UV DISINFECTION COST STUDY

Cost Study Report

FOR

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

VOLUME 1 OF 2

STICKNEY WATER RECLAMATION PLANT

September 9, 2008

Prepared By

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EXECUTIVE SUMMARY

Introduction

The Technical Memorandum 1WQ Disinfection Evaluation (TM1-WQ) was completed in August 2005 for the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC or District) as part a Water Quality (WQ) Strategy for affected Chicago Area Waterways. TM1-WQ reviewed the alternative disinfection technologies available for use at the District's North Side (NSWRP), Calumet (CWRP) and Stickney Water Reclamation Plants (SWRP) and provided an initial estimate of construction cost for the facilities. On the basis of that report, the District requested further investigation into UV disinfection. The findings of the Preliminary Cost Opinion for Ultraviolet (UV) Disinfection Facilities Study at the Stickney Water Reclamation Plant are presented in this Report.

Objectives

This evaluation is based upon the TM1-WQ, the comments received from the USEPA as part of the Use Attainability Analysis (UAA) evaluations, and new information obtained since the previous work. The primary objectives of the evaluation presented in this report are:

- To describe the conceptual facilities developed as part of this study including their basis of design and the assumptions used for their development.

- To develop a Level 3 Preliminary Opinion of Probable Construction Cost per the Association for the Advancement of Cost Engineering recommended practices for the proposed facilities at the SWRP, which represents an expectation that actual cost will deviate from the estimated cost by -15% to 30%.

- To develop annual maintenance and operations (M&O) costs for the conceptual facilities.

Proposed Facilities

This study reviewed the proposed facilities for the UV Disinfection Alternative in TM-1WQ including the four primary components: Site work, a low lift pump station, tertiary filters and UV disinfection. Through that review, it was determined that the low lift pump station and the tertiary filters required re-evaluation.

At the time TM-1WQ was developed, very little information was available regarding the water quality of the plant effluent as it related to ultraviolet light transmissivity, and the that data which was available indicated low transmissivity levels. In TM-1WQ, tertiary filters were included in the initial proposed facilities in order to improve disinfection effectiveness by removing components that would inhibit the disinfection process. Since that time, additional water quality data was collected for the NSWRP by the District during the North Side UV Disinfection Cost Study Report. A review of that data indicated that the UV transmissivity is within the minimum range necessary for UV disinfection without filtration. As a result, tertiary filters were not included in the North Side Cost Study and are not included in the proposed disinfection facilities presented in this report. However, the exclusion of tertiary filters from this report should not suggest that tertiary filters may not be required in the future to meet stricter suspended solids or total phosphorous limits, or that tertiary filters would not improve the effectiveness of a UV disinfection process. As concluded in the SWRP Master Plan, space would be reserved on the site for future tertiary filter facilities.

As tertiary filters would not be required as part of the implementation of UV disinfection, the need for a low lift pump station was questioned. Additional pumping would be required only if the head loss added by the new UV Disinfection Facilities and associated flow conduits and flow splitting structures exceeds the available head at the plant. To determine the required head through the UV Disinfection facilities, a hydraulics evaluation was performed.

Hydraulics

Hydraulic modeling was not included as part of the Master Plan for Stickney WRP and so a hydraulic model was developed for this report based on existing plant water levels as documented in previous design projects as well as projected water levels in the Ship and Sanitary Canal for a 100-year flood event based on the USACE's CUP Report. This model was modified to include the additional effluent conduits, gate structures, and UV channels/reactors required for the new facilities. The model was used to determine the required head following implementation of the new UV Disinfection Facilities.

The results of this evaluation showed that the projected head required through the proposed UV facilities exceeds the head available at the plant by over 8.7-ft and confirms the need for a Low Lift Pump Station (LLPS) in order to convey the peak flow of 1,440 MGD through the UV facilities at the 100-year flood elevation.

Disinfection Technology

The Trojan UV4000™Plus system, which utilizes medium pressure, high intensity type UV lamps, was used to develop the basis of design for the UV disinfection system at the SWRP. This type of UV system was selected due to the lower number of lamps required compared to other systems and based upon the recommendations of a team of disinfection experts that evaluated the available disinfection technologies during the Master Plan effort.

During the NSWRP UV Disinfection Cost Study, the details of the implementation of this UV technology were updated by consultation with the manufacturer and incorporated into the basis of design. In addition, a phone survey of other facilities of similar size and source water quality was conducted. This survey revealed several important conclusions including the following:

- When using ferric salt addition for improved settleability of solids or phosphorus removal in the treatment process upstream of UV disinfection, an increase in the fouling rate was experienced.
- The level of maintenance and operations efforts was highly variable and site specific, even with plants using the same technology and source water.
- The most effective method of power control for the UV system is highly site specific and has a great impact on the disinfection effectiveness and the energy effectiveness of the system.

Due to the size of the proposed SWRP UV Disinfection Facilities, which would be among the largest continually-operating UV disinfection systems in the world, CTE recommends the District undertake an extensive program which includes review of system specific independent validation studies, collimated beam testing, UV transmittance testing and a reasonably sized pilot facility. This program would determine, among other factors, the following information in-situ:

- Appropriate control sequences and optimization for the UV disinfection equipment, including appropriate sensing equipment to allow advanced power management.
- In-situ disinfection performance including fouling rates or the lamps with and without ferric salt addition.
- Actual M&O requirements in terms of labor and consumables as well as space requirements to complete required maintenance activities.

Site Layout

As part of the study, a proposed layout of the disinfection facilities at the SWRP was developed including the Low Lift Pump Station, UV Disinfection Facilities, related gate structures/effluent conduits and space reserved for future tertiary filters. **Figure ES-2** and Volume 2 of this report show the proposed site layout while **Figure ES-1** shows the proposed flow diagram for the new UV Disinfection Facilities.

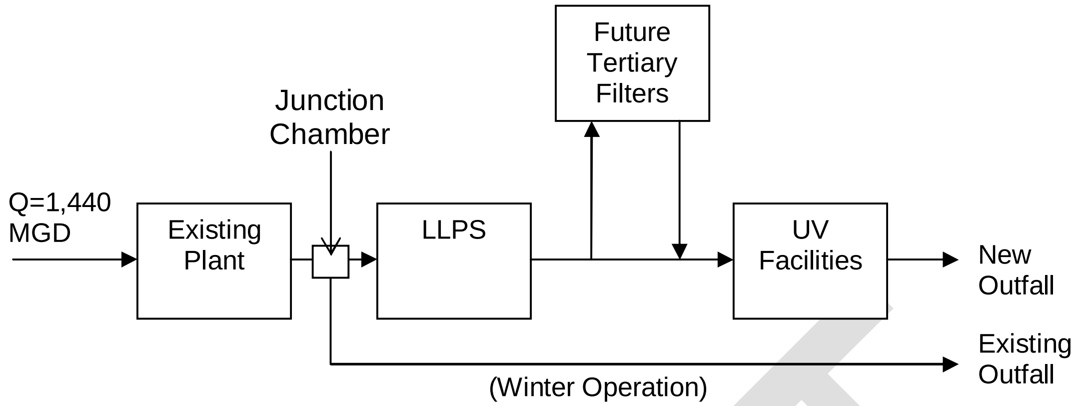


Figure ES 1 - Proposed UV Facilities Flow Diagram

Due to the limited space available upstream of the existing outfall, flow would be directed approximately 1,800-ft to the new facilities located to the southwest of the site. As a result of the location of the new facilities, it is recommended that a new plant outfall to the Ship and Sanitary Canal be constructed directly south of the new facilities (and west of the existing outfall) in lieu of installing an extensive return conduit back to the existing outfall. It should be noted that the new outfall would require permitting through the United States Army Corps of Engineers (USACE) and others. The cost of this new outfall is included in the cost opinion.

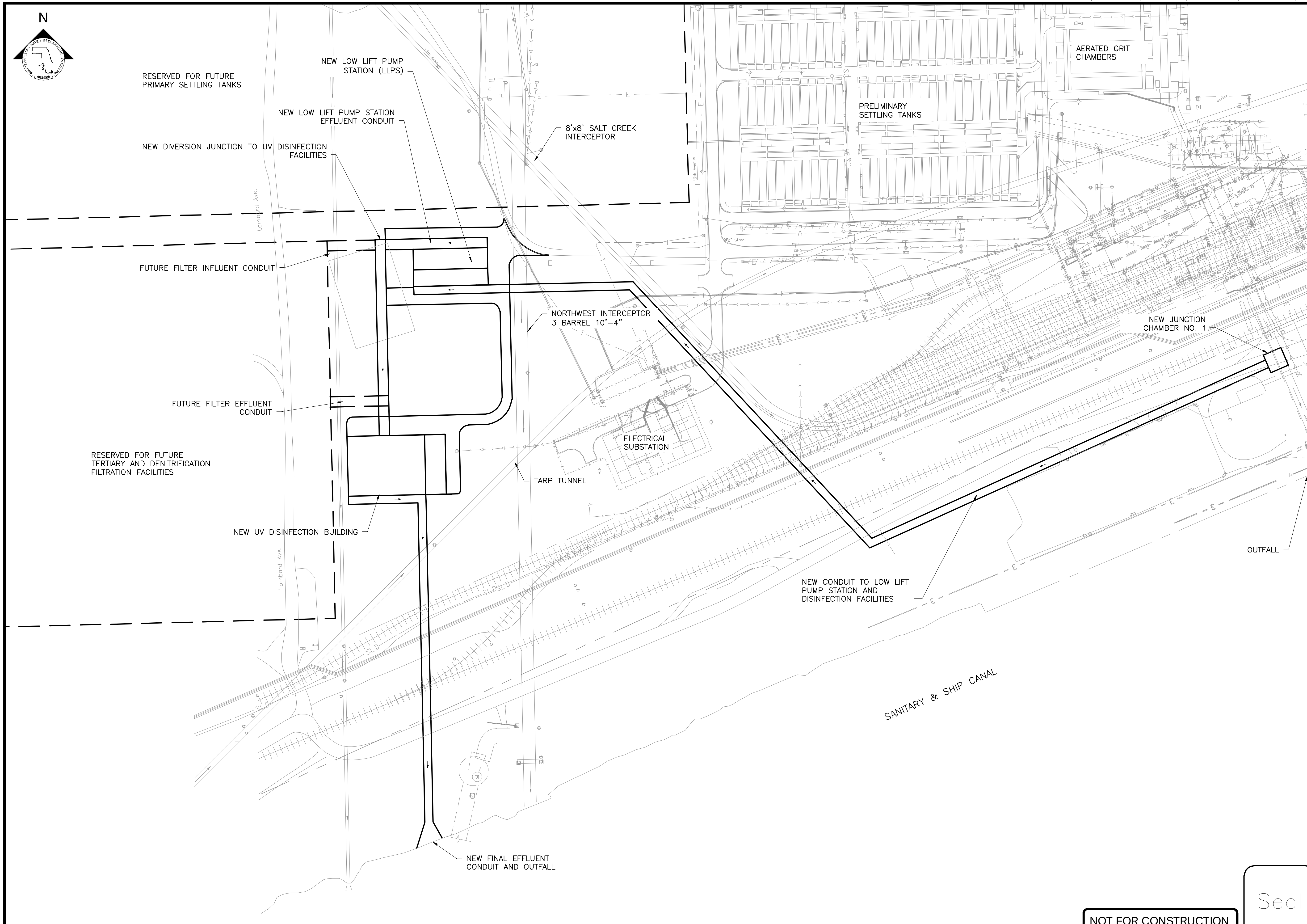
Preliminary Cost Opinion

The preliminary opinion of probable construction cost (OPCC) for SWRP UV Disinfection Facilities is shown in **Table ES-1** below. As shown, the projected construction cost for the SWRP UV Disinfection facilities is $542.9 million. The details of the basis of design for the proposed facilities and the methods of developing the OPCC are presented in the body of this report.

Table ES-1 – SWRP UV Disinfection Facilities Preliminary OPCC and M&O Costs

Capital Cost Estimates	
A. General Sitework	$61,890,000
B. Low Lift Pump Station	$86,220,000
C. Disinfection System	$112,420,000
Total Capital Cost	**$260,530,000**
Maintenance & Operations Cost Estimates	
A. General Sitework	$90,000/yr
B. Low Lift Pump Station	$2,540,000/yr
C. Disinfection System	$9,560,000/yr
Total Annual M&O Cost	$12,190,000/yr
Total Present Worth M&O Cost	$282,400,000
Total Present Worth	**$542,930,000**

All costs in 2007 dollars.



Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT
OF GREATER CHICAGO

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STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

SWRP
LOCATION PLAN

NOT FOR CONSTRUCTION

Seal

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1.0 INTRODUCTION

1.1 Background

This report has been developed to present the findings of the Preliminary Cost Opinion for Ultraviolet (UV) Disinfection Facilities Study at the Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC, or District) Stickney Water Reclamation Plant (SWRP) in Stickney, Illinois. This report continues the work began in TM1-WQ, which was developed previously as part of the comprehensive Infrastructure and Process Needs Feasibility Study (Master Plan) for the SWRP and a Water Quality (WQ) Strategy for affected Chicago Area Waterways.

The TM1-WQ documented the results of a CTE study of effluent disinfection alternatives for the District's North Side, Calumet and Stickney WRPs. In that study, a task force of national experts (referred to as the Blue Ribbon Panel) reviewed available disinfection technologies and their range of pathogen destruction efficiency, disinfection byproducts and impacts upon aquatic life and human health. Their investigation also included an examination of the environmental and human health impacts of the energy required for the operation of the facility and for the processing and production of process chemicals. Based on economic and non-economic evaluation of alternatives, ozone disinfection and UV disinfection were selected and preliminary design and cost estimates were developed. Based on the results of that subsequent evaluation, the District determined that UV disinfection is the most cost-effective alternative.

1.2 Objective

The District has requested further evaluation of the UV disinfection technology. This additional evaluation is based on the TM-1WQ, the comments received from the United States Environmental Protection Agency (USEPA) as part of the Illinois Environmental Protection Agency's (IEPA) Use Attainability Analysis (UAA) evaluations, and new information obtained since the previous work. The primary objectives of the evaluation presented in this report are:

- To describe the conceptual facilities developed as part of this study including their basis of design and the assumptions used for their development
- To develop a Level 3 (per the Association for the Advancement of Cost Engineering) Preliminary Opinion of Probable Construction Cost for the proposed facilities at SWRP, which represents a conceptual estimate with an expected deviation range from actual cost of -15% to +30%.
- To develop annual maintenance and operations (M&O) costs for the facilities

1.3 General Design Standards

Where applicable, the latest version of the codes and standards from the following institutions/organizations would govern the design:

State of Illinois, Illinois Recommended Standards for Sewage Works, Title 35.C.II.370.

Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, Recommended Standards for Wastewater Facilities (Ten States Standards).

National Fire Protection Association Standard 820 – Standard for Fire Protection in Wastewater Treatment and Collection Facilities.

International Building Code, 2003.

Metropolitan Water Reclamation District of Greater Chicago Standard Specifications.

1.4 Organization of this Report

The Cost Study Report is divided into two volumes. Volume 1 is the text and backup materials presenting the findings of the additional evaluation of the cost of implementation of UV disinfection at the SWRP. Volume 2 is the conceptual level drawings presenting the preliminary layouts and some details of the proposed facilities from which the preliminary opinion of construction cost was developed.

The basis of this evaluation is the proposed facilities necessary for UV Disinfection Facilities and related ancillary improvements at the SWRP. The sections of Volume 1 are organized as follows:

Section 2 – Discussion of the hydraulic analysis that was performed that forms the basis of decisions regarding the need for a low lift pump station and the general layout of the facilities.

Sections 3 through 8 – Discussion of the basis of design for the proposed facilities by design discipline and the assumptions necessary for development of the conceptual design presented in Volume 2.

Section 9 – Discussion of areas that require further analysis during the preliminary design of the proposed facilities due either to their critical nature regarding design decisions or their large impact on potential construction or operating costs.

Section 10 - Summary of the Preliminary Opinion of Probable Construction Cost (OPCC) and annual operating costs as well as discussion of the assumptions used to develop those costs.

2.0 HYDRAULICS

2.1 Hydraulic Analysis of the UV Disinfection Facilities

2.2.1 Objectives

Hydraulic analyses of the SWRP had not been performed as part of the SWRP Master Plan. For this study, a preliminary hydraulic model was created to evaluate the existing plant hydraulics which would be affected by the UV Disinfection Facilities. This model was then modified to include the effluent conduits, gate structures, UV channels and reactors and Low Lift Pump Station in order to provide a more comprehensive hydraulic evaluation of the UV disinfection facilities.

2.2.2 Overview

The hydraulic analysis was completed using a spreadsheet utilizing standard open channel and closed conduit flow equations. The hydraulics evaluated were for the Year 2040 conditions, including both infrastructure and permit-related improvements related to disinfection at a peak flow of 1,440 MGD. Flow in excess of 1,440 MGD is assumed to be diverted to the TARP system.

The flow path was modeled from the effluent aerator weir downstream of Battery B to the Sanitary and Ship Canal outfall. Due to site constraints, the new UV disinfection facilities were located to the southwest of the plant. Flow would be diverted via a new gate chamber downstream of the Pump and Blower Building, located approximately 800 ft upstream of the existing plant outfall. At this location, secondary effluent from all Aeration Batteries (A, B, C & D) could be diverted to the new disinfection facilities. Additionally, a new plant outfall was assumed to be provided rather than conveying the disinfected flow back to the original outfall.

The existing plant hydraulics were evaluated using a water surface elevation (WSE) in the Sanitary and Ship Canal of +3.5 CCD. This was based upon the hydraulic profile from the Contract 78-102-EP, West-Southwest Treatment Works, February, 1985[1]; however this is considered the typical annual high water level in the canal and not the 100-yr flood elevation.

For the conceptual design of the new UV facilities the water surface elevation of +9.0 CCD will be utilized in order to ensure the new facilities can operate during the 100-year flood. The 100-year flood elevation for the Sanitary and Ship Canal has been calculated using the USACE's Chicago Underflow Plan (CUP) Design Report. The CUP report used observed high water levels to model the predicted high water levels throughout the Chicago Area Waterways at each of the construction phases. Appendix A provides select pages from this report.

2.3 Assumptions

Due to the preliminary nature of the selected site plan, assumptions were made in the development of the hydraulic model. These assumptions are as follows:

1. SWRP drawings obtained from MWRDGC are on the Chicago City Datum (CCD) or the National Geodetic Vertical Datum (NGVD). All elevations were converted to CCD using conversion CCD = NGVD – 579.48.
2. The CCD has not changed since the plant was originally constructed in the 1920's.
3. UV Facilities should be operable at the 100 yr flood event. The estimated 100-yr flood elevation is +9.00 CCD, as calculated in the Chicago Canal System Model, UNET. Appendix A provides selected pages from the USACE's Chicago Underflow Plan (CUP) Design Report presenting these results. Pre-Stage 1 (Stage 1 of the McCook Reservoir Construction) values are used since the USACE's current estimate for completion of Stage 1 construction in 2020 or later. It should be noted that higher levels of +10.1 CCD have been predicted for storms greater than the 100-yr storm. At water levels rise higher than +9.00 CCD (100-yr flood) then flow bypassing would be necessary to avoid flooding the UV and other facilities.
4. Post Aeration hydraulics and space planning are not included in this study.
5. A new plant outfall will be provided to convey disinfected effluent to the Ship and Sanitary Canal.
6. Velocity in Disinfection Influent and Effluent Distribution Chambers is zero to allow adequate flow distribution.
7. Flow is divided equally between the Batteries A, B, C and D, with each receiving 360 MGD.
8. Batteries A, B, C and D are all at the same elevation.
9. The UV process requires approximately 6 ft of submergence, thus the disinfection channel effluent weir is assumed to be 5.5 ft above invert to ensure a submerged weir at low flow conditions.
10. The following modeling equations were used:
    a. Pressure Flow – Hazen Williams Equation
    b. Open-Channel Flow – Manning's Equation
    c. Flow junctions – Pressure Momentum Analysis.

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[1]El +3.5 is listed as the maximum water level in the Sanitary and Ship Canal to which the plant would not flood, based on a maximum design flow rate of 2,000 MGD. This profile appears to be the last official hydraulic profile conducted for the SWRP.

11. Hydraulic coefficients used in developing this model include:
   a. Hazen Williams – 110 (concrete)
   b. Manning's
      i. Regular channel – 0.013
      ii. Aerated channel – 0.035

2.4 Results

Table 2.4-1 presents the final water surface elevations (WSE's) through the plant, including the Low Lift Pump Station (LLPS) and UV Disinfection Building. The hydraulic profiles show the estimated WSE's at the maximum flow of 1,440 MGD. Flow that exceeds 1,440 MGD is diverted into the TARP system.

Table 2.4-1 – Summary of Proposed WSE including UV Disinfection Facilities

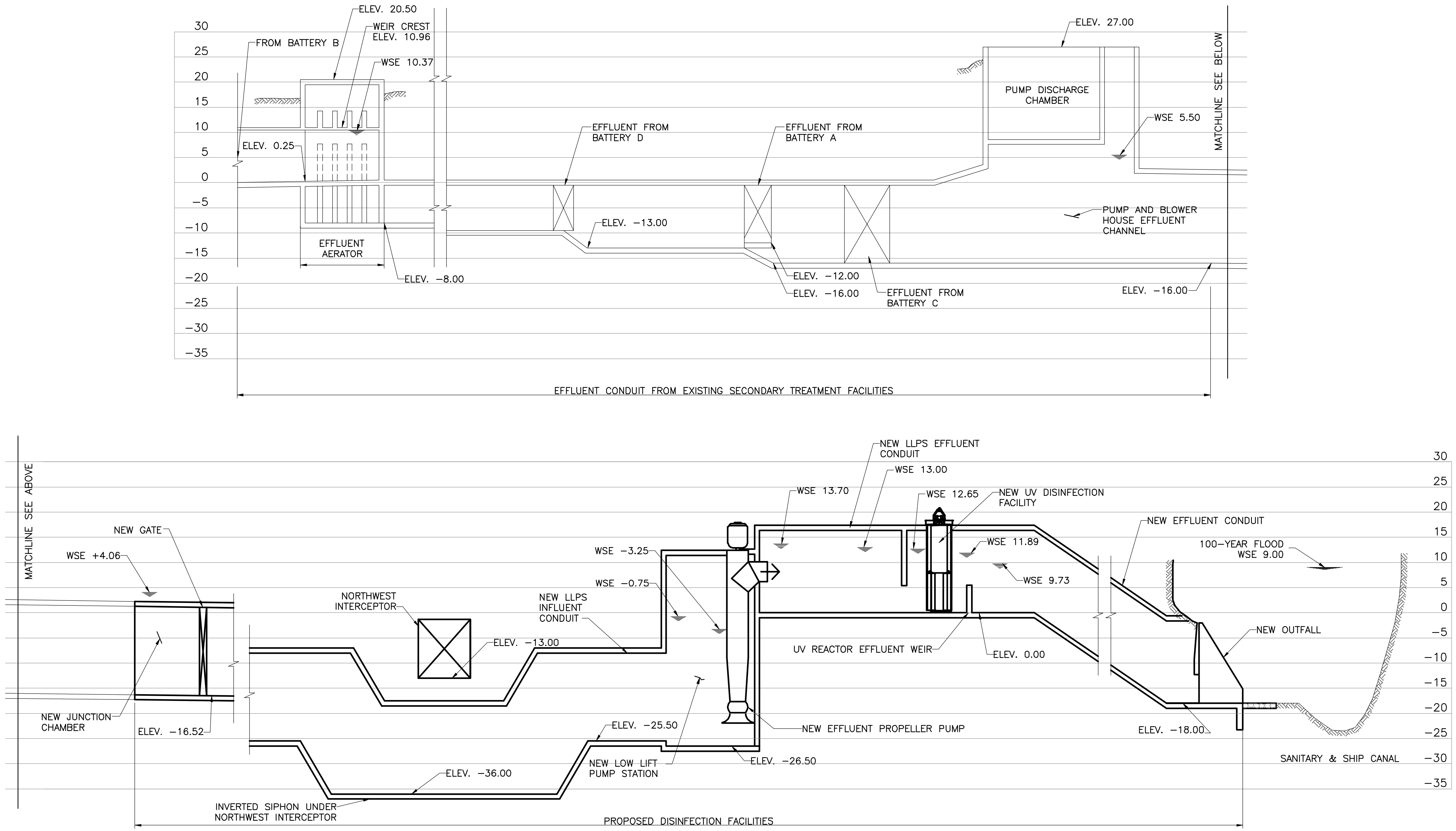
Location	WSE
WSE in Effluent Aerator	10.37
WSE just d/s of Pump Discharge Chamber	5.50
WSE at New Gate Chamber	4.06
WSE in LLPS Influent Conduit	-0.75
WSE in LLPS Wet Well just u/s of curtain wall	-3.25
WSE just D/S of Low Lift PS	13.70
WSE just U/S of Influent gate	13.00
WSE just U/S UV Reactor	12.65
WSE just U/S of Weir Gate	11.89
WSE just D/S of Weir gate	11.42
WSE @ D/S Disinfection Effluent Chamber	9.73
WSE in Sanitary and Ship Canal, Approximate 100 yr flood elevation	9.00

Notes: All WSE in CCD.
WSE – Water Surface Elevation
D/S – Downstream
U/S – Upstream

Figure 2.4-1 contains the hydraulic profile of the flow path from the new outfall in the Sanitary and Ship Canal through the new UV disinfection facilities and the available freeboard at the locations where water surface elevations (WSE's) were calculated at the peak day flow starting at the 100-year flood elevation.

2.5 Conclusion

Based on the preliminary hydraulic analysis performed as part of this study, the estimated total head required to convey flow through the new UV Disinfection facilities and associated structures is 8.7-ft. The available head downstream of the Pump and Blower Building is 1.95 ft. In order to maintain flow at the 100-yr flood, a new Low Lift Pump Station is required to lift flow 16.95-ft to convey flow via gravity through the new UV facilities to the new outfall in the Sanitary and Ship Canal.



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CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

EFFLUENT HYDRAULIC PROFILE
FOR DISINFECTION COST STUDY

Seal

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3.0 SWRP DISINFECTION PROCESS

3.1 Introduction

The District has preliminarily selected the medium-pressure high-intensity (MP-HI) UV disinfection technology for disinfection of final effluent at the SWRP. This section presents the results of further evaluation of the MP-HI UV disinfection technology per the District's requirement. In the following discussion, the basis of design of the MP-HI UV system is presented and a preliminary basis of design of the UV system to be used at the SWRP is provided. The low-lift pump station's basis of design, operation and layout are provided later in this section.

3.2 UV Disinfection System

3.2.1 Background

The Technical Memorandum on the UV Disinfection Technology performed as part of the North Side Disinfection Cost Study, included in Appendix B, incorporates the following:

- Information from literature including technical proceedings from the Water Environment Federation (WEF), Water Environment Research Foundation (WERF), proceedings from the latest Disinfection conference series undertaken by WEF, American Water Works Association (AWWA), and International Water Association (IWA). This information provided the latest updates in the UV disinfection technology.

- Updated recommendations on the UV system from four manufacturers – Trojan Technologies, Aquionics, Calgon Carbon, and Severn Trent Services (STS)/Quay.

- Reference information on experience of UV disinfection at five selected facilities – Racine WWTP (Racine, WI), R.L. Sutton WRF (Cobb County, GA), Grand Rapids WWTP (Grand Rapids, MI), Jacksonville WWTP (Buckman, FL), and Valley Creek WWTP (Valley Creek, AL). A summary of the information collected through the phone survey is provided in Appendix B, and important inferences from the phone survey are as follows.

  1. Fouling due to iron in the effluent has been a problem at the Racine, Sutton, and Grand Rapids facilities. Fouling results in lower then expected disinfection performance, higher operating costs, and higher M&O efforts. The iron in the effluent at all three plants was primarily from the chemical phosphorus removal using Ferric Chloride. At Grand Rapids WWTP, the chemical addition is upstream of the secondary treatment process; staining of sleeves was found only when the chemical addition was in the secondary clarifiers. At the Sutton WRF, fouling of lamps due to iron is observed although chemical addition is upstream of secondary process and sand filters are used upstream of the UV disinfection system. At the Racine WWTP, fouling may be due to ferric chloride addition and/or due to the additional iron brought by the ferric sludge from another water treatment plant, although operational controls are used to prevent both sources from occurring simultaneously.

  2. Calcium fouling due to hardness in the source water is not a significant problem because of the automatic mechanical/chemical cleaning system that dissolves and wipes away any scales. The lack of calcium hardness was observed in all five plants including the Racine and Grand Rapids utilities which have Lake Michigan source water and is attributed to the automatic cleaning system performance.

  3. The frequency of cleaning and changing of the cleaning solution is specific to the utility and would have to be determined only by experience.

  4. Labor requirements varied amongst facilities, with some facilities requiring more labor to handle the fouling caused by iron salt addition.

5. As long as other processes in the plant are performing as desired, all five facilities were satisfied with the UV disinfection system because it met their disinfection goals.

In conclusion, the phone survey had revealed that fouling of the quartz sleeves is a concern for this application, particularly if iron salts are added for phosphorous removal in the future. In addition, the phone survey results suggest that the manufacturer's recommended labor assumptions for routine maintenance including cleaning and inspection of the lamps is too low for this application. As transmissivity is directly related to lamp fouling, additional lamps and/or more frequent cleaning may be required in future if iron salts are to be utilized upstream of this technology.

Using this information and the updated information available from manufacturers, a preliminary basis of design of the MP-HI UV disinfection system has been developed for disinfection of the final effluent at the SWRP.

3.2.2 Basis of Design

The MP-HI system involves sending the secondary or tertiary effluent through channels containing banks of MP-HI UV lamps. Refer to the process drawings included in Volume 2 of this report. The Trojan UV4000™Plus system is used here to develop the basis of design for the UV disinfection system. The system consists of a power supply, an electrical system, a reactor, MP-HI lamps, a mechanical and chemical cleaning system, and a control system. The MP-HI UV lamps are enclosed in individual quartz sleeves for protection against dirt and breakage. Reactor chambers (open channels) hold the lamps in a horizontal configuration. The effluent weirs and level sensors are used to keep the lamps submerged under the effluent water. This submergence ensures that the lamps do not overheat, thereby preventing lamp life reduction or burnout.

The UV system is assumed to operate from March to November each year. During the winter months, the equipment would sit idle as the flow is bypassed around the LLPS and UV Disinfection Building. However, due to the size of the facility including twelve reactors and over 4000 lamps, maintenance activities would be conducted every working day from March to November and periodically during the winter months. It is reasonable to expect that the area would continue to experience normal weather patterns for the Chicago area including extreme weather during all four seasons. In order to protect the safety of the M&O staff, ensure operational and maintenance-related productivity, and protect the UV equipment from adverse weather common to the Chicago area including high winds, rain, lightning, snow, and extreme temperatures, the UV system would be enclosed in a building.

3.2.2.1 Influent Characteristics

The water quality characteristics that affect UV transmittance include iron, hardness, suspended solids, humic materials and organic dyes. These effluent constituents have a tendency to absorb UV light and thus impact the disinfection process. The UV transmittance generally needs to be above 65% for effective disinfection. The water quality testing done at the North Side WRP and Calumet WRP as part of the UV disinfection technology trials conducted by the District during 2006-2007 showed an average transmittance above this minimum value. Although testing was not done at Stickney WRP the characteristics are likely to be very similar. Refer to Appendix B for more information regarding the influent characteristic testing. The total suspended solids limit is projected to be 15 mg/L for the purposes of sizing the UV system.

3.2.2.2 Reactor Configuration and Hydraulics

An open channel is used as a reactor. Each channel has one reactor with two banks each. Each bank includes stainless steel UV modules with the MP-HI lamps mounted on them and arranged in a linear configuration to increase intensity along the linear axis by avoiding UV emission losses due to self absorption, reflection or refraction that can occur if a UV lamp were twisted into loops or spirals. The lamps are positioned horizontally and parallel to the flow.

The optimum hydraulic scenario for this system involves turbulent flow with mixing while minimizing head loss. Reactor design, including inlet and outlet flow distribution is done so that the unit operates close to a plug flow. Inlet conditions are designed to distribute the flow and equalize velocities. Sufficient length is provided in the channel upstream of the reactor to allow equalization of the flow. A motorized weir gate is provided downstream of each reactor to control the water level at a constant level with little fluctuation within the UV disinfection reactor.

3.2.2.3 Lamps and UV Intensity Control

The MP-HI lamps produce polychromatic radiation, which is concentrated at select peaks throughout the germicidal wavelength region. The IEPA requires a minimum UV dose of 40 mW-s/cm^2 which was considered during the design of the UV system. It may be possible to document a lower required dose to the regulating body (IEPA) during design development, but lacking such data, this study does not deviate from the required minimum dose.

Each lamp is enclosed in a quartz sleeve because quartz effectively protects the lamps while minimizing any UV transmission losses. Electronic ballast for each lamp is used to control the power to the lamp. If the UV dose is to be reduced, the variable output electronic ballast regulates the power to the lamp from 100% to 30%. Entire banks can also be turned off if there is no flow. This allows dose-pacing based on the secondary or tertiary effluent flow and quality, which helps save power and lamp life and hence reduce costs.

3.2.2.4 Lamp Fouling and Cleaning

The MP-HI lamps operate at a temperature range of 600 to 900 degree C. These warm temperatures promote fouling on the surface of the quartz sleeves when the lamps are placed directly within the wastewater stream. Iron is the most abundant metal in these scales along with other mineral salts and oil, grease, suspended solids deposits, and biofilms. If no tertiary treatment is provided, physical debris may contribute to fouling as well.

Since lamp fouling significantly reduces the effectiveness of UV disinfection by blocking the UV rays, calculation of the UV dose incorporates a term called the “fouling factor”, which allows the designer to estimate the effects of fouling on performance of the disinfection process. To combat fouling, a chemical and mechanical cleaning system is proposed for the MP-HI UV disinfection system. The latest technology uses a system of mechanical wipers and sleeves containing cleaning chemicals surrounding the lamp. The cleaning solution contains some acidic solution that prevents fouling. This cleaning system can be programmed to clean at a set frequency without the need for disrupting the disinfection process. The cleaning solution needs to be replaced periodically depending on the type of solution used and characteristics of the effluent water quality. Similar facilities using Lake Michigan as source water have found that changing the cleaning solution on a monthly basis is required for adequate performance.

Due to the mechanical and chemical features of the Trojan automatic cleaning system, the IEPA accepts the default value of 100% for the fouling factor in the UV_{dis} software package (dosage modeling software) for sizing the equipment. Based on the phone survey results that indicated a higher potential for fouling in the event of Lake Michigan source water with ferric salt addition, the District has elected to incorporate a safety factor of 10% by using a fouling factor of 90%.

3.2.3 Process Control

An automated process control must be provided to facilitate online pacing of the UV dose to prevent overdosing that wastes electricity and to avoid under-dosing that would not meet the disinfection regulatory requirements and goals. The process control should also allow the dose-pacing to be interfaced with the plant’s overall supervisory control and data acquisition (SCADA) system. The flow, lamp output, and water conditions are measured in pacing of the dose, and an algorithm is developed based on long-term measurements to predict necessary system adjustments, maintenance, and component replacements.

Programmable logic control (PLC) technology must be used for dose pacing in the MP-HI UV disinfection system. The PLC interacts with the ballasts, sensors, and online monitoring technology for each disinfection unit. The PLC then interacts with the plant's overall control system to allow remote monitoring and adjustment of the system. The PLC should be supplied by the manufacturer of the unit.

3.2.4 Safety

The high voltage power supplies for the MP-HI UV disinfection system may pose an issue as the lamps are submerged in the water most of the time and compliance with electrical safety codes is required. In addition, UV light poses a risk to personnel and can cause damage to skin or eyes upon exposure. Submerging a lamp in water, even if it is just a few inches below the surface, greatly reduces the intensity. During operation the system should be covered by hatches and should be designed to ensure constant water levels to minimize the risk of UV exposure.

3.2.5 Proposed Design Criteria for UV Disinfection Equipment

Based on a review of the information provided by the UV equipment manufacturers and the experience of five other facilities (Appendix B), it is observed that Trojan Technologies provides a widely-used low-maintenance solution for final effluent disinfection. The design of the MP-HI UV disinfection system for the Stickney WRP is based on the Trojan UV4000™Plus equipment provided by Trojan Technologies. The basis of design is given in **Table 3.2-1**.

Table 3.2-1 – Design Parameters for UV Disinfection Unit at SWRP

Parameter	Design Value
Capacity and Water Quality	
Design flow, MGD	1,440
Average flow, MGD	1,250
Maximum TSS[a], mg/L	15
Pre-Disinfection Effluent Fecal Coliform Count[b], cfu/100 mL, maximum (Assumed)	25,000
Post-Disinfection Effluent Fecal Coliform Count Target[c], cfu/100 mL	400
Effluent Hardness[d], mg/L as $CaCO_3$	270
Dosage	
UV transmittance, minimum, %	65
UV intensity[e], W/lamp	4,000
Lamp Life, hours	5,000
Fouling factor, %	90
Lamp aging factor, %	89
UV dose, mW-s/cm^2	40
Physical Characteristics	
Channel dimensions, WxD	106" x 172"
Number of channels	12 (11 plus 1 standby)
Number of reactors per channel	1
Number of banks per reactor	2
Number of modules per bank	7
Number of lamps per module	24
Total number of lamps	4,032
Total power requirement, kW	11,827
Average power requirement, kW	9,225
Hydraulics	
Headloss, UV reactor only	9"
Velocity in each channel, V, ft/s	1.87
Liquid level control in channel	Motorized Weir Gate

[a] Monthly permit limit 12 mg/L [c] Future requirement (monthly geometric average)
[b] Annual average [d] Mean value [e] 100% intensity at 100 hours of lamp use

The above design criteria are assumed based on available information and the current state of ultraviolet disinfection technology. A more extensive technology evaluation should be conducted prior to final design of the facility. Due to the extraordinary scale of this facility, CTE recommends the District undertake the following design process for selection and design of the UV disinfection equipment if final design is initiated:

1. Request and evaluate independent, full-scale validation data (also known as biodosimetry data) from manufacturers of candidate disinfection systems for similarly sized units or the largest size for which the manufacturer has data available. This evaluation would provide an initial level-of-confidence that the candidate systems can achieve the target disinfection levels. Data should be from systems using the same bulb, ballast, and control technology as proposed for the full-scale system. Candidate systems should include both medium pressure, high intensity as well as appropriate low pressure, high intensity systems,

2. Conduct a collimated beam testing program. This program would use site specific effluent and bacteria to determine the sensitivity of the site specific bacteria and pathogens to UV disinfection. The data would be used to size the UV lamps and reactors.

3. Increase frequency of UV transmittance testing at each plant to at least once per day for a period of one year or more to collect data on seasonal variability, daily variability, diurnal variability, and to capture the frequency of events that might reduce transmissivity such as wet weather and infrequent industrial discharges.

4. Conduct a more detailed life cycle cost analysis of the candidate disinfection systems based on the data collected during steps 1 through 3 above.

5. Construct a pilot testing facility (approximately 20 MGD, subject to change) designed to match lamp spacing, velocity profile and other design parameters of the proposed full scale units. The pilot testing facility would be used to determine:

    a. Appropriate control sequences and optimization for the UV disinfection equipment, including appropriate sensing equipment to allow advanced power management.

    b. In-situ disinfection performance including fouling rates of the lamps with and without ferric salt addition.

    c. Design life of lamps and other UV system parts.

    d. Actual M&O requirements in terms of labor and consumables as well as space requirements to complete required maintenance activities.

    e. Performance of alternate equipment manufacturers, if alternates are available at the time of piloting.

    f. Accuracy of life cycle cost analysis prior to final design of the full-scale system.

6. Conduct post-construction full-scale validation testing (biodosimetry testing) to confirm performance and determine operating parameters.

Using a program as described above, it may be possible to demonstrate the effective UV dosages to the regulators and optimize the equipment sizing criteria. For this study, reduction in the Illinois requirements for UV system sizing is not assumed based on the lack of data similar to that described above.

Budgetary costs for a 20 MGD pilot facility were included in the costs for implementation of the UV Disinfection Facilities at North Side Water Reclamation Plant, and as such are not included in this study.

3.3 Low Lift Pump Station

Based on the analysis of hydraulics of the proposed improvements described in Section 2 above, it is estimated that the low lift pumps would be required to raise the water approximately 23.5 feet (including static and friction losses) to the UV disinfection system influent, including estimated head to allow flow through the UV system. The static head equates to the difference in the estimated water surface elevation between the wet well and the discharge conduit plus an additional 2-ft of head added as a conservative factor to accommodate additional losses that may be identified during final design.

3.3.1 Basis of Design

Table 3.3-1 provides a summary of the basis of design for the Low Lift Pump Station.

Table 3.3-1 – Low Lift Pump Station Basis of Design

Peak Flow, MGD	1,440
Average Flow, MGD	1,250
Pumps	
Type	Axial Flow
Number	8 total (N+1+1)
Pumping Rates, gpm/pump	166,670
Static Head, ft	16.95
Dynamic Head, (inc. station losses), ft.	4.5
Total Dynamic Head, ft(1)	23.5
Motor, hp(2)	1,500
Submergence, minimum, ft	18.5
Peak Power Demand, kW	5,282
Average Power Demand, kW	4,455
Wet Well	
Length, ft.	86
Width, ft.	114

(1) The static head equates to the difference in the estimated water surface elevation between the wet well and the discharge conduit plus and additional 2-ft of head added as a conservative factor to accommodate additional losses that may be identified during final design.

(2) A 1,350 hp motor could be provided, however this is a non-standard size and only standard motor sizes were assumed for this conceptual study.

3.3.2 Pump Type

Initially, the Low Lift Pump Station would lift 1,440 MGD a total of 16.95 feet with a Total Dynamic Head (TDH) of 23.5 feet. If tertiary filtration is constructed in the future, the TDH would most likely increase but the flow would remain the same. Screw pumps will not easily accommodate this change in head without significant structural modifications to the pump station. However axial pumps can be modified for future head conditions. Structural modifications to the pump station to accommodate these changes, if required, should be minimal. Therefore, axial flow, propeller type pumps are recommended.

Vertical axial flow pump have been assumed here, but other configurations (including inclined or horizontal) could be considered in the future. In addition, because the total dynamic head required for the short and long term conditions is approaching the limit of axial flow pumps of this size, mixed flow pumps (e.g. vertical turbine pumps) may also be considered though the general space requirements and layouts would be similar to those assumed for this study. Final selection of pump type would be completed during preliminary design.

3.3.3 Proposed Operational Description

The pump station would have a total of eight pumps, with six duty pumps, one standby and one out of service (N+1+1). Five pumps would be driven by constant speed motors, three would be variable speed driven. In order to provide operational flexibility, the pump station would be divided into two wet wells, each containing four pumps. Normal wet well levels would be approximately -3.25 feet Chicago City Datum (CCD). Design average flow (1,250 MGD) could be handled by four constant speed and two variable speed pumps, leaving two pumps on standby. Peak flow (1,440 MGD) could be handled by six pumps, leaving two on standby. Minimum flow (365 MGD) would be handled by two variable speed pumps. Typically, at least one variable speed pump would operate at all times, to handle fluctuations in flow. **Table 3.3-2** illustrates an example of pump operation at minimum, design average flow, and peak flow:

Table 3.3-2 – Examples of Pump Operation

Flow, MGD	Pump Drive Type	Pump Flow, gpm	TDH, ft	Pump Eff.	Power Demand, kW
365 (5-year minimum)[1]	Variable speed	130,358	21.7	84%	637
	Variable speed	130,358	21.7	84%	637
1,250 (Design Average)	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Variable speed	100,694	20.6	84%	467
	Variable speed	100,694	20.6	84%	467
1,440 (Peak)	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Constant speed	166,667	23.5	88%	880
	Variable speed	166,667	23.5	88%	880

[1] 5-year minimum based on SWRP historical data.

In order to eliminate vortices, pumps require a minimum submergence as a function of pump suction bell diameter. For this flow condition, a 120-inch suction bell is required, which requires a minimum submergence of 16-feet. Submergence requirements should be verified by the pump manufacturer during final design.

Level sensors in the wet well would relay a signal to turn pumps on and off. The level control would be automatic under normal conditions, with manual override possible. Other control inputs that need to be monitored include discharge pipe pressure, flap gate position, and motor alarms.

3.3.4 Proposed Layout

Figure 3.3-1 below, shows the proposed flow diagram for the new UV disinfection facilities. During the disinfection period the flow would be diverted through the new facilities just upstream of the existing outfall.

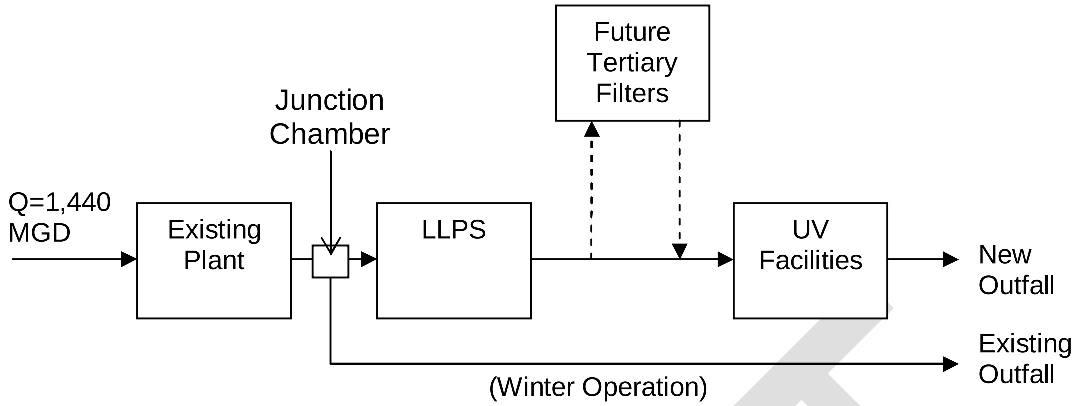

Figure 3.3-1 - Proposed UV Disinfection Flow Diagram

Refer to Sheet C-101 for a proposed site layout of the LLPS and UV Disinfection Building. The space available for the construction of the new UV disinfection facilities is constrained by the lack of space adjacent to the existing outfall. The LLPS would be located in the available space in the southwest area of the site. A new gate structure would direct the flow by gravity approximately 1,800-ft from a junction south of the Pump Discharge Chamber to the new LLPS. Due to the existing Northwest Interceptor, this new conduit will require an inverted siphon to pass underneath the interceptor, as shown in .

Referencing Sheet P-301, flow would enter the pump station at the south end of the wet well, where it would be directed perpendicularly to a wet well via six (6) 120-inch square slide gates. Pumps are located at the north end of the pump station. An ideal pump intake approach per Hydraulic Institute standards was not possible due to the prohibitively long approach length required.

To accommodate the non-ideal pump intake approach, design features, which have been shown to be effective in other installations, were incorporated in this design in order to meet HI standards. For example, perforated plates, curtain walls and floor and back wall splitters have been incorporated into the conceptual design. (See Volume 2 for a plan and section of the proposed layout). Sizing and details of these types of features are normally determined by physical scale modeling during detailed design. Furthermore, based on the total flow and flow per pump, the Hydraulic Institute recommends physical scale modeling.

4.0 SWRP CIVIL

Due to constraints of the site related to the proposed location of the disinfection facilities, several significant civil improvements would be required. Those improvements include the following:

1. Construction of new roadways to access the new facilities and future tertiary filters
2. Construction of a new gate structure and effluent conduits connecting the LLPS, UV Disinfection Building as well as a new plant outfall.
3. Construction of associated utilities including stormwater collection, city water, plant water, plant drain, electrical duct bank, and steam/condensate return.

4.1 Basis of Design

Refer to the Drawings C-101, C102 and C103 in Volume 2 of this report for a layout of the proposed facilities on the site. The basis of design of each of the civil related improvements is presented below.

4.1.1 Roadways and Other Site Improvements

Proposed roadways associated with the UV Disinfection Facilities are intended to provide access to the structures and site for normal operations as well as allow access to heavy construction vehicles and delivery vehicles. The roadway would be constructed in accordance with District guidelines. It would be designed for AASHTO H-20 loading with an assumed reinforced Portland cement concrete thickness of 12-inches. Curb and gutter (standard 12-inch wide gutter with 6-inch curb) would be provided to facilitate maintenance and stormwater collection.

4.1.2 Junction Chamber/Effluent Conduits

Final effluent conduits connecting the various facilities associated with the UV Disinfection Facilities would be constructed along with the primary facilities. All conduits are rectangular and are sized as follows:

- 17.5-ft x 15.75-ft for the influent to the LLPS,
- 16-ft x 20-ft for the influent conduit to the UV facilities
- 20-ft x 20-ft for the final effluent conduit.

The difference in conduit sizing reflects different hydraulic head loss requirements between facilities. All effluent conduits would be cast-in-place concrete construction designed for closed conduit flow. Due to the comparatively low weight of the conduits and water contained therein compared to the soil excavated, no deep foundations are anticipated at this time. Where possible, common wall construction with adjacent structures is assumed.

It should be noted that the LLPS Discharge Conduit would initially be designed for open channel flow. However, in the future, this conduit would be under pressure when the LLPS pumps are replaced to allow pumping to the tertiary filtration facility when it is constructed. As such, this conduit would be designed for pressure of approximately 15-feet of head above the top slab.

<u>Junction Chamber #1</u>

Referencing Sheet S-101, Junction Chamber #1 connects the new LLPS influent conduit to the existing plant outfall conduit. This structure would be designed to convey flow through the disinfection facilities when required or bypass the facilities to the existing plant outfall when not required. Motorized, fabricated stainless steel sluice gates on the upstream ends of the new LLPS and existing outfall conduits would be provided. No aboveground structures would be associated with the junction chamber, though its top would be 6-inches above grade. Guard rails and/or concrete bollards would prevent traffic over the junction chamber to protect the motor actuator.

During the disinfection period (March to November), the gate on the upstream of the existing outfall conduit would be normally closed to force flow from the existing site through the open gate on the LLPS influent conduit into the LLPS wet well. During the winter period (November to April), the gate operation would be reversed to allow bypass of existing site flow around the disinfection facilities. An access hatch would be provided to allow access to the structure.

Construction of Junction Chamber #1 would be cast-in-place concrete. The foundations for the chamber will be cast in place on undisturbed soil with at least 3 ksf allowable bearing capacity. The base of the structure would form the connection to the existing plant outfall conduit.

