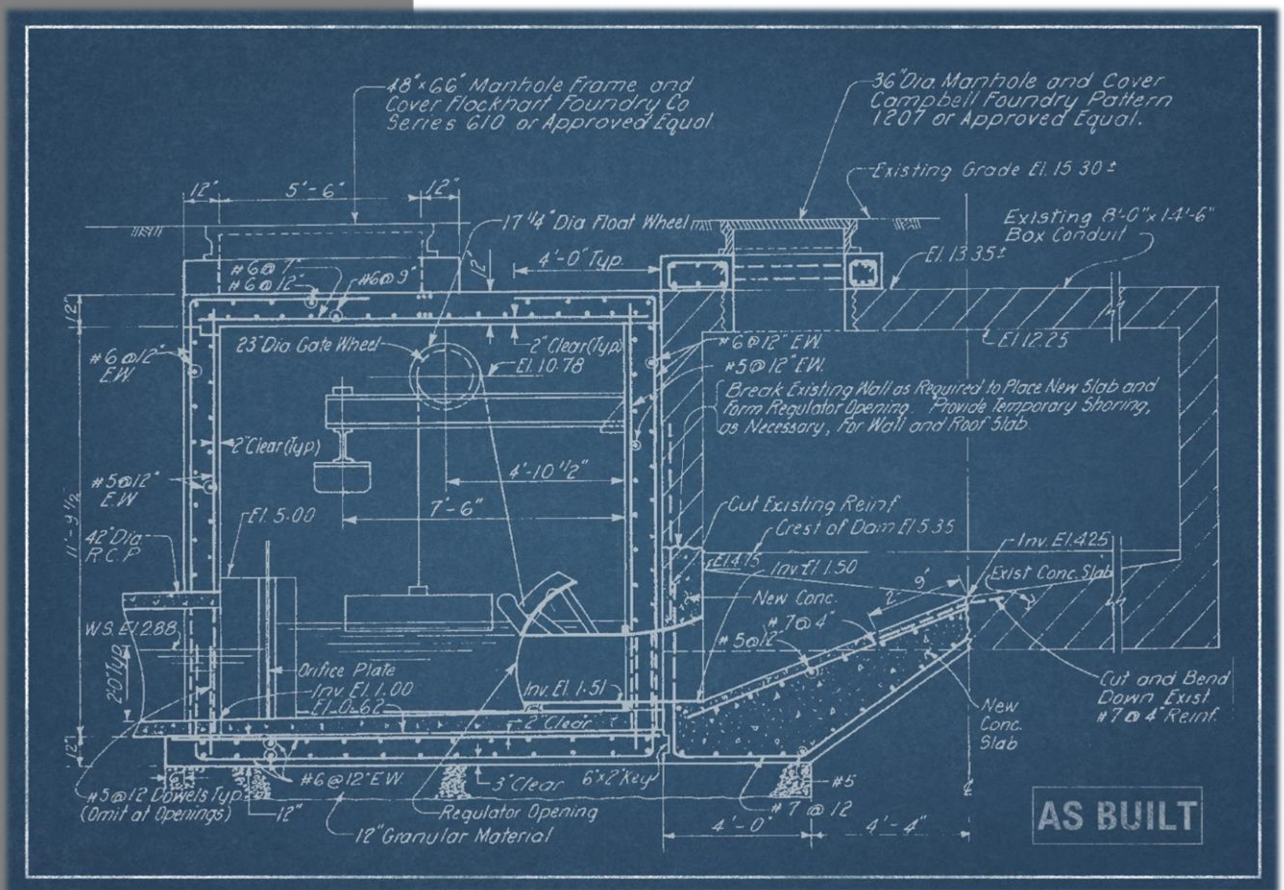
Joint Venture Team
albany pool



ALBANY WATER BOARD

BIG C DISINFECTION AND FLOATABLES CONTROL FACILITY

Preliminary Engineering Report

August 1, 2016

BIG C DISINFECTION AND FLOATABLES CONTROL FACILITY

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Albany Water Board

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ACRONYMS AND ABBREVIATIONS

APC	Albany Pool Communities
AWB	Albany Water Board
CDRPC	Capital District Regional Planning Commission
CSO	Combined Sewer Overflows
CSS	Combined Sewer System
CWSRF	Clean Water State Revolving Fund
Department	New York State Department of Environmental Conservation
LTCP	Long Term Control Plan
NPDES	National Pollutant Discharge Elimination System
NWRI	National Water Research Institute
PAA	Peracetic Acid
PER	Preliminary Engineering Report
RED	Reduction Equivalent Dose
SPDES	State Pollution Discharge Elimination System
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UVT	Ultraviolet Transmittance

EXECUTIVE SUMMARY

The Albany Pool Communities (APCs) represent six (6) Capital District municipalities (i.e., the cities of Albany, Cohoes, Rensselaer, Troy and Watervliet and the Village of Green Island) that collectively own and operate combined sewer overflows that discharge to the Hudson and Mohawk Rivers, and their tributaries. The Albany Pool Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) was finalized and approved by the New York State Department of Environmental Conservation (Department) in January 2014. The proposed **Big C Disinfection and Floatables Control Facility Project** is required under the executed Order on Consent, and the construction of these facilities is necessary for meeting current and future water quality standards in the Hudson River. The objective or purpose of the report is to obtain Department consensus in regards to the proposed disinfection and screening technologies to be employed on the project; as well as the suitability of the proposed sites in consideration of construction and operational issues, permitting and environmental justice issues, environmental benefits and potential impacts, and construction and long-term operational costs.

Based on discussions between the City of Albany and Albany Water Board (AWB), the following two (2) sites were identified for further consideration in regards to siting of the disinfection and floatables control facilities:

Broadway or "U-Haul" Site: this site is comprised of two parcels along the banks of the Hudson River at the Big C overflow discharge point; downstream of Rensselaer Street and I-787 at 75 Broadway (City Parcel No. 76.15-1-7, 1.17 acres) and 107 Broadway (City Parcel No. 76.15-1-6, 0.51 acres), both parcels are presently privately owned.

The following design considerations apply to the Broadway site:

- Recommended disinfection and screening facilities must be designed to capture and treat overflows up to 75 MGD. It is anticipated that the facilities will treat approximately 285 million gallons of overflow on an average annual basis.
- Due to the relatively poor soil conditions which include existing fill and soft soil, and the anticipated loadings associated with the proposed tanks and equipment, the use of conventional shallow foundations for these structures is anticipated to result in significant settlement which would impact the functionality of the proposed system. A pile foundation system is considered the most desirable feasible alternative for foundation support of the proposed improvements. Piles should be driven through the soft layers until deeper layers of glacial till or bedrock are encountered.
- Several elements (i.e., diversion/interceptor structure and piping, screening and pump station facilities) will need to be constructed below the normal operating range of the river. As a result, protection of the associated construction activities and operations would be required to prevent flooding or inundation of the construction zone. There is inherent cconstructability and risk issues at this site based on the proximity to floodplain/tidal zone.
- Pumping facilities would need to be incorporated into the site design in order to construct the disinfection tanks above the normal range of elevations in the river. Otherwise, typical river elevations would have the potential to create backwater effects which would impact to the hydraulic profile and restrict (or limit) flow conveyed through the facilities.

- Facilities would need to be designed to protect critical equipment and operations in consideration of the floodplain elevations and climate change factors.
- Erosion and sediment controls, in conjunction with the management of on-site runoff and flows conveyed through the Beaver Creek sewer, will be required during construction to protect the fish and wildlife, as well as water quality in the Hudson River.
- Measures would need be taken to ensure that any residuals from chemical oxidants are addressed prior to discharging to receiving waters.
- Measures would need to be taken to provide appropriate odor control for the screening and pumping facilities given the location and adjacent land uses.
- Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary and the Hudson River, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.
- The parcels necessary for construction of the proposed disinfection and floatables control facility are presently privately owned. It is likely that these parcels would need to be secured through the eminent domain process.

Lincoln Park Site: this parcel at 164 Delaware Avenue resides in Lincoln Park and is presently owned by the City of Albany (City Parcel No. 76.10-1-3). The area which is being considered for the proposed facilities lies between Delaware Avenue and South Swan Street.

The following design considerations apply to the Lincoln Park site:

- Recommended disinfection and screening facilities must be designed to capture and treat overflows up to 100 MGD. It is anticipated that the facilities will treat approximately 340 million gallons of overflow on an average annual basis.
- There is an existing condition of the Beaver Creek sewer that is resulting the formation of a sinkhole within Lincoln Park. In addition, during extreme weather events, the system can surcharge in the park resulting in discharges to the surface. Based on the proposed facility layout, a new five to six foot diameter sewer approximately 750 linear feet in length would be required to convey flows to the proposed screening and disinfection facilities. The new sewer would be used to convey both dry and wet weather flows up to 100 mgd; thereby alleviating the surcharging condition of the existing Beaver Creek sewer and converting the existing sewer into a relief sewer for extreme wet weather events. This solution would improve odors in Lincoln Park by eliminating the discharge of sewer flows to the surface; increase the resiliency of the combined sewer system, and allow for access and repair of the sewer thereby eliminating any safety concerns associated with the sink hole which is located in the park and adjacent to the elementary school.
- Excavation for these improvements will extend well below the bedrock surface and bedrock removal is anticipated. Bedrock removal will require the use of controlled blasting, drilling and

splitting, or mechanical hoe-rams to reduce bedrock to fragments manageable for standard excavation equipment.

- Based on the size and weight of the proposed tanks and structures proposed as part of this project, these structures should receive bearing support directly from the shale bedrock.
- Measures would need be taken to ensure that any residuals from chemical oxidants are addressed prior to discharging to receiving waters.
- Measures would need to be taken to provide appropriate odor control for the screening facility given the location and adjacent land uses.
- Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.
- The proposed facilities will be located within existing park lands. As such, park land alienation legislature and mitigation may be required.
- There is the potential for the public perception of impacts to the neighborhood, park and/or school (e.g., Environmental Justice Issues).

An analysis was performed in regards to the disinfection and screening technologies, and an alternative site evaluation was completed to determine the feasibility of the construction of the facilities at the respective sites. Possible disinfection alternatives were identified and screened during the development of the project, this study focused on ultraviolet (UV) disinfection, bulk liquid chlorination/dechlorination, and peracetic acid (PAA).

While UV is considered to be an innovative technology for CSO applications there remains limited full-scale CSO application data. Based upon the analysis performed, UV disinfection is not recommended for treatment of combined sewer flows at Big C due to the high variability and seasonal characteristics of the water quality conditions indicative within the system (e.g., TSS and large particle sizes characteristic of first flush of runoff). These conditions would likely cause interference or fouling of the UV lamps; thereby degrading performance of the technology due to the high solids loadings. The use of a high rate treatment system would also likely be required prior to the UV disinfection which would render this alternative to be cost prohibitive. In addition, this alternative would require high energy usage based on the large number of UV lamps required, and have significantly higher long-term operational and maintenance costs. As a result, UV disinfection was eliminated from consideration as a viable alternative for the project.

Based on the analyses performed, it is recommended that chemical disinfection be utilized for the treatment of flows based on the water quality goals and objectives of the project. The use of PAA as a wastewater and CSO disinfectant continues to increase across the US. However, to date it has not been approved for either application within New York; thereby making its path to implementation for the Big C Screening and Disinfection Facility more time consuming. Conversely, Chlorination/Dechlorination has been the most widely used disinfectant for wastewater, CSO and potable water applications in the United

States. Contributing factors include the reasonable costs to construct and operate the systems, reliable disinfection capabilities, and adequate supply. In addition, there is great familiarity with the operations and maintenance activities associated with these types of treatment systems.

Given the cost and non-cost considerations, it is recommended that Chlorination/Dechlorination be utilized as the disinfectant at the Big C Screening and Disinfection Facility. Chlorine is available in many forms including chlorine gas and chlorine products such as sodium and calcium hypochlorite. Liquid sodium hypochlorite has become widely used for wastewater disinfection due to its reliability and ease of handling. As the project moves forward additional sampling and testing will need to be performed to better define the sodium hypochlorite design dose for the facility.

Furthermore, different screening technologies were identified and evaluated to determine appropriate equipment suitable to achieve pre-treatment requirements for disinfection, protect downstream equipment, debris loading impacts on the ACSD South Treatment Plant, storage and handling of the screened materials, and floatables control and discharge to the Hudson River. In the end, the use of mechanically cleaned conventional bar screens are recommended based on an analysis of capital costs, and long term operational and maintenance considerations.

The AWB has determined that both sites evaluated are potentially feasible in regards to the construction of the disinfection and floatables control facilities. The AWB intends to work with the City of Albany to build and execute a more robust public outreach and education program with municipal leadership, interested stakeholders and the general public. The final site selection will be based on negotiations with the Department, as well as input and concerns expressed during the public outreach process.

The AWB will advance the dialogue with the Department in an effort to build consensus in regards to the technologies to be utilized, as well as the feasibility for the two (2) sites that were evaluated. Once a consensus has been formed, the AWB intends to:

- Address any comments the Department may have regarding the Preliminary Engineering Report and issue a Final Report;
- Finalize the Basis of Design criteria for the project;
- Work with the City of Albany to build and execute a more robust public outreach and education program with municipal leadership, interested stakeholders and the general public; and
- Begin advancing the Preliminary Design for the facilities.

1 PROJECT BACKGROUND AND HISTORY

Combined sewer overflows (CSOs) are point sources subject to National Pollutant Discharge Elimination System (NPDES) permit requirements; including both technology and water quality based requirements of the Clean Water Act. The Albany Pool Communities (APCs) represent six (6) Capital District municipalities (i.e., the cities of Albany, Cohoes, Rensselaer, Troy and Watervliet and the Village of Green Island) that collectively own and operate combined sewer overflows that discharge to the Hudson and Mohawk Rivers, and their tributaries.

The APCs joined together in a comprehensive inter-municipal venture, led by the Capital District Regional Planning Commission (CDRPC), to develop a regional CSO Long Term Control Plan (LTCP). The main goal of the LTCP is to provide a regional solution that achieves the water quality standards necessary to maintain the current Class C receiving water uses of the Hudson and Mohawk rivers. In addition to identifying projects that will reduce the amount of untreated sewage discharged to the river, the LTCP developed tools by which the communities could measure the effectiveness of the program including a water quality model for the Hudson River and a post-construction sampling and monitoring program. The Albany Pool CSO LTCP was finalized and approved by the New York State Department of Environmental Conservation (Department) in January 2014.

One of the projects required by the executed Order on Consent (Order) is the Big C Disinfection and Floatables Control Facility. The facility (or project) is intended to treat combined sewer discharges for the Beaver Creek Sewershed in the City of Albany (SPDES permitted outfall No. 016). CSO baseline conditions indicate that the Big C outfall overflows approximately 45 times per year (over a duration of 452 hours), discharging 532 million gallons of combined flows to the Hudson River on an annual basis. The proposed disinfection and floatable controls will provide for treatment at the City of Albany's largest CSO; and will serve to further reduce bacteria counts and enhance the "recovery time" for the Hudson River.

1.1 Purpose of the Preliminary Engineering Report

This preliminary engineering report (PER) has been prepared for the Albany Water Board (AWB) to advance planning level activities associated with the design and construction of the Big C Disinfection and Floatables Control Facility. The report has been developed to meet the new Clean Water State Revolving Fund (CWSRF) Engineering Report Outline (effective May 1, 2016) to ensure that CWSRF programmatic and technical requirements will be satisfied.

The Report includes:

- An Executive Summary
- Project Background and History
- Alternatives Analysis
- Summary and Comparison of Alternatives
- Conclusions and Next Steps

The objective or purpose of the report is to obtain Department consensus in regards to the proposed disinfection and screening technologies to be employed on the project; as well as the suitability of the proposed sites in consideration of construction and operational issues, permitting and environmental justice issues, environmental benefits and potential impacts, and construction and long-term operational costs.

1.2 Site Information

Based on discussions between the City of Albany and AWB, the following two (2) sites were identified for further consideration in regards to siting of the disinfection and floatables control facilities:

- **Broadway or "U-Haul" Site**: this site is comprised of two parcels along the banks of the Hudson River at the Big C overflow discharge point; downstream of Rensselaer Street and I-787 at 75 Broadway (City Parcel No. 76.15-1-7, 1.17 acres) and 107 Broadway (City Parcel No. 76.15-1-6, 0.51 acres), both parcels are presently privately owned.
- **Lincoln Park Site**: this parcel at 164 Delaware Avenue resides in Lincoln Park and is presently owned by the City of Albany (City Parcel No. 76.10-1-3). The area which is being considered for the proposed facilities lies between Delaware Avenue and South Swan Street.

Location maps for the two sites are included in **Appendix A**.

1.2.1 Broadway or "U-Haul" Site

1.2.1.1 Geological Conditions

Subsurface conditions at this site were evaluated based on historical subsurface data shown on record drawings for the Beaver Creek sewer. Two borings performed within the general vicinity of the site indicate the subsurface conditions consist of existing fill overlying layers of soft gray clay and loose sand. The borings extend to a maximum depth of approximately 40 feet, or to an elevation of 25 feet below sea level. The publication "Engineering Geology Classification of the Soils of the Albany, New York 15 Minute Quadrangle", NYS Museum Map and Chart Series No. 36 was also referenced. This publication includes a map titled "Geologic Hazards and Thickness of Overburden of the Albany, New York 15 Minute Quadrangle". The map indicates that the overburden thickness in the vicinity of the site is on the order of 50 to 100 feet. Based on previous experience in the general site area, it is expected that bedrock would be present on average at a depth of 60 feet below the ground surface.

Due to the relatively poor soil conditions of the existing fill and soft soil, and the anticipated loadings associated with proposed tanks and equipment, the use of conventional shallow foundations for these structures could result in significant settlement which would impact the functionality of the proposed system. A pile foundation system would likely be required for foundation support of the proposed facilities. Piles should be driven through the soft layers until deeper layers of glacial till or bedrock are encountered.

Groundwater elevations are representative of the Hudson River elevations due to its close proximity. Several elements (i.e., diversion/interceptor structure and piping, screening and pump station facilities) would need to be constructed below the normal operating range of the river. As a result, dewatering operations and protection of the associated construction activities would be required to prevent flooding or inundation of the construction zone.

1.2.1.2 Environmental Resources

The proposed facilities would reside along the banks of the Hudson River in the area immediately south of the existing parking. This area is currently classified as open space and is used to store vehicles and miscellaneous materials. The CSOs would be intercepted and returned back into the system up-gradient of the existing outfall. As such, it is not anticipated that the stream banks and/or other environmental resources will be disturbed or impacted as a result of the construction activities. However, erosion and sediment controls (in conjunction with the management of on-site runoff and flows conveyed through the Beaver Creek sewer) would be required during construction to protect the fish and wildlife, as well as water quality in the Hudson River.

Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary and Hudson River, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.

1.2.1.3 Floodplain Considerations

This site is currently located within the limits of the Hudson River 100-year floodplain. The 100-year and 500-year floodplain elevations are 20 feet and 24.5 feet NGVD, respectively (see **Figure 1-1**). Existing grades on site are approximately 14 feet NGVD; with the invert of the existing CSO outfall at an elevation of approximately 1.8 feet above mean sea level. As such, proposed facilities would need to be designed to protect critical equipment and operations in consideration of the floodplain elevations and climate change factors. In addition, pumping facilities would need to be incorporated into the design at this site in order to construct the disinfection tanks above the normal operating range of elevations in the river. Otherwise, typical river elevations would have the potential to create backwater effects which would impact to the hydraulic profile and restrict (or limit) flow conveyed through the facilities.

1.2.1.4 Special Considerations

The parcels necessary for construction of the proposed disinfection and floatables control facility are presently privately owned. It is likely that these parcels would need to be secured through the eminent domain process. In addition, there are inherent cconstructability and risk issues associated with this site based on the proximity to floodplain/tidal zone.

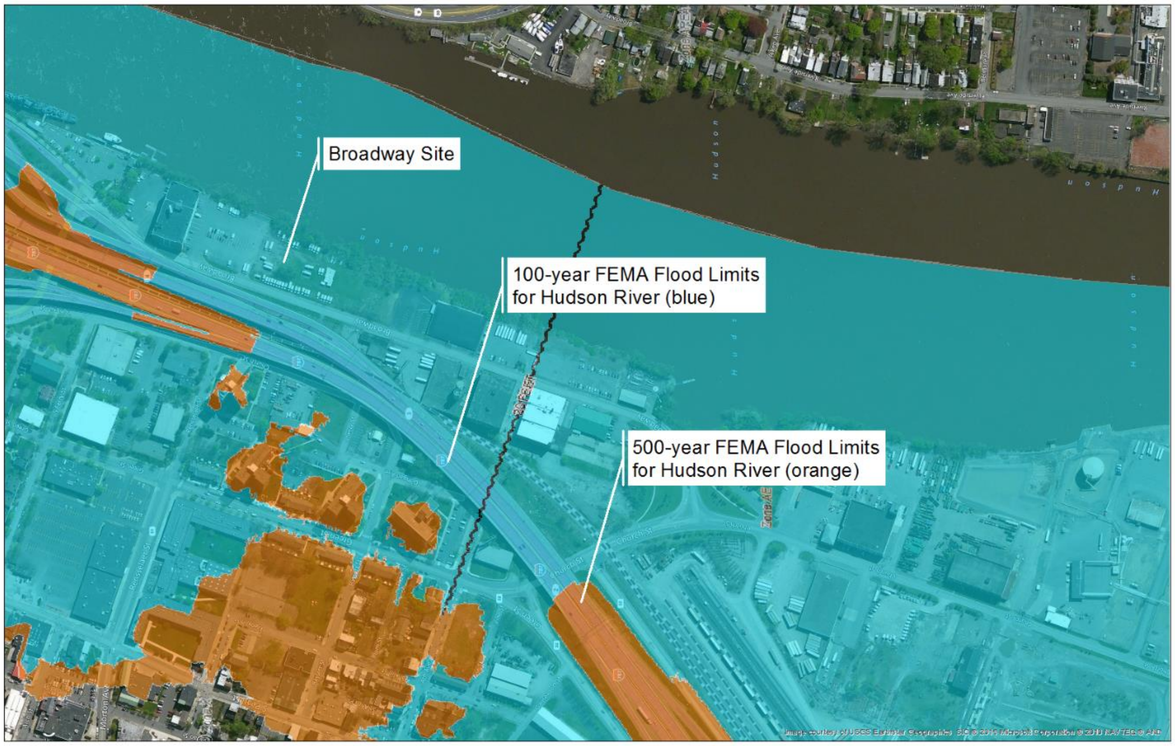


Figure 1-1
Hudson River FEMA Flood Floodplain Boundaries

1.2.2 Lincoln Park Site

1.2.2.1 Geological Conditions

At the Lincoln Park site, subsurface conditions we evaluated based on the results of four (4) test borings conducted in May 2016. In general, subsurface conditions consist of man-made fill to depths between 5 and 27 feet overlying layers of clayey silt or silty clay or completely weathered shale bedrock at depths between 8 and 28 feet; and competent shale bedrock at depths between 15 and 35 feet. Groundwater was evaluated based on two (2) observation wells installed within completed boreholes and was found to be present at depths of approximately 22 feet below the surface. Based on the size and weight of the proposed tanks and structures anticipated as part of this project, these structures should receive bearing support directly from the shale bedrock. Excavation for these improvements will likely extend well below the bedrock surface and bedrock removal is anticipated. Bedrock removal will require the use of controlled blasting, drilling and splitting, or mechanical hoe-rams to reduce bedrock to fragments manageable for standard excavation equipment.

1.2.2.2 Environmental Resources

Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance in the areas of deep excavation. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.

1.2.2.3 Floodplain Considerations

Not Applicable.

1.2.2.4 Special Considerations

The proposed facilities would be located within existing park lands. As such, park land alienation legislature and mitigation may be required. In addition, there is the potential for the public perception of impacts to the neighborhood, park and/or school (e.g., Environmental Justice Issues).

1.3 Design Flows

The project is defined within the Albany Pool CSO LTCP Order on Consent and requires that the facility is designed to capture and treat overflows up to 75 MGD. It was also defined that the facilities will need to treat approximately 285 million gallons of overflow on an average annual basis. This assumption was based upon the construction of the facility in the vicinity of the outfall, downstream of the "Big C" regulating chamber which controls flows to the ACSD Hudson River Interceptor for conveyance to the South Treatment Plant. These findings and recommendations were based upon the APCs providing treatment of 85 percent of all wet weather flows on a regional basis.

It should be noted that the Lincoln Park Site is located upstream of the regulating chamber; and as such, a percentage of the flows being treated at this location would be conveyed to the South Treatment Plant. In addition, a small percentage of the Beaver Creek Sewershed flows (less than 5 percent) would be conveyed to the City of Albany's CSS downstream of the satellite treatment facilities. As a result, the design flows for the Lincoln Park Site need to be greater than the prescribed 75 MGD limit in the Order on Consent to achieve the desired reduction of 285 million gallons of untreated discharges to the Hudson River on an annual basis. Based on hydraulic analysis performed using the SWMM model developed for the Albany Pool CSO LTCP, it was determined that the Lincoln Park Site needs to provide for treatment of flows up to 100 MGD; and corresponds to the total treatment of approximately 340 million gallons of flow on an annual basis.

Table 1-1: Design Flows and Annual Capture

Site Location	Peak Flow Rate (MGD)	Annual Treat Volume (MGal)
Broadway Site	75	285
Lincoln Park Site	100	340

1.4 Ownership and Service Area

The Beaver Creek Sewershed services an area of 3,290 acres within the City limits (see **Figure 1-2**). The City of Albany sewer system is owned, operated and maintained by the AWB. As part of the Albany Pool CSO LTCP requirements, the AWB is developing operations, maintenance and inspection plans for all critical facilities. The AWB is committed to sustainable infrastructure and understands the importance of proper operations and maintenance of our systems. The AWB maintains a staff of over 140 employees, with approximately 125 staff dedicated to the operations and maintenance of their facilities.

