City of Winnipeg
Water and Waste Department

# Combined Sewer Overflow Management Study

## PHASE 3 Technical Memoranda

# Appendix No. 3

# TREATABILITY

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Internal Document by:

WARDROP Engineering Inc. and TetrES CONSULTANTS INC.

In Association With:

Gore & Storrie Limited and EMA Services Inc.

# 1. INTRODUCTION

Appendix No. 3, "Treatability" comprises the attached report entitled "The City of Winnipeg, CSO Treatability Evaluation", prepared for Wardrop/Tetr*ES* and by XCG Consultants, dated December 23, 1996.

The purpose of the investigations, which led to the report, was to determine the effectiveness of the high rate treatment options in removing solids from the CS flow and in preparing these flows for disinfection. The evaluation proper was undertaken using overflows from the Aubrey District as being representative of CSOs in Winnipeg. The results of this study were summarized in Section 5.5.4, "Treatment Effectiveness", in the Phase 3, T.M. No. 1.

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ENVIRONMENTAL
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# THE CITY OF WINNIPEG
# CSO TREATABILITY EVALUATION

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## 1.0 PROJECT OVERVIEW

The City of Winnipeg has embarked upon a comprehensive CSO Management Strategy. The present project was initiated in support of strategy development with the purpose of evaluating the treatability and disinfectability of combined sewer overflow in the Winnipeg area. The investigations were limited to the Aubrey Street combined sewer overflow during August and September of 1996.

## 2.0 PROJECT OBJECTIVES

The overall objective of the study was to provide initial data which may be used for evaluating the feasibility of applying physical-chemical initial treatment for Combined Sewer Overflow (CSO) control in Winnipeg.

Specific objectives of the project were as follows:

1. To characterize overflow from a single CSO with respect to quality and quantity for a range of storm conditions.

2. To evaluate the settling characteristics of sampled particulate matter in the CSO over a minimum of three storm events.

3. To evaluate the removal efficiency of coagulant enhanced settling for selected pollutants.

4. To evaluate the disinfectability of the CSO using ultraviolet light disinfection and chlorination.

5. To prepare a brief report presenting study findings.

## 3.0 SITE DESCRIPTION AND MONITORING LOCATION

### Site Description

The Aubrey sewershed consists of a drainage area of 526 ha. It is primarily composed of industrial and residential development and is serviced by a combined sewer system. Flow control within the system is provided by an overflow weir acting as a diversion structure to an overflow conduit discharging to the Assiniboine River.

The site layout is as follows:

1. An overflow weir provides relief for the Aubrey combined sewer during high flow conditions by diverting excess flow to the Assiniboine River.

2. Downstream of the overflow weir a circular 1.52 m. diameter flap gate prevents river water from flowing into the sewer system.

3. A temporary rectangular weir was installed in the overflow sewer downstream of the flap gate to facilitate flow measurement and automatic sampler triggering. The weir was 1.84 m in length and 0.44 m in height.

4. Immediately downstream of the temporary weir is the concrete gate access chamber. A wooden platform was constructed 3.35 m above the sewer invert which housed the automatic sampling and flow metering equipment. The chamber spans 1.40 m down the length of the overflow sewer.

5. The remainder of the overflow sewer measured 13.41 m in length from the downstream end of the access chamber to the discharge point into the river.

### Monitoring Location

Samples were collected from an elliptical (2.16 m wide x 2.41 m high) overflow sewer. Access to the overflow sewer was available through a concrete gate access chamber immediately downstream of the temporary overflow weir.

The temporary overflow weir was installed to allow easy access to a flow monitoring station - the flap gate prevented accessibility to the diversion weir which was situated further upstream. The installation aided in providing a representative overflow sample by preventing river water from mixing with the CSO.

## 4.0 WORK PROGRAM OVERVIEW

An overview of the work program is shown in schematic form as Figure 1. The work program was performed utilizing the resources of the City of Winnipeg as well as those provided by the consulting team. The City provided rainfall, sampling and flow monitoring equipment. The City also provided resources including field crews to retrofit the existing site so that flow monitoring and sampling was made feasible. Monitoring equipment was installed and maintained by the City field staff. All flow and rainfall data along with CSO sample collection was provided by City field staff. XCG Consultants provided direction for the field program in addition to undertaking the particulate solids characterization, chlorine disinfection and coagulant bench scale testing. Trojan Technologies assisted by providing ultraviolet disinfectability testing. TetrES Consultants provided overall study management.

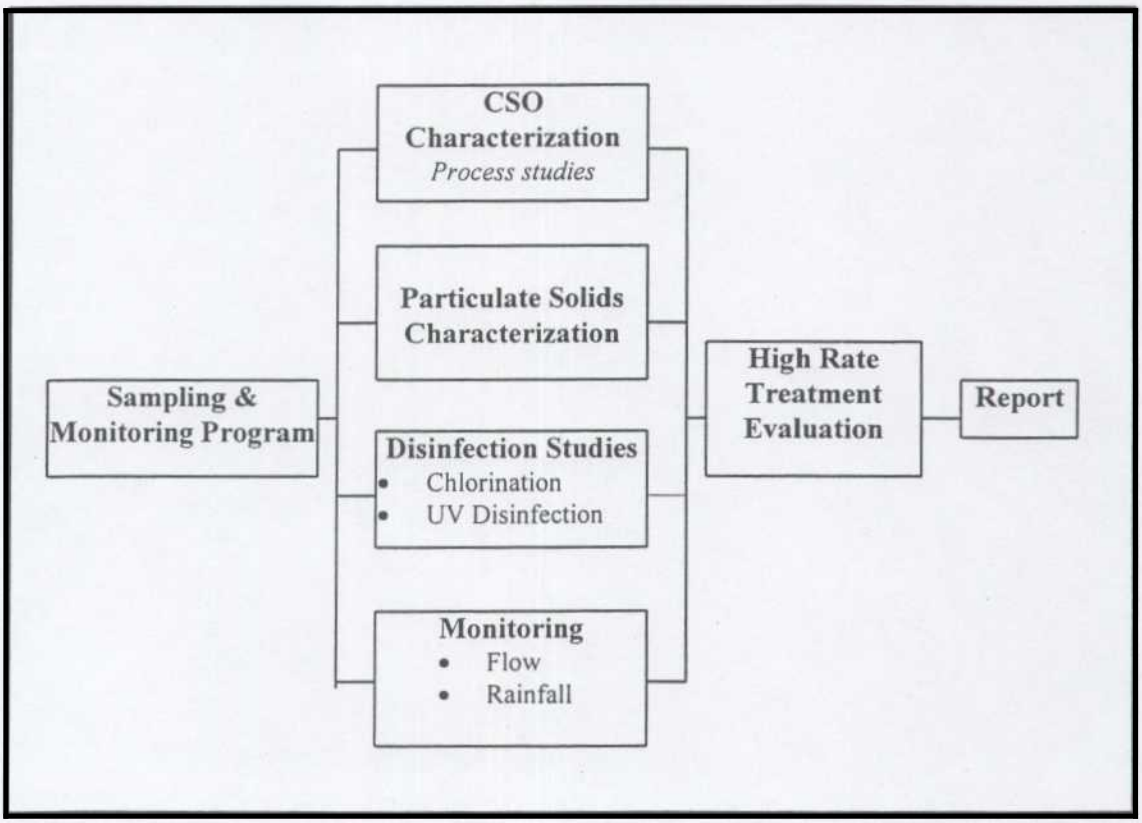



*Figure 1 - Work Program*

The work program was designed to develop specific data which could be used to measure the effectiveness of various types of unit processes in removing pollutants. Tasks were divided into studies related to wastewater characterization, treatability, settleability, and to disinfection testing.

## 5.0 CSO MONITORING AND SAMPLING PROGRAM

Both flow and rainfall data were collected to investigate the hydrologic response of the Aubrey Street overflow. The quantity of overflow was recorded using a suppressed (without end contractions) rectangular weir as the primary element fitted with corresponding level measuring and recording instrumentation. Flows were computed using an appropriate weir equation and recorded. Rainfall information was supplied by a rain gauging station designated as the Aubrey Flood Station. The station was situated immediately adjacent to the overflow chamber at Aubrey Street and was part of the City of Winnipeg Telemetry Rain Gauge Network. Station rain data was logged using a tipping bucket rain gauge and corresponding logger.

Sampling of CSO was performed by two automatic samplers, each having a triggering mechanism based on level of wastewater at the temporary overflow weir. Both samplers were triggered once flow exceeded the weir crest. One sampler was configured and programmed to collect 24 x 1,000 mL discrete samples and the other sampler collected composite samples throughout the duration of the storm event to capture average CSO quality.

The programming for each sampler is shown below in Table 1 and Table 2.

**Table 1**
**Automatic Sampler Configuration and Programming - Sequential Sampler**

| | Event #1 (Aug. 19) | Event #2 (Sept. 1) | Event #3 (Sept. 5) | Event #4 (Sept. 21) | Event #5 (Sept. 27) |
|---|---|---|---|---|---|
| Volume | 1 liter | 1 liter | 1 liter | 1 liter | 1 liter |
| Sample Interval | 5 minutes | 2 minutes | 2 minutes | 2 minutes | 2 minutes |
| Total No. of Samples | 24 | 24 | 24 | 24 | 24 |
| Sampling Duration | 2 hours | 48 minutes | 48 minutes | 48 minutes | 48 minutes |

The sequential automatic sampler was outfitted with twenty-four 1,000 mL bottles and used for determination of time varying CSO characteristics during storm events. Once the sampler was initiated by the level trigger, sample bottles were sequentially filled at fixed time intervals over the programmed sampling duration. Aliquots of the first six samples were aggregated to produce a composite sample reflecting first flush characteristics. The remainder of the samples were employed to characterize the time variation of solids through the course of the overflow event.

| Table 2<br>Automatic Sampler Configuration and Programming - Composite Sampler | | | | | |
|---|---|---|---|---|---|
| | Event #1 (Aug. 19) | Event #2 (Sept. 1) | Event #3 (Sept. 5) | Event #4 (Sept. 21) | Event #5 (Sept. 27) |
| Volume | 60 liters | 120 liters | 120 liters | 120 liters | 120 liters |
| Sample Interval | 1L/2 min. | 2L/ min. | 2L/ min. | 2L/min. | 2L/min. |
| Total No. of Samples | 1 | 1 | 1 | 1 | 1 |
| Sampling Duration | 2 hours | 1 hour | 1 hour | 1 hour | 1 hour |
| Total No. of Sample Aliquots | 60 | 60 | 60 | 60 | 60 |

The target sample volume for the composite sampler was 120 liters. Approximately 60 liters of wastewater were collected for the initial storm event since the testing program was deliberately limited while calibration and protocols were being developed. At first a period of two hours was assumed to correspond to a "typical" event. This duration was later adjusted to better represent observed storm events. The average storm composite sampler was initially programmed to collect 1 liter of sample volume at each 2 minute sample time interval, however this volume was increased to 2 liters per minute to capture a larger sample volume.

All samples were transported to the appropriate analytical laboratories for specified analysis. Samples were packed in ice during transport to maintain a sample container temperature of 4°C. Each container was sealed to maintain sample integrity. Figure 2 shows sample distribution.

The study was designed to collect monitoring data and CSO samples from three overflow events. Due to the unpredictability of an overflow occurrence and the variability of the nature of CSO wastewater, it was deemed necessary to collect samples from two additional overflow events to ensure a complete data set.

Five storm events having overflows were sampled through August and September of 1996. First flush and average event samples were collected for Storm Event #1, #3, and #4. Average event samples from Storm Event #2 and #5 only underwent settleable solids testing and UV disinfection testing respectively. Table 3 summarizes the study program.

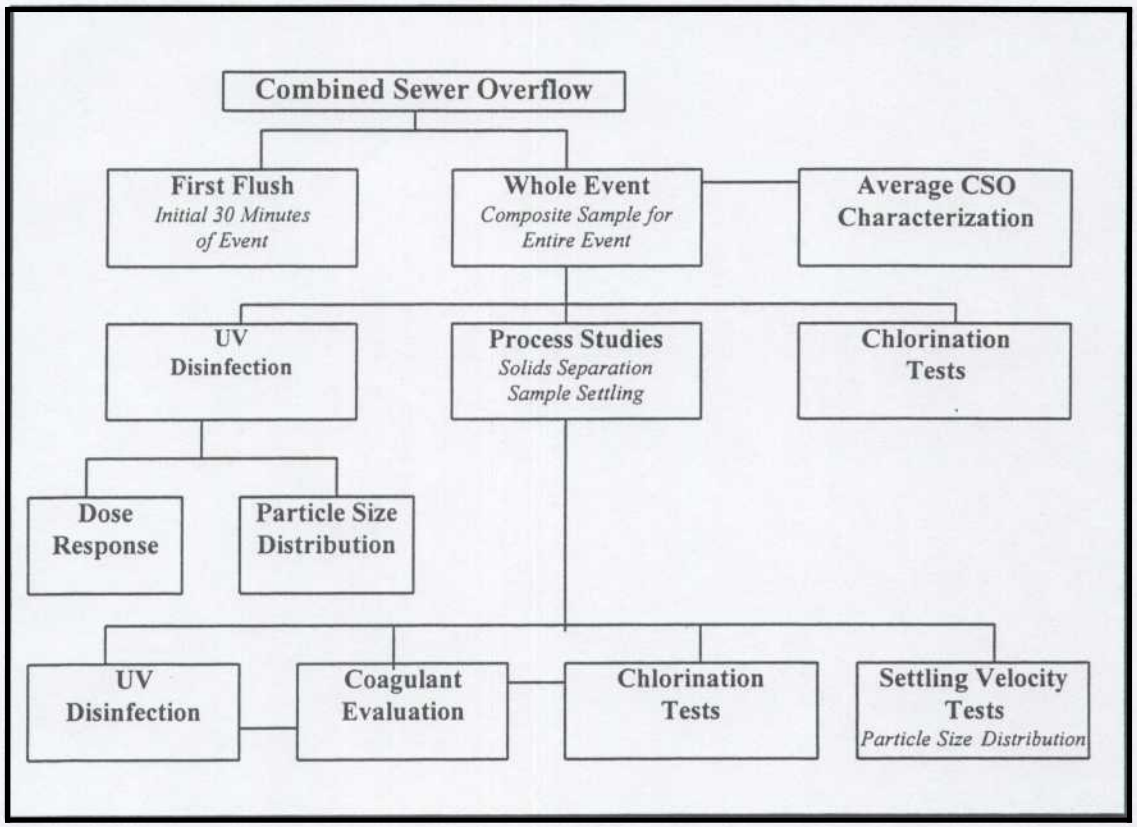



*Figure 2 - Sample Distribution*

## 6.0 CSO MONITORING RESULTS

Overflow volumes and rainfall data collected during five storm events have been summarized in Table 3.

The first sampled event occurred on August 19, 1996. Rainfall totalled 37.6mm over a five and a half hour period. Overflow was recorded for over 6 hours as shown in Figure 3. The overflow rate was uniform through its duration as rainfall continued throughout the entire period. Sampling commenced simultaneous for the samplers at 4:20 a.m. and continued for two hours. The collected sample represented the CSO quality for the initial two hours of the event.

The second overflow event began at 2:30 p.m. on September 1, 1996 and continued for seven hours until 9:30 p.m. A total of 19.6 mm of rain occurred over a two and a half hour period between 2:00 and 4:30 p.m. This intense rainfall period related to the heavy flows observed for the first hour of the event and is illustrated in Figure 4. Samples were collected and analyzed for settling characteristics - other analyses were not performed for this event.

