



# **Spring Creek Auxiliary Wastewater Treatment Plant**

## **CSO Disinfection Demonstration Study Results**



**June 2018**

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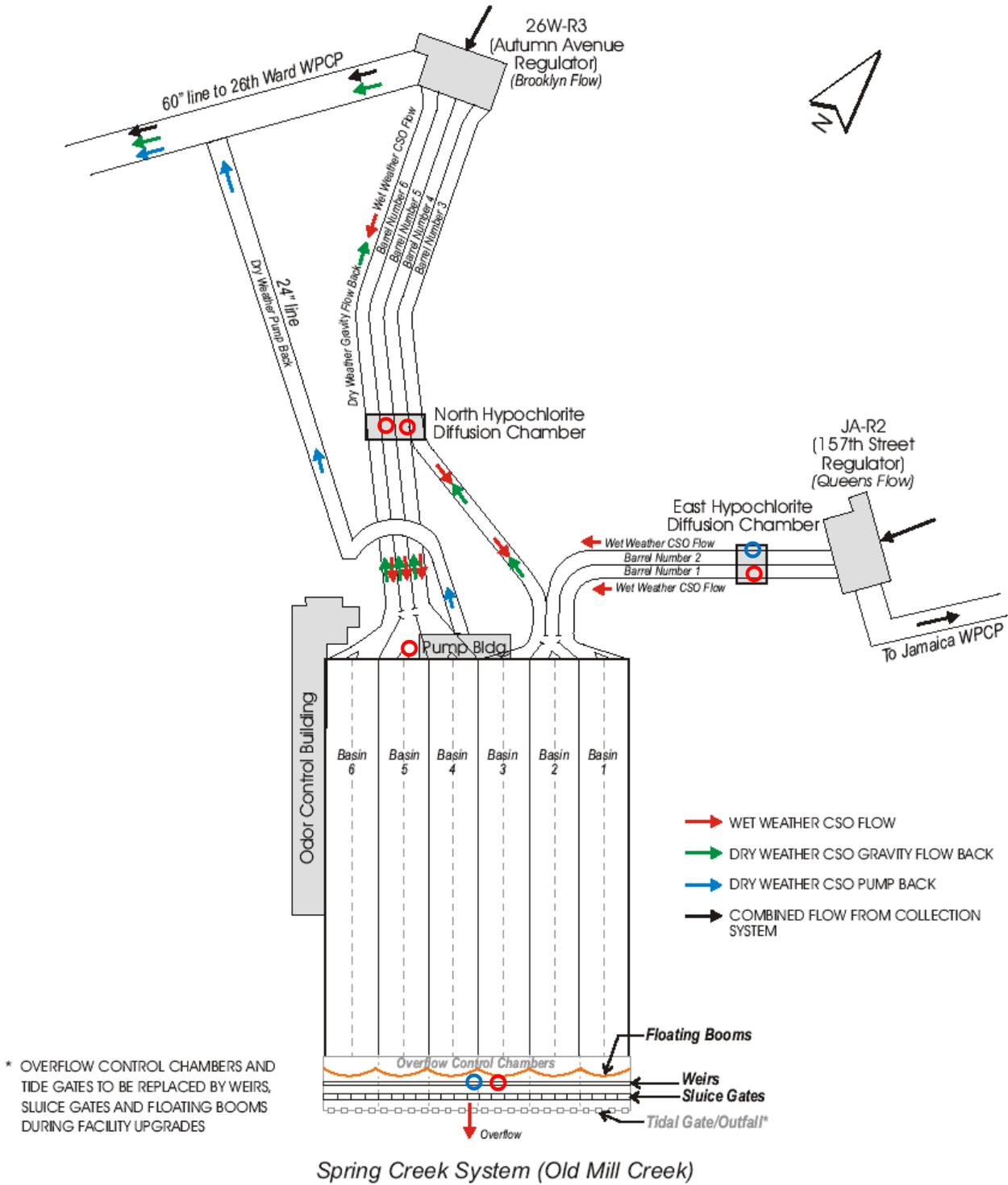
## **1. Introduction**

At the request of the NYS Department of Environmental Conservation (DEC), the NYC Department of Environmental Protection (DEP) initiated the Spring Creek Disinfection Demonstration Study to evaluate the efficacy of Combined Sewer Overflow (CSO) disinfection processes. The study plan was approved by DEC on December 16, 2015 to be conducted in Spring Creek. This one-year full-scale pilot program at Spring Creek Auxiliary Wastewater Treatment Plant (AWWTP) commenced operations on June 30, 2016. The results of the pilot study are documented in this report.

The existing chlorination system at the Spring Creek AWWTP was originally built for odor control purposes. As part of a later upgrade, an extensive odor control system was installed alleviating the need for influent flow chlorination. Subsequently, disinfection at the facility was ceased, as authorized by DEC in January 2009.

