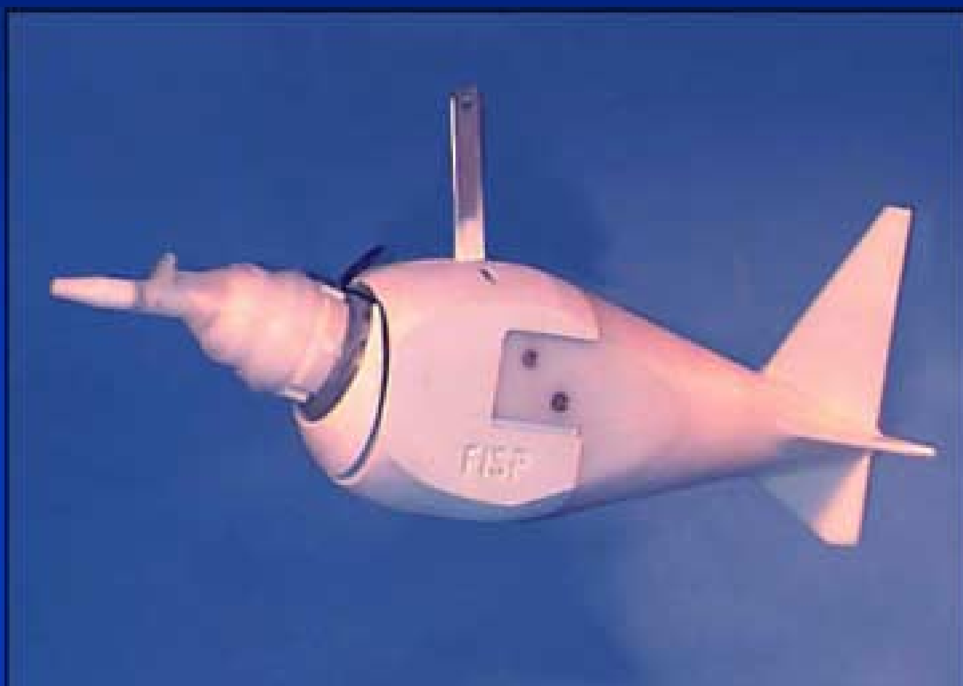
FISP™ ***Federal Interagency Sedimentation Project***



Report MM
Development of the US DH-95 Suspended-Sediment Sampler
May 2000

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REPORT MM

DEVELOPMENT OF
THE US DH-95 SUSPENDED-SEDIMENT SAMPLER

May 2000

By

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U.S. ARMY CORPS OF ENGINEERS

Published by

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FACTORS FOR CONVERTING INCH/POUND UNITS TO SI METRIC UNITS

Multiply	by	To Obtain
inches	25.4	millimeters
inches	2.54	centimeters
quarts, liquid	0.9464	liters

The use of brand names is this report is for identification purposes only and does not constitute endorsement by the United States Government.

ABSTRACT

The Federal Interagency Sedimentation Project designed and developed the US DH-95 suspended-sediment sampler, a depth-integrating instrument for use in streams not exceeding 15 feet in depth. The sampler collects a water-sediment sample at an inflow efficiency ranging 0.9 to 1.1 within its recommended velocity range and remains stable in stream velocities to 7.4 feet per second (ft/sec). The sampler weighs 29 pounds and has a streamlined body. The bronze body casting is coated with plastic and the tail section is constructed from plastic to reduce the potential for contamination when used for trace element sampling. The sampler is designed to accept either the 1-liter Teflon or 1-liter plastic bottle and the US D-77 sediment sampler cap and nozzles. An adapter is required to mate the US D-77 cap to the 1-liter Teflon bottle. No adapter is required when using the 1-liter plastic bottle. Three nozzles are available for the US D-77 cap: 3/16-, 1/4-, and 5/16-inch. The unsampled zone, the distance between the centerline of the nozzle and the streambed, is 4.8 inches when the sampler rests on the bottom. The recommended sample volume to be collected with the US DH-95 sampler is 800 milliliters (mL). The maximum sampling depth is 12 feet when using the recommended sample volume.

