City of Pinole

Pinole/Hercules WPCP Project

Technical Memorandum 12

Disinfection System Alternative Analysis

March 1, 2013

PRELIMINARY
FOR REVIEW ONLY

REGISTERED PROFESSIONAL ENGINEER
Craig Olson
NO. 39819
EXP. 12/31/12
CIVIL
STATE OF CALIFORNIA

Prepared under the responsible charge of

Engineer's Name
Registration Number

HDR

2365 Iron Point Road, Suite 300
Folsom, CA 95630

Contents

Executive Summary 1
Purpose 1
Disinfection Alternatives Pre-Screening and Evaluation 1
Conclusions 1

Introduction 2
Purpose and Objectives 2
Scope of Work 3
TM Overview 3

Design Criteria 4
Permit Requirements 4
Design Flows 5
Effluent Water Quality 8
Suspended Solids 8
UV Transmittance (UVT) 9
Chlorination Design Criteria 10
Chlorine Dose 10
Chlorination Contact Time 12
UV Design Criteria 13
UV Dose 13
UV Transmittance 14
Other Water Quality Considerations 14
Other Design Considerations 15
Project Area 15
Site Conditions 15
Hydraulics 15
Coagulation Flocculation 16
Standby Power 16
Other Chlorine Uses 16
Summary of Design Criteria 16

Alternative Evaluation Methodology 18
Evaluation Process 18
Define Process Methodology and Evaluation Criteria 18
Brainstorm and Screen Ideas 20
Technology Tour 20
Detailed Development and Evaluation 20
Review Workshops 20
Decision Workshop 20
Driving Forces 21
Permit Revisions 21
Safety Concerns 21
Space Limitation 21
Cost Evaluation of Alternatives 21

Alternative Prescreening 23
Alternative - No Action 23
Alternative 2 - Chlorination Expansion 24
Alternative 3 - UV Disinfection 25
Alternative 4 - Ozone 26
Pre-screening Recommendation 27

Recommended Alternative Evaluation 28
Chlorination System 28
Design Features 28
Estimated Construction and O&M Costs 29
Process Conceptual Layout 30
UV System 30
Design Features 30
Estimated Construction and O&M Costs 33
Process Conceptual Layout 35
Cost Comparison 35
Disinfection Alternative Recommendation 35

Recommended Project 38
Facility Description 38
Storage Tanks 38
Metering Pumps 41
Piping and Valving 41
Induction and Mixing 41
Cover 41
Containment and Drains 41
Safety Equipment 42
Potable Water System 42
Monitoring and Control 42
Facility Summary 42
Estimate of Probable Construction Cost 44

Appendix A. Construction and O&M Cost Estimate 45

Figures

Figure 12-1. Plant Existing Disinfection System 6
Figure 12-2. Plant Maximum Influent and Effluent Flows (2008-2011) 7
Figure 12-3. Plant Minimum Influent and Effluent Flows (2008-2011) 8
Figure 12-4. Plant Effluent TSS (2008-2011) 9
Figure 12-5. UV Transmittance Monitoring Data 10
Figure 12-6. Effluent Total Coliform (2008-2011) 11
Figure 12-7. Effluent Chlorine Residual (2008-2011) 11
Figure 12-8. Sodium Hypochlorite and Sodium Bisulfate Doses (May 2011-May 2012) 12
Figure 12-9. Effluent Ammonia and Nitrate (2008-2011) 13
Figure 12-10. UV Collimated Beam Test Results 14
Figure 12-11. Chlorination System Layout (Scenario 1 - Without Additional CCT) 31
Figure 12-12. Chlorination System Layout (Scenario 2 - With Additional CCT) 32
Figure 12-13. UV System Layout (Scenario 1 - Without BNR) 36
Figure 12-14. UV System Layout (Scenario 2 - With BNR) 37
Figure 12-15. Chlorination/Dechlorination Facility Site Plan 39
Figure 12-16. Chlorination/Dechlorination Facility Typical Layout 40

Tables

Table 12-1. Disinfection Alternative Costs 2
Table 12-2. Effluent Disinfection Regulatory Requirements 4
Table 12-3. Disinfection Design Criteria 17
Table 12-4. Evaluation Criteria 19
Table 12-5. Cost Estimating Procedure 22
Table 12-6. Advantage and Disadvantages of Gaseous Chlorination 23
Table 12-7. Advantage and Disadvantages of Chlorination Improvement 25
Table 12-8. Advantages and Disadvantages of UV Disinfection 26
Table 12-9. Result of Alternative Pre-screening 27
Table 12-10. Chlorination System Design Features 29
Table 12-11. Estimated Annual O&M Cost of Chlorination System (without BNR) 29
Table 12-12. Estimated Annual O&M Cost of Chlorination System (with BNR) 30
Table 12-13. UV System Design Features 33
Table 12-14. Estimated O&M Cost of the UV System (Scenario 1 - Without BNR) 34
Table 12-15. Estimated O&M Cost of the UV System (Scenario 2-With BNR) 34
Table 12-16. 20-year Net Present Worth Cost Comparison 35
Table 12-17. Summary of Chlorination/Dechlorination Facilities 43
Table 12-18. Probable Construction Cost of the New Disinfection Facility 44

TM 12 - DISINFECTION SYSTEM ALTERNATIVE ANALYSIS

Pinole/Hercules WPCP Project ***March 1, 2013***

Reviewed by: Craig Olson, P.E., Ted Kontonickas, P.E.
Prepared by: June Leng, Ph.D., P.E.

Executive Summary

Purpose

The objectives of the TM are to establish disinfection facility design criteria, investigate available wastewater disinfection technologies, and recommend the disinfection technology for implementation at the Pinole/Hercules Water Pollution Control Plant (WPCP).

Disinfection Alternatives Pre-Screening and Evaluation

Four alternatives are considered as viable options in terms of their applicability, reliability, and operational experiences. An economic evaluation was performed for each of the four alternatives.

- Alternative 1 – Chlorination/dechlorination with NO additional chlorination contact tank (CCT) expansion. The improvements would consist of new induction units, new metering pumps and relocation of existing chemical storage tanks and residual analyzers.
- Alternative 2 – Chlorination/dechlorination with CCT expansion. The improvements would consist of additional contact tank volume, new induction units, new metering pumps and relocation of existing chemical storage tanks and residual analyzers.
- Alternative 3 – UV Disinfection Facility sized for secondary effluent water quality without upstream process upgrade to biological nutrient removal (BNR), or under current treatment condition.
- Alternative 4 – UV Disinfection Facility sized for secondary effluent water quality with upstream process upgrade to BNR.

Conclusions

The 20-year present worth costs of these four (4) alternatives are summarized in Table 12-1.

Table 12-1. Disinfection Alternative Costs

Disinfection Alternative	Construction Cost	Annual O&M Cost	Net Present Worth 20-year	Percentage Comparison
Chlorination/Dechlorination with NO additional CCT	$924,000	$307,800	$4,450,000	100%
Chlorination/Dechlorination with additional CCT	$1,567,000	$307,800	$5,090,000	114%
UV Disinfection (Without BNR)	$4,066,000	$770,300	$12,890,000	285%
UV Disinfection (With BNR)	$1,680,000	$270,300	$4,780,000	107%

The 20-year net present worth indicate that the cost of chlorination/dechlorination with NO additional CCT improvement (Alternative 1) is the lowest of the alternatives. Although the O&M cost is higher than UV with BNR (Alternative 4).

The 20-year net present worth of UV disinfection without BNR upgrade is the highest of the four alternatives due to the facility requirement for disinfecting secondary effluent with low water quality.

The upstream process upgrades are critical in selecting the disinfection approach for the WPCP. If upstream process upgrades are included in this project, the disinfection alternative of chlorination/dechlorination with NO additional CCT is the least costly solution for disinfection at the WPCP.

UV disinfection should be considered as a viable alternative for disinfection at the WPCP when chlorination disinfection byproducts (DBPs) become a regulatory issue in the future. The WPCP is not regulated for DBPs currently because DBPs do not exceed the RWQCB's San Francisco Bay Basin Plan water quality objectives. In the long term, this could change because the EPA is promulgating nationwide limitations on DBPs such as THMs and haloacetic acids (HAA5). Facilities practicing chlorination would always be subject to potential future regulatory changes. If upstream process upgrades (i.e., conversion to BNR) are included now, conversion to UV disinfection in the future is viable and a UV system could be retrofitted into the existing chlorine contact tank.

Introduction

This Disinfection Technical Memorandum (TM) presents the results of a detailed alternative evaluation specific to the disinfection system at the WPCP.

Purpose and Objectives

The objectives of the TM are to:

- Evaluate wastewater disinfection technologies and recommend a technology for implementation.
- Establish the site-specific disinfection system design criteria to be used during detailed design.

A pre-screening evaluation was performed on all available disinfection technologies in wastewater treatment and disposal. The pre-screening evaluation resulted in a recommendation of the most applicable alternative for the WPCP. The recommended alternative was further evaluated with site-specific design conditions.

Scope of Work

This TM includes both general and conceptual information and basic details regarding the disinfection recommendation, and design of the proposed disinfection system and associated facilities. The scope of work represented by this study TM includes:

- Summary of the WPCP wastewater effluent flows and quality from year 2008 to 2011.
- Summary of the disinfection system design criteria for detailed system design.
- Consideration of redundancy, reliability and future facility expansion issues for detailed system design.
- Evaluation and comparison of applicable disinfection technologies, and evaluation of up to four (4) alternative UV disinfection system designs including detailed descriptions of the technology, site and facility layouts, and other associated equipment and devices in support of the alternative systems.
- Recommendation of a system design to be constructed at the treatment facility based on a comparison of reliability, benefits, capital, and operation and maintenance (O&M) costs.
- Development of an opinion of probable construction cost for the recommended facilities.

TM Overview

This TM is organized into the following section:

- Section 1 - Introduction
- Section 2 - Design Criteria
- Section 3 - Alternative Evaluation Methodology
- Section 4 - Alternative Pre-Screening
- Section 5 - Recommended Alternative Evaluation

The appendices bound in this TM contain supporting documentation including:

- Plant discharge permit
- Plant effluent monitoring data
- Manufacturer provided design information
- Life cycle cost analysis of the design alternatives
- The estimate of probable construction cost for the recommended project

Design Criteria

This section includes a summary of the design criteria for the proposed disinfection system and associated facility design. Key design parameters discussed in detail in this section include disinfection flows, secondary effluent quality, and redundancy requirements.

Permit Requirements

The purpose of the disinfection system is to provide disinfection for secondary effluent so that the discharge to the Deep Water Outfall meets the NPDES permit requirements outlined in TM 2. Design criteria were developed for the proposed disinfection system based on the WPCP's NPDES permit requirements.

A tentative discharge permit which became effective on October 1, 2012 and includes new disinfection criteria. Similar discharge limitations are anticipated in the plant's future NPDES permit. The requirements related to the design of the disinfection system are summarized in Table 12-2.

Table 12-2. Effluent Disinfection Regulatory Requirements

Limitations for Discharge to Deep Water Outfall EFF-001		
Pinole/Hercules WPCP (October 1, 2012 to September 30, 2017)	Enterococcus not exceed 35 MPN/100mL	Monthly Maximum
	Total Coliform not exceed 240 MPN/100mL	In at least five(5) samples collated within a calendar month
	Total Coliform not exceed 10,000 MPN/100mL	Any single sample
	Chlorine residual less than 0.0 mg/L	Instantaneous maximum
	Total ammonia as N not exceed 113 mg/L	Average monthly
	Total ammonia as N not exceed 182 mg/L	Maximum daily
	DO of 5.0 mg/L	Minimum

Note: MPN = Most Probable Number

The recent involvement of HDR staff in the activities of the Bay Area Clean Water Agencies (BACWA) revealed that potential changes to the future permits may include nutrient limits and organic loadings relating to nitrogen and phosphorous. Currently, total ammonia is required to be monitored on a monthly basis. TKN and nitrate/nitrite monitoring is not required and no limits are given in the Tentative Permit.

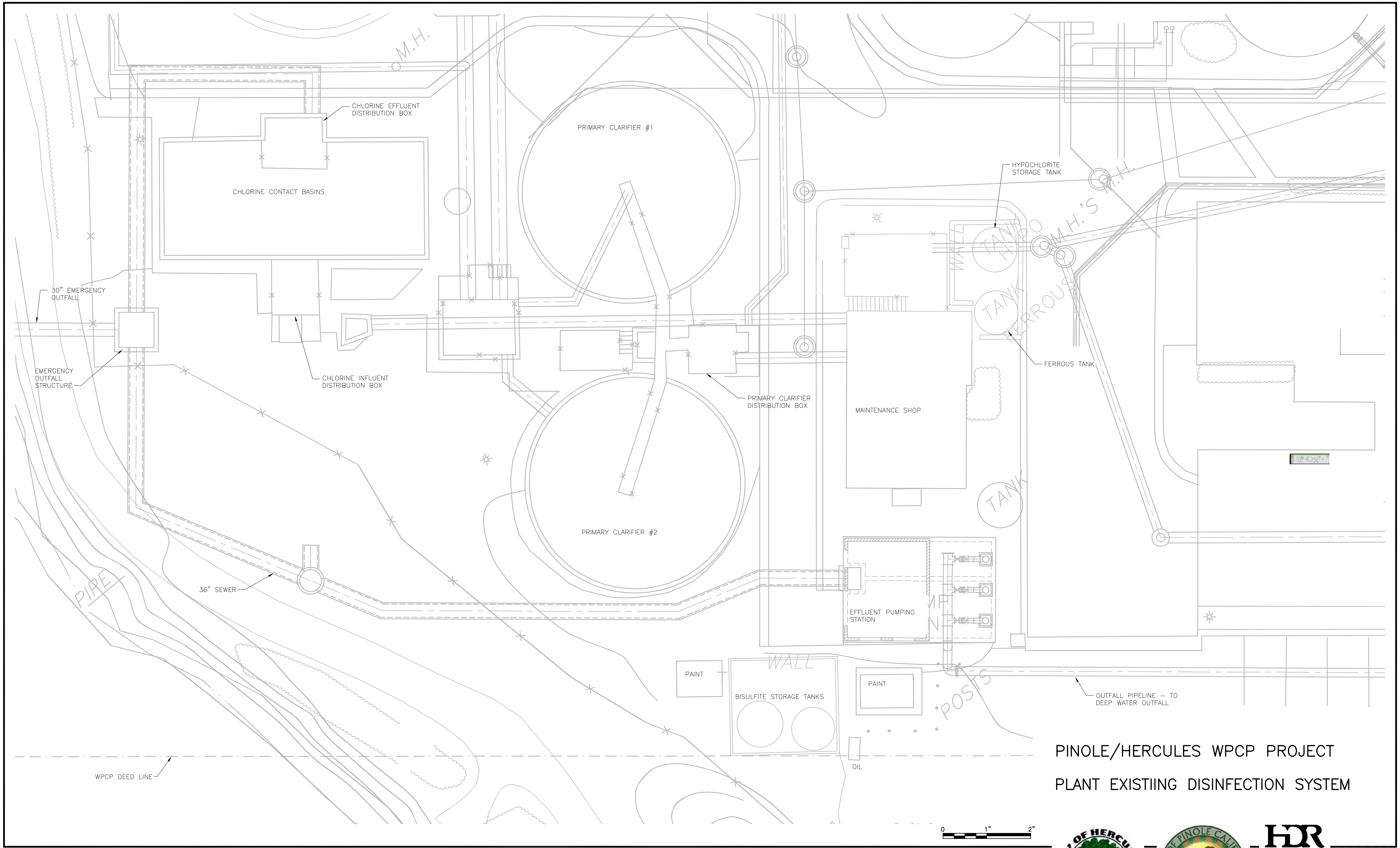
The limits on ammonia may be relevant to disinfection since ammonia in the water stream exerts a chlorine demand when chlorination is practiced. Ammonia reacts with chlorine to form chloramines; therefore, the chlorination mechanism is dominated by chloramination, not chlorination (with free chlorine). Chloramines are a weak disinfectant compared to free chlorine, yet chloramination generates fewer disinfection by-products such as trihalomethanes (THMs) than chlorination with free chlorine. Without ammonia in the effluent, chlorination with free chlorine occurs, which could result in breakpoint chlorination, therefore increasing the chlorine demand, as well as the potential for generating more disinfection by-products.