Underpinning of the existing and new conduits would be completed to prevent unexpected strain on the structures. The gate structure base would be constructed around the existing conduit. The final connection would be made "in the wet" by removing the top of the existing concrete and inserting a pre-constructed bulkhead along one side of the conduit. A water tight seal around the bulkhead is not likely to be possible and dewatering pumping is assumed necessary. It is assumed that plant flow would be controlled to maintain a narrow range of flows during this construction by diverting flows in excess of dry weather flow to TARP temporarily. The final connection would be made by sawcutting the opening and repairing the exposed surfaces before removal of the bulkhead.

Following the final completion of the connection, a second and third full pipe diameter bulkhead would be constructed upstream and downstream of the proposed gate in the existing plant outfall conduit to allow its installation. Plant flow would be diverted through the UV Disinfection Facilities during this work. Underwater construction techniques would be required to make the insertion and sealing of the bulkheads. Following installation of the gate, the bulkheads would be removed and the gate structure would be completed to grade.

Costs for the gate structures and special connections have been included in the opinion of probable construction cost included in Appendix F.

4.1.3 Site Utilities

Site utilities would be demolished, rerouted, and constructed to support the new facilities. The following utilities would be demolished or rerouted as shown on Sheet C-102:

1. Abandoned Site Utility – Demolished
2. Abandoned Railroad and Rail Yard – Demolished
3. Temporarily reroute active railroad tracks for construction of effluent conduit and outfall

The following site utilities would be added to support various functions for the new LLPS and UV Building:

1. City Potable Water – New potable water extended to the LLPS and UV Disinfection Building along the south side of the Preliminary Settling Tanks from the existing service adjacent to the south east corner of Preliminary Settling Tanks.

2. Non-Potable Water – Routed from the existing piping south of the Pump and Blower House to the LLPS and UV Building for wash down use.

3. Plant Drain – New sanitary plant drain installed from the LLPS and UV Building to a new connection at the existing Salt Creek Interceptor.

4. Stormwater Collection – New storm drains collect stormwater runoff from the new buildings and roadway and routed to aforementioned new plant drain.

5. Steam and Condensate – Constructed from existing services east of the Sludge Disposal Building to the LLPS and UV Disinfection Buildings.

4.1.5 Geotechnical Information

The project team has reviewed the Draft Geotechnical Design Report completed as part of the New Preliminary Treatment Facilities for Stickney and Calumet WRPs. This report reviewed boring logs and provided a preliminary opinion on suitable foundation type for the proposed preliminary treatment facilities which were located just north of the proposed UV disinfection facilities and LLPS. A copy of the report is provided in Appendix E.

The proposed site is within the former Ash Lagoons and the report indicates that in general, fill and topsoil are encountered near the ground surface. At Boring ST-13 in the area of the proposed LLPS, a buried 2-ft layer of top soil was encountered at a depth of 4-ft which was underlain by 14-ft layer of soft to stiff wet clay. Native soils encountered beneath the fill materials and organic materials generally consisted of stiff to very hard silty clay soils. Lenses of silt and clayey silt are encountered before reaching apparent bedrock at depths of 55-60 ft.

The proposed structures would be located 15 to 40-ft below the existing grade. The base of the structures would be located in the stiff silty clay soils. As a conceptual design, a mat foundation with rock anchors to resist the groundwater uplift force for the LLPS and the UV Building is provided. Based on the analysis performed for the Draft Geotechnical Design Report, it is anticipated that settlement would be approximately 1-inch.

A detailed subsurface investigation is recommended to characterize the stiff, silty clay layer and underlying soil layers in the vicinity of the proposed structures. Both strength and consolidation properties of these soils should be determined by field and laboratory testing. These data would be necessary for the final selection and design of the foundation system.

5.0 SWRP STRUCTURAL AND ARCHITECTURAL

5.1 Introduction

The objective of this Section is to document the design criteria for the structural, architectural components of this project, including recommendations, allowable stresses, and loadings that would be used in designing the new project structures and modifying existing structures. Refer to the structural and architectural drawings in Volume 2 of this report.

5.1.1 Codes and Specifications

The following codes would be used in addition to the general design standards listed in Section 1.2:

- The International Building Code 2003 (IBC) – Village of Skokie
- The International Fire Code 2003 (IFC)
- NPFA 101, Life Safety Code, 1997 Edition
- OSHA, United States Department of Labor, Occupational Safety and Health Administration, Latest Edition
- Building Code Requirements for Structural Concrete, (ACI 318-02) and Commentary, (ACI 318R-02).
- Code Requirements for Environmental Engineering Concrete Structures, ACI 350-01) and Commentary (ACI 350R-01).
- Seismic Design of Liquid Containing Concrete Structures, (ACI 350.3-01), and Commentary, (ACI 350.3R-01).
- ACI “Manual of Concrete Practice”, 2005, American Concrete Institute, Detroit, MI.
- ACI Committee 315, “Details and Detailing of Concrete Reinforcement, ACI 315-99.
- Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design, Ninth Edition, June 1, 1989
- Manual of Steel Construction Allowable Stress Design, Ninth Edition, 1989
- Building Code Requirements for Masonry Structures and Commentary, ACI 530-02, ASCE 5-02/TMS 402-02 and Specification for Masonry Structures and Commentary, ACI 530.1-02/ASCE 6-02/TMS602-02.
- American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures, ASCE 7-02.

- American Association of State Highway and Transportation Officials, AASHTO, Standard Specifications for Highway Bridges, Seventeenth Edition, 2002
- Soil Boring Logs in Contract 78-020-CP For Secondary Treatment Facilities at the North Side Sewage Treatment Works.
- The Illinois Accessibility Code 2004.
- The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) "Standard Specifications".
- The MWRDGC Design and Construction Manual, "Engineering Standards".
- United States Naval Facilities Command (NAVFAC), September 1986, "Design Manual 7.02, Foundations and Earth Structures".
- CFR 29 Parts 1900-1910.999 and Part 1926, OSHA
- American Society for Testing Materials (ASTM) Standards.
- American Welding Society, ANSI/AWS D1.1-98, "Structural Welding Code – Steel"

5.1.2 Loads

The following design loads would be used for the proposed structures:

Tanks, Channels and Structures below Grade:

- Hydrostatic liquid pressure-operating water level/flood water level – 62.4 psf.
- Lateral earth pressure for active, at-rest and passive conditions – Per Geotechnical Report (lateral load due to surcharge loading of H-20 truck would be added).
- Surcharge Load – 3 feet of soil.
- Frost depth – Minimum 3'-6" below finished grade.
- Design high ground water table elevations. All new structures would be checked for buoyancy for the case of high ground water table at finished grade and dead load of the structure only and is described in Part 6.1.4 below.

Roof Slab at or below Grade:

- DL: Weight of concrete slabs
- SDL: Backfill and other superimposed dead loads including underhung ancillary equipment and piping
- LL: The equivalent of 3 feet of soil or H-20 truck loading whichever governs

Buildings and Miscellaneous Structures:

- Loadings for design of the building would be obtained from appropriate codes; however, certain minimum loads would be used as shown in Part 6.1.2.3 below.

Minimum Uniform Live Loads:

- Checkered Plate: 150 psf
- Grating: 100 psf
- Stairs and catwalks: 100 psf
- Electrical control rooms: 250 psf - Estimate support area and equipment weights and assume loads applied anywhere in area
- Heavy Equipment rooms: 300 psf
- Dismantling and storage
- Storage areas: 150 psf - Determine reasonable stacking height and type of stored material
- Shop floors: 150 psf
- Garage floors: 150 psi

- Truck wheel loads per AASHTO and as appropriate
- All other: 150 psf
- Fastest mile wind speed (mph): 75 mph
- Snow (minimum): 30 psf - Snow drift loads would be checked where applicable in addition to all top supported and under hung ancillary equipment and piping
- Underhung piping and equipment where indicated, in addition to the required: 50 psf minimum roof live load
- Equipment live load plus 50 psf on adjacent areas, or minimum uniform live load, whichever is greater

Seismic Requirements – Cook County:

Buildings and Non-Liquid Containing Structures (IBC):

- Seismic use group: Group II
- Seismic design category: B
- Seismic Importance Factor: 1.25
- Spectral response acceleration for short period (SDS): 0.192
- Spectral response acceleration for 1 second period (SD1): 0.10
    - Soil profile name: Stiff soil profile
    - Site class: D

Liquid Containing Structures (ACI 350.3-01):

- Seismic zone factor: 0

5.1.3 Design Stresses

The following stresses would be used for design of the structures:

Concrete and Reinforcing Steel:

Liquid Containing Structures:

- Use ACI 350-01, Code Requirements for Environmental Engineering Structures (ACI 350-01) and Commentary (ACI 350R-01) and Seismic Design of Liquid Containing Concrete Structures (ACI 350.3-01) and Commentary (ACI 350.3R-01).
- Concrete compressive strength at 28 days : fc' = 5,000 psi
- Reinforcing steel (A 615, Gr. 60) flexural stress: fy = 60,000 psi

Building and Non-Liquid Containing Structures:

- Use Strength Design Method of Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02).
- Concrete compressive strength at 28 days: fc' = 5,000 psi
- Reinforcing steel (A 615, Gr. 60) flexural stress: fy = 60,000 psi

Structural Steel

- Conform to the AISC Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design, Ninth Edition, 1989, and the Manual of Steel Construction, Allowable Stress Design utilizing the following materials.

- ASTM A 992 for W shapes, unless otherwise specified
- ASTM A 36 for angles plates and bars
- ASTM A 325 high strength bolts
- ASTM A 307 or A 36 bar stock for anchor bolts

5.1.4 General Design

The following reinforced concrete structures would contain continuous PVC waterstops at all vertical and horizontal construction and expansion joints in walls and slabs:

1. All fluid containing structures.

2. All basements and below ground structures with one surface in contact with soil or water and the opposite surface dry and exposed.

Fluid applied waterproofing would be applied to the exterior surfaces of all walls with one surface in contact with soil and the opposite surface dry and exposed.

All structures below grade, including, but not limited to, basements, tanks, and other buried structures, would be designed to resist buoyancy for a groundwater table at finished grade. Only the dead weight of the concrete structure below ground and soil on the foundation footings around the outside of buildings, tanks, and other buried structures would be relied on to resist buoyancy. Pressure relief valves and/or perimeter drains and sump pits with pumps would not be used to resist buoyancy.

All access hatches and handrails would be stainless steel.

5.1.5 Foundation Design

The foundation design for the various structures was based on existing available borings and interpretations of these borings by an independent Geotechnical Engineer for use in estimating foundation costs for this preliminary phase of work. Based on this information, it was determined that a mat foundation can be used to support the UV Building and the LLPS, and for the purposes of this study, it would be assumed that 114 kip allowable capacity rock anchors would be required for the buoyancy support of the UV Building and the LLPS.

Prior to final design, a detailed subsurface investigation should be undertaken to characterize the soils, including soil borings, interpretation of the borings and for the final selection of the type of foundation that would be required.

5.2 SWRP UV Facility

The new UV Facility would be a one story reinforced concrete building with twelve (12) channels for the twelve (12) UV Reactors, an electrical room, a storage room, a control room and an effluent sampling room. The exterior wall construction would be a non-load bearing composite cavity wall composed of concrete masonry units, airspace, insulation and an exterior face brick. The exterior masonry materials and detailing would be similar to existing onsite masonry structures.

The roof structure would be constructed using one-way, cast-in-place reinforced concrete slabs spanning cast-in-place reinforced concrete beams. The beams would be supported by cast-in-place reinforced concrete columns. The roofing would be composed of fully adhered cold applied roofing membrane over tapered rigid insulation. The roof drainage would be directed to scupper boxes at the perimeter of the building. The scupper boxes would connect to downspouts leading drainage to grade. Aluminum skylights would be provided over each reactor to permit natural light into work areas. An aluminum framed window would be provided in the control room for visual access to the UV reactor room.

Personnel doors would be stainless steel frames and doors. The double doors in the electrical room would have a removable transom to provide access for large equipment. The overhead doors would be an insulated aluminum coiling door. Specialty floor hatches would be provided to accommodate the UV equipment maintenance. The interior floor finish in the building would be hardened concrete outside of the control room and effluent sampling room. The control room and effluent sampling room would have suspended acoustic ceilings and resilient tile flooring. Interior partitions and concrete structure would be painted.

The entire substructures, including channels and foundation grade beam/walls would be constructed of cast-in-place reinforced concrete supported on undisturbed soil of minimum 3 ksf allowable bearing capacity, with rock anchors to resist buoyancy. Gratings in the UV Reactor Room would be stainless steel with stainless steel perimeter angles and supports.

5.3 Low Lift Pump Station

The new LLPS would be a 40'+ steel supported split level building with a pump room and an electrical room. The exterior wall construction would be a non-load bearing composite cavity wall composed of concrete masonry units, airspace, insulation and an exterior face brick. The exterior masonry materials and detailing would be similar to existing onsite masonry structures.

The roof structure would be constructed using standard galvanized roof decking to span the steel support beams. The beams would be supported by steel columns. The roofing would be composed of fully adhered cold applied roofing membrane over tapered rigid insulation. The roof drainage would be directed to scupper boxes at the perimeter of the building. The scupper boxes would connect to downspouts leading drainage to grade. Removable, double hip-type, aluminum, structural skylights would be provided over each pump to permit natural light into work areas and removal of the pumps by crane in the future.

Personnel doors would be stainless steel frames and doors. The double doors in the electrical room would have a removable transom to provide access for large equipment. The overhead door would be an insulated aluminum coiling door. The interior floor finish in the building would be hardened concrete. Interior walls and concrete structure would be painted.

The entire substructures, including channels and foundation grade beam/walls, would be constructed of cast-in-place reinforced concrete supported on undisturbed soil with a minimum allowable bearing capacity of minimum 5 ksf bearing capacity with rock anchors to resist buoyancy.

6.0 SWRP ELECTRICAL

6.1 Codes/Standards

The following codes and standards are required for this project.

- NFPA-70 National Electrical Code, 2008 or latest version.
- ANSI/NFPA 780 - Lightning Protection Code.
- NFPA-820 Fire Protection in Wastewater Treatment and Collection Facilities, 2003.
- Institute of Electrical and Electronics Engineers (IEEE).
- MWRDGC GS, February 1997, or latest version.
- MWRDGC GSE, March 1994, or latest version.
- Underwriters Laboratories (UL).
- National Electrical Manufacturer's Association (NEMA).
- Insulated Power Cable Engineers (IPCEA).
- Illuminating Engineering Society (IES).

6.2 Electric Service

The Stickney Water Reclamation Plant (SWRP) receives electric service from three main ComEd transformers (T71, T72 & T73) located in ComEd Substation D799. Each transformer is rated 138 kV primary voltage, 13.8 kV secondary voltage and 30 MVA capacity giving the plant a total transformer capacity of 90 MVA.

As reported by the plant Enterprise Energy Management System, the average aggregate peak kW load for the Year 2006 was 33 MW. The anticipated connected load that will be added to the plant for the UV disinfection and intermediate pump station is estimated to be 24 MVA. As summarized in Table 1, it appears that the existing transformer capacity is sufficient for the proposed facilities.

Table 6.2-1 – Existing and Proposed SWRP Electrical Loads

Item	Value
Existing SWRP Transformer Capacity	30 MVA
Total Capacity (Three Transformers)	90 MVA
Average Aggregate Peak kW Load (2006)	33 MW
Existing Available Capacity	57 MW
Estimated UV Disinfection and LLPS Load	24 MVA
Estimated Remaining SWRP Capacity	33 MW

Referencing Sheets E-201 and E-302, the main 13.8 kV switchgear for the plant is located at the ComEd Substation. A redundant electric service to the UV Disinfection Facility and the Low Lift Pump Station would be provided. Spare breakers on Bus B and Bus C in the main switchgear would be utilized to feed the new UV Disinfection Facility. Medium voltage cable in underground ductbank would be provided from the existing plant main switchgear to supply the UV Disinfection Facility. A copy of the Electrical Evaluation Technical Memorandum is found in Appendix G.

6.3 System Grounding

Electrical systems shall be solidly grounded. Grounding shall be in accordance with the National Electrical Code for equipment grounding and bonding conductors for grounding raceway and equipment.

6.4 Conduit

Exposed conduit shall be PVC coated Rigid Galvanized Steel Conduit. Conduits in non-finished areas shall be installed either exposed on the surface of the structure or concealed in concrete floor slabs or below grade. Conduits below grade outside of the building shall be reinforced fiberglass and shall be encased in reinforced concrete. Ductbanks shall have spare conduits for future use.

Conduits shall conform to MWRDGC General Specifications: Electrical (GSE) Table 1 (Page GSE-8).

Spacing of supports for exposed conduit shall conform to MWRDGC GSE Table 3 (Page GSE-10).

6.5 Wire

600 volt insulated copper conductors in conduit shall be provided for all power, control, alarm, instrumentation, signal, lighting and grounding installations, unless otherwise indicated. The insulation shall meet ANSI/NFPA 70. The wire and cable shall conform to the MWRDGC GSE Table 4 (Page GSE-10).

Medium voltage cable shall be ethylene propylene rubber (EPR) insulated cable, U.L. listed and labeled MV-105, 133% insulation level, single conductor copper, Class B strand.

6.6 Motors (Except Low Lift Pump Motors)

Motors 1/2 horsepower and larger shall operate on 480 volt, 3-phase, AC power supplies, and motors smaller than 1/2 horsepower shall operate on 120 volts, single phase, AC power supplies.

6.7 Emergency Systems

Emergency lighting units would have unit batteries to provided final reserve source of current supply.

Emergency lighting and exit signage would be provided as per code requirements to illuminate the path of ingress/egress in emergency situations.

6.8 Lightning Protection

New structures shall be protected by a lightning protection system. The system shall be a conductor system protecting the entire building and consisting of stainless steel spline ball terminals on the building roof parapets; grounding electrodes; and copper interconnecting conductors.

The system shall be designed in accordance with ANSI/NFPA 780 - Lightning Protection Code and shall have a UL Master Label. The lightning protection system components shall conform to ANSI/UL 96 - Lightning Protection Components.

6.9 Specific Electrical Equipment

The basis of specific design equipment is described below.

6.9.1 Medium Voltage Switchgear

Table 6.9.1-1 describes medium voltage switchgear. **Table 6.9.1-2** describes the criteria to be used for circuit breakers. **Table 6.9.1-3** describes the criteria to be used for station batteries.

Table 6.9.1-1 – Medium Voltage Switchgear Criteria

Item	Criteria
Type	Medium Voltage Metal-clad Draw-out Switchgear
Standards	▪ NEMA SG.5 ▪ ANSI C37.20.2
Rated Voltage: 'MVSG-1' (UV BLDG.) 'MVSG-2'(LLPS BLDG.)	 13,200 Volts 13,200 Volts
Number of phases	3
Bus Material	Tin plated copper
Rated BIL	95,000 Volts, to be coordinated with surge arrester rating
Minimum Main Bus Rated Ampacity: 'MVSG-1' (UV BLDG.) "MVSG-2' (LLPS BLDG.)	 3,000 Amperes 2,000 Amperes
Minimum interrupting capacity	500 MVA
Arc Flash Protection	Arc resistant style switchgear with reinforced doors and venting. The need for arc extinguishing or arc terminating equipment will be evaluated during detailed design.

Item	Criteria
Mounting	Equipment shall be mounted on 4-inch structural steel embedded in the floor
Manufacturer	▪ Eaton Cutler Hammer. ▪ ABB - ASEA Brown Boveri. ▪ Siemens Energy and Automation. ▪ Approved equal.
Metering Type	Solid State Multifunction
Metering Location	Main circuit breaker and other critical feeder circuit breakers
Relaying Type	Solid state multifunction
Relaying Manufacturer	Schweitzer Engineering Laboratories, SEL Areva NP Co. Approved equal
Enclosure Rating	NEMA 1

Table 6.9.1-2 – Circuit Breaker Ratings and Features Criteria

Item	Criteria
Type	▪ Draw-out carriage type with racking mechanism. ▪ Circuit breakers shall be vacuum type.
Operator Voltage	Electric, 125 Vdc
Controls	Manually operated electric controls with piston grip switches and indicator lights. Location would be coordinated with Arc Flash analysis.
Minimum circuit breaker frame current rating.	1,200 Amperes
Manufacturer	Same as Switchgear manufacturer

Table 6.9.1-3 – Circuit Breaker Battery Criteria

Item	Criteria
Type	▪ Lead-acid ▪ Circuit breaker batteries shall be wet cell type. ▪ Charger shall be included.
System Voltage	125 Volts DC
Discharge Rate	8 Hours
End of Discharge Voltage	1.75 Volts
Cell charging voltage	2.3 Volts/Cell
Electrolyte full charge density	1215 kg/m3
Operating cell temperature	25 degrees Celsius
Nominal cell voltage	2.0 Volts/Cell
Manufacturer	▪ Exide.Battery Corporation ▪ EnerSys Inc. ▪ Chloride ▪ Approved equal

6.9.2 Secondary Unit Substation

Table 6.9.2-1 summarizes the design criteria for secondary unit substation.

Table 6.9.2-1 – Secondary Unit Substation

Item	Criteria
Type	Radial Secondary Unit Substation with close coupled air terminal compartment and close coupled Secondary Low Voltage Switchgear
Standards	NEMA 210 IEEE 100
Transformer Type	Dry type
Transformer insulation system	Vacuum pressure impregnation with polyester resin (VPI)
Primary equipment	Air terminal compartment
Primary Voltage	13,200 Volts
Primary Number of phases	3
Primary wiring configuration	Delta connection, 3-wire
Secondary Connection type	Bolt-on type bushing
Secondary Voltage	480/277 Volts
Secondary Number of phases	3
Secondary wiring configuration	4-wire, grounded
Efficiency	Peak efficiency point of transformers to be at 50% of efficiency rating.
Capacity	500-3,000 kVA or as required
Primary BIL	95,000 Volts, to be coordinated with surge protection rating
Secondary BIL	10,000 Volts, to be coordinated with surge protection rating
Winding Material	Copper
Nominal Impedance	5.75 percent
Temperature Rise	80 Degrees C
Minimum K factor	K4
Accessibility	Front and rear
Enclosure Rating	NEMA 1
Manufacturers	▪ Eaton Cutler-Hammer. ▪ ABB - ASEA Brown Boveri ▪ Square D ▪ Approved equal

6.9.3 Motor Control Centers

The design criteria for motor control centers are summarized in **Table 6.9.3-1**.

Table 6.9.3-1 – Motor Control Center Criteria

Item	Criteria
Rated Voltage	480 Volts
Number of phases	3
Main bus minimum current rating	600 Amperes
Bus Material	Tin-plated Copper

Item	Criteria
Minimum short circuit rating	65,000 Amperes
Accessibility	Front only
Wiring class	NEMA Class II-S, Type B.
Overload Protection type	Solid State Type.
Breakers	Ground Fault
Metering type	Digital Solid State multifunction meters.
Enclosure type	NEMA 1
Manufacturer	▪ Eaton Cutler-Hammer (Freedom Flashguard) ▪ Allen Bradley. ▪ Square D Corp. ▪ Siemens Energy and Automation. ▪ Approved equal

7.0 SWRP INSTRUMENTATION SYSTEM

The control of the process equipment shall be integrated into the existing DCS System which is provided by ABB.

The monitoring and control of the Low Lift Pump Station and the UV Disinfection Facility would be provided via the plant DCS System. Manual local control of the equipment would be provided. See Section 4.0 for a description of the control philosophy for the LLPS pumps and the UV Disinfection System.

7.1 Applicable Codes and Standards

Where applicable, the latest version of the codes and standards from the following institutions/organizations would govern the design:

- National Electrical Code (NFPA 70) – with Village of Skokie local amendments.
- National Fire Protection Association (NFPA) standards:
- NFPA 820 Fire Protection in Wastewater Treatment and Collection Facilities
- Underwriter's Laboratories (UL)
- Illuminating Engineering Society of North America (IESNA)
- Institute of Electrical and Electronic Engineers (IEEE)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Contractors Association (NECA)
- MWRDGC Standard Details and Specifications
- Variable Frequency Drives Reference Standards
- American National Standards Institute (ANSI)
- ANSI/IEEE 519 – IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters.
- ANSI/IEEE 597 – IEEE Practices and Requirements for General Purpose Thyristor DC Drives.
- National Electrical Manufacturers Association (NEMA)
- NEMA ICS 3.1 - Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable-Speed Drive Systems.
- NEMA ICS 7 - Industrial Control and Systems: Adjustable Speed Drives.

8.0 SWRP MECHANICAL AND PLUMBING

8.1. Mechanical Codes

Where applicable, the latest version of the codes and standards from the following institutions/organizations would govern the design:

- The International Mechanical Code 2003
- The International Plumbing Code 2003
- National Fire Protection Codes (NFPA), Section 820, 2007
- American National Standards Institute (ANSI)
- American Society For Testing Materials (ASTM)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- SMACNA – HVAC Duct Construction Standards
- International Building Code 2003

8.2 Basis of Design

The UV Disinfection Building and the LLPS would follow the International Building Codes for fire protection pending future direction by the District.

8.2.1 Ventilation Rates

The ventilation rates are selected based upon the need to conform to the recognized national standards applying to wastewater treatment plants. Specifically, NFPA 820, "Standard for Fire Protection in Waste Water Treatment and Collection Facilities" and the "International Fire Code" are used for the design.

8.2.2 Design Temperatures

Design temperatures are based upon local climatic data found in the latest edition of ASHRAE Handbook of Fundamentals

<u>8.2.2.1 Heating</u>

The design space temperature for all process areas would be 55ºF with an outdoor air temperature of -10ºF. The design space temperature for occupied areas would be 70ºF.

<u>8.2.2.2 Air Conditioning</u>

The design space temperature and humidity conditions for areas requiring air conditioning would be 78ºF DB, 50% RH with an outdoor air condition of 91ºF DB, 75ºF WB. Summer ventilation only spaces would have a maximum design space temperature rise of 15ºF.

8.2.3 Plumbing

The plumbing systems for the UV Disinfection Building and LLPS would be designed to the "International Plumbing Code", 2003.

<u>8.2.3.1 Potable Water</u>

Potable water would be supplied to the wash sink in the UV Disinfection Building from plant potable water distribution system.

<u>8.2.3.2 Effluent Water (Plant Service Water)</u>

Effluent water would be available from the plant effluent water distribution system. Effluent water would be provided for equipment wash down in the UV Disinfection Building and the LLPS.

8.2.3.3 Sanitary Drainage

General floor drainage would be provided in all rooms as required by codes. Drainage from the wash sink and the effluent water sampling sink would be routed to the plant sanitary drain. Floor traps and sink traps would be vented.

8.2.3.4 Fire Protection

The fire protection system would consist of portable fire extinguishers and fire hydrants, in accordance with the requirements of NFPA 820 and local code requirements.

8.3 Proposed Mechanical and Plumbing System

The following section details the proposed equipment and operation.

8.3.1 UV Disinfection Facility

Air-conditioning with electric heating would be provided for the operator control room, storage room and effluent sampling room. Heating for the electrical room would be provided by electric unit heaters. Ventilation heating for the UV disinfection room will be provided by a steam heating and ventilation unit. Envelope heating for the UV disinfection room will consist of steam unit and space heaters.

Summer ventilation for the electrical room and would be designed for a maximum space temperature increase of +10ºF over ambient. Temperature control would consist of cycling exhaust fans that are interlocked with filtered makeup air handlers.

UV disinfection room ventilation will consist of 2 air changes for general, year-round ventilation. Summer ventilation for the UV disinfection room will consist of 6 air changes. Exhaust fans for general ventilation and summer ventilation will be interlocked with associated intake louver dampers.

A steam pressure reducing station will be located in the UV disinfection room to reduce HPS (high pressure steam) to LPS (low pressure steam) for space heating in the UV disinfection room. This pressure reducing station will also provide LPS for space heating in the low lift pump station. A condensate pump will be located in the UV disinfection room to pump low pressure condensate back to the boiler house.

Effluent hydrants and hose reels would be provided for wash down of the UV system at the north and west doors. Potable water would be provided to the wash sink at the west door. An inline instant water heater would be provided for domestic hot water.

8.3.2 Low Lift Pump Station

Heating for the electrical room would be provided by electric unit heaters. Heating for the pump room would be provided by steam unit heaters. LPS for the pump room will be provided by steam pressure reducing station located in the UV disinfection facility. A condensate pump will be located in the pump room to pump low pressure condensate back to the boiler house.

Summer ventilation rates for the electrical room would be designed for a maximum space temperature of +10ºF over ambient. Temperature control would consist of cycling exhaust fan that are interlocked with filtered makeup air handlers. Exhaust fans for the electrical room would be designed for a 2/3 capacity.

Summer ventilation rates for the pump room would be designed for a maximum space temperature increase of +15ºF over ambient. Temperature control would consist of cycling exhaust fans that are interlocked with outside air intake dampers.

9.0 SWRP AREAS REQUIRING FURTHER ANALYSIS

The following areas require further analysis as part of a preliminary design effort prior to final design of the proposed facilities.

1. A detailed subsurface investigation is recommended to characterize the soft silty clay layer and underlying soil layers. Both strength and consolidation properties of these soils should be determined by field and laboratory testing. This data would be necessary for the final selection and design of the foundation system by a qualified geotechnical engineer.

2. A more detailed evaluation of potential pump types and arrangements for the LLPS. Historically, horizontal arrangements, similar to the existing Wilmette Lock pumps, have been used in flood control projects that might be applicable here.

3. A more detailed evaluation of the locations of the UV Disinfection Building and the LLPS is recommended. This would allow the optimization of the available space for any future facilities.

4. A more detailed evaluation of large-scale M&O requirements for the selected UV technology is recommended to ensure the appropriate equipment spacing, operations rooms, and storage space is provided in the new facilities. Existing large-scale facilities are either based on older technology or are operated intermittently as wet weather facilities. A pilot facility is recommended to provide this information.

5. Physical scale modeling during preliminary design of the LLPS is strongly recommended per Hydraulic Institute Standards for a pump station of this size and given the deviation from the ideal inlet configuration.

6. Perform CFD modeling on UV Distribution Channel to ensure proper flow balancing to all active reactors

10.0 SWRP PRELIMINARY COST OPINION

A preliminary opinion of probable construction (OPCC) of the North Side WRP UV Disinfection Facilities is estimated at approximately $542.9 million including engineering and administrative costs as shown in Table 10.0-1, which also presents annual operating costs and a 20-year net present worth value for the project. Annual operating costs are based on the facilities operating from March to November each year. Appendix F provides detailed line item summary tables for capital and M&O estimates. The Level 3 estimated construction cost is based on June 2007 dollars represented by an Engineering News Record (ENR) Construction Cost Index (CCI) of 7983.

Table 10.0-1 – SWRP UV Disinfection Facilities Preliminary OPCC and M&O Costs

Capital Cost Estimates	
A. General Sitework	$61,890,000
B. Low Lift Pump Station	$86,220,000
C. Disinfection System	$112,420,000
Total Capital Cost	**$260,530,000**
Maintenance & Operations Cost Estimates	
A. General Sitework	$90,000/yr
B. Low Lift Pump Station	$2,540,000/yr
C. Disinfection System	$9,560,000/yr
Total Annual M&O Cost	$12,190,000/yr
Total Present Worth M&O Cost	$282,400,000
Total Present Worth	**$542,930,000**

All costs in 2007 dollars.

Per District guidelines, this opinion is categorized as a Level 3 as defined by the Association for the Advancement of Cost Engineering Recommended Practice No. 18R-97 and represents an expectation that actual cost will deviate from the estimated cost by -15% to 30% assuming no substantial change in scope or extraordinary events and not including escalation from the date of this report to the start of construction.

10.1 Basis of Opinion of Capital Cost

The assumptions made used to develop the capital costs for the proposed facilities are summarized below and/or described in the previous sections:

- Design Flow: Maximum design flow was used (SWRP = 1,440 MGD).
- Proposed Effective Disinfection Limit (Fecal Coliform, cfu/100 ml): 400 monthly geo-mean for Stickney.
- UV Disinfection:
  - UV Transmission: 65% minimum per IEPA standard
  - UV Dosage: 40 mJ/cm^2 per UV_{dis} sizing software
- Each plant would disinfect effluent from March 1 through November 15. During the remaining months, the disinfection facilities, including LLPS, would be bypassed.
- Cost opinions were divided into the following categories:
  - Site Work
  - Low Lift Pump Station
  - UV Disinfection Building

  Costs for major equipment were obtained from the following vendors:

Technology/Process	Vendor
UV Reactors	Trojan Technologies, Inc.
Axial Flow Pumps	Morrison Pump
Flap Gates	Rodney Hunt
Slide Gates (various sizes)	Rodney Hunt

- UV channels were enclosed in a UV building.
- Redundancy
  - UV – multiple channels were used to meet the effluent limit at peak flow with one channel out of service.
  - Pumps were provided with N+1+1 redundancy per the District's standard guidelines.

10.2 Basis of Operation and Maintenance Costs

The assumptions used to develop the maintenance and operating costs are presented below:

- A power cost of $0.0684/kW-hr was used as a composite rate based on the District's 2007 power supply contract.
- Labor rates were developed based on the results of the phone survey of similar facilities, discussions with the manufacturer, and recommendations by the District.
- UV Disinfection Building and the LLPS would operate from March 1 to November 30 each year.
- Annual UV lamp replacement and disposal costs were based on the following replacement schedule:
    - Lamps replaced each year (100% per year)
    - Ballasts replaced every five years (20% per year)
    - Quartz sleeves replaced every 10 years (10% per year)
    - Wipers replaced every 3 years (33% per year)
    - Lamp disposal costs are included in the costs of the new lamps
- Miscellaneous parts and supplies assumed to be 5% of equipment costs including pumps, valves, piping, HVAC equipment, electrical equipment, etc. UV equipment not included.
- Labor rates were developed based on the data received from the District.
- The labor requirements presented in **Table 10.2-1** were assumed for the three components of the facilities.

Table 10.2-1 – M&O Labor Requirements

Activity	Labor Type	Number	Hours per Week per Worker
Site Work			
Routine Maintenance (Gates, Roads, Conduit, Utilities, Landscaping)	Laborer	1	10
Low Lift Pump Station			
Routine Maintenance (Pumps, Valves, Electrical Equipment)	Laborer	2	20
	Electrician	1	10
Operations	Operator	2	40
UV Disinfection Building			
Routine Maintenance	Electrician	1	2
Lamp Replacement	Electrician	2	20
Lamp Inspection/Cleaning	Electrician	4	40
Operations	Operator	2	40

10.3 Basis of Net Present Value Calculation

In order to develop a net present worth valve for comparison to other alternatives with differing M&O costs, a present worth factor of 23.17 was used for all present worth calculations, based on a nominal 4.875% interest rate for 20 years with a 3.0% inflation factor.

The interest rate is the 2007 nominal discount rate published by authority of the Water Resources Development Act of 1974. The use of this discount rate mirrors the United States Army Corps of Engineers policy related to calculation of life cycle costs for comparative analysis. The current annual rate can be obtained from the US Department of Agriculture, Natural Resources Conservation Service (http://www.economics.nrcs. usda.gov/cost/priceindexes/rates.html).

The inflation rate was developed by comparison of three common inflation indicators. Those indicators are:

1. Gross Domestic Product Deflator
2. Consumer Price Index (CPI)
3. Producer's Price Index (PPI)

As of the end of August 2007 (most recent available data), the three indicators have a 10-year rolling average inflation of 2.6%, 2.9%, and 2.6% respectively. Data for the GDP Deflator is available from the US Department of Commerce, Bureau of Economic Analysis, Table 1.1.9 (http://www.bea.gov/national/nipaweb/SelectTable.asp). Data for the CPI and PPI is available from the US Department of Labor, Bureau of Labor Statistics (http://www.bls.gov/home.htm). Therefore, a value of 3.0% was selected to provide a reasonable, yet conservative, estimate of inflation.

10.4 Discussion of Cost Estimate Line Items

The preliminary opinion of probable construction cost was developed based on the drawings developed as part of this study (see Volume 2), CTE's knowledge of local construction market, CTE's experience with similar projects, specific budgetary quotes from equipment suppliers, and industry standard practices. The quantities for each item included in the cost estimate were measured from the drawings or estimated based on CTE's understanding of probable means and methods of construction.

In general, unit costs for each line are considered assembly costs including labor and materials for that item plus ancillary items normally associated with that item unless included elsewhere. For example, concrete costs are given including formwork, rebar, and concrete, but not including excavation and backfilling, which are included as separate line items. While an explanation of all line items included in the estimate is not provided, specific line items that warrant additional information are described below in **Table 10.4-1**.

Table 10.4-1 – OPCC Selected Line Item Description

Line Item	Description/Additional Information
General Requirements	General requirements include project specific insurance (such as payment and performance bonds) and other project specific overhead costs (i.e. field personnel labor, field trailers, field office supplies, general quality control testing, shop drawing preparation, O&M manual preparation, and permit fees). It is assumed to be 15% of the total project direct costs.
Bulkheading and Removal at Gate Structure #1	This line item is a lump sum estimate of the cost to make the connection to the existing final effluent conduit at Gate Structure #1 including demolition, dewatering, bulkheading, restoration, and backfilling.
Utility Items (Site Work)	Assembly costs for utility line items include trenching, shoring, materials, installation, backfilling and placement of topsoil per linear foot of the utility.
Conduits (Site Work)	Assembly costs for conduit line items include excavation, shoring, formwork, rebar, concrete, backfilling and placement of topsoil per linear foot of the conduit.
Concrete (Base Slabs, Walls, and Elevated Slabs)	Assembly costs for concrete installation including rebar, formwork, and concrete. Does not include excavation or backfill.
Interior walls (masonry)	Assembly costs for construction of masonry interior wall including block, mortar, installation and ancillary costs. Does not include coatings.
Exterior walls (masonry)	Assembly costs for construction of masonry exterior wall including block, insulation, brick, mortar, installation and ancillary costs. Does not include coatings.

Line Item	Description/Additional Information
Pumps	Budgetary equipment costs from suppliers plus 25% for installation. Includes delivery, startup, and training services.
UV Reactors	Budgetary equipment costs from supplier plus 15% for installation. Includes delivery and installation certification services. Startup and M&O training included separately.
Escalation	Escalation is assumed to be 5% per year. Construction period is assumed to be 48 months. Therefore, escalation to the mid-point of construction is 10.0%.
Contractor's Markup on Subcontractors	Contractor's markup on subcontractors is assumed to be 5%. This markup is applied to all direct project costs except the general conditions line item.
Contractor's Overhead and Profit	Contractor's overhead of 5% includes general contractor overhead including front office costs and project manager's time. Profit is assumed to be 10%.
Contingency	Consistent with AACE guidelines for Level 3 estimates, and District policy, a contingency factor of 30% has been added to the OPCC to cover unknown costs associated with the project. Contingency does not include escalation from the point of time of estimate to beginning of construction, extraordinary events, or changes to the scope of the project.

APPENDIX A

HYDRAULIC TECHNICAL MEMORANDUM

DISINFECTION COST STUDY
HYDRAULIC EVALUATION

FOR

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

STICKNEY WATER RECLAMATION PLANT

TECHNICAL MEMORANDUM

June 2, 2008

Prepared By

CTE | AECOM

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MWRDGC Project No. 07-026-2P
CTE Project No. 60040695

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1 INTRODUCTION

This technical memorandum has been developed as part of the Preliminary Cost Opinion for Ultraviolet (UV) Disinfection Facilities Study at the Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC, or District) Stickney Water Reclamation Plant (SWRP) in Illinois. This memorandum continues the work that began in TM1-WQ which was developed previously as part of a Water Quality (WQ) Strategy for affected Chicago Area Waterways.

The TM1-WQ documented the results of a Consoer Townsend Envirodyne Engineers (CTE) study of effluent disinfection alternatives for the District's North Side, Calumet and Stickney WRPs. Based on economic and non-economic evaluation of alternatives, ozone disinfection and UV disinfection were selected and study-level basis of design and cost estimates were developed. Both alternatives were developed including three components: a low lift pump station, a tertiary filter facility, and a UV or ozone disinfection facility. The need for tertiary filtration to support disinfection was based on limited sampling that showed transmittance values less than the IEPA minimum of 65% and energy savings with a less turbid flow stream. Because of the limited available information, the estimates that were developed were broken into two alternatives for each disinfection technology: one with tertiary filters and one without tertiary filters. In both cases, a low lift pump station was included based on conceptual level evaluations of the available hydraulic driving head for the existing and proposed conditions.

Subsequent to the TM1-WQ evaluation, additional transmittance data was obtained and the District requested that the costs be further developed without including tertiary filtration. This additional evaluation is also based on the comments received from the United Stated Environmental Protection Agency (USEPA) as part of the Use Attainability Analysis (UAA) evaluations, and new information obtained since the previous work.

1.1 Objective

The primary objectives of the evaluation presented in this technical memorandum are:

- To update the hydraulic evaluation conducted during the preparation of TM-1WQ
- To develop the hydraulic basis of design for further evaluation and development of the conceptual design of UV disinfection facilities
- To determine the need for a low lift pump station with the addition UV disinfection facilities both prior to and after the potential addition of tertiary filters

For the purposes of the Disinfection Cost Study, sound engineering judgment will be used to make assumptions regarding the most likely arrangement of the proposed facilities based on the current status of the future planned improvements to the SWRP.

In the following discussion, the results of this evaluation are given. The sections that follow summarize the determination of the process flow through the UV Disinfection Facilities, the hydraulic profile through the proposed UV Disinfection System, and the details of the Low Lift Pump Station.

2 PROPOSED FACILITIES

The proposed facilities considered in this study revolve around adding disinfection process facilities to the existing process train and all associated improvements required due to that addition. As such, the improvements would include a disinfection facility/building based on ultraviolet disinfection technology, additional effluent flow conduits and a new plant outfall, gate structures to redirect flow to the new facilities, and a low lift pump station. Tertiary filters would not be included, although the proposed disinfection facilities would be designed to allow the future addition of tertiary filters. The decision to proceed with UV technology for disinfection was made by the District based on several factors including track-record of the technology, the need to avoid release of additional chemicals to the environment such as chlorination byproducts, security concerns related to chlorine use and storage and the cost comparison between the short-listed disinfection technology alternatives (ultraviolet treatment and ozonation) performed as part of TM-1WQ. UV technology was shown to be less costly than ozonation with substantially less concern regarding byproducts and security compared to chlorination/dechlorination.

2.1 Key Considerations for Design Development

In order to further develop the design for the UV Disinfection Facilities, CTE has reviewed the basis for the decisions that were incorporated into TM-1WQ in order to confirm the validity of those decisions. This review has identified several issues that must be addressed during the conceptual design of the facilities.

2.1.1 Site Constraints

Proposed Treatment Train

Disinfection facilities are usually located at the farthest possible downstream point in the process treatment train for the reason that the more treatment the effluent receives to remove both dissolved and suspended contaminants, the more effective the disinfection process.

One major change from TM-1WQ is the relaxation of the assumed need for tertiary filtration as part of the disinfection facilities. TM-1WQ presented scenarios with and without filtration based on the lack of information to demonstrate that filtration was not required for effective disinfection. For the purposes of this study, it is assumed that tertiary filtration would not be required in the near term. However, if tertiary filtration is implemented in the future, it would be beneficial for filtration to occur prior to disinfection to leverage the benefits of lower suspended solids and BOD concentrations that would make disinfection both more efficient and potentially allow the UV facilities to be downsized.

Space

Appendix A shows the proposed future site plan from the SWRP Master Plan as included in TM1-WQ. The TM1-WQ allocated space in the southwest area of the existing site for disinfection and tertiary filtration due to the amount of available open space and the relative proximity to the Ship and Sanitary Canal (SSC). However, this would require an extensive effluent conduit to convey flow from near the Pump and Blower Building nearly 1,500 LF to this location and a new effluent outfall into the SSC. Also, the majority of the space needs in this location are allocated to future tertiary filtration. The filter space allocated is based on denitrification media filtration at 1.5 gpm/sf. Although other filtration technologies are available with smaller space requirements, it is prudent at this time to assume denitrification filtration for planning purposes.

In consideration of these points, the location provided in TM-1WQ is recommended as it provides sufficient open space for the new facilities as well as provides flexibility for future implementation of tertiary filters is so required. The arrangement of the new facilities in the south-west area of the plant has been altered from TM-1WQ to provide for better usage of the site, as shown in **Figure 1**.

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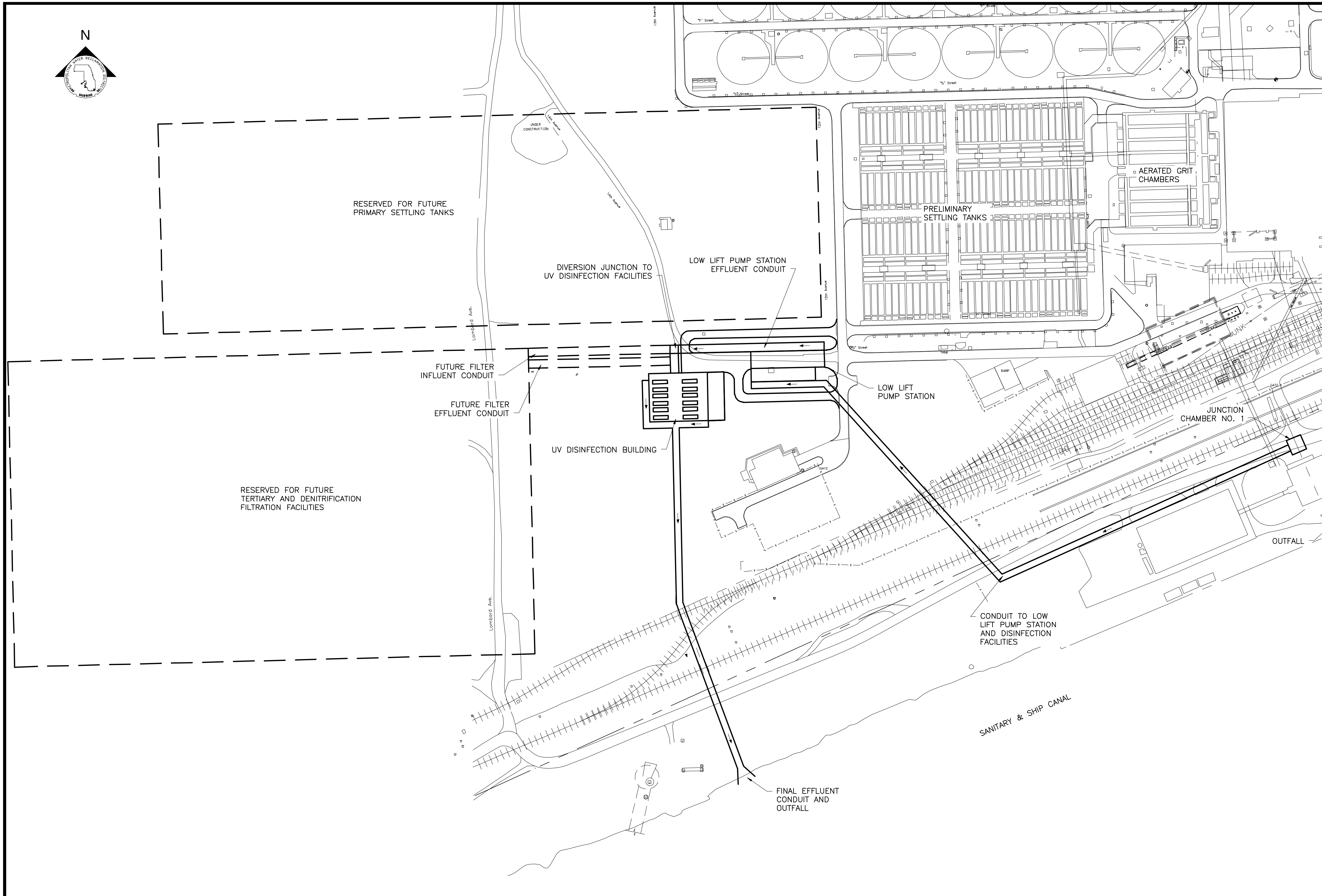

Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Approved: MWRD Assistant Chief Engineer

Correct: ENG

Designed by: XX	Checked by: XX
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Date: JUN 2008	Scale: 1:100

STICKNEY WATER RECLAMATION PLANT

CONTRACT 07-026-2P

UV DISINFECTION COST STUDY

SWRP
SITE PLAN

Sheet Number:
FIGURE 1
Page Number: XX

PRELIMINARY COPY

NOTE: This document is preliminary only and is not intended for any purpose except review and comment by the owner and its agents.

PLOT DATE: 6/2/2008 9:41 AM PLOTTED BY: WORTH, SELINA

2.1.2 Hydraulic Constraints/Need for Additional Pumping

The final key consideration for development of the potential disinfection facilities at SWRP is the hydraulic constraints that may limit the ability to convey flow through the facilities by gravity. CTE has completed hydraulic evaluations to estimate the headloss through the UV Disinfection Facilities including the required conduits to evaluate the ability to flow through the proposed facilities by gravity.

The flow through the SWRP is currently via gravity from Aeration Batteries A, B, C and D, underneath the Pump and Blower Building to the plant outfall discharging into the Ship and Sanitary Canal (SSC). The existing hydraulic condition was analyzed from the existing effluent aerator downstream of Battery B, as this represents a hydraulic break point, to the outfall in order to determine the head available for the disinfection facilities. CTE conducted this hydraulic evaluation based on three assumptions:

1. A water surface elevation (WSE) of 3.5 ft CCD in the SSC based on the hydraulic profile from the Contract 78-102-EP, West-Southwest Treatment Works, February, 1985[1] was used as the historical hydraulic basis of design for the existing facilities. This does not meet the 100-year flood requirements.

2. Secondary effluent to the new disinfection facilities would be diverted through a new junction chamber located just downstream of the Pump and Blower Building, at a point approximately 800-ft upstream of the outfall. At this location, secondary effluent from all Aeration Batteries (A, B, C & D) could be diverted to the new facilities.

3. Peak flow of 1,440 MGD was used to size the hydraulic conduits.

The difference between the water surface elevation at the Pump and Blower house and the historical water surface elevation in the SSC is the head available to convey flow through the new disinfection facilities by gravity. **Table 1** presents the results of that evaluation.

Table 1 - Theoretical Water Surface Elevation Assuming All Gravity Flow, Existing Conditions

Location	WSE
WSE just downstream of Pump and Blower House	5.45
WSE in SSC, taken from 1985 Hydraulic Profiles max water elevation	3.50
Available head, ft.	1.95

Note: All WSE in Chicago City Datum (CCD).