The sampler was tested during various stages of design in a 3-foot flume, a tow tank, and a clear-water lake. Prototypes also were field tested by U.S. Geological Survey personnel

INTRODUCTION

This report describes the development of the US DH-95 depth-integrating suspended-sediment sampler by the Federal Interagency Sedimentation Project (FISP). The US DH-95 has the following features: (a) it uses the existing US D-77 cap or US DH-95 cap and nozzle; (b) it meets the criteria for depth-integrating suspended-sediment samplers as stated in Edwards and Glysson, 1999, p. 6-7; and (c) it is designed to meet the U.S. Geological Survey (USGS) Office of Water Quality requirements for water-quality sampling. Details on requirements for water-quality sampling can be found in Wilde, F.D. and others, 1998, p. 17-32.

CRITERIA FOR SAMPLER DEVELOPMENT

The US DH-95 sampler (shown in Figures 1 and 2) was developed to meet the requirement for a hand-line suspended-sediment sampler capable of collecting non-contaminated samples for trace-element analysis. The sampler was to have no exposed metal surfaces. In addition, it was to use a 1-liter bottle rather than the 3-liter bottle used in the existing US D-77, while still using the US D-77 cap and nozzles. The use of the US D-77 cap and nozzles was required to allow the use of existing equipment that is already approved for sediment and water-quality data collection.

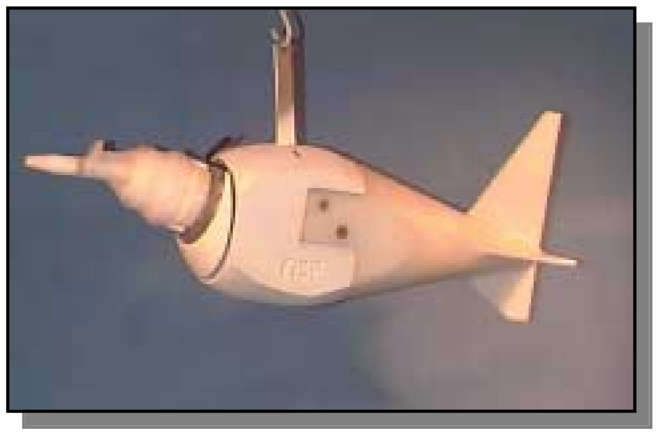


Figure 1: US DH-95 Sampler

PREVIOUS INVESTIGATIONS

The US D-77 sampler is a suspended-sediment sampler that is currently used by the USGS for water-quality sampling. It uses a plastic or Teflon cap, nozzle, and 3-liter bottle. The US D-77 is coated with plastic to prevent the user from contacting the metal surface of the sampler thereby reducing the potential for introducing metals contamination.

The US D-77 sampler is difficult to use properly because the transit rates at which the sampler is raised and lowered are very low. The low transit rates for the US D-77 are due to the time required to fill the sampler with water to adequately compress the 3-liters of air trapped in the sampler at the beginning of the transit. Information on acceptable transit rates for the US D-77 can be found in U.S. Geological Survey Office of Surface Water Technical Memorandum No. 99.01. The transit rates can be as low as 0.1 ft/sec. The requirement for the US D-95 to use a 1-liter bottle will allow faster transit rates and make the sampler easier to use properly.

DESIGN

The US DH-95 sampler was designed and developed by FISP at the Engineer Research and Development Center (ERDC), Vicksburg, Mississippi. FISP is an interagency project sponsored by six Federal agencies that has the mandate to design and develop standardized sediment and water-quality samplers. FISP developed a configuration drawing and presented it to the FISP Technical Committee for review and comment. The configuration drawing and general design criteria for the US DH-95 were also reviewed by the current FISP staff and USGS volunteers John V. Skinner, retired, Chief of FISP, and Dallas Childers, retired, Hydrologist.

FISP developed the construction drawings used to fabricate the plastic resin casting patterns for the silicon bronze casting of the body of the sampler. The bronze casting was coated with plastic (a commercially available product named "PlastiDip") to reduce the potential of trace element contamination. These drawings were also used to carry out the machining processes for the body of the sampler.