Generally, implementing nutrient removal favors UV disinfection over chlorination due to the following reasons:

- Typically, nutrient removal processes produce better quality secondary effluent with higher percentage UV transmittance.
- Nutrient removal eliminates ammonia in the secondary effluent; subsequent chlorination with free chlorine has potential to generate disinfection by-products.
- In absence of ammonia, breakpoint chlorination likely occurs, which potentially results in higher chlorine usage.

Design Flows

At the plant, the flow splits into two parallel streams after discharge from the primary clarifiers. After the split, each stream continues to the downstream secondary treatment train including aeration basin and final clarifiers. Two (2) parallel chlorine contact tanks are downstream of the final clarifiers. Effluent flows from the secondary clarifiers to the chlorine contact tanks by gravity. The existing clarifiers have limited capacity of approximately 8.6 mgd. Currently, peak flows above the clarifier capacity bypass the secondary treatment and blend back into the secondary effluent before flowing to the chlorine contact tank for disinfection. This blending will be eliminated after the next plant upgrade which will include new final clarifiers that are capable of handling the peak flow of 20 mgd. Figure 12-1 shows the existing treatment process units with the existing chlorine facilities labeled.



PINOLE/HERCULES WPCP PROJECT

PLANT EXISTIING DISINFECTION SYSTEM

Figure 12–1

C:\pwworking\sac\d0435431\Figure 12–1.dwg
03–01–13 15:40:31 RSNIDER

The sizing of the disinfection system is based on capacity of the upstream secondary treatment system. Disinfection system capacity is typically designed for treatment of the maximum flow feeding the system. The WPCP's NPDES permit indicates the peak wet weather secondary treatment capacity is 20 mgd after the upgrade. The peak flow of 20 mgd will be used as the design flow for the disinfection system, which matches upstream capacity of most of the treatment components. For flows above 20 mgd, a significant overall plant expansion or some type of flow equalization would be required. Current average dry weather flow is approximately 3.0 mgd with a minimum effluent flow rate approximately 1.0 mgd after applying the diurnal flow fluctuation factor. Projected average dry weather flow (ADWF) is approximately 4.06 mgd. The maximum influent and effluent flows of 2008 to 2011 at the plant are summarized in Figure 12-2. The highest discharge flow was 14.75 mgd in March 2011.

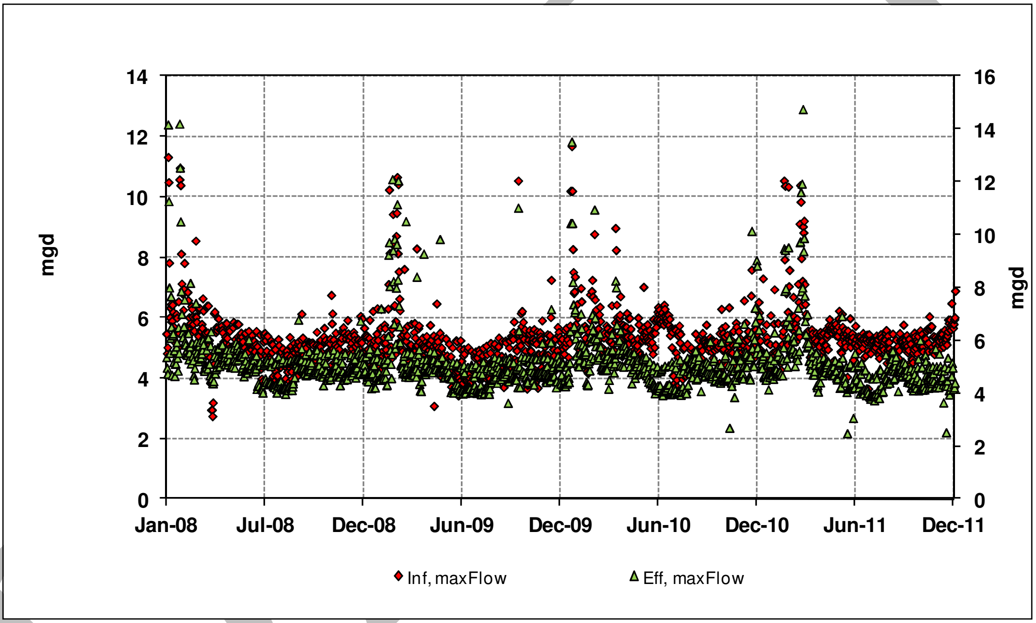


Figure 12-2. Plant Maximum Influent and Effluent Flows (2008-2011)

The minimum influent and effluent flows of 2008 through 2011 at the plant are summarized in Figure 12-3. Flow fluctuation between the minimum flow and the peak flow will be considered in the disinfection system design in order to conserve chemical or power usage. Minimum flow at the system startup estimated at approximately 1.0 mgd will be used for the UV disinfection system design.

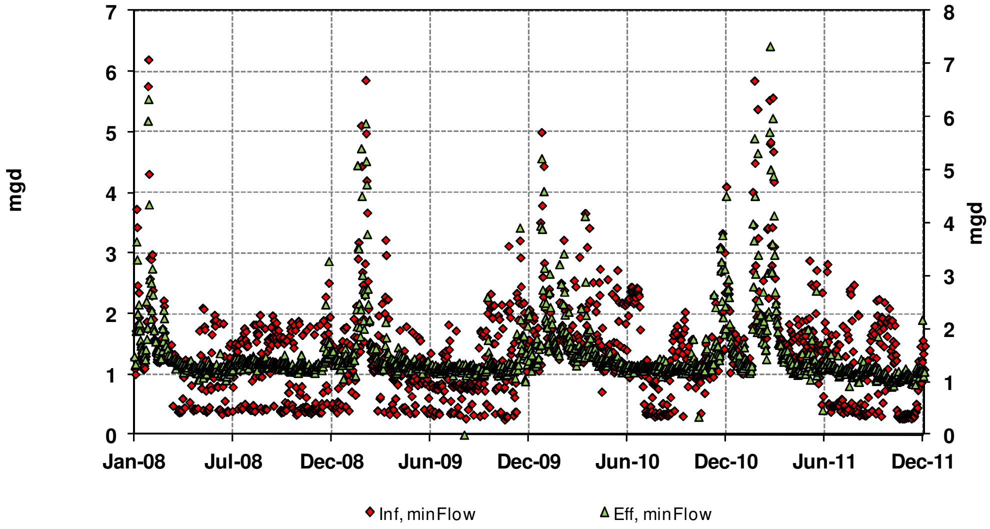


Figure 12-3. Plant Minimum Influent and Effluent Flows (2008-2011)

Effluent Water Quality

The secondary effluent water quality can have significant impact on chlorination or UV system design, performance, and operation and maintenance (O&M) costs. The existing secondary effluent water quality and UV and chlorine dose design criteria are described below.

Suspended Solids

For a viable disinfection technology such as UV, the system feed water concentration of Total Suspended Solids (TSS) determines how much UV radiation ultimately reaches the target organisms. The higher the TSS concentrations, the lower the UV radiation absorbed by the microorganisms, and the lower the inactivation rate. The feed flow to the potential future disinfection system is 100-percent secondary effluent. Historical effluent TSS data from the WPCP are summarized in Figure 12-4. The highest TSS in the WPCP secondary effluent was 252 mg/L in March 2008, which is a one-time excursion due to a brief secondary treatment process upset at the time. The TSS in the WPCP secondary effluent is typically under 20 mg/L with an average value of approximately 15 mg/L. Effluent particle count data are not available. In general, large particles are likely to provide shielding of microorganism in a UV system. High percentage (> 90 percent) of small particles (less than 10 micron) would favor UV disinfection.

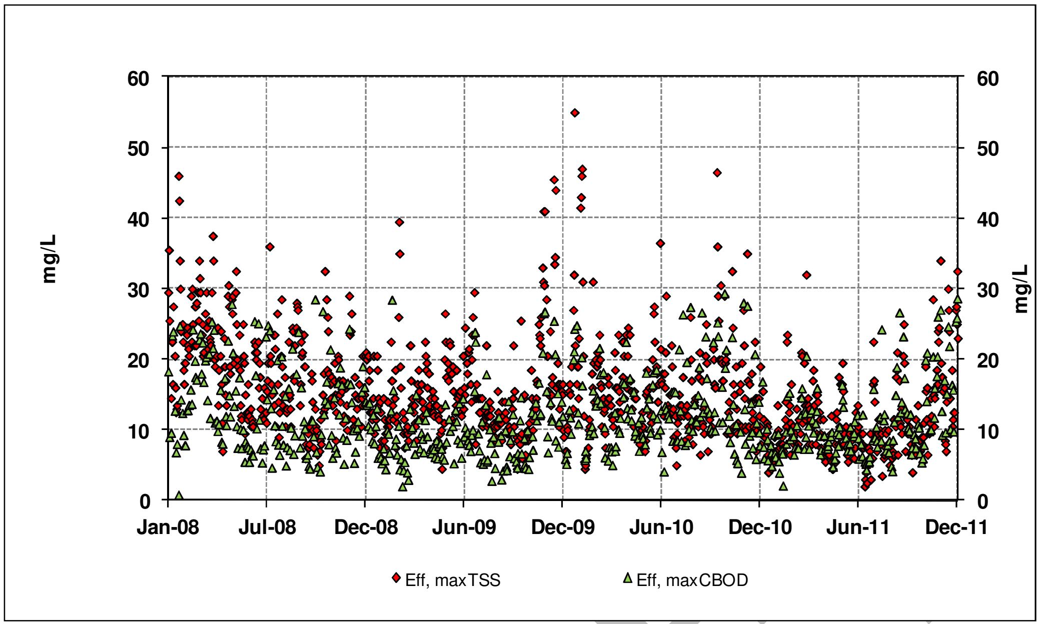


Figure 12-4. Plant Effluent TSS (2008-2011)

UV Transmittance (UVT)

A critical criterion for a UV system design is the feed water UV transmittance (UVT), or secondary effluent UVT. The design UVT is typically based on the lower 10th percentile UVT value so as to provide a system that conservatively meets dose and pathogen reduction targets under average conditions and marginally meets dose and pathogen reduction targets under stressed (low UVT, peak flow and high solids) conditions. A short task of UVT data collection program was carried out at the plant and a number of secondary effluent UVT readings were collected in a two-week period as shown in Figure 12-5. The secondary effluent UVT ranges from 50-percent to 65-percent. UVT of 55-percent will be used as UV system design criteria in the following sections.

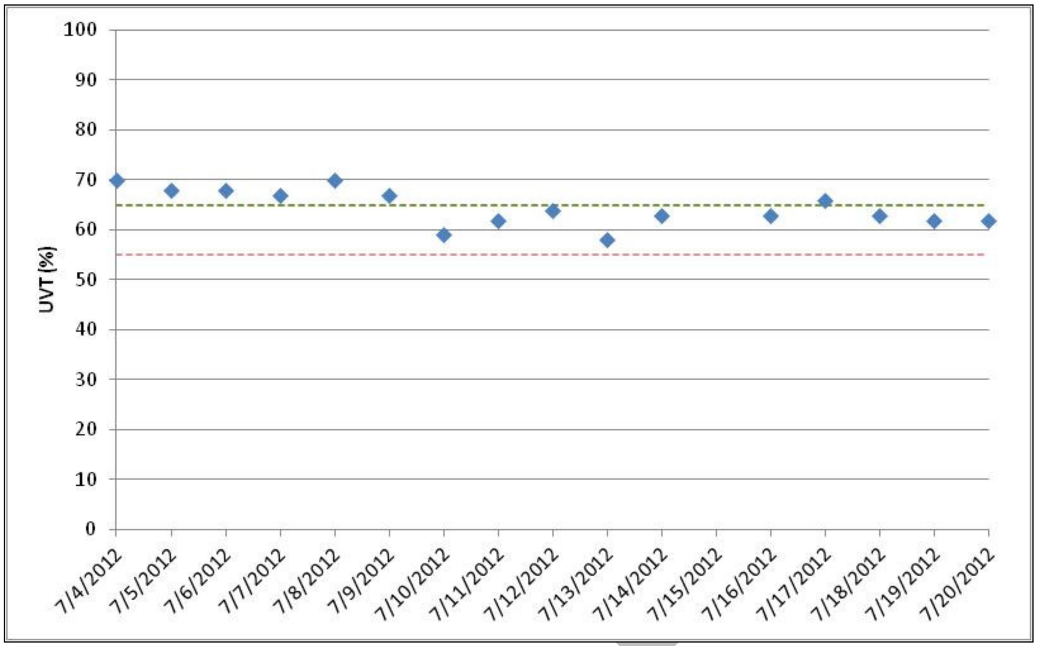


Figure 12-5. UV Transmittance Monitoring Data

Chlorination Design Criteria

Chlorine Dose

The WPCP is currently practicing disinfection with bulk purchased sodium hypochlorite. The facility final effluent has been meeting both the bacterial standards and the chlorine residual limit in the effluent. Current chlorination practice is year round for compliance with the NPDES permit requirement. The plant effluent total coliform counts of 2008 through 2011 are presented in Figure 12-6 and the chlorine residuals prior to dechlorination are summarized in Figure 12-7.

Chlorine dosage and bisulfite dosage from May 2011 through May 2012 are summarized in Figure 12-8. The typical chlorine dosage has been in the range of 10 mg/L to 35 mg/L with an average of approximately 20 mg/L. Historical data have shown that chlorine dose is increasing in the past six months. Enterococci limitations are included in the tentative NPDES permit in addition to total coliform limits. Studies have shown that higher chlorine residual is required to inactivate enterococci bacteria. For the purpose of this evaluation, chlorine dose of 25 mg/L based on the use of sodium hypochlorite will be used to size the chlorination facility. If nutrient removal is implemented, the improvement of effluent quality will potentially lower the chlorine dosages; therefore, for plant upgrade with nutrient removal, chlorine dose of 15 mg/L will be used to size the chlorination facility.

