluice Gates (60 inch)	each	40,000.00	8	320,000
Rotating Scum Weirs (18 in diameter, 10 ft long)	each	9,000.00	4	36,000
Mixers	each	50,000.00	4	200,000
Contact Basins Subtotal				*4,017,000*
Chemical Storage Building				
Building Superstructure and Slab	sq ft	201.00	2,000	402,000
Earthwork				
Structural Excavation	cu yd	20.00	194	3,889
Compacted Fill	cu yd	25.00	194	4,861
Granular Fill	cu yd	35.00	97	3,403
Concrete				
Slab on Grade/Footings	cu ft	530.00	-	-
Pump and Tank Pads	cu ft	630.00	20	12,405
Walls	cu ft	850.00	22	18,889
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded Accessories	LS			838
HVAC	sq ft	35.00	2,000	70,000
Plumbing	sq ft	10.00	2,000	20,000
Fire Protection	sq ft	3.50	2,000	7,000
Protective Coating for Chemical Storage Floors	sq ft	35.00	2,000	70,000
Piles	each	4,550.00	56	254,800
Sodium Hypochlorite				
FRP Storage Tanks	gallons	6.60	14,100	93,060
Level Transmitter	each	3,500.00	3	10,500
Level Gauge	each	2,100.00	3	6,300
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,500	30,000
2" PVC Piping around Tanks	lin ft	25.00	300	7,500
Piping Devices	LS/pump	3,500.00	3	10,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			48,672
Sodium Bisultfite				
FRP Storage Tanks	gallons	6.60	4,512	29,779
Level Transmitter	each	3,500.00	2	7,000
Level Gauge	each	2,100.00	2	4,200
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,000	20,000
2" PVC Piping around Tanks	lin ft	25.00	200	5,000
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 3 - On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (108 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Suppliers Costs (submittals, freight, profit)	LS			33,796
Chemical Storage Subtotal				*1,363,000*
On-site Generation Building				
Building Superstructure and Slab	sq ft	183.00	3,600	658,800
Earthwork				
Structural Excavation	cu yd	20.00	313	6,259
Compacted Fill	cu yd	25.00	313	7,824
Granular Fill	cu yd	35.00	156	5,477
Concrete				
Slab on grade/footings	cu ft	530.00	-	-
Walls	cu ft	850.00	-	-
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded accessories	LS			-
HVAC	sq ft	35.00	3,600	126,000
Plumbing	sq ft	10.00	3,600	36,000
Fire Protection	sq ft	3.50	3,600	12,600
Protective Coating for Chemical Storage Floors	sq ft	35.00	3,600	126,000
Piles	each	4,550.00	73	332,150
On-site Generation Building Subtotal				*1,311,110*
On-site Generation Equipment				
Onsite Generation Equipment (108 mgd)	LS			2,678,000
On-site Generation Equipment Subtotal				*2,678,000*
Alternative Subtotal				*9,615,000*
Electrical, Instrumentation, & Controls	LS	25%		2,404,000
Subtotal				*12,019,000*
Sitework	LS	10%		1,202,000
Subtotal				*13,221,000*
General Requirements	LS	12%		1,587,000
Flood Protection/Fill (placeholder)	cu yd	25.00	35,000	875,000
Site Remediation (placeholder)	cu yd	150.00	17,500	2,625,000
Subtotal				*18,308,000*
Contingency	LS	25%		4,577,000
Land Acquistion (placeholder)	sq ft	1.33	94,500	126,000
Opinion of Probable Construction Cost				***23,011,000***
Engineering, Legal, & Administration	LS	20%		4,602,000
Opinion of Probable Project Cost				**27,613,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternatives 4 and 5 - Ultraviolet Light (54 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Disinfection Influent Pipeline for WPF Flow (54 mgd)				
	lin ft	600.00	410	246,000
WPF Disinfection Influent Pipeline Subtotal				*246,000*
UV Building				
Building Superstructure and Slab	sq ft	194.00	2,500	485,000
Earthwork				
Structural Excavation	cu yd	20.00	896	17,926
Compacted Fill	cu yd	25.00	224	5,602
Granular Fill	cu yd	35.00	112	3,921
Concrete				
Slab on Grade/Footings	cu yd	530.00	19	9,815
Walls	cu yd	850.00	107	91,296
Suspended Slab and Beams	cu yd	950.00		-
Embedded Accessories	LS			2,519
HVAC	sq ft	35.00	2,500	87,500
Plumbing	sq ft	10.00	2,500	25,000
Fire Protection	sq ft	3.50	2,500	8,750
Piles	each	4,550.00	56	254,800
Bridge Crane	LS			46,735
Sluice Gates (60 inch)	each	40,000.00	3	120,000
UV Channel Grating	sq ft	55.00	660	36,300
UV Building Subtotal				*1,195,000*
UV Equipment				
UV Equipment (WEDECO as basis)	LS			2,280,000
UV Equipment Subtotal				*2,280,000*
Alternative Subtotal				*3,721,000*
Electrical, Instrumentation, & Controls	LS	25%		930,000
Subtotal				*4,651,000*
Sitework	LS	10%		465,000
Subtotal				*5,116,000*
General Requirements	LS	12%		613,920
Flood Protection/Fill (placeholder)	cu yd	25.00	3,700	92,500
Site Remediation (placeholder)	cu yd	150.00	1,900	285,000
Subtotal				*6,107,000*
Contingency	LS	25%		1,527,000
Land Acquistion (placeholder)	sq ft	1.33	10,000	13,000
Opinion of Probable Construction Cost				***7,647,000***
Engineering, Legal, & Administration	LS	20%		1,529,000
Opinion of Probable Project Cost				**9,176,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 4 - Bulk Sodium Hypochlorite/Bisulfite (61 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Contact Basins				
Basins (230 ft long by 45 ft wide by 12 ft depth, 4 cells)				
Earthwork				
Structural Excavation	cu yd	20.00	5,537	110,741
Compacted Fill	cu yd	25.00	852	21,296
Granular Fill	cu yd	35.00	426	14,907
Concrete				
Slab on Grade/Footings	cu yd	530.00	939	497,611
Walls	cu yd	850.00	1,004	853,778
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			38,867
Piles	each	4,550.00	218	991,900
Sluice Gates (60 inch)	each	40,000.00	8	320,000
Rotating Scum Weirs (18 in diameter, 10 ft long)	each	9,000.00	4	36,000
Mixers	each	50,000.00	4	200,000
Contact Basins Subtotal				*3,085,000*
Chemical Storage Building				
Building Superstructure and Slab	sq ft	194.00	2,450	475,300
Earthwork				
Structural Excavation	cu yd	20.00	215	4,296
Compacted Fill	cu yd	25.00	215	5,370
Granular Fill	cu yd	35.00	137	4,796
Concrete				
Slab on Grade/Footings	cu ft	530.00	-	-
Pump and Tank Pads	cu ft	630.00	23	14,578
Walls	cu ft	850.00	28	23,611
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded Accessories	LS			1,018
HVAC	sq ft	35.00	2,450	85,750
Plumbing	sq ft	10.00	2,450	24,500
Fire Protection	sq ft	3.50	2,450	8,575
Protective Coating for Chemical Storage Floors	sq ft	35.00	2,450	85,750
Piles	each	4,550.00	61	277,550
Sodium Hypochlorite				
FRP Storage Tanks	gallons	6.60	15,040	99,264
Level Transmitter	each	3,500.00	5	17,500
Level Gauge	each	2,100.00	5	10,500
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	2,500	50,000
2" PVC Piping around Tanks	lin ft	25.00	500	12,500
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			58,553
Sodium Bisultfite				
FRP Storage Tanks	gallons	6.60	2,538	16,751
Level Transmitter	each	3,500.00	2	7,000
Level Gauge	each	2,100.00	2	4,200
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,000	20,000
2" PVC Piping around Tanks	lin ft	25.00	200	5,000
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			31,190
Chemical Storage Subtotal				*1,550,000*