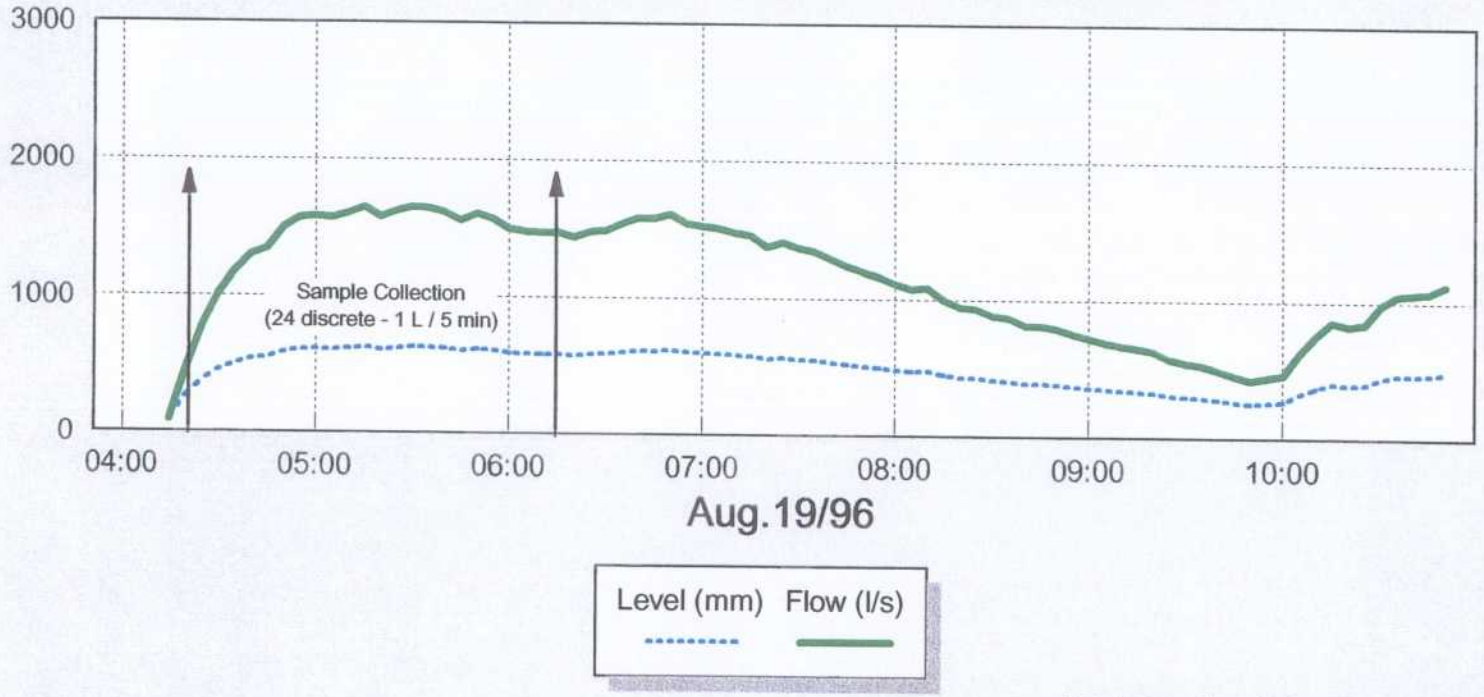
The third overflow event was captured four days later on September 5, 1996. Between 12:05 a.m. and 8:15 a.m. a total of 10.4 mm of rainfall was recorded. The rainfall occurred as follows: 2.8mm between 12:05 and 12:55 a.m., 4.0 mm between 3:15 and 3:40 a.m., 3.6 mm between 6:25 and 8:15 a.m. Overflow was recorded from 4:30 to 6:05 a.m. with response being gradual as illustrated in Figure 5. Total overflow volume was much less than observed values in the two prior storm events. Sampling commenced for both samplers at 4:40 a.m.

The fourth overflow event occurred on September 20-21 beginning at 11:10 p.m. and continued for two hours until 1:10 a.m. Flows are shown in Figure 6. A total of 3.6 mm of rainfall was recorded from 6:15 p.m. to 11:05 p.m. Total overflow volume and flowrate was similar to the previous observations recorded during the September 5, 1996 storm.

The fifth overflow event was captured five days later on September 27, 1996, and is illustrated in Figure 7. Samples were submitted for UV disinfection testing exclusively. A total of 13 mm of rainfall was recorded from 10:00 a.m on September 26, 1996 to 1:00 a.m. on September 27, 1996.

| Table 3<br>Summary of CSO Treatability Study | | | | | |
|---|---|---|---|---|---|
| | Event #1 (Aug. 19) | Event #2 (Sept. 1) | Event #3 (Sept. 5) | Event #4 (Sept. 20-21) | Event #5 (Sept. 26) |
| First Flush Characterization | Yes | No | Yes | Yes | No |
| Average CSO Characterization | Yes | No | Yes | Yes | No |
| Disinfection Testing<br>• Chlorination<br>• UV Light | Yes<br>√<br>√ | No | Yes<br>√<br>√ | Yes<br>√ | Yes<br><br>√ |
| Solids Characterization | Yes (Insufficient settling solids) | Yes | Yes | Yes | No |
| Treatability<br>• 5 Minutes Settled<br>• 50 Minutes Settled<br>• Chemically Enhanced 50 Minute Settled | Yes<br>√<br>√ | No | Yes<br>√<br>√<br>√ | Yes<br>√<br>√<br>√ | No |
| Rainfall<br>• time(s) | 37.6 mm<br>03:05-18:45 | 20.0 mm<br>14:10-16:25 | 2.8 mm-0:05-0:55<br>4.0 mm-3:15-3:40<br>3.6 mm-6:25-8:15 | 3.6 mm<br>18:15-23:05 | 13 mm<br>10:00-01:00 |
| Overflow Volume (m3) | 27,071 | 17,681 | 481 | 571 | -- |
| Sequential Sampler Operation | 04:20-06:15 | 14:35-15:21 | 04:40-05:28 | 23:15-00:03 | 13:10-13:58 |
| Composite Sampler Operation | 04:20-06:20 | 14:35-15:35 | 04:40-05:40 | 23:15-00:15 | 13:10-14:10 |

## Figure 3
## Overflow Monitoring - Event #1: Aug.19/96




Total Overflow Volume: 27,071 m3

Rainfall: 37.6mm-03:05-18:45

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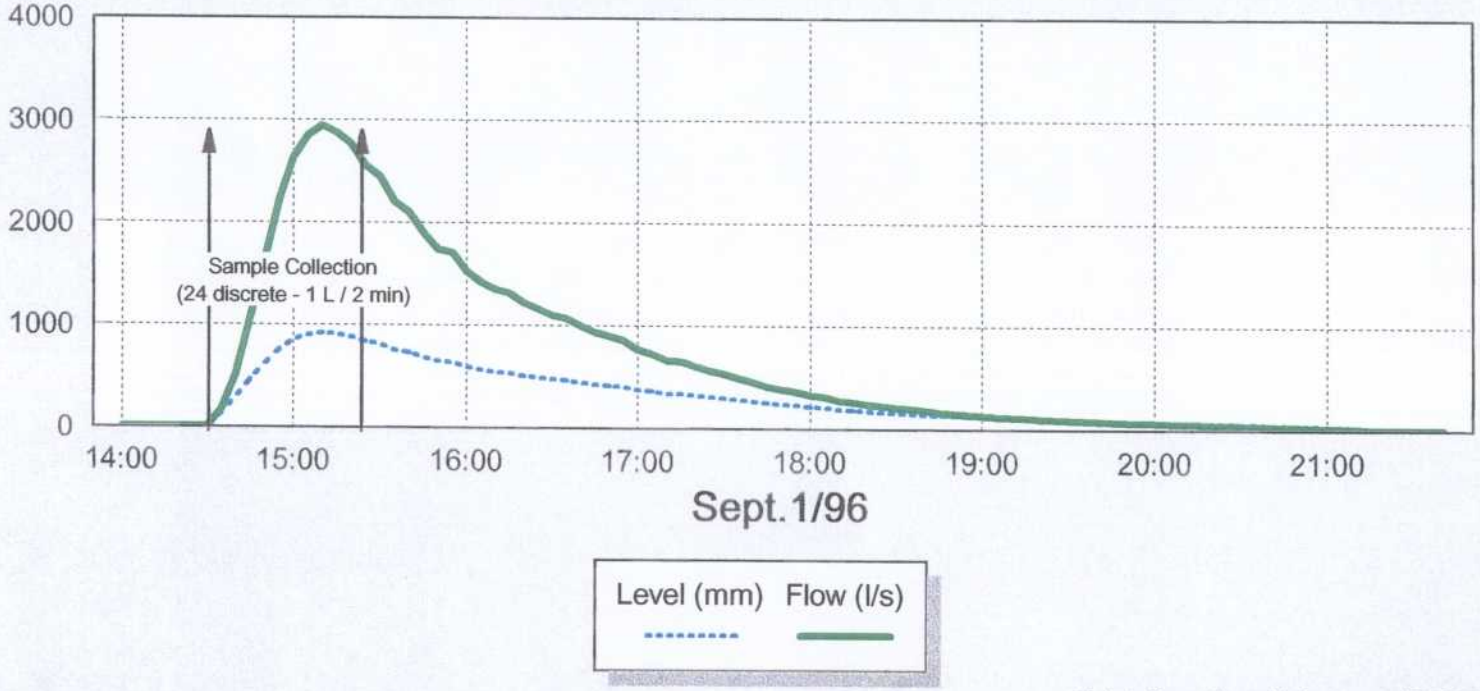
## Figure 4
## Overflow Monitoring - Event #2: Sept.1/96




Total Overflow Volume: 17,681 m3

Rainfall: 19.6mm-14:10-16:25 hrs

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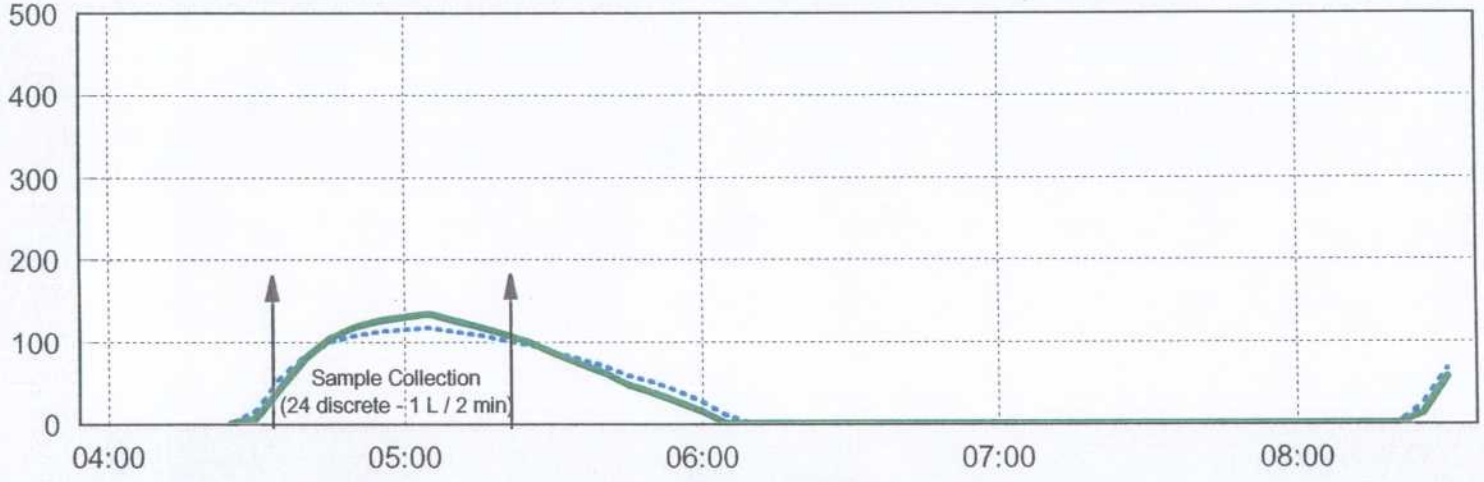
## Figure 5
## Overflow Monitoring - Event #3: Sept.5/96




Total Overflow Volume: 481 m3

Rainfall: 2.8mm-00:05-00:55 hrs; 4.0mm-03:15-03:40 hrs; 3.6mm-06:25-08

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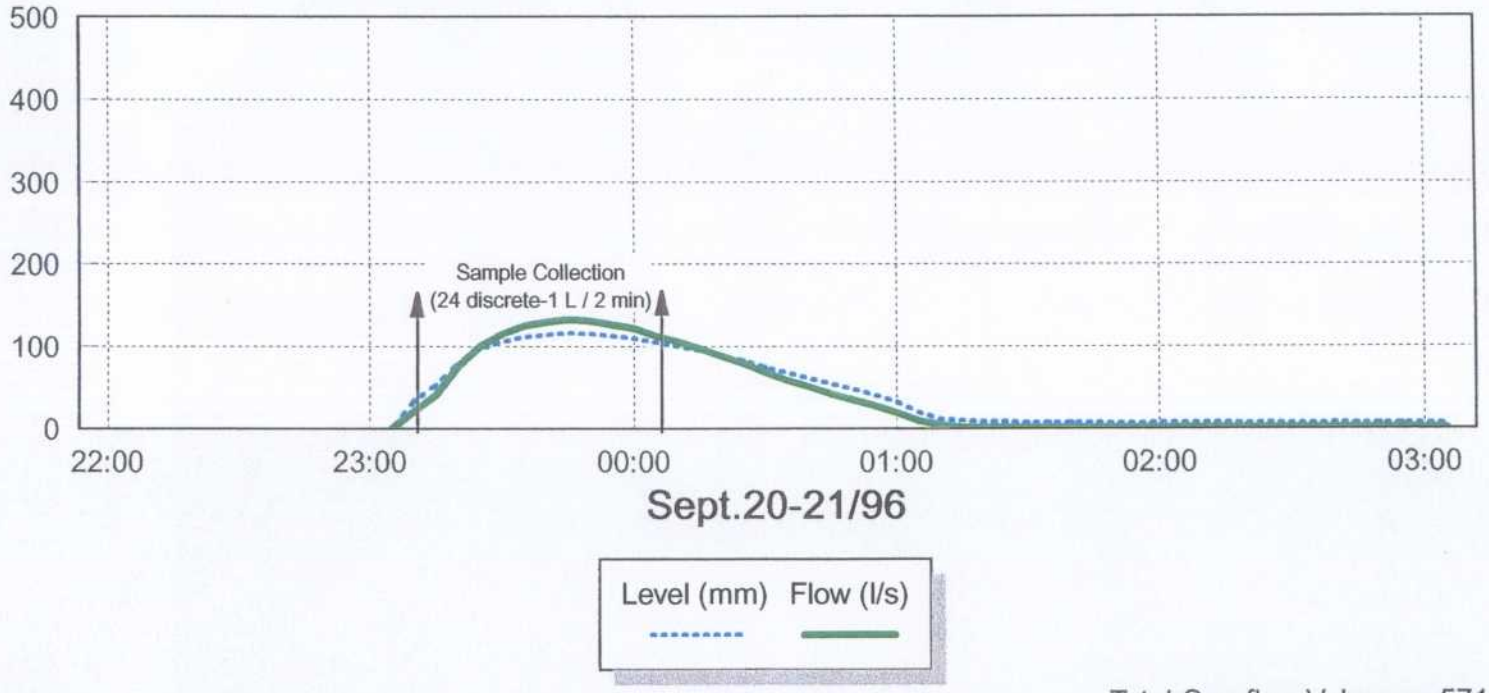
## Figure 6
## Overflow Monitoring - Event #4: Sept. 20-21/96