The Spring Creek AWWTP was placed into service in the 1970s to retain combined flow. The facility consists of six influent barrels that feed six basins whose volume provides for stormwater retention, floatables control and solids settling (Figure 1). Four barrels convey flow to the facility via the Autumn Avenue Regulator (26W-R3) located in the Borough of Brooklyn, and two barrels from the 157<sup>th</sup> Street Regulator (JA-R2) located in the Borough of Queens, as shown in the Figure 1. The facility provides approximately 20 million gallons (MG) of total storage, 13.8 MG attributed to the six basins and 6.2 MG to the influent barrels (NYC DEP Waterbody/Watershed Facility Plan, Jamaica Bay and CSO Tributaries, 2011).

During a rain event the basins and influent barrels are filled with combined stormwater and sanitary flow (combined flow), maximizing the reduction of CSO from the Spring Creek AWWTP. Approximately 7.0 MG of combined flow are stored in the basins above elevation - 7.50 feet and 8.9 MG are stored in the influent barrels above elevation -7.50. Once a rain event is concluded, the stored volume retained within the basins and influent barrels above elevation - 7.50 feet are drained by gravity back towards the Autumn Avenue regulator for treatment at the 26<sup>th</sup> Ward WWTP. The remaining retained volume is screened and pumped via the Dewatering Pumping System located within the Pump Building. This flow is pumped through another 24”/30” force main and discharges into the Autumn Creek Regulator.



**Figure 1.** Spring Creek AWWTP Overview.

(Sampling locations: ● Auto-sampler; ● Grab sampled locations)

## 2. Goals of the Pilot

The primary objective of the disinfection demonstration study was to enable DEP to obtain operational performance data for the variable flows and loads, associated with combined sewer overflows, in order to inform the design of the disinfection facilities that may be elements of waterbody specific Long Term Control Plans (LTCP).

### 2.1. Literature Review

Disinfection occurs as pathogens in stream flows are exposed to chemical oxidants, such as chlorine and ozone, or ultraviolet (UV) irradiation for inactivation of pathogenic microorganisms as a public health measure. Disinfection of drinking water, wastewater and CSO flows has been implemented and well documented over the past decades, especially in drinking water applications. The most widely used chemical disinfectant is chlorine, either in its liquefied gas form ( $\text{Cl}_2$ ) or as sodium hypochlorite ( $\text{NaOCl}$ ) solution, as it has proven to offer reliable reduction of pathogens and to be relatively inexpensive (USEPA, 1999).

Demonstration studies have been designed to gain better understanding of the required chlorine dosage and contact time for CSO discharges. Moffa et al. (WERF, 2005) demonstrated a chlorine dosage in the range of 8-28 mg/L for a contact time of five (5) minutes, with an optimal dose of 18.1 mg/L required to meet *E. Coli* criteria. Sharp et al. (2017) evaluated the effectiveness of chlorine disinfection for representative CSO samples on a bench-scale study. For chlorine doses of 6-7 mg/L, 3-log removal of both fecal coliform and *Enterococcus* were achieved with a contact time of less than 15 minutes, and resulting Total Residual Chlorine (TRC) concentration in the range of 4-5 mg/L.

In the late 1990's, DEP and EPA conducted a disinfection pilot study in an attempt to evaluate disinfection alternatives for the Spring Creek AWWTP and potentially at other CSO Facilities. The pilot study collected samples from the 26<sup>th</sup> ward WWTP's primary settling tank effluent channel instead of the Spring Creek AWWTP due to space and logistical constraints at the Spring Creek AWWTP site (EPA, 2003). The objectives of the pilot study were to evaluate five (5) disinfection technologies for targeted bacterial reduction for CSO treatment purposes,

however the results proved to be limited to the relative comparison of alternative disinfection technologies since the use of primary effluent wastewater was not adequate to achieve the stated goals of the study. Samples collected at this location are not representative of the typical range of wastewater quality found in the influent to the Spring Creek AWWTP. Sampling and analysis results for this component of the 26W WWTP primary effluent wastewater flow showed that for a contact time of five (5) minutes, chlorine doses of 12 mg/L and >22-24 mg/L were sufficient for a 3 log removal of fecal coliform and E. coli, respectively. For chlorine doses between 24 and 28 mg/L, no further bacterial reduction was observed. TRC concentrations ranged from 5.5 to 20 mg/L, and were at some extent influence by temperature.

### **3. Pilot Preparation**

#### **3.1. Flow Meter Installation**

To prepare for the pilot study, three (3) flow meters model ADS Intrinsically-Safe Triton+ were installed at the Spring Creek AWWTP. Two at the North (Brooklyn) influent barrels and one at the East (Queens) influent barrels, to determine flow rate through open-channel flow depth and velocity of flows from the respective regulators, 26W-R3 and JA-R2. Each flow meter characterized two barrels, thus metered flow was halved to correct for the representative system flow. Measurements from meter SC01 represents barrels 1 & 2, SC04 represents barrels 3 & 4 and SC05 represents barrels 5 & 6.