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 4 - Bulk Sodium Hypochlorite/Bisulfite (61 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Alternative Subtotal				*4,635,000*
Electrical, Instrumentation, & Controls	LS	25%		1,159,000
Subtotal				*5,794,000*
Sitework	LS	10%		579,000
Subtotal				*6,373,000*
General Requirements	LS	12%		765,000
Flood Protection/Fill (placeholder)	cu yd	25.00	23,600	590,000
Site Remediation (placeholder)	cu yd	150.00	11,800	1,770,000
Subtotal				*9,498,000*
Contingency	LS	25%		2,375,000
Land Acquistion (placeholder)	sq ft	1.33	63,800	85,000
Opinion of Probable Construction Cost				***11,958,000***
Engineering, Legal, & Administration	LS	20%		2,392,000
Opinion of Probable Project Cost				**14,350,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 5 - On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (61 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Contact Basins				
Basins (230 ft long by 45 ft wide by 12 ft depth, 4 cells)				
Earthwork				
Structural Excavation	cu yd	20.00	5,537	110,741
Compacted Fill	cu yd	25.00	852	21,296
Granular Fill	cu yd	35.00	426	14,907
Concrete				
Slab on Grade/Footings	cu yd	530.00	939	497,611
Walls	cu yd	850.00	1,004	853,778
Suspended Slab and Beams	cu yd	950.00	-	-
Embedded Accessories	LS			38,867
Piles	each	4,550.00	218	991,900
Sluice Gates	each	40,000.00	8	320,000
Rotating Scum Weirs (18 in diameter, 10 ft long)	each	9,000.00	4	36,000
Mixers	each	50,000.00	4	200,000
Contact Basins Subtotal				*3,085,000*
Chemical Storage Building				
Building Superstructure and Slab	sq ft	206.00	1,700	350,200
Earthwork				
Structural Excavation	cu yd	20.00	157	3,148
Compacted Fill	cu yd	25.00	157	3,935
Granular Fill	cu yd	35.00	79	2,755
Concrete				
Slab on Grade/Footings	cu ft	530.00	-	-
Walls	cu ft	850.00	22	18,889
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded Accessories	LS			444
HVAC	sq ft	35.00	1,700	59,500
Plumbing	sq ft	10.00	1,700	17,000
Fire Protection	sq ft	3.50	1,700	5,950
Protective Coating for Chemical Storage Floors	sq ft	35.00	1,700	59,500
Piles	each	4,550.00	49	222,950
Sodium Hypochlorite				
FRP Storage Tanks	gallons	6.60	8,566	56,536
Level Transmitter	each	3,500.00	2	7,000
Level Gauge	each	2,100.00	2	4,200
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,000	20,000
2" PVC Piping around Tanks	lin ft	25.00	200	5,000
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			39,147
Sodium Bisultfite				
FRP Storage Tanks	gallons	6.60	2,538	16,751
Level Transmitter	each	3,500.00	2	7,000
Level Gauge	each	2,100.00	2	4,200
Pumps	each	8,400.00	5	42,000
Pump Control Panels	each	6,300.00	5	31,500
1" PVC Piping	lin ft	20.00	1,000	20,000
2" PVC Piping around Tanks	lin ft	25.00	200	5,000
Piping Devices	LS/pump	3,500.00	5	17,500
Valves	each	300.00	40	12,000
Suppliers Costs (submittals, freight, profit)	LS			31,190
Chemical Storage Subtotal				*1,166,000*
On-site Generation Building				
Building Superstructure and Slab	sq ft	197.00	2,250	443,250

