DOWNSTREAM DEFENDER® TESTING USING MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION PROTOCOL UTILIZING OK-110 FEED SAND

JULY 2002

This report was reviewed by: Dr. Bob Andoh Technical Directory -Hydro International UK, and Pam Deahl, PE VP- Hydro International US July 2002.

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1. INTRODUCTION

Hydro International (Hydro) has set up a testing facility at its office in Portland, Maine. This facility is comprehensive and allows testing of the Downstream Defender® and other Dynamic Separators to be done under controlled conditions to comply with different laboratory testing protocols.

Hydro has conducted testing of a 4-ft diameter Downstream Defender® at its facility using the Maine DEP protocol for laboratory testing. This report presents the results of this testing which involved the use of U.S. Silica grade OK-110 foundry sand as the feed material. The results obtained confirm the ability of the 4-ft Downstream Defender® to remove greater than or equal to 80% of the feed material at 580 gpm.

The above performance conforms with the Maine DEP's 60% Total Suspended Solids (TSS) removal rating criteria and this report is submitted to Maine DEP in advance of a request for witness testing and verification prior to formal approval of the 60% rating.

2. LAB TEST FACILITY DESCRIPTION

The Hydro test facility consists of a 23,300-gallon clean water storage reservoir equipped with a Flygt submersible pump to provide feed water. The test unit is a 4-ft diameter Downstream Defender® with an 8-inch inlet. The Downstream Defender® is connected to the pump delivery with 8-inch diameter PVC pipe-work that incorporates clear standpipes, as well as a valved bypass, which directs excess flows back to the reservoir. This valve is required because the pump output rate is generally greater than the desired test flow rate. The delivery line is fitted with a Hershey VP-820 gearbox butterfly valve for accurate flow control. The overflow from the Downstream Defender® is sent back to the reservoir for re-circulation via a 12-inch PVC pipe.

Water and sand are mixed in a 60-gallon barrel to create a sand-slurry, which is fed into the test unit via the inlet piping. The sand-slurry is injected into the 8-inch inlet pipe upstream of the Downstream Defender® by a Watson-Marlow peristaltic pump.

A grab sample valve is incorporated in the inlet piping of the Downstream Defender®, and this consists of a simple 6-inch diameter gate valve with a T-handle. An automatic sampler is located upstream from the feed standpipe to sample background Total Suspended Solids concentrations in the feed from the clean water storage reservoir. The automatic sampler is a Sigma 900 portable sampler that takes about 820 ml per sample.

An ISCO UniMag Magnetic Flowmeter is located in the 8-inch diameter inlet piping upstream from the inlet to the Downstream Defender® test unit.

The underflow from the Downstream Defender® test unit is valved to an underflow collection tank with a weir wall and two baffles for sediment collection after a test. A clean-out port at the base of the Downstream Defender® allows for sediment collection and rinsing.

Materials and equipment used in the TSS analysis included:

- Distilled water, spray bottles, and containers
- Calibrated scales
- 47mm diameter glass fiber ProWeigh Filters with a 1.5 µm pore size
- Welch-Thomas vacuum pump
- Millipore Frit Glass base and stopper for 47mm filters
- VWR Scientific Products 1370 forced air oven
- A W.S. Tyler RX-29 ROTAP sieve shaker for the sieve analysis of sand

An arrangement drawing of the test facility is included in Appendix A and photographs showing aspects of the test set-up and equipment are included in Appendix B.

3. LABORATORY TESTING PROTOCOL

3.1 Flow Calibration

A number of iterations of the test sequence were performed to identify the loading rate that provided the required removal. The main pipe flow rate and sand slurry input were carefully monitored and measured.

Flow was measured using the ISCO UniMag Magnetic Flowmeter System which has an accuracy of plus/minus 0.5% of flow rate for mean velocities of 1 ft/s and greater. This equates to a minimum flow rate of 156 gpm for an 8-inch pipe. The appropriate flow rate to achieve the desired minimum removals of 80% was found to be 580 gpm (with an inlet velocity of 3.7 ft/s), which exceeds the minimum flow rate required to ensure an accuracy of plus/minus 0.5%.

The flow rate was also verified by an alternative measurement technique using volumetric, time-to-fill calculations. The container used for time-to-fill was greater than 200 gallons for accuracy.

The test sand slurry inflow was regulated through a peristaltic pump and was introduced into the inlet pipe via a tube into the feed standpipe. The slurry concentration was continuously stirred in the 60 gallon feed tank with a rotating stir rod with two propellers on a drill motor. The average TSS concentrations from the influent samples were in a range of 153 to 307 mg/l and averaged 235 mg/l overall.

3.2 System Equilibrium

The 4-ft diameter Downstream Defender® test unit has an effective treatment volume equal to:

$V=\pi \cdot r^2 \cdot h$ or $\pi \cdot r^3$ ($r=h=2$ ft) = 25.13 ft^3;

- where r = radius of treatment unit,
  h = distance between top of sloping part of benching skirt and the invert of the outlet (which excludes the benching and sediment storage areas).