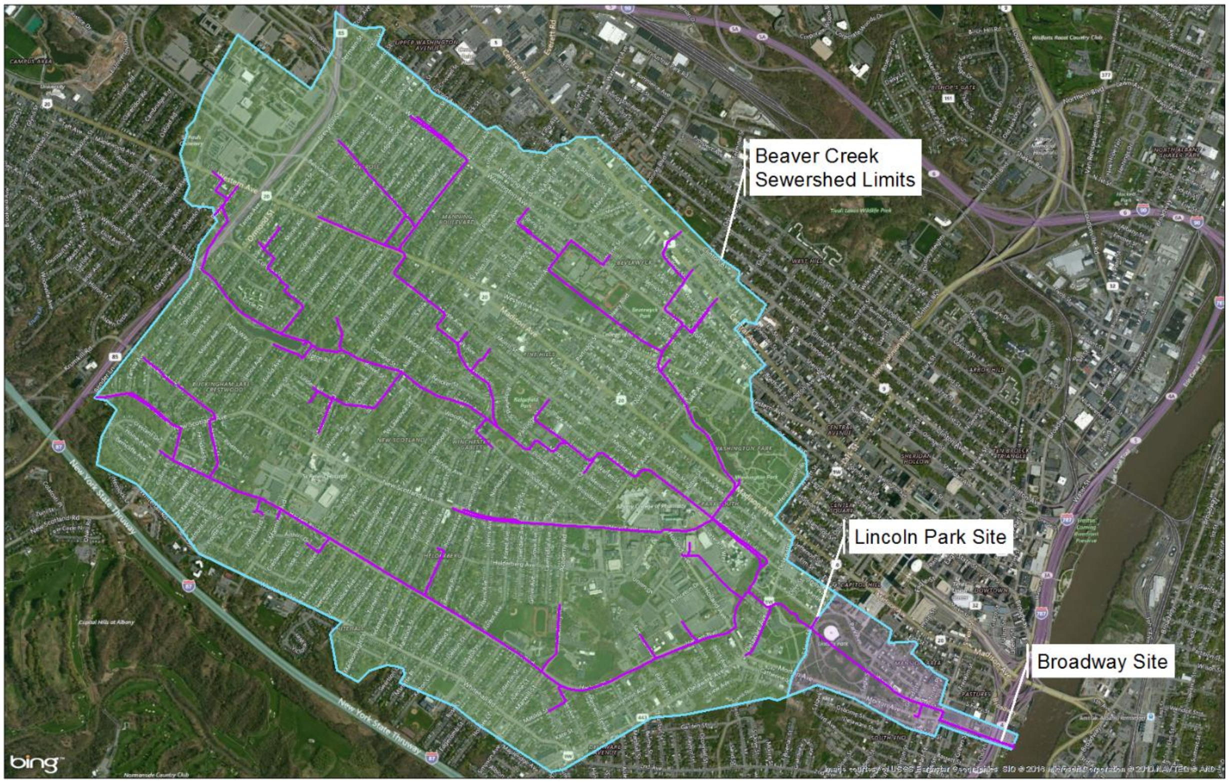


Figure 1-2
Beaver Creek Sewershed Boundaries

1.5 Existing Facilities and Present Conditions

The AWB does not presently own or maintain disinfection and/or floatables controls within the service area.

1.6 Project Need

Baseline annual combined sewer overflows at the "Big C" outfall were previously determined to be approximately 532 million gallons during the development of the Albany pool CSO LTCP. This represents approximately 72 percent of the total annual overflow volume for the City of Albany; and approximately 43% of the total annual overflows in the "Albany Pool". The proposed project is required under the executed Order on Consent for the Albany Pool CSO LTCP, and the construction of these facilities is necessary for meeting current and future water quality standards in the Hudson River.

1.7 Financial Status and Project Funding

The Albany CSO Pool Communities Corporation (Corporation) was formed as a New York not-for-profit and local development corporation by a pool of community municipalities consisting of the cities of Albany, Troy, Cohoes, Rensselaer, Watervliet, and the Village of Green Island, all of whom are members of the Corporation (together, the “Member Municipalities”), to lessen the burdens on local governments and provide a vehicle to jointly administer the construction, financing, operation, and maintenance of certain public utilities that will be repaired and constructed as part of the Albany Pool CSO LTCP and the Order.

The Corporation will facilitate the administration of more than 50 projects and programs (the “LTCP Programs”) that will aid in the clean-up of the Hudson River as identified in the Albany pool CSO LTCP. Projects listed under the Albany Pool CSO LTCP are financed based on an agreed upon cost allocation formula defined within the bylaws for the Corporation. Funding obligations for both the City of Albany and the City of Troy are presently met with financing secured through the CWSRF, as administered by the New York State Environmental Facilities Corporation (EFC).

2 ALTERNATIVE ANALYSIS

2.1 Introduction

Under the executed Order for the Albany Pool CSO LTCP, the APCs are required to identify and implement disinfection and floatables control strategies for the “Big C” combined sewer overflow in the City of Albany. The Big C Disinfection and Floatables Control Facility will provide for treatment at the City of Albany’s largest CSO; and will serve to further reduce bacteria counts and enhance the “recovery time” for the Hudson River. The following sections will present a detailed discussion in regards to the analysis and recommendations pertaining to the disinfection and screening technologies.

2.2 Disinfection Technology Overview

This section provides an evaluation of three (3) feasible disinfection technologies followed by a lifecycle cost comparison of each. The conceptual costs for implementing each technology were developed to aid in the identification of a preferred alternative. The description of each of the technologies presented in this section provides a basis for developing alternative costs. Possible alternatives were identified and screened during the development of the project, this evaluation focuses on ultraviolet (UV) disinfection, bulk liquid chlorination/dechlorination, and peracetic acid (PAA).

Disinfection of wastewater is commonly accomplished by the use of radiation, chemical oxidants, or mechanical treatment techniques. The primary types of radiation include electromagnetic (most commonly UV) and ionizing radiation. UV radiation as a disinfectant has been used for years, primarily in the sterilization of potable water and food products. Exposure to UV light will inactivate many organisms. UV is well demonstrated as an effective disinfection technology for water and wastewater treatment. With the advent of higher intensity lamps, UV has been considered a promising technology for CSO disinfection. Chemical oxidants that have been used as disinfectants include chlorine compounds, chlorine dioxide, PAA bromine, iodine, ozone, and other natural and synthetic chemical compounds. Of these, chlorine is the most widely used. Mechanical treatment techniques such as filtration and sedimentation offer some reduction of bacteria and other organisms found in wastewater. However, these techniques were not designed with the purposeful intent of bacterial reduction and provide marginal reduction at best, particularly for CSOs.

The competing goals of providing high levels of disinfection for CSOs while meeting effluent criteria for residual chlorine have fostered interest in alternatives to conventional chlorination. Also, the unique characteristics of CSOs (e.g., high flow rates, highly variable wastewater quality, and intermittent operation), coupled with the need to adopt high-rate, cost-effective disinfection facilities, have added to the interest in alternative disinfection technologies. PAA is an alternative disinfection technology that has been utilized as a CSO and wastewater disinfectant in North America.

2.2.1 Ultraviolet Light (UV)

The use of UV for disinfection of secondary effluent is an established technology with roughly 20 percent of the wastewater treatment facilities in North America utilizing it. While not as prevalent as its use in wastewater applications, UV is being utilized for disinfection of CSO at facilities around the United States and Europe.

UV light inactivation of microorganisms is a physical or biophysical process with the germicidal wavelengths occurring in the UV-B and UV-C regions. Electromagnetic radiation in this range alters cellular proteins and nucleic acids (i.e., DNA and RNA) through dimerization of nucleic acids. Because UV light inactivates pathogens by changing their genetic material, it is important to provide a sufficient dose so that enough damage is done to the genetic material that the microorganisms cannot repair this damage. The dose is a function of the UV intensity and the exposure time that CSO is retained in the UV reactor.

2.2.1.1 Factors Affecting UV Disinfection

The equation used to calculate UV dose is shown below:

Equation 1-1:

$$\text{UV Dose} = I \times t$$

Where:

I = UV intensity, in milliwatts per square centimeter (mW/cm^2)

t = exposure time, in seconds (s)

UV Dose, in $mW\text{-}s/cm^2$ or milliJoules per square centimeter (mJ/cm^2)

The actual UV intensity and exposure time are functions of the UV reactor configuration, operating parameters and water quality. For example, in order to reach pathogens, the UV radiation must travel through the quartz sleeve, CSO and particles (if the microbes are embedded in particles). Consequently, the UV intensity actually reaching the target organisms is lower than that at the surface of the UV lamp and varies throughout the reactor.

The exposure time is ideally the average hydraulic retention time within the UV reactor (the reactor volume divided by the flow rate). However, actual exposure is a function of reactor volume, flow rate, mixing conditions within the reactor and extent of short-circuiting. Another factor that can impact UV exposure is the distance between lamps, because even without absorption losses, UV intensity decreases with increasing distance from the lamp. Also, dead space in a reactor can reduce the effective reactor volume and shorten the average hydraulic retention time. Overall, the UV dose also depends on a range of water quality and lamp condition factors. Discussion of these factors is provided in the following sections.

2.2.1.1.1 Water Quality Parameters

Water quality affects the performance of a UV system by altering the UV intensity within the reactor and, consequently, the UV dose received by the organisms in the CSO. The most important water quality parameters are the UV transmittance (UVT) and total suspended solids (TSS) concentration and particle size. Because of the high TSS concentrations and large particle sizes observed during first flush events, these two parameters play a key role in properly sizing a UV system for a CSO application. In addition, dissolved solids may foul the quartz sleeves surrounding the lamps and decrease the effective UV output. Therefore, an understanding of the water hardness, iron content and other dissolved organics in the wastewater is important to designing and evaluating a UV disinfection system.

UVT is defined as the percentage of UV light, at the 254 nm wavelength, not absorbed (*i.e.*, transmitted) after passing through a 1-centimeter water sample. As UV light passes through wastewater, its intensity is attenuated by substances in the CSO. The relationship between intensity and transmittance is directly proportional - the higher the transmittance, the higher the intensity.

In addition to lowering UVT due to their ability to absorb and scatter UV light, TSS particles can shield microorganisms embedded in the particles, preventing them from receiving their required UV dose. While the rule of thumb for feasibility of UV disinfection at wastewater treatment plants is for TSS concentrations less than 30 mg/L, the design of a UV system for CSO disinfection can typically be performed such that it can overcome this limitation. Particle size is also important and should be considered in design; particles greater than 10 micrometers (µm) in size begin to show a shielding effect, with particles greater than 20 µm having a significant impact.

Other water quality parameters, such as dissolved organics, total hardness, and iron, absorb UV light and affect UV intensity. Increased concentrations of these parameters can decrease UV intensity and the effectiveness of a UV disinfection system. High concentrations of dissolved organics have been shown to absorb UV light. A summary of some of the compounds that are known to impact UVT is presented in **Table 2-1**.

In addition to absorbing UV light, high iron concentrations affect the performance of UV disinfection systems by precipitating iron on the UV lamps, thus promoting lamp fouling. Increased concentrations of inorganic magnesium and calcium carbonates can also increase fouling of the UV lamp quartz sleeves.

Table 2-1: Known UV Absorbing Compounds

Inorganics	Organics	Conjugated Rings
Bromine	Coloring agents	Anisole
Chromium	Organic dyes[a]	Benzene
Cobalt[a]	Extract of leaves[a]	Chlorobenzene
Copper	Humic acids[a]	o,m,p-cresol
Iodides	Lignin sulfonates	Cyanoanthracene
Iron[a]	Phenolic compounds	o-cyclohexyl phenol
Manganese	Tea	Cyclohexyl phenyl ketone
Nickel	Coffee	1-methyl-3,4-dihydronapthalene
Sulfates		o-methylstyrene
Stannous chloride		Phenyl propene
		Phenol
		Toluene

[a] Compound is a strong absorber of UV light at 254 nm.

2.2.1.1.2 Lamp and Sleeve Condition

Each lamp is encased in a quartz sleeve. The sleeve is made of quartz to allow UV light to pass through with minimal absorption, but the extent of absorption by the quartz sleeve is a function of its age and quality. Fouling on the quartz sleeve can occur either by organic or inorganic compounds, which can significantly reduce the UV light entering the CSO. Therefore, it is important that the quartz sleeve remain as free as possible from fouling and unwanted coatings to maintain optimum lamp intensity. The lamp itself can also impact intensity as a function of the lamp energy output, wavelength spectra of the UV lamp, power setting and lamp age.

2.2.1.2 Bioassay Based Sizing Criteria

Microbial responses to UV light vary significantly among species. The industry objective for UV disinfection is to have an accurate reactor-specific prediction of UV dose for the target organism requiring disinfection. The prediction of UV reactor performance and dose delivery is evolving. Computer simulation models have provided the industry with a better understanding of dose delivery, but the means of predicting reactor-specific performance is through bioassay testing. The challenge with this method is that the reduction equivalent dose (RED) measured using the bioassay method depends on both the test microbe's UV dose response and the reactor UV dose distribution. Because of these effects, the RED for the test microbe (surrogate) will differ from the RED delivered to a target pathogen or indicator microbe if the dose response of the test microbe differs from that of the pathogen or indicator. These differences are important enough that the industry has, for many years, debated which test microbe should be used to validate UV reactors for CSO facilities. An example of this is provided in **Figure 2-1,** which shows the log inactivation of various surrogate organisms for an open-channel pilot-scale microwave UV disinfection system on secondary wastewater effluent.

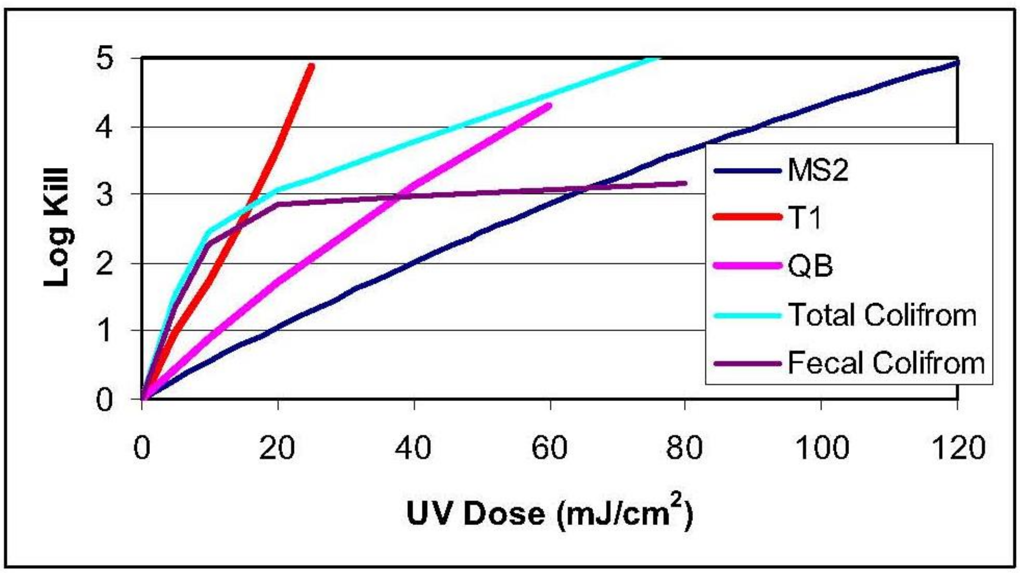


Figure 2-1
UV Dose Response Curves of MS2 Qβ and T1 Phage and Fecal and Total Coliform for the MicroDynamics™ UV System (Wright et al., 2009)

There have been recent publications developed in favor of a range of microbes and methods that should be used to validate and size wastewater reactors in efforts to match the surrogate microorganism to the appropriate pathogen being regulated. For example, male-specific-2 bacteriophage (MS2) phage and *B. subtilis* spores historically have been used for validation testing to receive treatment credit for *Cryptosporidium* and *Giardia*. Because their UV resistance is notably greater than that of *Cryptosporidium* and *Giardia*, other more sensitive microorganisms such as T1 and T7 phage are gaining favor.

Other challenge microorganisms that have been used for validation testing include nonpathogenic *E. coli, Saccharomyces cerevisae*, and Qβ phage. **Table 2-2** summarizes the UV sensitivity of some commonly used and some candidate bioassay microorganisms.

Table 2-2: UV Sensitivity of Challenge Microorganisms

Microorganism	Reported Delivered UV Dose (mJ/cm^2) to Achieve Indicated Log Inactivation			
	1-log	2-log	3-log	4-log
Bacillus subtilis	28	39	50	62
MS2 phage	16	34	52	71
Qβ	10.9	22.5	34.6	47.6
PRD-1 phage	9.9	17	24	30
B40-8 phage	12	18	23	28
ϕx 174 phage	2.2	5.3	7.3	11
E. coli	3.0	4.8	6.7	8.4
T7	3.6	7.5	11.8	16.6
T1	~5	~10	~15	~20

In response to calls from stakeholders for a protocol that could be widely adopted by regulatory organizations and the UV industry, the Manufacturer's Council of the International Ultraviolet Association (IUVA) developed the following approach to validation of wastewater applications. The *Uniform Protocol for Wastewater UV Validation Applications*, adopted in May 2011 as an official IUVA protocol, combines elements of the widely-used National Water Research Institute (NWRI) and USEPA guidelines in order to address wastewater applications.

In the *Uniform Protocol*, "wastewater application" is defined as a biological treatment plant that produces effluent with an average BOD and TSS of less than 30 mg/L each, with disinfection requirements of 126 cfu/100 mL *E. coli* (30-day geometric mean) or 200 cfu/100 mL fecal coliforms (30-day geometric mean). While Big C is a CSO application and will not meet these water quality criteria, it is recommended that the *Uniform Protocol* be utilized as the basis for validation of UV reactors. Similar to the USEPA guidance manual, the *Uniform Protocol* recommends the following procedures:

- Section 1 – Planning and Preparation covers requirements for the test equipment configuration, challenge microorganism (T1 phage, Q phage, or MS2 phage), testing conditions, quality assurance/quality control (QA/QC) samples, and third-party oversight.
- Section 2 – Microbiological Testing adopts and amends the USEPA guidance manual testing protocol for wastewater applications.
- Section 3 – Validation Data Analysis covers documentation of experimental data and calculation of the RED for each test, as well as additional analysis of RED data to produce the minimum setpoint value (as in the UV Intensity Setpoint Approach) or the UV dose-monitoring equation (as in the Calculated Dose Approach).

- Section 4 – Additional Analysis using Advanced Tools and Existing Data addresses the use of tools such as computational fluid dynamics (CFD) and Lagrangian Actinometry with Dyed Microspheres, establishes standards for UV equipment validated prior to the publication of the Uniform Protocol, and outlines recommendations for verification tests of related equipment (e.g., lamp output measurement, lamp age factor testing, and cleaning mechanism testing) that are also used in the sizing of UV equipment.
- Section 5 – Reporting recommends the use of the USEPA guidance manual reporting guidelines for preparation of the formal validation report.

Validation of UV reactors using this approach provides a basis for sizing UV reactors for both high and low UV dose applications, as well as the way in which validation data should be interpreted to account for the wide range of target microbes used to size a wastewater UV system. Only UV systems from manufacturers that have performed bioassays will be considered for installation at Big C.

2.2.1.3 Basic Components of a UV Disinfection System

In general, for UV disinfection, CSO flows through a confined chamber/reactor containing arrays of UV lamps, and the UV radiation from the lamps inactivates the microorganisms. A typical UV system consists of a power supply, an electrical system, reactors, lamps, quartz sleeves, a quartz sleeve cleaning/wiping mechanism, a mechanical system to hold the lamps, and a control system. A sensor system for monitoring UV intensity and an on-line UVT analyzer may also be included.

UV systems can be classified as closed-vessel or open-channel, the latter being the most common in wastewater treatment applications, however both systems can be utilized in CSO applications. In addition, UV systems are further classified by the output of the UV lamps (watts) and the orientation of the lamps (horizontal, vertical or inclined).

2.2.1.3.1 UV Lamps and Sleeves

UV lamps for wastewater applications can be categorized into three groups: low-pressure, low-output (LPLO); low-pressure, high-output (LPHO); and medium-pressure (MP). A new high-wattage LPHO lamp has recently been introduced to the market. Newer UV systems such as Trojan Technologies' TrojanUVSigna™ system, Wedeco's Duron® and Ozonia North America's Aquaray™ HiCap® UV system use these new high-wattage LPHO lamps. It is these high wattage LPHO lamps that are also utilized for CSO applications. Each lamp type emits a different spectrum and uses different operating parameters (**Figure 2-2** and **Table 2-3),** and presents different advantages and disadvantages.

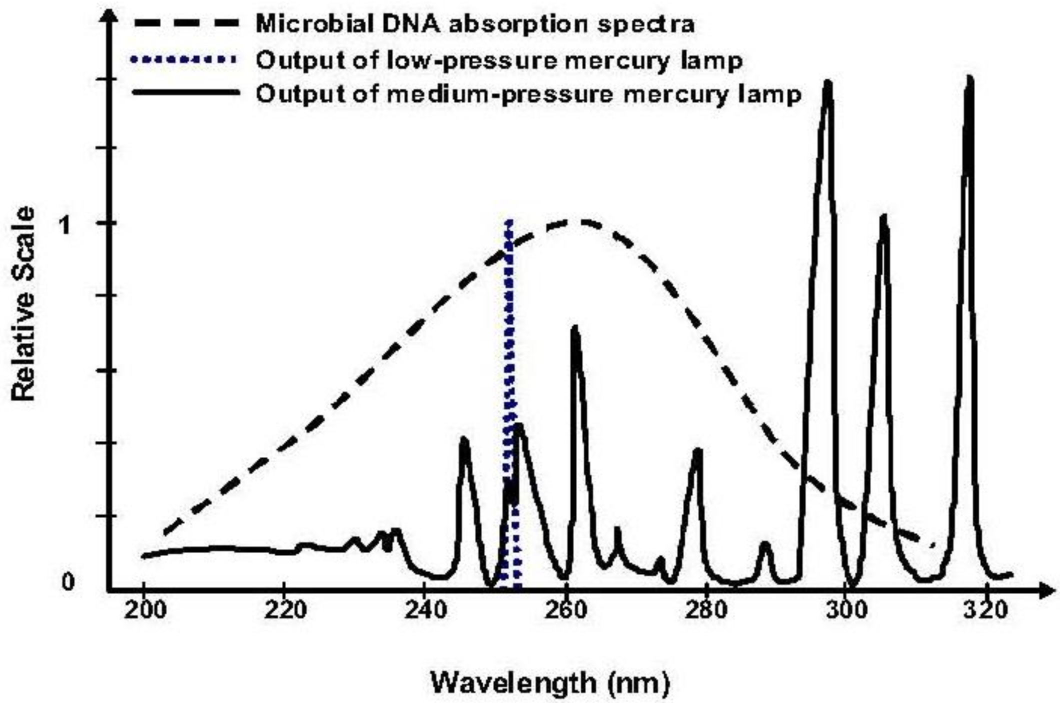


Figure 2-2
Output Spectra of Low- and Medium-Pressure Lamps and Microbial DNA Absorption Spectra – Not to Scale (Source: Kuo *et al.,* 2003)

Table 2-3: Comparison of Available UV Lamp Technologies

Lamp Type	LPLO	LPHO	High-Wattage LPHO	MP
Spectrum	Monochromatic	Monochromatic	Monochromatic	Polychromatic
Input Power (W/lamp)	70 – 90	200 – 400	600 – 1,000	1,300 – 5,000
Germicidal UV (as % input power)	40 – 45	35 – 40	30 – 35	15 – 20
Temperature (degrees C)	40 – 60	100 – 200	100 – 300	600 – 900
Lamp Life (hours)	8,000 – 13,000	8,000 – 12,000	Up to 15,000	3,000 – 5,000
Lamps Relative to MP System	10 – 15	4 – 8	1 – 3	1
Relative Footprint	Large	Medium	Small	Small

LPHO systems are widely used at WRRFs due to their energy efficiency, long lamp life, and lower operating temperature compared to MP lamps. The reduced operating temperature of the LPHO lamps results in less fouling and reduced maintenance.

Due to their polychromatic output, MP lamps can emit the wavelengths of light that are used by algae in their photosynthetic processes; hence, algae growth can be a problem in systems using MP lamps.

2.2.1.3.2 Lamp Power Supply and Ballast System

The power supply and ballast provide the necessary power to energize and operate the UV lamps. Power supplies and ballasts are available in many different configurations and are usually specific to a unique lamp type and application.

UV systems may use electronic ballasts or transformers. Electronic ballasts and transformers are solid state, modular (plug-in design), and energy efficient, and allow variation in the power supply to the lamps. In most designs, the electronic ballasts/transformers allow the lamps to be dimmed which provides for a more cost-effective use of the lamps and avoids turning lamps on and off. Electronic ballasts/transformers are specific for each manufacturer and can be located above the water level, in panels, or in a separate air-conditioned building. An example of a ballast cabinet is shown in **Figure 2-3**.

Figure 2-3
Ballast Cabinet (Trojan Technologies TrojanUVSigna™)

2.2.1.3.3 Reactors and UV System Configuration

Reactor design should optimize UV delivery dose and hydrodynamics (*e.g.*, through lamp placement, inlet and outlet conditions, and baffles) while providing redundancy and flexibility for variations in flow rates and water quality. There are generally two types of reactors, open-channel and closed-vessel reactors. Within the open channel reactor, UV lamps can be arranged in horizontal, vertical or inclined configurations. In all cases, appropriate water level control is required to ensure proper submergence of the UV lamps during all flow conditions.

Open-channel gravity UV disinfection systems consist of one or more channels with multiple banks of UV lamp modules spanning the width of each channel. A bank of lamps consists of one or more modules. Each module consists of a number of lamps. The number of lamps per module is dependent on the UV manufacturer's design and varies according to the design treatment capacity, water quality and head loss requirements. Open-channel systems are available with either LPHO, high-wattage LPHO or MP lamps.

In a multichannel design, it is of the utmost importance to provide a uniform flow split among channels as well as to ensure that the flow velocity profile is relatively uniform before the first module in the UV system. These goals can be achieved using good engineering practices during coordination with the UV manufacturer to provide the minimum straight length upstream of the system. In retrofit applications where space may be limited, computational fluid dynamics modeling is recommended to verify the flow split.

2.2.1.3.3.1 Horizontal Open-Channel Systems

In horizontal UV systems, LPHO or MP lamps are arranged in modules, with each module consisting of a stack of lamps oriented parallel to the direction of flow. Modules are placed side by side into the UV channel in a series of multiple-module banks, the configuration of which is dependent on the specific installation. Within each module, lamps are each installed inside a quartz sleeve. The modules are connected to their corresponding ballasts, located on the top of the module. A programmable logic controller (PLC), connected to each module, monitors the status of each lamp and controls output from the module. **Figure 2-4** shows the horizontal UV system.