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Alternative 5 - On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (61 mgd)

Item Description	Units	Unit Cost	Quantity	Total Cost
Earthwork				
Structural Excavation	cu yd	20.00	204	4,074
Compacted Fill	cu yd	25.00	204	5,093
Granular Fill	cu yd	35.00	102	3,565
Concrete				
Slab on Grade/Footings	cu ft	530.00	-	-
Walls	cu ft	850.00	-	-
Suspended Slab and Beams	cu ft	950.00	-	-
Embedded Accessories	LS			-
HVAC	sq ft	35.00	2,250	78,750
Plumbing	sq ft	10.00	2,250	22,500
Fire Protection	sq ft	3.50	2,250	7,875
Protective Coating for Chemical Storage Floors	sq ft	35.00	2,250	78,750
Piles	each	4,550.00	54	245,700
On-site Generation Building Subtotal				*889,556*
On-site Generation Equipment				
On-site Generation Equipment (61 mgd)	LS			2,040,000
On-site Generation Equipment Subtotal				*2,040,000*
Alternative Subtotal				*7,181,000*
Electrical, Instrumentation, & Controls	LS	25%		1,795,000
Subtotal				*8,976,000*
Sitework	LS	10%		898,000
Subtotal				*9,874,000*
General Requirements	LS	12%		1,184,880
Flood Protection/Fill	cu yd	25.00	26,900	672,500
Site Remediation (placeholder)	cu yd	150.00	13,400	2,010,000
Subtotal				*13,741,000*
Contingency	LS	25%		3,435,000
Land Acquistion (placeholder)	sq ft	1.33	72,500	96,000
Opinion of Probable Construction Cost				***17,272,000***
Engineering, Legal, & Administration	LS	20%		3,454,000
Opinion of Probable Project Cost				**20,726,000**

Assumed Structure for Service Life Assessment
Assumed Equipment for Service Life Assessment

Appendix D

O&M Cost Backup

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Summary of Annual O&M Costs by Alternative