The theoretical residence time is equal to the amount of time it takes one (1) unit volume to pass through the system at a given flow rate assuming plug flow conditions (no underflow). The residence times for our experiments were based on the volume between the sampling points. The residence time was calculated by dividing this volume by the flow rate through the system. To ensure that equilibrium conditions had been established, four (4) residence times passed before sampling commenced.

3.3 Sampling

Six (6) sets of samples were collected at 1-minute intervals from the inlet and outlet via grab sampling. Sample volumes were a minimum of 450 ml and averaged 813 ml. Automatic samples for determining background concentrations were also taken corresponding to the 6 inlet samples thus giving a total of 18 samples per test.

For example, for a test at a flow rate of 580 gpm, 4 unit volumes were allowed to pass before sampling to ensure equilibrium conditions. This meant that the first influent was sampled at 1:30 min/sec and the first effluent at 1:53 min/sec, after the start of the test. This reflects the 22.67 seconds residence time for that flow rate. The second samples were taken 1 minute after the first at 2:30 and so on.

To ensure there was no buildup at the gate valve and to ensure representative sampling, the valve was purged seconds before a sample was taken so that a more accurate and representative reflection of the influent stream was sampled.

4 LABORATORY TESTING PROCEDURE

The following is an outline description of the testing procedure.

4.1 Test

1. Start with a clean Downstream Defender® and clean water in the reservoir.
2. Accurately weigh out 6 lbs. of OK-110 influent feed sand. Fill the slurry feed tank with 30 gallons of clean water.

3. Take a sieve sample of the feed sand. The sieve analysis shows the consistency of feed sand used for each micron category to minimize variability in test results.
4. Make sure the bypass valve is fully open and the control valve is fully opened for unrestricted flow. Make sure the clean-out port is closed on the Downstream Defender® and the underflow valve is closed. Make sure the influent grab sample valve is closed.
5. Start the pump and watch for the Downstream Defender® to overflow into the reservoir and the flow rate to stabilize.
6. Adjust the flow rate using the control valve to the target rate of 580 gpm. (This flow rate was verified with at least 3 time-to-fill volumetric tests.)
7. Start the stirring motor in the slurry feed tank and then introduce the sand into the tank.
8. Turn on the peristaltic pump and automatic sampler.
9. Once sand slurry flow enters the pipe, start the automatic sampler and timer. The automatic sampler will take blank samples at 1-minute intervals corresponding with the influent sample times.
10. After 4 residence times have passed (i.e. 1:30 min/sec), take the first influent grab sample. Note: At 1:25 min/sec a purge or flush is performed by quickly opening and closing the valve immediately before taking the sample.
11. Take effluent sample 1 residence time (1:53) after influent sample (giving 5 residence times from sand introduction).
12. Take 6 sets of samples at 1-minute intervals. This yields a total of 18 samples.
13. Stop the sampling and test. Stop the pumps, stirring motor, and automatic sampler.
14. The unit is then drained, flushed twice, and cleaned to prepare for another test.
15. Samples are then analyzed using an equivalent standard to the TSS Test Method 2 Filtration in ASTM, 1999, D 3977-97. Specifically, the Standard Methods 19th Ed 1995 for the Examination of Water and Wastewater prepared and published by the American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF) chapter 2-2540 D Total Suspended Solids Dried at 103-105 deg C was used.

4.2 Calculation of Removal Efficiency

The average removal efficiency was calculated using:

(Mean inflow TSS concentration – Mean outflow TSS concentration) / Mean inflow TSS concentration

5 RESULTS AND DISCUSSION

After performing 3 tests at 580 gpm flow rate, the efficiency from the TSS analysis showed removal efficiencies equal to or greater than 80%. The observed removal efficiency range was 80.5% - 83.8% with an average influent concentration of 235 mg/l.

The results show that the 4-ft Downstream Defender® achieves greater than 80% TSS removal efficiencies with OK-110 sand at a flow rate of 580 gpm using the recommended protocol.

A simple Dixon Q Test was performed for every 6 sample-set to determine whether the data included any outliers within a 95% confidence interval. A statistical Dixon Q test was chosen to determine whether there is a determinate (systematic) or indeterminate (random) error in the data. This check showed that the influent and effluent data had no samples as outliers for a 95% confidence interval. The average influent sample was 235.686 mg/l and the average effluent sample was 40.599 mg/l, which shows an average removal efficiency of 82.77% within a 95% confidence interval.

The automatic samples (i.e. blanks), would measure any concentrations of trace background TSS amounts in the feed water. This data set does not include the blanks because the automatic samplers are currently being utilized for long term monitoring in the field. Experience from previous testing shows that the background measurements using the blanks typically result in a 2-6% increase in removal efficiency. Blanks will be taken during the witness/verification test.

See Appendix C for test data (4 pages).

