City and County of San Francisco
2030 Sewer System Master Plan

TASK 700
TECHNICAL MEMORANDUM NO. 701
AN EVALUATION OF ALTERNATIVE DISINFECTION TECHNOLOGIES FOR TREATED EFFLUENT

FINAL DRAFT
August 2009

2700 YGNACIO VALLEY ROAD • SUITE 300 • WALNUT CREEK, CALIFORNIA 94598 • (925) 932-1710 • FAX (925) 930-0208

CITY AND COUNTY OF SAN FRANCISCO
2030 SEWER SYSTEM MASTER PLAN

TASK 700

TECHNICAL MEMORANDUM
NO. 701

AN EVALUATION OF ALTERNATIVE DISINFECTION TECHNOLOGIES FOR TREATED EFFLUENT

TABLE OF CONTENTS

Page No.

1.0 OBJECTIVES 701-1

2.0 INTRODUCTION 701-1

3.0 DESCRIPTION OF TECHNOLOGIES 701-2
- 3.1 Ultraviolet (UV) Disinfection 701-2
- 3.2 Ozone 701-6
- 3.3 Membranes 701-6
- 3.4 Peracetic Acid (PAA) 701-7
- 3.5 BCDMH 701-8

4.0 SOUTHEAST WATER POLLUTION CONTROL PLANT (SEP) EVALUATION 701-8
- 4.1 UV and Ozone Disinfection System Options 701-9
- 4.2 Comparison of Alternatives 701-11
- 4.3 Technology Evaluation for Primary Effluent Disinfection 701-12

5.0 OCEANSIDE WATER POLLUTION CONTROL PLANT (OSP) EVALUATION 701-13
- 5.1 Evaluation of Alternatives 701-14
- 5.2 Comparison of Alternatives 701-15
- 5.3 Technology Evaluation for Primary Effluent Disinfection 701-16
- 5.4 Future Augmented Flow (65 mgd) 701-17

6.0 NORTH POINT FACILITY (NPF) EVALUATION 701-18
- 6.1 Evaluation of Alternatives – Existing Scenario 701-18
- 6.2 Evaluation of Alternatives – Secondary Effluent Scenario 701-19

7.0 UV TREATABILITY AND SIZING EVALUATION 701-21

8.0 HIGH-RATE CLARIFICATION (HRC) EFFLUENT ALTERNATIVES 701-23

9.0 OVERALL SELECTION SUMMARY 701-26

LIST OF APPENDICES

A - Surveys of Municipal UV Users
B - Water Quality and Hydrological Data for SEP, OSP, and NPF
C - Recurring Cost Calculations and Assumptions
D - List of Existing UV Installations

LIST OF TABLES

Table 1 Relative Comparison of Features of the Different UV Systems 701-3
Table 2 Characteristics Of Municipal Users Of Low Pressure, High Intensity Systems, Interviewed By WWE 701-5
Table 3 Characteristics Of Municipal Users Of Medium Pressure, High Intensity Systems, Interviewed By WWE 701-5
Table 4 SEP Primary Effluent TSS and COD Concentration 701-9
Table 5 Characteristics of SEP Secondary Effluent to Pier 80..... 701-9
Table 6 Characteristics of SEP Secondary Effluent (Wet Weather) to Islais Creek.. 701-9
Table 7 Features of UV Proposals for SEP Secondary Effluent Treatment..... 701-10
Table 8 Features of the Ozonia Proposal for SEP Secondary Effluent..... 701-11
Table 9 Capital and Recurring Costs for SEP Secondary Effluent..... 701-11
Table 10 UV Proposals for SEP Primary Effluent Disinfection..... 701-12
Table 11 Future Cost Evaluation for SEP Primary Effluent..... 701-13
Table 12 OSP Primary Effluent TSS and COD Concentration..... 701-13
Table 13 OSP Secondary Effluent TSS and BOD Concentration and Turbidity 701-14
Table 14 UV Manufacturers' Proposals for Disinfection of OSP Secondary Effluent 701-14
Table 15 Features of Ozonia's Proposal for OSP Secondary Effluent Disinfection .. 701-15
Table 16 Cost Evaluation for OSP Secondary Effluent..... 701-15
Table 17 Features of the UV Proposals for OSP Primary Effluent..... 701-16
Table 18 Estimations of Cost for Disinfection of OSP Primary Effluent 701-17
Table 19 UV Proposals Submitted for OSP Augmented Flow (65 mgd)..... 701-17
Table 20 Estimated Future Costs for OSP Augmented Flow..... 701-18
Table 21 NPF Influent Flow Summary 701-18
Table 22 NPF Effluent TSS, Total Coliform, and BOD_T..... 701-19
Table 23 Proposals Submitted for Disinfection of NPF Primary Effluent..... 701-19
Table 24 Estimated Future Costs for NPF Primary Effluent..... 701-20
Table 25 UV Proposals for Proposed NPF Secondary Effluent Flow..... 701-20
Table 26 Life Cycle Costs for NPF Secondary Effluent Alternatives..... 701-21
Table 27 UV Disinfection Target Criteria..... 701-22
Table 28 Enterococci Collimated-Beam Dose Response Results of Various Unfiltered Secondary Effluent Discharges to San Francisco Bay[(1)]..... 701-23
Table 29 UV Disinfection Design Criteria..... 701-24
Table 30 SEP HRC Actiflo Effluent Water Characteristics 2000..... 701-24
Table 31 NPF HRC effluent water characteristics 2003..... 701-24
Table 32 UV Proposals for Proposed NPF Secondary Effluent Flow..... 701-25
Table 33 Life Cycle Costs for NPF High-rate Clarification Effluent Alternatives 701-25
Table 34 Technologies Selection Summary Table..... 701-26

AN EVALUATION OF ALTERNATIVE DISINFECTION TECHNOLOGIES FOR TREATED EFFLUENT

1.0 OBJECTIVES

The primary objective of this study was to assess the feasibility of different disinfection alternatives for existing and potential future scenarios at each of three wastewater treatment facilities serving the City and County of San Francisco (City). In doing so, a comparative analysis and evaluation of existing hydraulic and water quality characteristics for primary and secondary effluent of Southeast Plant (SEP) and Oceanside Plant (OSP), as well as primary effluent of North Point Facility (NPF) is provided. In addition, scenarios involving the use of High-Rate Clarification (HRC) for the treatment of effluent at SEP and NPF are evaluated. The evaluation will consider the feasibility of each alternative in terms of capital cost, footprint, and effluent quality.

2.0 INTRODUCTION

As part of San Francisco's Wastewater Master Plan, the Wastewater Enterprise (WWE) is considering existing and future needs at each of its three treatment facilities. All three facilities – Southeast Plant (SEP), Oceanside Plant (OSP), and North Point Facility (NPF) – have existing chlorination/dechlorination systems in place. Final effluent is not currently disinfected at OSP. At SEP and NPF, sodium hypochlorite and sodium bisulfite are used for chlorination and dechlorination, respectively. It is the aim of this report to evaluate whether other innovative disinfection technologies could be employed at the plants. Any system selected should present an advantage over the existing chlorination system in terms of:

- Reducing human health and environmental risks, such as a reduction in the discharge of pathogenic microorganisms and chlorinated byproducts
- Reducing operating hazards
- Simplifying operation
- Cost

This Technical Memorandum will explain the technologies evaluated (Section 3) and identify those that were ultimately considered feasible. Sections 4 through 6 present an evaluation of the selected technologies for each of the three plants. At each plant, several scenarios were addressed, including disinfection of primary effluent at SEP and disinfection following proposed new treatment facilities at NPF. A discussion of the pertinent water quality and hydrological characteristics of each plant is included. Section 7 presents the results of a UV system treatability and sizing study for the City's WWTPs. Section 8 provides an overview of the alternatives for treating high-rate clarification effluent. The

feasibility of selected technologies is discussed with an eye to future planning efforts in Section 9.

3.0 DESCRIPTION OF TECHNOLOGIES

Initially, WWE performed a literature search and consulted with industry experts to establish possible disinfection technologies to be considered. Research was performed on each alternative, and attempts were made to contact and survey municipal users of the various technologies, see Appendix A. A discussion of each technology considered follows below.

3.1 Ultraviolet (UV) Disinfection

Approximately ten years ago, the WWE evaluated the potential usage of ultraviolet (UV) light disinfection at SEP. The technology then was relatively new, and limited to several manufacturers of medium pressure, high intensity systems. The study determined that the cost was too high and could not be justified given that the technology was relatively unproven. Around the same time, WWE decided to conduct bench scale tests of low pressure UV systems, in the hopes that these would be less energy consumptive. The performance of these systems proved to be inconsistent, and was thought to be related to changes in feedwater quality that are consistent with wastewater from a combined system. In order to build a reliable disinfection system using the low pressure technology, significant redundancy would have been necessary. The capital costs of such a system were considered unacceptable. Since that time, however, UV disinfection of wastewater has become an increasingly popular alternative to chlorine disinfection.

A 2004 WERF report, “Effects of Wastewater Disinfection on Human Health” compiled several comparison studies of UV disinfection and chlorine with respect to inactivation of various pathogens. Generally, this report identifies UV disinfection as being more effective than chlorine disinfection, with results varying slightly depending on the individual characteristics of the wastewater. While performance data for fecal coliform inactivation was similar between chlorine and UV, UV disinfection was more effective at inactivation of total bacteria, viruses, and protozoa. Inactivation of the latter two classes of pathogens is significant, as chlorination has been shown to be relatively ineffective against viruses, especially in the presence of ammonia. At doses of 20 mJ/cm^2, UV was extremely effective against chlorine resistant protozoa such as C. parvum and G. lamblia. The WERF studies demonstrated that reactivation was not a problem in the UV systems. UV also has the additional advantage of not experiencing a reduction in disinfection efficiency in the presence of ammonia, as chlorine does. Also, chlorination of amines, which are present in most effluents, can produce N-chlorinated compounds that have been shown to be more toxic than their parent compounds.

UV lamps use mercury or mercury amalgam, which, as electrons flow through the medium, creates UV light. As UV light penetrates through the cell wall and cytoplasmic membrane, it

causes a molecular rearrangement of the microorganism's DNA and RNA, which prevents it from reproducing. Once the exposure interrupts normal DNA and RNA replication, the microorganisms are inactivated.

UV systems fall into three basic categories: low pressure, low intensity; low pressure, high intensity; and medium pressure, high intensity. Of these, medium pressure, high intensity systems deliver the highest UV dosage per unit (as total dose delivered depends on the number of lamps and configuration), and are the most commonly used UV systems for larger municipalities. Low pressure, low intensity systems are generally considered applicable for smaller systems with higher quality (e.g. filtered) effluents, and so were not considered in this analysis. If, however, it was decided to use an MBR for treatment, this technology might be a possibility, although no vendors provided examples of large-scale installations. Low pressure, high intensity systems have evolved considerably over the last five years. Use of a mercury amalgam (instead of mercury) in the UV lamps provides 2 to 4 times the output of a low-pressure low intensity system. While these systems cannot necessarily match the output of a medium pressure, high intensity system, they have the advantage of using considerably less power. A comparison of the three systems is provided in Table 1. The size of existing installations was based on installation lists provided by three leading manufacturers, Appendix D.

Table 1 Relative Comparison of Features of the Different UV Systems
2030 Sewer System Master Plan
City and County of San Francisco

Item	Low Pressure, Low Intensity	Low Pressure, High Intensity	Medium Pressure High Intensity
Power Consumption	Low	Medium	High
Output/Dosage	Low	Medium	High
Efficiency	High	Medium	Low
Operating Temperature	Low	Medium	High
Footprint	High	Medium	Low
Size of Existing Installations	1.2-23 mgd	Up to 319 mgd	Up to 360 mgd
Considered Good for Large Municipalities	No	Variable (depends on manufacturer)	Yes
Considered Good for Lower Quality Effluents	No	Variable (depends on manufacturer)	Yes

WWE requested proposals from three major manufacturers of the low pressure, high intensity UV systems: Trojan Technologies UV 3000+, Wedeco TAK, and Infilco Degremont Aquaray 3X HO. In addition, two medium pressure, high intensity units were evaluated, owing to the fact that these have a much smaller footprint than the low pressure, high intensity systems: Trojan's UV 4000 and Aquionics InLine+. Lists of references for all but the Infilco Degremont system were obtained from the manufacturers. WWE staff interviewed at least three municipal users of each system in an effort to define

performance, reliability, and actual cost of the different units. Copies of the surveys are attached as Appendix A.

Staff at six municipal facilities were interviewed as to their opinion of the low pressure, high intensity systems. The facilities were mostly activated sludge plants; four of the six had filters (typically sand-anthracite) installed upstream of the UV system. Average flows at these plants ranged from 9 to 40 mgd. WWE attempted to interview users at larger municipalities, but received no response. Other relevant characteristics of these municipal systems are summarized in Table 2. Two of the facilities interviewed, like SEP, did not have filtration installed upstream of the UV system. The first, listed in Table 3 as Facility 2, uses a low pressure, high intensity system that delivers a UV dose of 30 mJ/cm^2 for an average effluent fecal coliform concentration of 30 cfm/100 mL. The average effluent TSS at this plant is between 4-8 mg/L. The facility does experience periodic problems with algal slough-off, which can create excursions from their normal values, but they have never violated their permit limits. This facility was generally happy with the system and appreciated the minimized risk and ease of operation of the UV system. The second facility that did not employ filtration, Facility 6, uses a UV dose of 35 mJ/cm^2 to obtain an average effluent fecal coliform value of 20 cfm/100 mL. The average effluent TSS at this plant is between 5-10 mg/L. Although this facility did report the need to hand clean the lamps once a month to remove lime deposits (the system comes with an automatic mechanical cleaning system), they generally felt it to be simpler to operate than the chlorination/dechlorination system.

Trojan has yet to install the UV 3000+ at a North American municipal plant with flows greater than 25 mgd, though representatives of Trojan state that a larger installation (on the scale of SEP) is certainly possible. Wedeco has experience with somewhat larger installations, from 30 to 71 mgd in North America, with larger installations (up to 320 mgd) abroad. In general, those customers using the low pressure, high intensity systems (Trojan UV3000+ and Wedeco TAK) were very satisfied with the performance of their units.

WWE staff also interviewed municipalities using the medium pressure, high intensity systems. These were mostly activated sludge plants, ranging in capacity from 800,000 gpd to 200 mgd. Other features of these plants are summarized in Table 3.

Those using Aquionics were pleased with the unit's consistent performance, although they stated that it was labor intensive to clean and the unit had a high power demand (one user stated that the bringing the UV unit on line doubles their power bill). Two municipalities surveyed had installed the Trojan UV 4000 system and were extremely dissatisfied with it. These users complained that in addition to its tremendous power consumption, it also required more maintenance than almost anything else at the facility, particularly with regards to bulb replacement. Trojan representatives claim that these problems have been fixed in the latest iteration of the UV 4000, released in 2000. Two other municipal users of the UV 4000 system (one installed in 1997, one in 2004) were reasonably happy with the installation and had few complaints, other than the high power consumption.

Table 2 Characteristics Of Municipal Users Of Low Pressure, High Intensity Systems, Interviewed By WWE
2030 Sewer System Master Plan
City and County of San Francisco

Facility	Average Dry Weather Flow (mgd)	Average Wet Weather Flow (mgd)	Peak Flow (mgd)	Type of Treatment System	Combined Sewer	Installation Date
Facility 1	12	25	60	a.s., s.a. filters (1)	No	2002
Facility 2	7	7.7	20	a.s., no filtration (1)	No	07/2004
Facility 3	6.4	9	Unknown	a.s., cloth filters (1)	No	01/2005
Facility 4	11.5	13	14.1	a.s., s.a. filters (1)	No (some I/I problems) (2)	01/2005
Facility 5	9	10	11	a.s., s.a. filters (1)	No (some I/I problems) (2)	01/2005
Facility 6	28	40	66	Oxidation ditch, no filters	No	07/2002

Notes:
(1) a.s. = activated sludge, s.a. = sand anthracite filters
(2) I/I = inflow and infiltration

Table 3 Characteristics Of Municipal Users Of Medium Pressure, High Intensity Systems, Interviewed By WWE
2030 Sewer System Master Plan
City and County of San Francisco

Facility	Average Dry Weather Flow (mgd)	Average Wet Weather Flow (mgd)	Peak Flow (mgd)	Type of Treatment System (1)	Combined Sewer	Installation Date
Facility 1	11	23	50	a.s., s.a. filters	No	12/2004
Facility 2	800,000 gpd	2	7	a.s., no filtration	No	1999
Facility 3	2	12	12	a.s, s.a. filters	Mostly combined	1997
Facility 4	10	14.5	14.5	a.s., s.a. filters	Partially combined	06/1999
Facility 5	70	130 – 140	235	a.s., biological aerated filters	Yes	2003
Facility 6	80	200	249 mgd	a.s., s.a. filters	Yes	2003
Facility 7	10	40	Unknown	trickling filter, no 3° filtration	No, but I/I issues	1997
Facility 8	17	30	50 mgd	a.s., s.a. filters	No	11/1998

Notes:
(1) a.s. = activated sludge, s.a. = sand anthracite filters
(2) I/I = inflow and infiltration

Of those municipal operators who knew their UV dosage, dosage was reported as being between 18 and 35 mJ/cm^2. It is important to note, however, that many of these municipalities have installed filters, typically sand-anthracite, upstream of the UV system. The majority of UV users do not separately meter power for the UV unit. Most respondents gave the answer that while they did not know the power draw of the UV unit; they knew that the power draw was considerable.