Total Overflow Volume: 571 m3

Rainfall: 3.6mm - Sept20@18:15-23:05

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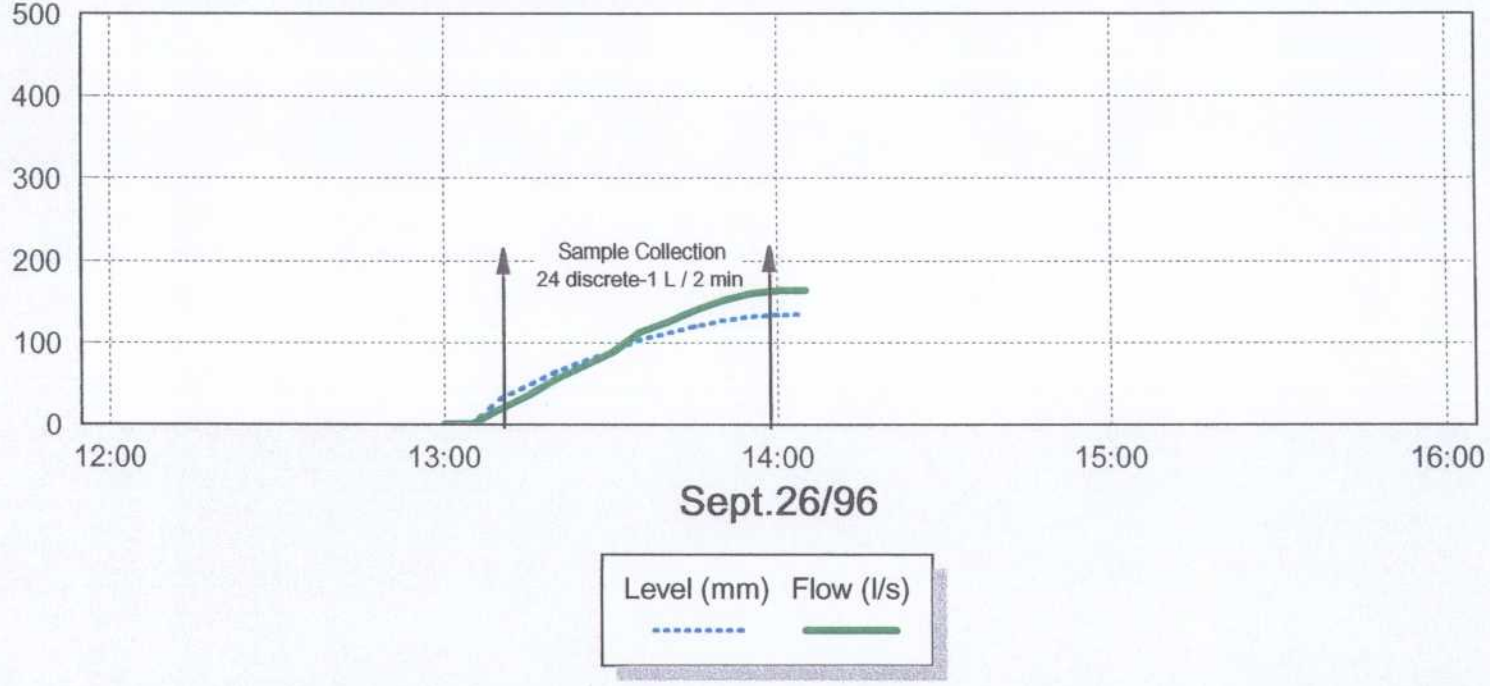
## Figure 7
## Overflow Monitoring - Event #5: Sept.26/96




Rainfall: 13mm-Sept.26@10:00-Sept.27@01:00

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# 7.0 CSO SAMPLING RESULTS

## 7.1 CSO CHARACTERIZATION - OVERVIEW

Combined sewer overflow samples were submitted for a number of chemical analyses which were performed by CANVIRO Analytical Laboratories. Microbiological analyses were carried out by Ryan Analytical Services.

## 7.2 CSO CHARACTERIZATION - RESULTS

### Conventional Parameters/Bacteria

Table 4 presents CSO quality for conventional parameters and bacteria for three monitored rainfall events which produced overflows at Aubrey. Both the overflow event average quality and the first flush quality are presented. First flush data reflects the averaged quality from three events during the first 10 to 30 minutes of each overflow event. The average quality of Aubrey CSO and typical quality from a number of other studies are presented for reference purposes.

Generally, the CSO quality observed at Aubrey compared with results from other studies. Concentrations of BOD as well as nitrogen and phosphorus are near the lower end of the range while TSS and bacteriological results are comparable to the values observed in other studies.

Comparison of first flush to average CSO concentrations observed at Aubrey show little variation in most parameters. Average first flush concentrations are generally slightly higher with ammonia being an exception. Complete sample analyses tables have been attached as Appendix A summarizing results for all parameters tested at Aubrey.

| Table 4<br>Aubrey CSO Quality-Conventional Parameters and Bacteria | | | | |
|---|---|---|---|---|
| Parameter | Units | Aubrey CSO Average Quality | Aubrey CSO First Flush Quality | Other Studies Typical CSO Range[1] |
| pH | pH units | 7.1 | 7.1 | 7.2-7.8 |
| Conductivity | µmhos/cm | 497 | 540 | - |
| Colour | TCU | 3.2 | 24 | - |
| Turbidity | NTU | 14 | 23 | - |
| BOD | mg/L | 81 | 171 | 2-357 |
| Total Phosphorus | mg/L | 2.1 | 2.4 | 1.4-8.2 |
| Dissolved Reactive Phosphorus | mg/L | <0.3 | 0.22 | 1.9-5.3 |
| Ammonia-N | mg/L | 5.1 | 4.4 | 0.1-48 |
| Total Kjeldahl Nitrogen | mg/L | 11 | 13 | 0.6-30 |
| Total Suspended Solids | mg/L | 207 | 293 | 77-522 |
| Volatile Suspended Solids | mg/L | 124 | 144 | - |
| Fecal Coliform | #/100 mL | 3,300,000 | 3,400,000 | 15-4,500,000 |
| E. Coli | #/100 mL | 1,700,000 | 2,700,000 | - |

Note:

1. *Assessment of Advanced Physical- Chemical Treatment Options for CSO*, The Municipality of Metropolitan Toronto, 1992.

## Metals Analyses

Table 5 presents averages of selected heavy metals observed in the first flush samples and composite CSO samples. As with the conventional parameters results, concentrations tend to be at the lower end of the typical range found in other studies. Comparison of first flush to average CSO concentration show little variation for most parameters. Complete sample analyses tables have been attached as Appendix A summarizing results for all metal parameters tested during the study.

**Table 5**
**Aubrey CSO Quality - Metals Analyses**

| Parameter (mg/L) | Aubrey CSO Average Quality | Aubrey CSO First Flush Quality | Other Studies Typical CSO Range[1] |
|---|---|---|---|
| Aluminum | 2.4 | 3.2 | 0.8-6.9 |
| Boron | 0.25 | 0.24 | - |
| Barium | 0.08 | 0.13 | - |
| Beryllium | <0.01 | <0.01 | - |
| Cadmium | <0.03 | <0.03 | - |
| Calcium | 34 | 50 | - |
| Chromium | 0.02 | 0.02 | 0.00005-0.04 |
| Cobalt | <0.09 | <0.09 | - |
| Copper | 0.15 | 0.21 | 0.25-0.55 |
| Iron | 2.7 | 4.2 | 2.5-11.5 |
| Lead | <0.10 | <0.10 | 0.18-0.35 |
| Magnesium | 16.6 | 24 | - |
| Manganese | 0.08 | 0.13 | 0.01-0.04 |
| Vanadium | <0.01 | <0.01 | - |
| Zinc | 0.28 | 0.28 | 0.02-0.5 |
| Nickel | <0.03 | <0.03 | 0-0.02 |
| Silver | <0.02 | <0.02 | - |
| Strontium | 0.12 | 0.14 | - |
| Sodium | 33 | 35 | - |
| Molybdenum | <0.04 | <0.04 | - |
| Titanium | 0.04 | 0.04 | - |
| Zirconium | <0.01 | <0.01 | - |

1. Note: *Assessment of Advanced Physical-Chemical Treatment Options for CSO,* The Municipality of Metropolitan Toronto, 1992.

## 7.3 CSO TREATABILITY - OVERVIEW

Simulated treatment effectiveness of various schemes were evaluated by varying the settling times of the sample. The five minute settling was used to simulate a vortex separator under design hydraulic loading while the 50 minute settling time was used to simulate conventional sedimentation basin performance. The 50 minute settling aided with chemical addition was designed to evaluate enhanced sedimentation using primary coagulants and coagulant aids.

Initial jar tests were performed on CSO from the first sampled overflow event using alum (aluminum sulphate) and ferric chloride with and without polymer addition. Both cationic and anionic high molecular weight polymers were supplied by Allied Colloids and evaluated. The jar testing matrix involved an extensive range of dosages typical for wastewater treatment. Polymers evaluated included Allied Colloids Percol 725 and Percol 757. Based on jar test results, the combination of alum (9 mg/L as Aluminum) and Percol 757 (cationic - 1.5 mg/L) was selected as producing the optimum results. This combination was then used in all subsequent tests. Jar tests involved rapid mixing after chemical addition for one minute followed by an additional slow mix for 3-4 minutes. A period of 50 minutes was then allowed for settling. Once settling times were reached, samples were then decanted and sent for disinfection analysis.

## 7.4 CSO TREATABILITY - RESULTS

### Conventional Parameters/Bacteria

Table 6 presents average analytical sample results for various simulated treatment schemes for overflows at Aubrey. Initial average CSO quality are presented together with average results after 5 minute settling, 50 minute settling, and 50 minute settling aided with chemical treatment. The 5 minute and 50 minute settled CSO averages were derived from three overflow events. The average 50 minute settled CSO sample aided with chemical treatment was derived from two overflow events.

**Table 6**
**Settling Testing Summary - Conventional Parameters and Bacteria**

| Parameter | Units | Aubrey CSO Average Quality | Aubrey CSO 5 Minute Settled | Aubrey CSO 50 Minute Settled | Aubrey CSO 50Minute Settled with Chemical Addition |
|---|---|---|---|---|---|
| pH | pH units | 7.1 | 7.0 | 7.2 | 7.1 |
| Conductivity | µmhos/cm | 497 | 487 | 487 | 610 |
| Colour | TCU | 32 | 31 | 33 | 10.4 |
| Turbidity | NTU | 14 | 11 | 11.5 | 1.2 |
| BOD | mg/L | 81 | 54 | 37 | 12.4 |
| Total Phosphorus | mg/L | 2.1 | 1.6 | 0.6 | 0.12 |
| Dissolved Reactive Phosphorus | mg/L | 0.3 | <-0.3 | <0.3 | <0.3 |
| Ammonia-N | mg/L | 5.1 | 5.4 | 4.6 | 5.5 |
| Total Kjeldahl Nitrogen | mg/L | 11 | 11.3 | 9.1 | 6.6 |
| Total Suspended Solids | mg/L | 207 | 195 | 94 | 12 |
| Volatile Suspended Solids | mg/L | 124 | 98 | 41 | 7 |
| Fecal Coliform | #100 mL | 3,300,000 | 1,800,000 | 1,600,000 | 1,800 |
| E. Coli | #100 mL | 1,700,000 | 1,450,000 | 1,300,000 | 1,600 |

Average pollutant removal percentages for each emulated treatment method are presented in Table 7. Chemically enhanced treatment with settling produced effective removals of nearly all conventional pollutant parameters. As expected and observed in previous studies the removal efficiency for ammonia was negligible. Bacteria reduction is minimal with 5 and 50 minute settled CSO. Chemically treated (undisinfected) 50 minute settled CSO yielded a more substantial 3 log reduction of bacteria.

| Table 7<br>Settling Testing - Percent Reduction of Conventional Parameters and Bacteria | | | |
|---|---|---|---|
| Parameter | 5 Minute Settled CSO | 50 Minute Settled CSO | 50 Minute Settled CSO with Chemical Addition |
| Turbidity | 21% | 18% | 91% |
| BOD | 33% | 54% | 85% |
| Total Phosphorus | 24% | 71% | 94% |
| Ammonia-N | 0% | 0% | 0% |
| Total Kjeldahl Nitrogen | 0% | 17% | 40% |
| Total Suspended Solids | 6% | 55% | 94% |
| Total Volatile Solids | 21% | 67% | 94% |
| Fecal Coliform | <1 log reduction | 1 log reduction | 3 log reduction |
| E. Coli | 1 log reduction | 1 log reduction | 3 log reduction |

### *Metals Analyses*

Table 8 summarizes heavy metals concentrations after undergoing simulated settling of 5 and 50 minutes. The 50 minute settling test was also run using chemical enhancement. Marginal differences in concentrations are observed when samples are settled for 5 and 50 minutes. Samples treated with coagulant followed with settling for 50 minutes showed little variance - zinc, copper and iron displayed the most variance.

**Table 8**
**Aubrey CSO Quality Settling Testing Summary - Metals Analyses**

| Parameter (mg/L) | Aubrey CSO Avera0e Quality | 5 Minute Settled CSO | 50 Minute Settled CSO | 50 Minute Settled CSO with Chemical Addition |
|---|---|---|---|---|
| Aluminum | 2.4 | 1.8 | 1.2 | 0.67 |
| Boron | 0.25 | 0.22 | 0.23 | 0.23 |
| Barium | 0.08 | 0.06 | 0.04 | 0.01 |
| Beryllium | <0.01 | <0.01 | <0.01 | <0.01 |
| Cadmium | <0.03 | <0.03 | <0.03 | <0.03 |
| Calcium | 34 | 31 | 29 | 28 |
| Chromium | 0.02 | 0.02 | 0.02 | <0.02 |
| Cobalt | <0.09 | <0.09 | <0.09 | <0.09 |
| Copper | 0.15 | 0.09 | 0.06 | <0.02 |
| Iron | 2.7 | 1.9 | 1.5 | 0.16 |
| Lead | <0.10 | <0.10 | <0.10 | <0.10 |
| Magnesium | 16.6 | 15.3 | 14.4 | 14 |
| Manganese | 0.08 | 0.07 | 0.07 | 0.05 |
| Vanadium | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 0.28 | 0.17 | 0.14 | 0.04 |
| Nickel | <0.03 | <0.03 | <0.03 | <0.03 |
| Silver | <0.02 | <0.02 | <0.02 | <0.02 |
| Strontium | 0.12 | 0.12 | 0.11 | 0.12 |
| Sodium | 33 | 33 | 32 | - |
| Molybdenum | <0.04 | <0.04 | <0.04 | <0.04 |
| Titanium | 0.04 | 0.03 | 0.03 | <0.01 |
| Zirconium | <0.01 | <0.01 | <0.01 | <0.01 |

Note:

1. *Assessment of Advanced Physical-Chemical Treatment Options for CSO*, The Municipality of Metropolitan Toronto, 1992.

# 8.0 CSO SOLIDS ANALYSES

## 8.1 TIME-VARIED SOLIDS ANALYSES

To characterize the time variation of solids through the course of an overflow event, samples collected using the sequential automatic sampler were submitted for solids analysis. Twenty-four discrete samples collected at fixed time intervals were analyzed for three overflow events. The time-varied solids results are listed in Table 9 for each event.