O&M Element	Alternative 1 108 mgd UV	Alternative 2 108 mgd Hypo	Alternative 3 108 mgd On-site	Alternative 4 54 mgd UV + 61 mgd Hypo	Alternative 5 54 mgd UV + 61 mgd On-site
UV					
Dry Weather					
Power	$54,000			$54,000	$54,000
Labor	$74,000			$74,000	$74,000
Bulb Replacement	$117,000			$117,000	$117,000
Ballast Replacement	$14,000			$14,000	$14,000
Sleeve Replacement	$17,000			$17,000	$17,000
Wiper Replacement	$2,000			$2,000	$2,000
Chemical Cleaning	$5,000			$5,000	$5,000
subtotal	*$283,000*			*$283,000*	*$283,000*
Wet Weather					
Power	$71,000			$29,000	$29,000
Labor	$41,000			$39,000	$39,000
Bulb Replacement	$10,000			$5,000	$5,000
Ballast Replacement	$5,000			$2,000	$2,000
Sleeve Replacement	$1,000			$1,000	$1,000
Wiper Replacement	$1,000			$500	$500
Chemical cleaning	$5,000			$5,000	$5,000
subtotal	*$134,000*			*$81,500*	*$81,500*
Bulk Hypochlorite					
Dry Weather					
Power		$1,000			
Labor		$15,000			
12.5% Bulk Sodium Hypochlorite		$1,600,000			
38% Sodium Bisulfite		$24,000			
subtotal		$1,640,000			
Wet Weather					
Power		$1,000		$1,000	
Labor		$16,000		$12,000	
12.5% Bulk Sodium Hypochlorite		$2,820,000		$1,900,000	
38% Sodium Bisulfite		$43,000		$28,000	
subtotal		*$2,880,000*		*$1,941,000*	
On-site Generation					
Dry Weather					
Power			$128,000		
Labor			$15,000		
Salt			$153,000		
Water			$1,000		
38% Sodium Bilsulfite			$24,000		
50% Sodium Hydroxide			$12,000		
32% Hydrochloric Acid			$53,000		
subtotal			*$386,000*		
Wet Weather					
Power			$88,000		$50,000
Labor			$16,000		$12,000
Salt			$105,000		$60,000
Water			$1,000		$500
38% Sodium Bilsulfite			$43,000		$28,000
50% Sodium Hydroxide			$8,000		$5,000
32% Hydrochloric Acid			$27,000		$15,000
subtotal			*$288,000*		*$170,500*
Total Annual O&M Cost	**$417,000**	**$4,520,000**	**$674,000**	**$2,305,500**	**$535,000**

Appendix E

Net Present Worth Backup

St. Joseph, Missouri
TM-CSO-11/TM-WW-5 - Disinfection Facilities
Summary of Net Present Worth by Alternative

Present Worth	Alternative 1 108 mgd UV	Alternative 2 108 mgd Hypo	Alternative 3 108 mgd On-site	Alternative 4 54 mgd UV + 61 mgd Hypo	Alternative 5 54 mgd UV + 61 mgd On-site
Capital	$16,933,000	$17,942,000	$26,295,000	$22,461,000	$28,701,000
O&M	$8,340,000	$90,400,000	$13,480,000	$46,110,000	$10,700,000
Net Present Worth	**$25,273,000**	**$108,342,000**	**$39,775,000**	**$68,571,000**	**$39,401,000**

St. Joseph, Missouri

TM-CSO-11/TM-WW-5 - Disinfection Facilities

Alternative 1 - Ultraviolet Light (108 mgd)

Net Present Worth

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Disinfection Influent Pipeline from WPF	2009	50	$246,000	$246,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$147,600		
UV Building																												
Structure	2009	50	$1,496,000	$1,496,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$897,600		
Equipment (not including UV modules)	2009	20	$536,000	$536,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$2,074,151		$2,074,151		
UV Equipment																												
Equipment Phase 1 (54 mgd)	2009	20	$2,280,000	$2,280,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$8,822,881		$8,822,881		
Equipment Phase 2 (54 mgd)	2009	20	$2,280,000	$2,280,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$8,822,881		$8,822,881		
Electrical, Instrumentation, and Controls	2009	20	$1,710,000	$1,710,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$6,617,160		$6,617,160		
Land Acquisition	2009	10,000	$36,000	$36,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$35,928		
Sitework	2009		$855,000	$855,000																								
General Requirements	2009		$1,128,000	$1,128,000																								
Flood Protection/Fill	2009		$250,000	$250,000																								
Site Remediation	2009		$750,000	$750,000																								
Contingency	2009		$2,883,000	$2,883,000																								
Construction Subtotal			$14,450,000	$14,450,000																				$26,340,000				
Engineering, Legal, and Administration 20%	2009		$2,890,000	$2,890,000																								
Interest During Construction (yrs)		0																										
Opinion of Probable Project Cost			$17,340,000	$17,340,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$26,340,000		$27,418,200		
Factored Totals				$17,340,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,927,000	$27,267,000	$10,333,631	**$16,933,369**	$1,400,000