A separate construction drawing was developed for the tail section of the sampler. The tail of the sampler was machined from a plastic polymer, High Density Polyethylene (HDPE). This material was chosen for its strength, malleability, buoyancy, and resistance to water absorption and to reduce the number of metal parts that might cause contamination during water quality sampling. The HDPE can be welded, which allows the tail vanes to be replaced if damaged or broken. The tail section is interchangeable, which will allow the operator to replace it without the requirement of returning the sampler to FISP for repairs. The neutrally buoyant characteristic of the polymer allows the sampler to be balanced around the center of the bronze casting. This balance point is approximately one third the total length of the sampler from the leading edge of the sampler body. The sampler weights 29 pounds.

When attached to a suspension line the sampler will assume a tail down attitude, insuring that the sampler will align the nozzle into the stream currents as it is lowered into the water. Once the sampler has entered the water the neutrally buoyant tail causes it to orient itself so the nozzle and sampler are horizontal with the nozzle pointing into the stream flow. The sampler connection point accepts the standard hanger bar and pin used on the US D-77 suspended-sediment sampler or a typical sounding-weight hanger bar and pin.

TESTING

The first tests conducted at ERDC in the 3-ft wide FISP flume consisted of visual checks of the sampler to verify the correct suspension point, orientation when entering the water, and alignment with the flow patterns when submerged. The sampler's balance point was correct; it entered the flow as designed, and maintained its alignment with the flow. Additional tests were conducted in a clear-water lake. The sampler was towed through the lake at various velocities to determine if it would remain stable at high velocities. These test velocities ranged from 1.5 to 8 ft/sec. A video camera equipped with a digital display was used to observe and record that the inflow nozzle was directed into the flow, and the sampler was stable throughout it operational range.

The second series of tests was conducted to determine the effects of the US DH-95 sampler design on the inflow efficiency of the US D-77 cap and nozzle. Inflow efficiency is defined here as the ratio of the nozzle inflow velocity to the ambient velocity. An inflow efficiency of 1.0 is defined as isokinetic. Information on the effects of inflow efficiencies on sediment concentrations can be found in Laboratory Investigation of Suspended Sediment Samplers, FISP Report 5, 1941.

The inflow efficiencies of the US DH-95 and a US DH-81 type wading sampler were compared. A US D-77 Teflon cap, nozzle, Teflon bottle adapter, 1-liter Teflon bottle, and US DH-81A adapter ring with wading rod were combined to form a US DH-81 type wading sampler. The US D-77 Teflon cap, nozzle, Teflon bottle adapter, and 1-liter Teflon bottle used in the US DH-81 type sampler were also used in the US DH-95 for these tests. Three Teflon nozzles with diameters of 3/16-, ¼-, and 5/16-inch were used. All samples were collected at a depth of one foot to eliminate errors due to possible transit-rate variations.

Prior to conducting the tests, the nozzles of the US DH-81 sampler were adjusted until their inflow efficiencies equaled approximately 1.0. This adjustment was made using an ambient flume velocity of 3.7 ft/sec. This velocity was used because it is the approximate mid-range of useable velocities for the majority of FISP samplers. It is also the velocity at which FISP samplers are calibrated. The adjustment consisted of modifications to the depth of the taper of the nozzle outlet.

To identify the usable range of the US DH-95 sampler, sample volumes were collected over a velocity range of 1.5 to 8.6 ft/sec. The flume velocity was measured using a Price AA meter before and after samples were collected. The velocity was measured at the point in the flume that the sampler nozzle was positioned when the test were conducted. The velocity was not changed between the tests of the two samplers. To obtain efficiencies for velocities greater than 6 ft/sec the sampler was towed in a lake.

The graphs of the inflow efficiencies for each nozzle diameter are given in figures 3, 4, and 5. Tables 1, 2, and 3 lists the raw data collected to produce figures 3, 4, and 5 respectively. The two lines plotted on each of these graphs at 0.9 and 1.1 inflow efficiencies are the acceptable upper and lower limits for FISP samplers. An acceptable velocity range is one that produces inflow efficiencies between 0.9 and 1.1. The 3/16-inch diameter nozzle, figure 3, produced an acceptable inflow efficiency at a velocity range of 2.1 to 6.2 ft/sec. The 1/4-inch diameter nozzle, figure 4, produced an acceptable inflow efficiency at a velocity range of 1.7 to 7.4 ft/sec. The 5/16-inch diameter nozzle, figure 5, shows that the US DH-95 produced an acceptable inflow efficiency at a velocity range of 2.1 to 7.0 ft/sec. To generalize the results, the US DH-95 will perform acceptably in a velocity range of 1.7 to 7.4 ft/sec, depending on the nozzle diameter being used.