WWE staff also interviewed Julie McLelland, a senior engineer with the Charlotte Municipal Utilities District (CMUD). Ms. McLelland was the co-author on a study presented at WEFTEC 2003, "Implementation of Best-Value UV Systems Through Competitive Life Cycle Cost Bidding Procedures," which compared the pilot performance of seven different UV systems. Following this study, CMUD installed Wedeco's TAK system at two of their smaller wastewater treatment plants (average flows of 10 and 13 mgd with significantly higher peak flows). Ms. McLelland stated that the units that WWE was evaluating all performed equally well in the pilot testing. In fact, CMUD went through preliminary design on four systems (Trojan UV 3000+ and 4000, Wedeco TAK, and Aquionics InLine+) prior to going out to bid; the CMUD staff felt that each unit had a lot to offer. The Wedeco system was selected based solely on the lowest bid. Following this interview, WWE staff decided to solicit proposals from each manufacturer. An overview of these proposals and their feasibility for each plant is provided in later sections.

3.2 Ozone

Ozone, an unstable gas produced when oxygen molecules are reacted with an electrical discharge, is the strongest oxidant of the disinfectants discussed in this report. Ozone is diffused into a reactor, where it contacts the wastewater; it is believed that ozone achieves bacterial kill through cell wall disintegration. It is advantageous because it produces no residual, and the off gas, oxygen, can be re-used in the process. The primary disadvantage of ozonation is its tremendous power consumption. Ozonation systems also tend to have very high capital costs and have the potential to produce harmful disinfection byproducts (DBPs). Historically, ozone has been used as a disinfectant at water treatment plants, but it has reportedly been used in some wastewater applications as well. Mr. Pedro daCruz of Ozonia did not respond to repeated requests for lists of reference installations. Mr. daCruz did state, however, that ozonation systems are most cost effective when constructed at pure oxygen activated sludge plants, because the cost of feed gas preparation is significant. Staff of the WWE contacted two ozone system vendors, Ozonia and NuTech. Only Ozonia responded to repeated inquiries.

3.3 Membranes

Membrane Biological Reactor (MBR) is increasingly becoming an important innovation in the biological wastewater treatment process. It combines membrane technology with biological reactors. In this disinfection evaluation study, MBR is being evaluated as one of the disinfection alternatives for NPF and OSP. Within a small footprint, the MBR process

combines COD, solids, and nutrient removal in a single unit. It can consistently produce high-quality effluent with almost non-detectable levels of TSS, and turbidity values less than 0.2 NTU. In Honolulu Wastewater Plant, a side-by-side testing was conducted to compare five manufacturers of MBR in terms of their performance and operational issues. The manufacturers were Enviroquip, Ionics, Zenon, US Filter, and Huber. With respect to performance, pretreatment needs, effluent water quality, power, and chemical usages were evaluated and compared. All MBRs tested required pretreatment. There were no significant differences in effluent water quality and chemical usage. For power usage, Enviroquip consumed higher energy on small systems. In terms of operation issues, operator availability, simplicity, maintenance, electricity costs, and screening requirements were evaluated. Enviroquip and Ionics had the most simple operation and maintenance requirements, while Huber fell in the middle. US Filter and Zenon had the most complex operation and maintenance needs. WWE contacted all of the manufactures for capital and operational cost estimates and recommendations in terms of effluent disinfection. Only Enviroquip and Zenon responded to the inquiry and only Zenon has provided the capital cost estimates. For NPF, with average of 13.8 mgd and maximum of 20.0 mgd daily flow, the budgetary system price is $11,850,600. For OSP, with average of 9.0 mgd and maximum of 13.0 mgd daily flow, the system price is $8,014,150. However, both manufactures did not recommend MBR for disinfection purposes. Although MBRs can produce effluent with extremely low levels of fecal coliform, MBRs are not designed for disinfection purposes. MBRs perform best in conjunction with complete treatment processes, including disinfection via UV or chlorine. MBRs cannot eliminate viruses and certain types of bacteria. With high capital cost and process complexity an MBR is not recommended here.

3.4 Peracetic Acid (PAA)

Peracetic acid (PAA) has long been used as a bactericide and fungicide in the food processing industry. Comprised of acetic acid and hydrogen peroxide, PAA has an oxidation capacity somewhere between that of ozone and sodium hypochlorite. PAA is considered a desirable disinfectant because it does not produce trihalomethanes (THMs) or other DBPs, but is as simple to use as sodium hypochlorite. It has an additional advantage over sodium hypochlorite in that no dechlorination is necessary. The main disadvantage of PAA is the high cost of the chemical. Due to its cost, there are no known installations of PAA in North America and very little experimental work has been performed on PAA as a disinfectant for secondary effluent. Some experimental work has shown that it is effective at similar concentrations and contact times as sodium hypochlorite (Zacheis et al, 2003; Atasi et al. 2001). WWE staff spoke with EnviroTech, a PAA manufacturer based in Modesto, California. EnviroTech staff stated that aquatic toxicology work on PAA has been completed for both salt and fresh waters, but the intended use of PAA at this time is for combined sewer overflow (CSO) disinfection and for enhancement of UV disinfection. It is currently considered cost prohibitive for secondary effluent based on typical doses and contact times. This is confirmed by a 2003 study presented at WEFTEC in which Orange

County Sanitation District (OCSD) compared the performance and cost of ozone, PAA, and sodium hypochlorite. OCSD found that PAA did not perform significantly better than sodium hypochlorite, although it costs considerably more. Therefore, at this time, WWE staff did not evaluate PAA any further for the treatment of secondary or high rate clarification effluent. PAA was carried forth for the cost benefit analyses on primary effluent. PAA could also be considered as an enhancement to a UV system for disinfection, if such a system were selected.

3.5 BCDMH

1-bromo-3-chloro-5,5-dimethylhydantoin, also known as BCDMH is a strong chemical disinfectant, currently in use to treat CSOs in Japan. BCDMH breaks down into hypobromic acid (HOBr) and hypochloric acid (HOCl), both of which are strong oxidants. Compared to sodium hypochlorite, the dose of BCDMH required to achieve comparable disinfection is about half, and disinfection is achieved in one-fifth the contact time. The use of BCDMH does, however, produce DBPs, including THMs. In addition, use of BCDMH as a disinfectant produces a chlorine and bromine residual, both of which would need to be treated with sodium bisulfite. There are no known installations of BCDMH disinfection systems in the United States and little toxicity information was available comparing the aquatic toxicity of bromine to that of chlorine. One study indicated that different test organisms might be more or less sensitive to bromine as compared to chlorine, but overall, bromine seems to be at least as toxic as chlorine. Thus, the use of BCDMH poses little potential advantage over the current use of sodium hypochlorite. It does not eliminate chemical usage in the disinfection system and it yields disinfection byproducts that are at least as toxic as those resulting from the usage of sodium hypochlorite. Furthermore, there is currently only one supplier of BCDMH in the United States, which could lead to supply problems. Therefore, WWE staff did not evaluate BCDMH any further.

4.0 SOUTHEAST WATER POLLUTION CONTROL PLANT (SEP) EVALUATION

Hydrologic and water quality data was gathered and analyzed for each plant. These characteristics were sent to UV and ozone vendors, as described above. Membrane technology and BCDMH evaluations were not carried forward to this stage, as they were initially found to be unfeasible. An evaluation of the flows, water quality, and best technology alternative for each plant follows.

Southeast Plant (SEP) is San Francisco’s largest wastewater treatment plant, providing secondary treatment for up to 150 million gallons per day (mgd) of wastewater and primary treatment of an additional 100 mgd of wastewater during wet weather events. An average of 36.4 mgd of primary effluent has been discharged to the Bay during wet weather events. Three treatment scenarios were evaluated for this plant: disinfection of secondary effluent, disinfection of primary effluent, and disinfection of high-rate clarification (HRC) effluent.

HRC is described separately, in Section 8. Tables 4, 5 and 6 summarize the SEP primary and secondary effluent characteristics for a seven-year period. (See Appendix B, Table 2 for effluent characteristics for each year). These, along with the NPDES permit limits for fecal coliform (currently a 30 day geometric mean of 500 cfu/100 mL), were provided to all manufacturers.

Table 4 SEP Primary Effluent TSS and COD Concentration
2030 Sewer System Master Plan
City and County of San Francisco

Parameter	Dry Weather			Wet Weather		
	Ave	***Max***	***Min***	***Ave***	***Max***	***Min***
TSS	112	1,144	12	105	1,240	26
COD	372	1,336	53	278	1,135	52

Table 5 Characteristics of SEP Secondary Effluent to Pier 80
2030 Sewer System Master Plan
City and County of San Francisco

Parameter	Dry Weather			Wet Weather		
	Ave	***Max***	***Min***	***Ave***	***Max***	***Min***
TSS	16	164	5	19	125	7
Turbidity	7	17	4	10	18	7
Fecal Coliform	121	100,000	9	144	16000	10

Table 6 Characteristics of SEP Secondary Effluent (Wet Weather) to Islais Creek
2030 Sewer System Master Plan
City and County of San Francisco

Parameter	Wet Weather		
	Ave	***Max***	***Min***
TSS	19	131	7
Turbidity	10	27	7
Fecal Coliform	59	1255	10

4.1 UV and Ozone Disinfection System Options

As stated previously, UV and ozone systems were the only technologies considered feasible for disinfection of secondary effluent. WWE staff solicited proposals from four UV manufacturers: Trojan Technologies, Wedeco, Infilco Degremont, and Aquionics. Of these, Trojan Technologies, Wedeco, and Aquionics submitted proposals. For the ozone evaluation, Ozonia and NuTech were contacted; only Ozonia responded with a proposal.

The UV systems evaluated included both low pressure, high intensity systems and medium pressure, high intensity systems. Therefore, proposals varied in terms of footprint, operations and maintenance costs, and power draw. The key components of each proposal are summarized in Table 7. Note that Trojan only chose to propose their medium pressure,

Table 7	Features of UV Proposals for SEP Secondary Effluent Treatment 2030 Sewer System Master Plan City and County of San Francisco		
Name of System	**Trojan UV 4000 Plus**	**Aquionics InLine 18000+**	**Wedeco TAK55 HP**
Type of System	Medium pressure, high output	Medium pressure, high output	Low pressure, high output
Cost	Moderate	Low-Moderate	Low-Moderate
Number of Lamps	672	234	1584
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)	Horizontal
Number of Channels	Two	Thirteen	Four
Footprint	39 feet by 16 feet (160 inches deep)	5.5 feet by 11 feet (32 inches deep)	35 feet by 35 feet (58 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic mechanical
Power Draw	1882 kW	1170 kW	570 kW
Estimated Lamp Life	5000 hours	8000 hours	12000 hours
Annual Operation and Maintenance Cost	Low-Moderate	Low-Moderate	Not provided

high output system, although they also manufacture a low pressure, high output system. Trojan representatives felt that the UV3000+, the low pressure, high output unit, would not meet the disinfection requirements at SEP based on the water quality and flow data provided. In addition, it should be noted that the Aquionics has a different design from most UV units – flow runs perpendicular to the lamps in compact, closed channel units.

As expected, the Wedeco system has the largest footprint, as considerably more lamps are needed when using a low pressure, high output system. Other noteworthy factors are the power draw and estimated lamp life for each unit. In talking to other municipalities using UV, power draw from UV units is a considerable cost of operation (even with the low pressure systems). The other significant cost of these systems, according to operators, is that of the lamps and the manpower expended to replace those lamps. With a larger system, lamp life becomes important; if the bulbs only need to be changed once a year, this can represent considerable savings in terms of both time and money. Therefore, WWE engineers attempted to get a more preliminary measure of operating costs, which is expressed in Table 9.

For the ozone systems, Ozonia provided a proposal for SEP, taking advantage of the use of pure oxygen at this plant. Salient features of this proposal are presented in Table 8. It is important to note that the power draw from the proposed unit is an order of magnitude higher than the UV systems, which adds considerably to the recurring costs for the unit, shown in Table 9.

Table 8	Features of the Ozonia Proposal for SEP Secondary Effluent 2030 Sewer System Master Plan City and County of San Francisco
Feature	**Value**
Number of ozone generators	4
Ozone dosage recommended	9,500 lbs/day at 8% concentration
Oxygen consumption per day	60 tons per day
Power draw	25,000 kWh per day
Total capital cost of unit	Moderate-High

Table 9 Capital and Recurring Costs for SEP Secondary Effluent
2030 Sewer System Master Plan
City and County of San Francisco

System	Total Capital Cost	Estimated Recurring Costs ($/yr)	Total Future Cost
Trojan UV4000	Moderate	Moderate	Moderate
Aquionics InLine 18000+	Low-Moderate	Low-Moderate	Low-Moderate
Wedeco TAK 55 HP	Low-Moderate	Low-Moderate	Low-Moderate
Ozonia Ozone System	Moderate-High	Very High	Very High
Existing Chlorination/ Dechlorination System	NA	Moderate	Moderate

4.2 Comparison of Alternatives

At this point, the feasible alternatives were brought forth for comparison. This analysis is rudimentary and entirely preliminary, as the manufacturers did not always provide specific information on replacement costs of equipment. The actual calculations are presented in Appendix C. An average flow at SEP of 74 mgd (this is from 2004 and includes wet weather events) was used to estimate power costs and lamp life. Power costs were assumed to be $0.12/kWh and labor costs were assumed to be $70/hr. The main replacement equipment cost is for bulb replacement; ballasts, wipers, and quartz sleeves should not need to be replaced on an annual basis. Trojan and Aquionics provided bulb replacement costs. For the Wedeco system, CMUD's 2003 analysis was used, adjusting for inflation at a rate of 3.5%. All of the UV units have automated cleaning systems, so the labor cost associated with cleaning was not considered.

The high recurring cost for the ozone system is largely due to the power consumption of the ozone generation system. This leads to a significantly higher future cost for this system overall. The future cost of two of the UV systems and the chlorination/dechlorination system are comparable, despite the higher capital cost associated with a UV system. The UV system also presents advantages in that it meets the project goals of increased pathogen

destruction with little risk of reactivation, no toxic byproducts, elimination of chemicals use (which carries associated risks in terms of both environmental impacts and cost), elimination of the risk of a chlorinated release, and increased ease of operation.

4.3 Technology Evaluation for Primary Effluent Disinfection

For the disinfection of primary effluent, UV, ozone, and PAA were initially considered feasible. WWE staff solicited proposals from four UV manufacturers: Trojan Technologies, Wedeco, Infilco Degremont, and Aquionics. Of these, only Trojan Technologies and Aquionics submitted proposals, both for their medium pressure, high output system. When WWE staff solicited a proposal from Ozonia, Ozonia's sales representative stated that the quality of SEP's primary effluent was outside of what is considered feasible to be treated by ozone. Costs for PAA were based on information provided by Envirotech, a PAA manufacturer. PAA dose was based on the hypochlorite dosage at SEP for 2003-2004 (for disinfection of primary effluent only).

Based on manufacturer provided information, the cost and features of the two UV systems are indicated in Table 10:

Table 10 UV Proposals for SEP Primary Effluent Disinfection
2030 Sewer System Master Plan
City and County of San Francisco

Name of System	Trojan UV 4000 Plus	Aquionics InLine 18000+
Type of System	Medium pressure, high output	Medium pressure, high output
Cost	Moderate	High
Number of Lamps	672	864
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)
Number of Channels	Two	Twenty-six
Footprint	39 feet by 16 feet (160 inches deep)	(32 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	1882 kW	4320 kW
Estimated Lamp Life	5000 hours	8000 hours
Annual Operation and Maintenance Cost	Low-Moderate	Moderate

The WWE estimation of the recurring costs of the two UV systems is presented alongside the PAA cost estimates in Table 11. Preliminary calculations, as with those for SEP secondary effluent disinfection, are provided in Appendix C. It was assumed that the existing chlorine feed system and pumps could be used for a PAA disinfection system.