Per Table 1, only 1.95 ft of head is available to convey flow through the proposed disinfection facilities by gravity under previous hydraulic analysis conditions. Without tertiary filters, the headloss through the UV disinfection facilities, including associated flow splitting and control systems, is estimated to be 7.64 feet. Thus the available head is insufficient to direct flow through the potential disinfection facility by gravity alone.

[1]El 3.5 ft CCD is listed as the water level in the Sanitary and Ship Canal for which the hydraulics were evaluated, based on a maximum design flow rate of 2,000 MGD. This profile appears to be the last official hydraulic profile conducted for the SWRP.

As a result, additional pumping would be required after the implementation of the UV disinfection facilities to meet the required peak flow rate of 1,440 MGD.

Considering that this is a conceptual level evaluation, additional headloss is possible and likely to be identified during final design as the details of flow splitting arrangements and other site constraints create less than ideal flow conditions.

3 HYDRAULIC ANALYSIS OF THE UV DISINFECTION FACILITIES

3.1 Objectives

Hydraulic analyses of the SWRP had not been performed as part of the Master Plan, thus the objective is to identify any possible hydraulic bottlenecks in the proposed disinfection facilities for the recommended site plan indicating where detailed analysis will be required during the design phase. For this study a preliminary model was created to evaluate the hydraulics following the addition of the UV Disinfection Facilities inclusive of the required addition effluent conduits, gate structures, UV channels and reactors and the Low Lift Pump Station (LLPS).

3.2 Overview

The hydraulic analysis was completed using a spreadsheet utilizing standard open channel and closed conduit flow equations to represent the SWRP from the effluent conduit at the Pump and Blower house through a new junction chamber to the new LLPS, through the new UV facility and discharged to the outfall. The hydraulics evaluated were for the year 2040 conditions, utilizing a peak flow of 1,440 MGD, which includes both infrastructure and permit-related improvements. The hydraulic analysis considered the existing plant hydraulics starting from the hydraulic break created by the effluent aerator, downstream of Battery B.

Although a WSE Elevation in the SSC of 3.5 ft CCD was utilized to determine if effluent pumping is required based on the historical hydraulic basis of design, the 100-year flood elevation for the Sanitary and Ship Canal has been calculated using the USACE's Chicago Underflow Plan (CUP) Design Report. The CUP report used observed high water levels to model the predicted high water levels throughout the Chicago Area Waterways at each of the construction phases. The observed high water level at the SWRP outfall is approximately 4.1 ft CCD (since 1965) and the peak modeled level for the 1957 event (estimated at greater than the 100-year flood) is 10.1 ft CCD. Appendix B provides select pages from this report.

From the CUP report, a water surface elevation of 9.0 ft CCD was estimated at the SWRP outfall for the 100-year flood. For the conceptual design of the new UV facilities in this study, the water surface elevation of 9.0 ft CCD will be utilized as a worst case hydraulic constraint in order to ensure the new facilities can operate during the 100-year flood.

3.3 Assumptions

Due to the preliminary nature of the selected site plan, assumptions were made in the development of the hydraulic model. These assumptions are as follows:

1. Peak flow of 1,440 MGD. Flows above 1,440 MGD are diverted to the TARP system.

2. SWRP drawings obtained from MWRDGC are on the Chicago City Datum (CCD) or the National Geodetic Vertical Datum (NGVD). All elevations were converted to CCD using conversion CCD = NGVD – 579.48.
3. The CCD has not changed since the plant was originally constructed in the 1920's.
4. The estimated 100-yr flood elevation is +9.00 CCD, as calculated in the Chicago Canal System Model, UNET. Appendix B provides selected pages from the USACE's Chicago Underflow Plan (CUP) Design Report presenting these results. Pre-Stage 1 (Stage 1 of the McCook Reservoir Construction) values are used since the USACE's current estimate for completion of Stage 1 construction in 2020 or later.
5. Post Aeration is not included in this study. Additional headloss and costs would be associated with the inclusion of post-aeration.
6. Velocity in Disinfection Influent and Effluent Distribution Chambers is zero to allow adequate flow distribution.
7. Batteries A, B, C and D are all at the same elevation and flow is equally divided between the Batteries A, B, C and D, with each receiving 360 MGD.
8. The UV process requires approximately 6 ft of submergence, thus the disinfection channel effluent weir is assumed to be 5.5 ft above invert to ensure a submerged weir at low flow conditions.
9. The following modeling equations were used:
    a. Pressure Flow – Hazen Williams Equation
    b. Open-Channel Flow – Manning's Equation
    c. Flow junctions – Pressure Momentum Analysis
10. Hydraulic coefficients used in developing this model include:
    a. Hazen Williams – 110 (concrete)
    b. Manning's
        i. Regular channel – 0.013
        ii. Aerated channel – 0.035

3.4 Results

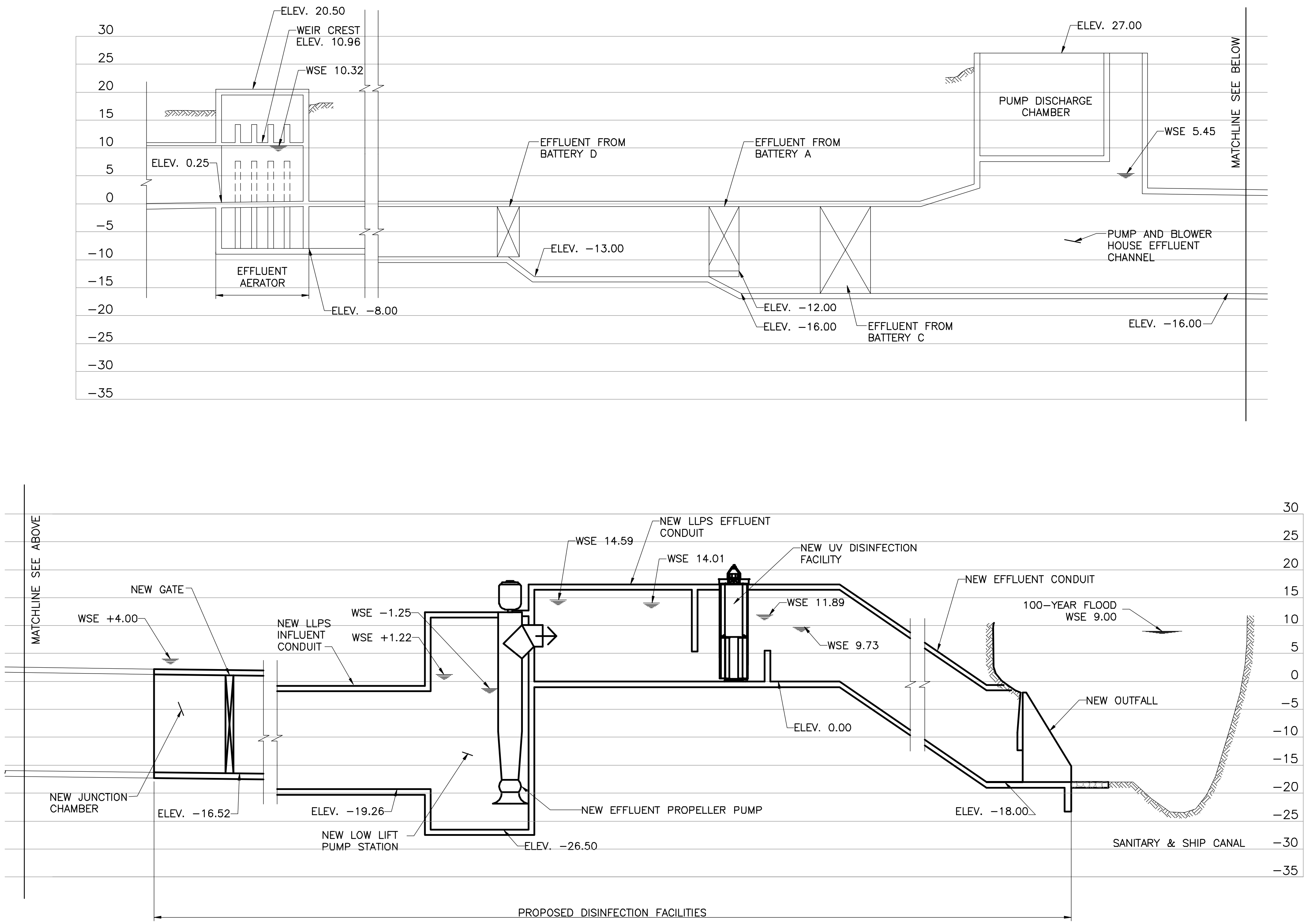
The results of the hydraulic analysis are presented in **Table 2**. Table 2 presents the estimated water surface elevations through the plant from the existing Effluent Aerator through the new LLPS and UV Disinfection Building and to the new outfall.

The flow path starts with a new effluent conduit that would direct secondary effluent by gravity approximately 1,500 ft west from the new junction chamber near the Pump and Blower Building to the new LLPS. Flow would then be lifted 15.8 ft to the new UV influent conduit. Flow would travel by gravity through the UV facilities, which would be split into two banks of six UV reactors, into an effluent conduit and to a new outfall discharging into the SSC.

Table 2 - Summary of Proposed WSE including UV Disinfection Facilities

Location	WSE
Effluent Aerator Discharge Weir Elevation	10.96
WSE in Effluent Aerator	10.32
WSE just downstream of Pump and Blower House	5.45
WSE at New Junction Chamber	4.00
WSE in LLPS Influent Conduit	1.22
WSE in LLPS Wet Well just u/s of curtain wall	-1.25
WSE just downstream of Low Lift PS	14.59
WSE just upstream of Influent gate	14.01
WSE just upstream of Effluent Weir gate	11.89
WSE at downstream of Disinfection Effluent Chamber	9.73
WSE in Sanitary and Ship Canal, Approximate 100 yr flood elevation	9.00

The estimated water service elevation at the existing effluent aerator remains below the existing aerator weir elevation, thus maintaining the existing hydraulic break. **Figure 2** contains the hydraulic profile of the flow path through the proposed UV disinfection facilities and the available freeboard at the locations where water surface elevations (WSE's) were calculated at the maximum day flow.



Rev.	Description	Appr	Date

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CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

PROPOSED HYDRAULIC PROFILE
DISINFECTION FACILITIES

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Sheet Number:
FIGURE 2
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4 UV DISINFECTION FACILITIES

The District has preliminarily selected the medium-pressure high-intensity (MP-HI) UV disinfection technology for potential disinfection of final effluent at its water reclamation plants. This section presents the preliminary basis of design of the UV system to be used at the SWRP.

4.1 Background

A Technical Memorandum on the UV Disinfection Technology was completed for the North Side WRP UV Disinfection Cost Study. The memorandum incorporated the following information which is relevant to the Stickney WRP:

- Information from literature including technical proceedings from the Water Environment Federation (WEF), Water Environment Research Foundation (WERF), proceedings from the latest Disinfection conference series undertaken by WEF, American Water Works Association (AWWA), and International Water Association (IWA). This information provided the latest updates in the UV disinfection technology.

- Updated recommendations on the UV system from four manufacturers – Trojan Technologies, Aquionics, Calgon Carbon, and Severn Trent Services (STS)/Quay.

- Reference information on experience of UV disinfection at five selected facilities – Racine WWTP (Racine, WI), R.L. Sutton WRF (Cobb County, GA), Grand Rapids WWTP (Grand Rapids, MI), Jacksonville WWTP (Buckman, FL), and Valley Creek WWTP (Valley Creek, AL). A summary of important inferences from the phone survey are as follows.

    1. Fouling due to iron in the effluent has been a problem at the Racine, Sutton, and Grand Rapids facilities. Fouling results in lower then expected disinfection performance, higher operating costs, and higher M&O efforts. The iron in the effluent at all three plants was primarily from the chemical phosphorus removal using Ferric Chloride. At Grand Rapids WWTP, the chemical addition is upstream of the secondary treatment process; staining of sleeves was found only when the chemical addition was in the secondary clarifiers. At the Sutton WRF, fouling of lamps due to iron is observed although chemical addition is upstream of secondary process and sand filters are used upstream of the UV disinfection system. At the Racine WWTP, fouling may be due to ferric chloride addition and/or due to the additional iron brought by the ferric sludge from another water treatment plant, although operational controls are used to prevent both sources from occurring simultaneously.

    2. Calcium fouling due to hardness in the source water is not a significant problem because of the automatic mechanical/chemical cleaning system that dissolves and wipes away any scales. The lack of calcium hardness was observed in all five plants including the Racine and Grand Rapids utilities which have Lake Michigan source water and is attributed to the automatic cleaning system performance.

    3. The frequency of cleaning and changing of the cleaning solution is specific to the utility and would have to be determined only by experience; however it is likely to be more than the typical case stated in the literature.

4. Labor requirements varied amongst facilities, with some facilities requiring more labor to handle the fouling caused by iron salt addition.

5. As long as other processes in the plant are performing as desired, all five facilities were satisfied with the UV disinfection system because it met their disinfection goals.

In conclusion, the phone survey had revealed that fouling of the quartz sleeves is a concern for this application, particularly if iron salts are added for phosphorous removal in the future. In addition, the phone survey results suggest that the manufacturer's recommended labor assumptions for routine maintenance including cleaning and inspection of the lamps is too low for this application. As transmissivity is directly related to lamp fouling, additional lamps and/or more frequent cleaning may be required in the future if iron salts are to be utilized in processes upstream of this technology.

Using this information and the updated information available from manufacturers, a preliminary basis of design of the MP-HI UV disinfection system has been developed for disinfection of the final effluent at the SWRP.

4.2 Basis of Design

The MP-HI system involves sending the secondary or tertiary effluent through channels containing banks of MP-HI UV lamps. The Trojan UV4000™Plus system is used here to develop the basis of design for the UV disinfection system. The system consists of a power supply, an electrical system, a reactor, MP-HI lamps, a mechanical and chemical cleaning system, and a control system. The MP-HI UV lamps are enclosed in individual quartz sleeves for protection against dirt and breakage. Reactor chambers (open channels) hold the lamps in a horizontal configuration. The effluent weirs and level sensors are used to keep the lamps submerged under the effluent water. This submergence ensures that the lamps do not overheat, thereby preventing lamp life reduction or burnout.

The UV system is assumed to operate from March to November each year. During the winter months, the equipment would sit idle as the flow is bypassed around the LLPS and UV Disinfection Building. However, due to the size of the facility including twelve reactors and over 4000 lamps, maintenance activities would be conducted every working day from March to November and periodically during the winter months. It is reasonable to expect that the area would continue to experience normal weather patterns for the Chicago area including extreme weather during all four seasons. In order to protect the safety of the M&O staff, ensure operational and maintenance-related productivity, and protect the UV equipment from adverse weather common to the Chicago area including high winds, rain, lightning, snow, and extreme temperatures, the UV system would be enclosed in a building.

4.2.1 Proposed Design Criteria for UV Disinfection Equipment

Based on a review of the information provided by the UV equipment manufacturers and the experience of five other facilities, it is observed that Trojan Technologies provides a widely-used low-maintenance solution for final effluent disinfection. The design of the MP-HI UV disinfection system for the SWRP is based on the Trojan UV4000™Plus equipment provided by Trojan Technologies.

4.2.2 Proposed Layout

Flow would enter the UV disinfection facilities at the north end of the influent chamber, where it would be directed east and west through 72-inch gates through two (2) banks of six (6) UV channels arranged on either side of the influent chamber. The effluent channels combine the flow to the south of the UV building and direct it to a new outfall. This layout provides for a compact site footprint and the enables the building size to be minimized.

The conceptual layout provides for a new effluent outfall to the SSC, rather than directing the disinfected effluent back to the existing outfall. However, it is likely that the construction of a new outfall would require permitting and an environmental impact assessment which may eliminate this option and necessitate the existing outfall being used during final design.

4.2.3 Proposed Basis of Design Criteria

The basis of design is given in **Table 3**.

Table 3 – Design Parameters for UV Disinfection Unit at NSWRP

Parameter	Design Value
Capacity and Water Quality	
Design flow, mgd	1,440
Average flow, mgd	1,250
Maximum TSS[a], mg/L	15
Pre-Disinfection Effluent E.Coli Count[b], cfu/100 mL, maximum (Assumed)	200,000
Post-Disinfection Effluent E.Coli Count Target[c], cfu/100 mL	400
Effluent Hardness[d], mg/L as $CaCO_3$	270
Dosage	
UV transmittance, minimum, %	65
UV intensity[e], W/lamp	4,000
Lamp Life, hours	5,000
Fouling factor, %	90
Lamp aging factor, %	89
UV dose, mW-s/cm^2	40
Physical Characteristics	
Channel dimensions, WxD	106" x 172"
Number of channels	12 (11 plus 1 standby)
Number of reactors per channel	1
Number of banks per reactor	2
Number of modules per bank	7
Number of lamps per module	24
Total number of lamps	4,032
Total power requirement, kW	11,827
Average power requirement, kW	9,225
Hydraulics	
Headloss, UV reactor only	9"
Velocity in each channel, V, ft/s	1.87
Liquid level control in channel	Motorized Weir Gate

[a] Monthly permit limit 12 mg/L
[b] Annual average
[c] Future requirement (monthly geometric average)
[d] Mean value
[e] 100% intensity at 100 hours of lamp use

The above design criteria are assumed based on available information and the current state of ultraviolet disinfection technology. A more extensive technology evaluation should be conducted prior to final design of the facility. Due to the extraordinary scale of this facility, CTE recommends the District undertake the following design process for selection and design of the UV disinfection equipment if final design is initiated:

1. Request and evaluate independent, full-scale validation data (also known as biodosimetry data) from manufacturers of candidate disinfection systems for similarly sized units or the largest size for which the manufacturer has data available. This evaluation would provide an initial level-of-confidence that the candidate systems can achieve the target disinfection levels. Data should be from systems using the same bulb, ballast, and control technology as proposed for the full-scale system.

2. Conduct a collimated beam testing program. This program would use site specific effluent and bacteria to determine the sensitivity of the site specific bacteria and pathogens to UV disinfection. The data would be used to size the UV lamps and reactors.

3. Increase frequency of UV transmittance testing at each plant to at least once per day for a period of one year or more to collect data on seasonal variability, daily variability, diurnal variability, and to capture the frequency of events that might reduce transmissivity such as wet weather and infrequent industrial discharges.

4. Conduct a more detailed life cycle cost analysis of the candidate disinfection systems based on the data collected during steps 1 through 3 above.

5. Construct a pilot testing facility designed to match lamp spacing, velocity profile and other design parameters of the proposed full scale units. The pilot testing facility would be used to determine:

    a. Appropriate control sequences and optimization for the UV disinfection equipment, including appropriate sensing equipment to allow advanced power management.

    b. In-situ disinfection performance including fouling rates of the lamps with and without ferric salt addition.

    c. Design life of lamps and other UV system parts.

    d. Actual M&O requirements in terms of labor and consumables as well as space requirements to complete required maintenance activities.

    e. Performance of alternate equipment manufacturers, if alternates are available at the time of piloting.

    f. Accuracy of life cycle cost analysis prior to final design of the full-scale system.

6. Conduct post-construction full-scale validation testing (biodosimetry testing) to confirm performance and determine operating parameters.

Using a program as described above, it may be possible to demonstrate the effective UV dosages to the regulators and optimize the equipment sizing criteria. For this study, reduction in the Illinois requirements for UV system sizing is not assumed based on the lack of data similar to that described above.

5 LOW LIFT PUMP STATION

This section will present the proposed arrangement and key characteristics of the proposed Low Lift Pump Station.

5.1 Pump Type

Several pump types were considered for this application. Pump types considered included screw pumps, vertical turbine pumps, centrifugal pumps, and axial flow pumps. Screw pumps and axial flow pumps appear to have the best operating performance for this condition.

It is estimated that the low lift pumps would lift 1,440 MGD of secondary effluent approximately 22.3 feet (TDH) to the UV disinfection system influent, including estimated head to allow flow through the UV system. The static head equates to the difference in the estimated water surface elevation between the wet well and the discharge conduit plus an additional 2-ft of head added as a conservative factor to accommodate additional losses that may be identified during final design.

If tertiary filtration is constructed in the future, the TDH would most likely increase but the flow would remain the same. Screw pumps will not easily accommodate this change in head, without significant structural modifications to the pump station. However, axial pumps can be modified for future head conditions. Structural modifications to the pump station to accommodate these changes, if required, should be minimal. Therefore, axial flow, propeller type pumps are recommended.

Vertical axial flow pumps have been assumed here, but other configurations (including inclined or horizontal) could be considered in the future.

5.2 Basis of Design

Table 4 provides a summary of the basis of design for the Low Lift Pump Station.

Table 4 - Low Lift Pump Station Basis of Design

Flow, MGD	1,440
Pumps	
Type	Axial Flow
Number	8 total (N+1+1)
Pumping Rates, gpm/pump	166,670
Static Head, ft	15.8
Dynamic Head (inc. station losses), ft.	4.5
Total Dynamic Head, ft.(1)	22.3
Motor, hp (2)	1,500
Suction Head, ft	18.5
Wet Well	
Length, ft.	86
Width, ft.	114

(1) The static head equates to the difference in the estimated water surface elevation between the wet well and the discharge conduit plus an additional 2-ft of head added as a conservative factor to accommodate additional losses that may be identified during final design.

(2) A 1,350 hp motor could be provided, however this is a non-standard motor size and only standard motor sizes were assumed for this conceptual study.

5.3 Proposed Operational Description

The pump station would have a total of eight pumps, with six duty pumps, one standby and one out of service (N+1+1). Five pumps would be driven by constant speed motors, three would be variable speed driven. In order to provide operational flexibility, the pump station would be divided into two wet wells, each containing four pumps. Design average flow (1,250 MGD) would be handled by four constant speed and two variable speed pumps operating at reduced speed, leaving two pumps on standby. Peak flow (1,440 MGD) would be handled by six pumps operating at full speed, leaving two on standby.

The pumps would operate 24 hours a day, seven days per week. Typically, at least one variable speed pump would operate at all times, to handle fluctuations in flow. **Table 5** illustrates an example of pump operation at design average flow and peak flow:

Table 5 - Summary of Pump Operation

Flow, MGD	Pump Drive Type	Pump Flow, gpm
700	Constant speed	166,667
	Constant speed	166,667
	Variable speed	152,777
1250 (Design Average)	Constant speed	166,667
	Constant speed	166,667
	Constant speed	166,667
	Constant speed	166,667
	Variable speed	100,694
	Variable speed	100,694
1440 (Peak)	Constant speed	166,667
	Constant speed	166,667
	Constant speed	166,667
	Constant speed	166,667
	Constant speed	166,667
	Variable speed	166,667

In order to eliminate vortices, pumps require a minimum submergence as a function of pump suction bell diameter. For this flow condition, a 120-inch suction bell is required, which requires a minimum submergence of 16 feet. Submergence requirements should be verified by the pump manufacturer during final design.

Level sensors in the wet well would relay signals to turn pumps on and off. The level control would be automatic under normal conditions, with manual override possible. Other control inputs that need to be monitored include discharge pipe pressure, flap gate position, and motor alarms.

5.4 Proposed Layout

Flow would enter the pump station at the south end of the wet well, where it would be directed perpendicularly to the north through eight 96-inch slide gates. Pumps are located at the north end of the pump station. Site constraints and pump station size appear to make this flow pattern necessary. Due to the excessively large area needed to meet Hydraulic Institute (HI) Standards, there is insufficient area available to meet the suggested dimensions directly.

A rectangular wet well is shown in the plan and section. Design features, which have been shown to be effective in other installations, were incorporated in this design in order to meet HI standards. For example, perforated plates, curtain walls, and floor and back wall splitters have been incorporated into the conceptual design. (See Appendix C for a plan and section of the proposed layout). Sizing and details of these types of features are normally determined by physical scale modeling during detailed design.

6 SUMMARY

A review of TM-1WQ confirms that the disinfection facilities would consist of UV technology without requiring tertiary filters, although filtration could potentially reduce the size of the UV facility via reductions in TSS and BOD. Additionally, the disinfection facilities are recommended to be located in the southwest corner of the existing site, adjacent to the space reserved for the future tertiary filters. In order to direct flow to the proposed location, a new junction chamber would be constructed just upstream of the existing outfall to divert flow to the new disinfection facility. It would also permit bypassing of the disinfection facility during winter months when disinfection is not required.

A hydraulic basis of design was developed for a peak plant flow of 1,440 MGD. This preliminary evaluation indicated that additional pumping would be required to lift secondary effluent up approximately 16-ft in order to flow through the proposed UV system. Axial flow pumps are recommended for the LLPS due to the low head conditions and the need to modify the discharge head when tertiary filters are added in the future.

Hydraulics were estimated starting from the existing effluent aerator, through the LLPS and UV facilities, and ending at a new outfall to the SSC.

The proposed conceptual layout of the new UV facilities consists of the following:

a. Junction chamber with isolation gates within the existing plant effluent conduit and an conduit to the LLPS,

b. LLPS:
   i. Building housing a wet well and eight (8) axial flow pumps.
   ii. Influent and effluent conduits with isolation gates.
   iii. Support facilities such as an operator and storage rooms.

c. UV Facility
   i. Building housing twelve (12) UV reactor channels.
   ii. Influent and effluent channels with isolation and level control gates.
   iii. Support facilities such as an operator room, storage room and an electrical room housing the switchgear and transformers for both the LLPS and the UV facilities.

d. A new effluent outfall to the Ship and Sanitary Canal.

The location and arrangement of these facilities was determined to accommodate future facilities as well as have functionality up to the 100-year flood elevation. A new effluent outfall is proposed, however permitting requirements may require this options to be reevaluated during final design

In conclusion, this review has confirmed the primary assumptions of the TM-1WQ in regards to the need for a low lift pump station, location of the facilities and arrangement of the facilities to accommodate future facilities.

APPENDIX A
Site Plan from the SWRP Master Plan

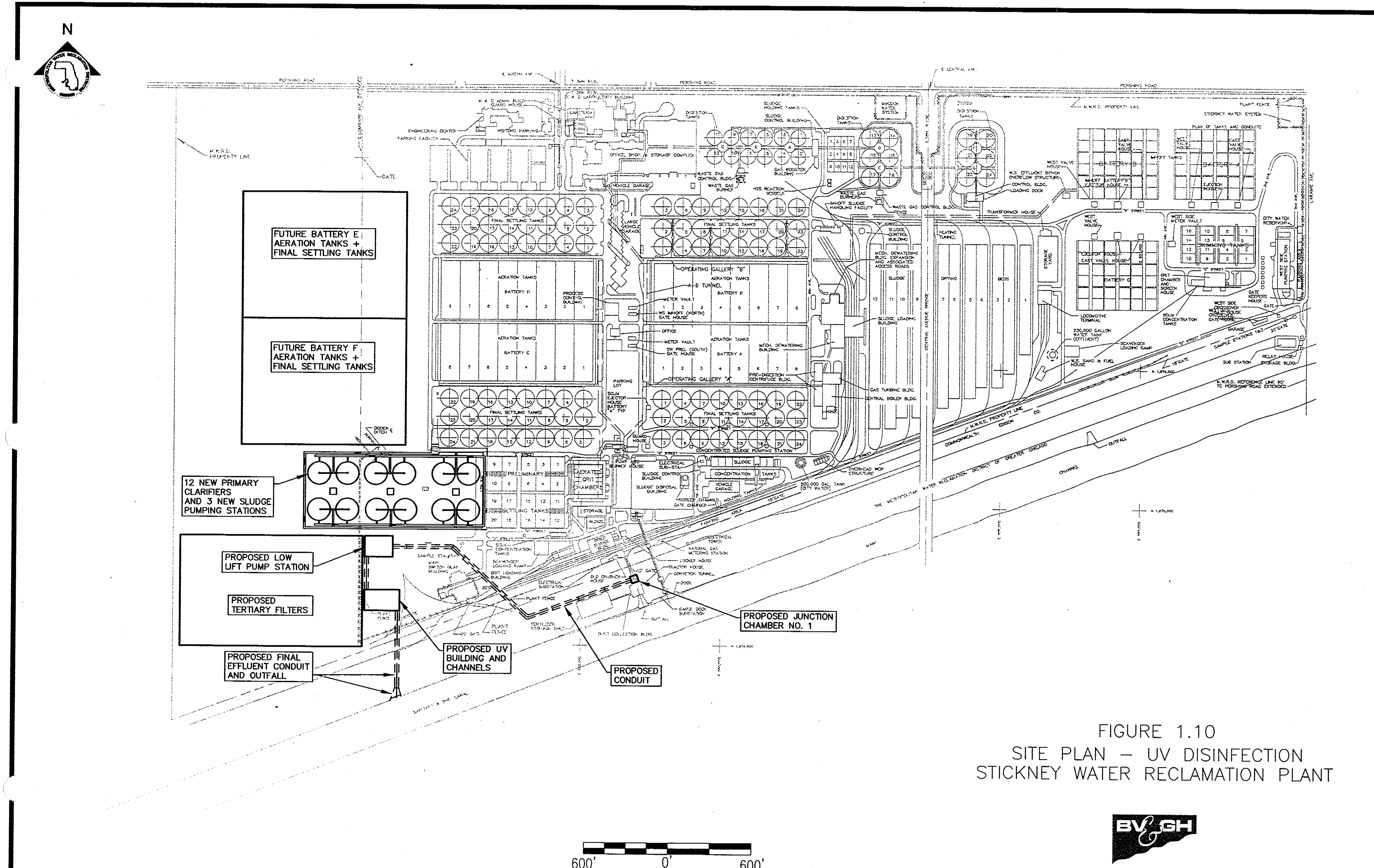


FIGURE 1.10
SITE PLAN – UV DISINFECTION
STICKNEY WATER RECLAMATION PLANT

APPENDIX B
Selected Pages from USACE CUP DDR

US Army Corps of Engineers®
CHICAGO DISTRICT

DESIGN DOCUMENTATION REPORT

CHICAGOLAND UNDERFLOW PLAN
McCOOK RESERVOIR, ILLINOIS

Volume I of VIII

NOVEMBER 1999

Table A-11. Canal System Observed and Modeled Maximum Water Surface Elevations

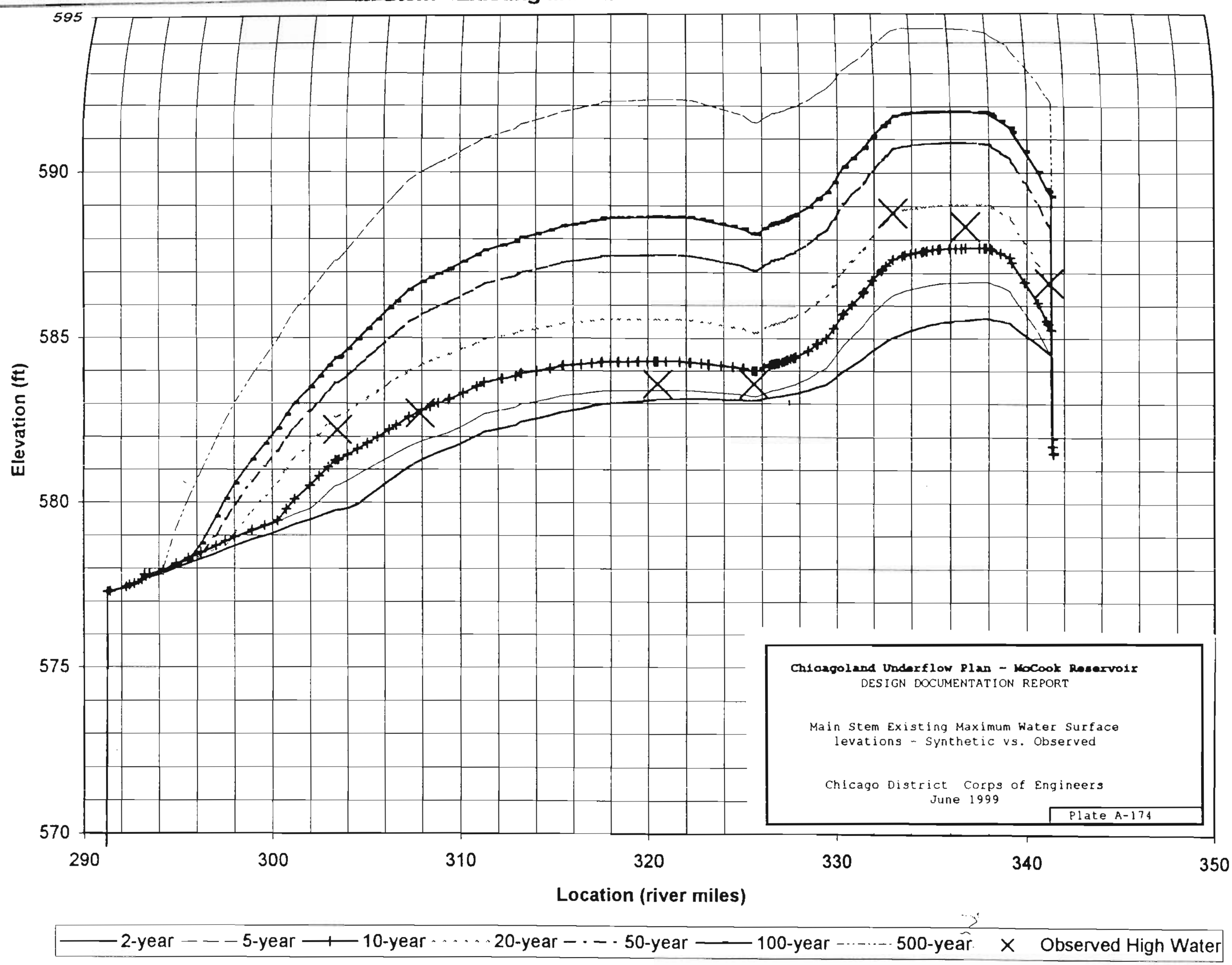
Location	Approx. River Mile	Maximum Water Surface Elevation (ft NGVD)						
			Modeled for Water Years 1951-1988			*Modeled 1% Chance Exceedance Event*		
		Observed, 1965 to present (Date)	Existing (Date)	Stage 1 Project (Date)	Stage 2 Project (Date)	Existing	Stage 1 Project	Stage 2 Project
Wilmette - NSC @ Sheridan Rd.	341.2	586.7 (4/18/75)	592.6 (7/57)	591.3 (7/57)	590.5 (7/57)	589.4	589.1	587.6
North Side SW - NSC @ Howard St.	336.8	588.4 (8/14/87)	594.9 (7/57)	593.1 (7/57)	592.6 (7/57)	591.8	590.9	589.5
North Branch PS - NSC @ Lawrence St.	333.0	588.8 (8/16/97)	594.6 (7/57)	592.2 (7/57)	592.2 (7/57)	591.7	589.8	588.4
Chicago River Controlling Works - Chicago River @ Lk Michigan*	325.6	583.6 (8/16/97)	589.1 (7/57)	585.3 (10/54)	583.9 (10/54)	588.2	585.0	583.2
31st & Western - CS&SC @ Willow Springs Rd.	320.5	583.6 (6/30/77)	589.6 (7/57)	585.4 (10/54)	583.9 (10/54)	588.7	585.1	583.0
Willow Springs - CS&SC @ Willow Springs Rd.	307.9	582.7 (7/18/96)	587.2 (7/57)	584.0 (10/54)	583.0 (10/54)	586.7	584.1	582.4
Sag Junction - Confluence of CS&SC and CSC	304.2	582.2 (7/18/96)	585.0 (7/57)	582.6 (10/54)	581.9 (10/54)	584.7	582.8	581.6
O'Brien Lock - Calumet River Downstream (south) of O'Brien Lock	325.8	583.8 (7/18/96)	585.0 (7/57)	584.6 (7/57)	584.6 (7/57)	584.7	584.0	583.8
Southwest Highway - CSC @ Southwest Hwy	310.8	583.7 (7/18/96)	585.0 (7/57)	584.3 (10/54)	584.3 (10/54)	585.0	583.5	583.1

*The approximated river mile is for the junction of the Chicago River and its North and South Branch.

NSC = North Shore Channel
CS&SC = Chicago Sanitary and Ship Canal
CSC = Calumet Sag Channel

Table A-12. Index of Major Bridges and Confluences for Chicago Canal Model

Reach Scheme (Canal Model)	Tributary Stream	Bridge Name	River Mile
2	North Shore Channel	Sheridan Road Lock	341.2 1/
2	"	Central Street	340.4
2	"	Green Bay Road	339.8
2	"	Church Street	338.7
2	"	Dempster, Il 58	338.2
2	"	Oakton Street	337.2
2	"	Touhy Avenue	336.2
2	"	Devon Avenue	335.2
2	"	Peterson, US 14	334.7
2	"	Foster Avenue	333.6
2	"	Jct. North Branch	333.5
1	North Branch	Touhy	51.4 2/
1		(05536000 gage)	
1	"	Devon Avenue	49.2
1	"	Edens Expwy.	46.2
1	"	Cicero Avenue	46.1
1	"	Foster Avenue	44.5
1	"	Kimball Avenue	43.9
1	"	Kedzie Avenue	43.6
1	"	Jct. North Shore Channel	43.3
3	"	Jct. North Shore Channel	333.5
3	"	Lawrence Ave.	333.1
3	"	Montrose Ave.	332.5
3	"	Irving Park Rd.	332.0
3	"	Addison Street	331.4
3	"	Belmont Ave.	330.9
3	"	Western Ave.	330.6
3	"	Diversy Ave.	330.2
3	"	Damen Ave.	329.9
3	"	Fullerton Ave.	329.5
3	"	Ashland Ave.	329.1
3	"	Cortland Street	328.6
3	"	North Ave.	327.9
4	North Br. (Goose Island West)	Division Street	327.4
4	"	Ogden Ave.	326.9
4	"	Halsted Street	326.6
5	North Br. (Goose Island East)	Division Street	327.0
5	"	Ogden Ave.	326.9
5	"	Halsted Street	326.85
6	North Branch	Chicago Ave.	326.4
6	"	Ohio/Kennedy Expwy.	326.1
6	"	Grand Ave.	326.0
6	"	Kinzie Street	325.8
6	"	Jct. South Branch	325.6
7	Chicago River	Franklin Street	325.65
7	"	Wells Street	325.7
7	"	LaSalle Street	325.8
7	"	Clark Street	325.9
7	"	Dearborn Street	326.0
7	"	State Street	326.1
7	"	Wabash Ave.	326.3
7	"	Michigan Ave.	326.4
7	"	Lake Shore Drive	326.9
8	South Branch	Lake Street	325.6
8	"	Randolph Street	325.5
8	"	Washington Street	325.4
8	"	Madison Street	325.3
8	"	Monroe Street	325.1
8	"	Adams Street	325.0

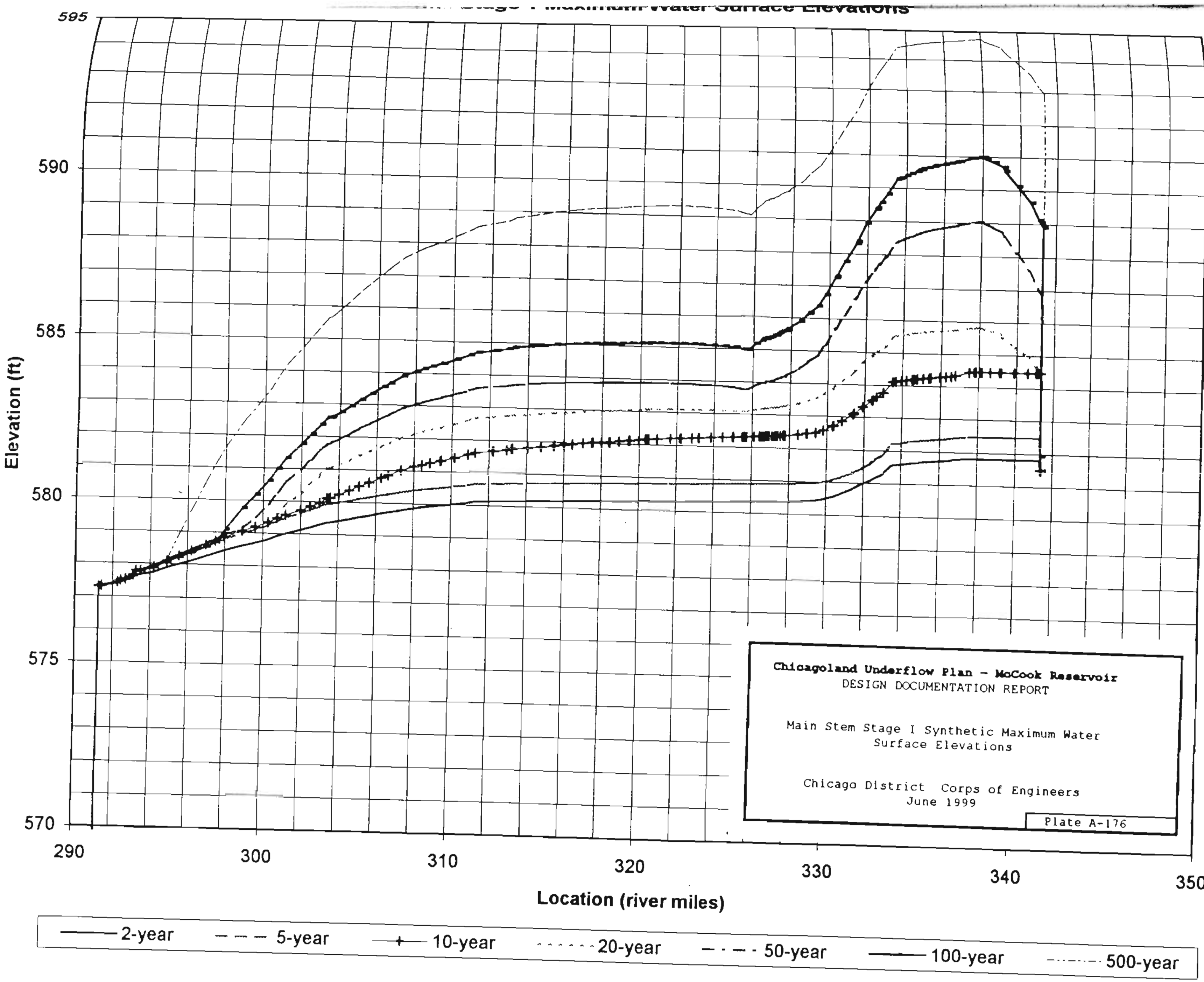


Chicagoland Underflow Plan - McCook Reservoir
DESIGN DOCUMENTATION REPORT

Main Stem Existing Maximum Water Surface
levations - Synthetic vs. Observed

Chicago District Corps of Engineers
June 1999

Plate A-174

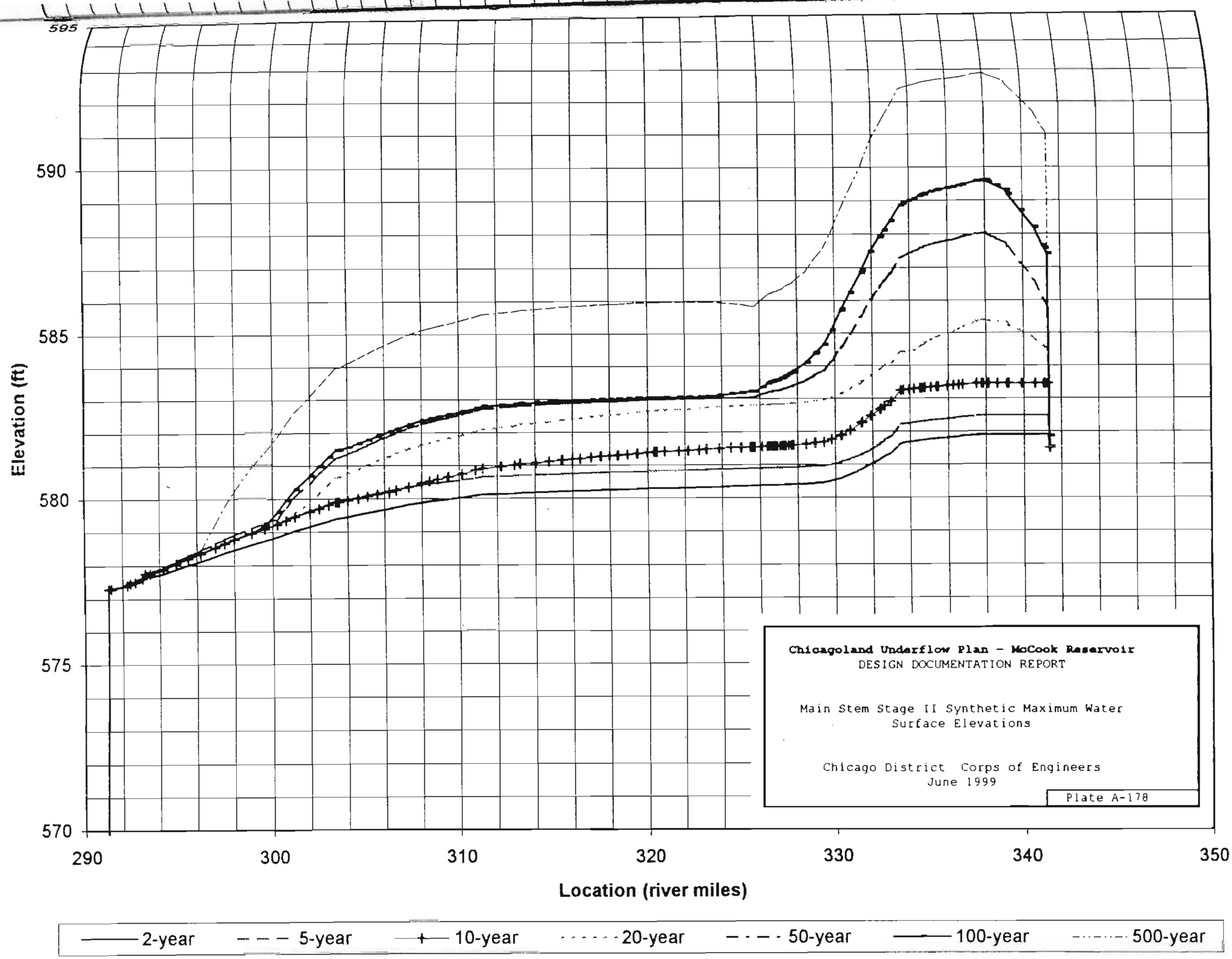


Chicagoland Underflow Plan - McCook Reservoir
DESIGN DOCUMENTATION REPORT

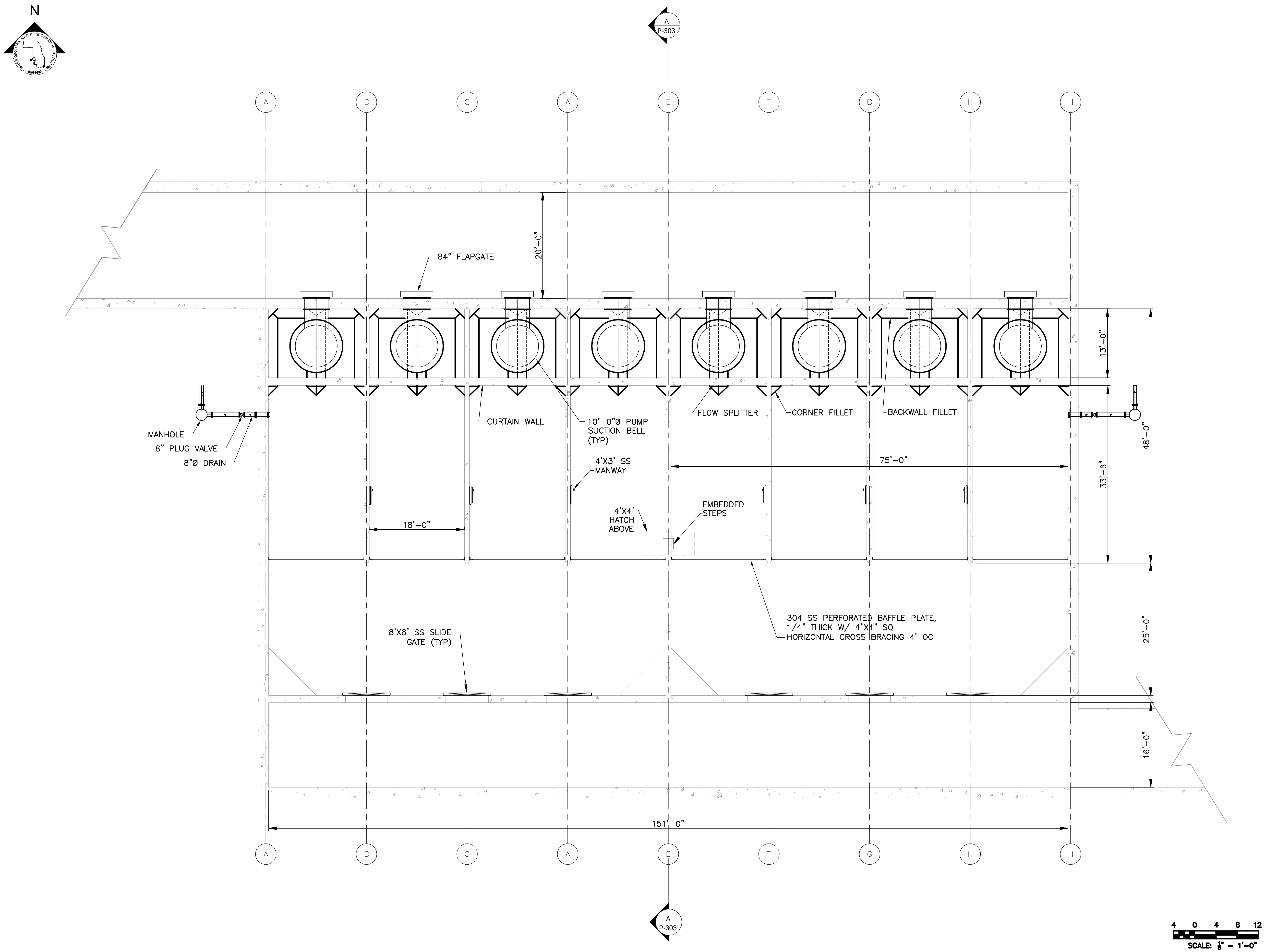
Main Stem Stage I Synthetic Maximum Water Surface Elevations