The US DH-95 sampler was field tested to determine the drift angle of the sampler during depth-integrating operations. For this report, drift angle (figure 6) is defined as the angle from vertical of the part of the suspension cable that is in the air with the sampler submerged to a depth of 15 feet. The sampler was suspended from a 3/16-inch diameter cable with the 1-liter container completely filled. The suspension point, on the boat, was 8 feet above the water surface. A diagram of the resulting configuration and an example of the effect of drift angle are provided in figure 6.

As the drift angle increases, additional cable must be payed out to touch the streambed. The graph in figure 7 shows the drift angle that the sampler can be expected to produce under different velocities using the configuration shown in figure 6. Additional information on the effect of drift angle on isokinetic sampling are discussed in Beverage, 1987; in Buchanan and Somers, 1969; and in S. E. Rantz and others, 1982.

With the testing of the US DH-95 suspended-sediment sampler completed at FISP, prototypes of the sampler were shipped to nine district offices of the USGS. Each recipient was requested to use the sampler in their normal field operations and provide FISP with comments and suggestions for any modifications needed before final production. Along with the samplers, a set of "Instructions for sampling with Depth-integrating Sampler" was supplied. These instructions included depth limitations (15 feet), velocity limitations (estimated to range from 1.5 to 6.0 ft/sec), filling-time table, and transit rate diagrams. The evaluations of the prototype samplers were positive, with only a couple of minor comments for improvement. One suggestion for improvement was to lengthen the hanger bar pin. Another suggestion was add a drain hole in the rear of the bottle cavity. Both suggestions were incorporated in the production sampler.

Limitations for Operation

Although the US DH-95 sampler uses a 1-liter bottle, it is recommended that the sample volume collected not exceed approximately 800 mL for the following reasons:

1. When the sampler is in the water collecting a sample, the nozzle is horizontal. If the sampler is filled to approximately 1-liter the level of the sample in the sample container is near the bottom of the nozzle. If the rear of the nozzle becomes submerged, the inflow velocity will be reduced and the sediment concentration may no longer reflect the ambient suspended-sediment concentration.

2. Part of the sample can be lost as the sampler exits the water, if the sampler contains 1-liter or more. Due to the downstream drift induced by drag on the sampler under high flow velocity conditions, the sampler may swing forward at a high velocity as it exits the water. A portion of the sample may be ejected through the nozzle and/or air exhaust port when the forward motion of the sampler is abruptly stopped by the tension in the suspension cable and the sampler begins to swing back.

3. FISP defines the recommended sample volume for its cable-suspended samplers as the volume of sample that is retained in the sampler when it is tilted 10-degrees nozzle-down. For the US DH-95 suspended-sediment sampler, this volume is 800 mL.

Figures 8 through 13 present transit rate diagrams for the US DH-95 with 3/16-, 1/4-, and 5/16-inch diameter nozzles. These diagrams were produced using a sample volume of 800 mL for "Recommended" transit rates. An area on each diagram labeled as "Acceptable" was produced using a sample volume of 1-liter. The transit rate diagrams were computed using formulas from Edwards and Glysson, 1998, p. 67-76.

Table 4 shows the relationship between stream velocity and corresponding filling times to produce samples of 800 mL in volume for the 3/16-, 1/4-, and 5/16-inch diameter nozzles. The filling time, in seconds, represents the total time to traverse the stream vertically in both directions. Use of this table will provide acceptable sample volumes and permit minor variations in total submerged time without invalidating the sample.

CONCLUSION

The US DH-95 suspended-sediment sampler is a depth-integrating instrument designed for use in streams not exceeding 15 feet in depth. The sampler collects water-sediment samples at acceptable inflow efficiencies and remains stable in stream velocities ranging from 1.7 to 7.4 ft/sec.