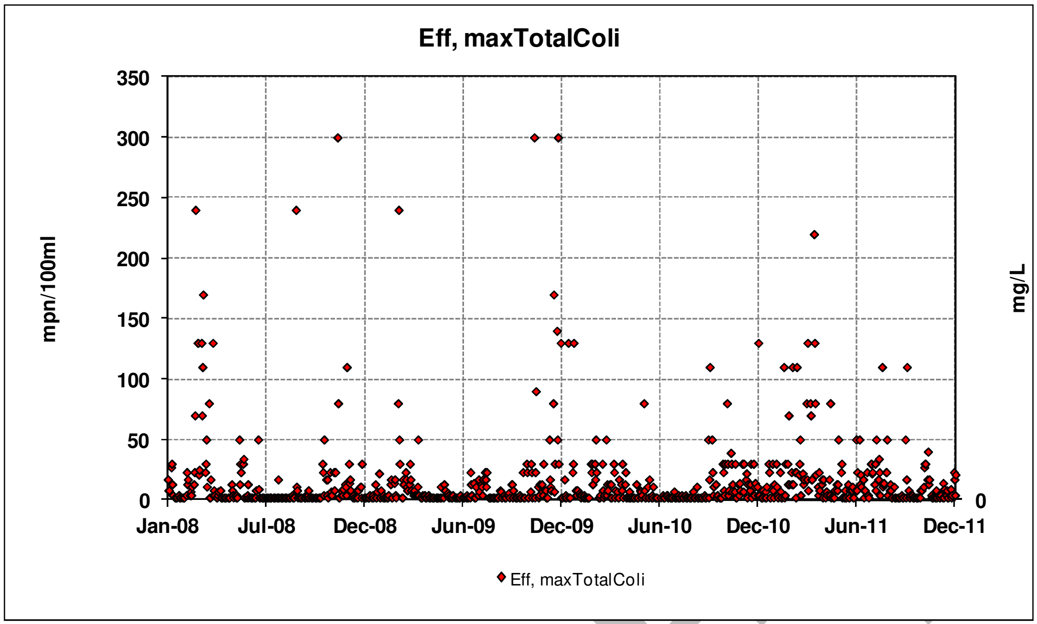


Figure 12-6. Effluent Total Coliform (2008-2011)

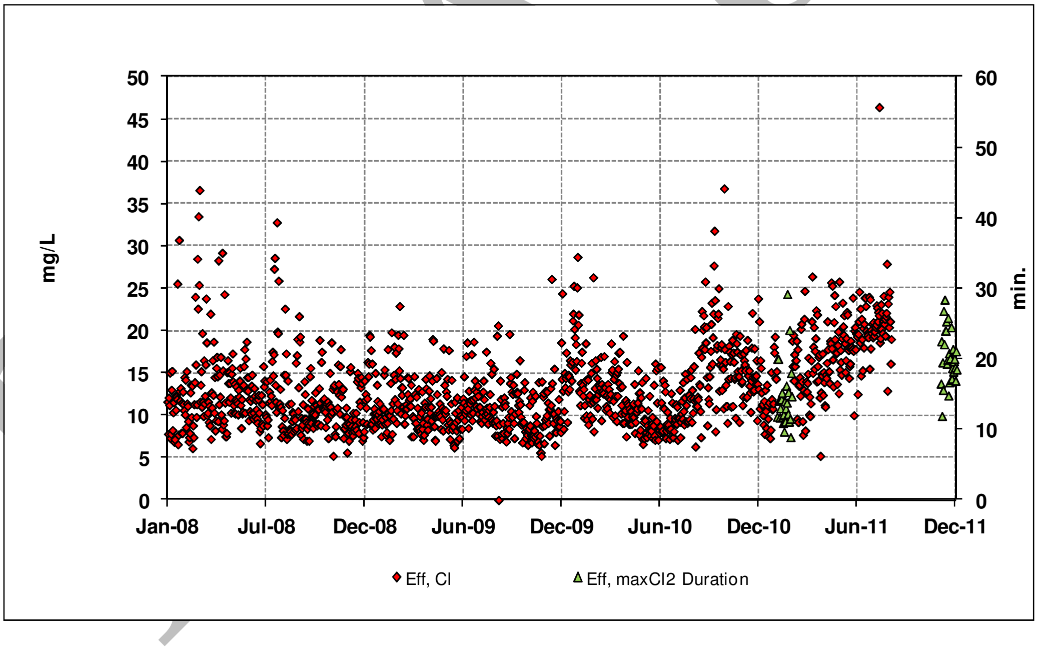


Figure 12-7. Effluent Chlorine Residual (2008-2011)

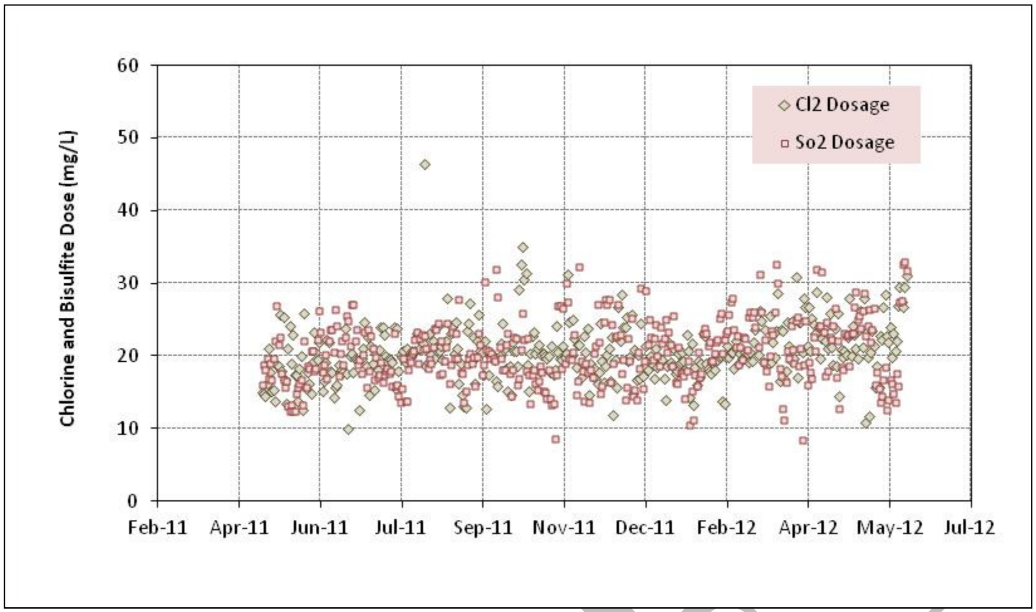


Figure 12-8. Sodium Hypochlorite and Sodium Bisulfate Doses (May 2011-May 2012)

Chlorination Contact Time

The existing chlorine contact tanks are located inside the plant. The total volume of the contact tanks is 50,000 gallons. There are two parallel tanks that contain a total of six (6) passes each, a total surface area of approximately 1,500-square feet, and a side water depth of 4.45-feet. Under the peak day flow of 20 mgd, the existing chlorine contact tanks provide a total contact time of 3.6 minutes, assuming 100-percent contact tank efficiency. However, the efficiency of contact tanks with similar configurations is typically less than 80 percent because of short circuiting; therefore the actual contact time is likely less than 3 minutes at peak flow. Typically, a minimum contact period of 15 minutes at peak flow is required for effective coliform inactivation. Based on this criterion, continuation of chlorination would require the existing chlorine contact tanks to be expanded to provide 15 minutes minimum effective contact time, or approximately 20 minutes theoretical contact time.

The alternative to the tank expansion is to meet the CT requirement instead of contact time requirement. CT is the product of chorine residual concentration and contact time. With high ammonia concentrations in the plant effluent (Figure 12-9), chlorine residual is mainly in the form of combined chlorines, or chloramines. High chlorine residual concentration is required to achieve the same disinfection goal with combined chlorine in comparison to free chlorine. In chlorination practice, higher chlorine doses are used to compensate for decreased contact time under peak flow conditions. According to the collected data from similar plants practicing effluent chloramination, the CT is typically approximately 75 mg-min/L with the maximum approximately 300 mg-min/L. Chlorination with these CT values has been proved to maintain facility discharges in compliance with the permit requirements in the past. For future chlorination operation, without chlorine contact tank expansion, increased chlorine dosage during peak flow events may be practiced. For example, a chlorine dose of 35 mg/L might be necessary to bring about 30 mg/L chlorine residual, in order to achieve the CT of 90 mg-min/L (= 30 mg/L chlorine residual x 3 minutes contact time).

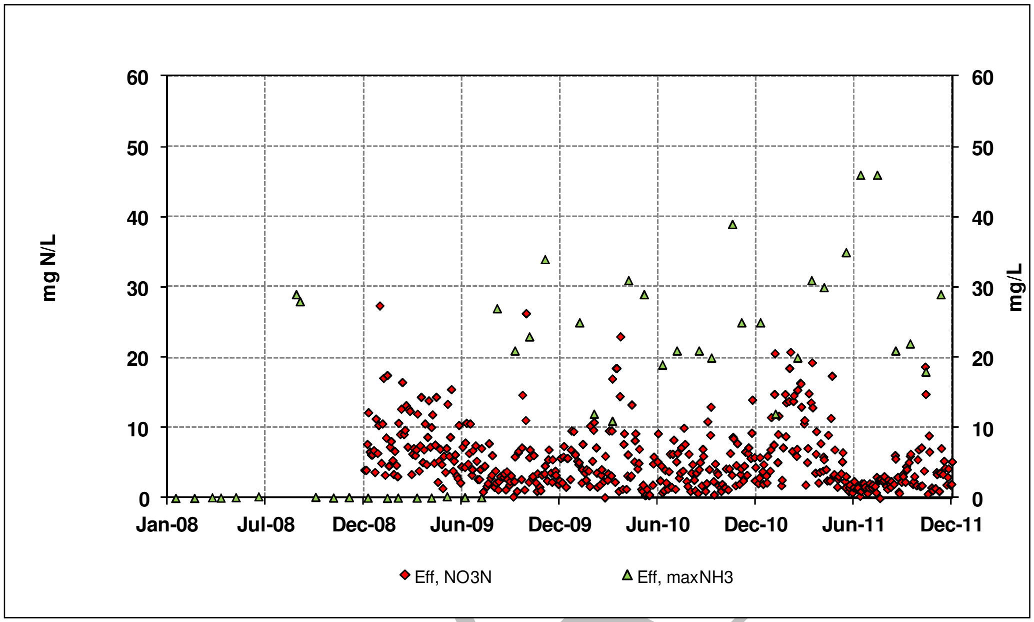


Figure 12-9. Effluent Ammonia and Nitrate (2008-2011)

UV Design Criteria

UV Dose

The determination of the proper UV dose to meet permit requirements is critical. UV dose is used for sizing UV disinfection systems. The secondary effluent samples were shipped to a specialized lab for performing collimated beam testing (CBT). Testing results are presented in Figure 12-10. The CBTs were performed on current plant secondary effluent in order to inactivate Enterococci to the permit level of 35 MPN/100mL; UV dose of 100mJ/cm^2 is estimated from the results.

The USEPA UV Design Guideline and Ten State Standards include a general guide in UV system sizing for an activated sludge effluent: “a UV dose not less than 30 mJ/cm^2 may be used.” Based on the site specific disinfection limits in terms of the indicating organism and associated numerical number, for the purpose of this TM, the minimum delivered UV dose of 100 mJ/cm^2 will be used under the condition of no upstream process upgrade; and 40 mJ/cm^2 will be used as criteria for the UV system design if upstream process upgrade is implemented. The designs will be adjusted if future collimated beam testing results, when available, show significant deviations from the estimated UV dose.

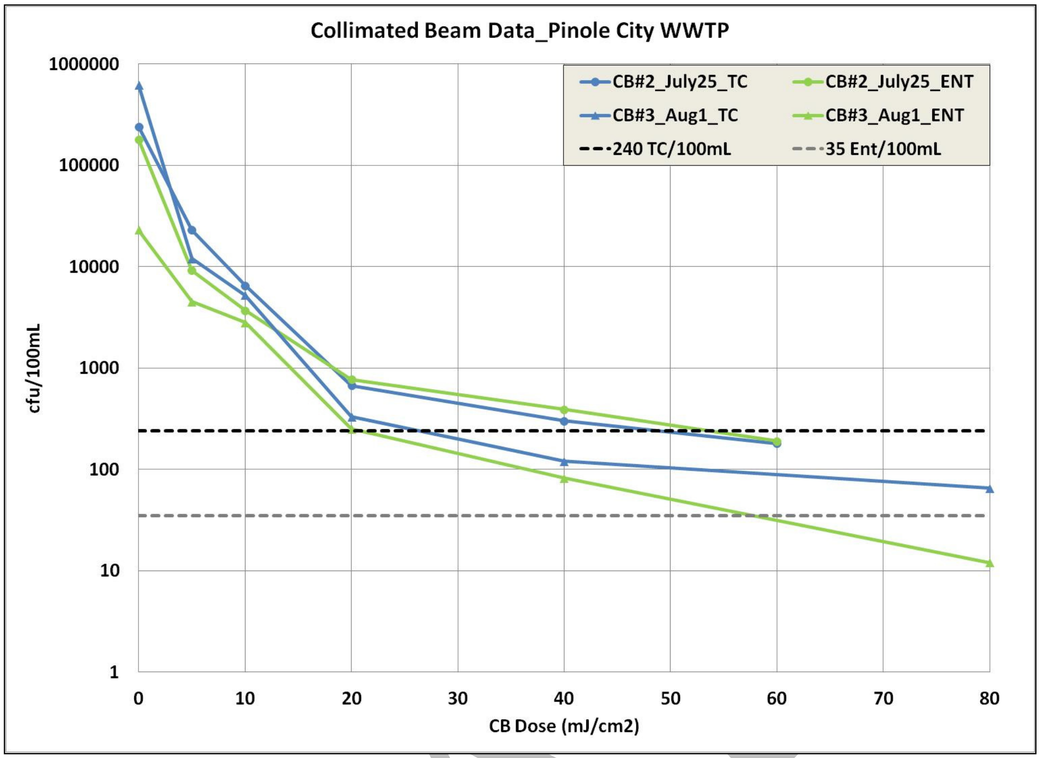


Figure 12-10. UV Collimated Beam Test Results

UV Transmittance

The recommended minimum design UVT is 55-percent according to typical design standards for secondary effluent in wastewater facilities. The disinfection limitation has also changed in terms of the indicating organism and associated numerical number. For the purpose of this TM, the UVT of 55-percent is used as criteria for UV system design. Higher UVT can only be achieved with secondary treatment processes upgrades. Biological treatment process upgrades such as nitrification and denitrification need to be implemented.

Other Water Quality Considerations

Other water quality considerations for the design of UV disinfection include concentration of constituents that can foul the UV lamps such as hardness, TDS and metals (iron, manganese and carbonates, etc). At high temperatures caused by the heat of lamps, metals form carbonates and sulfates that can deposit on the quartz sleeves of the lamps. These surface deposits cause the need for frequent lamp cleaning and increased maintenance effort. Iron, dyes, and aromatic organics can also absorb germicidal UV light and prevent UV light from reaching target microorganisms. There are no known significant contributions of any of those constituents-of-concern within the Pinole/Hercules sewer service area. The wastewater source to the facility is mainly domestic with a small portion of commercial wastewater.