**Table 9**
**Aubrey CSO Quality Event Sampling - Solids Variation**

| Event #1 | | | Event #3 | | | Event #4 | | |
|---|---|---|---|---|---|---|---|---|
| Bottle No. | Sample Time | TSS (mg/L) | Bottle No. | Sample Time | TSS (mg/L) | Bottle No. | Sample Time | TSS (mg/L) |
| 1 | 04:20 | 930 | 1 | 04:40 | 120 | 1 | 23:15 | 270 |
| 2 | 04:25 | 1,200 | 2 | 04:42 | 110 | 2 | 23:17 | 280 |
| 3 | 04:30 | 860 | 3 | 04:44 | 110 | 3 | 23:19 | 280 |
| 4 | 04:35 | 900 | 4 | 04:46 | 110 | 4 | 23:21 | 300 |
| 5 | 04:40 | 710 | 5 | 04:48 | 120 | 5 | 23:23 | 290 |
| 6 | 04:45 | 870 | 6 | 04:50 | 130 | 6 | 23:25 | 300 |
| 7 | 04:50 | 1,200 | 7 | 04:52 | 120 | 7 | 23:27 | 320 |
| 8 | 04:55 | 830 | 8 | 04:54 | 110 | 8 | 23:29 | 340 |
| 9 | 05:00 | 860 | 9 | 04:56 | 120 | 9 | 23:31 | 380 |
| 10 | 05:05 | 1,200 | 10 | 04:58 | 120 | 10 | 23:33 | 440 |
| 11 | 05:10 | 1,100 | 11 | 05:00 | 140 | 11 | 23:35 | 290 |
| 12 | 05:15 | 920 | 12 | 05:02 | 160 | 12 | 23:37 | 550 |
| 13 | 05:20 | 930 | 13 | 05:04 | 160 | 13 | 23:39 | 540 |
| 14 | 05:25 | 590 | 14 | 05:06 | 200 | 14 | 23:41 | 530 |
| 15 | 05:30 | 630 | 15 | 05:08 | 160 | 15 | 23:43 | 580 |
| 16 | 05:35 | 480 | 16 | 05:10 | 180 | 16 | 23:45 | 560 |
| 17 | 05:40 | 550 | 17 | 05:12 | 170 | 17 | 23:47 | 650 |
| 18 | 05:45 | 540 | 18 | 05:14 | 160 | 18 | 23:49 | 600 |
| 19 | 05:50 | 480 | 19 | 05:16 | 160 | 19 | 23:51 | 530 |
| 20 | 05:55 | 480 | 20 | 05:18 | 140 | 20 | 23:53 | 560 |
| 21 | 06:00 | 530 | 21 | 05:20 | 150 | 21 | 23:55 | 540 |
| 22 | 06:05 | 440 | 22 | 05:22 | 140 | 22 | 23:57 | 470 |
| 23 | 06:10 | 350 | 23 | 05:24 | 43 | 23 | 23:59 | 500 |
| 24 | 06:15 | 430 | 24 | 05:26 | 42 | 24 | 00:00 | - |

## 8.2 PARTICULATE SOLIDS CHARACTERIZATION

The purpose of this task was to establish the particulate settling characteristics of the Aubrey CSO and hence the feasibility of utilizing high rate solid separation devices such as vortex separators.

### 8.2.1 Column Testing

Three overflow events were sampled by the City of Winnipeg field staff for solids characterization. Column testing experiments were used to describe the settling characteristics of the combined sewer overflow. The settling column testing was based on procedures developed by Dr. H. Brombach (*Assessment of Advanced Physical-Chemical Treatment Options for CSO*, The Municipality of Metropolitan Toronto, 1992).

Settling velocity of settleable particles was measured using a settling column apparatus (see Figure 8). First, the raw sample was allowed to pre-concentrate for two hours in the settling column. Next, the bottom sludge was withdrawn and placed in a vertical perspex section having a feeding mechanism at the top, and materials again allowed to settle in a settling column filled with water. Bottom samples were withdrawn at logarithmic spaced intervals from the bottom of this perspex section through a tube. Samples were taken at intervals of 15 sec., 30 sec., 60 sec., 2 m, 4 m, 8 m, 15 m, 30 m, 60 m, 120 m starting whenever the particle cloud first arrived at the bottom of the column. Each sample withdrawn was then analyzed for total suspended solids (mg/L). The distribution of settleable mass was then directly obtained.

### 8.2.2 High Rate Treatment Evaluation

Figure 9 shows settling curves for Aubrey CSO. The curves are quite similar, with median velocities of about 0.3 cm/sec (range 0.15 - 0.4). A large fraction of relatively light material, with settling velocities between 0.1. cm/sec. and 0.6 cm/sec. is indicated by the steep slope of the curve. No material with settling velocities in excess of 1.0 cm/sec. (fine sand) was found. Also shown for reference is a settling curve based upon 50 experiments carried out throughout the United States.

No heavy grit was found in any of the samples. An extremely large fraction ($\approx$ 90%) of matter had settling velocities less than 0.5 cm/sec (range 0.3 - 0.7). This represents a majority of "very fine" solids fraction that likely would be too light for effective solids removal with a vortex solids separator. Conventional sedimentation technology at lower hydraulic loading rates coupled with screening for floatables would be more effective for solids/floatables control at Aubrey.

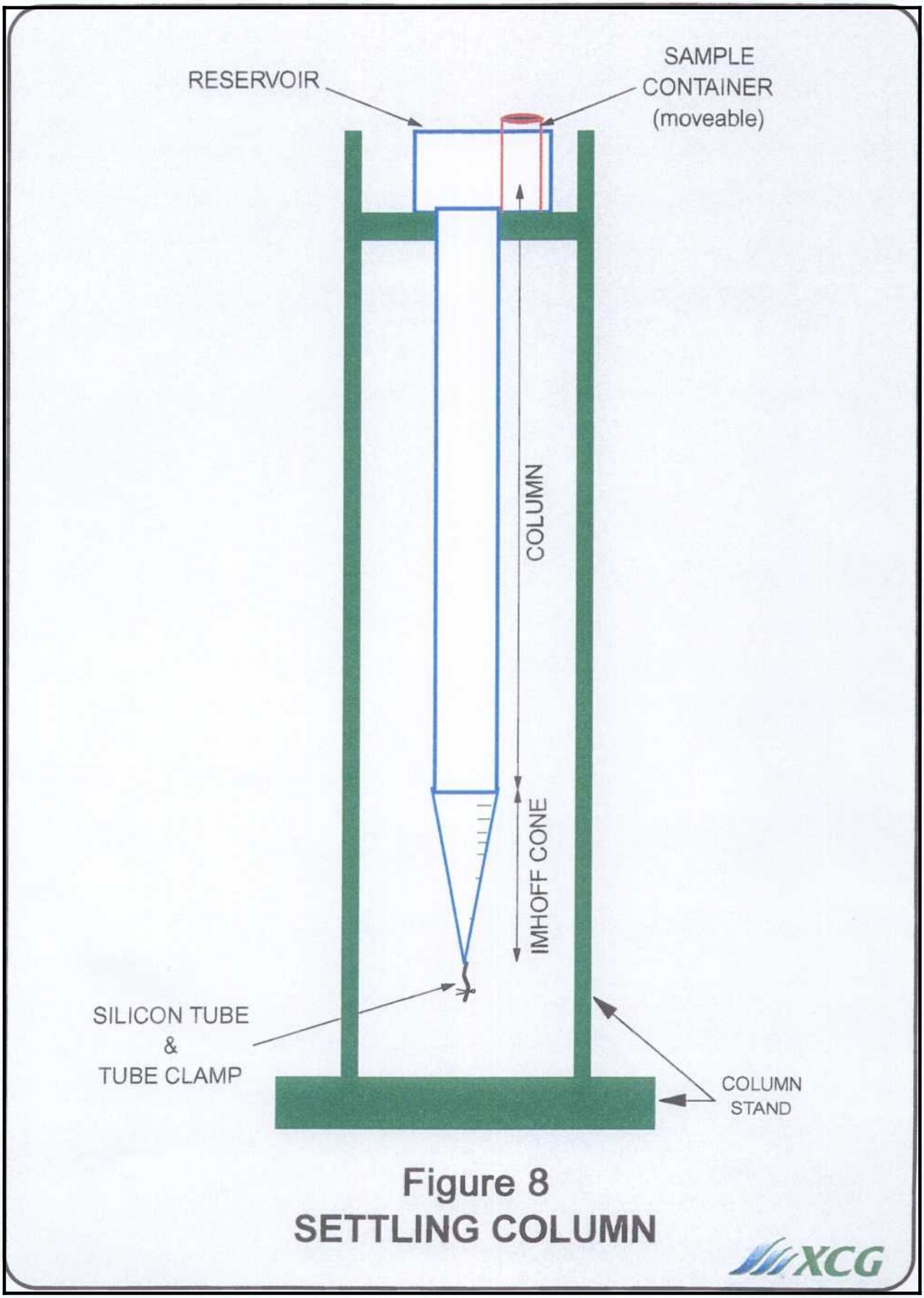
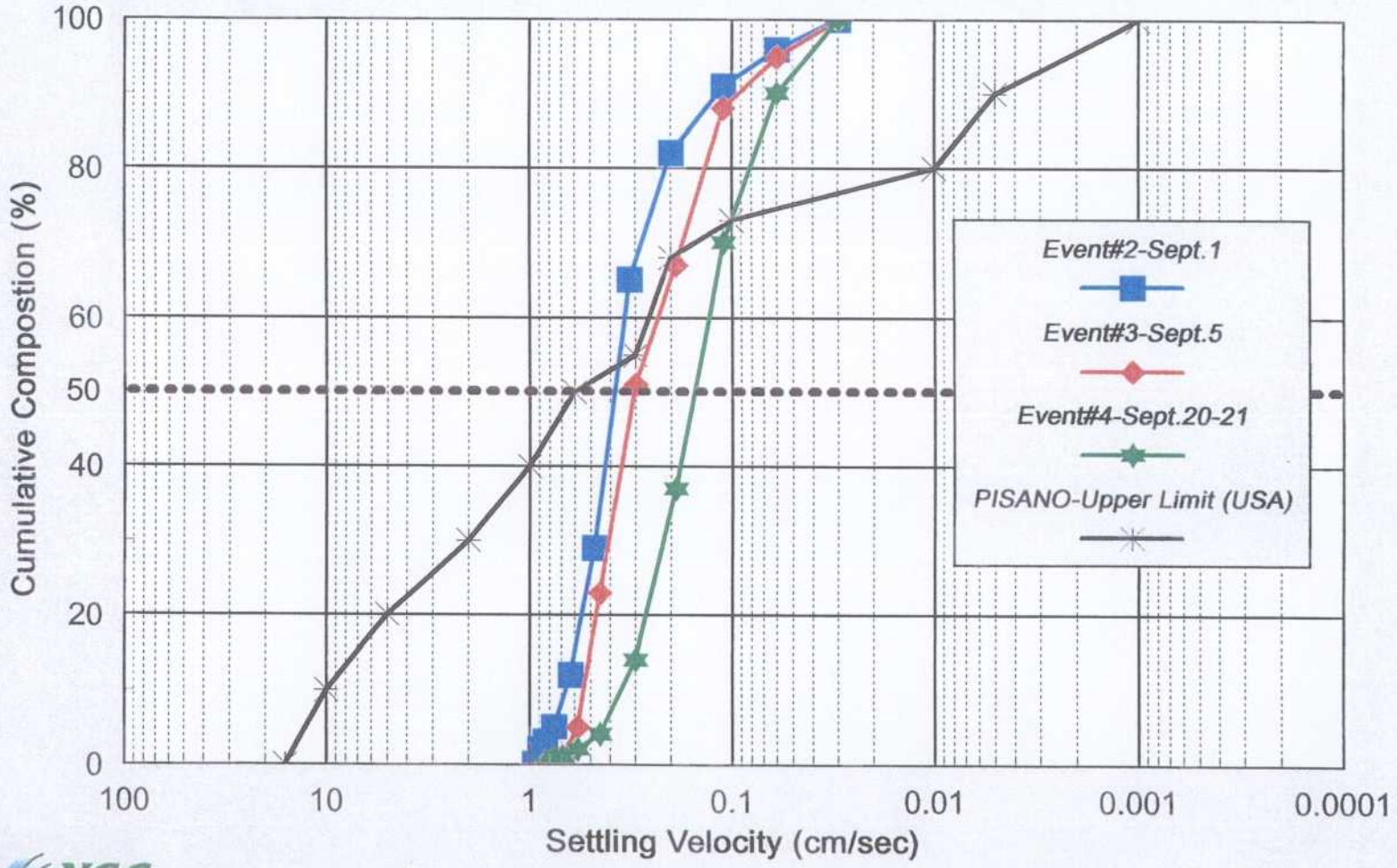



**Figure 8**
**SETTLING COLUMN**

# Figure 9
# Aubrey CSO - Settleable Solids Curves

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# 9.0 DISINFECTION STUDIES

## 9.1 OVERVIEW

The purpose of the disinfection studies was to establish the dose response relationships (bacteria reduction versus disinfectant dose and contact time) for both sodium hypochlorite and ultraviolet light irradiation. The chlorination studies were conducted by XCG Consultants while the ultraviolet light irradiation experiments were carried out by Trojan Technologies. The target effluent objective for fecal coliform was selected as 200 organisms per 100 mL. Generally a four to five log reduction is deemed necessary to achieve the target objective of fecal coliform densities ranging between $10^6$ and $10^7$ organisms per 100 mL.

In both cases it was assumed that a two-stage process would be followed:

- First Stage - Treatment by either physical or physical chemical means.
- Second Stage - Disinfection in a second vessel with hypochlorite or ultraviolet light irradiation.

## 9.2 ULTRAVIOLET LIGHT DISINFECTION - METHODOLOGY

Samples from three overflow events were analyzed for UV absorbance @ 254 nm (filtered and unfiltered), TSS and fecal coliform bacteria. In addition, UV dose-response curves were developed for two samples of untreated CSO and three samples of simulated sedimentation basin effluent. The sedimentation basin effluent simulated the design detention time of 50 minutes. One sample of chemically treated CSO with 50 minute settling also underwent UV disinfection tests. A collimated beam apparatus was used in the dose-response experiments.

## 9.3 ULTRAVIOLET LIGHT DISINFECTION - RESULTS

Results are presented as log organism reduction versus applied UV dosage and are presented in Figures 10, 11 and 12.

Figure 10 presents the dose response relationships for untreated (raw) CSO and 50 minute settled CSO. A four log fecal coliform reduction is achieved using UV dosage of 50 m Ws/cm$^2$. Little variation was found between the two samples. Figure 11 shows testing performed on untreated, 50 minute settled, and chemically enhanced 50 minute settled CSO. Target reduction is achieved at 20 m Ws/cm$^2$ and 14 m Ws/cm$^2$ for 50

minute settled and chemically enhanced 50 minute settled CSO respectively. Figure 11 shows 50 minute settled CSO achieving target reduction with a UV dose of 48 m $Ws/cm^2$. Typically, secondary effluent disinfection applications use dosages in the range of 20-40 m $Ws/cm^2$. Complete sample analyses tables for UV disinfection testing have been attached as Appendix B. Figure 13 presents the 50 minutes settled dose-response results from the three experiments. The three sets of results highlight the variability typically observed with CSO disinfection and reinforces the need for an adequate data set to finalize process effectiveness and process sizing decisions.

## 9.4 CHLORINATION - METHODOLOGY

Chlorination experiments were carried out on CSO samples from three wet weather overflow events. Initial experimentation was performed to establish relationships of applied dosage to total residual chlorine (TRC) for various contact times. Treated CSO was used to develop the chlorine dose to total residual chlorine ($Cl_2$ dose - TRC) relationship. The use of treated CSO provided an estimate of the required dose for application to different control technologies.

## 9.5 CHLORINATION - RESULTS

Figure 14 presents the $Cl_2$ dose - TRC relationship for two, seven and 20 minute contact times. At low dosages the contact time has the lowest impact and yields approximately the same $Cl_2$ residual concentrations. As dosage and contact time increases there is greater opportunity for chemical reaction resulting in lower residual concentrations for a given dosage at higher contact times.

Based on previous experience and the need for high rate chlorination, dosage response characteristics were established for two, seven and 20 minute contact times for the three simulated treatment technologies. The chlorination experiments were conducted to yield both low and high dosage response.

### Low $Cl_2$ Dosage - Response

Figure 15 shows the results of various contact times using 5 minute settled CSO - this effluent simulates the degree of solids separation afforded by a vortex separator. To achieve target reduction, a TRC of 10-12 mg/L as $Cl_2$ was required at a 20 minute contact time, equivalent to a dosage of about 12-14 mg/L as $Cl_2$.