In addition to installing the ADS flow meters, programming and SCADA graphic modifications were conducted on the new PLC/SCADA within the RK-2 panel that controls the Spring Creek AWWTP disinfection system. Additional work included implementing conduit cables routing and trenching was performed to provide communications and power from the East and North hypochlorite diffusion chambers with termination at the Spring Creek AWWTP.

#### **3.2. Control Strategies**

Wade Electric and Brown and Caldwell was contracted to update the control strategy by implementing SCADA system and programming changes to the PLC in the RK-2 panel for

disinfection system controls. The work involved utilizing the three (3) flow meter signals, located in the facility's North and East Hypochlorite Diffusion chambers, for chemical dosing control of the sodium hypochlorite (chlorine) disinfection system pumps.

The newly implemented control strategy presented multiple modes. A manual mode, automatic mode 1 and automatic mode 2. The operation of the disinfection system was based on operator inputs for target chlorine dosage (in mg/L) and the concentration of the sodium hypochlorite. Such information was entered into the TRC dosage equation programmed in the PLC control.

$$\text{Chlorine Pump Output (in GPH)} = \frac{(\text{Target TRC Dose}) * (\text{Total CSO Flow})}{0.1475 * (24)}$$

Disinfection modes of operation are described as follow:

- Manual Mode: chlorine pump flow rate set manually by the operator. Chlorination is initiated by the operator at any point during the filling of the basins. The operator selects a TRC dosage (mg/L) and the calculation above determines the feed rate.
- Automatic Mode 1: operator enters a trigger elevation in the CSO Basin to initiate disinfection and chlorine dosage (mg/L). The operator selects a minimum trigger elevation in the basins to initiate the chlorination process (El. -9.1 to EL +6), and a TRC dosage, and the corresponding chlorine flow is calculated and applied.
- Automatic Mode 2 (Table 1): allows for multiple (up to five) chlorine dosages based on water elevations in the basins and are set by the operator. The controller calculates the correct pump speed based on water elevation and measured totalized CSO flow rate. As the basins fill and the first basin level set point is reached, the metering pumps will supply the calculated theoretical chlorine feed rate based on the Target TRC dose as defined in input 1. The process is repeated for up to 5 set points.

**Table 1.** Automatic Mode 2

Trigger Water Elevation (ft) (-9.1 to +6.0)	Target TRC Dosage (mg/l)
Operator Input 1	Operator Input 1
Operator Input 2	Operator Input 2
Operator Input 3	Operator Input 3
Operator Input 4	Operator Input 4
Operator Input 5	Operator Input 5

#### 4. Demonstration Testing Results

The one-year disinfection demonstration study at Spring Creek AWWTP was conducted with seasonal sampling during July to November, 2016, and May to July, 2017. In this system, disinfection was performed with a 12.5% solution of sodium hypochlorite (chlorine) with dosage ranging from 2 to 16 mg/L to the combined influent flow at the North (Brooklyn) and East (Queens) Hypochlorite Diffusion chambers. Chemical feed pumps would dose chlorine based on the control strategies previously described. A summary of the sampled rainfall event during the disinfection study and its associated combined influent flow rate, rain volume and intensity, and chlorine dosage are presented in Table 2.

**Table 2.** Summary of rainfall events during the disinfection study.

Event	Event Type <sup>(1)</sup>	Date	Average Influent Flow(MGD) Queens	Average Influent Flow (MGD) Brooklyn	Rainfall Volume <sup>(2)</sup> (in)	Rainfall Intensity (in/hr)	Chlorine Dosage Range (mg/L)
0	Combined Influent Characterization	01/10/2016			1.2	0.14	NA
1	Filling	07/29/2016	110	67	0.65	0.081	4 – 6
2	Filling	09/19/2016	109	47	0.97	0.11	4 – 6
3	Filling	10/21/2016	35	40	1.1	0.14	4 – 6
4	Overflow	11/15/2016	55	83	1.2	0.15	4 – 6
5	Overflow	05/05/2017	233	270	2.2	0.32	2 – 4
6	Filling	05/13/2017	36	54	1.7	0.086	8 – 12
7	Filling	06/19/2017	247	102	1.1	0.22	11 – 16
8	Overflow	07/07/2017	192	167	1.9	0.27	8 – 12

<sup>(1)</sup> Filling represent events in which the facility stored combined flow, but an overflow was not triggered. Overflow represent events in which an overflow (CSO) occurred.

<sup>(2)</sup> Recorded at JFK INTL weather station.