Chicago District Corps of Engineers
June 1999

Plate A-176


595
590
585
580
575
570
Elevation (ft)
290
300
310
320
330
340
350
Location (river miles)
Chicagoland Underflow Plan - McCook Reservoir
DESIGN DOCUMENTATION REPORT
Main Stem Stage II Synthetic Maximum Water
Surface Elevations
Chicago District Corps of Engineers
June 1999
Plate A-178
2-year
5-year
10-year
20-year
50-year
100-year
500-year

APPENDIX C
LLPS Proposed Layout



Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Designed by: CMB | Checked by: XX | Correct: ANTHONY BOUCHARD | Approved: MWRD Assistant Chief Engineer

Drawn by: MB | Reviewed by: EPC

Date: 1/2008 | Scale: 1/8"=1'-0"

CTE | AECOM

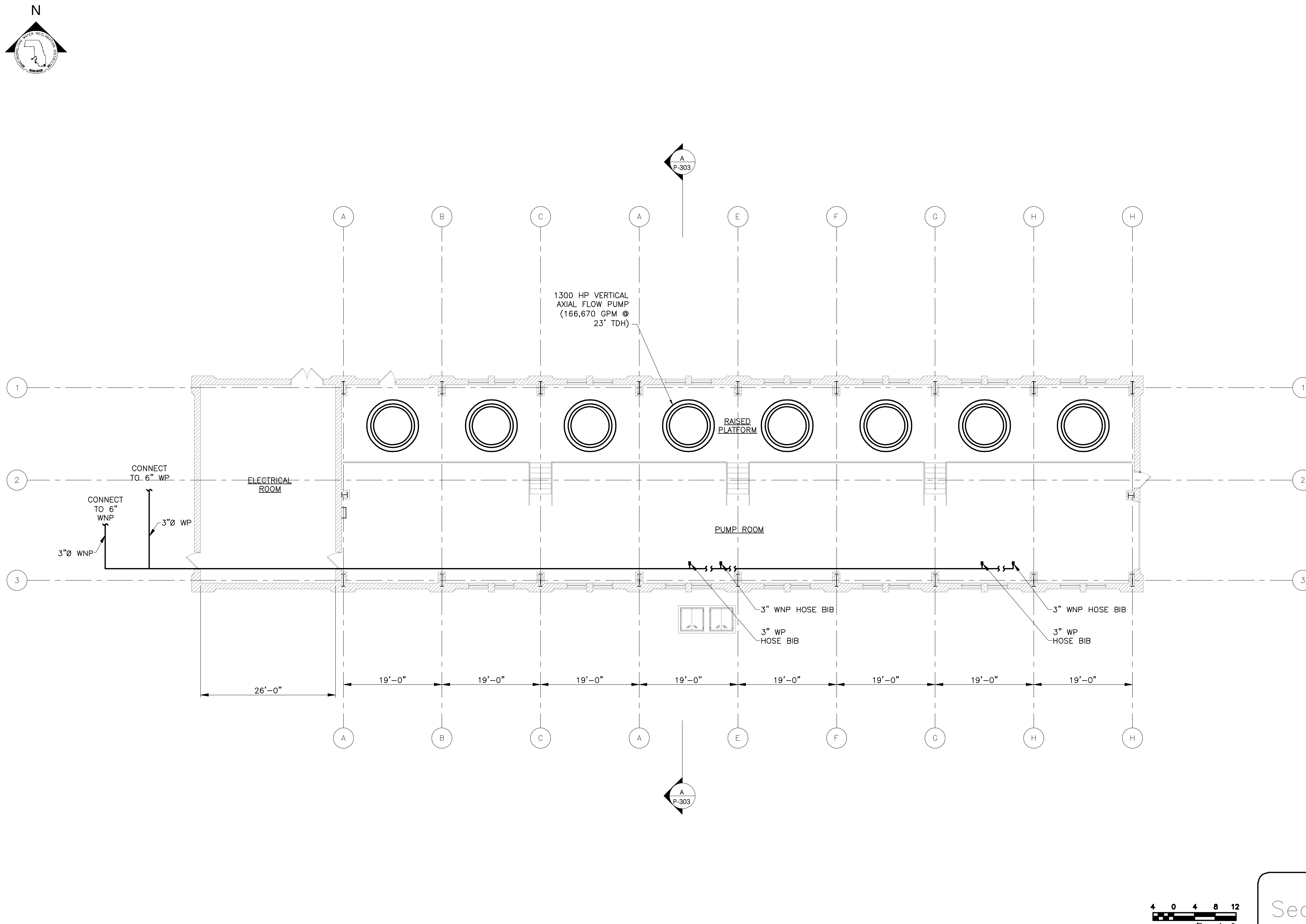
CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

LOW LIFT PUMP STATION LOWER LEVEL PLAN

Seal

Sheet Number: P-301

Page Number:



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Drawn by: MB	Reviewed by: EPC		
Date: 1/2008	Scale: 1/8"=1'-0"		

CTE AECOM

CTE 303 East Wacker Drive, Suite 600, Chicago, Illinois 60601-5276 T 312.938.0300 F 312.938.1109 www.cte.aecom.com

CONTRACT 07-026-2P

STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

LOW LIFT PUMP STATION UPPER LEVEL PLAN

Seal

Sheet Number: P-302

Page Number:

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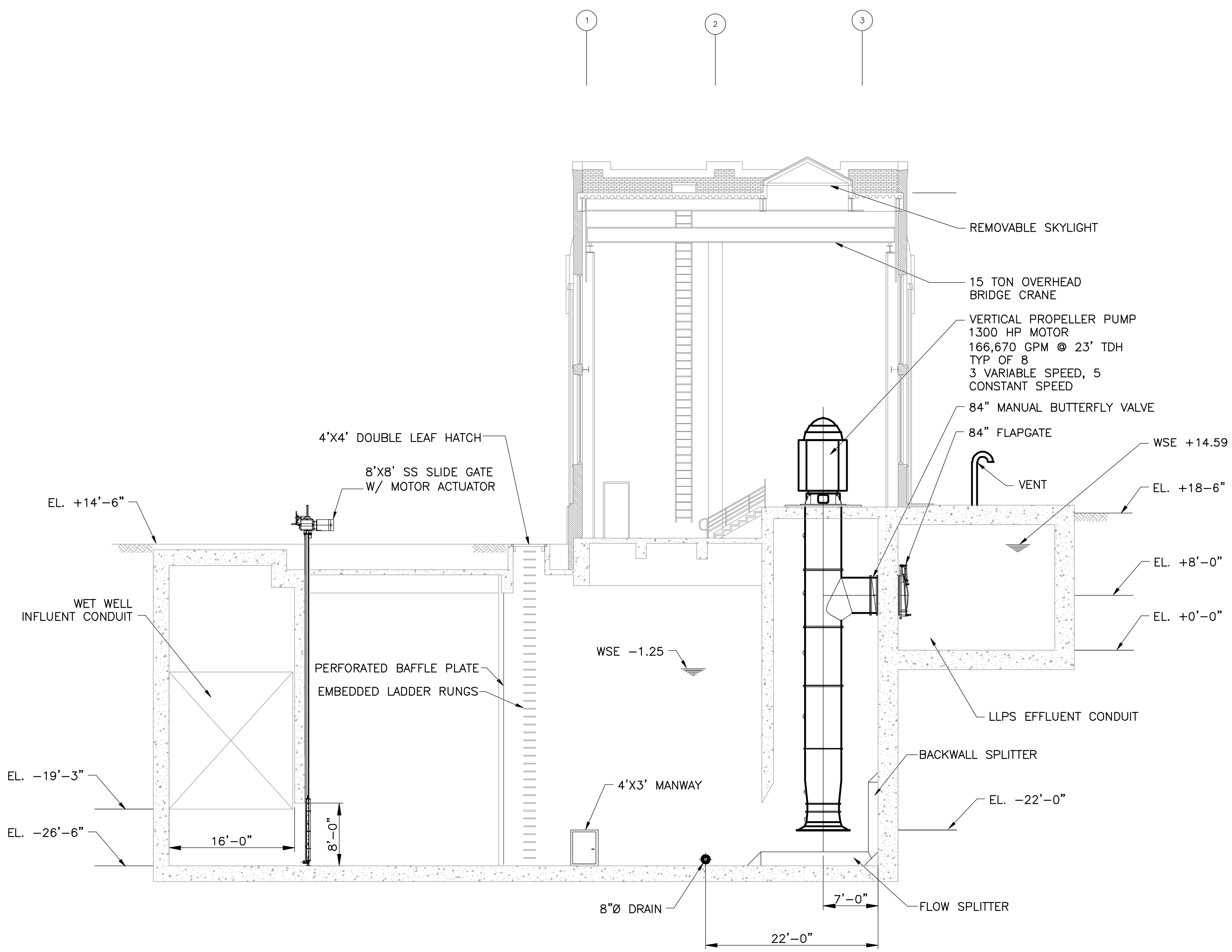

A
P-301
SECTION
SCALE: 1/8"=1'

4 0 4 8 12
SCALE: 1/8" = 1'-0"

Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Designed by: CMB
Checked by: XX
Correct: ANTHONY BOUCHARD
Approved: MWRD Assistant Chief Engineer
Drawn by: MB
Reviewed by: EPC
Date: 1/2008
Scale: 1/8"=1'-0"

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CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

LOW LIFT PUMP STATION
SECTION

Seal

Sheet Number:
P-303
Page Number:

APPENDIX B

NORTH SIDE WRP UV TECHNOLOGY TECHNICAL MEMORANDUM

DISINFECTION COST STUDY
ULTRAVIOLET DISINFECTION TECHNOLOGY EVALUATION

FOR

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

NORTH SIDE WATER RECLAMATION PLANT

TECHNICAL MEMORANDUM

OCTOBER 23, 2007

Prepared By

CTE | AECOM

303 EAST WACKER DRIVE, SUITE 600
CHICAGO, ILLINOIS 60601

MWRDGC Project No. 07-026-2P
CTE Project No. 60026610

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INTRODUCTION

Background

This technical memorandum has been developed as part of the Preliminary Cost Opinion for Ultraviolet (UV) Disinfection Facilities Study at the Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC, or District) North Side Water Reclamation Plant (NSWRP) in Skokie, Illinois. This memorandum continues the work began in TM1-WQ, which was developed previously as part of the comprehensive Infrastructure and Process Needs Feasibility Study (Feasibility Study) for the NSWRP and a Water Quality (WQ) Strategy for affected Chicago Area Waterways.

The TM1-WQ documented the results of a CTE study of effluent disinfection alternatives for the District's North Side, Calumet and Stickney WRPs. In that study, a task force of national experts (referred to as the Blue Ribbon Panel) reviewed different disinfection technologies and their range of pathogen destruction efficiency, disinfection byproducts and impacts upon aquatic life and human health. Their investigation also included an examination of the environmental and human health impacts of the energy required for the operation of the facility and for the processing and production of process chemicals. Based on economic and non-economic evaluation of alternatives, ozone disinfection and UV disinfection were selected and preliminary basis of design and cost estimates were developed. The UV disinfection system using medium pressure high intensity lamps provided by Trojan Technologies, Inc. was used as a basis of design and cost estimates for the UV system.

Objective

Per the District's request, further evaluation of the UV disinfection technology is required. This additional evaluation is based on the TM-1WQ, the comments received from the EPA as part of the UAA evaluations, and new information obtained since the previous work. The primary objectives of the evaluation presented in this technical memorandum are:

- To describe the current UV technologies being used to disinfect wastewater treatment plant effluent and to find if changes have occurred in the selected UV technology
- To get updated recommendations and costs from different vendors for the selected technology
- To incorporate information available from literature
- To provide references of experience in UV disinfection at other facilities

In the following discussion, the results of this evaluation are given. The sections that follow summarize the currently available UV technologies for disinfection and the experience of using such systems in WWTPs, and provide an updated basis of design for the selected UV disinfection system at the NSWRP.

AVAILABLE UV DISINFECTION TECHNOLOGIES

In the past 20 years, UV disinfection has gained popularity as it is becoming more feasible to implement due its advantages over alternate disinfection methods (i.e. chlorination/dechlorination, ozonation, etc) as noted in TM-1WQ. The UV disinfection systems have also become more sophisticated, reliable, and cost-effective. The currently available technologies of UV disinfection used are shown in Figure 1 (common configurations for municipal wastewater applications are shown bold).

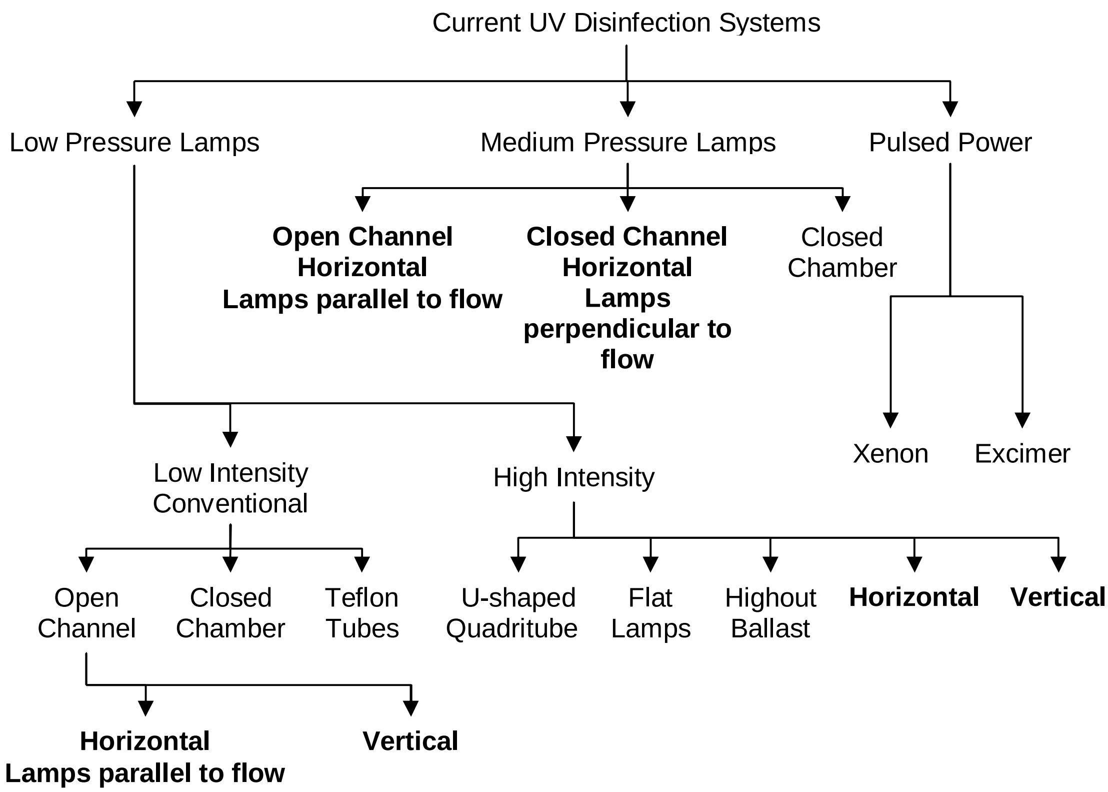

Figure 1 – Categories of Currently Available UV Disinfection Systems (Hunter, et al., 2006b)

To maximize the efficiency of the system, the light source must emit at the wavelength range where DNA and RNA molecules in the microorganisms exhibit a maximum absorbance of UV light (254 nM). Hence, the most important element of UV systems is the light source or lamp. Based on the source of UV, these disinfection systems are categorized into three categories. The important characteristics of these categories are given in Table 1. Here, “Pressure” refers to the pressure of gasses inside the lamp. “Intensity” refers to the energy output.

Low Pressure – Low Intensity (LP-LI)

Available for more than 20 years, low-pressure lamps are arranged in horizontal or vertical configurations submerged in relatively shallow flow channels. Enclosed and Teflon-tube systems are also available. Lamp control is limited to "on" and "off." These lamps are the most energy efficient lamps used for UV disinfection because 85% of their

Table 1 – Typical UV Technology Categories (Bazzazieh, 2005)

UV System	Low Pressure, Low Intensity	Low Pressure, High Intensity	Medium Pressure, High Intensity
Lamp mercury pressure, torr	10^{-3} to 10^{-2}	10^{-3} to 10^{-2}	10^{2} to 10^{3}
Lamp operating temperature, degrees C	40	90 to 250	600-900
Typical power use per lamp, watts	70 to 85	170 to 1,600	2,000 to 5,000
Cleaning	Manual	Automatic wipers	Automatic wipers

total emissions are near the peak for germicidal effectiveness (NYSERDA, 2004). The estimated lifetime of the lamp is approximately 13,000 hours. They are typically used at facilities where the design flow is less than 5 MGD (Hunter, et al., 2006b). Because more lamps are needed as flow increases, the related maintenance costs at large facilities may be higher than those for other UV systems.

Low Pressure – High Intensity (LP-HI)

Introduced within the last several years, early installations of low-pressure, high-intensity lamp systems were deliberately overdesigned, involving multiple banks of lamps and cumbersome hydraulic diversion controls designed to turn lamp banks on and off as operating conditions dictated. When these systems were on, all lamps in the bank or channel operated at full intensity. Newer improvements allow the lamp's wattage output to be varied to optimize dose delivery. These systems also include an automatic cleaning system. These lamps have an average lifetime of about 8,000 hours, with gradually falling lamp intensities (NYSERDA, 2004). These systems use about one-third the lamps of low-pressure systems but also about three times more than medium-pressure systems (Hunter, et al., 2006b).

Medium Pressure – High Intensity (MP-HI)

Medium-pressure lamps became available in open-channel and closed-pipe configurations during the last decade. They use more power and generate higher head losses than the low-pressure systems (Bazzazieh, 2005). An automatic cleaning system that periodically removes the solids that coat the quartz sleeves is also required. The lamps have an average lifetime of about 8,000 hours with intensity gradually declining over time (NYSERDA, 2004). Because they have higher UV output, medium-pressure systems use about one-tenth the number of lamps that a low-pressure system requires (Hunter, et al., 2006b). Medium pressure UV lamps are mostly recommended for larger wastewater treatment plants where the provisions for head requirements could be incorporated in the design, and where a smaller footprint and lower maintenance is needed.

Thus, the technologies are distinguished by the germicidal intensity given off by each lamp type, which correlates to the number of lamps required and the overall UV system size in order to provide a specified dose of energy to the target media (pathogens within the plant effluent). The lamp type selected is determined on a site-specific basis. For the NSWRP, the District has selected the MP-HI system of UV disinfection based on their interest in minimizing the total number of lamps required and the recommendations of the Blue Ribbon Panel during the NSWRP Master Plan. Further investigation of this technology is discussed in the following sections.

LITERATURE REVIEW OF SELECTED MP-HI UV TECHNOLOGY

Information on the latest developments and experience in using the MP-HI UV disinfection system was researched in literature including technical proceedings from Water Environment Federation (WEF), Water Environment Research Foundation (WERF), proceedings from the latest Disinfection conference series undertaken by WEF, American Water Works Association (AWWA), and International Water Association (IWA). In the following discussion, a description of the latest MP-HI technology is provided. This section also summarizes the experiences of some of the wastewater treatment facilities that have successfully implemented UV disinfection.

Typical MP-HI System Configuration

The MP-HI system involves sending the secondary or tertiary effluent through a confined space containing banks of MP-HI UV lamps. A typical MP-HI UV system currently consists of a power supply, an electrical system, a reactor, MP-HI lamps, a mechanical and/or chemical cleaning system, and a control system. The MP-HI UV lamps are enclosed in individual quartz sleeves for protection against dirt and breakage. Reactor chambers (open or enclosed channels) hold the lamps in either a horizontal or vertical configuration. In an open channel system, effluent weirs or automatic level control devices are used to keep the lamps submerged under the effluent water to ensure that the lamps to not overheat, which can reduce lamp life or result in lamp burnout. The whole UV system is also sometimes enclosed in a building to protect it from the natural elements.

The MP-HI UV systems can be divided into several key components for design and troubleshooting purposes including the quality of the influent to the UV system, hydraulics and headloss, the level of disinfection that must be attained for compliance with the regulatory requirements, the reactor configuration, the quartz sleeves, frames, the cleaning mechanisms, the lamps, ballasts or transformers, wiring, and the electrical control system. Brief descriptions of the important process, mechanical, and some of the electrical components are discussed in this section.

Influent Characteristics

The water quality characteristics that affect UV transmittance include iron, hardness, suspended solids, humic materials and organic dyes (NYSERDA, 2004). Dissolved iron can absorb UV light and precipitate on the UV system quartz tubes. Hardness affects the solubility of metals that absorb UV light and can precipitate carbonates on quartz tubes. Organic humic acids and dyes also absorb UV light. Depending on the disinfection system used, the UV transmittance needs to be above a certain level. The generally accepted minimum transmittance is 65%. However, some commercially available MP-HI systems claim to disinfect wastewater with UV transmittance as low as 15-percent.

Reactor Configuration and Hydraulics

An open channel or closed conduit is used as a reactor. One or more than one reactor may be necessary to disinfect the total amount of effluent. UV disinfection systems employ a variety of physical configurations but the most common ones have lamps arranged in linear configuration to increase intensity along the linear axis by avoiding UV emission losses due to self absorption, reflection or refraction that can occur if a UV lamp were twisted into loops or spirals.

The hydraulic characteristics of a reactor can strongly influence disinfection effectiveness. The optimum hydraulic scenario for UV disinfection involves turbulent flow with mixing while minimizing head loss. To maximize effectiveness, UV reactors are preferred to operate at a Reynolds Number of greater than 5,000 (NYSERDA, 2004). Reactor design, including inlet and outlet flow distribution, determines how close the unit operates to a plug flow. Inlet conditions are designed to distribute the flow and equalize velocities. UV system outlets are designed to control the water level at a constant level with little fluctuation within the UV disinfection reactor.

Lamps and UV Intensity Control

The MP-HI lamps contain mercury vapor and argon gas that produce polychromatic radiation, which is concentrated at select peaks throughout the germicidal wavelength region. Most commercially available MP-HI lamps look similar to a fluorescent tube light bulb, but they are made of quartz glass because quartz has the ability to transmit UV light.

The intensity of the lamp is unstable for the first 100 hours of operation and decreases more rapidly during that period. Hence the 100% intensity of the lamp is usually measured after this 100-hour time period. These lamps have a germicidal output of about 16 W/cm, which is about 80 times higher than LP-LI lamps (NYSERDA, 2004). Electronic ballasts for each lamp are used to control the power to the lamp. If the UV dose is to be reduced, variable output electronic ballast can regulate the power to the lamp from 100% to 30%. Entire banks can also be turned off if there is no flow. This allows dose-pacing based on the secondary or tertiary effluent flow and quality, which helps save power and lamp life.

Lamp Fouling and Cleaning

The MP-HI lamps operate at a temperature range of 600 to 900 degree C. The warm temperatures produced by UV lamps promote the precipitation of an inorganic, amorphous film (scale) on the surface of the quartz sleeves when the lamps are placed directly within the wastewater stream. Iron is the most abundant metal in these scales along with other mineral salts and oil, grease, suspended solids deposits, and biofilms (NYSERDA, 2004). If no tertiary treatment is provided, physical debris may contribute to fouling as well.

Lamp fouling significantly reduces the effectiveness of UV disinfection by blocking the UV rays. The MP-HI UV disinfection systems must be cleaned on a regular basis. Researchers have found that the lamp fouling increases linearly with the time elapsed after last cleaning, but the dependency of the cleaning frequency on the quality of effluent is not well predicted (NYSERDA, 2004). So, pilot testing is usually done to determine cleaning frequency. Most of the commercially available MP-HI UV disinfection systems require mechanical as well as chemical cleaning. The latest technology uses a system of mechanical wipers and sleeves containing cleaning chemicals surrounding the lamp. The cleaning solution usually contains some acidic solution that prevents fouling (Darby et al., 1995). This cleaning system can be programmed to clean at a set frequency without the need for disrupting the disinfection process. The cleaning solution needs to be replaced periodically depending on the type of solution used and characteristics of the site specific effluent water quality.

Process Control

The need to pace the dose in the MP-HI UV disinfection system is important because too much dosing wastes electricity and too little dosing would not meet the disinfection regulatory requirements and goals. Several process control options are available to control the dosing. Although manual control of the dosing is possible, an automated process control facilitates online pacing of the dose and also allows it to be interfaced with the plant's overall supervisory control and data acquisition (SCADA) system. The flow, lamp output, and water conditions are measured in pacing of the dose, and an algorithm is developed based on long-term measurements to predict necessary system adjustments, maintenance, and component replacements.

Programmable logic control (PLC) technology is the latest available process control technology for dose pacing in the MP-HI UV disinfection system (Hunter et al, 2006b). The PLC interacts with the ballasts, sensors, and online monitoring technology for each disinfection unit. The PLC then interacts with the plant's overall control system to allow remote monitoring and adjustment of the system. The PLC is usually supplied by the manufacturer of the unit.

Safety

The UV disinfection systems are one of the safest technologies available for disinfection. The high voltage power supplies for the MP-HI UV disinfection system may pose some issue as the lamps are submerged in the water most of the time, but compliance with normal electrical safety codes should mitigate the hazardous conditions. Submerging a lamp in water, even if it is just a few inches below the surface, will greatly reduce the intensity (NYSERDA, 2004). Thus, the MP-HI UV reactors should be designed to ensure constant water levels to minimize the risk of UV exposure.

Sudden or prolonged exposure to ultraviolet (UV) light can result in eye injury, skin burns, premature skin aging, or skin cancer. Individuals who work with UV disinfection systems – or in any area where UV light is used - are at risk of UV exposure if the appropriate protective equipment is not used. The UV radiation should be confined to a restricted area, and an interlocked access system should be in place so that the UV light is shut off when the protective enclosure is opened (Prentiss, 2004). A UV safety program for operators is usually undertaken to make them aware of the effects of UV exposure.

REVIEW OF AVAILABLE TECHNOLOGIES FROM MANUFACTURERS

As discussed previously, the Blue Ribbon Panel recommended medium pressure, high intensity technology based on the size of the proposed facilities and the District's interest in minimizing the total number of bulbs. Two commercially available medium pressure, high intensity systems are available for the municipal wastewater market. For comparison, low pressure, high intensity system manufacturers were also contacted. A review of the information available from the UV technology manufacturers has been summarized in Table 2 and discussed below.

Trojan Technologies – Trojan UV4000™Plus

Trojan Technologies recommends their Trojan UV4000™Plus model for disinfection of the effluent at the North Side WRP. The system is especially designed for large scale applications of 10 MGD or more, and uses MP-HI lamps horizontal and parallel with the flow incorporating an automatic chemical/mechanical cleaning system. Trojan claims that this system is capable of treating wastewater effluents with UV transmittance as low as 15-percent when appropriately sized. It has a PLC-based system to monitor and control all UV functions, and has automated dose delivery based on lamp age, and other water parameters such as flow rate, UV transmittance, and turbidity. The system has high efficiency ballasts that can vary output from 30% to 100% per bank to match the UV dose with effluent quality and flow rate. Trojan claims to have over 375 installations of this system worldwide.

Figure 2 – UV4000+ System
(Courtesy of Trojan Technologies)

Aquionics – InLine50,000+

Aquionics has recommended their InLine50,000+ system for disinfection of the effluent at the North Side WRP. The system uses horizontal high output medium pressure lamps aligned perpendicular to the flow in a closed conduit reactor, which enables treatment of high flows without bypass. The manufacturer claims the compact design achieves a low pressure drop even for gravity fed flows, although reported headloss is approximately 5-6 times that of an open channel system. It comes with advanced "fail-safe" UV monitors with all functions controlled by microprocessors.

Figure 3 – InLine50,000+ System
(Courtesy of Aquionics)

Calgon Carbon – C^{3}500™

The C^{3}500™ wastewater disinfection system recommended by Calgon Carbon employs low pressure, high intensity UV lamp technology with electronic ballasts to effectively disinfect wastewater plant effluent. The modular design can be quickly installed in an open channel parallel to the flow of wastewater. The C^3 Series™ is designed for simple operation and trouble-free maintenance. It has a control system that allows dose or flow pacing. The system has only automatic mechanical cleaning and does not utilize any automatic chemical cleaning. Other manufacturers that supply this type of system include ITT/Wedeco, and Infilco-Degremont/Ozonia.

Figure 4 – TAK25 System
(Courtesy of ITT/Wedeco)

Severn Trent Services (STS)/Quay – MicroDynamics™

STS/Quay has recommended their MicroDynamics™ system for disinfection of the final effluent at the North Side WRP. Their microwave ballast technology uses microwaves to energize low-pressure, high-output bulbs for wastewater disinfection. The bulbs light instantly and lamps can be switched on and off to match the flow. According to the manufacturer, the main advantage of the system is better control of power to the lamps, which significantly increases the lamp life. The system is based on a relatively new concept and no information is available on its application and experience at large wastewater treatment facilities.

Figure 5 – MicroDynamics System
(Courtesy of STS/Quay)

Table 2. Summary of Manufacturer-recommended UV Technologies for NSWRP

	Trojan Technologies	**Aquionics**	**Calgon Carbon**	**STS/Quay**
Recommended model	UV4000™Plus	InLine50000+	$C^3$500™	MicroDynamics™
Lamp type	MP-HI	MP-HI	LP-HI amalgam	LP-HI energized by microwaves
Channel dimensions LxWxD	40'6" x 8'10" x 14'4"	N/A	38'6" x 7'2.25" x 6'4"	N/A
Channels	5 (4 + 1 for redundancy)	18	15	N/A
Reactors/channel	1	1	1	N/A
Banks/reactor	2	1	2	N/A
Modules/bank	7	1	15 racks/bank	N/A
Lamps/module	24	32	8 lamps/rack	N/A
Total lamps	1680	576	3600	N/A
Lamp life, hours	5,000	8,000	12,000	27,000
Lamp configuration	Horizontal, parallel to flow	Horizontal, perpendicular to flow	Horizontal, parallel to flow	N/A
Headloss through Reactor	9"	56"	N/A	N/A
Cleaning system	Automatic mechanical and chemical	Automatic mechanical and chemical	Automatic mechanical, non-chemical	N/A
Price (excluding taxes)	$ 7,986,000	$ 5,221,000	$ 7,455,000	N/A

N/A – Not available

REFERENCE INFORMATION FROM OTHER OPERATING FACILITIES

Case Study: Clayton Water Reclamation Center (WRC), Atlanta, GA
Source: Goodman and Mills, 2002

The Clayton WRC is a biological nutrient removal plant serving portions of Fulton, DeKalb, and Gwinnett counties and much of the City of Atlanta, Georgia. The plant discharges into the Chattahoochee River. It has a maximum monthly flow of 122 MGD, with a permit limit of 30 mg/L of monthly average TSS in the final effluent. The maximum allowable Fecal Coliform in the final effluent is 200 counts/100 mL monthly maximum average and 400 counts/100 mL weekly maximum average.

The plant uses an open channel, gravity-flow MP-HI UV disinfection system consisting of medium-pressure vapor UV lamps, oriented horizontally and parallel to flow, arranged in modules, and installed inside enclosed reactors in open channels. The basis of design of the UV system is given in Table 3. At this facility, flow from the filters initially enters the influent channel of the disinfection structure, then flows over a weir into a common influent channel, and finally flows through four individual channels. Each of these channels is equipped with a UV lamp system. In order for the UV lamp system to work properly, a specified level of liquid must be maintained in the channel to ensure that the lamps are always submerged when in operation. To maintain the desired liquid level in each channel, downstream weirs are used prior to the flow entering the clearwell. Plant reuse pumps are located downstream of the UV system.

Table 3. Basis of Design – Clayton WRC

Number of channels	4 operational/1 future
Number of banks/channel	2
Number of modules/bank	9
Number of lamps/module	10
Total number of lamps	720
UV dose, mJ/cm^2	24

Before the design, installation and operation of the UV system, a collimated-beam dose-response testing was done to estimate the sensitivity of the in-situ fecal coliform to UV. Once the dose was determined using the pilot tests, the system was installed and came into operation. The initial operational data is given in Table 4.

Table 4. Operational Data – Clayton WRC (April to September, 2001)

Normal Daily Dose Range	24 to 49 $mW\text{-}sec/cm^2$
Overall Dose Range	18 to 100 $mW\text{-}sec/cm^2$
Normal Daily Transmittance Range	74% to 78%
Overall Transmittance Range	65% to 83%
Days of Coliform Data	182
Days Count was Below 400 per 100 mL	174
Days Where Fecal Count was Below 200 per 100 mL	170
Days Where Fecal Count was Below 23 per 100 mL	141

During the initial phase, the facility operated on a UV dose exceeding the one established during the dose-response testing. In the first couple of months of operation after the startup of the UV system, the Clayton operational staff fed a small dose of sodium hypochlorite downstream of the UV system, until they became comfortable with the system and its reliability. During initial operation, it was found that the normal transmittance range was 74% to 78%, which exceeded the conservative average design value of 68% established using unfiltered samples. The UV system was found to meet the Georgia state standards for reuse 77% of the time, and monthly averages 95% of the time.

Telephone Survey of Experience at Other Facilities

A telephone survey was done by calling relevant personnel at facilities that have been using UV technology to disinfect their secondary or tertiary effluent. Priority was given based on the following criteria for selection of the facility for the telephone survey.

- Facility should preferably be in the Midwest or other areas that treat hard water and may be prone to calcium fouling
- Facility should have a high treatment capacity, possibly greater than 100 MGD
- Facility should be using a MP-HI UV disinfection system

Five facilities were contacted and the personnel responsible for the operation and maintenance of the UV equipment were interviewed. A summary of the results of this telephone survey is given in Table 5. The facilities contacted were Racine WWTP in Racine (WI), R.L. Sutton WRF in Cobb County (GA), Grand Rapids WWTP in Grand Rapids (MI), Jacksonville WWTP in Buckman (FL), and Valley Creek WWTP in Valley Creek (AL). All these facilities have peak influent flows close to or above 100 MGD.

Following observations are made based on the telephone interview of facilities using a MP-HI UV system for disinfection of their secondary or tertiary effluent.

- Four out of the five facilities use a system provided by Trojan Technologies, Inc.
- The Jacksonville WWTP has low UV transmittance, sometimes as low as 8% during high industrial discharge to the plant. They have had a few permit violations, but otherwise their disinfection system helps them meet the permit limits.
- Calcium fouling due to hardness in the source water is not a significant problem because of the automatic mechanical/chemical cleaning system that dissolves and wipes away any scales. This was observed in all five plants including the Racine and Grand Rapids utilities which have Lake Michigan source water.
- Fouling due to iron in the effluent has been a problem at the Racine, Sutton, and Grand Rapids facilities. The iron in the effluent at all three plants was primarily from the chemical phosphorus removal using Ferric Chloride. At Grand Rapids WWTP, the chemical addition is upstream of the secondary treatment process; staining of sleeves was found only when the chemical addition was in the secondary clarifiers. At the Sutton WRF, fouling of lamps due to iron is observed although chemical addition is upstream of secondary process and sand filters are used upstream of the UV disinfection system. At the Racine WWTP, fouling may be due to ferric chloride addition and/or due to the additional iron brought by the ferric sludge from another water treatment plant, although operational controls are used to prevent both sources from occurring simultaneously.

- The Trojan ActiClean gel was found to be ineffective at the Racine and Grand Rapids plants experiencing fouling due to iron. These utilities and Sutton WRF used alternate chemicals to clean the lamp sleeves.
- The frequency of cleaning and changing of the cleaning solution is specific to the utility and would have to be determined only by experience.
- The facilities typically replace lamps after the lamps' rated service life of 5000 to 6000 hours, but many times the operators used the lamps until they failed (shorter lamp life) or burn out (lamp life up to 9000 hours).
- Labor requirements varied amongst facilities, with some facilities requiring more manhours to handle the fouling. The Jacksonville WWTP required more labor to mitigate the algal growth caused by high temperatures.
- Storage requirements were not significant at all the facilities. Only a few gallons of the cleaning solution were stored at a time. Lamps were also not stored on a large scale.
- None of the facilities had done an on-site pilot testing. Only collimated beam testing (by the manufacturer, at Grand Rapids and Jacksonville WWTPs) was done to analyze the UV dose-response. At Valley Creek WWTP, one of the smaller facilities had a functioning UV system by Trojan Technologies, and that prompted them to install the system at their larger plant without any pilot testing.

As long as other processes in the plant are performing as desired, all five facilities were satisfied with the UV disinfection system because it met their disinfection goals.

Table 5. Summary of Telephone Interviews of Utilities Using MP-HI UV Disinfection Systems

Facility	Racine WWTP	R.L.Sutton WRF	Grand Rapids WWTP	Jacksonville WWTP	Valley Creek WWTP
Location	Racine, WI	Cobb County, GA	Grand Rapids, MI	Buckman, FL	Valley Creek, AL
UV disinfection system	Trojan UV4000+	Aquionics	Trojan UV4000+	Trojan UV4000 with custom modifications	Trojan UV4000+
Startup date	2005	Dec 2005	Feb 2005	2001	Jul 5, 2005
Disinfection goals met	Yes	Yes	Yes	Yes	Yes
Plant maximum flow	108 mgd	120 mgd design	90 mgd	105 mgd	240 mgd
UV transmittance, %	60%-85%	N/A	60 to 65%	48% to 55%	80% to 85%
Coliforms, current (monthly permit)	N/A (400) E. Coli count/100 mL	1 (200) F. Coli count/100 mL	80 to 140 (200) F. Coli count/100 mL	200 (800) F. Coli count/100 mL	15 (1000) F. Coli count/100 mL
Target UV dose	~29 mJ/cm^2	50 mJ/cm^2	30 to 40 mJ/cm^2	N/A	32 mJ/cm^2
Tertiary filtration	No	Yes, sand filters.	No	No	Yes, sand filters
Chemical Phosphorus removal - Ferric Chloride addition	Yes, additional ferric sludge from water treatment plant.	Yes, addition before secondary treatment.	Yes, addition before secondary treatment.	No	No
Fouling – iron (staining of sleeves)	Yes	Yes, sleeves replaced 1.5 to 2 yr	When chemicals added to secondary clarifiers	N/A	N/A
Water hardness	Lake Michigan source	Not significant	Lake Michigan source	Well water	River water
Fouling – hardness	Yes, but insignificant	Negligible	Yes	Yes	Negligible
Cleaning Chemical Used	Lime-Away	Phosphoric acid	Lime-Away plus 10% phosphoric acid	Trojan ActiClean gel	Trojan ActiClean gel
Additional cleaning other than automatic cleaning and its frequency	Manual once/ week only if necessary. Change cleaning solution per 6-8 weeks	Once after shutting down a channel and once before startup.	Check for fouling every 2 weeks and replace the cleaning solution once a month.	Check and replace cleaning solution every 2 months.	Manual, if necessary
Storage of cleaning solution	7-8 cases with 1-gal container/case	Buy 5-gal acid crystals Make phosphoric acid in a storage tank.	1-gal container at North side and 1 gallon at South side.	2 to 3 cases with 4 gal/case.	4 cases, 16 bottles/case.
Lamp replacement frequency	~ 6000 hrs, or after burnoff at ~9000 hrs.	~ 5000 to 6000 hrs. About 1 lamp/week.	~ 5000 to 6000 hrs, or after failure.	~ 5000 hrs, or after failure.	~ 6200 hrs, or after failure or burnoff.
Lamp storage	N/A	Very few.	Very few (Trojan ships new lamps on time)	~100 lamps at a time.	Few new lamps. Partially used lamps stored for reuse.
Pilot testing on site	None	None	None	None	None
Other testing	Collimated beam	N/A	Collimated beam by Trojan	Collimated beam by Trojan	None
Labor requirement	8 hrs/ week	7-8 hrs/ week	8 hrs/week	18 to 20 hrs/week	12 hrs/bank to replace cleaning gel twice/yr. 25 hrs/bank to replace bulbs.

N/A – Not Available

DISTRICT UV EQUIPMENT TRIALS PROJECT AND SUPPORTING WATER QUALITY INFORMATION

Currently, the District is planning an ultraviolet disinfection technology disinfection trial at the Hanover Park WRP. The trial is intended to provide real world operating and performance data on several available UV systems. The trials will allow District staff to become familiar with design, implementation, operation, and monitoring of a UV disinfection system through a small scale application.

Due to the site and time limitations, the UV technologies to be tested are limited to low pressure, high intensity technology to match the low flows available for testing. Currently, the District has invited Trojan Technologies, ITT/Wedeco, Severn Trent Services/Quay, and Infilco-Degremont/Ozonia to set up small-scale pilot installations for startup and operation during the winter of 2007-2008.

In preparation for this testing and to support the District's ongoing investigations into the potential need for UV disinfection implementation, additional water quality data testing related specifically to UV disinfection has been completed at Hanover Park WRP, North Side WRP, and Calumet WRP in 2006-2007. Water quality data was collected once every two weeks on plant effluent grab samples for Fecal Coliform counts, Escherichia Coliform counts, Total Coliform counts, COD, and UV transmittance. This data was tested pre-filtered, post-laboratory filtered, and post-full scale filtered (Hanover Park WRP samples only). In addition, the District collected hourly grab sample UV transmittance data at Hanover Park for two days in June of 2007. Appendix A includes the complete data collected to date.

Table 6 below presents a summary of the unfiltered data at the NSWRP and CWRP sites.

Table 6. Summary of 2006/2007 Water Quality Testing

Site	Fecal[1]	E.Coli	Total Coliform	COD	UV Transmittance
	CFU/100 ml	CFU/100 ml	CFU/100 ml	mg/L	%
NSWRP					
Average	13,254	11,825	147,140	26	76.7
Std Dev	8,213	5,818	59,619	12	3.54
CWRP					
Average	10,804	9,878	120,321	27	71.3
Std Dev	7,292	5,270	55,471	9	2.22

[1] Prior to 2006, WRP outfall sampling indicated maximum fecal coliform counts of 200,000.

While additional data is suggested to increase the level of confidence in the maximum day data (98% confidence level), this information does provide a good indication of the UV transmittance data and normal range of the bacteria levels. This information can be used to develop appropriate assumptions for the UV disinfection sizing criteria.

Need for Pilot Testing

Although many manufacturers suggest that collimated beam testing of water samples is sufficient for design, full-scale pilot testing is useful for demonstrating the effectiveness and performance of the UV systems as well as establishing critical design parameters.

In this case, the proposed UV disinfection systems will be among the largest ever constructed in North America and none of the UV systems have been applied at this scale in their current configuration. In particular, the following three issues could be addressed during full-scale piloting:

1. In-situ determination of fouling factors and lamp aging factors based on actual site specific conditions. This data is critical to optimize the lamp dose calculations and system sizing.
2. In-situ determination of fouling potential with and without iron salt addition. The phone survey has indicated that Lake Michigan source water combined with iron salt addition creates more rapid fouling than other applications.
3. Actual development of maintenance and operating frequencies required for the specific system to be implemented including preventative maintenance, bulb replacement, sensor maintenance, operating modes, power optimization, etc. This data may influence system sizing if individual lamps are not replaced if they burn out early.

Additional site-specific data such as UV transmittance, optimum UV dose requirements, and effluent quality information could be obtained from a carefully designed pilot testing program. This data might permit the District to collect a body of data by which to present the case for a lower UV dose to more closely match the required log removal of bacteria.

BASIS OF DESIGN OF UV SYSTEM FOR NORTH SIDE WRP

Per the District's recommendation, the MP-HI UV disinfection system has been selected for disinfection of the final effluent at the North Side WRP. Based on a review of the information provided by the UV equipment manufacturers and the experience of five other facilities, it is observed that Trojan Technologies provides a widely-used low-maintenance solution for final effluent disinfection. The design of the MP-HI UV disinfection system for the North Side WRP is based on the Trojan UV4000™Plus equipment provided by Trojan Technologies. The basis of design is given in Table 7.

Table 7. Design Parameters for UV Disinfection Unit at NSWRP

Parameter	Design Value
Design flow, mgd	450
Average flow, mgd	333
Maximum TSS[a], mg/L	15
Pre-Disinfection Effluent E.Coli Count) [b], cfu/100 mL, maximum (Assumed)	200,000
Post-Disinfection Effluent E.Coli Count Target[c], cfu/100 mL	1030
Effluent hardness [d], mg/L as $CaCO_3$	270
UV transmittance, minimum, %	65
UV dosing	
UV intensity[e], W/lamp	4,000
Fouling Factor, %	90
Lamp Aging Factor, %	89
Lamp Age, hours	5,000
UV dose[f], $mW\text{-}s/cm^2$	40
Hydraulics	
Channel dimensions, WxD	106" x 172"
Number of channels	5 (4 plus 1 standby)
Number of reactors per channel	1
Number of banks per reactor	2
Number of modules per bank	7
Number of lamps per module	24
Total number of lamps	1680
Liquid level control in channel	Motorized Weir Gate
Headloss, UV reactor only	9"
Velocity in each channel, V, ft/s	1.74
Total power requirement, kW	5376
Average power requirement, kW	2903

[a] Monthly TSS permit limit, 12 mg/L
[b] Annual average
[c] Future requirement (monthly geometric average)
[d] Mean value
[e] 100% intensity at 100 hours of lamp use
[f] IEPA requirement

The lamp aging and fouling factors are based on recommendations of manufacturers. Trojan Technologies generally recommends a fouling factor of 95%, which was determined using Bioassay validation required by the State of California. USEPA's UVdis program (UV Dosing Modeling Software) recommends a fouling factor of 100% for a system that incorporates automatic mechanical and chemical cleaning, such as Trojan's UV4000™Plus. The IEPA accepts the results of the UVdis program to size the system to meet the IEPA's 40 mJ/cm2 dose requirement. Other UV disinfection systems' fouling factors range from approximately 80 to 85%, though these systems do not incorporate chemical cleaning systems into their design.

These values were taken into consideration when choosing a fouling factor for NSWRP's design. A value of 90% was settled upon to incorporate both Trojan's recommendations and good engineering judgement.

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APPENDIX A
2006 UV TRIAL WATER QUALITY DATA
NSWRP, CWRP, AND HPWRP

Table 1: HOURLY PERCENT UV TRANSMITTANCE DATA ON SECONDARY EFFLUENT SAMPLES COLLECTED AT HANOVER PARK WRP FROM 6/5/07 TO 6/8/07
Secondary Effluent Grab Samples Collected Hourly[1]

Date	Time	Percent UV Transmittance
6/5/2007	12:15	71
6/5/2007	13:15	73
6/5/2007	15:15	70
6/5/2007	15:15	71
6/5/2007	16:15	70
6/5/2007	17:15	67
6/5/2007	18:15	70
6/5/2007	19:15	70
6/5/2007	20:15	72
6/5/2007	21:15	69
6/5/2007	22:15	72
6/5/2007	23:15	74
6/6/2007	00:15	72
6/6/2007	01:15	68
6/6/2007	02:15	71
6/6/2007	03:15	72
6/6/2007	04:15	73
6/6/2007	05:15	73
6/6/2007	06:15	72
6/6/2007	07:15	74
6/6/2007	08:15	75
6/6/2007	09:15	75
6/6/2007	10:15	77
6/6/2007	11:55	73
6/6/2007	12:55	70
6/6/2007	13:55	71
6/6/2007	14:55	70
6/6/2007	15:55	76
6/6/2007	16:55	NS
6/6/2007	17:55	72
6/6/2007	18:55	72
6/6/2007	19:55	72
6/6/2007	20:55	75
6/6/2007	21:55	71

Table 1 (Continued): HOURLY PERCENT UV TRANSMITTANCE DATA ON SECONDARY EFFLUENT SAMPLES COLLECTED AT HANOVER PARK WRP FROM 6/5/07 TO 6/8/07
Secondary Effluent Grab Samples Collected Hourly[1]

Date	Time	Percent UV Transmittance
6/6/2007	22:55	72
6/6/2007	23:55	71
6/7/2007	00:55	71
6/7/2007	01:55	71
6/7/2007	02:55	71
6/7/2007	03:55	73
6/7/2007	04:55	74
6/7/2007	05:55	69
6/7/2007	06:55	71
6/7/2007	07:55	71
6/7/2007	08:55	70
6/7/2007	09:55	72
6/7/2007	10:30	77
6/7/2007	10:55	76
6/7/2007	11:30	78
6/7/2007	12:30	77
6/7/2007	13:30	77
6/7/2007	14:30	76
6/7/2007	15:30	77
6/7/2007	16:30	76
6/7/2007	17:30	76
6/7/2007	18:30	77
6/7/2007	19:30	76
6/7/2007	20:30	76
6/7/2007	21:30	76
6/7/2007	22:30	76
6/7/2007	23:30	76
6/8/2007	00:30	77
6/8/2007	01:30	77
6/8/2007	02:30	68
6/8/2007	03:30	76
6/8/2007	04:30	78
6/8/2007	05:30	76
6/8/2007	06:30	76

Table 1 (Continued): HOURLY PERCENT UV TRANSMITTANCE DATA ON SECONDARY EFFLUENT SAMPLES COLLECTED AT HANOVER PARK WRP FROM 6/5/07 TO 6/8/07
Secondary Effluent Grab Samples Collected Hourly[1]

Date	Time	Percent UV Transmittance
6/8/2007	07:30	75
6/8/2007	08:30	75
6/8/2007	09:30	75
Minimum		65.0
Maximum		69.0
Mean		66.7

NS = No sample.
[1]Samples collected from a manhole wherein the effluent from all eight final tanks mingle.

