PERFORMANCE EVALUATION OF SEDIMENT REMOVAL EFFICIENCY

STORMTECH® ISOLATOR™ ROW

Prepared for:
NJDEP/NJCAT

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October 20, 2006

EXECUTIVE SUMMARY:

This report details the experimental set up, testing protocols, results and findings of a full scale laboratory study conducted at Tennessee Tech University to determine the sediment removal efficiency of the StormTech® Isolator™ Row for two different silica-water slurry influent streams; one influent stream consisting of SIL-CO-SIL 106, with a median particle size of approximately 22 microns, and the other consisting of SIL-CO-SIL 250, with a median particle size of 45 microns. Both silica materials are used as surrogates in laboratory testing and verification protocols as a representation of very fine sediments contained in storm water runoff. Both influent streams were tested at a hydraulic loading rate of 3.2 gpm/sqft of filter area (179.6 gpm divided by 55.6 sqft of filter area). The SIL-CO-SIL 250 influent stream was also tested at 1.7 gpm/sqft.

Over the period of several test runs, it was observed that extremely fine particles accumulated in the flow stream tending to skew the average particle size of the distributions downward. This resulted in a particle size distribution with an approximate average particle size of 10 microns. The ability of a stormwater treatment system to remove such very fine particles is noteworthy. This report includes a limited analysis of the impact on TSS removal efficiency due to the fine particle accumulation.

Following is a brief synopsis of the results:

- 60% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 106 with accumulated fines (D_{50} = 10 microns)
- 66% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 106 (D_{50} = 22 microns)
- 71% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 250 with accumulated fines (D_{50} < 45 microns)
- 88% TSS Removal at 1.7 gpm/sqft for SIL-CO-SIL 250 with accumulated fines (D_{50} < 45 microns)

METHODS AND MATERIALS:

The main components of the laboratory set-up are shown in the design drawings (Figure 1). Two (2) SC-740 chambers are secured to a wooden frame and lay over a 12-in. bed of No. 3 angular stone (AASHTO M43 #3) contained in a wooden flume with interior W x L x H dimensions, 6.25-ft x 16.22-ft x 3-ft. The physical properties of the No. 3 stone are given in *Appendix 1.*

The chambers are covered with GEOTEX® 601 non-woven geotextile fabric with specifications given in *Appendix 2.* Two layers of GEOTEX® 315 ST woven geotextile fabric, with specifications given in *Appendix 3*, are placed at the bottom of the chamber to stabilize the stone foundation and to prevent scouring of the stone base. Both the nonwoven fabric covering the chamber and the woven fabric placed at the bottom provide filtration media for the Isolator Row.

An 8-inch pipe feeds the silica-water mixture through an expansion into the 12-inch inlet pipe of the isolator row. A 1.5 lb /gal silica-water slurry is introduced to the 8-inch pipe from a 35-gallon mixing tank using a Watson-Marlow323S/RL (220 rpm) pump. The silica–water slurry enters a 3/8" feed tap located 10 inches upstream of a butterfly valve, which introduces turbulence and promotes uniform mixing of the influent stream. The Isolator™ Row resides in the recirculating flume, which collects and drains water discharged by the chamber to the stone substrate through an 8-inch drain that discharges to the laboratory trench and sump. The water is recirculated with a 25 horsepower Allis Chalmers (model AC7V) variable speed pump. A 1-micron filter, designed for flows up to 1.5 cfs, is placed at the end of the outlet, which was intended to trap all sediment that is not removed by the chambers.

Flow rates are measured with a Thermo Electron Corporation Polysonic DCT7088 portable digital correlation transit time flow meter placed on the 8" aluminum water line. The DCT 7088 was factory calibrated by the manufacturer and is guaranteed accurate to ±0.5%. Specifications for the DCT-7088 flow meter and certificate of factory calibration are attached as *Appendix 4.*

The detailed testing protocol is provided in *Appendix 5*, including calibration details for the peristaltic pumps, detailed sediment loading rate calculations, which are used to determine the sediment loading rate required to achieve the target influent concentration of 200 mg/L, and an example of the laboratory data sheets completed for each experiment.

The product specification sheets for SIL-CO-SIL 106 and 250 are provided in Appendix 6. These sheets include size distributions, but particle sizes are only broadly classified. Calvert and Ritter (2004) recently obtained a more exact size distribution for a SIL-CO-SIL 106 sample taken directly from the material supplied by U.S. Silica. They found that more than 80% of the material is below 50 microns in size, indicating a silt-clay texture. In addition, they show that the SIL-CO-SIL 106 material size distribution is significantly less than the particle size distribution ranges recommended by Portland BES (2001) and APWA (1999) for the laboratory evaluation of stormwater BMPs. Particle size analyses by Micromeritics Analytical Services, which was conducted as part of this study, indicated that 80% of the SIL-CO-SIL 106 material was below 43 microns using the electrical sensing zone (ESZ) method; i.e. a smaller size compared to that reported by Calvert and Ritter (2004). For the SIL-CO-SIL 250, 80% was below 81 microns. The detailed reports of these analyses by Micromeritics are given in Appendix 7.

The removal efficiency η for the isolator row is calculated as

$$\eta = \frac{SSC_{Influent} - SSC_{Effluent}}{SSC_{Influent}} \times 100$$

where SSC is the suspended sediment concentration of the influent and the effluent grab samples, which are staggered by one detention time.

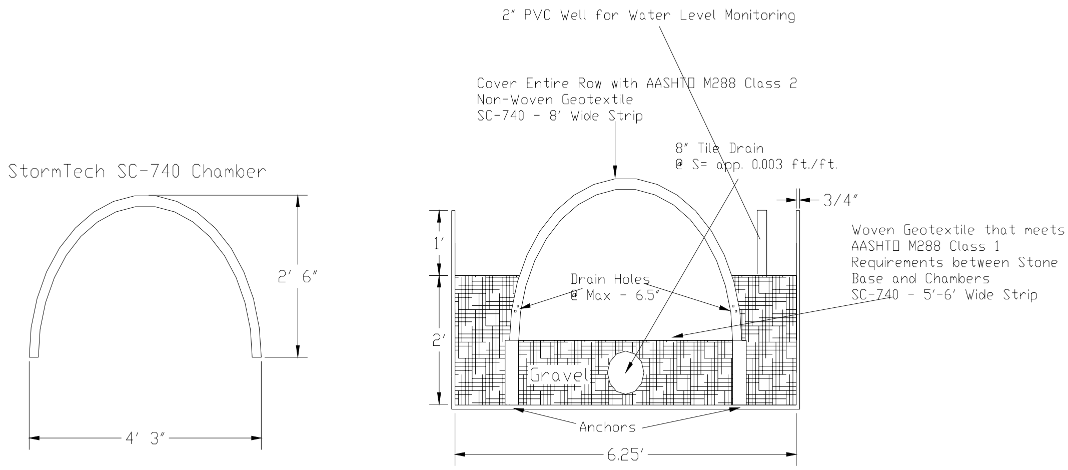


Figure 1.1: Section View of StormTech® Isolator™ Row as Installed in Lab

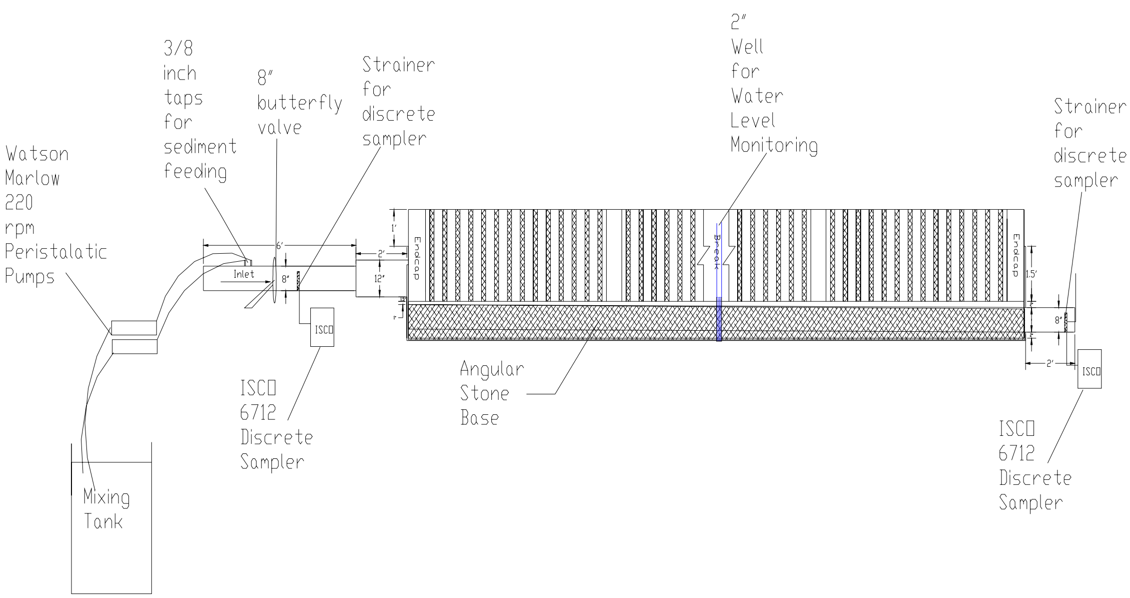


Figure 1. 2: Profile View of StormTech® Isolator™ Row as Installed in Lab.
Flow left to right.

RESULTS:

Test runs for both SIL-CO-SIL 106 and SIL-CO-SIL 250 were completed at a treatment flow rate of 180 gpm (0.4 cfs), which corresponds to a hydraulic loading rate of 3.2 gpm/sqft. Five (5) test runs were completed with SIL-CO-SIL 106 silica slurry. One (1) test run was completed with a SIL-CO—SIL 250 silica-water slurry. Additionally one (1) test run was completed with a SIL-CO-SIL 250 silica-water slurry at a treatment flow rate of 94 gpm (0.21 cfs) which corresponds to a hydraulic loading rate of 1.7 gpm/sqft. All tests lasted fifteen detention times.

SIL-CO-SIL 106 Results

Table 1 includes the results for the SIL-CO-SIL 106 test runs. Sample 3, 17-July (italicized) was rejected because the sample volume collected was below 200 mL due to a mechanical failure by the discrete sampler. Influent and Effluent Samples 5, 28-August, were replaced with a duplicate Influent-Effluent sample pair, which was taken to determine the size distribution of the influent sediments (see discussion below). The influent concentrations were generally above the target concentration of 200 mg/L, which indicates that the one-micron filter sock at the outlet was only partially effective at trapping the finer SIL-CO-SIL 106 particles. This was supported by visual observations, which noted that the trench went from clear to cloudy in less than one detention time. The effects of recirculating these finer particles on the size distribution of the influent silica particles are discussed below.

Chauvenet's criterion (Taylor 1982) was used to reject two influent concentrations (Sample 5, 17-July, and Sample 3, 25-July), italicized, which are lower than the mean value by more than two standard deviations. Sample 4, 25-July, was retained even though it was well below the target influent concentration of 200 mg/L; over two-standard deviations after eliminating the aforementioned outliers. After removing the two influent-effluent pairs corresponding to these outliers, the average removal efficiency for all test runs was 60±9%, with a minimum value of 44% and a maximum value of 75%. The average influent concentration was 270±59 mg/L, with a minimum value of 139 mg/L and a maximum value of 361 mg/L. The average effluent concentration was 109±35 mg/L, with a minimum value of 66 mg/L and a maximum value of 182 mg/L. These results are summarized in Table 2.

Table 1. Results SIL-CO-SIL 106 Tests

Date	Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
9-Jul	1	180	81	55
9-Jul	2	177	100	44
9-Jul	3	292	122	58
9-Jul	4	315	147	53
9-Jul	5	318	162	49
17-Jul	1	212	72	66
17-Jul	2	266	95	64
17-Jul	*3*	*189*	*124*	*34*
17-Jul	4	278	135	51
17-Jul	*5*	*70*	*170*	*-143*
25-Jul	1	236	77	67
25-Jul	2	229	66	71
25-Jul	*3*	*87*	*104*	*-20*
25-Jul	4	139	74	47
25-Jul	5	293	87	70
1-Aug	1	240	70	71
1-Aug	2	290	124	57
1-Aug	3	294	144	51
1-Aug	4	341	146	57
1-Aug	5	361	132	63
28-Aug	1	227	74	67
28-Aug	2	266	67	75
28-Aug	3	328	137	58
28-Aug	4	308	100	68
28-Aug	5	353	182	48
	Average	252	112	56
	Std. Dev.	78	35	44

Table 2. Results SIL-CO-SIL 106 Tests after Removing Outliers.

Date	Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
9-Jul	1	180	81	55
9-Jul	2	177	100	44
9-Jul	3	292	122	58
9-Jul	4	315	147	53
9-Jul	5	318	162	49
17-Jul	1	212	72	66
17-Jul	2	266	95	64
17-Jul	4	278	135	51
25-Jul	1	236	77	67
25-Jul	2	229	66	71
25-Jul	4	139	74	47
25-Jul	5	293	87	70
1-Aug	1	240	70	71
1-Aug	2	290	124	57
1-Aug	3	294	144	51
1-Aug	4	341	146	57
1-Aug	5	361	132	63
28-Aug	1	227	74	67
28-Aug	2	266	67	75
28-Aug	3	328	137	58
28-Aug	4	308	100	68
28-Aug	5	353	182	48
	Average	270	109	60
	Std. Dev.	59	35	9
	Max	361	182	75
	min	139	66	44

The observed variability in the influent and effluent concentrations was mainly due to the recirculation of fine grained particles not trapped by the filter sock. It was apparent starting with the first test (9-July) that the filter sock was not effective at trapping the fine effluent sediments and preventing their recirculation. As a result, there is a clear trend of increasing influent and effluent SSC concentrations with increasing detention time during each test run, as shown in Figures 2 and 3.

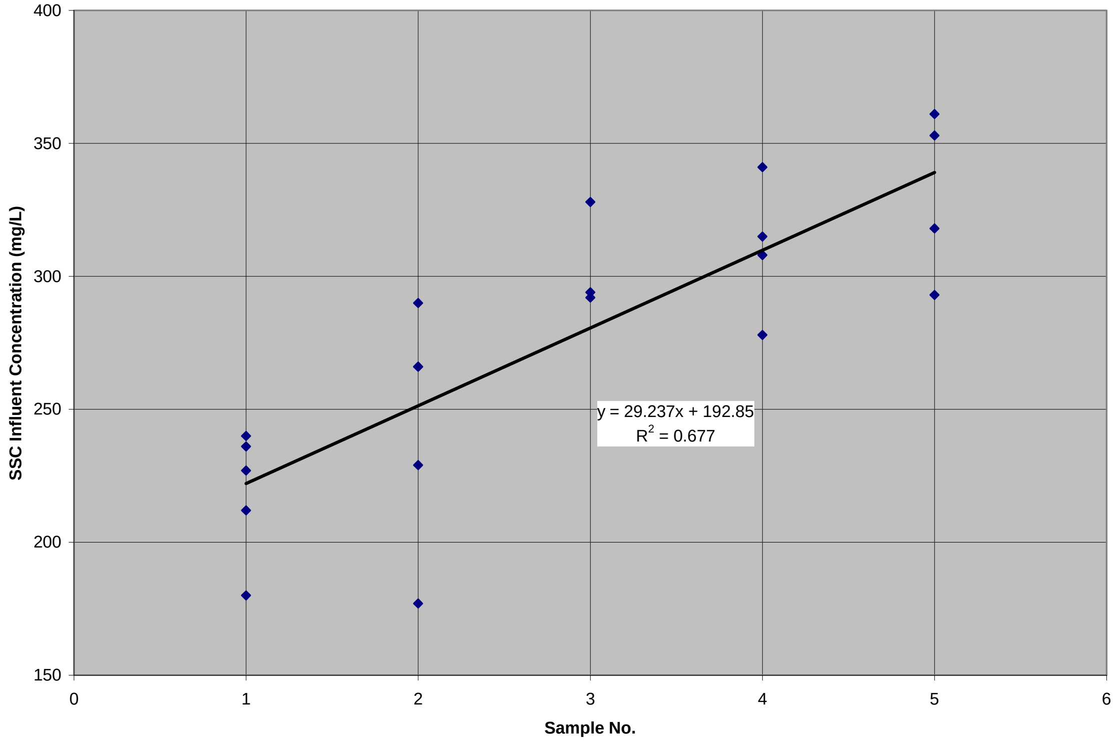


Figure 2. Average increase in influent concentrations over each test (15 detention times).

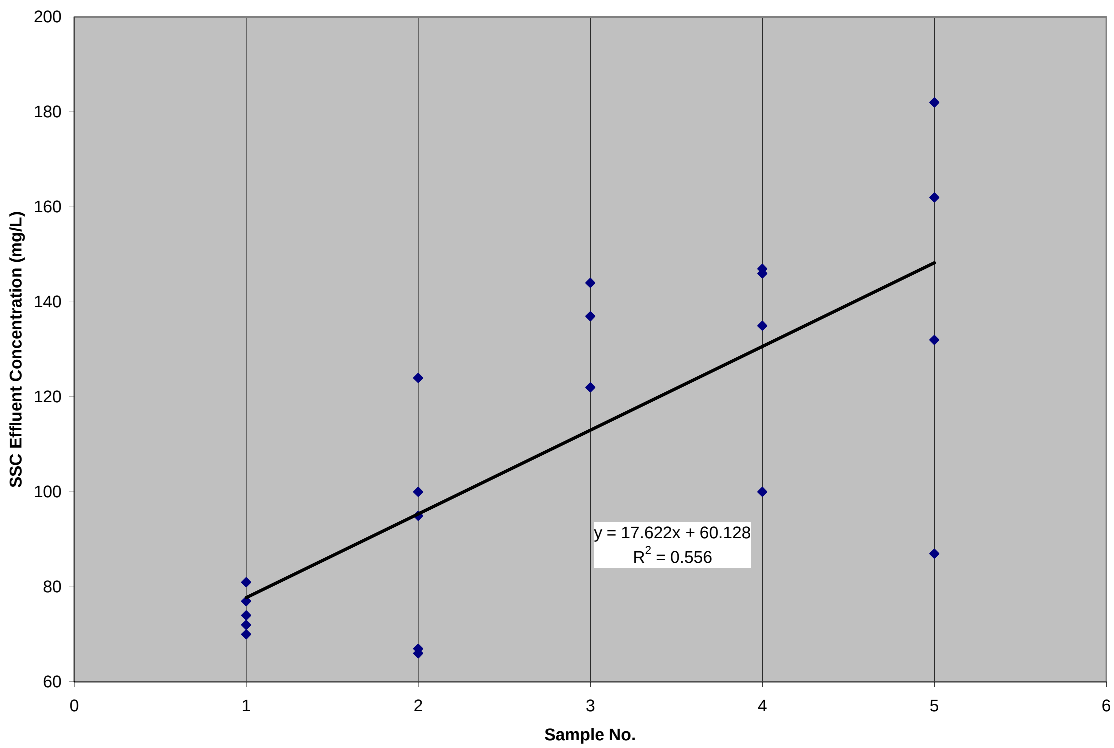


Figure 3. Average increase in effluent concentrations over each test (15 detention times).

Table 3 shows how the average removal efficiency decreased on average with detention time during each test run as a result of recirculation. The removal efficiencies are calculated by averaging all influent and effluent samples with the same sample number, respectively (e.g. all influent samples with sample number 1 and all effluent samples with sample number 2). The results indicate that at the beginning of the test recirculation has not significantly increased influent concentrations above the target level of 200 mg/L. The average influent concentration for sample one was 219 mg/L. In addition, as discussed below, one can speculate that the recirculation of predominantly fine particles has not reduced the particle size distribution of the influent significantly. Under these conditions, the average removal efficiency (based solely on the first samples of each test run) is 66%. However, as the test progresses and recirculation of fines increases, the removal efficiency is reduced.

Table 3. Reduction of removal efficiency with detention time.

Sample No.	No. of Det. Times	Avg. Influent SSC mg/L	Avg. Effluent SSC mg/L	Removal Eff. %
1	3	219	75	66
2	6	246	90	63
3	9	305	134	56
4	12	311	132	57
5	15	331	141	58

It was hypothesized that the lower removal efficiencies observed later in the test were a result of smaller size distributions due to increased recirculation of effluent as the test progressed. To confirm this hypothesis grab samples of influent were sent to Micromeritics Analytical Services, along with a composite dry sample of the SIL-CO-SIL 106 taken from five different 50-lbs. bags. In addition, corresponding grab samples of effluent were also sent for analysis. The detailed results of Micromeritics analyses are provided in Appendix 7. These results, summarized in Table 4, show a clear reduction in the particle size distribution of the influent sediments as a result of recirculation, with 16%, 50% (median), and 84% finer particle sizes of the composite influent samples approximately half the values of the composite dry sample. In addition, the effluent sediments consist mainly of very fine particles, 84% of which are 10 microns or smaller, 50% of which are only 4 microns and smaller.

Table 4. SIL-CO-SIL 106 size distribution summaries.

Sample	16% Finer Diameter (μm)	50% Finer Diameter (μm)	84% Finer Diameter (μm)
Dry Sample (5 Bags)	6.1	21.5	44.5
Composite Influent Grab	3.4	9.8	24.1
Composite Effluent Grab	2.0	4.0	10.0

Sediments occluded within the woven fabric and trapped in the gravel cannot be removed between each test run. As a result the initial condition cannot be reestablished once testing has begun, and the sediments trapped in previous test runs may washout, raising effluent and influent SSC concentrations at latter test runs. This condition is supported by the trends shown in Figures 4 and 5, which show an increase in influent and effluent SSC concentrations as the experiments progressed. One potential benefit of sediment occlusion and deposition over time may be increased removal efficiency as the geotextile fabric clogs and a filter cake develops on the isolator row bottom. Indeed there was a noticeable build up of sediments within the isolator row as the experiments progressed. Photos shown in Figure 6, which were taken after the completion of all tests, show increased sediment deposition from upstream to downstream, with accretion depths up to 4 mm in thickness. Figure 7, a plot of removal efficiency vs. the sample order number for all the experiments does indicate a subtle trend towards greater removal efficiencies, but more experiments are needed to verify this; and whether some threshold (optimal) removal efficiency would be reached.

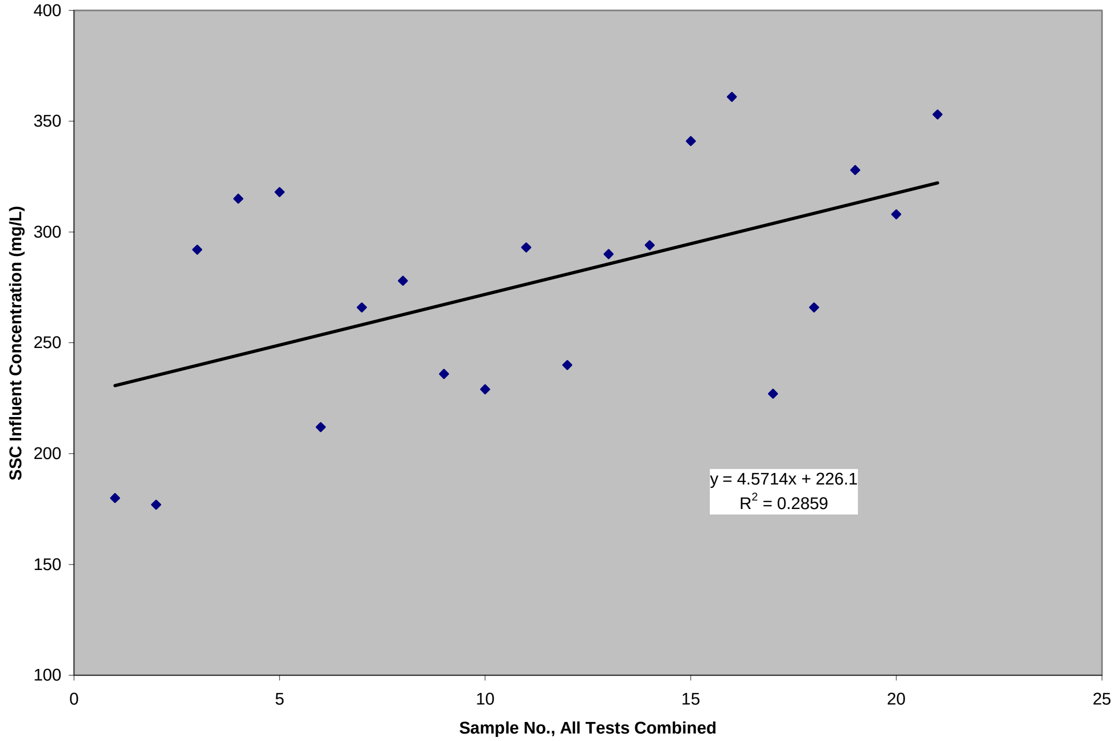


Figure 4. Average increase in influent concentration over entire test period.

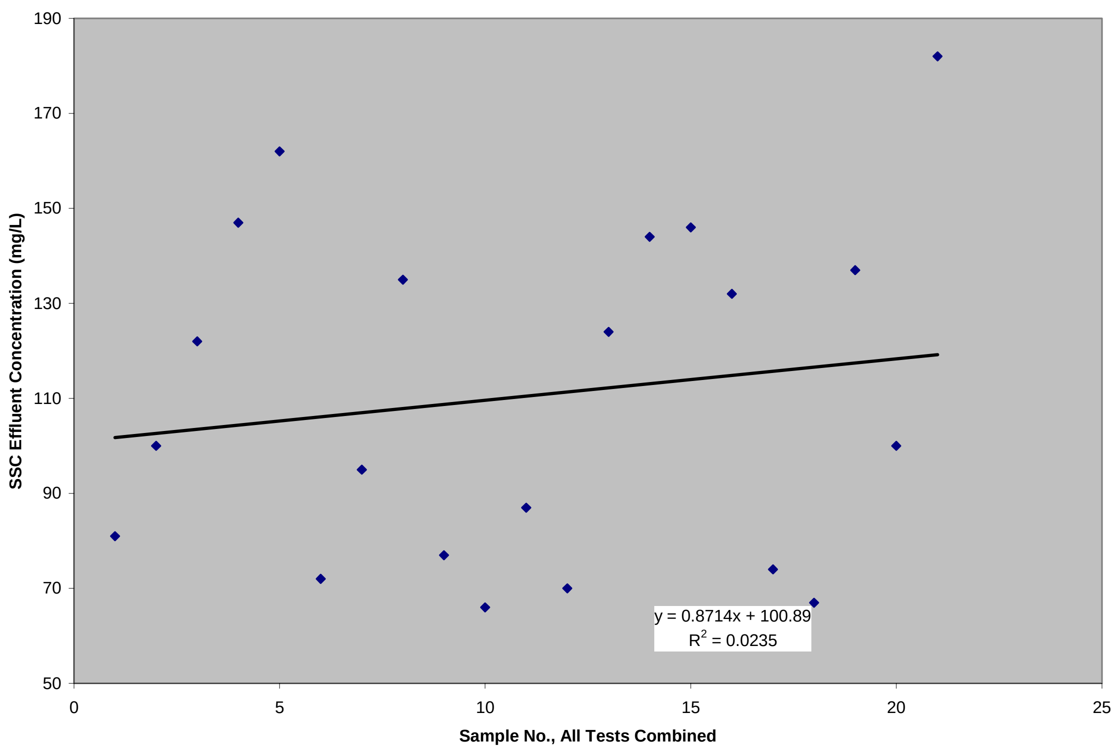
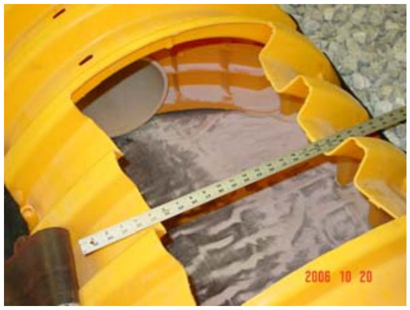


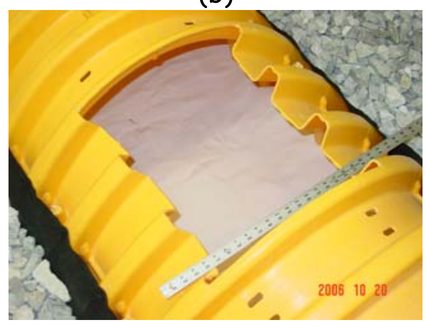
Figure 5. Average increase in effluent concentration over entire test period.



(a)

(b)

(c)



(d)

Figure 6. Photos of sediment accretion after the completion of all tests: (a) upstream-inlet; (b) mid-upstream; (c) mid-downstream; (d) downstream-outlet (October 20, 2006)

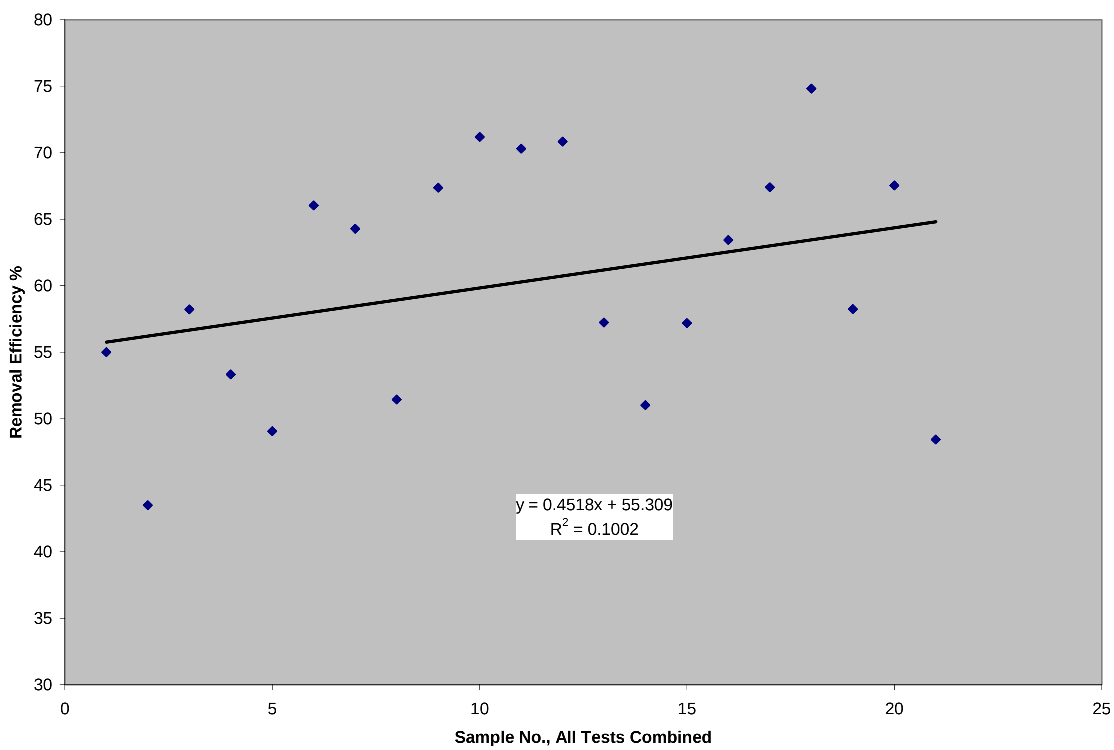


Figure 7. Average increase in removal efficiency over entire test period.

Sil-Co-Sil 250 Results

Results for the one SIL-CO-SIL 250 test are summarized in Tables 5 and 6. Although the influent concentration for Sample 5 (Table 5) is well below the target concentration of 200 mg/L, it was within two standard deviations and was retained. Recirculation of fine sediments was observed and would have reduced the particle size distribution of the influent concentrations below the mean particle size of D_{50}=45 microns. However, particle size analyses of influent sediments were not obtained as was done for the SIL-CO-SIL 106 experiment. Therefore, the following performance claims for SIL-CO-SIL 250 are for D_{50}<45 microns. The average removal efficiency was 71±14%, with a minimum value of 47% and a maximum value of 82%. Compared to the results for the SIL-CO-SIL 106, these values appear reasonable since one would expect higher removal efficiencies when the particle size distribution is greater.

Table 5. Results SIL-CO-SIL 250 Test at 3.2 gpm/sqft (July 19, 2006)

Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
1	226	40	82
2	169	47	72
3	244	53	78
4	288	67	77
5	129	68	47
Average	211	55	71
Std. Dev.	63	12	14
Max.	288	68	82
Min.	129	40	47

The influent concentrations in Table 6 are above the target concentrations of 200 mg/l. Effluent grab samples by hand were taken in lieu of automated samples due to the reduced stage in the effluent pipe.

Table 6. Results SIL-CO-SIL 250 Test at 1.7 gpm/sqft (July 19, 2006)
(effluent grab samples)

Sample	Influent SSC mg/L	Effluent grab SSC mg/L	Removal Eff. %
1	416	27	89
2	407	44	88
3	441	48	87
4	417	56	89
5	441	61	87
Average	424	47	88
Std. Dev.	16	13	1
Max.	441	61	89
Min.	407	27	87

CONCLUSIONS:

Sediment removal efficiencies were successfully estimated for the StormTech® Isolator™ Row despite problems associated with recirculation of fine sediments, which substantially reduced the particle size distribution of the influent sediments.

The average removal efficiency of the Isolator Row for influent sediments approximately half as coarse as SIL-CO-SIL 106 is 60%, indicating that the isolator row performs well. Based on the first samples, before recirculation is thought to significantly reduce the influent particle size distribution, removal efficiencies of 66% were obtained.

A less detailed study of sediment removal performance was conducted for the coarser grained SIL-CO-SIL 250, but an average removal efficiency of 71% at 3.2 gpm/sqft seems reasonable compared to SIL-CO-SIL 106 results and indicates good performance as well. At 1.7 gpm/sqft for SIL-CO-SIL 250, an average removal efficiency of 88% was demonstrated.

The study observed a slight trend of improved removal efficiencies as the testing progressed, which supports the hypothesis of improved removal efficiencies with progressively greater sediment occlusion and accretion (i.e. filter cake development).

REFERENCES:

Christensen, A. (2005) "Hydraulic Performance and Sediment Trap Efficiency of StormTech® SC-740 Isolator™ Row." M.S. Thesis, In Partial Fulfillment of M.S. Degree, Tennessee Tech University, December 2005, 132 pages including appendices. V.S. Neary, Advisor.

Taylor, J. R., (1982). An Introduction to Error Analysis: The Study of Uncertainty in Physical Measurements. University Science Books, Mill Valley, CA.

APPENDICES

APPENDIX 1

ANGULAR STONE BACKFILL SPECIFICATIONS

LOCATION: Ahgood DATE: 6/25/03 SIZE: #3's 2" mi.

SAMPLE #1

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	5.93	20.1	79.9	35-70
1"	25.35	85.9	14.1	0-15
3/4"	28.46	96.5	3.5	-
5/8"				-
1/2"	29.11	98.7	1.3	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2	—	—	100	100

ORIGINAL DRY WEIGHT	29.50
WEIGHT AFTER WASH	
WASH LOSS	
PERCENT LOSS	

SAMPLE #2

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	6.43	24.1	75.9	35-70
1"	23.33	87.6	12.4	0-15
3/4"	25.91	97.3	2.7	-
5/8"				-
1/2"	26.33	98.9	1.1	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2	—	—	100	100

ORIGINAL DRY WEIGHT	26.63
WEIGHT AFTER WASH	
WASH LOSS	
PERCENT LOSS	

SAMPLE #3

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2				100

ORIGINAL DRY WEIGHT	
WEIGHT AFTER WASH	
WASH LOSS	
PERCENT LOSS	

AVERAGE

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2				100

ORIGINAL DRY WEIGHT	
WEIGHT AFTER WASH	
WASH LOSS	
PERCENT LOSS	

Figure A.1. 1: Gravel Backfill Specifications

APPENDIX 2

GEOTEX® 601 non-woven geotextile fabric specifications

SI® Geosolutions

Product Data Sheet

GEOTEX® 601

GEOTEX 601 is a polypropylene, staple fiber, needlepunched nonwoven geotextile manufactured at one of SI Geosolutions' facilities that has achieved ISO-9002 certification for its systematic approach to quality. The fibers are needled to form a stable network that retains dimensional stability relative to each other. The geotextile is resistant to ultraviolet degradation and to biological and chemical environments normally found in soils. **GEOTEX 601** conforms to the property values listed below[1] which have been derived from quality control testing performed by one of SI Geosolutions' GAI-LAP accredited laboratories:

		MARV[2]	
PROPERTY	TEST METHOD	ENGLISH	METRIC
Physical			
Mass/Unit Area	ASTM D5261	5.0 oz/yd^2	170 g/m^2
Thickness	ASTM D5199	60 mils	1.5 mm
Mechanical			
Grab Tensile Strength	ASTM D4632	160 lbs	712 N
Grab Elongation	ASTM D4632	50%	50%
Puncture Strength	ASTM D4833	85 lbs	378 N
Mullen Burst	ASTM D3786	280 psi	1930 kPa
Trapezoidal Tear	ASTM D4533	60 lbs	267 N
Wide Width Tensile	ASTM D4595	720 lbs/ft	10.5 kN/m
Endurance			
UV Resistance @ 500 hrs	ASTM D4355	70%	70%
Hydraulic			
Apparent Opening Size (AOS)[3]	ASTM D4751	70 US Std. Sieve	0.212 mm
Permittivity	ASTM D4491	1.30 sec^{-1}	1.30 sec^{-1}
Permeability	ASTM D4491	0.24 cm/sec	0.24 cm/sec
Water Flow Rate	ASTM D4491	110 gpm/ft^2	4480 $l/min/m^2$
Typical Roll Sizes		150 in x 100 yds 180 in x 100 yds	3.81 m x 91.5 m 4.57 m x 91.5 m

NOTES:

[1] **The property values listed below are effective 12/2003 are subject to change without notice.**

[2] Values shown are in weaker principal direction. Minimum average roll values are calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported.

[3] Maximum average roll value. Statistically, it yields a 97.7% degree of confidence that samples taken from quality assurance testing will be below the value reported.

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Figure A.2. 1: GEOTEX® 601 non-woven geotextile fabric specifications

APPENDIX 3

GEOTEX® 315 ST woven geotextile fabric specifications

SI® Geosolutions

Product Data Sheet

GEOTEX® 315 ST

GEOTEX 315ST is a woven slit film geotextile manufactured at one of SI Corporations' facilities. The individual slit films are woven together in such a manner as to provide dimensional stability relative to each other. The construction of the geotextile makes **GEOTEX 315ST** ideal for soil separation and stabilization. The geotextile is resistant to ultraviolet degradation and to biological and chemical environments for normally found in soils. **GEOTEX 315ST** conforms to the property values listed below[1] which have been derived from quality control testing performed by one of SI Corporations' GAI-LAP accredited laboratories:

PROPERTY	TEST METHOD	MARV[2] ENGLISH	MARV[2] METRIC
Physical			
Mass/Unit Area	ASTM D5261	6.5 oz/yd^2	220 g/m^2
Thickness	ASTM D5199	20 mils	.5 mm
Mechanical			
Tensile Strength (Grab)	ASTM D4632	315 x 315 lbs	1,400 x 1,400 N
Elongation	ASTM D4632	15 x 15%	15 x 15%
Wide Width Tensile	ASTM D4595	175 x 200 lbs/in	30.6 x 35.0 kN/m
Wide Width Elongation	ASTM D4595	10 x 8%	10 x 8%
Puncture	ASTM D4833	125 lbs	555 N
Mullen Burst	ASTM D3786	650 psi	4475 kPa
Trapezoidal Tear	ASTM D4533	120 x 120 lbs	530 x 530 N
CBR Burst	GRI-GSI	1075 lbs	4780 N
Endurance			
UV Resistance	ASTM D4355	90%	90%
Hydraulic			
Apparent Opening Size (AOS)	ASTM D4751	70 US Std. Sieve	0.212 mm
Permittivity	ASTM D4491	0.05 sec^{-1}	0.05 sec^{-1}
Permeability	ASTM D4491	.003 cm/sec	.003 cm/sec
Water Flow Rate	ASTM D4491	4 gpm/ft^2	161 l/min/m^2
Roll Sizes		12.5 ft x 360 ft 15.0 ft x 300 ft 17.5 ft x 258 ft	3.81 m x 109.73 m 4.57 m x 91.44 m 5.33 m x 78.64 m

NOTES:

1. **The property values listed above are effective 03/24/2006 and are subject to change without notice.**
2. Values for machine (warp) and cross-machine (fill), respectively, under dry or saturated conditions. Minimum average roll values (MARV) are calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported.

6025 Lee Highway, Suite 435 • Chattanooga, Tennessee USA • (423) 899-0444 or (800) 621-0444 • FAX (423) 485-9068 • www.fixsoil.com

Figure A.3.1: GEOTEX® 315 ST woven geotextile fabric specifications

APPENDIX 4

THERMO-ELECTRON DCT-7088 FLOW METER SPECIFICATIONS

AND CALIBRATION

Thermo
ELECTRON CORPORATION

Process Instruments

9303 W. Sam Houston Pkwy.
Houston, TX 77099 USA
(713) 272-0404
(713) 272-2273 fax

Polysonics DCT7088 Portable Digital Transit Time Flowmeter Recommended Procurement Specification

1. The instrument will utilize ultrasonic, digital, and transit time correlation technologies to provide indication, totalization, and signal transmission of liquid flow rate in full pipes.

2. The instrument will measure flow rates of clean liquids with a velocity range from +/-0 to 40 ft/s (+/-0 to 12 m/s).

   2a. Accuracy will be +/-0.5% of velocity or +/-0.05 ft/s (+/-0.0152 m/s), typical, digital output.
   2b. Flow sensitivity will be 0.01 ft/s (0.003 m/s) at any flow rate including zero.
   2c. Linearity will be 0.1% of scale, digital output.

3. The instrument will be housed in a NEMA 6 (IP67) environmentally sealed enclosure and will be waterproof against accidental immersion and splashproof with lid open.

4. Two transducers will be supplied with the instrument and will be suitable for pipe sizes from 1 to 200 in (25mm to 5m).

   4a. Transducers will be of encapsulated design and suitable for operation from -40º to +212º F (-40º to +100º C).

   4b. They will attach to the outside of the pipe using a slide-track mounting method.

   4c. The standard transducer cable length will be 16 ft (5 m).

   4d. Optional high temp transducers suitable for operation from -40 to 392 deg F (-40 to 200 deg C)

5. The analog output will be an isolated, 4-20 mA (into 1K to 5K ohms) direct currentproportional to flow. Output current limiting circuitry will be incorporated in the instrument electronics. The instrument will have an RS232 serial interface.

6. The instrument will be powered by a rechargeable, internal battery suitable for 8 hours of continuous operation. An internal battery providing 16 hours of continuous operation will optionally be available. The battery must be fully recharged within a maximum of 8 hours.

7. The display will be a 40-character, 2-line, backlit, high resolution LCD.

8. Configuration will be via a front panel, 19-key keypad with tactile action. Input parameters will be password protected. The nonvolatile memory shall retain totalizer and user parameters for up to five years. Diagnostics will be accessible via the keypad.

9. The instrument electronics will be designed to operate at temperatures between -5º to +140º F (-20º to +60º C). All electronic circuits will be interchangeable with other instruments having the same model number. All circuit boards will be conformally coated with an anti-fungus compound.

Process Instruments
9303 W. Sam Houston Pkwy.
Houston, TX 77099 USA
(713) 272-0404
(713) 272-2273 fax

10. A 40,000-point data logger programmable in intervals of 1 s will be included as standard in the instrument. The *UltraScan* signal analysis and configuration software program for Windows® will be supplied with the instrument. The software will incorporate pull-down menus and pop-up windows to provide access to an extensive range of graphical diagnostic information. Low flow cutoff, bi-directional totalization with selectable resolution, automatic sound speed calculation of measured fluid, and adjustable damping will be standard with the software.

11. The instrument will have a built-in microprocessor to provide for adapting instrument hardware to existing piping and flow conditions. It will automatically calculate transducer spacing and read English or metric units.

12. The instrument enclosure will provide a facility for the attachment of a padlock to prevent unauthorized access to the display and front panel.

13. A test block will be supplied for instrument diagnostic testing.

14. The manufacturer will provide as an option a certified calibration in accordance with ANSI specification Z540.1.

15. The instrument will be manufactured in the USA at an ISO 9001 certified facility. The manufacturer will be Thermo Electron Corporation.

16. The instrument will be Thermo Electron Corporation's Polysonics DCT7088 Portable Digital Correlation Transit Time Flowmeter.

Windows® is a registered trademark of Microsoft Corporation in the United States and/or other countries.

Thermo
ELECTRON CORPORATION

Process Instruments
9303 W. Sam Houston Parkway S.
Houston, TX 77099-5298

713) 272-0404
Fax (713) 272-2272
www.thermo.com

CERTIFICATE OF CALIBRATION

Thermo Electron Corporation, Process Instruments certifies that the below listed instrument has been calibrated to meet or exceed published specifications using standards whose accuracies are traceable to the National Institute of Standards and Technology

PRODUCT INFORMATION

Customer:	TENNESSEE TECHNICAL	Device Serial Number:	53376
	UNIVERSITY WATER RESOU	Scale Factor:	1
	1020 STADIUM DRIVE	Full Scale Value (GPM):	900
	COOKEVILLE, TN 38505	Ambient Temperature:	75
Sales Order:	2142292	Relative Humidity	44%
Device Model:	DCT7088	Procedure Used:	1-0561-002 (A)

CALIBRATION DATA

FLOW RATE (GPM)	INSTRUMENT READING (GPM)	DIFFERENCE IN GPM	PERCENT ERROR	WITHIN SPECIFICATION?
650.35	648.76	1.59	0.24%	YES
449.62	448.52	1.10	0.24%	YES
368.97	367.25	1.72	0.47%	YES

Calibration Date: April 7, 2006

Recommended Calibration Due Date: April 7, 2007

Calibration Performed by:

Thermo Electron, Process Instruments Representative

Form FM1601(C)

APPENDIX 5

Lab Protocol, Sub-Appendices 5-a through 5-g

STORMTECH
REMOVAL EFFICIENCY EXPERIMENT
March 21, 2006

LAB PROTOCOL

1. Set up the slurry mixture in the mixing tank and make sure that the suction line of the peristaltic pump is midway between the propellers and also check for any constrictions. Also check if the direction of flow in the peristaltic pump is proper. (See **APPENDICES 5-a and 5-b**). NOTE: Two peristaltic pumps will be required when flow rates are above Q=0.6 cfs because the pump speed is limited to 220 rpm (See **APPENDIX 6-c**). To accommodate two peristaltic pumps, two taps are installed in the pipe upstream of the flume and butterfly valve.
2. Fill out test run information on laboratory test form (See **APPENDIX 5-d**).
3. See Stage-Discharge-Detention Time Calculation Table (**APPENDIX 5-e**) to determine the duration of the test run for each flow based on fifteen detention times.
4. Turn the Allis Chalmers pumps on, record the time on the test data sheet and set the flow rate. For setting the pumps refer to **APPENDIX 5-f**.
5. Slowly increase the flow rate until a steady flow condition is established. Record the time when this is established. For the flow meter setting refer to **APPENDIX 5-g.**
6. Measure and record water temperature with standard thermometer.
7. Record the time for the blank automated discrete samples at inlet and outlet and label the bottle with the test run code and I-B (influent blank), E-B (effluent blank).
8. Start and note the time the peristaltic pump is turned on. Refer to **APPENDIX 5-c** for setting the specified concentration as per required mg/L of sediment.
9. Wait 3 detention times before beginning sampling.
10. Start stopwatch to record the exact time of the test run.
11. Measure 3 lb of sediment and 2 gallon of water.
12. Monitor the level of the mixture in the mixer tank and make sure it is not dropping below the top propeller. If the slurry level in the mixing tank reaches the top propeller, pour contents into the mixing tank. Be sure to pour as far away as possible from the suction line of the peristaltic pump. Also, do not pour in to mixing tank just prior to a grab sample, as to avoid high concentrations of sediment.
13. Collect grab sample and label the bottle with the test run code and I-1.
14. Wait one (1) detention time and collect grab sample of effluent and label the bottle with the test run code and E-1.
15. Continue influent and effluent sampling at intervals of 3 detention times.
16. After fifteen (15) detention times the peristaltic pump, the stopwatch, and the main pumps are shut off at the same time.

APPENDIX-5-a

SETTING UP THE MIXER TANK

- Weigh 45 lb of the sediment and carefully transfer it into the mixer tank.
- Fill the mixer tank with 30 gal of water.
- Now the concentration of the mixture is 1.5 lb/gal.
- Set the angle of the mixer shaft according to the schematic below.
- Turn the motor driving the propellers ON.

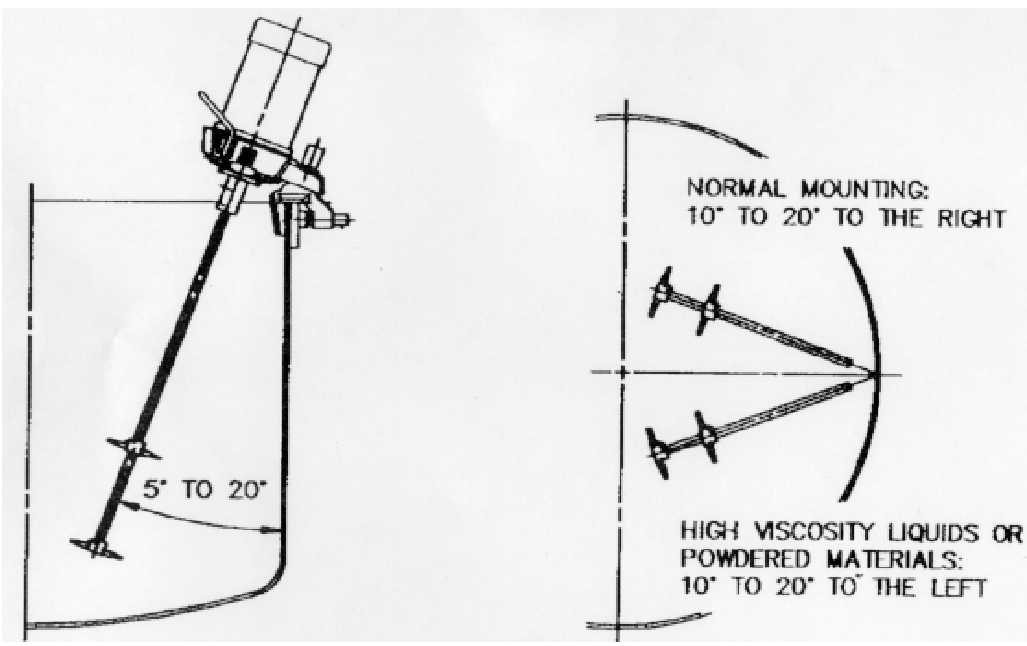


Figure A.5.1: Mixer Mounting Angle and Eccentric Angle.

APPENDIX 5-b

WATSON-MARLOW PERISTALTIC PUMP

1. Place the suction line in the mixer tank and the effluent line in the pipes that run to the concentrator. Make sure that the center screw of the pump is tight.
2. Turn the power ON and set the pump at the required rpm by using the arrow keys on the pump.
3. Before turning the pump ON, make sure that the propellers in the mixer tank are rotating properly and then give it sufficient time to ensure proper mixing.
4. Turn the pump on and simultaneously turn the stopwatch ON.
5. After the required time interval has elapsed, turn off the stopwatch and stop the pump simultaneously. Now the peristaltic pump can be turned OFF.
6. Carefully remove the suction line from the mixer tank and let the mixer tank drain.
7. For high flows two peristaltic pumps may be needed to attain required influent concentrations. The procedure remains the same for both pumps.

APPENDIX 5-c

SEDIMENT METERING CALCULATIONS AND PERISTALTIC PUMP CALIBRATION DETAILS

The loading rate calculations for the peristaltic pump to yield a target sediment concentration of 200 mg/L are based on the following equations:

$$Q_{sp} \div (Q_{wp} + Q_w) = 200 mg / L \qquad \text{A.5.1}$$

$$Q_{sp} \div Q_{sw} = 179{,}810\ mg / L \qquad \text{A.5.2}$$

where Q_{sp} is the discharge of sediment from the peristaltic pump, Q_{wp} is the discharge of water from peristaltic pump, and Q_w is the discharge of water from the inlet upstream of the sediment feed tap. *Equation A.5.1* expresses the target concentration and *Equation A5.2* expresses the sediment slurry concentration (1.5 lbs./gal. or 179,810 mg/L).

EXAMPLE

For 0.1 cfs, Q_w = 0.1*28.37 L/s = 2.837 L/s

$$179{,}810 \frac{Q_{sp}}{(Q_{wp} + 2.837)} = 200 \frac{mg}{lit}$$

$$\frac{Q_{sp}}{Q_{wp}} = 179{,}810 \frac{mg}{lit} \Rightarrow Q_{sp} = 179{,}810 \frac{mg}{lit} \times Q_{wp}$$

Solving for Q_{sp} and Q_{wp}:

$$Q_{wp} = \frac{200 \frac{mg}{s}}{179{,}810 \frac{mg}{lit}} = 0.00316 \frac{lit}{s}$$

And

$$Q_{sp} = 179{,}810 \frac{mg}{lit} \times 0.00316 \frac{lit}{s} = 568.032 \frac{mg}{s}$$

Extending these calculations for the rest of the flow rates, *Table A.5.1* is developed.

Table A.5.1: Sediment metering calculations

Q exper cfs	Q exper L/s	Target C mg/L	Mix C lbs/gal	Mix C mg/L	Q peristaltic L/s	Q sediment mg/s	Pump Spd rpm
0	0.00	200	1.5	179810	0.0000	0	0.0
0.1	2.84	200	1.5	179810	0.0032	568	33.6
0.2	5.67	200	1.5	179810	0.0063	1136	67.2
0.3	8.51	200	1.5	179810	0.0095	1704	100.8
0.4	11.35	200	1.5	179810	0.0126	2272	134.4
0.5	14.19	200	1.5	179810	0.0158	2840	168.0
0.6	17.02	200	1.5	179810	0.0190	**3408**	**201.6**
0.7	19.86	200	1.5	179810	0.0221	3976	235.2
0.8	22.70	200	1.5	179810	0.0253	4544	268.8
0.9	25.53	200	1.5	179810	0.0284	5112	302.4
1	28.37	200	1.5	179810	0.0316	5680	336.0
1.1	31.21	200	1.5	179810	0.0347	6248	369.6
1.2	34.04	200	1.5	179810	0.0379	6816	403.2

DETAILS OF PERISTALTIC PUMP CALIBRATION

A Watson-Marlow Model 323ES peristaltic pump meters the sediment-water slurry mixture to the inlet pipe. The pump was calibrated to determine the loading rate (mg/s) vs. pump speed (rpm) relationship. The pump operates in a range of 1-220 rpm.

Table A.5. 2: Calibration data of the peristaltic pump

rpm	Time (sec)	Sediment mixed (lb)	Mixture collected (lb)	Sediment collected (lb)	Sediment Left (lb)	Concentration (lb/gal)	Q sediment (lb/s)	Q sediment (mg/s)
20	7853	45	36.5	5.8	39.2	1.59	0.00073	335
50	3288	45	35.3	4.7	40.3	1.29	0.00142	649
90	1889	45	45.1	6.3	38.7	1.36	0.00333	1513
140	1223	45	39.9	6	39	1.49	0.00490	2226
180	619	45	28.5	4.3	40.7	1.49	0.00694	3152
220	564	45	32.3	5	40	1.54	0.00886	4022

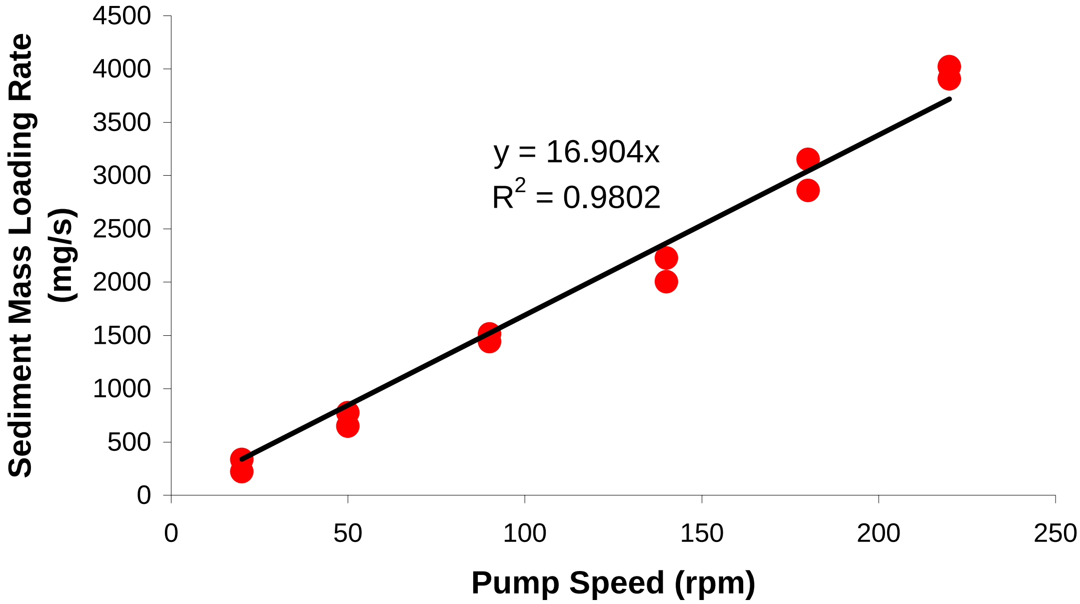


Figure A.5. 2: Calibration curve for the Watson-Marlow peristaltic pump

APPENDIX 5-d

LABORATORY DATA SHEET

TENNESSEE TECH UNIVERSITY: LABORATORY DATA SHEET **Lab_Test_Form.xls**

PROJECT: STORMTECH SC-740 CHAMBER SOLIDS REMOVAL EFFICIENCY

PERFORMED BY: **DATE:**

RUN INFO:

Test Name			
Q_{water}		cfs	gpm
$Q_{sediment}$		mg/s	
Max Stage		ft	
Volume		cu.ft.	
Detention Time		minutes	
START Sediment Wt. (lb)			
START Water (gal.)			
Mixture Concentration	1.5	lb/gal.	mg/L
Speed Peristaltic Pump		rpm	
Target $C_{influent}$	200	mg/L	

RECORD TIMES:

PRESTART		
FLOW STABILIZED		
WATER TEMPERATURE 1		
BLANK SAMPLE	^oC	
PERISTALTIC PUMP START		
THREE DETENTION TIMES		
GRAB SAMPLES	INFLUENT 1	EFFLUENT 1
Start sampling after 3	INFLUENT 2	EFFLUENT 2
detention times.	INFLUENT 3	EFFLUENT 3
Record times collected.	INFLUENT 4	EFFLUENT 4
Sample Effluent 1 detention	INFLUENT 5	EFFLUENT 5
time after Influent.		
FINISH		
WATER TEMPERATURE 2	^oC	

3*DETENTION TIME
45*DETENTION TIME

PHOTOS: Take photos at same exact place within chamber for each test run after test complete

OTHER OBSERVATIONS: sediment in trench, sump, etc.

APPENDIX 5-e

STAGE-DISCHARGE-DETENTION RELATIONS FOR RANGE OF FLOWS

Table A.5.3: Stage Discharge Results

Flow (cfs)	Stage Relative to Invert of Outlet (ft)	Depth of Water Inside Chamber (ft)	Volume of Water in All 4 Chambers (ft^3)*	Volume of Water in Gravel Beneath All Chambers (ft^3)	Total Volume (ft^3)	Detention Time, θ (min)	**15 X θ (min)**	Total Sediment Injected for 15 X θ (lbs) **	45 X θ (min)	Total Sediment Infected for 45 X θ (lbs) **	
0.10	0.70	0.00	0.00	33.52	33.52	5.59	**83.80**	6.30	251.40	18.89	
0.20	0.95	0.00	0.00	45.49	45.49	3.79	**56.86**	8.54	170.59	25.63	
0.40	1.11	0.13	13.77	46.92	60.69	2.53	**37.93**	11.40	113.79	34.20	***
0.50	1.23	0.25	26.32	46.92	73.24	2.44	**36.62**	13.76	109.86	41.27	
0.60	1.30	0.32	33.58	46.92	80.50	2.24	**33.54**	15.12	100.63	45.36	***
0.70	1.43	0.45	46.84	46.92	93.76	2.23	**33.49**	17.61	100.46	52.83	
0.80	1.53	0.55	56.85	46.92	103.77	2.16	**32.43**	19.49	97.28	58.47	
0.90	1.63	0.65	66.69	46.92	113.61	2.10	**31.56**	21.34	94.68	64.02	
1.00	1.67	0.69	70.57	46.92	117.49	1.96	**29.37**	22.07	88.12	66.20	
1.10	1.76	0.78	79.20	46.92	126.12	1.91	**28.66**	23.69	85.99	71.07	
1.20	1.84	0.86	86.70	46.92	133.62	1.86	**27.84**	25.10	83.51	75.29	

Volumes calculated using depth of water inside chamber and Table 6-SC740 of the StormTech Design Manual

Calculated using Table 7.1: Sediment metering Calculations of the StormTech Removal Efficiency Experiment Lab Protocol

Times for these flows are no longer needed but were included because they were already calculated

APPENDIX 5-f

SETTING PUMPS

SETTING THE PUMPS

1. Fill the trenches with water until the level is about an inch and a half from the standpipes.
2. First prime the pumps using the priming taps.
3. Open the hot water outlet tap and ensure that water runs through it.
4. Then turn ON the oil-recirculating pump and wait till oil flows through it.
5. Use the set pointer to set the required flow rate and adjust it so that fluctuations are reduced to the minimum. The Large pump generally only operates between 9 and 12 (on small gauge) for our range of flows.
6. The priming taps can now be shut off.
7. While chambers are filling, gradually increase pumping rate, while adding more water to the sump. Adding water to the sump distorts the flow meter.
8. After desired flow is achieved, allow flow to run for approximately 5-10 minutes, in order to ensure steady state.
9. Use the butterfly valve to ensure pipe fullness. At flow as low as 0.1-0.2 cfs butterfly valve should be at least ¾ closed. Check signal strength on flow meter to check that pipe is full. Opening and closing butterfly valve affects flow, so perform all adjustments prior to starting experiment.
10. After the experiment is finished, first turn the pump OFF and after a while turn the oil pump off.
11. Make sure to drain the water after each run and also turn the drain valve near the constant head tank ON.

APPENDIX- 5-g

FLOW METER

1. Set up the flow meter using the slide track on the overhead supply pipes.
2. After making the necessary connections, turn the flow meter ON and go to menu 01 to take readings for flow and velocity.
3. The flow rate for the experiment is set using the display of flow rate on the screen.
4. Disregard flow meter readings while adding water to sump. Adding water introduces air bubbles to the system, and distorts the flow measurements.
5. After desired flow is achieved, allow system to run for approximately 5-10 minutes to ensure flow does not change.
6. Check “Signal Strength” menu – should read 100%.
7. To turn the data logger ON, go to menu 80 and select the type of operation required i.e., time based data logger or automatic or just manual.
8. This data can be downloaded to a computer through a USB port and viewed. The data logger stores the data for up to 44 days.
9. Download data to computer in lab, via DOS program. Be sure to name files appropriately (i.e., file name should be recognizable, including desired flow rate, reference to the experiment, and date conducted).
10. Save data to zip drive
11. Then turn the flow meter OFF.

APPENDIX 6

SIL-CO-SIL 106 and 250 Specification Sheets, US Silica

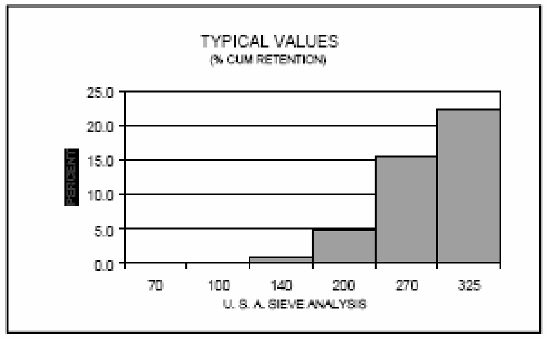
PRODUCT DATA

U.S. SILICA
Sands of Time

SIL-CO-SIL® 106

GROUND SILICA

PLANT: MILL CREEK, OKLAHOMA



USA STD SIEVE SIZE		TYPICAL VALUES		
		% RETAINED		% PASSING
MESH	MICRONS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	212	0.0	0.0	100.0
100	150	0.1	0.1	99.9
140	106	0.9	1.0	99.0
200	75	3.9	4.9	95.1
270	53	10.7	15.6	84.4
325	45	6.7	22.3	77.7

TYPICAL PHYSICAL PROPERTIES

HARDNESS (Mohs) **7**
MELTING POINT (Degrees F)........................ **3100**
MINERAL .... **QUARTZ**
pH.. **7**

REFLECTANCE (%) **89.4**
YELLOWNESS INDEX... **3.63**
SPECIFIC GRAVITY 2.65

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide)..................................... **99.7**
Fe_2O_3 (Iron Oxide).. **0.016**
Al_2O_3 (Aluminum Oxide)................................ **0.14**
TiO_2 (Titanium Dioxide)................................ **<0.01**
CaO (Calcium Oxide)................................... **<0.01**

MgO (Magnesium Oxide).. **<0.01**
Na_2O (Sodium Oxide).. **<0.01**
K_2O (Potassium Oxide)... **0.02**
LOI (Loss On Ignition).. **0.1**

May 29, 1998

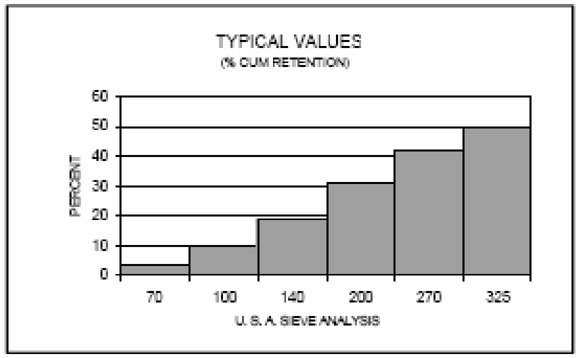
<u>DISCLAIMER</u>: The information set forth in this Product Data Sheet represents typical properties of the product described; the information and the typical values are not specifications. U.S. Silica Company makes no representation or warranty concerning the Products, expressed or implied, by this Product Data Sheet.

<u>WARNING</u>: The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer. **For detailed information on the potential health effect of crystalline silica - quartz, see the U.S. Silica Company Material Safety Data Sheet.**

U.S. Silica Company **P.O. Box 187, Berkeley Springs, WV 25411-0187** **(304) 258-2500**

U.S. SILICA®
Sands of Time

PRODUCT DATA



SIL-CO-SIL® 250

GROUND SILICA

PLANT: OTTAWA, ILLINOIS

USA STD SIEVE SIZE		TYPICAL VALUES		
		% RETAINED		% PASSING
MESH	MICRONS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	212	3.5	3.5	96.5
100	150	6.0	9.5	90.5
140	106	9.5	19.0	81.0
200	75	12.0	31.0	69.0
270	53	11.0	42.0	58.0
325	45	8.0	50.0	50.0

TYPICAL PHYSICAL PROPERTIES

HARDNESS (Mohs) **7**
MELTING POINT (Degrees F) **3100**
MINERAL .... **QUARTZ**
pH **7**
REFLECTANCE (%) **78**
YELLOWNESS INDEX **4.8**
SPECIFIC GRAVITY 2.65

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide) **99.8**
Fe_2O_3 (Iron Oxide) **0.035**
Al_2O_3 (Aluminum Oxide) **0.05**
TiO_2 (Titanium Dioxide) **0.02**
CaO (Calcium Oxide) **0.01**
MgO (Magnesium Oxide) .... **<0.01**
Na_2O (Sodium Oxide) .... **<0.01**
K_2O (Potassium Oxide) **0.02**
LOI (Loss On Ignition) **0.1**

December 15, 1997

DISCLAIMER: The information set forth in this Product Data Sheet represents typical properties of the product described; the information and the typical values are not specifications. U.S. Silica Company makes no representation or warranty concerning the Products, expressed or implied, by this Product Data Sheet.