Table 11	Future Cost Evaluation for SEP Primary Effluent 2030 Sewer System Master Plan City and County of San Francisco		
System	**Total Capital Cost**	**Estimated Recurring Costs ($/yr)**	**Total Future Cost**
Trojan UV4000	Moderate	Low-Moderate	Moderate
Aquionics InLine 18000+	High	Moderate-High	High
PAA	NA	Moderate-High	High
Chlorination/Dechlorination	NA	Low	Low

It is important to note that both the sodium hypochlorite/sodium bisulfite (Chlorination/ Dechlorination) and PAA recurring costs would be highly variable depending on the number of wet weather days per year (the average numbers from 2000 through 2004 were used for this calculation) and the individual chemical costs. According to Table 11, the Chlorination/Dechlorination system is by far the most economic feasible option for primary effluent treatment at SEP.

5.0 OCEANSIDE WATER POLLUTION CONTROL PLANT (OSP) EVALUATION

OSP is a secondary wastewater treatment plant with a peak secondary treatment capacity of 43 mgd. It provides treatment for all sewage flows from the west side of the City. During wet weather, the facility is able to provide primary treatment up to an additional 22 mgd of mixed storm water and sewage. All effluent is discharged to the Pacific Ocean by way of the Southwest Ocean Outfall (SWOO). In analyzing disinfection scenarios, an augmented future flow of 65 mgd was also considered.

The plant average dry weather flow is 17 mgd and average wet weather flow is 35 mgd. Appendix B has detailed flow and water quality data for OSP. Oceanside WPCP produces excellent quality dry weather and wet weather secondary effluent without any disinfectants. Tables 12 and 13 summarize the OSP primary effluent characteristics followed by the final effluent characteristics from the past seven years. OSP currently has no fecal coliform limit, so the data below, along with a potential limit of 500 cfu/100 mL, was provided to all manufacturers

Table 12	OSP Primary Effluent TSS and COD Concentration 2030 Sewer System Master Plan City and County of San Francisco					
Parameter	**Dry Weather**			**Wet Weather**		
	Ave	***Max***	***Min***	***Ave***	***Max***	***Min***
TSS	94	1306	35	94	1364	19
COD	351	1650	102	262	1500	38

Table 13	OSP Secondary Effluent TSS and BOD Concentration and Turbidity 2030 Sewer System Master Plan City and County of San Francisco					
Parameter	**Dry Weather**			**Wet Weather**		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*
TSS	11	540	4	16	109	5
Turbidity	7	29	3	11	70	4
BOD	16	95	5	16	95	4

5.1 Evaluation of Alternatives

As stated previously, UV and ozone systems were the only technologies considered feasible for evaluation for secondary effluent. As with the SEP evaluation, only Trojan Technologies, Wedeco, Aquionics, and Ozonia submitted proposals. The key components of each UV proposal are summarized in Table 14 below.

Table 14	UV Manufacturers' Proposals for Disinfection of OSP Secondary Effluent 2030 Sewer System Master Plan City and County of San Francisco			
Name of System	**Trojan UV 4000 Plus**	**Aquionics InLine 18000+**	**Trojan UV 3000 Plus**	**Wedeco TAK55 HP**
Type of System	Medium pressure, high output	Medium pressure, high output	Low pressure, high output	Low pressure, high output
Cost	Moderate	Low-Moderate	Moderate	Low-Moderate
Number of Lamps	240	72	576	432
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)	Horizontal	Horizontal
Number of Channels	Two	Four	Two	Two
Footprint	38 feet by 10.6 feet (160 inches deep)	5.5 feet by 3.5 feet (32 inches deep)	30 feet by 9 feet (54 inches deep)	35 feet by 9.4 feet (58 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic mechanical
Power Draw	672 kW	360 kW	144 kW	156 kW
Estimated Lamp Life	5000 hours	8000 hours	12000 hours	12000 hours
Annual O+M Cost	Moderate	Low-Moderate	Low	Not provided

A closer examination of operations and maintenance costs was also performed, and appears alongside the ozone cost estimates in the next section. The ozone proposal submitted by Ozonia, as with the proposal for SEP, takes advantage of the use of pure oxygen at the plant. As with the SEP proposal, the power draw from the ozonation system

is considerably greater than for the UV systems. Salient features of this proposal are presented in Table 15.

Table 15 Features of Ozonia's Proposal for OSP Secondary Effluent Disinfection
2030 Sewer System Master Plan
City and County of San Francisco

Feature	Value
Number of ozone generators	2
Ozone dosage recommended	2,800 lbs/day at 8% concentration
Oxygen consumption per day	18 tons per day
Power draw	7,500 kWh per day
Total capital cost of unit	High

5.2 Comparison of Alternatives

At this point, all feasible alternatives (four UV systems and the Ozonia ozone system) were brought forth for comparison. This analysis is rudimentary and entirely preliminary, as the manufacturers did not always provide specific information on replacement costs of equipment. The actual calculations are presented in Appendix C. An average flow at OSP of 19 mgd (this is from 2004 and includes wet weather events) was used to estimate power costs and lamp life. Power costs were assumed to be $0.12/kWh and labor costs were assumed to be $70/hr. The primary equipment cost is that associated with bulb replacement; ballasts, wipers, and quartz sleeves should not need to be replaced on an annual basis. Trojan and Aquionics provided bulb replacement costs. For the Wedeco system, CMUD's 2003 analysis was used, adjusting for inflation at a rate of 3.5%. All of the UV units have automated cleaning systems, so the labor cost associated with cleaning was not considered. Explanations of other assumptions are provided in Appendix C. Capital and recurring costs for the three systems are presented in Table 16.

Table 16 Cost Evaluation for OSP Secondary Effluent
2030 Sewer System Master Plan
City and County of San Francisco

System	Total Capital Cost	Estimated Recurring Costs ($/yr)	Total Future Cost
Trojan UV4000	Moderate	Moderate	Moderate
Aquionics InLine 18000+	Low-Moderate	Moderate	Moderate
Trojan UV3000	Moderate	Low-Moderate	Low-Moderate
Wedeco TAK 55 HP	Low-Moderate	Low-Moderate	Low-Moderate
Ozonia Ozone System	Moderate-High	Very High	Very High
Existing Chlorination/Dechlorination System	NA	Moderate	Moderate

The recurring costs on the Ozonia and Trojan UV4000+ systems are sufficiently high that these systems are not feasible at OSP. Of the UV systems, both of the low-pressure, high output systems have lower life cycle costs than the medium pressure systems.

5.3 Technology Evaluation for Primary Effluent Disinfection

For the disinfection of primary effluent, UV, ozone, and PAA were initially considered feasible. WWE staff solicited proposals from four UV manufacturers: Trojan Technologies, Wedeco, Infilco Degremont, and Aquionics. Of these, only Trojan Technologies and Aquionics submitted proposals, both for their medium pressure, high output system. When WWE staff solicited a proposal from Ozonia, Ozonia's sales representative stated that the quality of OSP's primary effluent was outside of what is considered feasible to be treated by ozone. Costs for PAA were based on information provided by Envirotech, a PAA manufacturer. Based on manufacturer provided information, the cost and features of the two UV systems are shown in Table 17:

Table 17 Features of the UV Proposals for OSP Primary Effluent
2030 Sewer System Master Plan
City and County of San Francisco

Name of System	Trojan UV 4000 Plus	Aquionics InLine 18000+
Type of System	Medium pressure, high output	Medium pressure, high output
Cost	Moderate	Moderate
Number of Lamps	336	216
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)
Number of Channels	One	Twelve
Footprint	39 feet by 8 feet (160 inches deep)	Not provided, but assumed to be comparable to SEP secondary effluent design (5.5 feet by 11 feet by 32 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	Not provided, but estimated to be around 940 kW, based on vendor provided estimates for other proposals	1080 kW
Estimated Lamp Life	5000 hours	8000 hours
Annual Operation and Maintenance Cost	Not provided	Moderate

Once again, WWE engineers attempted to better estimate the recurring costs of the two UV systems. The results are presented alongside the PAA cost estimates below. With high total capital and recurring costs of Trojan and Aquionics systems, Table 18 has shown that the existing Chlorination/Dechlorination system appears to be the most economic feasible option for primary effluent treatment at OSP.

Table 18	Estimations of Cost for Disinfection of OSP Primary Effluent 2030 Sewer System Master Plan City and County of San Francisco		
System	**Total Capital Cost**	**Estimated Recurring Costs ($/yr)**	**Total Future Cost**
Trojan UV4000	Moderate	Low-Moderate	Moderate
Aquionics InLine 18000+	Moderate	Low-Moderate	Moderate
PAA	NA	Moderate	Moderate
Existing Chlorination/Dechlorination System	NA	Low	Low

5.4 Future Augmented Flow (65 mgd)

As part of the Master Plan process, WWE engineers are considering the possibility of sending more flow to OSP; this is flow that is currently sent to SEP. This would necessitate an upgrade of the OSP facilities such that secondary treatment could be provided for 65 mgd of flow. Only two UV manufacturers chose to submit a proposal on this scenario, with Trojan submitting proposals for both its low and medium pressure systems. The proposals are shown in Table 19 below.

Table 19	UV Proposals Submitted for OSP Augmented Flow (65 mgd) 2030 Sewer System Master Plan City and County of San Francisco		
Name of System	**Trojan UV 4000 Plus**	**Aquionics InLine 18000+**	**Trojan UV 3000 Plus**
Type of System	Medium pressure, high output	Medium pressure, high output	Low pressure, high output
Cost	Moderate	Moderate	Moderate
Number of Lamps	240	162	544
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)	Horizontal
Number of Channels	Two	Four	Two
Footprint	38 feet by 5.3 feet (155 inches deep)	5.5 feet by 3.5 feet (32 inches deep)	30 feet by 5.7 feet (62 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	672 kW	810 kW	136 kW
Estimated Lamp Life	5000 hours	8000 hours	12000 hours
Annual Operation and Maintenance Cost	Low-Moderate	Moderate	Low

The recurring costs on chlorination/dechlorination, shown in Table 20, are extremely high as to result in a significantly huge life cycle cost as compared to all of the UV systems. Given the cost estimate above, the low-pressure, high output UV system (Trojan UV3000+) is more cost competitive than other systems in capital cost as well as recurring costs.

Table 20 Estimated Future Costs for OSP Augmented Flow
2030 Sewer System Master Plan
City and County of San Francisco

System	Total Capital Cost	Estimated Recurring Costs ($/yr)	Total Future Cost
Trojan UV4000	Moderate	Moderate	Moderate
Aquionics InLine 18000+	Moderate	Moderate	Moderate
Trojan UV3000+	Moderate	Low	Low-Moderate
Existing Chlorination/Dechlorination System	NA	High	High

6.0 NORTH POINT FACILITY (NPF) EVALUATION

Since 1983, NPF has functioned as a wet weather primary treatment facility, operating only during and shortly after rainfall. The NPF has the capacity to treat up to 150 mgd . For the days that the facility was put in operation, NPF has an average influent flow of 59 mgd and maximum influent flow of 122 mgd. Table 21 presents the effluent water characteristics in seven years. These data, along with a fecal coliform limit of 500 cfu/100 mL were provided to manufacturers for design and estimating purposes.

Table 21 NPF Influent Flow Summary
2030 Sewer System Master Plan
City and County of San Francisco

	Influent Flow (mgd)	
	Average	Max
1998	52	61
1999	49	73
2000	62	88
2001	67	88
2002	68	90
2003	52	65
2004	65	122

6.1 Evaluation of Alternatives – Existing Scenario

NPF currently treats up to 150 mgd of effluent to primary effluent quality. Only two UV manufacturers, Trojan Technologies and Aquionics, chose to submit proposals for the existing scenario. These proposals are presented in Table 23. WWE engineers also

estimated annual costs of a PAA system that would replace the existing chlorination system, but would not necessarily require new capital outlay. The PAA system costs are presented along with estimated UV recurring costs and chlorination/dechlorination costs, in Table 22.

Table 22 NPF Effluent TSS, Total Coliform, and BOD_T
2030 Sewer System Master Plan
City and County of San Francisco

Parameter	Wet Weather		
	Ave	***Max***	***Min***
TSS	106	1240	12
Total Coliform	152	16000	2
BOD_T	162	400	33

Table 23 Proposals Submitted for Disinfection of NPF Primary Effluent
2030 Sewer System Master Plan
City and County of San Francisco

Name of System	Trojan UV 4000 Plus	Aquionics InLine 18000+
Type of System	Medium pressure, high output	Medium pressure, high output
Cost	High	Moderate
Number of Lamps	1008	180
Horizontal/Vertical Array	Horizontal	Horizontal (flow runs perpendicular)
Number of Channels	Three	Ten
Footprint	39 feet by 24 feet (160 inches deep)	Not provided
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	Not provided, but estimated at a minimum of 1882 kW	900 kW
Estimated Lamp Life	5000 hours	8000 hours
Annual Operation and Maintenance Cost	Not provided	Not provided

Operations and maintenance costs are important in this scenario, as the plant does not disinfect year round. From Table 23, the existing disinfection system appears to be more cost competitive than other systems.

6.2 Evaluation of Alternatives – Secondary Effluent Scenario

One treatment option under the Wastewater Master Plan is the conversion of NPF to a small, local secondary treatment plant. WWE evaluated the cost of disinfection from such a

Table 24	Estimated Future Costs for NPF Primary Effluent 2030 Sewer System Master Plan City and County of San Francisco		
System	**Total Capital Cost**	**Estimated Recurring Costs ($/yr)**	**Total Future Cost**
Trojan UV4000	High	High	High
Aquionics InLine 18000+	Moderate	Moderate	Moderate
PAA	NA	Moderate	Moderate
Chlorination/Dechlorination	NA	Low	Low

facility, using a proposed flow of 30 mgd and water quality characteristics similar to those from the SEP secondary effluent. This was a conservative design, because the treatment technology for this proposed scenario had not yet been selected, and could potentially produce a higher quality effluent than traditional technologies. Trojan and Wedeco proposed their low-pressure high output systems, and Aquionics proposed its medium pressure high output system. Since it was unknown whether this would be a pure oxygen plant, Ozonia decided not to submit a proposal for this scenario. As with SEP and OSP, PAA was not evaluated in this scenario, as it is not considered cost effective at this time for the treatment of secondary effluent.

Table 25	UV Proposals for Proposed NPF Secondary Effluent Flow 2030 Sewer System Master Plan City and County of San Francisco		
Name of System	**Aquionics InLine 18000+**	**Wedeco TAK 55 HP**	**Trojan UV 3000 Plus**
Type of System	Medium pressure, high output	Low pressure, high output	Low pressure, high output
Cost	Moderate	Moderate	Moderate
Number of Lamps	54	324	416
Horizontal/Vertical Array	Horizontal (flow runs perpendicular)	Horizontal	Horizontal
Number of Channels	3	1	1
Footprint	Not provided	35 feet by 7 feet (117 inches deep)	30 feet by 6.5 feet (54 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	270 kW	116.7 kW	104 kW
Estimated Lamp Life	8000 hours	12000 hours	12000 hours
Annual Operation and Maintenance Cost	Low-Moderate	Not provided	Low

Table 26	Life Cycle Costs for NPF Secondary Effluent Alternatives 2030 Sewer System Master Plan City and County of San Francisco		
System	**Total Capital Cost**	**Estimated Recurring Costs ($/yr)**	**Total Future Cost**
Aquionics InLine 18000+	Moderate	Low-Moderate	Moderate
Wedeco TAK 55 HP	Moderate	Low	Low
Trojan UV 3000+	Moderate	Low	Low-Moderate
Chlorination/Dechlorination	NA	High	High

The recurring costs on chlorination/dechlorination system are extremely high and result in a total future cost that is an order of magnitude greater than that of any of the UV systems. Once again, the low-pressure, high output systems are the most cost competitive.

7.0 UV TREATABILITY AND SIZING EVALUATION

In 2007, Carollo evaluated the design and sizing criteria for unfiltered secondary effluent ultraviolet (UV) disinfection systems at SEP and OSP. The proposed systems have been sized to treat both current and potential future secondary effluent flows at each plant so that the disinfected effluent is in compliance with the future San Francisco Bay and Pacific Ocean microbial discharge standards. Table 27 outlines the approximate secondary effluent concentrations of test microorganisms (total coliform, fecal coliform, Enterococci, and E. coli) at both plants and compares those concentrations to the existing microbial discharge standards and expected future discharge standards. Based on this information, a 3.5-log removal of total coliform, 3.1-log removal of fecal coliform, and 1.8-log removal of Enterococci will be needed to meet the future discharge standards at SEP, while a 2.4-log removal of Enterococci will be needed at OSP.