TABLE 1: COMPARISON OF PRE-FILTER, LAB-FILTERED, AND FULL-SCALE POST-FILTER SECONDARY EFFLUENT (PLANT OUTFALL) SAMPLES COLLECTED FROM 11/16/05 TO 5/17/06 AT HANOVER PARK WRP

Date	Fecal Coliform[1] CFU per 100 mL			*Escherichia Coliform*[1] CFU per 100 mL			Total Coliforms[1] CFU per mL			COD[2] mg/L			Absorbance[2] abs_unit			Transmittance[2] %		
	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered	Pre-Filter	Full-Scale Post-Filter	Lab-Filtered
11/16/2005	22,000	9,500	3,300	17,330	8,160	1,920	155,300	92,100	6,870	n/a	n/a	n/a	n/a	0.153	n/a	n/a	70.31	n/a
11/30/2005	60,000	38,000	5,600	46,100	24,190	9,210	>241,900	>241,500	36,500	n/a	n/a	n/a	n/a	0.167	n/a	n/a	68.03	n/a
12/14/2005	14,000	9,400	4,500	18,500	15,530	4,610	241,900	173,300	24,190	n/a	n/a	n/a	n/a	0.149	n/a	n/a	70.92	n/a
1/11/2006	1,200	4,900	1,100	12,033	7,700	1,220	130,000	77,010	8,660	41	28	33	0.160	0.144	0.143	69.14	71.82	71.99
1/25/2006	4,700	3,800	380	6,870	2,610	450	77,000	46,100	2,050	49	37	36	0.158	0.145	0.136	69.50	71.57	73.11
2/8/2006	4,200	2,500	200	3,650	2,360	430	20,500	15,300	1,840	50	36	27	0.149	0.136	0.133	70.92	73.16	73.71
2/22/2006	6,700	2,900	700	6,130	4,610	771	61,300	32,600	2,760	59	36	27	0.134	0.131	0.129	73.41	74.00	74.34
3/8/2006	2,500	1,700	230	2,610	1,550	404	24,200	13,500	1,260	54	38	35	0.155	0.151	0.140	70.06	70.67	72.53
3/22/2006	3,800	2,000	280	3,260	3,450	504	43,500	19,900	1,270	79	29	29	0.156	0.150	0.143	69.78	70.84	71.99
4/5/2006	4,500	200	260	2,760	2,360	374	32,600	19,900	1,450	46	29	20	0.151	0.151	0.138	70.63	70.67	72.78
4/19/2006	5,800	3,100	440	4,880	3,650	520	51,700	32,600	2,190	57	42	29	0.159	0.148	0.144	69.34	71.20	71.78
5/3/2006	<100	<100	<20	20	<10	<10	355	97	10	48	31	40	0.172	0.138	0.142	67.34	72.82	72.19
5/17/2006	200	<100	<20	63	<10	<10	1,090	135	10	48	35	27	0.166	0.138	0.140	68.27	72.86	72.40
Average	10,800	7,091	1,545	9,554	6,923	1,856	69,954	43,729	6,851	53	34	30	0.156	0.146	0.139	69.84	71.46	72.68
Std. Dev	16,627	10,673	1,963	12,493	7,011	2,742	72,069	49,564	11,011	11	5	6	0.010	0.009	0.005	1.64	1.53	0.82

[1]Grab samples.

[2]24-hour composite plant samples taken for NPDES permit.

TABLE 3: CHARACTERIZATION OF PRE-FILTER AND LAB-FILTERED NORTH SIDE WRP OUTFALL SAMPLES COLLECTED FROM 11-15-05 TO 11-28-06

Date	Fecal Coliform[1] CFU per 100mL		*Escherichia* Coliform[1] CFU per 100mL		Total Coliforms[1] CFU per 100mL		COD[2] mg/L		Absorbance[2] abs_unit		Transmittance[2] %	
	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered
11/15/2005	9,300	700	15,530	910	198,600	4,350	n/a	n/a	n/a	0.114	n/a	77.00
11/29/2005	10,000	760	5,170	560	173,300	3,450	n/a	n/a	0.152	0.149	70.51	71.00
12/13/2005	11,000	640	8,660	600	241,900	2,910	n/a	n/a	0.104	0.104	78.75	78.70
1/10/2006	8,800	280	8,160	320	241,900	2,280	30	22	0.108	0.098	78.03	79.75
1/24/2006	7,700	1,100	11,200	1,070	>241,900	6,130	51	23	0.106	0.098	78.39	79.89
2/7/2006	10,000	1,500	15,500	1,270	141,000	5,790	29	25	0.098	0.093	79.85	80.68
2/21/2006	5,200	500	7,270	581	77,000	2,250	25	16	0.102	0.097	79.11	80.08
3/7/2006	9,400	620	13,000	697	173,000	4,110	46	46	0.152	0.152	69.66	70.43
3/21/2006	4,400	390	4,110	399	105,000	1,660	18	24	0.102	0.098	79.11	79.80
4/4/2006	2,400	100	2,760	155	24,200	1,080	22	14	0.111	0.102	77.40	79.07
4/18/2006	8,700	620	9,210	860	105,000	1,920	20	29	0.131	0.121	74.00	75.77
5/2/2006	20,000	2,100	19,900	798	141,000	4,880	20	38	0.118	0.115	76.21	76.78
5/16/2006	5,500	330	4,880	384	64,900	1,900	22	22	0.121	0.117	75.73	76.34
5/30/2006	7,800	860	8,660	1,320	98,000	7,270	20	18	0.108	0.100	78.07	79.43
6/13/2006	16,000	1,600	14,100	2,480	199,000	7,270	57	31	0.125	0.115	74.99	76.74
6/27/2006	7,600	440	6,870	759	130,000	3,870	41	18	0.180	0.172	66.07	67.30
7/11/2006	16,000	2,800	15,500	3,870	155,000	10,500	16	18	0.113	0.108	77.18	78.03
7/25/2006	26,000	2,300	12,000	2,220	120,000	9,210	14	14	0.103	0.099	78.98	79.62
8/8/2006	22,000	3,800	17,300	4,110	141,000	14,100	15	11	0.097	0.097	80.08	80.03
8/22/2006	20,000	3,900	24,200	3,870	242,000	12,000	31	5	0.112	0.103	77.36	78.89
9/5/2006	15,000	2,400	14,100	3,450	105,000	8,160	24	20	0.130	0.139	74.13	72.57
9/19/2006	27,000	5,600	19,900	5,170	242,000	14,100	16	16	0.114	0.121	76.96	75.64
10/3/2006	28,000	2,400	19,900	2,600	173,000	9,210	16	12	0.107	0.110	78.12	77.71
10/17/2006	32,000	2,800	17,300	2,380	173,000	10,500	18	12	0.107	0.111	78.12	77.49
10/31/2006	8,100	940	6,490	1,040	72,700	4,160	20	26	0.095	0.097	80.40	80.08
11/28/2006	6,700	600	5,790	624	141,000	1,860	26	24	0.095	0.105	80.40	78.48
Average	13,254	1,542	11,825	1,635	147,140	5,958	26	21	0.116	0.113	76.70	77.20
Std. Dev	8,213	1,374	5,818	1,417	59,619	3,946	12	9	0.020	0.020	3.54	3.40

[1]Grab samples.

[2]24-hour composite plant samples taken for NPDES permit.

TABLE 6: CHARACTERIZATION OF PRE-FILTER AND LAB-FILTERED CALUMET WRP OUTFALL SAMPLES COLLECTED FROM 11-17-05 TO 11-02-06

Date	Fecal Coliform[1] CFU per 100mL		*Escherichia* Coliform[1] CFU per 100mL		Total Coliforms[1] CFU per 100mL		COD[2] mg/L		Absorbance[2] abs_unit		Transmittance[2] %	
	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered	Pre-Filter	Lab-Filtered
11/17/2005	20,000	2,000	19,860	2,720	241,900	20,100	n/a	n/a	0.155	0.157	69.98	69.66
12/1/2005	8,000	1,400	9,800	2,060	155,300	11,200	n/a	n/a	0.146	0.148	71.53	71.20
12/15/2005	7,000	440	7,700	670	173,300	3,080	n/a	n/a	0.130	0.127	74.09	74.69
1/12/2006	6,000	1,100	7,270	880	120,300	7,270	n/a	30	0.141	0.137	72.24	72.99
1/26/2006	3,900	300	3,450	380	51,700	2,250	24	25	0.134	0.129	73.41	74.30
2/9/2006	7,600	820	8,160	712	77,000	3,260	31	27	0.140	0.135	72.40	73.28
2/23/2006	5,900	520	6,490	759	92,100	3,650	31	21	0.140	0.134	72.40	73.49
3/9/2006	23,000	2,500	26,000	3,450	173,000	13,000	53	42	0.149	0.146	71.00	71.41
3/23/2006	9,400	1,200	10,500	860	105,000	5,170	20	29	0.136	0.135	73.07	73.37
4/6/2006	9,300	880	10,500	1,530	130,000	12,000	31	12	0.121	0.114	75.64	76.87
4/20/2006	6,000	720	6,870	833	155,000	4,880	35	25	0.180	0.164	66.15	68.59
5/4/2006	2,900	340	4,350	504	61,300	2,140	38	35	0.168	0.164	67.96	68.55
5/18/2006	n/s	n/s	n/s	n/s	n/s	n/s	27	27	0.166	0.161	68.23	69.02
6/1/2006	15,000	1,200	10,500	1,400	173,000	9,800	40	18	0.154	0.143	70.15	71.94
6/15/2006	3,500	460	3,870	565	48,800	3,080	27	35	0.157	0.149	69.70	71.04
6/29/2006	21,000	2,400	17,300	4,350	173,000	24,200	24	22	0.167	0.163	68.16	68.71
7/13/2006	6,800	840	6,870	1,050	112,000	5,790	20	22	0.154	0.151	70.15	70.71
7/27/2006	4,700	400	3,610	464	77,000	3,870	24	24	0.148	0.139	71.12	72.65
8/10/2006	13,000	2,400	12,000	1,510	98,000	8,160	20	18	0.142	0.143	72.15	71.94
8/24/2006	6,600	700	8,660	798	81,600	3,450	26	16	0.156	0.151	69.90	70.71
9/7/2006	12,000	1,300	11,200	1,560	130,000	5,170	22	20	0.141	0.145	72.36	71.57
9/21/2006	5,700	480	8,660	670	64,900	2,490	23	20	0.131	0.138	74.00	72.74
10/5/2006	30,000	1,700	14,100	1,250	242,000	14,100	20	16	0.138	0.140	72.82	72.49
10/19/2006	22,000	720	11,200	867	86,600	6,870	16	16	0.138	0.142	72.78	72.11
11/2/2006	10,000	660	8,160	644	64,900	3,260	23	19	0.142	0.147	72.11	71.29
Average	10,804	1,062	9,878	1,270	120,321	7,427	27	24	0.147	0.144	71.34	71.81
Std. Dev	7,292	683	5,270	986	55,471	5,797	9	7	0.014	0.012	2.22	2.02

[1]Grab samples.

[2]24-hour composite plant samples taken for NPDES permit.

APPENDIX C

UV EQUIPMENT TECHNICAL INFORMATION

TROJANUV
WATER CONFIDENCE™

UV4000™PLUS PROPOSAL

March 27, 2008

PETERSON & MATZ, INC.
2250 Point Boulevard
Suite 300
Elgin, IL 60123
USA

Attention: Chuck Hansen
Reference: MWRDGC Stickney, IL
Quote No: EAG1533C

In response to your request, we are pleased to provide the following **Trojan System UV4000™Plus** proposal for the **MWRDGC Stickney** project. Since Trojan introduced the open channel approach to disinfection in 1982, many municipalities have selected ultraviolet as the preferred method for pathogen destruction at their facilities.

The **Trojan System UV4000™Plus** utilizes medium pressure lamp design, which requires a significantly lower number of lamps as well as reduced total space for installation. All of Trojan's UV systems are modular in design, with each design system customized in response to the effluent criteria. The lamps are oriented in a horizontal configuration parallel to the flow and incorporate a fully automated mechanical/chemical cleaning system that eliminates the need for manual sleeve cleaning. In addition, the Trojan System UV4000™Plus utilizes a variable output power supply so that power draw is optimized based on continuous effluent monitoring.

Please review carefully our design criteria for peak flow rate, total suspended solids, disinfection limit, and UV transmittance to ensure that the criteria used match actual project parameters. When detailed project design commences, please contact our office for a review of all design parameters, including dimensions and equipment requirements. In addition, Trojan is able to provide analytical services to quantify effluent quality and confirm design criteria.

Trojan's price for the attached design is **$21,900,000** (in US$). This quoted price includes the equipment as described, freight to site and start-up by qualified personnel. This quote **excludes** any taxes that may be applicable. The above information is to be used for budget estimates only and is valid for 90 days from this date.

Please do not hesitate to call me if you have any questions or would like additional information. Thank you for the opportunity to quote the **Trojan System UV4000™Plus** on this project.

With best regards,
Trojan Technologies

Stephen Payler
Stephen Payler
Municipal Applications
Encl.

DESIGN CRITERIA

Current Peak Design Flow:	**1440 US_MGD**
Future Peak Design Flow:	**1440 US_MGD**
UV Transmission:	**65 %,** minimum
Total Suspended Solids:	**15 mg/l** (Maximum; grab samples)
Max Average Particle Size:	**30 microns**
Disinfection Limit:	**400 fecal coliform** per 100 ml, based on a 1 day Maximum of consecutive daily grab samples
Design Dose:	40,000 $\mu Ws/cm^2$ **EPA Dose**

DESIGN SUMMARY

Based on the above design criteria, the Trojan System UV4000™Plus proposed consists of:

Number of Channels:	**12**
Number of Reactors per Channel:	**1**
Number of Banks per Reactor:	**2**
Number of Modules per Bank:	**7**
Total Number of UV Lamps:	**4032**
Number of Power Distribution Centers:	**24**
Number of System Control Centers:	**1**
Type of Level Controller:	**Fixed Weir Plate**
Automatic Mechanical/Chemical Cleaning:	**Included**
UV Module Lifting Device:	**Included**

EFFLUENT CHANNEL DIMENSIONS

L = Minimum length required for flow equalization: **40.5 ft**
W = Channel width based on number of UV modules: **106 in**
D = Maximum depth required for UV Module access: **172 in**

Dimensions are given for reference only. Consult Trojan Technologies for overall system detailed dimensions.

ELECTRICAL REQUIREMENTS

1. The UV System Control Center requires an electrical service of one (1) 120 Volt, 1 phase, 2 wire (plus ground), 16.7 Amps.

2. Each Power Distribution Center requires an electrical service of one (1) 277/480 Volt, 3 phase, 4 wire (plus ground), 568.89 kVA.

3. Each UV Reactor has one (1) Hydraulic Systems Center and requires an electrical services of one (1) 120 Volt, 2 phase, 1 wire (plus ground), 50 Amps.

NOTES

1. UV Disinfection Equipment specification is available upon request.
2. If there are site-specific hydraulic constraints that must be applied, please consult the manufacturer's representative to ensure compatibility with the proposed system.
3. Standard spare parts and safety equipment are included with this proposal.
4. Electrical disconnects required as per local state code are not included in this proposal.
5. Trojan Technologies warrants all components of the system (excluding UV lamps) against faulty workmanship and materials for a period of 12 months from date of start-up or 18 months after shipment, which ever occurs first.
6. Payment Terms: 10% after approved submittal, 80% upon delivery of equipment to site, 10% after equipment acceptance.

OPERATING COSTS FOR TROJAN SYSTEM UV4000™Plus

Design Criteria

Average Flow:	1250 US_MGD
Yearly Usage:	6240 hours
UV Transmission:	65%

Power Requirements

Total Power Draw:	11827.2 kW
Average Power Draw:	9225.2 kW
Annual Operating Hours:	6240 hours
Cost per kW Hour:	$0.05
Annual Power Cost:	***$2,878,262.4***

Replacement Lamp Costs

Number of lamps replaced per year:	2676
Price per lamp:	$215
Annual Lamp Replacement Cost:	***$575,340***

Total Annual Operation and Maintenance Costs are: $3,453,602.2

NOTES
1. O&M costs are based on system flow-pacing using a 4-20 mA signal from a flow meter (supplied by others).
2. O&M costs are based on the system operating at the average flow conditions.

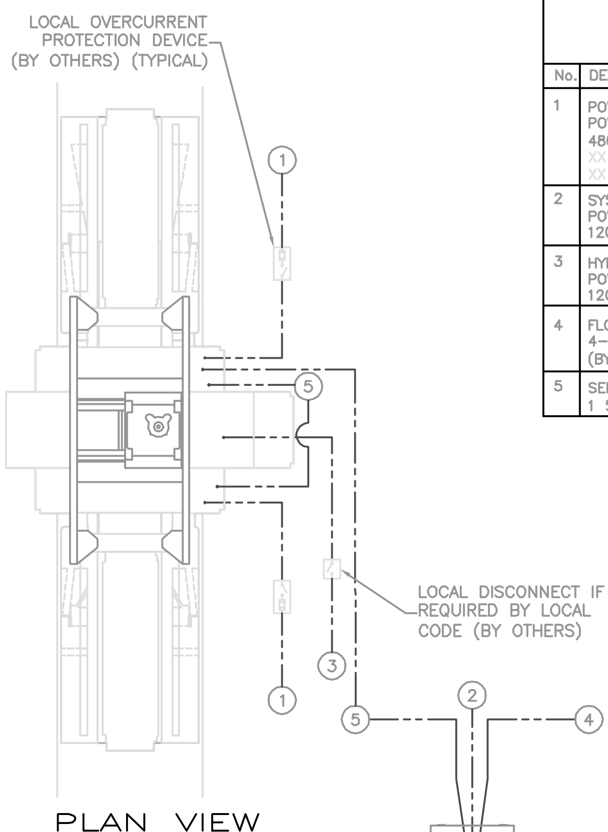
TROJAN UV4000™ PLUS

EQUIPMENT INTERCONNECTIONS

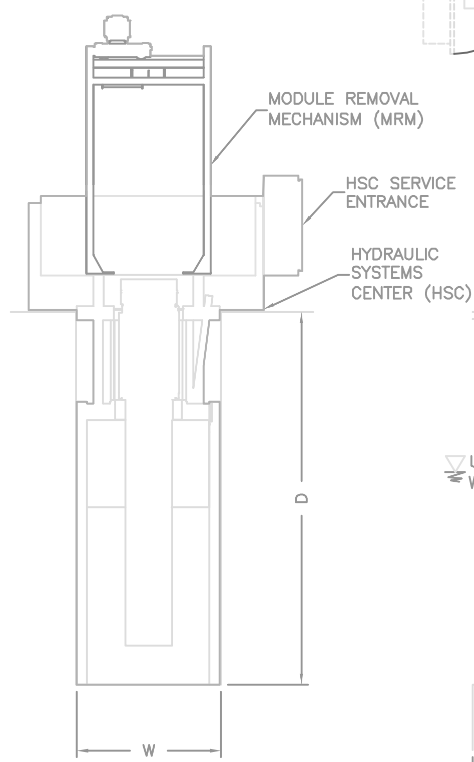
No.	DESCRIPTION	FROM	TO
1	POWER DISTRIBUTION CENTRE (PDC) POWER SUPPLY 480Y/277V, 3 PHASE, 4 WIRE + GROUND XX kVA POWER DRAW XX AMPS MAXIMUM CURRENT/PHASE	DISTRIBUTION PANEL (DP) (BY OTHERS) (NOT SHOWN)	PDC
2	SYSTEM CONTROL CENTRE (SCC) POWER SUPPLY 120V, 1 PHASE 2 WIRE + GROUND, XX AMPS	DP (BY OTHERS) (NOT SHOWN)	SCC
3	HYDRAULIC SYSTEMS CENTRE (HSC) POWER SUPPLY 120V, 1 PHASE, 2 WIRE + GROUND, 50 AMPS	DP (BY OTHERS) (NOT SHOWN)	HSC
4	FLOW METER 4–20 mA, DC ANALOG INPUT (BY OTHERS)	FLOW METER PANEL (NOT SHOWN)	SCC
5	SERIAL COMMUNICATION LINK (RS485) 1 SHIELDED TWISTED PAIRS (24 AWG)	SCC	PDC

NOTES:

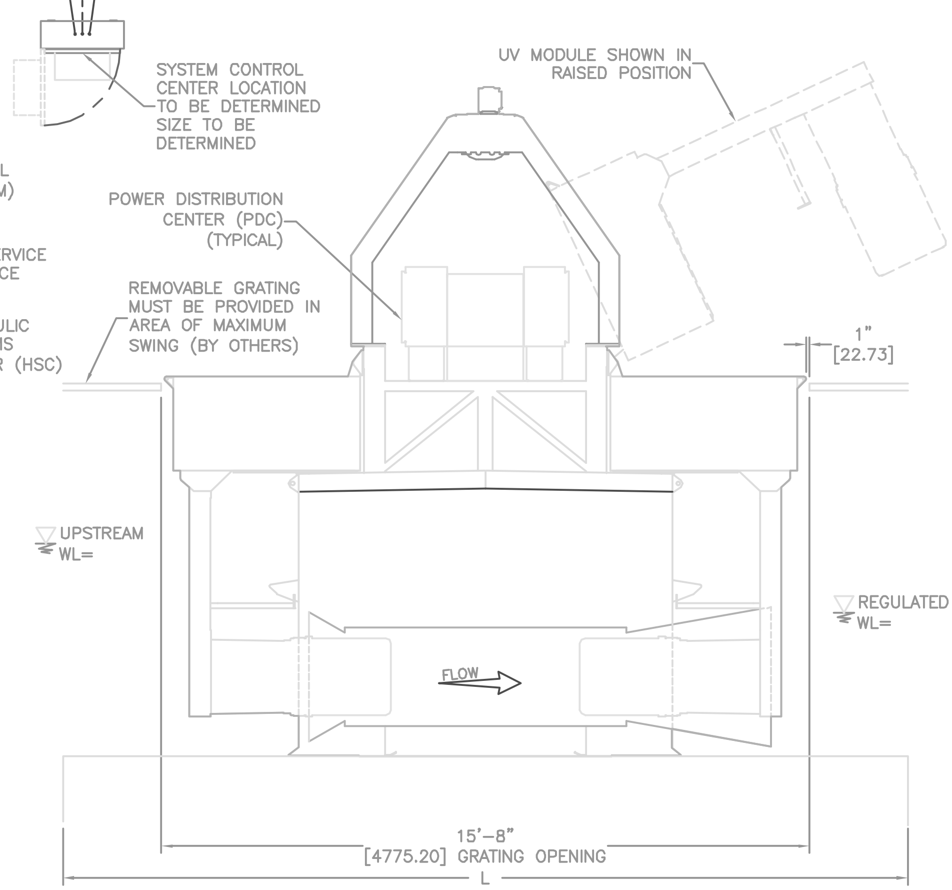
: DO NOT SLOPE CHANNEL FLOOR.
: CHANNEL WIDTH & DEPTH MUST BE KEPT WITHIN A TOLERANCE OF + OR – ¼" [6mm].
: ANCHOR BOLTS ARE NOT SUPPLIED BY TROJAN TECHNOLOGIES INC.
: SYSTEM CONDUIT, WIRING, DISTRIBUTION PANELS & INTERCONNECTIONS BY OTHERS.
: ELECTRICAL REQUIREMENTS SHOWN ARE TO SUPPLY TROJAN UV EQUIPMENT ONLY. ELECTRICAL INRUSH FACTOR TO BE ADDED AS PER LOCAL CODE.
: REMOVABLE GRATING SECTIONS SHALL BE EASILY REMOVED BY ONE PERSON. MAXIMUM WEIGHT OF THE SECTIONS SHALL BE IN ACCORDANCE WITH REQUIREMENTS OF THE APPLICABLE JURISDICTION.
: CONTRACTOR TO REVIEW ALL TROJAN TECHNOLOGIES INC. INSTALLATION INSTRUCTIONS PRIOR TO EQUIPMENT INSTALLATION.



PLAN VIEW
SCALE: NOT TO SCALE



END VIEW
SCALE: NOT TO SCALE

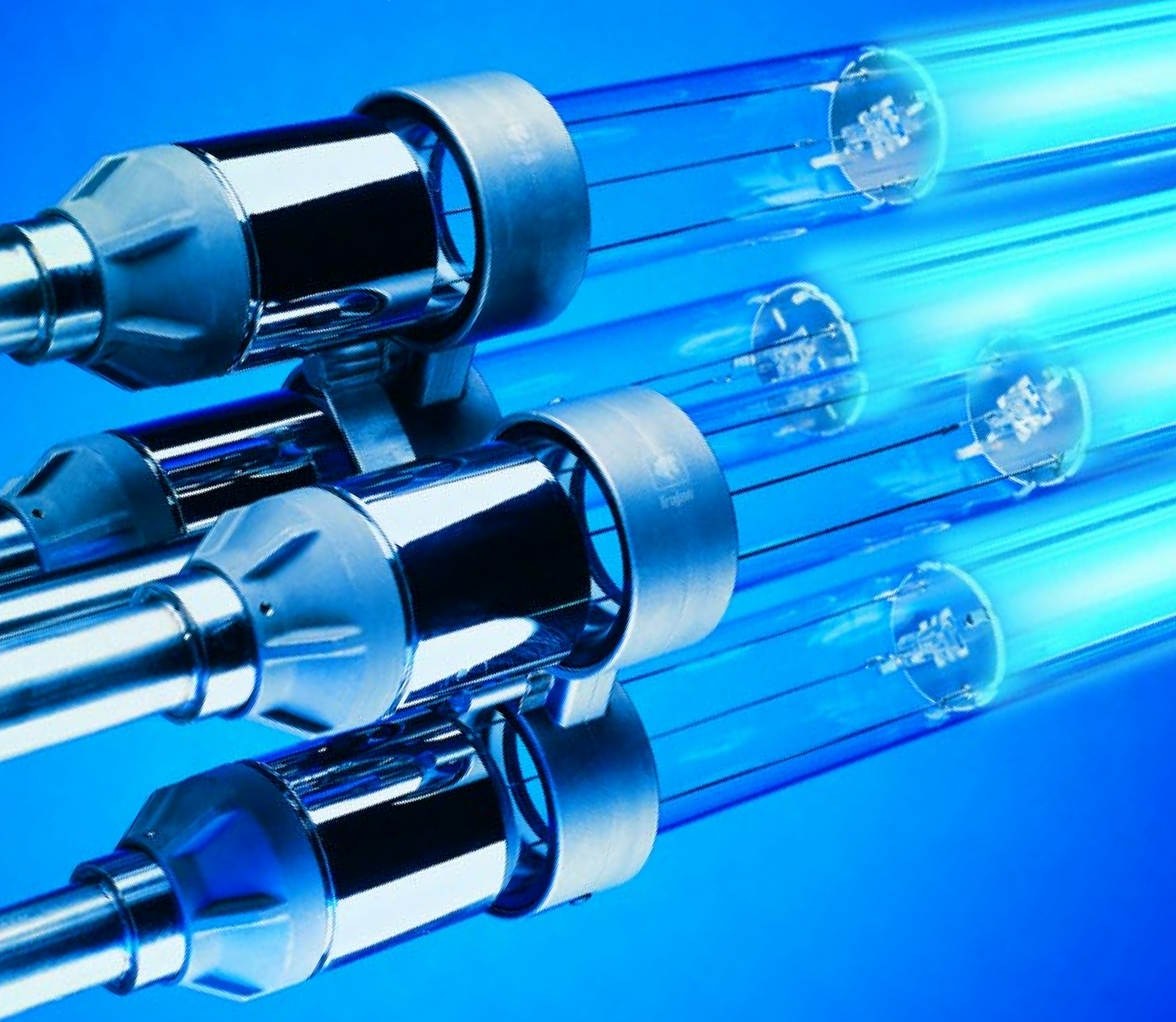


SIDE VIEW
SCALE:NOT TO SCALE

Trojan Technologies Inc.

DESCRIPTION: LAYOUT, UV4000PLUS REACTOR DRAWING		STANDARD DRAWING NO. 4M0218	
		REFERENCE NO. N/A	
DRAWN BY : JAW/CAR	DATE : 04JN21	DWG NO. D01	REV. B
CHECKED BY : PJM	DATE : 04JN22		
APPROVED BY : CMS	DATE : 04JN23		
SCALE (8½x11) : NOT TO SCALE	LOG NUMBER : N/A		

World Leader in UV Disinfection Systems



TROJAN SYSTEM **UV4000**™

Trojan Technologies

Trojan System UV4000™

The first choice for cost-effective UV wastewater disinfection – featuring Trojan's unique compact design and automated chemical and mechanical self-cleaning technology

More than 2,400 Trojan Technologies ultraviolet (UV) light wastewater disinfection systems operate in municipalities around the world. Commercially pioneered by Trojan in 1982, UV disinfection offers a chemical-free, cost-effective, and environmentally safe alternative to chlorine-based systems for treating effluents, reclaimed water, combined sewer overflows and storm water.

Technological advances in the Trojan System UV4000™

System UV4000™ builds on the features and advantages of earlier generation Trojan UV systems. Installed in an open channel, System UV4000™ UV lamps are mounted horizontally and parallel to the flow. This design optimizes hydraulics, inducing turbulence and dispersion, and ensures that wastewater is properly exposed to the UV output for the required duration. Gravity flow carries wastewater through the system, eliminating the need for pressurized vessels, piping, and pumps. Multiple banks of UV lamps can be placed in series in each UV channel. Typical installations use two banks in series for most standard applications and multiple banks in series for wastewater reclamation projects.

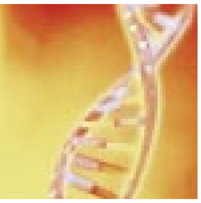
Medium-pressure, high-intensity UV lamps

The incorporation of medium-pressure, high-intensity UV lamps reduces the number of lamps required by 90 per cent, lessening space requirements and decreasing installation and maintenance costs.

The UV lamp array is positioned within the UV reactor providing a controlled water layer geometry at all flows. The unique design of the UV reactor eliminates the potential for short-circuiting of flow that could result in performance failure. High-intensity lamps also extend the applicability of UV disinfection to poorer quality effluents.

Fouled quartz sleeves come clean. The unique self-cleaning process of System UV4000™ reduces maintenance costs.

Two significant advances distinguish the System UV4000™ from conventional UV wastewater disinfection systems: medium-pressure, variable output high-intensity lamps and fully automated chemical and mechanical self-cleaning technology.



Variable lamp output improves disinfection control

The output of System UV4000™ high-intensity lamps can be varied as effluent quality and flow rates change. Matching lamp output to actual wastewater conditions conserves energy, prolongs lamp life, reduces operating costs, and ensures that an adequate dose is delivered regardless of the effluent quality and flow rate.

This process is fully automated using Trojan's On-line UV Transmission Monitor, which tracks changes in effluent quality. In conjunction with a flow signal, the effluent quality data is used to automatically adjust lamp output to maintain disinfection standards. Lamp life is extended and operating costs are reduced.

The Trojan Difference

- Fully automated chemical and mechanical self-cleaning technology cuts labor costs
- High-intensity lamps reduce total lamp requirements by 90 per cent; reduces operational costs
- Variable output ballasts allow UV output to be tailored to meet wastewater and flow conditions
- Open-channel, gravity flow configuration eliminates need for pressurized vessels, piping, and pumps
- Environmentally safe – no chlorine required; and no disinfection by-products created
- Dedicated regional field service staff ready to meet your needs
- In-house call center technicians available through 1-800 line
- Significant annual commitment to Research and Development for innovations such as: on-line chemical and mechanical cleaning; lamp and ballast testing laboratory; microbiology services; and reactor design and optimization

Automated chemical and mechanical self-cleaning technology

Effluents will eventually coat the quartz sleeves that house the UV lamps, reducing their effectiveness and increasing their energy consumption. To offer an alternative to costly and time-consuming manual cleaning, Trojan's scientists and engineers developed an automatic, self-cleaning system. With the System UV4000,™ the modules – while remaining in operation – are thoroughly cleaned by a combined chemical and mechanical self-cleaning system. Chemical cleaning has become the industry standard way to remove scaled deposits that accumulate on the quartz sleeve over time. In fact, the US EPA Design Manual on Municipal Wastewater Disinfection, when discussing design considerations for effective maintenance, explains that "periodic chemical and/or detergent cleaning will be required to maintain the outer quartz." *(EPA/625/1-86/02, p. 237)*

Trojan's sealed cleaning mechanism uses a small amount of solution to remove deposits on the quartz sleeves more effectively than mechanical cleaning alone can do. Cleaning cycles are activated by a timer and are programmed to clean modules sequentially within each operating bank.

The fully automated cleaning cycle is programmed for each installation and is set to operate as frequently as once an hour, depending on the rate of fouling. Plants that previously could not use conventional UV reactors because poor effluent quality led to rapid lamp fouling (e.g., primary effluent, CSOs) can now take full advantage of the economic, environmental, and safe benefits of ultraviolet light with System UV4000.™

Ease of Maintenance

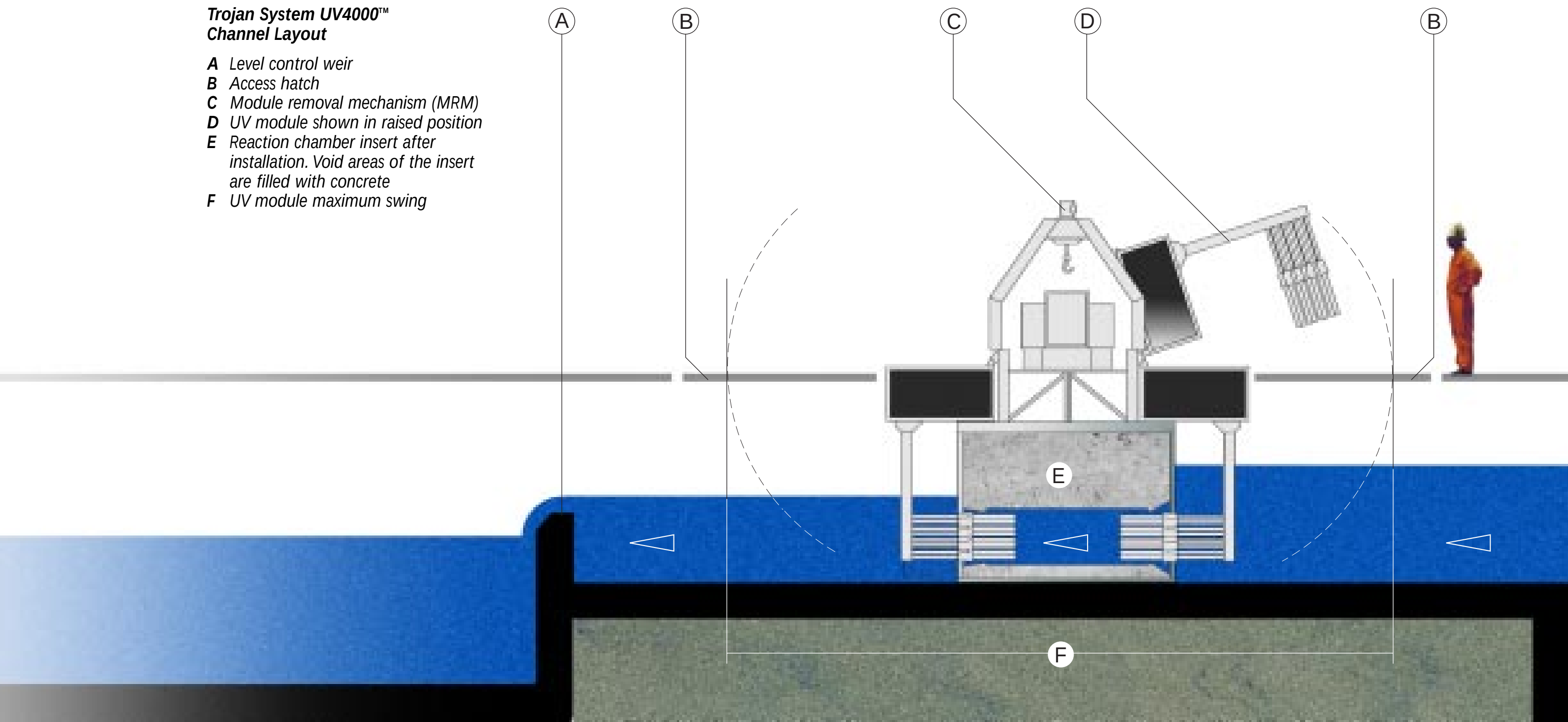
The self-cleaning technology of System UV4000™ allows the UV lamp modules to remain submerged in the channel until the lamps need replacing. When lamps need to be replaced, modules are lifted out of the channel by the Module Removal Mechanism (MRM). Using a reversible electric winch, the MRM raises lamp modules from the channel to a convenient working height. One person can replace single or multiple lamps in minutes.

General layout requirements

As with every Trojan UV System, the sizing of System UV4000™ in a particular application will depend on the effluent quality and flow rates, level of disinfection required, and the degree of equipment redundancy needed (for wastewater reclamation applications). Please contact Trojan's local representative for more information regarding the System UV4000™ or any of Trojan's products or services.

Trojan System UV4000™ Channel Layout

- ***A*** *Level control weir*
- ***B*** *Access hatch*
- ***C*** *Module removal mechanism (MRM)*
- ***D*** *UV module shown in raised position*
- ***E*** *Reaction chamber insert after installation. Void areas of the insert are filled with concrete*
- ***F*** *UV module maximum swing*

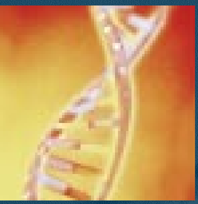


How does UV disinfection work?

Ultraviolet light disinfects wastewater by altering the genetic (DNA) material in cells so that bacteria, viruses, and other microorganisms can no longer reproduce. The UV light is produced by germicidal lamps submerged in an open channel. As wastewater flows past the UV lamps, microorganisms are exposed to a lethal dose of UV energy. The UV dose is a product of UV light intensity and exposure time.

PROTECTING THE ENVIRONMENT WITH UV DISINFECTION

Until recently, chlorine has been the disinfection treatment of choice. Today, however, an increasing number of governments have restricted the amount of chlorine residual that may be discharged into the environment. These restrictions have led to the adding of dechlorinating agents such as sulfur dioxide or sodium bisulfate. But this practice does not adequately protect the marine environment because chlorine combines with organic compounds in the wastewater to form known carcinogens that are not neutralized during the dechlorination process. UV disinfects without the formation of by-products, making UV a safe and cost-effective alternative to chemical-based disinfection.



Trojan Technologies: a pioneer and global innovator

For more than 20 years, Trojan Technologies has led the global improvement of water quality by continually refining its ultraviolet (UV) disinfection systems. Trojan innovations have set industry standards for treating both wastewater and drinking water. With the largest number of UV installations worldwide and an industry-leading research and development team, Trojan offers municipal water utility operators and engineers unmatched technical insight and experience.

Trojan constantly reengineers its systems to incorporate state-of-the-art technology and offer customers new and improved features, benefits, and conveniences.

Quality products, quality people

Trojan's systems are ISO 9001 certified, an internationally recognized designation that reflects the high quality of Trojan's design, development, production, installation, and service.

Behind the company's products are the most experienced and knowledgeable professionals in the industry. Comprising internationally recognized experts in microbiology, chemistry, physics, and engineering, Trojan's research and development team creates many of today's most successful UV technology innovations.

Trust ... integrity ... teamwork ... respect for employees and customers ... and a strong sense of purpose – these are the underpinnings of Trojan's corporate culture.

By creating a positive work environment that both challenges and rewards employees, Trojan is able to meet its commitments of providing lasting solutions to environmental problems.

Support from the industry leader keeps your system up and running

Trojan's global presence mirrors a strong commitment to its customers and to its future. With offices in Canada, the US, Europe and the UK, Trojan is able to serve customers no matter where they are located. An extensive network of professional manufacturer's representatives expands the company's reach into South America, Europe, the Middle East, and the Pacific Rim, giving Trojan comprehensive global coverage.

Trojan is recognized for its exceptional customer service. The company's highly trained technicians are strategically located at Trojan support centers around the world. This extensive support network allows Trojan to respond quickly to customer calls – no matter what the time zone or location. And the company's state-of-the-art technical support center permits technicians to dial up and diagnose problems on-line, quickly and effectively.

Products in this brochure may be covered by one or more of the following patents:
Can. 1,163,086 Can. 2,117,040 Can. 2,239,925 Can. 1,327,877
U.S. 4,482,809 U.S. 5,418,370 U.S. 5,590,390 U.S. 4,872,980 U.S. 5,006,244
Other patents pending.

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Fax: 011-44-1-905-772270

www.trojanuv.com

Trojan Technologies is a publicly traded company on the Toronto Stock Exchange under the symbol TUV.

TROJANUV4000PLUS™

WASTEWATER DISINFECTION

TROJANUV4000PLUS™

Proven UV Solutions for Low Quality Effluent & Large Flows

Selected for some of the world's largest & most challenging treatment applications

Trojan Technologies Inc. is an ISO 9001: 2000 registered company that has set the standard for proven UV technology and ongoing innovation for more than 25 years. With unmatched scientific and technical expertise, and a global network of water treatment specialists, representatives and technicians, Trojan is trusted more than any other firm as the best choice for municipal UV solutions. Trojan has the largest UV installation base – over 4,000 municipal installations worldwide. In North America alone, almost one in five wastewater treatment plants rely on our proven, chemical-free disinfection solutions.

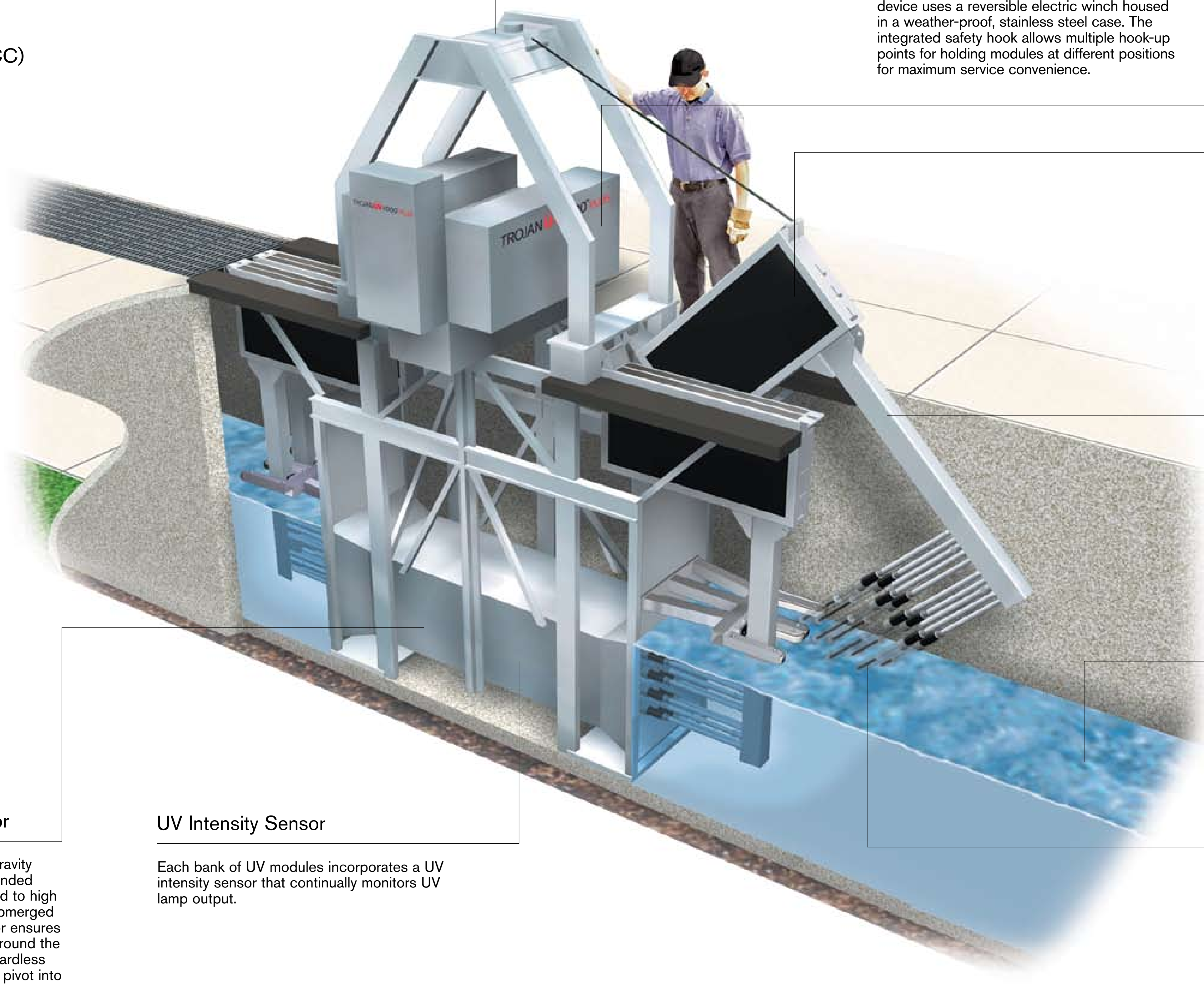
The TrojanUV4000Plus™ is one of the reasons why. This robust, high capacity system introduced the benefits of high intensity, medium-pressure lamp technology to wastewater treatment. It also redefined sleeve cleaning technology with Trojan's patented, dual-action, chemical/mechanical ActiClean™ system. With over 375 installations – including some of the largest wastewater treatment plants in the world – the TrojanUV4000Plus™ is allowing engineers and operators to incorporate chemical-free, UV disinfection for large flows of 10 MGD (1,578 m^3/hr) and greater in a minimal amount of space – with a fraction of the number of lamps required by low-pressure systems. The extremely compact system can be used for low UV transmittance applications previously unattainable with ultraviolet technology. It also offers the flexibility to treat a wide range of wastewater; from primary, secondary and blended effluents to combined and sanitary sewer overflows to water for reuse applications.

TROJANUV4000PLUS™

Providing high volume treatment effectively and reliably

System Control Center (SCC)

Continuously monitors and controls all UV functions and dose pacing. It incorporates a PLC and menu-driven, touch-screen interface for at-a-glance confirmation of system parameters, performance, and simple control of all system functions. The dose pacing program conserves power and extends lamp life by varying lamp intensity and controlling bank on/off status according to flow and water quality parameters. The SCC features discrete outputs and/or serial communication links to the plant SCADA system for full remote monitoring.



Submerged Effluent Reactor

All effluent in the channel flows by gravity through the fully submerged, open-ended reactor, where the effluent is exposed to high intensity UV light. The innovative, submerged design and contoured reactor interior ensures stringent control of the water layer around the lamps for consistent disinfection regardless of flow rate. Modules with UV lamps pivot into the reactor opening at both ends.

UV Intensity Sensor

Each bank of UV modules incorporates a UV intensity sensor that continually monitors UV lamp output.

Module Removal Mechanism (MRM)

The MRM lifts modules out of the channel to an optimal working height for maintenance. The device uses a reversible electric winch housed in a weather-proof, stainless steel case. The integrated safety hook allows multiple hook-up points for holding modules at different positions for maximum service convenience.

Power Distribution Center (PDC)

The PDC provides power to each bank of modules and monitors data from the module (including UV intensity signals), cleaning system control and status, hydraulic systems, and effluent level signals. PDCs are housed in TYPE 4X rated, stainless steel enclosures mounted directly on the system above the channel.

Electronic Ballast

High-efficiency, variable-output (30% - 100% power) electronic ballasts regulate the power to the UV lamps. The variable-output design permits the plant to dose pace based on flow rate and water quality. Ballasts (one per lamp) are inside the modules, and housed in weather-resistant, TYPE 6P rated enclosures. An integrated cooling system is contained within the ballast enclosure, eliminating the requirement for air conditioning and allows for the entire system to be installed outdoors.

UV Modules

UV lamps are mounted on stainless steel modules that are submerged in the effluent channel. The lamps are enclosed in quartz sleeves, positioned horizontally and parallel to the water flow. Modules consist of multiple lamps and are mounted in parallel to form a bank. Ballasts are mounted inside the modules, and all ballast and lamp wiring runs inside the stainless steel module frame to protect it from exposure to UV light and effluent.

Water Level Control

Water level in the UV channel can be controlled using either a motorized weir gate or a fixed weir located downstream of the reactor. Trojan's engineering staff will assist to design and select the most appropriate device based on hydraulic and site-specific considerations.

ActiClean™ Cleaning System

A chemical/mechanical cleaning system prevents fouling of the UV lamp sleeves. Hydraulically driven wiper collars filled with ActiClean™ gel surround the quartz sleeves. The gel is comprised of a non-corrosive, operator-friendly cleaning chemical that contacts the sleeves between the collar's two rubber wiper seals. Cleaning can be programmed to occur at preset intervals, and takes place online while the lamps are submerged and operating.

Key Benefits

TrojanUV4000Plus™

Increased operator, community and environmental safety. Uses environmentally-friendly ultraviolet light – the safest alternative for wastewater disinfection. No disinfection by-products are created, and no chlorine compounds must be transported, stored or handled.

Ideal for challenging wastewater applications. Treats a wide range of wastewater flows, including effluents with UV transmittance as low as 15%, combined & sanitary sewer overflows, and water for reuse applications.

Proven, regulatory-endorsed disinfection based on actual dose delivery testing (bioassay validation), and over 375 installations worldwide. Verified field performance data eliminates the sizing assumptions of theoretical dose calculations.

Reduced installation costs. Easily retrofitted into existing chlorine contact chambers, leaving the majority of the chamber available for storage, by-pass or emergency back-up – eliminating the expense and footprint associated with the construction of new structures.

Operator-friendly maintenance. Features significantly fewer lamps, modules that are electrically separate, and an integrated power winch to remove modules from the channel to a convenient working height.

Dual-action sleeve cleaning system improves performance and reduces labor costs. Unsurpassed chemical/mechanical cleaning system maintains maximum sleeve transmittance, and works online while disinfecting.

Optimized for efficient operation. Uses a fraction of the number of lamps required by conventional low-pressure systems, and features high efficiency, variable-output electronic ballasts and dose pacing to minimize power consumption.

Guaranteed performance and comprehensive warranty. Trojan systems include a Lifetime Disinfection Performance Guarantee. Ask for details.

Designed for Challenging & Large Scale Applications

System provides effective treatment of very low UVT effluent and large flows

Benefits:

- Use of high intensity lamps and chemical/mechanical sleeve cleaning overcomes operational limitations of low-pressure systems for low quality wastewater and large scale applications
- Capable of treating wastewater effluents with UV transmittance levels as low as 15% – eliminating the drawbacks and dangers of chemical disinfection
- Compact system designed for treatment of large wastewater flows of 10 MGD and greater
- Requires only 2.5 lamps per 1 MGD of secondary effluent
- Configurable in multiple channels, with single or multiple banks per channel, for optimal sizing based on upstream treatment processes & effluent quality

TrojanUV4000Plus™ Treatment Capabilities	
Disinfection Application	**Capability**
Primary Wastewater Effluent	Yes
Blended Wastewater Effluent	Yes
Secondary Wastewater Effluent	Yes
Fixed Film Processes	Yes
Tertiary Wastewater Effluent	Yes
Water Reuse Applications	Yes
Combined Sewer Overflows (CSO)	Yes
Sanitary Sewer Overflows (SSO)	Yes
Storm Sewer Overflows	Yes

The TrojanUV4000Plus™ has been optimized for disinfection of low quality wastewater using high intensity lamps, and vortex mixers (left) to increase flow turbulence around the lamps. Trojan's UV technology allowed the City of Honolulu, Hawaii to disinfect primary effluent at their Sand Island treatment facility (right), and thereby save hundreds of millions of dollars that would have been required to build secondary treatment facilities.