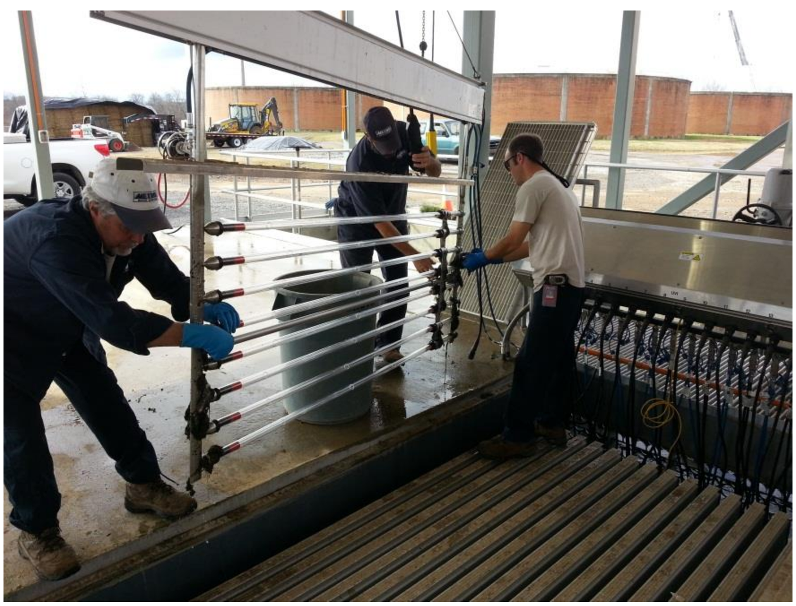


Figure 2-4
Horizontal Open-Channel UV System at MWS White's Creek WPCF

Transmittance of the quartz sleeves is maintained through the use of an automatic cleaning system. Trojan Technologies' cleaning system includes the use of in situ chemical injection to enhance the mechanical wiper's cleaning capabilities. For Trojan and other manufacturers, a hoisting or lifting system must be provided to allow the modules to be removed for replacement of lamps. Major manufacturers of horizontal open-channel UV systems include Calgon Carbon Corporation, Trojan Technologies, and Wedeco.

2.2.1.3.3.2 Vertical Open-Channel Systems

In vertical UV systems, modules are placed into the UV channel in a series of multiple-module banks, the configuration of which is dependent on the specific installation. Within each module, lamps are each installed inside a quartz sleeve, with all electrical connections above the water level and accessible from above the channel. The modules are connected to their corresponding ballasts, located either in the top of the module or remotely in separate enclosures. A PLC is connected to each module and monitors the status of each lamp and controls output from the module. **Figure 2-5** shows the modules of a vertical UV system.

Figure 2-5
Vertical Open-Channel UV System at Massard WPCF, Fort Smith, Arkansas

The sleeves in vertical modules are cleaned using a mechanical wiper plate, which has individual wipers for each sleeve and travels up and down the length of the sleeves. In addition to the wiper plate, an external chemical cleaning tank is usually provided as part of the system to aid in cleaning. One feature of

Ozonia North America's vertical-lamp systems is an optional air scour system, which can be used in-channel to remove any settled debris or algae in the channel, or in the external chemical cleaning tank. This air scour system, when combined with the mechanical wiper system in the cleaning tank, provides more effective sleeve cleaning. A hoisting system such as a jib crane or overhead bridge crane must be provided to allow the modules to be removed for periodic chemical cleaning. Ozonia's recently-introduced Aquaray™ HiCap® system reduces the need for lifting equipment by providing a built-in module lifting system.

2.2.1.3.3.3 Inclined Open-Channel Systems

Trojan Technologies, which has traditionally manufactured horizontal systems, recently introduced its TrojanUVSigna™ inclined systems to the market. This system, designed for large-scale retrofits of older plants that are converting from older style medium-pressure UV systems or chlorine disinfection to UV disinfection, places the lamps at an angle slightly off of vertical. **Figure 2-6** shows an inclined UV system in Auburn, Alabama. The Wedeco Duron® system is also an inclined open-channel UV system.

Figure 2-6
Inclined, Open-Channel UV System at H. C. Morgan WPCF, Auburn, Alabama
(UV module raised to service position)

The inclined system includes an automatic chemical/mechanical cleaning system, as well as an automatic bank raising mechanism that lifts the bank out of its channel for servicing. This mechanism can eliminate the need to install an overhead bridge crane or jib crane, which can provide construction cost savings. Control of the automatic cleaning system and the bank raising mechanism requires installation of an additional hydraulic system center enclosure along with the ballast enclosures.

Because inclined systems are relatively new to the market, there are significantly fewer inclined-lamp UV installations compared to horizontal and vertical systems. According to Trojan Technologies, the first inclined system in the U.S. was installed at the H.C. Morgan WPCF in Auburn, Alabama. Wedeco has two installations in the Capital District with one at the Rensselaer County Sewer District's WWTP and another at the Albany County Sewer District's South WWTP.

The advantages and disadvantages of vertical- versus horizontal-lamp arrays in open-channel systems have been debated extensively. In some cases, the hydraulics of the plant or the configuration of existing chlorine contact tanks being retrofitted can affect the decision. In all cases, appropriate water level control is required to provide proper submergence of the UV lamps during all flow conditions. With vertical systems, individual lamps can be easily replaced while leaving the lamp module in the channel.

The water level at the top of the lamps can vary up to a few inches in the vertical lamp system, while the water level in a horizontal system must be kept relatively constant and close to the top of the lamps to avoid short circuiting of flow which can lead to ineffective disinfection.

Table 2-4 compares some of the qualitative aspects of horizontal, vertical and inclined UV systems.

Table 2-4: Qualitative Comparison of Horizontal, Vertical and Inclined UV Systems

Evaluation Category	Horizontal Systems	Vertical Systems	Inclined Systems
Disinfection Effectiveness	Proven effectiveness Water level must be kept relatively constant Increased possibility of flow short-circuiting if a lamp burns out	Proven effectiveness Water level can vary by up to a few inches Reduced possibility of flow short-circuiting if a lamp burns out	New design; over a dozen systems installed including ACSD and RCSD Tolerant of water level fluctuations
Lamp Maintenance	Module must be removed from the channel prior to replacing a bulb	Lamps can be replaced without removing the module from the channel	Lamps can be replaced without removing the module from the channel
Ballast Maintenance	Ballasts located above modules or in a cabinet (depends on the system) Module may have to be removed from the channel prior to replacing ballasts	Ballasts located above modules or in a cabinet (depends on the system) Ballasts can be replaced without removing the module from the channel	Ballasts located in a cabinet Ballasts can be replaced without removing the module from the channel
Cleaning Systems	Mechanical or chemical or a combination of the two (depends on the system)	Mechanical wiper system and chemical dip tank (usually only needed bi-annually) Ozonia offers air scour system that can be used in the dip tank	Chemical and mechanical

Evaluation Category	Horizontal Systems	Vertical Systems	Inclined Systems
Dosage Control and Flexibility	Output of each lamp can be turned down to 50 to 60 percent of maximum power All lamps in a module must be powered to achieve disinfection Operating at lower output expends lamp life	Individual rows or half banks of lamps can be turned off in response to decreasing flow Possible to turn down output to less than 20 percent of the total module capacity Some systems (*e.g.*, Ozonia) can turn down individual row lamp output	Output of each lamp can be turned down to 30 percent of maximum power Banks or rows of lamps can be turned off in response to decreasing flow
Electrical Connection	Power connectors located below the operating water level	Individual lamp power connectors above operating water level	Individual lamp power connectors above operating water level
Risk of Flood Damage	Electrical components are submergence-rated Maintaining seals can be labor-intensive	Reduced risk if ballasts are located in a cabinet	Reduced risk due to rack-mounted ballasts located above channel
Risk of Debris Collection	Debris can pass through without getting trapped on the sleeves	More potential for debris collection at influent end Stringy solids (*e.g.*, algae) can get trapped on the sleeves Floating materials can be deposited on upper surfaces of sleeves exposed to air	Reduced potential for debris collection compared to vertical system
Head Loss	Generally higher net system head loss	Generally lower net system head loss	Headloss is managed through a unique level control weir structure
Ancillary Equipment Requirements	Influent and effluent control gates UV intensity monitor Online UVT analyzer High/low water level alarms Emergency backup power Jib crane	Influent and effluent control gates UV intensity monitor Online UVT analyzer High/low water level alarms Emergency backup power Jib crane	Influent and effluent control gates UV intensity monitor Online UVT analyzer High/low water level alarms Emergency backup power Hydraulic System Center (HSC) for cleaning system and bank raising mechanisms
Retrofit Considerations	Ballast cabinet location determines HVAC requirements	Ballast cabinets can be located outdoors Cabinet location determines HVAC requirements	Ballast cabinets can be located outdoors Channel inserts reduce reliance on concrete channel wall tolerances

2.2.1.3.3.4 Closed Vessel Systems

In a closed-vessel UV system, UV lamps are enclosed in a reactor, which is installed in a straight section of pipe that contains lamps that may be mounted perpendicular (cross-flow) or parallel (axial-flow) to the direction of flow. Valves upstream and downstream of each reactor are usually required to isolate the reactor for maintenance or repair. Automatic, mechanical and chemical-based cleaning systems are available. Closed-vessel UV systems have a smaller footprint due to their compact size, and they reduce the risk to operators by eliminating open channels and enclosing the UV lamps; however, many operators prefer to have easier access to the reactor for visual inspection and, in some cases, maintenance. **Figure 2-7** shows a closed-vessel system in Smyrna, GA.

Closed-vessel UV systems are available with either low- or medium-pressure lamps. Manufacturers such as ETS and Trojan Technologies offer LPHO and high-wattage LPHO systems, but these products are usually limited to high-level reuse or drinking water disinfection applications.

Figure 2-7
Closed-Vessel UV System at R.L. Sutton WRF, Smyrna, Georgia

2.2.1.3.4 Cleaning Mechanisms

The quartz sleeves/jackets that encase the lamps can be cleaned mechanically, chemically or using a combination of both methods. Cleaning is important to maintain transmittance of UV light through the quartz jackets, and most UV systems include a mechanical cleaning device. The mechanical cleaning device is a scraper or wiper that moves along the quartz jacket and removes any extraneous material and fouling. Mechanical wipers may be actuated pneumatically, electrically or hydraulically and can be timer controlled. If mechanical cleaning is used, cleaning takes place in-channel, so there is no need to remove a module or bank from the channel or even to remove it from service during cleaning.

2.2.1.3.5 Process Control and Online Monitoring

The complex interaction of factors affecting UV dose makes disinfection efficiency difficult to calculate or measure directly. However, delivery of the correct UV dose at the correct time is the key to providing compliance with discharge permit limits. As a result, process control is essential to successful UV operation. In order to maintain system control, both manual and automated methods may be used. There are two basic types of automated control: flow-paced and dose-paced. Flow-paced control adjusts the number of lamps in service (or percent power for variable power systems) based on the influent flow rate. This type of control is often used alone on LPLO systems, but can be integrated with other forms of control, which is typical on LPHO or MP systems. Dose-paced control is based on a calculated dose, derived from the flow rate, online UVT data and lamp power (including lamp age and online intensity sensor output). This type of control is more commonly used in MP systems with either online UV intensity or UVT monitors that allow dose adjustments in response to changing lamp output and water conditions. Automated controls should only be applied over the range of water quality and operational conditions for which the system has been validated.

2.2.1.4 Advantages/Disadvantages

The primary advantages of UV disinfection of CSO include:

- Eliminates the need to generate, handle, transport, or store disinfectant chemicals
- No known toxic byproducts are produced
- Eliminates the harmful effects that disinfectant residuals can have on human or aquatic life
- Short contact time
- The UV process is not dependent on the concentration of ammonia or nitrate
- Smaller footprint compared to other disinfection technologies
- Ability to deactivate wide range of pathogens

Disadvantages of UV disinfection of CSO are:

- Interference due to high solids loading associated with typical CSO "first flush" wastewater quality
- Large numbers of UV lamps required given the high CSO flow rates and variability in water quality
- Fouling of UV lamps
- Operation and maintenance cost required to sustain proper disinfection
- Safety considerations associated with the UV light
- UV is an innovative technology for CSO treatment, with limited full-scale CSO application data

2.2.2 Chlorination/Dechlorination

2.2.2.1 Chlorination

Chlorine has been the most widely used disinfectant for wastewater, CSO and potable water applications in the United States due to its low cost, reliable disinfection capabilities, and adequate supply. Chlorine is available in many forms including chlorine gas and chlorine products such as sodium and calcium hypochlorite. Liquid sodium hypochlorite has become widely used for wastewater disinfection due to its reliability and ease of handling. Sodium hypochlorite can be purchased in bulk forms of 12 to 15 percent available chlorine or can be manufactured on site. Bulk liquid sodium hypoclorite has limited shelf-life and is subject to loss of available chlorine content by decay to chlorine gas. For the application of CSO disinfection, bulk liquid sodium hypochlorite is often stored at a 5% concentration, which increases the storage volume needed at the site, but minimizes the available chlorine content decay. Alternatively, the chemical tanks could be maintained in a temperature controlled setting to help prolong the shelf-life of the sodium hypochlorite.

This type of disinfection has worked well due to the low resistance of *E. coli* to chlorine. Sufficient mixing, contact time, and dosages are necessary to maximize the use of chlorine disinfection.

Chlorination serves primarily to destroy or deactivate disease-producing microorganisms. Generally, bacteria are more susceptible to chlorination than viruses. The disinfection effectiveness is largely a function of the chemical form of the disinfecting species. Chlorine is applied to the waste stream in molecular (Cl_2) or hypochlorite (-OCl) form. Chlorine initially undergoes hydrolysis to form “free” chlorine consisting of hypochlorus acid (HOCl) and hydrochloric acid (HCl):

$$Cl_2 + H_2O \longrightarrow HCOl + HCl$$

Hypochlorus acid can further dissociate depending on pH and temperature to hypochlorite:

$$HOCl \longrightarrow -OCl + H+$$

A combination of hypochlorus acid and hypochlorite ion (i.e., “free” chlorine) exists at a neutral pH. Both contribute to the disinfection process; however, hypochlorus acid is the more effective disinfectant. Further reactions can occur if ammonia nitrogen is present in the CSO or wastewater to form compounds called chloramines. Formation of chloramines occurs under the following ordered processes:

$$NH_3 + HOCl \rightarrow NH_2Cl \text{ (monochloramine)} + H_2O$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 \text{ (dichloramine)} + H_2O$$

$$NHCl_2 + HOCl \rightarrow NCl_3 \text{ (Trichloramine)} + H_2O$$

These reactions are complex and the products can vary with time, ammonia present, and chlorine added. Monochloramine is the most effective chloramine, and it has a fast reaction and is formed first. Dichloramine reacts much slower, is formed after monochloramine, and has a lower efficacy compared to monochloramine. When chlorine is added to a CSO it will react with other compounds, in addition to the ammonia. These other compounds are called Chlorine Reducing Compounds (CRC), and they can generate a chlorine demand, which increases the amount of chlorine required to achieve the desired microbial inactivation. In addition to CRC, there are organic nitrogen compounds that react with chlorine to form organic chloramines. These are often confused with inorganic chloramines (mono-, di-, and trichloramine), and they have little or no germicidal properties. Collectively, chloramines are referred to as combined chlorine residual. The sum of free residual and combined chlorine residual is referred to as total residual chlorine (TRC) representing all forms of chlorine and toxicity to the receiving water. Previous EPA studies on CSO disinfection (EPA, 1975; EPA, 1979) have demonstrated the effectiveness of using high-rate mixing to increase disinfection performance and reduce contact time.

2.2.2.2 Dechlorination

Dechlorination is accomplished by reacting residual chlorine with a reducing agent; this process is generally a regulatory requirement based on water quality criteria to reduce the potentially toxic effects of free or combined chlorine on aquatic organisms. Based upon anticipated permit requirements related to disinfection at Big C, a dechlorination system is required if chlorine is used for disinfection. The most frequently used dechlorination agents are sulfur dioxide gas (SO_2) and liquid bulk sodium bisulfite ($NaHSO_3$).

Sulfur dioxide is a toxic gas, with federal Risk Management Plan (RMP) and Process Safety Management (PSM) thresholds of 5,000 pounds and 1,000 pounds, respectively. Sodium bisulfite, on the other hand, is not subject to RMP or PSM requirements. As a result, sodium bisulfite would be recommended as the means of dechlorination.

The chemical reactions for dechlorination with sodium bisulfite for free chlorine and monochloramine follow:

$$\mathrm{NaHSO_3} + \mathrm{Cl_2} + \mathrm{H_2O} \rightarrow \mathrm{NaHSO_4} + 2\mathrm{HCl}$$

$$\mathrm{NaHSO_3} + \mathrm{NH_2Cl} + \mathrm{H_2O} \rightarrow \mathrm{NaHSO_4} + \mathrm{Cl^-} + \mathrm{NH_4^+}$$

A potential problem with dechlorination is the possible depletion of dissolved oxygen by excess sulfite ion, so overdosing of sodium bisulfite should be avoided.

2.2.2.3 Operation and Maintenance Considerations

Sodium hypochlorite is stored in bulk storage tanks and is delivered to the injection point(s) via metering pumps. PVC piping is typically used to convey sodium hypochlorite. Chemical suppliers typically provide sodium hypochlorite between a 12.5 and 15 percent solution, by weight.

Like sodium hypochlorite, sodium bisulfite is stored in bulk storage tanks and delivered to the injection location via metering pumps. PVC piping is typically utilized for conveying sodium bisulfite. Sodium bisulfite does not require the same amount contact time, if well mixed, as sodium hypochlorite, as the dechlorination reaction occurs in 30 seconds (WERF, 2008). Sodium bisulfite solution freezes at 43°F, so this chemical will need to be stored in an enclosed, temperature controlled building.

2.2.2.4 Advantages/Disadvantages

The primary advantages of chlorination/dechlorination disinfection of CSO are:

- Widely used and accepted for many areas of disinfection
- Relatively low cost

Disadvantages of chlorination/dechlorination disinfection of CSO are:

- Produces toxic by products
- Short chemical shelf life
- Reacts with ammonia to form chloramines
- Corrosive nature of chlorine
- Disinfection effectiveness is pH dependent and is reduced at high pH (e.g., at pH greater than 8)

- Possible dissolved oxygen depletion of dechlorinated effluent
- Safety considerations associated with chlorination and dechlorination disinfection systems
- Two processes are necessary which requires double the storage facilities, pumping equipment, etc.

2.2.3 Peracetic Acid

Peracetic acid or PAA is an equilibrium mixture of hydrogen peroxide and acetic acid that is reacted and stabilized using proprietary additives. While this chemical has been applied to the food, beverage, medical and pharmaceutical industries for decades, its use has recently expanded to include wastewater treatment facilities, mainly in Europe. More recently, both the USEPA and the Canadian PRMA have approved PAA for use as a disinfectant to treat wastewater and CSO applications.

2.2.3.1 PAA Chemistry and Kinetics

Water quality parameters that may affect the performance of PAA include suspended solids, temperature, and pH. As with all disinfection technologies, suspended solids may shelter pathogens from disinfectants. Like chlorine, the disinfection efficacy of PAA decreases as temperature decreases, although PAA is less sensitive than chlorine to pH changes. PAA, however, is much less impacted by varying organics in the water, specifically nitrite and ammonia.

PAA is applied and controlled much like a bulk sodium hypochlorite; however, because of its chemistry, the CT (concentration x time) approach that has been applied to wastewater disinfection systems in North America, while long-successful, is not fully adequate to assess the effectiveness of PAA disinfection because of deviations from first order kinetics. There are a number of models that have been developed to address these deviations, and most are generalizations of the Chick–Watson formula. Among the published models, Hom's model (**Equation 2-2**) is probably the most widely used to account for deviations from the first-order kinetics of the Chick-Watson formula.

Equation 2-2:

$$log\left(\frac{N}{N_0}\right) = -L_S C^n t^m$$

Where:

Ls = the disinfection rate constant otherwise known as the specific coefficient of lethality and depends on the target organism (here, *E. coli*) and other factors such as bacterial association with total suspended solids (TSS)

C = the residual PAA concentration, mg/L

t = contact time, min

Where $n < m$, *t* (contact time) is the primary factor affecting inactivation and longer contact times will provide additional disinfection benefit

Where $n \sim m$, *t* (contact time) and PAA residual are similar in their effect on inactivation.

Where $n > m$, chemical residual overrides contact time with respect to disinfection efficacy.

When $m < 1$, there can be a tailing-off behavior at very long contact times.

In Hom's model, *m* is used to account for the shorter half-life of PAA (illustrated by the shoulders or tailing which may occur from a number of different factors). The model has been validated in several studies showing that Hom's model is the most appropriate for describing PAA disinfection of secondary wastewater effluent for coliform organisms. These studies evaluated PAA because of the need to address process control for disinfection at these facilities. There are two variations of Hom's model that describe disinfection efficiency. One model is applicable at low doses, generally in the range of 1 – 2 mg/L at long contact times, where the reaction is time dependent with an initial lag in PAA action for lower doses which is likely due to an initial resistance to diffusion throughout cellular membrane. The second is applicable at higher doses, >5 mg/L, where there is no impact of concentration based diffusion gradients approaching the target microorganisms. Bench and pilot scale studies which have been conducted have allowed clarification of model application for disinfection performance at doses between 2–5 mg/L; where, in this range, the model is site specific. Thus, the model parameters are typically empirically derived from site-specific testing allowing the appropriate kinetic parameters to be developed for the application.

The standard CT model utilizes residual concentration and time which are fitted to an exponential decay equation (**Equation 2-3)**:

Equation 2-3:

$$C = (C_0 - D) * e^{-kt}$$

Where:

C = the concentration of PAA at time, t

Co = the applied dose of PAA,

D = the instantaneous demand exerted by the wastewater

k = the specific decay rate of PAA

t = time

Another predictive model that can be utilized is the integral CT method, but uses a more complex correlation between CT and log inactivation. In this model, the bacterial population is divided into two parts, an easy to inactive portion which represents free floating bacteria, and a hard to inactivate portion, which represents particle associated bacteria. This relationship is descried by the following equation, (**Equation 2-4)**:

Equation 2-4:

$$N = N_o * fNd * e^{-k_d * CT} + N_o * fNp * e^{-k_p * CT}$$

Where:

N = the number of viable bacteria, MPN/100 mL

N_o = the number of bacteria in the wastewater prior to disinfection, MPN/100 mL

fNd = the fraction of the bacterial population that is "easy to inactive"

k_d = the specific decay rate of the "easy to inactive" bacteria

fNp = the fraction of the bacterial population that is "hard to inactive"

k_p = the specific decay rate of the "hard to inactive" bacteria

The results from the bench testing will determine which model will be utilized to best fit the data.

2.2.3.2 Design Approach for PAA Disinfection Systems

In order to apply the design approach that leverages the unique kinetics of PAA disinfection, a brief sampling and bench testing program are usually recommended prior to implementation to allow for collection of information on pre- and post-disinfection bacteria concentrations, disinfection dose and residual as well as contact time.

Once this information is obtained, the system may be sized and designed. The components of a PAA feed system are similar to typical sodium hypochlorite feed systems consisting primarily of bulk storage with secondary containment, suction and discharge piping, chemical metering pumps and controls, residual analyzers, and an injection point into a contact tank designed to provide contact time at peak flow. Peracetic acid does not require highly specialized equipment or instrumentation. Implementing PAA includes design and construction of a chemical feed and storage system along with any site improvements necessary to support the system, such as instrumentation and controls, electrical, site/civil upgrades (i.e., improving roads for access and providing dedicated chemical off-loading areas or providing adequate potable water), or control buildings where appropriate.

PAA is recommended to be stored in either linear HDPE tanks or in passivated stainless steel tanks. The piping should be passivated Type 316 stainless steel piping and fittings. A Material Safety Data Sheet (MSDS) on VigorOX II, a commercially available 15 percent concentration PAA solution is included in **Appendix C**. The MSDS provides a summary of storage and handling recommendations, health impacts, physical and chemical properties, toxicological and ecological data, disposal and regulatory information. PAA is stable for 12 to 18 months, so no special provisions are recommended for storage or chemical turnover.

2.2.3.3 Operations and Maintenance Considerations

PAA can be delivered in totes or bulk deliveries (4,500 to 4,700 gallons). Typical lead time for bulk shipments or drums/totes is less than a week. A 30-day chemical storage supply is recommended for this type of system. Staff should wear appropriate personal protective equipment when working with this system.

Once the facility has been designed, the simplest process strategy for managing a PAA disinfection system includes dose pacing and has proved successful where effluent quality is fairly consistent. However, since there will be a wide variation in flow and water quality at Big C, a process control approach that includes residual control may provide cost saving opportunities. Additionally, when there are temporal variations in PAA demand, it may be useful to identify and provide a feed forward signal for the relevant process control parameter once that has been determined.

2.2.3.4 Lifecycle Costs of PAA Disinfection

In order to develop a lifecycle cost for a PAA project, operations and maintenance time related to operating the system, receiving deliveries, maintaining equipment, optimizing the system operation to reduce chemical cost and performing preventative maintenance to keep the system operating at peak efficiency must be considered. The sales market for PAA serving municipal wastewater applications in North America is new and evolving. Currently, the purchase of PAA is limited to a few companies (PeroxyChem, Solvay, EnviroTech and U.S. Peroxide) that have registration for three PAA blends

(Vigorox WWT II, Proxitane WW-12, and PeraGreen 22WW). The procurement method for a PAA project could utilize of several approaches:

- Option 1 - Lease of chemical storage and feed equipment and purchase of chemical (similar to chlorine dioxide) with the Owner or the PAA Provider operating and/or maintaining the system.
- Option 2 - Chemical contract for disinfection paid for based on a dollar per million gallons of treated effluent, with the PAA Provider providing a complete package for operation and maintenance.
- Option 3- Installation of the Owner's own equipment and with the Owner operating and maintaining this equipment with a straight chemical purchase contract.

There are many advantages and disadvantages to each of these approaches and these are a function of staff availability and Owner preferences. The Owner's approach to how much of the system it owns and operates versus what it relies on the PAA Provider to provide and perform has different cost impacts to the project. For the purposes of this evaluation Option 1 was utilized.

2.2.3.5 Advantages/Disadvantages of PAA Disinfection

Peracetic acid has been demonstrated to be an effective disinfectant, requiring low doses of chemical to achieve bacterial inactivation in wastewater effluent.

Advantages of PAA include:

- Fast kinetics;
- Very short contact time requirements; and
- Problematic halogenated DBPs such as trihalomethanes (THMs), including DCBM, are not produced.

Disadvantages of PAA include:

- Limited use when compared to other, more mature disinfection technologies such as chlorination and UV disinfection. However, given the increasing number of installations for disinfection in North America, this will likely be a short-lived disadvantage. Until there are installations that are approved in individual states, pilot testing and regulatory coordination for permitting this relatively new technology may require additional time before the process can be implemented. Its use may require a pilot study to be performed.
- PAA will add carbonaceous bio-chemical oxygen demand (CBOD) to the CSO discharge. Because of the acetic acid component of the PAA solution, approximately 0.4 – 1.2 mg/L of CBOD is add per 1 mg/L of active PAA depending upon the formulation of PAA utilized.

2.2.4 Design Considerations

In order to compare the life cycle costs of the disinfection alternatives design criteria must be established and utilized as the basis for the development of costs for each technology. The key factors impacting the design criteria are flow rate and indicating organism inactivation.