The UV dose needed to meet the required log-removal of test microorganisms is typically determined by performing collimated-beam UV-dose response tests. Results from these tests have shown Enterococci to be more resistant to UV as compared to the total and fecal coliform. The results of a collimated beam dose response test performed for Enterococci on a different unfiltered secondary effluent that discharges to San Francisco Bay are provided in Table 28. Based on these results and the target microbial removals from the secondary effluent at SEP and OSP, Enterococci will require the highest UV dose to meet effluent standards at both plants, as compared to total and fecal coliform. Based on the data in Table 28, an average dose of 30 mJ/cm^2 and 35 mJ/cm^2 will ensure that the future microbial discharge standards are met at SEP and OSP, respectively, by reducing target microorganism concentrations to 10% of the effluent target value. As a measure of conservatism, due to the unknown variability in Enterococci at both plants, the dose of 35 mJ/cm^2 will be employed for both plants.

Table 27 UV Disinfection Target Criteria
2030 Sewer System Master Plan
City and County of San Francisco

Treatment Plant	**Approximate Undisinfected Microbial Concentrations** (MPN/100ml)	**Existing Microbial Discharge Standards** (MPN/100ml)	**Speculative Microbial Discharge Standards** (MPN/100ml) (dose-controlling microorganism in bold)	**Reclaimed Water Microbial Discharge Standards** (for reference)	**UV Dose Required to Meet Future Standards** [7] (with 1-log safety factor)	**Log Reduction of Pathogens Observed at Required UV Dose** [8]
SEP	826,000 total coliform [1] 239,000 fecal coliform [1] 2,111 Enterococci [2]	500 fecal coliform [3]	240 total coliform [4] 200 fecal coliform [4] 33 **Enterococci** [5] 126 *E. coli* [5]	**California** 5-log virus removal 2.2 MPN/100 ml total coliform	30 mJ/cm^2	>7 - *E. coli* >5 - *C. parvum* >4 - *G. lamblia* 4 - Polio virus 1 <1 - Adenovirus type 40
OSP	8,717 Enterococci [2]	None [3]	1000 total coliform [6] 200 fecal coliform [6] 33 **Enterococci** [6]		35 mJ/cm^2	>7 - *E. coli* >5 - *C. parvum* >4 - *G. lamblia* >4 - Polio virus 1 1 - Adenovirus type 40

Notes:
(1) Ho, et al. 1998. Water Environment Research, 70(6): 1142-1150.
(2) Average of samples collected on July 31, 2006.
(3) Arleen Navarret, Disinfection Evaluation Meeting, July 25, 2006.
(4) Water Quality Control Plan for San Francisco Basin, REC-1 standard.
(5) EPA REC-1 standard for fresh water.
(6) SWRCB REC-1 standard for shoreline waters.
(7) Collimated-beam dose response results of Enterococci, March 2006.
(8) Chevrefils, et al. 2006. IUVA News, 8(1): 38-45.

Table 28	Enterococci Collimated-Beam Dose Response Results of Various Unfiltered Secondary Effluent Discharges to San Francisco Bay(1) 2030 Sewer System Master Plan City and County of San Francisco
Average Dose (mJ/cm^2)	**Enterococci (CFU/ml)**
0	3000
5	500
10	32
25	<5

Note:
(1) Performed by BioVir Laboratories, Inc. for Carollo Engineers, March 2006.

The secondary effluent flows and UV transmissivity (UVT) at both SEP and OSP are listed in Table 29. In addition to the current secondary effluent flows at SEP and OSP, potential future flows at OSP are also provided. The potential acceptance of all current SEP secondary effluent flow at OSP would result in a flow of 193 million gallons per day (mgd). This information, along with the average UV dose requirements listed in Table 27, were used to determine the design requirements for each UV system[1]. A 2-bank system model was used for each system to provide a high level of disinfection reliability in the event of lamp or electrical failure. Table 29 presents the resulting design parameters, including the number of channels, the number of banks, the total number of lamps, and the footprint of each UV system under various flow conditions at both SEP and OSP.

8.0 HIGH-RATE CLARIFICATION (HRC) EFFLUENT ALTERNATIVES

HRC employs physical/chemical treatment and utilizes special flocculation and sedimentation systems to achieve rapid settling. The main benefits of HRC processes include reduced space requirements, rapid start-up and response times, relative insensitivity to fluctuations in raw water quality, and solids removal rates far greater than conventional treatment systems.

In order to evaluate their performance, HRC pilot studies were conducted at SEP and NPF in 2000 and 2003, respectively. The first study was a side-by-side comparison study of Densadeg 4D and Actiflo HRC. Actiflo HRC demonstrated a better performance with promising effluent quality. Therefore, a further Wet Start-up study on Actiflo HRC conducted at NPF followed. Both studies had shown that implementing this technology in the NPF would allow for 100 percent increased capacity in the current site and much improved effluent quality. Tables 30 and 31 summarize the water qualities of the HRC

[1] Reactor design based upon proprietary research by Carollo Engineers and Trojan Technologies, documented in the UV3000™ Plus Low Dose Wastewater Validation Draft Report, January 2006. The Qbeta model with 3-inch lamp spacing was used for the reactor design.

Table 29	UV Disinfection Design Criteria 2030 Sewer System Master Plan City and County of San Francisco						
Facility	**Design Flow (mgd)**	**UVT[4]**	**No. of Duty Channels**	**No. of Standby Channels**	**No. of Banks per Channel**	**Total No. of Lamps**	**Footprint (ft)**
SEP	150[1]	50%	8	1	2	3600	40 x 55
OSP	43[2]	50%	6	1	2	1120	40 x 40
	193[3]	50%	10	1	2	4400	40 x 65

Notes:
(1) SEP secondary treatment capacity flow, TM by Sierra & Huang, May, 2006
(2) OSP secondary treatment capacity flow, TM by Sierra & Huang, May, 2006
(3) Potential future flow, Alternatives #2 and #3, Sewer System Master Plan Alternatives Table, July 2006
(4) Annual 10th percentile UVT for unfiltered SEP secondary effluent, Ho, et al. 1998. Water Environment Research, 70(6): 1142-1150.

effluent for both studies. These were provided to the vendors for purposes of estimating and preliminary design.

Table 30	SEP HRC Actiflo Effluent Water Characteristics 2000 2030 Sewer System Master Plan City and County of San Francisco			
Wet Start-up		**Ave Influent**	**Ave Effluent**	**% Removal**
Turbidity	*Start-up*	82	1.4	98.3
	Initial SS	83	0.9	98.9
	Final SS	91	2.2	97.6
TSS	*Start-up*	92	20	78.3
	Initial SS	108	8	92.6
	Final SS	24	24	0.0
COD	*Start-up*	172	69.5	59.6
	Initial SS	208	80	61.5
	Final SS	270	61	77.4

Table 31	NPF HRC effluent water characteristics 2003 2030 Sewer System Master Plan City and County of San Francisco		
NPF HRC Pilot Study(mg/L) 2003			
	Average	**Max**	**Min**
TSS	26.5	172	0
COD	92.6	225	2
Alkalinity	39.0	77	4.4
G_O	16.3	48.4	0.4
Total Phosphorus	1.3	8.1	0.3

Three UV vendors chose to bid on the NPF alternative involving HRC – Trojan, Aquionics, and Wedeco. The proposals are presented in Table 32. Table 33 presents the life cycle costs of life cycle costs for NPF high-rate clarification effluent alternatives.

Table 32 UV Proposals for Proposed NPF Secondary Effluent Flow
2030 Sewer System Master Plan
City and County of San Francisco

Name of System	Aquionics InLine 18000+	Trojan UV 4000 Plus	Wedeco TAK 55 HP
Type of System	Medium pressure, high output	Medium pressure, high output	Low pressure, high output
Cost	High	Moderate	Moderate
Number of Lamps	1008	1344	3024
Horizontal/Vertical Array	Horizontal (flow runs perpendicular)	Horizontal	Horizontal
Number of Channels	2	3	6
Footprint	Not provided	39 feet by 8 feet (160 inches deep)	35 feet by 11 feet (58 inches deep)
Cleaning System	Automatic chemical/mechanical	Automatic chemical/mechanical	Automatic chemical/mechanical
Power Draw	5040 kW	Not provided	1089 kW
Estimated Lamp Life	8000 hours	5000 hours	12000 hours
Annual Operation and Maintenance Cost	Moderate	Not provided	Not provided

Table 33 Life Cycle Costs for NPF High-rate Clarification Effluent Alternatives
2030 Sewer System Master Plan
City and County of San Francisco

System	Total Capital Cost	Estimated Recurring Costs ($/yr)	Total Future Cost
Aquionics InLine 18000+	High	Moderate	Moderate-High
Trojan UV 4000	Moderate	Moderate	Moderate
Wedeco TAK 55 HP	Moderate	Moderate	Moderate
Chlorination/Dechlorination	NA	High	High

The recurring costs on the Chlorination/Dechlorination systems are once again extremely high as to result in a significantly higher life cycle cost as compared to the UV systems. The medium pressure, high output system turns out to be more cost competitive than other systems, even when considering the high capital cost of such a system.

9.0 OVERALL SELECTION SUMMARY

Table 34 summarizes the selected feasible disinfection alternative for each stream. As shown below, the chlorination/dechlorination disinfection system is the most cost-effective option for all of the conventional primary effluent streams. PAA was on the same order of magnitude as the chlorination/dechlorination option and could be considered a more feasible alternative in terms of environmental benefit (no DBPs) and simplicity. UV is feasible for all other streams. Further evaluation is necessary to better estimate unit sizing, capital costs, and recurring costs.

Table 34 Technologies Selection Summary Table
2030 Sewer System Master Plan
City and County of San Francisco

Sites	Selected Disinfection Technologies
SEP Secondary Effluent	Ultraviolet – Low pressure, high output
SEP Primary Effluent	Chlorination/Dechlorination
SEP High-Rate Clarification Effluent	Ultraviolet – Medium pressure, high output
OSP Secondary Effluent	Ultraviolet – Low pressure, high output
OSP Primary Effluent	Chlorination/Dechlorination
OSP Augmented Effluent	Ultraviolet – Low pressure, high output
NPF Primary Effluent	Chlorination/Dechlorination
NPF Secondary Effluent	Ultraviolet – Low pressure, high output
NPF High-Rate Clarification Effluent	Ultraviolet – Medium pressure, high output

REFERENCES

REFERENCES

Atasi, K. et al. *Alternative Disinfectants Evaluation for Combined Sewage Overflow (CSO): Detroit Baby Creek CSO Case Study,* WEFTEC, Atlanta, GA; Water Environment Federation, 2001.

Chen, D. et al. *Alternative Disinfection Mechanisms for Wastewaters Using Combined PAA/UV Processes,* Disinfection 2005, Mesa, AZ; Water Environment Federation, 2005.

Hunter, G. *Low Pressure – High Output UV: Is it the Wave of the Future?*, WEFTEC Chicago, IL; Water Environment Federation, 2002.

Samel, L. et al. *Implementation of Best Value UV Systems Through Competitive Life Cycle Cost Bidding Procedures,* WEFTEC, Los Angeles, CA; Water Environment Federation, 2003.

Wheeler, W. et al. *Challenges and Innovative Solutions for an Ultraviolet Disinfection System Upgrade at the Goldsboro Water Reclamation Facility, North Carolina,* WEFTEC, Los Angeles, CA; Water Environment Federation, 2003.

Wilde, E.W., R.J. Sorraco, L.A. Mayack, R.L. Shealy, T.L. Broadwell (1983). Acute Toxicity of Chlorine and Bromine to Fathead Minnows and Bluegills. *Bulletin of Environmental Contamination and Toxicology, 31,* 309-314.

Zacheis, G.A. et al. Laboratory Analysis of Disinfection Options for Orange County.

APPENDIX A - SURVEYS OF MUNICIPAL UV USERS

APPENDIX A - SURVEYS OF MUNICIPAL UV USERS

York, PA
Trojan Low Pressure, High Output

Date:	**3/23/2005**	
Plant:	**York, PA**	
Name of Contact:	**John Smith**	
Telephone #:	**717-845-2794**	x 104
Type of Disinfection Technology (if UV, be specific):	**Trojan UV 3000 Plus**	

1) **Plant Dry Weather Flow (Average, peak)** 12 mgd

2) **Plant Wet Weather Flow (Average, peak)** 25 mgd, peak at 60 mgd

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

They use the UV year-round, but they have a back up hypochlorite system in case of a hurricane or other emergency. They have used UV since 1988. At the time, they were the largest plant east of the Mississippi using UV. So the operators are very comfortable with the technology.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

Activated sludge plant (using surface aerators) A/O process with nutrient removal.

5) **Do you have a combined sewer system?**

No.

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

They have sand-anthracite filters upstream of the UV system. Therefore, their TSS runs between 1-2 mg/L TSS and their transmittance runs about 77%. They do not measure turbidity.

7) **When was your disinfection equipment installed?**

~3 years ago. They had an older Trojan system before (originally installed in 1988) and upgraded to this system when the technology improved. They have been pretty happy with both systems.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Had put temporary meters on about 10 years ago, but it is not on a separate meter and Mr. Smith doesn't know what the specific draw/usage of the UV system is.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

Mr. Smith doesn't know what the UV dose is. Typically get fecal coliform below detection limit or 1 cfu/100 mL. The contact time is about 1 second.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Units come on (or shut off) based on flow. The controls automatically vary the intensity of the lamps depending on both flow and transmittance for each unit.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

1 CFU/100 mL (fecal coliform)

12) **What is the approximate footprint of the disinfection unit?**

They retrofitted their old chlorine contact chamber, making the channels less deep. The whole building (which houses three channels) is about 60 by 30 feet.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

Trojan 3000+ (low pressure, high intensity) with 600 lamps (used to have 1800 with the low pressure, low intensity system). Each of three passes is rated at 19 mgd, usually only use one at a time.

14) **What operational and/or maintenance problems are you experiencing?**

Before they built a fiberglass building around the system, they had some problems with dust (plant roads were not paved) such that the lamps needed to get cleaned routinely (manually). In addition, leaves and other objects would blow into the unit and would interfere with its performance. They needed to dedicate staff to cleaning duty. With the construction of the building, these problems have been eliminated.

The only other problem they have is that the touch screen control panel is oriented west, making it difficult to read it in the afternoon because of the sunlight filtering through the building. They put a hood over top of the touch screen so they could read it.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

With their old Trojan system, they would need to manually clean the lamps, which took 1-2 men per day. The mechanical/chemical cleaning system on the new equipment works really well and they have not manually cleaned the lamps since the original installation 3 years ago. They did have some leaks initially in the cleaning system, but those have since been fixed. They have sand filters prior to the UV, Mr. Smith thinks this helps a lot in keeping the bulbs clean.

16) **If UV system, how often have you had to change how many lamps?**

They can get over two years out of a lamp. They are staggering the use of each pass, such that they never have to re-lamp all passes in the same year ($18,000 to relamp each pass). They bid an extended warranty on all parts in case anything goes wrong.

Want to be careful about part replacement when you get pricing - that is what separated two bids when they did their upgrade. Cost to re-lamp was significantly less with Trojan. Trojan changed price from bid on recent re-lamping of one of the channels

17) **What, do you find, are the benefits to your equipment?**

The system works really well and is very reliable. They don't have the day to day problems of adjusting the dose or worrying about residuals, as they did with chlorination, the unit just runs itself. They do still have a chlorine back up system in case of extended power loss.

18) **If equipment has recently been installed, what factors went into your decision making process?**

The City of York discharges to Chesapeake Bay, so regulators wanted to impose a zero chlorine limit. When considering the cost of operating both a chlorination and dechlorination system, UV was equal in price. They also like that there are no more hazardous gasses on site. But they are paying more for electricity.

Loveland CO,
Trojan lp, ho

Date:	**3/14/2005**
Plant:	**Loveland, CO**
Name of Contact:	**Al Picquet**
Telephone #:	**970-962-3000**
Type of Disinfection Technology (if UV, be specific):	**Trojan 3000Plus**

1) **Plant Dry Weather Flow (Average, peak)** The plant is rated at 10 mgd, but usually gets between 6 and 7 mgd during dry weather

2) **Plant Wet Weather Flow (Average, peak)** On average, wet weather flow is between 5-10% higher than dry weather flow). Typical high peaks are around 14 mgd, but they did once see one as high as 20 mgd.

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

They are disinfecting year-round and have dismantled the old chlorine system.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

Activated sludge with step feed using air. There are no filters upstream of the UV system.

5) **Do you have a combined sewer system?** No

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

The transmittance of the effluent entering the unit is in the high 60s. TSS is between 4-8 mg/L; they do not measure turbidity on a regular basis.