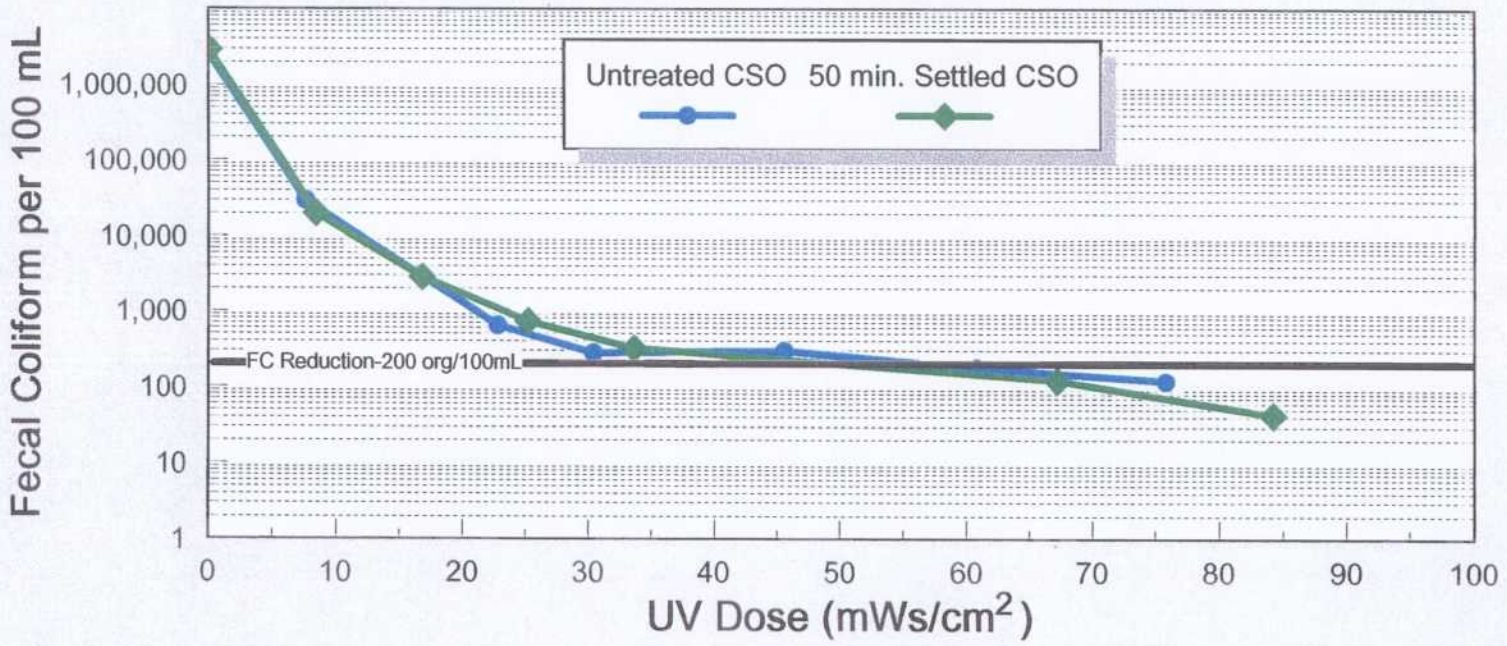
Figure 16 presents disinfection results for 50 minute settled CSO - this effluent simulates conventional sedimentation basin discharge. CSO settled for 50 minutes required a TRC of 3.5 mg/L as $Cl_2$. equivalent to a dosage of about 4-5 mg/L as $Cl_2$. at a 20 minute contact time - this was approximately one-third the TRC concentration observed for the 5 minute settled effluent. At the 20 minute contact time, the required TRC concentration is

reduced further when using chemically enhanced 50 minute settled CSO (see Figure 17). Using the chemically enhanced 50 minute settled effluent, as seen in Figure 17, target reduction can be achieved at 2 minutes contact time with TRC of 4 mg/L as $Cl_2$. To achieve the required TRC of 4 mg/L as $Cl_2$ (20 minute contact time) a dosage of about 5 mg/L as $Cl_2$ would be required (see Figure 14). While the results achieved at very low contact of times (2-5 minutes) show promise, previous studies (*Assessment of Advanced Physical - Chemical Treatment Options for CSO,* The Municipality of Metropolitan Toronto, 1992) have shown that disinfection performance may be inconsistent over the anticipated range of CSO variation. If it is desired to utilize very low contact times, additional process studies (bench and pilot scale) will be needed to confirm consistency of operation.

### *High $Cl_2$ Dosage - Response*

For lower contact times, higher TRC concentrations are required thereby needing a higher $Cl_2$ dosage. Figure 19 shows that to achieve target reduction a required TRC of 27 mg/L corresponding to the 2 minute contact time would need a $Cl_2$ dosage of about 30 mg/L. For a 7 minute contact time, Figure 19 shows that a required TRC of about 17 mg/L would need an 18mg/L $Cl_2$ dosage. In either case where a higher $Cl_2$ dosage is required, disinfection likely would need to be followed by dechlorination to eliminate any potential toxicity in the effluent. At lower dosages and lower residuals, there would still be a need for effluent dechlorination.

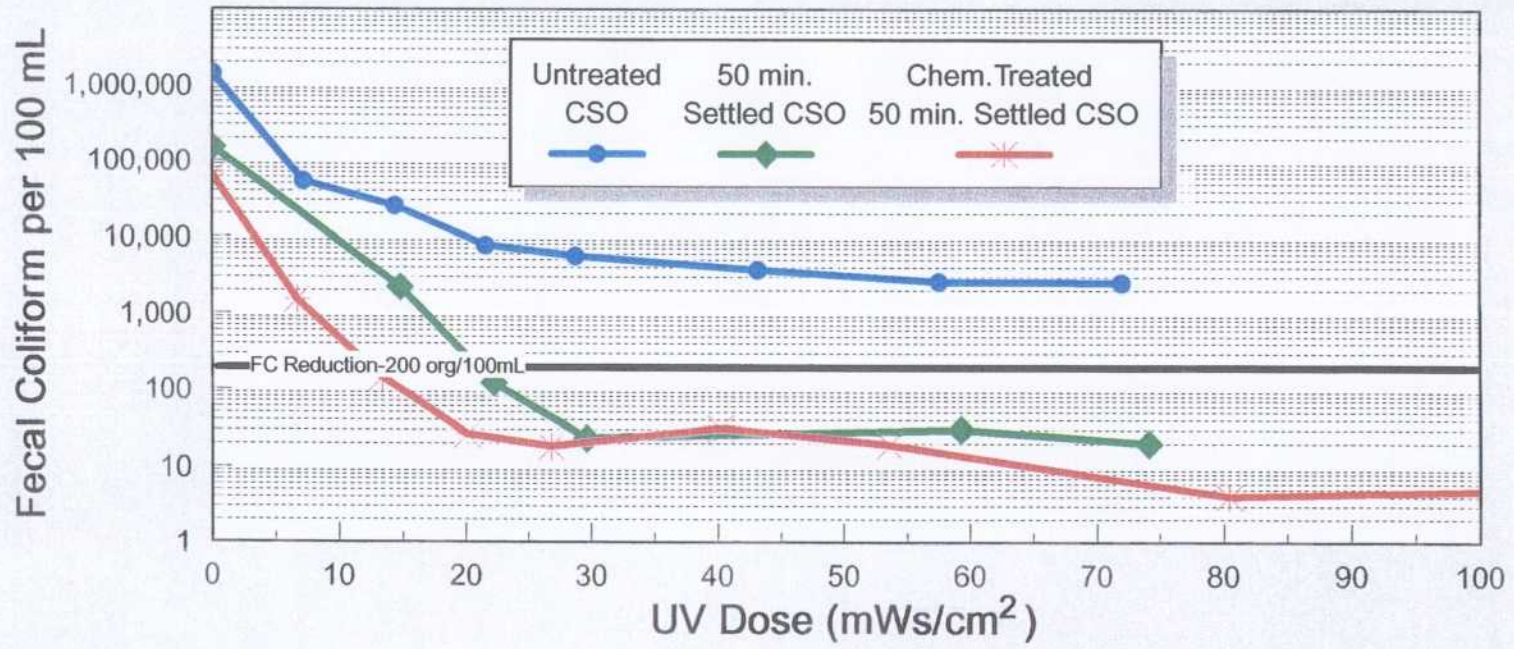
## Figure 10
## Collimated Beam Test - Event #1: Aug.19/96
## Untreated CSO vs 50 minute Settled CSO




Testing performed by TROJAN TECHNOLOGIES

XCG

## Figure 11
## Collimated Beam Test - Event #3: Sept.5/96
## Untreated CSO vs 50 minute Settled & Chemically Treated 50 minute Settled CSO




Testing performed by TROJAN TECHNOLOGIES

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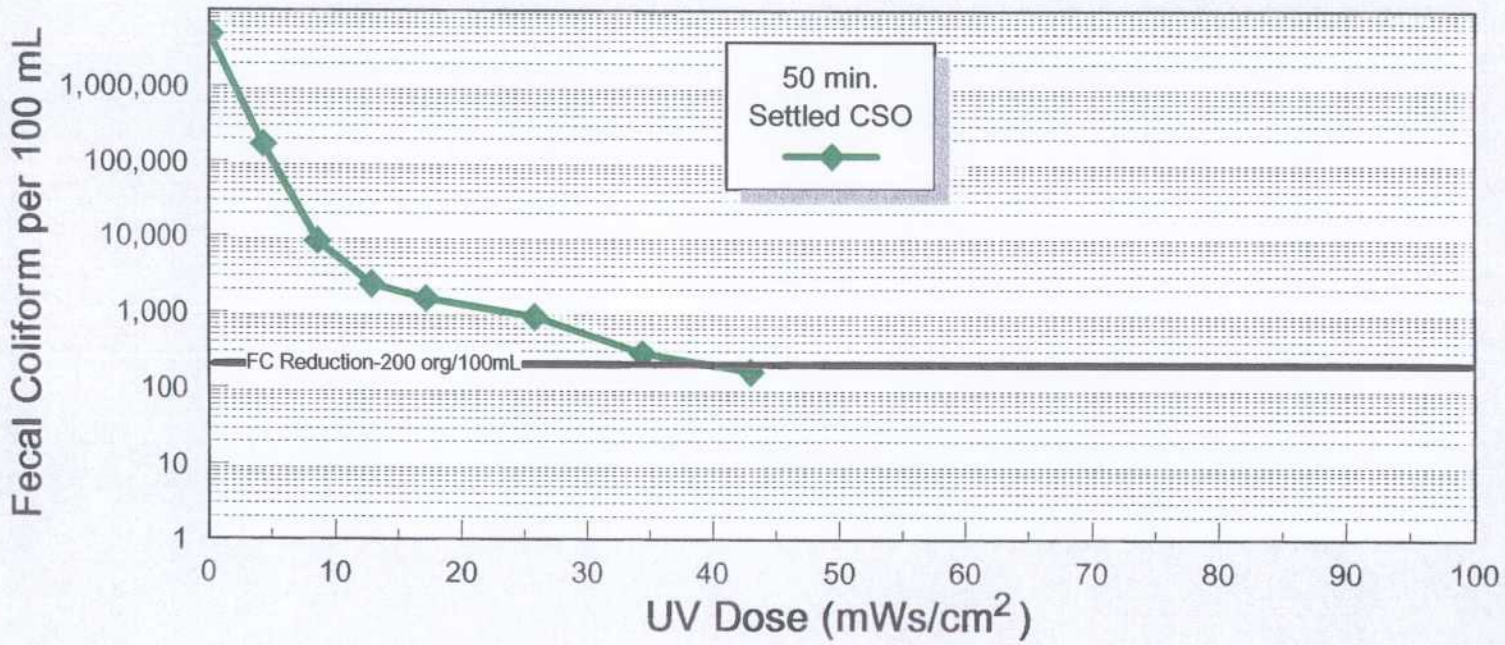
## Figure 12
## Collimated Beam Test - Event #5: Sept.26/96
## 50 minute Settled CSO




Testing performed by TROJAN TECHNOLOGIES

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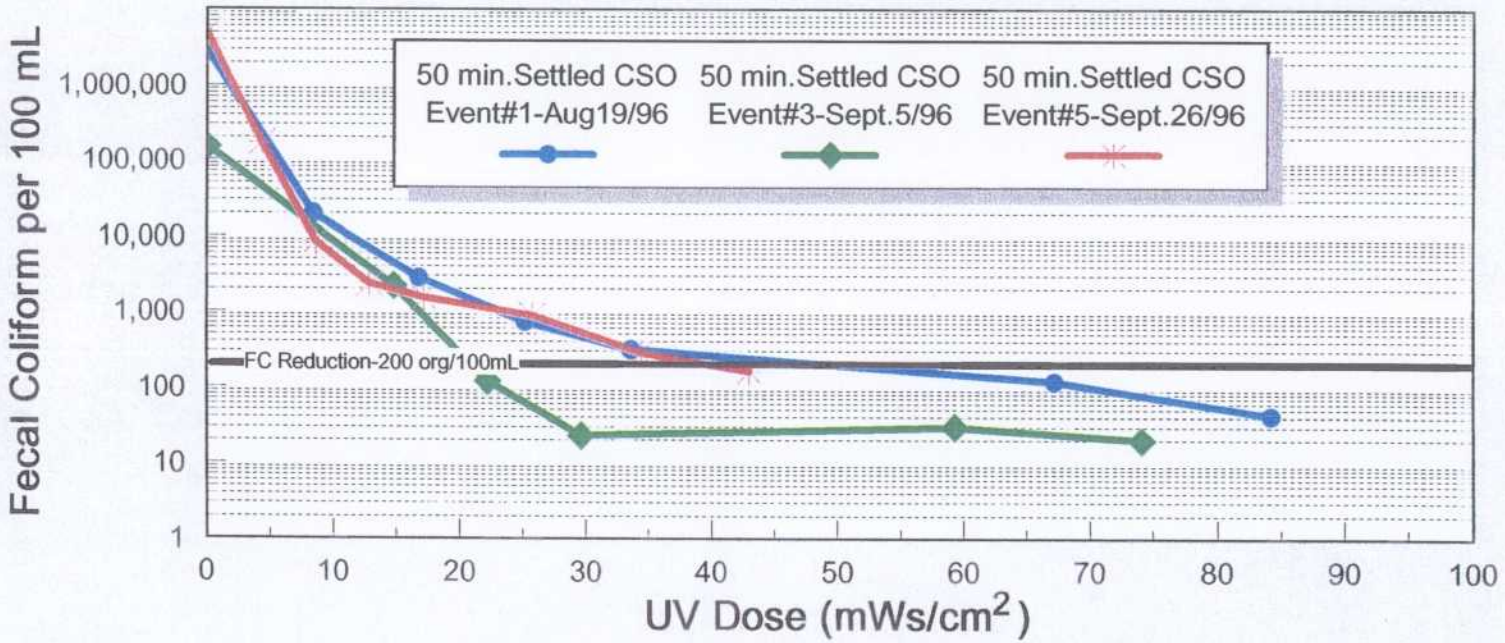
## Figure 13
## Collimated Beam Test - Pooled Data
## 50 minute Settled CSO

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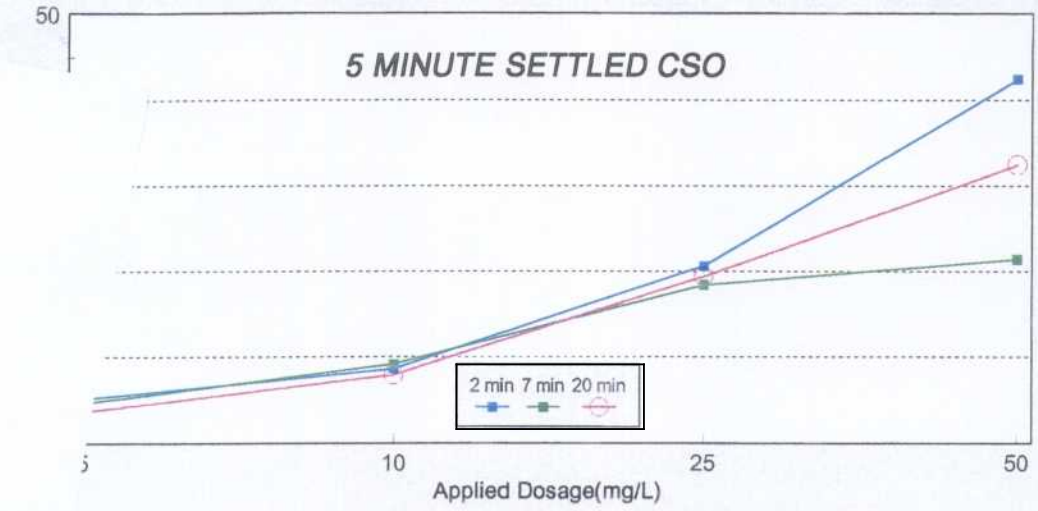