Inside the WPCP, ferrous chloride solution (32%) is added to the headworks for odor control at rate of approximately 30 gpd. Iron is the main foulant of UV lamps, but residual iron concentration in final effluent is not available at this time. Iron is the main foulant of UV lamps. If UV disinfection is adopted at the plant, replacement of ferrous chloride with other non-iron coagulants might be required.

The hardness concentration in the plant effluent is generally under 200 mg/L as $CaCO_3$ with an average of approximately 150 mg/L as $CaCO_3$. Hardness at this level could cause more frequent lamp cleaning due to the scaling on quartz sleeves. Mitigation practices for hardness reduction might be beneficial for UV operation.

Other Design Considerations

In addition to the system design criteria, site design issues that must be considered are described below.

Project Area

In the Pinole/Hercules WPCP, the existing chlorine contact tank and chlorine addition and storage facilities are located inside the plant. If chlorination/dechlorination is to continue in the future, the existing facility would be kept with potential minor improvements. A UV system, if selected, would preferably be installed inside one of the existing chlorine contact tanks modified as necessary. Figure 12-1 shows the site location of the existing disinfection system. Open channel UV systems are typically configured as single or multiple parallel long narrow channels housing UV banks in series.

Site Conditions

There are space constraints at the WPCP. There is no room for expansion of the contact tank or a new structure for UV in the future project area. Two options are to retrofit the UV system into the existing CCT, or remove one CCT and build UV basins on the spot. UV systems typically have smaller footprints than equivalent chlorination systems. Among UV technologies, vertical lamp systems typically have smaller footprints than horizontal lamp systems. A preliminary evaluation indicates that the existing chlorine contact tanks can accommodate a 20 mgd UV system with horizontal lamp configuration, but the tanks are not deep enough to accommodate a vertical lamp system.

Hydraulics

The UV system would likely be installed in either new channels or in the existing chlorine contact tank and receive secondary effluent from the final clarifiers through a common inflow channel. A hydraulic profile of the plant including the proposed UV system was briefly examined. The water surface elevation for the proposed UV system was developed using two flow scenarios: peak flow (20 mgd) and minimum flow (1 mgd). The hydraulic profile shows that the available head between the secondary clarifiers and the outfall pipe entrance invert is approximately eight (8) feet under normal discharge conditions. For the proposed UV system, the headloss through the entire UV system, including flow control mechanism, UV equipment and level control mechanism, is typically less than three (3) feet under the peak flow condition. Therefore, hydraulic constraints in the plant would not preclude the use of a UV system designed for gravity flow. This will be modeled as part of early design task to set elevations.

Coagulation Flocculation

As discussed previously, the TSS concentration in the secondary effluent has a significant impact on downstream disinfection processes. An efficient and proven cost-effective way to reduce the suspended solids is to employ a coagulation flocculation process. The WPCP is currently practicing coagulation flocculation at the secondary clarifiers with addition of polymer to all five (5) clarifiers on a continuous basis during high flow season. Polymer addition is not used during the summer months when flows are down. It has been observed that using the polymer greatly reduces the amount of solids carryover during high flow periods and process upsets.

The coagulation flocculation system consists of metering pumps, polymer storage tank(s) with rapid mixing mechanisms. During plant operation, polymer is injected immediately upstream of the final clarifiers where the highest flow turbulence occurs.

Standby Power

Continuous power supply is essential for reliable disinfection system operation. Currently, standby power is available on site with two 800 kW generators. If a UV system was installed, the standby power supply would need to be connected to the UV system. An electrical load study needs to be completed to determine whether the main power feed and the standby power are sufficient to support UV system power requirements. In case of a main feed line power outage, the standby generator must be able to supply power in a timely manner to prevent the discharge of un-disinfected effluent to the outfall.

Other Chlorine Uses

Chlorine has been added to RAS for filamentous control and a settling aid. Filamentous control is a year round practice. Even if a UV disinfection system is installed to replace the existing chlorination system for effluent disinfection, a small chlorination system would be needed on site for filamentous control and possibly foaming control in future operation.

A portable size hypochlorite storage and feed system is recommended for this purpose. Typically the system consists of a tote (i.e. 300 gallons) with self-containment and a metering pump.

Summary of Design Criteria

Design criteria used as the basis for a disinfection system at the Pinole/Hercules WPCP are summarized in Table 12-3. These design criteria will serve as the basis for equipment sizing, layouts and price quotes provided by various equipment suppliers. The design criteria may be updated when future testing results become available.

Disinfection systems are sized to handle peak hydraulic flow of 20 mgd. Operation and maintenance (O&M) costs for all design alternatives are calculated based on an average annual design flow of 4.6 mgd.

Table 12-3. Disinfection Design Criteria

Description	Units	Design Criteria	
Peak design flow	mgd	20	
Average design flow	mgd	4.6	
Minimum design flow	mgd	1.0	
Enterococcus	MPN/100mL, Monthly Maximum	not exceed 35	
Total Coliform	MPN/100mL, In at lest five (5) samples collated within a calendar month	not exceed 240	
	MPN/100mL, Any single sample	not exceed 10,000	
Secondary effluent suspended solids	mg/L	Less than 45	
Secondary effluent average particle size	microns	N/A	
Secondary effluent BOD5	mg/L	Less than 40	
Effluent temperature	min/max. °F	40/75	
Chlorination and Dechlorination Design Criteria			
		Without Upstream Process Upgrade	With Upstream Process Upgrade
Chlorine residual	mg/L Instantaneous maximum	Less than 0.0	
Contact Time(1)	minutes, minimum	15	
Chlorine dose (average)	mg/L	25	15
CT*	mg-min/L	300	75
UV Design Criteria			
		Without Upstream Process Upgrade	With Upstream Process Upgrade
UV dose (at the end of lamp life time)	μW-s/cm^2 @peak flow Minimum	100,00	40,000
UVT	Percent at 254nm Minimum	55	65
End of lamp life factor	(technology dependent)	0.5	
Quartz Sleeve Fouling Factor	(technology dependent)	0.8	

BOD = biochemical oxygen demand
CT = Chlorine residual concentration x contact time
UVT = UV transmittance
(1) under peak flow condition

Alternative Evaluation Methodology

This section presents the evaluation of alternatives for the disinfection system. The evaluation process included the following basic steps:

- Summarize the existing and future limitations of the individual process units and identify process improvements or expansion that will be required within the next ten to twenty years.
- List reasonable alternatives for detailed evaluation.
- Identify criteria to be used for evaluation.
- Develop alternatives in sufficient detail to permit a reasoned evaluation of their advantages and disadvantages.
- Develop capital and 20-year life cycle costs for reasonable alternatives.
- Identify a recommended plan.

Evaluation Process

Alternatives were identified and evaluated through an interactive process involving the City and WPCP staff and HDR. Major elements of the process are described below.

Define Process Methodology and Evaluation Criteria

To provide a consistent design basis, HDR and WPCP staff developed an evaluation methodology for the disinfection facilities. This process defined evaluation criteria outlined the decision-making process, and prescribed cost estimating procedures. The evaluation criteria are listed in Table 12-4. The evaluation criteria are divided into two major categories: non-economic criteria which will be evaluated using weighting factors developed with input from the WPCP staff and engineers; and economic criteria which include the 20-year net present worth costs.

Table 12-4. Evaluation Criteria

Non-Economic Criteria	Weighting
Regulatory Compliance	
Meets current and future NPDES requirements	10
Regulatory burden/relief (e.g. RMP, hazardous chemical transport, storage and handling)	8
Operation Considerations	
Ease of automation	6
Maintenance requirements	8
Safety for workers	10
Easy to contain	7
Staffing requirement	5
Implementation Criteria	
Expandability	8
Ease of construction	7
Impact on operation during construction	6
Permit/approval requirements	7
Compatible with existing facilities	
Space requirements	5
Upgradeability	5
Technology	6
Reliability	9
Safe/low use of hazardous chemicals	9
Proven performance	9
Complexity	6
Longevity	7
Community/Environmental Considerations	
Neighborhood acceptability	9
Air quality impacts (odor potential)	9
Noise potential	7
Vector potential	6
Traffic	6
Public safety	9
Security	5
Risk (potential for practice to fail due to changes in future regulations, public perception or land use)	9
Economic Criteria	
Construction Cost	
Operation and Maintenance Cost	
Life Cycle Cost	

The non-economic criteria will be reviewed with WPCP staff. Weighting factor opinions will be collected from the managers, engineers and plant operation team. Weighting factors on a scale from 1 to 10 will be assigned to each evaluation criterion so that a criterion given a weighting factor of 8 would be considered to be twice as important as one given a weighting factor of 4. Alternatives would then be assigned a score between 1 and 4 (with 4 being optimal) for each evaluation criterion. To obtain the final weighted score for each alternative, the score for the evaluation criteria would be multiplied by the weighting factors and then summed. The alternative with the highest sum is considered most favorable.

Brainstorm and Screen Ideas

Early discussions occurred to identify any and all potential alternatives for expanding or improving the WPCP's disinfection facility. Following the initial brainstorm session, an initial screening step was conducted to eliminate ideas that were fatally flawed, technically unproven, excessively expensive, or otherwise unworthy of detailed evaluation.

Technology Tour

A tour may be taken with participation of operation staff and HDR design engineers. The visiting installations will include major UV technologies applicable to wastewater disinfection. Operation and maintenance experiences will be learned first hand from the personnel who have been operating those UV systems for years.

Detailed Development and Evaluation

Alternatives surviving the initial screening step were developed in detail. Facility sizing and cost estimates were conducted for a system capacity of 20 mgd. Alternatives were compared based on cost (economic criteria) and non-economic criteria. Based on this analysis, preliminary recommendations for facility improvements were made.

Review Workshops

During the development process, monthly meetings were conducted with WPCP management and wastewater operations staff to review interim findings and refine the alternatives being evaluated. The meetings presented information on the evaluation process and input regarding the technical issues being considered and the planning process used was compiled.

Decision Workshop

Based on the results of the evaluation process, and incorporating the comments received during the monthly meetings, the project team developed final alternatives and recommendations for consideration by the WPCP staff review group. Future meetings will be held to select the elements of the recommended project. This will be followed with a pre-design meeting focused on layout and construction issues.

Driving Forces

Improvements to the WPCP disinfection system are needed to provide reliable disinfection capacity, to comply with more stringent regulatory requirements, and to improve operational safety for the workers. The key driving forces behind the needed improvements are summarized below.

Permit Revisions

The WPCP chlorination disinfection system uses bulk purchased hypochlorite. The current permit requirements for disinfection only require the WPCP to meet a total coliform count of no greater than 240 MPN/100mL. The tentative permit, effective as of October 1, 2012, contains modified future permit limits to require a monthly geometric mean Enterococcus count of no greater than 35 MPN/100mL. Chlorine residual limit remains to be 0.0 mg/L. Studies have demonstrated that higher chlorine dosage and higher UV dosage are required to inactivate Enterococcus to the regulatory level. Recent testing on the WPCP secondary effluent has shown the UV dose as high as 80 mJ/cm^2 barely gets Enterococci down to 35 MPN/100mL. Given this more stringent regulatory change, the WPCP is required to upgrade their existing disinfection facilities, i.e. provide longer contact time, more disinfectant usage, and/or provide alternative disinfection process.

Safety Concerns

Currently the plant is using high concentration sodium hypochlorite for its effluent disinfection. There is a safety concern regarding the transport, storage and handling of sodium hypochlorite. The potential for an accidental release remains as long as the chemical is stored and handled on site.

Space Limitation

The future projected flow and new regulatory disinfection limits mandate improvements to the existing chlorination system, particularly expansion of the existing chlorine contact tank. Space for expansion is limited on site. The WPCP is located along the bayside and boxed in with Bayfront Park, Pacific Railroad, and a creek around the plant. Any process expansion has to fit within the existing plant property.

Cost Evaluation of Alternatives

Construction costs are estimated on a planning level and expressed in 2013 dollars. The accuracy of all costs is order of magnitude. These estimates are approximations made without detailed engineering or site-specific data. Estimates of this type can be expected to vary from 50 percent less than to 30 percent more than actual final project costs.

The sources of construction cost data are:

- Construction cost data for the recent Bay area projects and the recent HDR California WWTP projects, adjusted to 2013 dollars.

- Recent construction costs for other, similar facilities, adjusted to regional market conditions and 2013 dollars.
- Equipment pricing from manufacturers, including installation, delivering, and on site storage costs.

All construction cost estimates include allowances for site work and yard piping; contractor mark-up; and contingencies. Engineering, legal and administration costs are not included at this time. The cost estimating procedure is presented in Table 12-5.

Table 12-5. Cost Estimating Procedure

CSI Division	Markup
Division 1 - General Requirements	5 percent
Division 2 - Site Work	
Division 3 - Concrete	
Division 5 - Metals	
Division 6 - Wood and Plastics	
Division 10 - Specialties	
Division 11 - Equipment	
Division 13 - Special Construction	
Division 14 - Conveying Systems	
Division 15 - Mechanical	
Division 16 - Electrical	20 percent
Subtotal	
Contingency	20 percent
Total Estimated Construction Cost	

For most treatment processes, the economic comparison of alternatives is strongly driven by construction costs. Consequently, O&M costs were developed only where there was a substantial difference in O&M requirements between the alternatives. For disinfection process in particular, the O&M cost consists of chemical purchasing, which in this case, consists of annual chlorine and bisulfite costs. The cost of chlorine has increased rapidly in the past five years. The trend of increasing this period has been on average 20 percent annually based on a recent white paper released by the Water Environment Research Foundation (WERF 2008). This rate of increasing chemical cost was incorporated into the 20-year net present worth cost analysis. Net present worth costs are calculated using a 6-percent discount rate and 20 years of operation.

Alternative Prescreening

The scope of work of the disinfection project includes a preliminary screening of the disinfection alternatives considered for this project and evaluating advantages and disadvantages of each alternative. The screening review is used to establish which alternative should be retained for further evaluation, and which should be eliminated from consideration beyond the prescreening.

The disinfection alternatives considered for evaluation include:

- Alternative 1 - No Action.
- Alternative 2 - Chlorination Expansion.
- Alternative 3 - UV Disinfection.
- Alternative 4 - Ozone.

Alternative - No Action

The no action alternative is to keep the existing chlorination and dechlorination system and continue performing effluent disinfection with bulk purchased sodium hypochlorite and using the existing chlorine contact tanks.

The primary advantage of continued use of the existing chlorination and dechlorination system is that the facilities already exist and the process is well understood by treatment plant personnel. The equipment for dosing and controlling the process is readily available. There is a safety concern regarding the storage and use of the concentrated chlorine. The key issue is the size of the existing chlorine contact tank, which has limited volume of 50,000 gallons and provides less than 3 minutes of contact time at the projected peak flow of 20 mgd assuming 80 percent of basin efficiency. Using CT approach as discussed previously, with this short contact time, significant increase of the hypochlorite dosage and subsequently bisulfite dosage are expected.