7) **When was your disinfection equipment installed?**

July 2004

8) **How much are you spending on power for the disinfection unit? What is its power draw?**
The unit draws about 34 Kw/hr, which is less than they expected. Mr. Picquet was uncertain of the power cost.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

The fecal limits are 210 cfu/100 mL; they will occasionally get an excursion when they wash the algae off the weirs, but the unit is doing a good job of disinfecting otherwise. The UV dosage required to meet the limit is 30 mJ/cm2.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Transmittance is monitored and dose is paced accordingly. Also monitor intensity, but that is not used in the dose programming, only an indicator of lamp age

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

30 cfu/100 mL

12) **What is the approximate footprint of the disinfection unit?**

The unit is inside a building that measures 30 feet by 50 feet. This building has room for an additional channel, if necessary. Each disinfection channel (there are two) is about 20 feet long.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

This is a Trojan 3000Plus, low intensity high output system. They have installed two disinfection channels with two banks each. They have 240 total lamps. The system is designed for 20 mgd with the provision to build a third channel if needed.

14) **What operational and/or maintenance problems are you experiencing?**

The plant had no other PLC controlled equipment prior to the installation of the UV system, so a lot of the problems were related to staff training. Fortunately, Trojan has a local rep nearby, so they were able to provide a lot of hands on support. The system is going through ballasts quicker than expected; these are warranteed by Trojan and are being replaced with no additional cost. Trojan has told them that the frequency of replacement should decrease once the operation of the equipment smoothes out. The only other problem is with algal slough-off, particularly if they do not clean the influent weir regularly.

If they were to use the water for reuse, they would have to put in some sort of strainer because they get a lot of snails growing on the walls outside the light area.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

The equipment has Trojan's mechanical and chemical cleaning system, which seems to be working fine. They had some problems initially, but Trojan came in and worked on training the staff; this has helped a lot. They haven't had to replace any equipment associated with the cleaning unit.

16) **If UV system, how often have you had to change how many lamps?**

They returned a few lamps that appeared to be "lemons." Otherwise, they haven't really replaced any lamps thus far (but they have only been in operation since last July).

17) **What, do you find, are the benefits to your equipment?**

Because of the redundancy of the design, it works very well; even when there are glitches, they haven't had permit violations. With the chlorination system, they would sometimes have compliance issues when ammonia levels were high. The UV system is quick and responsive to changes in flow and influent water quality, which was not possible with the chlorination system. Mr. Picquet likes that he only has one system to run instead of two (chlorination/dechlorination). The operating staff likes the alarm systems that come with the UV system, which helps them better track what is going on with the equipment.

Lastly, Mr. Picquet is happy that he doesn't need a risk management system anymore, as he did when they had chlorine gas on site. He also no longer has to worry about chlorine delivery trucks running through the neighborhood en route to the plant.

18) **If equipment has recently been installed, what factors went into your decision making process?**

The plant was under a new compliance order with lower fecal limits. At the same time, they wanted to reduce the risk management associated with chlorine. They calculated that the capital and operating costs under the new, tighter limits were similar for chlorine and UV.

They had also looked at medium pressure UV systems, but the power considerations ruled those out.

Lodi, CA
Trojan Low Pressure, High Output

Date:	**3/4/2005**
Plant:	**Lodi**
Name of Contact:	
Telephone #:	**209-333-6749**
Type of Disinfection Technology (if UV, be specific):	**UV3000 Plus - Trojan**

1) **Plant Dry Weather Flow (Average, peak)** 6.4 mgd (average)

2) **Plant Wet Weather Flow (Average, peak)** 9 mgd (average)

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

This is intended for use year-round except from May-August because they irrigate cropland with effluent then. While the chlorine system is not dismantled yet, they intend to dismantle it.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

4 aeration basins using air. 2 basins converted to an anaerobic zone, others have "sock type diffuser" -get complete nitrification. Aquadisc (cloth media) disc filters (4 discs per tank)
Filtration - tertiary

5) **Do you have a combined sewer system?** No

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

<1NTU (filters ahead of the UV), <2 mg/L TSS

7) **When was your disinfection equipment installed?** January 13th

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

No idea because they are still toying around with it - higher than they expected right now.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

100,000 milliwatts per square inch but they are still playing around with the dose. Have kicked it up to 130,000. They think they may need more detention time to prevent regrowth

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

The units have a transmittance and intensity meter that automatically controls the lamps, but they have taken it off the auto mode to allow for longer detention time (putting more banks into service). PLC unit allows you to control many aspects of the units (including cleaning frequency)

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

Filters are working great, need to meet 2.2 on weekly average, but are having trouble meeting this - get between <2 and 13 - are making adjustments, always under 23 (daily max) are working with Trojan to fix this.

12) **What is the approximate footprint of the disinfection unit?**

They have 5 banks per channel; the footprint is fairly confined 75 feet by 35 feet (wide)

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

Trojan UV3000 Plus, 5 banks per channel (1760 lamps) - 80-100 tubes per bank, 2 channels- flow is split evenly, each channel will handle 8.4 mgd so wet weather capacity of 16.4

14) **What operational and/or maintenance problems are you experiencing?**

Dosage control, regrowth - are still in the adjustment phase.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Mechanical and chemical cleaning procedure (wiper has chemical cleaning agent)

16) **If UV system, how often have you had to change how many lamps?**

Cannot answer this question as unit has not been in service long enough

17) **What, do you find, are the benefits to your equipment?** See above

18) **If equipment has recently been installed, what factors went into your decision making process?**

Meeting Title 22 Requirements and reducing chemical usage

Santa Rosa
Trojan mp, ho

Date:	**3/4/2005**
Plant:	**Santa Rosa**
Name of Contact:	**Joe Schwall**
Telephone #:	**707-543-3930**
Type of Disinfection Technology (if UV, be specific):	**Trojan UV4000**

1) **Plant Dry Weather Flow (Average, peak)**

17 mgd = average - not much variability in dry season

2) **Plant Wet Weather Flow (Average, peak)**

30 mgd = average, system is designed for a peak of 65 mgd, but they rarely see flows that high (peaks are more typically around 50 mgd).

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

The system is designed to operate year-round and meet Title 22 standards. They use a small dose (2-3 ppm) of hypochlorite to keep down algal growth. The old chlorine contact chambers are used for emergency storage in case of a power outage.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

Santa Rosa has tertiary treatment. The system is an activated sludge system using air; the system is designed for denitrification. Anthracite coal filters precede the UV system. As part of their 10 year CIP, they are considering the eventual replacement of these filters with membranes.

5) **Do you have a combined sewer system?**

Separate

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Post-filtration, the turbidity is consistently between 0.5-1 NTU. The TSS coming out of the filtration unit is between 4-6 mg/L, with a periodic maximum of about 11 mg/L every once in a while. Transmittance runs between 65-68%.

7) **When was your disinfection equipment installed?**

The system was installed in November 1998 under the 1993 UV guidelines. The updated guidelines have derated their system capacity by 20-30%.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Monthly cost is $60,000 low is about $43,000. 24 hour load is 27,000 kilowatt-hour. Flow is the biggest cost factor, dose is 50% greater than design (140) but cost doesn't fluctuate much with dose. Instantaneous load is 1.5 MW (2 channels on, 3 banks per channel - 90 lamps per bank, 360 banks per channel).

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

System is designed to Title 22 standards. These standards are met most of the time. Occasionally, they have difficulty meeting the 7 day average. For example, in the last 12 months, they had 2 days where they didn't meet their standard (on the weekly average basis). Very rarely, they will have an exceedance of the daily maximum limit. The log reduction test was done by pilot, prior to the unit's installation.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Parameters measured = flow, transmittance, and lamp age. On top of that, if turbidity exceeds 3 NTU, they have it programmed to bring on redundant bank.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

Typically less than 10 CFU/ 100 mL - meet Title 22 standards the majority of the time.

12) **What is the approximate footprint of the disinfection unit?**

Unsure, would have to look at old drawings.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

Wet weather = 0% redundancy, dry weather= 25% redundancy (1 redundant bank per channel)

14) **What operational and/or maintenance problems are you experiencing?**

When they installed the system, it was a newer technology, and he believes the Trojan system has improved. They are using a dose that is 50% higher than design, but he has heard of WWTPs using 100% higher dose than design. Operationally, the biggest problem has been particles in the water (i.e. algae sloughing off from channels downstream of filters or particles that are getting through the filters). They installed a particle counter, which typically measures about 200-400 particles/100 mL, but he does not feel that the particle count affects performance. Particle size may make a difference and they have made some operational changes to deal with this. The biggest improvement was seen when they began dosing with hypochlorite (2-3 ppm) 8 hours a day, year-round, after the filters. This drastically reduced the algal sloughing. They have also turned on the old flash mixer from their chlorine system to break apart larger particles. This system as a whole requires tremendous manpower. They visually inspect each bank at least once a month. Because the wiper assemblies fail periodically, they try to inspect more frequently than that.

They have also tested efficiency over the years and found it to be most economical to have two channels on line (out of three), even during low flow season. Overall, the learning curve with the system was very steep.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Mechanical wipers with phosphoric acid

16) **If UV system, how often have you had to change how many lamps?**

Mr. Schwall has a $260,000 budget for lamps, sleeves, and wipers. The lamps are supposed to have a 5000 hour life, but they typically need to be replaced sooner than that (after ~4000 hours). Since installing the UV system, Trojan has switched lamp manufacturers three times in an attempt to improve lamp longevity. The most recent lamps seem to have a lower failure rate. Trojan guarantees the first 2000 hours of lamp life, but you still need dedicated staff to inspect the lamps for failure. Monitoring 1080 lamps, sleeves, and ballasts is a tremendous use of labor resources. They also change about 5 to 8 ballasts per month (at a cost of $1000/ballast).

17) **What, do you find, are the benefits to your equipment?**

Mr. Schwall is glad there is no longer chlorine gas on site and that the WWTP is no longer adding chlorine to the environment. But he finds that the UV system is hard work and he "loses sleep worrying about the disinfection." It works most of the time but it's a big drain on the staff.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Getting rid of chlorine gas. They had looked at using hypochlorite, but it would have required a large amount of storage space and the local community wanted chlorine out of the wastewater. Ozone was given cursory consideration but considered unfeasible. Mr. Schwall thinks the UV system would not have worked without the installation of the filtration unit because the system is not stable enough to handle large particles (which shield the bacteria). One of the larger capital expenditures that the UV switch required was the construction of a substation at the WWTP for power reliability.

Santa Cruz
Trojan mp

Date:	3/29/2005	Survey filled out via e-mail
Plant:	**Santa Cruz Treatment Facility**	
Name of Contact:	**Mike Sanders Op supervisor**	
Telephone #:	**831-420-6056**	
Type of Disinfection Technology (if UV, be specific):	**Trojan medium pressure**	

1) **Plant Dry Weather Flow (Average, peak)** 10.00mgd

2) **Plant Wet Weather Flow (Average, peak)** 40.0 mgd

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

Flows up to 34 mgd receive UV disinfection. Flows above 34 mgd are disinfected with 12.5% bleach (SHC).

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

Secondary effluent from trickling filters with solids contact. SC blends flow above 34 MG with advanced treated primary effluent.

5) **Do you have a combined sewer system?**

No, not by design. SC has infiltration issues.

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Effluent TSS weekly and monthly average is 4 to 6 mg/l. Transmittance runs around 59%. Effluent turbidity is 3 to 4 NTU.

7) **When was your disinfection equipment installed?**

UV system was installed in 1997 and went into service in 1998

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Dry weather peak flows at average turbidity and TSS require about 130 kWs then down to 50Kw at low flows

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

100K Total Coliform and 20K Fecal Coliform. The UV dosage is set at 18. When using hypo. 0.8 mg/l residual

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Flow, transmittance

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

Less than 1000 cfu/100 mL Total Coliform and less than 100 cfu/100 mL fecal coliform

12) **What is the approximate footprint of the disinfection unit?**

40'x40'x18deep

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

Trojan Uv40000 medium pressure with lead lag channel. 144 bulbs per channel

14) **What operational and/or maintenance problems are you experiencing?**

In the first few years, SC had lots of bulb problems until Trojan addressed the issue. We also had communication board failures until the system was grounded correctly.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Hydraulic system cleans lens assemblies through a wiper system. When doing bulb maintenance, we will hand clean as needed.

16) **If UV system, how often have you had to change how many lamps?**

The bulbs last from 1000 hours up to 10000 hours; the average is 5000 hours

17) **What, do you find, are the benefits to your equipment?**

We are no longer required to have gas chlorine and associated equipment on site.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Regulatory issues associated with the use and storage of chlorine ton cylinders.

RM Clayton
Trojan mp, ho

Date:	**3/11/2005**
Plant:	**RM Clayton WRF**
Name of Contact:	**Tim Mullins**
Telephone #:	**404-350-4902**
Type of Disinfection Technology (if UV, be specific):	**Trojan UV 4000 (medium pressure)**

1) **Plant Dry Weather Flow (Average, peak)** Average flow is 80 mgd, pretty consistent

2) **Plant Wet Weather Flow (Average, peak)** Wet weather flow is typically around 200 mgd, but during a hurricane it can get up to 249 mgd.

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

The system is intended for year-round use. Although they dismantled their chlorine system, they now pour in about 300 gallons of sodium hypochlorite when they see the fecal numbers creeping up. This is especially true around this time of year when they have problems with regrowth downstream of the units.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**

What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

This is a tertiary BNR plant (activated sludge using air). They have tertiary filters (multimedia sand filters) upstream of the UV system.

5) **Do you have a combined sewer system?** Yes

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Effluent TSS is usually about 2-4 mg/L, turbidity is about 0.5 NTU, and transmittance is between 75-80%.

7) **When was your disinfection equipment installed?**

4 years ago

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

They do not have a separate meter for the UV system. They did have to install new transformers when the system was installed. They do not have a backup generator for the UV units.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

Their permit limit is 400 CFU/100mL and the corresponding UV dosage is 24-26 milliwatts-s/cm2. However, they have come extremely close to violating this limit since installing the UV system.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Yes, the unit automatically adjusts dosage based on turbidity and transmittance.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

The average effluent value is about 20-40 CFU/100 mL on a good day, but the numbers have shot up as high as 2900 (last year). They find that the effluent fecal values are "all over the map." They came close to violating their permit limit in January because of values around 1700 cfu/100 mL.

12) **What is the approximate footprint of the disinfection unit?** Not sure

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

This is a Trojan UV 4000 - medium pressure, high intensity system. Their system has 4 channels with 2 banks of lamps each for a total of 720 lamps. On a typical day they will turn on 2 channels; at peak flows, they will turn on a third channel. The fourth channel is only used in severe wet weather events, such as hurricanes. So they effectively have between 25% and 50% redundancy, depending on whether it is dry or wet weather. The system provides sufficient capacity for even their most severe peak flows.

14) **What operational and/or maintenance problems are you experiencing?**

Mr. Mullins hates this system, particularly because they get high fecal numbers even with system at its maximum capability. He feels that they have not received anywhere near the technical support that they need from Trojan. The system is extraordinarily labor intensive; Mr. Mullins states that they have to put at least one man on it, every day, 7 days a week just to keep up with the lamps that blow out (keeping track of them and actually replacing them). The lamps are supposed to provide at least 5000 hours of service, Mr. Mullins is getting about 500 hours, on average. In addition to the money he is spending on replacement parts, he is also spending money on overtime, because his operators cannot keep up with the equipment demands. Trojan told them that they were blowing lamps because during low flows (~20 mgd), the filter backwash was causing the flow through the UV unit to fluctuate, resulting in the lamps powering down and powering up too often. Even when they evened out the flow, this did not help with the lamp blowout. They are also experiencing a lot of problems with the hydraulic system associated with the wipers. The hydraulic pump

system that moves the wipers breaks down, setting off multiple alarms in the plant. They had to retrofit the hydraulic oil tank, but the pump system still breaks down.

You don't want this thing, very labor intensive, no help from Trojan

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Chemical/mechanical. When it's working, it is effective in cleaning. The wipers are set to clean 8 times per day.

16) **If UV system, how often have you had to change how many lamps?**

The frequency in lamp changeout depends on power; for example, a power "blip" may cause 40 lamps to blow out in one shot. They are getting about 500 hours of life out of each lamp. At one point, Trojan claimed that the plant was sent a bad batch of bulbs, but subsequent shipments don't seem to perform much better. Mr. Mullins has technicians coming in on weekends sometimes, just to keep up with lamp replacement. Replacement of parts on the UV system in general is one of the bigger expenses at the plant, as the sleeves, ballasts, and hydraulic pumps all need to be replaced rather often.

17) **What, do you find, are the benefits to your equipment?** None

18) **If equipment has recently been installed, what factors went into your decision making process?**

They had chlorine gas before, but they discharge to a drinking water source so there was pressure on them to reduce THMs. Also, development was increasing in the area, and the risk of having large quantities of gas on site made them want to switch to UV.

Syracuse
Trojan, mp

Date:	**4/5/2004**
Plant:	**Syracuse WWTP**
Name of Contact:	**Randy Ott**
Telephone #:	**315-435-2260 x 312**
Type of Disinfection Technology (if UV, be specific):	**Trojan 4000 (Medium Pressure)**

1) **Plant Dry Weather Flow (Average, peak)** Average flow is 70 mgd; peak flow is 80 mgd

2) **Plant Wet Weather Flow (Average, peak)** Average flow is between 130-140 mgd; peak flow is 235 mgd.