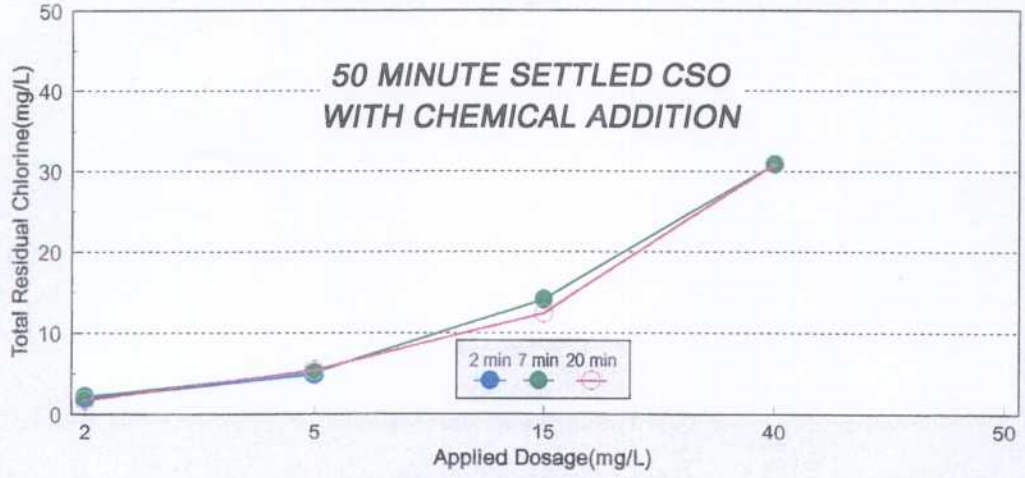


Figure 14
Chlorine Dose - Residual Chlorine

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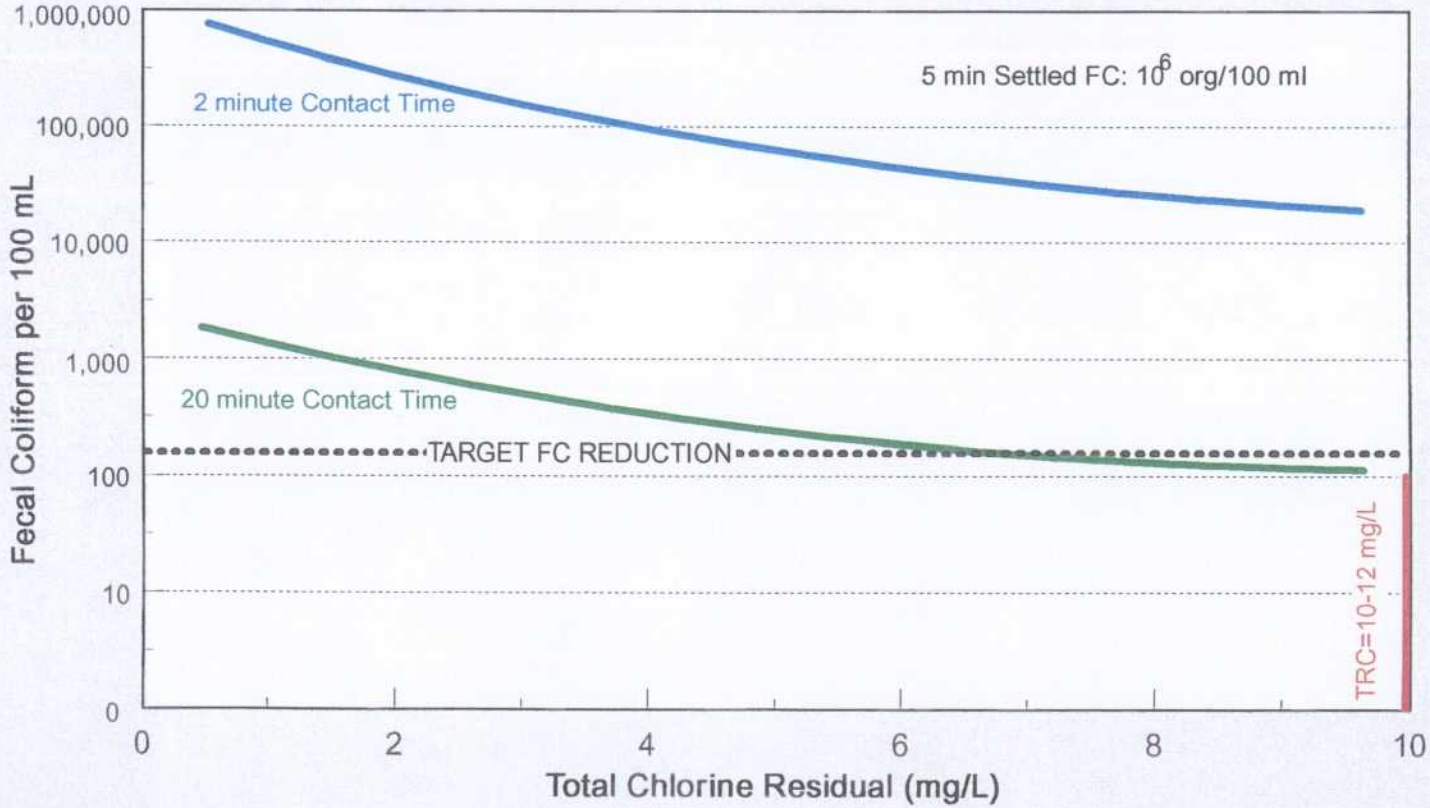
## Figure 15
## Fecal Coliform Reduction - Low Dose Response
## 5 Minute Settled CSO

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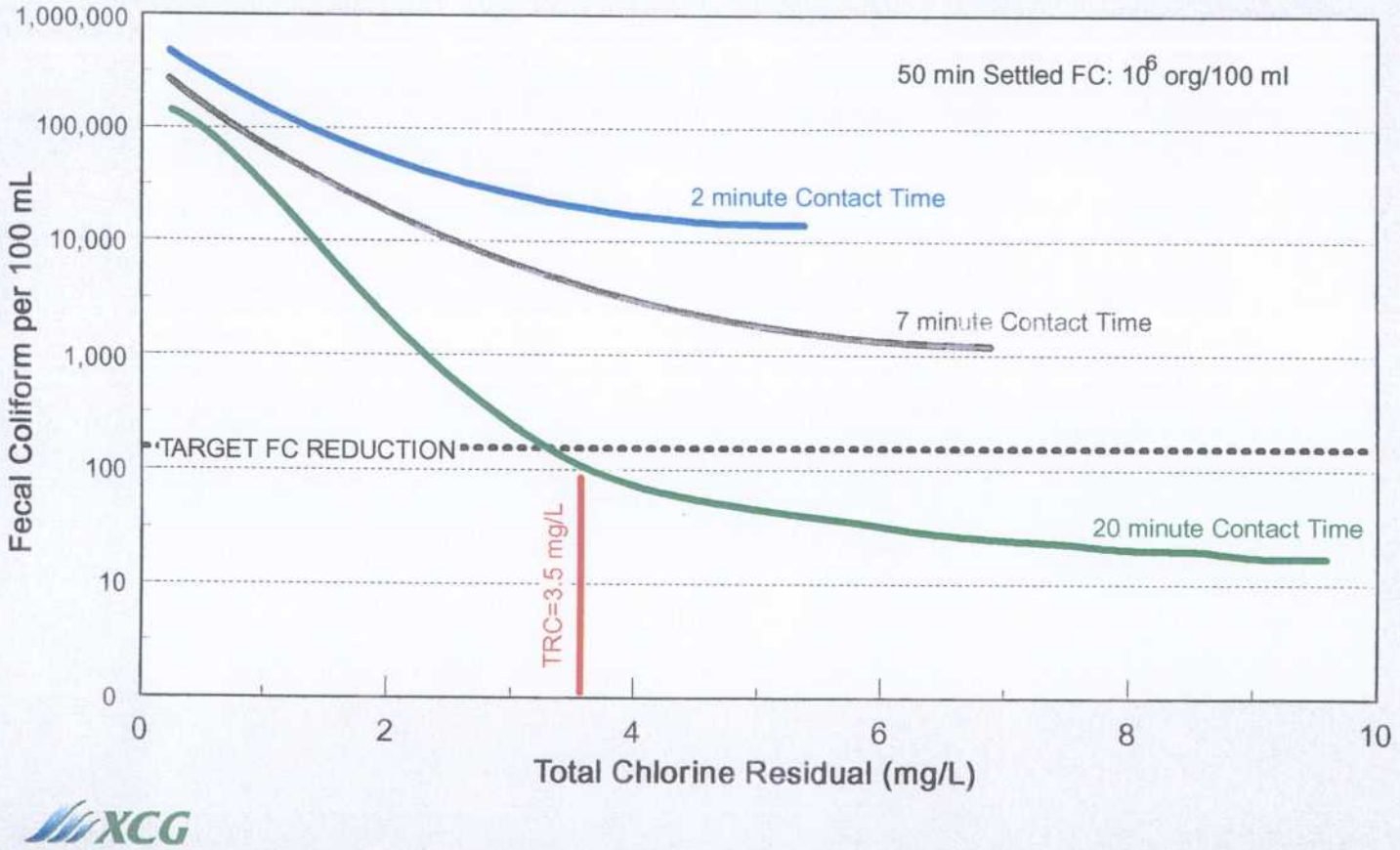
## Figure 16
## Fecal Coliform Reduction - Low Dose Response
## 50 Minute Settled CSO

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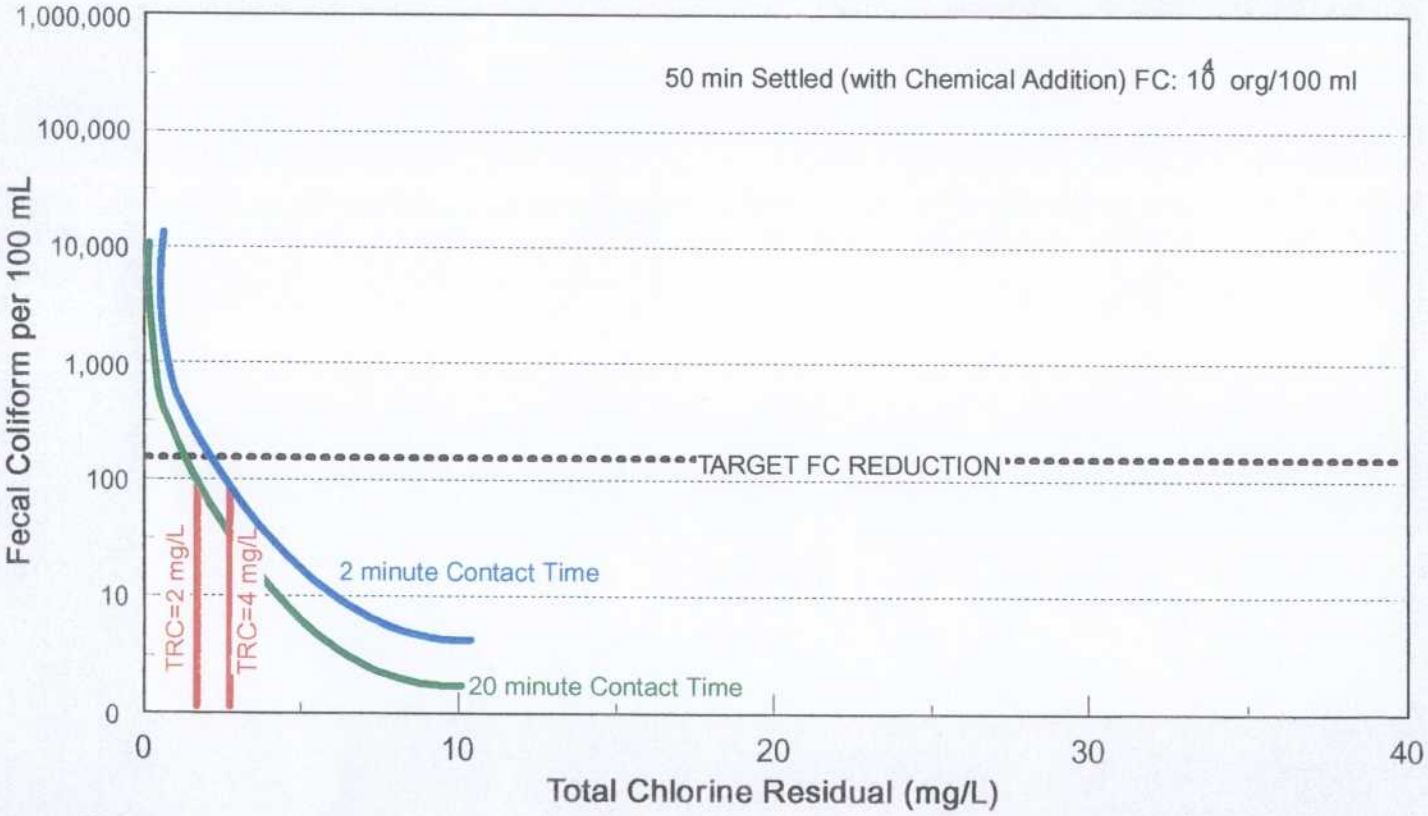
# Figure 17
# Fecal Coliform Reduction - Low Dose Response
# 50 Minute Settled CSO With Chemical Addition