6 SCALING

In accordance with the previously completed tests using the Laboratory Testing Protocol for Manufactured Treatment Systems, the scaling for the Downstream Defender® stormwater treatment device with an aspect ratio of 0.5 should be based on Froude's Law. Hydro International requests a total suspended solids (TSS) removal rating of 60% for the Downstream Defender® when 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:

$Q_{1ypf} = 580(D/4)^{2.5}$

Where:

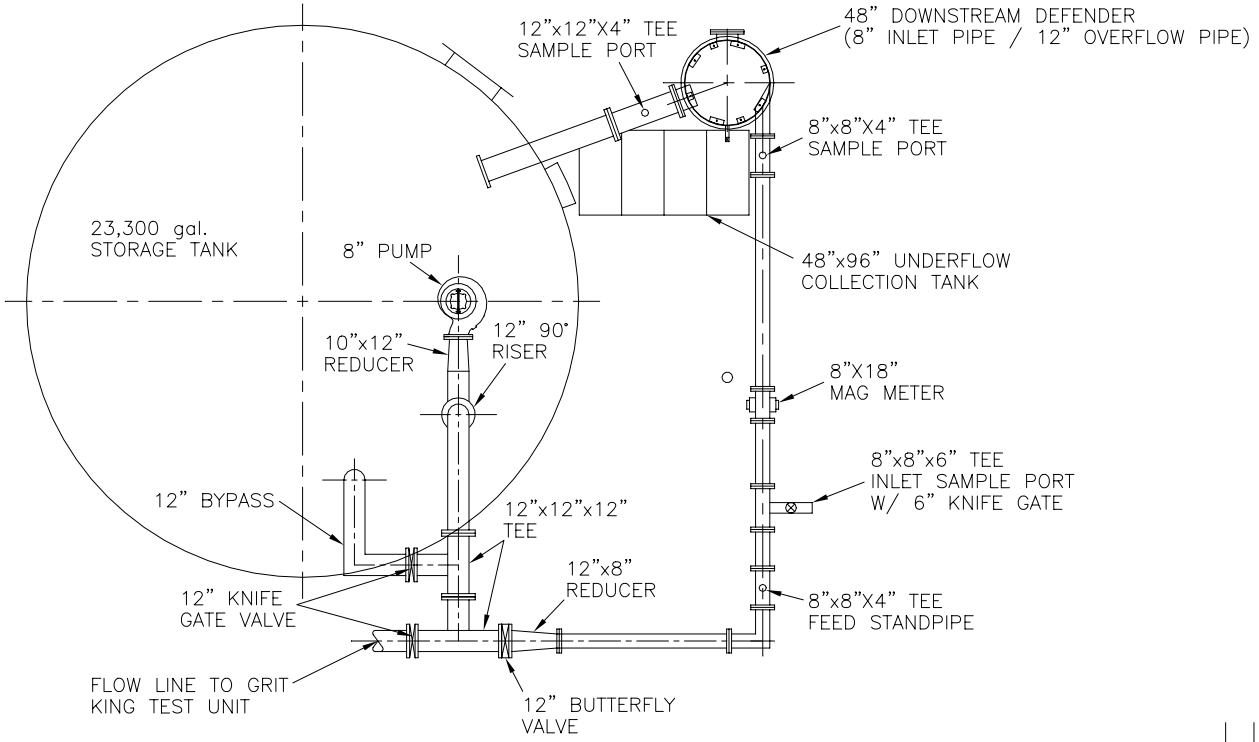
Q_{1ypf} = the projected one year peak flow from the device's drainage area and
D = the diameter in feet of the device's treatment chamber

7 ACKNOWLEDGEMENT

Hydro International would like to thank the Maine DEP for providing us the opportunity to participate in the new laboratory testing protocol. We highly appreciate the ME DEP for establishing the protocols to provide a uniform basis for the evaluation of the performance of all proprietary stormwater treatment systems. We look forward to our future correspondence in providing the latest information and concerns about other ratings and field testing protocols.

Appendix A
Lab Arrangement Diagram

DOWNSTREAM DEFENDER TEST FACILITY
HYDRO INTERNATIONAL
94 HUTCHINS DRIVE, PORTLAND, ME 04102



Hydro International

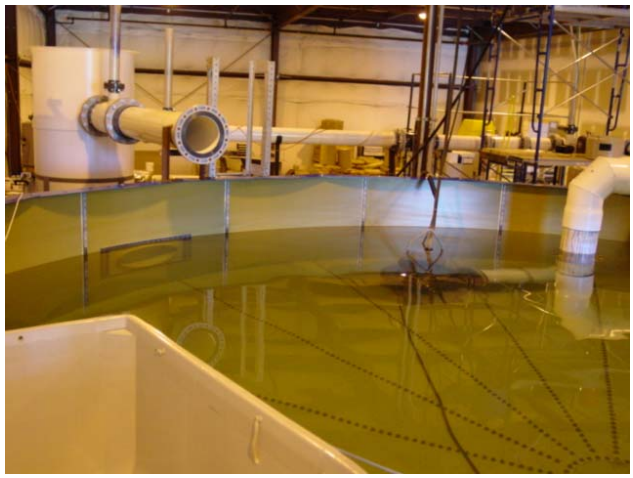
A	GM	9/14/01	ISSUE DATE

Drawn By: GM

CAD Ref: TESTFACILITY(DD1A)