Throughout the disinfection study, pre-chlorinated influent samples were collected upstream of the chlorine addition points at the North (Brooklyn) and East (Queens) Hypochlorite Diffusion chamber (Figure 1). In addition, auto-samplers were set-up before each rain event whenever possible. Grab samples of chlorinated flow were collected at the influent and effluent basin areas (Figure 1). During rain events samples were analyzed for fecal coliform, *Enterococcus*, and TRC. For some sampling events other parameters were analyzed in order to characterize the influent flow, including ammonia (NH<sub>3</sub>-N), nitrite (NO<sub>2</sub>-N), total chemical oxygen demand (tCOD), soluble chemical oxygen demand (sCOD), and total suspended solids (TSS) were analyzed. On site sampling and laboratory analysis were performed by the NELAP-certified CCNY Environmental Lab (NELAP Lab ID#11639). TRC samples were analyzed on site. Fecal and *Enterococcus* samples were transported to the CCNY Environmental Laboratory. The analytical methods are listed in Table 3.

**Table 3.** Analytical methods for analysis.

Analyte	Method	Note
Fecal coliforms	HACH Method 8074	USEPA approved 9222 D
<i>Enterococci</i>	USEPA Method 1600	
TRC	HACH Method 10101	Adapted from Standard Methods for the Examination of Water and Wastewater

#### 4.1. Influent Flow Characterization

In order to understand the influent flow characteristics, pre-chlorinated influent samples were collected at the North (Brooklyn) and East (Queens) Diffusion chambers on January 10, 2016. At approximately 3:51 am light rainfall began to flow and enter the Jamaica Regulator (JA-R2) drainage and 26th Ward Regulator (26W-R3) areas. The rain intensity peaked at 5:51 am with 0.31 inch and tapered down to on average 0.18 in/hr until 8.51 am. The total rainfall for the day was 1.28 inches. The CCNY Environmental Lab research team collected grab samples from the Brooklyn and Queens barrels at 9:45 am and 9:50 am, respectively, once the rainfall had stopped. The characterization of the Spring Creek AWWTP influent samples are depicted in Table 4, along with the 26th Ward WWTP influent and effluent sample characterization for the same day.

**Table 4.** Characterization of Spring Creek AWWTP influent and 26<sup>th</sup> Ward WWTP influent and effluent samples collected on January 10, 2016.

Parameters	Spring Creek Influent		26 <sup>th</sup> Ward WWTP	
	Queens Barrels	Brooklyn Barrels	Influent Daily Average	Effluent Daily Average
NH <sub>3</sub> -N (mg-N/L)	0.72	1.51	4.4	7.2
NO <sub>2</sub> -N (mg-N/L)	0.026	0.028	0.05	0.08
tCOD (mg/L)	21.2	60	Not Measured	Not Measured
sCOD (mg/L)	8.55	35.5	Not Measured	Not Measured
TSS (mg/L)	27.6	15.7	48	20
Fecal coliform (CFU/100 mL)	56,000	62,500	Not Measured	33
<i>Enterococcus</i> (CFU/100 mL)	19,000	54,000	Not Measured	Not Measured

The comparison between the Spring Creek AWWTP influent and the 26<sup>th</sup> Ward WWTP influent samples demonstrate that the influent is highly diluted when compared to the average daily wastewater entering 26<sup>th</sup> Ward WWTP. Moreover, Brooklyn influent samples demonstrated significant inferior water quality levels as compared to Queens influent. Ammonia (NH<sub>3</sub>-N) concentrations from the Spring Creek AWWTP Queens and Brooklyn barrels are respectively 611% and 292% lower than the 26<sup>th</sup> Ward WWTP influent. Comparing nitrite (NO<sub>2</sub>-N) concentrations from the Spring Creek AWWTP Queens and Brooklyn barrels there is respectively 192% and 179% less nitrite than that at 26<sup>th</sup> Ward influent wastewater. The total suspended solids (TSS) for the Queens and Brooklyn barrels are respectively 174% and 306% less than the daily average of TSS concentration in the wastewater entering the 26<sup>th</sup> Ward WWTP, for the same day.

#### 4.2. Chlorine Degradation Analysis

During the rain event on September 19, 2016 samples for a bench-scale chlorine degradation analysis were collected to determine the specific chlorine dose requirements for bacterial inactivation. The rain duration was between 06:00 am to 2:00 pm and total volume as recorded from the JFK INTL weather station was 0.97 inches. In preparation for the rain event auto samplers were programed for a 12-hour period between 8:30 am to 8:30 pm with sampling at 30

minutes intervals. Actual sample collection began between 11:00 am and continued through 2:30 pm.