WARNING: The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer. **For detailed information on the potential health effect of crystalline silica - quartz, see the U.S. Silica Company Material Safety Data Sheet.**

U.S. Silica Company **P.O. Box 187, Berkeley Springs, WV 25411-0187** **(304) 258-2500**

APPENDIX 7

Micromeritics Size Distribution Analyzes

APPENDIX 7.1

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Dry Sample

from 5, 50 lbs. bags.

Micromeritics Analytical Services

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Combined Report

Summary Report

Sample Statistics

Total Number 67549081
Total Surface Area 1.2644e+09 µm²
Total Volume 2.1331e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	25.35	Mode	36.57
Median	21.54		

Weighted Statistics (Number Distribution)

Mean	1.762	Mode	1.378
Median	1.354		

Geometric Statistics (Volume Distribution)

Mean	17.57	Mode	36.57
Median	21.54		

Geometric Statistics (Number Distribution)

Mean	1.445	Mode	1.378
Median	1.354		

Micromeritics Analytical Services

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
109.97	1.4988×10^6	0.1	99.9	2	0.0	100.0
104.72	1.2942×10^6	0.1	99.9	2	0.0	100.0
99.72	2.2350×10^6	0.1	99.8	4	0.0	100.0
94.96	2.8948×10^6	0.1	99.6	6	0.0	100.0
90.42	3.7494×10^6	0.2	99.5	9	0.0	100.0
86.11	4.6764×10^6	0.2	99.2	13	0.0	100.0
81.99	5.9016×10^6	0.3	99.0	19	0.0	100.0
78.08	8.0461×10^6	0.4	98.6	30	0.0	100.0
74.35	1.0653×10^7	0.5	98.1	46	0.0	100.0
70.80	1.2998×10^7	0.6	97.5	65	0.0	100.0
67.42	1.6576×10^7	0.8	96.7	96	0.0	100.0
64.20	2.0128×10^7	0.9	95.8	135	0.0	100.0
61.13	2.3302×10^7	1.1	94.7	181	0.0	100.0
58.21	2.6902×10^7	1.3	93.4	242	0.0	100.0
55.43	3.0524×10^7	1.4	92.0	318	0.0	100.0
52.79	3.3568×10^7	1.6	90.4	405	0.0	100.0
50.27	3.6142×10^7	1.7	88.7	505	0.0	100.0
47.87	3.8252×10^7	1.8	86.9	619	0.0	100.0
45.58	4.0820×10^7	1.9	85.0	765	0.0	100.0
43.40	4.3356×10^7	2.0	83.0	941	0.0	100.0
41.33	4.6986×10^7	2.2	80.8	1181	0.0	100.0
39.36	4.9022×10^7	2.3	78.5	1427	0.0	100.0
37.48	5.0575×10^7	2.4	76.1	1705	0.0	100.0
35.69	5.1918×10^7	2.4	73.7	2027	0.0	100.0
33.98	5.1730×10^7	2.4	71.2	2339	0.0	100.0
32.36	5.1237×10^7	2.4	68.8	2683	0.0	100.0
30.82	5.1646×10^7	2.4	66.4	3132	0.0	100.0
29.34	5.1088×10^7	2.4	64.0	3588	0.0	100.0

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
27.94	5.0568×10^{7}	2.4	61.6	4113	0.0	100.0
26.61	4.9534×10^{7}	2.3	59.3	4666	0.0	100.0
25.34	4.8510×10^{7}	2.3	57.0	5292	0.0	99.9
24.13	4.6961×10^{7}	2.2	54.8	5933	0.0	99.9
22.98	4.5409×10^{7}	2.1	52.7	6644	0.0	99.9
21.88	4.4031×10^{7}	2.1	50.6	7461	0.0	99.9
20.83	4.2749×10^{7}	2.0	48.6	8389	0.0	99.9
19.84	4.1462×10^{7}	1.9	46.7	9423	0.0	99.9
18.89	4.0102×10^{7}	1.9	44.8	10555	0.0	99.9
17.99	3.8466×10^{7}	1.8	43.0	11725	0.0	99.9
17.13	3.7302×10^{7}	1.7	41.3	13168	0.0	99.8
16.31	3.6257×10^{7}	1.7	39.6	14823	0.0	99.8
15.53	3.4564×10^{7}	1.6	37.9	16365	0.0	99.8
14.79	3.2550×10^{7}	1.5	36.4	17848	0.0	99.8
14.09	3.0816×10^{7}	1.4	35.0	19569	0.0	99.7
13.41	2.9190×10^{7}	1.4	33.6	21467	0.0	99.7
12.77	2.8038×10^{7}	1.3	32.3	23880	0.0	99.7
12.16	2.7346×10^{7}	1.3	31.0	26973	0.0	99.6
11.58	2.6654×10^{7}	1.2	29.8	30448	0.0	99.6
11.03	2.5638×10^{7}	1.2	28.6	33918	0.1	99.5
10.50	2.5676×10^{7}	1.2	27.4	39339	0.1	99.5
10.00	2.4925×10^{7}	1.2	26.2	44225	0.1	99.4
9.52	2.4257×10^{7}	1.1	25.1	49846	0.1	99.3
9.07	2.3948×10^{7}	1.1	23.9	56992	0.1	99.3
8.64	2.2852×10^{7}	1.1	22.9	62981	0.1	99.2
8.22	2.2398×10^{7}	1.1	21.8	71492	0.1	99.1
7.83	2.2640×10^{7}	1.1	20.7	83690	0.1	98.9
7.46	2.1619×10^{7}	1.0	19.7	92548	0.1	98.8

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
7.10	2.1045×10^7	1.0	18.7	104337	0.2	98.6
6.76	2.0412×10^7	1.0	17.8	117198	0.2	98.5
6.44	2.0028×10^7	0.9	16.8	133179	0.2	98.3
6.13	1.9594×10^7	0.9	15.9	150895	0.2	98.0
5.84	1.8814×10^7	0.9	15.0	167790	0.2	97.8
5.56	1.7969×10^7	0.8	14.2	185600	0.3	97.5
5.29	1.7408×10^7	0.8	13.4	208232	0.3	97.2
5.04	1.6260×10^7	0.8	12.6	225247	0.3	96.9
4.80	1.5528×10^7	0.7	11.9	249121	0.4	96.5
4.57	1.5157×10^7	0.7	11.2	281620	0.4	96.1
4.35	1.4757×10^7	0.7	10.5	317528	0.5	95.6
4.15	1.3984×10^7	0.7	9.8	348478	0.5	95.1
3.95	1.3297×10^7	0.6	9.2	383763	0.6	94.5
3.76	1.2619×10^7	0.6	8.6	421757	0.6	93.9
3.58	1.2227×10^7	0.6	8.1	473274	0.7	93.2
3.41	1.1782×10^7	0.6	7.5	528145	0.8	92.4
3.25	1.1111×10^7	0.5	7.0	576827	0.9	91.6
3.09	1.0718×10^7	0.5	6.5	644398	1.0	90.6
2.94	1.0432×10^7	0.5	6.0	726354	1.1	89.5
2.80	1.0019×10^7	0.5	5.5	807933	1.2	88.4
2.67	9.6578×10^6	0.5	5.1	901928	1.3	87.0
2.54	9.3270×10^6	0.4	4.6	1008754	1.5	85.5
2.42	8.9843×10^6	0.4	4.2	1125332	1.7	83.9
2.30	8.4425×10^6	0.4	3.8	1224667	1.8	82.0
2.19	8.0901×10^6	0.4	3.4	1359090	2.0	80.0
2.09	7.7077×10^6	0.4	3.1	1499584	2.2	77.8
1.99	7.2266×10^6	0.3	2.7	1628277	2.4	75.4
1.89	6.8223×10^6	0.3	2.4	1780245	2.6	72.8

Micromeritics Analytical Services

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
1.80	6.2511×10^6	0.3	2.1	1889088	2.8	70.0
1.72	5.8376×10^6	0.3	1.8	2043052	3.0	66.9
1.64	5.3915×10^6	0.3	1.6	2185292	3.2	63.7
1.56	4.8298×10^6	0.2	1.4	2267112	3.4	60.4
1.48	4.4669×10^6	0.2	1.2	2428306	3.6	56.8
1.41	3.8922×10^6	0.2	1.0	2450401	3.6	53.1
1.35	3.3707×10^6	0.2	0.8	2457600	3.6	49.5
1.28	2.9018×10^6	0.1	0.7	2450277	3.6	45.9
1.22	2.4681×10^6	0.1	0.6	2413616	3.6	42.3
1.16	2.0825×10^6	0.1	0.5	2358455	3.5	38.8
1.11	1.7561×10^6	0.1	0.4	2303217	3.4	35.4
1.05	1.4677×10^6	0.1	0.3	2229321	3.3	32.1
1.00	1.2299×10^6	0.1	0.3	2163566	3.2	28.9
0.96	1.0500×10^6	0.0	0.2	2139102	3.2	25.7
0.91	882477.94	0.0	0.2	2082104	3.1	22.6
0.87	753261.94	0.0	0.1	2058234	3.0	19.6
0.82	635830.86	0.0	0.1	2012058	3.0	16.6
0.79	534818.96	0.0	0.1	1959999	2.9	13.7
0.75	459398.90	0.0	0.1	1949796	2.9	10.8
0.71	385111.96	0.0	0.0	1892938	2.8	8.0
0.68	324344.98	0.0	0.0	1846319	2.7	5.3
0.65	273695.07	0.0	0.0	1804333	2.7	2.6
0.61	231712.02	0.0	0.0	1769084	2.6	0.0

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

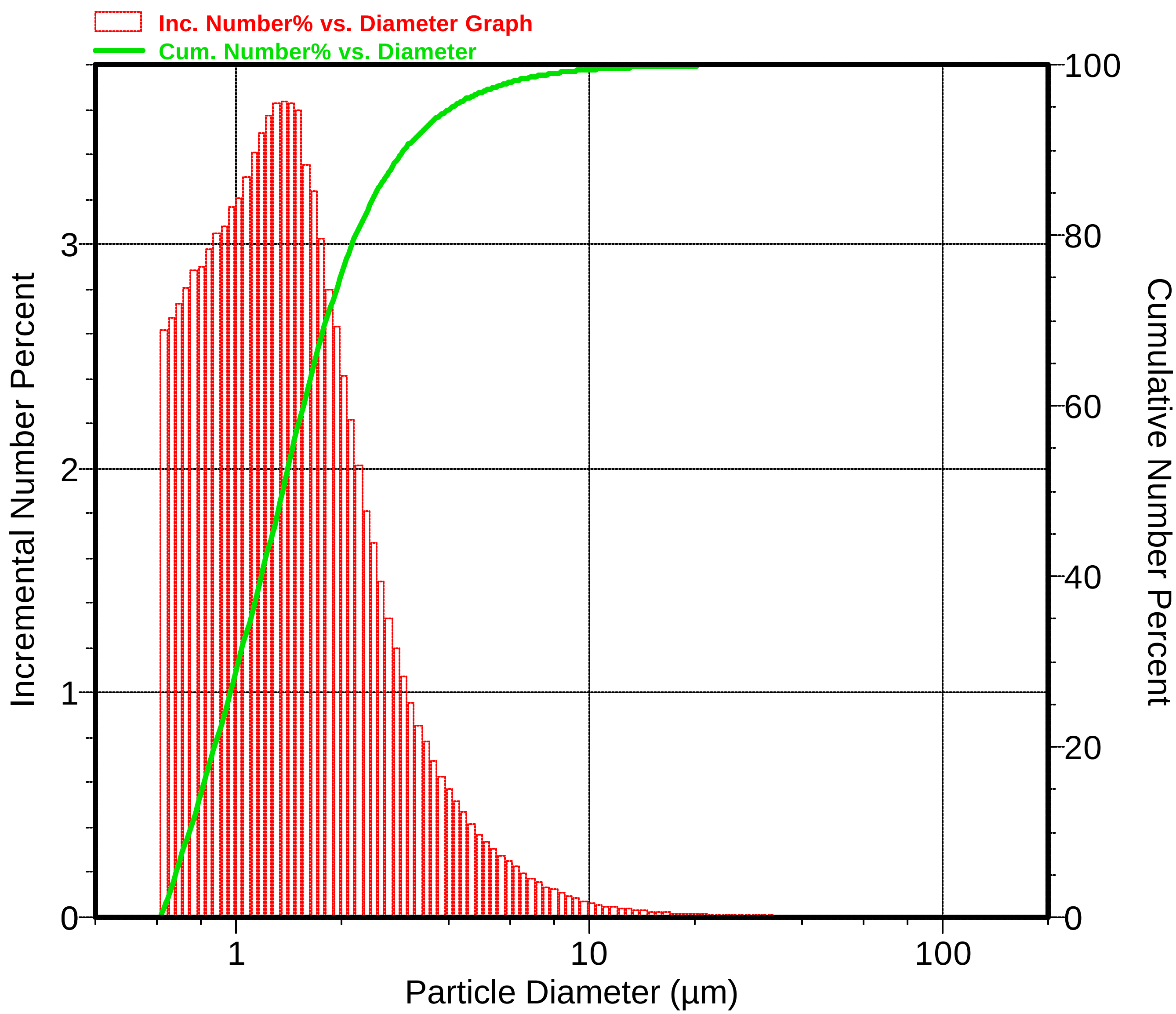
Report by Number Percent

Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
21.3	8.05	2.7	1.97	0.7	1.27	0.1	0.80
15.8	6.08	2.1	1.81	0.5	1.18	0.1	0.74
9.7	4.11	1.7	1.67	0.4	1.10	0.0	0.67
6.2	3.00	1.3	1.55	0.3	1.02	0.0	0.63
4.5	2.50	1.1	1.45	0.2	0.94		
3.4	2.19	0.8	1.35	0.1	0.87		

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

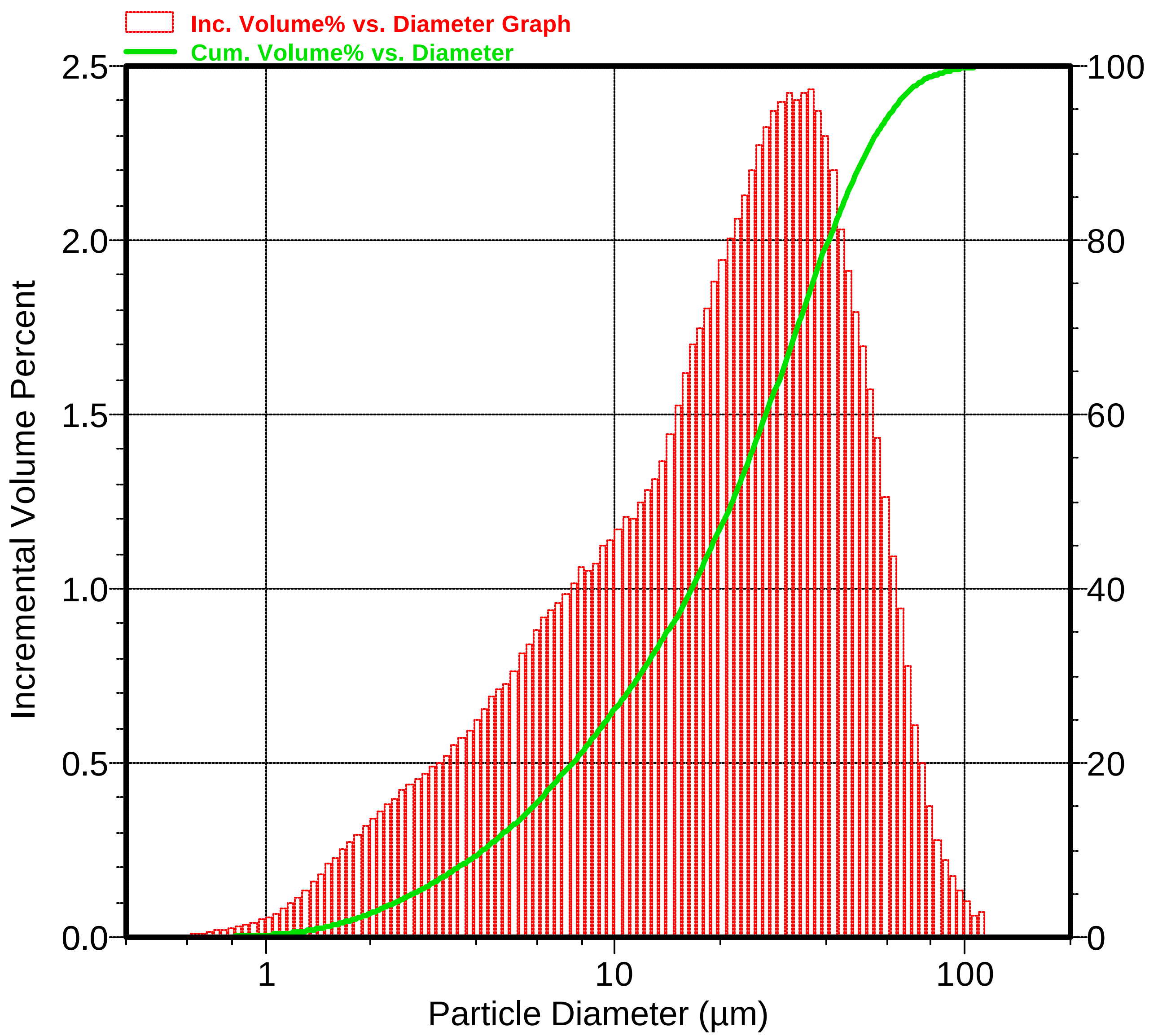
Incremental Number Percent vs. Particle Diameter Graph



Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Incremental Volume Percent vs. Particle Diameter Graph



APPENDIX 7.2

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Influent

Sample from 28-August Test Run

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Combined Report

Summary Report

Sample Statistics

Total Number 476062711
Total Surface Area 8.0686e+09 µm²
Total Volume 8.1841e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	13.98	Mode	14.43
Median	9.770		

Weighted Statistics (Number Distribution)

Mean	1.841	Mode	1.448
Median	1.476		

Geometric Statistics (Volume Distribution)

Mean	9.356	Mode	14.43
Median	9.770		

Geometric Statistics (Number Distribution)

Mean	1.563	Mode	1.448
Median	1.476		

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
121.28	5.0256×10^6	0.1	99.9	5	0.0	100.0
115.49	0.00	0.0	99.9	0	0.0	100.0
109.97	0.00	0.0	99.9	0	0.0	100.0
104.72	0.00	0.0	99.9	0	0.0	100.0
99.72	2.7937×10^6	0.0	99.9	5	0.0	100.0
94.96	2.4123×10^6	0.0	99.9	5	0.0	100.0
90.42	4.5826×10^6	0.1	99.8	11	0.0	100.0
86.11	3.9569×10^6	0.0	99.8	11	0.0	100.0
81.99	3.4167×10^6	0.0	99.7	11	0.0	100.0
78.08	5.6323×10^6	0.1	99.7	21	0.0	100.0
74.35	7.4108×10^6	0.1	99.6	32	0.0	100.0
70.80	8.5987×10^6	0.1	99.5	43	0.0	100.0
67.42	1.2950×10^7	0.2	99.3	75	0.0	100.0
64.20	1.7593×10^7	0.2	99.1	118	0.0	100.0
61.13	1.7251×10^7	0.2	98.9	134	0.0	100.0
58.21	2.7346×10^7	0.3	98.5	246	0.0	100.0
55.43	2.6781×10^7	0.3	98.2	279	0.0	100.0
52.79	2.8843×10^7	0.4	97.9	348	0.0	100.0
50.27	3.2993×10^7	0.4	97.5	461	0.0	100.0
47.87	4.1404×10^7	0.5	97.0	670	0.0	100.0
45.58	4.0020×10^7	0.5	96.5	750	0.0	100.0
43.40	4.6674×10^7	0.6	95.9	1013	0.0	100.0
41.33	4.7741×10^7	0.6	95.3	1200	0.0	100.0
39.36	5.4896×10^7	0.7	94.6	1598	0.0	100.0
37.48	6.0572×10^7	0.7	93.9	2042	0.0	100.0
35.69	6.9386×10^7	0.8	93.1	2709	0.0	100.0

Micromeritics Analytical Services

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
33.98	7.5726×10^{7}	0.9	92.1	3424	0.0	100.0
32.36	8.1410×10^{7}	1.0	91.1	4263	0.0	100.0
30.82	8.5202×10^{7}	1.0	90.1	5167	0.0	100.0
29.34	9.2764×10^{7}	1.1	89.0	6515	0.0	100.0
27.94	9.6561×10^{7}	1.2	87.8	7854	0.0	100.0
26.61	1.0248×10^{8}	1.3	86.5	9653	0.0	100.0
25.34	1.0646×10^{8}	1.3	85.2	11614	0.0	100.0
24.13	1.1778×10^{8}	1.4	83.8	14880	0.0	100.0
22.98	1.2496×10^{8}	1.5	82.3	18284	0.0	100.0
21.88	1.3254×10^{8}	1.6	80.6	22458	0.0	100.0
20.83	1.3822×10^{8}	1.7	79.0	27124	0.0	100.0
19.84	1.4390×10^{8}	1.8	77.2	32704	0.0	100.0
18.89	1.4958×10^{8}	1.8	75.4	39370	0.0	100.0
17.99	1.5337×10^{8}	1.9	73.5	46750	0.0	99.9
17.13	1.5337×10^{8}	1.9	71.6	54142	0.0	99.9
16.31	1.5527×10^{8}	1.9	69.7	63478	0.0	99.9
15.53	1.5716×10^{8}	1.9	67.8	74412	0.0	99.9
14.79	1.5717×10^{8}	1.9	65.9	86178	0.0	99.9
14.09	1.5717×10^{8}	1.9	64.0	99805	0.0	99.9
13.41	1.5528×10^{8}	1.9	62.1	114194	0.0	99.8
12.77	1.5554×10^{8}	1.9	60.2	132472	0.0	99.8
12.16	1.5233×10^{8}	1.9	58.3	150256	0.0	99.8
11.58	1.5282×10^{8}	1.9	56.4	174572	0.0	99.7
11.03	1.5500×10^{8}	1.9	54.5	205059	0.0	99.7
10.50	1.5184×10^{8}	1.9	52.7	232642	0.0	99.7
10.00	1.4727×10^{8}	1.8	50.9	261314	0.1	99.6

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
9.52	1.5207×10^{8}	1.9	49.0	312488	0.1	99.5
9.07	1.4671×10^{8}	1.8	47.2	349144	0.1	99.5
8.64	1.4881×10^{8}	1.8	45.4	410118	0.1	99.4
8.22	1.5476×10^{8}	1.9	43.5	493956	0.1	99.3
7.83	1.4541×10^{8}	1.8	41.8	537509	0.1	99.2
7.46	1.4853×10^{8}	1.8	39.9	635865	0.1	99.0
7.10	1.4121×10^{8}	1.7	38.2	700105	0.1	98.9
6.76	1.3761×10^{8}	1.7	36.5	790113	0.2	98.7
6.44	1.4098×10^{8}	1.7	34.8	937463	0.2	98.5
6.13	1.4021×10^{8}	1.7	33.1	1079735	0.2	98.3
5.84	1.3539×10^{8}	1.7	31.4	1207490	0.3	98.0
5.56	1.3279×10^{8}	1.6	29.8	1371537	0.3	97.7
5.29	1.2938×10^{8}	1.6	28.2	1547560	0.3	97.4
5.04	1.2615×10^{8}	1.5	26.7	1747536	0.4	97.1
4.80	1.2533×10^{8}	1.5	25.2	2010666	0.4	96.6
4.57	1.2283×10^{8}	1.5	23.7	2282141	0.5	96.2
4.35	1.1535×10^{8}	1.4	22.3	2482121	0.5	95.6
4.15	1.1144×10^{8}	1.4	20.9	2777097	0.6	95.0
3.95	1.0699×10^{8}	1.3	19.6	3087575	0.6	94.4
3.76	1.0401×10^{8}	1.3	18.3	3476467	0.7	93.7
3.58	1.0104×10^{8}	1.2	17.1	3911145	0.8	92.8
3.41	9.8073×10^{7}	1.2	15.9	4396377	0.9	91.9
3.25	9.5102×10^{7}	1.2	14.7	4937260	1.0	90.9
3.09	9.0646×10^{7}	1.1	13.6	5449934	1.1	89.7
2.94	8.6188×10^{7}	1.1	12.6	6001276	1.3	88.5
2.80	8.3218×10^{7}	1.0	11.5	6710575	1.4	87.1

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
2.67	7.9358×10^{7}	1.0	10.6	7411169	1.6	85.5
2.54	7.7660×10^{7}	0.9	9.6	8399256	1.8	83.7
2.42	7.3182×10^{7}	0.9	8.7	9166422	1.9	81.8
2.30	7.3771×10^{7}	0.9	7.8	10701161	2.2	79.6
2.19	6.6106×10^{7}	0.8	7.0	11105429	2.3	77.2
2.09	6.3975×10^{7}	0.8	6.2	12446777	2.6	74.6
1.99	5.9525×10^{7}	0.7	5.5	13412024	2.8	71.8
1.89	5.6117×10^{7}	0.7	4.8	14643417	3.1	68.7
1.80	5.1313×10^{7}	0.6	4.2	15506980	3.3	65.5
1.72	4.6973×10^{7}	0.6	3.6	16439710	3.5	62.0
1.64	4.2352×10^{7}	0.5	3.1	17166079	3.6	58.4
1.56	3.9036×10^{7}	0.5	2.6	18323716	3.8	54.6
1.48	3.6267×10^{7}	0.4	2.2	19715457	4.1	50.4
1.41	3.2321×10^{7}	0.4	1.8	20348633	4.3	46.2
1.35	2.7424×10^{7}	0.3	1.5	19995359	4.2	42.0
1.28	2.3180×10^{7}	0.3	1.2	19573088	4.1	37.8
1.22	1.9693×10^{7}	0.2	0.9	19258270	4.0	33.8
1.16	1.6271×10^{7}	0.2	0.7	18427579	3.9	29.9
1.11	1.2904×10^{7}	0.2	0.6	16924559	3.6	26.4
1.05	1.0534×10^{7}	0.1	0.4	16000370	3.4	23.0
1.00	8.1173×10^{6}	0.1	0.3	14279363	3.0	20.0
0.96	6.3301×10^{6}	0.1	0.3	12896203	2.7	17.3
0.91	4.9244×10^{6}	0.1	0.2	11618490	2.4	14.9
0.87	3.9918×10^{6}	0.0	0.2	10907360	2.3	12.6
0.82	3.2475×10^{6}	0.0	0.1	10276648	2.2	10.4
0.79	2.5492×10^{6}	0.0	0.1	9342445	2.0	8.4

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
0.75	2.0945×10^{6}	0.0	0.1	8889622	1.9	6.6
0.71	1.7085×10^{6}	0.0	0.0	8397681	1.8	4.8
0.68	1.3958×10^{6}	0.0	0.0	7945304	1.7	3.1
0.65	1.1573×10^{6}	0.0	0.0	7629405	1.6	1.5
0.61	964147.51	0.0	0.0	7361111	1.5	0.0

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Number Percent

Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
39.6	7.40	6.3	2.10	1.7	1.39	0.2	0.91
31.2	5.80	5.1	1.93	1.3	1.31	0.1	0.82
20.8	4.13	4.1	1.79	1.0	1.24	0.0	0.72
13.8	3.12	3.3	1.67	0.7	1.16	0.0	0.63
10.3	2.63	2.7	1.57	0.5	1.08		
8.0	2.33	2.1	1.48	0.3	1.00		

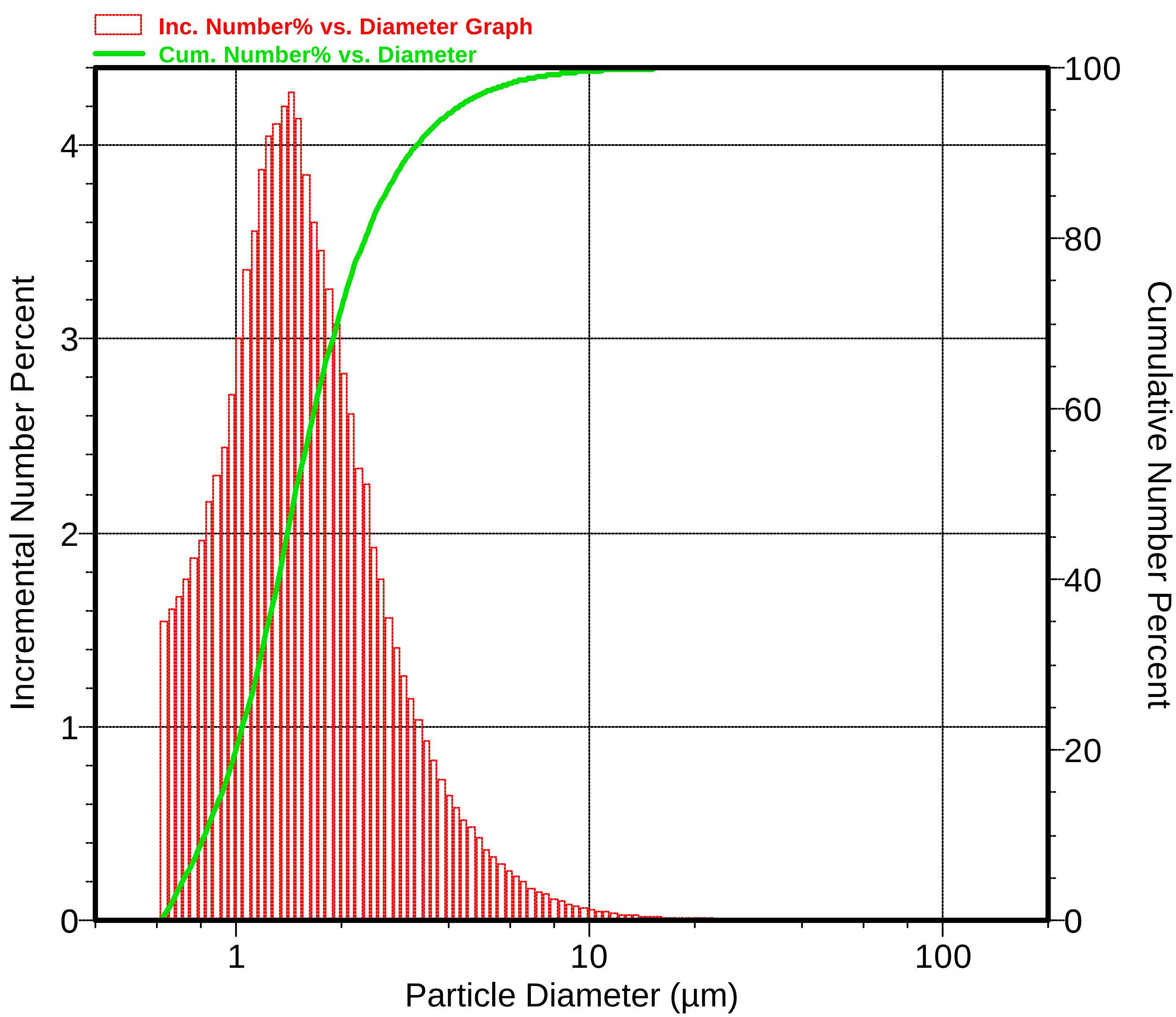
Micromeritics Analytical Services

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Incremental Number Percent vs. Particle Diameter Graph



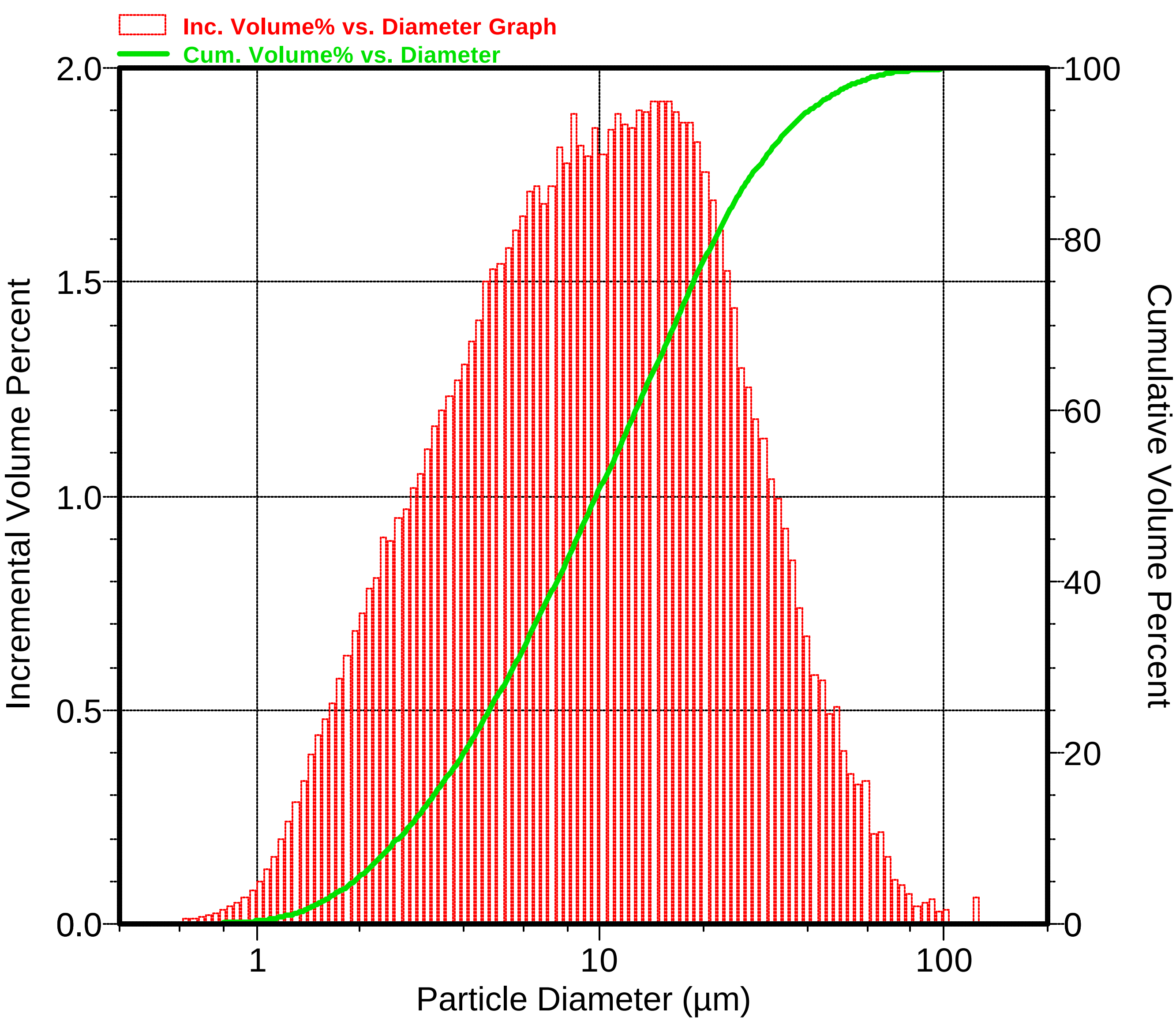
Micromeritics Analytical Services

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Incremental Volume Percent vs. Particle Diameter Graph



APPENDIX 7.3

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Effluent

Sample from 28-August Test Run

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Combined Report

Summary Report

Sample Statistics

Total Number 223341704
Total Surface Area 2.6223e+09 µm²
Total Volume 1.4599e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	6.680	Mode	3.326
Median	3.954		

Weighted Statistics (Number Distribution)

Mean	1.677	Mode	1.448
Median	1.447		

Geometric Statistics (Volume Distribution)

Mean	4.382	Mode	3.326
Median	3.954		

Geometric Statistics (Number Distribution)

Mean	1.490	Mode	1.448
Median	1.447		

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
162.66	4.8501×10^6	0.3	99.7	2	0.0	100.0
154.89	0.00	0.0	99.7	0	0.0	100.0
147.50	0.00	0.0	99.7	0	0.0	100.0
140.45	0.00	0.0	99.7	0	0.0	100.0
133.75	0.00	0.0	99.7	0	0.0	100.0
127.36	0.00	0.0	99.7	0	0.0	100.0
121.28	0.00	0.0	99.7	0	0.0	100.0
115.49	0.00	0.0	99.7	0	0.0	100.0
109.97	0.00	0.0	99.7	0	0.0	100.0
104.72	1.2942×10^6	0.1	99.6	2	0.0	100.0
99.72	0.00	0.0	99.6	0	0.0	100.0
94.96	0.00	0.0	99.6	0	0.0	100.0
90.42	0.00	0.0	99.6	0	0.0	100.0
86.11	1.4389×10^6	0.1	99.5	4	0.0	100.0
81.99	0.00	0.0	99.5	0	0.0	100.0
78.08	0.00	0.0	99.5	0	0.0	100.0
74.35	0.00	0.0	99.5	0	0.0	100.0
70.80	0.00	0.0	99.5	0	0.0	100.0
67.42	690678.55	0.0	99.4	4	0.0	100.0
64.20	298191.88	0.0	99.4	2	0.0	100.0
61.13	0.00	0.0	99.4	0	0.0	100.0
58.21	222328.67	0.0	99.4	2	0.0	100.0
55.43	0.00	0.0	99.4	0	0.0	100.0
52.79	331531.76	0.0	99.4	4	0.0	100.0
50.27	500971.51	0.0	99.3	7	0.0	100.0
47.87	432576.44	0.0	99.3	7	0.0	100.0

Micromeritics Analytical Services

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
45.58	1.1739×10^6	0.1	99.2	22	0.0	100.0
43.40	691123.65	0.0	99.2	15	0.0	100.0
41.33	596768.08	0.0	99.1	15	0.0	100.0
39.36	755765.12	0.1	99.1	22	0.0	100.0
37.48	1.0975×10^6	0.1	99.0	37	0.0	100.0
35.69	1.6392×10^6	0.1	98.9	64	0.0	100.0
33.98	2.5213×10^6	0.2	98.7	114	0.0	100.0
32.36	1.9670×10^6	0.1	98.6	103	0.0	100.0
30.82	2.2756×10^6	0.2	98.4	138	0.0	100.0
29.34	2.5060×10^6	0.2	98.3	176	0.0	100.0
27.94	3.3195×10^6	0.2	98.0	270	0.0	100.0
26.61	3.1211×10^6	0.2	97.8	294	0.0	100.0
25.34	3.6758×10^6	0.3	97.6	401	0.0	100.0
24.13	4.3692×10^6	0.3	97.3	552	0.0	100.0
22.98	4.7090×10^6	0.3	97.0	689	0.0	100.0
21.88	5.0694×10^6	0.3	96.6	859	0.0	100.0
20.83	5.6614×10^6	0.4	96.2	1111	0.0	100.0
19.84	6.1513×10^6	0.4	95.8	1398	0.0	100.0
18.89	6.9301×10^6	0.5	95.3	1824	0.0	100.0
17.99	7.7620×10^6	0.5	94.8	2366	0.0	100.0
17.13	8.1867×10^6	0.6	94.2	2890	0.0	100.0
16.31	9.1677×10^6	0.6	93.6	3748	0.0	100.0
15.53	9.8233×10^6	0.7	92.9	4651	0.0	100.0
14.79	1.0806×10^7	0.7	92.2	5925	0.0	100.0
14.09	1.1459×10^7	0.8	91.4	7277	0.0	100.0
13.41	1.2635×10^7	0.9	90.5	9292	0.0	100.0

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
12.77	1.3425×10^7	0.9	89.6	11434	0.0	100.0
12.16	1.4080×10^7	1.0	88.7	13888	0.0	100.0
11.58	1.4596×10^7	1.0	87.7	16673	0.0	100.0
11.03	1.5172×10^7	1.0	86.6	20071	0.0	100.0
10.50	1.6150×10^7	1.1	85.5	24743	0.0	99.9
10.00	1.7296×10^7	1.2	84.3	30690	0.0	99.9
9.52	1.7355×10^7	1.2	83.1	35662	0.0	99.9
9.07	1.8296×10^7	1.3	81.9	43540	0.0	99.9
8.64	1.8338×10^7	1.3	80.6	50542	0.0	99.9
8.22	1.9215×10^7	1.3	79.3	61330	0.0	99.8
7.83	1.9958×10^7	1.4	77.9	73776	0.0	99.8
7.46	2.0455×10^7	1.4	76.5	87566	0.0	99.8
7.10	2.1385×10^7	1.5	75.1	106022	0.0	99.7
6.76	2.2644×10^7	1.6	73.5	130013	0.1	99.7
6.44	2.3722×10^7	1.6	71.9	157743	0.1	99.6
6.13	2.4301×10^7	1.7	70.2	187143	0.1	99.5
5.84	2.4918×10^7	1.7	68.5	222231	0.1	99.4
5.56	2.6200×10^7	1.8	66.7	270613	0.1	99.3
5.29	2.7838×10^7	1.9	64.8	332991	0.1	99.1
5.04	3.0459×10^7	2.1	62.7	421941	0.2	99.0
4.80	3.4296×10^7	2.3	60.4	550217	0.2	98.7
4.57	3.6580×10^7	2.5	57.9	679653	0.3	98.4
4.35	3.8504×10^7	2.6	55.2	828516	0.4	98.0
4.15	3.8648×10^7	2.6	52.6	963101	0.4	97.6
3.95	3.9304×10^7	2.7	49.9	1134295	0.5	97.1
3.76	3.8799×10^7	2.7	47.3	1296767	0.6	96.5

Micromeritics Analytical Services

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
3.58	3.9305×10^7	2.7	44.6	1521376	0.7	95.8
3.41	3.9305×10^7	2.7	41.9	1761942	0.8	95.0
3.25	3.9305×10^7	2.7	39.2	2040548	0.9	94.1
3.09	3.8651×10^7	2.6	36.5	2323823	1.0	93.1
2.94	3.8324×10^7	2.6	33.9	2668469	1.2	91.9
2.80	3.7941×10^7	2.6	31.3	3059517	1.4	90.5
2.67	3.7428×10^7	2.6	28.7	3495359	1.6	89.0
2.54	3.5850×10^7	2.5	26.3	3877302	1.7	87.2
2.42	3.4245×10^7	2.3	23.9	4289392	1.9	85.3
2.30	3.3586×10^7	2.3	21.6	4871909	2.2	83.1
2.19	3.1634×10^7	2.2	19.5	5314347	2.4	80.7
2.09	3.1529×10^7	2.2	17.3	6134110	2.7	78.0
1.99	2.9456×10^7	2.0	15.3	6637000	3.0	75.0
1.89	2.7666×10^7	1.9	13.4	7219294	3.2	71.8
1.80	2.5490×10^7	1.7	11.7	7703101	3.4	68.3
1.72	2.3920×10^7	1.6	10.0	8371553	3.7	64.6
1.64	2.1390×10^7	1.5	8.5	8669726	3.9	60.7
1.56	1.9438×10^7	1.3	7.2	9124243	4.1	56.6
1.48	1.7896×10^7	1.2	6.0	9728546	4.4	52.3
1.41	1.5957×10^7	1.1	4.9	10045920	4.5	47.8
1.35	1.3433×10^7	0.9	4.0	9794182	4.4	43.4
1.28	1.1763×10^7	0.8	3.2	9932990	4.4	38.9
1.22	9.5847×10^6	0.7	2.5	9372922	4.2	34.7
1.16	7.7209×10^6	0.5	2.0	8744096	3.9	30.8
1.11	6.2303×10^6	0.4	1.6	8171574	3.7	27.2
1.05	5.0503×10^6	0.3	1.2	7671203	3.4	23.7

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (μm^3)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
1.00	3.8530×10^6	0.3	1.0	6777979	3.0	20.7
0.96	3.0936×10^6	0.2	0.7	6302572	2.8	17.9
0.91	2.4702×10^6	0.2	0.6	5828132	2.6	15.3
0.87	1.9848×10^6	0.1	0.4	5423260	2.4	12.8
0.82	1.5792×10^6	0.1	0.3	4997361	2.2	10.6
0.79	1.2642×10^6	0.1	0.2	4633130	2.1	8.5
0.75	1.0464×10^6	0.1	0.2	4441006	2.0	6.5
0.71	817666.46	0.1	0.1	4019070	1.8	4.7
0.68	668796.94	0.0	0.1	3807096	1.7	3.0
0.65	535028.66	0.0	0.0	3527173	1.6	1.5
0.61	425029.66	0.0	0.0	3245033	1.5	0.0

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Number Percent

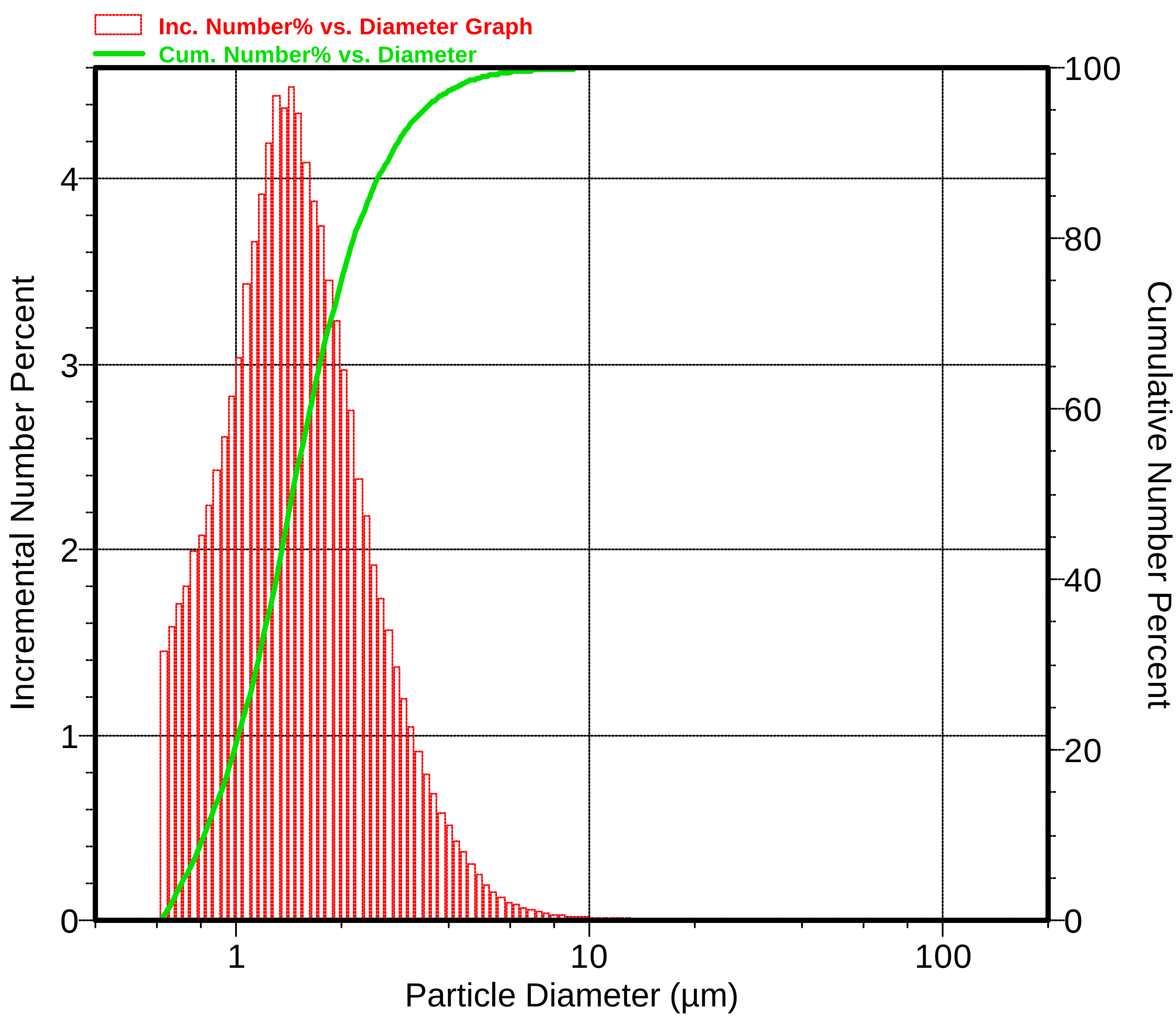
Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
63.3	5.10	15.3	1.99	4.3	1.37	0.6	0.90
55.1	4.34	12.5	1.85	3.4	1.30	0.3	0.81
41.7	3.40	10.2	1.73	2.6	1.22	0.1	0.72
30.4	2.76	8.3	1.62	1.9	1.15	0.0	0.64
23.6	2.40	6.7	1.53	1.3	1.07		
18.9	2.16	5.4	1.45	0.9	0.99		

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Smoothing: Off
Coinc. Correction: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Incremental Number Percent vs. Particle Diameter Graph



Sample: E-2A+E-3A+E-4A
Operator: RS
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Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
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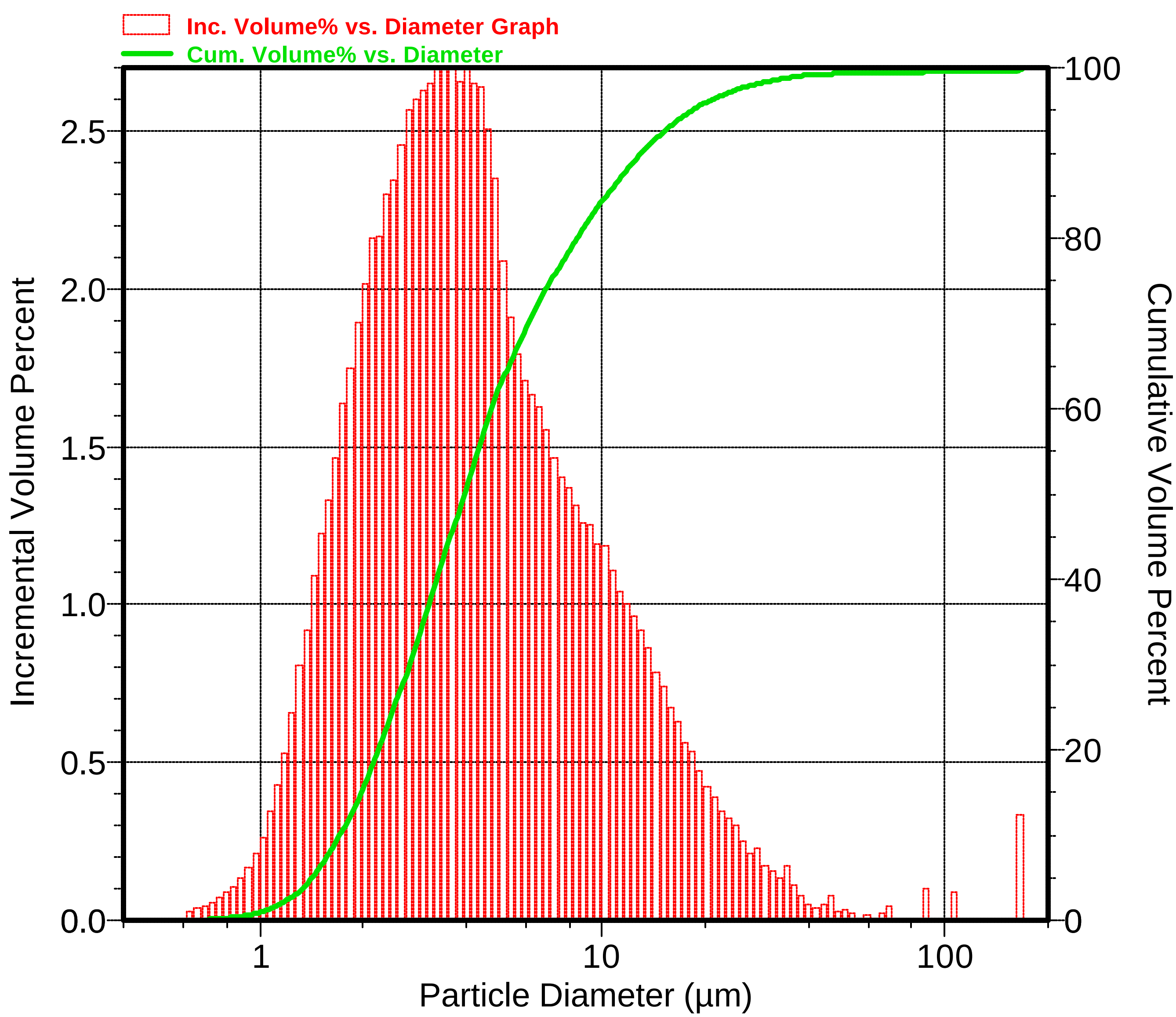
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Incremental Volume Percent vs. Particle Diameter Graph



Hydraulic Performance and Sediment Trap Efficiency

for the

StormTech® SC-740 Isolator™ Row

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February 23, 2005

Executive Summary

Testing was conducted at Tennessee Tech University for the purpose of determining the sediment removal efficiency of the StormTech Isolator™ Row. The results show that trap efficiencies of the US Silica OK-110 sediment exceeded 94% at all operating rates tested with influent concentrations of approximately 200 mg/L. Trap efficiencies exceeded 95% at the manufacturer's suggested maximum design hydraulic loading rate of 0.5 cfs (8.1 gpm/ft^2 of bottom area). Of this, approximately 80% removal occurred on the woven bottom fabric, where captured sediment can be accessed and removed by maintenance operations.

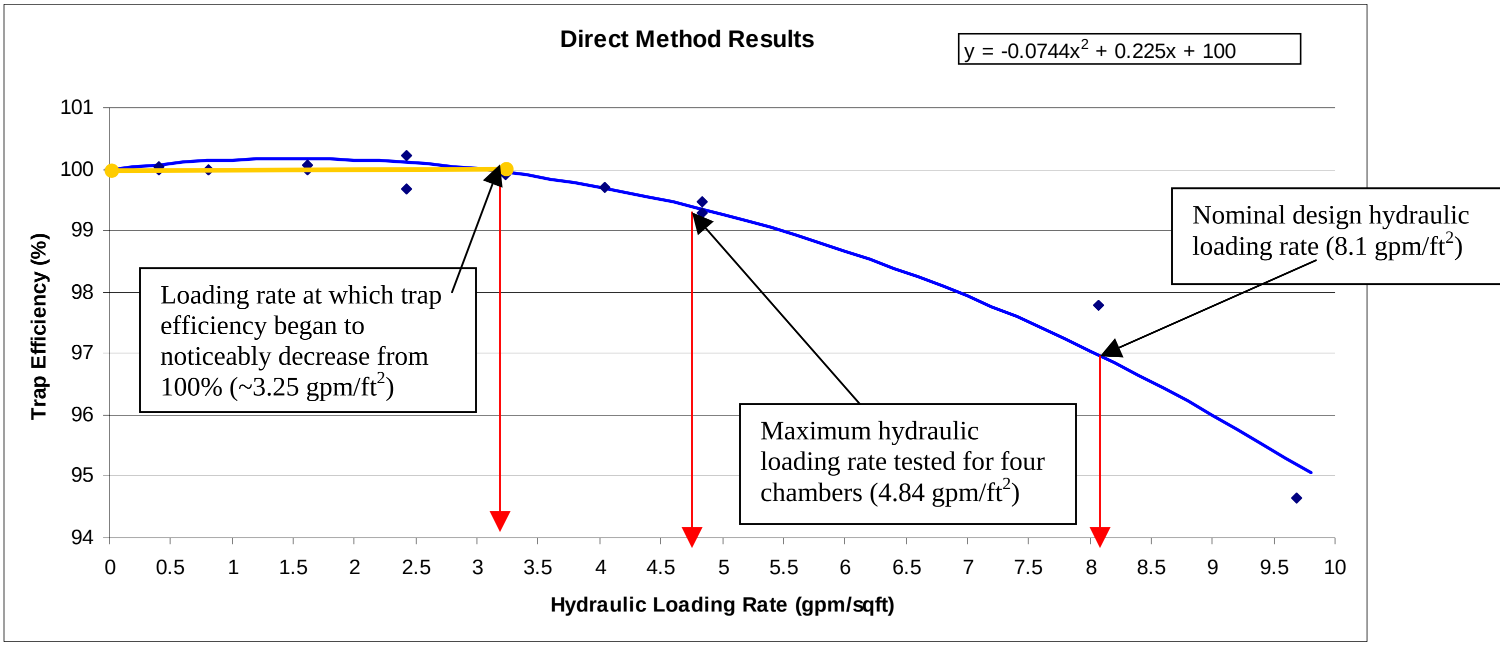
Trap efficiencies were determined using both direct and indirect methods. The direct method required the collection, removal, and weighing of influent sediments, sediment captured on the bottom fabric and effluent sediments to enable a direct calculation of the trap efficiency. The indirect method required the collection of five influent and five effluent samples, from which mean influent and effluent suspended solid concentrations (SSC) were determined and trap efficiencies were calculated by comparing mean influent and effluent concentrations. The indirect method followed the Maine DEP laboratory testing protocol for manufactured stormwater treatment systems.

Two SC-740 Isolator Row configurations were tested. The first test series configuration consisted of a row of four SC-740 chambers (about 28 feet long) and flows up to a hydraulic loading rate of 4.8 gpm/ft^2 corresponding to a flow rate of 0.3 cfs per chamber. The second test series consisted of a row of two SC-740 chambers (about 14 feet long) and included flows up to a hydraulic loading rate of 9.6 gpm/ft^2 corresponding to a maximum flow rate up to 0.6 cfs per chamber.

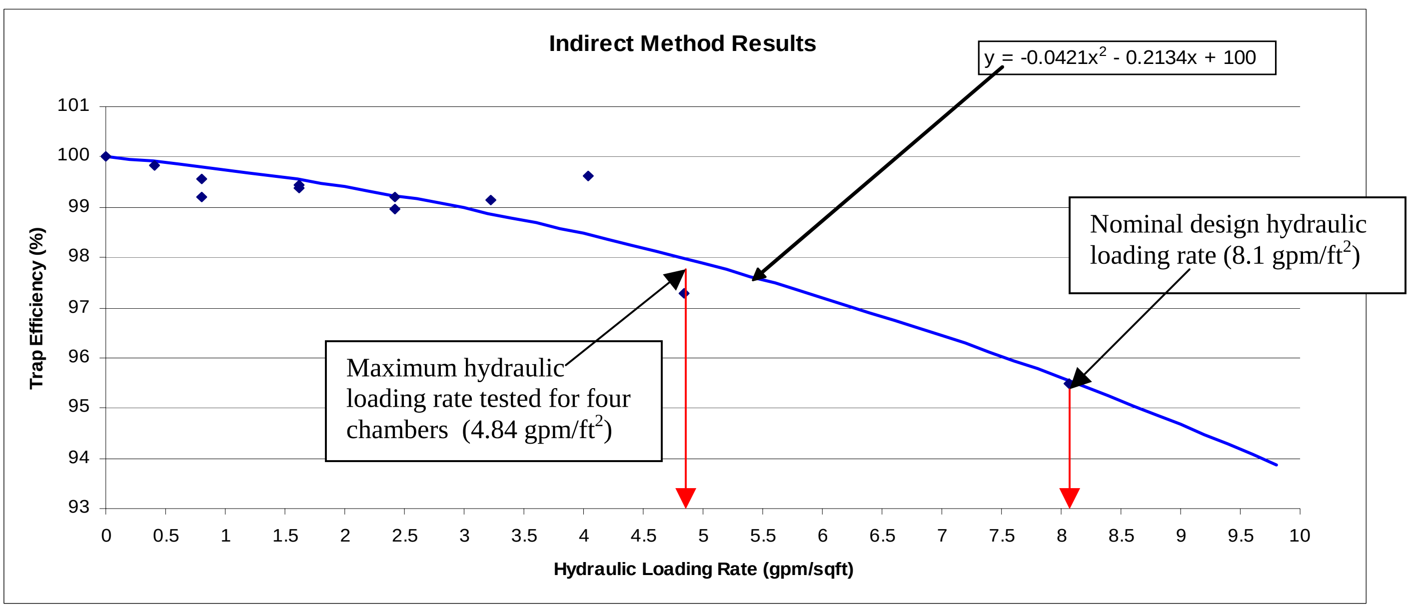
An estimated maintenance schedule for periodic cleaning of the four-chamber Isolator Row was calculated assuming a 1-acre catchment and a runoff coefficient of 0.9 corresponding to a paved surface. Annual sediment loadings were assumed to be 300 - 1000 lb/acre-yr based on values reported in the literature. The useful capacity for the four-chamber Isolator Row was assumed to be 26.32 cubic ft, the volume at which the depth of sediment within the chambers reaches three inches and does not cover the lateral chamber perforations. Conservatively assuming 100% trap efficiency, it is estimated that an Isolator Row four chambers in length would need to be cleaned out every 2-6 years for one acre of paved surface, with an average maintenance interval of 3 years.

The study shows that application of the indirect method, which relies on grab samples, may result in much higher than actual sediment concentrations, due to a variety of factors, including stratification of sediment at low flows leading to higher sediment concentrations near the bed. However, higher than actual influent concentrations appear to be offset by higher than actual effluent concentrations, which results in reasonable estimates of trap efficiency. Assuming that the direct method results represent true values of influent concentration, effluent concentration and trap efficiency, the accuracy of the indirect method is quantified and ranges from 0.5% to 2.3%.

This report incorporates additional testing conducted during November of 2004 into the report of earlier testing dated July 26, 2004 thereby superceding the July report. Future objectives for testing should attempt to determine the accuracy of scaling the experiment to achieve higher hydraulic loading rates. It would also be beneficial to better quantify the error involved with respect to the indirect method and to formulate procedures to reduce this error.



Trap Efficiency vs. Hydraulic Loading Rate (Direct Method)



Trap Efficiency vs. Hydraulic Loading Rate (Indirect Method)

Introduction

Effective stormwater management is needed to offset the hydrologic effects of urbanization. StormTech subsurface chambers are designed to provide underground detention, retention, and storage, eliminating the need for surface detention ponds and thereby optimizing space. Applications include commercial, residential, recreational, agricultural, and highway drainage.

An underground system of chambers is accompanied by an "Isolator™" Row, which is a series of chambers encased in geotextile fabric for sediment filtration. *Figure 1* is a profile view of the Isolator Row as installed in the field. The Isolator™ Row typically rests on a 6 – 18 inch foundation of No. 3 gravel overlaid with a woven geotextile filter fabric.

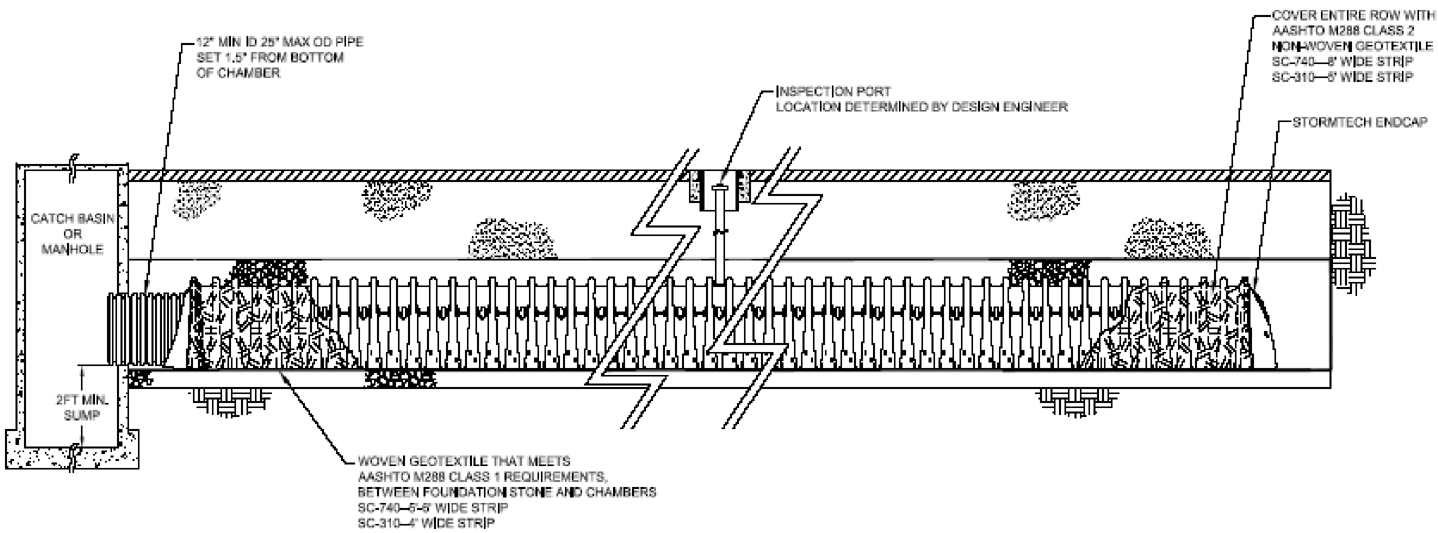


Figure 1: StormTech® Isolator™ Row as Installed in Field

The purpose of this experimental study is to determine: (1) The hydraulic performance, i.e., the relationship between stage, storage, discharge, and detention time; (2) The percentage of injected sediment that is trapped within the system (i.e., trap efficiency) as a function of the hydraulic loading rate in gpm/ft^2. This curve can be used, given a site's estimated annual sediment load, to determine the sedimentation rate in the Isolator Row, and the schedule for sediment removal; and (3) The percentage of retrievable sediment in the Isolator Row (i.e., the sediment that is not occluded in the filter fabric or washed into the gravel substrate foundation).

Dimensions for StormTech® chambers are defined as follows in *Figure 2*:

Chamber Designation	Nominal Height (in)	Nominal Width (in)	Installed Length (in)	Rise (in)	Span (in)	Average[1] Open Bottom Area (Footprint) (sqft)	Sidewall Orifice Area 24 at 0.63 sqin ea (sqin)
SC-740[2]	30	51	85.4	26.7	43	27.8	15
SC-310	16	34	85.4	13.1	26	17.7	15

1 See Appendix 1 for detailed calculation of average bottom areas (footprints).
2 Rows of SC-740 chambers were tested for this evaluation.

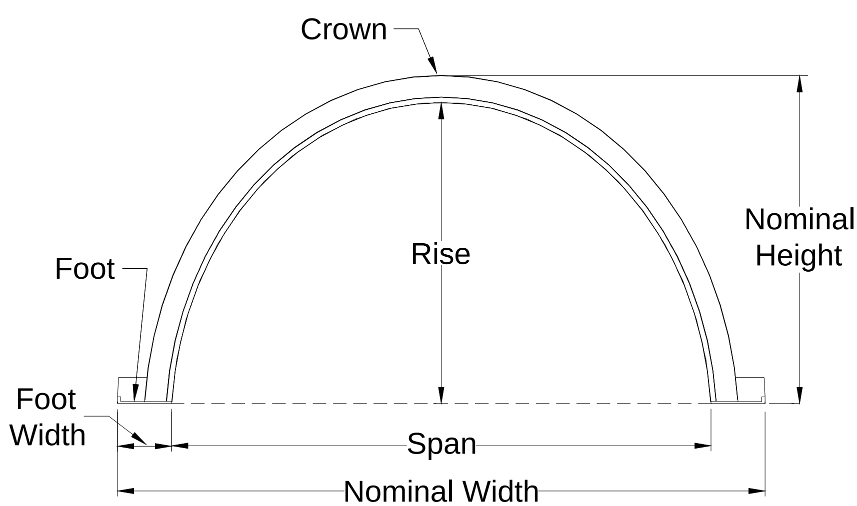


Figure 2: StormTech® Chamber Dimensions

Methods

Experimental Set-up

The main components of the laboratory set-up are shown below in *Figure 3*. The SC-740 chambers are secured to a wooden frame and are resting on a 12- in. bed of No. 3 angular stone (AASHTO M43 # 3) substrate contained in a wooden flume with interior W x L x H dimensions of 6.25-ft x 30.45-ft x 3 ft. The physical properties of the No. 3 stone are given in *Appendix 2*.

The chambers are covered with Mirafli 160N non-woven geotextile fabric, meeting AASHTO M288 Class 2 standards. Technical data for the Mirafli 160N is available in *Appendix 3.* Mirafli 600X woven geotextile fabric meeting AASHTO's M288 Class 1 requirements is placed at the bottom of the chamber to stabilize the stone foundation and to prevent scouring of the stone base. Technical data for the Mirafli 600X woven geotextile fabric is available in *Appendix 4.* Both the nonwoven fabric covering the chamber and the woven fabric placed at the bottom provide filtration media for the Isolator Row.