Appendix B
Lab Photographs

Downstream Defender

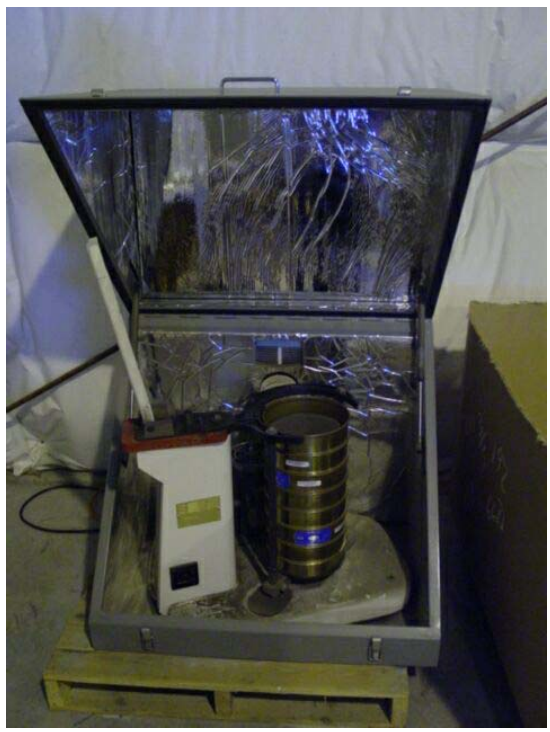


DD Outlet Into Test Tank

TSS Lab, Scale, Vacuum Pump

Feed and Sample Valves and DD

Volumetric Time-To-Fill Tank



Sand Seive Shaker

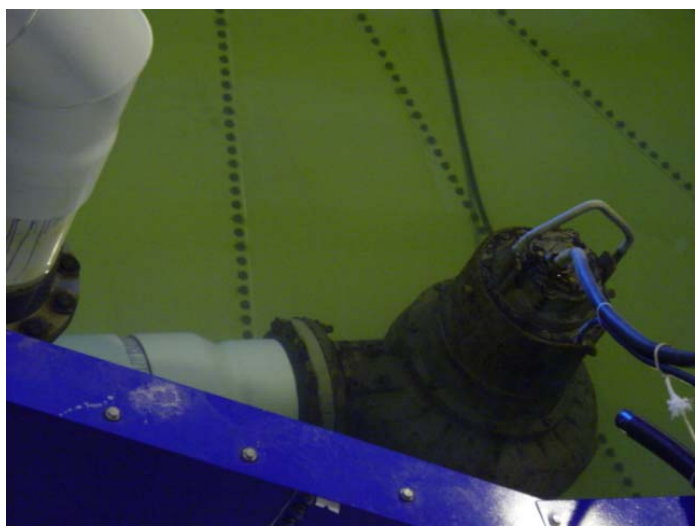
Forced Air Dryer and Scale

UNIMAG Flow meter

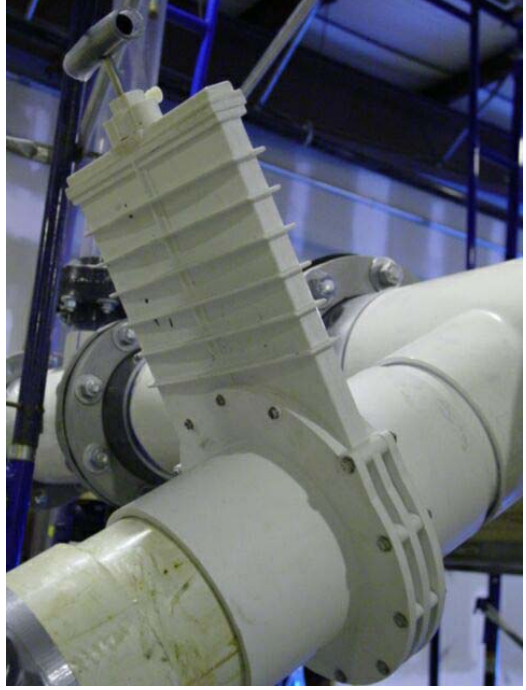
Watson-Marlow Peristaltic Pump

Sigma Automatic Sampler

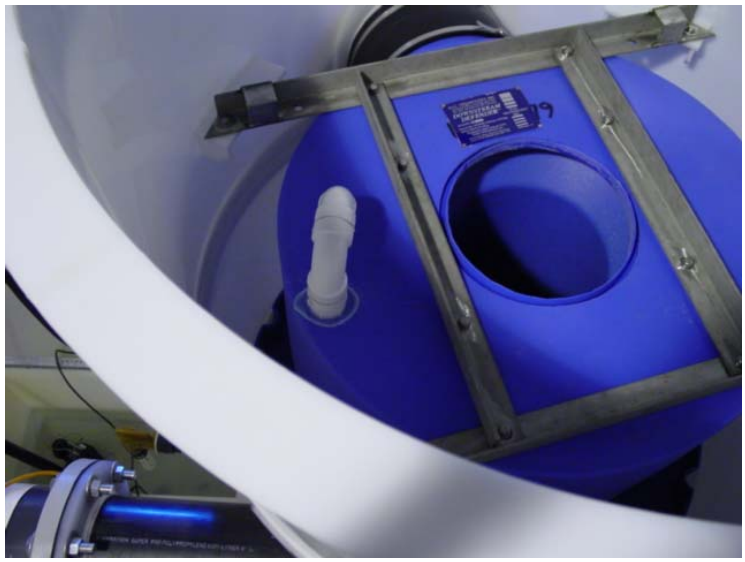
Control Valve



Flygt Submersible Pump

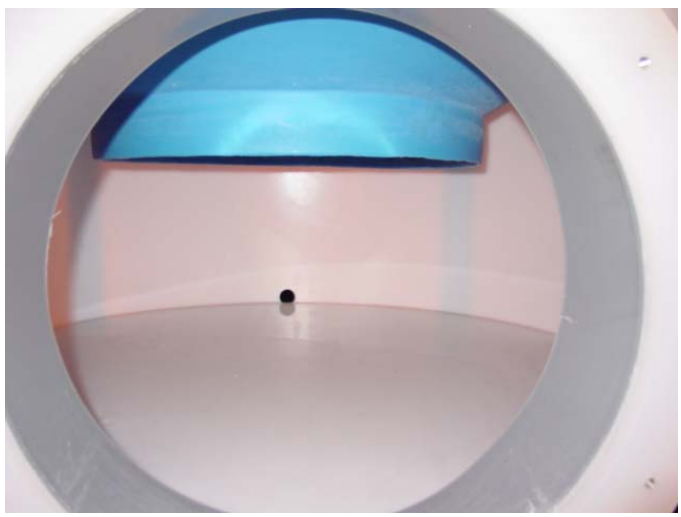


Influent Sample Valve (Gate)



DD Internal Components

DD Cleanout Port and
Sediment Storage Facility



Appendix C
Test Data

OK 110 Sand Testing

Target Flow Rate =	580	gpm	3-Jul-02
Peristaltic Pump Speed =	77	rpm	Test 54
Weight of Sand =	6	lb	
Volume of Water =	30	gallons	

INFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	740	0.740	2.686	2.912	226	305.405
2	825	0.825	2.691	2.906	215	260.606
3	725	0.725	2.701	2.812	111	153.103
4	790	0.790	2.701	2.89	189	239.241
5	770	0.770	2.695	2.828	133	172.727
6	795	0.795	2.716	2.92	204	256.604
AVG	774.2	0.7742			179.67	231.281

EFFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	920	0.920	2.706	2.736	30	32.609