The bench-scale study evaluated the immediate TRC demand and the demand after 1 hour. The experiment was setup with four separate 500 mL raw samples vessels, which were spiked with chlorine dosages of 5, 10, 15, and 20 mg/L, respectively. TRC was measured and recorded for approximately 30-min intervals to simulate a detention time of the CSO retention tank. After 1 hour, each chlorinated sample was mixed with 500 mL of Jamaica Bay water at an equal ratio, and TRC was measure at 30-min intervals. First order chlorine decay rates were determine using the equation below:

$$C_{(t)} = C_{(0)}e^{-kt}$$

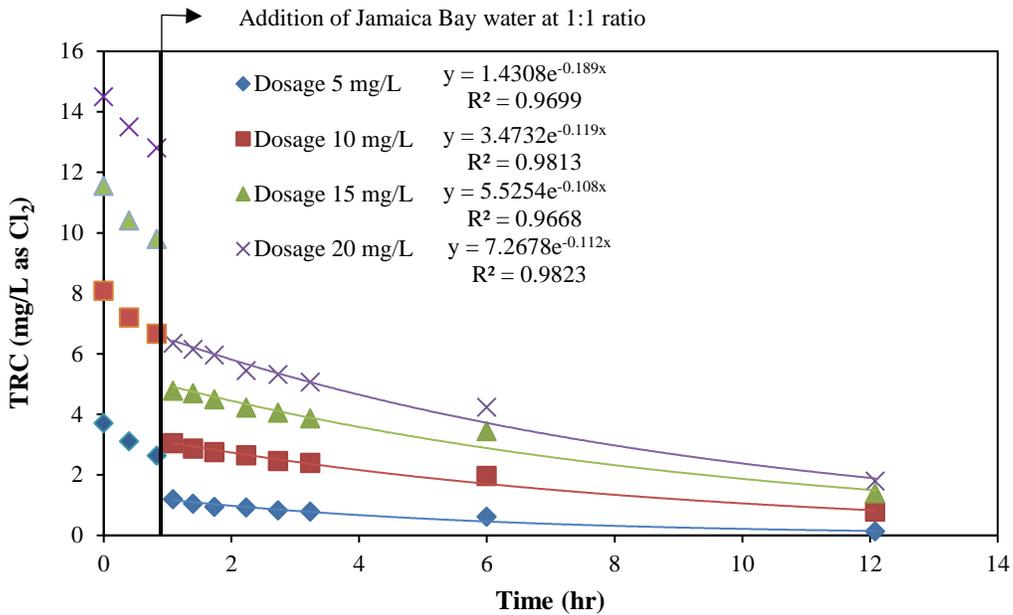
where,  $C_{(t)}$  is the chlorine concentration at any time  $t$ , mg/L;  $C_{(0)}$  is the initial concentration of chlorine, mg/L;  $t$  is time, hrs; concentration;  $k$  is the decay rate constant,  $\text{hr}^{-1}$

Figure 2 depicts the TRC decay curves for a 12-hour period for all four applied chlorine dosages. The chlorine decay curves show a significant chlorine uptake in the initial 30-min interval, which increased under higher applied dose, as expected. The overall chlorine uptake averaged  $1.48 \pm 0.27$  mg/L across all four applied dosages. An abrupt decrease in TRC concentration upon addition of Jamaica Bay water was observed due to dilution, following a steady chlorine uptake throughout the 12-hours period of contact. Table 5 shows the chlorine decay rates for the sample and Jamaica Bay 1:1 ratio water mixture samples, and the time required to reach a TRC concentration of 0.15 mg/L. As the initial chlorine applied dose increases the decay rate constant decreases, demonstrating a relatively high chlorine demand from high applied dose.

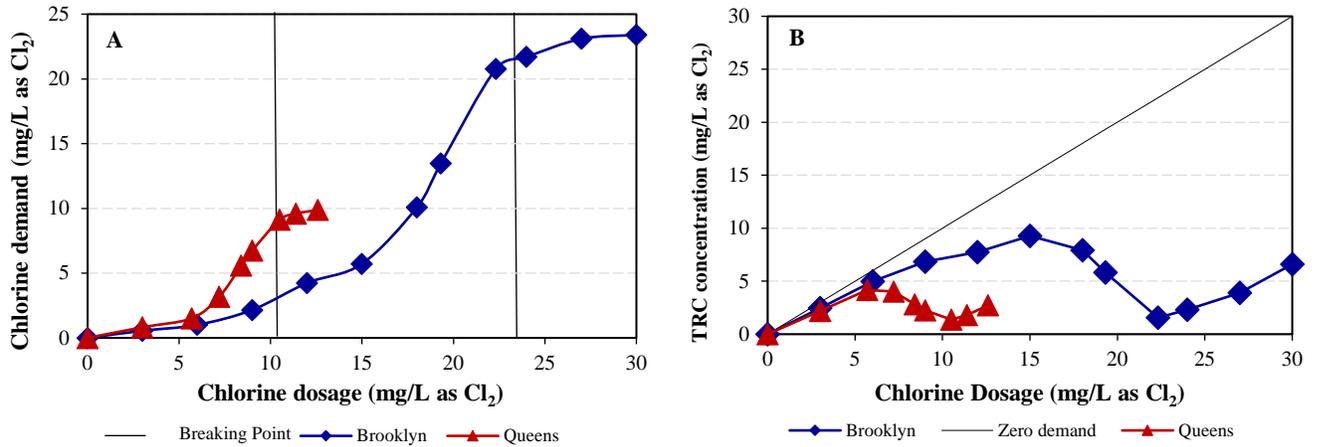
**Table 5.** Total chlorine residual concentration for studied chlorine dosages.