An 8-inch pipe feeds the water-sediment mixture through an expansion into a 12-inch pipe, which simulates the inlet to the Isolator Row. A 1.5 lb/gal sediment slurry is introduced to the 8-inch pipe from a 35-gallon mixing tank via (2) Watson-Marlow323S/RL (220 rpm) pumps. The Isolator Row resides in the recirculating flume, which collects and drains water discharged by the chamber to the stone substrate through an 8-inch drain that discharges to the laboratory trench and sump. The water is recirculated with a 25 horsepower Alice Chalmers variable speed pump (model AC7V). A 50-micron filter sock, designed for flows up to 1.5 cfs, is placed at the end of the outlet to trap all sediment that is not captured by the chambers; thereby avoiding the recirculation of sediment. An eight-inch butterfly valve is located between the sediment feed and sampling port to introduce turbulence and to aid in sediment mixing. The inflow rates vary from 0.1 to 1.2 cfs, and are measured and collected by a ThermoPolysonic DCT 7088 ultrasonic flow meter placed on the 8" aluminum water line.

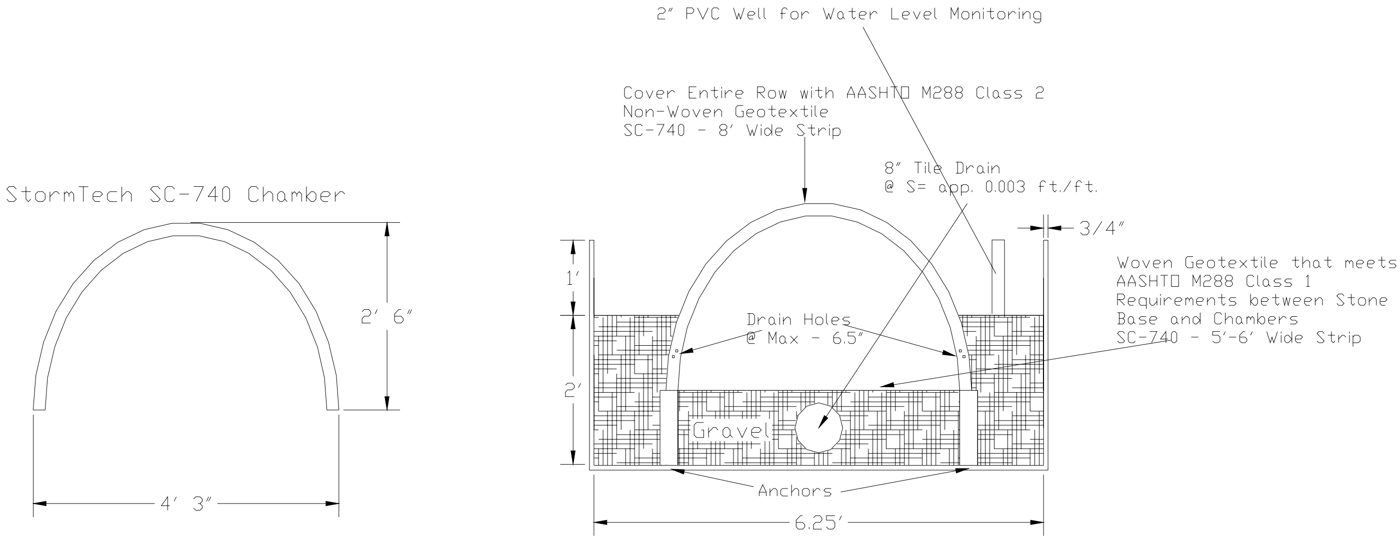


Figure 3a: Section View of StormTech® Isolator™ Row as Installed in Lab

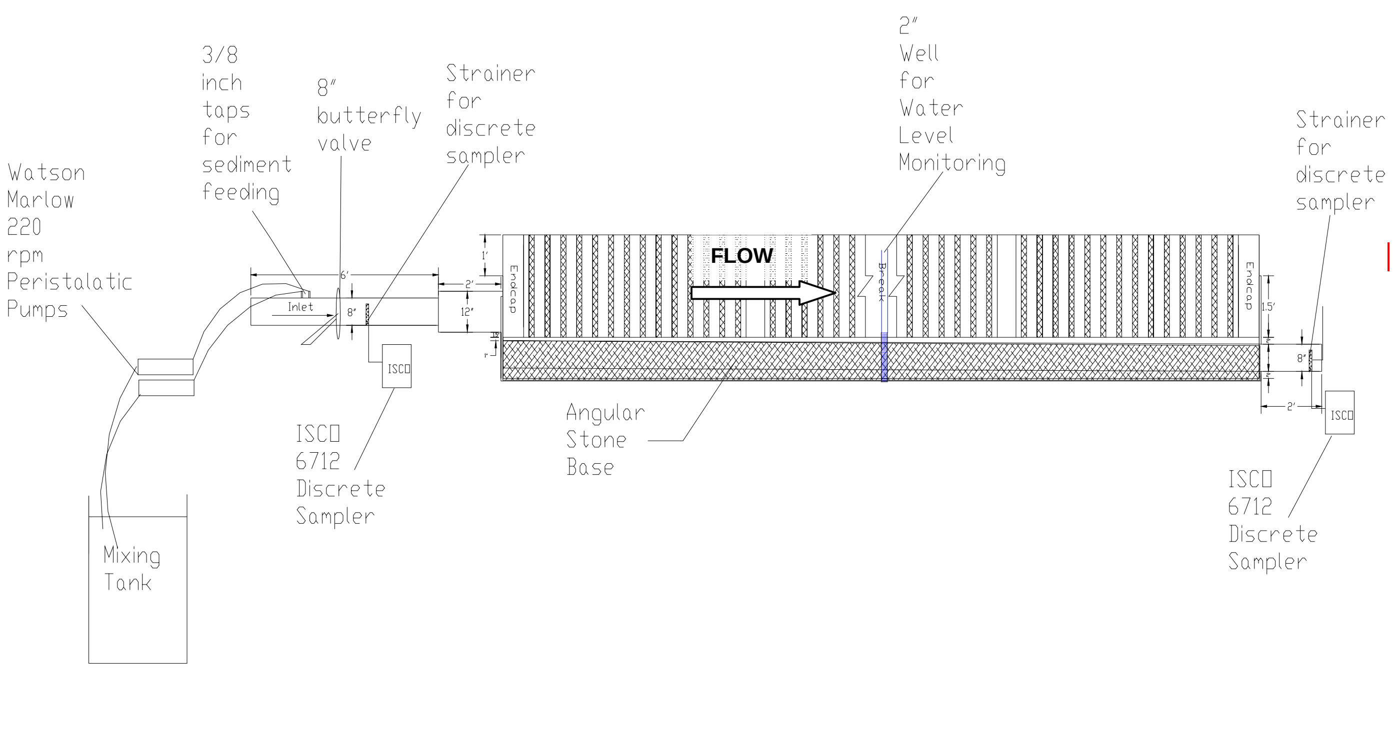


Figure 3b: Profile View of StormTech® Isolator™ Row as Installed in Lab. Flow right to left

Hydraulic Performance

The stage/discharge relationship was obtained by surveying the water surface levels in a well with respect to the invert of the outlet pipe over flows ranging from 0.1 to 1.2 cfs. The well was installed at the mid-point of the flume. A sketch is shown below in *Figure 4*. The well was fabricated using a 12-in. slotted PVC well screen and a 24-in. solid PVC riser. The well was backfilled with the same No. 3 angular stone used throughout the experiment. Stage measurements were repeated for each flow.

The 0.5 scale, two-chambered experiments did not utilize the well. The water level within the chambers was simply measured, and added to the measured distances between the invert of the outlet pipe and the bottom of the chambers.

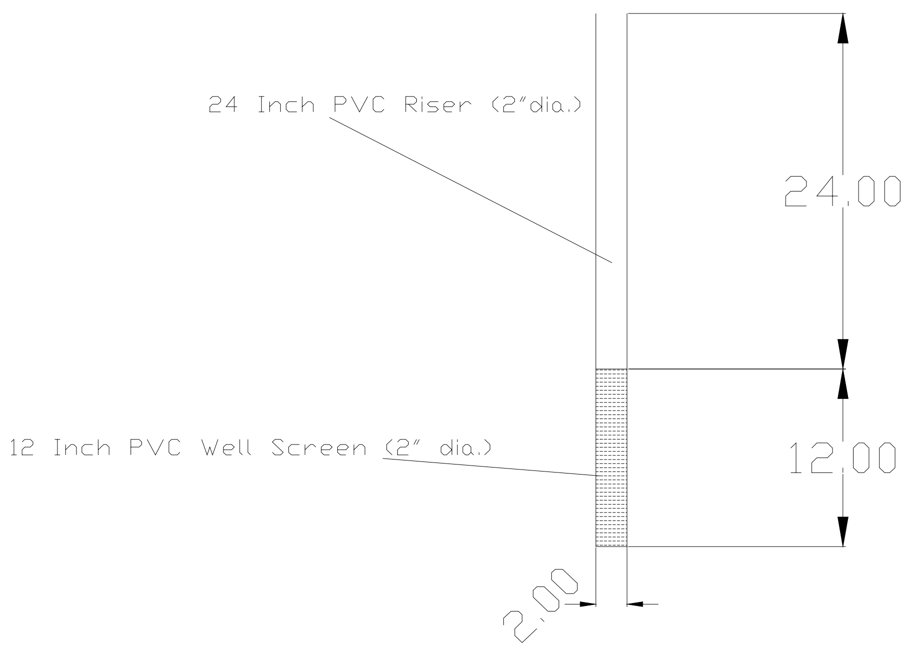


Figure 4: Diagram of 2” Well for Water Level Monitoring

Trap Efficiency

The trap efficiency for the StormTech® Isolator™ Row was determined by using both the direct and indirect methods. A detailed laboratory protocol (for both direct and indirect methods) was developed for the experiments and is provided in *Appendix 5*. A sediment – water slurry is introduced from a mixing tank into the 8 – inch inlet line through two 3/8" feed taps located 10 and 11 inches upstream of the butterfly valve via two Watson – Marlow 323S/RL (220 rpm) peristaltic pumps. The peristaltic pumps have been calibrated for the full range of flows, and the calibration details are available in *Appendix 5-c*. It should be noted that, in order to ensure sufficient mixing, consistent pumping rates, and similar conditions to those used in calibration, the sediment slurry level within the mixing tank was kept above the mixing paddles by adding pre-measured amounts of sediment and water. Thus, typically only ~30% of the sediment from the mixing tank was introduced to the system. The amount of sediment introduced to the system was then calculated by subtracting the dry weight of the remaining (post-experiment) sediment in the mixing tank and inlet pipe from the dry weight of total sediment introduced to the mixing tank for each experiment. The sediment concentration of the influent is held constant at 200 mg/L for all flow rates. The detailed sediment loading rate calculations, which were used to determine the sediment loading rate requirements to achieve 200 mg/L, are summarized in *Appendix 5-c*. The sediment slurry consists of a US Silica grade OK-110 (physical properties of OK-110 given in *Appendix 6*) mixed with water at a concentration of 1.5 lbs per gallon of water. Details for each run, including detention times, pre and post-run weights, and other observations were recorded in a laboratory data sheet. An example of a completed data sheet is available as *Appendix 7*.

Direct Method

The direct method utilizes a mass balance of all sediment that goes into the system. The total weight of sediment added to the mixing tank is known. The following samples are then dried and weighed: Sample A – sediment deposited in the chambers; Sample B – sediment remaining in mixing tank (and therefore not entering system); Sample C – Sediment in the filter sock (i.e., all sediment not removed by the chambers); Sample D – sediment remaining in inlet pipe (this sediment is flushed and collected following collection of Sample A). If M is the original weight of all sediment added to mixing tank, than the trap efficiency can be calculated as follows:

$$\text{Trap Efficiency}(\%) = \left(\frac{\text{Load}_{\text{In}} - \text{Load}_{\text{Out}}}{\text{Load}_{\text{In}}}\right) \times 100 \quad \text{.........} \mathit{1}$$

$$\text{Load}_{\text{In}} = \text{M} - \text{B} - \text{D} \quad \text{.........} \mathit{2}$$

$$\text{Load}_{\text{Out}} = \text{C} \quad \text{.........} \mathit{3}$$

The direct method also allows an estimate of the percentage of irretrievable sediment. This sediment is deposited behind the portholes, occluded in the fabric, or deposited in the gravel sub-base. The amount of irretrievable sediment is calculated by drying and weighing all sediment collected following each experiment, and is illustrated in *Equations 4 and 5*.

$$\text{Irretrievable (lb)} = \text{Load}_{\text{In}} - \text{Load}_{\text{Out}} - \text{Retrievable Material} \quad \text{.........} \mathit{4}$$

$$\text{Retreivable Material} = \text{A} \quad \text{.........} 5$$

Indirect Method

The Indirect Method follows the Maine DEP Standard Protocol, which is detailed in *Appendix 8*. An ISCO 6712 discrete sampler was placed at both the inlet and outlet to take samples at pre-determined intervals. A strainer was inserted through the pipe invert and oriented vertically in both the inlet and outlet pipes and connected to the sampler, in order to get a more accurate measure of the sediment concentration. The inlet strainer was placed 12-inches downstream of the mixture aiding butterfly valve, 51 inches upstream of the inlet. The outlet strainer was placed approximately 22 inches from the outlet of the flume. Six 1-liter discrete samples were taken prior to the inlet and following the outlet for each flow, one blank, and five spaced equally throughout the experiment. The duration of the experiment was determined by the hydraulic performance experiments, and was set at 15 detention times. Grab samples were also taken at the inlet to verify results. The samples were then tested by the Tennessee Tech University Water Center for suspended sediment concentration (SSC). Trap efficiency was then calculated as follows:

$$\text{Trap Efficiency}(\%) = \frac{\text{SSC}_\text{I} - \text{SSC}_\text{E}}{\text{SSC}_\text{I}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where,

$$\text{SSC}_\text{I} = \text{Mean Influent Concentration (mg/L)} \quad \ldots\ldots\ldots\ldots\ldots 7$$

$$\text{SSC}_\text{E} = \text{Mean Effluent Concentration (mg/L)} \quad \ldots\ldots\ldots\ldots\ldots 8$$

SSC versus Total Suspended Solids (TSS)

The fundamental difference between the SSC and TSS analytical methods stems from preparation of the sample for subsequent filtering, drying and weighing. A TSS sample normally entails withdrawal of an aliquot of the original sample for subsequent analysis. As noted by Gray et al. (2000), there is evidence of inconsistencies in methods used in the sample preparation phase of the TSS analyses. The SSC analytical method measures all sediment and the mass of the entire water-sediment mixture. Additionally the percentage of sand size and finer material can be determined as part of the SSC method, but not as part of the TSS method. As stated in Gray et al. (2000),

"If a sample contains a substantial percentage of sand size material, then stirring, shaking, or otherwise agitating the sample before obtaining a sub-sample, it will rarely produce an aliquot representative of the SSC and particle-size distribution of the original sample. This a by-product of the rapid settling properties of the sand size material, compared to those for silt and clay size materials, given virtually uniform densities and shapes."

The OK-110 material with median, d_{50} = 110 microns would be classified as a very fine sand defined as quartz (i.e. silica) sediments with size ranges between 62 and 125 microns (Chang 1989).

Based on these points, all trap efficiency testing in the laboratory with OK-110 as the surrogate sediment should adopt SSC analysis in place of TSS.

Scaled Experiments

Following the completion of the four-chambered experiments, the experimental set-up was modified to two chambers in order to test at higher hydraulic loading rates, including the maximum design hydraulic loading rate suggested by StormTech. The maximum design hydraulic loading rate for two Stormtech® SC-740 chambers is 8.1 gpm/ft^2, or 0.5 cfs per chamber. The

Maine Department of Environmental Protection (MDEP) sent a representative to observe the test at the maximum hydraulic loading rate and to verify the indirect testing protocol. All methods for performing the trap efficiency experiments for the two-chamber Isolator Row (direct and indirect) were identical to the four-chamber Isolator Row. Influent and effluent samples from the test witnessed by the Maine DEP were analyzed by a laboratory chosen by the Maine DEP.

Results and Discussion

Hydraulic Performance

The results for the stage discharge relationship of the 4-chambered StormTech Isolator Row are shown in *Table 1* and *Figure 5* below.

Flow (cfs)	Stage Relative to Invert of Outlet (ft)	Depth of Water Inside Chamber (ft)	Volume of Water in All 4 Chambers (ft^3)*	Volume of Water in Gravel Beneath All Chambers (ft^3)	Total Volume (ft^3)	Detention Time, θ (min)	15 X θ (min)	Total Sediment Injected for 15 X θ (lbs) **
0.1	0.7	0	0	33.52	33.52	5.59	83.8	6.3
0.2	0.95	0	0	45.49	45.49	3.79	56.86	8.54
0.4	1.11	0.13	13.77	46.92	60.69	2.53	37.93	11.4
0.5	1.23	0.25	26.32	46.92	73.24	2.44	36.62	13.76
0.6	1.3	0.32	33.58	46.92	80.5	2.24	33.54	15.12
0.7	1.43	0.45	46.84	46.92	93.76	2.23	33.49	17.61
0.8	1.53	0.55	56.85	46.92	103.77	2.16	32.43	19.49
0.9	1.63	0.65	66.69	46.92	113.61	2.1	31.56	21.34
1	1.67	0.69	70.57	46.92	117.49	1.96	29.37	22.07
1.1	1.76	0.78	79.2	46.92	126.12	1.91	28.66	23.69
1.2	1.84	0.86	86.7	46.92	133.62	1.86	27.84	25.1

Table 1: Hydraulic Properties and Detention Times for Range of Flows (4-Chambers)

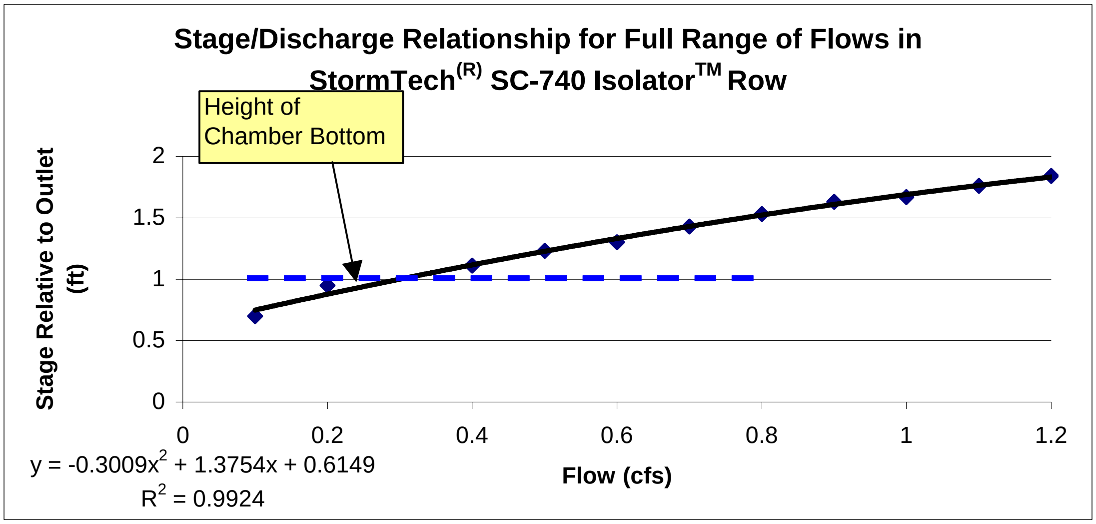


Figure 5: Stage vs. Discharge Plot (4-Chambers)

As would be expected, the stage increased steadily along with flow, and the detention time decreased as flow increased. At the maximum flow tested, 1.2 cfs; the stage reaches 1.84 feet above the invert of the outlet. The stage of two lowest flows tested, 0.1 and 0.2 cfs, remained below the bottom of the chambers, with the 0.1 cfs stage reaching 0.7 feet above the invert of the outlet. The detention times varied from 1.86 minutes at the highest flow to 5.59 minutes at the lowest flow. These detention times were used to scale the duration of the trap efficiency experiments. A duration of 15 detention times was chosen for all test runs, which corresponded to durations ranging from 83.8 minutes for the Q=0.1 cfs test flows to 27.8 minutes for the Q=1.2 cfs test flows.

Table 2 and *Figure 6* show the stage/discharge relationships for the experiments with the 0.5 scale, two-chamber set-up. Reducing the set-up to two chambers significantly increased the stage within the chambers, with a maximum increase of 0.43 feet at the 1.2 cfs flow. This increase is likely due to the decrease in drainage area (½ as many drainage holes and ½ the bottom drainage area), while still pumping the same rate of water through the system, thus achieving the objective of increasing the hydraulic loading rate. The maximum stage was raised from 1.84 feet for four chambers to

2.27 feet for the two-chambered experimental set-up.

Flow (cfs)	Stage Relative to Invert of Outlet (ft)	Depth of Water Inside Chamber (ft)	Volume of Water in 2 Chambers (ft^3)*	Volume of Water in Gravel Beneath Both Chambers (ft^3)	Total Volume (ft^3)	Detention Time, θ (min)	15 X θ (min)	Total Sediment Injected for 15 X θ (lbs) **
0.4	1.355	0.375	23.84	23.46	47.3	1.79	26.85	8.06
1.0	2.19	1.21	58.85	23.46	82.3	1.37	20.55	15.91
1.2	2.27	1.29	62.28	23.46	85.74	1.19	17.85	16.08

Table 2: Hydraulic Properties and Detention Times for Range of Flows (2-Chambers)

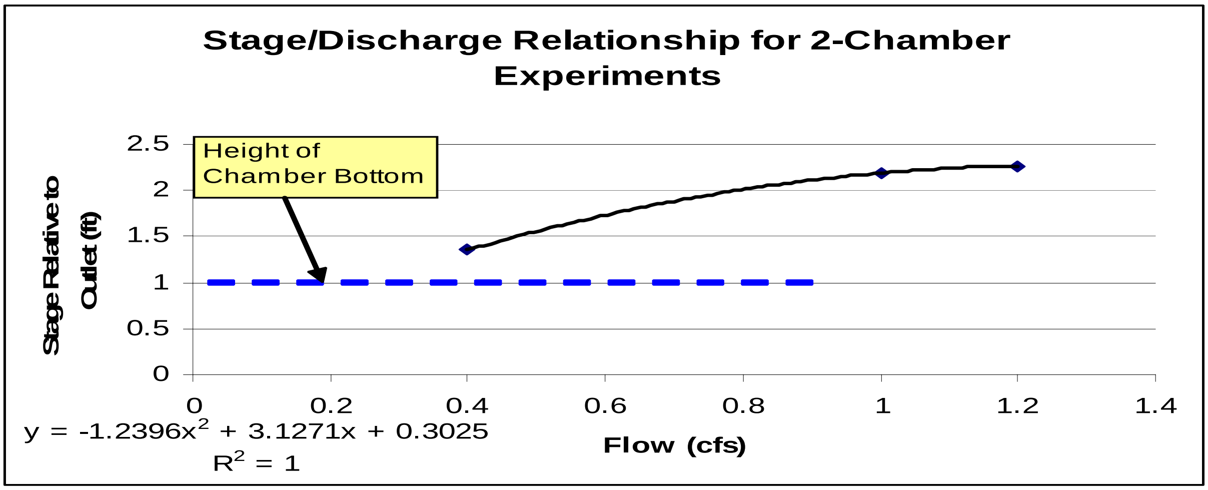


Figure 6: Stage vs. Discharge Plot (2-Chambers)

Trap Efficiency Experiments

The trap efficiencies for the various flows as a function of hydraulic loading rate for the direct and indirect methods are shown below in *Figures 7 and 8*. *Figures 7 and 8* include each of the data points from the original, four-chambered experiments (with max hydraulic loading rate of 4.84 gpm/ft^2), as well as additional points from the 0.5 scale, two-chambered experiments (max hydraulic loading rate of 9.68 gpm/ft^2), which are explained below.

As shown in *Figure 7*, the calculated trap efficiencies for the direct method display little variation below the initial peak hydraulic loading rate of 4.84 gpm/ft^2. Each flow was repeated, with results from both tests shown in the graph. All calculated trap efficiencies were greater than 99% for the four-chambered experiments. The trap efficiency gradually decreases as the flow (i.e. hydraulic loading rate) increases due to the decrease in the amount of sediment captured within the chambers. The amount of sediment not captured by the Isolator Row is trapped in the filter sock, and is plotted versus the flow in *Figure 9*. *Figure 9* shows that there is an expected increase in the amount of sediment not captured during the higher flows.

It should be noted that in both the first and second series of flows, some of the trap efficiencies obtained were greater than 100%; this is obviously not true, and resulted from the corresponding weights of sediment retained in the filter sock being negative. The percentage over 100% was marginal, and is likely attributed to antecedent moisture levels in the filter sock, which varied with humidity, in combination with minor weighing errors. The three trap efficiencies greater than 100% ranged between 100.04% and 100.21%, and are a direct result from the post-experiment dry filter sock weights decreasing between 0.9 and 4.6 grams from the pre-experiment filter sock weights. These weight decreases are relatively small, and indicate trap efficiencies for these experiments are at or near 100% (i.e., there is little or no sediment deposited on the filter sock, and therefore sediment is retained within the system). Detailed results are available in *Appendix 9*.

Similar to the direct method, the indirect method resulted in very little reduction in trap efficiency as the hydraulic loading increased. The trap efficiencies for the entire range of flows are shown below in *Figure 8*. *Figure 8* shows three separate trap efficiency curves, one for each of the three methods for obtaining influent sediment concentrations (discrete samples, grab samples, and directly calculated average). Again, each test was repeated, with results from both tests shown in the graph. *Figure 8* also includes one data point from the 0.5 scale experiments. This data point is at the manufacturer's suggested nominal design hydraulic loading rate of 8.1 gmp/ft^2, or 0.5 cfs per chamber. The lowest trap efficiency recorded for the four-chambered set-up, 97.3% at 1.2 cfs, is likely an outlier since it was lower than the trap efficiency given by the direct method. *Figure 8* further illustrates increased variability of the indirect method, as the direct method results are more precise and exhibit a relatively smooth trend. Detailed results are provided in *Appendix 9.*

The laboratory analyzed SSC concentrations from the discrete sampler at the inlet were typically higher than the target concentration of 200 mg/L. This problem is common and partly due to stratification of sediment at low flows that result in higher than actual influent sample concentrations. The actual, average sediment influent concentrations for each test have been calculated from the measured weight of all sediment injected and the calculated volume of water entering the system for each experiment (flow*duration). These average influent sediment concentrations ranged from 140 to 230 mg/L, with an average of 183.18 mg/L, and are illustrated in *Figure 10*. One comparison of the sediment influent concentrations, the first, 0.1 cfs experiment, resulted in the discrete, laboratory analyzed SSC concentration of 613 mg/L when the actual, average sediment influent concentration is calculated to be 212 mg/L. This significant sediment concentration difference represents the largest discrepancy between the discrete and calculated concentrations, yet results in only a 0.67% increase in calculated sediment trap efficiency. Detailed laboratory and calculated SSC results for each experiment are available in *Appendix 10*. Notably, the grab samples taken at the inlet were more accurate and consistent than the discrete samples. The effect that these differing influent sediment concentrations have on the calculated trap efficiencies is illustrated in *Figure 8*. As expected, the high influent SSC concentrations obtained from the discrete sampler result in higher trap efficiencies than the grab samples or directly calculated average influent sediment concentrations. There was little variation in the SSC concentrations of the outlet samples due to the high trap efficiency of the chambers.

Similar to the high influent SSC concentrations, the discretely sampled effluent SSC concentrations were substantially higher than actual. The differences ranged from approximately 1 mg/L at the lowest hydraulic loading rate to 6 mg/L at the highest. Assuming that the direct method is accurate, the error introduced from the indirect method ranged from 0.5% to 2.3% for the series of hydraulic loading rates tested. Detailed comparisons between influent and effluent concentrations (discrete, grab, and direct) as well as their effect on trap efficiency are available in *Appendix 10* (in particular, *Figures A10.1 – A10.4*).

Following the completion of the four-chambered experiments, higher hydraulic loading rates were tested by scaling the set-up down to two chambers. The data points from these experiments are included in *Figures 7 and 8.* All data points higher than 4.84 gpm/ft^2 were obtained from the two-chamber set-up. At the nominal design hydraulic loading rate of 8.1 gpm/ft^2, trap efficiency was calculated to be 97.8% by the direct method and 95.5% by the indirect method. *Figures 7 and 8* also illustrate that the scaled experiments agree relatively well with the quadratic trend-lines, as the additional data points fall near the curve. The Maine Department of Environmental Protection (Maine DEP) sent a representative to observe the 1.0 cfs, two-chamber experiment to validate the testing protocols and recommend the StormTech chambers for use in stormwater treatment. Maine DEP concluded that the Stormtech® SC-740 Isolator™ Row stormwater treatment device could be expected to remove greater than 80% of the specified OK-110 sand, and approved the system to remove greater than 60% of the total suspended solids (TSS) from stormwater runoff. The Maine DEP's full report, results, and conclusions are available as *Appendix 11*.

The accuracy of the "scalability" of this experiment is not well known. Currently, there is only one hydraulic loading rate (3.22 gpm/ft^2) with results from both the four- and two-chambered experimental set-ups, direct method only. The corresponding flows to these results are 0.8 cfs for the four-chamber and 0.4 cfs for the 2-chambered experiments. The resulting trap efficiencies are 99.92% (average of two results) for four chambers and 99.98% for two chambers, which appears to show relatively good agreement.

The trapped sediment can be grouped into retrievable and irretrievable sediment. The retrievable sediment is that captured by the fabric and stored within the chambers. The irretrievable sediment is either occluded in the filter fabric, or deposited in the gravel substrate. The amount of retrievable sediment trapped appears independent of hydraulic loading; with an average of approximately 80% being retrievable over the range of hydraulic loadings tested. Approximately 16to 20% (maximum) of the trapped sediment was occluded in the woven fabric or deposited in the stone foundation substrate; and was therefore considered irretrievable. These results are also available in detail in *Appendix 9.*

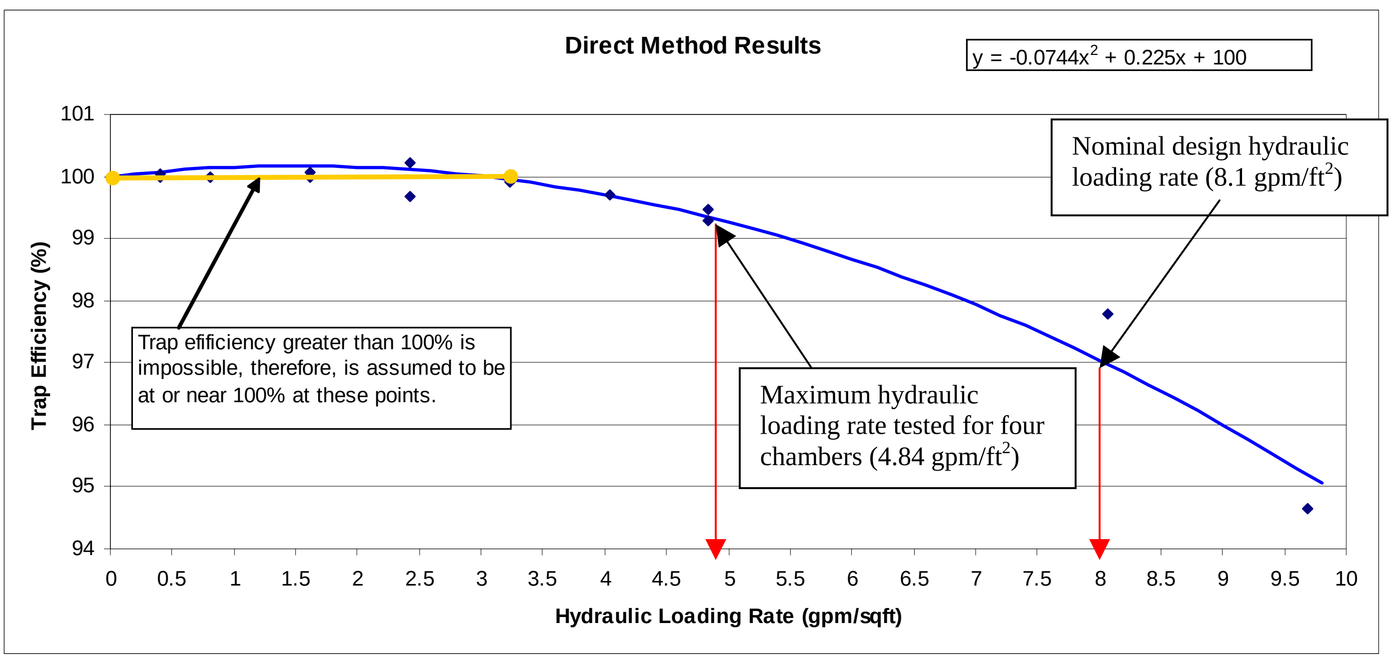


Figure 7: Trap Efficiency vs. Hydraulic Loading Rate (Direct Method)

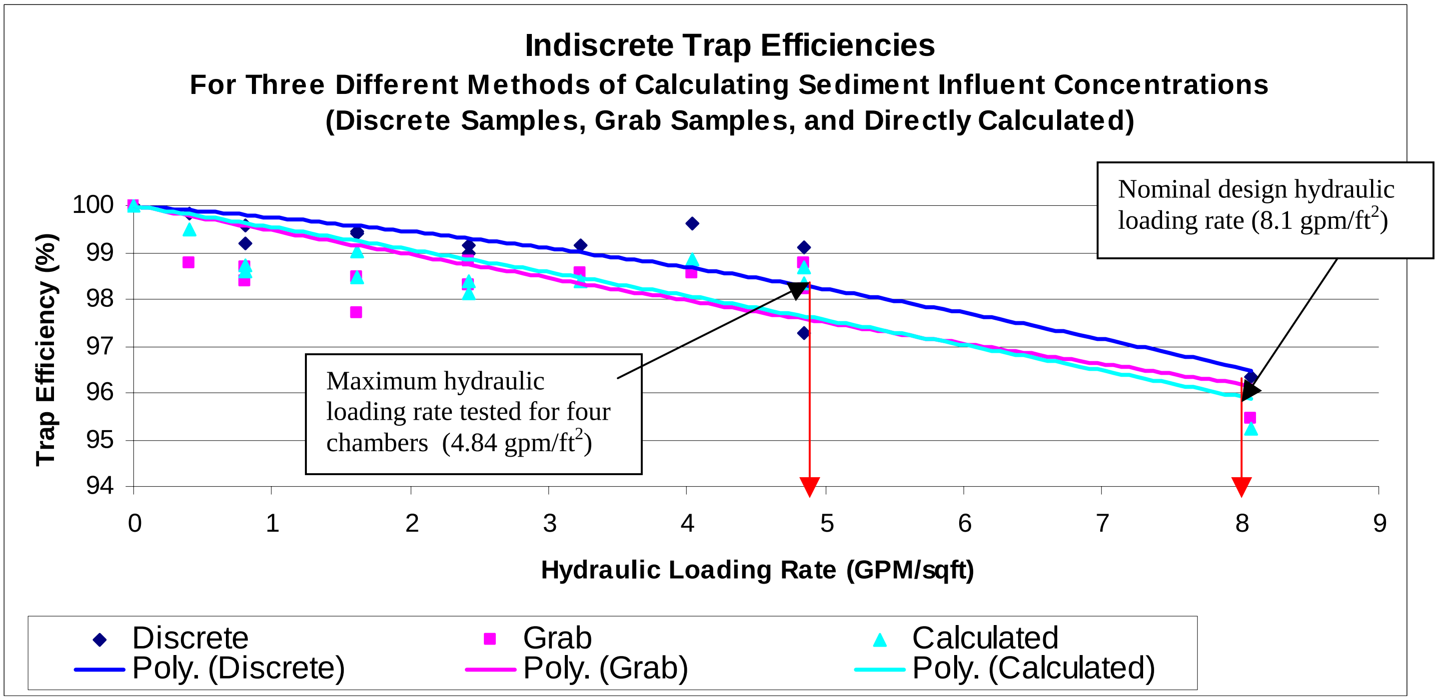


Figure 8: Trap Efficiency vs. Hydraulic Loading Rate (Indirect Method)

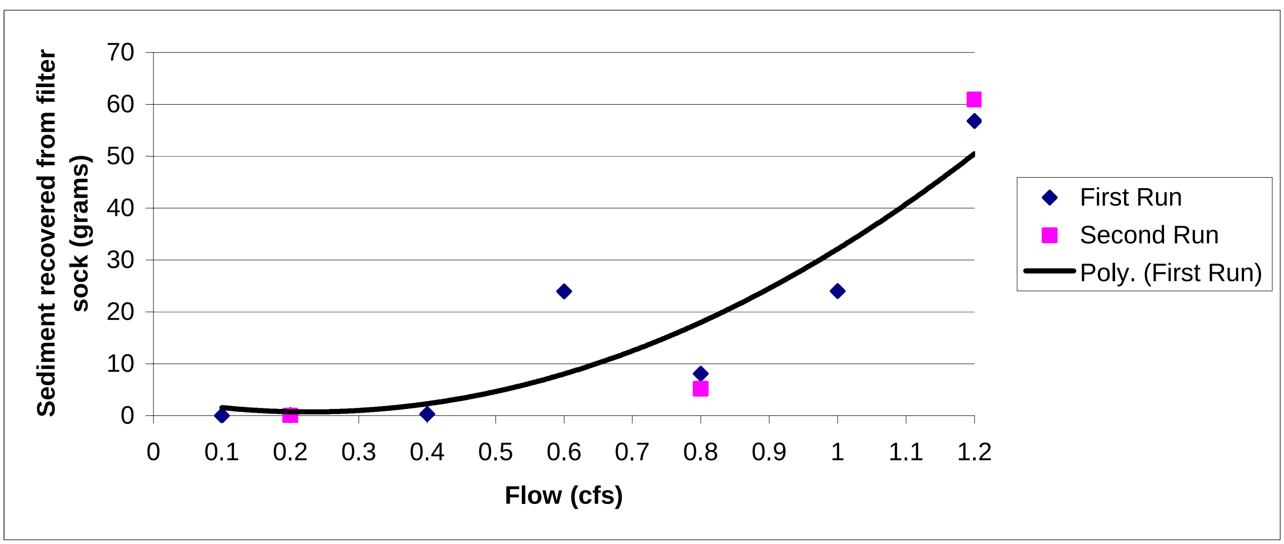


Figure 9: Illustration of Increase in Sediment Trapped by Filter Sock at Higher Flows.

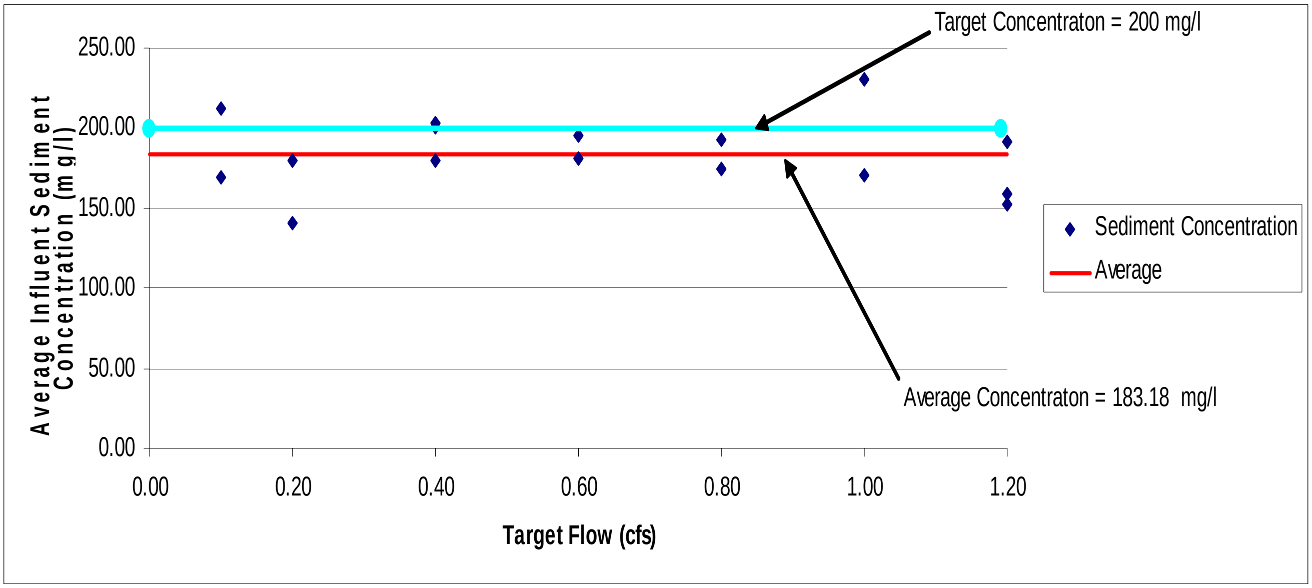


Figure 10: Calculated Average Sediment Influent Concentrations

Sediment Distribution

The sediment distribution varied with the flow magnitude. For the higher flows (0.8 – 1.2 cfs), it was deposited evenly throughout all chambers. For the lower flows below 0.8 cfs, the sediment was deposited predominantly in the first two chambers. The distribution was affected by scouring by the inlet flow in the first two chambers as the pumps were shut down. The higher flows also resulted in depositing sediment in the fabric behind the portholes. Pictures illustrating sedimentation at various flows are available in *Appendix 12*.

Estimated Maintenance Schedule

The storage life expectancy of the Isolator Row chambers (prior to cleaning) can be projected, and is useful in scheduling maintenance of the Isolator Row. The following example is for a 1-acre catchment (paved surface) with an average annual sediment inflow of 300-1000 lb/acre-yr (Neary et al 2002). The useful volume of the chambers is calculated to be 6.58 cubic feet per chamber (26.32 cubic feet for four chambers), or when the sediment accumulation reaches three inches from the bottom of the chambers. Assuming a uniform sediment distribution and a specific weight for sediment of 75-lb/cubic ft, it is estimated that 300–1000 lb/yr would be deposited. This annual mass loading would translate to 4-13 cubic ft per year, and the chamber would have to have sediment removed approximately every 2–6.5 years, with an average of approximately 3 years for a typical 1-acre catchment.

Conclusions

Study objectives were successfully met using the laboratory protocols detailed in this report. The calculated trap efficiencies for the StormTech SC-740 Isolator Row were very high (>94% at all hydraulic loading rates) regardless of which method (direct or indirect) was used in the calculations. The trap efficiency for higher hydraulic loading rates was tested by reducing the experimental set-up to two chambers. At the manufacturer's suggested nominal maximum design hydraulic loading rate (8.1 gpm.ft^2, or 0.5 cfs per chamber), the trap efficiency remained greater than 95%. The Maine Department of Environmental Protection (MDEP) observed one of the 0.5 scale experiments, and approved the StormTech SC-740 Isolator Row stormwater treatment system for removal of greater than 60% of stormwater runoff total suspended solids. .

The study found problems with the indirect method of calculating sediment trap efficiency, mainly due to the difficulty obtaining discrete samples that are representative of the actual, average sediment concentrations (influent and effluent). The discretely sampled, laboratory analyzed suspended sediment concentrations (SSC) were as much as three times higher than actual for influent concentrations, and typically ranged from two to seventeen times higher for the effluent samples. However, assuming the trap efficiencies obtained from the direct method represent true values the indirect method resulted in errors of only +0.5 %– +2.3% because the overbiasing of the influent concentration is offset by overbiasing of the effluent concentration. It is suspected that this error would increase significantly at lower trap efficiencies (<90%). Based on the comparison of these two methods, the authors recommend that the direct method of calculating sediment trap efficiency be used whenever possible, particularly in a laboratory setting, and that the indirect method only be relied on when it is not practical to reclaim the sediment injected to a stormwater treatment system during testing.

Transferability of Trap Efficiency Curves to Other Units

Since the flow rate in gpm is normalized by the footprint are in square feet, the trap efficiency curve can be readily applied to any sized StormTech Isolator chamber (e.g., StormTech SC-310 Isolator Row chamber). For example, a four- chamber StormTech SC-310 Isolator Row has a footprint of 17.7 sq.ft. X 4 = 70.80 sq.ft with a maximum rated flow rate of 0.3 cfs X 4 = 1.2 cfs (539 gpm). The hydraulic loading rate at this maximum hydraulic capacity is therefore 7.6 gpm/sq.ft.. At this hydraulic loading rate, the trap efficiency is approximately 97.5%.

References

Gray, J.R., G.G. Douglas, L.M. Turcios, and G.E. Schwartz (2000) "Comparability of Suspended Sediment Cocentration and Total Suspended Solids Data," U.S. Geological Survey, Water Resources Investigation Report 00-4191

Neary, V.S., Neel, T.C., J.B. Dewey, G.K. Stearman, and D.B. George (2002) "Pollutant Washoff and Loading from Parking Lots in Cookeville, Tennessee." *9th Intnl. Conf. on Urban Drainage.* Portland, Oregon, September 8-13, 2002.

Maine Department of Environmental Protection, "Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems."

Appendix 1:

Open Bottom Area Calculations

Open Bottom Area Calculations (Footprint)

SC-740 CHAMBER

SECTION	Width In.	Length In.	%Open[1] %	Area In^2	Area Ft^2
SPAN	43.0	85.4	NA	3672.2	25.5
CORRUGATED	5.0	85.4	77	328.8	2.3
					27.8 Open Bottom Area per Chamber

SC-310 CHAMBER

SECTION	Width In.	Length In.	%Open[1] %	Area In^2	Area Ft^2
SPAN	26.0	85.4	NA	2220.4	15.4
CORRUGATED	5.0	85.4	77	328.8	2.3
					17.7 Open Bottom Area per Chamber

[1] The corrugated section has an alternating pattern of blocked and open parts along the length of the chamber. 77% is open and is included in the open bottom area. 33% is blocked off and not included in the open area calculation.

Appendix 2:

Angular Stone Backfill Specifications

LOCATION: Ahgood DATE: 6/25/03 SIZE: #3's 2" mt.

SAMPLE #1

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	5.93	20.1	79.9	35-70
1"	25.35	85.9	14.1	0-15
3/4"	28.46	96.5	3.5	-
5/8"				-
1/2"	29.11	98.7	1.3	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2½	—	—	100	100

ORIGINAL DRY WEIGHT 29.50
WEIGHT AFTER WASH
WASH LOSS
PERCENT LOSS

SAMPLE #2

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	6.43	24.1	75.9	35-70
1"	23.32	87.6	12.4	0-15
3/4"	25.91	97.3	2.7	-
5/8"				-
1/2"	26.33	98.9	1.1	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2½	—	—	100	100

ORIGINAL DRY WEIGHT 26.63
WEIGHT AFTER WASH
WASH LOSS
PERCENT LOSS

SAMPLE #3

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2½				100

ORIGINAL DRY WEIGHT
WEIGHT AFTER WASH
WASH LOSS
PERCENT LOSS

AVERAGE

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2½				100

ORIGINAL DRY WEIGHT
WEIGHT AFTER WASH
WASH LOSS
PERCENT LOSS

Appendix 3:

Mirafli N-Series Geotextile Specifications

Technical Data MIRAFI

Engineered Solutions for an Innovative World

product

Mirafi® N-Series Nonwoven Polypropylene Geotextiles

for Soil Separation, Filtration, and Protection

Property / Test Method	Units	140NL	140NC	140N	160N	170N	180N	1100N	1120N	1160N
MECHANICAL PROPERTIES										
Grab Tensile Strength ASTM D 4632										
Strength @ Ultimate	kN (lbs)	0.40 (90)	0.45 (100)	0.53 (120)	0.71 (160)	0.80 (180)	0.9 (205)	1.11(250)	1.34 (300)	1.69 (380)
Elongation @ Ultimate	%	50	50	50	50	50	50	50	50	50
Mullen Burst Strength	kPa	1205	1447	1550	2100	2273	2618	3445	4030	5098
ASTM D 3786	(psi)	(175)	(210)	(225)	(305)	(330)	(380)	(500)	(585)	(740)
Trapezoidal Tear Strength	kN	0.18	0.20	0.22	0.27	0.33	0.36	0.45	0.51	0.62
ASTM D 4355	(lbs)	(40)	(45)	(50)	(60)	(75)	(80)	(100)	(115)	(140)
Puncture Strength	kN	0.24	0.30	0.30	0.42	0.46	0.58	0.69	0.78	1.05
ASTM D 4833	(lbs)	(55)	(65)	(65)	(95)	(105)	(130)	(155)	(175)	(235)
UV Resistance after 500 hrs. ASTM D 4355	% strength	70	70	70	70	70	70	70	70	70
HYDRAULIC PROPERTIES										
Apparent Opening Size (AOS)	US Sieve	60	70	70	70	80	80	100	100	100
ASTM D 4751	mm	0.25	0.212	0.212	0.212	0.180	0.180	0.150	0.150	0.150
Permittivity ASTM D 4491	sec^{-1}	2.0	1.9	1.8	1.4	1.4	1.2	1.0	0.8	0.7
Flow Rate ASTM D 4491	$l/min/m^2$ ($gal/min/ft^2$)	5907 (145)	5698 (140)	5500 (135)	4477 (110)	4278 (105)	3866 (95)	3056 (75)	2648 (65)	2037 (50)
Packaging										
Roll Width	m(ft)	3.8 (12.5) 4.5 (15.0)	3.8 (12.5) 4.5 (15.0)	3.8 (12.5) 4.5 (15.0)	4.5 (15.0)	4.5 (15.0)	4.5 (15.0)	4.5 (15.0)	4.5 (15.0)	4.5 (15.0)
Roll Length	m(ft)	110 (360)	110 (360)	110 (360)	91 (300)	91 (300)	91 (300)	91 (300)	91 (300)	46 (150)
Est. Gross Weight	kg(lbs)	60 (133) 70 (160)	64 (142) 75 (166)	67 (148) 89 (197)	103 (227)	113 (249)	124 (273)	150 (331)	158(348)	114 (251)
Area	$m^2(yd^2)$	418 (500) 502 (600)	418 (500) 502 (600)	418 (500) 502(600)	418 (500)	418 (500)	418 (500)	418 (500)	418 (500)	209 (250)

NOTE: All Mechanical Properties and Hydraulic Properties shown are Minimum Average Roll Values (MARV).

<u>Appendix 4:</u>

Mirafli X-Series Geotextile Specifications

MIRAFI® TECHNICAL DATA SHEET

Mirafi® 600X

Mirafi® 600X is composed of high-tenacity polypropylene yarns, which are woven into a stable network such that the yarns retain their relative position. 600X is inert to biological degradation and resistant to naturally encountered chemicals, alkalis, and acids.

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Wide Width Tensile Strength	ASTM D 4595	kN/m (lbs/in)	30.6 (175)	30.6 (175)
Grab Tensile Strength	ASTM D 4632	kN (lbs)	1.40 (315)	1.40 (315)
Grab Tensile Elongation	ASTM D 4632	%	15	
Trapezoid Tear Strength	ASTM D 4533	kN (lbs)	0.53 (120)	0.53 (120)
Mullen Burst Strength	ASTM D 3786	kPa (psi)	4134 (600)	
Puncture Strength	ASTM D 4833	kN (lbs)	0.65 (145)	
Percent Open Area	COE-02215-86	%	1	
Apparent Opening Size (AOS)	ASTM D 4751	mm (U.S. Sieve)	0.425 (40)	
Permittivity	ASTM D 4491	sec^{-1}	0.05	
Flow Rate	ASTM D 4491	$l/min/m^2$ ($gal/min/ft^2$)	163 (4.0)	
UV Resistance (at 500 hours)	ASTM D 4355	% strength retained	70	

Physical Properties	Test Method	Unit	Typical Value	
Weight	ASTM D 5261	g/m^2 (oz/yd^2)	203 (6.0)	
Thickness	ASTM D 5199	mm (mils)	0.64 (25)	
Roll Dimensions (width x length)	--	m (ft)	3.8 x 110 (12.5 x 360)	5.3 x 78.7 (17.5 x 258)
Roll Area	--	m^2 (yd^2)	418 (500)	418 (500)
Estimated Roll Weight	--	kg (lb)	109 (240)	109 (240)

Ten Cate Nicolon

Appendix 5:

Lab Protocol

Sub-Appendices 5-a through 5-i

STORMTECH
REMOVAL EFFICIENCY EXPERIMENT
March 26, 2004

LAB PROTOCOL

1. Weigh the filter sock to be used in the experiment.
2. Set up the mixture in the mixing tank and make sure that the suction line of the peristaltic pump is midway between the propellers and also check for any constrictions. Also check if the direction of flow in the peristaltic pump is proper. (See **APPENDICES 5-a and 5-b**). NOTE: Two peristaltic pumps will be required when flow rates are above Q=0.6 cfs because the pump speed is limited to 220 rpm (See **APPENDIX 5-c**). To accommodate two peristaltic pumps, two taps are installed in the pipe upstream of the flume and butterfly valve.
3. Fill out test run information on laboratory test form (See **APPENDIX 5-d**).
4. See Stage-Discharge-Detention Time Calculation Table (**APPENDIX 5-e**) to determine the length of the test run for each flow based on fifteen detention times. Before beginning each experiment, determine the times at which each grab sample will be taken in order for the five grab samples to be evenly spaced.
5. Turn the Allis Chalmers pumps on, record the time on the test data sheet and set the flow rate. For setting the pumps refer to **APPENDIX 5-f**.
6. Establish a steady flow rate. Record the time when this is established. For the flow meter setting refer to **APPENDIX 5-g**.
7. Measure and record water temperature with standard thermometer.
8. Record the time for the blank automated discrete samples at inlet and outlet and label the bottle with the test run code and BLANK-I (sample from inlet), BLANK-O (sample from outlet).
9. Start and note the time the peristaltic pump is turned on. Refer to **APPENDIX 5-c** for setting the specified concentration as per required mg/L of sediment.
10. Wait three (3) detention times before beginning sampling.
11. Start stopwatch to record the exact time of the test run.
12. Measure 3 lb of sediment and 2 gallon of water. When slurry level in the mixing tank reaches the top propeller, pour buckets' (1 sediment and 1 water) contents into the mixing tank. Be sure to pour as far away as possible from the suction line of the peristaltic pump. Also, do not pour in to mixing tank just prior to a grab sample, as to avoid high concentrations of sediment. NOTE: Step 10. in its entirety will probably have to be executed more than once during each experiment. Thus, have two 3 lb sediment and two 2gallons of water measured before beginning
13. Collect automated discrete sample and label the bottle with the test run code and I-1. Also collect (as check) grab sample of influent and label with the test run and IG-1. See **APPENDIX 5-h** for detailed protocol on operating ISCO 6712 portable samplers.
14. Wait one (1) detention time and collect automated discrete sample of effluent and label the bottle with the test run code and O-1.
15. Continue influent and effluent sampling at predetermined times spaced equally apart.
16. Keep observing the level of the mixture in the mixer tank and make sure it is not dropping below the top propeller. In case the level appears to be going below, add the sediment and water mixture from step 12 to get the level above propeller.
17. Keep noting the time of all the events in the data sheet and record temperature measurements of water in the flume after each sample.

18. After fifteen (15) detention times the peristaltic pump, the stopwatch, and the main pumps are shut off at the same time.
19. For direct testing, the following protocol will be followed:
    a. Sediment in the chamber (**Sample *A***) is collected using a handheld wet/dry vacuum.
    b. Sediment left in the mixing tank (**Sample *B***) is carefully collected and spread into a thin layer on a tarp where it is left to air dry. Both samples will then be oven dried and their dry weights recorded. See **APPENDIX 9** for drying and weighing procedure.
    c. All sediment that would have been in the trench and sump should be in the filter sock and accounted for in **Sample *C*.**
    d. The material in the outlet pipe is flushed into the filter sock using a garden hose and labeled **Sample *C***. The material from the tube of the effluent sampler is also added to this sample.
    e. Carefully remove the filter sock from the outlet pipe and place in a previously weighed tare. Tare and filter sock are then oven dried. The weight of sediment in **Sample C** is calculated by subtracting the weight of the tare and dry filter sock.
    f. The material in the pipes of the Watson-Marlow peristaltic pump is carefully pumped back into the mixer tank and added to **Sample *B***.
    g. The trench and sump will be inspected to make sure there is no sediment that passed through the filter sock.
    h. Sediment remaining in the inlet pipe will be removed last by flushing into the Stormtech chamber, collected, dried and weighed (**Sample *D***).
    i. Record the weights for the samples *A* through *D*, and *M*.
    j. Calculate solid removal efficiencies as follows, where M is the original dry weight in the mixing tank (and 3 lbs. additions) prior to running the test:

$$\text{Trap Efficiency}\,(\%) = \left(\frac{\text{Load}_{\text{In}} - \text{Load}_{\text{Out}}}{\text{Load}_{\text{In}}}\right)\times 100 \quad \text{...5.}1$$

$$\text{Load}_{\text{In}} = \text{M} - \text{B} - \text{D} \quad \text{...5.}2$$

$$\text{Load}_{\text{Out}} = \text{C} \quad \text{...5.}3$$

NOTE: THE UNRETRIEVABLE AMOUNT OF SEDIMENT U (I.E. SEDIMENT DEPOSITED BEHIND PORTHOLES, OCCLUDED IN THE FABRIC, AND IN THE GRAVEL) CAN BE ESTIMATED AS:

$$\text{Irretrievable (lb)} = \text{Load}_{\text{In}} - \text{Load}_{\text{Out}} - \text{Retreivable Material} \quad \text{.................................5.4}$$

$$\text{Retreivable Material} = \text{A} \quad \text{..5.5}$$

20. For indirect testing, following the Maine DEP protocol, the samples will be analyzed for Suspended Sediment Concentration (SSC) in a manner equivalent to the method described in Test Method 2. Filtration in ASTM, 1999, D 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, Annual Book of Standards, Water and

Environmental Technology, 1999, Volume 11.02, p 389-394. (The Suspended Sediment Concentration method will be used in the final test because it requires filtration of the entire sample thus avoiding the potential loss of coarse material when taking the 100-milliliter sub-sample prescribed by the TSS standard method.

21. The average removal efficiency will be calculated, assuming steady state conditions, as follows:

$$\text{Trap Efficiency}(\%) = \frac{SSC_I - SSC_E}{SSC_I} \quad \text{……………………..…………………………5.6}$$

Where,

$$SSC_I = \text{Mean Influent Concentration (mg/L)} \quad \text{……………………………………..5.7}$$

$$SSC_E = \text{Mean Effluent Concentration (mg/L)} \quad \text{…………………………………..….5.8}$$

The testing results must be submitted to the Department and a representative for the Maine DEP will oversee the performance of a full test at the loading rate indicated by the submitted test results to assure quality and repeatability. A laboratory of the Department's choosing will analyze samples collected at this confirmation test.

<u>**APPENDIX-5-a**</u>

SETTING UP THE MIXER TANK

1. Weigh 45 lb of the sediment and carefully transfer it into the mixer tank.
2. Fill the mixer tank with 30 gal of water.
3. Now the concentration of the mixture is 1.5 lb/gal.
4. Set the angle of the mixer shaft according to the schematic below.
5. Turn the motor driving the propellers ON.

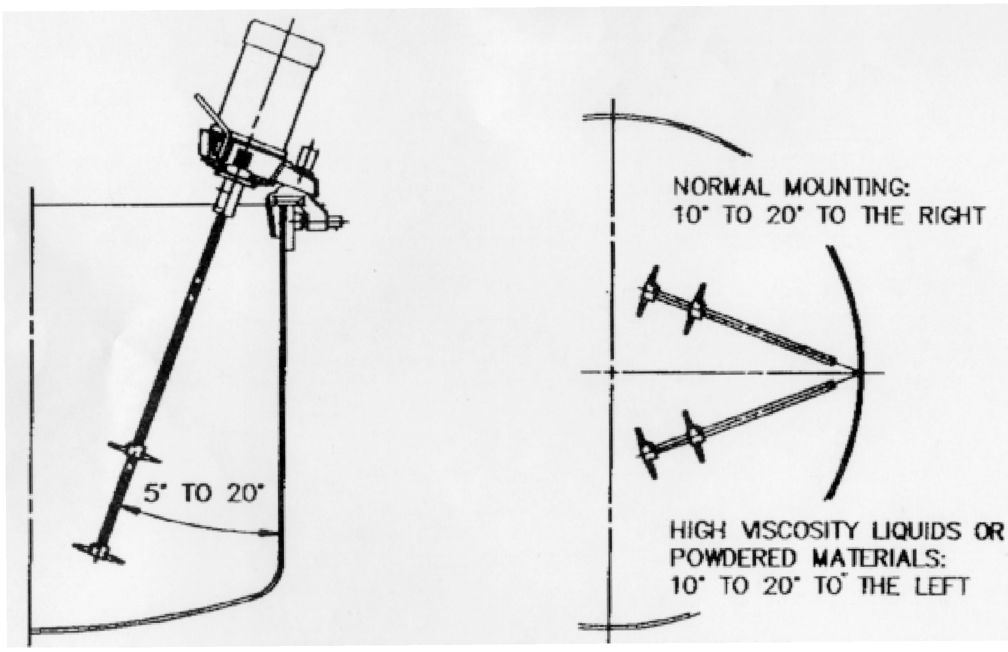


Figure A5.1: Mounting Angle and Eccentric Angle.

APPENDIX 5-b:

WATSON-MARLOW PERISTALTIC PUMP

1. Place the suction line in the mixer tank and the effluent line in the pipes that run to the concentrator. Make sure that the center screw of the pump is tight.
2. Turn the power ON and set the pump at the required rpm by using the arrow keys on the pump.
3. Before turning the pump ON, make sure that the propellers in the mixer tank are rotating properly and then give it sufficient time to ensure proper mixing.
4. Turn the pump on and simultaneously turn the stopwatch ON.
5. After the required time interval has elapsed, turn off the stopwatch and stop the pump simultaneously. Now the peristaltic pump can be turned OFF.
6. Carefully remove the suction line from the mixer tank and let the mixer tank drain.
7. For high flows two peristaltic pumps will be needed to attain required rpm's. The procedure remains the same for both pumps.

APPENDIX 5-c:

Sediment Metering Calculations and Peristaltic Pump Calibration Details

The loading rate calculations for the peristaltic pump to yield a target sediment concentration of 200 mg/L are based on the following equations:

$$Q_{sp} \div (Q_{wp} + Q_w) = 200 mg / L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots A5.8$$

$$Q_{sp} \div Q_{sw} = 179{,}810\ mg / L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots A5.9$$

Where, Q_{sp} is the discharge of sediment from the peristaltic pump, Q_{wp} is the discharge of water from peristaltic pump and Q_w is the discharge of water from the inlet upstream of the sediment feed tap. *Equation A5.8* expresses the target concentration and *Equation A5.9* expresses the sediment slurry concentration (1.5 lbs./gal. or 179,810 mg/L).

EXAMPLE

For 0.1 cfs, $Q_w = 0.1*28.37 \text{ L/s} = 2.837 \text{ L/s}$

$$179{,}810 \frac{Q_{sp}}{(Q_{wp} + 2.837)} = 200 \frac{mg}{lit}$$

$$\frac{Q_{sp}}{Q_{wp}} = 179{,}810 \frac{mg}{lit} \Rightarrow Q_{sp} = 179{,}810 \frac{mg}{lit} \times Q_{wp}$$

Solving for Q_{sp} and Q_{wp}:

$$Q_{wp} = \frac{200 \frac{mg}{s}}{179{,}810 \frac{mg}{lit}} = 0.00316 \frac{lit}{s}$$

And

$$Q_{sp} = 179{,}810 \frac{mg}{lit} \times 0.00316 \frac{lit}{s} = 568.032 \frac{mg}{s}$$

Extending these calculations for the rest of the flow rates, *Table A5.1* is developed.

Q exper cfs	Q exper L/s	Target C mg/L	Mix C lbs/gal	Mix C mg/L	Q peristaltic L/s	Q sediment mg/s	Pump Spd rpm
0	0.00	200	1.5	179810	0.0000	0	0.0
0.1	2.84	200	1.5	179810	0.0032	568	33.6
0.2	5.67	200	1.5	179810	0.0063	1136	67.2
0.3	8.51	200	1.5	179810	0.0095	1704	100.8
0.4	11.35	200	1.5	179810	0.0126	2272	134.4
0.5	14.19	200	1.5	179810	0.0158	2840	168.0
0.6	17.02	200	1.5	179810	0.0190	**3408**	**201.6**
0.7	19.86	200	1.5	179810	0.0221	3976	235.2
0.8	22.70	200	1.5	179810	0.0253	4544	268.8
0.9	25.53	200	1.5	179810	0.0284	5112	302.4
1	28.37	200	1.5	179810	0.0316	5680	336.0
1.1	31.21	200	1.5	179810	0.0347	6248	369.6
1.2	34.04	200	1.5	179810	0.0379	6816	403.2

Table A5.1: Sediment metering calculations

DETAILS OF PERISTALTIC PUMP CALIBRATION

A Watson-Marlow Model 323ES peristaltic pump meters the sediment-water slurry mixture to the inlet pipe. The pump was calibrated to determine the loading rate (mg/s) vs. pump speed (rpm) relationship. The pump operates in a range of 1-220 rpm.

rpm	Time (sec)	Sediment mixed (lb)	Mixture collected (lb)	Sediment collected (lb)	Sediment Left (lb)	Concentration (lb/gal)	Q sediment (lb/s)	Q sediment (mg/s)
20	7853	45	36.5	5.8	39.2	1.59	0.000739	335
50	3288	45	35.3	4.7	40.3	1.29	0.001429	649
90	1889	45	45.1	6.3	38.7	1.36	0.003335	1513
140	1223	45	39.9	6	39	1.49	0.004906	2226
180	619	45	28.5	4.3	40.7	1.49	0.006947	3152
220	564	45	32.3	5	40	1.54	0.008865	4022

Table A5.2: Calibration data of the peristaltic pump

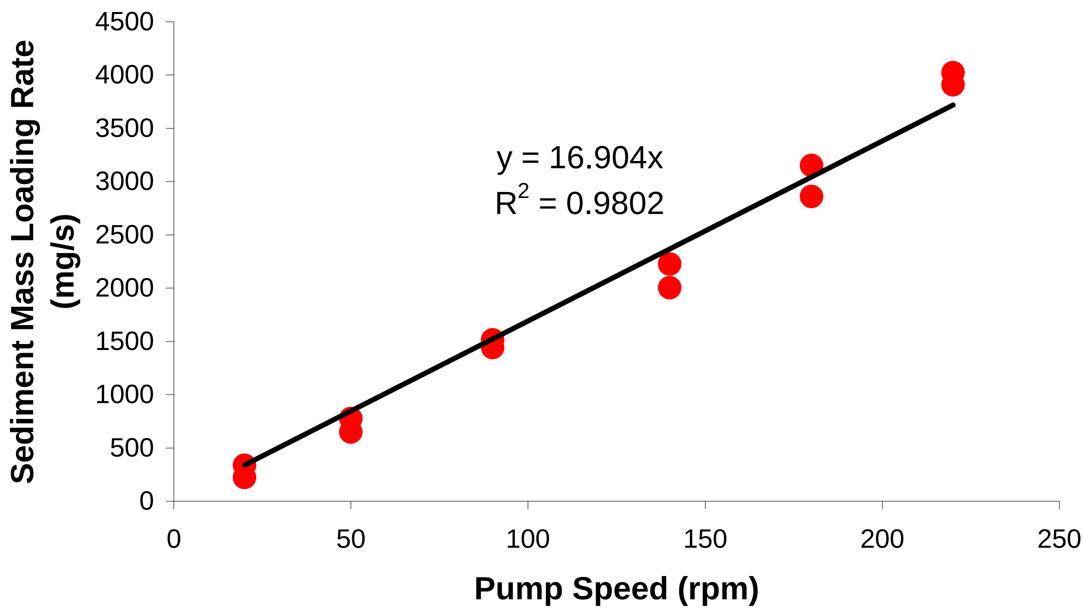


Figure A5.2: Calibration curve for the Watson-Marlow peristaltic pump

APPENDIX 5-d

Laboratory Data Sheet

TENNESSEE TECH UNIVERSITY: LABORATORY DATA SHEET

PROJECT: STORMTECH SC-740 CHAMBER SOLIDS REMOVAL EFFICIENCY

PERFORMED BY: **DATE:**

RUN INFO:

Test Name:	RE-**Q**-200		File Name:	
Q_{water}		Cfs		gpm
Qsediment		mg/s	Number of 3 lb. Buckets of sediment added:	Number of 2 gal. Buckets of water added:
Max Stage		Ft		
Volume		ft^3		
Detention Time		minutes		
15*Detention Time		minutes		
START Sediment Wt.		lb.		
START Water		Gal		
Mixture Concentration	1.5	lb./gal		mg/L
Speed Peristaltic Pump		Rpm		
Target $C_{influent}$	200	mg/L		
Tare Wt. Sample A(chamber)		lb.	Sample A dry	
Tare Wt. Sample B(Mixing)		lb.	Sample B dry	
Tare Wt. Sample C(filter sock)		Gm	Sample C dry	
Tare Wt. Sample D(Inlet)		Lb	Sample D dry	
Filter Sock Wt.		Gm		
Valve Position (1-10)				

RECORD TIMES:

PRESTART

FLOW STABILIZED

WATER TEMP. 1 °C

BLANK SAMPLE

PERISTALTIC PUMP START

THREE DETENTION TIMES

Start sampling after three detention times. Record times collected. Sample effluent one detention time after influent sampling.