The sampler weighs 29 pounds and has a streamlined body. The bronze body casting is coated with plastic (a commercially available product named "PlastiDip") and the tail section is constructed from plastic (HDPE) to reduce the potential for metal contamination when used for water-quality sampling. The sampler is designed to accept either the 1-liter Teflon or 1-liter plastic bottle and the US D-77 sediment sampler cap or the US D-95 cap and nozzles. Three nozzles are available for the US D-77 cap: 3/16-, 1/4-, and 5/16-inch. The unsampled zone, the distance between the centerline of the nozzle and the streambed, is 4.8 inches. The recommended sample volume to be collected with the US DH-95 sampler is 800 mL.

REFERENCES

Beverage, Joseph P., 1987, Determining True Depths of Samplers Suspended in Deep Swift Rivers, Federal Interagency Sedimentation Project Report GG, 56 p.

Buchanan, T.J., and Somers, W.P., 1969, Discharge Measurements at Gaging Stations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. a8, 65 p.

Edwards, T.K., and Glysson, G.D., 1999, Field Methods for Measurement of Fluvial Sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. c2, 89 p.

Laboratory Investigation of Suspended Sediment Samplers, FISP Report 5, 1941, St. Paul U.S. Engineer District Sub-Office Hydraulic Laboratory, University of Iowa, Iowa City, Iowa, 99 p.

Rantz, S.E., and others, 1982, Measurement and Computation of Streamflow: Volume I. Measurement of Stage and Discharge, and Volume II, Computation of Discharge: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

U.S. Geological Survey, 1999, Guidance for collecting Discharge-Weighted Samples in Surface Water Using an Isokinetic Sampler: Office of Surface Water Technical Memorandum 99.01, accessed March 21, 2000 at URL http://water.usgs.gov/admin/memo/SW/sw99.01.html

Wilde, F.D., Radtke, D.B., Gibs, J., and Iwatsubo, R.T., eds., 1998, National Field Manual for the Collection of Water Quality Data. Selection of equipment for water sampling: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A2, p. 17-32.