2	885	0.885	2.719	2.75	31	35.028
3	875	0.875	2.701	2.738	37	42.286
4	905	0.905	2.691	2.719	28	30.939
5	890	0.890	2.693	2.73	37	41.573
6	870	0.870	2.689	2.727	38	43.678
AVG	890.83	0.8908			33.50	37.686

	Flow (gpm)
1	580
2	576
3	579
4	564
5	582
6	579
AVG	576.667

Total Efficiency =	83.706 %
Efficiency Sample 1 =	89.323 %
Efficiency Sample 2 =	86.559 %
Efficiency Sample 3 =	72.381 %
Efficiency Sample 4 =	87.068 %
Efficiency Sample 5 =	75.931 %
Efficiency Sample 6 =	82.978 %

OK 110 Sand Testing

Target Flow Rate =	580	gpm	3-Jul-02
Peristaltic Pump Speed =	77	rpm	Test 55
Weight of Sand =	6	lb	
Volume of Water =	30	gallons	

INFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	790	0.790	2.731	2.974	243	307.595
2	760	0.760	2.72	2.901	181	238.158
3	840	0.840	2.681	2.923	242	288.095
4	750	0.750	2.735	2.918	183	244.000
5	800	0.800	2.68	2.861	181	226.250
6	875	0.875	2.732	2.972	240	274.286
AVG	802.5	0.8025			211.67	263.0640

EFFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	860	0.860	2.734	2.756	22	25.581
2	910	0.910	2.721	2.757	36	39.560
3	850	0.850	2.716	2.751	35	41.176
4	900	0.900	2.687	2.729	42	46.667
5	740	0.740	2.698	2.733	35	47.297
6	870	0.870	2.682	2.73	48	55.172
AVG	855.00	0.8550			36.33	42.5758