Chlorine dosage, mg/L	Decay Constant (K) hr <sup>-1</sup>	Initial TRC concentration after mixed with Jamaica Bay water (C <sub>0</sub> ), mg/L	Final TRC concentration, (C <sub>t</sub> ), mg/L	Required time to reach (C <sub>t</sub> ), hrs.
5	-0.189	1.43	0.15	12
10	-0.119	3.47	0.15	26
15	-0.108	5.53	0.15	33
20	-0.112	7.27	0.15	34

Based on the distinct characteristics of the Queens and Brooklyn influent samples, as depicted in Table 4, a bench-scale chlorine demand and residual analysis was conducted to determine the specific dose requirements for each influent. Figure 3 shows the chlorine demand and chlorination curve obtained with samples collected during the January 10, 2016 rain event.



**Figure 2.** Spring Creek chlorine degradation at varying chlorine dosages.



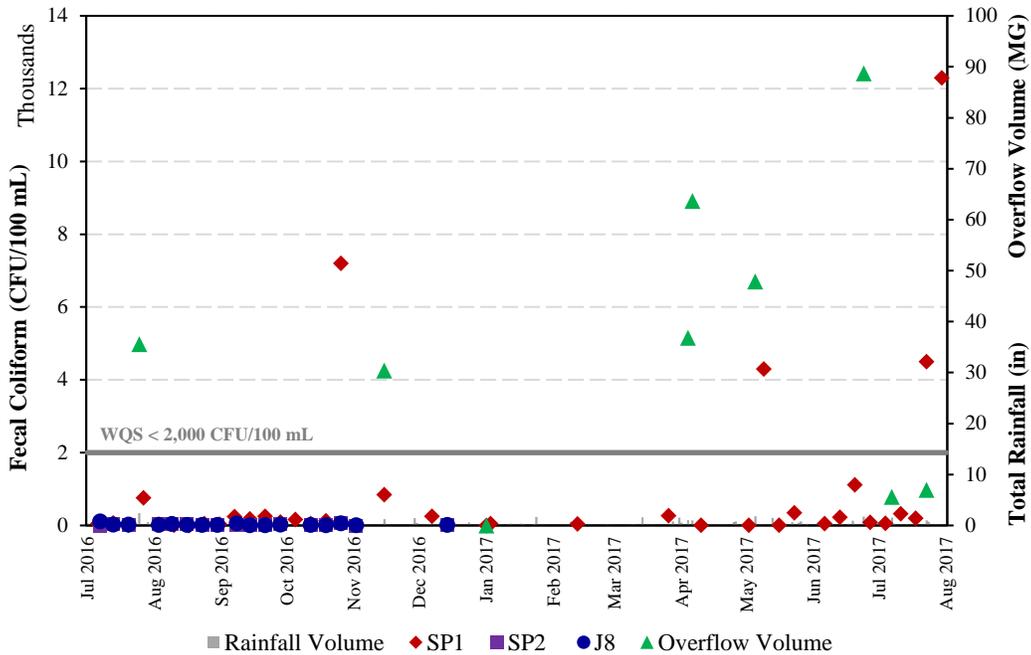
**Figure 3.** (A) Breakpoint chlorination and (B) Chlorine demand for Queens and Brooklyn influent CSO samples.

Figure 3A demonstrates a greater demand for chlorine from the Brooklyn influent stream as compared to Queens influent. As a result, breakpoint chlorination, which is where chlorine dosage meets the demand created by the reducing agents (e.g. ammonia and organic matter) and TRC begins to form, is approached differently at each influent barrel. Breakpoint for Brooklyn influent is approximately at a chlorine dosage of 24 mg/L, while the Queens influent stream has an approximate breakpoint chlorine dosage of 11.4 mg/L. The typical profile of chlorination curve, as depicted in Figure 3B, is attributed to the formation and destruction of combined chlorine residual.