High Intensity UV Lamps

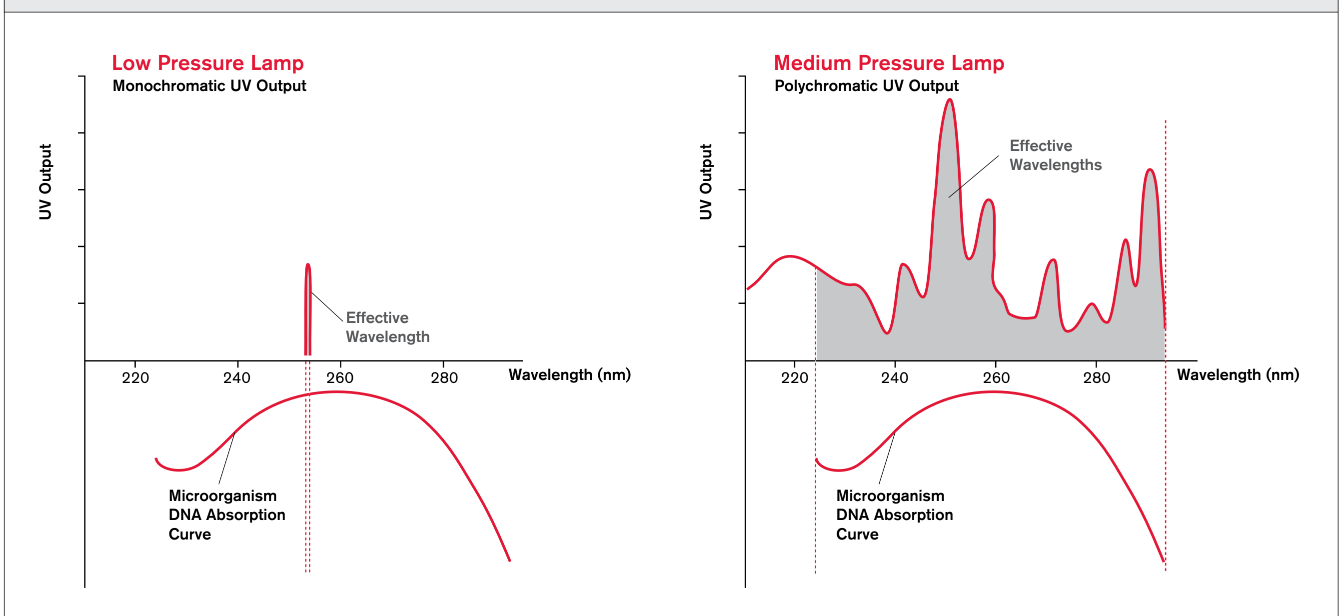
Medium-pressure lamp technology reduces number of lamps significantly

Benefits:

- High intensity, medium-pressure lamps produce significantly more UV energy than low-pressure lamps
- Reduced number of lamps – the TrojanUV4000Plus™ uses a fraction of the lamps required by conventional low-pressure UV systems
- Medium-pressure lamps are polychromatic, and produce a broad range of wavelengths – the majority of which are effective against microorganisms (see below)
- Fewer lamps allow the system to be located in compact spaces, reducing installation costs
- Minimize number of related components (sleeves, seals, wipers, ballasts, etc.), reducing O&M costs

Trojan pioneered the use of high intensity, medium-pressure ultraviolet lamps for wastewater disinfection. The technology minimizes the system footprint, and offers the capability of treating high flow rates, and low quality effluents with UVT levels as low as 15%.

Comparison of Low-Pressure and Medium-Pressure Lamp Technologies



The intensity and breadth of UV wavelengths delivered by medium-pressure lamps are significantly greater than low-pressure lamps. A larger portion of the ultraviolet light that medium-pressure lamps emit is absorbed by the DNA of microorganisms, which results in effective disinfection with fewer lamps.

User-Friendly Controls & Operation

Intuitive, touch-screen controller allows at-a-glance system monitoring and control

Benefits:

- PLC-based system monitors and controls all UV functions via an operator-friendly, touch-screen display on the System Control Center (SCC)
- Menu-driven interface simplifies access to all system functions, set points, and alarm reporting for fast accurate diagnostics of process or maintenance issues
- Automated dose delivery is based on lamp age, and other water parameters from optional sensors, including flow rate, UV transmittance, turbidity, etc.
- Discrete outputs and/or serial communication links to the plant SCADA system enable full remote monitoring

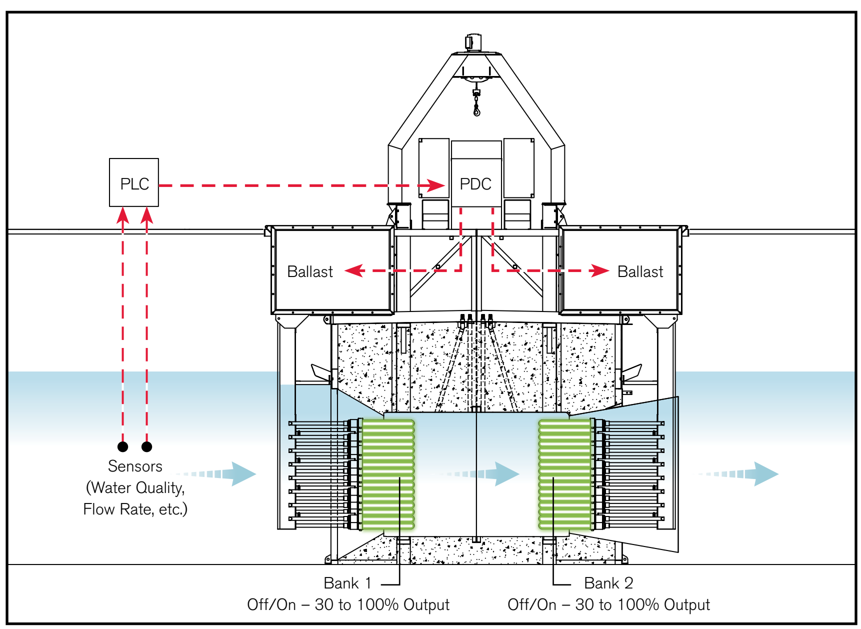
The PLC-based controller combines sophisticated system operation and reporting with an operator-friendly, touch-screen display.

Dose Pacing Reduces O&M Costs

System accurately matches UV output to disinfection requirements

Benefits:

- High efficiency ballasts vary output from 30 – 100% per bank in order to match UV dose with effluent quality and flow rate
- UV lamps are "dimmed" to optimize UV dose, and banks can be turned off during periods of no or low flow
- Multiple sensor inputs allow maximum efficiency so disinfection requirements are fully met using the minimum amount of power
- Dose pacing increases the operating life of UV lamps, thereby reducing the frequency, expense and labor required for lamp replacement



The dose pacing system of the TrojanUV4000Plus™ uses a PLC-based controller that monitors lamp age and water quality (e.g. flow rate, UVT, turbidity) and adjusts lamp output to ensure full disinfection is achieved using minimal power.

Design Flexibility Reduces Installation Costs

Compact system minimizes footprint and allows easy retrofit into existing facilities

Benefits:

- High intensity, medium-pressure lamps and unparalleled sleeve cleaning allow maximum disinfection in minimal space – over 100 MGD (15,780 m^3/hr) in a single effluent channel
- Requires only 1/8th to 1/15th the amount of space of chlorine disinfection, reducing construction and capital costs substantially
- System is designed for simplified retrofit into existing chlorine contact tank infrastructure, minimizing construction costs – and leaving the majority of the contact tank available for storage, by-pass or emergency back-up
- Electronic ballasts are inside the modules, eliminating the need for large ballast panels mounted beside the UV channel
- All system components can be installed outdoors

In this retrofit installation, each reactor was installed in one pass of the existing chlorine contact basin with only minor modifications to the channels. This allows the majority of the basin to be used for storage, by-pass or emergency back-up.

The eight TrojanUV4000Plus™ reactors used to disinfect 600 MGD (94,680 m^3/hr) at this large wastewater treatment facility require a footprint measuring only 80' x 120' (24 x 36 m) – a fraction of the space needed for chlorine disinfection.

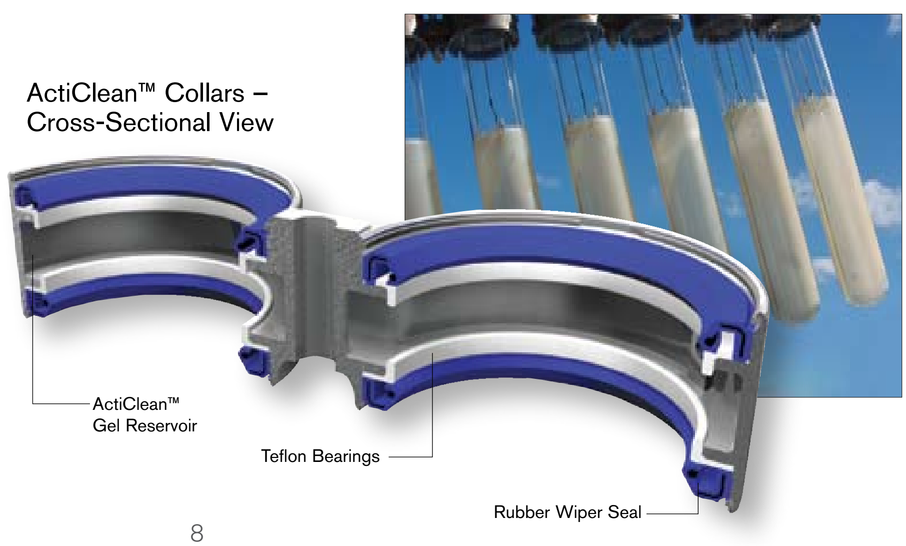
Unsurpassed Chemical/Mechanical Sleeve Cleaning

ActiClean™ dual-action cleaning system eliminates fouling and reduces maintenance costs

Benefits:

- Unsurpassed chemical/ mechanical cleaning system ensures optimal sleeve transmittance so maximum UV energy is delivered to the effluent
- Cleans automatically at preset intervals without disrupting disinfection, thereby reducing downtime and O&M costs of manual cleaning

ActiClean™ Collars – Cross-Sectional View



TROJANUV4000PLUS™

Operator Comments About the TrojanUV4000Plus™

"It does the job and it's simple to operate."

"It's user-friendly and low maintenance."

"We're getting a better kill than we expected. We've always dealt with chlorine and sulphur dioxide, but this does every bit as well. It doesn't seem to need as much maintenance – there's no dangerous chemicals, and it's cleaner."

System Specifications

System Characteristics	TrojanUV4000Plus™
Typical Applications	10 MGD and greater; primary, secondary, blended, and tertiary wastewater, CSO, SSO, and water reuse applications
Lamp Type	Medium-pressure, polychromatic UV output
Ballast Type	Electronic; variable-output (30 – 100%)
Input Power Per Lamp	3,200 Watts
Lamp Configuration	Horizontal, parallel to flow
Lamps Per Module	6 to 24
Modules Per Bank	2 to 7
Level Control Device Options	Fixed weir or motorized weir gate
Enclosure Ratings	
Module Ballast Enclosure	TYPE 6P (IP67)
All Other Enclosures	TYPE 4, 4X or 3R (IP56, IP65 or IP14)
Ballast Cooling Method	Closed loop system; no air conditioning or forced air required
Structural Materials	Wetted parts: 316 SST; Non-wetted parts: 304 SST
Maximum Ambient Temperature	122° F (50°C)
Sleeve Cleaning System	
ActiClean™ Cleaning System	Dual-action; chemical/mechanical; programmable for automated cleaning at defined intervals; manual override
ActiClean™ Cleaning Gel	Non-corrosive, operator-friendly
System Control Center	
Controller	Various PLC options; Ask your Trojan Representative for details
UV Intensity Monitoring	1 sensor per bank
Inputs Required / Optional	4-20 mA flow signal / 4-20 mA UVT signal
Typical Outputs Provided	Bank status, common alarms and SCADA communication
Maximum Distance from UV Channel	500 ft. (152 m)
Electrical Requirements	
Power Distribution Centers	50/60 Hz, 277/480V, 3 phase, 4 wire + ground or 50/60 Hz, 230/400V, 3 phase, 4 wire + ground
Hydraulic System Center	50/60 Hz, 120V, single phase, 2 wire + ground or 50/60 Hz, 230V, single phase, 2 wire + ground
System Control Center	50/60 Hz, 120V, single phase, 2 wire + ground or 50/60 Hz, 230V, single phase, 2 wire + ground

Find out how your wastewater treatment plant can benefit from the TrojanUV4000Plus™ – call us today.

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Trojan Technologies Deutschland GmbH (Germany): +49 6024 634 75 80
Hach/Trojan Technologies Inc. (China): 86-10-65150290

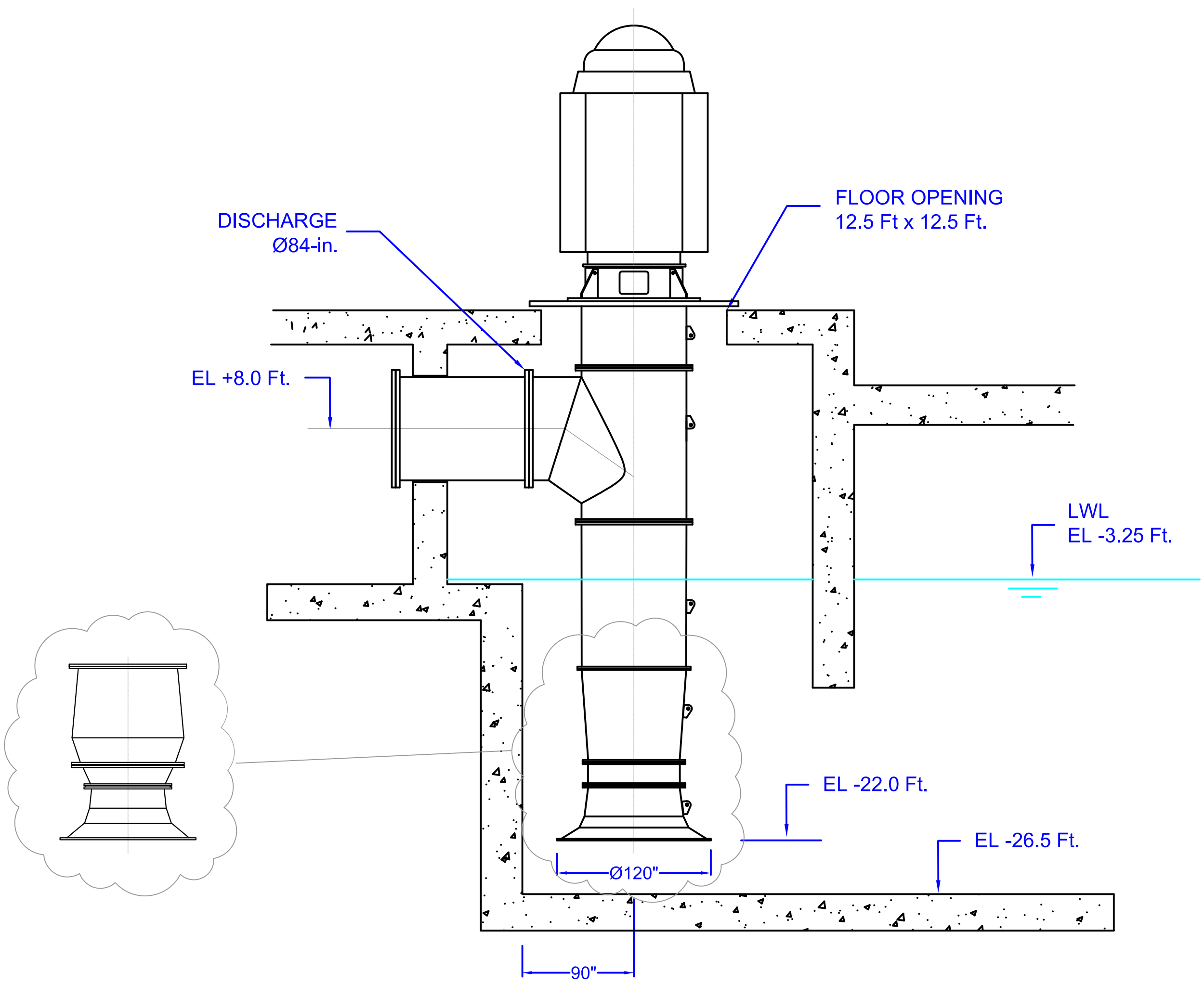
Products in this brochure may be covered by one or more of the following patents:
U.S. 5,418,370; RE 36,896; 6,342,188; 6,635,613; 6,663,318; 6,719,491; 6,984,834; 7,018,975
Can. 2,117,040; 2,239,925; 2,286,309
Other patents pending.

TROJANUV
WATER CONFIDENCE™

MWW-004 (1006) TROW-1035

APPENDIX D

PUMP TECHNICAL INFORMATION



NOTES:

- LAYOUT IS FOR GENERAL REFERENCE ONLY.
- FLOOR OPENING REQUIREMENT = 12.5' x 12.5' SQUARE; PUMP BASEPLATE = 14' x 14'
- PUMP DISCHARGE = Ø84-INCHES.
- PHASE 1 = AXIAL FLOW PUMP BOWL (167,000 GPM @ 23.5 FT. TDH) WITH 1350 HP @ 255 RPM MOTOR
- PHASE 2 = MIXED FLOW PUMP BOWL (167,000 GPM @ 32.0 FT. TDH) WITH 1850 HP @ 255 RPM MOTOR

MORRISON PUMP COMPANY

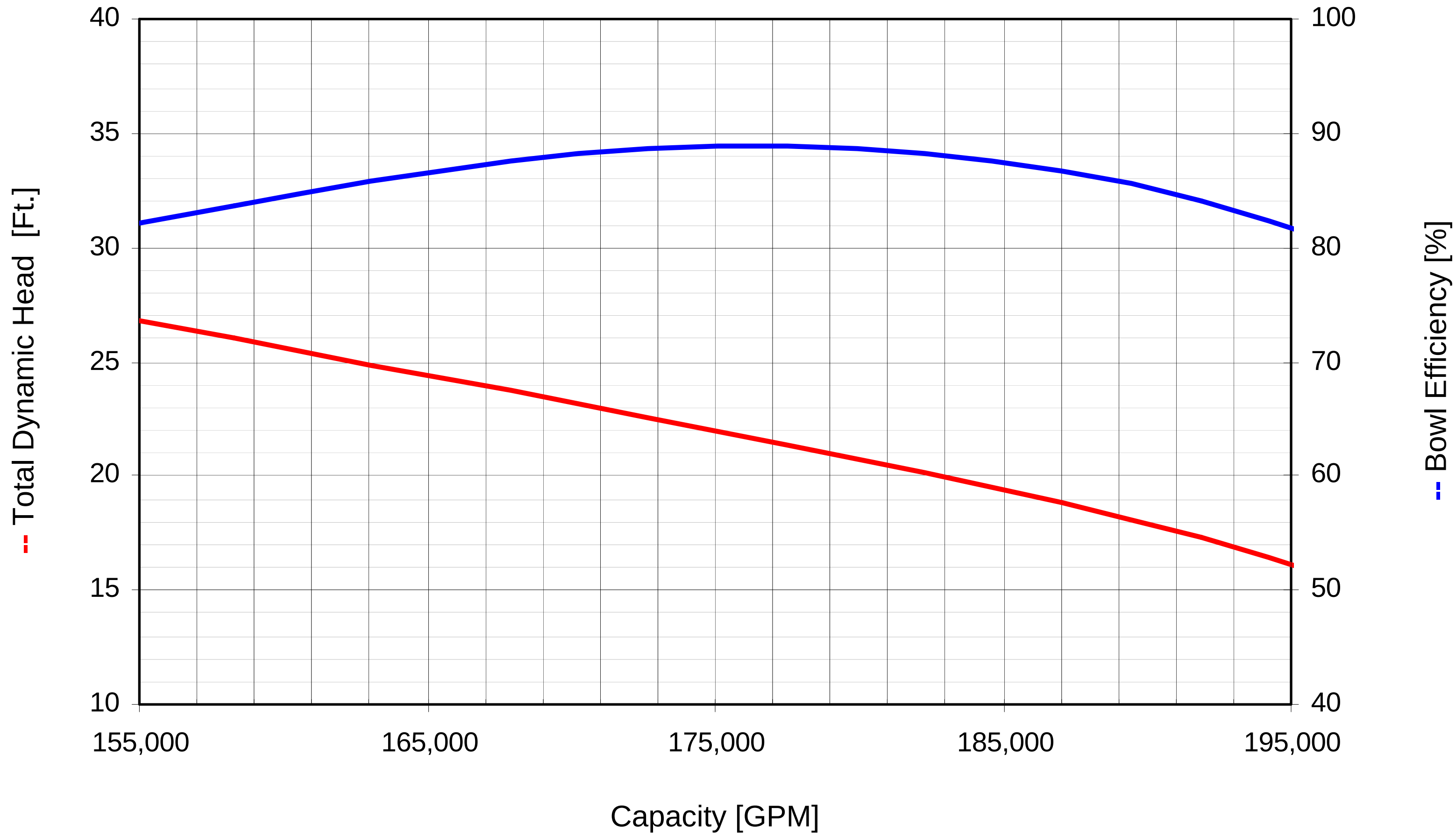
DWG. TITLE: Morrison Pump Model VPS-84-71 Station Layout	DWG NO.: DWG-28112-002C
FILE NAME: MWRDGC Stickney Water Reclamation Plant - CTE Engineering	DATE: 24-JULY-2008

Pump Performance

Axial Flow Impeller, Single Stage, High-Efficiency

Project No.: 28112-C1
Project Name: CTE – MWRDGC Stickney Reclaim Pumps
Date: 25-July-2008

Phase 1 : Design Point = 167,000 @ 23.5 Ft. TDH



Pump Bowl Model No.: MP-71-04-MH
Impeller Diameter: 70.25 in
Shaft Speed: 255 RPM

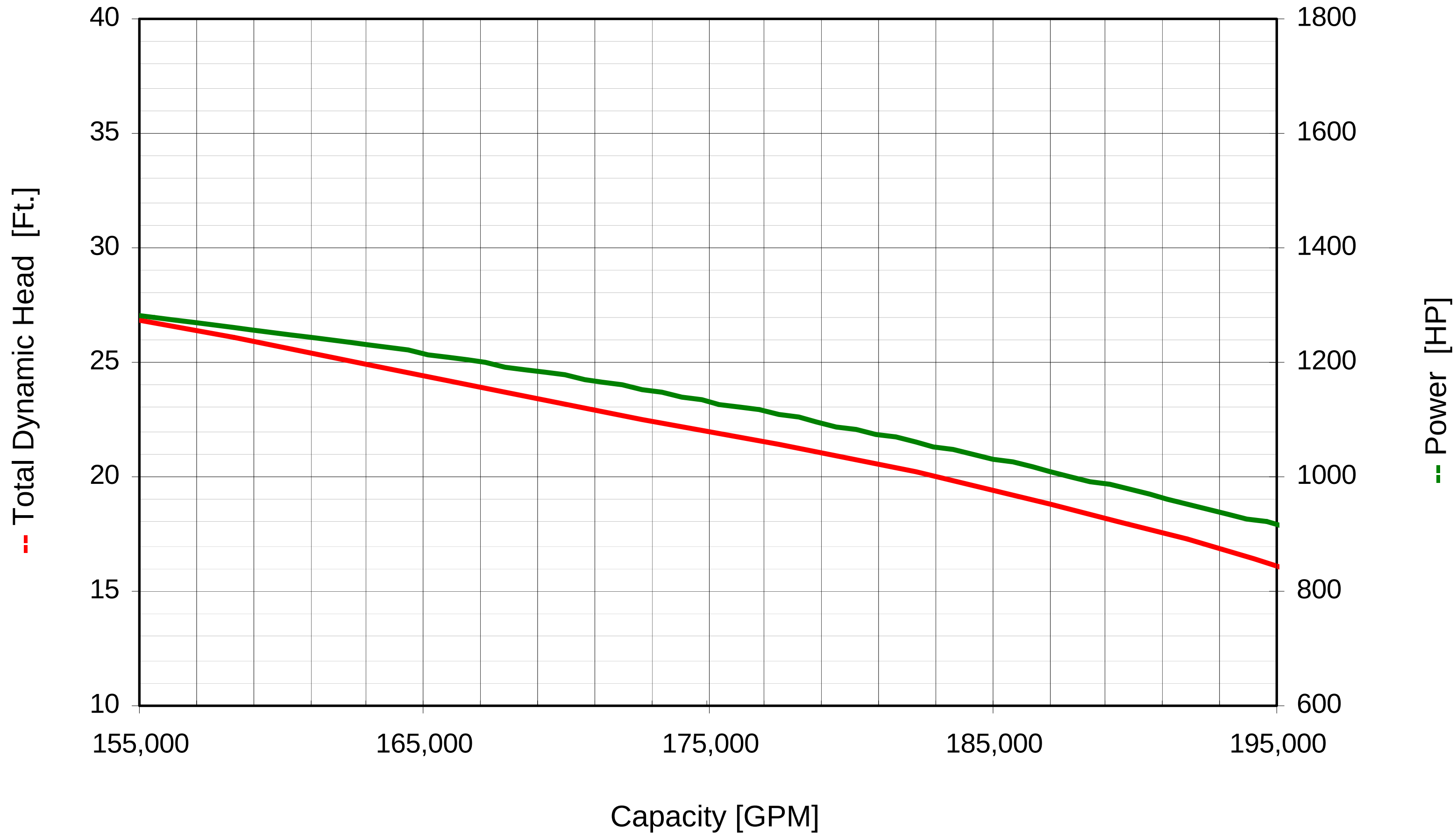
MORRISON PUMP COMPANY

Pump Performance

Axial Flow Impeller, Single Stage, High-Efficiency

Project No.: 28112-C1
Project Name: CTE – MWRDGC Stickney Reclaim Pumps
Date: 25-July-2008

Phase 1 : Design Point = 167,000 @ 23.5 Ft. TDH



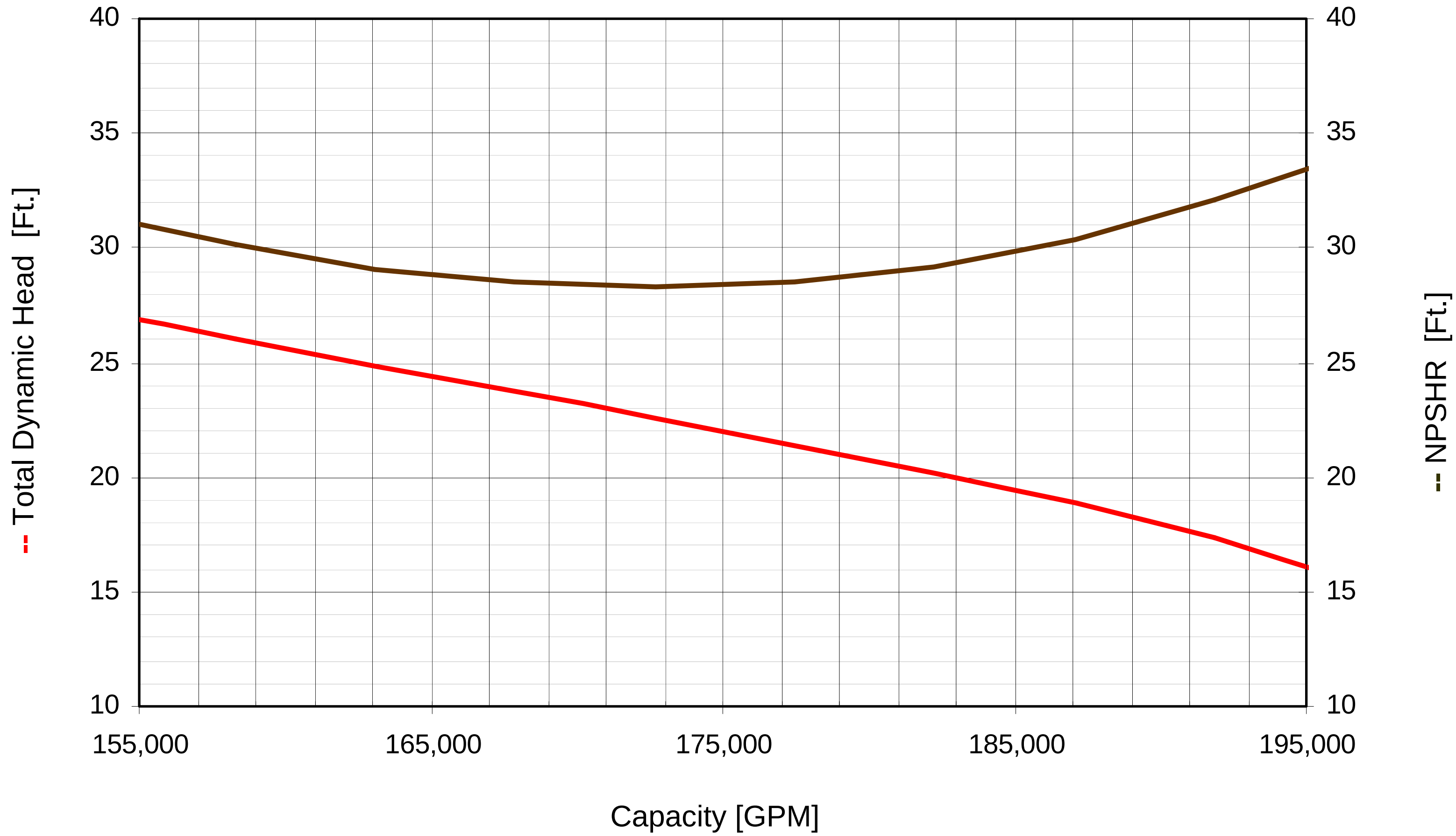
Pump Bowl Model No.:	MP-71-04-MH
Impeller Diameter:	70.25 in
Shaft Speed:	255 RPM

MORRISON PUMP COMPANY

Pump Performance
Axial Flow Impeller, Single Stage, High-Efficiency

Project No.: 28112-C1
Project Name: CTE – MWRDGC Stickney Reclaim Pumps
Date: 25-July-2008

Phase 1 : Design Point = 167,000 @ 23.5 Ft. TDH



Pump Bowl Model No.: MP-71-04-MH
Impeller Diameter: 70.25 in
Shaft Speed: 255 RPM

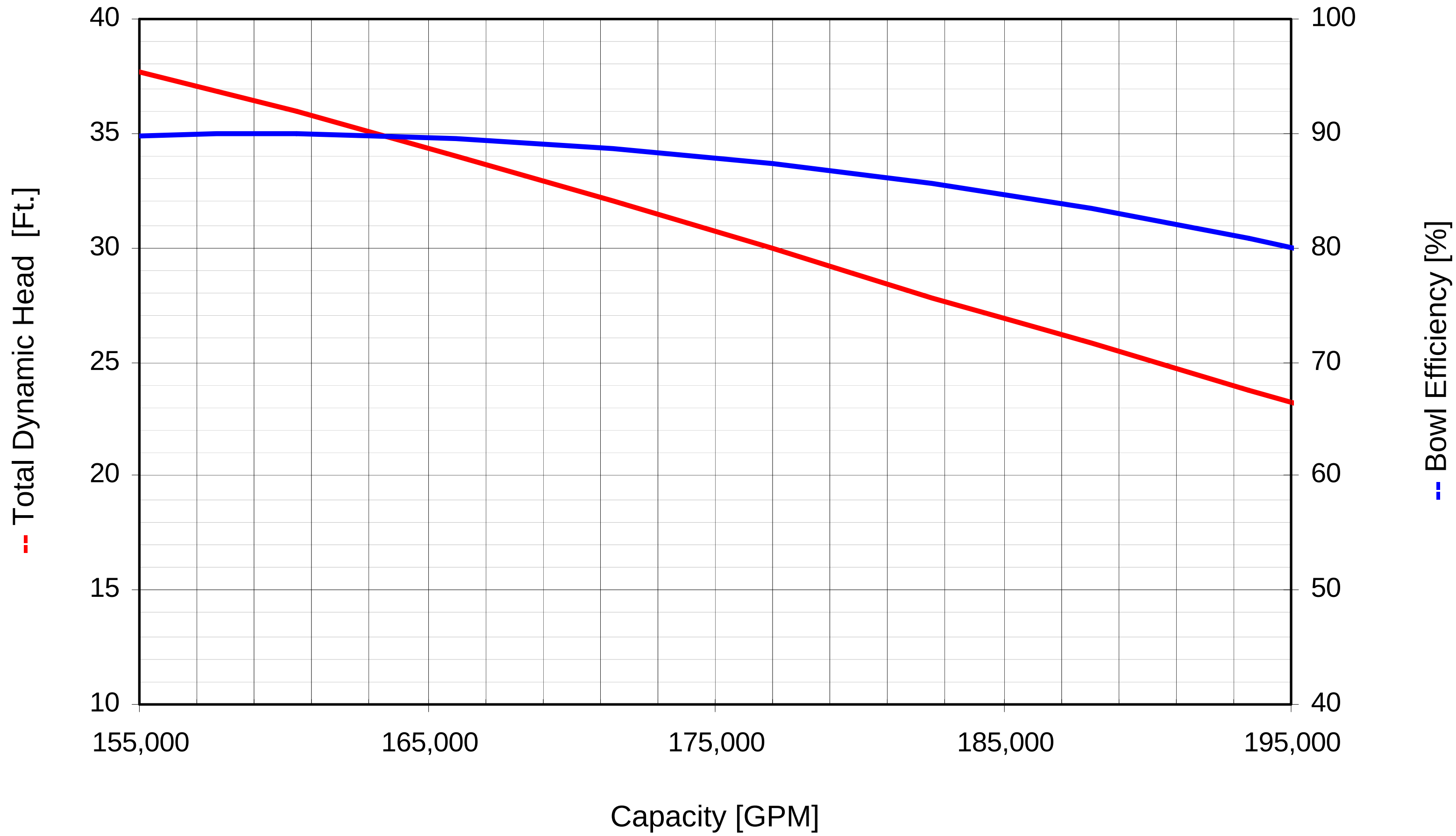
MORRISON
PUMP COMPANY

Pump Performance

Mixed Flow Impeller, Single Stage, High-Efficiency

Project No.: 28112-C2
Project Name: CTE – MWRDGC Stickney Reclaim Pumps
Date: 25-July-2008

Phase 2 : Design Point = 167,000 @ 32.0 Ft. TDH



Pump Bowl Model No.: MP-71-MB
Impeller Diameter: 70.5 in
Shaft Speed: 255 RPM

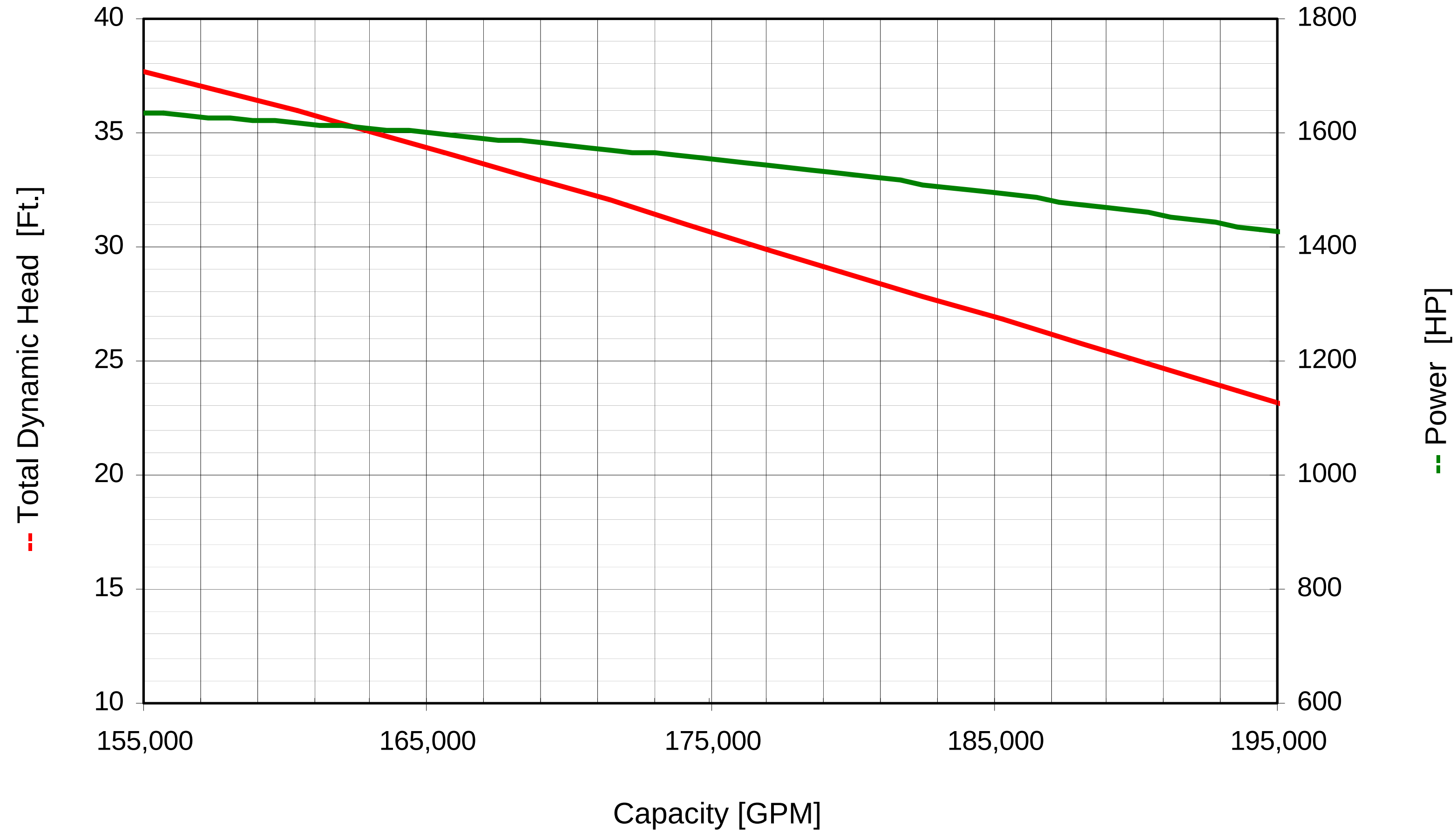
MORRISON PUMP COMPANY

Pump Performance

Mixed Flow Impeller, Single Stage, High-Efficiency

Project No.:	28112-C2
Project Name:	CTE – MWRDGC Stickney Reclaim Pumps
Date:	25-July-2008

Phase 2 : Design Point = 167,000 @ 32.0 Ft. TDH



Pump Bowl Model No.:	MP-71-MB
Impeller Diameter:	70.5 in
Shaft Speed:	255 RPM

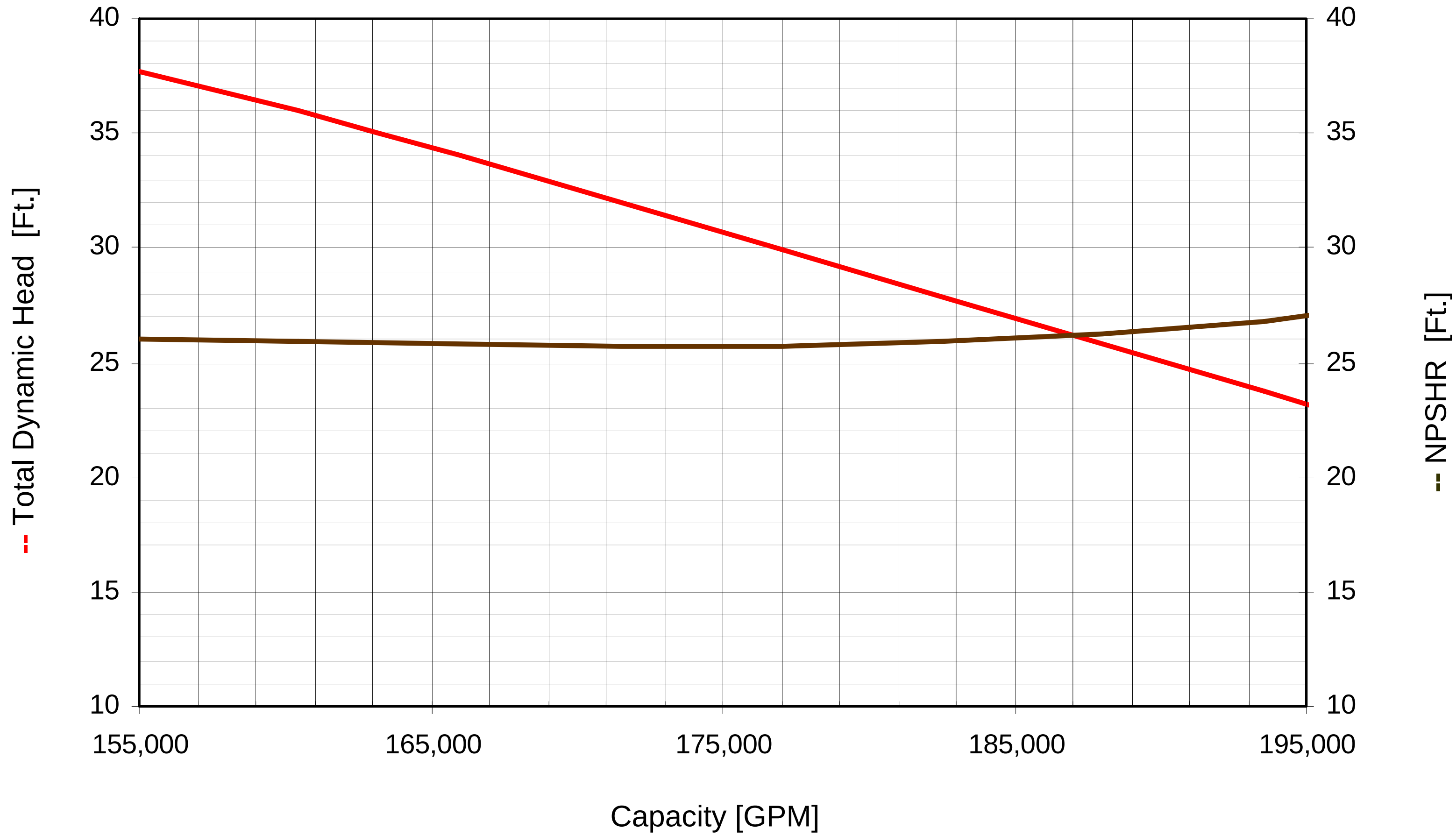
MORRISON PUMP COMPANY

Pump Performance

Mixed Flow Impeller, Single Stage, High-Efficiency

Project No.: 28112-C2
Project Name: CTE – MWRDGC Stickney Reclaim Pumps
Date: 25-July-2008

Phase 2 : Design Point = 167,000 @ 32.0 Ft. TDH



Pump Bowl Model No.: MP-71-MB
Impeller Diameter: 70.5 in
Shaft Speed: 255 RPM

MORRISON PUMP COMPANY

APPENDIX E

DRAFT GEOTECHNICAL DESIGN REPORT
FOR NEW PRELIMINARY TREATMENT FACILITIES AT STICKNEY AND CALUMET WRPS

Draft Geotechnical Design Report for Stickney WRP Phase I & IA

for

New Preliminary Treatment Facilities at Stickney and Calumet WRPs

Contract No. 04-823-3P

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

October 2007

1.0 GENERAL

This report provides preliminary geotechnical design recommendations for the design and construction of the new Preliminary Treatment Facilities at the Stickney Water Reclamation Plant (WRP) in Chicago, Illinois. Subsurface investigations were planned to be implemented in two phases. Phase I subsurface investigation was performed by O'Brien & Associates in 2006 during the preliminary design. Phase II subsurface investigation will be performed during the final design. In follow up to Phase I, a supplemental subsurface investigation was performed in 2007 as Phase IA. The purpose of Phase IA investigation was to better define the consolidation parameters of subsurface silty clay soils such that settlement of the proposed facility structures can be estimated with confidence.

The Phase II subsurface investigation is intended to identify the subsurface conditions underlying the finalized locations of the proposed facility structures. It is intended that this report will be updated at the conclusion of the Phase II investigation to provide a complete document summarizing the subsurface investigations at the site and final geotechnical recommendations.

A geotechnical data report was prepared by O'Brien & Associates for the Phase I and Phase IA investigations. Test boring locations are shown in the attached Figure 1. The proposed facilities layout is shown in Figure 2. For boring logs and associated field and laboratory test results refer to the Geotechnical Data Report, O'Brien & Associates, October 2007.

2.0 PROJECT DESCRIPTION

The new Preliminary Treatment Facilities at the Stickney WRP will consist of the addition of eight 225 ft diameter primary settling tanks (PSTs) with associated sludge and scum pumping facilities, a service tunnel, a new electrical building, and miscellaneous modifications of existing facilities. The new preliminary treatment facilities will be constructed west of the existing Preliminary Settling Tanks area. The eastern portion of the proposed site was previously used as ash lagoons and decommissioned several years ago. The western portion of the existing Preliminary Settling Tanks will be demolished to make room for the new facilities. The layout of the new facilities is shown in Figure 2.

The existing roadway network will be extended to provide vehicle and crane access to the proposed facilities and for operational needs.

3.0 PROJECT DATUM

The ground surface elevations and other elevations referred to throughout the report are based upon Chicago City Datum (CCD).

4.0 SITE INVESTIGATION

Twenty one test borings were drilled within the proposed project site as part of Phase I and Phase IA investigations. All of the test borings were sampled continuously from the ground surface to the apparent depth of the groundwater table or 20 feet (whichever was less) for geotechnical and environmental evaluations. Below the depth of continuous sampling, the borings were sampled at 5-ft intervals during Phase 1 and at 2.5-ft intervals during Phase 1A to the depth of boring. The test borings were drilled to the following depths:

Boring No.	Ground Surface Elevation	Depth of Boring (ft)	Depth to Groundwater (ft)	Groundwater Elevation	Top of Bedrock Elevation
ST-1	11.1	60	15 (see note 2)	-3.9	-48.9
ST-2	11.2	78.5	6 (see note 1)	5.2	-56.3
ST-3	17.0	71	33 (see note 3)	-16.0	-54.0
ST-4	18.5	61	12 (see note 3)	6.5	-42.5
ST-5	11.2	60	4 (see note 1)	7.2	-48.8
ST-6	13.1	67.5	14 (see note 3)	-0.9	-54.4
ST-7	13.1	70	43.5 (see note 1)	-30.4	-51.9
ST-8	18.9	75	20 (see note 1)	-1.1	-41.1
ST-9	19.4	59	14 ((see note 1)	5.4	-39.6
ST-10	18.4	61.5	6 (see note 3)	12.4	-43.1
ST-11	11.9	66	12 (see note 2)	-0.1	-48.1
ST-12	13.2	64	15 (see note 2)	-1.8	N.E.
ST-13	14.9	75	24 (see note 1)	-9.1	-48.1
ST-14	18.0	63.5	19 (see note 1)	-1.0	-45.5
ST-15	16.3	67.0	N.E.	N.E.	-50.7
ST-16	23.0	74	43.5 (see note 3)	-20.5	-51.0
ST-17	23.6	73	23 (see note 1)	0.6	-43.9
ST-18	23.2	76	18 (see note 1)	5.2	-53.8
ST-19	11.57	63.5	N.E.	N.E.	-50.9
ST-20	12.47	62	N.E.	N.E.	-48.0
ST-21	18.64	62.5	N.E.	N.E.	-43.1

Note 1. Observed groundwater level while drilling
Note 2. Observed groundwater after boring
Note 3. Observed groundwater level 24 hours or more after boring

- N.E. indicates 'Not Encountered'.

All borings were backfilled with cement grout to the ground surface upon completion. Observation wells W-1, W-2, and W-3 were installed at the offset locations to test borings ST-1, ST-12 and ST-4, respectively.

Figures 3, 4, and 5 show the geologic profiles within the proposed Preliminary Treatment Facilities.

During Phase I investigation the soil samples collected above the apparent groundwater table were screened in the field for volatile organic compounds (VOCs) using a photo-ionization detector (PID). PID readings varied between 0 and 84 ppm and are included in the Phase I and IA Geotechnical Data Report (October 2007).

In addition to the present Phase I and Phase IA investigations, other investigations were performed previously north and east of the proposed site. The following list includes the previous investigations:

1. 1946 Drawings: West- Southwest Sewer Treatment Work – Aeration Tanks, Final Settling and Operation Gallery. Sheet P-3 shows the boring and test pit logs (only subsurface soil layers are identified).
2. 1965 Drawings: West-Southwest Sewer Treatment Work – Division AE (excavation and piling plan). Sheets P-6, P-7, and P-8 show the location and profiles of test pits and borings (only subsurface soil layers are identified).
3. 1968 Soil Testing Services, Inc. report on Subsurface Investigation for the proposed West Influent Conduit.

5.0 SITE CONDITIONS

The proposed facilities will be constructed at the southwest area of the Stickney WRP site. The eastern portion of the proposed site was previously used as ash lagoons. The 1946 drawings of Aeration Tanks, Final Settling and Operation Gallery show the existing grade at EL +10 to +12. The 1967 drawings of Alteration of Existing Preliminary Tanks show construction of Ash Lagoons at the eastern portion of the proposed site. The Ash Lagoons were subsequently decommissioned and the area is currently covered with soil to EL +18. It is not known how much of the ash has been removed prior to decommissioning the lagoons and filling with soil. Further discussion on the environmental evaluation of the Ash Lagoons is provided in Section 10.0 of this report.

The western portion of the proposed site is generally at EL +11 ±.

There is an existing interceptor, the Salt Creek Interceptor, that runs diagonally across the proposed site and is buried below existing grade. There is also an existing interceptor, the Northwest Interceptor, that runs north-south across the site.

The final grade surrounding the proposed facilities will approximately be at EL +20.5.

6.0 REGIONAL GEOLOGY

The surficial geology indicates that the project is located on the flat glacial lacustrine deposits associated with Lake Chicago (present day Lake Michigan). Niagrian Age limestone forms the bedrock in this area. The bedrock is overlain by approximately 50 ft of overburden soils at the site.

At the beginning of the Pleistocene Age, this region had a moderate layer of residual soil overlying the bedrock and the topographic relief was greater than at present. A series of continental ice sheets planed down the limestone bedrock surface and deposited a layer of soil and rock fragments on top of the bedrock. Several of the ice sheets advanced beyond the edge of Lake Chicago and built up higher ridges or terminal moraines composed predominantly of glacial till. The glacial till may be variable in texture and is primarily a heterogeneous mixture of sand and gravel bound in a dense clay and silt matrix. Typically boulders are encountered in the glacial till.