Advantages and disadvantages of using hypochlorite are listed in Table 12-6.

Table 12-6. Advantage and Disadvantages of Gaseous Chlorination

Advantages	Disadvantages
Existing process with experienced and trained personnel	Risk of accidental release during transport
Long history of successful application in wastewater treatment	Risk of accidental release at the plant
Proven effectiveness against most pathogenic organisms	Increasing chemical cost
Provides measureable residual	Generates disinfection by-products
Ready available chemicals	Impacts environment if dechlorination is incomplete
	Significant increasing chemical usages

No Action is a viable alterative for the following reasons:

- Chemical purchase process is in place and the operations crew is familiar with the existing hypochlorination practice.
- CT can be used to compensate for short contact time at peak flow. The existing chlorine contact tank cannot provide minimum 15 minutes contact time under peak flow conditions with the current tank volume. Under peak flow condition, which is typically in a short time period, the disinfection requirement can be met with the effective CT value by increasing chlorine dosage.
- No additional space needed for contact basin expansion. Space constraint is the major obstacle for contact basin expansion. No readily available space around existing contact tank for expansion.

Alternative 2 - Chlorination Expansion

The alternative is to keep the existing chlorination and dechlorination system. Plant effluent will be disinfected with sodium hypochlorite and dechlorinated with sodium bisulfite to comply with the discharge permit requirement for chlorine residual.

In the previous No Action Alternative, the advantages and disadvantages of continuously using chlorination were presented. To have 15 minutes minimum contact time would require expansion of the chlorine contact tank at a minimum.

A cost advantage associated with this alternative would not be expected due to the significant expansion of the contact tank. This alternative might be viable and will be further evaluated for the following reasons:

- Expansion of the chlorine contact tank is required to provide at least 15 minutes of contact time under peak flow condition. Expansion of the total contact volume is required along with improvements to assure plug flow conditions. Relocation and installation of chemical feed system(s) are also required.
- Sodium hypochlorite and sodium bisulfite are classified as a hazardous materials. The risk remains for the public and plant personnel who are involved in transporting, storing and handling highly corrosive chemicals.
- Cost of chemicals is increasing making O&M costs a large budget issue.
- Additional volume and footprint are expected to be significantly larger than the existing contact tanks. Site space might not be available for the expansion.
- Chlorination poses a problem associated with generation of the disinfection by-products. Although the chlorination by-products are not regulated with the current permit, the regulatory trend is that the by-products such as trihalomethanes (THMs) and haloacetic acids (HAA5) limitations will be regulated in the future by USEPA for all surface water discharges nationwide.

The evaluation of this alternative includes expansion of the chlorine contact tank. Advantages and disadvantages of using liquid sodium hypochlorite and sodium bisulfite are listed in Table 12-7.

Table 12-7. Advantage and Disadvantages of Chlorination Improvement

Advantages	Disadvantages
Long history of successful application in wastewater treatment	Increasing chemical cost
Proven effectiveness against most pathogenic organisms	Risk of accidental spill during transportation
Existing process with experienced and trained personnel	Impact to environment if dechlorination is incomplete
Not expected to impact the plants overall electrical load	Generation of disinfection by-products
Provides measureable residual material	Generation of additional TDS

NaOCl - sodium hypochlorite
TDS - total dissolved solids

At the facility’s design flows and typical chlorine dose for secondary effluent, disinfection would require average and peak chlorine usages of approximately 1,000 pounds per day and 4,200 pounds per day, respectively. Currently, the bulk hypochlorite cost in the area is about \$1.0 per pound chlorine. The price of sodium hypochlorite is also rising fast; the price is anticipated to increase approximately 20 percent a year. The chemical cost increase will be taken into consideration in the life cycle cost analysis later in the TM.

Alternative 3 - UV Disinfection

UV disinfection technologies have been used routinely in wastewater treatment, reclaimed water, and other industrial and commercial disinfection applications. With UV disinfection, specific electromagnetic wavelengths are used to inactivate microorganisms through denaturing of their DNA. Wavelengths ranging from 250 to 270 nm are readily absorbed, effectively inactivating pathogens found in municipal wastewater by rendering them unable to replicate. The dose of UV light is measured as the product of intensity and exposure time, as milliwatt-seconds per square centimeter (mW-s/cm^2). Typical design doses for activated sludge secondary effluent are in the range of 30 to 50 mW-s/cm^2, which should be verified during pre-design through bench or pilot scale testing.

UV disinfection systems are more compact compared to chlorine contact tanks. UV disinfection is a pure physical process. UV systems do not require any chemicals for disinfection and do not produce any known hazardous by-products.

Testing prior to design is important, since the UV design dose is highly dependent on influent water quality. By far, the most important quality parameter is UV transmittance (UVT). UVT is a measure of how much UV light at a specific wavelength is absorbed by the effluent. Suspended solids can shield organisms from exposure to UV, and color and organics can absorb UV energy, reducing its effectiveness as a disinfectant.

In UV systems, wastewater effluent is disinfected by flowing past arrays of UV lamps that are submerged in channels. A UV system consists of a power supply, lamps, reactor chambers, cleaning equipment, flow control, and controls and instrumentation. In wastewater applications, open channel UV systems are commonly used.

The major O&M cost of a UV system is its power consumption. The average power cost in the Pinole/Hercules area is $0.15 to $0.17 per kWh, which is higher than the national average.

Advantages and disadvantages of using UV disinfection are listed in Table 12-8.

Table 12-8. Advantages and Disadvantages of UV Disinfection

Advantages	Disadvantages
No toxic by-products of disinfection	Higher power consumption
Chlorination improvement	Requires O&M training
No in-stream chemicals required for disinfection or dechlorination	May still need small chlorine system for Nocardia, filamentous, RAS, and non-potable service water chlorination
Many existing full-scale facilities in operation	System requires cleaning and routine checking
Less space required	

Alternative 4 - Ozone

Ozone (O3) is a very strong oxidant and virucide. Ozone is generated when oxygen molecules are disassociated into oxygen atoms by a high voltage current. The oxygen atoms collide with oxygen molecules to form unstable gas ozone. Water and wastewater treatment plants generate ozone onsite because it is unstable and decomposes to elemental oxygen shortly after generation.

When ozone decomposes in water, the hydrogen peroxide and hydroxyl radicals that are formed have great oxidizing capacity and play an active role in the disinfection process. Mechanism of pathogen destruction by ozone includes cell lysis, direct destruction of cell wall, reactions with radical by-products of ozone decomposition, damage to constituents of nucleic acids, and depolymerizaton by breaking carbon-nitrogen bonds.

The effectiveness of ozone is dependent on the dosage, time of exposure, and the resistance of pathogens. Key components of an ozone system include ozone generators, ozone transfer system (e.g. nozzles or diffusers), contact tanks and an ozone destruct system. Disinfection byproduct formation of bromate with ozone disinfection is a concern in waters containing bromide, however, bromate is currently only regulated for drinking water systems.

The dose required for disinfection using ozone is not known for the WPCP effluent. Bench testing and/or pilot studies would be required to determine demand and viability of ozone disinfection. Typically, secondary effluent without filtration requires ozone doses between 4 and 8 mg/L to achieve an effluent total coliform limit of 240 MPN/100mL. This high dose would require ozone generation equipment of such magnitude that ozone is likely not an economic alternative for the WPCP unless other effluent limitations, such as endocrine disrupters or pharmaceutical/personal care products, become a concern. Ozone would have higher power costs and capital costs than a UV system and increased safety risks associated with pure oxygen generation type equipment.

Pre-screening Recommendation

Based on the discussion of available disinfection alternatives in this section, two out of four general alternatives are considered as viable options in terms of their applicability, reliability, and facility experiences. The prescreening results are summarized in Table 12-9.

Table 12-9. Result of Alternative Pre-screening

Alternative	Pre-screening Result
No action alternative	Regulatory acceptable and implementation feasible; carry forward to detailed alternative analysis
Expand existing bulk purchased hypochlorite and bisulfite	Regulatory acceptable and implementation feasible; carry forward to detailed alternative analysis
UV disinfection	Regulatory acceptable and implementation feasible; carry forward to detailed alternative analysis
Ozone	Higher costs and risks, not recommended

Keeping the existing chlorination and dechlorination system requires either more chemical usage or significant expansion of the chlorine contact tank(s). The increasing chemical cost might make the chlorine options cost prohibitive in the long term. A 20-year net present worth cost analysis is provided in the following sections to compare the viable alternatives in terms of long-term cost.

UV is a “Green” disinfection alternative among all options. The amount of equipment installation could pose high initial cost. As discussed previously, the O&M cost is mainly from power consumption, likely comparable to the chlorination due to the increasing chemical costs. A 20-year net present worth cost analysis is provided in the later sections to show the long-term cost impact of implementing UV.

The detailed system evaluation and design criteria including system sizing and optional layouts will be developed during the predesign phase of the project.

Recommended Alternative Evaluation

This section contains evaluation and comparison of chlorination and the UV technology applicable to wastewater disinfection at the Pinole/Hercules WPCP. Four (4) alternative designs are presented in this section, along with a life cycle cost comparison for the design alternatives. At the end of the section, a recommendation is provided based on the non-economic impacts and cost effectiveness of the design.

Chlorination System

The design of improvements of the chlorination system using bulk purchased hypochlorite and bisulfite is based on the design criteria summarized in Section 2 of this TM.

Design Features

Continued use of chlorination would require either of the following scenarios:

- Scenario 1 – Without contact basin expansion. As discussed previously in this TM, the existing chlorine contact tank volume can only allow 3 minutes contact time under peak flow conditions. Under peak flow condition, which is typically in a short time period, the disinfection requirement can be met with the effective CT value by increasing chlorine dosage. CT approach can be used under peak flow condition to meet the disinfection requirements.
- Scenario 2 – With contact basin expansion. As discussed previously in this TM, the existing contact tank could provide 3 minutes of effective contact time for the design flow of 20 mgd. In order to meet the minimum 15 minute contact time the additional volume is estimated to be approximately 228,000 gallons or 30,500 cubic feet. The expanded contact tank would provide 15 minutes effective contact time assuming the basin efficiency is 75-percent, for a maximum flow of 20 mgd.

The existing chemical storage and delivery facilities will remain in use, but might be relocated to accommodate other plant process upgrades. The chemical feed system will also remain in use. For a more efficient use of chlorine, vacuum type induction units will be used to replace the existing perforated pipes. Based on the design criteria, a dosage of 25 mg/L as chlorine for sodium hypochlorite and 40 mg/L as sulfur dioxide for sodium bisulfite is assumed. These dosages are close to the current practice at the plant. The chlorine and sulfite residual analyzers might be relocated due to the demolishing of the Maintenance Shop Building where analyzers are currently located.

For the purpose of this TM, a 12.5 percent concentration of sodium hypochlorite (1 lb chlorine per gallon) and 25-percent concentration of sodium bisulfite (2.5 lb sulfur dioxide per gallon) are assumed.

The features of the improved chlorination and dechlorination system are summarized in Table 12-10.

Table 12-10. Chlorination System Design Features

Feature	Chlorination/Dechlorination System	
	Scenario 1- without contact basin expansion	Scenario 2- with contact basin expansion
Storage tank (hypochlorite)	2 tanks; 6,000- gallon each (relocate existing)	2 tanks; 6,000- gallon each (relocate existing)
Storage tank (bisulfite)	2 tanks; 2,500- gallon each (relocate existing)	2 tanks; 2,500- gallon each (relocate existing)
Induction unit	2 (new)	2 (new)
Chlorine residual analyzer	2 (new; 1 for compliance; 1 for feed control)	2 (new; 1 for compliance; 1 for feed control)
Distribution piping (double contained), additional	150 feet (new)	150 feet (new)
Bisulfite analyzer	1 (new; for feed control)	1 (new; for feed control)
Distribution piping (double contained; heat tracing), additional	100 feet (new)	100 feet (new)
Additional Chlorine Contact Tank Volume	0 gallons	228,000 gallons
New Chlorine Contact Tank Dimension	n/a	L 105 ' x W 70' x side water depth 7.5'

Estimated Construction and O&M Costs

The estimated construction cost of a hypochlorite and bisulfite system is approximately $0.92 million for Scenario 1 (without additional CCT) and $1.57 million for Scenario 2 with CCT expansion. A summary of costs is presented in Appendix A. Table 12-11 and Table 12-12 summarize the estimated O&M cost of the chlorination system under different upstream treatment scenarios: Without BNR and with BNR.

Table 12-11. Estimated Annual O&M Cost of Chlorination System (without BNR)

Design Criteria	Quantity	Unit	Unit Cost ($)	Annual Cost ($)
Annual Operating Days	365	days		
Average Flow	4.6	mgd		
Hypochlorite Dosage	25	mg/L		
Bisulfite Dosage	40	mg/L		
Chemicals				
Sodium Hypochlorite	959	gallon/day	$1.000	$350,000
Sodium Bisulfite	619	gallon/day	$1.000	$226,000
Power Consumption	15	kWh/day	$0.150	$800
Supplies and Materials	1	unit	$12,500	$15,000
Supervision and Labor	0.5	FTE	$75,000	$38,000
Testing	1	ea	$12,000	$12,000
Other expenses such as chemical delivery and offloading	1	unit	$5,000	$5,000
			Total Annual O&M Cost	**$646,800**

Table 12-12. Estimated Annual O&M Cost of Chlorination System (with BNR)

Design Criteria	Quantity	Unit	Unit Cost ($)	Annual Cost ($)
Annual Operating Days	365	days		
Average Flow	4.6	mgd		
Hypochlorite Dosage	15	mg/L		
Bisulfite Dosage	8	mg/L		
Chemicals				
Sodium Hypochlorite	575	gallon/day	$1.000	$210,000
Sodium Bisulfite	124	gallon/day	$1.000	$45,000
Power Consumption	15	kWh/day	$0.150	$800
Supplies and Materials	1	unit	$12,500	$12,000
Supervision and Labor	0.3	FTE	$75,000	$23,000
Testing	1	ea	$12,000	$12,000
Other expenses such as chemical delivery and offloading	1	unit	$5,000	$5,000
			Total Annual O&M Cost	**$307,800**

Process Conceptual Layout

The conceptual layout of the chlorination/dechlorination system is presented in Figure 12-11 and Figure 12-12.