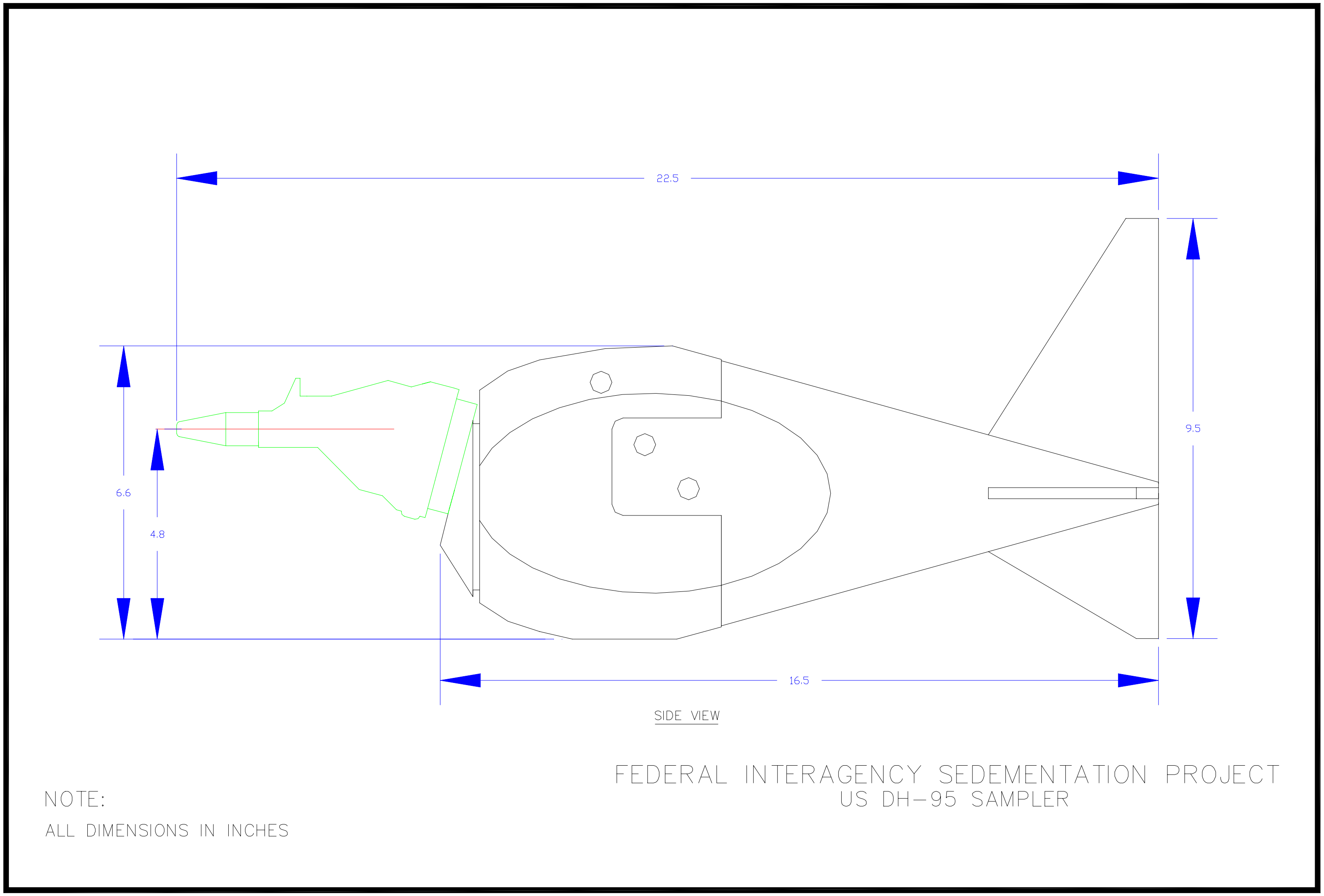


Figure 2. Schematic of the US DH-95 Suspended-Sediment Sampler

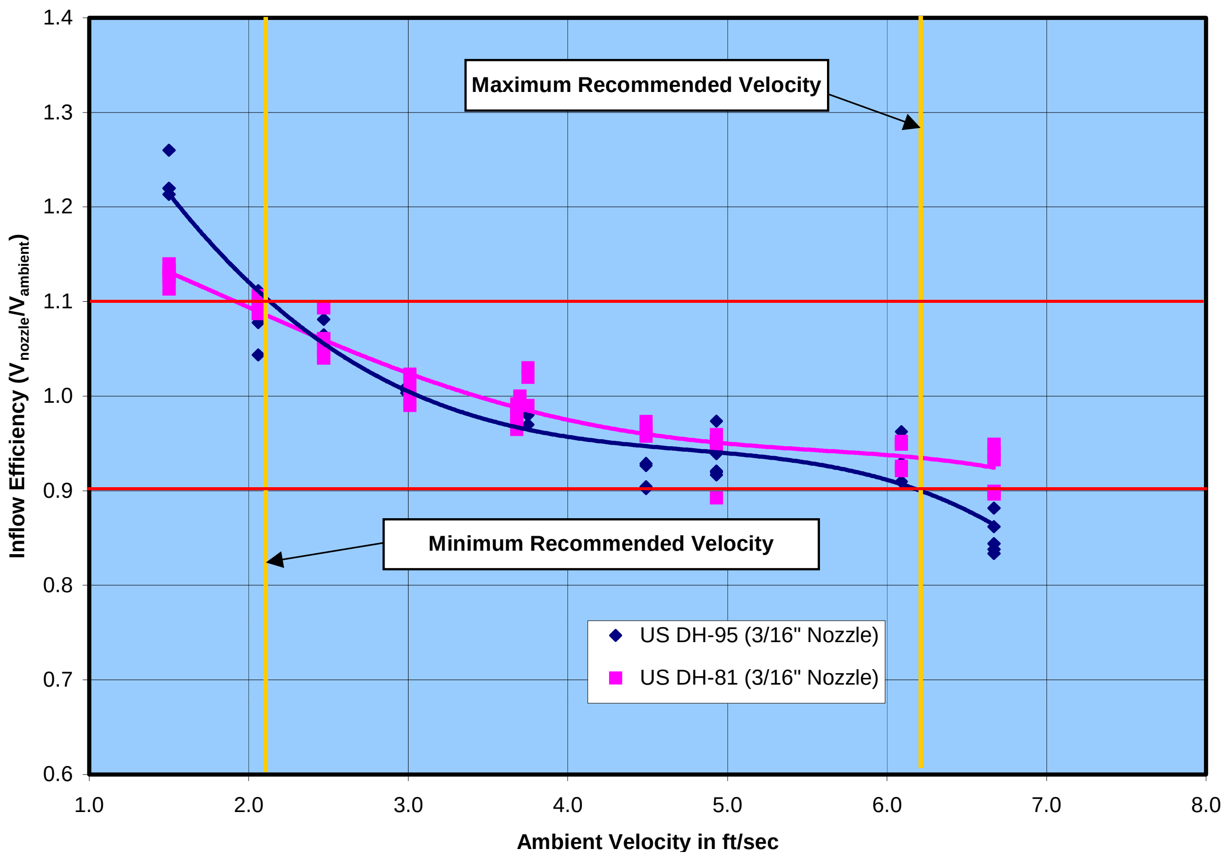