As the last glaciers (Wisconsinan Stage) receded, the melt waters formed Lake Chicago; drift materials were deposited in the lake and formed what is referred to as glacial lake bed sediments or glaciolacustrine soils. The glaciolacustrine materials are predominantly layers of bedded silt and silty clay containing thin beds of more plastic clay with local lenses of sand along beaches.

Several stages of Lake Chicago existed during the glacial period. During the low water level periods, desiccation occurred resulting in zones of higher strength soils. Variations of shear strength and compressibility of the soils at the site can be partially attributed to this desiccation.

7.0 SUBSURFACE CONDITIONS

Specific soil conditions encountered in the borings are indicated on the soil boring logs included in the Phase I and IA Geotechnical Data Report, October 2007, by O'Brien & Associates. As indicated on the logs, variable fill materials and organic clays were encountered to a depth range of 7 ft to 14 ft in the borings performed within the former Ash Lagoon. In the borings performed in the paved areas east of the lagoon, fill materials and organic clays were encountered to a depth range of 14 ft to 18 ft. In the borings performed in the area west of the lagoon, topsoil and/or variable fill materials were generally encountered to a depth range of 3.5 ft to 6 ft; however, deeper fill was encountered at boring ST-3 to a depth of 10 ft and at boring ST-1, 7 ft of fill material was underlain by a one-foot layer of fibrous peat. At boring ST-6, 4 ft of low strength and high moisture organic clay was encountered at a depth of 21 ft to 25 ft. At boring ST-13, a buried 2 ft layer of top soil was encountered at a depth of 4 ft which was underlain by 14-ft layer of soft to stiff wet clay.

Native soils encountered beneath the fill materials and organic materials generally consisted of stiff to very hard silty clay soils. These soils underwent a color change from brown and gray to gray within a depth range of 8 ft to 16 ft below ground surface in the borings performed west of the former Ash Lagoons, within a depth range of 12 ft to 18 ft in the borings performed within the lagoon area and at an approximate depth of 22 ft in the borings performed east of the lagoons. In most of the borings, the gray silty clay was observed to have discontinuous sand or silt seams and slightly higher granular contents at deeper elevations and was observed to become hard to very hard within elevations ranging from EL-10 to EL -22.

The gray silty clay soils were underlain by fractured rock encountered within a depth range of 59 ft to 76 ft which corresponds to elevations ranging from EL -48.9 to EL -60.1. At boring ST-8, rock cores recovered from EL-41.1 to EL -56.1 were noted to consist of cobbles and boulders or highly fractured rock. At boring ST-7, the rock core recovered from EL -51.9 to EL -56.9 was noted to consist of light gray, highly fractured Silurian Dolomite with horizontal to wavy bedding and a Rock Quality Designation (RQD) of 16.7%.

8.0 GROUNDWATER EVALUATION

Observation wells W-1, W-2, and W-3 were installed at the offset locations from test borings ST-1, ST-12 and ST-4, respectively, during the Phase I investigation to obtain groundwater readings over an extended period of time of one to two years to establish long-term groundwater fluctuations. The bottom of well screens ranged from EL -7.8 to EL +0.5. Groundwater readings from W-1, W-2, and W-3 are shown in the following table.

Date of Reading	Groundwater Elevation		
	Obs. Well W-1 Adjacent to ST-1 Ground EL +11.6	**Obs. Well W-2 Adjacent to ST-12 Ground EL 13.8**	**Obs. Well W-3 Adjacent to ST-4 Ground EL 18.5**
5/18/06	-3.39		
6/2/06		-1.06	
6/16/06			+6.54
4/9/07	+4.68	+12.09	+11.16
9/21/07	+4.58	+11.89	+10.96

The District will be taking groundwater readings at the observation wells on a periodic basis. It should be noted that groundwater level fluctuates with precipitation, season, construction activities and other factors. As a result, water levels during construction may vary from those observed during the subsurface investigation.

There are two components with respect to the groundwater within the overburden soils above the bedrock. The first is the piezometric head or the hydrostatic level measured by a piezometer or an observation well; and the second is the ability of the overburden soils to release/produce water during an excavation, which relates to the soil permeability.

Hydrostatic Level: The hydrostatic level is normally measured by installing a piezometer or an observation well within the depth of interest.

Soil Permeability: The overburden soils above the bedrock, in general, consist of silt and clay and therefore are considered to have low permeability. Soils with low permeability are not likely to produce much water during the temporary excavation and construction period (i.e., one to two years). However, the overburden soils will return to their hydrostatic equilibrium during the design life of the facility structures, which is 50 years or more. This hydrostatic equilibrium will saturate the fill soils placed under and around the facility structure. The surrounding fill soils and groundwater below and around the facility structure forms a "bath tub" effect, resulting in hydrostatic uplift and floatation of structures and hydrostatic pressure on the exterior below grade walls.

In summary, temporary excavation during construction period may not produce much water that would require a major dewatering effort. However, during the service life of the structure the hydrostatic level will be at a level consistent with the existing overall site groundwater level. Seasonal fluctuations in the groundwater should be expected depending upon variations in precipitation, evaporation, and surface run-off. Man-made items influencing/balancing the groundwater level within the proposed site include water seepage through bedding stone around large diameter pipes, seepage and percolation of surface water, and possible leakages from nearby tanks and conduits.

In deciding the design groundwater table, considerations must be given to the influence of inevitable seepage and percolation of surface water and possible leakage from underground conduits. The prevailing cohesive soils will retard downward percolation of this infiltration and the effect of trapped water on the below ground structure walls will be similar to the static water table. Considering the available data and topography of the nearby area to the west and south of the site, a preliminary design groundwater at EL +12.0 is recommended for the proposed facilities.

9.0 TESTING

The results of Phase I and IA laboratory testing are provided in the Geotechnical Data Report (O'Brien & Associates, October 2007).

The laboratory testing of soil and rock characteristics consisted of grain-size analysis (ASTM D422), moisture content (ASTM D2216), Atterberg limits (ASTM D4318), unconfined compressive strength of soil (ASTM D2166) and consolidation testing (ASTM D2435). Based upon the grain-size analysis and Atterberg Limits, the subsurface soils were mostly classified as CL (clay with low plasticity) in accordance with the Unified Soil Classification (USC) system.

Soil samples were tested in accordance with the corrosion testing series AASTHO T-288 to T-291. The testing results indicate that the chloride concentration ranges from 16 to 170 parts per million (ppm). The American Concrete Institute (ACI) does not publish recommendations for submersion in concrete; however, the recommended limit for chloride in mixing water is 100 ppm. The sulfate concentration ranges from 815 to 1309 ppm. This is in the range classified by ACI 201, *Guide to Durable Concrete*, as the high end of "Moderate" sulfate exposure. ACI 201 requires the use of ASTM C 150 Type II cement limited to a water-cement ratio of 0.42 and a minimum design strength of 4500 pounds per square inch (psi). If the requirements of the Metcalf & Eddy Cast-in-Place Concrete specification are met, the effect of chloride and sulfate concentrations on the facilities concrete should be negligible. The pH of samples ranges from 6.9 to 7.5. This range of pH is not a concern for acid attack on concrete.

10.0 ENVIRONMENTAL ASSESSMENT OF ASH LAGOONS

MWRDGC has informed M&E/CDM Design Partners that it believes that the ash that was disposed in the former ash lagoons at the site of the proposed primary settling tanks was the end product of the Zimpro System process. The Zimpro System process was apparently a heat treatment process wherein biosolids were treated using heat and air with final operating temperatures of 350 to 600 degrees F. The residual "ash" was subsequently dewatered in these drainage beds or ash lagoons.

A regulatory analysis has not been conducted. Generally, the wastewater treatment process, the biosolids, and stabilized sludge are considered to be regulated under the Clean Water Act and are exempted from the body of regulations which manages solid and hazardous waste. Illinois Title 35, Subtitle C, Chapter II, Part 391 Design Criteria for Sludge Application on Land permits the application of stabilized sludge to the treatment plant grounds by specifically permitted generators. It is not clear whether the related non-ash material, such as affected soil, could be handled similarly. We have not investigated whether the facility is permitted to land-apply stabilized sludge although they are permitted elsewhere (Fulton County, IL). If the ash or affected soil is removed from the NPDES-permitted process (currently known as Remediation General Permit or RGP), such as excavated and transported from the current location, it may be interpreted that the material is a solid waste and is subject to attendant waste regulations.

Ash was not reported on the boring logs drilled in the area of the ash lagoons and it is assumed that ash was removed prior to closure. Based on the identification of "fill" and "organic clay" the thickness of the fill materials ranged from seven feet in ST-15 to 14.5 feet in ST-4. The lateral extent of the former ash lagoons and fill was not determined.

Testing Summary: Chemical testing of the soil in the area of the former ash lagoons indicates that it contains certain regulated chemicals, classes of chemicals, and elements. The volatile organic chemical, methylene chloride, was detected in soil sample ST-14 S-9 at a concentration of 0.0235 mg/Kg. This concentration in soil is below the State cleanup guideline concentrations that have been established for direct exposure for industrial, commercial, and residential use. *This concentration is, however, above the State cleanup guidelines for concentrations in soil that are considered protective of Class I groundwater but below that which is considered protective of Class II groundwater*. Acetone, 2-butanone, carbon disulfide, and toluene were detected at concentrations below State guidelines for cleanup in ST-9 (acetone and 2-butanone), ST-4 (carbon disulfide), ST-10 (carbon disulfide), and ST-14 (carbon disulfide). Semi-volatile organic chemicals and PCBs for which the samples were tested were not detected. Diesel-range organic and gasoline-range organic chemicals were detected in several samples but there are no state standards for these.

Cadmium was detected at a concentration of 0.0244 mg/L and 0.0099 mg/L in soil sample ST-4 S5 and St-14 S5, respectively. Lead was detected at concentrations of 0.0383 mg/L, 0.0192 mg/L, and 0.0103 mg/L in soil samples ST-4 S3, ST-4 S5, and ST-14 S5, respectively. These concentrations in soil are below the State cleanup guideline concentrations that have been established for direct exposure for industrial, commercial, and residential use. *These metals were however, detected at concentrations greater than the State guidelines for cleanup that are considered protective of Class I groundwater but were below that which is considered protective of Class II groundwater.*

The material sampled is reported to exhibit low moisture content and is assumed not to be a liquid. The material is not aqueous. There is no indication that the material is or would be expected to be reactive. There is no indication that the material is ignitable. TCLP analysis of the samples tested indicates the leached concentrations of detected analytes are below disposal standards. The material does not appear to be a characteristic hazardous waste. Depending on the regulatory status and the need to remove the ash and surrounding soil, the material may be required to be managed as a special waste and transported and disposed of according to state requirements.

Discussion: Based on MWRDGC's assessment of the genesis of the ash, a regulatory analysis could be conducted to determine: a) the regulatory status of the ash, b) the regulatory status of related soil, and c) if MWRDCG has a permit to apply stabilized sludge directly on the facility. During subsequent sampling and analysis, specific testing could be conducted to confirm that the impacted material is not a characteristic waste so that a determination for disposal can be made. Based on the regulatory analysis, subsequent testing could be conducted to determine the classification (Class I or Class II) of groundwater beneath the facility.

It was noted that measurements made by a photoionization detector (PID) of soil collected during the geotechnical testing indicates elevated ionizable organic vapor. Although this field screening is not species-specific, it is a useful indicator that ionizable organic chemicals are likely present in the soil or groundwater. It may be valuable to note that methane is not detectable using this instrument. The PID instruments which are commonly employed respond to elevated moisture by registering a lower value, often a negative value. Future work could include efforts to confirm whether the relevant soil or groundwater contains organic chemicals that may have implications regarding handling and management of these materials.

11.0 GEOTECHNICAL DESIGN PARAMETERS

Based on the review of geotechnical laboratory test results of the test borings and soil descriptions from the boring logs, the following preliminary average soil parameters were established:

Fill around structures:

Total unit weight = 130 pounds per cubic foot (pcf)

Silty Clay between EL +3.0 and EL -12.0:
Total unit weight = 130 pcf
Compression Coefficient, Cc = 0.21
Recompression Coefficient, Cr = 0.02
Initial Void Ratio, e_0 = 0.55

Silty Clay below EL -12.0 to top of bedrock:
Total unit weight = 130 pcf
Compression Coefficient, Cc = 0.11
Recompression Coefficient, Cr = 0.01
Initial Void Ratio, e_0 = 0.55

Maximum Past Pressure: Based on the consolidation tests performed during Phase I and IA, the entire Silty Clay layer is over-consolidated with an average over-consolidation ratio of 2.7. In 90% of the consolidation test results it was found that the maximum past pressure is larger than the vertical effective overburden pressure plus the additional pressures from the proposed facility construction. Therefore, the settlement calculations were made based on the recompression ratios of the silty clay soils.

12.0 PROPOSED FACILITY FOUNDATION INFORMATION

The main components of the Preliminary Treatment Facilities include the following:

1. Primary Settling Tanks: The primary Settling Tanks (PSTs) consist of eight, approximately 225 ft diameter concrete tanks. The tanks will have a conical bottom with vertical side walls. The bottom of foundation at the outside edge of each tank is approximately EL +4.75 sloping down to EL -16.2 at the center hopper area. Note that for the purpose of estimating the bottom elevation of foundations, a 2-ft thick concrete foundation mat was assumed and the elevations were rounded to 0.5 ft.

2. Influent and Effluent Conduits and Junction Chambers: The Influent and Effluent Conduit's bottom of foundation elevations are at approximately EL +6.0 and EL -11.5 respectively. The Junction Chambers' bottom of foundation is at EL-11.5.

3. Service Tunnel: The bottom of foundation elevation of the Service Tunnel is approximately at EL +3.5.

4. Tunnel Access Pump Stations 1 and 2: The bottom of foundation elevation is approximately at EL -1.0.

5. Other miscellaneous structures (such as the new Guard House) and water main improvements.

13.0 FOUNDATION TYPE OF EXISTING FACILITY STRUCTURES

The foundation types of the existing facility structure adjacent to the proposed facilities are as follows:

1. The 1946 drawings of the Stickney Plants show that the Final Settling Tanks 1 through 24 (Battery C) immediately north of the proposed site are soil supported (i.e., no pile foundation) (refer to Figure 6). The Final Settling Tanks are 126 ft in diameter (I.D.). The bottom of foundation at the outside edge of each tank is approximately EL 1.0 sloping down to approximately EL -4.0 at the center hopper area. Groundwater pressure relief valves are shown at the bottom of the tanks on the design drawings for these facilities. The presence of pressure relief valves suggest that the anticipated design groundwater must have perceived to be high and therefore the pressure relief valves were used to mitigate tank floatation.

2. The 1965 drawings of Stickney Plant expansion show that the Preliminary Settling Tanks number 7 to 10 and 17 to 20 at the east of the proposed site are pile supported. The 1965 drawings and specifications indicate that 25 ft pressure treated timber piles with 20-ton capacity were used. Piles were driven 15 ft in to the clay layer to achieve 20-ton capacity. Prevailing top of piles are approximately at EL 9.5, therefore, the top of bearing stratum was anticipated at approximate EL -0.5.

3. The 1968 Soil Report by Soil Testing Services, Inc. for the West Influent Conduit, Battery D, which is located immediately east and north of the proposed site, recommended 3000 psf net allowable bearing pressure at EL -0.5 (i.e., the bottom of conduit). The conduit is 10 to 28 ft wide and 12 ft high. Top of conduit is at EL 16.88. Subsequent 1969 design drawings of the conduit, Sheets C-107 & 108, show that the north-south leg of conduit adjacent to the Preliminary Settling Tanks is supported on 24" diameter concrete caissons with a bottom bell diameter of approximately 5 ft. The remaining portion of the conduit is shown to be soil supported. The caissons are indicated to be embedded a minimum of 10 ft in to the glacial till. No other information is available to substantiate the purpose of the caissons.

4. The 1969 Drawings of Battery D show that all Battery D Final Settling Tanks (1 though 24) are supported on concrete caissons (Tanks are approximately 1500 ft) north of the proposed site). The caisson shafts are 18" in diameter and embedded a minimum of 10 ft in to the glacial till. Based on the design drawings, the top of glacial till in the area of the final settling tanks varied from EL -1.0 to EL -19.0. The tanks are 126 in diameter. The bottom of foundation at the outside edge of each tank is at EL +0.5 and the bottom of center hopper is at EL -12.8. Drawing sheet C-88 indicated that the caissons were designed for 10,000 pounds per square foot of bearing capacity suggesting that each caisson can carry a compressive load of 63 tons. Reinforcing steel rebars in most caissons extend to the bottom of bell suggesting that caissons may have

been designed for tensile load (resisting uplift) as well as compressive load. A total of 4,848 caissons were used to support the Battery D Final Settling Tanks. Battery D Aeration Tanks south of the Battery D Final Settling Tanks are not pile supported. Two feet thick underdrain is shown under the entire foundation footprint with steel sheet pile cutoff walls around the perimeter of aeration tanks.

Figure 6 shows the location of the above mentioned existing facility structures with respect to the proposed site of the PSTs.

14.0 PRELIMINARY GEOTECHNICAL RECOMMENDATIONS

1. Based on the proposed PSTs estimated foundation pressure of 2000 pounds per square foot and placement of excess fill to raise the grade around the proposed PSTs to EL +20.5, the total settlement of the PSTs is estimated to be less than 1.0 in. at the center of tank and 0.5 in. or less at the edge of tank. The settlement associated with fill placement around the PSTs is estimated to be 1.0 in. Therefore the total tank settlement is estimated at less than 1.5 in. and the differential settlement between the center and the edge of the tank is estimated to be in the order of 0.5 in. which is within the allowable settlement range of concrete mat foundation. A published computer program entitled SAF-1 (Productivity Tools for Geotechnical Engineers, Vol. I by John T Christian and Alfredo Urzua, Magellan Press, 1996) was used to calculate the one dimensional consolidation settlement.

   The above calculated settlement is based on the consolidation characteristics of underlying natural soils below the proposed facility structures. The consolidation parameters were established based on twenty consolidation tests and other physical and mechanical properties testing of the underlying silty clay soils. It should be noted that there are pockets or lenses of soft organic clay within the site which extends to an EL -12 (encountered in boring ST-6). The organic clay pockets will contribute to a significant local settlement in addition to the overall consolidation settlement. Therefore during the Phase II subsurface investigations, the thickness, extent, and consolidation characteristics of the organic clay pockets, if encountered, should be established to the extent possible and practical.

   The total settlements of Influent and Effluent Conduits, Junction Chambers, Service Tunnel and Tunnel Access Pump Stations are estimated to be less than 1.0 inch. This settlement is due to placement of fill to raise the grade to EL +20.5. The differential settlement is estimated to be 0.5 in. or less within 100 ft length of the conduits. These settlements are within allowable range for concrete mat foundations.

   Foundation recommendations for miscellaneous structures (such as new Guard House) and water main improvements will be provided during the final design once subsurface investigations are performed for these items during Phase II.

2. The proposed Influent and Effluent Conduits and Service Tunnel must cross over the existing Northwest and Salt Creek Interceptors. In order to protect these interceptors from additional loads exerted by the proposed conduits and by the fill placed to raise the

grade elevation around the proposed PSTs, a concrete relieving platform should be constructed over the interceptors and the load from the proposed conduits transferred to the soils below the interceptors via pile foundation. The piles should be non-displacement in order to avoid damage to the existing interceptors. Accordingly, 14-inch diameter bored piles (drilled Shafts) with an allowable axial compression capacity of 50 tons are recommended. The piles should derive their capacities from the soil/bedrock below the invert of the existing interceptors. The invert elevation of Salt Creek interceptor is approximately at EL -26.0 and the invert elevation of Northwest interceptor is at El -13 and deeper. Pile design and static and dynamic pile load testing requirements will be established during the final design.

3. A design groundwater level of EL +12 is recommended for hydrostatic uplift calculations. As discussed in a previous section of this report, the design groundwater accounts for long term (i.e., design life) fluctuations of groundwater level. It is also recommended that groundwater readings continue to be taken by the District through the end of the final design phase to provide data on the fluctuations of groundwater levels to the construction contractor. Pressure relief valves integrated with the proposed structures may be considered to counterbalance the buoyancy.

4. For lateral earth pressure calculations on the below grade foundation walls of the proposed facility structures, equivalent fluid unit weights of 85 pcf and 110 pcf are recommended above and below the design groundwater table, respectively, to EL +3.0. This recommendation is based on re-use of suitable on-site excavated silty clay materials. Lateral earth pressures may be lower if imported granular materials are used for backfill. Foundation walls below EL 3.0 should be designed for an equivalent fluid unit weight of 130 pcf. The equivalent unit weights of 110 and 130 pcf include hydrostatic pressure. These equivalent fluid unit weights are based on the at-rest condition due to wall restraint against rotation.

   A uniform vertical surcharge load of 300 psf at grade is recommended for the foundation wall design. The resulting uniform lateral pressure is 200 psf along the top 20 ft of wall height for all structures. Wheel load for trucks and cranes should also be considered as point loads in the design of below grade walls in accordance with Figure 7. Furthermore, lower level foundation walls should be designed for an additional uniform lateral pressure equal to 0.65 times the vertical pressure of upper levels foundation mat.

5. Seismic Design Requirements: For the design of above ground structures, seismic site coefficient should be 1.0 in accordance with the BOCA National Building Code. Applicable requirements of the Chicago Building Code should be considered in the seismic design.

6. Liquefaction potential was evaluated for the soils below the foundation. The foundation soils are sufficiently dense and contain over 50% fines. Based upon the density and fine content, the foundation soils are not susceptible to liquefaction.

7. Foundation preparation consisting of 6-inch layer of screened gravel over 6-inch layer of sand is recommended. See attached Detail 2-9.1.2 (Figure 8). Alternatively 4-in. thick layer of concrete mud mat may be placed over the compacted foundation subgrade.

15.0 CONSTRUCTION CONSIDERATIONS

1. Backfill around structures: The excavated on-site materials free from organic silt or organic clay, peat, ash or sludge, vegetation, wood or roots, biodegradable matter, construction debris or refuse may be used around structures as approved by the geotechnical engineer. If additional materials are required, suitable soils should be imported.

2. Uncontrolled/undocumented fill material shall be removed within the entire area of the proposed facility. After removal of fill material, the subgrade soils shall be proof-rolled and then backfilled with structural fill (IDOT CA-6) to the foundation subgrade. The structural fill material shall be placed in 8-in. loose lifts and compacted to 95% of maximum dry density in accordance with ASTM D1557. A qualified geotechnical engineer under supervision of an Illinois Registered Professional Engineer should inspect the prepared subgrade and also supervise the placement of structural fill. The excavated on-site materials do not appear to be suitable as structural fill under foundations.

3. The construction contractor shall be held responsible for the excavation work in accordance with the applicable federal and state laws and regulations, including OSHA. If any temporary excavation support system is utilized by the construction contractor, the design of such systems shall be performed by the contractor's Professional Engineer registered in Illinois.

4. The bottom of excavation for the proposed facilities should be checked by the temporary excavation support system designer for adequate factor of safety against basal heave.

5. The construction contractor shall be held responsible for the dewatering system design and operations. The design of the dewatering system shall be performed by the construction contractor's Professional Engineer registered in Illinois and in accordance with Dewatering Specification. Dewatering discharge should be in accordance with EPA permits in accordance with 40 CFR Part 122 and 61 CFR 19284, May 1, 1996. The excavation and foundation construction shall be performed in the dry.

6. Attached geotechnical details (Figures 7 and 8) should be included in the design drawings for the proposed facilities.

7. The following geotechnical specifications will be required.

02140 Dewatering
02160 Temporary Excavation Support System
02210 Earth Excavations, Backfill, Fill and Grading
02300 Bored Piles

These specifications should be prepared and included in the construction contract documents during the final design.

16.0 PROPOSED PHASE II INVESTIGATIONS

The Phase II geotechnical investigations are recommended to collect supplemental subsurface information and fill any data gaps for geotechnical and environmental evaluations. The Phase II investigations should include installing vibrating wire piezometers to establish the piezometric head within the clay layer and also include additional consolidation tests to confirm the consolidation characteristics of silty clay soils. The following items should also be considered in the Phase II investigation.

- Elevation, thickness and consolidation characteristics of organic clay and soft clay.
- Conduct subsurface investigations inside the existing Preliminary Tanks if permitted by District and if accessible. As part of demolition, timber piles and fill materials shall be removed to reach firm subgrade.
- Better characterization of extent of fill materials in the former Ash Lagoon area.

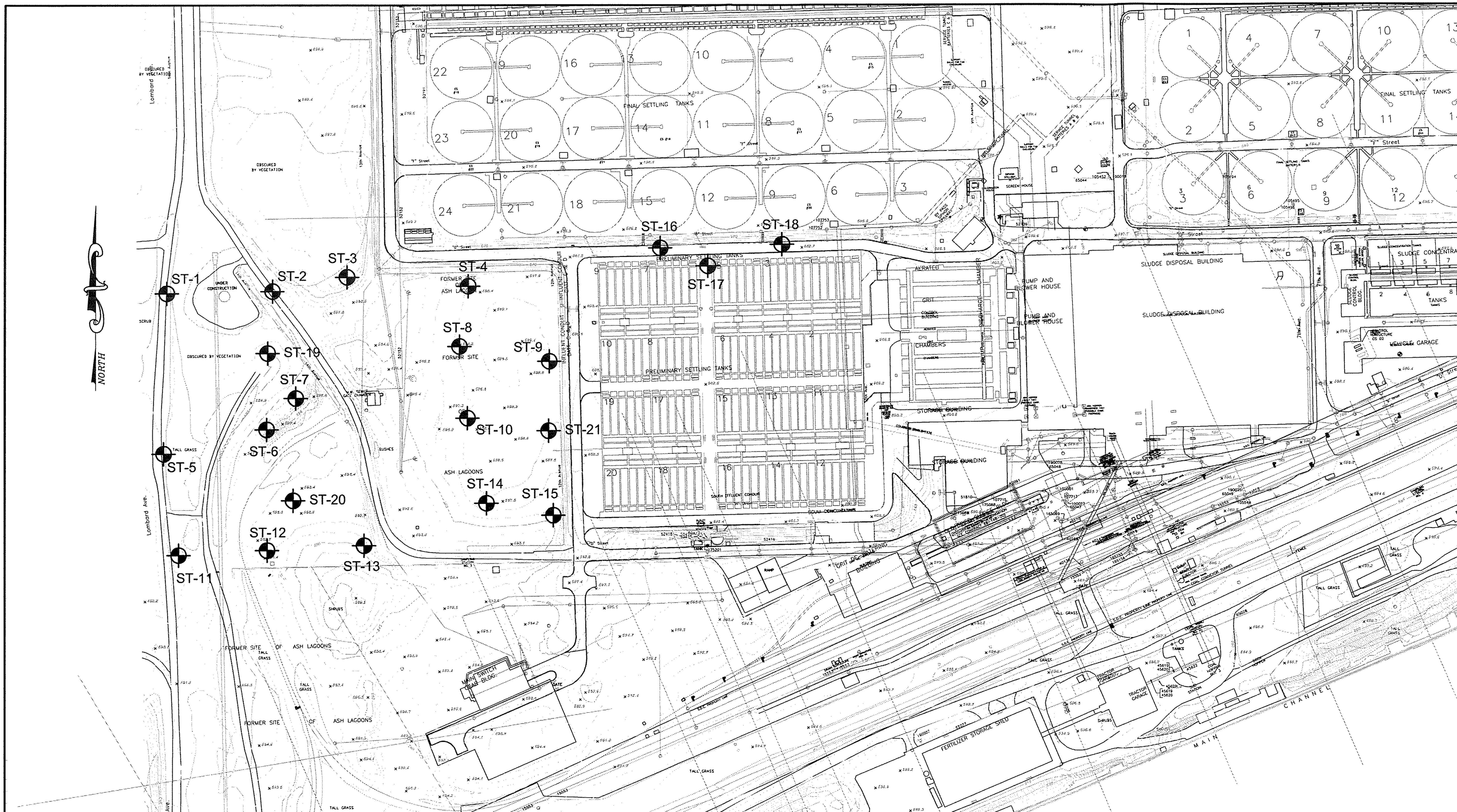
17.0 LIMITATIONS

This Geotechnical Design Report contains an evaluation of the specific factual data and which form the basis of the design recommendations for the preliminary design of the new Preliminary Treatment Facilities at the Calumet Water Reclamation Plant (WRP) in Chicago, Illinois. No representation is made or implied that interpretation of the subsurface conditions between boreholes is accurate. This report should be read in conjunction with the Geotechnical Data Report to assist in understanding the considerations used to establish the design.

18.0 REFERENCES

O'Brien & Associates, Inc., October 2007, "Phase I and IA Geotechnical Data Report" prepared for Metcalf and Eddy at the Proposed Stickney WRP Preliminary Treatment Facilities, Chicago, Illinois

John T. Christian and Alfredo Urzua, Productivity Tools for Geotechnical Engineers, Vol. I, Magellan Press, 1996



LEGEND

SOIL BORING ⊕ ST-

O'BRIEN & ASSOCIATES, INC.
CONSULTING ENGINEERS
1235 E. DAVIS ST./ARLINGTON HTS., IL 60005
(847)398-1441 × FAX(847) 398-2376

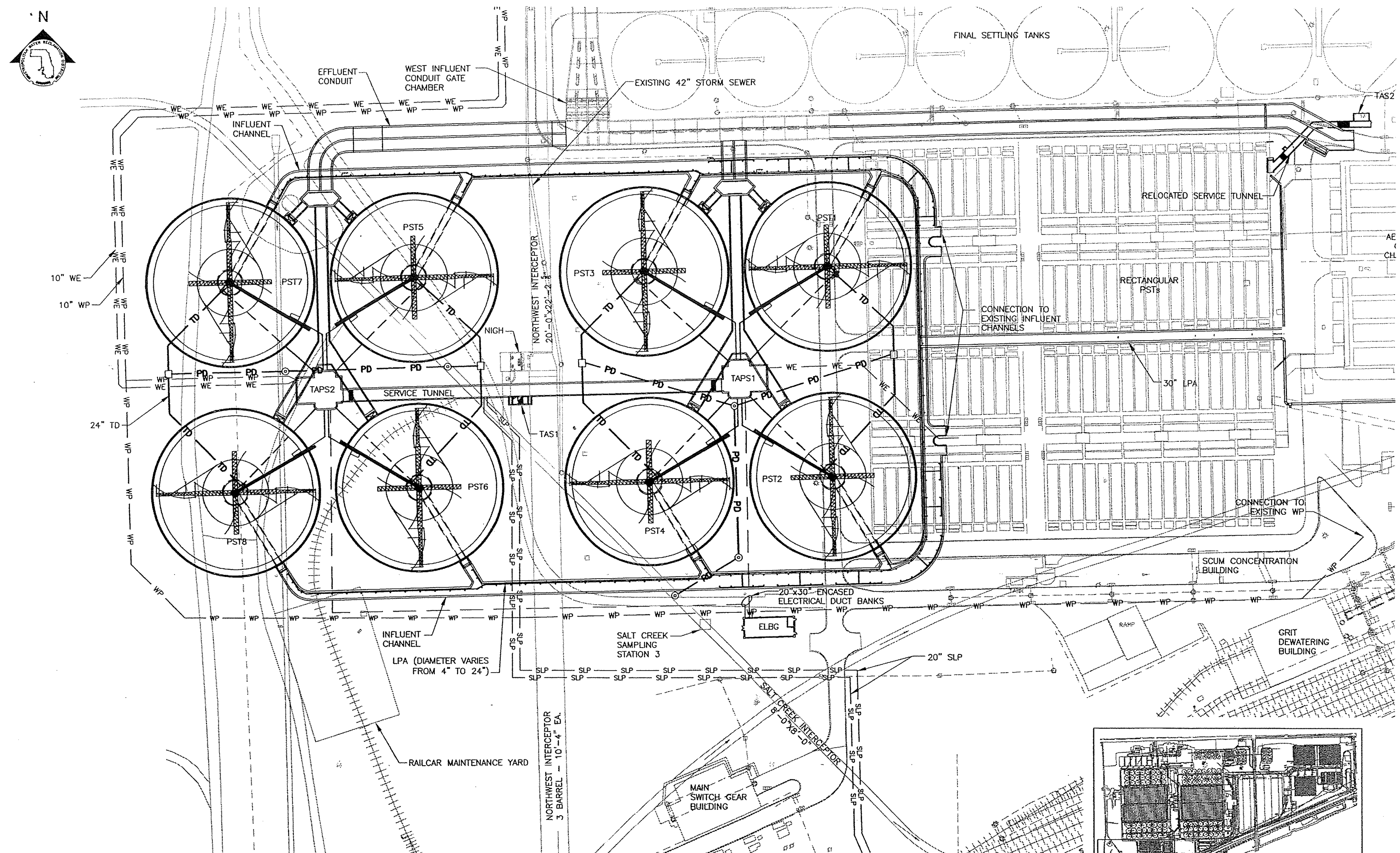
REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

New Preliminary Treatment Facility at Stickney Water Reclamation Plant
Stickney, Illinois

Figure 1 – Boring Location Plan

SIZE	REV.	OBA Job No.	DRAWN BY	APPROVED BY
B	1	06567	RWC	DOB
SCALE: 1"=200'		DATE: 9-24-2007	SHEET: 1 OF 1	



KEY MAP

PST	N	E
1	1,875,208.69	652,329.18
2	1,874,925.20	652,336.38
3	1,875,202.24	652,080.26
4	1,874,918.75	652,087.61
5	1,875,194.18	651,769.53
6	1,874,910.69	651,776.88
7	1,875,187.73	651,520.62
8	1,874,904.24	651,527.97

PRIMARY SETTLING TANKS FACILITIES SITE PLAN

SCALE = 1"=60'

Figure 2 – Proposed Facility Layout

Scale: 1"=60'

60' 0 60' 120' 180' 240' 300'

PRELIMINARY COPY

NOTE: This document is preliminary only and is not intended for any purpose except review and comment by the owner and its agents.

Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Designed by: BC	Checked by: XX	Correct: Project Manager	Approved: MWRD Assistant Chief Engineer
Drawn by: BC	Reviewed by: XX		
Date: SEPT 2007	Scale: 1"=60'		

M&E/CDM Design Partners

A Joint Venture

STICKNEY WATER RECLAMATION PLANT

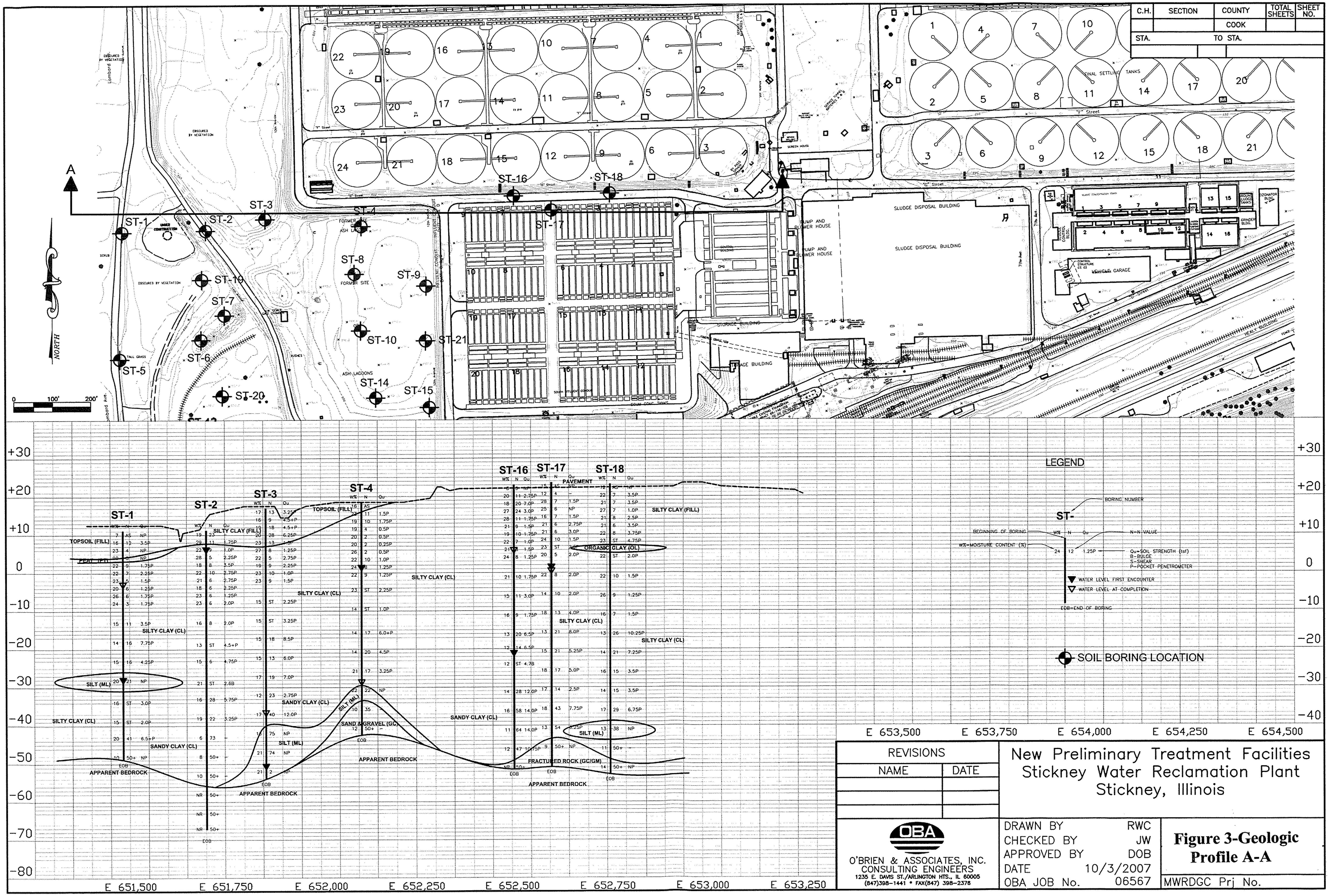
CONTRACT 04-823-3P

NEW PRELIMINARY TREATMENT FACILITIES AT STICKNEY AND CALUMET WRPs

PRIMARY SETTLING TANKS FACILITIES SITE PLAN

Sheet Number: C-106

Page Number: XX



REVISIONS

NAME	DATE

New Preliminary Treatment Facilities
Stickney Water Reclamation Plant
Stickney, Illinois

OBA
O'BRIEN & ASSOCIATES, INC.
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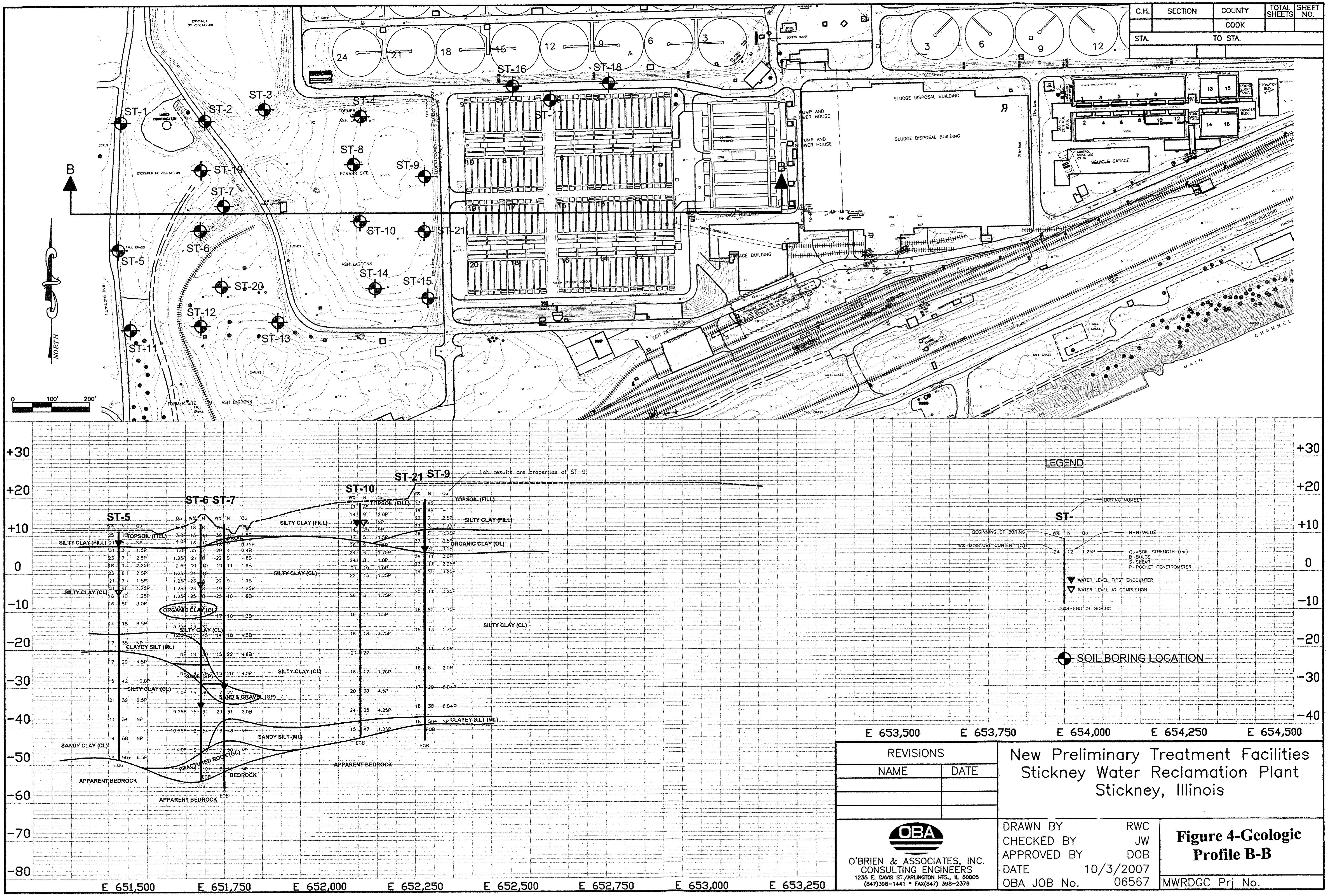
DRAWN BY	RWC
CHECKED BY	JW
APPROVED BY	DOB
DATE	10/3/2007
OBA JOB No.	06567

Figure 3-Geologic Profile A-A

MWRDGC Prj No.



REVISIONS	
NAME	DATE

New Preliminary Treatment Facilities
Stickney Water Reclamation Plant
Stickney, Illinois

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O'BRIEN & ASSOCIATES, INC.
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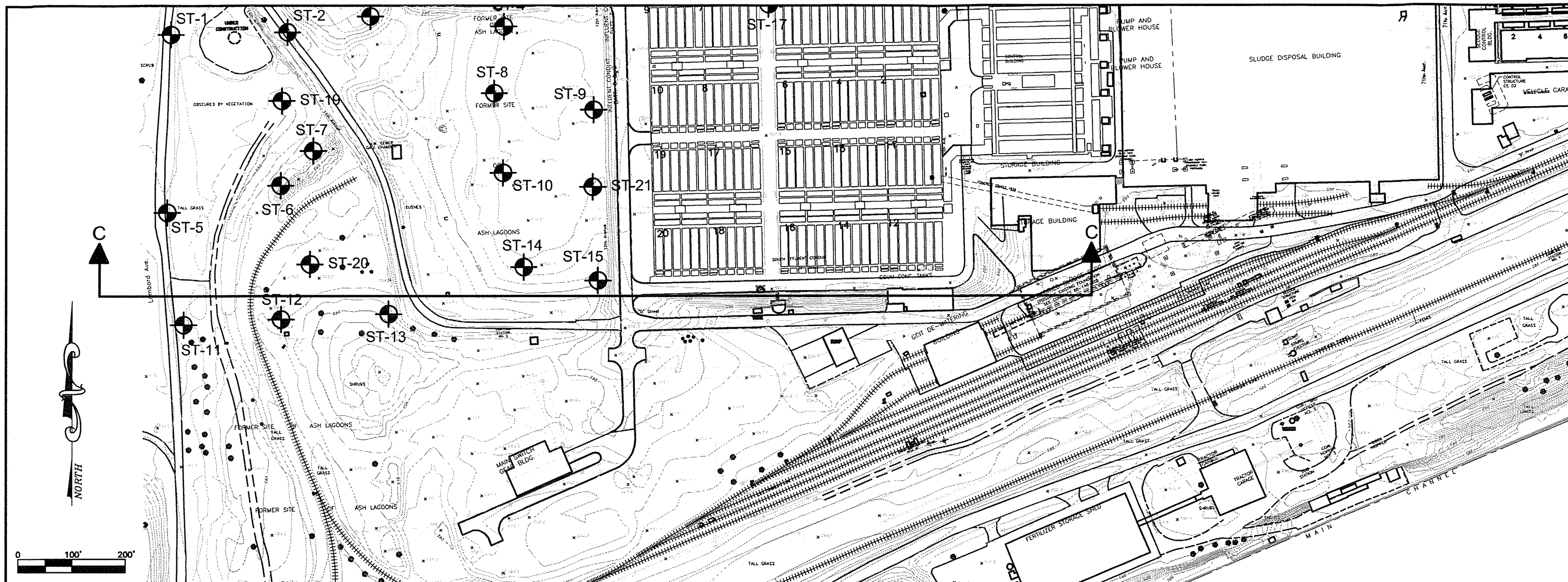
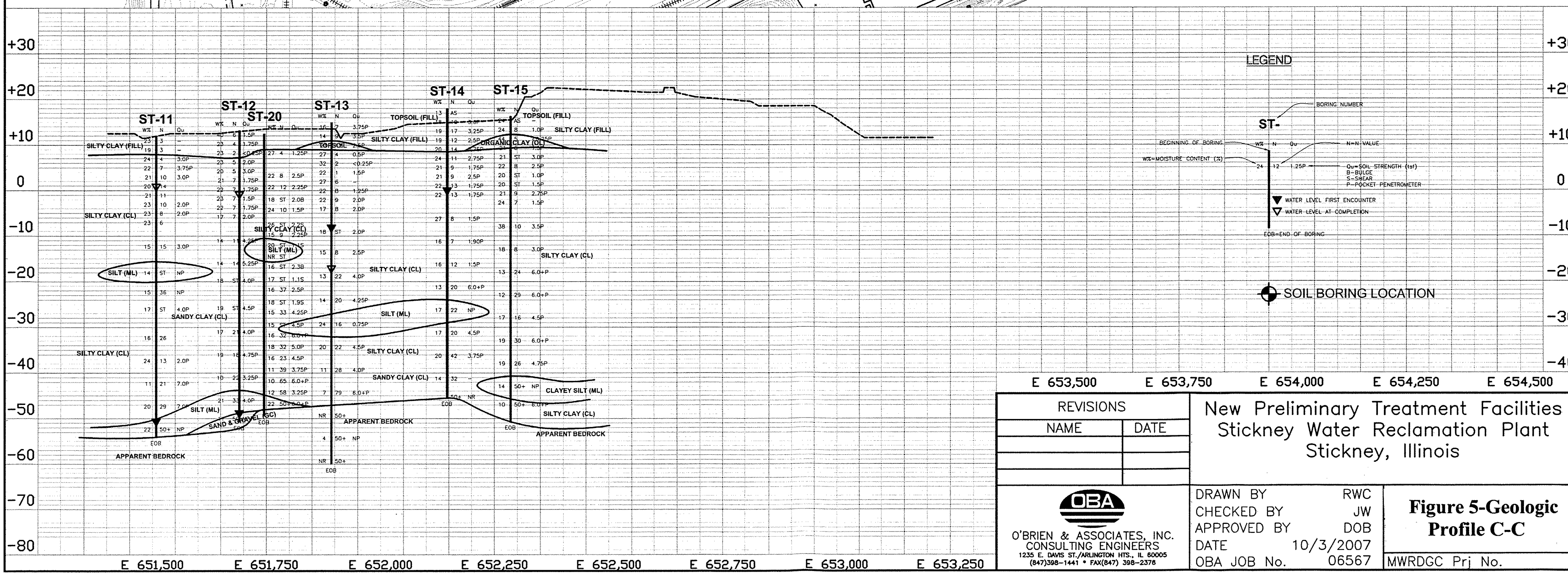
CHECKED BY	JW
APPROVED BY	DOB
DATE	10/3/2007
OBA JOB No.	06567

Figure 4-Geologic Profile B-B

MWRDGC Prj No.

C.H.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
		COOK		
STA.		TO STA.		





REVISIONS	
NAME	DATE

New Preliminary Treatment Facilities
Stickney Water Reclamation Plant
Stickney, Illinois

OBA

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APPROVED BY	DOB
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OBA JOB No.	06567

Figure 5-Geologic Profile C-C

MWRDGC Prj No.