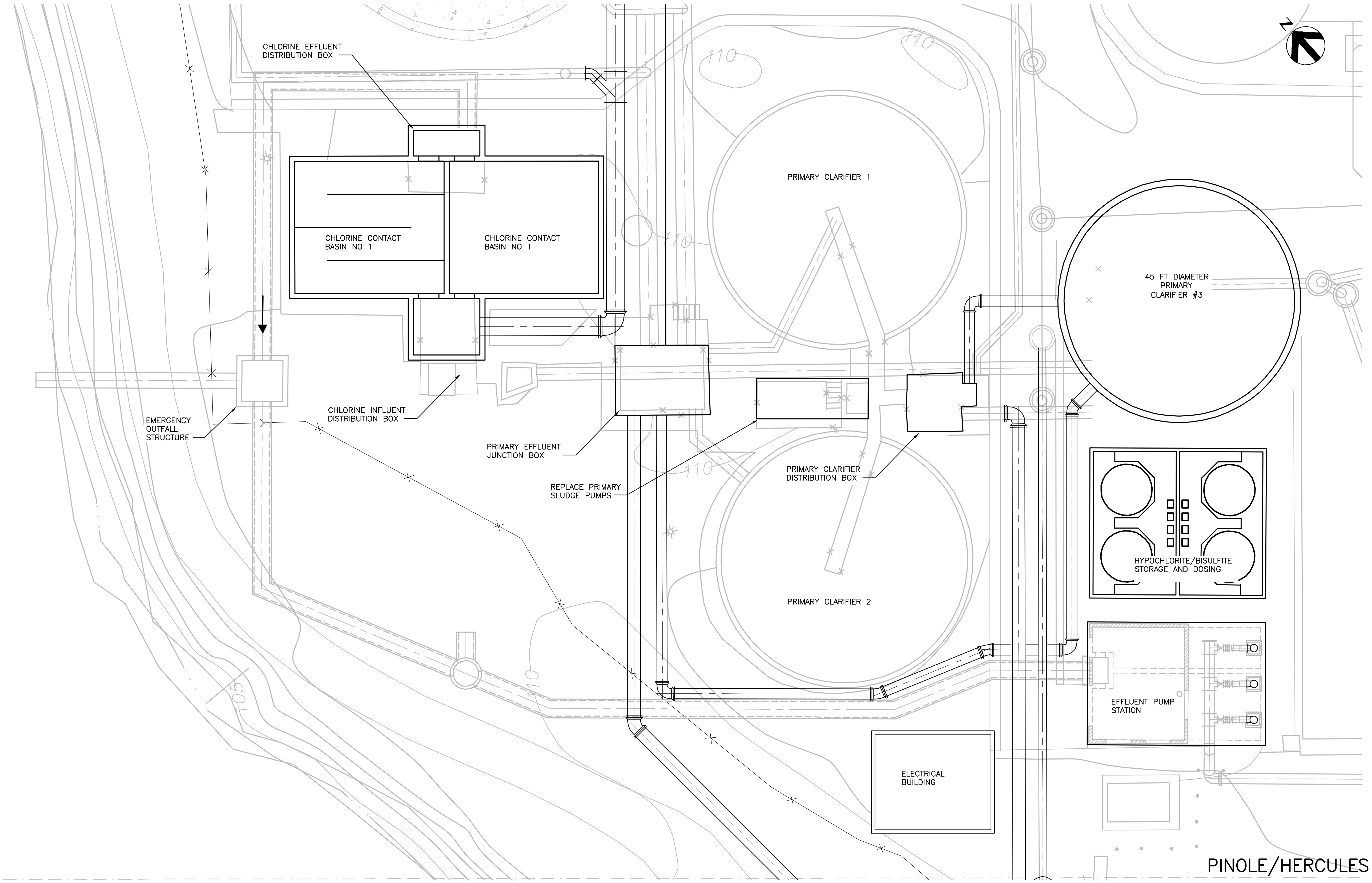
UV System

The design of the UV disinfection system is based on the design criteria summarized in Section 2 of this TM.

Design Features

UV can be applied in two basic configurations: open channel or closed vessel. Most wastewater UV is provided in an open-channel installation. Open-channel UV disinfection systems are available in three different lamp systems: low pressure/low intensity (LP/LI), low pressure/high intensity (LP/HI), and medium pressure/high intensity (MP/HI). LP/LI systems are not effective in treating wastewater with high total dissolved solids (TDS) and require a large number of lamps. MP/HI systems have a shorter operating life, lower efficiency for the conversion of energy in the germicidal range, and increased fouling due to high operating temperatures. Therefore, LP/HI systems are chosen for the preliminary evaluation of the UV system.

The UV basin would be sized based on the peak flow of 20 mgd as discussed earlier in this TM. Table 12-13 presents preliminary design features for the UV system at the Pinole/Hercules WPCP. The UV system is sized based on two treatment scenarios, different minimum UV dose and transmittance (UVT) described as follows:



PARTIAL SITE PLAN

1" = 10'

0 1" 2"

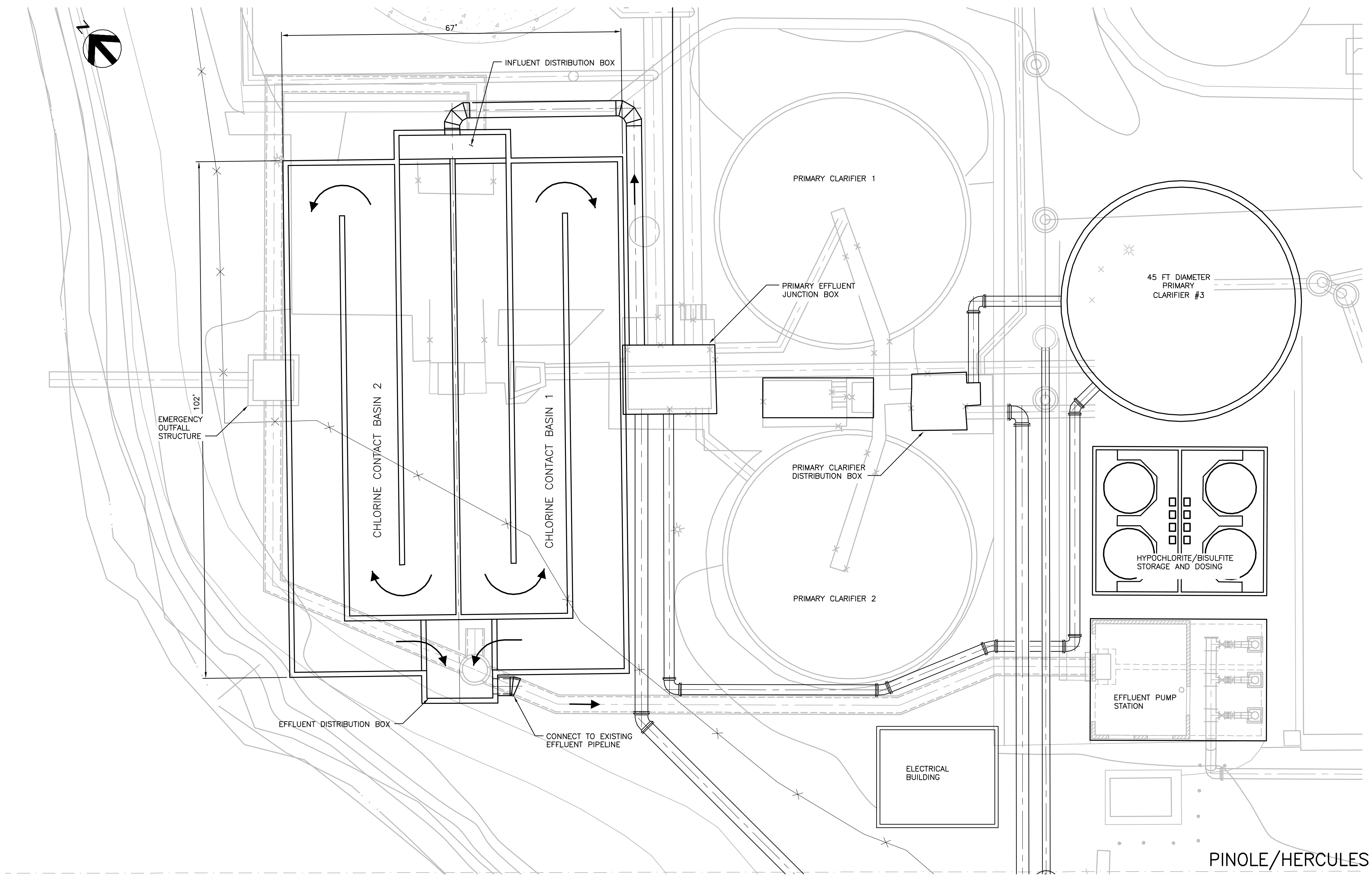
PINOLE/HERCULES WPCP PROJECT

CHLORINATION SYSTEM LAYOUT
SCENARIO 1 – WITHOUT ADDITIONAL CCT

HDR

FIGURE 12–11

C:\pwworking\sac\d0435431\Figure 12-11.dwg
03-01-13 RSNIDER 15:08:57



PARTIAL SITE PLAN
1" = 10'

0 1" 2"

PINOLE/HERCULES WPCP PROJECT

CHLORINATION SYSTEM LAYOUT
SCENARIO 2 – WITH ADDITIONAL CCT

HDR

Figure 12–12

C:\pwworking\sac\d0435431\Figure 12–12.dwg
03–01–13 RSNIDER 14:55:37

- Scenario 1 – Without upstream process upgrade to biological nutrient removal (BNR): 55% UVT, 100 mJ/cm^2 dose.
- Scenario 2 – With upstream process upgrade to biological nutrient removal (BNR); 65% UVT, 40 mJ/cm^2 dose.

Table 12-13. UV System Design Features

Features	Low Pressure High Output UV System	
	Scenario 1- Without BNR	Scenario 2- With BNR
Number of channels	2	2
Dimension of the channel	L80ft x W58in x D84in	L65ft x W29.5in x D84in
Number of banks per channel	6	3
Number of modules per bank	2	1
Total number of banks	12	6
Total number of modules	24	6
Number of lamps per module	36	36
Total number of UV lamps	864	216
Number of power distribution center	2	2
Number of system control centers	1	1
Number of level controller	2 (1 per channel)	2 (1 per channel)
Type of level controller	Trough Weir	

A redundant design for UV systems requires that the system must be capable of producing disinfected water during any component failure prior to discharge, or emergency storage must be provided to retain non-disinfected wastewater during the period of UV system failure. In the presented parallel-channel design, the redundancy would be provided by a redundant UV bank in each channel under peak flow condition. One of the two channels can be taken out of service under average flow condition. In addition, an available spare module is recommended for quick change out when needed.

Another option to meet redundancy requirements could be use of the existing chlorination system. The existing chlorination system could be retained after the UV system is installed. In case of entire UV system failure, which would be a rare case, the secondary effluent could be diverted to existing contact tank for disinfection prior to discharge. Overdosing chlorine could be done with the existing chlorination system to meet the CT for pathogen reduction requirement when contact time is not sufficient.

Estimated Construction and O&M Costs

The estimated construction cost of a UV system installed into the existing chlorine contact tank is approximately $3.86 million for Scenario 1 (without BNR) and $1.68 million for Scenario 2 (with BNR). A cost summary is provided in Appendix A. Table 12-14 and Table 12-15 list the estimated O&M cost of the UV system. O&M cost estimates are based on operating conditions provided by a manufacturer and estimates of equipment life.

Table 12-14. Estimated O&M Cost of the UV System (Scenario 1 - Without BNR)

Design Criteria	Quantity	Unit	Unit Cost ($)	Annual Cost $)
Annual Operating Hours	8,760	hours		
Peak Design Flow	20	mgd		
Average Flow	4.6	mgd		
UV dosage	100	mJ/cm^2		
Power Draw (average)	350	kW		
Power Consumption	3,066,000	kWh/yr	$0.150	$460,000
Replacement Parts				
Lamps	864	ea	$180	$156,000
Wipers	86	ea	$50	$4,000
Ballast	43	ea	$350	$15,000
Quartz sleeves	32	ea	$120	$3,800
Chemicals	1	ea	$1,500	$1,500
Testing	1	ea	$12,000	$12,000
Supervision and labor	1.5	FTE	$75,000	$113,000
Other Expenses, i.e. parts handling	1	unit	$5,000	$5,000
			Total Annual O&M Cost	**$770,300**

Table 12-15. Estimated O&M Cost of the UV System (Scenario 2-With BNR)

Design Criteria	Quantity	Unit	Unit Cost ($)	Annual Cost ($)
Annual Operating Hours	8,760	hours		
Peak Design Flow	20	mgd		
Average Flow	4.6	mgd		
UV dosage	40	mJ/cm^2		
Power Draw (average)	88	kW		
Power Consumption	770,880	kWh/yr	$0.150	$116,000
Replacement Parts				
Lamps	216	ea	$180	$39,000
Wipers	22	ea	$50	$1,100
Ballast	10	ea	$350	$3,500
Quartz sleeves	22	ea	$120	$2,600
Chemicals	1	ea	$1,500	$1,500
Testing	1	ea	$12,000	$12,000
Supervision and labor	1.2	FTE	$75,000	$90,000
Other Expenses, i.e. parts handling	1	unit	$5,000	$5,000
			Total Annual O&M Cost	**$270,700**

Process Conceptual Layout

The conceptual layout of the UV system is presented in Figure 13 and Figure 14. The UV system layouts are based on Ozonia 3X and Trojan 3000plus system configurations.

Cost Comparison

The 20-year net present worth costs of these four (4) alternatives are summarized in Table 12-16. The annual O&M costs of chlorination/dechlorination alternatives are based on the scenario that upstream BNR will be implemented. The BNR process will likely improve the effluent water quality, therefore reducing the chemical usages for effluent disinfection.