	Flow (gpm)
1	580
2	581
3	574
4	579
5	585
6	586
AVG	580.833

Total Efficiency =	83.815 %
Efficiency Sample 1 =	91.683 %
Efficiency Sample 2 =	83.389 %
Efficiency Sample 3 =	85.707 %
Efficiency Sample 4 =	80.874 %
Efficiency Sample 5 =	79.095 %
Efficiency Sample 6 =	79.885 %

OK 110 Sand Testing

Target Flow Rate = 580 gpm
Peristaltic Pump Speed = 77 rpm
Weight of Sand = 6 lb
Volume of Water = 30 gallons

5-Jul-02
Test 56

INFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	670	0.670	2.706	2.83	124	185.075
2	710	0.710	2.713	2.871	158	222.535
3	745	0.745	2.725	2.92	195	261.745
4	765	0.765	2.721	2.88	159	207.843
5	695	0.695	2.706	2.848	142	204.317
6	765	0.765	2.711	2.86	149	194.771
AVG	725.0	0.7250			154.50	212.7143

EFFLUENT

Sample	Volume (mL)	Volume (L)	Combined Empty Mass (g)	Combined Dried Mass (g)	Δ Mass (mg)	mg/L
1	880	0.880	2.702	2.736	34	38.636
2	740	0.740	2.676	2.703	27	36.486
3	870	0.870	2.742	2.771	29	33.333
4	840	0.840	2.687	2.729	42	50.000
5	780	0.780	2.711	2.748	37	47.436
6	900	0.900	2.728	2.767	39	43.333
AVG	835.00	0.8350			34.67	41.5376

	Flow (gpm)
1	586
2	570
3	563
4	583
5	579
AVG	576.200

Total Efficiency = 80.473 %
Efficiency Sample 1 = 79.124 %
Efficiency Sample 2 = 83.604 %
Efficiency Sample 3 = 87.265 %
Efficiency Sample 4 = 75.943 %
Efficiency Sample 5 = 76.783 %
Efficiency Sample 6 = 77.752 %

DIXON Q TEST		**for 95% confidence Q6=0.621**						
TEST RUN		INFLUENTS: 6 samples arranged lowest to highest						
	1	**153.103**	**172.727**	**239.241**	**256.604**	**260.606**	**305.405**	
Q calculated:		0.1288493	0.1288493	0.1140038	0.1402805	0.0262767	0.2941458	all < Q6 = no outliers
	2	**226.250**	**238.158**	**244.000**	**274.286**	**288.095**	**307.595**	
Q calculated:		0.1463888	0.0718176	0.0718176	0.1697584	0.1697584	0.2397197	all < Q6 = no outliers
	3	**185.075**	**194.771**	**204.317**	**207.843**	**222.535**	**261.745**	
Q calculated:		0.1264641	0.1245076	0.0459893	0.0459893	0.1916265	0.5114125	all < Q6 = no outliers
Average Influents:		235.686						

DIXON Q TEST		**for 95% confidence Q6=0.621**						
TEST RUN		EFFLUENTS: 6 samples arranged lowest to highest						
	1	**30.939**	**32.609**	**35.028**	**41.573**	**42.286**	**43.678**	
Q calculated:		0.1310935	0.1310935	0.1898893	0.0559699	0.0559699	0.1092707	all < Q6 = no outliers
	2	**25.581**	**39.560**	**41.176**	**46.667**	**47.297**	**55.172**	
Q calculated:		0.4724072	0.0546112	0.0546112	0.0212903	0.0212903	0.2661282	all < Q6 = no outliers
	3	**33.333**	**36.486**	**38.636**	**43.333**	**47.436**	**50.000**	
Q calculated:		0.1891762	0.1289974	0.1289974	0.2461751	0.1538369	0.1538369	all < Q6 = no outliers
Average Effluents:		40.599						

Hydro International OK-110 Sand
SSC (TSS) Removal Confirmation Test
July 12, 2002

Reported by Jeff Dennis
Division of Watershed Management, DEP

On July 12, 2002 I witnessed a confirmation test of the ability of a 4 ft diameter Downstream Defender® unit to remove OK-110 grade silica sand. The test was performed in the laboratory of the Hydro International office on Hutchins Drive in Portland, Maine. The target flow rate for the test was 580 gpm.

Lab Set-Up

The laboratory set-up for the test consists of a 23,300 gallon clean water storage reservoir from which water is pumped into an 8 in pipe which feeds water to a 4 ft diameter Downstream Defender® unit. The pipe from the storage reservoir is fitted with a valved bypass to divert excess flows back to the storage reservoir, a butterfly valve for flow control, and a flowmeter. OK-110 sand is fed into the inflow pipe from an elevated 60 gal sand slurry barrel. The sand is kept in a relatively uniform suspension in the slurry tank using a propeller type mixer. Slurry is pumped through plastic tubing from the slurry tank into the inflow pipe by a peristaltic pump. An automatic sampler is located upstream of the slurry feed to collect background samples. Several feet downstream of the slurry feed in the inflow pipe there is a 6 inch T with a sluice gate for collection of inflow samples.