Discrete Samples (ISCO):	SAMPLE	TIME	SAMPLE	TIME	TEMP.
Perfrom Grab Samples at influent at same time as ISCO takes sample from influent. Perform 5 grab samples, one for each discrete sample.	INFLUENT1		EFFLUENT1		°C
	INFLUENT2		EFFLUENT2		°C
	INFLUENT3		EFFLUENT3		°C
	INFLUENT4		EFFLUENT4		°C
	INFLUENT5		EFFLUENT5		°C

FINISH

WATER TEMP. 2

PHOTOS: Take photos at same exact place within chamber for each test run after test completion. At least one photo taken from outlet looking back towards inlet.

OTHER OBSERVATIONS: Sediment in trench, sump, etc

APPENDIX 5-e

STAGE-DISCHARGE-DETENTION RELATIONS FOR TEST CASES

Flow (cfs)	Stage Relative to Invert of Outlet (ft)	Depth of Water Inside Chamber (ft)	Volume of Water in All 4 Chambers (ft^3)*	Volume of Water in Gravel Beneath All Chambers (ft^3)	Total Volume (ft^3)	Detention Time, θ (min)	**15 X θ (min)**	Total Sediment Injected for 15 X θ (lbs) **	45 X θ (min)	Total Sediment Infected for 45 X θ (lbs) **	
0.10	0.70	0.00	0.00	33.52	33.52	5.59	**83.80**	6.30	251.40	18.89	
0.20	0.95	0.00	0.00	45.49	45.49	3.79	**56.86**	8.54	170.59	25.63	
0.40	1.11	0.13	13.77	46.92	60.69	2.53	**37.93**	11.40	113.79	34.20	
0.50	1.23	0.25	26.32	46.92	73.24	2.44	**36.62**	13.76	109.86	41.27	***
0.60	1.30	0.32	33.58	46.92	80.50	2.24	**33.54**	15.12	100.63	45.36	
0.70	1.43	0.45	46.84	46.92	93.76	2.23	**33.49**	17.61	100.46	52.83	***
0.80	1.53	0.55	56.85	46.92	103.77	2.16	**32.43**	19.49	97.28	58.47	
0.90	1.63	0.65	66.69	46.92	113.61	2.10	**31.56**	21.34	94.68	64.02	
1.00	1.67	0.69	70.57	46.92	117.49	1.96	**29.37**	22.07	88.12	66.20	
1.10	1.76	0.78	79.20	46.92	126.12	1.91	**28.66**	23.69	85.99	71.07	
1.20	1.84	0.86	86.70	46.92	133.62	1.86	**27.84**	25.10	83.51	75.29	

Volumes calculated using depth of water inside chamber and Table 6-SC740 of the StormTech Design Manual

Calculated using Table 7.1: Sediment metering Calculations of the StormTech Removal Efficiency Expiriment Lab Protocal

Times for these flows are no longer needed but were included because they were already calculated

Table A5.3: Stage Discharge Results

APPENDIX – 5-f

:

SETTING THE PUMPS

1. Fill the trenches with water until the level is about an inch and a half from the standpipes.
2. First prime the pumps using the priming taps.
3. Open the hot water outlet tap and ensure that water runs through it.
4. Then turn ON the oil-recirculating pump and wait till oil flows through it.
5. Use the set pointer to set the required flow rate and adjust it so that fluctuations are reduced to the minimum. The Large pump generally only operates between 9 and 12 (on small gauge) for our range of flows.
6. The priming taps can now be shut off.
7. While chambers are filling, gradually increase pumping rate, while adding more water to the sump. Adding water to the sump distorts the flow meter.
8. After desired flow is achieved, allow flow to run for approximately 5-10 minutes, in order to ensure steady state.
9. Use the butterfly valve to ensure pipe fullness. At flow as low as 0.1-0.2 cfs butterfly valve should be at least ¾ closed. Check signal strength on flow meter to check that pipe is full. Opening and closing butterfly valve affects flow, so perform all adjustments prior to starting experiment.
10. After the experiment is finished, first turn the pump OFF and after a while turn the oil pump off.
11. Make sure to drain the water after each run and also turn the drain valve near the constant head tank ON.

<u>APPENDIX-5-g</u>:

FLOW METER

1. Set up the flow meter using the slide track on the overhead supply pipes.
2. After making the necessary connections, turn the flow meter ON and go to menu 01 to take readings for flow and velocity.
3. The flow rate for the experiment is set using the display of flow rate on the screen.
4. Disregard flow meter readings while adding water to sump. Adding water introduces air bubbles to the system, and distorts the flow measurements.
5. After desired flow is achieved, allow system to run for approximately 5-10 minutes to ensure flow does not change.
6. Check "Signal Strength" menu – should read 100%.
7. To turn the data logger ON, go to menu 80 and select the type of operation required i.e., time based data logger or automatic or just manual.
8. This data can be downloaded to a computer through a USB port and viewed. The data logger stores the data for up to 44 days.
9. Download data to computer in lab, via DOS program. Be sure to name files appropriately (i.e., file name should be recognizable, including desired flow rate, reference to the experiment, and date conducted).
10. Save data to zip drive
11. Then turn the flow meter OFF.

APPENDIX 5-h:

ISCO 6712 PORTABLE SAMPLER MANUAL OPERATING PROTOCOL

1. Take the first sample before introducing sediment. Set up sampler to operate manually and adjust sample volume to desired level (at least 1000mL). After setting up the ISCO sampler, manually take samples at each pre-determined time.
2. Start by turning on the sampler
3. Use the up and down arrows to go to “other functions”, then press the “enter” key.
4. Then to the “ Manual Function” press “enter”
5. Then “grab sample” press “enter”
6. Set the sample volume using the key pad then “enter”
7. When ready , the sample is taken by pressing the “enter” key

APPENDIX 5-i:

DRYING AND WEIGHING (DIRECT METHOD ONLY)

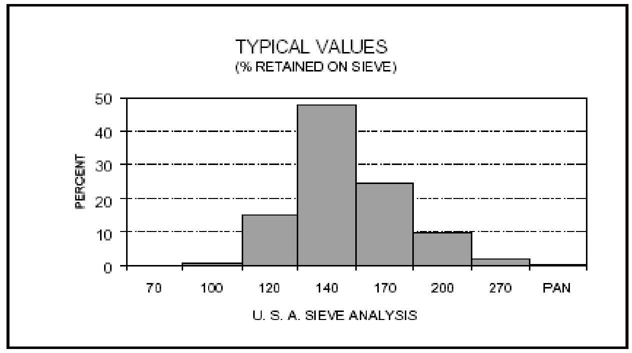
1. Measure and record the masses of the empty containers. Also mark on the container, its weight when empty and record weights on Data Sheet under "Tare Weight".
2. Carefully collect the samples in the containers to be cooked.
3. Decant water carefully without losing the sediment.
4. Place these containers in the oven and cook them at constant temperatures till the whole sample is dry. The cooking time typically ranges from 14 hours to 24 hours.
5. Make sure to stir the samples occasionally when they are cooking.
6. Remove the dry samples from the oven, weigh them on the weighing scales and record the weights carefully.
7. Put these samples back in the oven for further cooking.
8. After every hour, record the weights of the samples and continue cooking till the weights of the samples do not change anymore.
9. This is the point where the samples are totally dry and are devoid of any moisture.
10. Record these weights in the data sheet and calculate removal efficiency.

<u>Appendix 6:</u>

US Silica – OK-110 Physical Properties

U.S. SILICA
Sands of Time

PRODUCT DATA



OK-110

UNGROUND SILICA

PLANT: MILL CREEK, OKLAHOMA

		TYPICAL VALUES		
USA STD SIEVE SIZE		% RETAINED		% PASSING
MESH	MILLIMETERS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	0.212	0.0	0.0	100.0
100	0.150	1.0	1.0	99.0
120	0.125	15.0	16.0	84.0
140	0.106	48.0	64.0	36.0
170	0.088	24.2	88.2	11.8
200	0.075	9.7	97.9	2.1
270	0.053	1.9	99.8	0.2
PAN		0.2	100.0	0.0

TYPICAL PHYSICAL PROPERTIES

AFS[1] ACID DEMAND (@pH 7) 0.5
AFS(GRAIN FINENESS 119
COLOR... WHITE
GRAIN SHAPE .... ROUND
HARDNESS (Mohs) 7
(1) AMERICAN FOUNDRYMEN'S SOCIETY

MELTING POINT (Degrees F) 3100
MINERAL .... QUARTZ
MOISTURE CONTENT (%) .... <0.2
pH 7.2
SPECIFIC GRAVITY 2.65

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide)..................................... 99.6
Fe_2O_3 (Iron Oxide)... 0.018
Al_2O_3 (Aluminum Oxide)................................ 0.10
TiO_2 (Titanium Dioxide)............................... <0.01
CaO (Calcium Oxide) .... <0.01

MgO (Magnesium Oxide).. <0.01
Na_2O (Sodium Oxide).. <0.01
K_2O (Potassium Oxide).. 0.05
LOI (Loss On Ignition).. 0.1

DISCLAIMER: The information set forth in this Product Data Sheet represents typical properties of the product described; the information and the typical values are not specifications. U.S. Silica Company makes no representation or warranty concerning the Products, expressed or implied, by this Product Data Sheet.

WARNING: The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer. **For detailed information on the potential health effect of crystalline silica - quartz, see the U.S. Silica Company Material Safety Data Sheet.**

March 1, 2002

U.S. Silica Company   P.O. Box 187, Berkeley Springs, WV 25411-0187   (304) 258-2500

Figure A8.1: US Silica OK110 Physical Properties and Product Data

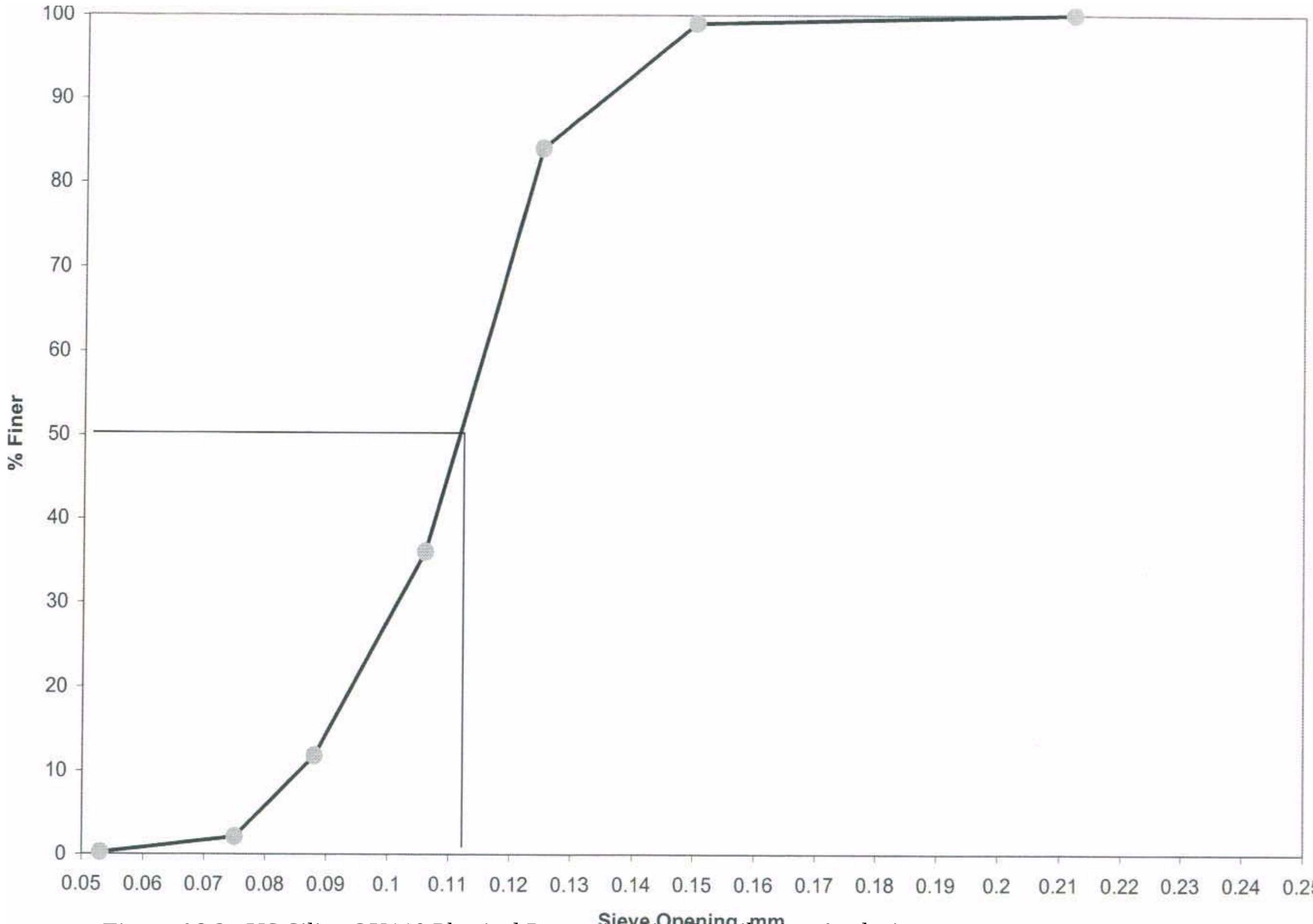


Figure A8.2: US Silica OK110 Physical Properties Size Distribution Analysis

Appendix 7:

Completed Laboratory Data Sheet

TENNESSEE TECH UNIVERSITY: LABORATORY DATA SHEET

PROJECT: STORMTECH SC-740 CHAMBER SOLIDS REMOVAL EFFICIENCY

PERFORMED BY: Michael Clay **DATE: 6/22/04**

RUN INFO:

Test Name:	RE-**Q**-200		File Name: 062204_0.6	
Q_{water}	0.6	cfs	269.28	gpm
Qsediment	3408	mg/s	Number of 3 lb. Buckets of sediment added: 3	Number of 2 gal. Buckets of water added: 3
Max Stage	1.3	ft		
Volume	80.5	ft^3		
Detention Time	2.24	minutes		
15*Detention Time	33.54	minutes		
START Sediment Wt.	45	lb.		
START Water	30	gal		
Mixture Concentration	1.5	lb./gal	178810	mg/L
Speed Peristaltic Pump	202	rpm		
Target $C_{influent}$	200	mg/L		
Tare Wt. Sample A(chamber)	11.74	lb.	Sample A dry	10.62
Tare Wt. Sample B(Mixing)	54.48	lb.	Sample B dry	49.28
Tare Wt. Sample C(filter sock)	2184.5	gm	Sample C dry	-4.6
Tare Wt. Sample D(Inlet)	0	lb	Sample D dry	0
Filter Sock Wt.	1390.7	gm		
Valve Position (1-10)	5			

RECORD TIMES:

PRESTART	11 00	
FLOW STABILIZED	11 30	
WATER TEMP. 1	20	°C
BLANK SAMPLE	11 37	
PERISTALTIC PUMP START	0 00	
THREE DETENTION TIMES	6 43	

Start sampling after three detention times. Record times collected. Sample effluent one detention time after influent sampling.

Discrete Samples (ISCO):	SAMPLE	TIME	SAMPLE	TIME	TEMP.
Perfrom Grab Samples at influent at same time as ISCO takes sample from influent. Perform 5 grab samples, one for each discrete sample.	INFLUENT1	6 43	EFFLUENT1	8 58	20 °C
	INFLUENT2	12 52	EFFLUENT2	15 06	20 °C
	INFLUENT3	19 01	EFFLUENT3	21 15	20 °C
	INFLUENT4	25 09	EFFLUENT4	27 24	20 °C
	INFLUENT5	31 18	EFFLUENT5	33 32	20 °C
FINISH	33 32				
WATER TEMP. 2		20			

PHOTOS: Take photos at same exact place within chamber for each test run after test completion. At least one photo taken from outlet looking back towards inlet.

OTHER OBSERVATIONS: Sediment in trench, sump, etc: Textbook run. Sediment heaviest at center of chamber.

<u>Appendix 8:</u>

Maine Department of Environmental Protection (DEP)

Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems

Maine Department of Environmental Protection

Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems

This document provides protocol for the laboratory testing of manufactured stormwater treatment systems to define an efficiency rating for the purpose of meeting stormwater quality standards under Maine's Stormwater Management Law and Site Location of Development Law. As of October 1, 2000, and until DEP approves field testing of a manufactured system, all flow-through systems that rely on the settling of sediments will be assigned a net removal rate that factors in the expected drop in efficiency for removal of small particle sizes.

Based on data collected in accordance with the following protocol, a 50% TSS removal rate will apply to systems that are sized to provide for 80 % removal of U.S. Silica grade F-95 foundry sand at a flow rate equivalent to the peak flow from a one-year 24-hour storm. A 60% TSS removal rate will apply to systems that are sized to provide for 80 % removal of U.S. Silica grade OK-110 sand for the same flow rate. The Department will provide these sands upon request. The materials will have been tested for consistency in particle sizing and the results will be provided with the sand.

Combined flow-through manufactured systems utilizing a sediment settling device in series with a filtration device will receive a rating of 65% provided the filter is sized to provide for at least 80 % removal of particles that are 75 microns (all particles must pass the U.S. Standard #200 sieve screen).

Laboratory Testing Protocol

To maintain consistency in testing the different proprietary systems, the following protocol will be followed. Several iterations of the test sequence will need to be performed to identify the loading rate that will provide the required removal.

1. The system should be brought to the flow rate being tested. Flow measurement should be verified by an alternative measurement technique (i.e. volumetric: stopwatch/volume change). When the flow rate is stabilized, the test sand should be introduced into the inflow at a rate that results in an inflow TSS concentration between 100 and 300 mg/l. TSS concentration in the inflow should be maintained at as constant a level as possible throughout the test.).
2. Once the flow rate is stabilized and sand introduction has begun the system should be allowed to come into equilibrium. After a minimum of 3 unit volumes has passed through the system, sampling may commence.
3. A minimum of 5 paired samples (inflow/outflow) should be collected at regular intervals from the inflow and the outflow in a way that insures that all suspended sediment is sampled. The method of collection at the inflow and the outflow must be identical, or at least sufficiently similar to insure that the efficiency of capture over the entire range of sediment particle sizes is effectively identical. Outflow samples should be staggered from inflow samples by the system's residence time at the test flow. Samples should be a minimum of 450 ml and should be consistently similar in volume.
4. During preliminary tests samples may be analyzed for either Total Suspended Solids or Suspended Sediment Concentration. During final confirmation tests, samples will be analyzed for Suspended

Sediment Concentration in a manner equivalent to the method described in Test Method 2. Filtration in ASTM, 1999, D 3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, Annual Book of Standards, Water and Environmental Technology, 1999, Volume 11.02, p 389-394. The Suspended Sediment Concentration method will be used in the final test because it requires filtration of the entire sample thus avoiding the potential loss of coarse material when taking the 100 milliliter sub-sample prescribed by the TSS standard method.

For a test to be valid, little variation should be found in the concentration of inflow samples and in the removal efficiency indicated by each pair of samples.

5. The average removal efficiency will be calculated as follows:

$$TrapEfficiency(\%) = \frac{SSC_I - SSC_E}{SSC_I} \quad \text{A10.1}$$

Where,

$$SSC_I = Mean\ Influent\ Concentration\ (mg/l) \quad \text{A10.2}$$

$$SSC_E = Mean\ Effluent\ Concentration\ (mg/l) \quad \text{A10.3}$$

The testing results must be submitted to the Department and a representative for the Maine DEP will oversee the performance of a full test at the loading rate indicated by the submitted test results to assure quality and repeatability. Samples collected at this confirmation test will be analyzed by a laboratory of the Department's choosing

Appendix 9:

Detailed Results and Graphs

Results for Indirect Method for Calculating Trap Efficiency				
Series 1				
Flow (cfs)	Average Discrete Influent (mg/l)	Average Grab Influent (mg/l)	Average Discrete Effluent (mg/l)	Trap Efficiency (%)
0.100	613	86.	1.1	99.8
0.200	324	192	2.6	99.2
0.400	514	207	3.1	99.4
0.600	411	175	3.3	99.2
0.800	407	193	2.8	99.1
1.000	526	173	2.0	99.6
1.200	116	178	3.2	97.3
Average	404	172	2.6	99.1
St Dev	166	40	0.8	0.8
Median	411	179	2.8	99.2
Series 2				
Flow (cfs)	Average Discrete Influent (mg/l)	Average Grab Influent (mg/l)	Average Discrete Effluent (mg/l)	Trap Efficiency (%)
0.100	Awaiting Results	Awaiting Results	Awaiting Results	Awaiting Results
0.200	398	109	1.778	99.6
0.400	358	86	1.960	99.5
0.600	329	200	3.407	99.0
0.800	Effluent Samples	Unreasonably High		
1.000	Peristaltic Pump Damaged	And Awaiting Repair		
1.200	227	164	1.995	99.1
Average	328	139	2.285	99.3
St Dev	73	52	0.754	0.276
Median	344	136	1.978	99.3

Table A11.1: Detailed Indirect Trap Efficiency Results

Results for Direct Method of Calculating Trap Efficiency										
Series 1	M	Sample B	Sample C	Sample C	Sample A		Sample D			
Flow (cfs)	Beginning Weight (lb)	Amount Remaining in Mixing Tank (lb)	Amount on Filter Sock (grams)	Amount on Filter Sock (lb)	Amount Collected from Chambers (lb)	Percent Trapped from fabric	Amount Retrieved from Inlet Pipe	Amount Irretrievable (lb)	Percent trapped in irretrievable locations	Trap Efficiency (%)
0.1	48	41.06	0	0.0000	5.22	78.6%	0.3	1.420	21.4%	100
0.2	50	41.36	0.1	0.0002	7.32	85.1%	0.04	1.280	14.9%	99.997
0.4	55	40.88	0.3	0.0007	10.56	74.8%	0	3.559	25.2%	99.995
0.6	53	37.086	23.96	0.0528	9	56.6%	0	6.861	43.1%	99.668
0.8	63	43.92	8.1	0.0179	15.52	81.8%	0.1	3.442	18.1%	99.906
1	60	41.5	24	0.0529	17.68	95.6%	0	0.767	4.1%	99.714
1.2	63	39.46	56.8	0.1252	19.24	81.7%	0	4.175	17.7%	99.468
									Average	99.821143
Series 2										
0.1	48	42.82	-0.9	-0.0020	3.86	75.4%	0.06	1.262	24.6%	100
0.2	51	44.78	0	0.0000	5.34	85.9%	0	0.880	14.1%	100
0.4	51	39.74	-3.5	-0.0077	8.84	78.5%	0	2.428	21.6%	100
0.6	54	40.28	-4.6	-0.0101	10.62	77.4%	0	3.110	22.7%	100
0.8	57	38.4	5.2	0.0115	14.74	79.2%	0	3.849	20.7%	99.938
1	Peristaltic	Pump	Damaged		And Awaiting		Repair			
1.2	57	38.24	60.9	0.1343	18.82	100.3%	0	-0.194	-1.0%	99.284
					Average	79.2%		Average	20.7%	99.870333

Table A11.2: Detailed Indirect Trap Efficiency Results

Results from ½ scale experiments (Direct Method)

Flow (cfs)	Hydraulic Loading Rate (gpm/ft^2)	Trap Efficiency (%)
1.2	9.686331	94.65
1	8.071942	97.78
0.4	3.228777	99.98

Table A11.4: ½ Scale Direct Trap Efficiency Results

Results from ½ scale experiments (Indirect Method, MDEP observed)

Flow (cfs)	Hydraulic Loading Rate (gpm/ft^2)	Trap Efficiency (%)
1	8.071942	95.5

Table A11.5: ½ Scale Indirect Trap Efficiency Results

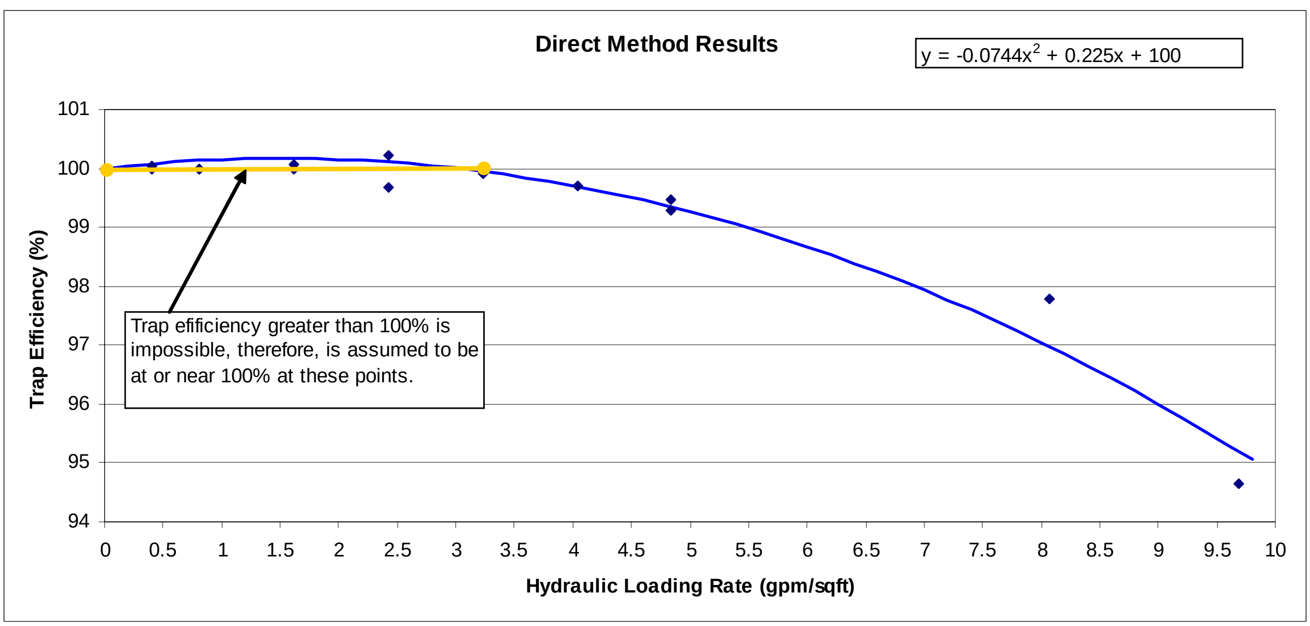


Figure A11.1: Direct Method Trap Efficiency Results

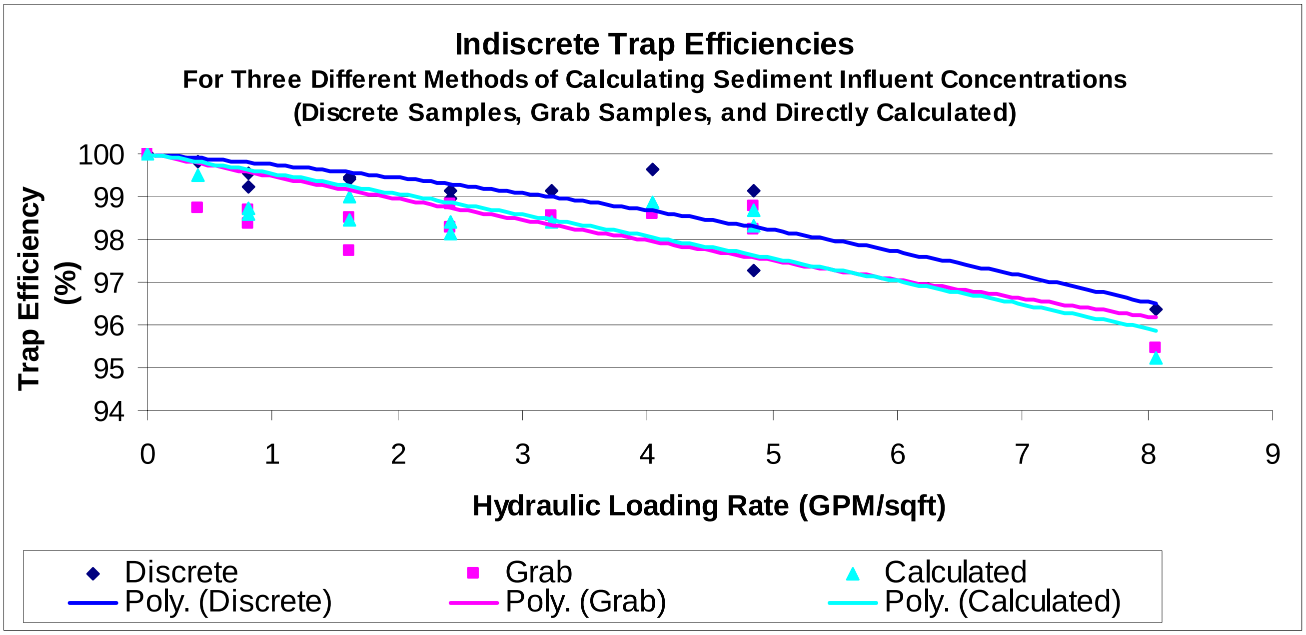


Figure A11.2: Indirect Method Trap Efficiency Results

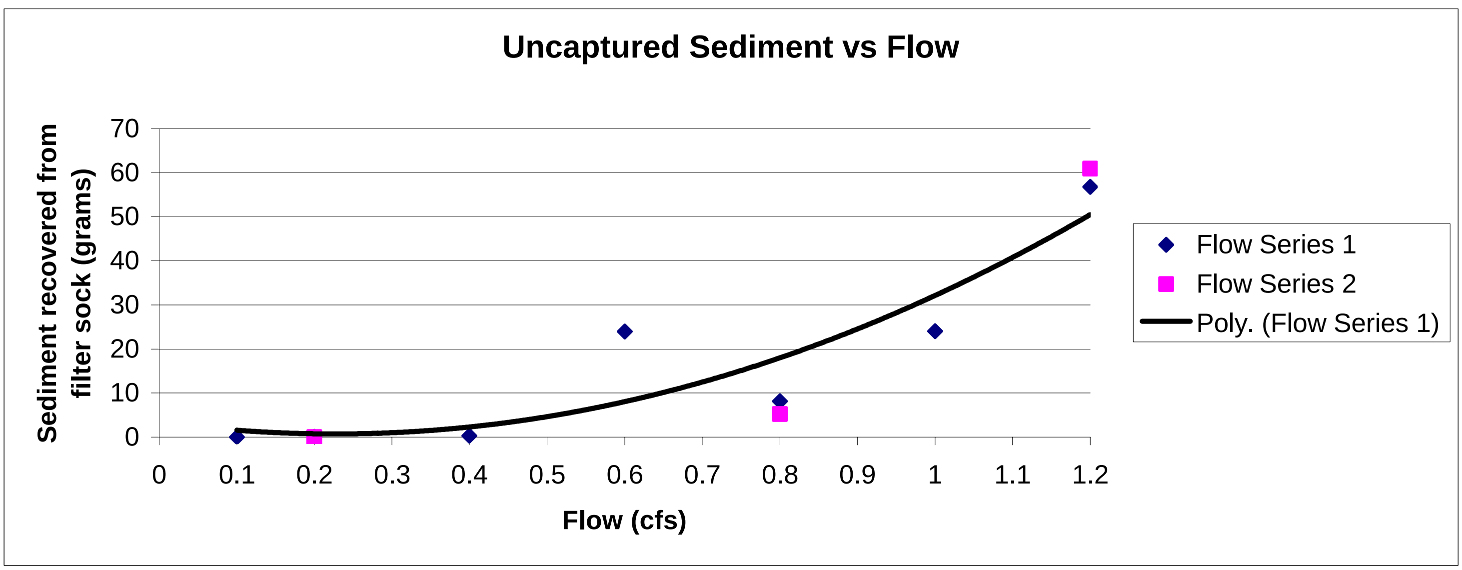


Figure A11.3: Uncaptured Sediment as a Function of Flow

Appendix 10:

Detailed SSC Results and Influent Sediment Concentrations

Date of Test:	5/24/2004
Q =	0.1 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC mg/L	Sample Volume ml		
0304555-001	0.1 CFS G1	**37.7**	1050	Avreage Grab Influent	
0304555-002	G2	**107**	980	86.16	
0304555-003	G3	**88.9**	1000		
0304555-004	G4	**101**	950		
0304555-005	G5	**96.2**	1000		
0304555-006	I Blank	**64.7**	1000	Average Discrete Influent	
0304555-007	I1	**556**	240	613.75	
0304555-008	I2	**626**	1080		
0304555-009	I3	**632**	250		
0304555-010	I4	**641**	1070		
0304555-011	I5	**1450**	320		
0304555-012	E Blank	**1.53**	600	Average Effluent	
0304555-013	E1	**1.40**	580	1.08	
0304555-014	E2	**0.52**	1050		
0304555-015	E3	**0.81**	540		
0304555-016	E4	**0.46**	1000		
0304555-017	E5	**2.21**	1000		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
5/24/2004	0.10	0.0981	5354	14852	3150760	212.10

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment retrieved (mg)	Influent Concentration (mg/L)
5/24/2004	0.10	0.0981	5354	14852	0	0.00

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	613.75	86.16	212	212
Effluent Concentration	1.08	1.08	1.08	0
Trapl Efficiency (%)	99.82	98.75	99.49	100.00

Date of Test:	4/1/2004
Q =	0.2 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC	Sample Volume		
	mg/L	ml			
0304426-001	Grab 1	254	1000	Average Grab Influent	
0304426-002	Grab 2	175	1000	192	
0304426-003	Grab 3	140	900		
0304426-004	Grab 4	199	1000		
0304426-005	I1	303	1100	Average Discrete Influent	
0304426-006	I2	309	1030	324.4	
0304426-007	I3	260	1100		
0304426-008	I4	371	1090		
0304426-009	I5	379	1090	Average Effluent	
0304426-010	E Blank	4.96	1000	2.558	
0304426-011	E1	1.87	1100		
0304426-012	E2 - E5	2.73	1120		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
4/1/2004	0.20	0.2142	3600	21803	3922560	179.91

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment retrieved (mg)	Influent Concentration (mg/L)
4/1/2004	0.20	0.2142	3600	21803	100	0.00459

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	324.4	192	179.91	179.91
Effluent Concentration	2.558	2.558	2.558	0.00459
Trapl Efficiency (%)	99.21	98.67	98.58	100.00

Date of Test:	4/7/2004
Q =	0.4 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description mg/L	SSC ml	Sample Volume		
0304458-001	g1	227	790	Average Grab Influent	
0304458-002	g2	206	730	207.6667	
0304458-003	g3	190	620		
0304458-004	I1	538	900		
0304458-005	I2	578	790	Average Discrete Influent	
0304458-006	I3	523	820	514.6	
0304458-007	I4	441	830		
0304458-008	I5	493	820		
0304458-009	E Blank	5.14	1000	Average Effluent	
0304458-010	E1	1.47	1060	3.14	
0304458-011	E2, E5	4.30	570		
0304458-012	E4	2.49	1070		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
4/7/2004	0.40	0.3888	2880	31660	6410480	202.50

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Influent Concentration (mg/L)
4/7/2004	0.40	0.3888	2880	31660	300	0.01

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	514.6	207.67	202.5	202.5
Effluent Concentration	3.14	3.14	3.14	0.01
Trapl Efficiency (%)	99.39	98.49	98.45	100.00

Date of Test:	6/2/2004
Q =	0.6 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description mg/L	SSC ml	Sample Volume	
0304459-001	g1	229	950	
0304459-002	g2	157	900	175
0304459-003	g3	139	1000	
0304459-004	I Blank	25	800	
0304459-005	I1	402	830	
0304459-006	I2	359	830	411.8
0304459-007	I3	375	800	
0304459-008	I4	457	790	
0304459-009	I5	466	800	
0304459-010	E Blank	5.06	800	
0304459-011	E1	2.92	830	
0304459-012	E2	3.03	790	3.342
0304459-013	E3	3.68	800	
0304459-014	E4	3.02	830	
0304459-015	E5	4.06	790	

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
4/12/2004	0.60	0.5883	2220	36927	7227680	195.70

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
4/12/2004	0.60	0.5883	2220	36927	23960	0.65

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	411.8	175	195.7	195.7
Effluent Concentration	3.342	3.342	3.342	0.65
Trapl Efficiency (%)	99.19	98.09	98.29	99.67

Date of Test:	6/2/2004
Q =	0.8 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC mg/L	Sample Volume ml		
0405007-032	G1	**147**	660	Average Grab Influent	
0405007-033	G2	**173**	775	193	
0405007-034	G3	**169**	665		
0405007-035	G4	**282**	775		
0405007-036	G5	**194**	740		
0405007-037	I Blank	**139**	960		
0405007-038	I2	**382**	955	Average Discrete Influent	
0405007-039	I3	**326**	930	325.4	
0405007-040	I4	**448**	990		
0405007-041	I5	**471**	950		
0405007-042	E Blank	**3.81**	910		
0405007-043	E1	**3.76**	910	Average Effluent	
0405007-044	E2	**3.65**	910	2.802	
0405007-045	E3	**2.90**	700		
0405007-046	E4	**1.99**	890		
0405007-047	E5	**1.71**	890		
0304555-048	E3	**1.67**	820		
0304555-049	E4	**0.67**	870		
0304555-050	E5	**1.52**	810		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
6/2/2004	0.80	0.8069	2169	49485	8662320	175.00

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
6/2/2004	0.80	0.8069	2169	49485	8100	0.16

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	325.4	193	175	175
Effluent Concentration	2.802	2.802	2.802	0.16
Trapl Efficiency (%)	99.14	98.55	98.40	99.91

Date of Test:	6/7/2004
Q =	1.0 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC mg/L	Sample Volume ml		
0304555-035	1.0 CFS G2	**205**	870	Avreage Grab Influent	
0304555-036	G3	**194**	750	137.2	
0304555-037	G4	**185**	830		
0304555-038	G5	**102**	860		
0304555-039	I Blank	**25.0**	980		
0304555-040	I1	**431**	970	Average Discrete Influent	
0304555-041	I2	**547**	900	525.6	
0304555-042	I3	**547**	950		
0304555-043	I4	**581**	950		
0304555-044	I5	**522**	1000		
0304555-045	E Blank	**4.71**	830		
0304555-046	E1	**2.80**	810	Average Effluent	
0304555-047	E2	**3.14**	840	1.96	
0304555-048	E3	**1.67**	820		
0304555-049	E4	**0.67**	870		
0304555-050	E5	**1.52**	810		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
6/7/2004	1.00	0.9932	1753	49234	8399000	170.60

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
6/7/2004	1.00	0.9932	1753	49234	24000	0.49

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	525.6	137.2	170.6	170.6
Effluent Concentration	1.96	1.96	1.96	0.49
Trapl Efficiency (%)	99.63	98.57	98.85	99.71

Date of Test:	5/20/2004
Q =	1.2 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC mg/L	Sample Volume ml		
0304555-018	1.2 CFS G1	**186**	880	Avreage Grab Influent	
0304555-019	G4	**180**	500	178.6	
0304555-020	G2	**187**	760		
0304555-021	G3	**152**	820		
0304555-022	G5	**188**	530		
0304555-023	I Blank	**17.8**	960	Average Discrete Influent	
0304555-024	I1	**106**	980	116.4	
0304555-025	I2	**125**	960		
0304555-026	I3	**112**	990		
0304555-027	I4	**107**	990		
0304555-028	I5	**132**	1000		
0304555-029	E Blank	**6.27**	830	Average Effluent	
0304555-030	E1	**3.64**	910	3.1775	
0304555-031	E2	**3.47**	920		
0304555-032	E3	**2.75**	910		
0304555-033	E4	**2.85**	820		
0304555-034	1.0 CFS G1	**182**	930		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
5/20/2004	1.20	1.1948	1651	55781	10687160	191.60

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
5/20/2004	1.20	1.1948	1651	55781	56800	1.02

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	116.4	178.6	191.6	191.6
Effluent Concentration	3.18	3.18	3.18	1.02
Trapl Efficiency (%)	97.27	98.22	98.34	99.47

Date of Test:	6/11/2004
Q =	0.2 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	**Sample Description**	**SSC mg/L**	**Sample Volume ml**		
0405007-061	G1	**102**	725	Average Grab Influent	
0405007-062	G2	**132**	815	108.76	
0405007-063	G3	**87.0**	835		
0405007-064	G4	**159**	770		
0405007-065	G5	**63.8**	770		
0405007-066	I Blank	**201**	990		
0405007-067	I1	**394**	990	Average Discrete Influent	
0405007-068	I2	**407**	1000	398.2	
0405007-069	I3	**379**	1000		
0405007-070	I4	**414**	980		
0405007-071	I5	**397**	960		
0405007-072	E Blank	**2.92**	780		
0405007-073	E1	**2.03**	760	Average Effluent	
0405007-074	E2	**2.41**	820	1.778	
0405007-075	E3	**1.83**	810		
0405007-076	E4	**1.43**	755		
0405007-077	E5	**1.19**	780		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
6/11/2004	0.20	0.1994	3572	20134	2823880	140.25

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated
Influent Concentration	398.2	108.76	140.25
Effluent Concentration	1.778	1.778	1.778
Trapl Efficiency (%)	99.55	98.37	98.73

Date of Test:	6/25/2004
Q =	0.4 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	**Sample Description**	**SSC mg/L**	**Sample Volume ml**		
0405007-015	G1	**117**	850	Average Grab Influent	
0405007-016	G2	**113**	790	85.74	
0405007-017	G3	**59.3**	690		
0405007-018	G4	**64.6**	790		
0405007-019	G5	**74.8**	860		
0405007-020	I Blank	**16.0**	1000		
0405007-021	I1	**346**	930	Average Discrete Influent	
0405007-022	I2	**346**	870	358.8	
0405007-023	I3	**366**	920		
0405007-024	I4	**364**	950		
0405007-025	I5	**372**	935		
0405007-026	E Blank	**2.65**	960		
0405007-027	E1	**2.65**	1100	Average Effluent	
0405007-028	E2	**3.88**	925	1.96	
0405007-029	E3	**1.19**	1050		
0405007-030	E4	**1.33**	1070		
0405007-031	E5	**0.75**	1100		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentra (mg/L)
6/25/2004	0.40	0.4006	2254	25526	5112040	20

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated
Influent Concentration	358.8	85.74	200.3
Effluent Concentration	1.96	1.96	1.96
Trapl Efficiency (%)	99.45	97.71	99.02

Date of Test:	6/22/2004
Q =	0.6 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description mg/L	SSC ml	Sample Volume		
0405007-001	G1	**168**	770	Average Grab Influent	
0405007-002	G2	**229**	780	200	
0405007-003	G3	**225**	810		
0405007-004	G4	**197**	830		
0405007-005	G5	**181**	730		
0405007-006	I Blank	**43.2**	930	Average Discrete Influent	
0405007-007	I1	**305**	920	329.5	
0405007-008	I2	**325**	960		
0405007-009	I3	**353**	900		
0405007-010	I4	**335**	920		
0405007-011	E Blank	**6.05**	750		
0405007-012	E1	**4.89**	750	Average Effluent	
0405007-013	E3	**3.44**	780	3.406667	
0405007-014	E5	**1.89**	800		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
6/22/2004	0.60	0.6000	1999	33916	6138080	180.98

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated
Influent Concentration	329.5	200	180.98
Effluent Concentration	3.41	3.41	3.41
Trapl Efficiency (%)	98.97	98.30	98.12

Date of Test:	6/28/2004
Q =	0.8 cfs

Actual Calculated Average Sediment Influent Concentrations

	Target Flow	Average Flow	Duration	Volume	Total Sediment	Influent Concentration
DATE	CFS	CFS	(seconds)	Liters)	Injected (mg)	(mg/L)
6/28/2004	0.80	0.8008	1942	43962	8444400	192.10

Actual Calculated Average Sediment Effluent Concentrations

	Target Flow	Average Flow	Duration	Volume	Total Sediment	Effluent Concentration
DATE	CFS	CFS	(seconds)	Liters)	Retreived (mg)	(mg/L)
6/28/2004	0.80	0.8008	1942	43962	5200	0.12

Trap Efficiencies

Method	Directly Calculated Concentrations
Influent Concentration	192.1
Effluent Concentration	0.12
Trapl Efficiency (%)	99.94

Date of Test:	6/15/2004
Q =	1.2 cfs

SSC Laboratory Results (Tennessee Tech Water Center)

Sample Number	Sample Description	SSC mg/L	Sample Volume ml	
0405007-048	G1	**205**	960	Average G
0405007-049	G2	**120**	950	164.4
0405007-050	G3	**177**	970	
0405007-051	G4	**167**	935	
0405007-052	G5	**153**	940	
0405007-053	I Blank	**84.3**	970	
0405007-054	I1	**216**	1000	Average I
0405007-055	I4	**239**	960	227.5
0405007-056	E Blank	**5.62**	925	
0405007-057	E1	**3.12**	940	Average E
0405007-058	E3	**2.30**	960	1.995
0405007-059	E4	**1.78**	940	
0405007-060	E5	**0.78**	940	

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
6/15/2004	1.20	1.2012	1651	56080	8517040	151.87

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
6/15/2004	1.20	1.2012	1651	56080	60900	1.09

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	227.5	164.4	151.87	151.87
Effluent Concentration	1.995	1.995	1.995	1.09
Trapl Efficiency (%)	99.12	98.79	98.69	99.28

Date of Test:	11/15/2004
Q =	0.4 cfs (scaled)

Actual Calculated Average Sediment Influent Concentrations

	Target Flow	Average Flow	Duration	Volume	Total Sediment	Influent Concentration
DATE	CFS	CFS	(seconds)	Liters)	Injected (mg)	(mg/L)
11/15/2004	0.4	0.4	1611	18220	3268800	179.4

Actual Calculated Average Sediment Effluent Concentrations

	Target Flow	Average Flow	Duration	Volume	Total Sediment	Effluent Concentration
DATE	CFS	CFS	(seconds)	Liters)	Retreived (mg)	(mg/L)
11/15/2004	0.4	0.4	1611	18220	600	0.032930845

Trap Efficiencies

Method	Directly Calculated
Influent Concentration	179.4
Effluent Concentration	0.033
Trapl Efficiency (%)	99.98

Date of Test:	11/8/2004
Q =	1.0 cfs

SSC Laboratory Results (Sawyer Environmental Research Laboratory)

Sample Number	**SSC mg/L**		
STGB	**17.7**	Avreage Grab Influent	
STG1	**256.2**	241.78	
STG2	**255.6**		
STG3	**245**		
STG4	**232.7**		
STG5	**220**	Average Discrete Influent	
STIB	**9**	302	
STI1	**268**		
STI2	**296**		
STI3	**306**		
STI4	**308.70**		
STI5	**330.60**	Average Effluent	
STEB	**10.40**	11	
STE1	**9.20**		
STE2	**10.30**		
STE3	**10.50**		
STE4	**10.80**		
STE5	**13.30**		

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
11/8/2004	1	1	1220	34489	7945000	230.36

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
11/8/2004	1	1	1220	34489	175500	5.088578967

Trap Efficiencies

Method	Discrete	Grab	Directly Calculated	
Influent Concentration	302	241.78	230.36	230.36
Effluent Concentration	11	11	11	5.09
Trapl Efficiency (%)	96.36	95.45	95.22	97.79

Date of Test:	11/1/2004
Q =	1.2 cfs (scaled)

Actual Calculated Average Sediment Influent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Injected (mg)	Influent Concentration (mg/L)
11/1/2004	1.2	1.2	1024	34730	5511560	158.7

Actual Calculated Average Sediment Effluent Concentrations

DATE	Target Flow CFS	Average Flow CFS	Duration (seconds)	Volume Liters)	Total Sediment Retreived (mg)	Effluent Concentration (mg/L)
11/1/2004	1.2	1.2	1024	34730	294000	8.465303772

Trap Efficiencies

Method	Directly Calculated
Influent Concentration	158.7
Effluent Concentration	8.47
Trapl Efficiency (%)	94.66

Indirect Trap Efficiencies

			Trap Efficiencies (Discrete Effluent (%)			Direct Only
Q (CFS)	Q (GPM)	HLR (GPM/ft^2)	Discrete	Grab	Calculated	
0	0	0	100	100	100	100
0.1	44.88	0.40	99.82	98.75	99.49	100
0.2	89.76	0.81	99.21	98.67	98.58	99.997449
0.4	179.52	1.61	99.39	98.49	98.45	99.995062
0.6	269.28	2.42	99.14	98.82	98.40	99.667859
0.8	359.04	3.23	99.14	98.55	98.40	99.908571
1	448.80	4.04	99.63	98.57	98.85	99.712778
1.2	538.56	4.84	97.27	98.22	98.34	99.467641
0.2	89.76	0.81	99.55	98.37	98.73	100
0.4	179.52	1.61	99.45	97.71	99.02	100
0.6	269.28	2.42	98.97	98.30	98.12	100
1.2	538.56	4.84	99.12	98.79	98.69	99.282281
1.0 (Scaled)	448.80	8.07	96.36	95.45	95.22	97.790415

Summary of Influent and Effluent Sediment Concentrations

			Influent			Effluent	
Q (CFS)	Q (GPM)	HLR (GPM/ft^2)	Discrete	Grab	Calculated	Discrete	Calculated
0	0	0	0	0	0	0	0
0.1	44.88	0.40	613.75	86.16	212	1.08	0
0.2	89.76	0.81	324.4	192	179.91	2.558	0.00459
0.4	179.52	1.61	514.6	207.67	202.5	3.14	0.01
0.6	269.28	2.42	411.8	175	195.7	3.342	0.65
0.8	359.04	3.23	325.4	193	175	2.802	0.16
1	448.80	4.04	525.6	137.2	170.6	1.96	0.49
1.2	538.56	4.84	116.4	178.6	191.6	3.18	1.02
0.2	89.76	0.81	398.2	108.76	140.25	1.778	0
0.4	179.52	1.61	358.8	85.74	200.3	1.96	0
0.6	269.28	2.42	329.5	200	180.98	3.41	0
1.2	538.56	4.84	227.5	164.4	151.87	1.995	1.09
1.0 (Scaled)	448.80	8.07	302	241.78	230.36	11	5.09
Average	265.83	2.70	342.15	151.56	171.62	2.94	0.65

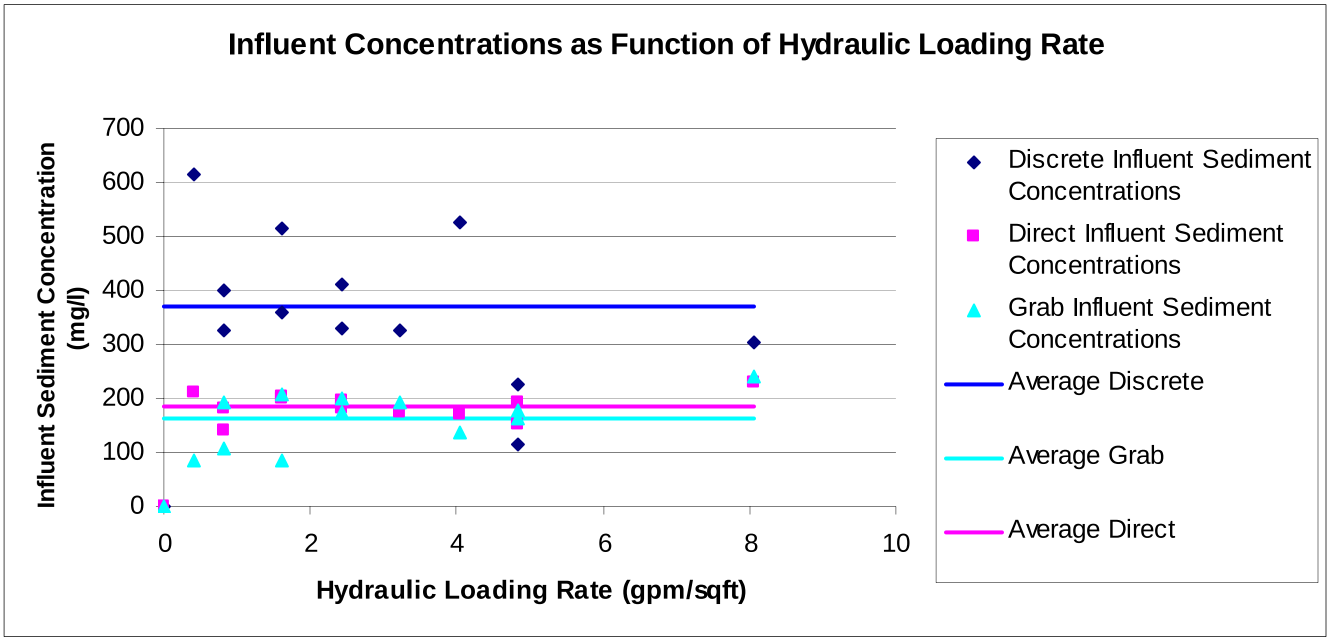


Figure A10.1: Illustration of various methods of determining sediment influent concentration

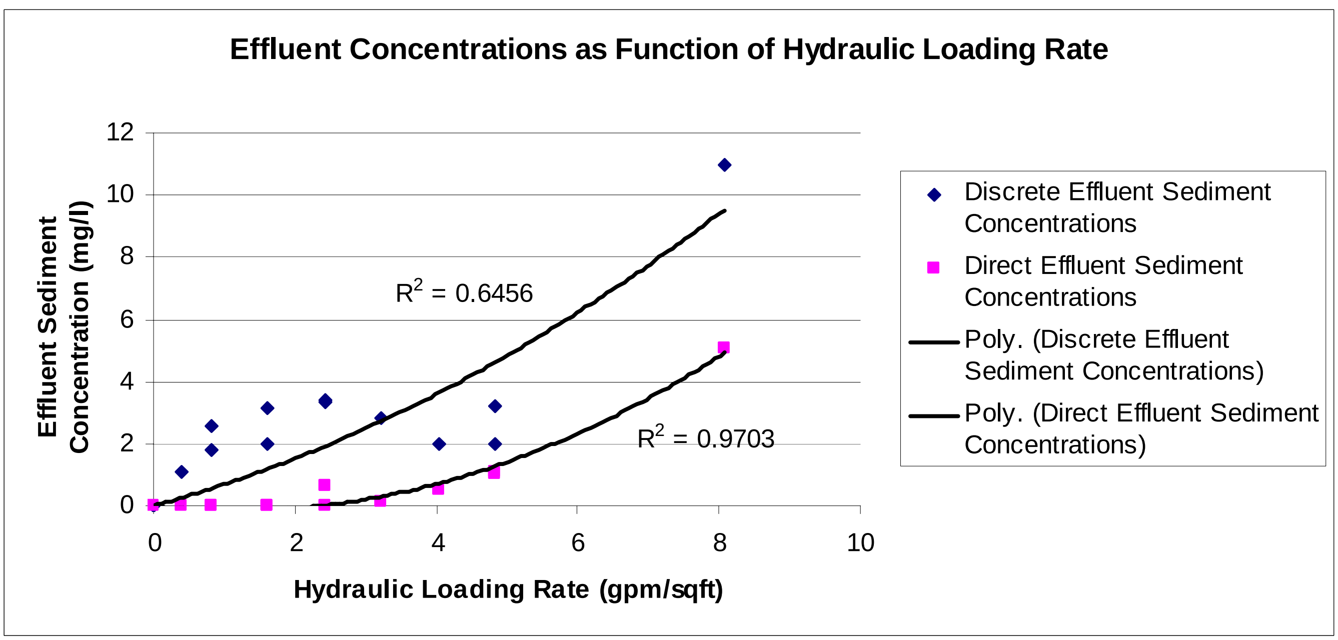


Figure A10.2: Illustration of various methods of determining sediment effluent concentration

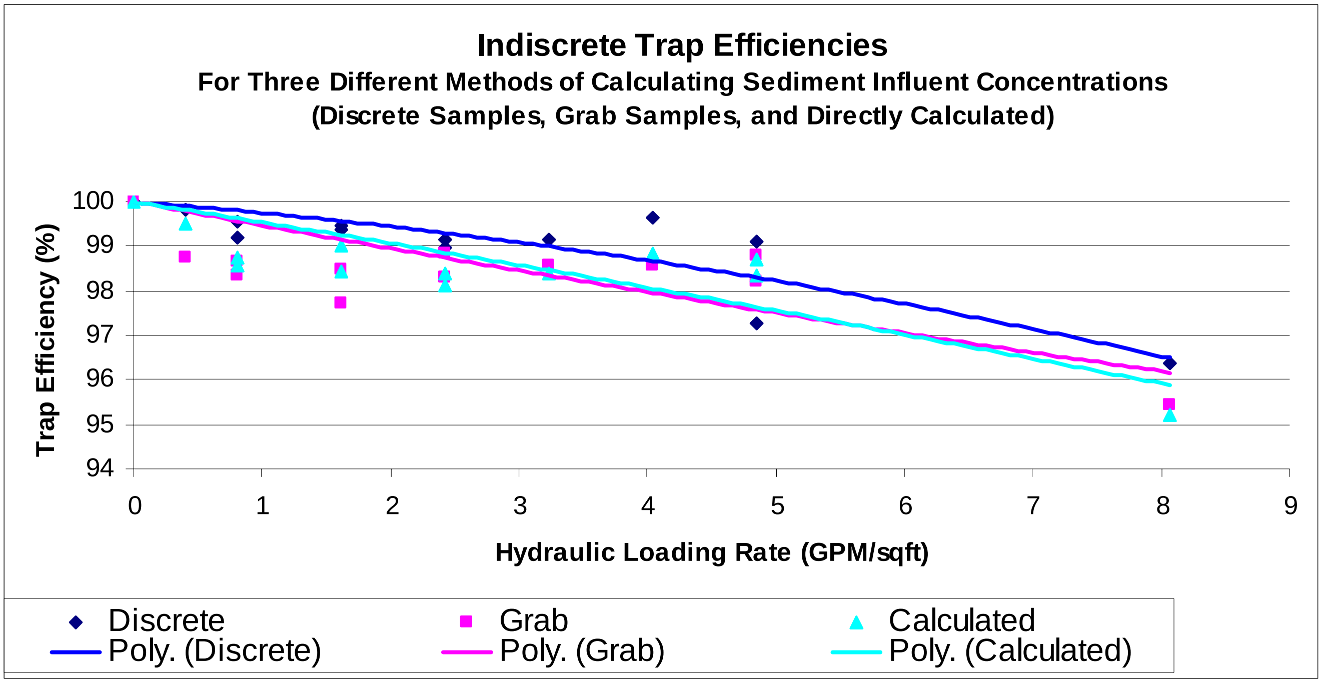


Figure A10.3: Illustration indirectly calculated trap efficiency using three different methods of determining influent sediment concentrations.

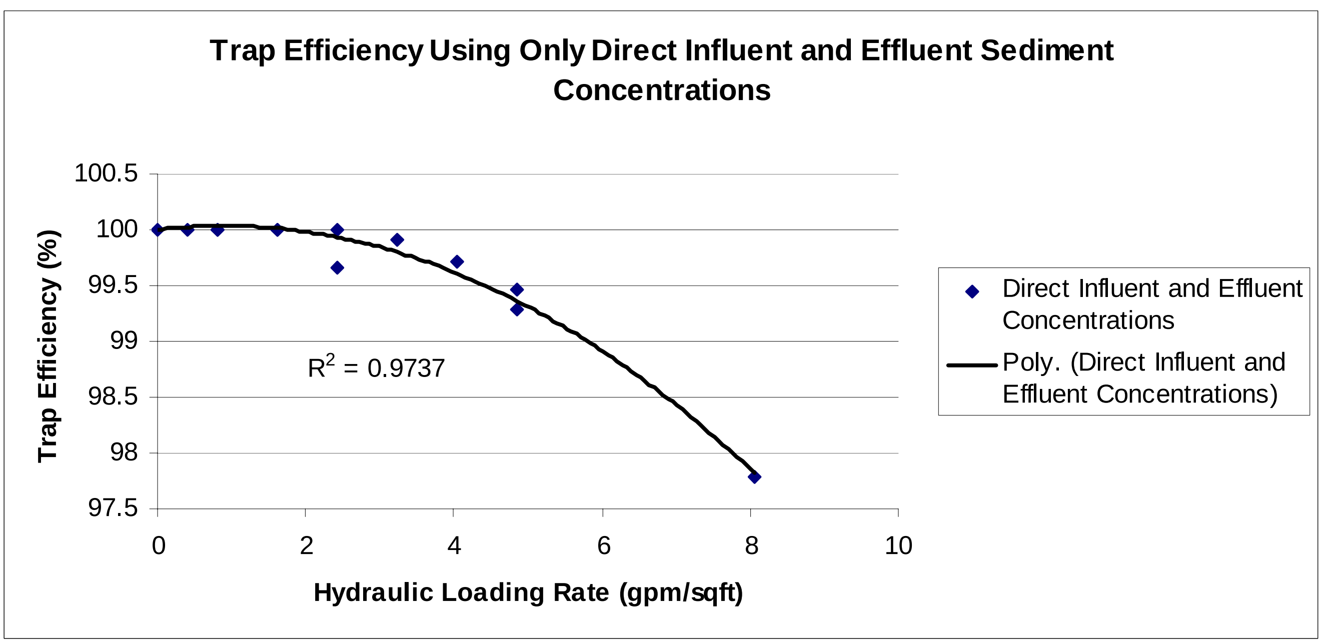


Figure A10.4: Illustration of trap efficiency calculated using only directly determined influent and effluent concentrations.

Appendix 11:
Maine Department of Environmental Protection Results, Observations, and Conclusions

STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION

N ELIAS BALDACCI
GOVERNOR

DAWN R. GALLAGHE
COMMISSIONER

December 13, 2004

Gregg Novick and David Mailhot
StormTech, LLC.
20 Beaver Road, Suite 104
Wethersfield, CT 06109

Dear Sirs,

The purpose of this letter is to inform you that, in accordance with the Laboratory Testing Protocol for Manufactured Treatment Systems and based on the results of the confirmation test for removal of OK-110 grade silica sand performed on November 8,2004 and described in the attached report, the Stormtech SC-740 Isolator Row stormwatter treatment device is approved for a total suspended solids (TSS) removal rating of 60%, provided that the device is sized such that the projected one year peak flow from the device's drainage area does not exceed the flow indicated by the following formula:

Q_{1ypf} = (0.5 cfs)(number of SC-740 treatment chambers in the Isolator Row)

This sizing factor is based on the fact that a two chamber StormTech SC-740 Isolator Row has been shown to provide at least 80 % removal of OK-110 grade silica sand at a flow of 1.0 cfs (see attached report). In the confirmation test the unit demonstrated an average OK-110 silica sand removal rate of 95.5%.

The StormTech Isolator Row does not provide for removal of floating hydrocarbons. It is therefore recommended that it be preceded by some type of device or practice that will serve this function if the area draining to the device is a likely source of hydrocarbons (i.e. parking lots, roads, drive-through commercial enterprises).

If you have any questions regarding this letter or the attached report, please feel free to call Jeff Dennis at 207-287-7847.

Sincerely,

Donald T. Witherill
Division of Watershed Management

A
HOUSE STATION
A, MAINE 04333-0017
7688
G., HOSPITAL ST.

BANGOR
106 HOGAN ROAD
BANGOR, MAINE 04401
(207) 941-4570 FAX: (207) 941-4584

PORTLAND
312 CANCO ROAD
PORTLAND, MAINE 04103
(207) 822-6300 FAX: (207) 822-6303

PRESQUE ISLE
1235 CENTRAL DRIVE, SKYWA
PRESQUE ISLE, MAINE 04769-
(207) 764-0477 FAX: (207) 764-15

StormTech SC-740 Isolator Row OK-110 Sand SSC (TSS) Removal Confirmation Test
November 8, 2004

Reported by Jeff Dennis
Division of Watershed Management, DEP

On November 8, 2004 I witnessed a confirmation test of the ability of a two chamber StormTech SC-740 Isolator Row unit to remove OK-110 grade silica sand. The test was performed in Dr. Vince Neary's hydraulics laboratory at Tennessee Tech University in Cookeville, Tennessee. The target flow rate for the test was 1.0 cfs or 0.5 cfs per chamber.

Lab Set-Up

The laboratory set-up for the test consists of two SC-740 chambers secured to a wooden frame and resting on a 12 inch bed of No. 3 angular stone (AASHTO M43#3) substrate contained in a wooden flume with interior W x L x H dimensions of 6.25 ft x 16.2 ft x 3 ft. The chambers are covered with Mirafli 160N non-woven geotextile fabric. Miralfi 600X woven geotextile fabric is placed at the bottom of the chamber to stabilize the stone and to prevent scouring of the stone base.

Water is delivered to the chambers by an 8" aluminum pipe that is fed by a 25 horsepower variable speed pump. It discharges from the flume bed via an 8" drain to the laboratory trench that feeds the sump. A 50 micron filter sock is located in the trench at the outlet of the drain to prevent recirculation of sediment not captured by the chambers. Flow rates are measured by a ThermoPolysonic DCT 7088 ultrasonic flow meter.

The slurry of OK-110 sand is fed via a peristaltic pump into the inflow pipe upstream of the ISCO inflow sampling port. A butterfly valve is located between the slurry feed and the sampling port to promote sediment mixing. The inflow sampling port is located 51 inches upstream of the inlet to the chambers and 12 inches downstream of the butterfly valve. There is also an ISCO sampling port in the outflow drain pipe 22 inches from the outlet of the flume.

Test Procedure

The operating rate being tested was 1.0 cfs, or 0.5 cfs per chamber. The mean water detention time in the system at this flow rate is 1 minute 22 seconds. Outflow samples lagged their inflow pair by this amount. The interval between samples for both the inflow and outflow samples was 3 minutes and 45+ seconds. Back ground samples were taken every minute. Flow was recorded every minute during the test.

For this test two sets of inflow samples were collected. The first set was collected by an ISCO 6712 discrete sampler via and inlet strainer in the inflow sampling port. The second set was a grab sample taken as a sweep across the face of the inlet pipe where it flowed into the chambers. Two systems were used because there is a possibility that an ISCO strainer in the pipe might selectively sample in the lower portion of the pipe, perhaps collecting more sediment than would be representative of the mean concentration in the inflow. This should not be the case with the grab sweep sample, which would theoretically yield a more conservative value for the inflow concentration. The outflow sample was collected using an ISCO 6712 discrete sampler with the intake strainer located in the 8 inch outlet drain pipe.

The flow rate was stabilized and the slurry feed pump started by 3:11 PM. The system was then allowed to reach equilibrium for at least a period of three detention times, or 4 minutes 7 seconds, before the first inflow sample, was taken at 3:15. Outflow sampling commenced 1 minute 22 seconds later, at 3:16+. Flow was monitored continuously during the test to insure that it stayed relatively constant at the selected test flow of 1.0 cfs.

Samples were taken to the Sawyer Environmental Chemistry Lab for Suspended Sediment Concentration analysis. The analysis was performed by John Cangelosi.