2.2.4.1 Flow Rate

As discussed previously, two different flow rates will be utilized to evaluate the disinfection alternatives, one set for the Broadway site, and one set for the Lincoln Park site. **Table 2-5** summarizes the flow rates utilized during this evaluation.

Table 2-5: Design Criteria – Flow Rates

Location	Minimum (MGD)	Design (MGD)	Annual Volume Treated (MG)
Broadway	12	75	285
Lincoln Park	19	100	340

2.2.4.2 Indicating Organism Inactivation

Any disinfection system utilized at the Big C Screenings and Disinfection Facility must be able to meet the seasonal (May 1 through October 31) permit limits set forth by the Department, however at this time a permit has not been issued for this facility. In order for disinfection systems to be sized, assumptions need to be made on both the indicating organism to be utilized in the permit and the corresponding indicating organism limits, as well as the necessary log inactivation of the selected indicating organism.

2.2.4.2.1 Indicating Organism and Limits

The Environmental Protection Agency (EPA) published an update to the Recreational Water Quality Criteria (RWQC) in November 2012. The new RWQC recommendations may be adopted by primacy states, which include New York to establish water quality standards. As a primacy state, New York must adopt, at a minimum, the new RWQC recommendations but may adopt more stringent requirements if desired. The new 2012 RWQC rely on the latest research and science, including studies that show a link between illness and fecal contamination in recreational waters. They are based on the use of two bacterial indicators of fecal contamination, *E. coli* and enterococci. The new criteria are designed to protect primary contact recreation, including swimming, bathing, surfing, water skiing, tubing, water play by children, and similar water contact activities where a high degree of bodily contact with the water, immersion and ingestion are likely.

The 2012 RWQC recommendations consist of three components: magnitude, duration and frequency. The magnitude of the bacterial indicators is described by both a geometric mean (GM) and a statistical threshold value (STV) for the bacteria samples. The STV approximates the 90th percentile of the water quality distribution and is intended to be a value that should not be exceeded by more than 10 percent of the samples taken. Water quality criteria recommendations are intended as guidance in establishing new or revised water quality standards, and the EPA has provided two recommendations for magnitude as shown in **Table 2-6**. With respect to duration and frequency, the recommendations specify that the water body GM should not be greater than the selected GM magnitude in any 30-day interval. There should not be greater than a ten percent excursion frequency of the selected STV magnitude in the same 30-day interval. One of the key changes from the previous RWQC is the recommendation to use an STV instead of a daily maximum.

Table 2-6: Summary of 2012 RWQC Recommendations for Magnitude

Criteria Elements	Recommendation 1 Estimated Illness Rate 36/1,000		Recommendation 2 Estimated Illness Rate 32/1,000	
Indicator	**GM (cfu/100 mL)**	**STV (cfu/100 mL)**	**GM (cfu/100 mL)**	**STV (cfu/100 mL)**
Enterococci (marine & fresh)	35	130	30	110
E. coli (fresh)	126	410	100	320

For the purposes of this disinfection alternative evaluation Enterococci will be utilized as the indicating organism. For the sizing of the disinfection technologies the limits from Recommendation 1, specifically the geometric mean value of 35 CFU/100mL.

2.2.4.2.2 Log Inactivation

In an effort to develop a conceptual set of design criteria for each disinfection technology, a wet weather event was sampled and analyzed. Three samples were collected at a drop structure in the upper section of Lincoln Park (near the proposed Lincoln Park site of the facility) during a wet weather event on the morning of June 5, 2016. Samples were collected, packaged and shipped to CDM Smith's laboratory in Bellevue, Washington for analysis. Each sample was tested for both *E. coli* and Enterococci without any chemical disinfectant (PAA or Sodium Hypochlorite) added, and then after 15 minutes at various chemical doses. The purpose of the testing was to help establish the bacteria counts of the non-disinfected wet weather flow, which in turn would be utilized to develop the conceptual log inactivation required. In addition, the testing would determine the conceptual chemical disinfectant dose necessary to achieve the conceptual log inactivation. The results of this preliminary testing are summarized in **Table 2-7** below.

To determine the conceptual log inactivation of enterococci to be applied for this disinfection alternative evaluation, the maximum non-disinfected enterococci count from the sampling event was utilized (120,330 CFU/100mL). Therefore, the required conceptual log inactivation is:

- *Conceptual Log Inactivation Rate Required:* $\log(1.2 \times 10^5) - \log(3.5 \times 10^1) = 3.5$

Table 2-7: Summary of Results from June 5, 2016 Sampling after 15 Minute Contact Time

Disinfectant & Dose	CSO Sample 1		CSO Sample 2		CSO Sample 3	
	E. coli (CFU/100 mL)	Entero (CFU/100 mL)	*E. coli* (CFU/100 mL)	Entero (CFU/100 mL)	*E. coli* (CFU/100 mL)	Entero (CFU/100mL)
Non-disinfected	68,000	120,330	100,800	86,640	79,000	92,080
Chlorine						
3 mg/L	889	110	161	75	85	41
6 mg/L	10	<10	<10	<10	10	<10
12 mg/L	<10	<10	<10	<10	45	30
20 mg/L	<10	20	<10	<10	<10	20
PAA						
2 mg/L	2,187	>24,169	10,462	19,863	1,182	>24,196
4 mg/L	197	571	145	266	663	728
8 mg/L	241	41	41	20	96	20
12 mg/L	98	75	145	31	107	41

2.2.4.3 Additional Design Criteria

The Chlorination/Dechlorination and PAA disinfection systems are sized based upon the amount of chemical that needs to be delivered and the contact time required to achieve the desired indicating organism inactivation. For this evaluation, the chemical doses required to achieve the conceptual log inactivation rate of 3.5 were based upon the analyses performed on the samples collected on Jun 5, 2016. The log inactivation rates vs. chemical doses observed are shown in **Figure 2-8.**

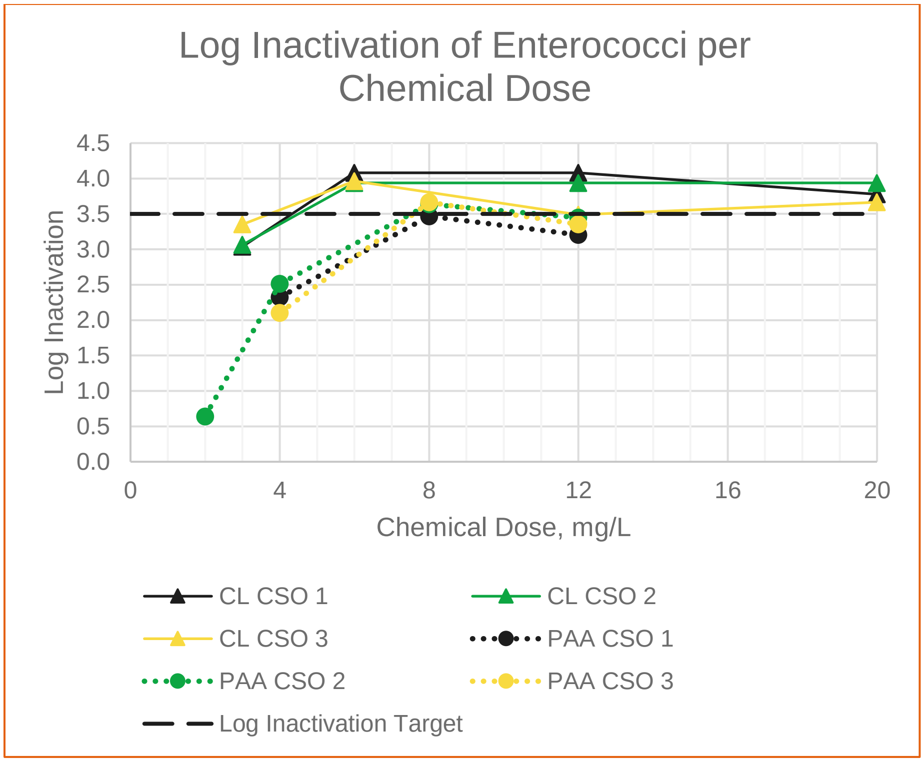


Figure 2-8
Log Inactivation of Enterococci vs. Chemical Dose

Based upon this information the Chlorination/Dechlorination system will be sized based upon an average dose of 6 mg/L. The initial bench testing showed that a PAA dose of 8 mg/L will achieve the desired 3.5 log inactivation of enterococci, however studies have shown that a mixing factor needs to be utilized when applying doses from bench or scaled pilot tests to full scale applications. Typically that mixing factor is 30 percent, which will be applied in this evaluation of PAA. Therefore, the PAA system will be sized utilizing an average dose of 10.4 mg/L. Both alternatives will utilize a 15 minute contact time for the purposes of this evaluation.

The sizing of the UV disinfection system will also be based upon a conceptual log inactivation of 3.5 for enterococci and a UVT value of 30 percent based upon the UVT analyses performed on the three CSO samples (31.1, 38 and 37.7 percent UVT).

2.2.5 Life Cycle Costs

This section provides a description of the assumptions and other detailed information necessary to estimate construction and operations and maintenance costs for each of the process alternatives described earlier in this section. These alternatives have been sized to meet a conceptual log inactivation rate of 3.5 for enterococci, a seasonal disinfection requirement, as well as any relevant requirements outlined in the *Ten States Standards,* with the exception being the UVT design criteria.

2.2.5.1 UV Disinfection

While UV is considered to be an innovative technology for CSO applications there remains limited full-scale CSO application data. Based upon the analysis, UV disinfection is not recommended for treatment of combined sewer flows at Big C due to the high variability and seasonal characteristics of the water quality conditions indicative within the system (e.g., TSS and large particle sizes characteristic of first flush of runoff). These conditions would likely cause interference or fouling of the UV lamps; thereby degrading performance of the technology due to the high solids loadings. The use of a high rate treatment system would likely be required prior to the UV disinfection which would render this alternative as cost prohibitive. In addition, this alternative would require high energy usage based on the large number of UV lamps required, and have significantly higher long-term operational and maintenance costs. As a result, UV disinfection will no longer be considered as a viable alternative for the project.

2.2.5.2 Bulk Liquid Chlorination/Dechlorination

A bulk liquid chlorination/dechlorination system at either site would include the construction of the following:

- Chlorine contact tank with 15 minute contact time
- Liquid sodium hypochlorite storage and feed room
- Liquid sodium bisulfite storage and feed room
- Electrical/control room
- New tepid water systems at each building for the emergency eyewash/shower units.
- New on-line TRC analyzers.
- New PLC to control both chemical storage and feed systems.
- New chemical injection equipment.
- Necessary heating, ventilation and air conditioning (HVAC), fire sprinkler, and other building systems to meet the current building code requirements.

As discussed earlier, the chlorine dose utilized for sizing the bulk liquid sodium hypochlorite system is 6 mg/L which, based upon preliminary sampling and analyses, allows for a 3.5 log inactivation of enterococci. The feed pumps will be able to deliver twice the design dose (peak dose), or up to 12 mg/L of chlorine. The storage tanks are sized using a dose of 6 mg/L. The storage tank configuration is based upon storing 5% sodium hypochlorite, which is done to reduce the degradation of the chemical as it sits in the storage tanks. The storage tank requirements are based upon 3 days of storage at the design flow rate, and at 5% chemical. In addition, a bulk receiving sodium hypochlorite tank will be provided. This tank will be sized to receive a full tanker delivery of 15% sodium hypochlorite, which will then be transferred to the dilute storage tanks.

The bulk liquid sodium bisulfite system metering pumps were sized assuming the complete peak chlorine dose (12 mg/L) would need to be dechlorinated. Should this alternative be selected further bench testing will be performed to better determine the total residual chlorine (TRC) that needs to be removed after 15 minutes of contact time. The bulk liquid sodium bisulfite storage tanks are sized based upon neutralizing a chlorine dose of 6 mg/L and 3 days worth of storage at the design flow rate.

2.2.5.2.1 Chlorination/Dechlorination - Broadway

The chlorine contact tank for the Broadway site will be located downstream of the pump station and screening facility, and will be elevated to eliminate flooding issues from the Hudson River. The bulk liquid sodium hypochlorite system equipment sizes for the Broadway site are presented in **Table 2-8**.

Table 2-8: Summary of Bulk Liquid Sodium Hypochlorite System Equipment – Broadway Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Chemical Receiving Storage Tank	1/0	6,000 gallons
Dilute Storage Tank	3/0	9,000 gallons
Transfer Pump	1/1	120 gpm
Metering Pumps	3/1	4.3 – 0.05 gpm

The bulk liquid sodium bisulfite equipment sizes for the Broadway site are presented in **Table 2-9.**

Table 2-9: Summary of Bulk Liquid Sodium Bisulfite System Equipment – Broadway Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	4,400 gallons
Metering Pumps	2/1	1 – 0.013 gpm

The conceptual layout for the bulk liquid chlorination/dechlorination system at the Broadway site is shown in **Appendix C**.

2.2.5.2.2 Chlorination/Dechlorination – Lincoln Park

The chlorine contact tank for the Lincoln Park site will be located downstream of the screening facility, as the system will be gravity fed due to the advantageous hydraulics at this location. The bulk liquid sodium hypochlorite system equipment sizes for the Lincoln Park site are presented in **Table 2-10**.

Table 2-10: Summary of Bulk Liquid Sodium Hypochlorite System Equipment – Park Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Chemical Receiving Storage Tank	1/0	6,000 gallons
Dilute Storage Tank	3/0	12,000 gallons
Transfer Pump	1/1	120 gpm
Metering Pumps	3/1	5.6 – 0.09 gpm

The bulk liquid sodium bisulfite equipment sizes for the Lincoln Park site are presented in **Table 2-11.**

Table 2-11: Summary of Bulk Liquid Sodium Bisulfite System Equipment – Park Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	5,800 gallons
Metering Pumps	2/1	1.3 – 0.013 gpm

The conceptual layout for the bulk liquid chlorination/dechlorination system at the Lincoln Park site is shown in **Appendix C**.

2.2.5.3 Peracetic Acid

For this evaluation it is assumed that the equipment and controls for the bulk liquid PAA storage and feed system at either site would be supplied via a lease agree with a PAA supplier. Therefore, PeroxyChem was contacted to obtain quotes for both sites. The bulk liquid PAA storage and feed system include the construction of the following:

- PAA contact tank with 15 minute contact time
- Liquid PAA storage and feed room
- Electrical/control room
- New tepid water systems at each building for the emergency eyewash/shower unit
- New on-line analyzers
- Necessary heating, ventilation and air conditioning (HVAC), fire sprinkler, and other building systems to meet the current building code requirements.
- Equipment provided and installed by the PAA Supplier include:
  - Chemical Unloading Pump Skid
  - Chemical Storage Tanks
  - Chemical Feed Pump Skids
  - Piping and Valving system
  - Handheld PAA residual analyzer
  - PLC based Control System

In order to estimate the cost of this disinfection option, an average design dose of 10.4 mg/L was utilized, based upon preliminary bench testing and utilizing a 30 percent mixing factor, which allows for a 3.5 log inactivation of enterococci. Because PAA is a stable chemical that can be stored for up to 12 months without degrading, this chemical is able to be stored without being diluted. As a result, three days of storage capacity can be achieved in two 6,100 gallon stainless steel tanks.

The US EPA label for PeroxyChem's 15% PAA solution includes a recommended PAA residual calculation that is dependent upon the maximum flow of the disinfected effluent and the 7Q10 flow of the receiving body. The PAA residual is calculated by determining a dilution factor (DF) and then multiplying that by 0.09. The DF is calculated by taking the sum of the disinfected effluent plus the 7Q10 flow and dividing it by the disinfected effluent. If the DF is less than 12, then the PAA residual should be limited to

1 mg/L. The Green Island, New York USGS stream gauge (USGS 01358000) has a 70 year record of flow in the Hudson River and it is only 8 miles upstream from Albany, New York. The 7Q10 value from the Green Island stream gauge was determined to be 1,472 cubic feet per second (CFS). The design flow for the Broadway and Lincoln Park sites are 116 CFS (75 mgd) and 155 CFS (100 mgd) respectively. These design flows, along with the 7Q10 yield the following DF and PAA residuals:

- Broadway site – DF of 13.7, PAA Residual of 1.2 mg/L
- Lincoln Park site – DF of 10.5, PAA Residual of 1.0 mg/L

A scaled PAA pilot test should be performed to refine the PAA dose required to achieve the 3.5 log inactivation of enterococci and to better determine the PAA residual and the need for quenching for this application. For the purposes of this disinfection alternative evaluation, a sodium bisulfite system will be included to quench the PAA residual.

2.2.5.3.1 PAA – Broadway

The PAA contact tank for the Broadway site will be located downstream of the pump station and screening facility, and will be elevated to eliminate flooding issues from the Hudson River. The bulk liquid PAA system equipment sizes for the Broadway site are presented in **Table 2-12**.

Table 2-12: Summary of Bulk Liquid PAA System Equipment – Broadway Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	6,100 gallons
Unloading Pump	1/0	40 gpm
Metering Pump Skid w/ Redundant Pump	1/0	0.83 - 0 gpm

The bulk liquid sodium bisulfite equipment sizes for the Broadway site are presented in **Table 2-13.**

Table 2-13: Summary of Bulk Liquid Sodium Bisulfite System Equipment – Broadway Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	3,500 gallons
Metering Pumps	1/1	0.83 – 0 gpm

The conceptual layout for the bulk liquid PAA system at the Broadway site is shown in **Appendix C**.

2.2.5.3.1 PAA – Lincoln Park

The PAA contact tank for the Lincoln Park site will be located downstream of the screening facility, as the system will be gravity fed due to the advantageous hydraulics at this location. The bulk liquid PAA system equipment sizes for the Lincoln Park site are presented in **Table 2-14**.

Table 2-14: Summary of Bulk Liquid PAA System Equipment – Park Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	6,100 gallons
Unloading Pump	1/0	40 gpm
Metering Pump Skid w/ Redundant Pump	1/0	0.83 - 0 gpm

The bulk liquid sodium bisulfite equipment sizes for the Lincoln Park site are presented in **Table 2-15.**

Table 2-15: Summary of Bulk Liquid Sodium Bisulfite System Equipment – Park Location

Equipment	Number of Units (Duty/Standby)	Capacity per Unit
Bulk Storage Tank	2/0	3,500 gallons
Metering Pumps	1/1	0.83 – 0 gpm

The conceptual layout for the bulk liquid PAA system at the Lincoln Park site is shown in **Appendix C**.

2.2.5.4 Summary of Disinfection Costs

The construction and O&M costs for this analysis were based upon the appropriate design flows and average annual treatment volumes for the various alternatives and sites. The 20 year present worth for chlorination/dechlorination facilities and PAA/quenching facilities ranged between $10M and $14M for the Broadway site and between $15M and $19M at the Lincoln Park site. Refer to Section 3.3 for a discussion of actual project costs for each site.

2.2.6 Recommended Disinfection Technology

The use of PAA as a wastewater and CSO disinfectant continues to increase across the US. However, to date, it has not been approved for either application within New York thereby making its path to implementation for the Big C Screening and Disinfection Facility more time consuming. Conversely, use of sodium hypochlorite as a disinfectant is well established for CSO applications, and there is general acceptance of this technology within the industry for the treatment of combined sewer flows. In addition, operating costs for these systems are relatively low and there is great familiarity with the operations and maintenance activities associated with these types of treatment systems.

The differences in lifecycle costs between PAA/Quenching and Chlorination/Dechlorination at either site is less than 10%, which makes these alternatives comparable and is within the margin of error for the level of Project definition (feasibility study). Given the cost and non-cost considerations, it is recommended that Chlorination/Dechlorination be utilized as the disinfectant at the Big C Screening and Disinfection Facility. As the project moves forward additional sampling and testing will need to be performed to better define the sodium hypochlorite design dose for the facility.

2.3 Floatables Control Technologies

This section provides background and information on potential floatables control technologies. Different technologies were preliminarily evaluated to determine appropriate equipment suitable for floatables control for this application. Systems described herein have been utilized for floatables control in United States, Canada, and/or Europe.

Untreated combined sewage can contain high levels of floatable materials, suspended solids, BOD, oils and grease, toxic pollutants, and/or pathogenic microorganisms. Floatables are often the most noticeable and problematic combined sewage pollutant. There are numerous methods available for floatables control, including baffles, catch basin modifications, netting systems, containment booms, skimming processes, and screening and trash rack devices. In order to provide adequate disinfection treatment and remove floatables and debris from the combined sewage, screening technologies were assessed herein.

Screens for combined sewage applications are typically constructed of steel parallel bars, wire mesh, grating or perforated plate. In general, the openings are circular or rectangular slots, varying in spacing from 0.1 to 6 inch. Coarse screens are typically 1 to 6 inches in spacing and fine screens are 0.1 to 1 inch in spacing.

2.3.1 Preliminary Assessment of Technologies

To determine if a specific technology is appropriate the following preliminary assessment was completed to assess the impacts on the following:

- Floatables control and discharge to the Hudson River;
- Protection of downstream equipment;
- Disinfection system pretreatment requirements;
- Hydraulic impacts to the combined sewage system and need for pumping flows through the CSO treatment facility;
- Screenings and debris loading impacts on the ACSD South Treatment Plant, and;
- Screenings handling at CSO treatment facility remote from the ACSD South Treatment Plant.

2.3.1.1 Mechanically Raked CSO Bar Screens

Mechanically raked CSO bar screens are stationary fine screens that are mechanically cleaned. These screens are typically installed below ground, and can be arranged either in the horizontal or vertical position to the CSO flow. The screen consists of modules of horizontal or vertical fixed bar rack and cleaning assemblies mounted along a weir wall. Each module is made of stainless steel bars with pre-determined spacing. Bar spacing typically ranges between 0.2 to 0.5 inches. The rake assembly consists of a series of combs powered by a hydraulic pack. As combined sewage enters the screening chamber, the rake begins its cleaning operation before the combined sewage overflows to the outfall sewer. In horizontal configurations, the flow is upward through the screen to the outfall sewer discharging to the receiving body of water, while floatables are retained in flow to incepting sewer and directed to the wastewater treatment plant. These screens are mechanically cleaned, but require periodic cleaning, by facility operators, using a high-pressure hose in order to dislodge and wash away accumulated materials. Figure 2-9 presents a typical mechanically raked CSO bar screen installation.

Preliminary assessment:

- Screen configuration will not preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration may require additional downstream screening for UV disinfection;
- Screen configuration may increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will not require remote screenings handling for chemical disinfection, but may require remote screenings handling for UV disinfection.

Figure 2-9: Mechanically Raked CSO Bar Screen (Westech ROMAG) – Vertical Screen Installation

2.3.1.2 Mechanically Cleaned Conventional Bar Screens

Mechanically cleaned conventional screens are typically mounted in combined sewage channels and discharge chutes are contained in aboveground facilities to facilitate screenings removal at the remote location. These screens utilize numerous mechanical cleaning methods to keep the stationary screen mounted in the flow channel free of debris accumulation, such as:

- Flexible rakes;
- Climber-type rakes;
- Rotating perforated plates;
- Catenary screens, and;

- Chain and rake screens.

This screen type is used for the removal of floatables and debris from open channels. A bar spacing of 0.25 to 1 inch is typically used for combined sewage floatables control. Mechanically cleaned conventional screens collect floatables from the face of the submerged bar rack and discharge screenings to a receptacle where they are accumulated. Following a wet weather event, containerized residuals must be either transported by truck for offsite disposal. Figure 2-10 presents a typical mechanically cleaned CSO bar screen. Recent combined sewage applications typically have been flexible rake type screens.

Preliminary assessment:

- Screen configuration will preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration may require additional downstream screening for UV disinfection;
- Screen configuration will not increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will require remote screenings handling for chemical disinfection and UV disinfection.

Figure 2-10: Mechanically Cleaned Conventional Bar Screen

2.3.1.3 Horizontal Band Screens

This type of screen is a mechanically cleaned rotating fine screen that is oriented horizontally to the wastewater flow. Combined sewage enters the screen in an upward direction where it is screened and directed over a weir to the outfall sewer. The screen has perforated stainless steel panels with openings of 0.25 inches that travel around the screen. A rotating brush positioned on the downstream end of the screen removes screened material from the rotating perforated panels and directs the debris back into the wastewater flow and routed to the intercepting sewer. Figure 2-11 presents a typical horizontal band screen.

Preliminary Assessment:

- Screen configuration will not preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration will not additional downstream screening for UV disinfection;
- Screen configuration may increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will not require remote screenings handling for chemical disinfection or for UV disinfection.

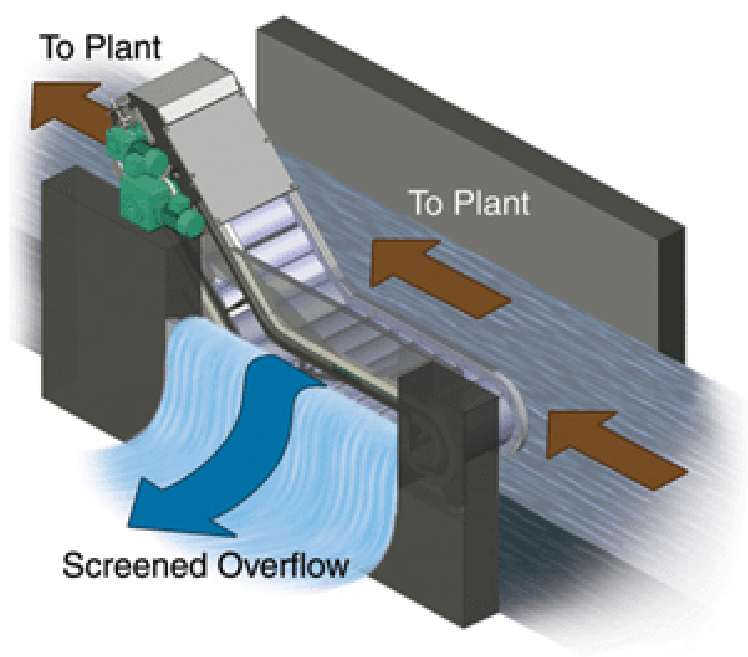


Figure 2-11: Horizontal Band Screen

2.3.1.4 Vertical Band Screens

This type of screen is a mechanically cleaned rotating fine screen that is oriented vertically to the wastewater flow. Flow enters the center of the screen, where it is screened to both sides of the rotating screen. The screen has perforated stainless steel panels with openings of 0.25 inches that travel around the length of the units opening. A series of spray nozzles positioned at the top of the unit removes screened material from the rotating perforated panels and directs the collected debris into an integral washing compactor. Figure 2-13 presents a typical vertical band screen.

Preliminary Assessment:

- Screen configuration will preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will require an upstream coarse screen to remove large debris;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration will not require additional downstream screening for UV disinfection;
- Screen configuration will not increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will require remote screenings handling for chemical disinfection and for UV disinfection.