Since each influent barrel presents distinct chlorine demands due to differences in the drainage area characteristics, it is not possible to ascertain a specific chlorine dosage for the Spring Creek AWWTP. Moreover, the variability of each event in terms of flow and contact time between the influent and chlorine, imposes further challenges for dosage control. Therefore, the dosage range (5-20 mg/L) proposed for this disinfection study was set based on literature review and initial bench-scale chlorine degradation analysis.

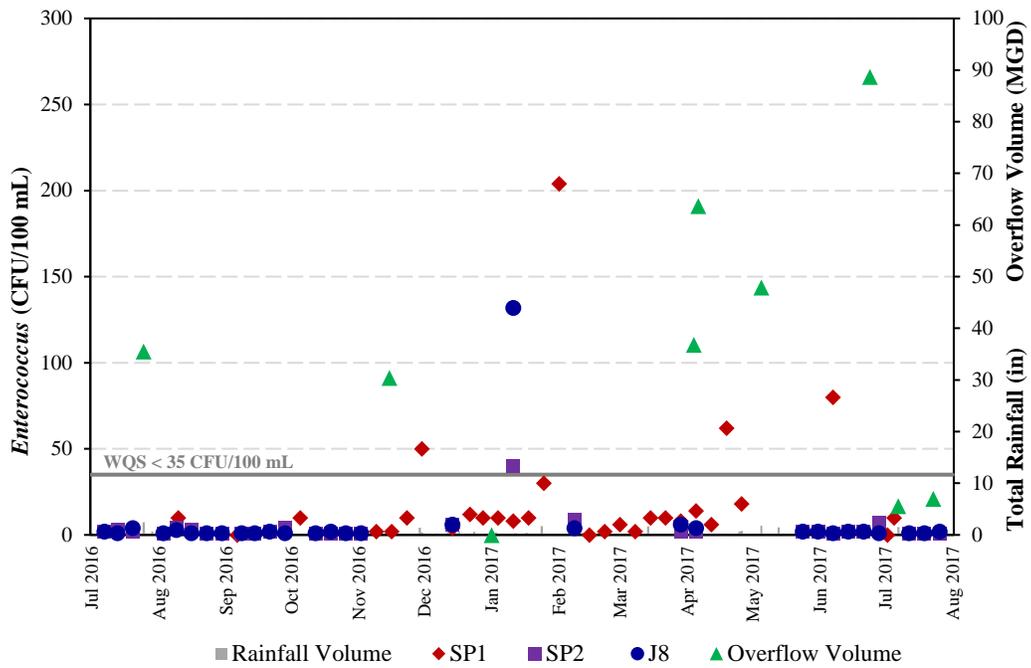
### 4.3. Spring Creek Ambient Water Monitoring Results

As part of the Post-construction Compliance Monitoring, samples were collected and analyzed from sampling stations SP1, SP2 and J8, during the Spring Creek Disinfection Demonstration study period. Results for fecal coliform and *Enterococcus* are shown below in Figures 4 and 5, respectively. Sampling stations SP1 and SP2 are located in Spring Creek and sampling station J8 is located in Jamaica Bay are shown in Figure 6.



**Figure 4.** Fecal coliform concentrations (CFU/100 mL) at Spring Creek sampling stations SP1, SP2 and J8 during the demonstration study, total rainfall volume (in), overflow volume (MG), and Water Quality Standard (WQS).

As shown in Figure 4, during the demonstration study period, only 4 samples at SP1 resulted in fecal coliform higher than 2,000 cfu/100ml, with only 1 exceedance correlating to an overflow event. No fecal coliform exceedances were observed during the entire period at SP2 or J8. Figure 5 indicates only one occurrence in which the sample taken at SP2 and J8 resulted in an *Enterococcus* concentration higher than 35 cfu/100 ml. Other overflow events did not result in a significant increase in *Enterococcus* concentration in the receiving water sampling locations.



**Figure 5.** *Enterococcus* concentrations (CFU/100 mL) at Spring Creek sampling stations SP1, SP2 and J8 during the demonstration study, total rainfall volume (in), overflow volume (MG), and Water Quality Standard (WQS).