The outflow pipe from the Downstream Defender® unit has a free-fall discharge back into the storage reservoir. Outflow samples are collected by passing the sample bottle through the free fall discharge into the reservoir.

Test Procedure

The target test flow for the test was 580 gpm. The mean water detention time in the system at this flow rate is 22.67 seconds. Outflow samples lagged inflow samples by this amount. The interval between samples for both the inflow and outflow samples was 60 seconds. Back ground samples were collected at the same time as inflow samples. Flow was observed throughout the test.

The flow rate was stabilized at around 580 gpm and the slurry feed pump started. The system was then allowed to reach equilibrium for a period in excess of four detention times, before the first inflow sample was taken. Outflow sampling commenced about 23 seconds later. Background sampling commenced prior to inflow sampling and continued throughout the test. Six sets of samples were taken.

Inflow, outflow and background samples were taken to the University of Maine Environmental Chemistry Lab for Suspended Sediment Concentration analysis. The analyses was performed by Mike Hanley.

Results

Results of the test are presented in the attached tables. Inflow concentrations ranged from 158.7.0 mg/l to 311.0 mg/l. Outflow concentrations ranged from 24.9 mg/l to 40.5 mg/l. Background concentrations ranged between 3.4 and 9.0 mg/l.

The removal efficiencies indicated by inflow/outflow pairs ranged from 76.6% up to 90.9%, with a mean of 86.4%. When adjusted for recycled background concentrations, efficiencies were slightly higher, from 80.3% to 93.0% with a mean of 88.6%.

Flow for the test varied from 579 gpm to 590 gpm with a mean of 583 gpm, virtually at the target flow rate.

Conclusions

All the paired background adjusted removal efficiencies exceeded 80%, as did their mean as well as the mean for the non adjusted pairs, so there is little question that at 583 gpm, a 4 ft diameter Downstream Defender® unit can remove at least 80% of OK-110 grade silica sand. Variation in paired removal efficiencies was low, and variation in inflow concentration was high, but still acceptable.

Therefore, the conclusion of this report is that the test performed on May 9, 2001, in substantial accordance with the Lab Testing Protocol, indicates that a 4 ft diameter Downstream Defender® unit operating at an average flow rate of 583 gpm provides at least 80% removal of the specified OK-110 grade silica sand.