3) **What is your operating strategy - e.g., is the system for dry weather only? Is it supplemented with a chlorine-based system?**

The disinfection season lasts April through October. Flows up to 130 mgd are provided tertiary treatment followed by UV disinfection. Wet weather flows above 130 mgd are provided primary treatment with disinfection by sodium hypochlorite, followed by dechlorination before discharge through a separate outfall.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))? What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?**

This is an activated sludge plant. Prior to UV disinfection, effluent is sent through a biological aerated filter for ammonia removal and a Kruger/Actiflo unit for phosphorus removal. The effluent is then sent to the UV system.

5) **Do you have a combined sewer system?** Yes

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Both BOD and TSS are typically less than 10 mg/L. They do not measure turbidity. The Trojan unit measures transmittance, which is usually between 65-70%, though it can go down as low as 55%.

7) **When was your disinfection equipment installed?**

The unit was installed in 2003, but they didn't start operating it until the 2004 disinfection season.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

The unit/room is not separately metered, but it uses "a pretty good chunk of power". Prior to installation, they hired a consultant to do a cost benefit analysis comparing sodium hypochlorite (with dechlor) and the UV system and found that the costs were similar. The costs of hypochlorite have risen since then, so they believe that the UV system is rapidly becoming equally cost effective.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

The regulatory limit during the disinfection season is a 7 day average of 400 CFU/100 mL and a 30 day average of 200 CFU/100 mL. 25 is the set dose (started at 20) but it ranges as the quality changes. They may still have to increase the set dose because they seem to have an iron interference due to the Actiflo unit. When they started disinfection with the UV unit last year, the Actiflo was not yet in service, and the UV system was working well. Because the Actiflo requires the addition of ferric chloride, they are now seeing a loss of UV transmittance (they are dosing with 25 mg/L of ferric chloride).

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Adjusts dose based on flow and transmittance; are still getting kill below 200 even at high flow.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

When they used chlorine, their effluent fecal coliform counts were below 10 CFU/100 mL. Last year, they were getting effluent counts around 100 CFU/100 mL (they don't have numbers from this year yet).

12) **What is the approximate footprint of the disinfection unit?**

Don't know exact footprint.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

UV 4000+ unit, medium pressure, 2 banks of lamps, 7 modules, 22 lamps per module, 308 total lamps.

14) **What operational and/or maintenance problems are you experiencing?**

Gate downstream was supplied by general contractor, wish they had it supplied by Trojan; doesn't modulate flow very well. Vibrations loosened some of the modules in the channels. Many servicing problems due to non-multi-channel design

Installed them front and back (instead of two separate channels). Makes it very difficult to service control gates. One unit alone will handle the entire flow.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Automatic mechanical chemical. Runs about 6 months before chemical needs to be replaced (chemical appears to be an anti-calcium agent). Works really well. Without the chemical, they would have to hand clean them. Cleans every 4 hours.

16) **If UV system, how often have you had to change how many lamps?**

Lamps are guaranteed 5000 hours (this is enough to get them through their season). Initially, had lamps that were blowing out more often, but Trojan replaced the lamps with better lamps and haven't had too many issues. Do occasionally have a lamp burn out before its time. Smaller number of lamps is why they picked the UV 4000. Originally quoted a price of $200/lamp, are now being quoted a higher price; sleeves and ballast costs went up 50% this year. Only one sleeve has broken so far. Replace all the bulbs at the end of the disinfection season. Just assume in their annual budget that they will replace all the bulbs annually.

17) **What, do you find, are the benefits to your equipment?**

Biggest one is that they have significantly reduced the amount of sodium hypochlorite (only use it on primary effluent, wet weather flow); only one tank instead of three on site. Still struggling with a few issues related to the iron, but the system has worked pretty well and it hasn't been too bad to maintain.

Get away from dechlor

18) **If equipment has recently been installed, what factors went into your decision making process?**

Would have had to construct a dechlorination system. They were adding two more unit processes and had to redo their chlorine contact chambers anyway. The capital costs, etc. were comparable for UV, even though they couldn't reuse their contact chambers.

The size of this unit is extremely small for size of flow. The system was a lot more compact than the low pressure. Didn't do any pilot work for UV, just did it based on cost and footprint. Are using the 3000+ system at their other plant, which has much less flow. Start up is hard, so it was nice working with Trojan because they sent knowledgeable people out.

Yellow River, GA
Aquionics, mp, ho

Date:	**11-Mar-05**
Plant:	**Yellow River, GA**
Name of Contact:	**Caroll Ferguson**
Telephone #:	**770-564-4630**
Type of Disinfection Technology (if UV, be specific):	**Aquionics UV Inline 2500**

1) **Plant Dry Weather Flow (Average, peak)**

Permitted at 12.5 mgd, average around 10 mgd most of the year and get peak flows (usually during wet weather) of 14.5 mgd

2) **Plant Wet Weather Flow (Average, peak)**

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

Since installation in June 1999, they have used strictly UV. The system operates year-round.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**

What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

They are disinfecting effluent from an activated sludge (air) system with secondary clarifiers and dual media (sand-anthracite) filters.

5) **Do you have a combined sewer system?** Parts of the system are combined, most of it is separate. They only treat domestic waste.

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

The effluent TSS value is usually around 2 mg/L, while transmissivity is between 70-80%. They do not record turbidity.

7) **When was your disinfection equipment installed?** Jun-99

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Have never separated out the power for the unit from the total power unit - don't notice that it is significantly larger than the chlorine unit's draw. They did have to install an extra transformer and a backup generator when they installed the UV system

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

The regulatory limit is 25/100 mL, Mr. Ferguson has never really paid attention to the dose needed to meet this limit. The unit has low, medium, and high settings that are manually adjusted depending on flow into the plant.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

They base their dose control on flow.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

They take measurements three times per week and usually get between 1 and 11 cfu/100 mL in the effluent.

12) **What is the approximate footprint of the disinfection unit?**

Each unit is about 36 inches in diameter and about 5 feet long. The lamps run perpendicular to the flow.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

They have four 10 mgd units, so even in wet weather/peak flows, they have 200% redundancy.

14) **What operational and/or maintenance problems are you experiencing?**

Overall, the UV units are much more labor intensive, more sensitive and fragile than the chlorine system they had previously. They cleaning system is an ultra-wipe system, which they no longer use because the cleaning solution freezes in cold weather. They now hand clean the lamps (each unit has two banks with 8 lamps each for a total of 64 lamps) with citric acid to dissolve iron deposits. This cleaning procedure is done about once per month. The lamps have a service life of up to 10,000 hours (variable).
Mr. Ferguson believes that some mechanical advancements have been made to the unit since its installation at his plant. The system is equipped with alarms to notify the operators of low intensity, overheating, and voltage drops. In addition, plant staff monitor intensity by checking the units four times per 24 hour period.

They are looking at putting in deep bed filters upstream of the UV system in order to meet proposed NPDES permit limits (if they decide to expand, their effluent fecal and TSS values will be tightened).

They had some issues with power reliability initially, which created problems because the units take 10 minutes to start up after power loss.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

The lamp sleeves have a viton wiping ring through which a cleaning solution is injected. Because this solution freezes in cold weather, they no longer use the automatic system and hand clean the lamps once per month. The solution used is a citric acid based product called "Purple Power," an automotive cleaner. This is very effective at controlling iron deposits and maintaining the system.

16) **If UV system, how often have you had to change how many lamps?**

The lamp service life varies between 5-10,000 hours, but he has some lamps that have lasted longer than that.

17) **What, do you find, are the benefits to your equipment?**

The system allows them to achieve very consistent treatment and keeps them in compliance with their permit limits. It's pretty easy to operate, it just requires attention. They "have a good bit of money tied up in spare parts, because you need to keep them on hand." This includes o-rings, seals, lamps, ballasts, etc. For the most part, the o-rings have lasted pretty well (they are all viton) - they just replaced one that had been in since installation.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Back in the 90s when the chlorine containment issue came up, Gwinett Co decided to start looking at UV (at the time, they were keeping 10-20 ton cylinders of chlorine gas on site). In addition, subdivisions began encroaching on the facility and they were worried about storage and transport of the gas.

New Castle, IN
Aquionics

Date:	**3/24/2005**
Plant:	**New Castle, Indiana**
Name of Contact:	**Sydney Meese**
Telephone #:	**765-521-6836**
Type of Disinfection Technology (if UV, be specific):	**Aquionics In 35000**

1) **Plant Dry Weather Flow (Average, peak)** 2 mgd

2) **Plant Wet Weather Flow (Average, peak)** 10 mgd, 12 mgd (peak)

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

6 months out of the year; by-pass the system the rest of the year (disinfection season = April 31-October 1 - to protect against secondary contact recreation)

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?
Tertiary filters (sand anthracite). Activated sludge plant using diffused air

5) **Do you have a combined sewer system?** Mostly combined

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Don't know

7) **When was your disinfection equipment installed?** 1997

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Mr. Meese has been told that it doubles their power cost (e.g. $10,000 a month for electric without the unit on-line, $20,000 when they turn it on).

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**
Their limit is 120 cfu/100 mL (e. coli) as a daily max with a monthly average of 100 cfu/100 mL. Mr. Meese didn't know the exact dose (they are running the equipment on level "2" out of 3).

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

They base their dosing on the lab results (e. coli counts) and control the unit manually.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

10 cfu/100 mL or less.

12) **What is the approximate footprint of the disinfection unit?**

The pipes themselves are 48 inches in diameter and about 5 feet long. The building dedicated to the system is a two story, 30 by 20 foot structure that houses eight electrical banks in addition to the disinfection channels.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

The unit is an Aquionics, medium pressure, high output system with a total of 48 lamps (24 to a side). Each channel is designed to treat 10 mgd, so they have 100% redundancy most of the time. Their operational strategy is to run one at a time and use the second as backup or during a wet weather event.

14) **What operational and/or maintenance problems are you experiencing?**

The biggest problem is keeping up with cleaning the tubes. If they let it go two weeks without cleaning, they can see a significant difference in the e. coli counts. The bulbs are expensive, but can be easily changed in 10 minutes. The annual maintenance (when they usually change out all the bulbs in one channel) is a little time consuming.

Initially, they had no surge protection on the UV building, so they "fried" some of the wires inside the units. They contracted with UV Doctor (based in Las Vegas), who fixed this problem. Over the long term, they are happy with the system.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

The unit is equipped with wipers for the quartz sleeves. They alternate the units every other week; when a unit is off-line, they spray lime-a-way on the tubes. This strategy has worked pretty well for them.

16) **If UV system, how often have you had to change how many lamps?**

Change one side a year; if they get a lot of bad weather such that the power goes out, they can lose extra bulbs from the start- stop.

17) **What, do you find, are the benefits to your equipment?**

They had chlorine before, he never had to work with that system, but feels it is beneficial to not have the risk of holding the chlorine on site.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Safety

Silverton, OR
Aquionics mp, ho

Date:	**3/24/2005**
Plant:	**New Castle, Indiana**
Name of Contact:	**Sydney Meese**
Telephone #:	**765-521-6836**
Type of Disinfection Technology (if UV, be specific):	**Aquionics In 35000**

1) **Plant Dry Weather Flow (Average, peak)** 2 mgd

2) **Plant Wet Weather Flow (Average, peak)** 10 mgd, 12 mgd (peak)

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

6 months out of the year; by-pass the system the rest of the year (disinfection season = April 31-October 1 - to protect against secondary contact recreation)

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?
Tertiary filters (sand anthracite). Activated sludge plant using diffused air

5) **Do you have a combined sewer system?** Mostly combined

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Don't know

7) **When was your disinfection equipment installed?** 1997

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

Mr. Meese has been told that it doubles their power cost (e.g. $10,000 a month for electric without the unit on-line, $20,000 when they turn it on).

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**
Their limit is 120 cfu/100 mL (e. coli) as a daily max with a monthly average of 100 cfu/100 mL. Mr. Meese didn't know the exact dose (they are running the equipment on level "2" out of 3).

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

They base their dosing on the lab results (e. coli counts) and control the unit manually.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

10 cfu/100 mL or less.

12) **What is the approximate footprint of the disinfection unit?**

The pipes themselves are 48 inches in diameter and about 5 feet long. The building dedicated to the system is a two story, 30 by 20 foot structure that houses eight electrical banks in addition to the disinfection channels.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

The unit is an Aquionics, medium pressure, high output system with a total of 48 lamps (24 to a side). Each channel is designed to treat 10 mgd, so they have 100% redundancy most of the time. Their operational strategy is to run one at a time and use the second as backup or during a wet weather event.

14) **What operational and/or maintenance problems are you experiencing?**

The biggest problem is keeping up with cleaning the tubes. If they let it go two weeks without cleaning, they can see a significant difference in the e. coli counts. The bulbs are expensive, but can be easily changed in 10 minutes. The annual maintenance (when they usually change out all the bulbs in one channel) is a little time consuming.

Initially, they had no surge protection on the UV building, so they "fried" some of the wires inside the units. They contracted with UV Doctor (based in Las Vegas), who fixed this problem. Over the long term, they are happy with the system.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

The unit is equipped with wipers for the quartz sleeves. They alternate the units every other week; when a unit is off-line, they spray lime-a-way on the tubes. This strategy has worked pretty well for them.

16) **If UV system, how often have you had to change how many lamps?**

Change one side a year; if they get a lot of bad weather such that the power goes out, they can lose extra bulbs from the start- stop.

17) **What, do you find, are the benefits to your equipment?**

They had chlorine before, he never had to work with that system, but feels it is beneficial to not have the risk of holding the chlorine on site.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Safety

Noon Day Creek, GA
Aquionics

Date:	**22-Mar-05**
Plant:	**Noon Day Creek, Georgia**
Name of Contact:	**Manuel Matthews**
Telephone #:	**770-591-3165**
Type of Disinfection Technology (if UV, be specific):	**Aquionics In2500**

1) **Plant Dry Weather Flow (Average, peak)** 10-11 mgd (design 20 mgd)

2) **Plant Wet Weather Flow (Average, peak)** 22-3 mgd (peak = 50 mgd)

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

This is designed for year-round operation. They got rid of chlorine gas years ago and went to bleach prior to installing UV; they still keep hypochlorite on site to disinfect their filters.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

They are disinfecting secondary effluent from their activated sludge system (using air). They have sand-anthracite filters with automatic backwash ahead of the UV system.

5) **Do you have a combined sewer system?** Separate

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Transmittance is around 80, TSS is around 1.1 mg/L (after filters) though they may occasionally get 4 or 5 mg/L, and turbidity is not monitored.

7) **When was your disinfection equipment installed?**

Installed late last year and started running it around December 2004.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

don't currently have the ability to separate out, noticed a substantial increase in the power draw. Put in new electrical feed and transformers prior to installation. Has heard that the Aquionics transformers are more dependable than Trojan's. Have about a 10% failure on the bulbs. This should drop once they stop testing. They are doing a lot of start and stop right now. Bulbs are guaranteed about 7000 hours. Less than 3000 hours, they replace outright and pro-rate after that.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

NPDES limit is 100 cfu/100 mL monthly average; Mr. Matthews doesn't know what the dosage is.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

It monitors transmittance and changes the dose accordingly.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

The effluent value is averaging about 1 cfu/100 mL, although they have seen values as high as 50 cfu/100 mL.

12) **What is the approximate footprint of the disinfection unit?**

200 feet by 75 feet.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

They have eight banks with 24 bulbs to a bank, for a total of 192 bulbs. Typically, only two banks are in use. At low flow, they many only have one bank running. During a typical storm event, they have 3-4 banks running, so most days, they have at least 100% redundancy.

14) **What operational and/or maintenance problems are you experiencing?**

The only problems they had were during construction - they had a lot of debris getting in the UV units and would have wiper failures, but this wasn't the equipment's fault. Also, they experienced shortened bulb life due to frequent start-stops (allegedly). The bulbs are supposed to average about a 5% failure rate (from manufacturer) but they are currently experiencing a 10% failure rate, which is supposed to be normal for startup. Also, they had some loose connections in the ballasts after installation, but that has since been fixed.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Has an o-ring-type wiper that wipes up and down. The system also has an acid wash that kicks in when the bulbs get really dirty - this may get used approximately once per year.

16) **If UV system, how often have you had to change how many lamps?**

They've had some failures due to the testing they've been doing in the early months of operation. They expect that frequency to go down. The bulbs on this system are extremely easy to change (no hoist necessary); it takes about 5 minutes.