Figure 2-12: Horizontal Band Screens

2.3.1.5 Low Profile Overflow Screens

The low profile overflow screen is a mechanically cleaned fine screen consisting of a profiled weir assembly, modular curved bar rack and a motor driven rake mechanism. The screen retains floatables from the combined sewage by means of a curved bar rack located on a profiled weir assembly. Flow is routed over the profiled weir and down through the screen into the effluent channel. The profile weir assembly is used to evenly distribute the wastewater flow across the entire width of the screen. Floatables and debris are directed by the rake to a collection trough located behind the screen. The screenings are then flushed to the wastewater into the interceptor. Figure 2-14 presents a typical low profile overflow screen.

Preliminary Assessment:

- Screen configuration will not preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration may require additional downstream screening for UV disinfection;
- Screen configuration will increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will not require remote screenings handling for chemical disinfection and may require remote screenings handling for UV disinfection.

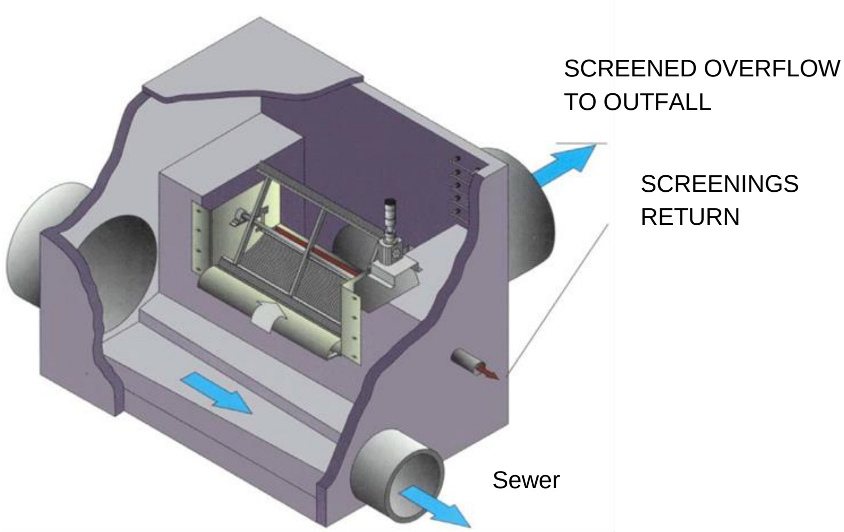


Figure 2-13: Low Profile Overflow Screen (John Meunier)

2.3.1.6 Rotary Drum Sieve Screens

This type of screen consists of a large perforated stainless steel cylindrical rotary sieve mounted on a weir wall. The sieve is turned slowly by a hydraulic motor on a gear wheel in a direction such that the clean side is facing the oncoming combined sewage flow. A brush adjacent to the sieve rotates in the opposite direct from the sieve and directs the collected material back into the wastewater flow. The sieve sizes are available in 0.2 to 0.25 inch wide slots. Figure 2-15 presents a typical rotary drum sieve screen.

Preliminary Assessment:

- Screen configuration will not preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration will not additional downstream screening for UV disinfection;
- Screen configuration may increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will not require remote screenings handling for chemical disinfection or for UV disinfection.

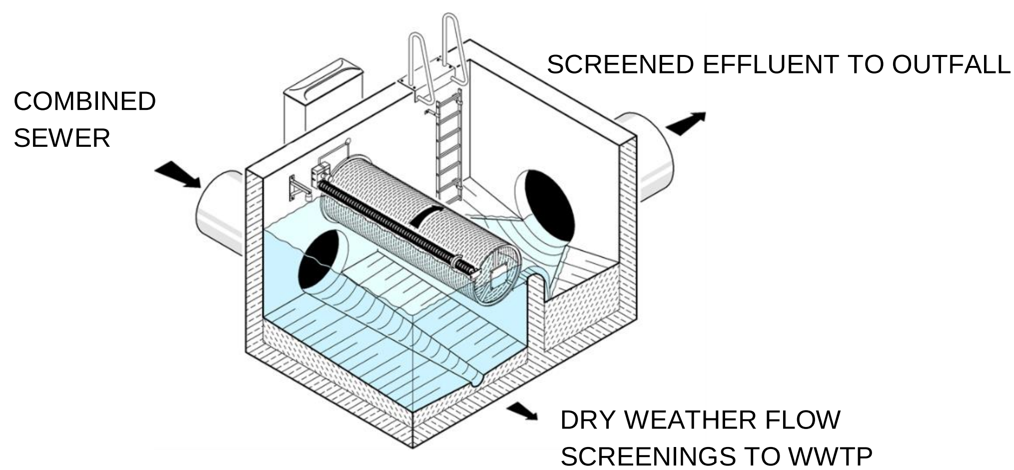


Figure 2-14: Rotary Drum Sieve Screen (John Meunier Hydrovex)

2.3.1.7 Pump Action Screens

Pump action screens are fine screens fabricated from stainless steel plate consisting of 6 mm perforations typically mounted on the flow side of an overflow weir just below the weir level. There are no mechanical moving parts within the screen itself. The pump action screen is kept clean using a pump that entrains air into the wastewater flow. The power of the air/water mixture scours the underside of the screen, transporting debris past the end of the screen and on into the wastewater flow that is directed to the intercepting sewer preventing the screen from blinding. Figure 2-16 presents a typical pump action screen installation.

Preliminary Assessment:

- Screen configuration will not preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration may require additional downstream screening for UV disinfection;
- Screen configuration will increase floatables and debris loading at the ACSD South treatment Plant, and;
- Screen configuration will not require remote screenings handling for chemical disinfection and may require remote screenings handling for UV disinfection.

Figure 2-15: Pump Action Screen (CSO Technik)

2.3.1.8 Hydrodynamic Vortex Separators

Hydrodynamic Vortex Separators use vortex separation technology to screen the floatables and debris from the wastewater flow. Hydrodynamic vortex separators generally consist of a cylindrical tank that uses a physical barrier, typically a fine screen, between the influent flow and outlet discharge. Flows enter the hydrodynamic vortex separators tangentially and are deflected from the discharge by entering a deep sump. Flows are conveyed into the center of the sump and must pass through a screen with 0.05 inch to 0.25 inch perforations before proceeding to the outfall sewer. The continuous swirling action in the sump causes heavier solids to fall to the bottom and keeps them away from the screen, thereby eliminating the need for a cleaning mechanism. After an event, the trapped floatables and solids retained in the sump require removal by maintenance personnel via vacuum truck or clamshell bucket. This technology was developed for solids removal in stormwater systems. Figure 2-16 presents a typical hydrodynamic vortex separation installation.

Preliminary Assessment:

- Screen configuration will preclude discharge of floatables to the Hudson River;
- Screen configuration will protect downstream equipment;
- Screen configuration may require an upstream coarse screen to remove large debris;
- Screen configuration will adequately remove floatables and debris for chemical disinfection;
- Screen configuration will not require additional downstream screening for UV disinfection;
- Screen configuration may increase floatables and debris loading at the ACSD South treatment Plant;
- Screen configuration will not require remote screenings handling for chemical disinfection and for UV disinfection, and;
- Screen configuration may reduce the volume of downstream tankage required for adequate contact time in chemical disinfection applications.

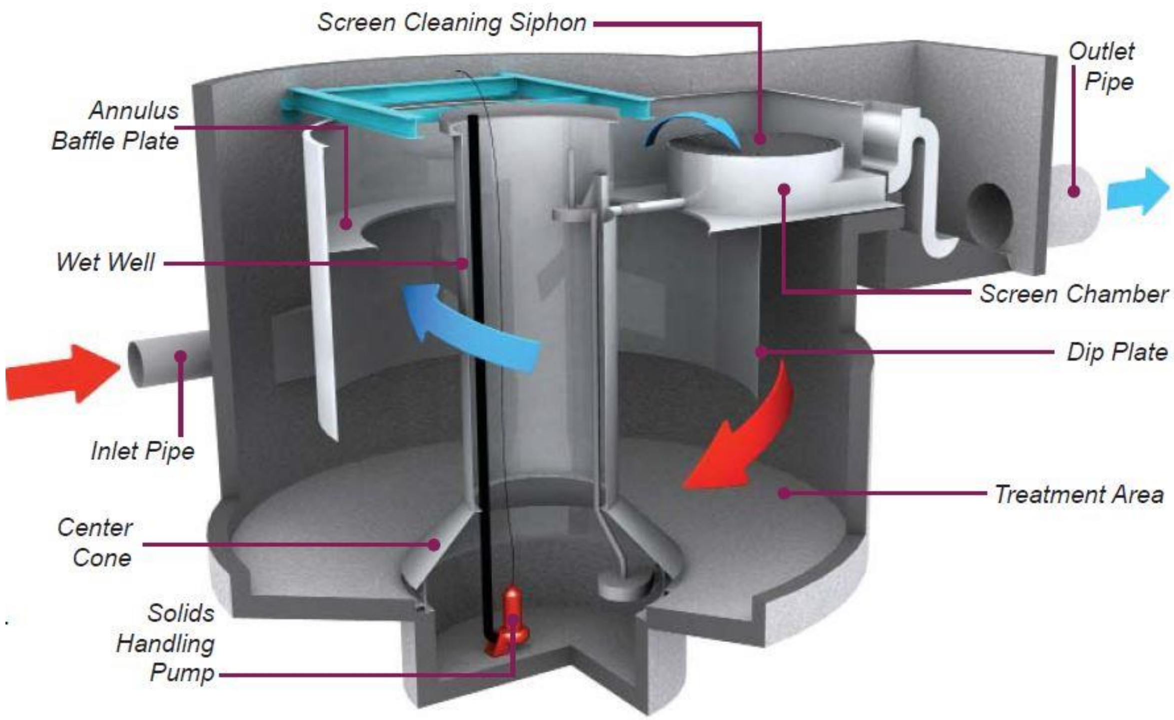


Figure 2-16: Hydrodynamic Vortex Separators (Storm King)

2.3.2 Analysis of Feasible Technologies

Based on the preliminary assessment of technologies, the technologies that provide adequate floatables control for combined sewage discharging to the Hudson River and adequate protection of downstream equipment are:

- Chemical disinfection:
  - Mechanically cleaned conventional bar screens, and;
  - Continuous deflection separation systems.
- UV disinfection:
  - Mechanically cleaned conventional bar screen with downstream vertical band screens, and;
  - Continuous deflection separation systems

Based on the selection of sodium hypochlorite as the method of disinfection, further discussion of the feasible technologies is presented below and conceptual layout sketches for the screening facilities are presented in **Appendix D**.

2.3.2.1 Mechanically Cleaned Conventional Bar Screens

The subsequent analysis for mechanically cleaned conventional bar screens will be based on a flex rake type bar screen as manufactured by Duperon Corporation. The flex rake type screen was initially designed to remove large debris from storm events for large flood control facilities, which has advantages for combined sewer applications as opposed to more traditional mechanically cleaned conventional bar screens that were developed for wastewater applications. The flex rake allows it to lift and pivot around debris and clean to bottom of the channel. This screen does not have a lower drive sprocket, eliminating service needed below the liquid line.

Table 2-16: Mechanically Cleaned Conventional Bar Screen Design Criteria

	Broadway Site	Lincoln Park Site
Number Required	3	3
Maximum Flow (mgd)	75	100
Minimum Flow (mgd)	12.5	19
Channel Width (ft)	6	8
Maximum Headloss (in) [(a)]	3	3
Bar Spacing (in.)	0.25 – 0.5	0.25 – 0.5
Maximum Velocity (fps) [(a)]	1.2	1.2

(a) Assuming one unit out of service

For each site, the screens would be housed in a building that comes to grade for removal and disposal of screenings off site. Each system would be equipped with a washer/compactor to reduce the total tonnage of screenings to be disposed of off-site.

For the Broadway site screening facility, pumping of the CSO flow would be required after screening. Four 215-hp centrifugal pumps rated 25 mgd at a total dynamic head of 35 feet would be required. The Lincoln Park site would flow through the facility by gravity. The preliminary capital costs for each facility, excluding site work and project cost additions is estimated to between $5.4M and $6.7M for the Broadway site and $4.9M and $6.2M for the Lincoln Park site. The O&M costs for the screenings equipment at both sites are very similar, with the Lincoln Park site being slightly higher due to the greater amount of flow being screened. The only significant cost difference between the sites is the power and maintenance on the pumps at the Broadway site, which is estimated to be between $53,000 and $63,000 on an annual basis.

2.3.2.2 Hydrodynamic Vortex Separators

The subsequent analysis for hydrodynamic vortex separators will be based on a Storm King CSO treatment basin as manufactured by Hydro International. The SanSep hydrodynamic vortex separator manufactured by Process Wastewater Technologies, LLC (PWTech) was initially considered, as there is operational experience at the City of Cohoes, but was eliminated from consideration based on the large number of units that would be required and the associated operational challenges. The manufacturer is only currently providing 12.5 mgd systems. In addition, as the CSO flow enters the Storm King unit and is screened, the flow is quite turbulent, providing excellent mixing of chemical disinfectants (such as the sodium hypochlorite that was selected). The manufacturer has experience with chemical additional of sodium hypochlorite and PAA for CSO disinfection purposes. At the peak flow rates shown in **Table 2-17** below the system can provide approximately 9-10 minutes of contact time.

Table 2-17: Hydrodynamic Vortex Separator Design Criteria

	Broadway Site	Lincoln Park Site
Number Required	3	4
Maximum Flow (mgd)	75	100
Minimum Flow (mgd)	12.5	19
Basin Diameter (ft)	44	44
Maximum Headloss (in)	20	20
Screen Size (mm.)	4	4
Chemical Detention Time (min) [(a)]	9.2	10.4
Chemical Detention Time (max) [(b)]	13.8	15.6

(a) Assuming maximum flow, one unit out of service
(b) Assuming maximum flow, all units in service

For each site, the basins would be located at ground level. The collected screenings and settled solids from the underflow of each basin would be pumped from the base of the unit back into the CSS (after the event) for conveyance to the Albany County interceptor, where it would continue to the ACSD South treatment Plant. Only the larger debris in the CSO flow that is captured by the trash rack (with 6 inch bar spacing) would have to be handled at the site.

For the Broadway site screening facility, pumping of the CSO flow would be required prior to the Storm King basins. Four 215-hp centrifugal pumps rated 25 mgd at a total dynamic head of 35 feet would be required. The Lincoln Park site would flow through the facility by gravity. The preliminary capital costs for each facility, excluding site work and project cost additions is estimated to between $10.6M and $13.2M for the Broadway site and $11.8M and $14.7M for the Lincoln Park site. The O&M costs for the screenings equipment at both sites are very similar, with the Lincoln Park site being slightly higher due to the greater amount of flow being screened. The only significant cost difference between the sites is the power and maintenance on the pumps at the Broadway site, which is estimated to be between $53,000 and $63,000 on an annual basis.

2.3.3 Recommended Screening Technology

Both of the screening options detailed above provide protection to the Hudson River, the equipment downstream of the screens, and provide adequate screening for the sodium hypochlorite system that was selected as the method of disinfection. However, the mechanically cleaned conventional bar screens are recommended, as opposed to the hydrodynamic vortex separators, for the following reasons:

- Capital Costs: While the hydrodynamic vortex separation system could eliminate the need for a contact tank, the costs of screens, a screening building and contact tank is estimated to be between $7.6M and $8.9M for the Broadway site and $7.8M and $9.1M for the Lincoln Park site, as compared to costs ranging from $10.6M to $14.7M for hydrodynamic vortex separation systems without contact tanks. Excavation and rock removal costs are similar and do not overcome the difference in major equipment, concrete and building costs. Annual O&M costs would be similar for mechanically cleaned bar screens and hydrodynamic vortex separation systems.
- Odor Control: Hydrodynamic vortex separation units are open to the atmosphere and will require either concrete or aluminum covers to prevent nuisance odors from occurring. This would be more sensitive in the Lincoln Park site as the community will be utilizing lands in very close proximity to the facility. Odor control for a mechanically cleaned conventional bar screen facility would be incorporated into the normal ventilation system.

3 SUMMARY AND COMPARISON OF ALTERNATIVES

3.1 Introduction

As discussed previously, the following two (2) sites were identified in regards to the siting of the disinfection and floatables control facilities:

- Broadway or "U-Haul" Site
- Lincoln Park Site

This section outlines any special design considerations associated with the respective sites, as well as the advantages/disadvantages for both sites. Sketches of the conceptual layouts for the two sites are included in **Appendix E**.

3.2 Design Considerations

3.2.1 Broadway or "U-Haul" Site

- Recommended disinfection and screening facilities must be designed to capture and treat overflows up to 75 MGD. It is anticipated that the facilities will treat approximately 285 million gallons of overflow on an average annual basis.
- Due to the relatively poor soil conditions which include existing fill and soft soil, and the anticipated loadings associated with the proposed tanks and equipment, the use of conventional shallow foundations for these structures is anticipated to result in significant settlement which would impact the functionality of the proposed system. A pile foundation system is considered the most desirable feasible alternative for foundation support of the proposed improvements. Piles should be driven through the soft layers until deeper layers of glacial till or bedrock are encountered.
- Several elements (i.e., diversion/interceptor structure and piping, screening and pump station facilities) will need to be constructed below the normal operating range of the river. As a result, protection of the associated construction activities and operations would be required to prevent flooding or inundation of the construction zone. There is inherent constructability and risk issues at this site based on the proximity to floodplain/tidal zone.
- Pumping facilities would need to be incorporated into the site design in order to construct the disinfection tanks above the normal range of elevations in the river. Otherwise, typical river elevations would have the potential to create backwater effects which would impact to the hydraulic profile and restrict (or limit) flow conveyed through the facilities.
- Facilities would need to be designed to protect critical equipment and operations in consideration of the floodplain elevations and climate change factors.
- Erosion and sediment controls, in conjunction with the management of on-site runoff and flows conveyed through the Beaver Creek sewer, will be required during construction to protect the fish and wildlife, as well as water quality in the Hudson River.

- Measures would need be taken to ensure that any residuals from chemical oxidants are addressed prior to discharging to receiving waters.
- Measures would need to be taken to provide appropriate odor control for the screening and pumping facilities given the location and adjacent land uses.
- Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary and the Hudson River, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.
- The parcels necessary for construction of the proposed disinfection and floatables control facility are presently privately owned. It is likely that these parcels would need to be secured through the eminent domain process and removed from the tax roles.

3.2.2 Lincoln Park Site

- Recommended disinfection and screening facilities must be designed to capture and treat overflows up to 100 MGD. It is anticipated that the facilities will treat approximately 340 million gallons of overflow on an average annual basis.
- There is an existing condition of the Beaver Creek sewer that is resulting the formation of a sinkhole within Lincoln Park. In addition, during extreme weather events, the system can surcharge in the park resulting in discharges to the surface. Based on the proposed facility layout, a new five to six foot diameter sewer approximately 750 linear feet in length would be required to convey flows to the proposed screening and disinfection facilities. The new sewer would be used to convey both dry and wet weather flows up to 100 mgd; thereby alleviating the surcharging condition of the existing Beaver Creek sewer and converting the existing sewer into a relief sewer for extreme wet weather events. This solution would improve odors in Lincoln Park by eliminating the discharge of sewer flows to the surface; increase the resiliency of the combined sewer system, and allow for access and repair of the sewer thereby eliminating any safety concerns associated with the sink hole which is located in the park and adjacent to the elementary school.
- Excavation for these improvements will extend well below the bedrock surface and bedrock removal is anticipated. Bedrock removal will require the use of controlled blasting, drilling and splitting, or mechanical hoe-rams to reduce bedrock to fragments manageable for standard excavation equipment.
- Based on the size and weight of the proposed tanks and structures proposed as part of this project, these structures should receive bearing support directly from the shale bedrock.
- Measures would need be taken to ensure that any residuals from chemical oxidants are addressed prior to discharging to receiving waters.
- Measures would need to be taken to provide appropriate odor control for the screening facility given the location and adjacent land uses.

- Due to the fact that the proposed site is located in the immediate vicinity of the old Beaver Creek tributary, the project area has high sensitivity for prehistoric remains. The survival of prehistoric archaeological remains is possible if previous grading and filling activities did not result in significant subsurface disturbance. In addition, because the project area was part of the City of Albany or its immediate environs since the colonial period, there is high sensitivity for historic remains.
- The proposed facilities will be located within existing park lands. As such, park land alienation legislature and mitigation may be required. However, this would not remove additional lands within the City from the current tax roles.
- There is the potential for the public perception of impacts to the neighborhood, park and/or school (e.g., Environmental Justice Issues).

3.3 Cost Summary

3.3.1 Cost Estimate Methodology

The American Association of Cost Engineers (AACE) defines three levels of cost estimates: 1) order-of-magnitude, 2) budgetary, and 3) definitive, each of which is applicable at a different stage of a project. The comparative cost estimates presented in this report are intended to represent order-of-magnitude estimates for equipment capital and O&M costs as defined by AACE, with estimates being made without detailed engineering data. Costs developed in this preliminary analysis are based on general requirements & sizing of each system, including storage & treatment requirements, energy costs, auxiliary equipment requirements, etc.

The estimates rely on the use of budget quotes from equipment suppliers, previous estimates for similar projects, historical data from comparable work, estimating guides, handbooks and costing curves, and are intended for planning purposes and comparing alternatives. For that reason, subtotaled and totaled costs have been rounded to four significant figures. Costs were provided in current (2016) dollars and then escalated to the midpoint of construction. It is assumed construction will start in April 2020 and be completed in April 2022, and that the annual escalation rate will be 1.4 percent. The actual cost of any project will depend on actual labor and material costs for competitive bids, project complexity, competitive market condition, actual site conditions, final scope of work, implementation schedule, continuity of personnel and engineering. **Table 3-1** presents the construction cost markups used to produce the estimates in this report.

Cost proposals for major equipment and chemical costs, where obtained from manufacturers/suppliers. In all cases where vendor proposals were obtained, conservative assumptions regarding equipment redundancy, specifically EPA Class I Reliability guidelines which requires redundant piece of equipment to be provided, were applied to each system. Therefore, with more detailed engineering information, the equipment costs and associated contingencies may be reduced by some fraction.

Table 3-1: Construction Cost Factors and Lifecycle Cost Parameters

Cost Item	Value
Installation Labor, Const. Equipment, Misc. Materials (unless included elsewhere)	30 percent
Instrumentation and Controls (unless included elsewhere)	10 percent
Electrical (unless included elsewhere)	10 percent
Plumbing (unless included elsewhere)	5 percent
Construction Contingency	25 percent
Contractor's General Conditions/Risk	5 percent
Contractor's Indirect Costs and Overhead & Profit (OH&P)	20 percent
Contractor's Bonds	2 percent
Admin, Legal & Insurance	5 percent
Cost Baseline	July 2016
Midpoint of Construction	April 2021
Escalation Duration, months	57
Escalation Rate	1.4 percent
Escalation to Midpoint of Construction	6 percent

Lifecycle costs were developed utilizing a 20 year net present value (NPV) analysis that included lifecycle cost parameters shown in **Table 3-2**. Based on SWMM model results, it is estimated that the disinfection and floatables facility will operate approximately 30 days (full-time equivalency days) between May and November.

Table 3-2: Lifecycle Cost Parameters

Cost Item	Value
Lifecycle	20 years
Discount Rate	4.13 percent
Inflation Rate	2.5 percent
Power Cost Escalation Rate	3 percent
Power Cost ($/kWh)	$0.10
Labor Costs ($/hr)	$40.00

3.3.2 Broadway or "U-Haul" Site Project Costs

Table 3-3 summarizes the total project cost for the construction of a facility at the Broadway site.

Table 3-3: Project Construction Costs for Broadway Site

Item	Unit or Factor	Cost
Chemical Contact Tank & Equipment	LS	$2,187,000
Screenings Foundation and Structures	LS	$1,600,000
Chemical Building	LS	$1,768,000
Screenings Building	LS	$2,400,000
Screenings & Pumping Equipment	LS	$3,408,000
Odor Control	LS	$820,000
Site Work	LS	$7,200,000
Installation Labor, Construction Equipment & Misc. Materials	30%	$1,930,000
Electrical	10%	$650,000
Instrumentation & Controls	10%	$650,000
Plumbing	5%	$280,000
Direct Construction Costs Subtotal		***$22,900,000***
Contractor's General Conditions and Risk	5%	$1,150,000
Subtotal		***$24,100,000***
Contractor Indirect Costs and OH&P	20%	$4,820,000
Subtotal		***$28,900,000***
Contractor's Bonds	2%	$580,000
Construction Contingency	25%	$7,370,000
Total Construction Cost		***$36,900,000***
Admin, Legal, & Insurance	5%	$1,850,000
Engineering & Construction Administration	LS	$4,500,000
Land Acquisition	LS	$1,000,000
Total Cost in Today's Dollars		***$43,700,000***
Escalation to Midpoint of Construction	6%	$2,700,000
Total Project Cost		***$47,00,000***

The largest factors impacting the costs at the Broadway site include:

- Construction of the facilities is in the 100 year floodplain and would require provisions to raise critical equipment above the 100 year elevation in addition to climate change factors, or approximately the 500 year floodplain elevation.
- Construction of the facilities in poor quality soils requiring piles.
- Maintenance of overflows to the Hudson River with tidal considerations would be challenging requiring a temporary box culvert or plastic lined open channel during the construction.
- High groundwater would require temporary dewatering for deep excavations required for a 75 mgd pump station.
- The larger electrical demand due to the 75 mgd pump station will require a large electrical service and generator.

- The Broadway site was recently rezoned to promote riverfront development along the Hudson River, which will impact the cost for land acquisition of the required parcels.

3.3.3 Lincoln Park Site Project Costs

Table 3-4 summarizes the total project cost for the construction of a at the Lincoln Park site.

Table 3-4: Construction Cost for Lincoln Park Site

Item	Unit or Factor	Cost
Chemical Contact Tank & Equipment	LS	$2,880,000
Chemical Building	LS	$1,350,000
Screenings Foundation and Structures	LS	$1,840,000
Screenings Building	LS	$1,425,000
Screenings Equipment	LS	$2,489,000
Odor Control	LS	$900,000
Site Work	LS	$8,170,000
Installation Labor, Construction Equipment & Misc. Materials	30%	$1,890,000
Electrical	10%	$540,000
Instrumentation & Controls	10%	$540,000
Plumbing	5%	$270,000
Direct Construction Costs Subtotal		***$22,300,000***
Contractor's General Conditions and Risk	5%	$1,120,000
Subtotal		***$23,400,000***
Contractor Indirect Cost and, OH&P	20%	$4,680,000
Subtotal		***$28,100,000***
Contractor's Bonds	2%	$560,000
Construction Contingency	25%	$7,170,000
Total Construction Cost		***$35,800,000***
Admin, Legal, & Insurance	5%	$1,790,000
Engineering & Construction Administration	LS	$5,000,000
Total Cost in Today's Dollars		***$42,600,000***
Escalation to Midpoint of Construction	6%	$2,600,000
Total Project Cost		***$45,200,000***

The largest factors impacting the costs at the Lincoln Park site include:

- Construction of the facilities will require larger equipment and contact tanks for the treatment of 100 mgd.
- Construction of the facilities will require the development of approximately 750 linear feet of a five to six foot diameter sewer to convey 100 mgd flow to the facility. The new sewer would have to be tunneled in bedrock.
- Maintenance of existing flows during construction do not present much risk. The new facilities and sewer could be constructed under normal operating conditions, with the existing Beaver Creek sewer only requiring special maintenance of flows during the tie-in periods.