O&M Elements	2009 Annual Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Dry Weather (WPF Flow)	$283,000		$297,150	$312,008	$327,608	$343,988	$361,188	$379,247	$398,209	$418,120	$439,026	$460,977	$484,026	$508,227	$533,639	$560,321	$588,337	$617,754	$648,641	$681,073	$715,127	$750,883		
Wet Weather (HRT Flow)	$134,000		$140,700	$147,735	$155,122	$162,878	$171,022	$179,573	$188,551	$197,979	$207,878	$218,272	$229,185	$240,645	$252,677	$265,311	$278,576	$292,505	$307,130	$322,487	$338,611	$355,542		
Opinion of Probable O&M Cost	$417,000	-	$437,850	$459,743	$482,730	$506,866	$532,209	$558,820	$586,761	$616,099	$646,904	$679,249	$713,212	$748,872	$786,316	$825,631	$866,913	$910,259	$955,772	$1,003,560	$1,053,738	$1,106,425		
Factored Totals		$0	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	$417,000	**$8,340,000**	$669,223

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

Net Present Worth = $25,273,000

St. Joseph, Missouri

TM-CSO-11/TM-WW-5 - Disinfection Facilities

Net Present Worth

Alternative 2 - Bulk Sodium Hypochlorite/Bisulfite (108 mgd)

Capital Project Elements		1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Disinfection Influent Pipeline from WPF		2009	50	$246,000	$246,000	-	-	-	-	-	-	-	-	-	-
Contact Basin															
Structure		2009	50	$3,461,000	$3,461,000	-	-	-	-	-	-	-	-	-	-
Equipment		2009	20	$556,000	$556,000	-	-	-	-	-	-	-	-	-	-
Chemical Storage Building															
Structure		2009	50	$1,201,000	$1,201,000	-	-	-	-	-	-	-	-	-	-
Equipment		2009	20	$864,000	$864,000	-	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls		2009	20	$1,582,000	$1,582,000	-	-	-	-	-	-	-	-	-	-
Land Acquisition		2009	10,000	$104,000	$104,000	-	-	-	-	-	-	-	-	-	-
Sitework		2009		$791,000	$791,000										
General Requirements		2009		$1,044,000	$1,044,000										
Flood Protection/Fill		2009		$725,000	$725,000										
Site Remediation		2009		$2,175,000	$2,175,000										
Contingency		2009		$3,161,000	$3,161,000										
Construction Subtotal				$15,910,000	$15,910,000										
Engineering, Legal, and Administration	20%	2009		$3,182,000	$3,182,000										
Interest During Construction (yrs)			0												
Opinion of Probable Project Cost				$19,090,000	$19,090,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals					$19,090,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Disinfection Influent Pipeline from WPF	-	-	-	-	-	-	-	-	-	-		$147,600		
Contact Basin														
Structure	-	-	-	-	-	-	-	-	-	-		$2,076,600		
Equipment	-	-	-	-	-	-	-	-	-	$2,151,545		$2,151,545		
Chemical Storage Building														
Structure	-	-	-	-	-	-	-	-	-	-		$720,600		
Equipment	-	-	-	-	-	-	-	-	-	$3,343,407		$3,343,407		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	$6,121,841		$6,121,841		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	$103,792		
Sitework														
General Requirements														
Flood Protection/Fill														
Site Remediation														
Contingency														
Construction Subtotal										$11,620,000				
Engineering, Legal, and Administration														
Interest During Construction (yrs)														
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$11,620,000		$14,665,385		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,379,000	$23,469,000	$5,527,229	**$17,941,771**	$1,400,000

O&M Elements	2009 Annual Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Dry Weather (WPF Flow)	$1,640,000		$1,722,000	$1,808,100	$1,898,505	$1,993,430	$2,093,102	$2,197,757	$2,307,645	$2,423,027	$2,544,178	$2,671,387
Wet Weather (HRT Flow)	$2,880,000		$3,024,000	$3,175,200	$3,333,960	$3,500,658	$3,675,691	$3,859,475	$4,052,449	$4,255,072	$4,467,825	$4,691,217
Opinion of Probable O&M Cost	$4,520,000	-	$4,746,000	$4,983,300	$5,232,465	$5,494,088	$5,768,793	$6,057,232	$6,360,094	$6,678,099	$7,012,004	$7,362,604
Factored Totals		$0	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000

O&M Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Dry Weather (WPF Flow)	$2,804,957	$2,945,204	$3,092,465	$3,247,088	$3,409,442	$3,579,914	$3,758,910	$3,946,856	$4,144,198	$4,351,408		
Wet Weather (HRT Flow)	$4,925,777	$5,172,066	$5,430,670	$5,702,203	$5,987,313	$6,286,679	$6,601,013	$6,931,063	$7,277,617	$7,641,497		
Opinion of Probable O&M Cost	$7,730,734	$8,117,271	$8,523,134	$8,949,291	$9,396,755	$9,866,593	$10,359,923	$10,877,919	$11,421,815	$11,992,906		
Factored Totals	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	$4,520,000	**$90,400,000**	$7,253,930