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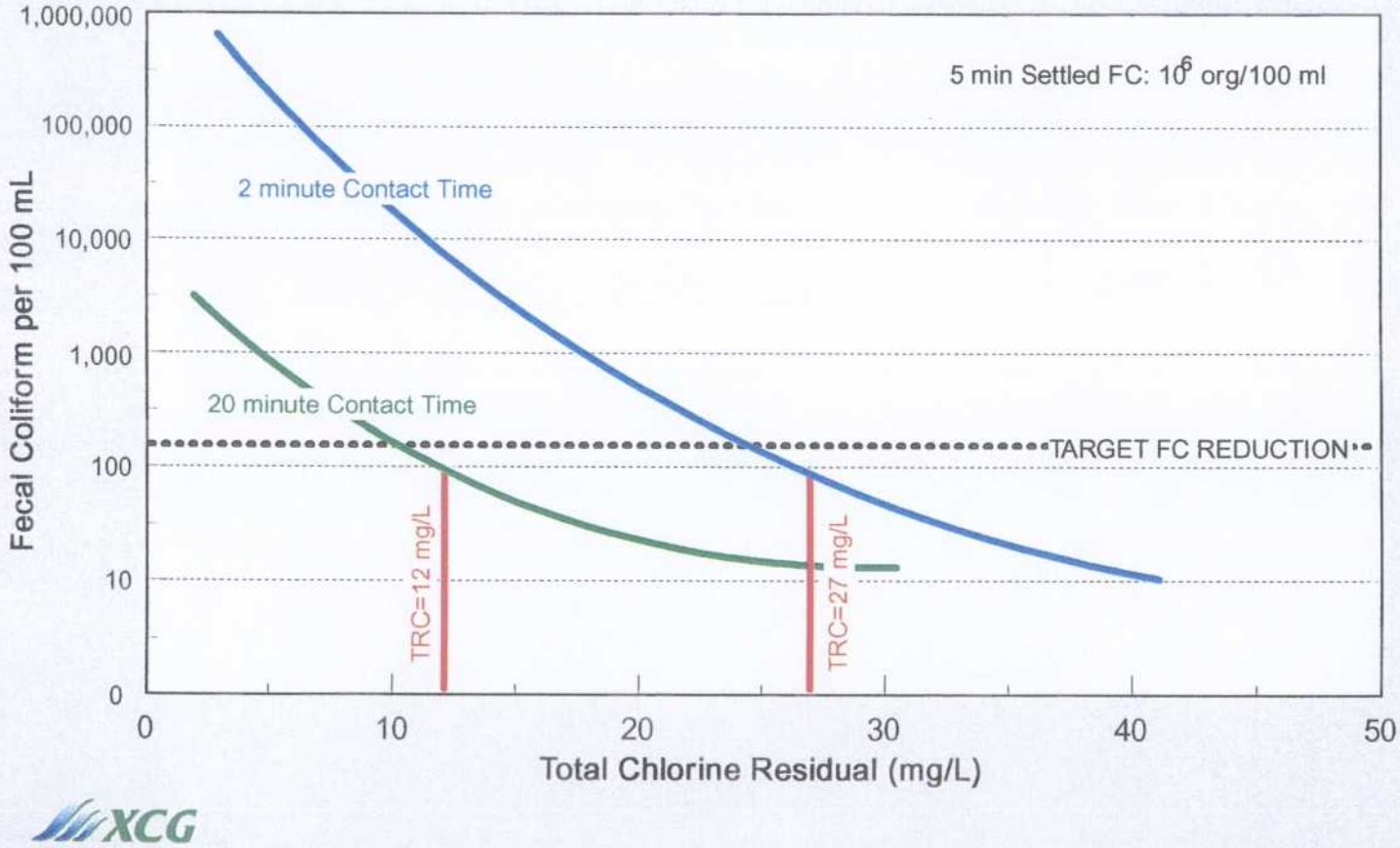
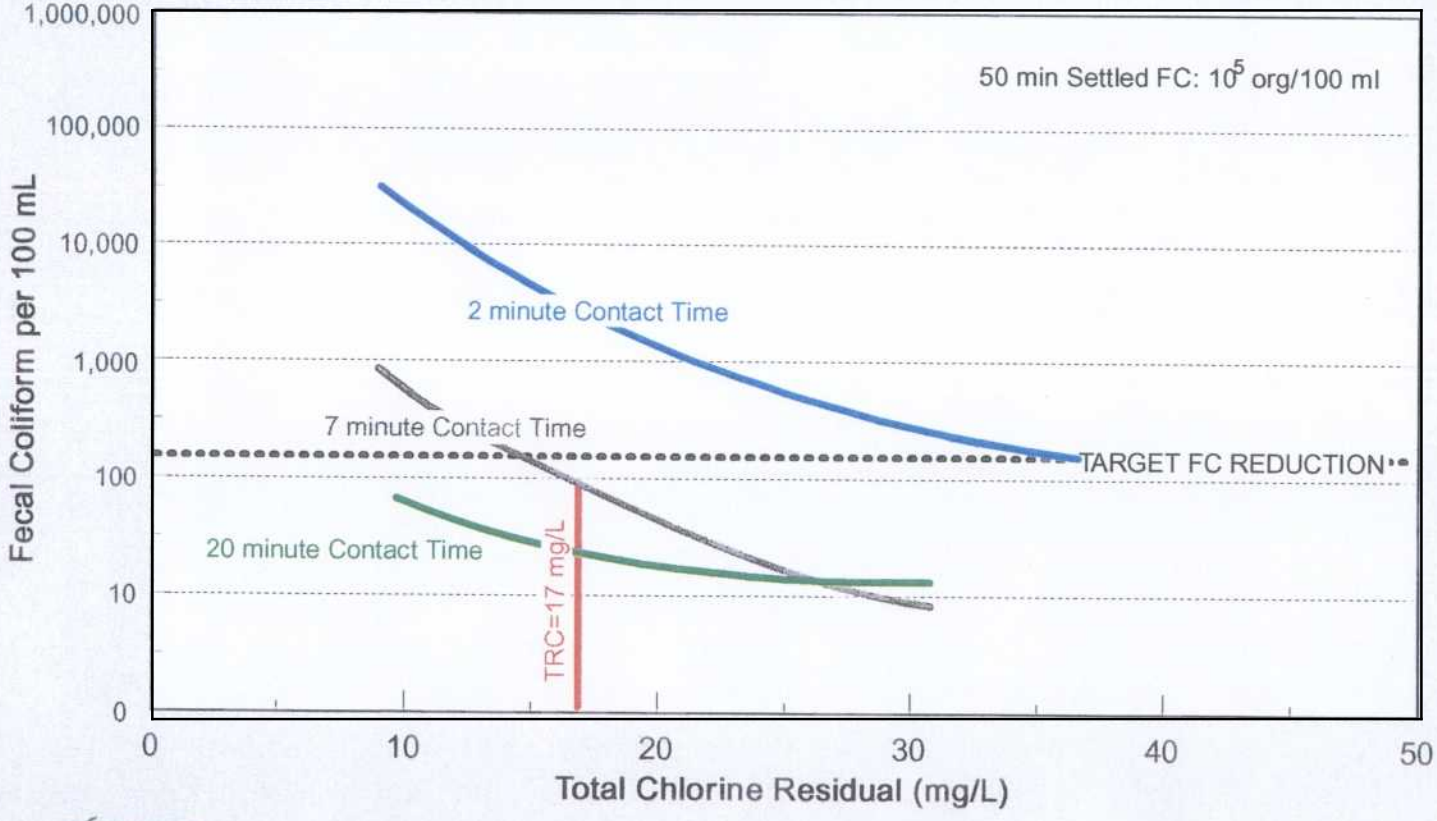
## Figure 18
## Fecal Coliform Reduction - High Dose Response
## 5 Minute Settled CSO



# Figure 19
# Fecal Coliform Reduction - High Dose Response
# 50 Minute Settled CSO

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## 10.0 SUMMARY OF RESULTS

Characterization of the hydrologic and CSO quality characteristics of the Aubrey sewershed was undertaken through field monitoring and sample analysis. Monitoring activities spanned the period August to late September of 1996. During this period, five storm events having overflows at Aubrey were sampled and used as the basis for Aubrey sewershed characterization. Flow and rainfall monitoring data were also collected over the duration of the monitoring program and used to assess the catchment hydrologic response. Overflow sampling, combined with quality analysis, column testing (settling velocity), and laboratory analysis was used to characterize the Aubrey CSO. Finally, treatability (solids separation) and disinfectability testing were employed to estimate parameters for CSO treatment facility design.

The following summarizes results found during the Treatability Evaluation for Aubrey CSO. It should be emphasized that the conclusions presented are founded on results that are specific to the Aubrey site.

## 10.1 SUMMARY OF CSO CHARACTERIZATION

- The average concentrations observed in the Aubrey CSO were comparable with results from other studies for TSS, fecal coliform, and metals as shown in Table 10.
- The average concentrations of phosphorus, nitrogen, and BOD observed in the Aubrey CSO were low relative to data from other studies as shown in Table 10.
- Comparison of first flush TSS concentrations to average CSO concentrations for TSS observed at Aubrey show little variation (see Table 10).

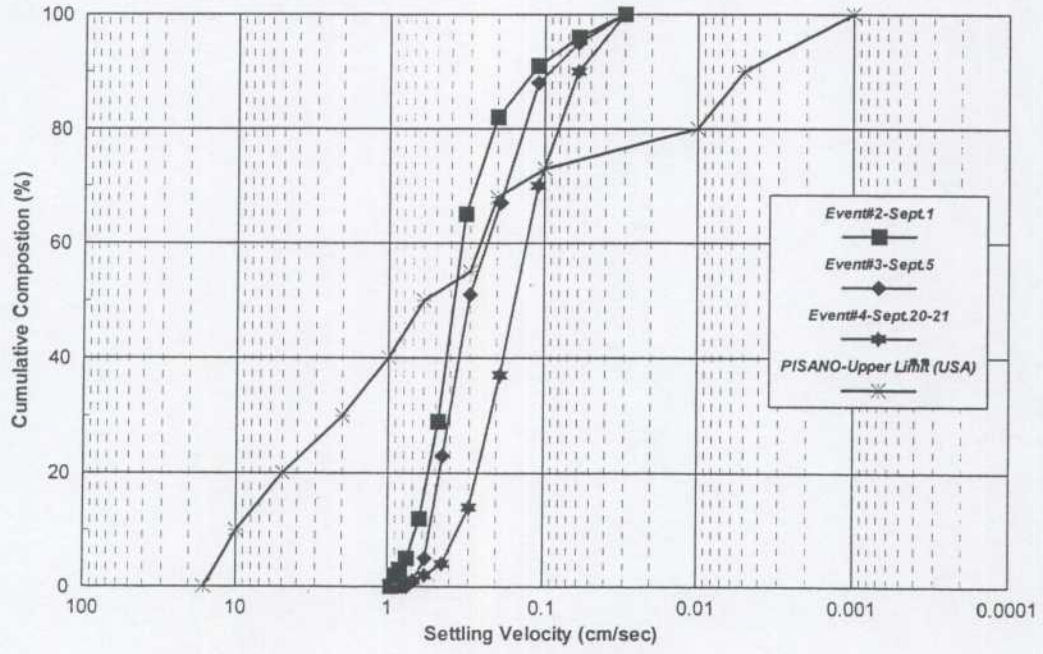
**Table 10**
**Summary of Aubrey CSO Quality**

| Parameter | Units | Aubrey CSO Average Quality | Aubrey CSO First Flush Quality | [1] Other Studies Typical CSO Range |
|---|---|---|---|---|
| TSS | mg/L | 207 | 293 | 77 - 522 |
| Fecal Coliform | #/100mL | 3,300,000 | 3,400,000 | 15 - 4,500,000 |
| Aluminum | mg/L | 2.4 | 3.2 | 08 - 6.9 |
| Chromium | mg/L | 0.02 | 0.02 | ~ 0 - 0.04 |
| Copper | mg/L | 0.15 | 0.21 | 0.25 - 0.55 |
| Iron | mg/L | 2.7 | 4.2 | 2.5 - 11.5 |
| Zinc | mg/L | 0.28 | 0.28 | 0.02 - 0.5 |
| BOD | mg/L | 81 | 171 | 2 - 357 |
| Total Phosphorus | mg/L | 2.1 | 2.4 | 1.4 - 8.2 |
| Dissolved Reactive Phosphorus | mg/L | <0.3 | 0.22 | 0.19 - 5.3 |
| Ammonia-N | Mg/L | 5.1 | 4.4 | 0.1 - 48 |
| TKN | mg/L | 11 | 13 | 0.6 - 30 |

Note:1. Assessment of Advanced Physical-Chemical Treatment Options for CSO, The Municipality of Metropolitan Toronto,1992.

- Particulate analyses of Aubrey CSO show similar settling curves for each sampled event with median velocities of 0.3 cm/sec as shown in Figure 20.
- A large fraction of Aubrey CSO is of relatively light material, with settling velocities between 0.1 and 0.6 cm/sec as indicated by the steep slope of the settling curve (see Figure 20).
- No material with settling velocities in excess of 1.0 cm/sec (fine sand) was found.
- No heavy grit was found - approximately 90% of material had settling velocities less than 0.5 cm/sec.

**Figure 20**
**Aubrey CSO - Settleable Solids Curve**



## 10.2 SUMMARY OF CSO TREATABILITY - SETTLING TESTS

- A number of alternative solids separation treatment schemes were simulated by varying settling times of the CSO sample:
  - ⇒ 5 minute settling was used to simulate a vortex separator.
  - ⇒ 50 minute settling was used to simulate conventional sedimentation basin performance.
  - ⇒ 50 minute settling aided with chemical addition was used to evaluate enhanced sedimentation using primary coagulants and coagulant aids.
- Jar tests were undertaken on Aubrey CSO using aluminum sulphate(alum) and ferric chloride with and without polymer addition for 50 minute settled CSO.
- An extensive range of dosages typical for wastewater treatment were tested for alum and ferric chloride, and based on the jar test results, alum with polymer was selected as producing the most optimum results.
- Coagulant doses were in the range (Alum: 6-12 mg/L as aluminum) generally used to treat raw wastewater.
- Alum proved to be effective as a primary coagulant in aiding pollutant removal. (Initial jar testing showed that ferric chloride was not more effective, therefore, the problem of having iron salts interfering with UV disinfection was not incurred.)
- Simulated vortex separator removal efficiencies were estimated from column testing using five minute settled sample - solids removals averaged 6% while some parameters such as ammonia and TKN were, as expected, not removed at all.
- Simulated sedimentation basin removal efficiencies were estimated using a 50 minute column settling time. Solids removal averaged 67% for untreated 50 minute settled sample, and over 90% for chemically treated sample following with 50 minute settling.
- The 50 minute settled sample aided with chemical enhancement averaged ≥85% reduction for most conventional parameters, with ammonia and TKN excepted.
- Average pollutant removal for chemically enhanced treatment with settling produced effective removals of most conventional pollutant parameters.
- Removal efficiency for ammonia was negligible.
- Bacterial reduction was minimal with 5 and 50 minute settled CSO.
- Chemically treated 50 minute settled CSO yielded a 3 log reduction of bacteria densities prior to disinfection tests.

- A summary of Aubrey CSO Solids Separation Treatability Testing is shown below in Table 11:

**Table 11**
**Summary of Aubrey CSO Solids Separation Treatability Testing Results**
**Settling Testing - Percent Reduction of Conventional Parameters and Bacteria**

| Parameter | 5 Minute Settled CSO | 50 Minute Settled CSO | 50 Minute Settled CSO with Chemical Addition |
|---|---|---|---|
| Turbidity | 21% | 18% | 91% |
| BOD | 33% | 54% | 85% |
| Total Phosphorus | 24% | 71% | 94% |
| Ammonia-N | 0% | 0% | 0% |
| Total Kjeldahl Nitrogen | 0% | 17% | 40% |
| Total Suspended Solids | 6% | 55% | 94% |
| Total Volatile Solids | 21% | 67% | 94% |
| Fecal Coliform | < 1 log reduction | 1 log reduction | 3 log reduction |
| E. Coli | 1 log reduction | 1 log reduction | 3 log reduction |

- Very little reduction in metals concentrations were observed in 5 and 50 minute settled CSO samples - chemically treated samples settled for 50 minutes also showed little reduction in metals concentrations.

## 10.3 SUMMARY OF CSO TREATABILITY - DISINFECTABILITY

- The study approach for disinfection analyses was such that sufficient contact time and dosage would be applied to achieve a target fecal coliform density of 200 organisms per 100mL.
- UV dosage requirements to achieve target fecal coliform densities of 200 organisms per 100 mL were 20-40 $mWs/cm^2$ - this is in the same range used in secondary effluent applications and may be an effective technology to treat Aubrey CSO.
- U.V. Light Transmittance tests (%T @ 254 nm) for raw CSO from Aubrey yielded an average Transmittance of 23%.
- % Transmittance improved slightly when the CSO was settled for 50 minutes - substantial optical improvement was observed with chemically treated 50 minute settled CSO yielding a 62% Transmittance.
- Dose-response experiments for chlorination of CSO indicated the following TRCs and $Cl_2$ dosages at the contact times indicated below in Table 12:

**Table 12**
**Summary of Results from Chlorination Testing**

| Simulated Process | Wastewater | Contact Time | TRC (mg/L as $Cl_2$) | $Cl_2$ Dosage (mg/L) |
|---|---|---|---|---|
| Vortex Separator | 5 minute settled | 2 | 27 | 28 |
| | | 20 | 12 | 15 |
| Conventional Sedimentation Basin | 50 minute settled | 2 | >40 | - |
| | | 7 | 17 | 20 |
| | | 20 | 4.0 | 5.0 |
| | Chemically enhanced 50 minute settled | 2 | 4.0 | 5.0 |
| | | 20 | 2.0 | 3.0 |

- As pretreatment is enhanced, lower chlorine dosages are required to obtain target fecal coliform densities.
- Both UV disinfection and chlorination appear as effective alternatives for disinfection of Aubrey CSO.