Results

Results of the test are presented in the attached tables. ISCO collected inflow concentrations ranged from 267.7 mg/l to 330.6 mg/l, with a mean of 301.8 mg/l. Grab sweep inflow concentrations were somewhat lower, ranging from 219.7 mg/l to 256.2 mg/l, with a mean of 241.8 mg/l. Outflow concentrations ranged from 9.2 mg/l to 13.3 mg/l, with a mean of 10.2 mg/l.

Using the more conservative grab sweep inflow concentrations, the removal efficiencies indicated by inflow/outflow pairs ranged from 93.9% to 96.4%, with a mean of 95.5%.

Flow for the test was remarkably constant, varying only from 0.99 cfs to 1.02 cfs with a mean of 1.005 cfs, very near the target flow rate.
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Conclusions

The mean removal efficiency of OK-110 grade silica sand using the more conservative grab sweep inflow concentrations was 95.5%, so the test indicates that, at a flow rate of 1.0 cfs, a two chamber StormTech SC-740 Isolator Row unit can remove 80% or more of OK-110 grade silica sand. Variation in paired removal efficiencies was acceptably low, and variation in inflow concentration acceptable.

Therefore, the conclusion of this report is that the test performed on November 8, 2004, in substantial accordance with the Lab Testing Protocol, indicates that a two chamber StormTech SC-740 Isolator Row unit operating at an average flow rate of 1.0 cfs can be expected to provide more than 80% removal of the specified OK-110 grade silica sand.

Signed: Jeffrey Dennis Date: December 13, 2004

StormTech SC-740 Isolator Row OK-110 Sand Confirmation Test
11/8/04

	Inflow (mg/l) ISCO	Inflow (mg/l) Grab	Time	Outflow (mg/l) ISCO	Time	Background	Rem. Eff. ISCO/ISCO	Rem. Eff. Grab/ISCO
						9.1/17.7		
1	267.7	256.2	3:15	9.2	3:16		96.6	96.4
2	296.0	255.6	3:18	10.3	3:20		96.5	96.0
3	306.3	244.7	3:22	10.5	3:24		96.6	95.7
4	308.7	232.7	3:26	10.8	3:29		96.5	95.3
5	330.6	219.7	3:30	13.3	3:32		96.0	93.9
						10.4		
Mean	301.8	241.8		10.8			96.4	95.5

Flow	cfs
1	1.01/1.01
2	1.01/1.00
3	1.02/1.00
4	1.02/0.99
5	1.01/1.00
mean	1.005

Note: Mean Residence Time = 1.37 minutes, Test Flow = 1.0 cfs, OK-110 sand 52 lb from DEP, 8 lb T. Tech

Sawyer Environmental
Chemistry Research Laboratory

1865 THE UNIVERSITY OF
MAINE

5764 Sawyer Environmental
Research Center
Orono, Maine 04469-5764
Tel: 207-581-3288/3415
Fax: 207-581-3290
www.umaine.edu

December 6, 2004

David Mailhot
StormTech
20 Beaver Road
Suite 104
Wethersfield, CT 06109

Dear Mr. Mailhot:

Here is an invoice and a hard copy of the sediment concentration in water data. I have also sent the data to Jeff Dennis. If you have any questions please let me know.

Sincerely,

John Cangelosi

John Cangelosi
Sawyer Environmental Chemistry Research Laboratory
5764 Sawyer Environmental Research Center
University of Maine
Orono, ME 04469-5764
(207) 581-3239
Fax: 581-3290

John.Cangelosi@umit.maine.edu

Sawyer Environmental
Chemistry Research Laboratory

1865 THE UNIVERSITY OF MAINE

5764 Sawyer Environmental
Research Center
Orono, Maine 04469-5764
Tel: 207-581-3288/3415
Fax: 207-581-3290
www.umaine.edu

Sample ID	Sediment conc. (mg/L)
STGB	17.7
STG1	256.2
STG2	255.6
STG3	244.7
STG4	232.7
STG5	219.7
STIB	9.1
STI1	267.7
STI2	296.0
STI3	306.3
STI4	308.7
STI5	330.6
STEB	10.4
STE1	9.2
STE2	10.3
STE3	10.5
STE4	10.8
STE5	13.3

Sawyer Environmental
Chemistry Research Laboratory

1865 THE UNIVERSITY OF MAINE

5764 Sawyer Environmenta
Research Cente
Orono, Maine 04469-576
Tel: 207-581-3288/341
Fax: 207-581-329
www.umaine.ed

Invoice: 800932

Date: December 8, 2004

David Mailhot
StormTech
20 Beaver Road
Suite 104
Wethersfield, CT 06109

Purchase Order Number: None

Credit Account Number: 5-1-79321-040

Date	Quantity	Description	Unit Price	Amount
December 2004 Billing				
12/6/2004	18	Total sediment concentration in water	$32.00	$576.00
			Total Price:	**$576.00**

If you have any questions regarding this invoice, please contact
Jean Ketch, Sawyer Environmental Chemistry Research Laboratory, 202 Sawyer Environmental Research Center
University of Maine, Orono, ME 04469 Tel: (207) 581-3415 Fax: (207) 581-3290
Email: jean.ketch@umit.maine.edu

Make Check Payable to: University of Maine

Mail Payment to: University of Maine
Attn: Kim Hickson, Accounts Receivable, 5703 Alumni Hall, Room 100, Orono, ME 04469-5703

Please Reference Invoice Number on Payment. Thank you

<u>Appendix 12:</u>
Pictures

Pictures from the Stormtech SC -740Sediment Removal Efficiency Experiments

Note: All pictures are taken post-run, following draining of all water. Pictures also contain shadows, which can be misleading.

O.4 CFS

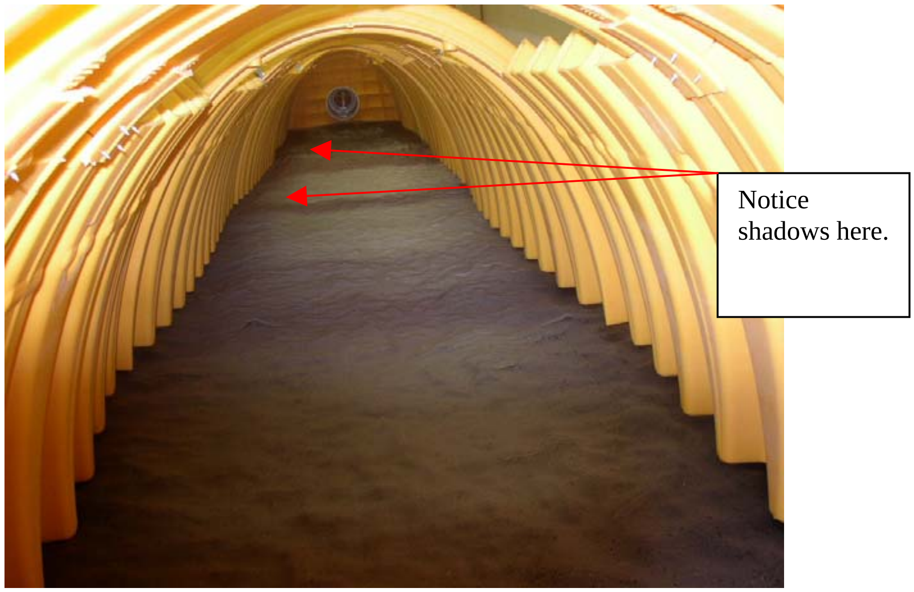


Figure A12.1– View from fourth chamber looking upstream at the inlet pipe. Hydraulic loading rate = 1.61 gpm/ft^2 (6/29/04)

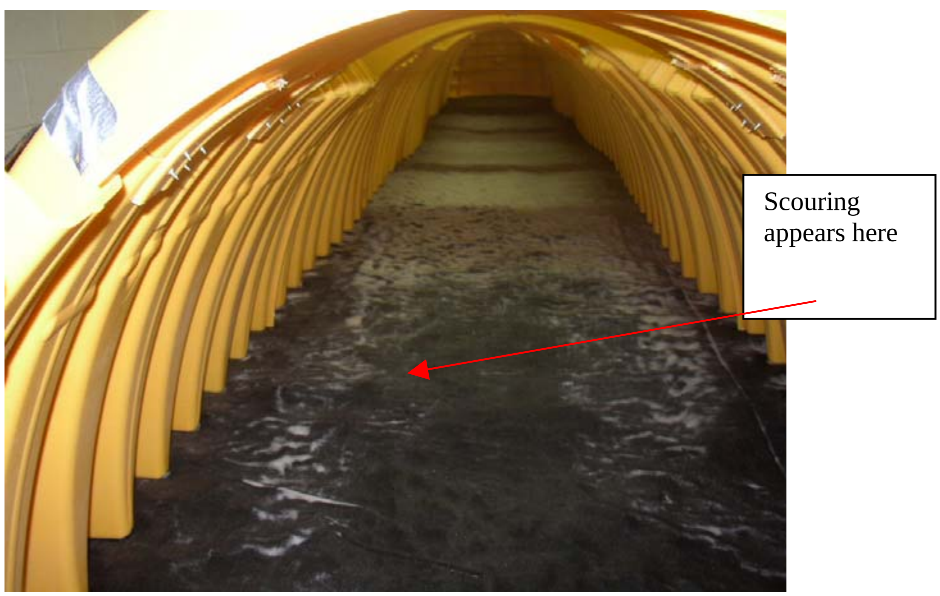


Figure A12.2– View from first chamber looking downstream. Notice the bare area where scouring of the sediment appears to have occurred. . Hydraulic loading rate = 1.61 gpm/ft^2 (6/29/04)

0.4 CFS - Continued

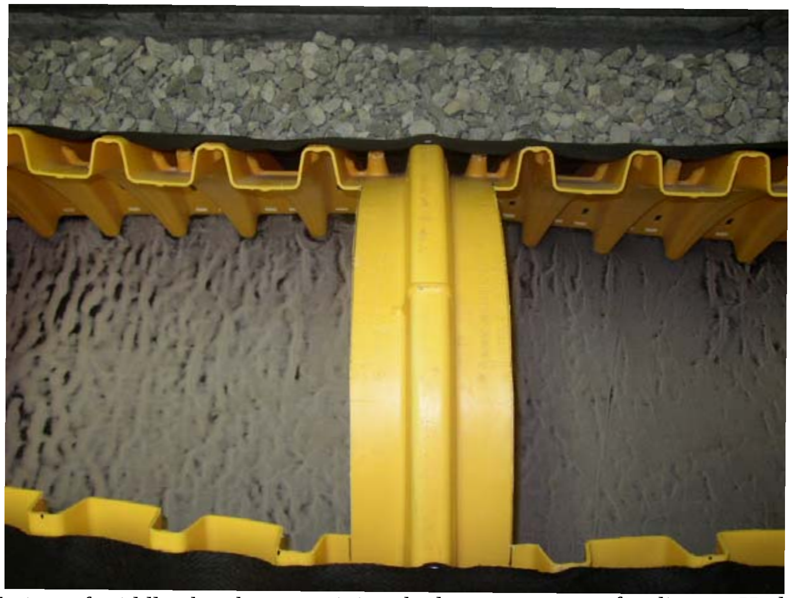


Figure A12.3– Overhead view of middle chamber containing the largest amount of sediment. Hydraulic loading rate = 1.61 gpm/ft^2 (6/29/04)

Pictures from the Stormtech SC -740Sediment Removal Efficiency Experiments

Note: All pictures are taken post-run, following draining of all water. Pictures also contain shadows, which can be misleading.

1.2 CFS

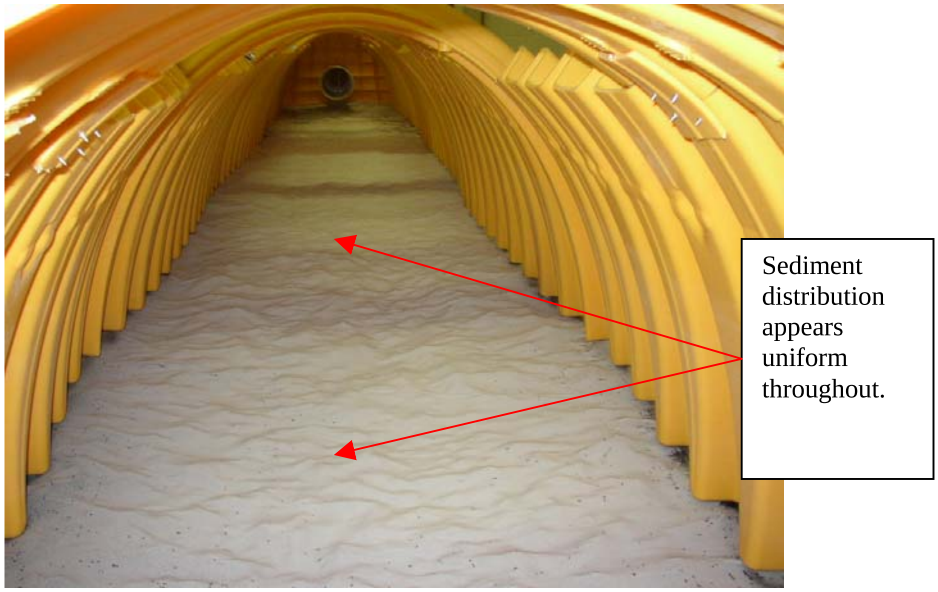


Figure A12.4- View from fourth chamber looking upstream at the inlet pipe. Notice the large volume and uniform distribution of sediment at this high flow. Hydraulic loading rate = 4.84 gpm/ft^2 (6/19/04)

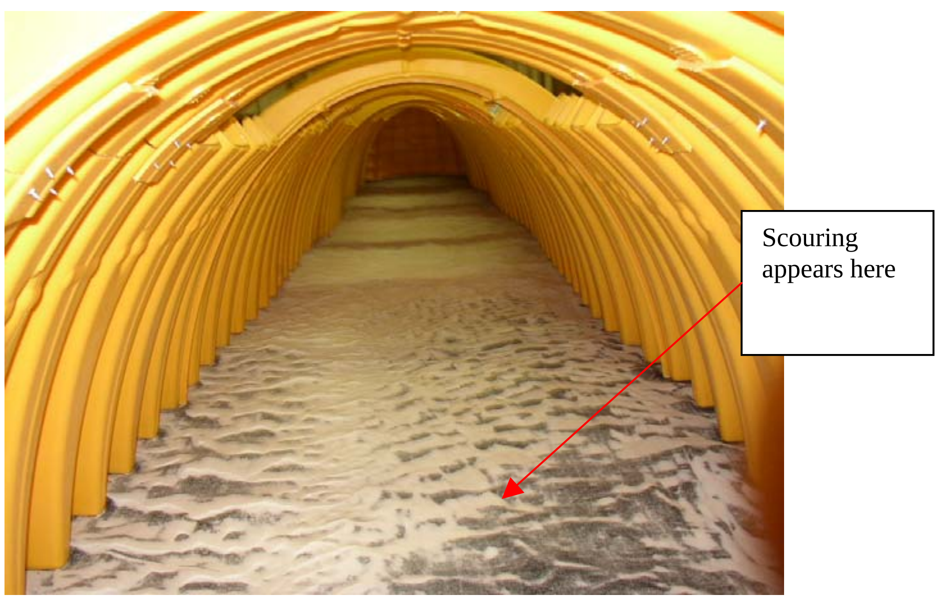


Figure A12.5– view looking downstream from first chamber. Again, scouring of sediment occurs near inlet, however, not to the degree of the lower flows. Hydraulic loading rate = 4.84 gpm/ft^2 (6/19/04)

1.2 CFS - Continued

Figure A12.6 – Overhead view of middle chambers with largest volume of sediment. At this high flow, sediment distribution was particularly uniform. . Hydraulic loading rate = 4.84 gpm/ft^2 (6/19/04)

Pictures from the Stormtech SC -740Sediment Removal Efficiency Experiments

Note: All pictures are taken post-run, following draining of all water. Pictures also contain shadows, which can be misleading.

0.1 cfs

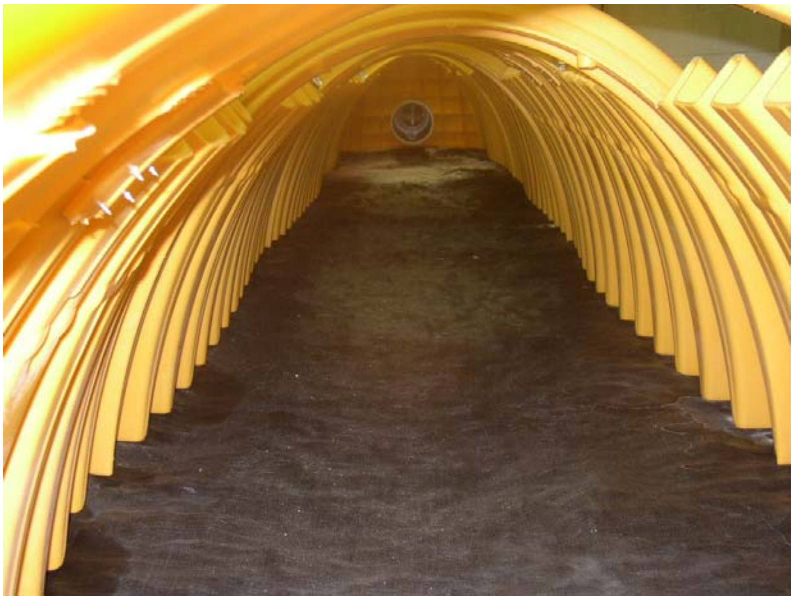


Figure A12.7 - View from fourth chamber looking upstream at the inlet pipe. Notice that all sediment is deposited within first chamber. Hydraulic loading rate = 0.4 gpm/ft^2 (7/4/04)

Figure A12.8 – view looking downstream from first chamber. Again, scouring of sediment occurs near inlet, and sediment is deposited mainly in first chamber. Hydraulic loading rate = 0.4 gpm/ft^2 (7/4/04)

0.1 CFS – Continued

Figure A12.9 – Overhead view of first chamber containing majority of sediment. Hydraulic loading rate = 0.4 gpm/ft^2 (7/4/04)

CITY of CHARLOTTE
Pilot SCM Monitoring Program

Cherry Gardens Senior Apartments
Storm Tech Chambers Stormwater Treatment Structure

Final Monitoring Report

July 2013

Prepared By:

Steve Jadlocki
Kyle Hall, EI
Jeff Price

Charlotte-Mecklenburg Storm Water Services

INTRODUCTION

The City of Charlotte through its Stormwater Services Division maintains an aggressive Pilot Stormwater Control Measure (SCM) Program. The purpose of the pilot program is to monitor various types of structural SCMs within varied land use types to determine their best use and effectiveness in Charlotte's overall stormwater quality management program. Specifically, the program strives to determine the cost benefit, pollutant removal and load reduction efficiency, quantity control, and operation & maintenance costs/requirements of the various structural SCMs within the pilot program. The City utilizes information gained under the Pilot SCM Program to support water quality management efforts and the development and refinement of local SCM standards for land development projects.

During 2008, the City of Charlotte began reviewing plans for the Cherry Gardens Senior Apartments in Charlotte. The developer for the project had requested to utilize Storm Tech Chambers, a proprietary SCM technology in lieu of conventional stormwater treatment for the site. Although this proprietary technology was not approved for use within the City, under the Pilot SCM program the City was able to grant approval for installation of the SCM technology within the project stormwater system design.

Storm Tech chambers feature a unique sub-surface design of open bottom polypropylene chambers set on a stone bed within an excavation trench. The internal volume of the chambers, as well as the void space of the stone bedding and chamber surrounding stone material provide stormwater storage volume designed to meet water quality and detention requirements. In addition, the system features an "isolator row" to provide water quality treatment of stormwater as it enters the system. The isolator row features a typical Storm Tech chamber wrapped with filter fabric. Stormwater first enters the isolator row which traps sediments and pollutants via the filter fabric and then allows stormwater to pass through the fabric in a treated state to the adjacent chambers and stone material via hydrostatic flow. The overall system typically features a 6-inch HDPE perforated under drain line placed along one side of the excavation bottom to provide flow discharge control from the system. Because the excavation for the system is typically unlined, some infiltration of stormwater can be expected if sub-surface soils are conducive to infiltration.

This monitoring report will focus on the installation, monitoring, and water quality treatment effectiveness of the Storm Tech Chambers installed to treat the parking lot portion of the site. Additional information about the SCM is available at the Storm Tech website: www.stormtech.com

PROJECT DESIGN

The project design called for the installation of a Storm Tech Chamber system to treat 0.41 acres of the site. The watershed area draining to the SCM consisted of approximately 85% impervious surface comprised of a parking lot and adjoining sidewalk within a residential land use. The SCM system was designed to treat the 1-inch water quality volume and meet the stormwater detention requirements for Charlotte. The system was also designed with a bypass pipe to allow higher flows to bypass the isolator row and flow directly into adjoining chambers in the system.

The overall system design called for 5 rows of Storm Tech chambers, one of which was the isolator row. **Figures 1 and 2** show the plan view layout and SCM details for the project respectively.

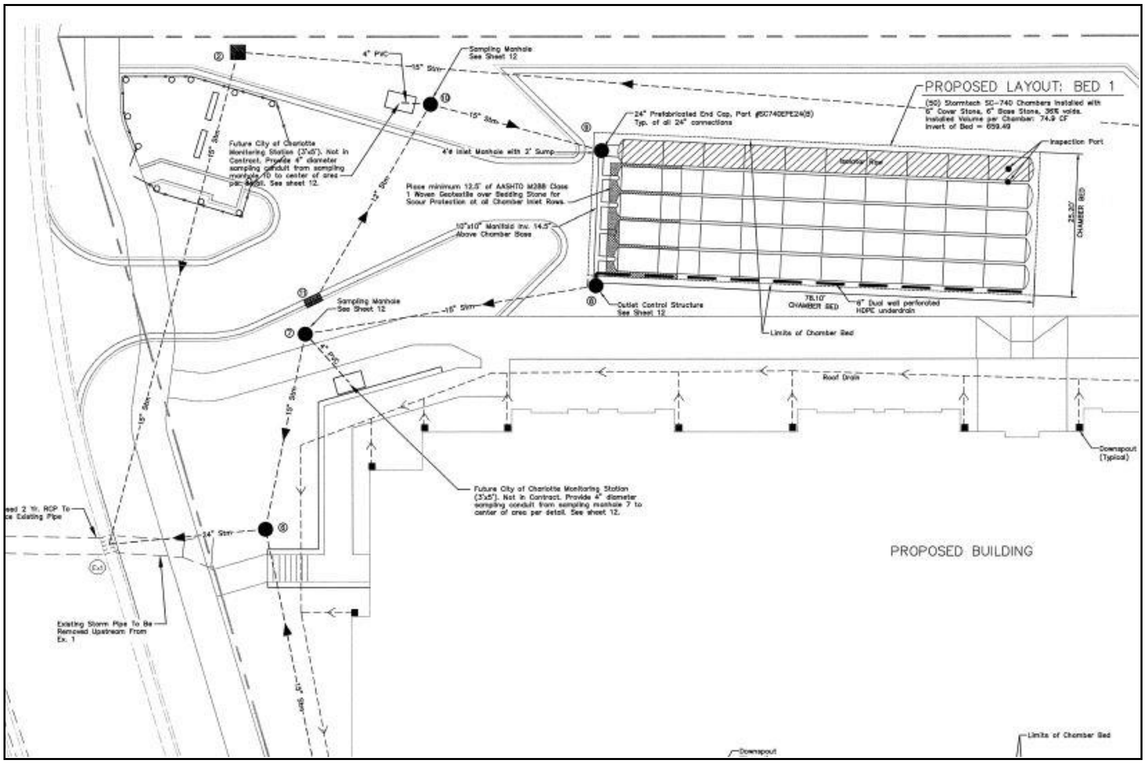
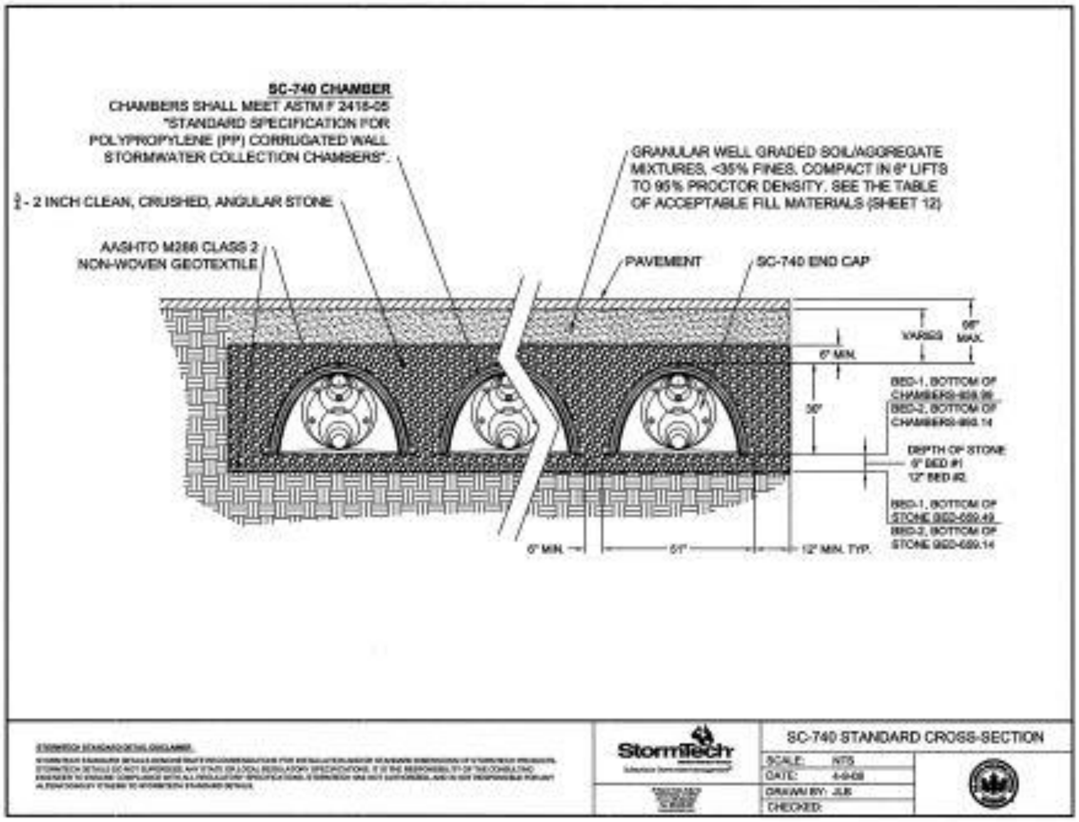


Figure 1: Cherry Gardens Storm Tech Plan View Layout



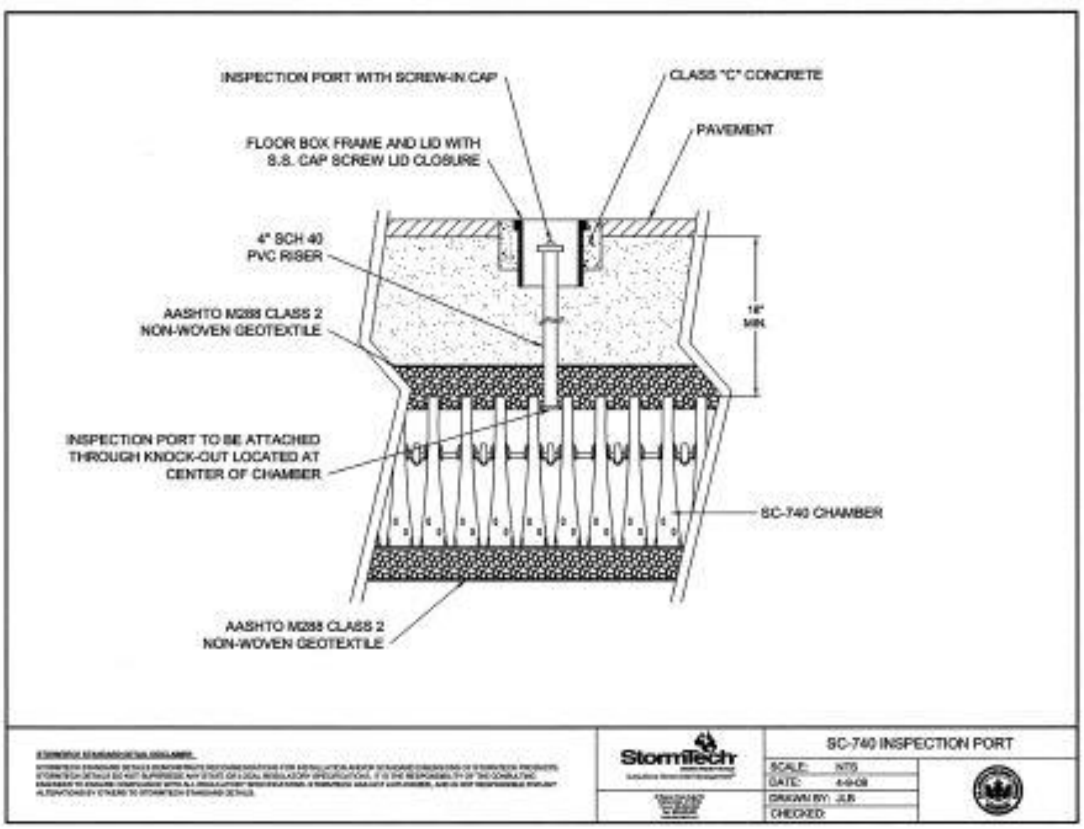


Figure 2: Storm Tech Details

Figure 3 shows the installation of the Storm Tech unit at Cherry Gardens. Note the five Storm Tech chamber rows with the Isolator Row at the left.

Figure 3: Storm Tech Unit Installation – *Photo courtesy of Dan Trask, Storm Tech*

SCM PERFORMANCE MONITORING

Performance monitoring for the Storm Tech Chambers SCM on site consisted of conducting full storm hydrograph flow-weighted composite sampling of the stormwater influent to and effluent from the SCM. Teledyne ISCO Avalanche Model 6712 refrigerated auto-sampling equipment with ISCO Model 720 bubbler flow module was used to conduct the monitoring. In-line weirs were placed at the influent and effluent sampling locations as a primary device for flow measurement in conjunction with the ISCO Model 720 bubbler flow module.

Composite samples were collected over the period from December 2010 to May 2012 and yielded 14 paired storm event samples suitable for statistical analysis. Laboratory sample analysis was conducted for the parameters shown in **Figure 6** with each sample result yielding an Event Mean Concentration (EMC) for each parameter at each monitoring location. Monitoring and subsequent statistical data analysis was based on guidance provided by the EPA and ASCE in the 2002 and 2009 publications, *Urban Stormwater Performance Monitoring*. **Figures 4 and 5** show typical monitoring equipment utilized. **Appendices B, C, and D** discuss the Pilot SCM program monitoring protocols and operating procedures. **Appendix F** discusses the Charlotte-Mecklenburg monitoring program QAPP.

Figure 4: In-Line Monitoring Weir

Figure 5: Automated Monitoring Equipment

DATA ANALYSIS

As stated above, project monitoring yielded data from 14 paired storm event samples suitable for statistical analysis. This produced Event Mean Concentrations (EMCs) for each parameter analyzed for both the SCM influent and effluent monitoring points. The data were analyzed using non-parametric statistical methods that account for data below detection limits (Helsel, 2005). Specifically robust regression on order statistics were used to calculate summary statistics, including the median event mean concentrations used to calculate the percent concentration reduction for each parameter. The modified sign test was used to test for significant differences between influent and effluent paired samples. For parameters where data analysis did not produce a statistically significant result, a value of zero percent (0%) reduction was assigned to the parameter as non-significant results are considered to be not statistically different from zero.

Figure 6 shows the parameters sampled and corresponding information including median event mean concentrations and statistically significant percent reductions. **Appendix E** discusses the Pilot SCM program data analysis protocol.

Parameter	Units	# of paired samples	Influent (median values)	Effluent (median values)	% Reduction	P-Value	Significant at 0.05
Ammonia Nitrogen	**mg/L**	**14**	**0.32**	**0.09**	**71.5%**	**0.0182**	**Y**
Nitrite + Nitrate	mg/L	14	0.28	0.35	0%	0.9713	N
TKN	**mg/L**	**13**	**1.10**	**0.45**	**59.5%**	**0.0001**	**Y**
Total Nitrogen	**mg/L**	**13**	**1.24**	**0.78**	**37.1%**	**0.0001**	**Y**
Total Phosphorus	**mg/L**	**14**	**0.19**	**0.06**	**68.1%**	**0.0001**	**Y**
SSC	**mg/L**	**13**	**98.0**	**5.90**	**94%**	**0.0017**	**Y**
TSS	**mg/L**	**14**	**54.0**	**5.60**	**89.6%**	**0.0001**	**Y**
Turbidity	**NTU**	**13**	**18.0**	**6.85**	**61.9%**	**0.0001**	**Y**
Chromium	ug/L	14	2.11	*	*	*	*
Copper	ug/L	14	10.20	9.50	0%	0.6047	N
Lead	ug/L	14	1.55	*	*	*	*
Zinc	**ug/L**	**14**	**54.50**	**13.0**	**76.1%**	**0.0001**	**Y**

* Data set contained too many non-detect values to accurately calculate summary statistics or provide statistical analysis

Figure 6: Cherry Gardens Apartments – Storm Tech Chambers - Data Analysis Results

CONCLUSIONS

The results of the data analysis for the Storm Tech Chambers SCM showed statistically significant event mean concentration reductions of the median values of various parameters, including Ammonia Nitrogen by 71.5%; TKN by 59.5%; Total Nitrogen by 37.1%; Total Phosphorus by 68.1%; Suspended Sediment Concentration (SSC) by 94%; TSS by 89.6%; Turbidity by 61.9%; and Zinc by 76.1%. While all parameter data collected and analyzed under the Pilot SCM Program is vital for water quality management efforts, one of the most important parameters for evaluating SCM performance is Total Suspended Solids (TSS) and the percent removal efficiency thereof. This is because the City's NPDES MS4 Stormwater permit requires that SCMs (BMPs) be capable of achieving a target removal efficiency of 85% for TSS and data evaluated under the Pilot SCM Program can assist in determining whether or not a particular SCM is approved for use within the City's Local BMP manual.

For this particular study site, the Storm Tech Chambers showed excellent removal of TSS at a statistically significant event mean concentration reduction of 89.6%. It should be noted that the watershed draining to the SCM was very small at 0.41 acres and produced a median inflow volume of 821 cf for monitored events. In addition, landscaped areas around the site parking lot likely would have produced increased input of sediments to the parking lot during heavy rain events due to their graded slopes toward the parking lot, and thus raising median influent TSS values. Mulch materials were noted on the parking lot surface during several site visits during the study period, which would support this assumption.

While this study yielded a positive result in the evaluation of TSS removal, more performance monitoring study of the Storm Tech Chambers SCM will be needed within the City's Pilot SCM program to adequately determine the performance capabilities of this SCM within other varying watershed sizes and land use types.

Appendix A shows data graphs for the Cherry Gardens Storm Tech Chambers SCM based on the SCM data analysis discussed in this report.

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Helsel, 2005. *Nondetects And Data Analysis: Statistics for Censored Environmental Data*. Wiley Publishers 250p.

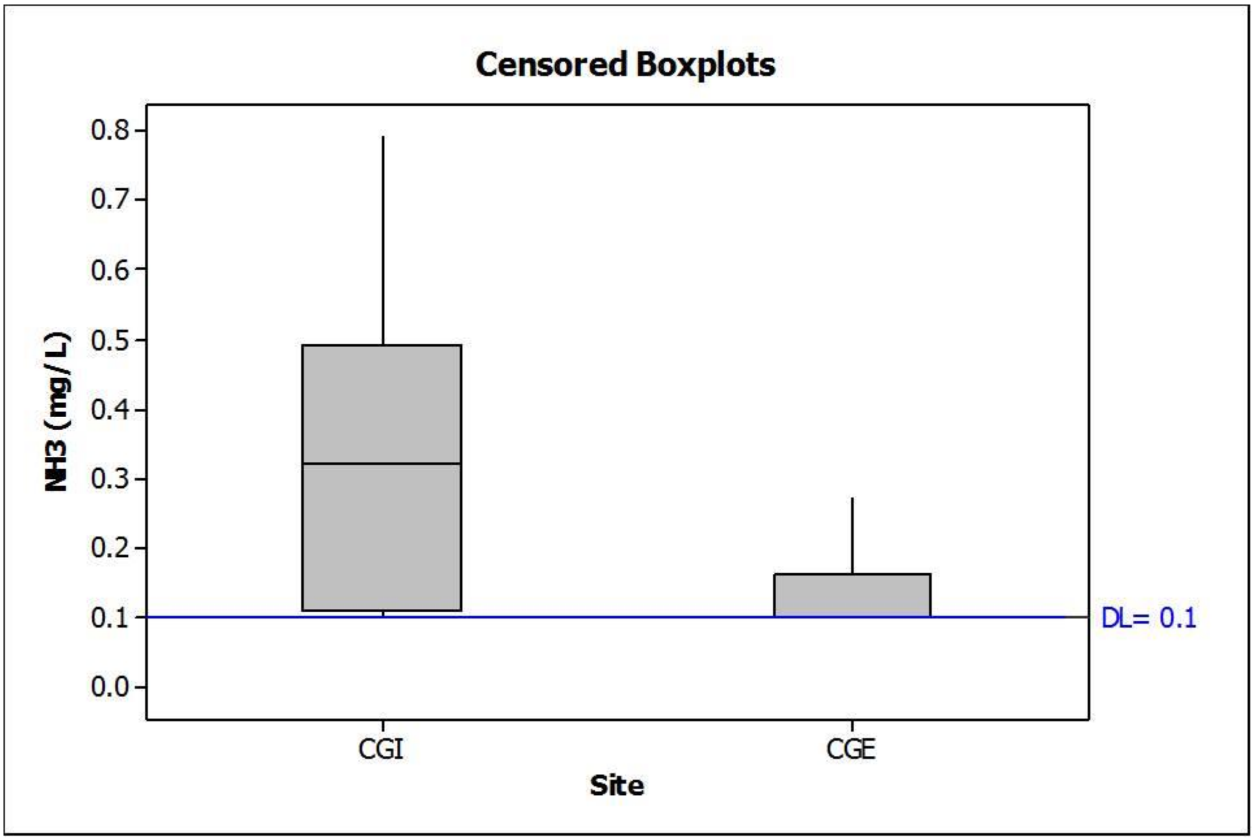
EPA and ASCE, 2002. *Urban Stormwater Performance Monitoring*

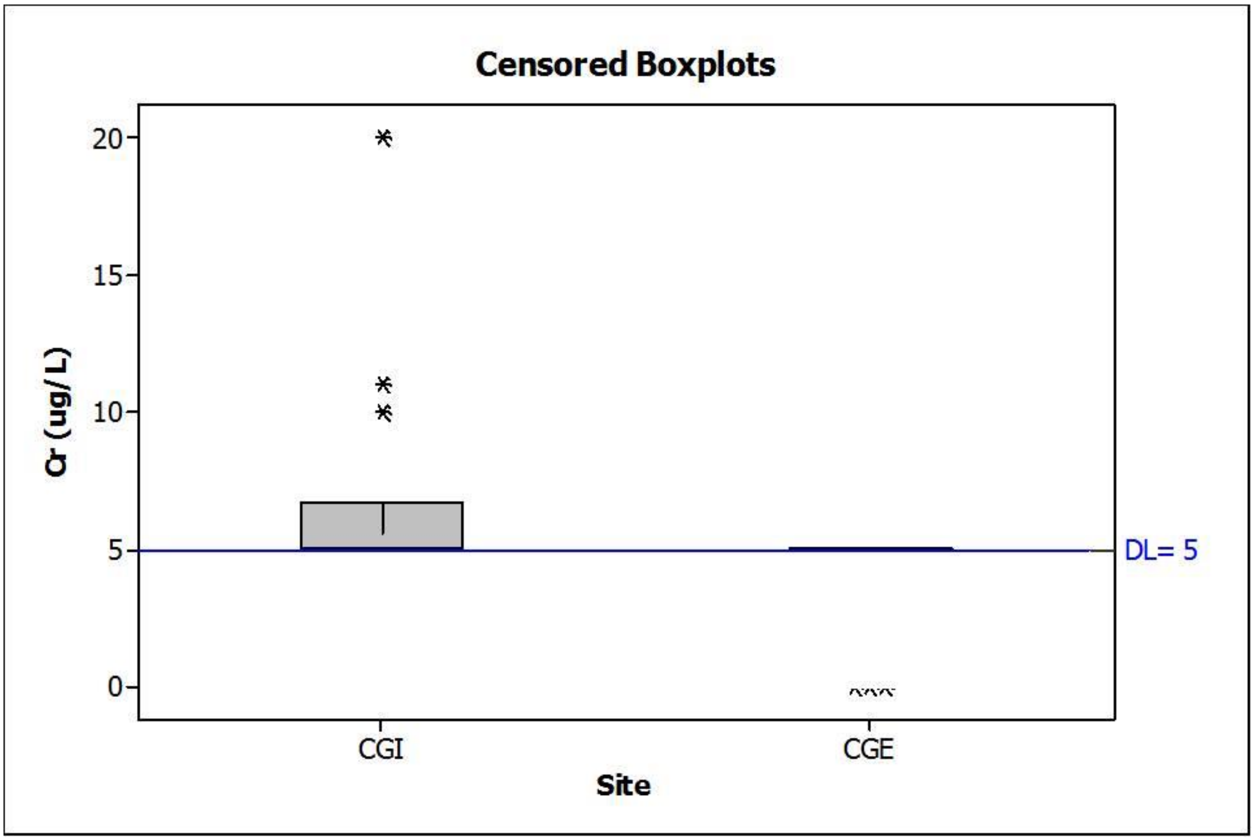
EPA and ASCE, 2009. *Urban Stormwater Performance Monitoring*

Storm Tech website: www.stormtech.com

APPENDIX A

Data Analysis Figures

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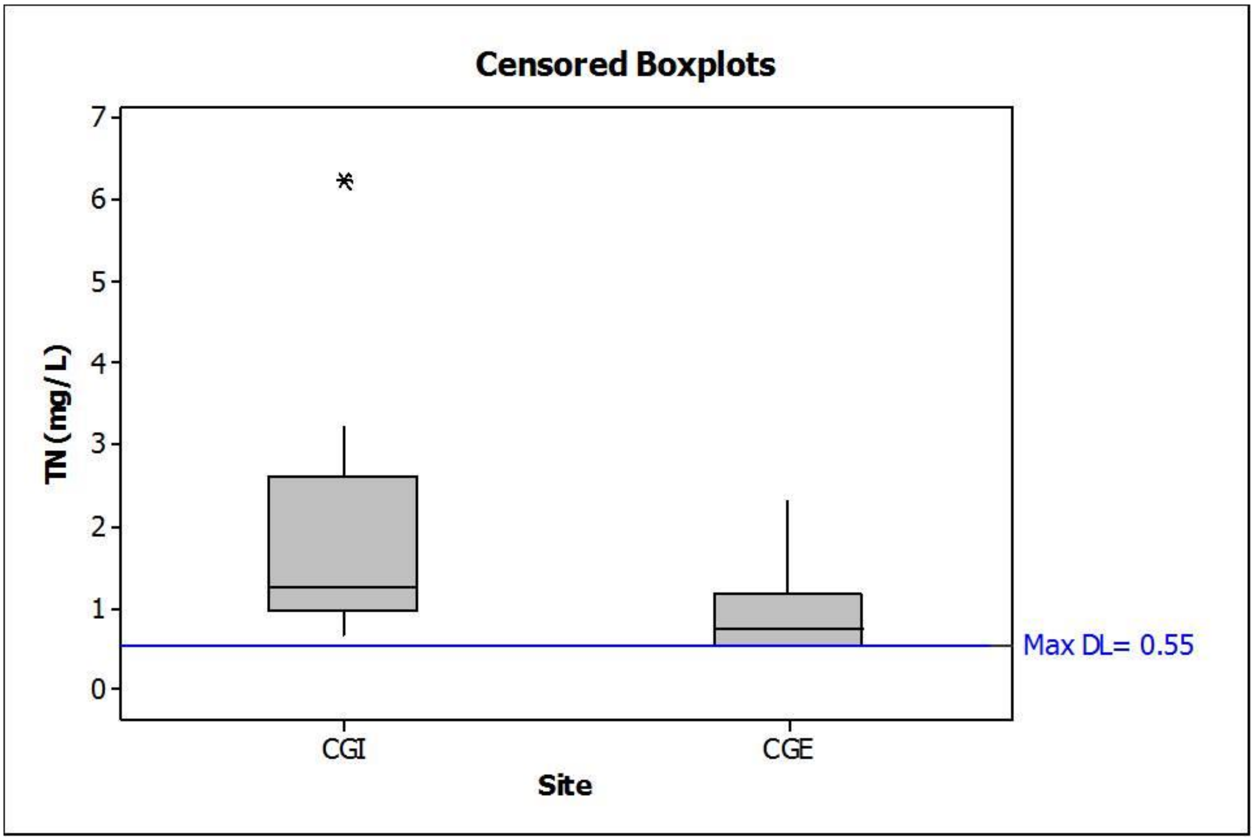
CGI
CGE
Site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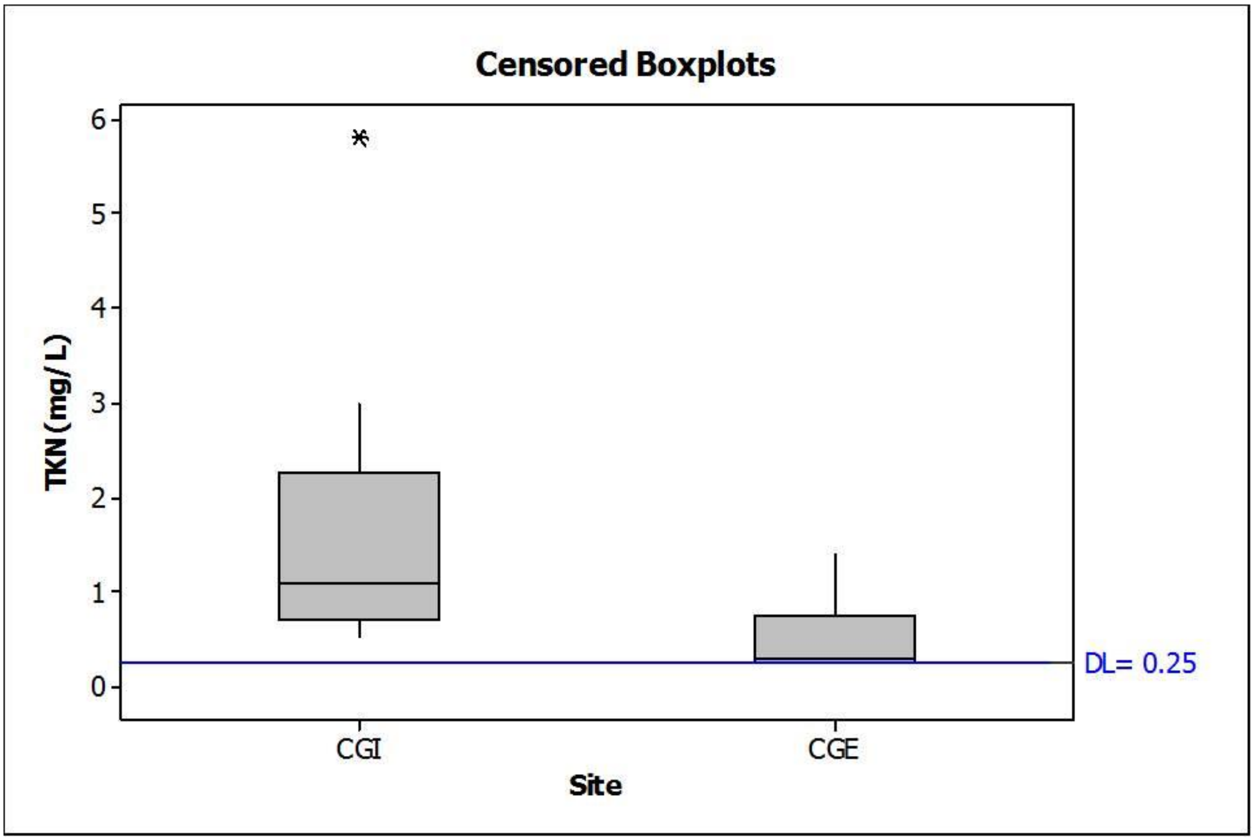
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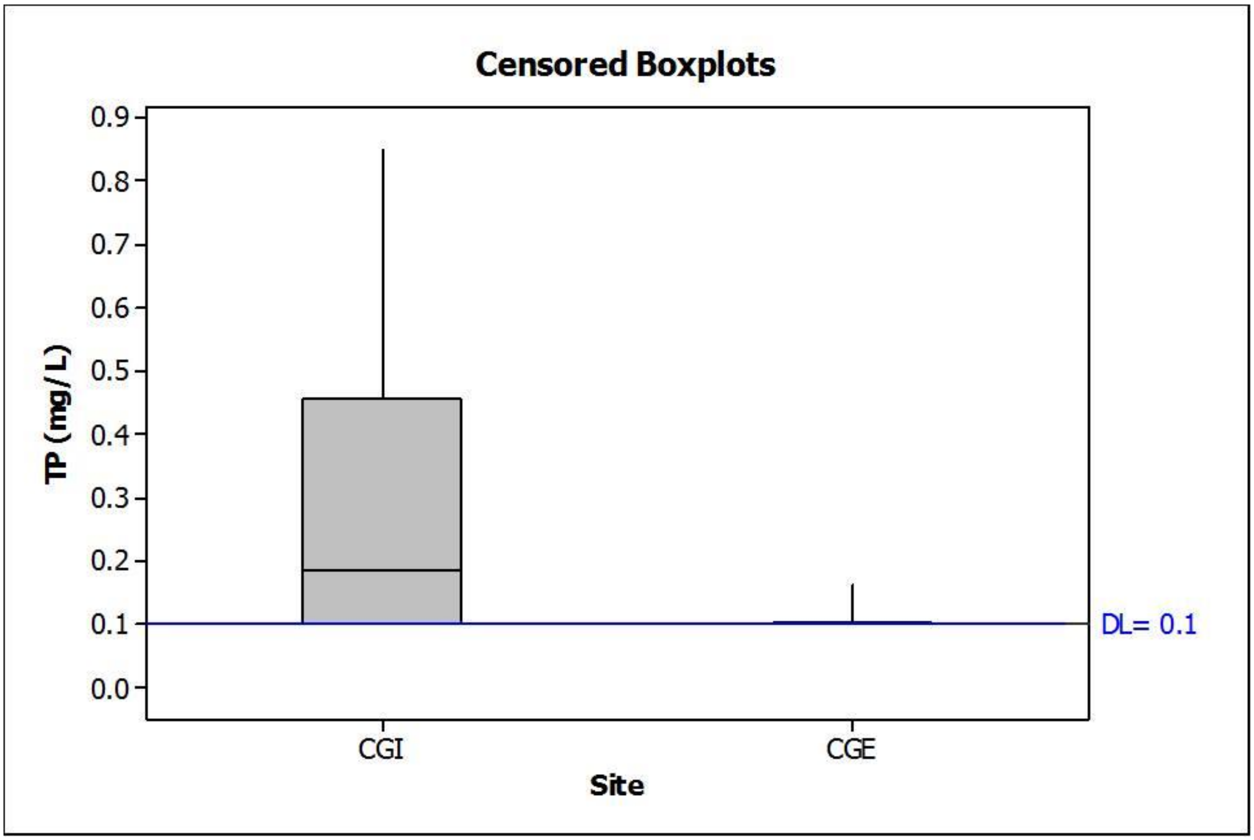
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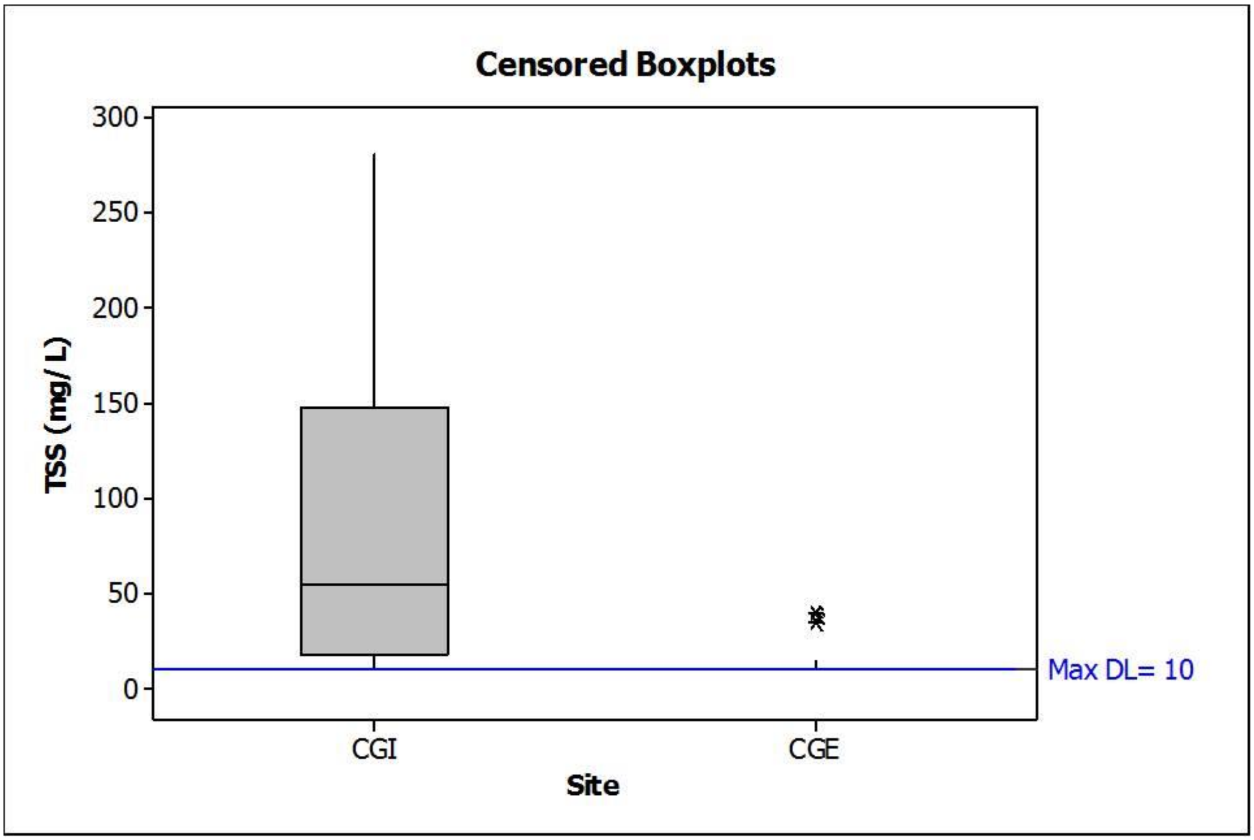
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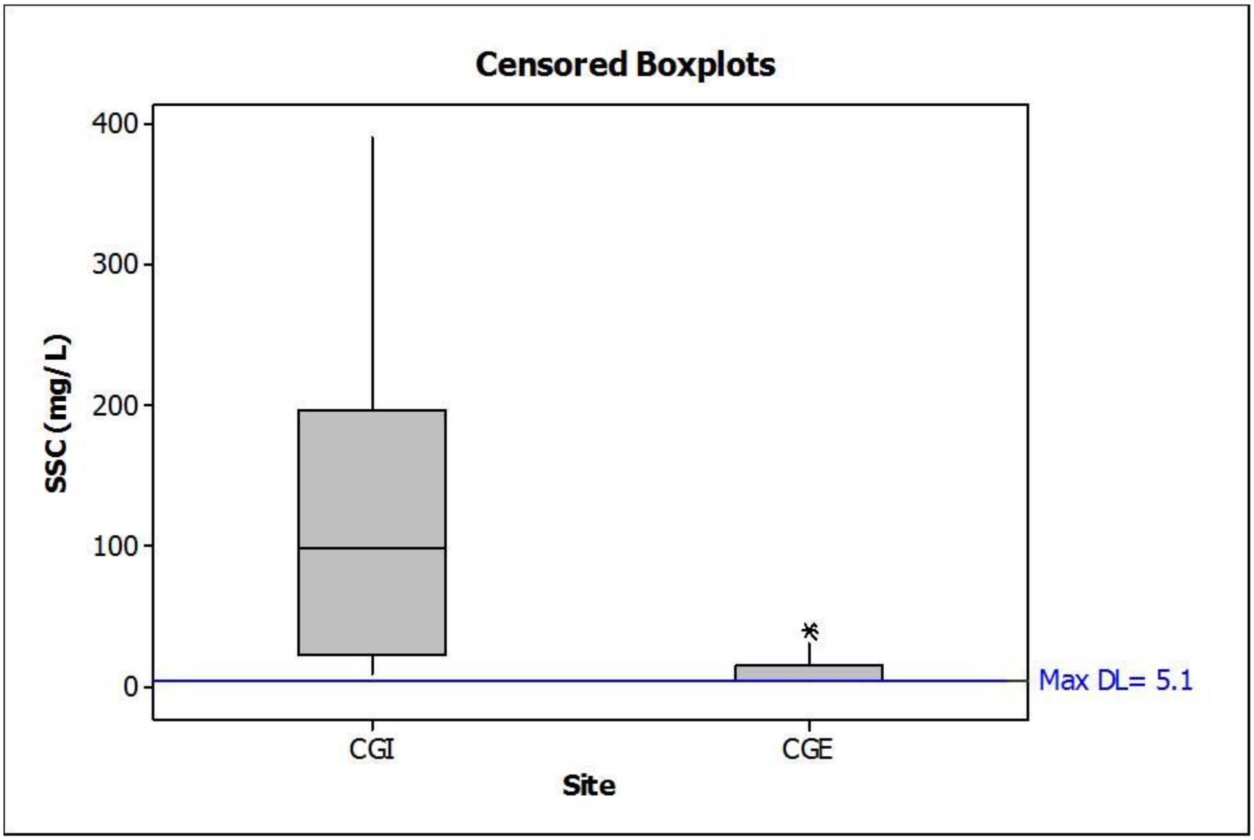
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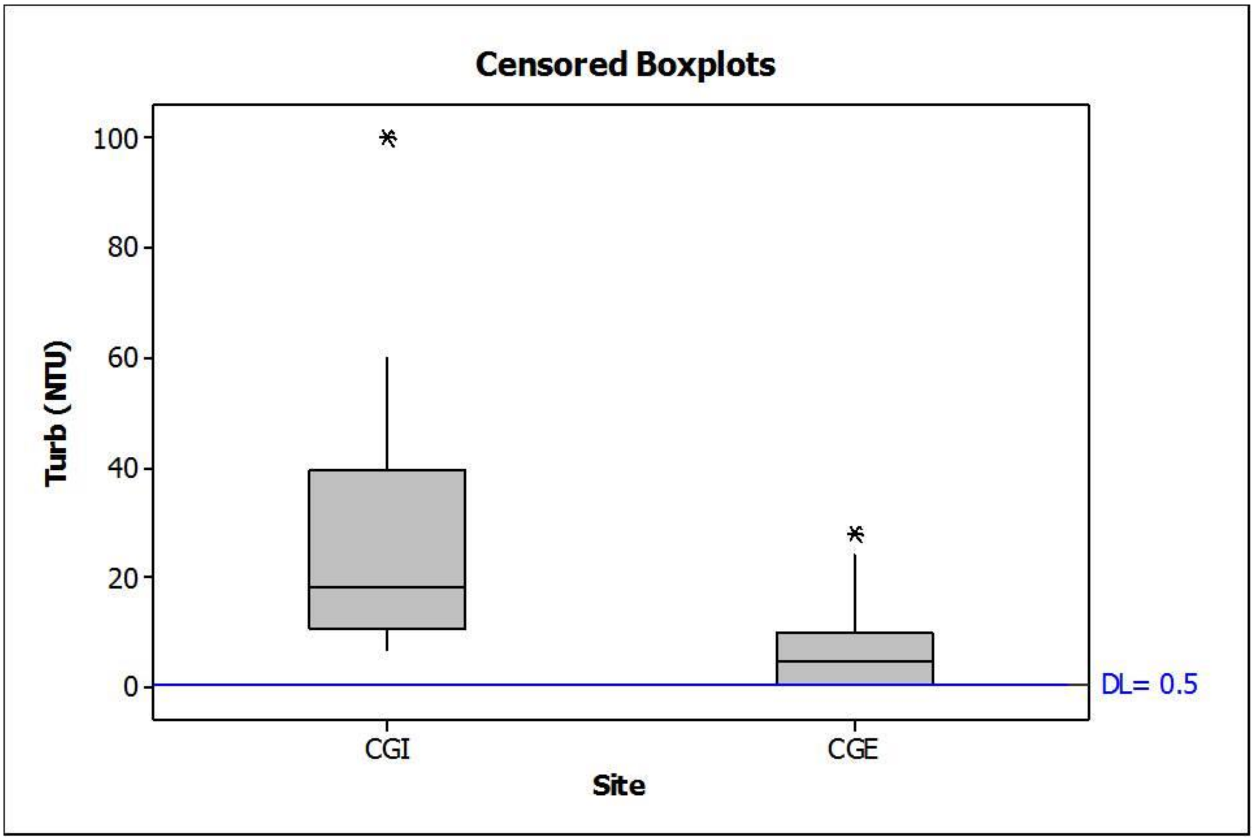
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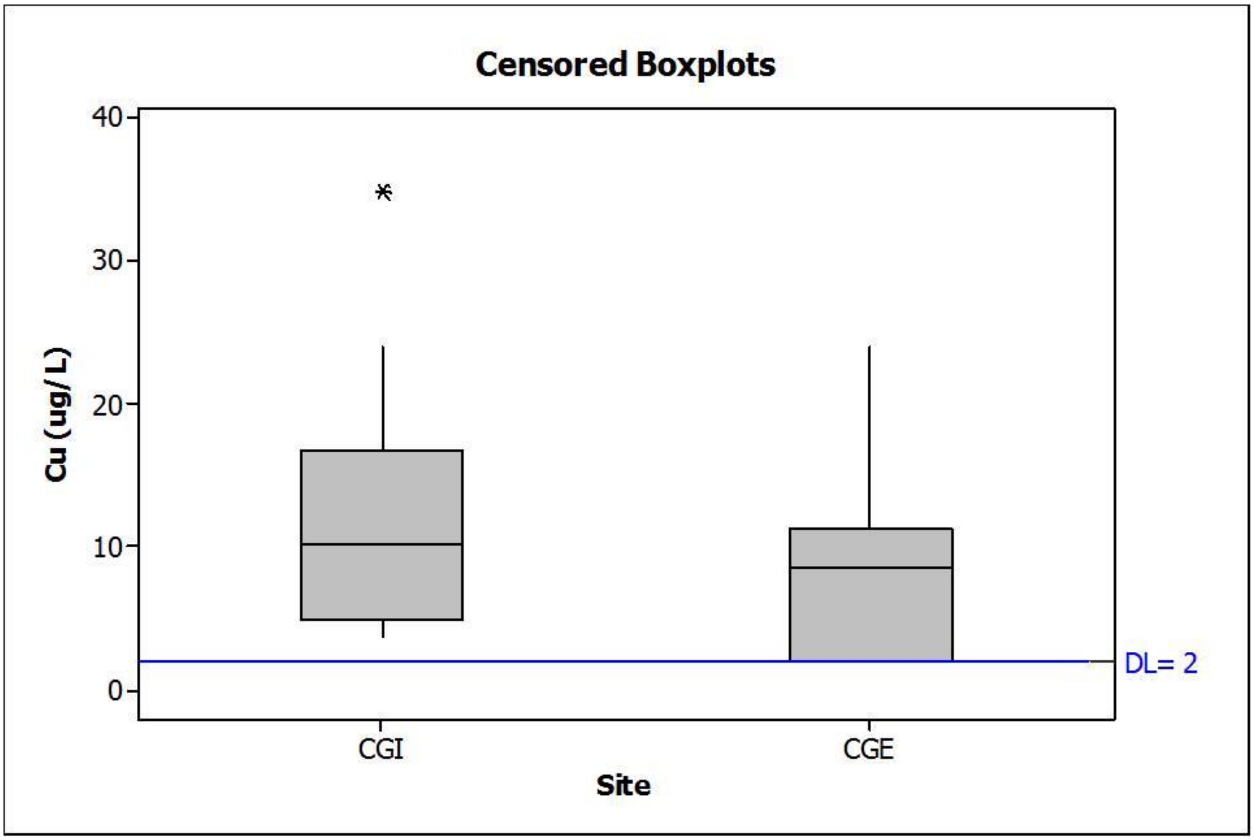
CGE
Site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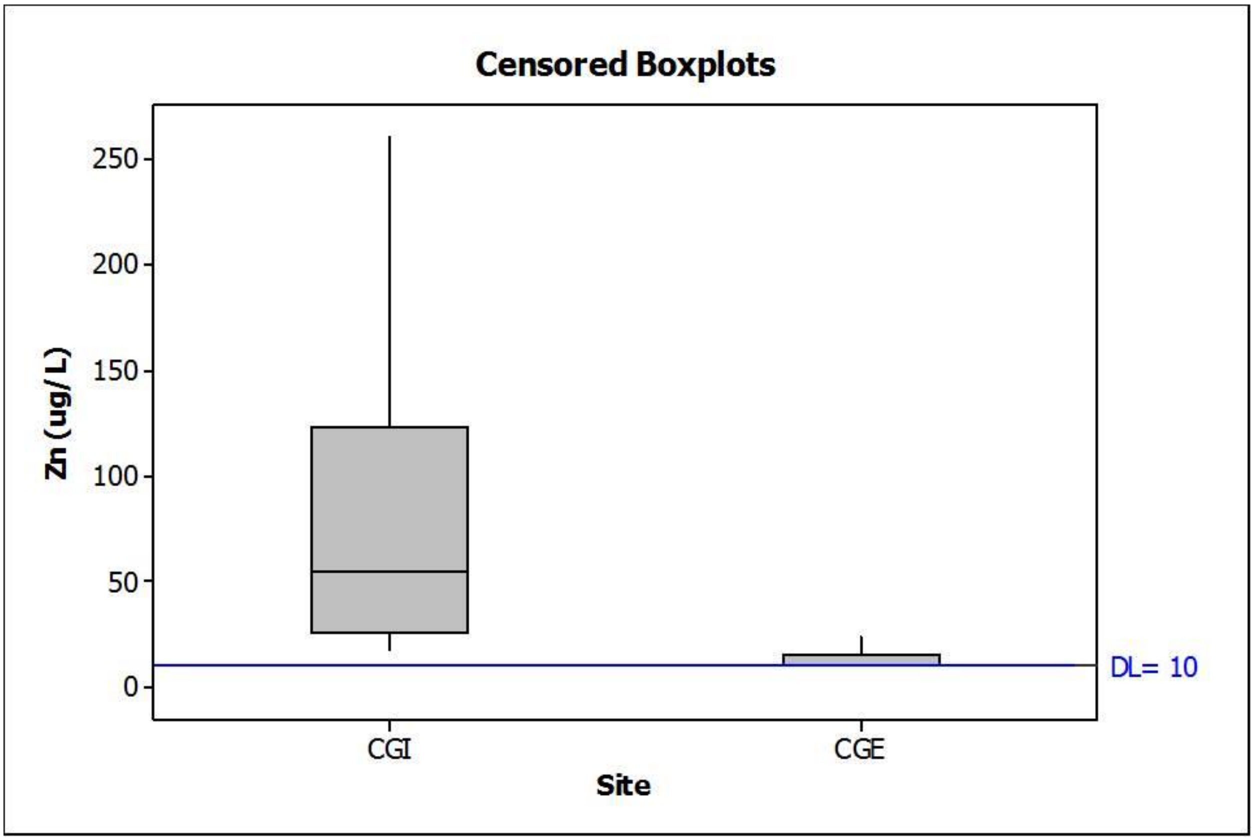
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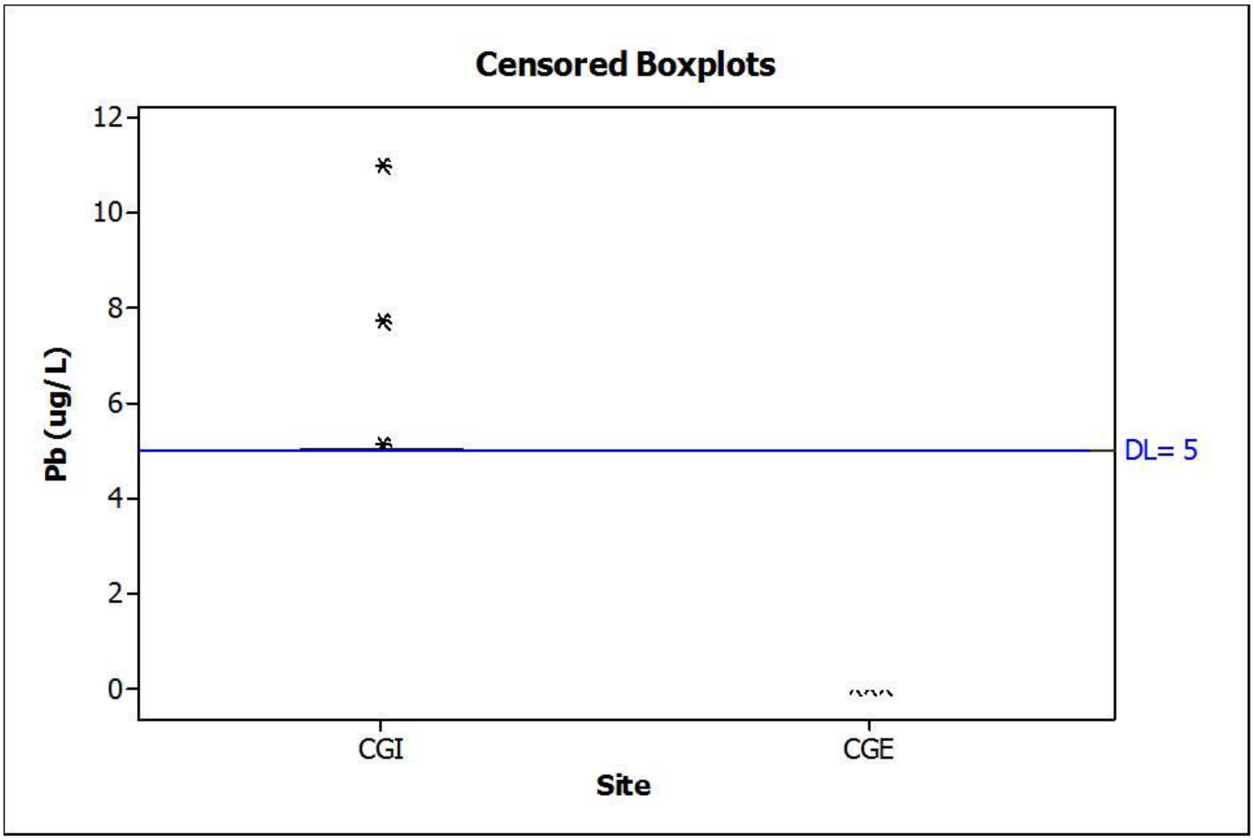