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

Net Present Worth = $108,342,000

St. Joseph, Missouri

TM-CSO-11/TM-WW-5 - Disinfection Facilities

Net Present Worth

Alternative 3 - On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (108 mgd)

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Disinfection Influent Pipeline from WPF	2009	50	$246,000	$246,000	-	-	-	-	-	-	-	-	-	-
Contact Basin														
Structure	2009	50	$3,461,000	$3,461,000	-	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$556,000	$556,000	-	-	-	-	-	-	-	-	-	-
Chemical Storage Building														
Structure	2009	50	$771,000	$771,000	-	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$592,000	$592,000	-	-	-	-	-	-	-	-	-	-
On-site Generation Building														
Structure	2009	50	$1,137,000	$1,137,000	-	-	-	-	-	-	-	-	-	-
Equipment (not including onsite generation equipment)	2009	20	$175,000	$175,000	-	-	-	-	-	-	-	-	-	-
On-site Generation Equipment	2009	20	$2,678,000	$2,678,000	-	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls	2009	20	$2,404,000	$2,404,000	-	-	-	-	-	-	-	-	-	-
Land Acquisition	2009	10,000	$126,000	$126,000	-	-	-	-	-	-	-	-	-	-
Sitework	2009		$1,202,000	$1,202,000										
General Requirements	2009		$1,587,000	$1,587,000										
Flood Protection/Fill	2009		$875,000	$875,000										
Site Remediation	2009		$2,625,000	$2,625,000										
Contingency	2009		$4,577,000	$4,577,000										
Construction Subtotal			$23,012,000	$23,012,000										
Engineering, Legal, and Administration 20%	2011		$4,602,400	$4,602,400										
Interest During Construction (yrs)		0												
Opinion of Probable Project Cost			$27,610,000	$27,610,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals				$27,610,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Disinfection Influent Pipeline from WPF	-	-	-	-	-	-	-	-	-	-		$147,600		
Contact Basin														
Structure	-	-	-	-	-	-	-	-	-	-		$2,076,600		
Equipment	-	-	-	-	-	-	-	-	-	$2,151,545		$2,151,545		
Chemical Storage Building														
Structure	-	-	-	-	-	-	-	-	-	-		$462,600		
Equipment	-	-	-	-	-	-	-	-	-	$2,290,853		$2,290,853		
On-site Generation Building														
Structure	-	-	-	-	-	-	-	-	-	-		$682,200		
Equipment (not including onsite generation equipment)	-	-	-	-	-	-	-	-	-	$677,195		$677,195		
On-site Generation Equipment	-	-	-	-	-	-	-	-	-	$10,363,015		$10,363,015		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	$9,302,721		$9,302,721		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	$125,748		
Sitework														
General Requirements														
Flood Protection/Fill														
Site Remediation														
Contingency														
Construction Subtotal										$24,790,000				
Engineering, Legal, and Administration 20%														
Interest During Construction (yrs)														
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$24,790,000		$28,280,077		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,343,000	$36,953,000	$10,658,464	**$26,294,536**	$2,100,000

O&M Elements	2009 Annual Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391
Dry Weather (WPF Flow)	$386,000		$405,300	$425,565	$446,843	$469,185	$492,645	$517,277	$543,141	$570,298	$598,813	$628,753
Wet Weather (HRT Flow)	$288,000		$302,400	$317,520	$333,396	$350,066	$367,569	$385,948	$405,245	$425,507	$446,783	$469,122
Opinion of Probable O&M Cost	$674,000	-	$707,700	$743,085	$780,239	$819,251	$860,214	$903,224	$948,386	$995,805	$1,045,595	$1,097,875
Factored Totals		$0	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000

O&M Elements	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Dry Weather (WPF Flow)	$660,191	$693,201	$727,861	$764,254	$802,466	$842,590	$884,719	$928,955	$975,403	$1,024,173		
Wet Weather (HRT Flow)	$492,578	$517,207	$543,067	$570,220	$598,731	$628,668	$660,101	$693,106	$727,762	$764,150		
Opinion of Probable O&M Cost	$1,152,769	$1,210,407	$1,270,928	$1,334,474	$1,401,198	$1,471,257	$1,544,820	$1,622,061	$1,703,164	$1,788,323		
Factored Totals	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	$674,000	**$13,480,000**	$1,081,670

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

Net Present Worth = $39,775,000

St. Joseph, Missouri

TM-CSO-11/TM-WW-5 - Disinfection Facilities

Net Present Worth

Alternative 4 - Ultraviolet Light (54 mgd) and Bulk Sodium Hypochlorite/Bisulfite (61 mgd)