## 10.4 CONCLUSIONS

Listed below is a summary of conclusions derived from the results of the Treatability Evaluation at Aubrey:

- Aubrey CSO average quality for TSS, bacteria, and metals was similar to CSO average quality observed in other studies.
- No pronounced first flush was observed at Aubrey.
- The particulate analyses showed an atypical distribution of solids when results were compared to other studies - fine and heavy material was absent.
- Settling column tests revealed that a majority of the solids were light in nature. An absence of heavier grit was evident.
- Vortex separator technology would not be applicable for this location.
- Conventional settling basin technology with screening for floatables removal would be an effective method of solids removal.
- Coagulant addition enhanced solids removal, as well as removal of most conventional parameters and bacteria (Fecal Coliform and E. Coli).
- Disinfection tests indicated both U.V. light disinfection and chlorination were effective in achieving target Fecal Coliform densities.
- Solids separation results are applicable for preliminary process design for satellite treatment facilities at Aubrey.
- Disinfection results are applicable for preliminary process design for satellite treatment facilities at Aubrey.
- For preliminary design, a surface settling rate of 70 m3/m2.day is recommended to achieve required treatment efficiency.
- Additional characterization at one or more sites for an additional season would provide a comprehensive characterization of CSO water quality.

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# *Appendix A*

# *AUBREY CSO QUALITY DATA*

## Table A.1

### Event #1: Aug. 19/96 - Conventional Parameters

| Parameter | Units | Untreated CSO | First Flush* | 5 min settled CSO | 50 min settled CSO | Other Studies Typ. CSO Range(1) |
|---|---|---|---|---|---|---|
| pH | - | 7 | 6.8 | 6.9 | 7 | 7.2 - 7.8 |
| Conductivity | (umhos/cm) | 280 | 350 | 270 | 280 | - |
| Colour | (TCU) | 4.6 | 14 | 5.2 | 5 | - |
| Turbidity | (NTU) | 4 | 30 | 3.9 | 3.6 | - |
| BOD | (mg/L) | 16 | 360 | 16 | 17 | 2 - 357 |
| Total Phosphorus | (mg/L) | 0.74 | 3.3 | 0.61 | 0.73 | 1.4 -8.2 |
| Dissolved Reactive Phosphorus | (mg/L) | 0.35 | 0.29 | 0.29 | 0.35 | 1.9 - 5.3 |
| Ammonia-N | (mg/L) | 2 | 1 | 3.1 | 1.5 | 0.1 - 48 |
| Total Kjeldahl Nitrogen | (mg/L) | 4.4 | 15 | 4.9 | 5.6 | 0.6 - 30 |
| Total Suspended Solids | (mg/L) | 70 | 460 | 74 | 54 | 77 - 522 |
| Volatile Suspended Solids | (mg/L) | 30 | 210 | 24 | 6 | - |
| Fecal Coliform | (#org./100 ml) | 2900000 | 4100000 | 1200000 | 670000 | 15 - 4500000 |
| E. coli | (#org./100 ml) | 790000 | 3300000 | 620000 | 440000 | - |

*First flush composite consists of the first half hour of sampling

(1) *Assessment of Advanced Physical/Chemical Treatment Options for CSO*, The Municipality of Metropolitan Toronto, 1992

Table A.2

Event #1: Aug. 19/96 - Metal Analysis

| Parameter | Untreated CSO | 5 min settled CSO | 50 min settled CSO | First flush comp. |
|---|---|---|---|---|
| Aluminium | 1.2 | 1.1 | 1.1 | 7.3 |
| Boron | 0.25 | 0.2 | 0.25 | 0.25 |
| Barium | 0.03 | 0.03 | 0.03 | 0.27 |
| Berylium | <0.01 | <0.01 | <0.01 | <0.01 |
| Cadmium | <0.03 | <0.03 | <0.03 | <0.03 |
| Calcium | 22 | 22 | 23 | 73 |
| Chromium | 0.04 | 0.03 | 0.04 | 0.03 |
| Cobalt | <0.09 | <0.09 | <0.09 | <0.09 |
| Copper | 0.04 | 0.04 | 0.04 | 0.37 |
| Iron | 1.8 | 1.6 | 1.6 | 8.3 |
| Lead | <0.1 | <0.1 | <0.1 | 0.13 |
| Magnesium | 8.7 | 8.8 | 9.1 | 30 |
| Manganese | 0.07 | 0.06 | 0.07 | 0.21 |
| Vanadium | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 0.1 | 0.11 | 0.13 | 0.43 |
| Nickel | <0.03 | <0.03 | <0.03 | <0.03 |
| Silver | <0.02 | <0.02 | <0.02 | <0.02 |
| Strontium | 0.08 | 0.07 | 0.08 | 0.15 |
| Sodium | 15 | 15 | 16 | 18 |
| Molybdenum | <0.04 | <0.04 | <0.04 | <0.04 |
| Titanium | 0.03 | 0.03 | 0.03 | 0.14 |
| Zirconium | <0.01 | <0.01 | <0.01 | <0.01 |

## Table A.3

### Event #3: Sept. 5/96 - Conventional Parameters

| Parameter | Units | Untreated CSO | First Flush* | 5 min settled CSO | 50 min settled CSO | 50 min settled CSO + chem. | Other Studies Typ. CSO Range(1) |
|---|---|---|---|---|---|---|---|
| pH | - | 7.6 | 7.5 | 7.2 | 7.6 | 7.1 | 7.2 - 7.8 |
| Conductivity | (umhos/cm) | 540 | 580 | 540 | 530 | 540 | - |
| Colour | (TCU) | 8 | 10 | 8.5 | 8.8 | 2.8 | - |
| Turbidity | (NTU) | 21 | 31 | 15 | 16 | 1.5 | - |
| BOD | (mg/L) | 36 | 24 | 15 | 14 | 7.7 | 2 - 357 |
| Total Phosphorus | (mg/L) | 1.2 | 1.5 | 1.2 | 0.73 | 0.1 | 1.4 -8.2 |
| Dissolved Reactive Phosphorus | (mg/L) | <0.3 | <0.3 | <0.3 | <0.3 | <0.3 | 1.9 - 5.3 |
| Ammonia-N | (mg/L) | 4 | 3.9 | 4 | 4 | 3.8 | 0.1 - 48 |
| Total Kjeldahl Nitrogen | (mg/L) | 9.2 | 10 | 12 | 7.6 | 4.6 | 0.6 - 30 |
| Total Suspended Solids | (mg/L) | 130 | 140 | 150 | 38 | 16 | 77 - 522 |
| Volatile Suspended Solids | (mg/L) | 62 | 63 | 70 | 16 | 7.6 | - |
| Fecal Coliform | (#org./100 ml) | 1600000 | 1650000 | 940000 | 970000 | 480 | 15 - 4500000 |
| E.coli | (#org./100 ml) | 1200000 | 1450000 | 920000 | 880000 | 450 | - |

*First flush composite consists of the first 12 minutes of sampling

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Table A.4

Event #3: Sept. 5/96 - Metal Analysis

| Parameter | Untreated CSO | 5 min settled CSO | 50 min settled CSO | 50 min settled CSO + chem | First flush comp. |
|---|---|---|---|---|---|
| Aluminium | 1.6 | 0.79 | 0.72 | 0.79 | 1.5 |
| Boron | 0.23 | 0.21 | 0.22 | 0.22 | 0.22 |
| Barium | 0.06 | 0.03 | 0.03 | 0.02 | 0.05 |
| Berylium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Cadmium | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Calcium | 36 | 30 | 29 | 27 | 36 |
| Chromium | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Cobalt | <0.09 | <0.09 | <0.09 | <0.09 | <0.09 |
| Copper | 0.14 | 0.04 | 0.06 | <0.02 | 0.1 |
| Iron | 2.2 | 0.94 | 0.98 | 0.08 | 1.9 |
| Lead | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Magnesium | 22 | 19 | 18 | 18 | 23 |
| Manganese | 0.07 | 0.05 | 0.06 | 0.04 | 0.07 |
| Vanadium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 0.41 | 0.14 | 0.14 | 0.07 | 0.11 |
| Nickel | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Silver | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Strontium | 0.15 | 0.14 | 0.14 | 0.14 | 0.16 |
| Sodium | 36 | 36 | 35 | 37 | 37 |
| Molybdenum | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 |
| Titanium | 0.04 | 0.02 | 0.02 | <0.01 | 0.03 |
| Zirconium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

## Table A.5

## Event #4: Sept. 22/96 - Conventional Parameters

| Parameter | Units | Untreated CSO | First Flush* | 5 min settled CSO | 50 min settled CSO | 50 min settled CSO + chem. | Other Studies Typ. CSO Range(1) |
|---|---|---|---|---|---|---|---|
| pH | - | 6.8 | 6.9 | 6.8 | 6.9 | 7.1 | 7.2 - 7.8 |
| Conductivity | (umhos/cm) | 670 | 690 | 650 | 650 | 680 | - |
| Colour | (TCU) | 84 | 49 | 78 | 86 | 18 | - |
| Turbidity | (NTU) | 17 | 7.4 | 14 | 15 | 0.84 | - |
| BOD | (mg/L) | 190 | 130 | 130 | 80 | 17 | 2 - 357 |
| Total Phosphorus | (mg/L) | 4.3 | 3.5 | 2.9 | 2.8 | 0.14 | 1.4 - 8.2 |
| Dissolved Reactive Phosphorus | (mg/L) | <0.3 | ** | <0.3 | <0.3 | <0.3 | 1.9 - 5.3 |
| Ammonia-N | (mg/L) | 9.3 | 8.2 | 9.1 | 8.3 | 7.2 | 0.1 - 48 |
| Total Kjeldahl Nitrogen | (mg/L) | 19 | 14 | 17 | 14 | 8.5 | 0.6 - 30 |
| Total Suspended Solids | (mg/L) | 420 | 280 | 360 | 190 | 8 | 77 - 522 |
| Volatile Suspended Solids | (mg/L) | 280 | 160 | 200 | 100 | 7 | - |
| Fecal Coliform | (#org./100 ml) | 7800000 | 5800000 | 5300000 | 6500000 | 6800 | 15 - 4500000 |
| E.coli | (#org./100 ml) | 6500000 | 4200000 | 4200000 | 5700000 | 6100 | - |

*First flush composite consists of the first 12 minute of sampling

**Interferences, therefore result high due to dilution factor

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Table A.6

Event#4: Sept. 22/96 - Metal Analysis

| Parameter | Untreated CSO | 5 min settled CSO | 50 min settled CSO | 50 min settled CSO + chem. | First flush comp. |
|---|---|---|---|---|---|
| Aluminium | 4.5 | 3.4 | 1.9 | 0.55 | 2.3 |
| Boron | 0.27 | 0.26 | 0.23 | 0.23 | 0.24 |
| Barium | 0.15 | 0.12 | 0.06 | 0.01 | 0.08 |
| Berylium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Cadmium | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Calcium | 44 | 41 | 34 | 29 | 42 |
| Chromium | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Cobalt | <0.09 | <0.09 | <0.09 | <0.09 | <0.09 |
| Copper | 0.26 | 0.19 | 0.09 | <0.02 | 0.15 |
| Iron | 4 | 3 | 1.8 | 0.24 | 2.5 |
| Lead | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Magnesium | 19 | 18 | 16 | 14 | 18 |
| Manganese | 0.11 | 0.1 | 0.08 | 0.06 | 0.1 |
| Vanadium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 0.33 | 0.27 | 0.15 | 0.01 | 0.29 |
| Nickel | <0.03 | <0.03 | <0.03 | <0.03 | <0.03 |
| Silver | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Strontium | 0.14 | 0.14 | 0.12 | 0.1 | 0.12 |
| Sodium | 47 | 47 | 45 | 45 | 50 |
| Molybdenum | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 |
| Titanium | 0.06 | 0.04 | 0.03 | <0.01 | 0.04 |
| Zirconium | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

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## *Appendix B*

## *UV LIGHT DISINFECTION QUALITY DATA*

| Table B.1<br>Event #1 - August 19/96 - Parameter Analyses | | | | | |
|---|---|---|---|---|---|
| Sample | % Transmittance | % T Filtered | TSS (ppm) | Mean Particle Size (microns) | Particles % >31 (microns) |
| Whole Effluent #479 | 30 | 52 | 75 | 48.9 | 58.4 |
| #480P | - | - | - | 27.9 | 30.3 |
| Settled Effluent #481 | 35 | 52 | 46 | 39.9 | 49.9 |

| Table B.2<br>Event #1 - August 19/96 - Collimated Beam Results | | | |
|---|---|---|---|
| Fecal Coliform /100 mL (geometric mean of replicate samples) | | | |
| UV Dose mWs/cm$^2$ | Whole Effluent | UV Dose mWs/cm$^2$ | 50 Minute Settled Effluent |
| 0 | 2,600,000 | 0 | 2,900,000 |
| 7.6 | 29,000 | 8.4 | 20,000 |
| 22.8 | 632 | 16.8 | 2,800 |
| 30.4 | 274 | 25.2 | 724 |
| 45.6 | 290 | 33.6 | 315 |
| 60.8 | 173 | 67.2 | 120 |
| 75.8 | 117 | 84.2 | 42 |

| Table B.3<br>Event #3 - September 5/96 - Parameter Analyses | | | | | |
|---|---|---|---|---|---|
| Sample | % Transmittance | % T Filtered | TSS ppm | Mean Particle Size (microns) | Particles % > 31 (microns) |
| Whole Effluent #548 | 28 | 46 | 145 | 76.1 | 72.96 |
| #575P | - | - | - | 36.6 | 52.1 |
| Settled Effluent #549 | 29 | 49 | 50 | 36.7 | 47.7 |
| Chemically Treated Effluent #550 | 62 | 62 | 4 | 41.9 | 53.5 |

| Table B.4<br>Event #3 - September 5/96 - Collimated Beam Results | | | |
|---|---|---|---|
| Fecal Coliform /100 mL (geometric mean of replicate samples) | | | |
| UV Dose mWs/cm$^2$ | Whole Effluent | UV Dose mWs/cm$^2$ | 50 Minute Settled Effluent |
| 0 | 1,400,000 | 0 | 150,000 |
| 7.2 | 53,000 | 7.4 | *1,200 |
| 14.4 | 25,000 | 14.8 | *2,200 |
| 21.6 | 7,700 | 22.2 | 120 |
| 28.8 | 5,600 | 29.6 | 23 |
| 43.2 | 3,700 | 59.3 | 30 |
| 57.6 | 2,600 | 74.1 | 20 |
| 72 | 2,500 | | |
| Note:<br>* Sample volume too small for accurate counts. | | | |

| Table B.5<br>Event #3 - September 5/96 - Collimated Beam Results | |
|---|---|
| Fecal Coliform /100 mL (geometric mean of replicate samples) | |
| UV Dose mWs/cm$^2$ | Chemically Treated Effluent 50 Minute Settled |
| 0 | 64,000 |
| 6.7 | 1,500 |
| 13.4 | 141 |
| 20.1 | 26 |
| 26.8 | 18 |
| 40.2 | 31 |
| 53.6 | 19 |
| 80.4 | 4 |
| 107.2 | 5 |
| 134 | 2 |

| Table B.6<br>Event #5 - September 26/96 - Parameter Analyses | | | | | |
|---|---|---|---|---|---|
| Sample | % Transmittance | % T Filtered | TSS ppm | Mean Particle Size (microns) | Particles % > 31 (microns) |
| Whole Effluent #663 | 11 | 39 | 149 | 48.15 | 58.05 |
| #665P | - | - | - | 50.79 | 54.51 |
| Settled Effluent #664 | 13 | 33 | 105 | 23.11 | 24.76 |

| Table B.7<br>Event #5 - September 26/96 - Collimated Beam Results | |
|---|---|
| Fecal Coliform /100 mL (geometric mean of replicate samples) | |
| UV Dose $mWs/cm^2$ | 50 Minute Settled Effluent |
| 0 | 4,900,000 |
| 4.3 | 170,000 |
| 8.6 | 8,500 |
| 12.9 | 2,300 |
| 17.2 | 1,500 |
| 25.8 | 860 |
| 34.4 | 280 |
| 43 | 160 |