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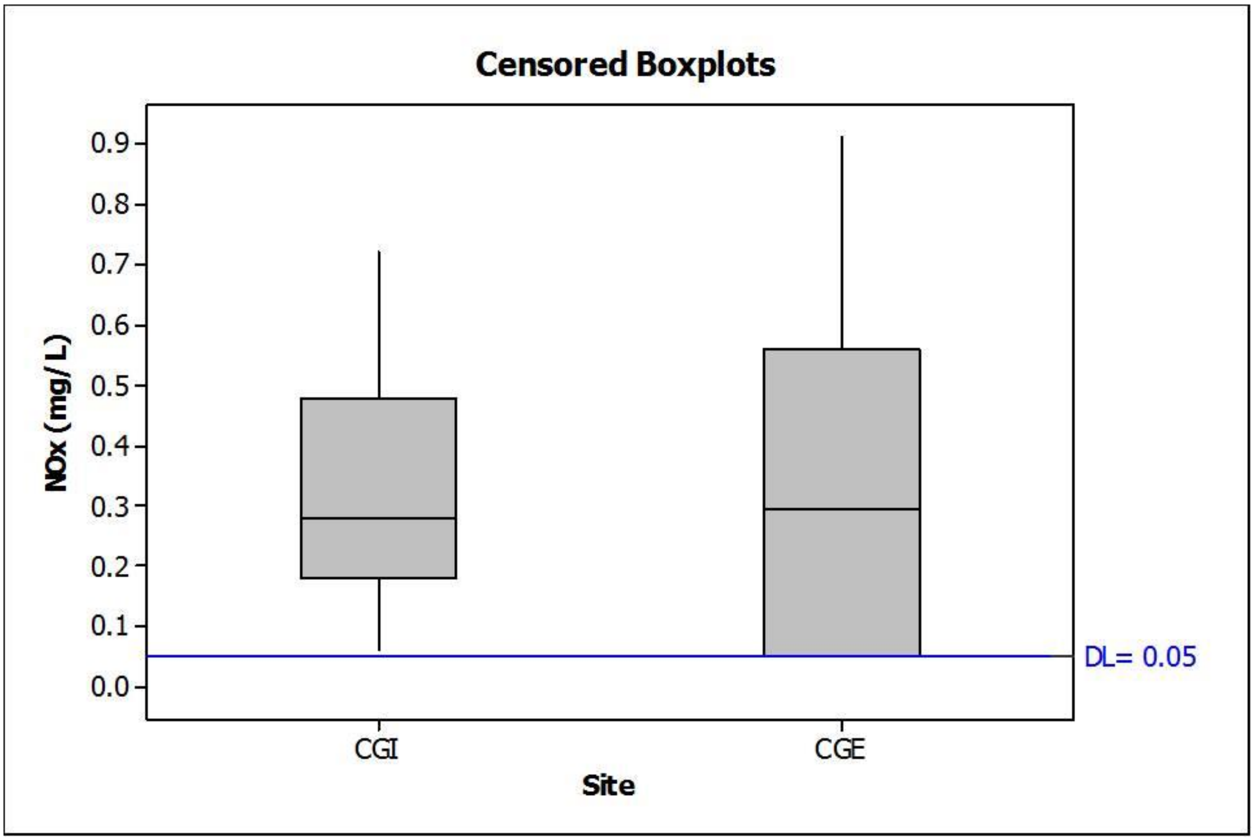
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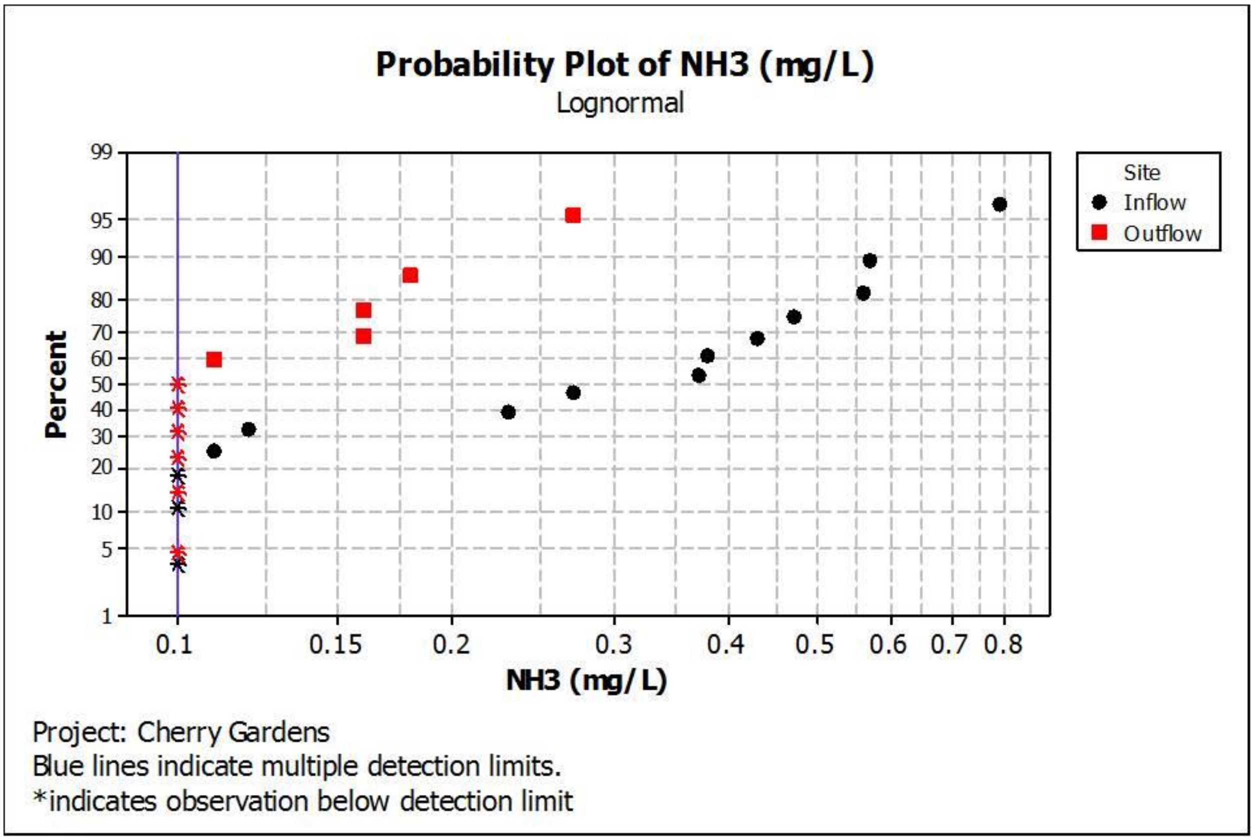
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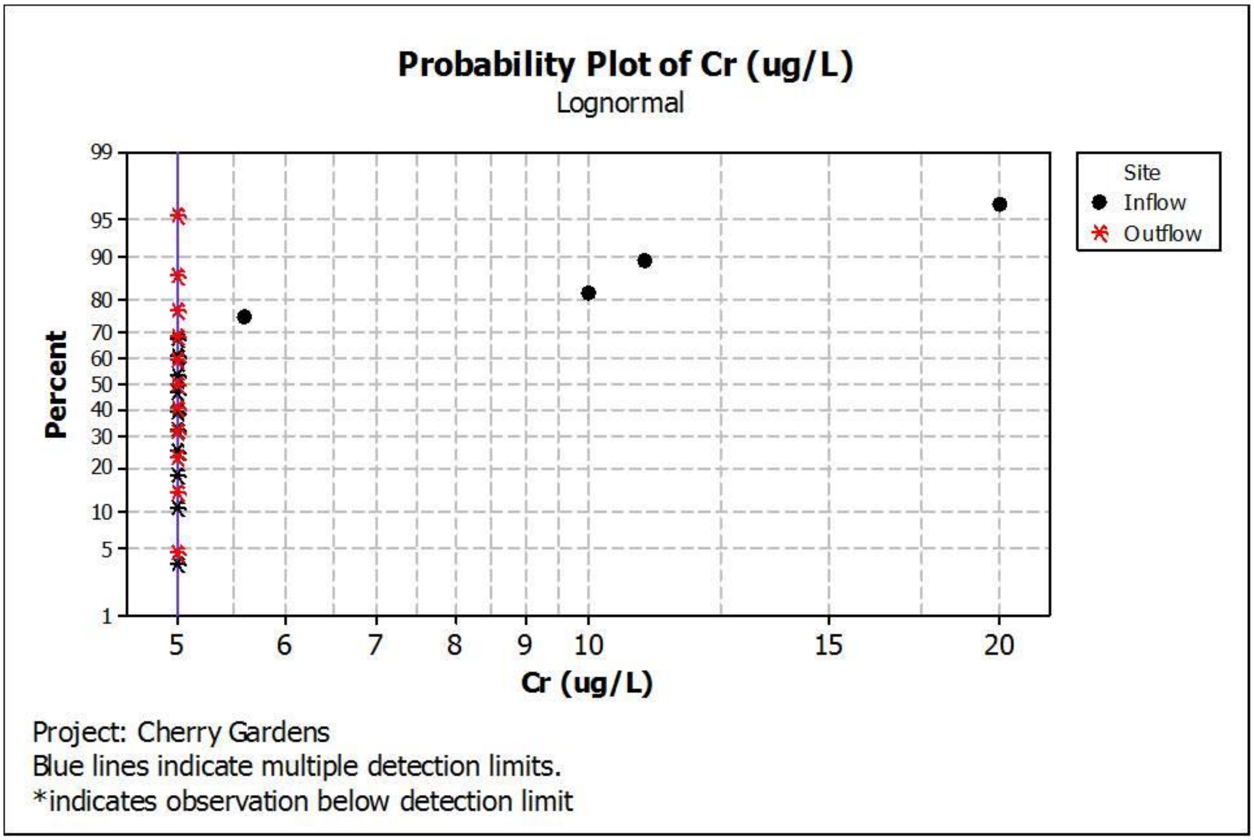
0.1
0.15
0.2
0.3
0.4
0.5
0.6
0.7
0.8
NH3 (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Cr (ug/L)
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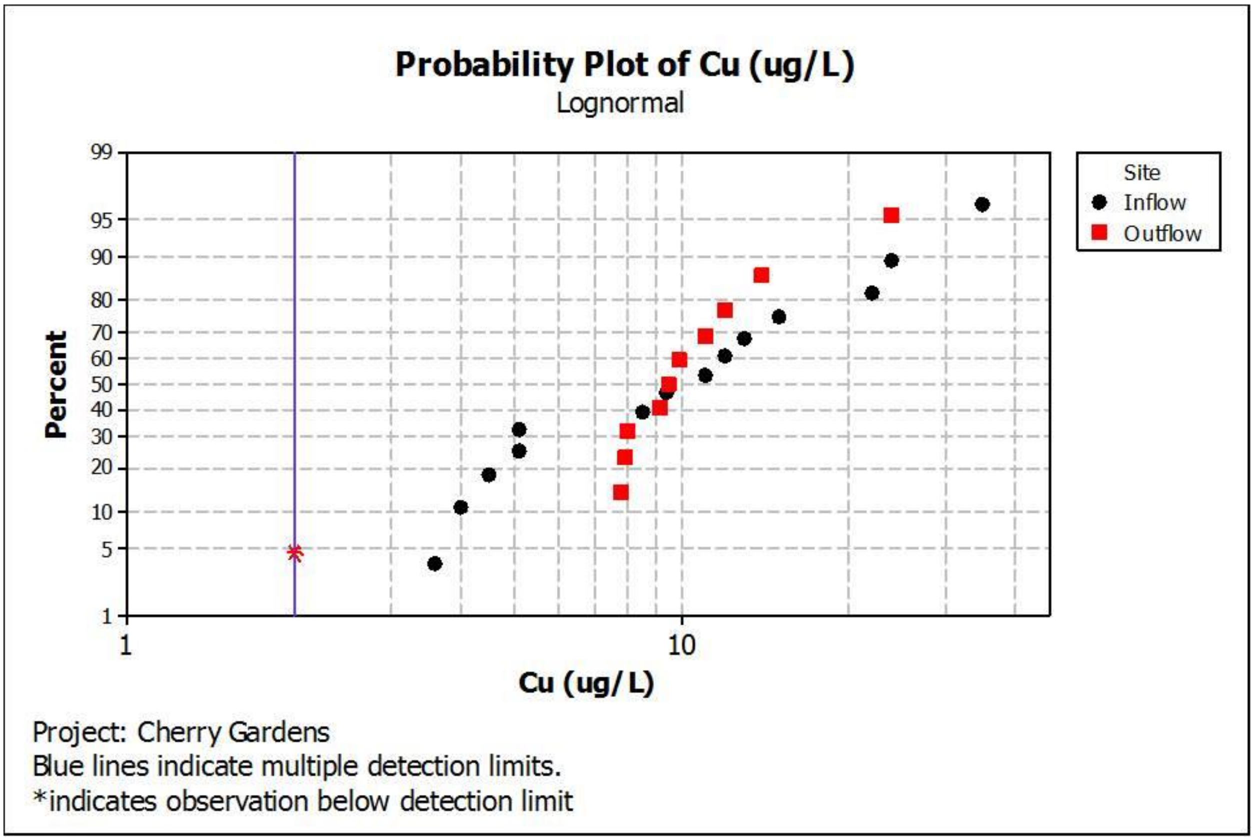
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Cu (ug/L)
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Inflow
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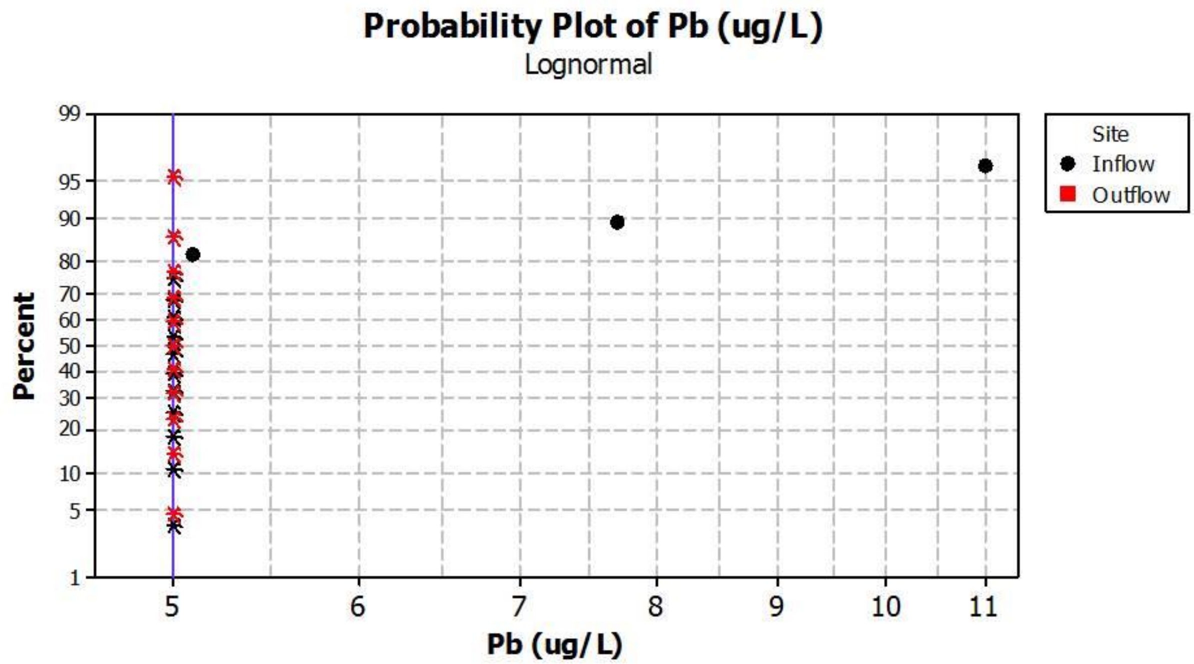
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit



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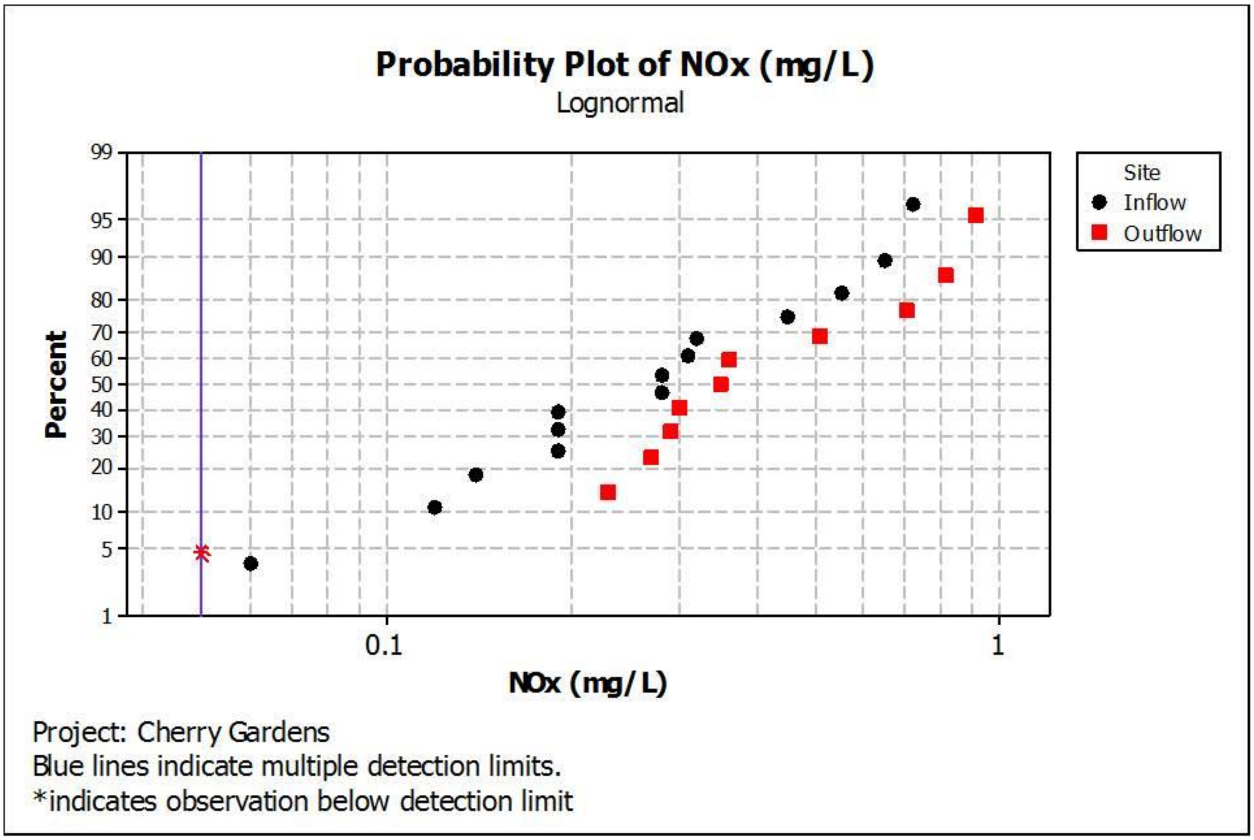

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NOx (mg/L)
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Inflow
Outflow
Project: Cherry Gardens
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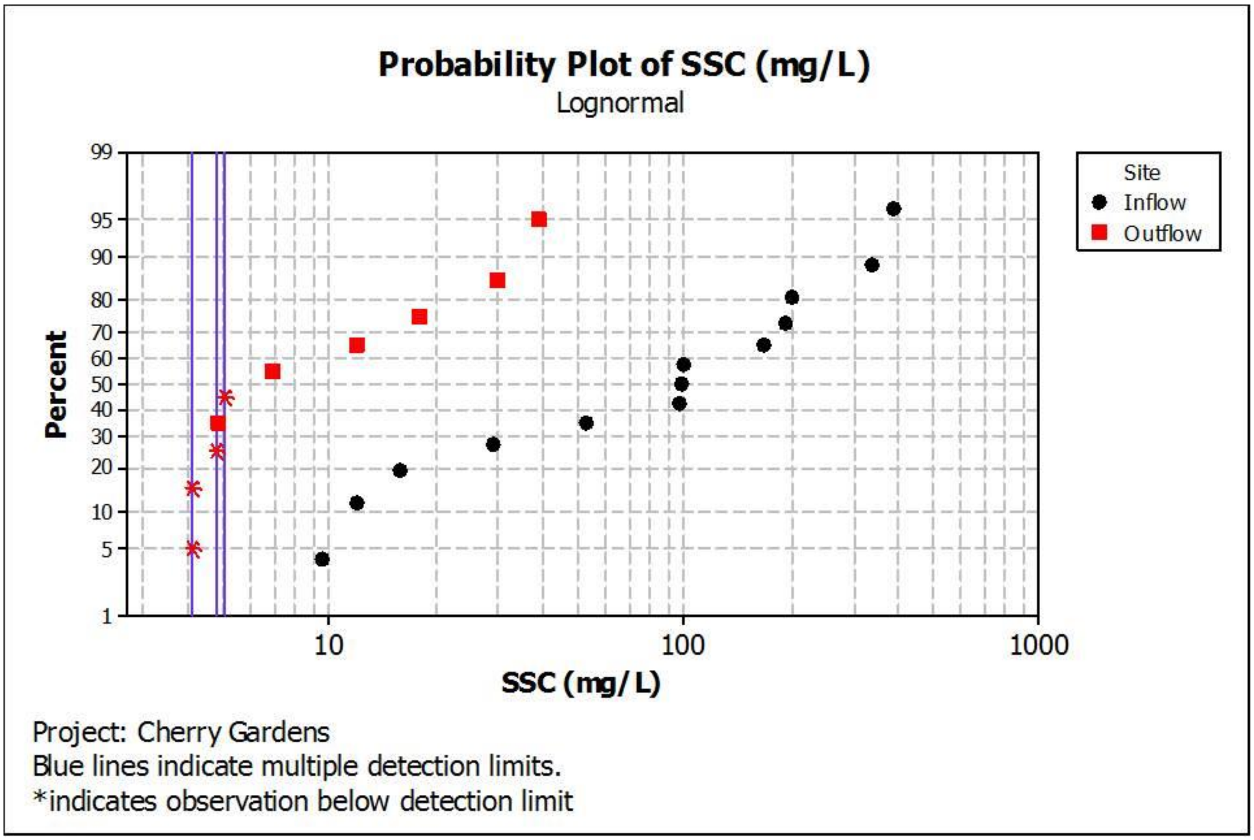
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Inflow
Outflow
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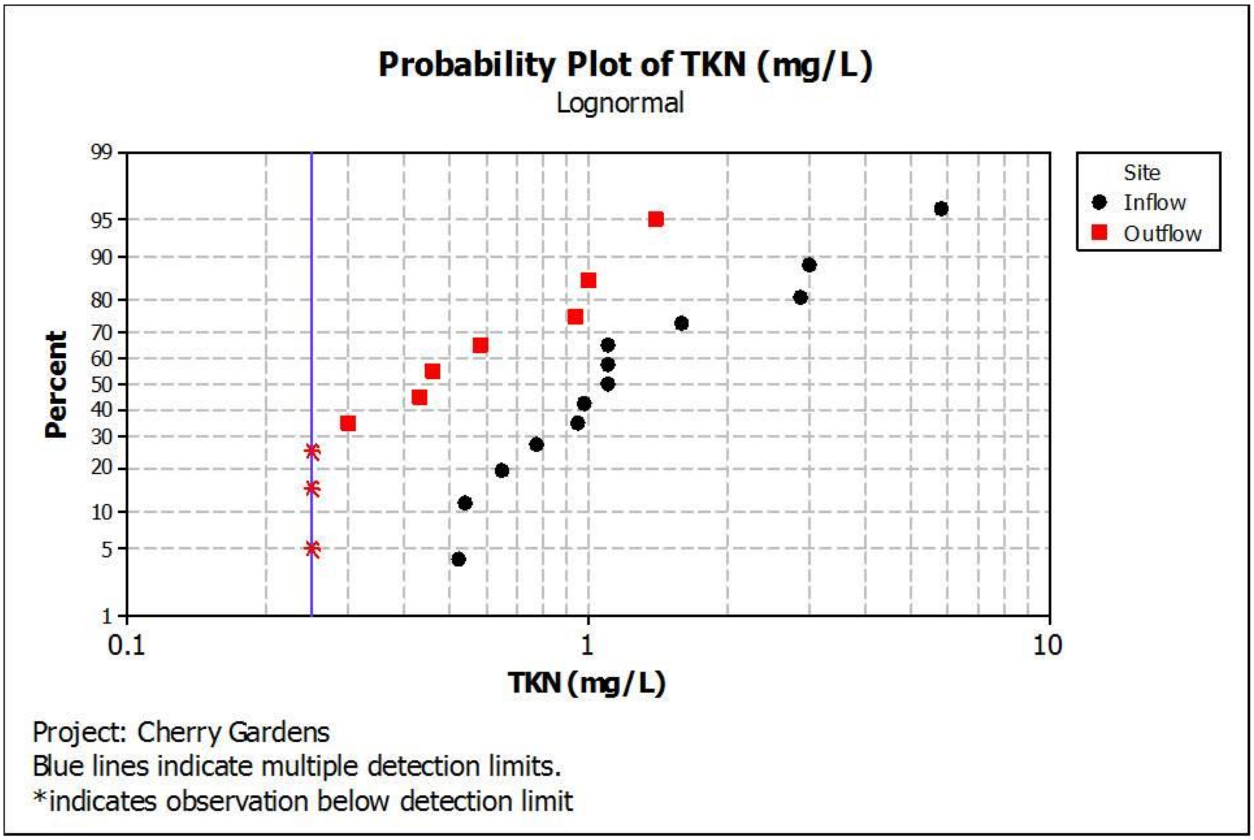
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Percent
TKN (mg/L)
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Outflow
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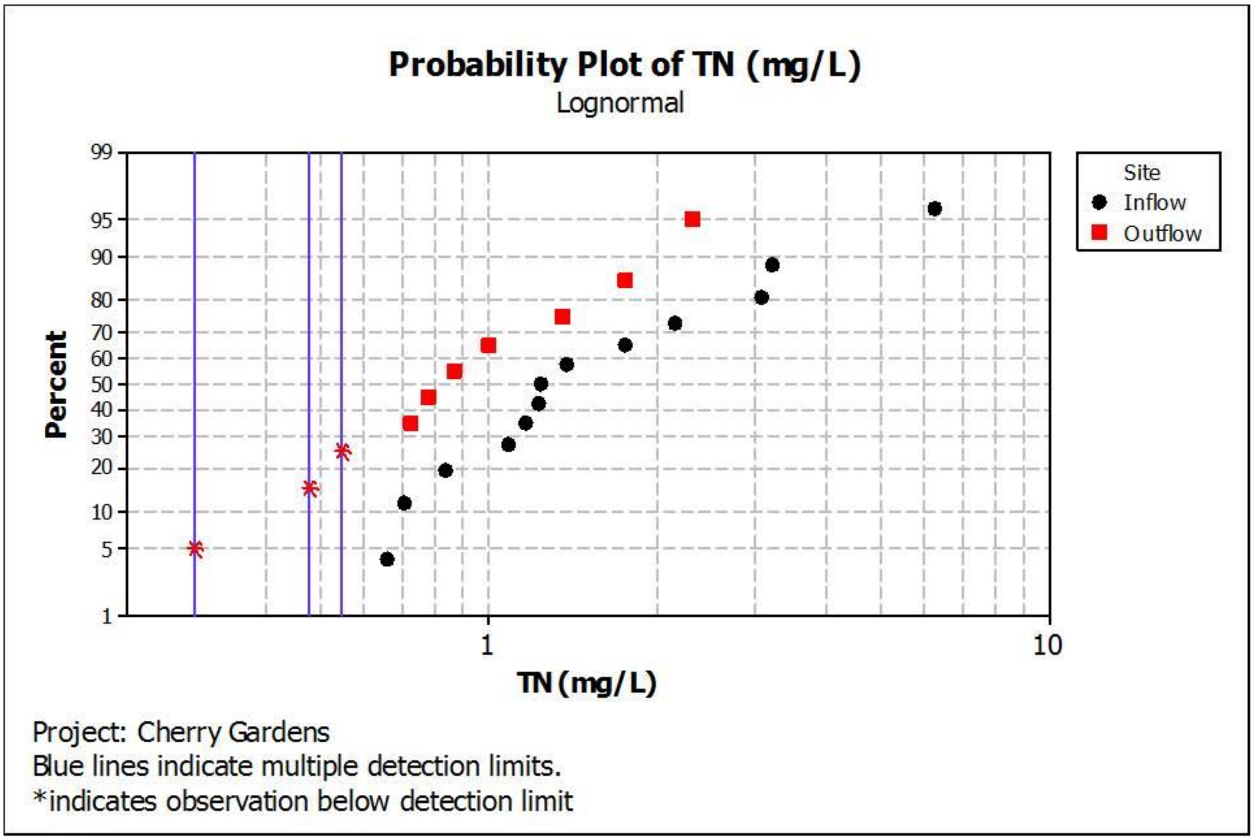
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Inflow
Outflow
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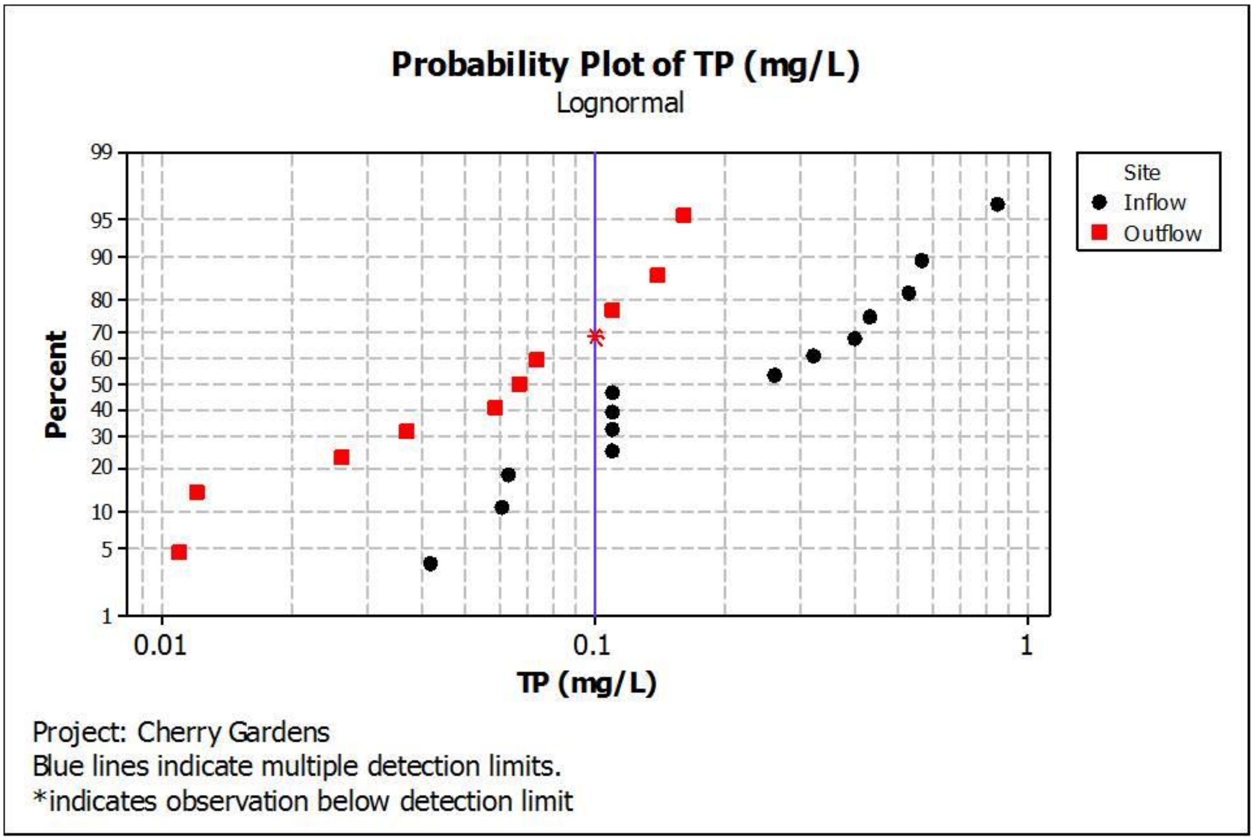
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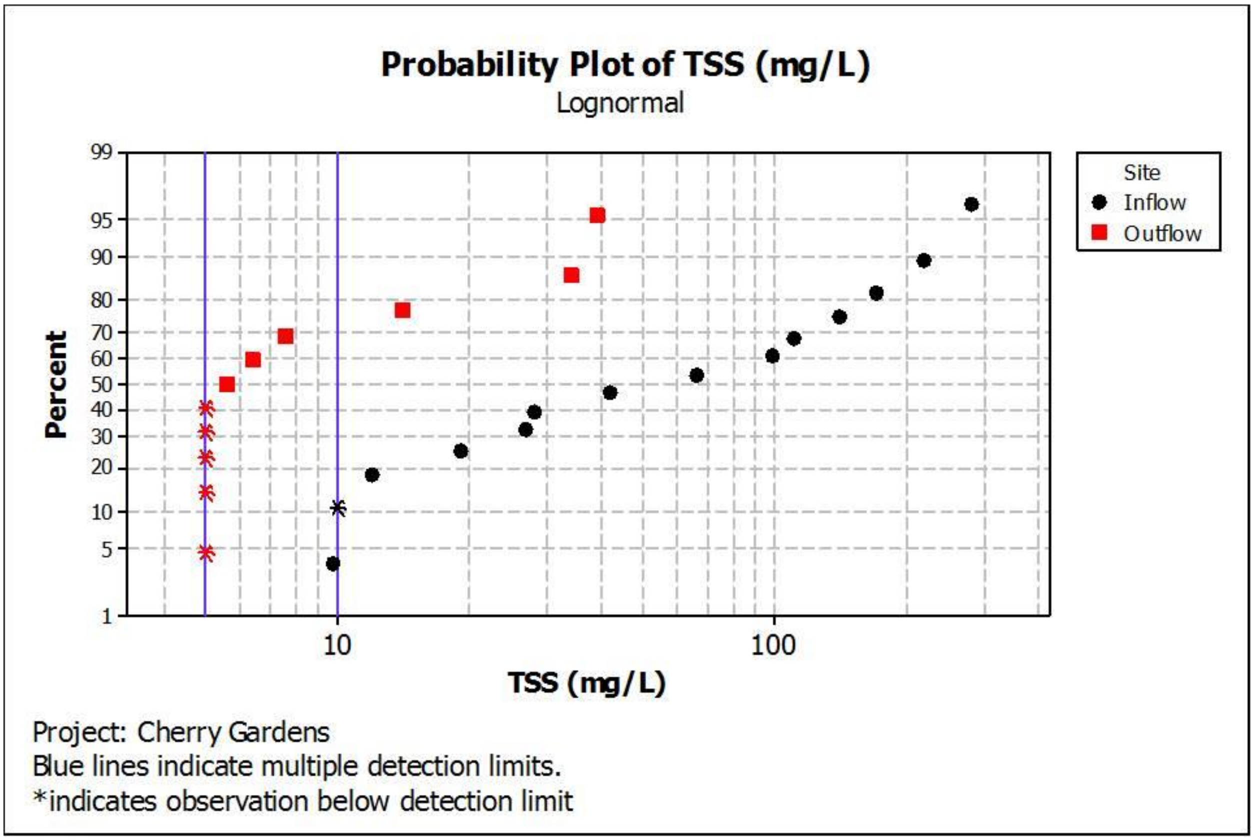
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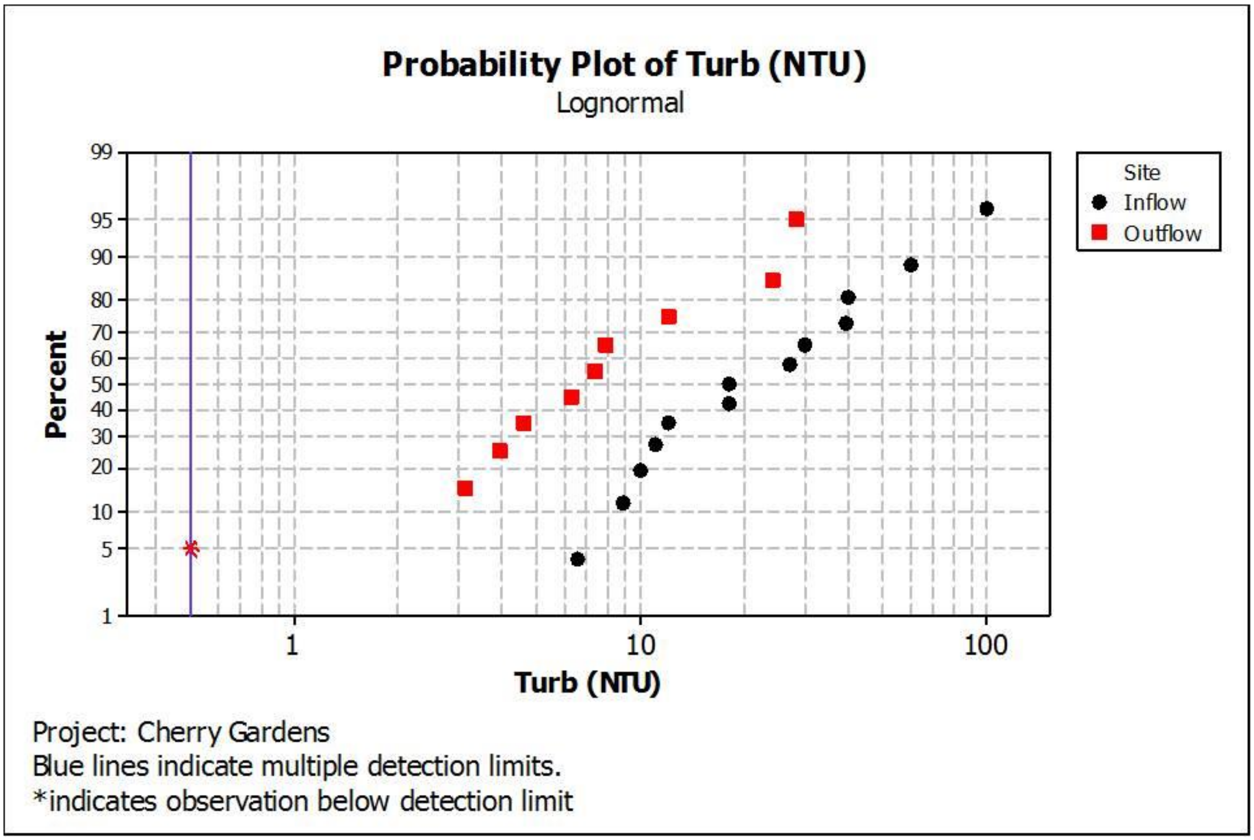
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Turb (NTU)
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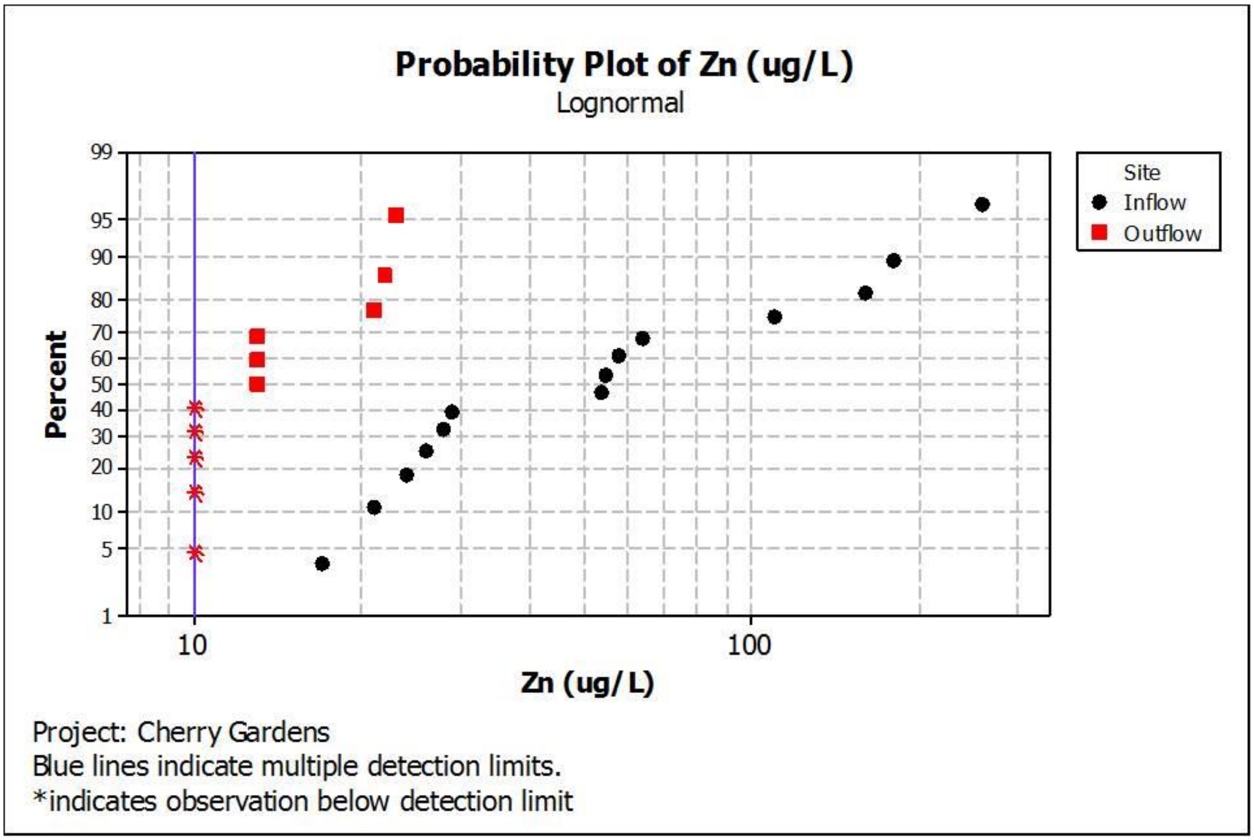
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10
100
Zn (ug/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit

APPENDIX B

Pilot SCM General Monitoring Protocol

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Prepared for:
City of Charlotte – Storm Water Services

Table of Contents

Acknowledgments

The authors would like to thank the following persons and organizations for their assistance and support while producing this document.
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Ronald Eubanks Mecklenburg County-LUESA Water Quality
Richard Farmer Mecklenburg County-LUESA Water Quality

Updated March 2013 by *Steve Jadlocki* – City of Charlotte-Stormwater Services

1. Introduction

The purpose of this document is to provide the City of Charlotte with information necessary in order to quickly and easily develop and implement a monitoring system to assess the performance of Pilot Stormwater Control Measures (SCMs). The guidelines recommended here will allow the reader to collect data meeting the United States Environmental Protection Agency (US-EPA) national Stormwater BMP data base requirements. These requirements are discussed in more detail in "Urban Stormwater BMP Performance Monitoring" (EPA 2009). The reader is encouraged to refer to this guidance for more information.

Specifically these methodologies will be incorporated into the City's Pilot SCM monitoring program. This program currently has the following goals:

- Determine overall removal efficiencies of Stormwater SCMs common to the Charlotte area, as well as new and/or innovative SCM types.
- Compare removal efficiencies among different SCMs.
- Determine seasonal effects on removal efficiencies of SCMs.
- Determine periodic maintenance needs of SCMs.
- Determine cost/benefit of SCMs
- Determine annual maintenance costs
- Provide SCM data, if warranted, to the National EPA database and other national, state, local or regional agencies for use in research and developing SCM design standards.

2. Characteristics to Monitor

a. What storms to monitor

Unfortunately, it is very difficult to design a monitoring system to collect stormwater runoff samples and data from all precipitation events. Larger storms often exceed the design capacity of SCMs and stormwater drainage systems making measurements difficult. Smaller storms produce relatively small amounts of runoff often resulting in sample volumes insufficient for complete chemical analysis. In addition, the high cost of chemical analysis strains budgets and laboratory personnel. It is important then to identify the storm size and frequency to warrant data collection.

The inability to accurately predict the precipitation depth of individual storms requires that each sampler be programmed to accommodate a range of storm sizes. Precipitation events larger than 2 inches occur only a few times annually in the piedmont region of North Carolina. As a result it is not advisable to design a sampling system to accommodate such events. Likewise, events of less than 0.1 inches of rainfall will typically produce very little or no runoff. It is not advised that storms smaller than 0.1 inches be targeted for sampling. See Section 6 for more information on setting up samplers for the targeted storm size.

In order to statistically defend the results of a monitoring program a sufficient number of storms must be collected during the monitoring period. Ultimately, determining the number of samples to collect in order to satisfy statistical analysis will depend on the monitoring goals of the project. More information on selecting sample numbers to match monitoring goals can be found in *Development of Performance Measures* (EPA 1999). Collecting samples from at least 10 storms covering all four seasons in a year period will enable defending the goals and hypotheses discussed in Section 1. Samples should be collected at a minimum frequency of one per month in order to determine the effect of seasonal variations on pollutant removal performance. See Table 2.1 for recommendations on storm size, frequency and number of samples.

Table 2.1 Recommendations for storm size and frequency for monitoring

	Minimum recommended	Maximum recommended
Storm Size	0.1 inches	2 inches
Storm sampling frequency	1/ month	2/ month
Number of samples	10/ yr	20/yr
Inter-Event Dry Period	6 hours	N/A
Antecedent Dry Period	24 hours	N/A

The most basic information that can be collected from stormwater runoff is its physical characteristics. Such information as flow rate, volume, and temperature are important pieces of information when analyzing SCM performance. No other single parameter is more important to SCM performance analysis than continuously recorded flow rate. For SCMs with a storage/detention component inherent to their function it is preferred that flow be measured at both the inflow and outflow locations. For SCMs without any detention component inherent to their design it is possible to measure flow at only one sampling station to save on equipment costs. Structures and instrumentation necessary to monitor flow are discussed in later sections.

Any performance monitoring program should also include continuously monitored rainfall. For smaller sites such as most stormwater SCMs it is acceptable to use a single rain gage at one of the monitoring stations or even a nearby gauging station such as a USGS precipitation gage. For larger SCMs it may be necessary to use a multiple gauging locations sited within the watershed to accurately determine the net precipitation amount treated by the SCM.

In many portions of the US thermal pollution as a result of stormwater runoff is a very important issue. Relative to other parameters, temperature is very economical to measure and record. Where possible it is advised that temperature be measured and recorded at both the inflow and outflow points of the SCM.

Listed below are the physical parameters which should be measured and recorded at each sampling location:

Physical parameters to monitor include:

1. Flow rate
    - inflow station
    - outflow station (optional for non-detention SCM)
2. Rainfall
3. Temperature (continuous recording)
    - Inflow
    - Outflow
4. pH (optional)

Selection of chemical analysis to be completed on stormwater runoff can be a very challenging task. Specific analysis may be chosen to satisfy the following questions.

- For what pollutants have TMDL's been established within the watershed of interest?
- What pollutants will the SCM potentially have an impact on?
- What pollutants are regulated by state or regional regulations?

Listed below are the chemical analyses that are recommended for inclusion into this study.

Composite Samples:

Total Suspended Solids
Suspended Sediment Concentration
Total Kjeldahl Nitrogen
Nitrate-Nitrite Nitrogen
Ammonia-Nitrogen
Total Phosphorus
Copper
Chromium
Lead
Zinc
Aluminum*

*Aluminum collected and analyzed for proprietary filter cartridge SCMs only

Grab Samples:

Fecal Coliform Bacteria
E-Coli Bacteria
Enterococcus Bacteria

Additional pollutants may be included in the chemical analysis as a "suite" of pollutants (for instance a metals suite might include Cadmium, Magnesium as well as Iron) or additional pollutants may be analyzed in order to compare samples to other types of water quality data such as stream flow. Chemical analysis of water quality samples should be analyzed using methods described in Methods for Determination of Metals and Inorganic Chemicals in Environmental Samples (USEPA 1996).

3. Choosing Equipment

Many instrumentation suppliers have responded to the need for equipment for monitoring stormwater runoff. The most common style of stormwater sampler consists of a peristaltic pump operated by a main sampler controller depositing samples in one or a combination of bottles within the sampler housing. The sampler controller may have in-situ physical or chemical monitoring capability built into it. If not, accessory equipment should allow for monitoring of the parameters discussed in the previous section. Samples collected by the sampler are usually deposited within the sampler housing body into either a single or multiple bottles of either glass or polypropylene. The selection of bottle type will primarily be dependent on the types of analysis to be conducted. The user should consult the standards and methods book for when polypropylene bottles will be acceptable.

For the City of Charlotte's Pilot SCM monitoring program, ISCO Avalanche samplers will be used, which consist of a refrigerated single bottle system. Fig 3.1 shows a sampler in use at one of the monitoring sites. In addition to the sampler's flow monitoring modules use a bubbler flow meter system to measure and record flow at each station. The model 730 bubblers should be used where a flume, weir or orifice is used as a primary device. This should be considered the preferred system of flow measurement as it results in typically more accurate readings and repairs to damaged bubbler tubes are very easy and economical. Model 750 area velocity meters can be used in areas where a defined flow channel exists such as a culvert or chute of known dimensions. Area velocity meters have the advantage of operating under submerged flow conditions (such as with a tail water) and are useful when a limited head loss is available. However they should not be considered as accurate as the bubbler type model 730 flow meters matched with an appropriate primary device. The user should consult the ISCO operating manuals for more information on selecting equipment to match individual sites.

Fig 3.1 ISCO Avalanche Model 6712 sampler

4. Selecting SCMs to monitor

When choosing SCMs to monitor, it is important to keep in mind the reasons for monitoring in the first place. For a regional or municipal stormwater program such as the City of Charlotte, monitoring of SCMs might be necessary to determine types of practices to recommend to developers. It is not advisable to research SCMs that will not be easily accepted into local use. Table 3.1 lists the most common SCMs currently in use in the Piedmont area of North Carolina as well as others which might see additional use in the future.

Table 3.1 Structural Stormwater Control Measure usage and potential for monitoring

Type	Current Use	Future Use	Recommended sites
Wet pond	High	medium	5
Wet detention pond	High	medium	5
Wet detention pond with littoral Shelf	medium	high	5
Dry detention pond	medium	medium	5
Stormwater Wetland	medium	medium	10
Bioretention	low	high	10
Pervious pavements	very low	medium	5
Greenroofs	very low	medium	2
Sand filter	low	medium	3
Proprietary devices	low	unknown	20

i. Correctly designed stormwater SCMs

When choosing SCMs for monitoring one should be careful to identify not only SCM types that fit within the guidelines mentioned above, but also individual SCMs that have been designed and constructed according to the desired local, regional, or national design standard. The most common design guidelines used are those specified in the North Carolina Stormwater BMP Design Manual (NCDENR, 2012) as well as the Charlotte-Mecklenburg BMP Design manual. Some SCMs installed in North Carolina may be constructed according to the State of Maryland Stormwater Manual (MDE,2000) One of the primary purposes of developing a monitoring program is to enable the comparison of specific SCMs to one another. Comparing two SCMs designed under different criteria will produce results that are hard to support or defend. In North Carolina, most detention SCMs are designed for the "first flush" event. In the Lower Piedmont this "first flush" event would currently constitute the runoff associated with 1 inch of rainfall.

ii. Identifying Sites for suitability

Many individual stormwater SCMs currently in use are either impossible or extremely difficult to monitor. The most common characteristic inhibiting monitoring is the existence of multiple inflow points requiring multiple sampling stations thereby driving up the cost and labor requirement. Additionally, it is important that a location at each sampling point be identified which will allow accurate monitoring of flow. However for many SCMs, such as bioretention, sheet flow at the inlet is a recommended design characteristic. It is still possible to monitor flow in such a case however a well-defined watershed must exist. Setting up a sampling system under such conditions is discussed further in Chapter 6. Fig 3.2 lists a number of criteria for determining if a site is a good candidate for monitoring.

Fig 3.2 Checklist for Individual site suitability for monitoring

- ☐ Does the site have a single inflow and outflow?
- ☐ Is it possible to collect a well-mixed sample at each sampling station?
- ☐ Is the flow path at the inflow and outflow well defined?
- ☐ If inflow is sheet flow, is watershed well defined and mostly impervious?
- ☐ Will inlet or outlet have a free flowing outfall during storm event?
- ☐ No backwater conditions are present that would affect proper flow measurement

If the answer to each of these questions is yes then the site may be a good candidate for stormwater monitoring. It is the author's experience that less than 5% of all stormwater SCMs are good candidates for performance monitoring. As the reader gains experience in setting up monitoring systems, it will become easier to determine which sites are suitable.

5 Installing Structures and Equipment for Monitoring

Where possible, individual sites will be chosen in order to minimize retrofitting required to allow monitoring as discussed in section 4. However nearly all sites will require some efforts in order to accurately measure performance.

Weirs, flumes or orifices may need to be installed to allow the measurement of flow. Such devices should be designed to accommodate the full range of storm flows expected from monitoring events. For the Pilot Stormwater Monitoring Program, structures should be sized to allow measurement of flows up to the peak discharge from the 2-yr 24-hr storm. Additionally the structures should be built such that they do not cause damage to the SCMs when larger storm events occur Fig 5.1 shows a V-notch weir being used to measure runoff from a parking lot.

Fig 5.1 120 degree V-notch weir measuring flow from a parking lot.

The designer should keep in mind that sampler intakes will need to be placed in a well-mixed area that does not impair the measurement of flow. Also, measurement sensors will need to be placed where they will not become clogged with debris. Design features should allow the attachment of sensors and sampler intakes to the structure.
Table 5.1 lists the preferred placement of sensors and intakes for Weir and Orifice type structures. For information on setting up flumes correctly see ISCO (1978).

Table 5.1 Preferred structure and sensor placement

	Weir	Orifice	Culvert
Geometry	V- Notch	Circular	Circular
Material	Cold Rolled Steel or 1/8" Aluminum	Stainless Steel,	Existing storm drainage system
Placement of	0.0-1.0" below invert	0.0-1.0" below invert	Invert of culvert

Sensor			
Location of Sensor	At a distance of 4X maximum head expected if possible upstream of invert	N/A	N/A
Placement of intake	At invert	At invert	Invert of culvert or in center of plunge pool downstream
Location of Intake	Upstream of outlet a minimum of 4 X maximum expected head	2X Diameter of orifice upstream	Downstream of Sensor

Samplers themselves should be installed as near to the sampling points as possible to reduce the amount and length of intake tubing and sensor cable required. For area-velocity cables, maximum cable length is 30 feet requiring that samplers be installed within that distance to the structure/measurement point. Likewise bubbler tubes should be limited to 30' to reduce the effect of friction within the bubbler tube on water level readings. It is advisable that the sampler itself be installed at an elevation higher than the intake point to allow the intake tube to fully discharge after each sub-sample is collected. Ideally the sampler should be installed 5-25 feet above the intake point. If the sampler is installed at an elevation higher than 25 feet above the intake, the sampler pump will have difficulty drawing a sample.

Automatic tipping bucket rain gages such as ISCO model 674 should be installed in a location away from interference from overhanging trees or power lines. Care should be taken to ensure that the tipping mechanism is installed as close to horizontally level as possible. In most cases the rain gage can be installed adjacent to the sampler housing. It is recommended that a backup method of measuring rainfall be utilized such as a second tipping bucket system or a manual rain gage.

6. Programming Monitoring Equipment

In order to calculate Event Mean Concentration (EMC) values, each sampler station shall collect a flow-weighted composite sample. A flow-weighted sample is a sample of known volume that is collected each time a predetermined volume of flow passes by the sampling point. Flow values shall be measured and collected in the electronic memory of each sampler. It is advised that for most SCMs flow values should be logged at a frequency of every 5 minutes or less. The frequency of sample collection will depend on a number of factors including the sample size desired and SCM watershed characteristics. When beginning monitoring efforts at a site a user has two options for determining sampler program setting. A predictive model such as the NRCS CN method (USDA 1986) can be used to estimate the runoff volume associated with the desired storms. For small highly impervious watersheds of well-known dimensions it is more accurate to directly relate runoff to rainfall assuming some reduction due to initial abstraction. Another option is to install the samplers and monitor several storms to determine a rainfall-runoff response curve. Regardless of approach the user may be required to further adjust the sampler settings as monitoring efforts continue to satisfactorily collect the correct sample volume.

For sites identified for the Pilot SCM monitoring program, individual monitoring protocols should be developed detailing the sampler settings for each sampler station. These protocols are included in Section 11 of this document. In addition, information on how to set up and program samplers are included in the operational manuals for the samplers, and flow modules (ISCO 2001).

8. Data Analysis

As discussed in the introduction, one of the overall objectives of this project is to provide data that can be included into the USEPA National Stormwater BMP database, if applicable. In order to produce defensible data, statistical analysis of the collected data will need to be completed. There are several different statistical methods which may be used depending on the type of SCM, hypothesis of the test, and type of data available for analysis.

The Effluent Probability Method will most likely become a standard statistical method for use with the National Stormwater Database. Where possible this analysis will be completed for the data collected in this study. However there are other methods which may prove useful. For instance the Summation of Loads method may be used to estimate efficiencies and the Mean Concentration method may be used for some comparisons of SCM effectiveness.

Data analysis for all water quality analysis and flow monitoring data was completed initially by NCSU project personnel for the first 12 SCMs in the study. Upon completion of the study, technical reports were provided to the City of Charlotte detailing the results of the monitoring efforts. As of 2009, City and County staff has conducted all data analysis internally.

9. Maintenance of Sites and Equipment

Proper maintenance of stormwater SCMs is important to ensure proper operation and removal efficiency. When conducting monitoring at a site, proper maintenance becomes even more critical. Maintenance issues such as clogging around structures can impair sensor and intake operation. Monitoring equipment also has its own maintenance requirements.

Failure to conduct proper maintenance on a SCM may cause a reduction in pollutant removal efficiency over time or even structural damage to the SCM. Such changes make statistical analysis of data problematic. As part of this study, general maintenance guidelines will be developed for the SCM sites included in the study. When available, these guidelines should be consulted for specific instructions on site maintenance. Any maintenance conducted during the study period should be recorded in the in the sampling log book for each site. In general, the inlet and outlet structures should be cleared of any debris prior to each sampling event.

In order to keep monitoring equipment operating properly, regular maintenance should be performed. The following figures describe the maintenance to be performed for each type of equipment. More specific maintenance recommendations are discussed in the operational manuals for each type of sampler or sensor (ISCO, 2001), the user is encouraged to refer to these documents for more information.

The following maintenance items should be performed on ISCO Samplers prior to each sampling event.

1. Check that power supply is sufficient to power sampler thru sampling event
2. Remove debris collected around intake strainer
3. Inspect intake tubing for cuts or crimps, replace if necessary
4. Verify that desiccant indicator window in sampler controller is blue
5. Remove debris that has collected in rain gage if applicable

The following maintenance should be performed on ISCO Model 730 Bubble Module prior to each sampling event.

1. Inspect bubbler tube for damage or crimps, replace if necessary
2. Calibrate water level of bubbler sensor to ensure that it is within acceptable limits
3. Verify that bubbler pump is working and producing "bubbles"

The following maintenance should be performed on ISCO Model 750 Area Velocity Meter prior to each sampling event.

1. Inspect cable for nicks or cuts.
2. Verify that module is situated properly in bottom of culvert or flume.
3. Calibrate water level over module if possible.

10. References

ISCO. 2003 6712 Portable Sampler Instruction Manual. ISCO Inc. Lincoln NE

ISCO. 2003 730 Bubbler Module Instruction Manual. ISCO Inc. Lincoln NE

ISCO. 2003 750 Area-Velocity Module Instruction Manual. ISCO Inc. Lincoln NE

NC DENR. 1997. Stormwater Best Management Practices Design Manual. North Carolina Department of Environment and Natural Resources-Division of Water Quality. Raleigh, NC.

US Environmental Protection Agency (USEPA). 1996. Methods for Determination of Metals and Inorganic Chemicals in Environmental Samples. United States Environmental Protection Agency. Cincinnati, OH.

US Environmental Protection Agency (USEPA). 2002. Urban Stormwater Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements.EPA-821-B-02-001. Washington, DC.

US Environmental Protection Agency (USEPA). 2009. Urban Stormwater Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements. Washington, DC.

Grant, D.M. and Dawson, B.D. 1978. ISCO Open Channel Flow Measurement Handbook. ISCO Inc., Lincoln, NE.

11. Appendices

Appendix 1
General Monitoring Protocol

Introduction

The protocols discussed here are for use by City of Charlotte and Mecklenburg County Water Quality personnel in setting up and operating the stormwater SCM monitoring program. The monitoring program is detailed in the parent document "Stormwater Control Measure (SCM) Monitoring Plan for the City of Charlotte"

Equipment Set-up

For the program, 1-2 events per month will be monitored at each site. As a result, equipment may be left on site between sampling events or transported to laboratory or storage areas between events for security purposes. Monitoring personnel should regularly check weather forecasts to determine when to plan for a monitoring event. When a precipitation event is expected, sampling equipment should be installed at the monitoring stations according to the individual site monitoring protocols provided. It is imperative that the sampling equipment be installed and started prior to the beginning of the storm event. Failure to measure and capture the initial stages of the storm hydrograph may cause the "first flush" to be missed.
The use of ISCO refrigerated single bottle samplers will be used in the study. Two different types of flow measurement modules will be used depending on the type of primary structure available for monitoring

Programming

Each sampler station will be programmed to collect up to 96 individual aliquots during a storm event. Each aliquot will be 200 mL. in volume. Where flow measurement is possible, each sampling aliquot will be triggered by a known volume of water passing the primary device. The volume of flow to trigger sample collection will vary by site depending on watershed size and characteristic.

Sample and data collection

Due to sample hold time requirements of some chemical analysis, it is important that monitoring personnel collect samples and transport them to the laboratory in a timely manner. For the analysis recommended in the study plan, samples should be delivered to the lab no more than 48 hours after sample collection by the automatic sampler if no refrigeration or cooling of samples is done. Additionally, samples should not be collected/retrieved from the sampler until the runoff hydrograph has ceased or flow has resumed to base flow levels. It may take a couple of sampling events for the monitoring personnel to get a good "feel" for how each SCM responds to storm events. Until that time the progress of the sampling may need to be checked frequently. Inflow sampling may be completed just after cessation of the precipitation event while outflow samples may take 24-48 hours after rain has stopped to complete. As a result it may be convenient to collect the inflow samples then collect the outflow samples several hours or a couple of days later.

As described above, samples are collected in single bottle containers. Once the composited sample has been well mixed in the container, samples for analysis should be placed in the appropriate container as supplied by the analysis laboratory.

Chain of custody forms should be filled in accordance with CMU Laboratory requirements.

Collection of rainfall and flow data is not as time dependent as sample collection. However it is advised that data be transferred to the appropriate PC or storage media as soon as possible.

Data Transfer

Sample analysis results as well as flow and rainfall data will be QA/QC'd per standard operating procedure and entered into the water quality database (WQD).

APPENDIX C

STANDARD ADMINISTRATIVE PROCEDURE

Structural Best Management Practice (BMP) Monitoring
CR-MP (3), SWIM2 McDowell

Mecklenburg County
Land Use and Environmental Services Agency
Water Quality Program

Jon Beller	Sr. Environmental Specialist	Project Officer
Jeff Price	Environmental Analyst	QA/QC Officer
Rusty Rozzelle	Water Quality Program Manager	

City of Charlotte
Engineering and Property Management
Storm Water Services

Steve Jadlocki	WQ Administrator	
Daryl Hammock	Water Quality Program Manager	

Charlotte-Mecklenburg Storm Water Services
Charlotte, NC

Standard Administrative Procedure
Modification / Review Log

Version	Eff. Date	Author	Summary of Changes	Approved
1.0		Jeff Price	Original Draft.	Jeff Price
1.1	8/13/07	Jeff Price	Formatting changes – minor.	Jeff Price
1.2	1/1/08	Jeff Price	Minor formatting changes, updates.	Jeff Price
1.3	4/1/09	Jeff Price	Minor formatting changes, updates.	Jeff Price
1.4	8/10/09	Jeff Price	Added Bacteriological sample collection utilizing automated samplers.	Jeff Price
1.5	9/2/09	Jon Beller	Updated site list, removed PSD sampling requirements.	Jeff Price
1.6	7/1/10	Jon Beller	Updated site list	
1.7	7/1/11	Jon Beller	Updated site list, updates.	

1.0 Purpose

1.1 To collect stormwater runoff data in support of the City of Charlotte's Pilot BMP Study Program and Mecklenburg County Special project sites, including the North Mecklenburg Recycling Center and CMC Huntersville sites.

2.0 Applicability

2.1 This Standard Administrative Procedure (SAP) is applicable to all storm water runoff events collected from BMPs under the Charlotte-Mecklenburg - Water Quality Work Plan; Program Elements CR-MP (3), and SWIM Phase II McDowell.