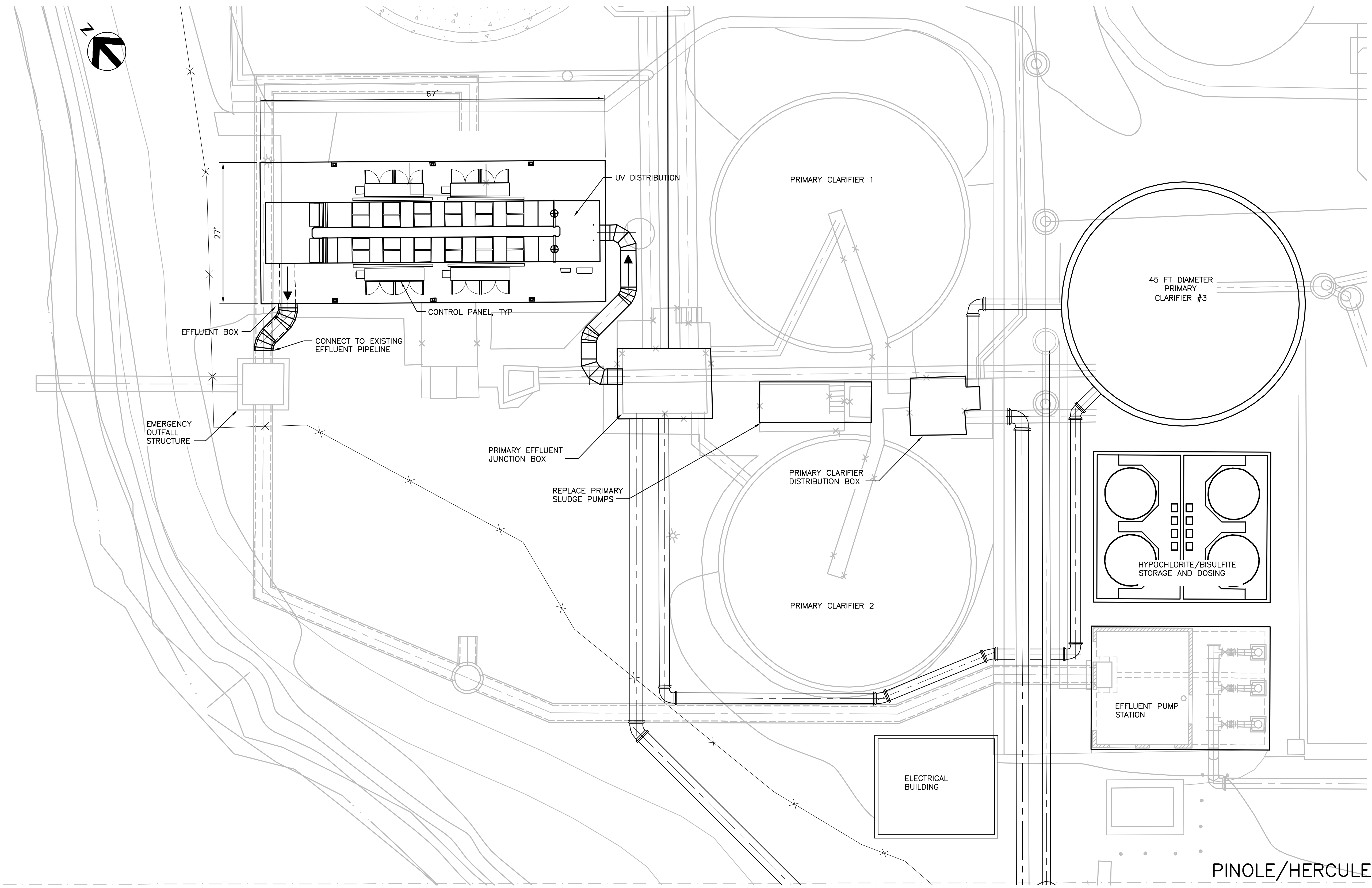
Table 12-16. 20-year Net Present Worth Cost Comparison

Disinfection Alternative	Construction Cost	Annual O&M Cost	Net Present Worth 20-year	Percentage Comparison
Chlorination/Dechlorination with NO additional CCT	$924,000	$307,800	$4,450,000	100%
Chlorination/Dechlorination with additional CCT	$1,567,000	$307,800	$5,090,000	114%
UV Disinfection (Without BNR)	$4,066,000	$770,300	$12,890,000	285%
UV Disinfection (With BNR)	$1,680,000	$270,700	$4,780,000	107%

Disinfection Alternative Recommendation

The 20-year net present worth costs have shown that the cost of chlorination/dechlorination with NO additional CCT is the lowest among all alternatives. The 20-year present worth of UV with BNR is 7-percent higher than that of the chlorination/dechlorination with NO additional CCT; but the capital cost is approximately $750,000 more than the capital cost of chlorination/dechlorination with NO additional CCT, even though the O&M cost is about $37,000 lower on annual basis. Other two alternatives cost significantly higher (greater than 10 percent) in the long term. Additional CCT will add more than a half million to the capital cost and approximately 14-percent more in a long term. UV without BNR is the most costly alternative.

The chlorination/dechlorination with NO additional CCT has the lowest construction cost and 20-year net present worth. The chlorination/dechlorination with NO additional CCT is recommended as the disinfection process for final effluent disinfection at the Pinole/Hercules WPCP. System description and preliminary design details are provided in the following sections.



PARTIAL SITE PLAN

1" = 10'

PINOLE/HERCULES WPCP PROJECT

UV SYSTEM LAYOUT

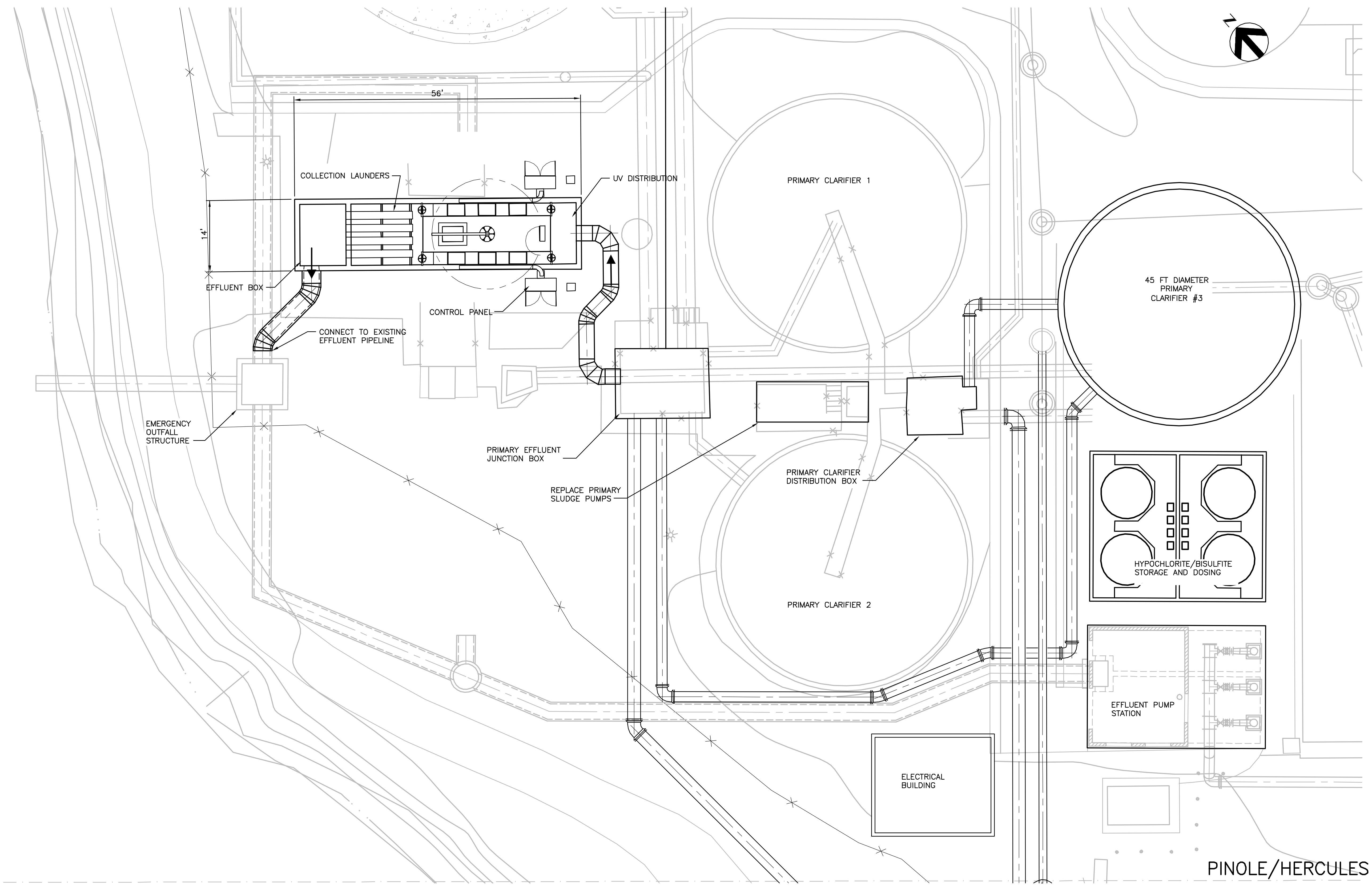
SCENARIO 1 – WITHOUT BNR

0 1" 2"

HDR

Figure 12–13

C:\pwworking\sac\d0435431\Figure 12–13.dwg
03–01–13 RSNIDER 14:38:52



PARTIAL SITE PLAN

1" = 10'

0 1" 2"

PINOLE/HERCULES WPCP PROJECT

UV SYSTEM LAYOUT
SCENARIO 2 – WITH BNR

HDR

Figure 12–14

C:\pwworking\sac\d0435431\Figure 12–14.dwg
03–01–13 RSNIDER 14:38:04

As discussed in the previous sections, disinfection by-products are of concern with chlorination disinfection. Although the by-products are not currently regulated in the Pinole/Hercules WPCP discharge permit, the EPA is promulgating nationwide limitations on those identified chlorination by-products such as THMs and haloacetic acids (HAA5). Facilities practicing chlorination would always face the potential of regulatory changes. When the chlorination byproducts become a major concern in the future, UV disinfection should be considered as a viable alternative for disinfection at Pinole/Hercules WPCP. A UV system with disinfection capacity of 20 mgd can be retrofitted into the existing chlorine contact tank.

Recommended Project

The Pinole/Hercules WPCP secondary effluent will be disinfected by chlorination using sodium hypochlorite, followed by dechlorination using sodium bisulfite. As a part of the plant upgrade, the disinfection system modification will entail the following major components:

- For hypochlorite induction, the existing diffusers will be replaced with two (2) rapid mixing induction units.
- For chemical storage, the existing two (2) hypochlorite tanks and two (2) bisulfite tanks will be relocated to the new disinfection facility.
- For chemical feed, two (2) chemical metering pump skids will be installed, one (1) for hypochlorite feed and one (1) for bisulfite feed.
- For residual monitoring, the existing analyzers will be relocated.

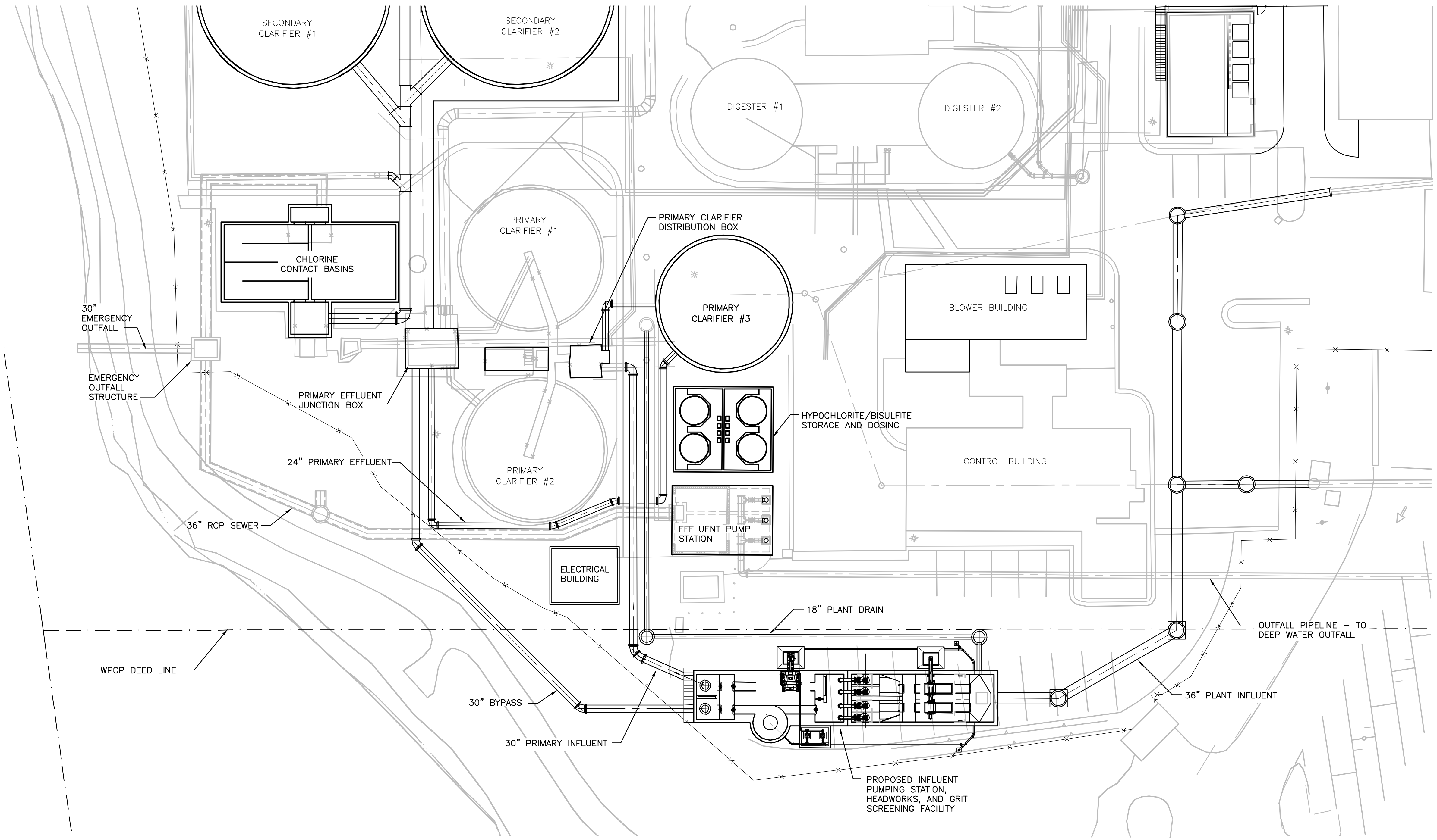
Figure 12-15 shows the location of the new chlorination/dechlorination facility. The existing Maintenance Shop will be demolished. The new facility will fit into the area along with a new primary clarifier on the north side. The existing CCT will be retained in operation without any volume expansion. Minor modifications will be required for installation of the induction units at the entrance side of the CCT.

Facility Description

Figure 12-16 shows the general layout of the new chlorination/dechlorination facility. The new facility will include separated containments for hypochlorite and bisulfite with common wall construction and the entire containment area will be covered under a pre-engineered metal canopy. Both the hypochlorite system and bisulfite system will consist of storage tanks, metering pumps, piping, valves, instrumentation and controls, and miscellaneous components.

Storage Tanks

The two (2) existing hypochlorite tanks will be relocated to the new chlorination/dechlorination facility inside the hypochlorite containment; and the two (2) existing bisulfite tanks will be relocated into the bisulfite containment in the new facility. During the relocation, hypochlorite and bisulfite can be supplied with temporary totes.