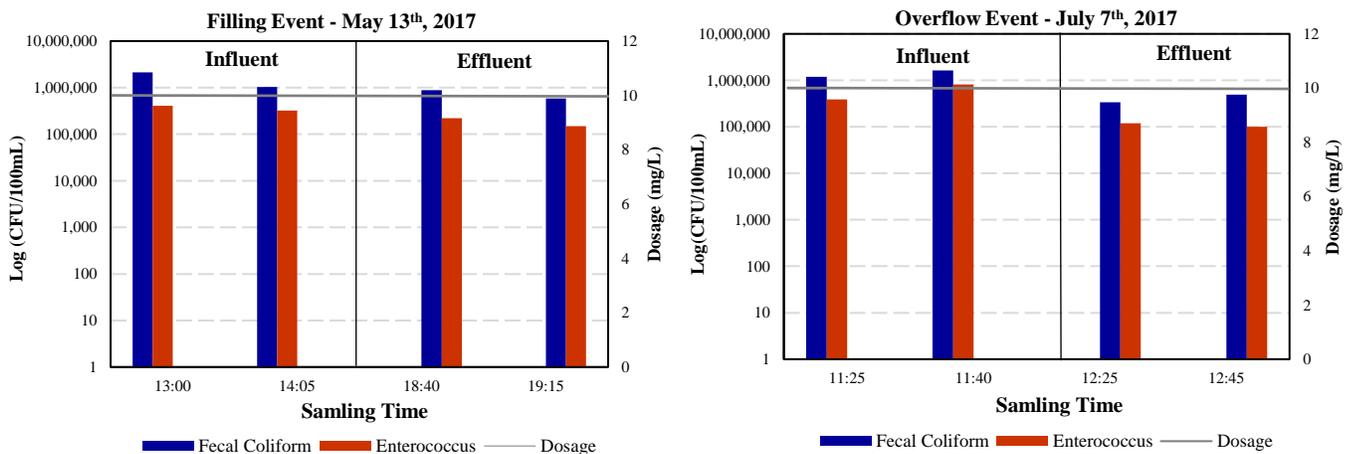


**Figure 6.** Sampling stations SP1 and SP2 locations in Spring Creek and sampling stations J8 in Jamaica Bay.

#### 4.4. CSO Disinfection Performance

As disinfection takes place by selective inactivation of pathogenic microorganisms, effective disinfection occurs when enough disinfectant (e.g. chlorine) application results in a desired bacterial kill. For this one-year disinfection demonstration study at Spring Creek AWWTP, the desired bacterial kill goal was set at a 2-log reduction per rain event. Therefore, disinfection performance was evaluated on a per event basis based on a 2-log bacteria reduction. Chlorine dosage set points were established based on results from the chlorine degradation analysis and the literature, as discussed in Section 4.2

During the demonstration study period, eight (8) rain events were sampled; in which (3) represented CSO overflow events. Average chlorine daily dosages observed during sampling rain events ranged from 2 mg/L to 16 mg/L. Figure 7 illustrates results from one (1) filling and (1) overflow CSO event captured during the study period. Daily average dosage for those selected event was 10 mg/L. Results show a decrease in both fecal coliform and *Enterococcus* counts, within the contact time experienced at the basins, for each event, with a less than 2-log bacteria reduction observed. Based on literature, chlorine dosages of 20 mg/L or more could result in higher disinfection performance, depending on the contact time. Target limits for effluent TRC concentration below 0.15 mg/L, makes operation challenging. For this study, effluent TRC ranged from non-detectable to 0.20 mg/L.



**Figure 7.** Disinfection Performance.

It is possible that one of the reasons why limited disinfection was observed was due to the limited contact time available in the existing basins. Fast developing rain events caused increased influent flows from 80 MGD to 600 MGD in less than 10 minutes. ADS flow meters reported influent flows up to 1,235 MGD, with poorest water quality attributed to the initial influx of influent flow from drainage areas into the facility due to rain, and seasonal bacterial counts variability.

## 5. Conclusions

The Disinfection Demonstration Study was successful in providing critical information by defining protocols for data collection, influent characterization, bench scale testing, and sampling, which could be useful during the planning and design of any future CSO disinfection facilities. For example, sudden and unexpected changes in the weather presented unique challenges for sample collection, which proved to be extremely time sensitive. Main conclusions of the study are included in the following table:

<b>Observation</b>	<b>Main Conclusion</b>
During the Demonstration Study chlorine dosages significantly varied mainly due to the differences in water quality from the distinct drainage area characteristics.	Each drainage area is unique and it is recommended that for any future projects a site-specific sampling plan be developed to determine dosing requirements
Each storm presented different challenges for dosage control. Variability of flows entering the facility created a wide range of events for targeted disinfection.	Any future projects must be designed to accommodate significant flow and quality variability.
Dosages used during the study did not produce significant bacteria reduction nor did they result in significant effluent TRC levels.	Due to high variability of the drainage areas and rain events, chlorine dosages cannot be standardized and will be specific to each CSO treatment facility and receiving waterbody.

## **6. Recommendations**

The results obtained during this demonstration study support the need of a site-specific sampling plan during the early planning stages of any future CSO disinfection facilities. The development and implementation of a site-specific sampling plan could allow the designer to understand influent characteristics, as well as water quality of the CSO receiving water body. Effects on the receiving waters should define the objectives for facilities performance, thus, ambient water quality should be monitored. Other parameters that should be considered during any future CSO disinfection facilities design and that could affect disinfection efficiency include decay rates, and contact time required for disinfection to occur.

## **7. References**

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