3.0 Program Summary

3.1 Collect flow-weighted storm water composite samples from the influent(s) and effluent of each of the BMP sites identified in Attachment 10.1

3.2 The data end-user will utilize the sample results to calculate pollutant removal efficiencies for each BMP sampled.

4.0 Health and Safety Warnings

4.1 Always exercise caution and consider personal safety first. Surface water sampling poses a number of inherent risks, including steep and hazardous terrain negotiation, threatening weather conditions, deep and/or swift moving water, stinging insects and incidental contact with wild animals.

4.2 Always were gloves and exercise universal precautions. Decontaminate hands frequently using a no-rinse hand sanitizer. Urban surface waters pose potential for pathogenic contamination.

4.3 Always exercise caution in handling the equipment. Automated samplers utilize 12-volt DC power sources and peristaltic pumps. Electrical and mechanical hazards are inherent in their maintenance and use.

4.4 Never lift or carry more than you can comfortably handle give site conditions. 12-volt batteries and 20-liter carboys full of sample water are very heavy.

5.0 Interferences

5.1 For pre-preserved sample collection bottles; overfilled, spilled or otherwise damaged containers should be discarded and a new sample should be collected. This reduces the risk of sample contamination and improper chemical preservation.

5.2 ISCO sample collection containers should be thoroughly mixed prior to pouring up individual sample collection bottles. This will ensure that representative samples are submitted for analysis.

5.3 Any observed equipment problems or any identified inconsistencies with Standard Operating Procedures during a sample event should be reported to the QA/QC Officer immediately. Issues identified in conflict with programmatic Data Quality Objectives may result in re-samples, additional samples, a scratched run or a scratched sample event.

6.0 Sample Collection Procedure

Preparation

6.1 Identify staff resources responsible for sample collection. Coordinate the sample event details with staff resources and the CMU lab as necessary.

6.2 For each site sampled, print the following:

6.2.1 Chain of Custody forms (Attachment 10.2)
6.2.2 BMP Event Data Sheet (Attachment 10.3)
6.2.3 Sample collection bottle labels (Attachment 10.4)

Note: Bottle labels require the use of special adhesive backed, waterproof label paper and a label printer. Otherwise, labels may be printed by hand utilizing

6.3 Assemble sets of the following sample collection bottles for each site; one set per sampler.

Note: *Bacteriological samples are not required at all sites, see Attachment 10.1.

6.3.1 1 x 1000ml (unpreserved) – TSS, Turbidity
6.3.2 1 x 500ml (HNO_3) – Metals (Cr, Cu, Pb, Zn)
6.3.3 1 x 500ml (H_2SO_4) – Nutrients (N-NH_3, NOX, TKN, TP)
6.3.4 3 x 100ml (sterile, $NA_2S_2O_3$) – Bacteriological (Fecal Coliform, E Coli, Enterococcus)*
6.3.5 1 x 250ml (unpreserved) – SSC

6.4 Affix the self-adhesive labels to the appropriate sample collection bottles. Leave the Sample Collection Time blank. The sample collection time will be recorded from the automated monitoring equipment.

Sample Collection

6.5 At **each** sample site location; collect automated flow-weighted composite samples utilizing the Automated Surface Water Sample Collection procedure (Ref. 9.2).

6.6 Where required; collect bacteriological samples directly from the automated flow-weighted composite.

6.7 Create entry in Water Quality Database (WQD) stating what site was set-up and the date of set-up and sample collection.

6.8 When sample is collected, Monitoring Team Lead will enter event data into WQD for each site.

6.9 For failed events, staff will enter reason(s) event failed into WQD and forward to Monitoring Team Lead for review.

7.0 Performance / Acceptance Criteria

7.1 For each site, a complete sample event includes a flow weighted composite and in-stream instantaneous measurements for the following parameters, where appropriate.

F Coliform	TKN	*Chromium	Dissolved O2	*% Hydrograph
E Coli	*TP	*Copper	Sp. Conductivity	*Rainfall
Enterococcus	*TSS	*Lead	pH	
N-NH3	*SSC	*Zinc	*ISCO Flow	
NOx	*Turbidity	*Temp	*Event Duration	

* Denotes critical parameters.

7.2 Samples must be analyzed by a NC State certified laboratory for each parameter identified in 7.1 in order to be considered complete.

7.3 If utilized, YSI multi-parameter sondes must be calibrated before use and checked-in after use. All calibration data must be recorded in the calibration log.

7.4 Samples should be collected only after a minimum of 72 hours dry weather. Samples should be submitted for analysis only if all key ISCO samplers functioned for the entire event, as defined by the percentage of storm event hydrograph collected. Samples must meet or exceed 70% of the hydrograph in order to be considered complete. For additional guidance regarding ISCO Bacteriological sample collection, see Attachment 10.5.

7.5 All data must be submitted to the QA/QC Officer.

8.0 Data and Records Management

8.1 All field data must be entered by staff into WQD. Data is reviewed by Monitoring Team Lead and submitted to the QA/QC Officer for final approval.

8.2 All lab data must be submitted to the QA/QC Officer in electronic format.

8.3 All completed COCs must be submitted to the QA/QC Officer.

8.4 Electronic transfer of analytical data from the Laboratory database to the WQDR will be administered by the QA/QC Officer.

8.5 Transfer of all collected field data (flow and instantaneous in-stream measurements) to the WQDR will be administered by the QA/QC Officer.

9.0 References

9.1 YSI SOP – YSI Multiprobe Calibration and Field Data Collection (Short-term Deployment).

9.2 ISCO SOP - Automated Surface Water Sample Collection.

10.0 Attachments

10.1 – Example Chain of Custody

CHARLOTTE-MECKLENBURG UTILITIES - LABORATORY SERVICES DIVISION
Hal Marshall Laboratory, 700 North Tryon St., Charlotte, NC 28202, 704/336-5460

CLIENT:	MECKLENBURG COUNTY, LUESA - WATER QUALITY PROGRAM
FACILITY:	NA
PROJECT:	Pilot BMP Monitoring
LAB CODE:	CRMP3

Report To:	Jeff Price
	700N Tryon St. Ste. 205
	Charlotte, NC 28202

CHAIN OF CUSTODY RECORD			
PAGE	1	OF	1
COC#:			
Sampled By (Print Name)			

		Sample Collection				Sample Temp		Sample Type				Sample Containers			Chemical / Preservative							Analyses Requested							
Location Code		Staff ID	Date	Time	Chlorinated	Coll Temp	Rcpt Temp	Depth Comp	Auto Comp	Hand Comp	Grab	Plastic	Glass	# Containers	None	HNO3	H2SO4	NaOH	HCl	Na2S2O3	pH Correct	Fecal Coliform	E Coli	Nutrients	TSS	Turbidity	SSC	Metals	PSD
W-	Influent				N						X	100 ml		2						X		X	X						
W-	Influent				N				X			500 ml		1			X							X					
W-	Influent				N				X			1000 ml		1	X										X	X			
W-	Influent				N				X			250 ml		1	X												X		
W-	Influent				N				X			500 ml		1		X												X	
W-	Influent				N				X			250 ml		1	X														X
W-	Effluent				N						X	100 ml		2						X		X	X						
W-	Effluent				N				X			500 ml		1			X							X					
W-	Effluent				N				X			1000 ml		1	X										X	X			
W-	Effluent				N				X			250 ml		1	X												X		
W-	Effluent				N				X			500 ml		1		X												X	
W-	Effluent				N				X			250 ml		1	X														X

NOTES: Complete yellow shaded sections; each "X" needs to be circled.	Relinquished By: (Signature)	Received By: (Signature)	Date	Time
Metals = Cr, Cu, Pb, Zn				
Nutrients = NH3, NOx, TKN, TP	Relinquished By: (Signature)	Received By: (Signature)	Date	Time
Form Revision 2; effective 7/01/07				

10.2 – Example BMP Event Data Sheet

BMP Pilot Monitoring CR-MP(3)

Site Name:	

Composite Sample Information	**Sampling Date:**
Total Rainfall	
Total Rainfall Duration	
Days Since Previous Rain Event	
ISCO Event Duration	
Aliquots Sampled	
Sampler Pacing	
Sampled Storm Volume	
Total Discharge	
Percent of Hydrograph	

Grab Sample Information	**Sampling Date:**
pH	
Conductivity	
Dissolved Oxygen	
% Dissolved Oxygen	
Temperature	

Comments:

10.3 – BMP Example Sample Collection Bottle Label

Mecklenburg County LUESA/WQP BMP Monitoring	
Sample ID: (W–Site Name)	
Date: **/**/**	Time:____________
Sample Type: Composite	Staff ID:__________
Preservative: (Preservative)	Bottle: (Vol) ml (type)
Tests: (Parameter)	

10.4 – ISCO Bacteriological Sample Collection Guidance

The following guidelines must be met in order to collect valid Bacteriological samples:

1. At the time of collection, the composite sample must be comprised of ≥15 sample aliquots.

2. Bacteriological samples must be pulled from the composite sampler ≤24 hours from the time that the first sample aliquot is collected.

3. ISCO refrigeration unit must be functional and the sample must be cooled to ≤4°C at the time of bacteriological extraction.

4. Bacteriological samples must be extracted in the field and immediately placed in a cooler on ice, for direct transport to the CMU lab.

APPENDIX D

STANDARD OPERATING PROCEDURE

AUTOMATED SURFACE WATER SAMPLE COLLECTION

Mecklenburg County
Land Use and Environmental Services Agency
Water Quality Program

Jon Beller	Sr. Environmental Specialist	Project Officer
Jeff Price	Environmental Analyst	QA/QC Officer
Rusty Rozzelle	Water Quality Program Manager	

City of Charlotte
Engineering and Property Management
Storm Water Services

Steve Jadlocki	WQ Administrator	
Daryl Hammock	Water Quality Program Manager	

Charlotte-Mecklenburg Storm Water Services
Charlotte, NC

Standard Operating Procedure
Modification / Review Log

Version	Eff. Date	Author	Summary of Changes	Approved
1.0	2/26/07	Jeff Price	Original Draft	Jeff Price
1.1	1/1/08	Jeff Price	Formatting changes – minor	Jeff Price
1.2	7/1/08	Jon Beller	Field Validation, minor formatting changes	Jeff Price
1.3	1/1/09	Jeff Price	Formatting changes – minor	Jeff Price
1.4	9/2/09	Jon Beller	New updates to account for ISCO Automated Fecal collection	Jeff Price
1.5	9/8/11	Jon Beller	New updates to account for addition of Water Quality Database	Jeff Price

1.0 Scope and Applicability

1.1 This SOP is applicable to the collection of flow-weighted composite surface water samples utilizing portable auto-samplers. Flow weighted auto-composite samples are suitable for both chemical and physical parameter analysis.

1.2 Automated samplers are not sterilized and therefore bacteriological samples collected in this manner are known to be in conflict with standard methods and commonly accepted protocols. However, bacteriological samples will be collected from full storm composites for research purposes. This data will be identified as special purpose data and utilized as such.

6.0 Summary of Method

3.1 Flow-weighted composite samples of surface water are collected from either free flowing streams or impounded water sources utilizing automated samplers.

3.2 Surface water sub-samples, or aliquots, are pumped from the source utilizing a peristaltic pump and a computer-controlled sampling "head". The sample aliquots are drawn from the source in proportion to measured water flow (discharge in cf) so that the final composite sample represents the entire range of flow conditions, or hydrograph, observed at a site during a precipitation event.

3.3 The final composite sample is distributed among various certified clean, pre-preserved bottles suitable for relevant laboratory analysis. All samples are submitted to a NC State certified laboratory for the analysis and quantification of surface water pollutants.

6.0 Health and Safety Warnings

3.1 Caution should always be exercised and personal safety considerations must be considered paramount for field monitoring. Surface water sampling poses a number of inherent risks, including steep and hazardous terrain negotiation, deep and/or swift moving water, stinging insects and occasional contact with wild animals.

3.2 Always wear gloves when sampling and decontaminate hands frequently using a no-rinse hand sanitizer. Universal precautions should be exercised when exposed to urban surface waters with unknown potential for contamination.

3.3 Always exercise caution in handling the equipment. Automated samplers utilize 12-volt DC power sources and peristaltic pumps. Electrical and mechanical hazards are inherent in their maintenance and use.

3.4 Never lift or carry more than you can comfortably handle give site conditions.
12-volt batteries and 20-liter carboys full of sample water are very heavy.

4.0 Interferences

4.1 Improper sample pacing. Automated samplers are limited by the number of aliquots (of a given volume) that can be drawn before the sample carboy is filled. Improperly paced sampling equipment has potential to miss portions of a precipitation event.

4.2 Improperly cleaned (or contaminated) sampling equipment. Sample collection carboys must be cleaned and QC equipment blanks are used to verify equipment decontamination.

4.3 Cross-contamination of samples during transport. Always place filled samples collection bottles (samples) upright in the cooler so that the neck and cap are above the level of the ice. Drain ice melt-water from coolers periodically to ensure that sample bottles are not submerged.

4.4 Battery failure following sample collection. Failed refrigeration due to battery failure results in improperly preserved samples.

4.5 Vandalism of equipment. Sampling equipment is often placed near inhabited areas that have the potential to be damaged by vandalism.

5.0 Equipment and Supplies

5.1 The following equipment is generally needed for automated, flow-weighted composite surface water sample collection:

- ISCO 6712 Avalanche refrigerated auto-sampler
- ISCO 750 Area Velocity Flow Module or ISCO 730 Bubbler Flow Module
- Continuous Temperature Probe
- ISCO 674 Rain Gage
- ISCO 581 Rapid Transfer Device
- Cleaned 18.9-liter sample collection carboy
- 12-volt deep cycle battery
- Sampler collection tubing
- Stainless steel bubbler tubing
- Metal job box
- Chain
- Lock
- Anchor

- CMU Lab Chain of Custody Form (Attachment 13.1)
- CMU Sample Collection Bottle Selection Guidance Chart (Attachment 13.2)
- Certified clean, pre-preserved sample collection bottles appropriate for intended parameter analysis (provided by CMU)
- Sample bottle self-adhesive labels
- 4-liters of lab distilled/de-ionized reagent grade water
- CMU lab sterilized buffered bacteriological blank solution
- Sharpie, pen
- Map Book
- Gloves
- Hip waders, rubber boots
- Hand sanitizer

6.0 Automated Sampling Site Set Up

6.5 Identify a suitable site to locate the auto-sampler depending on objectives of the sampling program.

6.6 Set up metal job box near the stream or site to be sampled but far enough away to be out of the flow range during storm events.

6.7 Screw the trailer anchors into the ground near the job box and lock the job box to the anchor with the safety chain.

6.8 Place the ISCO 6712 Avalanche automated sampler in the job box along with a 12-volt battery.

6.9 Attach the strainer tube and metal bubbler or Area Velocity sensor at the desired height in the stream, pipe or pond.

6.10 Connect a measured length of vinyl tubing from the sampler through the bottom of the job box to the strainer.

6.11 Depending on the configuration, either connect a piece of vinyl tubing from the sampler to the metal bubbler tube or connect the cable to the Area Velocity module.

6.12 Connect the power cables to the 12 V battery.

6.13 Complete the initial programming of the 6712 Sampler using the procedure in Section 7.0. Refer to the ISCO Operating manual or consult the Monitoring Team Supervisor for further details.

6.14 Create new BMP entry for each site set-up in the Water Quality Database (WQD).

7.0 ISCO 6712 Avalanche Auto-Sampler General Set-up and Programming

Note: Programming steps represent general examples and choices only. Actual programming is unique to an individual site and must be modified in order to collect representative samples. Modification of the programming steps is based on knowledge of the site, expected conditions, professional judgment and experience.

7.1 Place a cleaned, 18.9-liter sample collection carboy in the auto-sampler's refrigerated sample collection compartment. Insure that lid is removed and sample tube is placed into the carboy.

7.2 Place a charged 12-volt battery in the auto-sampler Job-Box and connect the unit's power lead to the battery terminals.

7.3 Insert appropriate Flow Module into auto-sampler unit.

7.4 Turn on the auto-sampler "Power".

7.5 Select "Program".

7.6 Enter the Program Name (site id).

7.7 Enter the Site Description (site id repeated).

7.8 Enter Units as follows:

- Length (ft.)
- Temperature (C)
- Flow Rate (cfs – BMPs / Mgal - ISM)
- Flow Volume (cf)
- Velocity (fps)

7.9 Select the Mode of Operation based on the hardware configuration selected in 8.3 and the site installation (unique to site; subsequent detailed information required):

- Bubbler Flow Module 730
  - V-Notch Weir (most common):
    - Specify V-Notch angle (Ex. 90º)
  - Data Points (less common – orifice plates and ISM storm water)
    - New Set
    - Clear Data Set
    - Change Name

        - Edit Data Points (enter up to 50 data points; level and cfs)
    - Flume (uncommon)

- Area*Velocity Flow Module 750
    - Flow Meter
    - Area*Velocity
    - Channel Shape
    - Enter Type
        - Round Pipe (most common)
    - Pipe Diameter (ft.) (Eg. 18 inch pipe = 1.5 ft. diameter)

7.10 Enter Current Level (ft.).

- For BMP sites - storm flow only.
    - Bubbler
        - Enter water depth from bubbler to bottom of V-Notch in weir (ft.)
            - Water level below bubbler
                - Distance from bubbler to invert of V-notch weir (negative ft.)
            - Water level above bubbler
                - Difference between water level and invert of V-notch weir (negative ft. – below invert; 0.0 ft. at invert; positive ft. above invert)

Note: Measure distances in inches and divide by 12 to determine distances in ft. Eg. Water level is below bubbler; bubbler is set 1 inch below V-notch weir. Set water depth at -0.08 ft. (1 inch divided by 12 inches/ft. = 0.08 ft.)

    - Area*Velocity
        - Enter (0.000 ft.) when no flow is present.
        - If flow is present, consult the Monitoring Team Supervisor.

- For Stream sites - flow present.
    - Determine current water level from USGS internet website.
    - Enter level (ft.).

7.11 Enter Offset (0.000 ft.) if prompted.

7.12 Enter Data Interval (5 minutes).

7.13 Enter sample collection container information.

- Bottles (1).
- Volume (18.9 L).
- Suction Line (Length of sampler tubing (ft.)).

- Auto Suction Head
- 0 Rinse
- 0 Retry

7.14 Select One-Part Program.

7.15 For Pacing;

- Flow Paced
- Flow Module Volume
- Enter (cf) - unique to site; based upon drainage area, forecast precipitation volume, professional judgment and experience.
- No Sample at Start.

7.16 Run Continuously? - No.

7.17 Enter number of aliquots to Composite (90).

7.18 Enter Sample Volume (200 ml).

7.19 Select "Enable"

- Bubbler Module.
  - Select "Level".
  - For BMP sites;
    - Water level below invert
      - Enter (>0.001 ft.).
    - Water level at or above invert
      - Enter current water level + (0.01 ft.).
  - For Stream sites; Enter (current water level + 0.05 ft.) - current level + margin of safety before sampler enable.

- Area*Velocity Module.
  - Select "Level".
  - For dry pipe;
    - Enter (>0.005 ft.)
  - For pipe with flow;
    - Enter (current water level + 0.02 ft.) - current level + margin of safety before sampler enable.

7.20 Enable.

- Repeatable Enable.
- No Sample at Enable.
- No Sample at Disable.

7.21 Countdown Continues While Disabled.

7.22 No Delay to Start.

7.23 Run This Program.

8.0 Auto-Sampler Composite Retrieval

8.1 Stop Program and View "Sampling Report".

8.2 Scroll through the sampling report and record the time and date of the last aliquot sampled. Enter this information on the Lab COC.

8.3 Connect ISCO RTD 581 to the auto-sampler's Interrogator port. Disconnect RTD when "Download Complete" is indicated by steady green light.

8.4 Turn off the auto-sampler "Power".

8.5 Disconnect the battery leads to the auto-sampler.

8.6 Replace the cap on sample collection carboy.

8.7 Remove the sample collection carboy from the auto-sampler's refrigerated sample compartment and put in cooler for transport to the composite bottling staging area.

9.0 Auto-Sampler Composite Bottling

9.1 Print the appropriate COC forms required for the event.

9.2 Coordinate the sample collection event details with required staff resources and with the CMU lab (number of sites, parameters for analysis, etc.)

9.3 Assemble the required sample collection bottles for each site to be sampled. Pre-print all known information on self-adhesive sample collection bottle labels. Make sure to leave the Sample Collection Time blank (this will be completed when the last aliquot collection time is determined).

9.4 Label the sample collection bottles with the approximate <u>Sample Collection Time</u> (+/- 5 minutes).

9.5 Remove the sample collection bottle cap(s) and place the bottle(s) on a level, stable surface.

9.6 Shake the auto-sampler composite carboy to thoroughly mix the sample.

9.7 Fill the sample collection bottle(s) to the bottom of the neck or to the indicated mark with the auto-sampler composite, approximately 80-90% full. Be careful not to overfill the sample collection bottles!

9.8 Replace the sample collection bottle cap(s).

10.0 Auto-Sampler Grab Sample Collection (pump-grab)

Note: Pump grabs are not commonly collected, but may be utilized in special circumstances, as required.

10.1 Turn on the auto-sampler "Power".

10.2 Select "Other Functions", "Manual Functions", "Grab Sample".

10.3 Enter sample <u>Volume</u> (ml), based on collection container.

10.4 Disconnect large diameter sample collection tubing from the peristaltic pump housing on the front, left-side of the auto-sampler unit.

10.5 Carefully open the sample collection bottle cap. Be sure not to contact any inside surface of the bottle cap or the bottle.

10.6 Press Enter when ready to collect the sample.

10.7 Allow a small amount of sample water to flow through the tube, onto the ground to clear the line.

10.8 Direct the flow from the large diameter sample collection tubing into the sample collection bottle, but do not contact any surfaces of the collection bottle.

10.9 Fill the sample collection bottle to the indicated volume. Do not overfill bottle.

10.10 Replace the sample collection bottle cap.

10.11 Re-connect the large diameter sample collection tubing.

11.0 Post-Sample Collection

11.1 For failed events, document reason for failure (power fail, pacing…) in WQD and forward to Monitoring Team Lead for review.

11.2 Place all sample collection bottles (and blanks) upright in the cooler. Do not submerge sample bottles in ice-melt water as indicated in 4.3.

11.3 For potential valid samples, give RTD to Monitoring Team Lead for pre-sample screening.

11.4 Monitoring Team Lead will download RTD to Flowlink software.

11.5 Validate sample by determining if ≥70% of hydrograph collected. If <70% of the hydrograph was represented, discard the sample and follow 11.1.

11.6 Complete the COC.

11.7 Deliver all sample bottles in the cooler on ice to the CMU Lab for analysis.

11.8 Monitoring Team Lead will enter field data and Flowlink software data into WQD and forward to WQ Data Manager for final review.

11.9 Submit a copy of the completed COC form to the WQ Data Manager.

12.0 Field QC Blank Collection (when required)

12.1 When required by a project or program element, assemble one set of sample collection bottles for QC blanks.

12.2 When QC blanks are required, fill a certified-clean 4-liter bottle with lab distilled/de-ionized reagent grade water for each auto-sampler.

12.3 Replace the small diameter auto-sampler sample collection tubing on the back, left-side of the unit with a short section of clean, new tubing.

12.4 Remove the cap from the distilled/de-ionized reagent grade water or the sterilized buffered bacteriological blank solution as appropriate.

12.5 Insert the short section of new sample collection tubing into the distilled/de-ionized reagent grade water to draw the blank solution up through the auto-sampler unit.

12.6 Turn on auto-sampler "Power".

12.7 Select "Other Functions", "Manual Functions", "Grab Sample".

12.8 Enter sample <u>Volume</u> (2500 ml required min for full parameter suite analysis).

12.9 Press Enter when ready to collect the sample.

12.10 Collect the required volume of sample blank in the sample collection carboy.

12.11 Remove the blank collection bottle cap(s).

12.12 Shake the auto-sampler composite carboy to thoroughly mix the sample (blank).

12.13 Place the blank collection bottle(s) on level, stable surface. Fill the blank collection bottle(s) to the bottom of the neck or to the indicated mark with the appropriate blank solution, approximately 80-90% full. Be careful not to overfill the blank collection bottles!

12.14 Replace the blank collection bottle cap(s).

12.15 Refer to Section 11.0 for Post Sample Collection procedures.

13.0 References

13.1 ISCO 6712 Avalanche Operating Manual.

APPENDIX E

Pilot SCM Data Analysis Protocol

Charlotte-Mecklenburg Storm Water Services (CMSWS) conducts routine BMP Performance Monitoring for both regulatory and non-regulatory purposes. Regulatory monitoring may be utilized to ensure BMP compliance with water quality standards or performance criteria mandated by State or local government, as required by Phase I and Phase II NPDES permits, the Charlotte-Mecklenburg Post-Construction Ordinance, etc. Non-regulatory monitoring is generally utilized to satisfy grant requirements for Capital Improvement Projects as well as assessing the general performance and efficiency of select BMPs.

BMP monitoring may include both inter-site and intra-site comparisons, depending on the monitoring goals. Inter-site comparisons (site to site) can test varying BMP designs on similar land-use types, and test varying land-use types on one specific BMP design. Intra-site comparisons can test long term efficiency, maintenance intervals, site stabilization, etc. at one site over a specified time period. Both inter-site and intra-site analysis of BMP performance can be utilized to optimize BMP design and to conserve limited resources.

Charlotte-Mecklenburg Storm Water Services will base routine BMP Performance Monitoring and analysis on guidance provided in the October 2009 publication, *Urban Stormwater BMP Performance Monitoring* prepared by Geosyntec Consultants and Wright Water Engineers under contract with the EPA. In addition to the EPA, the guidance preparation was sponsored by the American Society of Civil Engineers (ASCE), the Water Environment Research Foundation (WERF), and the Federal Highway Administration. The published guidance recommends that BMP performance monitoring be analyzed utilizing what is termed the **Effluent Probability Analysis** method. Each section below describes components of the Effluent Probability Analysis approach in detail, where applicable.

A great deal of environmental data is reported by analytical laboratories as "below detection limit" (nondetect). This does not mean that the target pollutant was not present, it simply means that the level of pollutant was too small to quantify given the limits of the analytical test procedure. There is still valuable information in a reported nondetect. However, traditionally, analysts have simply substituted the detection limit or some arbitrary number (like ½ the detection limit) for these unspecified values. This introduces an invasive pattern in the data, artificially reduces variability and subsequently narrows the error measurement range. This can affect hypothesis testing and increase the likelihood of accepting incorrect conclusions. Therefore, in an effort to improve the accuracy of calculated estimates and hypothesis testing results, and to ensure that the results of all analysis are considered "defensible" to the larger scientific community, CMSWS will treat nondetect data in accordance with published guidance from Dr. Dennis Helsel, formerly of the United States Geologic Survey (USGS) and currently director of *Practical Stats*. Dr. Helsel published *Nondetects and Data Analysis; Statistics* *for Censored Data* in 2005, specifically addressing the issues of non-detect data and how to best treat such data during analysis. This book will serve as guidance on handling nondetect values encountered in CMSWS BMP performance monitoring data.

At a minimum, a complete performance analysis report will include a review and qualification of the storm events sampled, descriptive statistics and calculated pollutant removal efficiencies for each analyte of interest. All statistical analysis will be performed using some combination of Minitab 16 with add-in macros from Dr. Helsel (NADA – Practical Stats), Analyze-It for Microsoft Excel, DOS-based software developed by the USGS, or other commercially available software. Each section below includes an example analysis based on data previously collected by CMSWS.

5.2.1 Storm Event Criteria Qualification

Not every storm event is suitable for sampling; nor is each sampled storm event suitable for use in performance analysis. In fact, some storm events sampled are not submitted to the lab for analytical results in an effort to conserve resources. These are complex decisions based on various factors, including: storm duration, intensity, precipitation amount, antecedent weather conditions, the volume of discharge collected, and the percentage of the storm hydrograph captured. Each of these factors plays a very important role in storm event qualification.

It is important to note that storm event qualification occurs prior to review of the analytical data. It is also important to note that analytical data quality control is an independent process completely separated from event qualification. This process was not intended or expected to bias results, but rather simply to control exogenous variables and therefore minimize variability in the dataset. The overall goal of this approach is to use only events that meet specified data quality objectives in order to achieve statistically significant (or non-significant) results from the smallest dataset possible in order to conserve resources.

In general, CMSWS does not monitor an event unless it has been dry weather for 3 days prior to the target storm event. CMSWS defines an acceptable “dry” weather period preceding monitored events as 3 consecutive 24 hour periods during which no more than 0.1 inches of precipitation fell during any one period. This antecedent dry weather period is consistent with guidance from the State of North Carolina Department of Environment and Natural Resources (NC DENR) and is thought to be the minimum sufficient time for pollutants to “build up” on a site between storm events.

CMSWS also does not monitor storm events that exceed the 2-year design storm. For the Charlotte-Mecklenburg area of the NC Piedmont, the 2-year design storm is approximately 3.12” in 24 hours. For BMP efficiency monitoring analysis, CMSWS utilizes only storms that meet BMP design criteria. For many BMPs the specified design criteria is a 1-inch rain event in a 24 hour period. However, this does not apply to many proprietary “flow-thru” devices and other BMPs designed to different or specific standards. In this way, storm flow bypasses, which may introduce additional uncertainty in an analysis, are excluded. Events monitored that exceed the BMP design capacity would be utilized for watershed level land use estimates of loading only.

CMSWS only submits storm samples to the lab for analysis if there were enough aliquots collected in the composite to provide the laboratory with sufficient sample volume to analyze any identified critical parameters. The typical target is 15 aliquots minimum; however sufficient volume can be produced from fewer aliquots and should be reviewed case-by-case. On the other end of the spectrum, no storm samples will be analyzed if the auto compositor finishes its cycle of 90 aliquots before the storm ends, unless at least 70% of the hydrograph was represented. The criterion to sample a minimum of 70% of the hydrograph is intended to ensure that the composite sample is representative of the overall storm flow discharge. This threshold is consistent with Technology Acceptance Reciprocity Partnership (TARP) Tier II protocols (July 2003, Sect. 3.3.1.2 – Identifying Storms to Sample). Any noted flow problems, power failure or other equipment related interferences may result in a discarded sample. Only samples that are deemed suitable for analysis by these criteria are utilized in the determining the overall performance of a BMP.

Special situations or certain projects may arise that require lower standards for acceptable storm event criteria. Any deviations from the aforementioned criteria will be noted in the associated performance report in order to clearly identify which criteria were compromised, why the standards were lowered, and what bias or influence may be realized, if known. It is again important to note that these storm event criteria will be applied to data sets prior to any exploratory analysis and without preconceived ideas or goals for the outcome. In this way, bias to an objective outcome will be minimized.

5.2.2 Characterizing Discharge (Storm Volume Reduction)

BMP performance analysis begins with understanding the nature of the storm events sampled. Once the storm events have been reviewed and qualified as approved for analysis, discharge data will be used to determine if practice level storm volume reduction has been realized. It should be noted that this component of the analysis is not appropriate for all BMPs. Those BMPs designed as flow-thru devices, with no expectation of storm water retention or infiltration will be treated accordingly. Many such BMPs are equipped with influent flow measurement equipment only. In these cases, the influent storm volume is assumed to equal the effluent storm volume, with treatment realized in pollutant concentration reduction only.

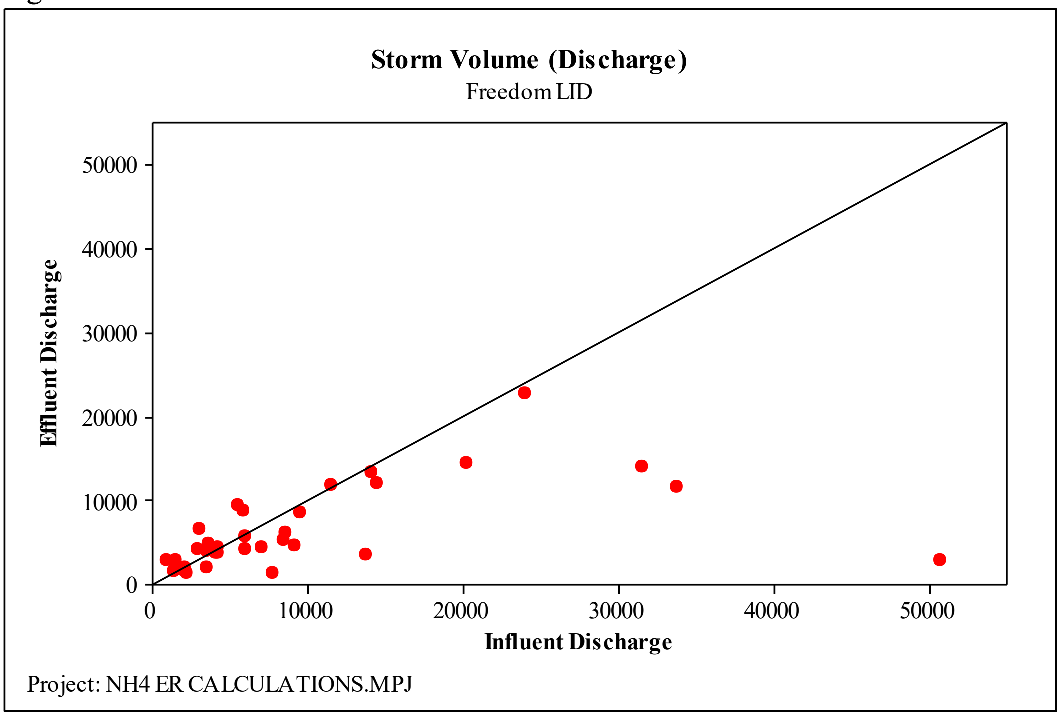
For those BMPs with some expectation of storm water retention or infiltration, characterization and analysis of the storm events and the discharged storm volume is critical. There are five relatively simple ways that this analysis can be conducted and storm events characterized; presence/absence of effluent discharge, absolute volume reduction, relative volume reduction, discharged volume per area and discharged volume per impervious area. The metrics themselves are fairly self-explanatory and simple to calculate.

The most practical of these approaches is likely the absolute volume reduction, realized over time. For this analysis, only paired influent-effluent discharge data can be utilized. For data sets where there are fewer paired observations, the error in estimates will be greater. Essentially, each paired observation is evaluated as:

Absolute Volume Reduction = Influent Volume – Effluent Volume

The volume reductions are then summed over the period of observation. Once the data have been summed, the relative reduction will also be evident, if any. The graphic created in Figure 4 can be helpful to understanding and interpreting this concept visually. Absolute storm flow volumes for the paired influent and effluent samples are plotted as independent (x-axis) and dependent variables (y-axis), respectively. The diagonal line represents the point at which influent volume is equal to effluent volume. Events represented in the lower and right portion of the graphic indicate that influent volume exceeded effluent volume, and consequently some reduction in absolute volume was realized. If a majority of the events fall in this area, as in this example, it is likely that long term reductions will be realized as well.

Figure 4



Discharge data and volume reductions should be tested for statistical significance. Hypothesis testing for paired discharges, influent and effluent, should utilize the Sign test to determine if any reductions in storm volume discharge realized were statistically significant. In this example, the paired influent and effluent samples were found to be significantly different (p=0.0326). If paired discharges are not available, other suitable nonparametric hypothesis tests, such as the Mann-Whitney test should be utilized on the pooled event data; influent vs. effluent. Specifics about hypothesis testing are covered in Section 5.2.4.

5.2.3 Descriptive Statistics

For each analyte of interest, the following information will be provided, where appropriate: n (number of observations), Mean, 95% Confidence Interval (CI) of the mean, Standard Error (SE), Standard Deviation (SD), Minimum value observed, 1st Quartile value, Median, 95% Confidence Interval (CI) of the median, 3rd Quartile value, Maximum value observed, and the Inter-Quartile range (IQR). Descriptive statistics are often accompanied by a graphic indicating the data distribution and any identified outliers.

Figure 5 indicates an example of descriptive statistics, which provide basic parametric and nonparametric information on the distribution of the data collected.

Figure 5

ROS Estimated Statistics for FLIDU-NH4

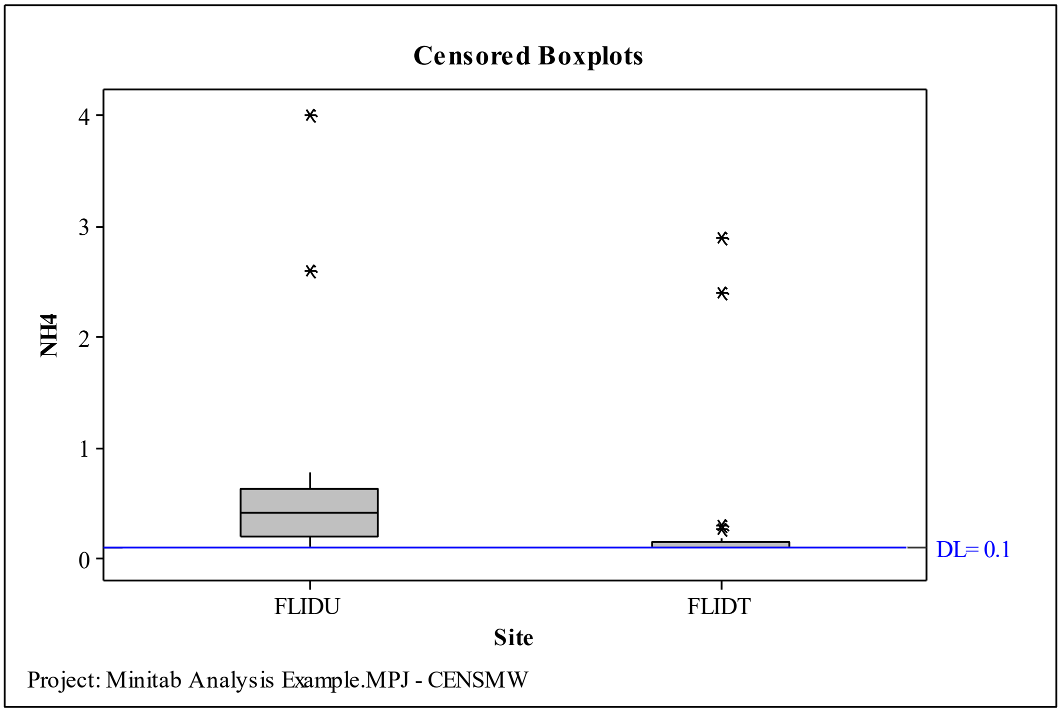
```
Variable    N  N*   Mean  SE Mean  StDev  Minimum     Q1  Median     Q3
Maximum
ESTIMATE   36   0  0.540    0.122  0.734    0.042  0.195   0.410  0.635
4.000

Variable    IQR
ESTIMATE  0.440
```

ROS Estimated Statistics for FLIDT-NH4

```
Variable    N  N*   Mean  SE Mean  StDev  Minimum     Q1  Median     Q3
Maximum
ESTIMATE   36   0  0.212    0.101  0.608    0.001  0.007   0.030  0.155
2.900

Variable    IQR
ESTIMATE  0.148
```

These descriptive statistics are represented graphically in Figure 6 below, in order to gain a visual understanding of the data distribution. A box plot can be utilized to quickly identify relative differences between the sampling sites.

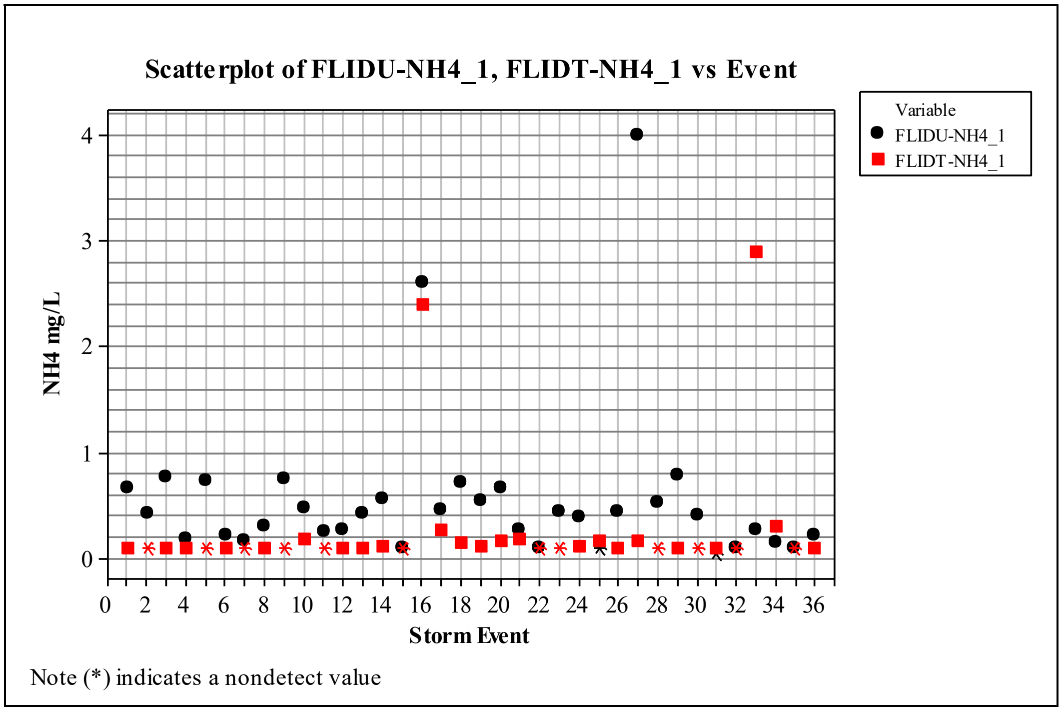
Figure 6



The top of each box represents the 3rd Quartile value (75th percentile), whereas the bottom of each box represents the 1st Quartile (25th percentile). The difference between the top and the bottom of a box represents the Inter-quartile Range. The "waist" or central line within a box represents the Median. The upper and lower line extending from the box often represent the extent of the observed data within 1.5 IQRs of the upper and lower quartile. The example plot in Figure 6, displays outliers beyond 1.5 IQRs as asterisks (*). In some cases, outliers beyond 3 IQRs are represented as plus signs (+). It is important to note that outliers could be removed for the purposes of visualization, but should not be removed from the dataset prior to analysis. The blue horizontal line in Figure 6 marked as "DL=0.1" indicates the laboratory detection limit for NH_4, which in this analysis was 0.10 mg/l. Data below the laboratory detection limit cannot be accurately represented in a box plot.

The graphic in Figure 7 can also be helpful to visualize the data set in relation to the individual storm events that produced the runoff. Influent and effluent concentrations are paired by storm event, where possible. In this particular graphic, numerous values were reported as nondetect and 1 value (FLIDU - event #31) was reported at 0.04 mg/l (*) which is well below the typical detection limit of 0.10 mg/l. Any values that appear at or below the specified detection limit should be treated and viewed only as unspecified values occurring anywhere below that value.

Figure 7



5.2.4 Hypothesis Testing: Pairs or Groups

In general, environmental data is not normally distributed and in most cases, non-parametric hypothesis tests are utilized to test the difference in median location of two or more populations. However, in the event that data sets are found to be normally distributed, parametric statistical tests could be utilized for analysis, if advantageous.

The most common parametric tests utilized will be the Student's T-Test and the Analysis of Variance (ANOVA) for comparison of means. However, the occurrence of normally distributed data and the use of parametric analysis techniques will likely be the exception, rather than the rule. For this reason, the examples and discussion to follow will focus on typical, non-parametric analysis techniques for non-normally distributed environmental data sets.

The first step in selecting the most appropriate nonparametric test method is to determine if there are a sufficient number of data pairs for analysis. For sites with large numbers of unpaired observations, the use of the hypothesis tests for groups (pooled data) would be most appropriate. However, for sites where there are significant numbers of paired observations, hypothesis tests designed for paired data will have more power to detect differences.

5.2.4.1 Hypothesis Testing – Group (Pooled) Data

The most commonly utilized non-parametric hypothesis tests for **pooled** datasets are the Mann-Whitney U test for 2 groups (also known as the Wilcoxon Rank Sum test) and the Kruskal-Wallis test for 3 or more groups. Both tests utilize rank or rank scores, rather than raw data observations, so there is no need to transform data. These 2 tests are analogous to the traditional T- tests utilized for parametric data, with the exception that the non-parametric tests compare the location of the median score, rather than the mean, and are appropriate for small data sets with non-normal distributions. Both the Mann-Whitney U test and the Kruskal-Wallis test are appropriate for small data sets; however a minimum of 12-15 observations are often required to discern statistical differences. Unless otherwise specified, p-values <0.05 will be considered significant.

Figure 8 represents an example output from a Mann-Whitney non-parametric test, when applied to an example **pooled** Ammonia-Nitrogen data set. Based on the box plot constructed for the dataset (see Figure 6), the influent NH_4 concentration appeared to be much greater than the effluent concentration. Therefore, the hypothesis tested was directional; H_O: Influent>Effluent. The corresponding 1-tailed p-value ($p=0.0000$) indicated that the observed difference between the influent and the effluent was highly significant.

If 3 test groups had been present, for example, Influent, Fore bay and Effluent, the Kruskall-Wallis test could have been utilized to test all 3 groups against a control or against each other. Such contrasts can provide additional useful information. In this example, it may be interesting to determine if there is a significant pollution concentration difference between the influent sample and the fore bay.

Figure 8

```
Mann-Whitney Test and CI: FLIDU, FLIDT

        N   Median
FLIDU  36   0.4100
FLIDT  36  -1.0000

Point estimate for ETA1-ETA2 is 1.1900
95.1 Percent CI for ETA1-ETA2 is (0.3399,1.3900)
W = 1729.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)

Use tie adjustment.  All values below 0.1 were set = -1.
If a median = -1, it means the median is <0.1
```

5.2.4.2 Hypothesis Testing – Paired Data

The most commonly utilized non-parametric hypothesis tests for **paired** datasets are the Sign test and the Wilcoxon Signed Ranks test. The main difference between these 2 tests is that the Wilcoxon Signed Ranks test assumes that the 2 groups have a similar shape or distribution of data. The Sign test makes no assumptions about the shape of the data distribution, and therefore is more often utilized. Both tests are appropriate for small datasets and unless otherwise specified, p-values <0.05 will be considered significant.

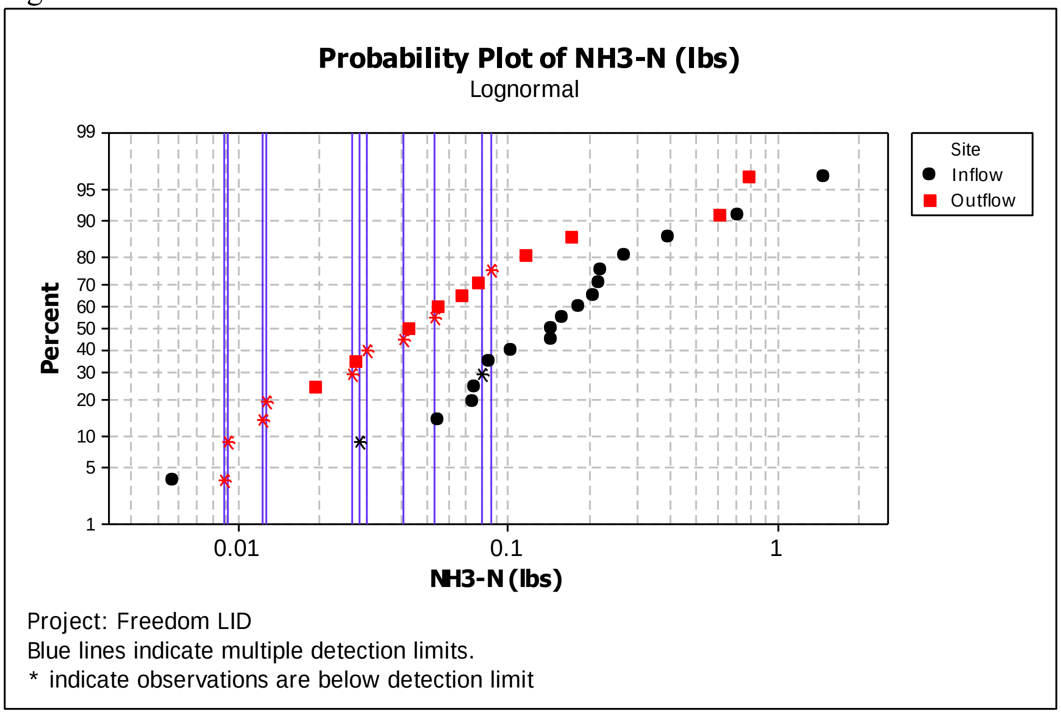
Figure 9 represents an example output from a Sign test, when applied to an example Ammonia-Nitrogen **paired** data set (Influent-Effluent for each event sampled). Based on the box plot constructed for the dataset (see Figure 6), the influent NH_4 concentration appeared to be much greater than the effluent concentration. Therefore, the hypothesis tested was directional; H_O: Influent>Effluent. The corresponding 1-tailed p-value (p=0.0007) indicated that the observed difference between the influent and the effluent was highly significant.

Figure 9

```
Sign Test for Median: FLIDU-NH4_1-FLIDT-NH4_1

Sign test of median =  0.00000 versus not = 0.00000

                          N  Below  Equal  Above       P
Median
FLIDU-NH4_1-FLIDT-NH4_1  36      4      4     28  0.0000
0.2400

p-value (adjusted for 'Equal' ties) = 0.0007

Median difference adjusted for nondetects = 0.28
```

The box plot referenced in Figure 6 indicates one traditional way to visually explore the difference between the influent NH_4 concentration and the effluent concentration. A second way to visually explore the differences is to generate a probability plot based on the observed values at various percentiles. Figure 10 represents a probability plot generated from the example data set, and indicates that reduced effluent concentrations were observed over the range of observations.

Figure 10



In some cases when there is a single detection limit, the observations may "flatten" out and form straight, vertical-dropping lines. This typically indicates that the analytical Detection Limit (DL) has been realized. In this particular case, there were multiple detection limits for NH_4 storm water dilutions below 0.10 mg/l. Although there are points represented in this graphic as asterisks (*), they represent nondetects and should be treated as unspecified values with a true location anywhere between the y-intercept and the x-axis.

5.2.5 BMP Efficiency

BMP Efficiency is commonly reported and there are many recognized metrics. CMSWS will typically report BMP efficiency by analyte in 1 of 3 ways; Pollutant Concentration Removal, Summation of Load [Reduction], or Individual Storm Load [Efficiency]. Each of these methods for calculating BMP efficiency is based on varying assumptions and each has both strengths and limitations. As a consequence, each metric may yield differing results when applied to the same dataset. An *a priori* effort will be made to utilize the most appropriate metric(s), based on the detailed pros and cons of each as published in Appendix B of the *October 2009 Guidance*.

5.2.5.1 Efficiency Ratio – Pollutant Concentration

Where appropriate, the calculated Efficiency Ratio (ER), which is sometimes referred to as the Pollutant Removal Efficiency, will be provided for each analyte of interest. ER is typically expressed as a percentage of the analyte concentration removed from the influent, when compared to the effluent sample. Ideally, ERs are calculated based on complete data pairs; however, there are situations where sample results are aggregated or grouped as "influent" and compared to grouped "effluent" samples.

The formula typically used to calculate the pollutant concentration ER utilizes the average influent and effluent Event Mean Concentration (EMC) for each analyte of interest. However, because the EMC data in the example data set is not normally distributed, the average or mean concentration has very little real value. Simply averaging the influent EMCs and the effluent EMCs presents a potentially biased result. According to the *October 2009 Guidance*, "The median EMC may be more representative of the typical or average site storm event discharge concentration because the value is more robust in the presence of outliers, when compared to the mean. The mean EMC for a site, on the other hand, may be completely biased by a single event that had an abnormally high discharge concentration due to an anomalous point source mass release (e.g., a silt fence failing at a construction site)." Therefore, the formula used for calculating Efficiency Ratio will be:

$$\text{Efficiency Ratio (ER)} = \frac{\text{Median Influent EMC} - \text{Median Effluent EMC}}{\text{Median Influent EMC}}$$

In the specific case of the example NH_4 data set, the ROS median of the influent concentration was 0.410 mg/l, whereas the median effluent concentration was 0.030 mg/l. Using this calculation, the ER for the example data set NH_4 would be 0.93, or approximately 93% NH_4 concentration removed.. The ROS median was used in this case because analytical values for NH_4 were often reported as nondetect. Simply using the detection limit for these values greatly biases the dataset and produces inaccurate results. The ROS procedure determines the most accurate, least biased median score in the presence of nondetect data even when the percentage of non-detect data exceeds 50% of the total observations. When there are no nondetect values are present in the dataset, the true median (50^{th} percentile observation) should be utilized.

5.2.5.2 Summation of Load (Reduction) - SOL

For some BMPs, the pollutant load reduction may be of more interest than the pollutant concentration reduction. This is especially true when the BMP is designed for infiltration so that the total discharge volume is significantly less than the influent volume (see section 5.2.2). A pollutant "load" is simply the mass of a pollutant, determined from the pollutant concentration and the total storm volume discharge, adjusted for units. Essentially, pollutant concentration (mass per volume) multiplied by storm volume produces a result of pollutant mass. The pollutant mass (load) is typically reported in pounds.

The Summation of Loads (SOL) is one methodology that will most likely be utilized when paired influent and effluent events are limited or altogether unavailable. In these cases, all influent load values will be summed, even if there is no corresponding effluent load data for that event. Likewise, all effluent load data will be summed. SOL is then calculated as follows:

$$\text{Sum of Loads (SOL)} = 1 - \frac{\text{Sum of Effluent Loads}}{\text{Sum of Influent Loads}}$$

Calculating a load based on a nondetect observation is problematic. The most conservative approach is to use the method detection limit (DL) as the concentration value for the calculation, but carry the nondetect qualifier with it. For example, if an observed concentration of NH_4 in a sample was reported at <0.10 mg/l (non-detect) for a discharged volume of 10,000 cubic feet, the converted load would be reported as <0.062 lbs.; derived as follows:

$10{,}000\ ft^3 \times 28.317\ liters/ft^3 = 283{,}168.5$ liters

$283{,}168.5$ liters $\times <0.10$ mg/l $NH_4 = <28{,}316.85$ mg NH_4

$<28{,}316.86$ mg $NH_4 \times 2.204 \times 10^{-6}$ mg/pound $= <0.062$ lbs. NH_4

The observation of <0.062 lbs. NH_4 represents only 1 load from 1 event. If there are 15 events, each of these loads must be summed. If there are more than a few nondetects in the dataset, the answers become less certain. The most conservative approach at this point is to present the load as a range to encompass the uncertainty inherent in the nondetect data. The range minimum would be calculated based on the assumption that all of the nondetect observations were true zero (0) observations. The range maximum would be calculated based on the assumption that all nondetect observations were equal to the reporting limit. Because of this limitation, the Summation of Load methodology is less useful in the presence of significant nondetect data.

In the example of the FLID Ammonia dataset, the Summation of Load pollutant reduction was determined to be SOL = **70.4%**, calculated as follows:

Summation of Load Calculations - FLID

Sum Influent Load 446,791.9 pounds NH_4
Sum Effluent Load 132,298.1 pounds NH_4

$$SOL = 1 - \frac{132{,}298.1}{446{,}791.9} = 0.704$$

SOL = 70.4% NH_4 removed

5.2.5.3 Individual Storm Load (Efficiency) – ISL

$$\text{Storm Efficiency} = 1 - \frac{\text{Effluent Load}}{\text{Influent Load}}$$

According to the *October 2009 Guidance*, the average efficiency of all of the paired events represents the ISL. However, as discussed in other sections, the average is a biased measure in this situation, particularly in the presence of nondetect data. Another complication observed in calculating ISL comes in the form of negative storm efficiencies. Negative efficiencies represent an export of pollutants from a BMP, suggesting that the structure itself is a source or generator. These values may very well be real and cannot be ignored in the calculation. Unfortunately, nonparametric statistics do not tolerate negative values. Therefore several techniques must be combined in order to treat this data in an unbiased manner in order to produce the best result possible.

First, the nondetect qualifiers must be carried along with the individual storm efficiencies when calculated. Second, a positive fixed value, greater than or equal to the absolute value of the most negative individual storm efficiency observed must be added to each, so that all efficiencies are made positive. Third, use Kaplan-Meier statistics to estimate the median efficiency score in the presence of nondetect data. Make sure to use the correct directional qualifier in the test to ensure that the efficiencies are treated as right-censored values where appropriate. Finally, subtract the fixed value added in step 2 from the estimated median to reveal the most accurate, unbiased ISL available for a dataset with both negative efficiencies and nondetect observations present.
Following the 2009 Guidance for the FLID NH_4 dataset, the Average Storm Efficiency was
-**25.2**% of the pollutant load removed. This produces a highly biased estimate, as discussed, due to the presence of a few extreme observations, negative efficiencies and nondetect data.

In order to develop an unbiased estimate, the values were flipped using a fixed value of 8.0 (most negative value observed was (ISL > -7.712) and running the Kaplan-Meier statistics for right-censored data on the transformed dataset. When the fixed value was subtracted from the KMStats estimate, the unbiased representative storm efficiency was determined to be ISL = **66.5**%.

Figure 11

Statistics using Kaplan-Meier, with Efron bias correction

```
Right-Censored data (+8)

Largest value is censored, so estimated mean is biased low.

Mean ISL+8             8.56851
Standard error         0.108785
Standard Deviation     0.652711
90th Percentile        *
75th Percentile        8.97080
Median                 8.66483
25th Percentile        8.51893
10th Percentile        8.03425

* NOTE * One or more variables are undefined
* NOTE * Subtract 8 from each value in this example
```

A complete statistical analysis will be completed for a site upon request; however a minimum of 12 complete, acceptable sample events must be collected and analyzed first, as described in section 5.2. Assuming 12 events are collected each fiscal year, as is typically requested, an annual analysis and evaluation of each site would be appropriate, if requested.

Identifying statistical significance in storm water samples is inherently difficult, given the dynamic nature of storm events, variable pollutant build-up, lab error, sampling error, etc. All exogenous factors must be minimized in order to tease out subtle differences between sites, over time. Problems with sampling equipment, site installation, and BMP design can easily obscure any differences that may otherwise have been evident. More focused effort on fewer sites has quality benefits that are easy to realize.

It is important to have confidence in the process in order to have confidence in the final product. Adopting standard protocols for site specific sampling has obvious benefits. Limiting the range of storms sampled to those that produce adequate flow / intensity but do not exceed design capacity, and allowing sufficient time for pollutant build-up, along with various other targets increase confidence in the samples and in the data. Following protocols, similar to those set forth in the TARP TIER II project, build confidence in the final product.

The Environmental Analyst will develop a generalized reporting format for BMP Performance Monitoring Data Analysis. This format will likely be modified several times before a final format is approved, but there are numerous components that must be included at a minimum. The following sections will be included in each BMP Monitoring Data Analysis Report, where appropriate:

1. Background
    a. BMP installation purposes
    b. Goal (why installed)
2. Site Characteristics
    a. Land-Use description, drainage area
    b. BMP design / equipment set-up
3. Data Quality Objectives
    a. What indicates good data
    b. Stated performance goals
4. Storm Event Characterization
    a. Storm event criteria
    b. Acceptable events
5. Analytical Results
    a. Discharge
    b. Analytes
    c. Graphics
6. Summary and Conclusions

7. Raw data (attachment)
8. Stats output (attachment)

Additional report sections may be added or modified to suit the purposes of the specific BMP and situation. The target audience for the general reports will be Charlotte-Mecklenburg Storm Water Services staff and stake-holders, unless otherwise specified.

APPENDIX F

Charlotte-Mecklenburg Storm Water Services
Quality Assurance Project Plan (QAPP)

A1. Signature and Approval Sheet

APPROVED BY:

Rusty Rozzelle, Water Quality Program Manager	Date
Jeff Price, QA/QC Officer	Date
Tony Roux, Bioassessment Lab Supervisor	Date
David Buetow, Field Measurement Lab Supervisor	Date
Steve Jadlocki, Charlotte NPDES Administrator	Date
State of North Carolina Representative	Date

A2. Table of Contents

Appendices

A3. Distribution List

A4. Project Organization

All water quality sampling and field measurement collection conducted by the Mecklenburg County Water Quality Program (MCWQP) is performed by permanent or temporary staff of the MCWQP. Data management and Quality Assurance/Quality Control activities are either conducted or supervised by the MCSWQP QA/QC Officer. Field work is performed by staff in each of the three sections, which correspond to three distinct geographic areas of Mecklenburg County. Chemical, physical and bacteriological analyses are performed by the Charlotte Mecklenburg Utilities (CMU) Laboratory. Macro invertebrate and fish sampling and analysis are performed by the Mecklenburg County Bioassessment Laboratory. Results of the MCWQP sampling efforts are provided to several entities; Charlotte-Mecklenburg Storm Water Services, Charlotte Mecklenburg Utilities, the Towns of Davidson, Cornelius, Huntersville, Pineville, Matthews and Mint Hill, the North Carolina Department of Environment and Natural Resources (NC DENR), private developers and the citizens of Mecklenburg County.

An abbreviated organizational chart for the MCWQP indicating all entities involved in the water quality sampling program is provided in Figure A4.1. A complete organizational chart for the entire MCWQP is provided in Appendix 1. Information concerning individuals assigned to each role can be obtained by contacting Rusty Rozzelle at 704-336-5449 or rusty.rozzelle@mecklenburgcountync.gov.

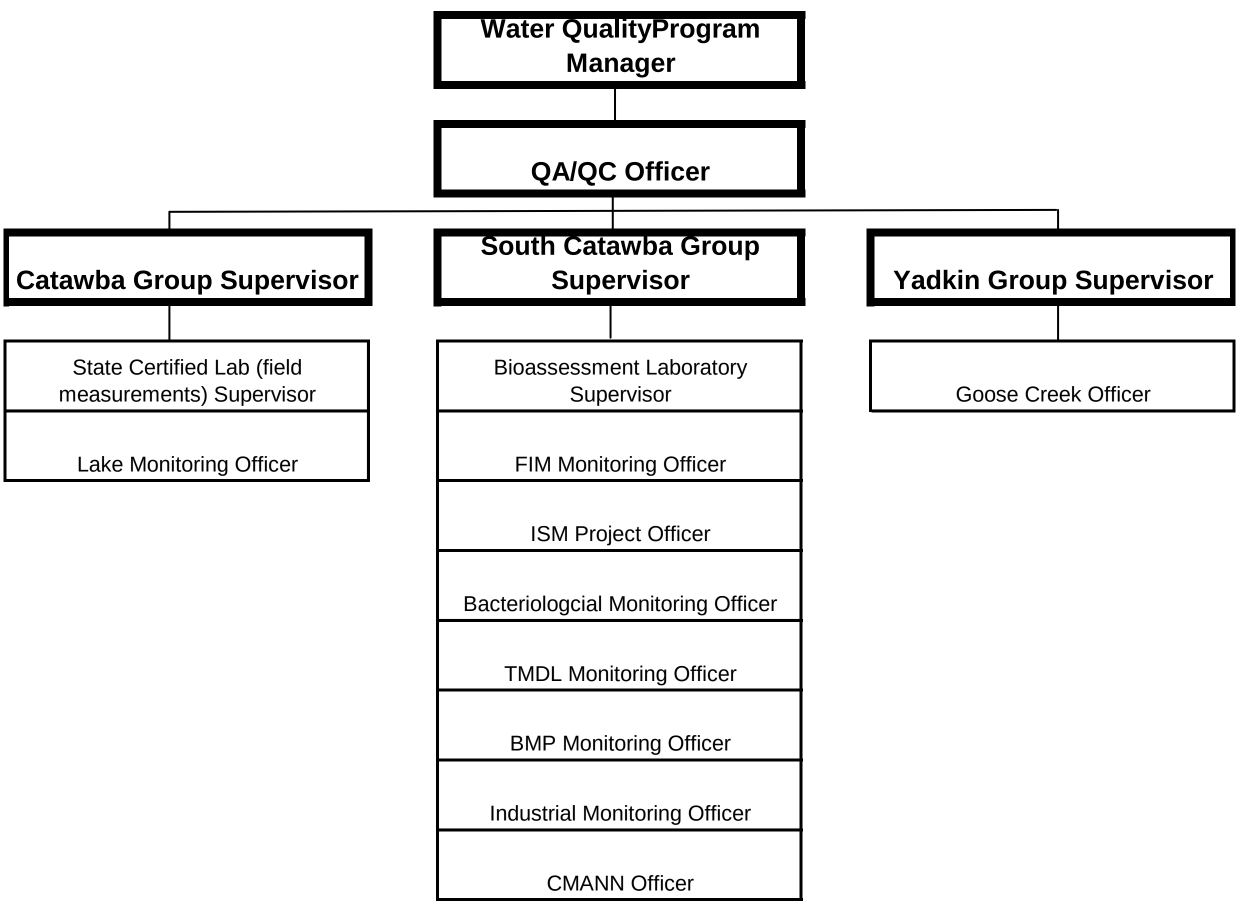


Figure A4.1 – MCWQP Organizational Chart

Project Manager and Supervision

Program Manager
Rusty Rozzelle
MCWQP – Program Manager

- Manages MCWQP
- Supervises QA/QC Officer, Group Supervisors and Administrative Support Staff
- Ultimately responsible for ensuring that the program is conducted in accordance with this QAPP
- Reviews and approves all reports, work plans, corrective actions, QAPP and other major work products and revisions
- Approves changes to program; ensures changes are consistent with program objectives and customer needs
- Program Development
- Reports to Mecklenburg County & Towns elected officials

QA/QC Officer
Jeff Price
MCWQP – Senior Environmental Specialist

- Acts as liaison between program manager and supervisors, project officers and field personnel
- Coordinates logistics of program, including sampling schedule, production and maintenance of forms and station database
- Responds to issues raised by program manager, customers or citizens. Recommends response action or change when necessary.
- Performs all aspects of data management for MCWQP monitoring program
- Fulfills requests for raw data
- Assists in training field staff
- Conducts periodic field audits to ensure compliance with QAPP and SOP
- Calculates SUSI index and communicates results to staff, elected officials and general public
- Performs data screening and action/watch reports and communicates results to MCWQP Supervisors to assign follow-up activities

Water Quality Supervisor
David Caldwell – Catawba Group
John McCulloch – South Catawba Group
Richard Farmer – Yadkin Group

- Supervise project officers and field staff ensuring that deadlines are met and tasks are completed in a timely manner
- Assign follow up activities when action/watch levels are exceeded (communicated to the supervisors by QA/QC Officer)
- Assign staff resources as necessary to complete monitoring activities
- Conduct sampling as necessary to fulfill work plan requirements
- Supervise Bioassessment Laboratory Supervisor
- Supervise State Certified Laboratory Supervisor (field measurements)

- Supervise all activities of MCWQP in their respective geographic area of responsibility
- Act as follow-up, emergency response and service request monitoring project officer for their geographic area

Field Activities

Project Officers

Meredith Moore	TMDL Stream Walks
	Industrial Monitoring
Olivia Edwards	CMANN
Jon Beller	FIM
	Bacteriological Monitoring
	ISM Monitoring
	BMP Monitoring
David Buetow	Lake Monitoring
Tony Roux	Biological Monitoring

- Coordinate and conduct sampling events
- Ensure staff are properly trained in procedures for individual project area
- Compile annual reports
- Act as point of contact for individual project area
- Calculate Lake Water Quality Index (David Buetow)
- Review automated CMANN data for threshold exceedances (Olivia Hutchins)
- Work with QA/QC Officer to ensure deadlines and other project requirements (such as specific parameters) are met
- Responsible for maintaining specialized sampling equipment for assigned projects

Field Staff

Chris Elmore
Don Cecerelli
Amber Lindon
Jason Klingler
Ron Eubanks
Heather Davis
Catherine Knight
Tara Stone
Brian Sikes
Michael Burkhard
Corey Priddy
Heather Sorensen
Andrew Martin
Vacant Inspector Position

- Perform sampling events in accordance with QAPP and SOPs
- Notify supervisor or QA/QC Officer of any issues encountered

Laboratory Analysis

Bioassessment Laboratory Supervisor- Biological Certificate Number - 036

Tony Roux – Senior Environmental Specialist

- Manage MCWQP Bioassessment Laboratory
- Responsible for oversight of all biological sample collection (fish and macro invertebrates)
- Responsible for developing training materials and training staff on proper biological sampling techniques
- Responsible for oversight of all biological sample analysis and reporting of results and indexes
- Responsible for maintaining North Carolina State Certification for MCWQP Bioassessment Laboratory
- Responsible for maintaining all sampling equipment

State Certified Laboratory (Field Parameter Only) Supervisor – Certificate No. 5235
David Buetow – Senior Environmental Specialist

- Responsible for ensuring that all chemical/physical monitoring equipment and procedures are in compliance with state certified laboratory requirements
- Responsible for training staff in the proper use of field instruments
- Responsible for maintenance of field instruments
- Responsible for ensuring that field parameter check-in/check-out procedures and forms are properly used and are in compliance with state certified laboratory requirements.