17) **What, do you find, are the benefits to your equipment?**

Compared to a Trojan system, the Aquionics system is much easier to do maintenance on, especially bulb changeout. The system is more robust due to the arrangement of the lamps; even if something large comes in (i.e. rags, sticks, etc.), the wiper mechanism will catch it and the bulbs won't be damaged (as they would in a Trojan system). The startup has been relatively painless, compared to a year that it took to debug a Trojan system at a neighboring plant. They are also happy that they don't have to do risk management for chlorine gas anymore.

18) **If equipment has recently been installed, what factors went into your decision making process?**

The risk management and safety aspects of chlorine gas were worrisome. The UV system is better for the environment. Overall, he is pretty happy with this system, it's been working pretty well during start-up. They have experienced construction related problems that were independent of the system.

Date:	
Plant:	**CMUD - Irwin and Sugar Creek Plants**
Name of Contact:	**Julie McLellan**
Telephone #:	**704-391-5126**
Type of Disinfection Technology (if UV, be specific):	**Wedeco Low Pressure, High Output**

1) **Plant Dry Weather Flow (Average, peak)** 13 mgd (Sugar), 10 mgd (Irwin)

2) **Plant Wet Weather Flow (Average, peak)** Unsure, maybe 1.5 -2 times dry weather values

3) **What is your operating strategy - e.g is the system for dry weather only? Is it supplemented with a chlorine-based system?**

Year round, chlorine dismantled.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**

What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

Secondary effluent with filters afterwards (sand-anthracite); activated sludge plants using air

5) **Do you have a combined sewer system?**

Not intentionally

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

Unknown

7) **When was your disinfection equipment installed?**

Installed in January, they are still tweaking things, have shut down, switch over to chlorine.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

Limit is currently 200/400; limit is changing

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

Not sure, Tom will know

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

From January's (QA/QC) highest was 6, most days were less than 1. In February, max was 41. Have done a lot of start up and shut down.

12) **What is the approximate footprint of the disinfection unit?**

Sugar is 33 by 58; at Irwin it is 46 by 67

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

Sugar has 360 (capacity for 40 mgd), Irwin has capacity for 30 mgd (672); the latter includes a bank for reuse - have two at each plant. Have flow equalization, flows are very steady. At Irwin, they have 50% extra. At Sugar, they don't have equalization, but the unit is able to disinfect peak flows.

At Sugar they have hypochlorite in the plant water; at Irwin no hypo

14) **What operational and/or maintenance problems are you experiencing?**

HVAC was a problem (Square D undersized it - looks like there was miscommunication between Wedeco and Square D). Have had some electrical coordinating issues (replacing transformers that were too small). Had some fuses that blew, original fuses were sensitive to overheating; changed fuses and now the problem is OK. Wedeco has been slow with the training and the operating screens. One ORC is angry about it. Seem to only have one IT guy - their support is worst in this department. If you don't like their standard formats, this seems to be a big problem- after operating three months (have been asking for this, still don't have the right screens). Has been disappointed in their product support. Just took chlorine out of Sugar, so she is getting a little scared about the support.

Also, the influent gate jammed a little bit initially. Some problems may be a result of the general contractor.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

Cleaning system is mechanical, not sure if there's any chemical in it. Wipers have not given any problems, do a good job of cleaning.

16) **If UV system, how often have you had to change how many lamps?**

Not yet

17) **What, do you find, are the benefits to your equipment?**

System seems to perform well. Got rid of the chemicals, it's a lot safer (no worry about potential gas leaks), it will allow them to meet permit limits for many years to come (even if limits get lower), gives them flexibility for reuse.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Chemical costs were going up, had to do risk management plans and other worker safety planning issues. Both plants are surrounded by residential and commercial spaces. Had a scare at Irwin in the late 90s in which the chlorine building got flooded and the cylinders started floating; nothing was released, but it made them nervous. It would have taken quite a bit of work to get the buildings as safe as they would have liked, so UV seemed like a good answer. They also thought their fecal limits might go down.

Their largest WWTP still has sodium hypochlorite, other four plants all have UV. They never had problems with the chlorine.

Have one of the vertical systems in place at one of the other plants (6-8 months old); vendor ODI. This system does not seem to be as good.

South Valley Utah
Wedeco Low intensity, High Output

Date:	**3/22/2005**
Plant:	**South Valley WWTP**
Name of Contact:	**John Hayes (maintenance) and Hugh Hedges (process)**
Telephone #:	**801-566-7711 and 801-495-5441**
Type of Disinfection Technology (if UV, be specific):	**Wedeco Low Pressure, High Output**

1) **Plant Dry Weather Flow (Average, peak)** 28 mgd

2) **Plant Wet Weather Flow (Average, peak)** Average 40 mgd, peak of 66 mgd

3) **What is your operating strategy - e.g. is the system for dry weather only? Is it supplemented with a chlorine-based system?**

   UV is used year-round, but since they don't have back-up power for the UV, they have the option of diverting flow to a back-up chlorination/dechlorination system if they lose power.

4) **What type of effluent is being treated at the facility/disinfected (e.g. primary, secondary, combined (ratio?))?**
   What types of processes are in use upstream (air, pure oxygen, SBR, etc.)?

   Secondary effluent; this is an oxidation ditch facility with no filtration

5) **Do you have a combined sewer system?**

   No

6) **What is your average and 95 percentile (else max week or max month) effluent TSS, transmittance and turbidity?**

   TSS is about 5 to 10 mg/L, turbidity is 3 NTU or less, and transmissivity is between 80-90%. The UV system was designed for 75% transmissivity.

7) **When was your disinfection equipment installed?**

   UV system went on line in July 2002.

8) **How much are you spending on power for the disinfection unit? What is its power draw?**

   Don't have that as a separate number.

9) **Do you have a regulatory limit for bacteria (e.g. fecal coliform)? If so, what are the limits and what is the disinfection dosage required to meet this limit?**

   The limit on total coliform is 2000/100 mL; it's is 200/ 100 mL for fecal coliform. Each lamp provides 330 watts and the minimum design dose is 35 mW-s/cm^2, though he doesn't know the actual dose off the top of his head.

10) **Are you monitoring any feedwater parameters (turbidity, etc.) "real time" for dose control?**

They monitor transmittance, but it doesn't drive the dosage. They set the dose they want and monitor the results of that dose. They then adjust the dose accordingly.

11) **What is the average and 95 percentile fecal coliform (or other bacteriological standard) value in your final, disinfected effluent?**

The UV system usually disinfects to 200/100 mL for total coliform and 20/100 mL for fecal coliform.

12) **What is the approximate footprint of the disinfection unit?**

The footprint of building (have two channels with air conditioned ballast "room" in the center) is 50 feet by 80 feet. It's a fairly compact building with room to work; they have two rooms with banks and lamps, a center room with the ballasts, and storage rooms at the end of each channel where lamps and spare parts are kept.

13) **If UV system, provide make, model, type (medium pressure, etc.), number of lamps, % redundancy**

It's a Wedeco high intensity, low pressure system. They have installed two channels, each with two banks of lights, each bank has 7 modules with 18 lamps, for a total of 504 lamps. Each channel is designed to treat an average flow of 20 mgd and a peak flow of 33 mgd.

14) **What operational and/or maintenance problems are you experiencing?**

A little hard for the operator to understand the automatic control system - could not override the automatic system, have since changed it to allow for a manual override. They have modified the controls a lot and are still working on deciding what is considered an "alarm situation", etc.

They had a series of problems with the ballasts (were losing more than they should have). Wedeco replaced over 200 ballasts. The ballast would fail and put high voltages across the low voltage control system which led to a domino effect with other ballasts. They were experiencing about 20% failure with the old ballasts, and now get about a 4% failure rate on the new ballasts.

15) **If UV, what is the cleaning procedure (method and frequency)? Do you consider it to be effective?**

It is equipped with an automatic, mechanical cleaning system that turns on every 15 minutes. Because of hardness issues, the operators pull the modules out and hand wipe them once a month (not very labor intensive) with Lime-a-Way and they check the wipers for wear at the same time. This takes about 2 hours every month (for 1/4 of the lamps). It works pretty well.

16) **If UV system, how often have you had to change how many lamps?**

They have about 516 bulbs, and get about 12,000 hours (and up to 17,000 hours) out of the bulbs. It takes two days to change out a bank (one quarter of the bulbs) and requires a hoist based system (like the Trojan).

17) **What, do you find, are the benefits to your equipment?**

They find that it is less work than their old chlorine system (no analyzers, no bulk chlorine off-loading, no injector systems to worry about). It also seems to be cleaner, safer, and they get a good, reliable kill. The lamp life on the system is great; they get 12,000 hours plus. The mechanical wiping system works very well. Operate these about every 15 minutes and have had no trouble with the wiper system. They have high hardness, so they hand clean sleeves with lime-a-way (which is more often than is probably necessary).

The power consumption isn't as bad as what they thought it would be and they are pretty happy with the system overall.

18) **If equipment has recently been installed, what factors went into your decision making process?**

Because the 2002 Winter Olympics were being held there (post 9/11), there were safety concerns with the bulk chemicals systems. The installation of UV allowed them to dismantle their chlorine system prior to the Olympics. In addition, development pushes had houses being built right up to the fence line of the plant, some of which were fewer than 100 yards from the bulk chlorine systems. They knew it would not be cost effective, but it is much safer. They piloted three systems at the time (IDI, Wedeco, and Trojan). They had heard very bad things about the Trojan medium pressure system, and were happier with the performance of the Wedeco system (note: the IDI system was a low-low system).

APPENDIX B - WATER QUALITY AND HYDROLOGICAL DATA FOR SEP, OSP, AND NPF

I. SEP water quality characteristics.

Table 1- SEP Influent Flow Summary.

	INFLUENT FLOW [mgd]			
	Dry Weather		Wet Weather	
	Average	*Max*	*Average*	*Max*
1998	69	83	127	251
1999	67	83	111	232
2000	68	84	116	252
2001	66	83	129	249
2002	63	81	122	248
2003	64	87	109	211
2004	66	87	117	249

Table 2 - SEP Primary Effluent TSS and COD Concentration.

Primary Effluent Pier 80 TSS Concentration [mg/L]							Primary Effluent Pier 80 COD [mg/L]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	99	276	41	98	340	26	*1998*	364	545	88	240	434	52
1999	141	647	30	141	410	75	*1999*	404	811	53	328	586	103
2000	95	320	18	97	329	42	*2000*	391	796	66	297	796	49
2001	114	1144	49	103	1240	28	*2001*	390	1135	53	282	1135	64
2002	110	304	12	101	154	39	*2002*	341	645	59	281	480	72
2003	106	694	58	96	152	57	*2003*	371	1336	196	279	418	78
2004	120	269	77	100	172	53	*2004*	361	788	99	260	520	107

Table 3 - SEP Secondary Effluent to Pier 80 TSS and BOD Concentration and Turbidity.

EFFLUENT Pier 80 TSS [mg/L]							EFFLUENT Islais Creek TSS [mg/L]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	17	38	4	16	32	5	*1998*	-	-	-	18	131	3
1999	16	53	5	19	59	7	*1999*	-	-	-	21	108	9
2000	15	40	6	17	35	5	*2000*	-	-	-	17	35	6
2001	15	32	3	18	41	8	*2001*	-	-	-	17	41	8
2002	15	164	3	19	38	8	*2002*	-	-	-	19	38	8
2003	16	48	6	15	32	9	*2003*	-	-	-	19	40	7
2004	18	49	5	28	125	8	*2004*	-	-	-	20	34	11

EFFLUENT Pier 80 Turbidity [NTU]							EFFLUENT Islais Creek Turbidity [NTU]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	7	13	3	7	8	6	*1998*	-	-	-	9	18	5
1999	8	17	4	14	18	11	*1999*	-	-	-	11	13	9
2000	7	16	3	9	13	6	*2000*	-	-	-	11	27	3
2001	8	12	3	10	12	6	*2001*	-	-	-	11	14	8
2002	7	10	4	\	\	\	*2002*	-	-	-	14	15	13
2003	7	10	5	\	\	\	*2003*	-	-	-	6	6	6
2004	7	10	4	\	\	\	*2004*	-	-	-	-	-	-

EFFLUENT Pier 80 Fecal Coliform [CFU/100mL]							EFFLUENT Islais Creek Fecal Coliform [CFU/100mL]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	41	370	10	367	16000	10	*1998*	-	-	-	99	1100	7
1999	611	100000	10	153	1500	10	*1999*	-	-	-	81	1255	10
2000	60	2100	10	53	700	10	*2000*	-	-	-	87	950	10
2001	55	1800	10	28	200	10	*2001*	-	-	-	34	425	10
2002	19	270	10	289	6700	10	*2002*	-	-	-	37	270	10
2003	25	330	10	89	1300	10	*2003*	-	-	-	34	160	10
2004	35	550	2	29	310	10	*2004*	-	-	-	38	230	10

II. OSP hydraulic and water quality characteristics.

Table 4 - OSP Influent Flow Summary

INFLUENT FLOW [mgd]				
	Dry Weather		Wet Weather	
	Average	*Max*	*Average*	*Max*
1998	18	21	36	60
1999	17	20	35	64
2000	17	20	35	65
2001	17	21	38	59
2002	17	20	37	57
2003	17	22	30	59
2004	16	23	31	59

Table 5 - OSP Primary Effluent TSS and COD Concentration.

Primary Effluent TSS Concentration [mg/L]							Primary Effluent COD [mg/L]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	75	222	54	92	1164	25	*1998*	301	493	176	245	1500	42
1999	84	590	42	73	265	36	*1999*	338	1091	178	237	322	151
2000	98	1306	56	100	1364	19	*2000*	348	1267	193	257	1028	59
2001	103	583	36	93	372	50	*2001*	377	1164	102	260	554	59
2002	87	321	35	84	190	44	*2002*	346	806	215	239	818	82
2003	105	914	53	87	244	31	*2003*	376	1650	221	284	589	84
2004	107	859	41	128	632	28	*2004*	368	707	108	312	1052	38

Table 6 - OSP Secondary Effluent TSS, Turbidity, and BOD Levels.

EFFLUENT TSS [mg/L]							EFFLUENT Turbidity [NTU]						
	Dry Weather			Wet Weather				Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*		*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	11	26	3	13	38	3	*1998*	-	-	-	-	-	-
1999	10	30	3	15	29	3	*1999*	-	-	-	-	-	-
2000	14	34	6	18	39	8	*2000*	9	25	5	10	21	5
2001	14	540	4	18	38	5	*2001*	8	29	3	12	22	4
2002	10	22	4	15	28	5	*2002*	6	14	3	9	14	5
2003	10	26	4	15	31	4	*2003*	7	18	3	10	24	4
2004	9	41	5	16	109	6	*2004*	6	21	3	14	70	4

EFFLUENT BOD [mg/L]						
	Dry Weather			Wet Weather		
	Ave	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	16	35		18	29	
1999	14	34		12	17	
2000	15	34		19	34	
2001	14	26		18	31	
2002	15	28		14	24	
2003	16	27	5	10	24	4
2004	18	95	6	21	95	6

III. NPF hydraulic and water quality characteristics of each stream.

Table 7 - NPF Influent flow Summary

INFLUENT FLOW [mgd]		
	Average	Max
1998	52	61
1999	49	73
2000	62	88
2001	67	88
2002	68	90
2003	52	65
2004	65	122

Table 8 - NPF Effluent TSS, Total Coliform, and BOD_T.