- Permitting and engineering costs were estimated to be approximately $500,000 higher than the Broadway site due to the additional architectural, odor control and public input considerations due to construction of the facilities in an existing park.
- Construction of the facilities will require rock removal.

3.3.4 Summary of Costs

Cost summaries for the treatment alternatives for the Big C Disinfection and Floatables Control Facility are provided in **Table 3-5**. The Broadway site facilities would be designed to treat up to 75 mgd and the Lincoln Park site would designed to treat up to 100 mgd. In general, the facilities will treat approximately the same number of wet weather events during the recreational period, however, the facilities at the Lincoln Park site will need to treat a larger volume of combined sewage to provide the same net reduction in annual untreated overflows. Since the Lincoln Park site will treat higher flows, there will be an increase in chemical costs required for disinfection and dechlorination. The annual costs for chemicals at the Broadway site are estimated to approximately $25,000, as compared to $31,000 annually at the Lincoln Park site.

Since the number of wet weather events will be the same, the labor required to maintain the facilities should be the same. The volume of debris removed from the flow should be fairly similar in quantities and content as most debris will occur during the first flush and loads will “trail off” as the wet weather event continues.

The largest difference in operational costs between the two sites is the estimated electrical costs. Since the Lincoln Park site can take advantage of the topography and operate as gravity driven facility there is no need for a pump station. The larger equipment (FlexRakes and chemical feed pumps) required to treat 100 mgd are equipped with small motors similar to the Broadway site. The pump station required for the Broadway site will require will require an additional $61,000 annually for electricity and maintenance of the pumps.

Table 3-5: Summary of Alternative Disinfection Costs for the Big C Disinfection and Floatables Control Facility

Alternative	Total Project Cost	Annual O&M Costs	20-Year NPV of O&M	20-Year NPV of Project
Broadway Site	$47,000,000	$231,000	$3,900,000	$51,000,000
Lincoln Park Site	$45,200,000	$178,000	$3,000,000	$48,200,000

The Lincoln Park site is estimated to have a savings of nearly $3,000,000 in net present value as compared to the Broadway site. This savings is attributed to the lower total project costs and annual operation and maintenance savings.

4 SUMMARY, CONCLUSIONS AND NEXT STEPS

4.1 Summary and Conclusions

Under the executed Order for the Albany Pool CSO LTCP, the APCs are required to identify and implement disinfection and floatables control strategies for the “Big C” combined sewer overflow in the City of Albany. The Big C Disinfection and Floatables Control Facility will provide for treatment at the City of Albany’s largest CSO; and will serve to further reduce bacteria counts and enhance the “recovery time” for the Hudson River. An analysis was performed in regards to the disinfection and screening technologies, and an alternative site evaluation was completed to determine the feasibility of the construction of the facilities at the respective sites.

Possible disinfection alternatives were identified and screened during the development of the project, this study focused on ultraviolet (UV) disinfection, bulk liquid chlorination/dechlorination, and peracetic acid (PAA). While UV is considered to be an innovative technology for CSO applications there remains limited full-scale CSO application data. Based upon the analysis performed, UV disinfection is not recommended for treatment of combined sewer flows at Big C due to the high variability and seasonal characteristics of the water quality conditions indicative within the system (e.g., TSS and large particle sizes characteristic of first flush of runoff). These conditions would likely cause interference or fouling of the UV lamps; thereby degrading performance of the technology due to the high solids loadings. The use of a high rate treatment system would also likely be required prior to the UV disinfection which would render this alternative as cost prohibitive. In addition, this alternative would require high energy usage based on the large number of UV lamps required, and have significantly higher long-term operational and maintenance costs. As a result, UV disinfection was eliminated from consideration as a viable alternative for the project.

Based on the analyses performed, it is recommended that chemical disinfection be utilized for the treatment of flows based on the water quality goals and objectives of the project. The use of PAA as a wastewater and CSO disinfectant continues to increase across the US. However, to date it has not been approved for either application within New York; thereby making its path to implementation for the Big C Screening and Disinfection Facility more time consuming and costly. Conversely, Chlorination/Dechlorination has been the most widely used disinfectant for wastewater, CSO and potable water applications in the United States. Contributing factors include the reasonable costs to construct and operate the systems, reliable disinfection capabilities, and adequate supply. In addition, there is great familiarity with the operations and maintenance activities associated with these types of treatment systems.

Given the cost and non-cost considerations, it is recommended that Chlorination/Dechlorination be utilized as the disinfectant at the Big C Screening and Disinfection Facility. Chlorine is available in many forms including chlorine gas and chlorine products such as sodium and calcium hypochlorite. Liquid sodium hypochlorite has become widely used for wastewater disinfection due to its reliability and ease of handling. As the project moves forward additional sampling and testing will need to be performed to better define the sodium hypochlorite design dose for the facility.

Furthermore, different screening technologies were identified and evaluated to determine appropriate equipment suitable to achieve pre-treatment requirements for the disinfection, protect downstream equipment, debris loading impacts on the ACSD South Treatment Plant, storage and handling of the screened materials, and floatables control and discharge to the Hudson River. In the end, the use of mechanically cleaned conventional bar screens are recommended based on an analysis of capital costs, and long term operational and maintenance considerations.

The AWB has determined that both sites evaluated are potentially feasible in regards to the construction of the disinfection and floatables control facilities. The AWB intends to work with the City of Albany to build and execute a more robust public outreach and education program with municipal leadership, interested stakeholders and the general public. The final site selection will be based on negotiations with the Department, as well as input and concerns expressed during the public outreach process.

4.2 Next Steps

The AWB would like to advance the dialogue with the Department in an effort to build consensus in regards to the technologies to be utilized, as well as the feasibility for the two (2) sites that were evaluated. Once a consensus has been formed, the AWB intends to:

- Address any comments the Department may have regarding the Preliminary Engineering Report and issue a Final Report;
- Finalize the Basis of Design criteria for the project;
- Work with the City of Albany to build and execute a more robust public outreach and education program with municipal leadership, interested stakeholders and the general public; and
- Begin advancing the Preliminary Design for the facilities.

APPENDIX A

Site Location Maps

Joint Venture Team albany pool

BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

BROADWAY SITE PARCELS

PROJECT NO. 31615	
DATE: 07/21/16	
FIGURE A-1	

Joint Venture Team
albany pool

BIG C DISINFECTION AND
FLOATABLES CONTROL PROJECT
LINCOLN PARK SITE PARCELS

PROJECT NO.
31615

DATE: 07/21/16

FIGURE A-2

PLAN VIEW
AS NOTED

PROFILE VIEW
SCALE: AS NOTED

Joint Venture Team
albany pool

BIG C DISINFECTION AND
FLOATABLES CONTROL PROJECT
LINCOLN PARK SITE

PROJECT NO.
31615

DATE: 07/21/16

FIGURE A-3

APPENDIX B

Borings

Joint Venture Team albany pool

BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

LINCOLN PARK BORING LOCATION PLAN

PROJECT NO. 31615

DATE: 07/21/16

FIGURE B-1

LEGEND TO SUBSURFACE LOGS

SAMP./CORE NUMBER	SAMP. ADV(ft) LEN CORE(ft)	RECOVERY (ft)	Blows per 6" on Split Spoon Sampler	"N" VALUE or RQD%	SAMPLE	DEPTH (Feet)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, water return, etc	WATER LEVELS AND/OR WELL DATA
S1	2.0	1.8	2-3-4-5	7				f. SAND, Some Silt, trace f. gravel, brown, loose, moist (SM)	100		
R1	2.0	2.0	N/A	88%				Mica SCHIST, gray, soft, slightly weathered, closely fractured, good RQD			
1	2	3	4	5	6	7	8	9 10	11	12	13

Subsurface Logs present material classifications, test data, and observations from subsurface investigations at the subject site as reported by the inspecting geologist or engineer. In some cases, the classifications may be made based on laboratory test data when available. It should be noted that the investigation procedures only recover a small portion of the subsurface materials at the site. Therefore, actual conditions between borings and sampled intervals may differ from those presented on the Subsurface Logs. The information presented on the logs provide a basis for an evaluation of the subsurface conditions and may indicate the need for additional exploration. Any evaluation of the conditions reported on the logs must be performed by Professional Engineers or Geologists.

1. SAMP./CORE NUMBER – Samples are numbered for identification on containers, laboratory reports or in text reports.

2. SAMP.ADV/LEN.CORE – Length of sampler advance or length of coring run measured in feet.

3. RECOVERY – Amount of sample actually recovered after withdrawing sampler or core barrel from bore hole measured in feet.

4. SAMPLE BLOWS/6" – Unless otherwise noted, blow counts represent values obtained by driving a 2.0" (O.D.), 1-3/8" (I.D.) split spoon sampler into the subsurface strata with a 140 pound weight falling 30" as per ASTM International D1586. After an initial penetration of 6" to seat the sampler into undisturbed material, the sampler is then driven an additional 2 or 3 six inch increments. Refusal is defined as a resistance greater than 50 blows per 6" of penetration.

5. "N" Value or RQD % – "N" VALUE – The sum of the second and third sample blow increments is generally termed the Standard Penetration Test (SPT) "N" value. Refusal (R) is defined as a resistance greater than 50 blows for 6 inches of penetration. CORE RQD – Core Rock Quality Designation, RQD, is defined as the summed length of all pieces of core equal to or longer than 4 inches divided by the total length of the coring run. Fresh, irregular breaks distinguishable as being caused by drilling or recovery operations are ignored and the pieces are counted as intact lengths. RQD values are valid only for cores obtained with NX size core barrels.

6. SAMPLE – Graphical presentation of sample type and advance or core run length. See Table 1.

7. DEPTH – Depth as measured from the ground surface in feet.

8. GRAPHICS – Graphical presentation of subsurface materials. See Table 4. Dual soil classification and rock graphics may vary and are not shown on Table 4.

9. DESCRIPTION AND CLASSIFICATION – SOIL – Recovered samples are visually classified in the field by the supervising geologist or engineer unless otherwise noted. Particle size and plasticity classification is based on field observations, and using the Unified Soil Classification System (USCS). See Table 4. USCS symbols are presented in parentheses following the soil description. Where necessary, dual symbols may be used for combinations of soil types. Relative proportions, by weight and/or plasticity, are described in general accordance with "Suggested Methods of Test for Identification of Soils" by D.M. Burmister, ASTM Special Publication 479, 6-1970. See Table 2. Soil density or consistency description is based on the penetration resistance. See Table 3. Soil moisture description is based on the observed wetness of the soil recovered being dry, moist, wet, or saturated. Water introduced into the boring during drilling may affect the moisture content of the materials. Other geologic terms may also be used to further describe the subsurface materials. ROCK – Rock core descriptions are based on the inspector's observations and may be examined and described in greater detail by the project engineer or geologist. Terms used in the description of rock core are presented in Table 5.

10. DIVISION LINES – Division lines between deposits are based on field observations and changes in recovered material. Solid lines depict contacts between two deposits of different geologic depositional environment of known elevation. Dashed lines represent estimated elevation of contacts between two deposits of different geologic depositional environment. Dotted lines depict transitions of deposits within the same depositional environment, such as grain size or density.

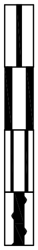
11. ELEVATION – Elevation of strata changes in feet.

12. REMARKS – Miscellaneous observations.

13. WATER LEVELS & WELL DATA – Hollow water level symbol, if present, represents level at which first saturated sample or water level was encountered. Solid water level symbol, if present, depicts the most probable static water elevation at the time of drilling or as measured in an installed observation well at a later date. Subsurface water conditions are influenced by factors such as precipitation, stratigraphic composition, and drilling/coring methods. Conditions at other times may differ from those described on the logs. For graphical presentation of observation/monitoring well construction, see Table 6. Elevations of changes in construction are noted at the bottom of each section.

LEGEND TO SUBSURFACE LOGS

TABLE 1
TYPICAL SAMPLE TYPES



- SPLIT SPOON (1 3/8" I.D.)
- NX SIZE ROCK CORE
- SHELBY TUBE "UNDISTURBED"
- AUGER SAMPLE

TABLE 2
SAMPLE MATERIAL PROPORTIONS

ADJECTIVE	PERCENTAGE OF SAMPLE
"and"	35% – 50%
"some"	20% – 35%
"little"	10% – 20%
"trace"	< 10%

Standard split spoon samples may not recover particles with any dimension larger than 1 3/8". Therefore, reported gravel percentages may not reflect actual conditions.

TABLE 3
DENSITY/CONSISTENCY

GRANULAR SOILS		COHESIVE SOILS	
Blows/ft.	Density	Blows/ft.	Consistency
< 5	Very Loose	< 2	Very Soft
5–10	Loose	2–4	Soft
11–30	Med. Compact	5–8	Med. Stiff
31–50	Compact	9–15	Stiff
> 50	Very Compact	16–30	Very Stiff
		> 30	Hard

TABLE 4
USCS CLASSIFICATION, PARTICLE SIZE, & GRAPHICS

	MAJOR PARTICLE SIZE DIVISION	USCS SYMBOL	GRAPHIC SYMBOL	GENERAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL Coarse: 3"–3/4" Fine: 3/4"–#4 Classification based on > 50% being gravel	GW		Well graded gravels, gravel & sand mix.
		GP		Poorly graded gravels, gravel & sand mix.
		GM		Gravel, sand and silt mix.
		GC		Gravel, sand and clay mix.
	SAND Coarse: #4–#10 Med.: #10–#40 Fine: #40–#200 Classification based on > 50% being sand	SW		Well graded sand, sand & gravel mix.
		SP		Poorly graded sand, sand & gravel mix.
		SM		Sand and silt mix.
		SC		Sand and clay mix.
FINE GRAINED SOILS	SILT & CLAY Classification based on > 50% passing #200 sieve.	ML		Inorganic silt, low plasticity.
		CL		Inorganic clay, low plasticity.
		OL		Organic silt/clay, low plasticity.
		MH		Inorganic silt, high plasticity.
		CH		Inorganic clay, high plasticity.
		OH		Organic silt/clay, high plasticity.
	ORGANIC SOILS	Pt		Peat and other highly organic soils.
	FILL	Fill		Miscellaneous fill materials.

TABLE 5
ROCK CLASSIFICATION TERMS

HARDNESS:

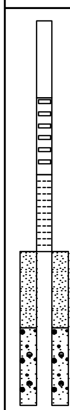
Very Soft	Carves
Soft	Grooves with knife
Med. Hard	Scratched easily with knife
Hard	Scatched with difficulty
Very Hard	Cannot be scratched with knife

WEATHERING:

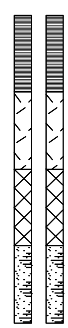
Fresh	Slight or no staining of fractures, little or no discoloration, few fractures.
Slightly	Fractures stained, discoloration may extend into rock 1", some soil in fractures.
Moderately	Significant portions of rock stained and discolored, soil in fractures, loss of strength.
Highly	Entire rock discolored and dull except quartz grains, severe loss of strength.
Complete	Weathered to a residual soil.

BEDDING:		FRACTURE SPACING:		RQD:	
Massive	> 40"	Massive/V. Wide	> 6'	Excellent	> 90%
Thick	12' – 40"	Thick/Wide	2' – 6'	Good	76% – 90%
Medium	4" – 12"	Med./Med.	8" – 24"	Fair	51% – 75%
Thin	< 4"	Thin/Close	2 1/2" – 8"	Poor	25% – 50%
		V. Thin/V. Close	< 2 1/2"	V. Poor	< 25%

TABLE 6
WELL CONSTRUCTION



- SOLID PVC PIPE
- SCREENED PVC PIPE
- STAINLESS STEEL SCREENED PIPE
- FINE GRAINED WASHED SAND
- WASHED SAND



- BENTONITE PLUG
- AIR ENTRAINED CEMENT
- NATURAL SOIL/ ROCK FILL
- BENTONITE/ CEMENT GROUT

PROJECT NUMBER: 31615.1000.32000

Big C Disinfection & Floatables
SUBSURFACE LOG
HOLE NUMBER B-1

LOCATION: Albany, New York		DRILL FLUID: Water @ 20.6'	DRILLING METHOD: 3.25" H.S.A.
CLIENT: Albany Pool Joint Venture Team		HAMMER TYPE: Automatic	ROD SIZE: AW
CONTRACTOR: Atlantic Testing Laboratories, Inc.		DRILL RIG TYPE & MODEL: Truck Rig, CME 45	
DRILLER: T. Weston	INSPECTOR: N. DeFlorio		
START DATE and TIME: 5/31/2016 2:00:00 PM			
FINISH DATE and TIME: 6/2/2016 3:00:00 PM			
SURFACE ELEV: 176.0 (ft; Estimated)	CHECKED BY: S. Doehla		

WATER LEVEL OBSERVATIONS	DATE	TIME	READING TYPE	WATER DEPTH (ft)	CASING BOTTOM (ft)	HOLE BOTTOM (ft)
	6-3-16	7:36 AM	Static	21.3	32.5	32.5
	6-8-16	3:22 PM	Static	22	32.5	32.5
	6-30-16	8:20 AM	Static	22.7	32.5	32.5

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	DEPTH (Feet)	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.
S-1	2	0.8	4-5-6-5	11		**SILT**, little f.m. sand, trace timber, trace red brick, brown, m. compact, moist **(FILL)**	175	Groundwater observations made during drilling may not represent static conditions. Driller installed 2" PVC pipe to a depth of 32.5'. 10-slot screen section was from 22.5-32.5'. Well backfill consisted of grout from approximately 0.3-11', bentonite from 11-14', and sand from 14-32.5'.
S-2	2	1.1	4-3-4-6	7	5	**Clayey SILT**, trace f.m. sand, trace red brick, brown, loose, moist **(FILL)**	170	
S-3	2	1	2-2-3-4	5	10	**Silty CLAY**, little f.m. sand, brown, m. stiff, moist **(CL)**	165	
S-4	2	1.3	7-9-12-16	21	15	**SILT**, little f.m.c. sand, brown, m. compact, moist **(ML)**	160	
S-5	0.6	0.4	47-50/4"	R	20	**f.m.c. SAND**, Some Silt, brown, v. compact, moist **(COMPLETELY WEATHERED BEDROCK)**	155	Increased resistance encountered when advancing auger. Advanced auger to 21' to begin coring.
R-1	5	3.1		6%		**SHALE**, dark gray, m. hard, highly weathered, v. thin/v. close fracture spacing, v. poor RQD		

PROJECT NUMBER: 31615.1000.32000

Big C Disinfection & Floatables

SUBSURFACE LOG

HOLE NUMBER B-1

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	SAMPLE	DEPTH (Feet)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.	WATER LEVELS AND/OR WELL DATA
								SHALE, dark gray, m. hard, highly weathered, thin/close fracture spacing, v. poor RQD	150		
R-2	5	4.3		16%		30			145		
								SHALE, dark gray, m. hard, moderately weathered, thin/close fracture spacing, poor RQD			
R-3	4	3.3		46%		35					
								End of Boring at 20.6 ft	140		

Depth scale: 30, 35, 40, 45, 50, 55. Elevation scale: 150, 145, 140, 135, 130, 125.

PROJECT NUMBER: 31615.1000.32000

Big C Disinfection & Floatables
SUBSURFACE LOG
HOLE NUMBER B-2

LOCATION: Albany, New York	DRILL FLUID: Water @ 16'
CLIENT: Albany Pool Joint Venture Team	DRILLING METHOD: 3.25" H.S.A.
CONTRACTOR: Atlantic Testing Laboratories, Inc.	HAMMER TYPE: Automatic
DRILLER: T. Weston	ROD SIZE: AW
INSPECTOR: N. DeFlorio	DRILL RIG TYPE & MODEL: Truck Rig, CME 45
START DATE and TIME: 6/3/2016 8:40:00 AM	
FINISH DATE and TIME: 6/7/2016 9:00:00 AM	
SURFACE ELEV: 162.6 (ft; Estimated)	CHECKED BY: S. Doehla

WATER LEVEL OBSERVATIONS

DATE	TIME	READING TYPE	WATER DEPTH (ft)	CASING BOTTOM (ft)	HOLE BOTTOM (ft)
6-3-16	10:38 AM	During Drilling	None	15	15.9
6-6-16	1:30 PM	Start of Day	3	19	19.2
6-6-16	4:52 PM	End of Day	6.6	19	31

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	DEPTH (Feet)	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.	WATER LEVELS AND/OR WELL DATA
					0	**TOPSOIL (TOPSOIL)**		Groundwater observations made during drilling may not represent static conditions.	
S-1	2	0.6	2-4-5-5	9		**SILT**, Some f. Sand, trace organics, brown, loose, moist **(ML)**	160		
S-2	2	1.5	2-4-4-6	8	5	**Silty CLAY**, trace f. sand, brown, m. stiff, moist **(CL)**	155		
S-3	2	1.8	3-7-15-23	22	10	becomes v. stiff **(CL)**			
						Silty CLAY, Some f.m.c. Sand, trace f. gravel, brown/black, v. stiff, moist **(COMPLETELY WEATHERED BEDROCK)**	150	Auger grinding from 13-14 feet.	
S-4	0.9	0.5	50-50/5"	R	15	**f.m.c. SAND**, trace f. gravel, gray, v. compact, moist **(COMPLETELY WEATHERED BEDROCK)**		Encountered split spoon refusal at 15.9'. Advance auger to 16' to begin coring.	
R-1	5	0		0%		No Recovery	145	Core barrel dropped approximately 4" when coring began. Steady core bit advancement from 16-21 feet indicative of weathered shale.	
R-2	5	0.1		0%	20	Insufficient Recovery	140	Switched casing method to F.J.C. Advanced F.J.C. casing to 19'. Steady core bit advancement and gray wash water from 21-26 feet indicative of weathered shale.	

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SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	SAMPLE	DEPTH (Feet)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.	WATER LEVELS AND/OR WELL DATA
								Insufficient Recovery *(continued)*			
								SHALE, dark gray/black, m. hard, moderate weathering, thin/close fracture spacing, v. poor RQD	135		
R-3	5	2.5		0%		30					
								End of Boring at 31 ft	130		
						35			125		
						40			120		
						45			115		
						50			110		
						55					

Big C Disinfection & Floatables
SUBSURFACE LOG
HOLE NUMBER B-3

PROJECT NUMBER: 31615.1000.32000

LOCATION: Albany, New York		DRILL FLUID: Water @ 5'	DRILLING METHOD: 3.25" H.S.A.
CLIENT: Albany Pool Joint Venture Team		HAMMER TYPE: Automatic	ROD SIZE: AW
CONTRACTOR: Atlantic Testing Laboratories, Inc.		DRILL RIG TYPE & MODEL: Truck Rig, CME 45	
DRILLER: T. Weston	INSPECTOR: N. DeFlorio		
START DATE and TIME: 6/7/2016 9:45:00 AM			
FINISH DATE and TIME: 6/8/2016 11:30:00 AM			
SURFACE ELEV: 136.7 (ft; Estimated)	CHECKED BY: S. Doehla		

WATER LEVEL OBSERVATIONS	DATE	TIME	READING TYPE	WATER DEPTH (ft)	CASING BOTTOM (ft)	HOLE BOTTOM (ft)
	6-8-16	3:40 PM	Well Install	13.3	24	24
	6-21-16	8:45 AM	Static	22.3	24	24
	6-30-16	8:34 AM	Static	22.4	24	24

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	DEPTH (Feet)	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.
					0	**ASPHALT PAVEMENT**		Advanced auger through asphalt surface to sample.
S-1	2	0.7	8-10-9-5	19		**f.m.c. SAND**, little silt, trace f. gravel, brown, m. compact, moist **(FILL)**	135	Driller installed 2" PVC pipe to a depth of 24'. 10-slot screen section was from 14-24'. Well backfill consisted of grout from approximately 0.5-5', bentonite from 5-12', and sand from 12-14'.
S-2	2	1.1	3-4-2-17	6	5	**f.m.c. SAND**, And clayey Silt, brown/orange, loose, moist **(FILL)**	130	Hammer bouncing 6.5'-6.8'.
S-3	1.7	1.2	16-13-32-50/2"	45	10	**f.m.c. SAND**, Some clayey Silt, little f. gravel, brown/gray, compact, moist **(COMPLETELY WEATHERED BEDROCK)**	125	Groundwater observations made during drilling may not represent static conditions. Split spoon refusal at 11.7'.
R-1	5	0		0%	15	No Recovery	120	Advanced roller bit to 15'. Advanced casing to 15'. Steady core bit advancement from 15 to 20 feet indicative of weathered shale.
R-2	5	2.5		8%	20	**SHALE**, dark gray/black, m. hard, moderate weathering, v. thin/v. close fracture spacing, v. poor RQD	115	

End of Boring at 25 ft

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Big C Disinfection & Floatables
SUBSURFACE LOG
HOLE NUMBER B-4

PROJECT NUMBER: 31615.1000.32000

LOCATION: Albany, New York		DRILL FLUID: Water @ 35'	DRILLING METHOD: 3.25" H.S.A.
CLIENT: Albany Pool Joint Venture Team		HAMMER TYPE: Automatic	ROD SIZE: AW
CONTRACTOR: Atlantic Testing Laboratories, Inc.		DRILL RIG TYPE & MODEL: Truck Rig, CME 45	
DRILLER: T. Weston	INSPECTOR: N. DeFlorio		
START DATE and TIME: 6/8/2016 11:40:00 AM			
FINISH DATE and TIME: 6/9/2016 12:00:00 PM			
SURFACE ELEV: 157.2 (ft; Estimated)	CHECKED BY: S. Doehla		

WATER LEVEL OBSERVATIONS	DATE	TIME	READING TYPE	WATER DEPTH (ft)	CASING BOTTOM (ft)	HOLE BOTTOM (ft)
	6-9-16	8:25 AM	Start of Day	None	35	35