Primary Data End-Users

Charlotte Storm Water Services
Steve Jadlocki – Charlotte's NPDES Phase I Permit Administrator – 704-336-4398

- Responsible for ensuring that all monitoring conducted to fulfill the requirements of Charlotte's Phase I NPDES permit are completed. MCWQP is under contract with the City of Charlotte to conduct monitoring and other activities.
- Provides parameter lists, sampling schedule and basic requirements of monitoring program
- Reviews data

Mecklenburg County Phase II Jurisdictions
Anthony Roberts – Cornelius Town Manager – 704-892-6031
David Jarrett – Huntersville Public Works Director – 704-875-7007
Ralph Massera - Director of Public Works – 704-847-3640
Brian Welch – Mint Hill Town Manager – 704-545-9726
Mike Rose – Pineville Town Manager – 704-889-4168
Leamon Brice – Davidson Town Manager – 704-892-7591

- MCWQP is under contract with each of Mecklenburg County's Phase II jurisdictions to provide water quality monitoring services to fulfill requirements of the Phase II permits held by each of the towns.

State of North Carolina
319 Grant Administrator
Alan Clark – NCDENR – 919-733-5083
Clean Water Management Trust Fund Administrator
Bern Schumak – CWMTF – 336-366-3801

- MCDWP and Charlotte-Mecklenburg Storm Water Services have received several grants for the installation of BMPs, creation of stream restoration projects, watershed studies and TMDL implementation projects. Each project has specific monitoring requirements to demonstrate the effectiveness of the project. Data are typically reported on an annual basis to each grant's administrator.

A5. Problem Definition and Background

Introduction

The City of Charlotte and Mecklenburg County are located along a drainage divide between the Catawba River Basin and the Yadkin River Basin. Therefore, approximately 98% of the streams in Charlotte and Mecklenburg County originate within the county borders. Streams located in the western portion of the county, as indicated in the map below, drain to the Catawba River in North Carolina. The Catawba River along the western border of the county has been damned to form Lake Norman, Mountain Island Lake and Lake Wylie. Each of the lakes is utilized for water supply purposes for various communities and industries throughout the region. Streams located in the eastern portion of the county drain to the Yadkin River, which has been designated as potential future habitat for the Carolina Heelsplitter, a federally endangered freshwater mussel. Streams located in the southern portion of the county drain to the Catawba River in South Carolina. These streams drain the most developed portion of Charlotte and Mecklenburg County, which is predominated by the City of Charlotte. Strong development pressure throughout Mecklenburg County has led to increased degradation of surface water from non-point source runoff.

The Mecklenburg County Water Quality Program (MCWQP) was created in 1970 under the umbrella of the Mecklenburg County Health Department. Recently, the MCWQP has been merged with several other entities to form Charlotte-Mecklenburg Storm Water Services. The MCWQP is engaged in water quality monitoring efforts on reservoirs, streams and ponds. Moreover, the MCWQP enforces storm water pollution prevention ordinances, enforces erosion control ordinances, conducts NPDES permit holder inspections and conducts watershed planning. The MCWQP is a storm water fee funded program of the Mecklenburg County Government. Its purpose is to ensure the safety and usability of Mecklenburg County's surface water resources including; ponds, reservoirs and streams. Stream and lake monitoring are a critical component of ensuring the safety and usability of Mecklenburg County's surface water resources and elected officials and citizens rely upon communication of the monitoring results to determine the conditions of those resources.

The MCWQP conducts several water quality monitoring programs. These programs include the fixed interval monitoring network (FIM), in-stream storm water monitoring (ISM) program, biological monitoring program (macro invertebrates and fish – these activities are conducted by the Bioassessment Lab), lake monitoring program, best management practice (BMP) monitoring program and bacteriological monitoring. Monitoring sites for the FIM program were located in order to determine the water quality of a particular basin or sub-basin. Figure A5.1 shows the distribution of watersheds in Charlotte and Mecklenburg County. Sites for the BMP program were selected based upon BMP type in order to assess performance of many different types and designs of BMPs. Monitoring sites for the lake monitoring program were selected to determine the general water quality in the three reservoirs of the Catawba and to, more specifically, target swimming areas and areas of intense development.

The MCWQP has created this document to ensure that all data collected conforms to strict QA/QC guidelines in the collection of samples, management of information and communication of results. It is also intended to communicate the policies and procedures of the MCWQP so that data it collects may be considered by other entities in local, regional or national studies.

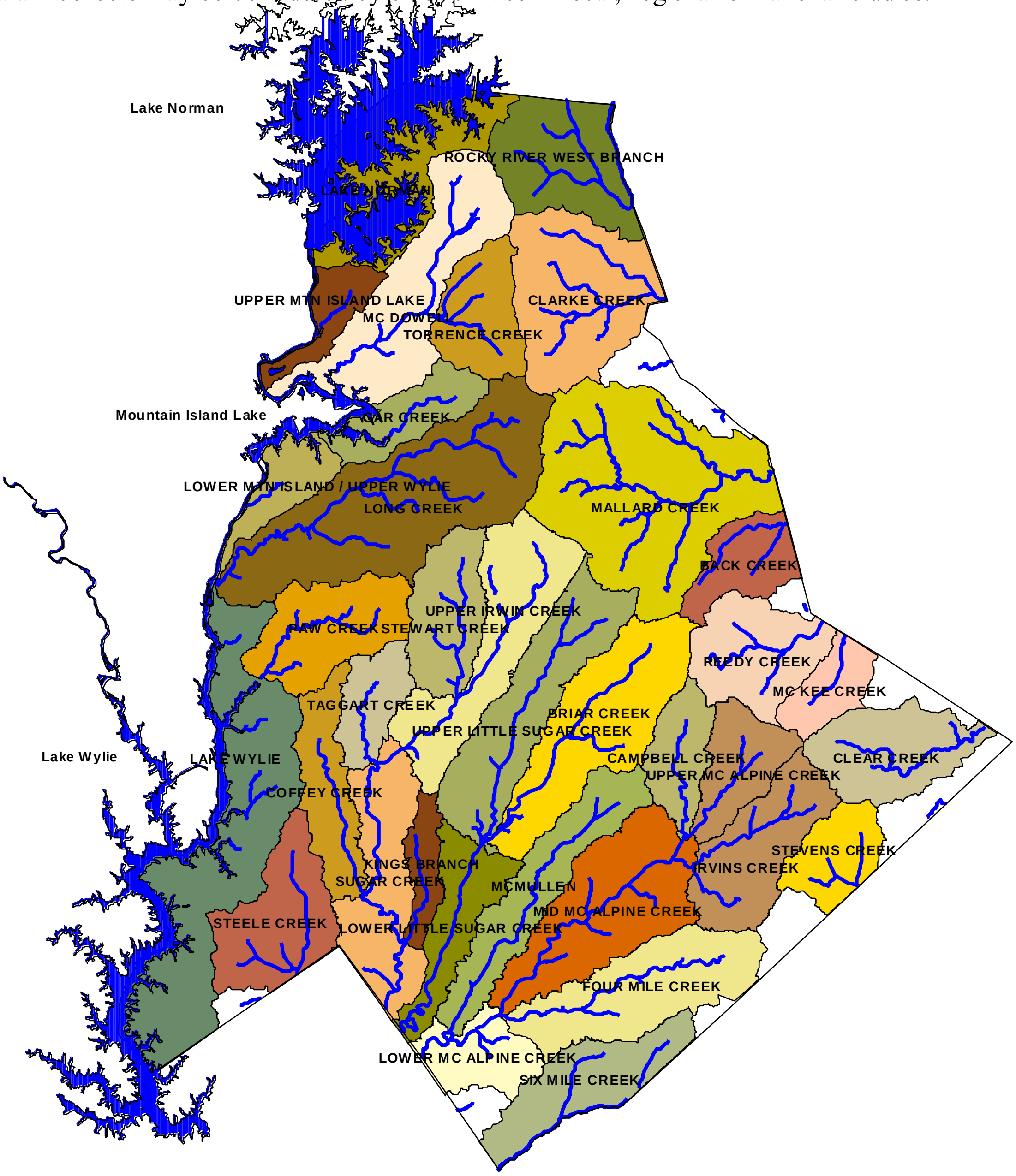


Figure A5.1 – Mecklenburg County Watersheds and Reservoirs

Stream classifications and water quality standards

The state of North Carolina has developed water quality standards for many parameters dependent upon the classification of the stream. All named water bodies in the state have been classified by intended use. Mecklenburg County has Class B, C and WS IV water bodies. Monitoring results are compared to the water quality standards by MCWQP to determine compliance with the standard for communication of results and assessment of the usability of the water for its intended use.

MCWQP Monitoring Program Objectives

There are several objectives of the MCWQP monitoring program; however, the primary objective is to ensure the safety and usability of Mecklenburg County's surface water resources. Samples are collected to determine compliance with applicable state standards and to locate sources of water quality impairment (such as broken sanitary sewer lines). In addition to safety and usability, the MCWQP collects and analyzes samples to determine the effectiveness of watershed planning efforts (BMP monitoring and habitat assessments).

A6. Project/Task Description and Schedule

The MCWQP and its predecessors have conducted monitoring of Mecklenburg County's surface waters since the early 1970s. The program has evolved into many different projects with distinct purposes and desired outcomes. A Standard Administrative Procedure (SAP) has been developed for each specific monitoring project conducted by the MCWQP. The SAPs are included with this document as Appendix 2.

Fixed Interval Monitoring Program

The primary focus of the fixed interval monitoring program is to monitor the overall health of the streams within the Charlotte and Mecklenburg County and to identify chronic pollution problems at the watershed scale. The purpose of the program is to provide on-going baseline data that can be used to determine the long-term condition of Charlotte and Mecklenburg County streams. Fixed Interval monitoring is conducted monthly at 29 sites throughout Mecklenburg County. Sites were located to monitor all of the major watersheds in the County. Monitoring events are typically conducted on the third Wednesday of each month; however, events may be postponed if unsafe conditions exist in the streams.

FIM samples are collected by hand (grab samples) and are delivered to the CMU laboratory in less than 6 hours (fecal coliform hold time). Physical parameters (field parameters) measured at the time of sample collection include temperature, dissolved oxygen, pH and conductivity. These parameters are measured using a YSI Multiprobe instrument, which has sensors for each of the parameters to be measured. Most FIM sites are located at USGS gauging stations and the stage of the stream is recorded from the USGS Internet website. The level of the stream at the time of collection and comments pertaining to the stream flow are noted on the field sheets along with the field parameter readings. Samples are submitted to the CMU laboratory for all other parameters including fecal coliform bacteria, *E-Coli* bacteria, Ammonia Nitrogen (N-NH3), Nitrate + Nitrite (NO2+NO3), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Suspended Solids (TSS), USGS Suspended Sediment Test (SSC), Turbidity, Copper, Zinc, Chromium and Lead. The sample analysis results along with the physical measurements are used in the calculation of the Stream Use Support Index (SUSI), which is a programmatic level reporting tool developed by Charlotte-Mecklenburg Storm Water Services.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The primary focus of the bacteriological monitoring program is to identify sources of fecal coliform in Charlotte-Mecklenburg streams. Several of these streams are listed on North

Carolina's 303(d) list for fecal coliform, which has caused the MCWQP to focus efforts on finding and eliminating sources of fecal coliform. Samples are collected monthly from 72 locations throughout the county during base flow (minimum 72 hours prior without rain) conditions. In addition to the monthly sampling, 5 sites are sampled 5 times per month for fecal coliform. These locations correspond to NC DENR compliance points in watersheds listed for fecal coliform impairment on North Carolina's 303(d) list. These sites are sampled under all conditions in order to assess compliance with the fecal coliform standard.

Bacteriological samples are collected by hand (grab samples) and are delivered to the CMU laboratory in less than 6 hours (fecal coliform hold time). In addition to the fecal coliform sample, temperature of the stream at the time of sample collection is measured and recorded in the field data sheet.

In-Stream Storm Water Monitoring Program

The primary focus of the in-stream storm water monitoring program is to characterize the quality of receiving streams during rainfall events to support various Charlotte-Mecklenburg water quality projects. Samples are collected during runoff events on a regular basis (2 sites are sampled 2 times per month and 2 sites are sampled monthly for a total of 72 samples).

Automated sampling equipment collects the samples during the runoff event, set to start based upon the level of the stream. A flow-weighted composite sample is compiled by the sampler as prescribed by a site specific program uploaded to the sampler, which is based upon estimations of rainfall and runoff. Individual aliquots are collected at site specific volume (discharge) intervals during a runoff event. After the runoff event has ceased the samplers are retrieved and the sample transferred to sample bottles and turned into the CMU laboratory. Parameters analyzed by the laboratory include N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead.

Service Request/Emergency Response/Follow-up Monitoring Program

Water quality samples are occasionally collected during investigation of a citizen request for service. Samples may be collected from any location along any stream pond or reservoir within Charlotte and Mecklenburg County. Most of the samples collected are for fecal coliform along with measurements for physical parameters. Typically, samples are collected to "bracket" or otherwise identify a pollution source. Frequently, physical parameters alone are enough to identify a pollution source, which can be visually identified.

TMDL Stream Walk Monitoring Program

The TMDL stream walk program is conducted to identify pollution sources in the streams in Charlotte and Mecklenburg County with existing TMDLs for fecal coliform. Teams of 2 staff members wade or float sections of streams and collect samples from small tributaries, storm water outfalls and drainage ditches for the purpose of identifying whether a source of fecal coliform is located upstream. If fecal coliform is detected in the sample above 3000 c.f.u./100 ml, follow-up activities are initiated to identify and eliminate the source.

Grab samples are collected at each confluence, storm water outfall and drainage ditch exhibiting dry weather flow (stream walks are only performed during dry weather). The samples are submitted to the CMU laboratory no more than 6 hours (hold time for fecal coliform) from the time of sample collection. Samples are analyzed for fecal coliform and nutrients. YSI multiprobes are used to collect field measurements for turbidity, dissolved oxygen, turbidity, pH and temperature. Field tests are also performed to detect the presence of chlorine.

BMP Monitoring Program

The monitoring of BMP's is conducted to research the effectiveness of various kinds of BMP, such as bioretention, storm water wetlands, wet ponds, grassed swales and dry detention basins. BMPs are installed to improve the quality of urban storm water runoff before the water entering local streams and lakes. Monitoring is conducted using automatic sampling equipment during rain events (similar to in-stream monitoring). Physical and chemical monitoring takes place at both the inlets and outlets of these BMPs to determine their pollutant removal efficiency. Flow into and out of the device is usually assessed using a bubbler meter or Doppler flow meter.

Automated sampling equipment collects the samples during the runoff event, set to start based upon the initiation of runoff. A flow-weighted composite sample is compiled by the sampler as prescribed by a site specific program uploaded to the sampler, which is based upon estimations of rainfall and runoff. Individual aliquots are collected at site specific discharge intervals during a runoff event. After the runoff event has ceased the samplers are retrieved and the sample transferred to sample bottles and turned into the CMU laboratory. Parameters analyzed by the laboratory include N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead.

Lake Monitoring Program

The reservoirs comprising Mecklenburg County's western border are monitored on a routine basis to assess their and usability for water supply and recreation. Samples are collected more frequently in the summer months when recreational use of the reservoirs increases.

Grab samples and depth integrated samples are collected from various locations throughout the reservoirs. Physical parameters are measured throughout the water column for temperature, DO, Specific Conductivity, turbidity and pH, as well as in situ chlorophyll *a*. Secchi Depth is also recorded at each sample collection site. Samples are submitted to the CMU laboratory for several parameters including NO3-N, Total Phosphorus, Alkalinity, and Chlorophyll-*a*. From nine of these parameters, a WQI rating is determined, which summarizes the overall quality of the water. The WQI values are primarily used to communicate the overall lake water quality conditions to the citizens of Mecklenburg County. Several of the local marine commissions utilize the WQI values in their evaluations of reservoir conditions.

Industrial Facility Monitoring Program

The industrial facility monitoring program is conducted to satisfy an element of the City of Charlotte's Phase I NPDES permit. Samples are collected from industrial facilities during runoff events where previous inspections have identified poor material handling or storage practices at the site. Only sites with NPDES permits are inspected and sampled. Typically, approximately 15 sites are sampled each year.

Grab samples are collected from storm water outfalls or drainage swales during runoff events. Special care is taken to ensure the runoff sampled originated from the site or facility in question. Field measurements are collected using a YSI multiprobe for dissolved oxygen, pH, temperature and conductivity. Samples are submitted to the CMU laboratory to be analyzed for fecal coliform, *E-coli* bacteria, N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead and any other parameters specifically identified in a facilities' NPDES discharge permit (if one exists). Additional parameters may be added to the list of analytes if those materials are suspected to be stored or used on site.

Continuous Monitoring and Alert Notification Network

The Continuous Monitoring and Alert Notification Network (CMANN) program along with the NC DOT Long Creek project are a system of automated monitoring units used to detect illicit connections and other in-stream pollution sources. The units are semi-permanently installed at locations throughout Charlotte and Mecklenburg County, typically at USGS stream flow gauging stations corresponding to FIM sites. The units continuously monitor the stream for pH, turbidity, DO, conductivity and temperature and transmit the readings via cell modem to a database server housed and maintained by a private vendor (NIVIS). The data collected for the Long Creek DOT project is maintained on an in-house server. The data is then accessible through a website. The system also has an alert notification component, which sends specified individuals email messages when certain parameter thresholds have been exceeded.

Goose Creek Recovery Program Monitoring

Water quality monitoring for fulfillment of the Goose Creek Recovery Program is comprised of 3 elements; fecal coliform monitoring at NC DENR compliance point, land-use monitoring for fecal coliform and stream walks to identify sources of fecal coliform. Compliance point monitoring is covered under the bacteriological monitoring program (5 samples collected in 30 days) and the stream walks are covered under the TMDL stream walk monitoring program. The land-use monitoring is a requirement of the Goose Creek Recovery Program intended to categorize the amount of fecal coliform produced by various land-uses in the Goose Creek Watershed. Land uses to be monitored during FY07-08 are 0.25 – 0.5 acre residential, commercial, institutional, 0.5 – 1 acre residential and I-485.

Grab samples are collected from storm water outfalls or drainage swales during runoff events from each individual land-use. Special care is taken to ensure the runoff sampled originated from the land-use in question. Field measurements are collected using a thermometer for temperature. Samples are submitted to the CMU laboratory to be analyzed for fecal coliform. Estimates of rainfall depth for each runoff event sampled are obtained from the nearest USGS rain gauge.

Biological Monitoring

Biological monitoring is performed at 48 stream sites throughout Charlotte and Mecklenburg County. Macro invertebrate samples are collected and habitat assessments are performed at all 48 sites. Fish population samples are collected at 8 sites. Biological sampling and analysis is conducted by the Mecklenburg County Bioassessment Laboratory under a Standard Operating Procedure submitted to NC DENR and accepted in 2004. Biological monitoring is included in this QAPP to document sampling locations and data reporting mechanisms.

Sampling Schedule

Each of the monitoring projects has a specific sampling schedule. The individual project sampling schedule by program element and by site is provided in the SAP, which are in Appendix 2. The following is a general discussion of the sampling interval for each monitoring project.

Fixed Interval Monitoring Program

Samples under the FIM program are collected the third Wednesday of each month. This results in 12 samples per year per site. The FIM monitoring program is intended to provide long-term data on the health of stream water quality at the watershed scale; however SUSI values are calculated from the results on a monthly basis.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The bacteriological monitoring program is intended to provide short term data on the presence of sources of fecal coliform in the streams of Charlotte and Mecklenburg County. The sites are sampled once per month, usually during the first available sampling day with a minimum of 72 hours without rainfall preceding. The reason for the 72 hours preceding is to ensure base flow conditions in the streams. An additional component of the bacteriological monitoring program is to collect five fecal coliform samples during any given 30 day period at NC DENR TMDL compliance points within watersheds with fecal coliform TMDL implementation strategies in place. The purpose of this component is to assess the effectiveness of the implementation strategies. Typically, one sample will be collected during each of the four weeks during a month with an additional sample collected during the third week of the month.

In-Stream Storm Water Monitoring Program

The ISM program is intended to provide information on the characteristics of stream flow during runoff events in the City of Charlotte. This monitoring used to support various watershed and BMP projects within Charlotte and Mecklenburg County. Monitoring is conducted quarterly during a runoff event with a minimum of 72 hours dry weather preceding.

Service Request/Emergency Response/Follow-up Monitoring Program

The SR/ER/follow-up monitoring program is intended to provide information during the investigation of a water quality pollution source. As such, it is performed on an as needed basis to attempt to 'bracket' or locate a pollution source. Many samples or field measurements may be performed over a very short time period to locate a pollution source.

TMDL Stream Walk Monitoring Program

The TMDL stream walk monitoring program is intended to provide information on sources of fecal coliform impairment in Mecklenburg County streams. Stream walks are performed year round with the only requirement being safety (walks are not performed during swift water conditions). No set schedule is in place for conducting stream walks, rather a goal of the number of miles to be walked during a given year is set. The project officer is responsible for setting a loose schedule with milestones of the number of miles to be walked during a given quarter (3 month period).

BMP Monitoring Program

The BMP Monitoring program is intended to provide information on the efficiency of various BMPs at removing water quality pollutants from runoff. A total of 12 samples are typically collected from the inflow and outflow of each BMP in the program during each year during runoff events. An effort is made to spread sample collection across all seasons; however extended dry periods are unavoidable.

Lake Monitoring Program

The lake monitoring program has been designed to provide data on the long term water quality conditions in Lake Norman, Mountain Island Lake and Lake Wylie and to provide short term information on the usability of these lakes for recreation (swimming). Samples are collected monthly during the warm months (May – September) and every other month during the colder months. Additional fecal coliform sampling sites are monitored from May through September to coincide with peak usage time on the lakes.

Industrial Facility Monitoring Program

The industrial facility monitoring program is designed to assess the runoff from individual NPDES Discharge Permitted facilities. Samples are collected during a runoff event once during the fiscal year in which the facility is inspected. If water quality standards or permit limits are exceeded, additional sampling may be initiated under the follow-up monitoring program.

Continuous Monitoring and Automated Notification Network

The CMANN program has been designed to provide real time (or near real time) data on the health of Charlotte and Mecklenburg county's streams. Field measurements are automatically collected once per hour, year round. Collection intervals are occasionally temporarily reduced to once per 15 minutes if necessary.

Goose Creek Recovery Program Monitoring

The Goose Creek recovery program monitoring effort is a requirement of the Goose Creek Water Quality Recovery Program for fecal coliform. The TMDL stream walks in Goose Creek are covered under the TMDL stream walks section, the 5/30 monitoring and compliance point monitoring are covered under the bacteriological monitoring section. Land-use samples are collected 12 times per year from each site during runoff events. An effort is made to spread the samples out evenly over each of the four seasons during a year; however extended dry periods may make monthly sampling impractical.

Biological Monitoring

Typically biological samples are collected once per year during the period of time between May and September; however occasionally samples are collected in October because of scheduling issues. Samples are collected during base flow conditions.

Measurement methods overview

Field Measurements

Measurements made in the field include water temperature, specific conductance, stream flow (or pipe flow), chlorine, Secchi depth, DO, turbidity and pH. Field measurements are discrete and are to be made *in situ* by field staff at the time of sample collection. All field activities are to be performed in accordance with the YSI Multiprobe Calibration and Field Data Collection (Short-term Deployment) SOP, which is included in Appendix 3.

Analytical Methods

Samples are submitted to the CMU laboratory for analysis for fecal coliform bacteria, *E-coli* bacteria, ammonia nitrogen, nitrate + nitrite, TKN, total phosphorus, TSS, suspended sediment, turbidity (lab), copper, zinc, chromium and lead. Other specific parameters may be analyzed on a case by case basis (such as industrial sampling).

Data management

All results are to be sent to the QA/QC officer, who is responsible for the compilation, review, verification, validation, and warehousing of all water quality monitoring data products by the MCWQP. Field staff provides completed field data sheets and copies of COCs to the QA/QC officer on the same day the samples and field measurements are collected. The CMU laboratory will provide finalized data electronically and in hard copy to the QA/QC officer within 45 days of sample collection. The only exception to this is the CMANN program. CMANN data is reviewed and quality assured by the CMANN project officer and submitted to the QA/QC officer electronically.

On at least a monthly basis, data will be compiled, quality assured and added to the Water Quality Data Repository (WQDR).

Reporting

Annual Reports

Annual reports are prepared for each monitoring program (specifically, an annual report for each program element will be prepared – most monitoring programs are comprised of several program elements). At a minimum, the annual report will include basic descriptive statistics (minimum, maximum, median, 25th percentile and 75th percentile) of the sample results from the CMU laboratory and the field measurements collected under the program. Additionally, a count of the number of action/watch and state standard exceedances are prepared for each parameter analyzed or measured. Current year results are compared to previous years and, where applicable, water quality trends are identified. These reports are submitted to the customer and are available to citizens and outside agencies by contacting Rusty Rozzelle at 704-336-5449 or rusty.rozzelle@mecklenburgcountync.gov.

Water Quality Indexes and Program Measures

Two primary indexes are calculated using MCWQP monitoring results and subsequently reported to elected officials and the citizens of Mecklenburg County. The Stream Use Support Index (SUSI) is an index developed by Charlotte/Mecklenburg Storm Water Services to communicate the health of Mecklenburg County's streams. It takes into account FIM, biological monitoring and CMANN results. The lake water quality index (LWQI) is calculated for each of the reservoirs in Mecklenburg County. The LWQI takes into account lab analysis and physical parameters of lake water quality. Documentation of both indexes is included with this document in Appendix 4. Several other program measures use results from water quality data collection for their calculation. These are described in Appendix 5.

Program Indicators

Several program indicators are also calculated using MCWQP data. Program indicators are used to assess MCWQP progress toward meeting programmatic goals, which are required by the Mecklenburg County Manager. They are part of the county manager's M4R program. Goals are set for each program indicator at the beginning of each fiscal year and progress on meeting the goal is determined at the end of the fiscal year. These results are used by the county manager to judge the effectiveness of the MCWQP. The indicators include miles suitable for human contact, assessment of TMDL implementation strategies and turbidity levels in McDowell Creek. A description of the program indicators determined from water quality monitoring is included in Appendix 4 and Appendix 5.

A7. Quality Objectives and Criteria

Precision, accuracy and sensitivity

Results from the MCWQP monitoring program are compared to the NC water quality standards and internal action/watch levels (Appendix 6), so reporting limits for these parameters should be at or below these critical values. All of the reporting limits used by the CMU Laboratory meet these criteria.

Bias

The MCWQP monitoring program is based in judgmental sampling design, so by definition bias will exist due to station locations. However, this is acceptable given that stations are generally established for targeted long term monitoring of known or suspected areas of concern; identification of temporal patterns at these static locations are major objective or the program.

Other sources of bias include:

- Grab sampling is performed only during the weekly business day.
- Stations are only sampled on Monday – Thursday.
- Almost all stations are located at road crossings.

Use of consistent sampling methods, SOPs, and analytical methods minimizes bias from other sources.

Representativeness

Environmental monitoring data generally show high variation due to natural conditions such as precipitation, seasonal and diurnal patterns, and biological activity. It is important to ensure that the variations over time and/or space that are seen in the results are truly representative of the system under study. Monitored water bodies must have sufficient flow year-round at the specified sampling point to allow for the sampling of well-mixed areas (as required by SOP) of the water body. Sampling of BMPs must focus upon representative (or average) storm events within the device's design standard. This allows the samples to represent an "average" condition of the water body at that point in time. Careful selection of station locations on larger perennial water bodies (higher-order streams and rivers, estuaries, and reservoirs) allows representative samples to be obtained year-round.

Comparability

Fixed station locations and standardized operating procedures for sampling and analytical methods ensure that comparable samples are taken at each site visit.

Completeness

It is expected that some site visits or samples will be missed due to problems such as inclement weather, temporary station inaccessibility due to bridge construction, equipment problems, and staff issues such as illness or vacant positions. Many of these impediments are unavoidable. However, under anything but extraordinary circumstances it is expected that at least 90% of scheduled station visits and samples be completed annually.

A8. Special Training/Certification

Field Staff

Since new employees can vary greatly in their background, experience, and knowledge, field staff's direct supervisor should determine training needs on a case-by-case basis and ensure that these needs are met. At the time of hiring, each field staff member is assessed by a Group Supervisor and provided with an appropriate amount of training specific to their assignments. At a minimum, all field staff are to be trained in the methods described in the appropriate SOPs (Appendix 3), this QAPP, and the appropriate SAPs (Appendix 2) pertinent to their work plan (assigned tasks). Every new field employee will be trained in YSI calibration, safety, required documentation, sampling methods, sample handling, safety and other field activities. Training activities at time of hire are documented on the Employee Training Form, which is included in this document at Appendix 7. This training is generally performed by Senior Environmental Specialists, Group Supervisors and experienced Environmental Specialists. This is augmented by the QA/QC Officer, particularly concerning data management, documentation and problem identification. Completed Employee Training Forms are retained by the QA/QC Officer during the employee's term of employment with MCWQP. Experienced field staff will continue to accompany all new field staff during sampling activities until the new staff member exhibits proficiency in the field, as determined by the trainer's observations.

After initial training at the time of hire, refresher training is conducted at least annually for all monitoring activities. A sign-in sheet is circulated at the time of annual training. Staff not present at the training are responsible for scheduling make up training with the trainer. Sign-in sheets will be retained by the QA/QC Officer. At a minimum, each field staff member will receive the following refresher training annually:

- YSI Calibration and Operation
- Grab sample collection
- Proper sample documentation (COC and field data sheets)
- Bacteriological sample collection

Field staff are assessed on an ongoing basis by the direct supervisor and the QA/QC Officer to ensure field staff are performing activities in accordance with SOPs, SAPs and this QAPP. Results of the field audits are retained by the QA/QC Officer for each project and employee.

Laboratory (analytical) staff

All analytical samples are submitted to the CMU Laboratory, which is a North Carolina certified analytical lab. CMU Laboratory staff training is performed in accordance with the requirements inherent in this Certification. If another laboratory is used, it must have North Carolina certification for all analysis performed.

A9. Documentation and Records

Quality assurance information, SOPs, and other support documentation

Once all approval signatures have been obtained, the QA/QC Officer will electronically distribute copies of the approved QAPP to persons on the distribution list in Section A3 of this document. Copies must be disseminated within 30 days of final approval. The original hard copy with approval signatures will be kept on file in the QA/QC Officer's office at the Hal Marshall Center, 700 North Tryon Street, Charlotte, NC 28202.

The QA/QC Officer is to be notified of changes made to SOPs, SAPs, analytical methods, or any other documentation referenced by this QAPP. The QA/QC Officer will then be responsible for distributing the information, as described above. The QA/QC Officer will also be responsible for keeping current copies of all these documents on file at the Hal Marshall Center (address above). Since the MCWQP monitoring program is ongoing, this QAPP will be reviewed on at least an annual basis by the QA/QC officer, and, if appropriate, any changes or updates made at that time. However, critical revisions can be made at any time. The QA/QC Officer is responsible for completing revisions, obtaining signatures of approval, and disseminating the revised document to those on the distribution list within 30 days of final approval. The version or revision number and date shall be easily identifiable by the document control information on each page. A complete list of all revisions/updates will be provided with each annual update.

Program records

The records produced by the MCWQP monitoring program, their location, retention time, format, and disposition at the end of the required retention time are summarized in Table A9.1.

Table A9.1: Program Records

	Minimum Retention Time	Format	Disposition
QA/QC Officer			
Field data sheets	5 years	Hard copy	TBD
Field data electronic	5 years	SQL	TBD
Analytical Reports – hard copy	5 years	Hard copy	TBD
Analytical Reports – electronic	5 years	SQL	TBD
CMANN Data electronic submittals	5 years	SQL	TBD
CMU Laboratory			
Analytical Reports – hard copy	5 years	Hard Copy	TBD
Analytical data - electronic	5 years	SQL	TBD

Data assessment reports

An annual assessment of the monitoring data generated by the MCWQP is prepared annually. It is prepared to document issues with the previous year's data set and to document format, data qualifiers and any know issues that may affect the quality of the year's dataset.

SECTION B: DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

The design of the MCWQP monitoring program is based upon specific project requirements. Each project has unique goals and criteria, therefore each project will be addressed in turn.

Fixed Interval Monitoring

The FIM program was designed as a long-term, watershed scale monitoring project. Portions of the FIM network of stations have been in existence since the 1970s. There are currently 29 monitoring stations throughout Charlotte and Mecklenburg County.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Sites must drain at least 6 square miles. There has been much speculation regarding the ability of 1st order streams to support diverse macro invertebrate and fish populations. In order to ensure comparability of all results, sites draining less than 6 square miles have been excluded

- Fairly uniform coverage of all Watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites with established USGS Stream Gages were given greater importance.

- Sites corresponding to NC-DENR compliance points were given greater importance.

- Single geographic features, such as the Charlotte Douglas Airport were not given greater importance.

A complete current site list and site map is provided in the Fixed Interval Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 15 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Not directly below large amounts of debris or other temporary impoundments

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as specific conductance are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit. All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Fixed Interval Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Fixed Interval Monitoring SAP, which references the appropriate SOPs.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The bacteriological monitoring program was designed as a short-term, base flow, watershed and catchments' scale monitoring project focused on identifying sources of fecal coliform.

Station Locations

Stations are typically established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed, catchment or known source of fecal coliform (such as a WWTP effluent). The following criteria were considered during the site selection process:

- Fairly uniform coverage of all watersheds.
- Sites with established USGS Stream Gages were given greater importance.
- Sites corresponding to NC-DENR compliance points were given greater importance.

A complete current site list and site map is provided in the Bacteriological Monitoring Program SAP, which is included with this document as Appendix 2.

The short term nature of the bacteriological monitoring program necessitates that sites move frequently and are added and subtracted. Generally, the network is stable during an entire fiscal year, however mid-year changes do occur. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Suspected source of fecal coliform
- Changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

Indicators measured and sampling frequency

The only routine indicator monitored for the Bacteriological Program is fecal Coliform, however *E-coli* is monitored at all TMDL compliance points. The fecal coliform standard by stream classification is included in Appendix 6. There currently is no state water quality standard for *E-coli*, however the samples are collected and analyzed with the expectation that a standard is forthcoming.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit.

All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Fixed Interval Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Bacteriological Monitoring SAP, which references the appropriate SOPs.

In-Stream Storm Water Monitoring Program

The ISM program was designed to assess the impacts of non-point source pollution on stream water quality. Portions of the ISM network of stations have been in existence since the mid 1990's. There are currently 4 monitoring stations in the City of Charlotte.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at bridge crossings. It is a requirement that ISM stations be located at USGS stream gauging stations. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed or development.

A complete current site list and site map is provided in the In-stream Monitoring SAP, which is included with this document as Appendix 2.

Requests from MCWQP staff for station establishment and/or discontinuation of a site will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy
- Changes to program needs or direction

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Samples are collected automatically using ISCO samplers. Actual sampling points (tubing influent) are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as specific conductance are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit.

All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The In-stream Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the In-stream Monitoring SAP, which references the appropriate SOPs.

Service Request/Emergency Response/Follow-up Monitoring Program

The service request monitoring program was designed as a short term, catchment scale monitoring project. The service request monitoring program is designed to identify active sources of water quality pollution.

Station Locations

There is no established network of sites or sampling locations. Sites are sampled based solely on the discretion of the field staff engaged in the investigation. An attempt is made to 'bracket' or narrow down the possible sources of a pollution problem through intensive sampling in the immediate vicinity of a suspected pollution source. Typically, service request monitoring is initiated after a citizen complaint or discovery of an action/watch exceedance from the FIM or bacteriological monitoring programs.

Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those suspected of being released to surface water by the pollution source. Field staff determine indicators based upon professional judgment and knowledge of the incident (action/watch report or citizen provided information).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Service Request Monitoring SAP, which references the appropriate SOPs.

TMDL Stream Walk Monitoring Program

The TMDL stream walk monitoring program was designed as a short term, catchment scale monitoring project. The program is designed to identify active sources of fecal coliform in TMDL watersheds.

Station Locations

There is no established network of sites or sampling locations. Sites are sampled based solely on the discretion of the field staff engaged in the investigation and guidance provided in the TMDL Stream Walk SAP (Appendix 2). Typically, all tributaries and storm water outfalls and swales encountered during a TMDL stream walk are sampled. Other suspected sources, such as straight pipes, are also sampled.

Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The indicators measured are listed in the TMDL Stream Walk Monitoring SAP (Appendix 2).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the TMDL Stream Walk Monitoring SAP (Appendix 2), which references the appropriate SOPs.

BMP Monitoring Program

The BMP monitoring program was designed as a short term, individual device scale monitoring project. The program is designed to characterize the pollution removal efficiency of certain BMPs in Charlotte, NC. Currently there are 18 BMP devices being monitoring.

Station Locations

There is no established network of sites or sampling locations. BMPs are generally selected for sampling by Charlotte Storm Water Services. Factors such as upstream land-use, impervious area and drainage area size are considered. A complete list of the sites sampled is included in the BMP Monitoring Program SAP, which is included in Appendix 2. BMP locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The indicators measured are listed in the BMP Monitoring Program SAP (Appendix 2).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the BMP Monitoring Program SAP (Appendix 2), which references the appropriate SOPs.

Lake Monitoring Program

The lake monitoring program was designed as a long-term and short term watershed scale monitoring project. Portions of the lake monitoring network of stations have been in existence since the 1970s. There are currently 32 monitoring stations in the five impoundments (3 reservoirs) of the Catawba River in Mecklenburg County. Stations are visited at the regular intervals outlined in the Lake Monitoring Program SAP (Appendix 2).

Station Locations

Most lake stations are established at publicly accessible, fixed locations that are accessible by boat. However, in several instances where launching a boat is problematic, samples are collected off of the end of private docks (Lake Cornelius and Lake Davidson primarily). Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific section or cove of a reservoir or impoundment. The following criteria were considered during the site selection process:

- Sites should be indicative of overall water quality.

- Sites should be located along the primary flow path through the reservoir. Additionally, sites should be located in major coves along the Mecklenburg County shoreline.

A complete current site list and site map is provided in the Lake Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 30 years and the focus on long-term data is integral to identifying temporal patterns within a reservoir and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points may be in open water, coves, or near the confluence with tributaries of interest that enter the reservoir at points determined by field staff as representative of the water body or subsection of the water body.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as Secchi depth are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit. All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Lake Monitoring Program SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the lake monitoring SAP, which references the appropriate SOPs.

Industrial Facility Monitoring Program

The industrial facility monitoring program was designed as a short term, site scale monitoring project to determine an NPDES discharge permit holder’s compliance with state water quality standards and permit requirements.

Station Locations

There is no established network of sites or sampling locations. Sampling locations are situated at sites with poor material handling and housekeeping procedures discovered during the industrial inspection program. Sites are usually storm water outfalls conveying runoff from the industrial facility in question. Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those suspected of being released to surface water by the industrial facility in question. At a minimum, indicators identified in the NPDES discharge permit are selected. Field staff determines additional indicators based upon professional judgment and knowledge of the industrial facility (generally, the staff member completing the industrial inspection will collect the samples from the site runoff).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Industrial Facility Monitoring SAP, which references the appropriate SOPs.

Continuous Monitoring and Automated Notification Network

The CMANN program was designed as a short-term, watershed and catchment scale monitoring project to identify sources of pollution in Charlotte and Mecklenburg County Streams. Subsequently, the program has evolved into a long-term project with 39 stations (4 mobile stations and 35 fixed stations) used to identify water quality trends for the parameters measured.

Station Locations

Fixed stations are established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Fairly uniform coverage of all watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites with established USGS Stream Gages were given greater importance.

- Sites corresponding to NC-DENR compliance points were given greater importance.

Mobile stations are established downstream of suspected sources of water quality pollutants. By nature, these locations are moved frequently (approximately monthly) to monitor other suspected sources of surface water pollution.

A complete current site list and site map is provided in the CMANN SAP, which is included with this document as Appendix 2.

Many of the current fixed stations have been active for over 2 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

Mobile stations can be moved at the discretion of field staff to locations downstream of suspected sources of surface water pollution.

Indicators measured and sampling frequency

The nature of the equipment limits the indicators to field measurements (conductivity, pH, turbidity, temperature and DO). A summary of standards by stream classification is included in Appendix 2.

The CMANN SAP (Appendix 2) lists the frequency of measurement.

Sampling and measurements

Measurements are collected in accordance with the CMANN SAP, which references the appropriate SOPs.

Goose Creek Recovery Program Monitoring

The Goose Creek Recovery program was designed as a long-term, catchment scale monitoring project to characterize the fecal coliform loading rates of certain land-uses in the Goose Creek Watershed. The monitoring sites are to be established during FY07-08.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at storm water outfalls. Locations and their latitude and longitude will be identified using GPS units or ESRI GIS software. Stations are strategically located to monitor a specific land-use. Monitoring stations will be located downstream of specific land-uses, including; 0.25 – 0.5 acre residential, commercial, institutional, 0.5 – 1 acre residential and I-485.

A complete current site list and site map is provided in the Goose Creek Recovery Program SAP, which is included with this document as Appendix 2.

Requests from MCWQP staff for station establishment and/or discontinuation of monitoring stations will be assessed on the value gained from a land-use characterization perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally end of pipe, or as determined by field staff as representative of the runoff from the land-use.

Indicators measured and sampling frequency

The only indicator is fecal coliform bacteria.

The Goose Creek Recovery Program SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Fixed Interval Monitoring SAP, which references the appropriate SOPs.

Biological Monitoring

The biological monitoring program was designed as a long-term, watershed scale monitoring project. Portions of the biological monitoring network of stations have been in existence since the 1980s. There are currently 48 macro invertebrate and habitat monitoring stations and 8 fish monitoring stations throughout Charlotte and Mecklenburg County. The Mecklenburg County Bioassessment Laboratory is a State of North Carolina Certified Biological Lab (Certificate Number 036). It conducts all biological sampling for the MCWQP in accordance with its certification requirements.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at bridge crossings corresponding to a FIM location. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Sites must drain at least 6 square miles (unless a specific project site). There has been much speculation regarding the ability of 1st order streams to support diverse macro invertebrate and fish populations.

- Fairly uniform coverage of all watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites corresponding to NC-DENR compliance points were given greater importance.

- Single geographic features, such as the Charlotte Douglas Airport were not given greater importance.

A complete current site list and site map is provided in the Biological Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 20 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added.

Indicators measured and sampling frequency

Samples are collected for macro invertebrates and fish. Field measurements are made for habitat assessment.

The biological monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Biological samples are collected, handled and analyzed in accordance with the Biological Laboratory Certification requirements.

B2. Sampling Methods

Samples and measurements are to be taken in accordance with all SOPs (Appendix 3). Any irregularities or problems encountered by field staff should be communicated to the QA/QC

Officer, either verbally or via email, who will assess the situation, consult with other project personnel if needed, and recommend a course of action for resolution.

The SAPs (Appendix 2) identify sampling methods to be used for each monitoring program. The SOPs (Appendix 3) describe specific sampling and measurement techniques. Table B2.1 displays the types of samples and measurements collected for each monitoring program.

Table B2.1: Sample Collection Matrix

Monitoring Program	Grab Samples	ISCO Samples	Field mmts	Fish & Bug
Fixed Interval Monitoring Program	X		X	
Bacteriological Monitoring Program (Including 5/30 Monitoring)	X		X	
In-Stream Storm Water Monitoring Program		X	X	
Service Request/Emergency Response/Follow-up Monitoring Program	X		X	
TMDL Stream Walk Monitoring Program	X		X	
BMP Monitoring Program	X	X	X	
Lake Monitoring Program	X		X	
Industrial Facility Monitoring Program	X	X	X	
Continuous Monitoring and Automated Notification Network			X	
Goose Creek Recovery Program Monitoring	X			
Biological Monitoring				X

B3. Sample Handling and Custody

All samples are to be handled by field staff in accordance with the applicable SAPs (Appendix 2) and SOPs (Appendix 3).

Sample preservation

Chemical preservation of water samples occurs instantaneously, in that MCWQP utilizes pre-preserved sample collection containers for all direct-grab surface water samples. Samples should then be place in coolers with ice. The chemical preservatives utilized for each sample are listed in Table XX. Biological samples are preserved according to their approved SOP.

Sample submission forms

Sample submission forms (also known as chain of custody forms or COCs) are developed by the QA/QC Officer for all monitoring programs with the exception of the Biological Monitoring Program. The biological monitoring program follows the sample submission protocol outlined in their approved SOP. Each sheet corresponds to one monitoring event for one monitoring program (samples collected for multiple monitoring programs must be submitted to the laboratory under separate forms).

Examples of COCs for each monitoring program are provided in the SAP (Appendix 2) for the program. Typically, they will include the following information:

- Sample collectors initials
- Date and time of sample collection
- Depth (for lake samples)
- Notes

Field data is recorded on the field data sheets for the monitoring program. Example field data sheets are provided in the SAP (Appendix 2) for the program.

Sample bottle labels

Sample bottle labels for each program are provided in the SAP (Appendix 2) for the program. They should be filled out using waterproof ink or be pre-printed with the equivalent information. The bottle labels are printed from the special printer in the tech area on water proof, self-adhesive stock. Bottles labels should be affixed to the sample containers prior to departure for the field.

Sample Transport

Immediately after sampling, labeling, and chemical preservation, samples are placed in coolers on ice along with a "super" (trip, field, equipment) blank. Coolers are then hand delivered by field staff to the CMU Laboratory for check-in and subsequent analysis.

Laboratory

Once samples are checked into the CMU Laboratory, laboratory staff handles the samples in accordance with the procedures outlined in their laboratory certification. Samples submitted by field staff that are either out of hold time or fail the check-in temperature test may be rejected by the CMU Laboratory.

B4. Analytical Methods

Field measurements

Refer to the YSI Multiprobe Calibration and Field Data Collection SOP (Appendix 3) or appropriate YSI manual for field measurement analytical methods.

Lab analyses

Samples are submitted for analysis to the CMU Laboratory in Charlotte, NC. Results should be reported to the QA/QC Officer within 30 days of sample submission.

A summary of methods and PQLs (the Laboratory Section's minimum reporting limit) are listed below in Table B4.1.

Table B4.1: Analytical method references and lower Reporting Levels (RLs)

Analyte	RL	Units	Reference	Samp Vol	Hold Time	Preservative
ALKALINITY	3.00	mg/L	SM 2320-B	100	14	None
AMMONIA-NITROGEN	0.10	mg/L	SM 4500-NH3H	30	28	H_2SO_4
CHLOROPHYLL A	1.00	ug/L	SM 10200	250	14 days	None
CHROMIUM	5.00	ug/L	EPA 200.8	*500	180	HNO_3
COPPER	2.00	ug/L	EPA 200.8	*500	180	HNO_3
E. COLI	1.00	MPN /100 ml	SM 9223-B	125	0.25	$Na_2S_2O_3$
FECAL COLIFORM	1.00	CFU/100 ml	SM 9222-D	125	0.25	$Na_2S_2O_3$
LEAD	3.00	ug/L	EPA 200.8	*500	180	HNO_3
MANGANESE	10.00	ug/L	EPA 200.8	*500	180	HNO_3
MERCURY	0.20	ug/L	EPA 200.8	*500	180	HNO_3
NITRATE/NITRITE	0.05	mg/L	EPA 353.2	30	28	H_2SO_4
ORTHO-PHOSPHATE	0.01	mg/L	SM 4500-PF	30	2	None
SUSPENDED SEDIMENT CONCENTRATION	2.00	mg/L	ASTM D3977-97	250	7	None
TOTAL KJELDAHL NITROGEN	0.25	mg/L	EPA 351.2	30	28	H_2SO_4
TOTAL PHOSPHORUS	0.01	mg/L	SM 4500-PF	30	28	H_2SO_4
TOTAL SOLIDS	5.00	mg/L	SM 2540-B	100	7	None
TOTAL SUSPENDED SOLIDS	1.00	mg/L	SM 2540-D	250	7	None
TURBIDITY	0.05	NTU	SM 2130-B	100	2	None
VOC	VAR	ug/L	EPA 8620	80	14	HCl
ZINC	10.00	ug/L	EPA 200.8	*500	180	HNO_3

*500 ml = sufficient volume for all metals requested

p = Plastic

pS = Sterile Plastic

pO = Opaque Plastic

g = glass

B5. Quality Control

The Mecklenburg County Water Quality Program implements a comprehensive Quality Control (QC) program designed to monitor the integrity of both field measurements and laboratory samples. The program consists primarily of blanks, but also equipment blanks and field checks of know standards to ensure that all field data and samples collected are of the highest quality.

A majority of the routine monitoring run blanks (i.e. direct surface water grab samples) are considered by MCWQP to be “super-blanks”, or high-level scoping blanks that cover the practical extent of our sampling efforts. These blanks encompass error introduced from a number of common sources; including reagent water (or buffer solution for bacteriological parameters), pre-preserved sample containers, field methods and cooler / trip blanks. In the event that a parameter “hit” is observed in a super-blank, additional investigations must be initiated in order to determine the source of the contamination. This will result in additional work and consequently additional expense when contamination is discovered. Over a period of years, however MCWQP has determined that contamination problems of this nature are almost non-existent.

Any combination of the following traditional blanks and any other means deemed necessary to identify a source of sample contamination may be employed at any time.

- Bottle blank
- Field blank
- Reagent blank
- Sample container blank
- Transport, storage (cooler)

- Equipment (ISCO) blank

In general, one super-blank is included with each routine sampling run. A sampling run generally consists of approximately 10 sites on average. ISCO automated sample collection containers are blanked at least annual to ensure the cleaning procedures are adequate.

The Charlotte-Mecklenburg Utilities Laboratory (CMU), contracted by MCWQP for all sample analysis, is a NC State Certified lab for water and wastewater sample analysis. CMU lab is certified as EPA NC00125. The CMU lab conducts thorough and complete quality control in accordance with EPA and State standards for Certified Laboratory Practices. The CMU lab routinely conducts the following:

- Matrix spike
- Matrix spike replicate
- Analysis matrix spike
- Surrogate spike
- Analytical (preparation + analysis) bias
- Analytical bias and precision
- Instrument bias
- Analytical bias
- Zero check
- Span check
- Mid-range check
- Calibration drift and memory effect
- Calibration drift and memory effect
- Calibration drift and memory effect
- Replicates, splits, etc.
- Field co-located samples
- Field replicates
- Field splits
- Laboratory splits
- Laboratory replicates
- Analysis replicates
- Sampling + measurement precision
- Precision of all steps after acquisition
- Shipping + inter-laboratory precision
- Inter-laboratory precision
- Analytical precision
- Instrument precision

Annually, MCWP reports all instances of Quality Control violations. All violations are investigated and corrective actions are implemented wherever possible to eliminate additional sources of contamination.

B6. Instrument/Equipment Testing, Inspection, and Maintenance

Field Equipment

All field staff are responsible for regular cleaning, inspection, and maintenance of equipment they use for sampling activities. All equipment should be visually inspected daily for damage or dirt, and repaired or cleaned if needed before use. If meters are stored for long periods (> 1 week) without being used, it is recommended that they be calibrated and inspected at least weekly to keep them in good working order. Other required maintenance on field meters is conducted in accordance with the MCWQP Field Parameter Laboratory certification.

Laboratory analytical equipment

Laboratory analytical equipment is maintained in accordance with CMU Laboratory's Analytical Laboratory Certification requirements.

B7. Instrument Calibration and Frequency

Field meters

All field meters are to be inspected and calibrated at a minimum at the beginning and end of each day and checked at the end of each day they are used (Note: field meters are not re-calibrated at the end of use, rather they are checked). Field staff should record calibration information on the appropriate form (located in the meter calibration area of the tech room). Calibration and documentation should occur in accordance with the YSI Multiprobe Calibration and Field Data Collection SOP (Appendix 3).

Meters should also be checked against standards periodically throughout the day and recalibrated if needed if any of the following occur:

- Physical shock to meter;
- DO membrane is touched, fouled, or dries out;
- Unusual (high or low for the particular site) or erratic readings, or excessive drift;
- Extreme readings (e.g., extremely acidic or basic pH; D.O. saturation >120%);
- Measurements are outside of the range for which the meter was calibrated.

Laboratory instrument calibration

CMU laboratory instrument calibration shall occur in accordance with their analytical laboratory certification.

B8. Inspection/Acceptance Requirements for Supplies and Consumables

The CMU laboratory performs quality assurance of sample bottles, reagents, and chemical preservatives that are provided to field staff. Containers that are purchased as pre-cleaned should be certified by the manufacturer or checked to ensure that the parameters tested are below the published reporting limits. Containers should be stored in a manner that does not leave them susceptible to contamination by dust or other particulates and should remain capped until use. Any containers that show evidence of contamination should be discarded. Certificates for glass containers certified by the manufacturer should be kept on file by the CMU Laboratory.

Field staff shall inspect all bottles before use. Any bottles that are visibly dirty or those with lids that have come off during storage should be discarded.

Certificates of purity for all preservatives obtained from an outside source should be provided when purchased, and these certificates kept on file by the CMU Laboratory. Any preservatives that show signs of contamination, such as discoloration or the presence of debris or other solids, should not be used and should be discarded. A summary of inspections to be performed by field staff is presented in Table B8.1.

Table B8.1: Consumable inspections and acceptance criteria

Item	Acceptance Criteria
Sample Bottles	- No visible dirt, debris or other contaminants
pH standards	- No visible discoloration, debris or other contaminants
Conductivity Standards	- No visible discoloration, debris or other contaminants
Acid preservatives	- No visible debris or other contaminants
Distilled or deionized water	- No visible discoloration, debris or other contaminants

B9. Non-Direct Measurements

All data will be generated through program field and activities and consequent lab analyses, with two exceptions:

- Precipitation: Data are to be obtained from the USGS database through their website at http://nc.water.usgs.gov/char/. Currently there are data available from more than 50 sites in and around Charlotte and Mecklenburg County. Data should be obtained from the nearest rain gauge. Figure B9.1 shows the distribution of rain gauges in and around Charlotte and Mecklenburg County
- USGS Flow data: Charlotte-Mecklenburg Storm Water Services has a cooperative agreement to help the US Geological Survey fund approximately 54 stream gages for the measurement of stream flow in and around Charlotte and Mecklenburg County. Data should be obtained from the stream gauge at the site at http://nc.water.usgs.gov/char/. Figure B9.2 shows the distribution of stream gauges in and around Charlotte and Mecklenburg County.

Figure B9.1: USGS Rain gauge network in and around Mecklenburg County

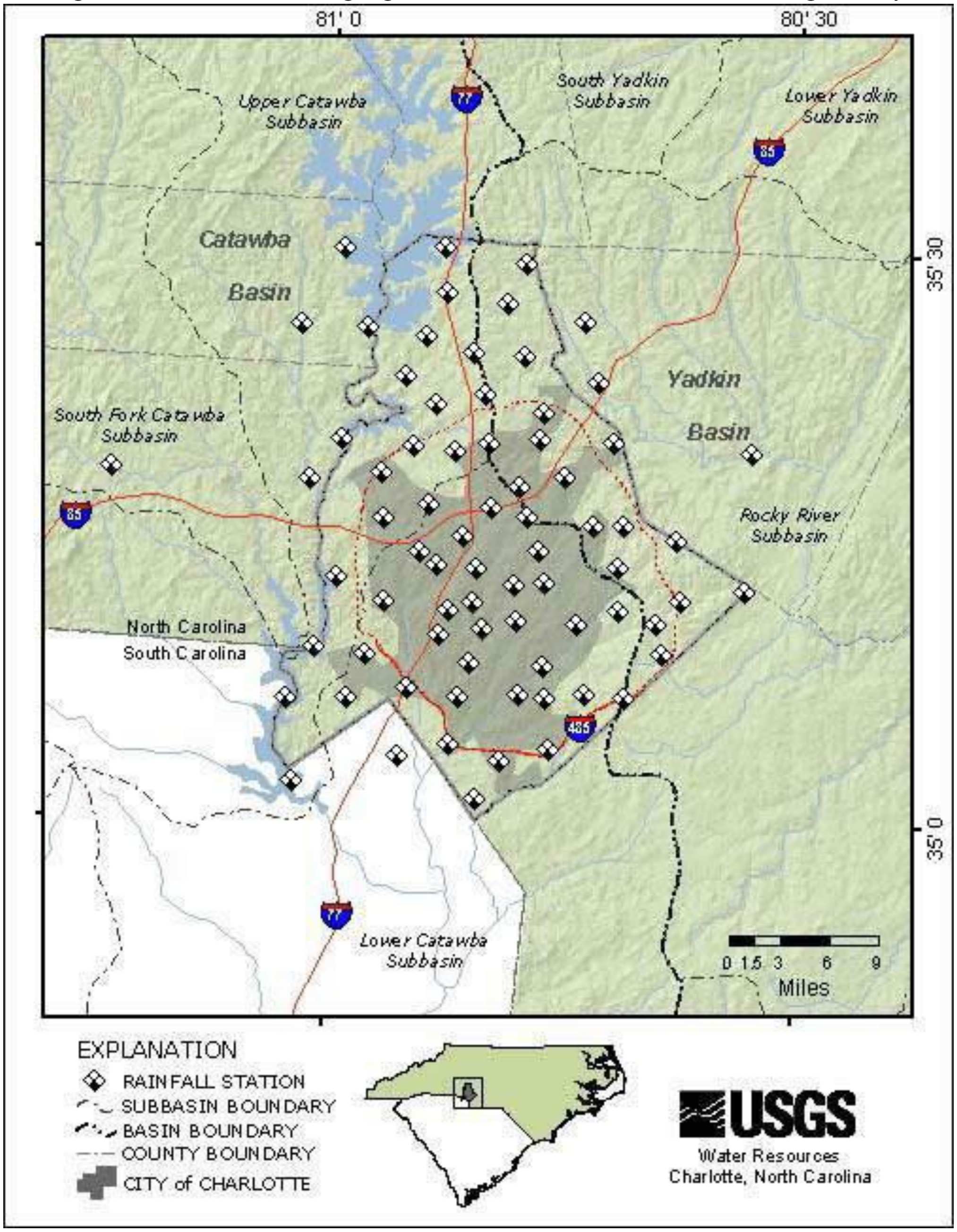
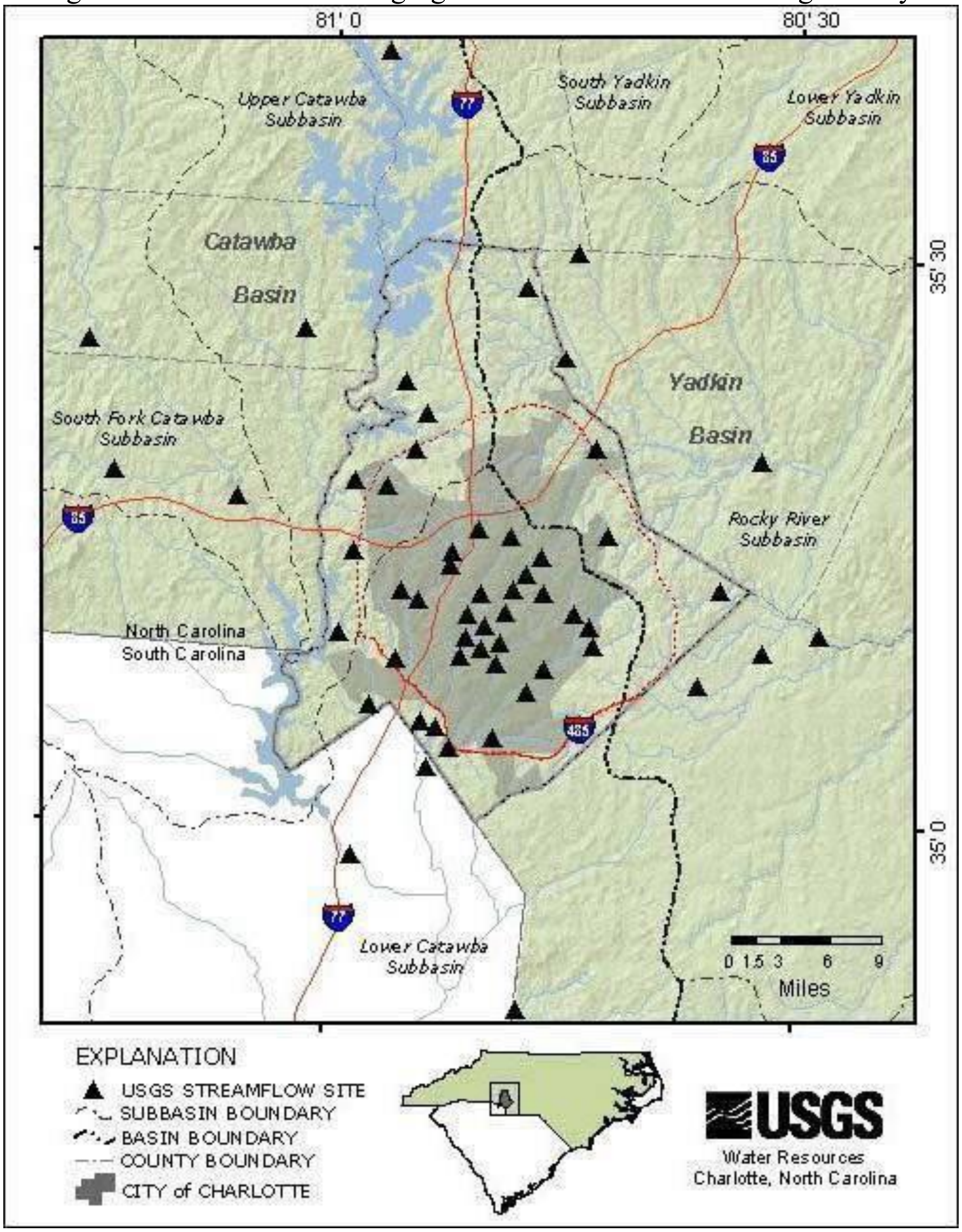


Figure B9.2: USGS Stream gauges in and around Mecklenburg County.



B10. Data Management

MCWQP produces approximately 17,000 analytical data points annually. In addition there are numerous Macro invertebrate assessments, fish counts, and habitat scores, as well as approximately $1.7x10^6$ remote water quality data points produced every year. Due to the quantity and complexity of information being produced, organized data management is critical. An overview of the data flow is given in Figure B10.1.

Analytical results are submitted to the Data Manager electronically and in hard copy format from the CMU laboratory. Occasionally samples are subcontracted by the CMU lab to outside sources. All outside sub-contract labs must be State Certified and provide data to MCWQP in both electronic and hard copy formats.

Field data is submitted in hard-copy on formatted field data sheets. Hard copy formatted original field data must be hand-key entered into electronic format for use and storage. Remote data from CMANN automated water quality sondes and USGS flow and precipitation data are routinely downloaded from the respective internet servers in .csv file format.

Individual data points are uniquely identified using a combination of Program Element Code, Location Code, Location Description, Date/Time Collected and analyte. All data received are reviewed by the Data Manager / QC Officer for completeness, data entry errors, unlikely or impossible values, etc., prior to approval.

All approved data is then uploaded into a secured SQL database utilizing a custom, web-interface application, the Water Quality Data Repository (WQDR). Approved data is available to MCWQP staff through the Environmental Data Management System (EDMS), or through Open Database Connectivity (ODBC) using Microsoft Access.

SECTION C: ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

The QA/QC Officer acts as the liaison between field staff, the CMU Laboratory, program management and data end users. Issues with any aspect of the program noted by any of these should report them as soon as possible to the QA/QC Officer, who will assess the issue, consult with other parties as needed, and determine the course of action to be taken.

The QA/QC Officer will conduct field audits of each monitoring program at least annually. The main purpose of these audits is to ensure that field staff are performing activities in accordance with current SOPs and to determine if there are any other issues that need to be addressed. Concerns or irregularities noticed by the QA/QC Officer will be discussed with the field staff and project officer. If significant issues arise, the QA/QC Officer will notify the Program Manager, and the field staff member's direct supervisor and issue a corrective action report. If the issue continues after the notification, the QA/QC officer will prepare a memorandum, describing the issue and providing recommendations for correcting the issue. The field staff member's direct supervisor is responsible for ensuring that these significant issues are resolved.

C2. Reports to Management

The QA/QC Officer reports significant issues to the Program Manager verbally and/or via written updates. The QA/QC Officer also maintains a database of the sampling schedule, which includes an accounting of all samples collected, samples to be collected and any issues with samples collected to date. The QA/QC Officer delivers periodic updates to the supervisors, project officers and field staff on the status and schedule of the monitoring program. These updates occur at monthly staff meetings and monthly supervisor meetings.

SECTION D: DATA VALIDATION AND USABILITY

D1. Data Review, Verification and Validation

Data verification and validation occurs at every step of water quality data generation and handling. Field staff, laboratory staff, project officers and the QA/QC Officer are each responsible for verifying that all records and results they produce or handle are completely and correctly recorded, transcribed, and transmitted. Each staff member and project officer is also responsible for ensuring that all activities performed (sampling, measurements, and analyses) comply with all requirements outlined in the SAPs and SOPs pertinent to their project. The QA/QC Officer is responsible for final verification, validation and acceptance of all results. One exception is the CMAN program where the CMANN project officer reviews all measurements and performs final verification, validation and acceptance of results.

D2. Validation and Verification Methods

Field staff

Field staff will visually check the following items as produced to ensure that they are complete and correct:

- Sample bottle labels
- COCs
- Field data sheets

Laboratory staff

CMU laboratory staff will perform data validation and verification in accordance with their Analytical Laboratory Certification requirements.

If circumstances arise where samples or analysis do not meet laboratory criteria, the Laboratory Section will report this using a text comment field attached to the result record.

QA/QC officer

The MCWQP QA/QC Officer (QCO) is responsible for data review, validation, and verification. These duties are conducted on an ongoing basis. As received, the QCO reviews hard copy lab reports and electronic data transfers from the CMU Lab, remote databases (CMANN) and from outside vendors (subcontracted labs). The QCO also reviews data that has been hand-key entered by MCWQP staff.

The QCO consults with the CMU Laboratory Manager and / or designated staff for clarification or corrections as needed. When errors or omissions are discovered or suspected, a focused investigation will be conducted. In the event that errors are discovered in electronic data transfers from CMU or CMANN, the QCO will contact the CMU Lab Manager, the CMU QC Lab Coordinator, or the designated MCWQP staff for resolution. In the event that errors are discovered in hand-key entry data, the QCO will consult hard-copy field data sheets and / or staff to resolve any identified issues. Final decisions on qualified or rejected data are the responsibility of the QCO.

Results in question that are found to be in error when compared to the original documentation will be corrected by the QCO. “Impossible” values (e.g., pH of 19) will be rejected or corrected if a value can be determined from original documentation. "Unusual" values that are confirmed by original documentation are left intact and unqualified.

Validated and verified data are uploaded to the Water Quality Data Repository by the QCO.

Data end-users

The individuals that request data from the MCWQP may note odd or possibly incorrect values. These questionable data should be brought to the attention of the QA/QC officer for focused verification. For most data, original lab reports and field data submissions are on file at the Hal Marshall Center (700 North Tryon Street, Charlotte, NC 28202). These will be consulted to determine if correction or deletion of any records in WQDR is required, using the same criteria as described above for data reviews. If original documentation for data collected is not available, confirmation and/or correction are not possible. This historic data will remain unchanged in the main warehouse and it is up to each data user to determine the proper handling of these results.

D3. Reconciliation with User Requirements

Section 7.0 – Performance Acceptance Criteria of each individual SAPs (Appendix 2) for each monitoring project outlines the acceptance criteria for each project.

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