	TSS Concentration [mg/L]			Fecal Coliform [CFU/100mL]			BOD_T [mg/L]		
	Ave	*Max*	*Min*	*Average*	*Max*	*Min*	*Ave*	*Max*	*Min*
1998	98	276	26	90	2286	2	154	350	56
1999	108	598	53	883	16000	10	173	240	68
2000	94	320	18	10	10	10	152	218	33
2001	112	1240	28	10	10	10	171	400	78
2002	109	304	12	47	760	10	168	245	91
2003	104	694	57	10	10	10	166	240	83
2004	116	269	13	10	10	10	153	252	51

APPENDIX C - RECURRING COST CALCULATIONS AND ASSUMPTIONS

APPENDIX C - RECURRING COST CALCULATIONS AND ASSUMPTIONS

SEP Secondary

Operating hours	8760	
Power Cost		
# of lamps	1584	
Power draw with all lamps on	570.3 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	281.348	
Power draw per year	2464608 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	**$295,753** $/year	
Bulb Replacement Cost		
Unit cost of bulb	$164	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	792	
Bulb Replacement Cost	**$130,116** (per year)	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	3	
Hours to Change Bulbs (0.24 bulbs/hr)	190.08	
Cost of Labor	70 $/hr	
Total Cost of Bulb Changeout	$39,917 $/yr	
Time per Week	0.5 hours	
Weeks in a Year	52	
Hours per Year	26	
Routine Labor Costs per Year	$1,820	
Labor Costs per Year	**$41,737**	

Wedeco - SEP	
UV Capital Cost	$2,742,200
Power Cost	$295,753
Bulb Replacement Cost	$130,116
Estimated Labor Cost	$41,737
Total Recurring Costs	$467,606

SEP Secondary

TROJAN UV 4000

Operating hours	8760	
Power Cost		
# of lamps	672	
Power draw with all lamps on	1881.6 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	928.256	
Power draw per year	8131523 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$975,783 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 4 channels per year)	672	
Bulb Replacement Cost	$86,251	
Labor		
Laborers	161.28	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$33,869 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$35,689	
Labor Costs per Year	$69,558	

Trojan - SEP	
UV Capital Cost	$3,300,000
Power Cost	$975,783
Bulb Replacement Cost	$86,251
Estimated Labor Cost	$69,558
Total Recurring Costs	$1,131,592

SEP Secondary

TROJAN UV 4000

Operating hours	8760	
Power Cost		
# of lamps	672	
Power draw with all lamps on	1881.6 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	928.256	
Power draw per year	8131523 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$975,783 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 4 channels per year)	672	
Bulb Replacement Cost	$86,251	
Labor		
Laborers	161.28	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$33,869 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$35,689	
Labor Costs per Year	$69,558	

Trojan - SEP	
UV Capital Cost	$3,300,000
Power Cost	$975,783
Bulb Replacement Cost	$86,251
Estimated Labor Cost	$69,558
Total Recurring Costs	$1,131,592

SEP Primary

AQUIONICS INLINE 18000+

Operating hours	1536	
Power Cost		
# of lamps	864	
Power draw with all lamps on	4320 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	2131.2	
Total power draw per year	6635520 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$796,262 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume quarter of the channels per year)	216	
Bulb Replacement Cost	$70,200	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	51.84	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$10,886 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$12,706	
Labor Costs per Year	$23,593	

Aquionics - SEP	
UV Capital Cost	$7,783,100
Power Cost	$796,262
Bulb Replacement Cost	$70,200
Estimated Labor Cost	$23,593
Total Recurring Costs	$890,055

SEP Primary

PAA

Expected Dose	9	ppm
Solution	15	%
Cost	$9	per gallon
Wet Weather Days	64	
Average primary effluent flow	36.4	mgd
Need	5.26E-05	gallons soln/gallon wastewater
Average chemical use per wet weather day	1914	gallons
Cost per wet weather day	$17,222	per day
Chemical cost per year (average)	**$1,102,183**	
Labor	2	hrs/day
	56	hrs/year
Cost	$70	per hour
Total labor cost per year	**$3,920**	per year
Total cost of PAA	**$1,106,103**	

TROJAN UV 4000

Operating hours	1536		
Power Cost			
# of lamps	672		
Power draw with all lamps on	1881.6	kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49		
Power draw for average flow	928.3		
Total power draw per year	2890138	kWh/year	
Unit cost of power	0.12	$/kWh	
Total cost of power	$346,817	$/year	
Bulb Replacement Cost			
Unit cost of bulb	$128		
Bulb Life	5,000	hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 1 channel per year)	168		
Bulb Replacement Cost	$21,563		Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor			
Laborers	40.32		
Hours to Change Bulbs (0.24 bulbs/hr)	70	$/hr	
Cost of Labor	$8,467	$/yr	
Total Cost of Bulb Changeout	0.5	hours	
Time per Week	52		
Weeks in a Year	26		
Hours per Year	1,820		
Routine Labor Costs per Year	$10,287		
Labor Costs per Year	$18,754		

Trojan UV4000 - SEP	
UV Capital Cost	$3,530,000
Power Cost	$346,817
Bulb Replacement Cost	$21,563
Estimated Labor Cost	$18,754
Total Recurring Costs	$387,134

OSP Secondary

WEDECO

Operating hours	8760	
Power Cost		
# of lamps	432	
Power draw with all lamps on	155.6 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	76.8	
Power draw per year	672441 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	**$80,693** $/year	
Bulb Replacement Cost		
Unit cost of bulb	$164	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 1 channel per year)	216	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	**$35,486** (per year)	
Cost of Labor	70 $/hr	
Total Cost of Bulb Changeout	$10,886 $/yr	
Time per Week	0.5 hours	
Weeks in a Year	52	
Hours per Year	26	
Routine Labor Costs per Year	$1,820	
Labor Costs per Year	**$12,706**	

Wedeco - SEP	
UV Capital Cost	$858,350
Power Cost	$80,693
Bulb Replacement Cost	$35,486
Estimated Labor Cost	$12,706
Total Recurring Costs	$128,886

AQUIONICS - INLINE 18000+

Operating hours	8760	
Power Cost		
# of lamps	72	
Power draw with all lamps on	360 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	177.6	
Power draw per year	1555776 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$186,693 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume half of the channels per year)	36	
Bulb Replacement Cost	$11,700	
Labor		
Laborers	8.64	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$1,814 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$3,634	
Labor Costs per Year	$5,449	

Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.

Aquionics - SEP	
UV Capital Cost	$683,900
Power Cost	$186,693
Bulb Replacement Cost	$11,700
Estimated Labor Cost	$5,449
Total Recurring Costs	$203,842

OSP Secondary

TROJAN 3000+

Operating hours	8760	
Power Cost		
# of lamps	576	
Power draw with all lamps on	144 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	71.0	
Power draw per year	622310 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$74,677 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$150	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 1 channel per year)	288	
		Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$43,200	
Cost of Labor	$14,515 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$16,335	
Labor Costs per Year	$30,850	

Trojan - 3000+ - OSP	
UV Capital Cost	$1,069,500
Power Cost	$74,677
Bulb Replacement Cost	$43,200
Estimated Labor Cost	$30,850
Total Recurring Costs	$148,728

OSP Secondary

TROJAN UV4000+

Operating hours	8760	
Power Cost		
# of lamps	240	
Power draw with all lamps on	672 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	331.52	
Power draw per year	2904115 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$348,494 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	240	
Bulb Replacement Cost	$30,720	
Labor		
Laborers	57.60	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$12,096 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$13,916	
Labor Costs per Year	$26,012	

Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.

Trojan - 4000+ - OSP	
UV Capital Cost	$1,453,000
Power Cost	$348,494
Bulb Replacement Cost	$30,720
Estimated Labor Cost	$26,012
Total Recurring Costs	$405,226

OSP Primary

AQUIONICS INLINE 18000+

Operating hours	1632	
Power Cost		
# of lamps	216	
Power draw with all lamps on	1080 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	532.8	
Power draw per year	1762560 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$211,507 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume quarter of the channels per year)	54	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$17,550	
Cost of Labor	$2,722 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$4,542	
Labor Costs per Year	$7,263	

Aquionics - SEP	
UV Capital Cost	$1,979,900
Power Cost	$211,507
Bulb Replacement Cost	$17,550
Estimated Labor Cost	$7,263
Total Recurring Costs	$236,320

OSP Primary

PAA		
Expected Dose	9	ppm
Solution	15	%
Cost	$9	per gallon
Wet Weather Days	68	
Average primary effluent flow	5.88	mgd
Need	0.088	mL soln/1L wastewater
or	8.79E-05	gallons soln/gallon wastewater
Average chemical use per wet weather day	517	gallons
Cost per wet weather day	$4,651	per day
Chemical cost per year (average)	**$316,237**	
Labor	2	hrs/day
	56	hrs/year
Cost	$70	per hour
Total labor cost per year	**$3,920**	per year
Total cost of PAA	**$320,157**	

OSP Primary

TROJAN UV 4000+

Operating hours	1632	
Power Cost		
# of lamps	336	
Power draw with all lamps on	941 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	464.128	
Power draw per year	1535386 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$184,246 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 1 channel per year)	84	
		Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$10,781	
Cost of Labor	$4,234 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$6,054	
Labor Costs per Year	$10,287	

Trojan - SEP	
UV Capital Cost	$1,800,000
Power Cost	$184,246
Bulb Replacement Cost	$10,781
Estimated Labor Cost	$10,287
Total Recurring Costs	$205,315

OSP Augmented

TROJAN UV4000+

Operating hours	8760	
Power Cost		
# of lamps	240	
Power draw with all lamps on	672 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	331.52	
Power draw per year	2904115 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$348,494 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (all replaced once)	240	
Bulb Replacement Cost	$30,720	
Labor		
Laborers	57.60	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$12,096 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$13,916	
Labor Costs per Year	$26,012	

Trojan - 4000+ - OSP	
UV Capital Cost	$1,453,000
Power Cost	$348,494
Bulb Replacement Cost	$30,720
Estimated Labor Cost	$26,012
Total Recurring Costs	$405,226

OSP Augmented

AQUIONICS INLINE 18000+

Operating hours	8760	
Power Cost		
# of lamps	162	
Power draw with all lamps on	810 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	399.6	
Power draw per year	3500496 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$420,060 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	81	
Bulb Replacement Cost	$26,325	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	19.44	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$4,082 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$5,902	
Labor Costs per Year	$9,985	

Aquionics - SEP	
UV Capital Cost	$1,075,000
Power Cost	$420,060
Bulb Replacement Cost	$26,325
Estimated Labor Cost	$9,985
Total Recurring Costs	$456,369

OSP Augmented

TROJAN 3000+

Operating hours	8760	
Power Cost		
# of lamps	544	
Power draw with all lamps on	136 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	67.093333	
Power draw per year	587738 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$70,529 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$150	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 4 channels per year)	544	
Bulb Replacement Cost	$81,600	
Labor		
Laborers	130.56	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$27,418 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$29,238	
Labor Costs per Year	$56,655	

Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.

Trojan - 3000+ - OSP	
UV Capital Cost	$1,025,200
Power Cost	$70,528.51
Bulb Replacement Cost	$81,600
Estimated Labor Cost	$56,655
Total Recurring Costs	$208,784

TROJAN UV 4000+

Operating hours	1536	
Power Cost		
# of lamps	1008	
Power draw with all lamps on	2821.5 kW	>Scaled up from SEP value provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	1391.94	
Power draw per year	12193394 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$1,463,207 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (replace one channel)	336	
Bulb Replacement Cost	$43,008	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	80.64	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$16,934 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$18,754	
Labor Costs per Year	$35,689	

Trojan - 4000+ - OSP	
UV Capital Cost	$5,310,000
Power Cost	$1,463,207
Bulb Replacement Cost	$43,008
Estimated Labor Cost	$35,689
Total Recurring Costs	$1,541,904

NPP

Operating hours	1536	
Power Cost		
# of lamps	180	
Power draw with all lamps on	900 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	444	
Power draw per year	3889440 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$466,733 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	90	
Bulb Replacement Cost	$29,250	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	21.60	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$4,536 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$6,356	
Labor Costs per Year	$10,892	

Aquionics - SEP	
UV Capital Cost	$3,269,500
Power Cost	$466,733
Bulb Replacement Cost	$29,250
Estimated Labor Cost	$10,892
Total Recurring Costs	$506,875

NPP

PAA		
Expected Dose	15	ppm
Solution	15	%
Cost	$9	per gallon
Wet Weather Days	64	
Average primary effluent flow	32.2	mgd
Need	0.088	mL soln/1L wastewater
or	8.79E-05	gallons soln/gallon wastewater
Average chemical use per wet weather day	2830	gallons
Cost per wet weather day	$25,467	per day
Chemical cost per year (average)	$1,629,905	
Labor	2	hrs/day
	128	hrs/year
Cost	$70	per hour
Total labor cost per year	$8,960	per year
Total cost of PAA	**$1,638,865**	

NPP_sec

WEDECO TAK

Operating hours	8760	
Power Cost		
# of lamps	324	
Power draw with all lamps on	116.7 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	57.6	
Power draw per year	504330.72 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	**$60,520** $/year	
Bulb Replacement Cost		
Unit cost of bulb	$164	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	162	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	**$26,615** (per year)	
Cost of Labor	70 $/hr	
Total Cost of Bulb Changeout	$8,165 $/yr	
Time per Week	0.5 hours	
Weeks in a Year	52	
Hours per Year	26	
Routine Labor Costs per Year	$1,820	
Labor Costs per Year	**$9,985**	

Wedeco - NPF	
UV Capital Cost	$622,700
Power Cost	$60,519.69
Bulb Replacement Cost	$26,615
Estimated Labor Cost	$9,985
Total Recurring Costs	$97,119

NPP_sec

TROJAN 3000+		
Operating hours	8760	
Power Cost		
# of lamps	416	
Power draw with all lamps on	104 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	51.3	
Power draw per year	449446 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$53,934 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$150	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	208	
		Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$31,200	
Cost of Labor	$10,483 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$12,303	
Labor Costs per Year	$22,786	

Trojan - 3000+ - NPF	
UV Capital Cost	$785,000
Power Cost	$53,934
Bulb Replacement Cost	$31,200
Estimated Labor Cost	$22,786
Total Recurring Costs	$107,920

NPP_HRC

WEDECO TAK

Operating hours	1536	
Power Cost		
# of lamps	3024	
Power draw with all lamps on	1089 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	537.2	
Power draw per year	825201 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	**$99,024** $/year	
Bulb Replacement Cost		
Unit cost of bulb	$164	
Bulb Life	12,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	1512	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	**$248,403** (per year)	
Cost of Labor	70 $/hr	
Total Cost of Bulb Changeout	$76,205 $/yr	
Time per Week	0.5 hours	
Weeks in a Year	52	
Hours per Year	26	
Routine Labor Costs per Year	$1,820	
Labor Costs per Year	**$78,025**	

Wedeco - NPF	
UV Capital Cost	$2,742,200
Power Cost	$99,024
Bulb Replacement Cost	$248,403
Estimated Labor Cost	$78,025
Total Recurring Costs	$425,452

TROJAN UV 4000

Operating hours	1536	
Power Cost		
# of lamps	1344	
Power draw with all lamps on	104 kW	>Information provided by manufacturer
Ratio of flow with 416 bulbs to total flow	2.42	
Power draw for average flow	252	
Power draw per year	387072 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$46,449 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$128	
Bulb Life	5,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume 2 channels per year)	1344	
		Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$172,032	
Cost of Labor	$67,738 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$69,558	
Labor Costs per Year	$137,295	

Trojan - 4000+ - NPF	
UV Capital Cost	$6,375,000
Power Cost	$46,449
Bulb Replacement Cost	$172,032
Estimated Labor Cost	$137,295
Total Recurring Costs	$355,776

NPP_HRC

AQUIONICS INLINE 18000+

Operating hours	1536	
Power Cost		
# of lamps	1008	
Power draw with all lamps on	5040 kW	>Information provided by manufacturer
Ratio of average flow to total flow	0.49	
Power draw for average flow	2486.4	
Power draw per year	3819110 kWh/year	
Unit cost of power	0.12 $/kWh	
Total cost of power	$458,293 $/year	
Bulb Replacement Cost		
Unit cost of bulb	$325	
Bulb Life	8,000 hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume half of the channels per year)	504	
Bulb Replacement Cost	$163,800	Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Labor		
Laborers	120.96	
Hours to Change Bulbs (0.24 bulbs/hr)	70 $/hr	
Cost of Labor	$25,402 $/yr	
Total Cost of Bulb Changeout	0.5 hours	
Time per Week	52	
Weeks in a Year	26	
Hours per Year	1,820	
Routine Labor Costs per Year	$27,222	
Labor Costs per Year	$52,623	

Aquionics - NPF	
UV Capital Cost	$9,072,700
Power Cost	$458,293
Bulb Replacement Cost	$163,800
Estimated Labor Cost	$52,623
Total Recurring Costs	$674,716

TROJAN UV 4000

Operating hours	1536		
Power Cost			
# of lamps	1008		
Power draw with all lamps on	2822	kW	>Information provided by manufacturer
Ratio of flow with 416 bulbs to total flow	2.42		
Power draw for average flow	6837		
Power draw per year	10501189	kWh/year	
Unit cost of power	0.12	$/kWh	
Total cost of power	$1,260,143	$/year	
Bulb Replacement Cost			
Unit cost of bulb	$128		
Bulb Life	5,000	hours	Estimate of bulb life provided by manufacturer.
Bulbs Replaced per Year (assume all channels replaced)	1008		
			Based on information provided by the operators at South Valley, it takes 2 men two days to replace 136 bulbs. It would therefore take a crew of three men approximately 0.24 hours to change one bulb at SEP. Estimate of routine maintenance time provided by Aquionics.
Bulb Replacement Cost	$129,024		
Cost of Labor	$50,803	$/yr	
Total Cost of Bulb Changeout	0.5	hours	
Time per Week	52		
Weeks in a Year	26		
Hours per Year	1,820		
Routine Labor Costs per Year	$52,623		
Labor Costs per Year	$103,426		

Trojan - 4000+ - SEP	
UV Capital Cost	$4,805,000
Power Cost	$1,260,143
Bulb Replacement Cost	$129,024
Estimated Labor Cost	$103,426
Total Recurring Costs	$1,492,593

APPENDIX D - LIST OF EXISTING UV INSTALLATIONS