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	SAMPLE	DEPTH (Feet)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.	WATER LEVELS AND/OR WELL DATA
S-1	2	0.8	3-4-5-5	9				**TOPSOIL (TOPSOIL)** **Clayey SILT**, Some f.m. Sand, brown, stiff, moist **(FILL)**	155	Groundwater observations made during drilling may not represent static conditions.	
S-2	2	1.5	3-3-5-5	8		5		**Silty CLAY**, little f.m. sand, brown, m. stiff, moist **(FILL)**	150		
S-3	2	1.6	3-3-5-6	8		10		**Similar Soil (FILL)**	145		
S-4	2	1.3	4-3-3-4	6		15		**f.m. SAND**, Some Silt, brown, loose, moist **(FILL)** **Silty CLAY**, trace f.m. sand, trace red brick, brown, m. stiff, moist **(FILL)**	140		
S-5	2	1.6	2-4-4-5	8		20		grades to trace red brick, trace wood **(FILL)**	135		

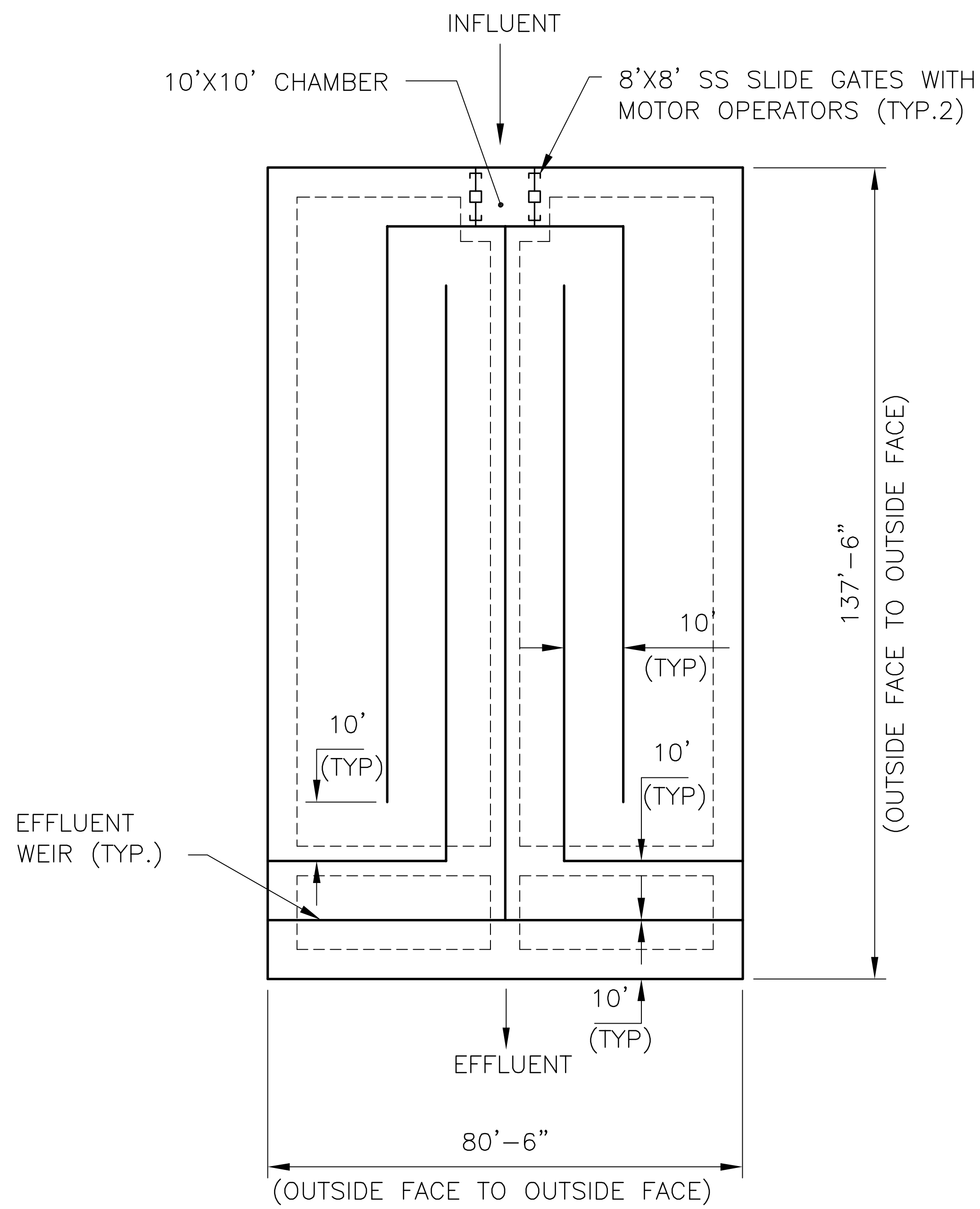
PROJECT NUMBER: 31615.1000.32000

Big C Disinfection & Floatables
SUBSURFACE LOG
HOLE NUMBER B-4

SAMP./CORE NUMBER	SAMP. ADV. (ft) LEN. CORE (ft)	RECOVERY (ft)	Blows Per 6" on Split Spoon Sampler	"N" Value or RQD%	SAMPLE	DEPTH (Feet)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEVATION (Feet)	Remarks on Character of Drilling, Water Return, etc.	WATER LEVELS AND/OR WELL DATA
S-6	2	0.4	5-4-6-4	10				**Clayey SILT**, Some f.m.c. Sand, trace f.c. gravel, trace red brick, brown, stiff, moist **(FILL)**	130		
S-7	2	1.7	4-5-8-38	13		30		**Clayey SILT**, Some f.m.c. Sand, little f. gravel, gray, stiff, moist **(COMPLETELY WEATHERED BEDROCK)**	125		
R-1	5	4.3		33%		35		**SHALE**, dark gray/black, m. hard, moderate weathering, thin/close fracture spacing, poor RQD becomes highly weathered, v. thin/v. close fracture spacing becomes mod. weathered, thin/close fracture spacing	120	Split spoon refusal encountered at 35'.	
						40		End of Boring at 40 ft	115		
						45			110		
						50			105		
						55					

APPENDIX C

Disinfection Alternatives



PLAN

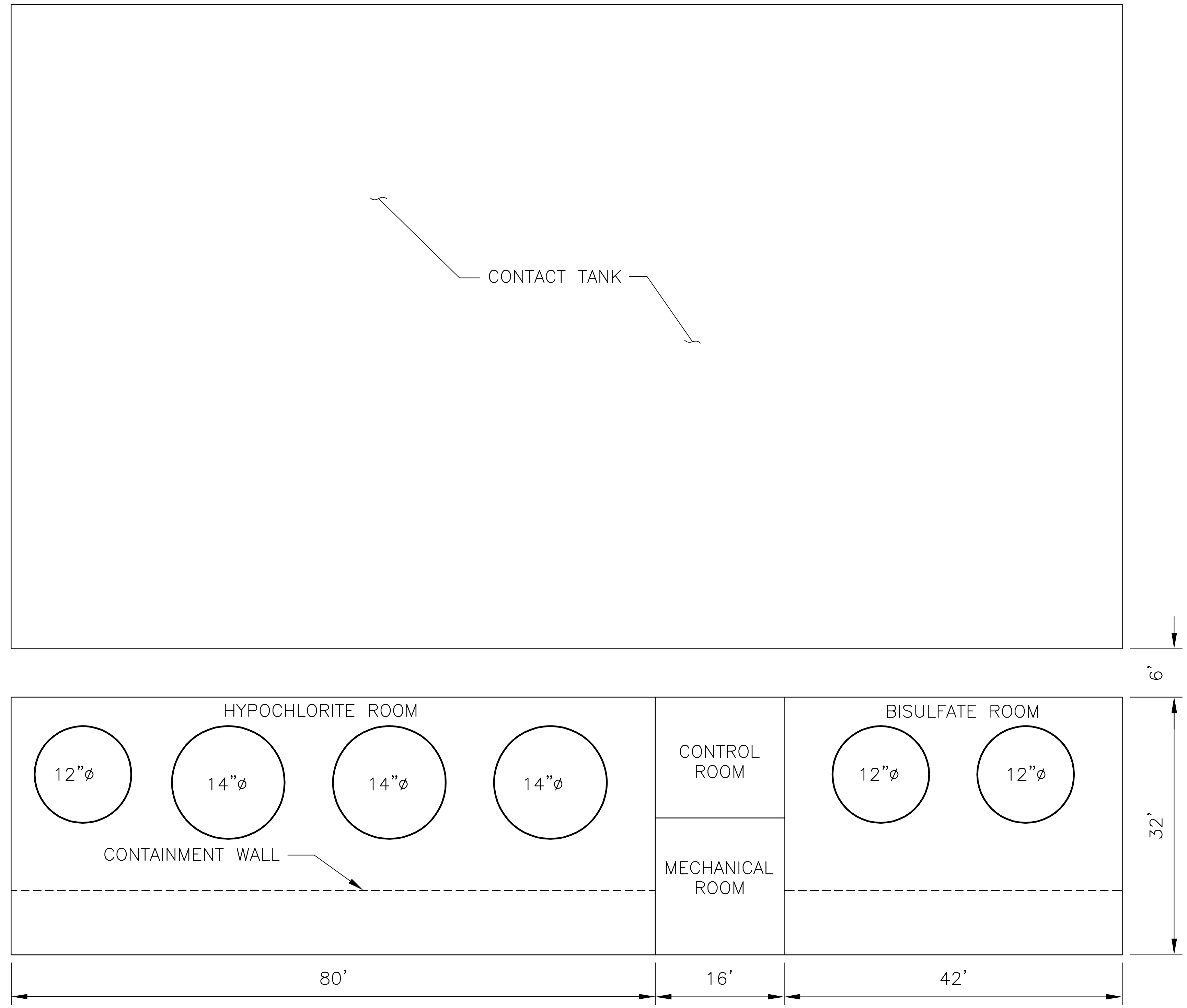
1" = 30'

ASSUMPTIONS:

1. ALL WALLS ARE 1.5 FEET THICK.
2. TANK SLAB EXTENDS BEYOND EXTERIOR FACE OF PERIMETER WALLS BY 2 FEET IN EACH DIRECTION.
3. TANK SLAB IS 2 FEET THICK.
4. ALL WALKWAYS ARE 5 FEET WIDE AND 0.75 FEET THICK.
5. SIDEWATER DEPTH = 14 FEET.
6. DISTANCE BETWEEN OPERATING LEVEL AND WATER = 2 FEET.
7. ALL DIMENSIONS ARE INSIDE FACE TO INSIDE FACE UNLESS NOTED OTHERWISE.
8. LIMITS OF WALKWAYS ARE SHOWN BY DASHED LINES.
9. THIS TANK WILL NOT BE ENCLOSED BY A CONCRETE CEILING.

1" = 30'
15 0 30

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT BROADWAY SITE CONTACT TANK	PROJECT NO. 31615 DATE: 07/21/16 FIGURE C-1



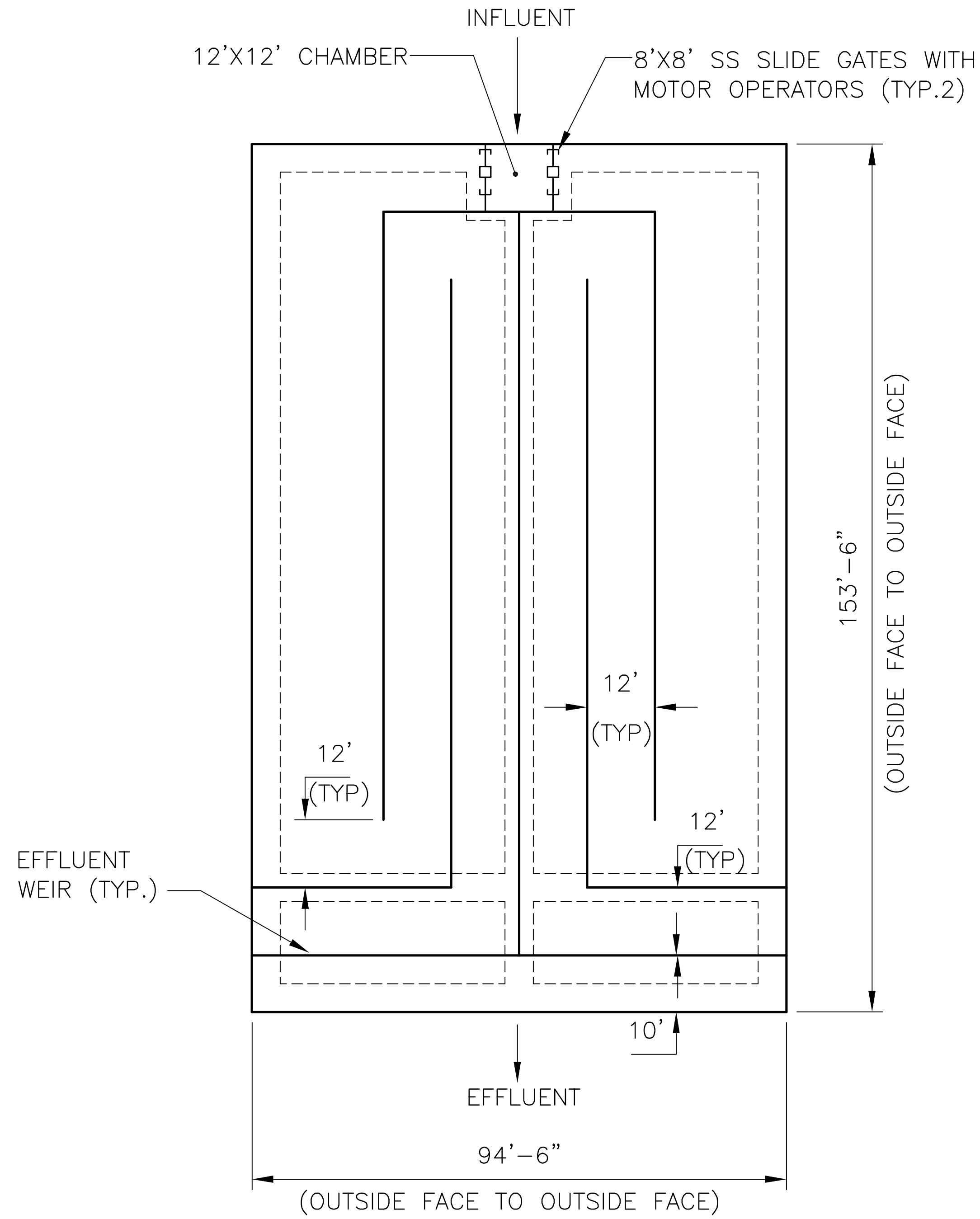
PLAN

1/16" = 1'-0"

1/16" = 1'- 0"

8 4 0 8 16

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT BROADWAY SITE HYPOCHLORITE CHEMICAL	PROJECT NO. 31615 DATE: 07/21/16 FIGURE C–2



PLAN

1" = 30'

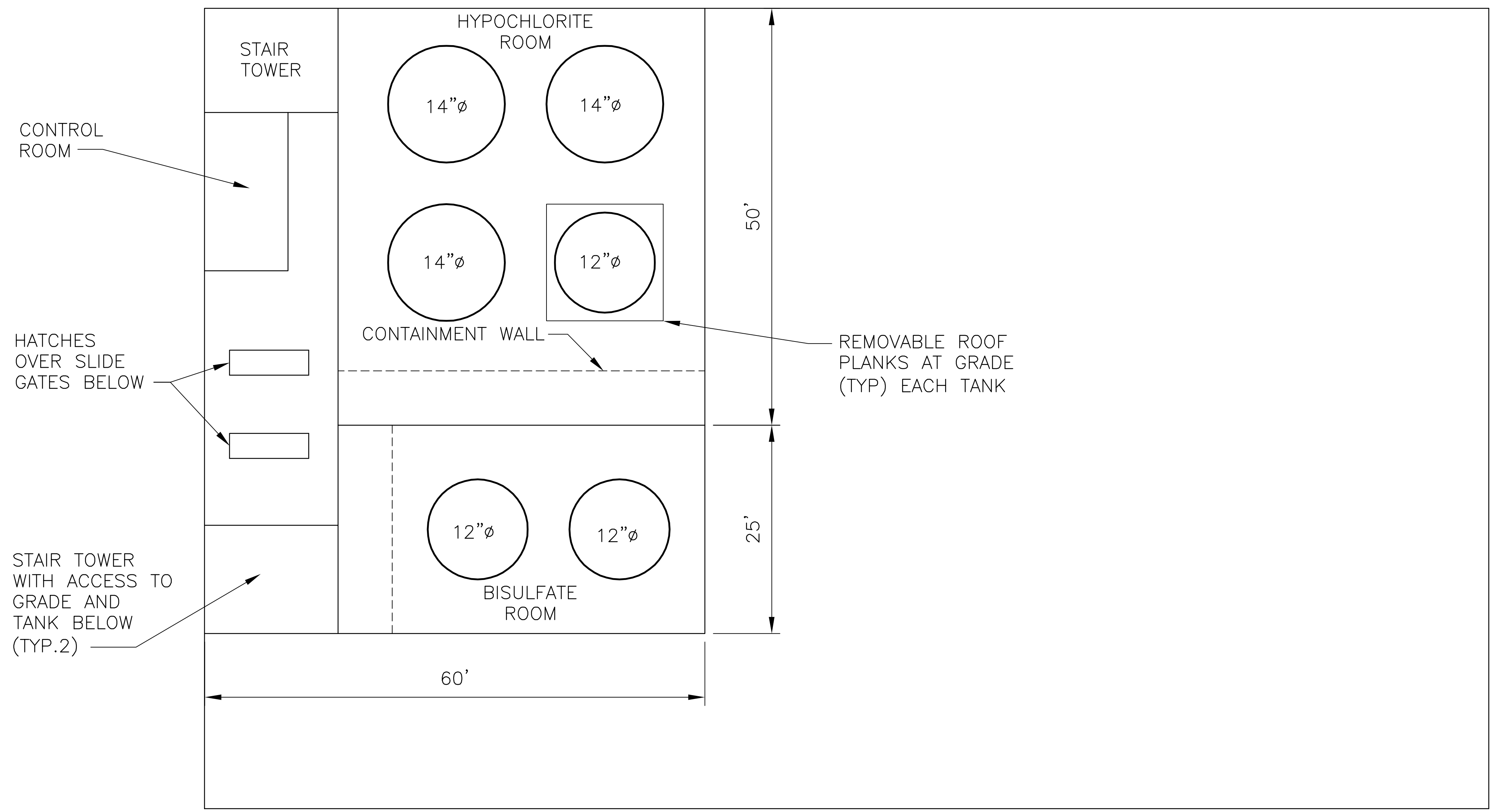
ASSUMPTIONS:

1. ALL WALLS ARE 1.5 FEET THICK.
2. TANK SLAB EXTENDS BEYOND EXTERIOR FACE OF PERIMETER WALLS BY 2 FEET IN EACH DIRECTION.
3. TANK SLAB IS 2 FEET THICK.
4. ALL WALKWAYS ARE 5 FEET WIDE AND 0.75 FEET THICK.
5. PERIMETER WALL EXTENDS UP 12 FEET ABOVE OPERATING LEVEL (WALKWAYS).
6. CEILING SLAB IS 2 FEET THICK WITH 10 BEAMS THAT ARE 2'X2'.
7. THERE ARE 10 COLUMNS FROM THE OPERATING WALKWAYS UP TO THE BEAMS.
8. COLUMNS ARE 1.5'X1.5'.
9. SIDEWATER DEPTH = 14 FEET.
10. DISTANCE BETWEEN OPERATING LEVEL AND WATER = 2 FEET.
11. ALL DIMENSIONS ARE INSIDE FACE TO INSIDE FACE UNLESS NOTED OTHERWISE.
12. LIMITS OF WALKWAYS ARE SHOWN BY DASHED LINES.

1" = 30'

15 0 30

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT LINCOLN PARK SITE CONTACT TANK	PROJECT NO. 31615 DATE: 07/21/16 FIGURE C–3

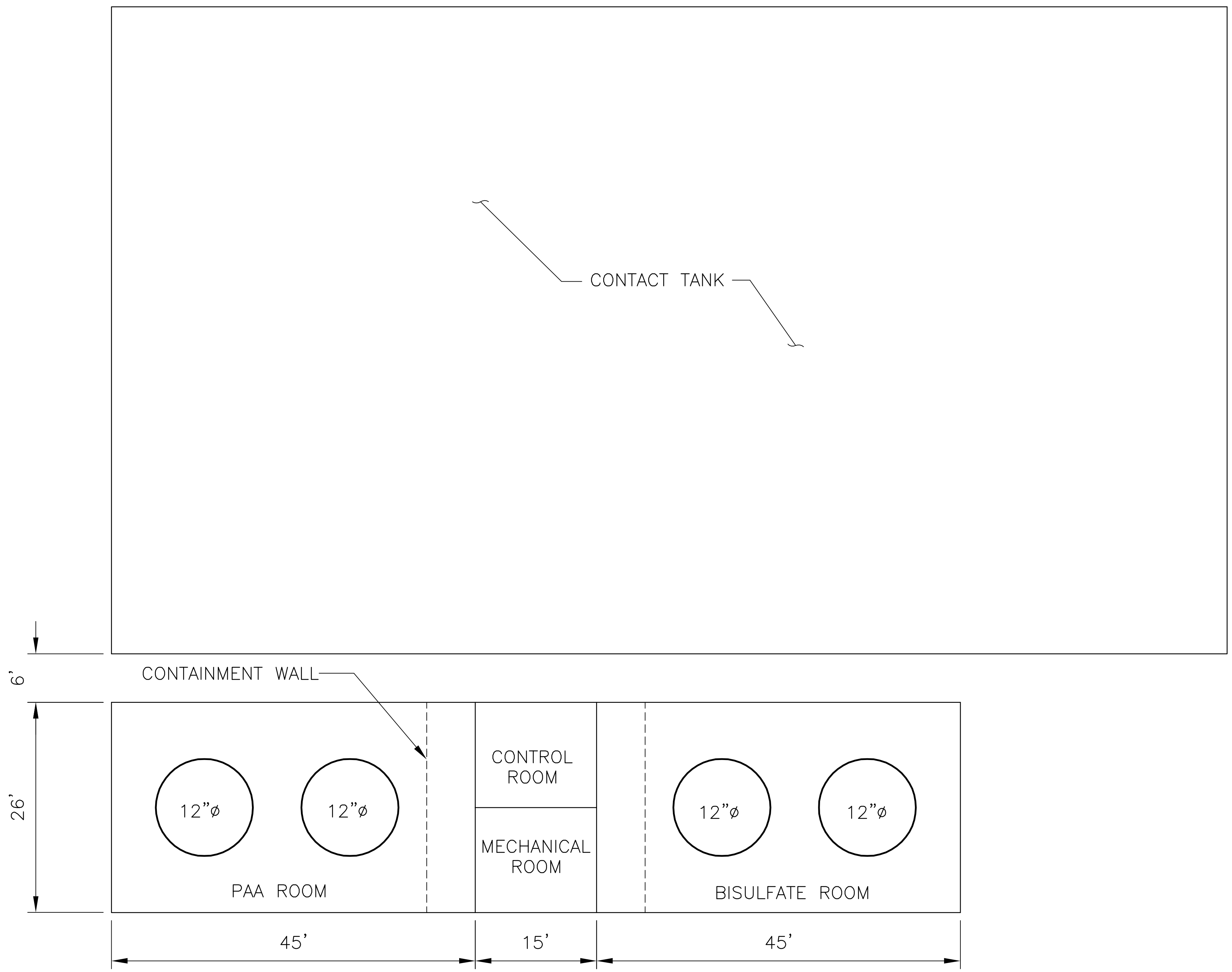


PLAN

1/16" = 1'–0"

1/16" = 1'– 0"
8 4 0 8 16

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT LINCOLN PARK SITE HYPOCHLORITE CHEMICAL	PROJECT NO. 31615 DATE: 07/21/16 FIGURE C–4



PLAN

1/16" = 1'–0"

1/16" = 1'– 0"
8 4 0 8 16

albany pool Joint Venture Team

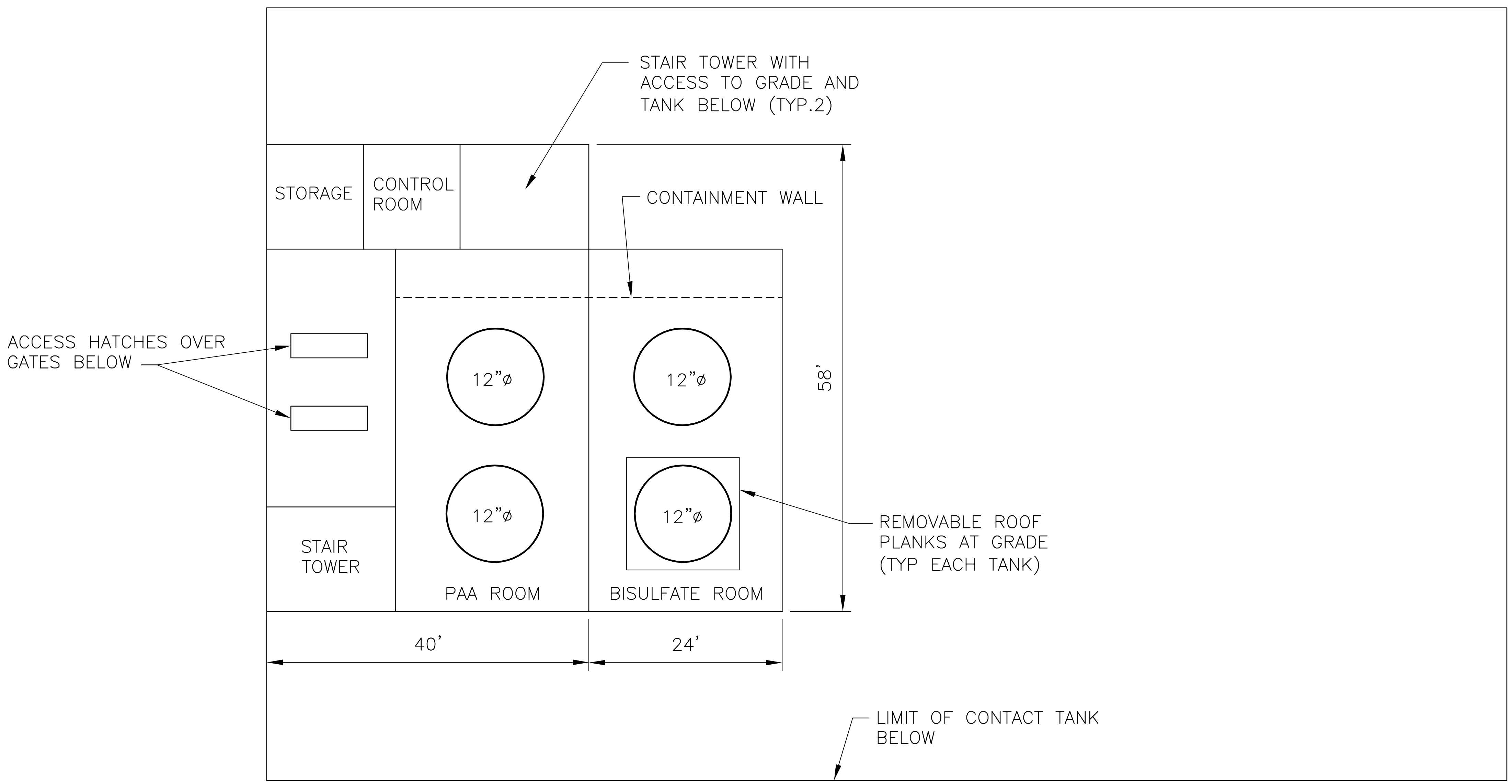
BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