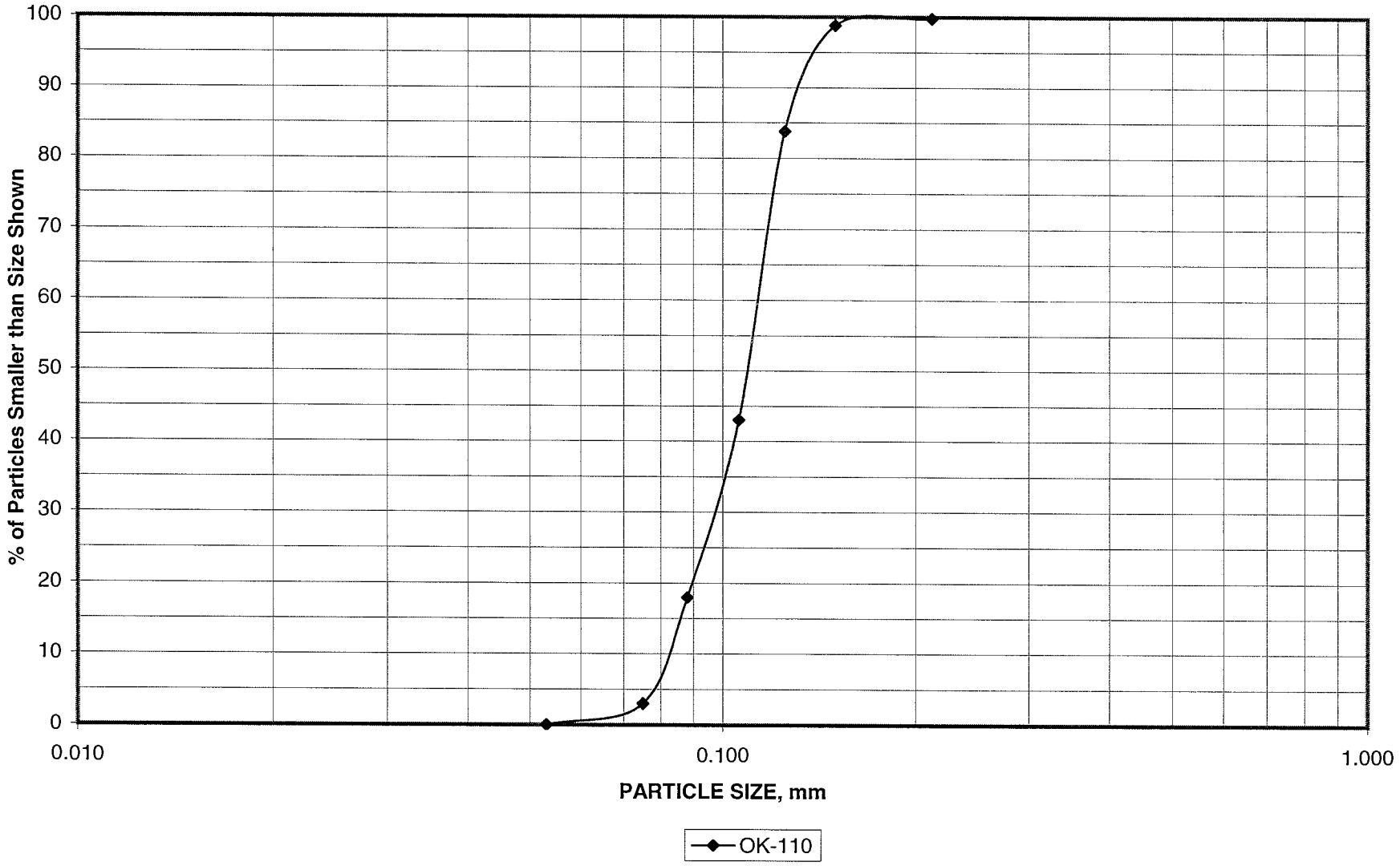
Signed: _____ Date: 2/24/03

Downstream Defender OK-110 Sand Confirmation Test - 7/12/02

	Inflow (mg/l)	Time	Outflow (mg/l)	Time	Background	Rem. Eff.	Inflow - BG	Outflow - BG	BG adj. Rem. Eff.
1	270.4		31.2		3.4	88.5	267.0	27.8	89.6
2	311.0		28.7		7.6	90.8	303.4	21.1	93.0
3	273.4		24.9		4.6	90.9	268.8	20.3	92.4
4	268.2		40.5		5.0	84.9	263.2	35.5	86.5
5	166.9		34.8		9.0	79.1	157.9	25.8	83.7
6	158.7		37.2		7.3	76.6	151.4	29.9	80.3
Mean	241.4		32.9		6.2	86.4	235.3	26.7	88.6

Flow	gpm
1	580
2	586
3	582
4	579
5	582
6	590
mean	583.2

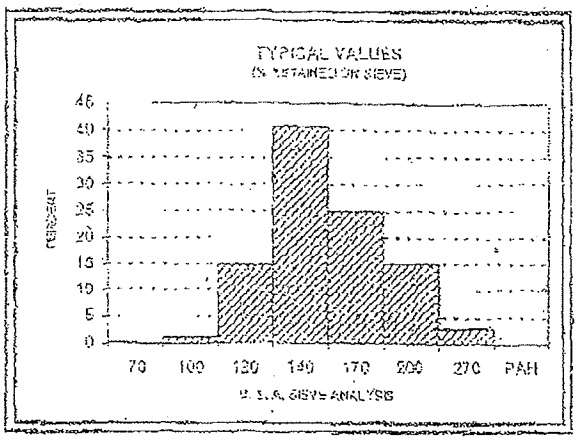
GRAIN SIZED DISTRIBUTION CURVE



US SILICA

Sands of Time

PRODUCT DATA



OK-110

UNGROUND SILICA

PLANT: MILL CREEK, OKLAHOMA

USA STD SIEVE SIZE		TYPICAL % RETAINED		TYPICAL % PASSING
MESH	MILLIMETERS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	0.212	0.2	0.2	99.8
100	0.150	1.0	1.2	98.8
120	0.125	15.0	16.2	83.8
140	0.106	40.8	57.0	43.0
170	0.088	25.0	82.0	18.0
200	0.075	15.0	97.0	3.0
270	0.053	3.0	100.0	0.0
PAN		0.0	100.0	

TYPICAL PHYSICAL PROPERTIES

AFS[1] ACID DEMAND (@pH 7)	0.5	MELTING POINT (Degrees F)	3100
AFS GRAIN FINENESS	119	MINERAL	QUARTZ
COLOR	WHITE	MOISTURE CONTENT (%)	<0.2
GRAIN SHAPE	ROUND	pH	7.2
HARDNESS (Mohs)	7	SPECIFIC GRAVITY	2.65

[1] AMERICAN FOUNDRYMEN'S SOCIETY

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide)	99.71	MgO (Magnesium Oxide)	<0.01
Fe_2O_3 (Iron Oxide)	0.018	Na_2O (Sodium Oxide)	<0.01
Al_2O_3 (Aluminum Oxide)	0.10	K_2O (Potassium Oxide)	<0.01
TiO_2 (Titanium Dioxide)	<0.01	LOI (Loss on Ignition)	0.10
CaO (Calcium Oxide)	<0.01		

09-15-00

SEE REVERSE SIDE FOR MORE INFORMATION

U.S. Silica Company • P.O. Box 187, Berkeley Springs, WV 25411-0187 • (800) 243 7500

Original Test Sample