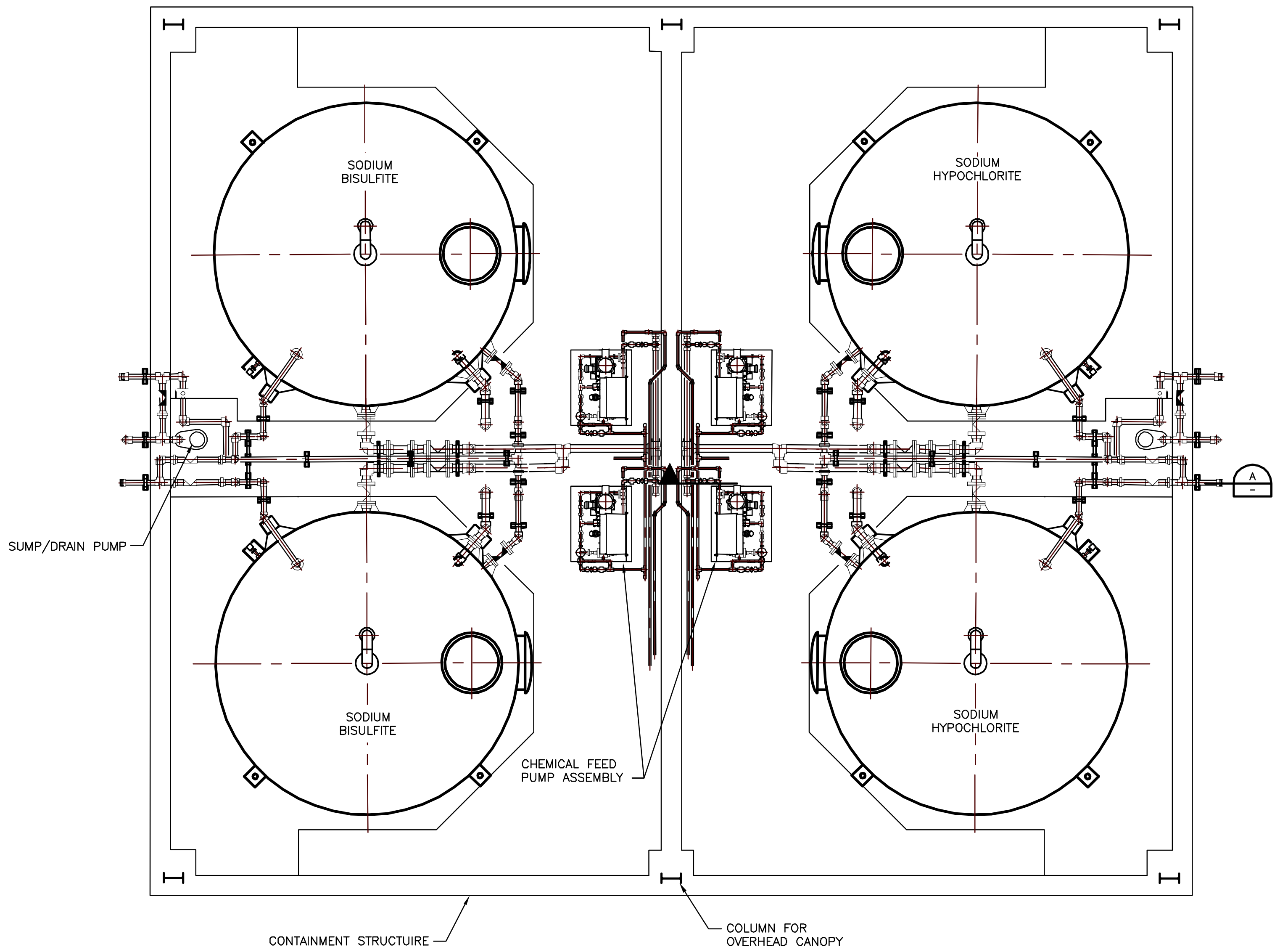
C:\pwworking\sac\d0435431\Figure 12–15.dwg
03–01–13 RSNIDER 16:17:08

PINOLE/HERCULES WPCP PROJECT

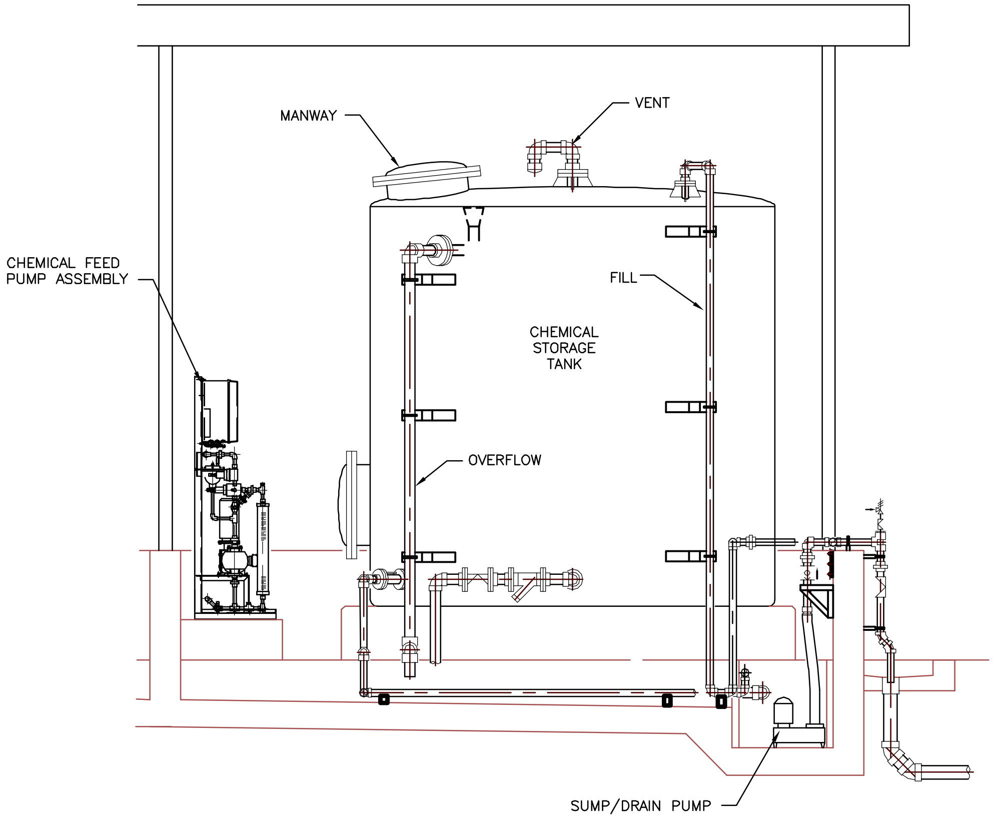
CHLORINATION/DECHLORINATION FACILITY
SITE PLAN

0 1" 2"

Figure 12–15



PLAN
NTS



SECTION
NTS

A
–

PINOLE/HERCULES WPCP PROJECT

CHLORINATION/DECHLORINATION FACILITY
TYPICAL LAYOUT

0 1" 2"

HDR

Figure 12–16

C:\pwworking\sac\d0435431\Figure 12–16.dwg
03–04–13 RSNIDER 10:43:44

Metering Pumps

Two metering pump skids will be installed in the new facility, one (1) for hypochlorite feed and the other for bisulfite feed. Each pump skid will include metering pumps, calibration columns, back pressure valves, chemical flow meters and miscellaneous piping and valves. One (1) duty and one (1) standby metering pump will be provided in each skid. The chlorination pump skid will be used to deliver 12.5-percent sodium hypochlorite solution with an operating capacity between 0 to 200 GPH. The dechlorination pump skid will be used to deliver 25-percent sodium bisulfite solution with an operating capacity between 0 to 60 GPH. The turndown ratio is needed to meet the wide range of dosage rates.

Piping and Valving

System piping will be chemical-resistant PVC or CPVC. Piping in the containment areas will be single-wall. Pipe that is extended to the feed point or that is buried will be double-wall to ensure no leakage of chemical. The double containment piping between the metering pump and induction unit likely consist of PVC, wire-reinforced, carrier tubing run within a 6-inch PVC containment pipe. Two carrier tubes will be run in each pipe, with one serving as a spare. Long radius elbows will be used to allow the piping to be removed if needed.

Various sizes of piping will be used throughout the system ranging from small connections at the metering pumps up to 3-inch to 4-inch diameter pipes for fill, vent, overflow and containment lines.

Valves will be designed and constructed for chemical resistance to the pumped fluids for all parts of the valves contacting the pumped fluids. Valves will also include provisions to vent off-gases to prevent gas buildup and pumping malfunctions.

Induction and Mixing

It is proposed to replace the existing hypochlorite diffuser with two (2) induction units, one (1) duty and one (1) standby. This replacement will allow for rapid mixing of sodium hypochlorite feed with the plant effluent prior to entering CCT.

Cover

A pre-engineered metal canopy shall be provided to protect the chemical tanks from rain and UV rays while allowing air movement for cooling.

Containment and Drains

Containment for both chemical storage areas will be provided by a surrounding curb. Drainage within the curb-line will be provided by a drain line that will route spillage to the plant Headworks. The drain line piping shall be corrosion resistant.

Safety Equipment

Safety equipment shall be provided for use by operation personnel in the new facility for both the sodium hypochlorite and sodium bisulfite systems and near the chemical storage tanks. This equipment shall include emergency eyewash and shower stations. Signage and labeling will be provided on all piping systems, storage tanks and general areas.

Potable Water System

Potable water systems shall be provided for general clean-up activities and for flushing the sodium hypochlorite and sodium bisulfite system components and piping. Tepid water (60°F to 95°F per ANSI) will be required for the eyewash/shower stations. Instantaneous water heaters may be used to meet this requirement.

Monitoring and Control

The existing chlorine residual analyzers will be removed out of the Maintenance Shop and relocated to locations proximate to residual monitoring points.

Either flow pacing or residual pacing can be used for automatic hypochlorite feed control. Residual analyzers installed prior to dechlorination will be used to control the sodium hypochlorite metering pumps. In residual pacing mode, readings from these analyzers will be used to automatically adjust pumping rates to maintain adequate chlorine residual for effluent disinfection. Readings from these analyzers will also be used to automatically adjust sodium bisulfite pumping rates for dechlorination.

Compliance monitoring will be required for chlorine residual and Enterococci counts. The compliance monitoring frequency is delineated in the plant's NPDES permit (Appendix A). During analyzer relocation, grab sampling can be used for compliance monitoring.

Facility Summary

Table 12-17 provides a summary of the equipment in the new chlorination/dechlorination facility.

Table 12-17. Summary of Chlorination/Dechlorination Facilities

Facility	Chlorination System	Dechlorination System
Delivery		
Tanker Truck Capacity, each	4,500 gallons	
Storage		
	Existing	Existing
Type	Vertical	
Total Volume	12,000 gallons	6,000 gallons
Tank Capacity, each	6,000 gallons	3,000 gallons
Number	2	2
Installation	Outdoor under canopy	
Metering Pumps		
	New	New
Pump Type	Diaphragm; peristaltic; or gear	
Capacity, each	0 - 200 gph	0 - 60 gph
Number	2 (1 duty; 1 standby)	2 (1 duty; 1 standby)
Piping		
Size	0.5-inch to 4-inch diameter	0 5-inch to 4-inch diameter
Piping Material	Single-wall PVC or CPVC	
Buried Piping	PVC tubing in PVC pipe	
Valves		
Type	Varies for service. Includes ball valves with capacity to vent off-gases	
Induction Unit		
	New	Existing
Type	Induction unit	Diffuser
Number	2 (1 duty; 1 standby)	1

Estimate of Probable Construction Cost

A summary of estimated construction costs is included in Table 12-18. The estimate includes a 20-percent contingency and escalation to the midpoint of construction.

Table 12-18. Probable Construction Cost of the New Disinfection Facility

CSI Division	Estimated Construction Cost
1 – General Requirements	$ 91,000
2 – Site Work	$ 34,000
3 – Concrete	$ 50,000
4 – Masonry	$ -
5 – Metals	$ 113,000
6 – Wood and Plastic	$ -
7- Thermal and Moisture Protection	$ 15,000
8 – Doors and Windows	$ -
9 – Finishes	$ 25,000
10 – Specialties	$ 15,000
11 – Equipment	$ 110,000
13 – Instrumentation	$ 250,000
14 – Conveyance	$ -
15 – Mechanical	$ 82,000
16 – Electrical	$ -
Subtotal Construction Cost	$ 785,000
Construction Contingency (20%)	$ 139,000
Total Construction Cost	**$ 924,000**
Engineering and Administration (25%)	$ 231,000
Total Project Cost	**$ 1,155,000**

Appendix A. Construction and O&M Cost Estimate

Alternative 1 Cost Estimate:Chlorination/Dechlorination with No CCT Expansion

CSI Division	Markup
Division 1 - General Requirements	$91,000
Division 2 - Site Work	$34,000
Division 3 - Concrete	$50,000
Division 4 - Masonry	$0
Division 5 - Metals	$113,000
Division 6 - Wood and Plastics	$0
Division 7 – Thermal and Moisture Protection	$15,000
Division 8 – Doors and Windows	$0
Division 9 - Finishes	$25,000
Division 10 - Specialties	$15,000
Division 11 - Equipment	$110,000
Division 13 - Instrumentation	$250,000
Division 14 - Conveyance	$0
Division 15 - Mechanical	$82,000
Division 16 - Electrical	$0
Subtotal Construction Cost	$785,000
Construction Contingency (20%)	$139,000
Total Construction Cost	**$924,000**
Engineering and Administration (25%)	$231,000
Total Project Cost	**$1,155,000**

Alternative 2 Cost Estimate: Chlorination/Dechlorination with Additional CCT

CSI Division	Markup
Division 1 - General Requirements	$91,000
Division 2 - Site Work	$96,000
Division 3 – Concrete	$525,000
Division 4 – Masonry	$0
Division 5 – Metals	$113,000
Division 6 - Wood and Plastics	$0
Division 7 – Thermal and Moisture Protection	$15,000
Division 8 – Doors and Windows	$0
Division 9 – Finishes	$25,000
Division 10 – Specialties	$15,000
Division 11 – Equipment	$110,000
Division 13 – Instrumentation	$250,000
Division 14 – Conveyance	$0
Division 15 – Mechanical	$82,000
Division 16 – Electrical	$0
Subtotal Construction Cost	$1,321,000
Construction Contingency (20%)	$246,000
Total Construction Cost	**$1,568,000**
Engineering and Administration (25%)	$392,000
Total Project Cost	**$1,960,000**

Alternative 3 Cost Estimate: UV Disinfection with BNR

CSI Division	Markup
Division 1 - General Requirements	$204,000
Division 2 - Site Work	$35,000
Division 3 - Concrete	$193,000
Division 4 - Masonry	$0
Division 5 - Metals	$63,000
Division 6 - Wood and Plastics	$6,000
Division 7 – Thermal and Moisture Protection	$25,000
Division 8 – Doors and Windows	$0
Division 9 - Finishes	$25,000
Division 10 - Specialties	$15,000
Division 11 - Equipment	$600,000
Division 13 - Instrumentation	$68,000
Division 14 - Conveyance	$15,000
Division 15 - Mechanical	$180,000
Division 16 - Electrical	$179,000
Subtotal Construction Cost	$1,608,000
Construction Contingency (20%)	$280,000
Total Construction Cost	**$1,888,000**
Engineering and Administration (25%)	$472,000
Total Project Cost	**$2,360,000**

Alternative 4 Cost Estimate: UV Disinfection without BNR

CSI Division	Markup
Division 1 - General Requirements	$204,000
Division 2 - Site Work	$35,000
Division 3 - Concrete	$295,000
Division 4 - Masonry	$0
Division 5 - Metals	$99,000
Division 6 - Wood and Plastics	$6,000
Division 7 – Thermal and Moisture Protection	$25,000
Division 8 – Doors and Windows	$0
Division 9 - Finishes	$25,000
Division 10 - Specialties	$15,000
Division 11 - Equipment	$2,000,000
Division 13 - Instrumentation	$95,000
Division 14 - Conveyance	$30,000
Division 15 - Mechanical	$180,000
Division 16 - Electrical	$413,000
Subtotal Construction Cost	$3,422,000
Construction Contingency (20%)	$644,000
Total Construction Cost	**$4,066,000**
Engineering and Administration (25%)	$1,017,000
Total Project Cost	**$5,083,000**