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461
Disinfection Influent Pipeline from WPF	2009	50	$246,000	$246,000	-	-	-	-	-	-	-	-	-
UV Building													
Structure	2009	50	$907,000	$907,000	-	-	-	-	-	-	-	-	-
Equipment (not including UV modules)	2009	20	$288,000	$288,000	-	-	-	-	-	-	-	-	-
UV Equipment													
Equipment (54 mgd)	2009	20	$2,280,000	$2,280,000	-	-	-	-	-	-	-	-	-
Contact Basin													
Structure	2009	50	$2,529,000	$2,529,000	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$556,000	$556,000	-	-	-	-	-	-	-	-	-
Chemical Storage Building													
Structure	2009	50	$892,000	$892,000	-	-	-	-	-	-	-	-	-
Equipment	2009	20	$657,000	$657,000	-	-	-	-	-	-	-	-	-
Electrical, Instrumentation, and Controls	2009	20	$2,089,000	$2,089,000	-	-	-	-	-	-	-	-	-
Land Acquisition	2009	10,000	$98,000	$98,000	-	-	-	-	-	-	-	-	-
Sitework	2009		$1,044,000	$1,044,000									
General Requirements	2009		$1,378,920	$1,378,900									
Flood Protection/Fill	2009		$682,500	$682,500									
Site Remediation	2009		$2,055,000	$2,055,000									
Contingency	2009		$3,902,000	$3,902,000									
Construction Subtotal			$19,604,420	$19,604,400									
Engineering, Legal, and Administration 20%	2009		$3,920,884	$3,920,880									
Interest During Construction (yrs)		0											
Opinion of Probable Project Cost			$23,530,000	$23,530,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
Factored Totals				$23,530,000	$0	$0	$0	$0	$0	$0	$0	$0	$0

Capital Project Elements	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Disinfection Influent Pipeline from WPF	-	-	-	-	-	-	-	-	-	-	-		$147,600		
UV Building															
Structure	-	-	-	-	-	-	-	-	-	-	-		$544,200		
Equipment (not including UV modules)	-	-	-	-	-	-	-	-	-	-	$1,114,469		$1,114,469		
UV Equipment															
Equipment (54 mgd)	-	-	-	-	-	-	-	-	-	-	$8,822,881		$8,822,881		
Contact Basin															
Structure	-	-	-	-	-	-	-	-	-	-	-		$1,517,400		
Equipment	-	-	-	-	-	-	-	-	-	-	$2,151,545		$2,151,545		
Chemical Storage Building															
Structure	-	-	-	-	-	-	-	-	-	-	-		$535,200		
Equipment	-	-	-	-	-	-	-	-	-	-	$2,542,383		$2,542,383		
Electrical, Instrumentation, and Controls	-	-	-	-	-	-	-	-	-	-	$8,083,771		$8,083,771		
Land Acquisition	-	-	-	-	-	-	-	-	-	-	-	-	$97,804		
Sitework															
General Requirements															
Flood Protection/Fill															
Site Remediation															
Contingency															
Construction Subtotal											$22,720,000				
Engineering, Legal, and Administration 20%															
Interest During Construction (yrs)															
Opinion of Probable Project Cost	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$22,720,000		$25,557,252		
Factored Totals	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$8,563,000	$32,093,000	$9,632,259	**$22,460,741**	$1,800,000

O&M Elements	2009 Annual Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461
Dry Weather (WPF Flow)	$283,000		$297,150	$312,008	$327,608	$343,988	$361,188	$379,247	$398,209	$418,120	$439,026
Wet Weather (HRT Flow)	$2,022,500		$2,123,625	$2,229,806	$2,341,297	$2,458,361	$2,581,279	$2,710,343	$2,845,861	$2,988,154	$3,137,561
Opinion of Probable O&M Cost	$2,305,500	-	$2,420,775	$2,541,814	$2,668,904	$2,802,350	$2,942,467	$3,089,590	$3,244,070	$3,406,274	$3,576,587
Factored Totals		$0	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500

O&M Elements	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Dry Weather (WPF Flow)	$460,977	$484,026	$508,227	$533,639	$560,321	$588,337	$617,754	$648,641	$681,073	$715,127	$750,883		
Wet Weather (HRT Flow)	$3,294,439	$3,459,161	$3,632,119	$3,813,725	$4,004,412	$4,204,632	$4,414,864	$4,635,607	$4,867,387	$5,110,757	$5,366,295		
Opinion of Probable O&M Cost	$3,755,417	$3,943,187	$4,140,347	$4,347,364	$4,564,732	$4,792,969	$5,032,617	$5,284,248	$5,548,461	$5,825,884	$6,117,178		
Factored Totals	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	$2,305,500	**$46,110,000**	$3,699,986