BROADWAY SITE PAA CHEMICAL AREA

PROJECT NO. 31615

DATE: 07/21/16

FIGURE C–5



PLAN

1/16" = 1'–0"

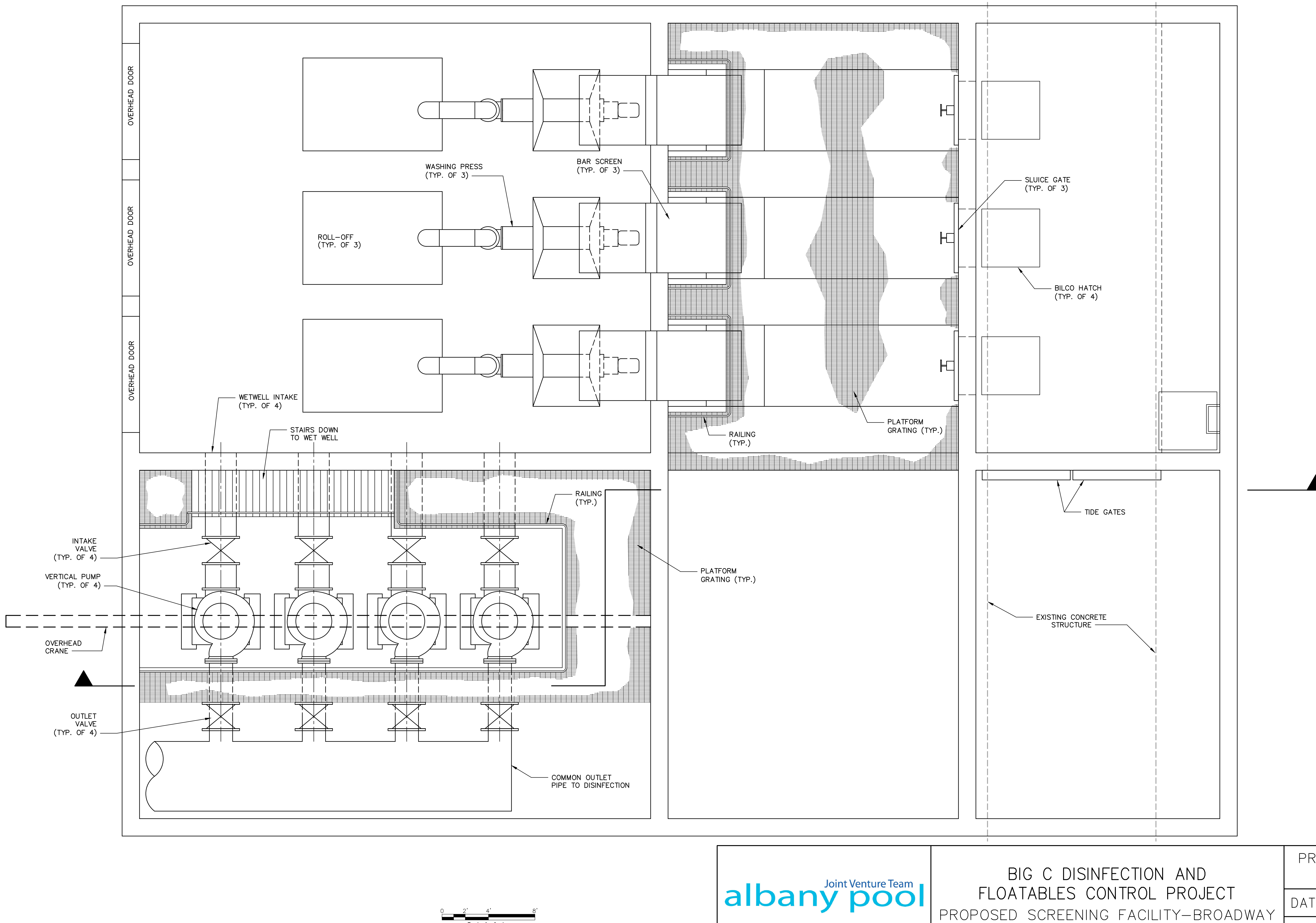
1/16" = 1'– 0"

8 4 0 8 16

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT LINCOLN PARK SITE PAA CHEMICAL AREA	PROJECT NO. 31615 DATE: 07/21/16 FIGURE C–6

APPENDIX D

Screening Alternatives



FILENAME: G:\ACAD\PROJ\00241009.0000\FIGURES\FOR STEVE\ALBANY CSO-BROADWAY.DWG

albany pool Joint Venture Team

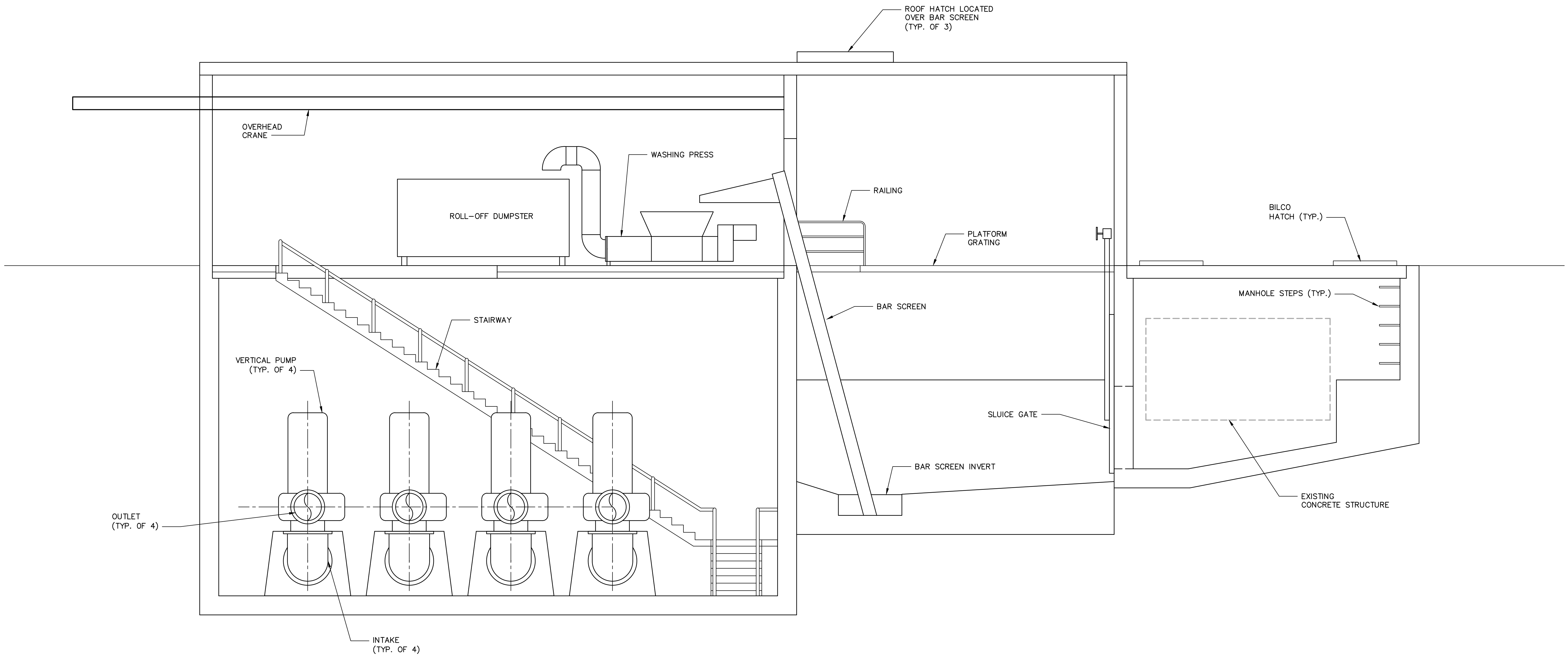
BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

PROPOSED SCREENING FACILITY–BROADWAY PLAN

PROJECT NO. 31615

DATE: 07/21/16

FIGURE 1



0 2' 4' 8'
Scale in feet

albany pool Joint Venture Team

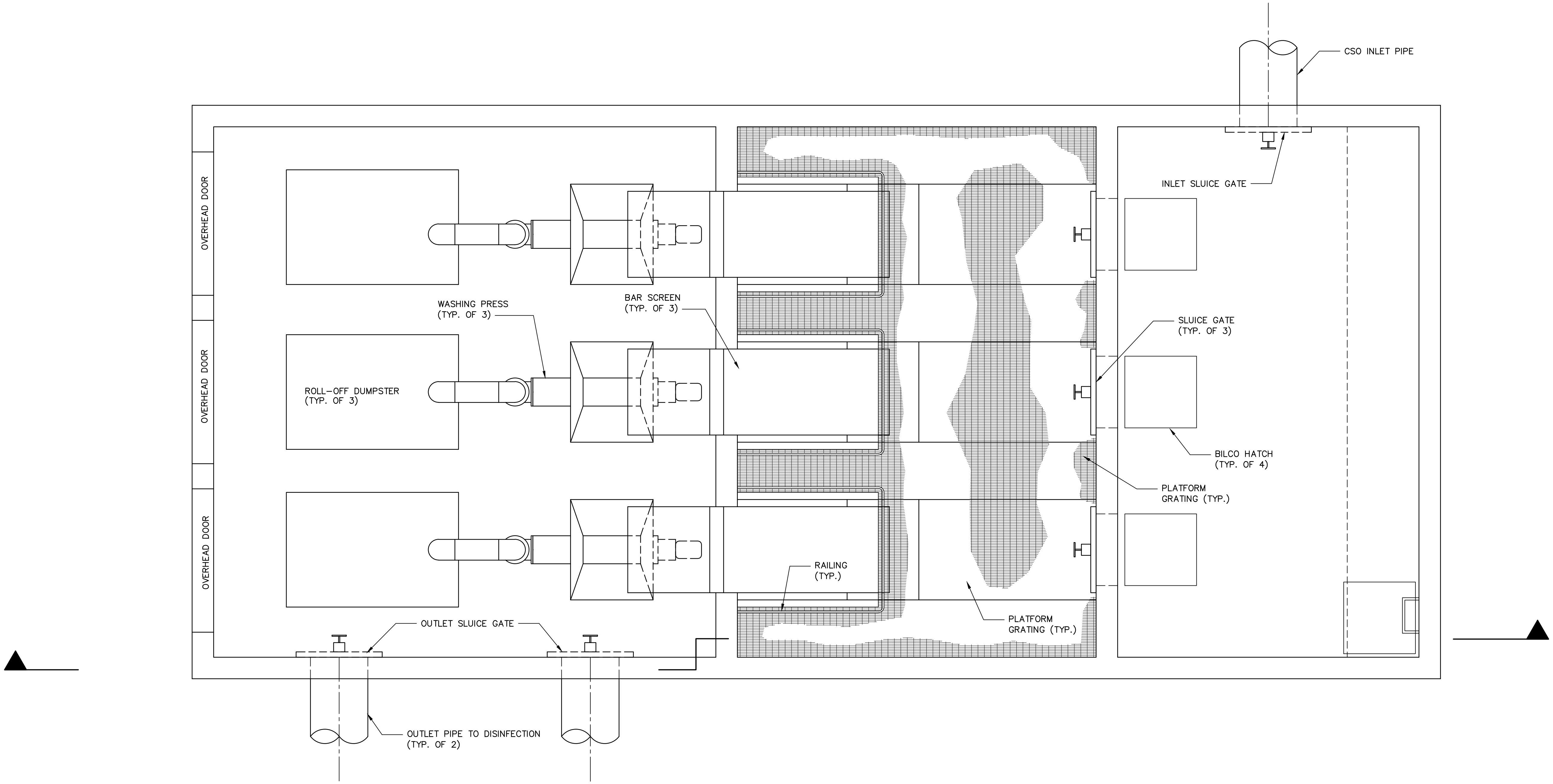
BIG C DISINFECTION AND
FLOATABLES CONTROL PROJECT
PROPOSED SCREENING FACILITY–BROADWAY
SECTION

PROJECT NO.
31615

DATE: 07/21/16

FIGURE 1A

FILENAME: G:\ACAD\PROJ\00241009.0000\FIGURES\FOR STEVE\ALBANY CSO-BROADWAY.DWG



albany pool Joint Venture Team

BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

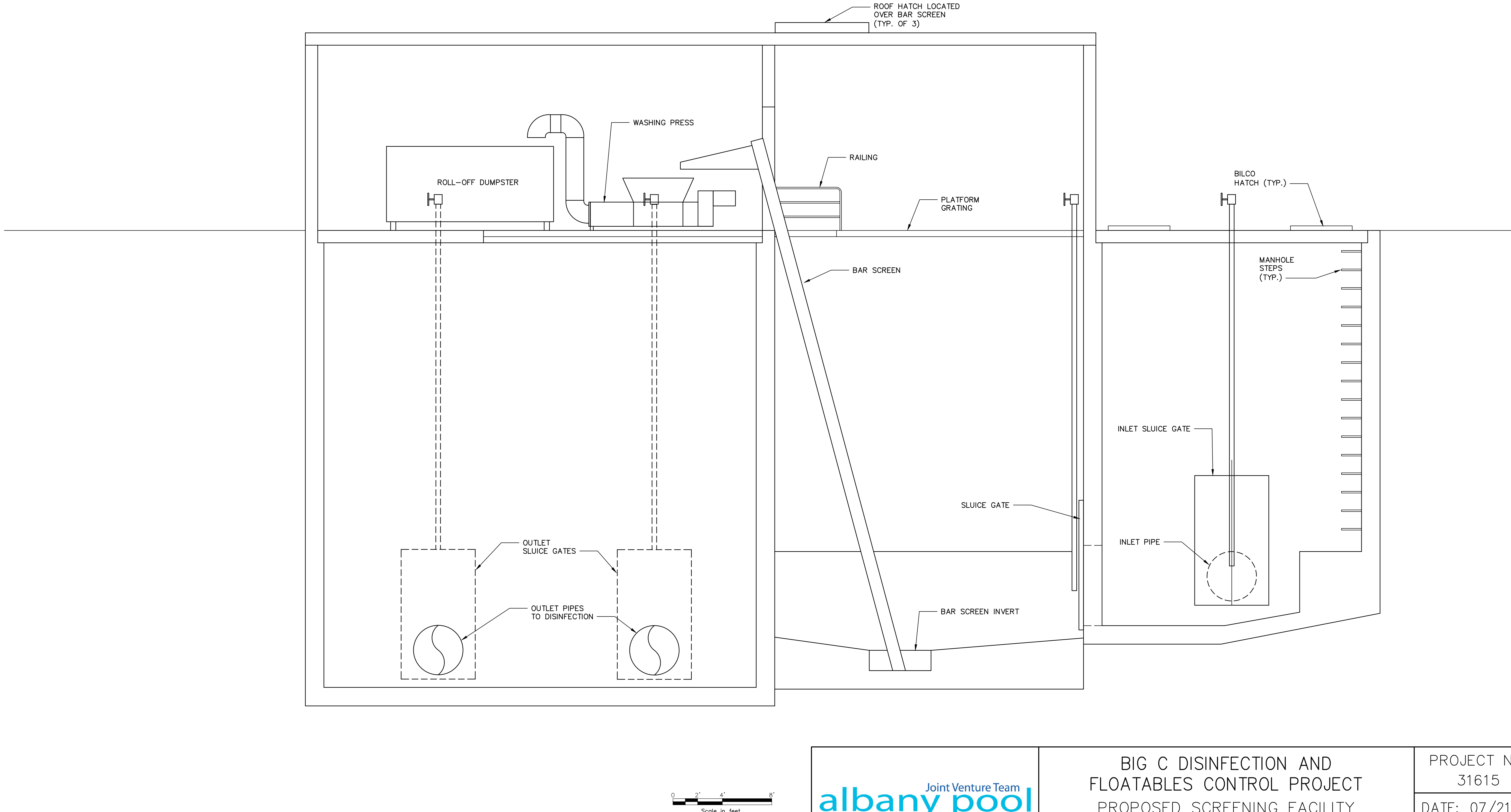
PROPOSED SCREENING FACILITY
LINCOLN PARK
PLAN

PROJECT NO. 31615

DATE: 07/21/16

FIGURE 2

FILENAME: G:\ACAD\PROJ\00241009.0000\FIGURES\FOR STEVE\ALBANY CSO-LINCOLN PARK.DWG



albany pool Joint Venture Team

BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT

PROPOSED SCREENING FACILITY
LINCOLN PARK
SECTION

PROJECT NO. 31615

DATE: 07/21/16

FIGURE 2A

FILENAME: G:\ACAD\PROJ\00241009.0000\FIGURES\FOR STEVE\ALBANY CSO-LINCOLN PARK.DWG

APPENDIX E

Site Layout Sketches

Joint Venture Team
albany pool

BIG C DISINFECTION AND
FLOATABLES CONTROL PROJECT
BROADWAY SITE

PROJECT NO.
31615

DATE: 07/21/16

FIGURE E-1

PLAN VIEW
AS NOTED

PROFILE VIEW
SCALE: AS NOTED

albany pool Joint Venture Team	BIG C DISINFECTION AND FLOATABLES CONTROL PROJECT LINCOLN PARK SITE	PROJECT NO. 31615 DATE: 07/21/16 FIGURE E-2

APPENDIX F

Cost Estimating

Albany Water Board

Big C Screening & Disinfection Facility - Alternatives Evaluation

Summary of Costs for Bar Screening & Chlorination/Dechlorination

Broadway Site

Capital Costs		
Chemical Contact Tank & Equipment	LS	$2,187,000
Screeings Foundation and Structures	LS	$1,600,000
Chemical Building	LS	$1,768,000
Screenings Building	LS	$2,400,000
Screenings & Pumping Equipment	LS	$3,408,000
Odor Control	LS	$820,000
Site Work	LS	$7,200,000
Installation Labor, Construction Equipment & Misc. Materials	30%	$1,930,000
Electrical	10%	$650,000
Instrumentation & Controls	10%	$650,000
Plumbing	5%	$280,000
Direct Construction Costs Subtotal		$22,900,000
Contractor's General Conditions/Risk	5%	$1,150,000
Subtotal		$24,100,000
Contractor Indirects, OH&P	20%	$4,820,000
Subtotal		$28,900,000
Contractor's Bonds	2%	$580,000
Construction Contingency	25%	$7,370,000
Total Construction Cost		$36,900,000
Admin, Legal, & Insurance	5%	$1,850,000
Engineering & Construction Administration	LS	$4,500,000
Land Acquisition	LS	$1,000,000
Total Cost in Today's Dollars		**$44,300,000**
Escalation to Midpoint of Construction	6%	$2,700,000
Total Cost		**$47,000,000**

Annual Costs			
Screening System			
Annual Average Run Time, Hours/year	452.0		
Days per year of treatment	30		
Annual Material Costs		$	164,300
Electrical Usage (1000 kWh/yr)			
Pumps	102.3		
Screenings equipment	3.08		
Odor Control	4.00		
Building	25		
Annual Electrical Costs		$	13,400
Operation & Maintenance, hours/treatment day	12		
Fully loaded labor rate, $/hour	$40.00		
Annual Personnel Costs		$	14,000
Sodium Hypochlorite System			
Annual Average treated volume, mg	285.0		
Days per year of treatment	30		
Hypochlorite dose, mg/L	6.0		
Percent solution NaOCL, %	12.5		
NaOCL - lbs of chlorine available/gallon of solution	1.04		
Gallons per year, as delivered	13,700		
Price per gallon, as delivered	$0.60		
Annual chemical costs for NaOCL		$	8,200
Operation & Maintenance, hours/treatment day	12		
Fully loaded labor rate, $/hour	$40.00		
Annual maintenance costs		$	14,000
Sodium Bisulfite System			
Average treated flow, mgd	285.0		
Days per year of treatment	30		
NAHSO3 dose, mg/L	25.5		
Percent solution NAHSO3 %	38		
Specific density of NAHSO3 lbs/gal	11.1		
Gallons per year, as delivered	14,400		
Price per gallon, as delivered	$1.20		
Annual chemical costs for NAHSO3		$	17,000
Lifecycle in years	20	*P/A factor =* 17.02	
Discount rate	4.13%		
Inflation rate	2.50%		
Annual Costs		$	231,000
Present Value of Annual Costs		$	3,900,000
Present Value of Lifecycle Cost		**$**	**50,900,000**

Albany Water Board

Big C Screening & Disinfection Facility - Alternatives Evaluation

Capital Costs for Broadway Site, Chlorination/Dechlorination, Bar Screening

No.	Cost Item	Quantity	Units	Unit Cost	Subtotal
1	Chlorine Contact Tank Cast-in-place concrete	1,900	CY	$ 800	$1,520,000
2	Chlorine Contact Tank Equipment	1	EA	$ 155,000	$155,000
3	Screenings Structures Cast-in-place concrete	2,000	CY	$ 800	$1,600,000
4	Screenings Equipment	1	EA	$ 1,558,000	$1,558,000
5	Pumping Equipment	1	EA	$ 650,000	$650,000
6	Flow Metering	1	LS	$ 75,000	$75,000
7	Chemical Building	4,420	SF	$ 400	$1,768,000
8	Screenings Building	6,000	SF	$ 400	$2,400,000
9	Chemical Tanks, Pumps, and Controls	1	EA	$ 512,000	$512,000
10	Odor Control	1	EA	$ 820,000	$820,000
11	Generator and ATS	1	EA	$ 500,000	$500,000
12	Piping	1	LS	$ 625,000	$625,000
13	Piles	1	LS	$ 3,000,000	$3,000,000
14	MOPO	1	LS	$ 1,000,000	$1,000,000
15	Dewatering	1	LS	$ 1,500,000	$1,500,000
16	Sheeting	1	LS	$ 1,500,000	$1,500,000
17	Excavation	1	LS	$ 200,000	$200,000
				Total	**$19,390,000**

Albany Water Board

Big C Screening & Disinfection Facility - Alternatives Evaluation

Summary of Costs for Bar Screening & Chlorination/Dechlorination

Lincoln Park Site

Capital Costs			
Chemical Contact Tank & Equipment	LS	$	2,880,000
Chemical Building	LS	$	1,350,000
Screeings Foundation and Structures	LS	$	1,840,000
Screenings Building	LS	$	1,425,000
Screenings Equipment	LS	$	2,489,000
Odor Control	LS	$	900,000
Site Work	LS	$	8,170,000
Installation Labor, Construction Equipment & Misc. Materials	30%	$	1,890,000
Electrical	10%	$	540,000
Instrumentation & Controls	10%	$	540,000
Plumbing	5%	$	270,000
Direct Construction Costs Subtotal		$	22,300,000
Contractor's General Conditions/Risk	5%	$	1,120,000
Subtotal		$	23,400,000
Contractor Indirects, OH&P	20%	$	4,680,000
Subtotal		$	28,100,000
Contractor's Bonds	2%	$	560,000
Construction Contingency	25%	$	7,170,000
Total Construction Cost		$	35,800,000
Admin, Legal, & Insurance	5%	$	1,790,000
Engineering & Construction Administration	LS	$	5,000,000
Total Cost in Today's Dollars		**$**	**42,600,000**
Escalation to Midpoint of Construction	6%	$	2,600,000
Total Cost		**$**	**45,200,000**

Annual Costs			
Screening System			
Annual Average Run Time, Hours/year	452.0		
Days per year of treatment	30		
Annual Material Costs		$	113,000
Electrical Usage (1000 kWh/yr)			
Pumps	0		
Screenings equipment	2.99		
Odor Control	5.00		
Building	25		
Annual Electrical Costs		$	3,300
Operation & Maintenance, hours/treatment day	14		
Fully loaded labor rate, $/hour	$40.00		
Annual Personnel Costs		$	17,000
Sodium Hypochlorite System			
Annual Average treated volume, mg	340.0		
Days per year of treatment	30		
Hypochlorite dose, mg/L	6.0		
Percent solution NaOCL, %	12.5		
NaOCL - lbs of chlorine available/gallon of solution	1.04		
Gallons per year, as delivered	16,400		
Price per gallon, as delivered	$0.60		
Annual chemical costs for NaOCL		$	9,800
Operation & Maintenance, hours/treatment day	12		
Fully loaded labor rate, $/hour	$40.00		
Annual maintenance costs		$	14,000
Sodium Bisulfite System			
Average treated flow, mgd	340.0		
Days per year of treatment	30		
NAHSO3 dose, mg/L	25.5		
Percent solution NAHSO3 %	38		
Specific density of NAHSO3 lbs/gal	11.1		
Gallons per year, as delivered	17,100		
Price per gallon, as delivered	$1.20		
Annual chemical costs for NAHSO3		$	21,000
Lifecycle in years	20	*P/A factor =* 17.02	
Discount rate	4.13%		
Inflation rate	2.50%		
Annual Costs		$	178,000
Present Value of Annual Costs		$	3,000,000
Present Value of Lifecycle Cost		**$**	**48,200,000**

Albany Water Board

Big C Screening & Disinfection Facility - Alternatives Evaluation

Capital Costs for Lincoln Park Site, Chlorination/Dechlorination, Bar Screening

No.	Cost Item	Quantity	Units	Unit Cost	Subtotal
1	Chlorine Contact Tank Cast-in-place concrete	3,400	CY	$ 800	$2,720,000
2	Chlorine Contact Tank Equipment	1	EA	$ 155,000	$155,000
3	Screenings Structure Cast-in-place concrete	2,300	CY	$ 800	$1,840,000
4	Screenings Equipment	1	EA	$ 1,295,000	$1,295,000
5	Flow Metering	1	EA	$ 100,000	$100,000
6	Chemical Building	4,500	SF	$ 300	$1,350,000
7	Screenings Building	3,000	SF	$ 475	$1,425,000
8	Chemical Tanks, Pumps, and Controls	1	EA	$ 524,000	$524,000
9	Odor Control	1	EA	$ 900,000	$900,000
10	Generator and ATS	1	EA	$ 150,000	$150,000
11	Piping	1	LS	$ 420,000	$420,000
12	MOPO	1	LS	$ 250,000	$250,000
13	Rock Excavation	1	CY	$ 500,000	$500,000
14	Flow Control	1	LS	$ 500,000	$500,000
15	Relief Sewer	750	LF	$ 8,000	$6,000,000
16	Excavation	1	CY	$ 500,000	$500,000
				Total	**$18,630,000**

albany pool Joint Venture Team

Joint Venture Team

albany pool