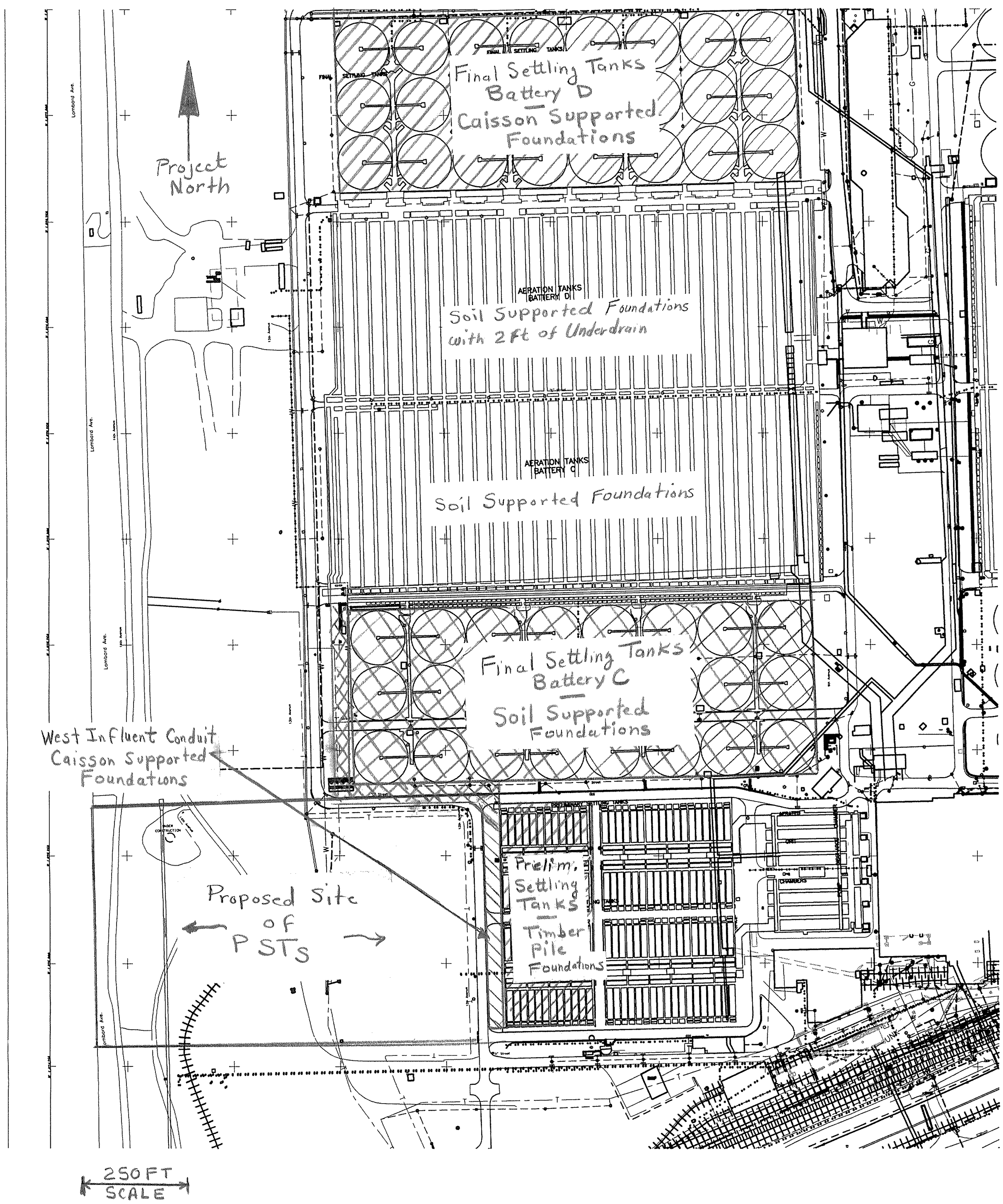
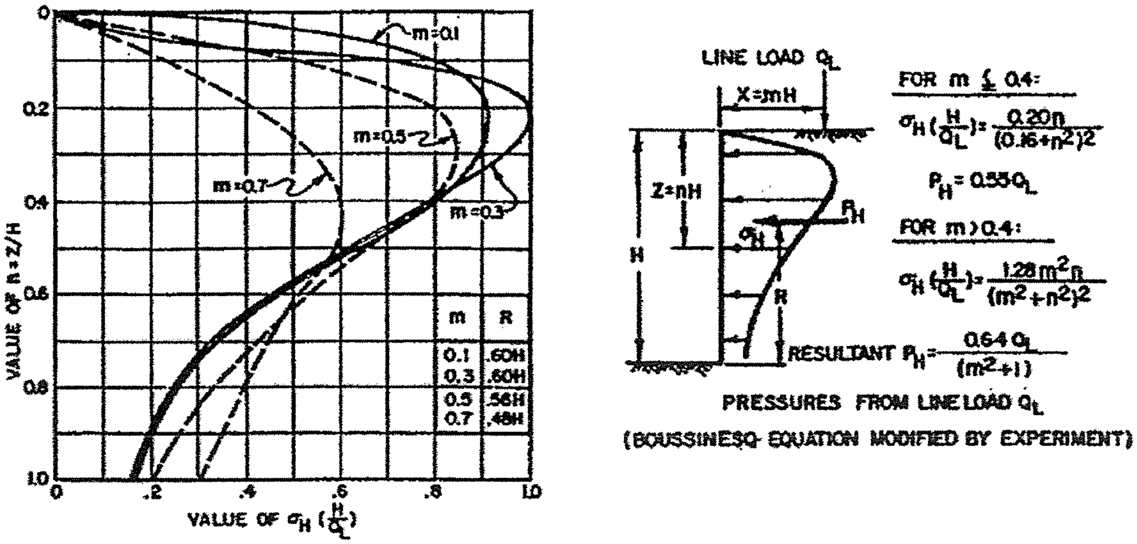
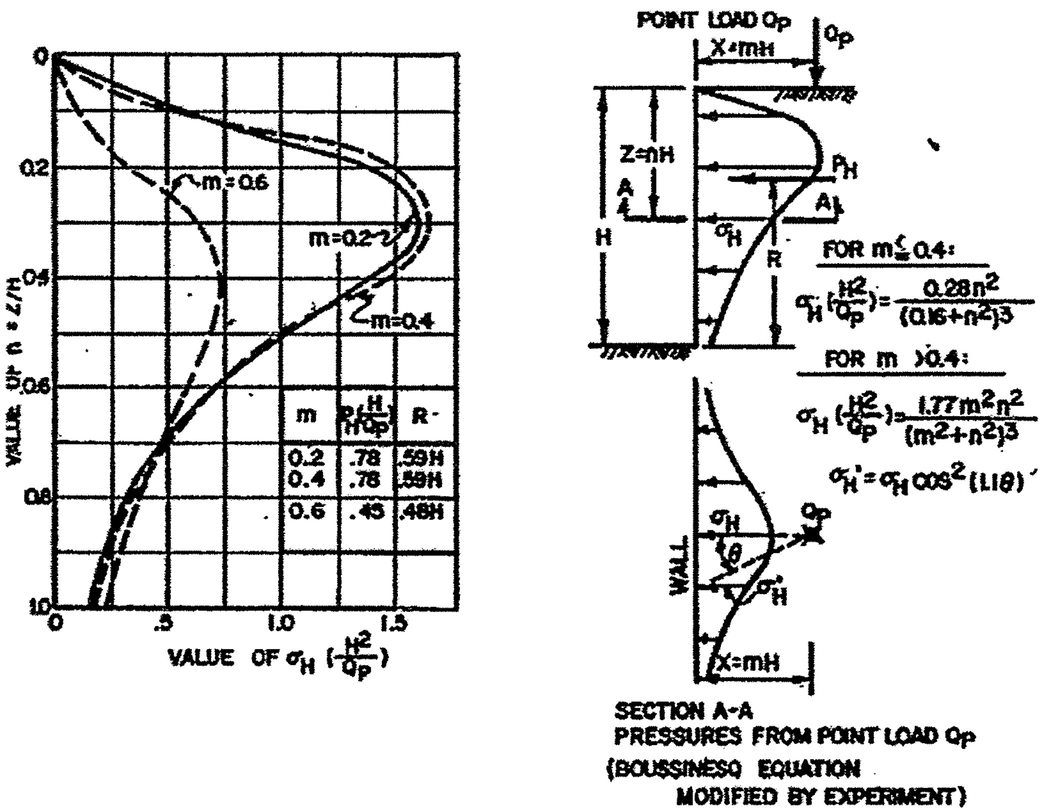


Figure 6 – Foundation Type of Existing Facility Structures Adjacent to Proposed PSTs

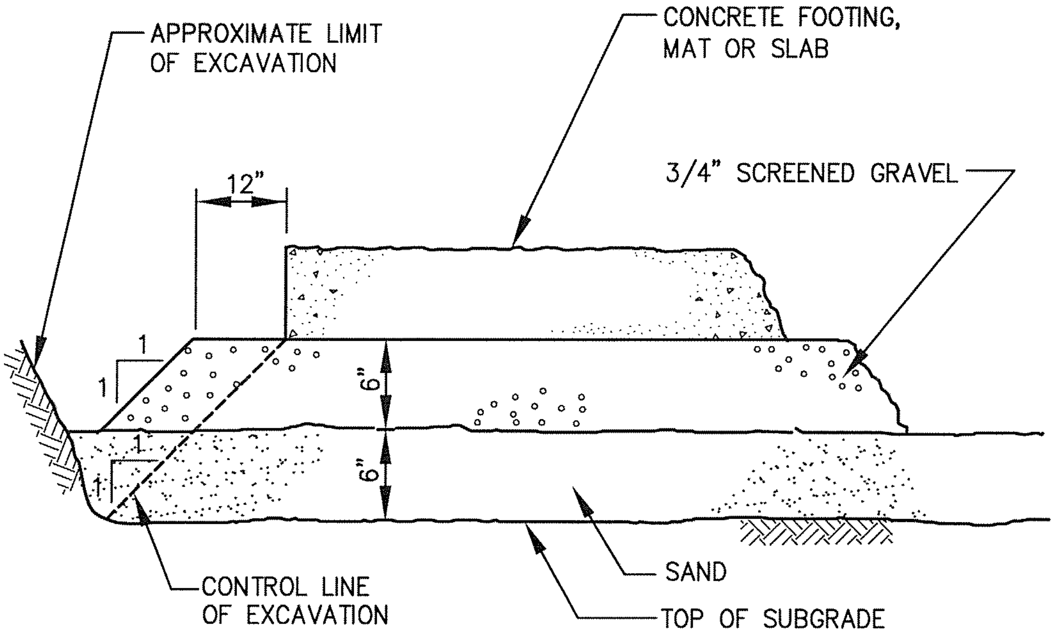


PRESSURE ON FOUNDATION WALL DUE TO A SURFACE LINE LOAD



PRESSURE ON FOUNDATION WALL DUE TO A SURFACE POINT LOAD

FIGURE 7- LATERAL EARTH PRESSURE DUE TO POINT AND LINE LOADS



GRADATION REQUIREMENTS

SIEVE SIZE	PERCENTAGE BY WEIGHT PASSING	
	3/4" SCREENED GRAVEL	SAND
1"	100	
3/4"	90 – 100	
3/8"	20 – 55	100
#4	0 – 10	95 – 100
#8	0 – 5	–
#16		50 – 85
#50		10 – 30
#100		2 – 10

Figure 8

M&E/CDM Design Partners *A Joint Venture*	FOUNDATION PREPARATION			
	SCALE: NONE	9-3-98		2-9.1.

APPENDIX F

COST ESTIMATE BREAKDOWN TABLES

SWRP CAPITAL COST ESTIMATION FOR ULTRAVIOLET DISINFECTION SYSTEM AND LOW LIFT PUMP STATION

A. GENERAL SITEWORK

DIVISION	ITEM DESCRIPTION	UNITS	NO.	MATERIAL & LABOR UNIT COST	INSTALLED COST TOTAL
1	GENERAL REQUIREMENTS (Field personnel, Field Offices, Testing & Misc. Project Overheads)				$3,833,142
2	SITEWORK				
	General Equipment Mobilization/Demob (not including pile driving equipment)	LS	1	$10,000.00	$10,000
	Road work (Concrete Pavement)	SY	2,222	$232.81	$517,309
	Temporary Fencing	LF	2,000	$49.69	$99,382
	Fence Gates (20')	EA	2	$3,574	$7,147
	Rail Demolition	LF	1,832	$12.54	$22,979
	Clearing and Grubbing	SF	225,000	$0.50	$112,500
	Strip topsoil and stockpile	SY	25,500	$1.43	$36,451
	Final Grading	SY	25,500	$1.00	$25,500
	Bulkheading and Removal at Gate Structure #1	LS	1	$120,000.00	$120,000
	Erosion Control/Final Seeding	SF	225,000	$0.40	$89,926
	Silt Fence	LF	6,700	$3.00	$20,100
	Survey, Construction Staking	Days	120	$1,095.52	$131,462
	Temporary Power Feed	EA	2	$5,000.00	$10,000
	Temporary Connections	EA	10	$500.00	$5,000
	Temporary Heating	SF	28,300	$11.86	$335,564
	Temporary Lighting	SF	28,300	$14.40	$407,518
	Power Use for Temporary Facilites	csf/Mo	131	$3.14	$4,936
	Water Bill	Mo	36	$70.30	$2,531
	Temp Access Road	SY	2,222	$10.83	$24,056
	CPM Scheduling	Proj	260,530,000	0.04%	$104,212
	Cleaning	Proj	260,530,000	0.30%	$781,590
	Commissioning	Proj	260,530,000	0.50%	$1,302,650
	Special Equipment Startup	Days	125	$725.82	$90,727
	PIPES				
	Non-potable Water (6" dia)	LF	1,200	$55.70	$66,840
	WNP Hydrants	EA	4	$1,874.69	$7,499
	Drain Line to CS (8" dia)	LF	1,200	$61.86	$74,232
	Process Water Line (3" dia)	LF	1,200	$49.26	$59,112
	Potable Water Service Line (1" dia)	LF	1,200	$28.05	$33,660
	3" STL Casing Pipe with 1" PVC Sampling Line	LF	100	$47.62	$4,762
	City Water (6" dia)	LF	1,200	$55.70	$66,840
	Potable Fire Hydrants	EA	4	$1,874.69	$7,499
	EFFLUENT CONDUITS				
	Conduit, 17'-6"'x15'-9", JC1 to LLPS	LF	2,005	$5,100.00	$10,225,500
	Conduit, 16'x20', LLPS to UV Bldg	LF	605	$5,100.00	$3,085,500
	Conduit, 20'x20', UV Bldg to Outfall	LF	885	$5,100.00	$4,513,500
	MANHOLES				
	Manholes	EA	20	$2,542.54	$50,851
	Inlet/Catch Basin	EA	24	$1,318.14	$31,635
	GATE STRUCTURES				
	Junction Chamber #1	LS	1	$900,000.00	$900,000
	OUTFALL				
	Excavation	CY	6,265	$24.07	$150,775
	General Backfill	CY	2,481	$7.09	$17,587
	Engineered Backfill	CY	152	$25.13	$3,820
	Disposal of Spoil	CY	3,784	$19.65	$74,352
	Dewatering	Days	90	$3,467.97	$312,117
	Concrete				
	Base Slabs (includes labor)	CY	271	$500.00	$135,500
	Walls (includes labor)	CY	561	$920.00	$516,120
	Elevated Slabs (includes labor)	CY	183	$1,000.00	$183,300
	Permanent Steel Sheeting (Shoreline)	SF	1,960	$35.03	$68,659
	Cofferdam	SF	5,400	$48.59	$262,386
	Rail Demolition	LF	90	$12.54	$1,129
	Temporary Rail	LF	600	$175.15	$105,090
	Temp Rail Removal	LF	600	$12.54	$7,526
	Rail Replacement	LF	90	$175.15	$15,764
16	ELECTRICAL DUCT BANK				
	6 cells, 5" conduit from sub-station to UV Building	LF	400	$200.00	$80,000
	6 cells, 5" conduit from sub-station to Low-Lift Pump Station	LF	500	$200.00	$100,000
	500 kcmil (15 kV)	LF	2,025	$20.00	$40,500
	4/0 AWG (600 V)	LF	1,125	$7.00	$7,875
	Electrical Manholes	EA	4	$12,500.00	$50,000
	Site Lighting Poles	EA	10	$3,280.70	$32,807
	SUBTOTAL				**$29,387,419**
	GC Markup on Subs @ 5% (except for General Conditions)				**$1,277,714**
	Subtotal				**$30,665,133**
	Escalation to Midpoint of Construction @ 10%				**$3,066,513**
	Subtotal				**$33,731,646**
	Contractor OH&P @ 15%				**$4,599,770**
	Subtotal				**$35,264,903**
	Planning Level Contingency @ 30%				**$10,579,471**
	Subtotal				**$45,844,374**
	Misc. Capital Costs				
	Legal and Fiscal Fees @ 15%				**$6,876,656**
	Engineering Fees including CM @ 20%				**$9,168,875**
	Subtotal				**$16,045,531**
	GENERAL SITEWORK PROJECT TOTAL				**$61,890,000**

SWRP CAPITAL COST ESTIMATION FOR ULTRAVIOLET DISINFECTION SYSTEM AND LOW LIFT PUMP STATION

B. LOW LIFT PUMP STATION

DIVISION	ITEM DESCRIPTION	UNITS	NO.	MATERIAL UNIT COST	INSTALLED COST TOTAL
1	GENERAL REQUIREMENTS (Field personnel, Field Offices, Testing & Misc. Project Overheads)				$5,045,389
2	SITEWORK				
	Excavation	CY	24,000	$24.07	$577,591
	Engineered Backfill	CY	3,300	$25.13	$82,937
	Disposal of Spoil	CY	24,000	$19.65	$471,577
	Drilling Mobilization	LS	1	$13,942.98	$13,943
	Rock Anchors (45')	EA	285	$2,800.00	$798,000
	Rock Anchor Load Test	EA	3	$18,805.44	$56,416
	Temporary Sheeting/Shoring	SF	18,000	$29.39	$528,943
	Dewatering	LS	1	$250,000	$250,000
	PIPES				
	Process Water Line (3" dia)	LF	174	$49.26	$8,571
3	CONCRETE				
	Base Slabs (includes labor)	CY	1,382	$500.00	$691,000
	Walls (includes labor)	CY	2,004	$920.00	$1,843,680
	Elevated Slabs (includes labor)	CY	822	$1,000.00	$822,000
4	MASONRY				
	Exterior Walls	SF	18,850	$45.00	$848,250
5	METALS				
	Handrails and Railings	LF	211	$100.00	$21,100
	Structural Steel	TONS	98	$5,000	$490,250
	SS Ladder (Roof Access)	LF	45	$745.80	$33,561
	Metal Stairs	EA	3	$8,000.00	$24,000
	Metal Decking (Roof) (includes insulation)	SF	7,298	$3.10	$22,596
6	WOOD & PLASTICS				$0
7	THERMAL & MOISTURE PROTECTION				
	Roofing System	SF	7,298	$7.00	$51,086
	Roof Drainage System	SF	7,298	$5.00	$36,490
8	DOORS & WINDOWS				
	Doors (SS) single	EA	3	$6,500	$19,500
	Doors (SS) double	EA	1	$6,500	$6,500
	Windows	SF	1,344	$25	$33,600
	Skylights	SF	968	$45	$43,560
	Overhead Door	EA	1	$15,000	$15,000
	Submerged Manways	EA	6	$7,500	$45,000
	Hatches (SS)	EA	2	$10,170	$20,340
9	FINISHES				
	High Performance Coating (Walls)	SF	27,056	$2.00	$54,112
	Floor Coating	SF	7,300	$2.25	$16,425
10					
11	EQUIPMENT				
	Pumps (includes motors)	EA	8	$2,437,500	$19,500,000
	Perforated Plate Baffles	EA	8	$73,000	$584,000
13	SPECIAL CONSTRUCTION (incl. INSTRUMENTATION)				
	Lightning Protection Systems	LS	1	$10,000	$10,000
	Distributed Control System (DCS) Modifications	LS	1	$40,000	$40,000
	Input/Output (I/O) Point List	EA	146	$1,500	$219,000
14	CONVEYING SYSTEMS				
	Bridge Crane/Hoist	LS	1	$85,466	$85,466
15	MECHANICAL				
	Plant Water	LS	1	$20,000	$20,000
	City Water	LS	1	$20,000	$20,000
	Slide Gates	EA	6	$117,000	$702,000
	Slide Gates (Bonnet)	EA	6	$234,000	$1,404,000
	Plug Valves (8")	EA	2	$1,300	$2,600
	Motorized Louvres, Med	EA	8	$2,000	$16,000
	Exhaust Fans, Wall	EA	8	$2,800	$22,400
	Unit Heaters, Suspended	EA	8	$2,000	$16,000
	Building Plumbing	LS	1	$50,000	$50,000
	Butterfly Valves (84") manual	EA	8	$75,600	$604,800
	Flap Gate (84")	EA	8	$30,000	$240,000
16	ELECTRICAL				
	Building Systems				
	Basic Material	SF	7,300	$4.62	$33,738
	Devices	SF	7,300	$0.35	$2,557
	Equipment Connections	SF	7,300	$2.67	$19,468
	Service & Distribution	SF	7,300	$2.11	$15,426
	Lighting	SF	7,300	$5.65	$41,245
	Intercom System	SF	7,300	$0.47	$3,465
	Fire Alarm & Detection	SF	7,300	$0.51	$3,712
	Low Voltage Switchgear				
	Transformer, 13kV to 5kV	EA	4	$128,300	$513,200
	Main Breaker, 3000A w/ Metering	EA	2	$77,114	$154,228
	Tie Breaker, 3000A	EA	1	$74,614	$74,614
	Feeder Breaker, 1600A	EA	10	$36,348	$363,480
	Space for Future Breaker	EA	2	$5,500	$11,000
	MCC RVSS	EA	5	$22,500	$112,500
	Variable Frequency Drive, 1500 horsepower	EA	3	$275,000	$825,000
	SUBTOTAL				**$38,681,316**
	GC Markup on Subs @ 5% (except for General Conditions)				**$1,681,796**
	Subtotal				**$40,363,112**
	Escalation to Midpoint of Construction @ 10%				**$4,036,311**
	Subtotal				**$42,717,627**
	Contractor OH&P @ 15%				**$6,407,644**
	Subtotal				**$49,125,271**
	Planning Level Contingency @ 30%				**$14,737,581**
	Subtotal				**$63,862,852**
	Misc. Capital Costs				
	Legal and Fiscal Fees @ 15%				**$9,579,428**
	Engineering Fees including CM @ 20%				**$12,772,570**
	Subtotal				**$22,351,998**
	LOW LIFT PUMP STATION PROJECT TOTAL				**$86,220,000**

C. UV DISINFECTION BUILDING

DIVISION	ITEM DESCRIPTION	UNITS	NO.	MATERIAL UNIT COST	INSTALLED COST TOTAL
1	GENERAL REQUIREMENTS (Field personnel, Field Offices, Testing & Misc. Project Overheads)				$6,578,609
2	SITEWORK				
	Excavation	CY	11,000	$24.07	$264,729
	Engineered Backfill	CY	3,200	$25.13	$80,424
	Disposal of Spoil	CY	11,000	$19.65	$216,140
	Drilling Mobilization	LS	1	$13,942.98	$13,943
	Rock Anchors (65')	EA	304	$3,600.00	$1,094,400
	Rock Anchor Load Test	EA	3	$18,805.44	$56,416
	Temporary Sheeting/Shoring	SF	12,400	$29.39	$364,383
	Dewatering	LS	1	$50,000.00	$50,000
	PIPES				
	Process Water Line (2" dia)	LF	336	$39.83	$13,383
	Drain Line to CS (8" dia)	LF	310	$61.86	$19,177
	3" STL Casing Pipe with 1" PVC Sampling Line	LF	95	$47.62	$4,524
3	CONCRETE				
	Base Slabs (includes labor)	CY	2,880	$500.00	$1,440,000
	Walls (includes labor)	CY	3,555	$920.00	$3,270,600
	Elevated Slabs (includes labor)	CY	450	$1,000.00	$450,000
4	MASONRY				
	Interior Walls	SF	11,200	$25.00	$280,000
	Exterior Walls	SF	12,980	$45.00	$584,100
5	METALS				
	SS Ladder (Roof Access)	LF	20	$745.80	$14,916
	Structural Steel	Tons	3	$5,000.00	$12,500
	Gratings	SF	2,184	$30.00	$65,520
6	WOOD & PLASTICS				
	Misc Blocking	LS	1	$10,000.00	$10,000
7	THERMAL & MOISTURE PROTECTION				
	Roofing System	SF	21,237	$7.00	$148,659
	Roof Drainage System	SF	21,237	$5.00	$106,185
8	DOORS & WINDOWS				
	Doors (SS)	EA	8	$6,500	$52,000
	Windows	SF	768	$25.00	$19,200
	Skylights	SF	1,728	$30.00	$51,840
	Overhead Door	EA	1	$15,000.00	$15,000
	Hatches	EA	2	$10,170.00	$20,340
9	FINISHES				
	High Performance Coatings (walls)	SF	13,300	$2.00	$26,600
	Floor Coating	SF	21,000	$2.25	$47,250
	Accoustic Ceiling	SF	19,272	$4.00	$77,088
10	SPECIALITIES				$0
11	EQUIPMENT				
	UV Reactors	LS	1	$25,185,000.00	$25,185,000
	Effluent Sampling System, Pump/Sampler	LS	1	$10,000.00	$10,000
	Hose Reel	EA	4	$10,000.00	$40,000
	Sink	EA	1	$10,000.00	$10,000
	Floor Drain	EA	12	$10,000.00	$120,000
13	SPECIAL CONSTRUCTION (incl. INSTRUMENTATION)				
	Lighting Protection Systems	LS	1	$14,000.00	$14,000
	Distributed Control System (DCS) Modifications	LS	1	$40,000.00	$40,000
	Online UV Tranmittance Controller	EA	2	$10,000.00	$20,000
	Flow Transmitter	LS	1	$10,000.00	$10,000
	Input/Output (I/O) Point List	EA	394	$1,000.00	$394,000
14	CONVEYING SYSTEMS				$0
15	MECHANICAL				
	Misc. Piping	LS	1	$50,000.00	$50,000
	Weir Gates, Motorized	EA	12	$169,000.00	$2,028,000
	Slide Gates, Motorized	EA	12	$188,500.00	$2,262,000
	Motorized Louvres, Med	EA	6	$860.00	$5,160
	Motorized Louvres, Large	EA	4	$2,000.00	$8,000
	Exhaust Fans, Wall	EA	8	$1,300.00	$10,400
	Exhaust Fans, Roof	EA	8	$3,125.00	$25,000
	Unit Heaters, Suspended	EA	10	$2,000.00	$20,000
	Unit Heaters, Overhead	EA	4	$4,500.00	$18,000
	Air Handling Units	EA	1	$3,500.00	$3,500
	AHU/ACCU	EA	1	$10,500.00	$10,500
	Building Plumbing	LS	1	$20,000.00	$20,000
	Flow Meters, A/V	EA	4	$20,190.00	$80,760
	Mud Valves	EA	10	$1,000.00	$10,000
	Hatches, Special	EA	24	$15,000.00	$360,000
16	ELECTRICAL				
	Building Systems				
	Basic Material	SF	21,000	$4.62	$97,056
	Devices	SF	21,000	$0.35	$7,356
	Equipment Connections	SF	21,000	$2.67	$56,003
	Service & Distribution	SF	21,000	$2.11	$44,375
	Lighting	SF	21,000	$5.65	$118,650
	Intercom System	SF	21,000	$0.47	$9,967
	Fire Alarm & Detection	SF	21,000	$0.51	$10,679
	Medium-Voltage Circuit Breaker Switchgear				
	Main Breaker	EA	2	$109,050.00	$218,100
	Tie Breaker	EA	1	$109,050.00	$109,050
	Feeders (2 high)	EA	8	$188,364.00	$1,506,912
	Control Power Section	EA	2	$48,630.00	$97,260
	Control Power Transformer, 75 KVA	EA	2	$25,250.00	$50,500

	Secondary Unit Substations				
	Transformer, 2500 KVA, 80 deg C, VPI	EA	6	$128,300.00	$769,800
	Transformer, 500 KVA	EA	2	$80,000.00	$160,000
	Feeder Breaker, 1600A	EA	26	$36,348.00	$945,048
	Space for Future Breaker	EA	6	$5,500.00	$33,000
	SUBTOTAL				**$50,436,000**
	GC Markup on Subs @ 5% (except for General Conditions)				**$2,192,870**
	Subtotal				**$52,628,869**
	Escalation to Midpoint of Construction @ 10%				**$5,262,887**
	Subtotal				**$55,698,887**
	Contractor OH&P @ 15%				**$8,354,833**
	Subtotal				**$64,053,720**
	Planning Level Contingency @ 30%				**$19,216,116**
	Subtotal				**$83,269,836**
	Misc. Capital Costs				
	Legal and Fiscal Fees @ 15%				**$12,490,475**
	Engineering Fees including CM @ 20%				**$16,653,967**
	Subtotal				**$29,144,442**
	UV DISINFECTION BUILDING PROJECT TOTAL				**$112,420,000**
	PROJECT GRAND TOTAL				**$260,530,000**

SWRP ANNUAL O&M COSTS FOR UV DISINFECTION SYSTEM AND LOW LIFT PUMP STATION

PRESENT WORTH FACTOR	
Life, N	**20**
Interest, i	4.875
Inflation, j	3
Present Worth Factor	**23.17**

Average Energy Cost, $/kWh	$0.0684

A. GENERAL SITEWORK

Item	Operating (kW)	Time of Operation (hrs/day)	Power Usage (kW-hr/day)	Energy Cost ($/day)	Annual Cost ($)	Present Worth Factor	Present Worth ($)
OPERATIONS							
Energy - Electrical	10	24	240.0	$16.42	$5,994	23.17	$138,887
Subtotal					**$5,994**		**$138,887**
	No. of Operators (per day)	**Time (hrs/day/operator)**	**Total Time (hrs/day)**	**Labor Rate ($/hr)**	**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
MAINTENANCE							
Routine Maintenance	1	2	2	$95.00	$69,350	23.17	$1,606,840
Labor - Operator	0	0	0	$95.00	$0	23.17	$0
Electrician	0	0	0	$165.00	$0	23.17	$0
Subtotal		NSWRP			**$69,350**		**$1,606,840**
	Construction Cost of New Equip. & Piping ($)	**% for Annual Parts & Supplies**			**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
PARTS AND SUPPLIES							
Parts and Supplies	311,182	5%			$15,559	23.17	$360,504
Subtotal					**$15,559**		**$360,504**
General Sitework Total Annual O&M					**$90,903**		
General Sitework Total Present Worth O&M Cost							**$2,106,231**

B. LOW LIFT PUMP STATION

Item	Operating (kW)	Time of Operation (hrs/day)	Power Usage (kW-hr/day)	Energy Cost ($/day)	Annual Cost ($)	Present Worth Factor	Present Worth ($)
OPERATIONS							
Energy - Electrical	1118.55	24	26845.2	$1,836.95	$477,608	23.17	$11,066,172
Subtotal					**$477,608**		**$11,066,172**
	No. of Operators (per day)	**Time (hrs/day/operator)**	**Total Time (hrs/day)**	**Labor Rate ($/hr)**	**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
MAINTENANCE							
Routine Maintenance	2	4	8	$95.00	$277,400	23.17	$6,427,358
Labor - Operator	2	8	16	$95.00	$395,200	23.17	$9,156,784
Electrician	1	2	2	$165.00	$120,450	23.17	$2,790,827
Subtotal					**$793,050**		**$18,374,969**
	Construction Cost of New Equip. & Piping ($)	**% for Annual Parts & Supplies**			**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
PARTS AND SUPPLIES							
Parts and Supplies	25,355,433	5%			$1,267,772	23.17	$29,374,269
Subtotal					**$1,267,772**		**$29,374,269**
Low Lift Pump Station Total Annual O&M					**$2,538,429**		
Low Lift Pump Station Total Present Worth O&M Cost							**$58,815,409**

C. DISINFECTION SYSTEM

Item	Operating (kW)	Time of Operation (hrs/day)	Power Usage (kW-hr/day)	Energy Cost ($/day)	Annual Cost ($)	Present Worth Factor	Present Worth ($)
OPERATIONS							
Energy - Electrical	9,225	24	221,405	$15,150.20	$3,939,052	23.17	$91,267,843
Subtotal					**$3,939,052**		**$91,267,843**
*Annual Energy Costs based on 24 hours operation for 9 months (March thru November)							
	No. of Operators (per day)	**Time (hrs/unit-time/operator)**	**Total Time (hrs/unit-time)**	**Labor Rate ($/hr)**	**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
MAINTENANCE							
Electrician for routine maintenance	1	2 per week	2 per week	$165.00	$12,257	23.17	$283,998
Electrician to replace UV lamps	2	20 per week	40 per week	$165.00	$344,143	23.17	$7,973,790
Electrician for lamp cleaning/inspection	4	40 per week	160 per week	$165.00	$1,376,571	23.17	$31,895,160
Labor - Operator	2	8 per day	16 per day	$95.00	$395,200	23.17	$9,156,784
Subtotal					**$2,128,171**		**$49,309,732**
*Annual Maintenance Costs based on - (a) operation for 9 months (March thru November); (b) based on 365 days only for lamp replacement.							
	Construction Cost of New Equip. & Piping ($)	**% for Annual Parts & Supplies**	**Number of Units Replaced per Year**	**Cost per Unit ($)**	**Annual Cost ($)**	**Present Worth Factor**	**Present Worth ($)**
PARTS AND SUPPLIES							
Parts and Supplies	34,510,075	5%			$1,725,504	23.17	$39,979,922
Lamp (replacement)			4032	$215.00	$866,880	23.17	$20,085,610
Ballast (replacement)			807	$877.50	$708,143	23.17	$16,407,662
Quartz sleeve (replacement)			403	$338.00	$136,282	23.17	$3,157,645
Scraper wiper (replacement)			1331	$40.00	$53,222	23.17	$1,233,163
Subtotal					**$3,490,030**		**$80,864,001**
UV System Total Annual O&M					**$9,557,254**		
UV System Total Present Worth O&M Cost							**$221,441,576**
Project Grand Total Annual O&M					**$12,190,000**		
Project Total Present Worth O&M Cost							**$282,400,000**

APPENDIX G

ELECTRICAL EVALUATION TECHNICAL MEMORANDUM

DISINFECTION COST STUDY
ELECTRICAL EVALUATION

FOR

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

STICKNEY WATER RECLAMATION PLANT

TECHNICAL MEMORANDUM

August 1, 2008

Prepared By

CTE | AECOM

303 EAST WACKER DRIVE, SUITE 600

CHICAGO, ILLINOIS 60601

MWRDGC Project No. 07-026-2P

CTE Project No. 60040695

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APPENDICES

1.0 INTRODUCTION

This technical memorandum has been developed as part of the Preliminary Cost Opinion for Ultraviolet (UV) Disinfection Facilities Study at the Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC, or District) Stickney Water Reclamation Plant (SWRP) in Illinois. This memorandum continues the work that began with the Hydraulic Memorandum developed previously as part of this study.

The hydraulic memorandum outlines a basis of design for the proposed UV disinfection facilities which included a proposed low lift pump station.

2.0 OBJECTIVE

The primary objectives of the evaluation presented in this technical memorandum are:

- To determine the power requirements based on the conceptual UV disinfection facilities proposed in the Hydraulic Technical Memorandum.

- To determine if the existing SWRP electrical grid can support the power requirements for a proposed UV or what modifications would be required.

- To develop the electrical basis of design for the conceptual design of UV disinfection facilities

3.0 CODES/STANDARDS

The following codes and standards are required for this project.

- NFPA-70 National Electrical Code, 2008 or latest version.
- ANSI/NFPA 780 - Lightning Protection Code.
- NFPA-820 Fire Protection in Wastewater Treatment and Collection Facilities, 2003.
- Institute of Electrical and Electronics Engineers (IEEE).
- MWRDGC GS, February 1997, or latest version.
- MWRDGC GSE, March 1994, or latest version.
- Underwriters Laboratories (UL).
- National Electrical Manufacturer's Association (NEMA).
- Insulated Power Cable Engineers (IPCEA).
- Illuminating Engineering Society (IES).

4.0 ELECTRICAL BASIS OF DESIGN

4.1 Electric Service

The Stickney Water Reclamation Plant (SWRP) receives electric service from three main ComEd transformers (T71, T72 & T73) located in ComEd Substation D799. Each transformer is rated 138 kV primary voltage, 13.8 kV secondary voltage and 30 MVA capacity giving the plant a total transformer capacity of 90 MVA.

As reported by the plant Enterprise Energy Management System, the average aggregate peak kW load for the Year 2006 was 33 MW. The anticipated connected load that will be added to the plant for the UV disinfection and intermediate pump station is estimated to be 24 MVA. As summarized in Table 1, it appears that the existing transformer capacity is sufficient for the proposed facilities.

Table 1 Existing and Proposed SWRP Electrical Loads

Item	Value
Existing SWRP Transformer Capacity	30 MVA
Total Capacity (Three Transformers)	90 MVA
Average Aggregate Peak kW Load (2006)	33 MW
Existing Available Capacity	57 MW
Estimated UV Disinfection and LLPS Load	24 MVA
Estimated Remaining SWRP Capacity	33 MW

The main 13.8 kV switchgear for the plant is located at the ComEd Substation. A redundant electric service to the UV Disinfection Facility and the Low Lift Pump Station would be provided. Spare breakers on Bus B and Bus C in the main switchgear would be utilized to feed the new UV Disinfection Facility. Medium voltage cable in underground ductbank would be provided from the existing plant main switchgear to supply the UV Disinfection Facility.

4.2 System Grounding

Electrical systems shall be solidly grounded. Grounding shall be in accordance with the National Electrical Code for equipment grounding and bonding conductors for grounding raceway and equipment.

4.3 Conduit

Exposed conduit shall be PVC coated Rigid Galvanized Steel Conduit. Conduits in non-finished areas shall be installed either exposed on the surface of the structure or concealed in concrete floor slabs or below grade. Conduits below grade outside of the building shall be reinforced fiberglass and shall be encased in reinforced concrete. Ductbanks shall have spare conduits for future use.

Conduits shall conform to MWRDGC General Specifications: Electrical (GSE) Table 1 (Page GSE-8).

Spacing of supports for exposed conduit shall conform to MWRDGC GSE Table 3 (Page GSE-10).

4.4 Wire

600 volt Insulated copper conductors in conduit shall be provided for all power, control, alarm, instrumentation, signal, lighting and grounding installations, unless otherwise indicated. The insulation shall meet ANSI/NFPA 70. The wire and cable shall conform to the MWRDGC GSE Table 4 (Page GSE-10).

Medium voltage cable shall be ethylene propylene rubber (EPR) insulated cable, U.L. listed and labeled MV-105, 133% insulation level, single conductor copper, Class B strand.

4.5 Motors (Except Low Lift Pump Motors)

Motors 1/2 horsepower and larger shall operate on 480 volt, 3-phase, AC power supplies, and motors smaller than 1/2 horsepower shall operate on 120 volts, single phase, AC power supplies.

4.6 Emergency Systems

Emergency lighting units would have unit batteries to provided final reserve source of current supply.

Emergency lighting and exit signage would be provided as per code requirements to illuminate the path of ingress/egress in emergency situations.

4.7 Lightning Protection

New structures shall be protected by a lightning protection system. The system shall be a conductor system protecting the entire building and consisting of stainless steel spline ball terminals on the building roof parapets; grounding electrodes; and copper interconnecting conductors.

The system shall be designed in accordance with ANSI/NFPA 780 - Lightning Protection Code and shall have a UL Master Label. The lightning protection system components shall conform to ANSI/UL 96 - Lightning Protection Components.

4.8 Specific Electrical Equipment

The basis of specific design equipment is described below.

Medium Voltage Switchgear

Table 2 describes the medium voltage switchgear. **Table 3** describes the criteria to be used for circuit breakers. **Table 4** describes the criteria to be used for station batteries.

Table 2 Medium Voltage Switchgear Criteria

Item	Criteria
Type	Medium Voltage Metal-clad Draw-out Switchgear
Standards	▪ NEMA SG.5 ▪ ANSI C37.20.2
Rated Voltage: 'MVSG-1' (UV BLDG.) 'MVSG-2'(LLPS BLDG.)	 13,200 Volts 13,200 Volts
Number of phases	3
Bus Material	Tin plated copper
Rated BIL	95,000 Volts, to be coordinated with surge arrester rating
Minimum Main Bus Rated Ampacity: 'MVSG-1' (UV BLDG.) "MVSG-2' (LLPS BLDG.)	 3,000 Amperes 2,000 Amperes
Minimum interrupting capacity	500 MVA
Arc Flash Protection	Arc resistant style switchgear with reinforced doors and venting. The need for arc extinguishing or arc terminating equipment will be evaluated during detailed design.

Item	Criteria
Mounting	Equipment shall be mounted on 4-inch structural steel embedded in the floor
Manufacturer	▪ Eaton Cutler Hammer. ▪ ABB - ASEA Brown Boveri. ▪ Siemens Energy and Automation. ▪ Approved equal.
Metering Type	Solid State Multifunction
Metering Location	Main circuit breaker and other critical feeder circuit breakers
Relaying Type	Solid state multifunction
Relaying Manufacturer	Schweitzer Engineering Laboratories, SEL Areva NP Co. Approved equal
Enclosure Rating	NEMA 1

Table 3 Circuit Breaker Ratings and Features Criteria

Item	Criteria
Type	▪ Draw-out carriage type with racking mechanism. ▪ Circuit breakers shall be vacuum type.
Operator Voltage	Electric, 125 Vdc
Controls	Manually operated electric controls with piston grip switches and indicator lights. Location would be coordinated with Arc Flash analysis.
Minimum circuit breaker frame current rating.	1,200 Amperes
Manufacturer	Same as Switchgear manufacturer

Table 4 Circuit Breaker Battery Criteria

Item	Criteria
Type	▪ Lead-acid ▪ Circuit breaker batteries shall be wet cell type. ▪ Charger shall be included.
System Voltage	125 Volts DC
Discharge Rate	8 Hours
End of Discharge Voltage	1.75 Volts
Cell charging voltage	2.3 Volts/Cell
Electrolyte full charge density	1215 kg/m3
Operating cell temperature	25 degrees Celsius
Nominal cell voltage	2.0 Volts/Cell
Manufacturer	▪ Exide.Battery Corporation ▪ EnerSys Inc. ▪ Chloride ▪ Approved equal

Secondary Unit Substation

Secondary unit substations are located in the UV Disinfection Facility and are used to provide power to the UV Reactors. **Table 5** summarizes the design criteria for secondary unit substation.

Table 5 Secondary Unit Substation Criteria

Item	Criteria
Type	Radial Secondary Unit Substation with close coupled air terminal compartment and close coupled Secondary Low Voltage Switchgear
Standards	NEMA 210 IEEE 100
Transformer Type	Dry type
Transformer insulation system	Vacuum pressure impregnation with polyester resin (VPI)
Primary equipment	Air terminal compartment
Primary Voltage	13,200 Volts
Primary Number of phases	3
Primary wiring configuration	Delta connection, 3-wire
Secondary Connection type	Bolt-on type bushing
Secondary Voltage	480/277 Volts
Secondary Number of phases	3
Secondary wiring configuration	4-wire, grounded
Efficiency	Peak efficiency point of transformers to be at 50% of efficiency rating.
Capacity	500-3,000 kVA or as required
Primary BIL	95,000 Volts, to be coordinated with surge protection rating
Secondary BIL	10,000 Volts, to be coordinated with surge protection rating
Winding Material	Copper
Nominal Impedance	5.75 percent
Temperature Rise	80 Degrees C
Minimum K factor	K4
Accessibility	Front and rear
Enclosure Rating	NEMA 1
Manufacturers	▪ Eaton Cutler-Hammer. ▪ ABB - ASEA Brown Boveri ▪ Square D ▪ Approved equal

Motor Control Centers

The design criteria for motor control centers are summarized in **Table 6.**

Table 6 Motor Control Center Criteria

Item	Criteria
Rated Voltage	480 Volts
Number of phases	3
Main bus minimum current rating	600 Amperes
Bus Material	Tin-plated Copper
Minimum short circuit rating	65,000 Amperes
Accessibility	Front only
Wiring class	NEMA Class **II**-S, Type B.
Overload Protection type	Solid State Type.
Breakers	Ground Fault
Metering type	Digital Solid State multifunction meters.
Enclosure type	NEMA 1
Manufacturer	▪ Eaton Cutler-Hammer (Freedom Flashgard). ▪ Allen Bradley. ▪ Square D Corp. ▪ Siemens Energy and Automation. ▪ Approved equal

4.9 One Line Diagram

The proposed one-line diagrams for the proposed UV and LLPS Facilities are shown in Appendix A.

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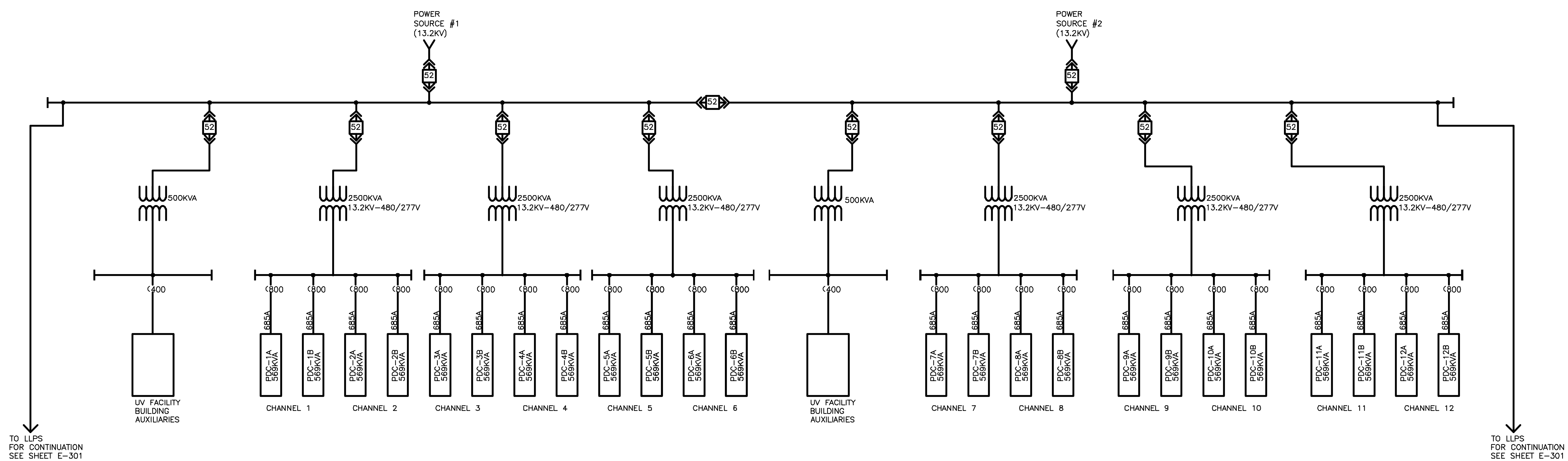

Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Designed by: DES/BMW
Checked by: CFB
Correct: ANTHONY BOUCHARD
Approved: MWRD Assistant Chief Engineer
Drawn by: LK
Reviewed by: EPC
Date: SEPT 2008
Scale: NOT TO SCALE

CTE | AECOM

CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

UV DISINFECTION FACILITIES
POWER DISTRIBUTION

Seal

Sheet Number: E-201

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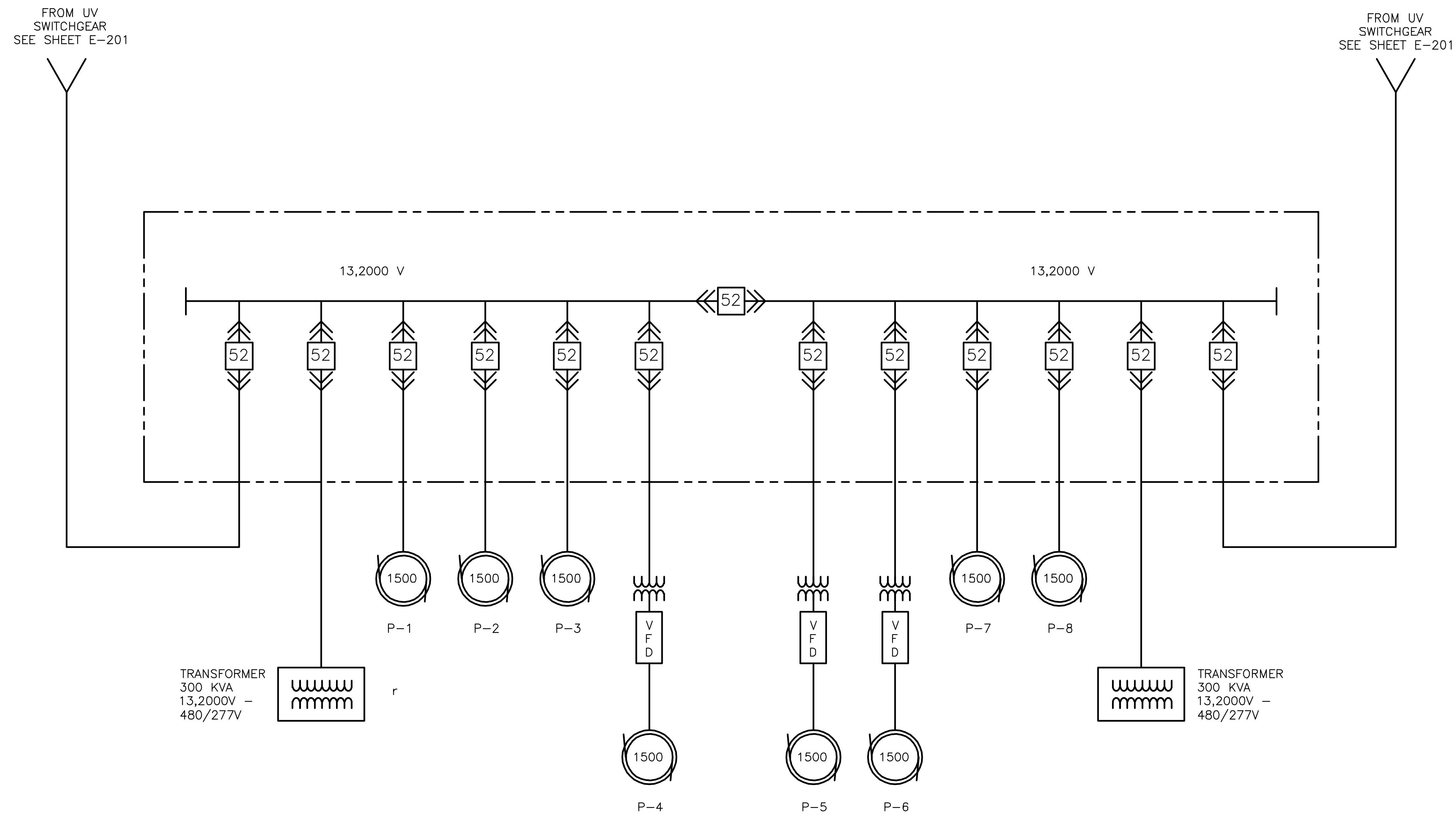

1 LOW LEVEL PUMP STATION (LLPS)
SCALE: N.T.S.

SCALE: 1/8" = 1'-0"

Rev.	Description	Appr.	Date

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

Designed by: BW/DS
Checked by: CFB
Correct: ANTHONY BOUCHARD
Approved: MWRD Assistant Chief Engineer
Drawn by: LK
Reviewed by: EPC
Date: SEPT 2008
Scale: 1/8"=1'-0"

CTE AECOM

CONTRACT 07-026-2P
STICKNEY WATER RECLAMATION PLANT
ULTRAVIOLET DISINFECTION FACILITIES

LOW LIFT PUMP STATION
ELECTRICAL PLAN

Seal

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