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

Net Present Worth = $68,571,000

St. Joseph, Missouri

TM-CSO-11/TM-WW-5 - Disinfection Facilities

Net Present Worth

Alternative 5 - Ultraviolet Light (54 mgd) and On-site Generation of Sodium Hypochlorite/Bulk Sodium Bisulfite (61 mgd)

Capital Project Elements	1st Year Acquired or Installed	Life (Years)	2009 Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	REMAINING VALUE 0.37689	NET PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Disinfection Influent Pipeline from WPF	2009	50	$246,000	$246,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$147,600		
UV Building																												
Structure	2009	50	$907,000	$907,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$544,200		
Equipment (not including UV modules)	2009	20	$288,000	$288,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,114,469		$1,114,469		
UV Equipment																												
Equipment (54 mgd)	2009	20	$2,280,000	$2,280,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$8,822,881		$8,822,881		
Contact Basin																												
Structure	2009	50	$2,529,000	$2,529,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$1,517,400		
Equipment	2009	20	$556,000	$556,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$2,151,545		$2,151,545		
Chemical Storage Building																												
Structure	2009	50	$662,000	$662,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$397,200		
Equipment	2009	20	$504,000	$504,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$1,950,321		$1,950,321		
On-site Generation Building																												
Structure	2009	50	$780,000	$780,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		$468,000		
Equipment (not including onsite generation equipment)	2009	20	$109,000	$109,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$421,796		$421,796		
On-site Generation Equipment	2009	20	$2,040,000	$2,040,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$7,894,156		$7,894,156		
Electrical, Instrumentation, and Controls	2009	20	$2,725,000	$2,725,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$10,544,890		$10,544,890		
Land Acquisition	2009	10,000	$109,000	$109,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$108,782		
Sitework	2009		$1,363,000	$1,363,000																								
General Requirements	2009		$1,798,800	$1,798,800																								
Flood Protection/Fill	2009		$765,000	$765,000																								
Site Remediation	2009		$2,295,000	$2,295,000																								
Contingency	2009		$4,962,000	$4,962,000																								
Construction Subtotal			$24,918,800	$24,918,800																				$32,900,000				
Engineering, Legal, and Administration 20%	2009		$4,983,760	$4,983,760																								
Interest During Construction (yrs)		0																										
Opinion of Probable Project Cost			$29,900,000	$29,900,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$32,900,000		$36,083,239		
Factored Totals				$29,900,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$12,400,000	$42,300,000	$13,599,393	**$28,700,607**	$2,300,000

O&M Elements	2009 Annual Cost ($)	2009 Year 0 1.00000	2010 Year 1 0.95238	2011 Year 2 0.90703	2012 Year 3 0.86384	2013 Year 4 0.82270	2014 Year 5 0.78353	2015 Year 6 0.74622	2016 Year 7 0.71068	2017 Year 8 0.67684	2018 Year 9 0.64461	2019 Year 10 0.61391	2020 Year 11 0.58468	2021 Year 12 0.55684	2022 Year 13 0.53032	2023 Year 14 0.50507	2024 Year 15 0.48102	2025 Year 16 0.45811	2026 Year 17 0.43630	2027 Year 18 0.41552	2028 Year 19 0.39573	2029 Year 20 0.37689	TOTAL PRESENT WORTH	EQUIVALENT ANNUAL COST 0.08024
Dry weather (WPF Flow)	$283,000		$297,150	$312,008	$327,608	$343,988	$361,188	$379,247	$398,209	$418,120	$439,026	$460,977	$484,026	$508,227	$533,639	$560,321	$588,337	$617,754	$648,641	$681,073	$715,127	$750,883		
Wet weather (HRT Flow)	$252,000		$264,600	$277,830	$291,722	$306,308	$321,623	$337,704	$354,589	$372,319	$390,935	$410,481	$431,006	$452,556	$475,184	$498,943	$523,890	$550,084	$577,589	$606,468	$636,791	$668,631		
Opinion of Probable O&M Cost	$535,000	-	$561,750	$589,838	$619,329	$650,296	$682,811	$716,951	$752,799	$790,439	$829,961	$871,459	$915,032	$960,783	$1,008,822	$1,059,263	$1,112,227	$1,167,838	$1,226,230	$1,287,541	$1,351,918	$1,419,514		
Factored Totals		$0	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	$535,000	**$10,700,000**	$858,596

Economic Analysis Criteria:

Interest Rate =	5.00%
Capital Escalation Rate =	7.00%
O&M Escalation Rate =	5.00%
Baseline for costs =	May-09
ENR Building Cost Index =	4773

Net Present Worth = $39,401,000