Figure 3. Inflow Efficiency, US DH-95, 3/16-inch Nozzle

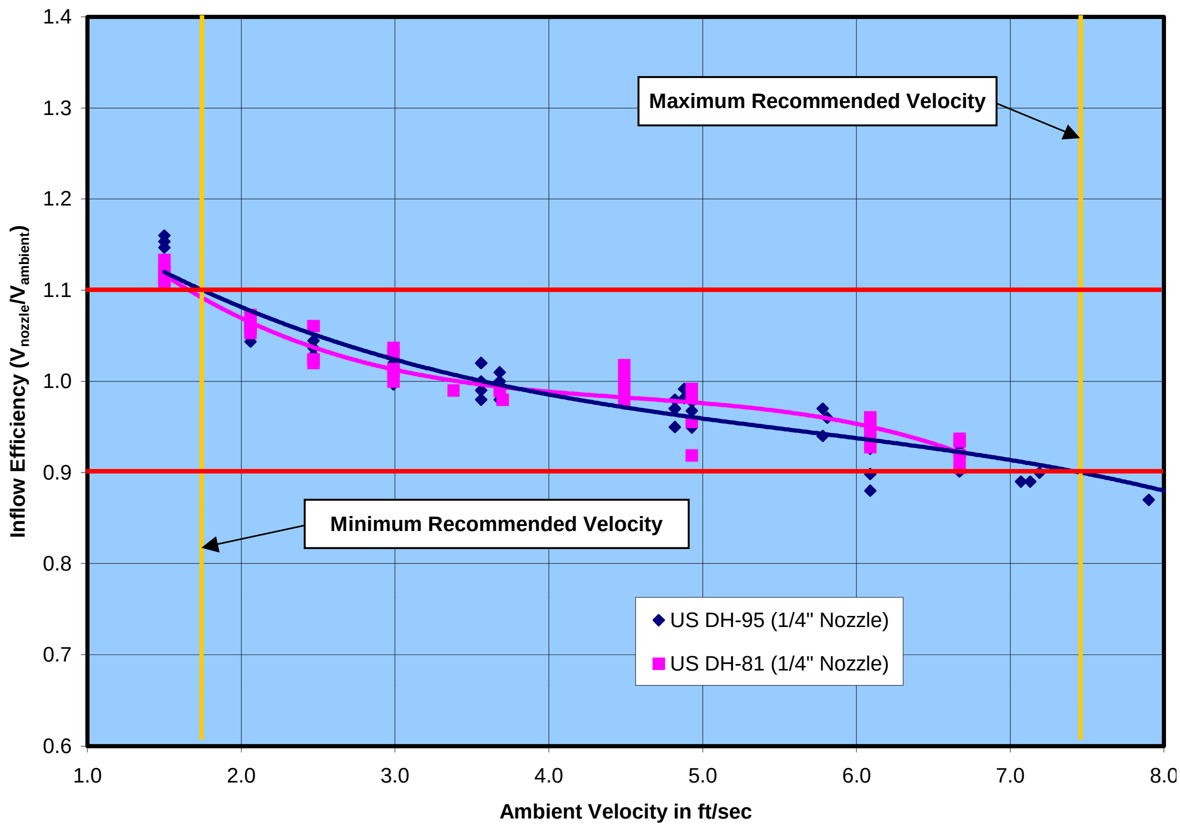


Figure 4. Inflow Efficiency, US DH-95, 1/4-inch Nozzle

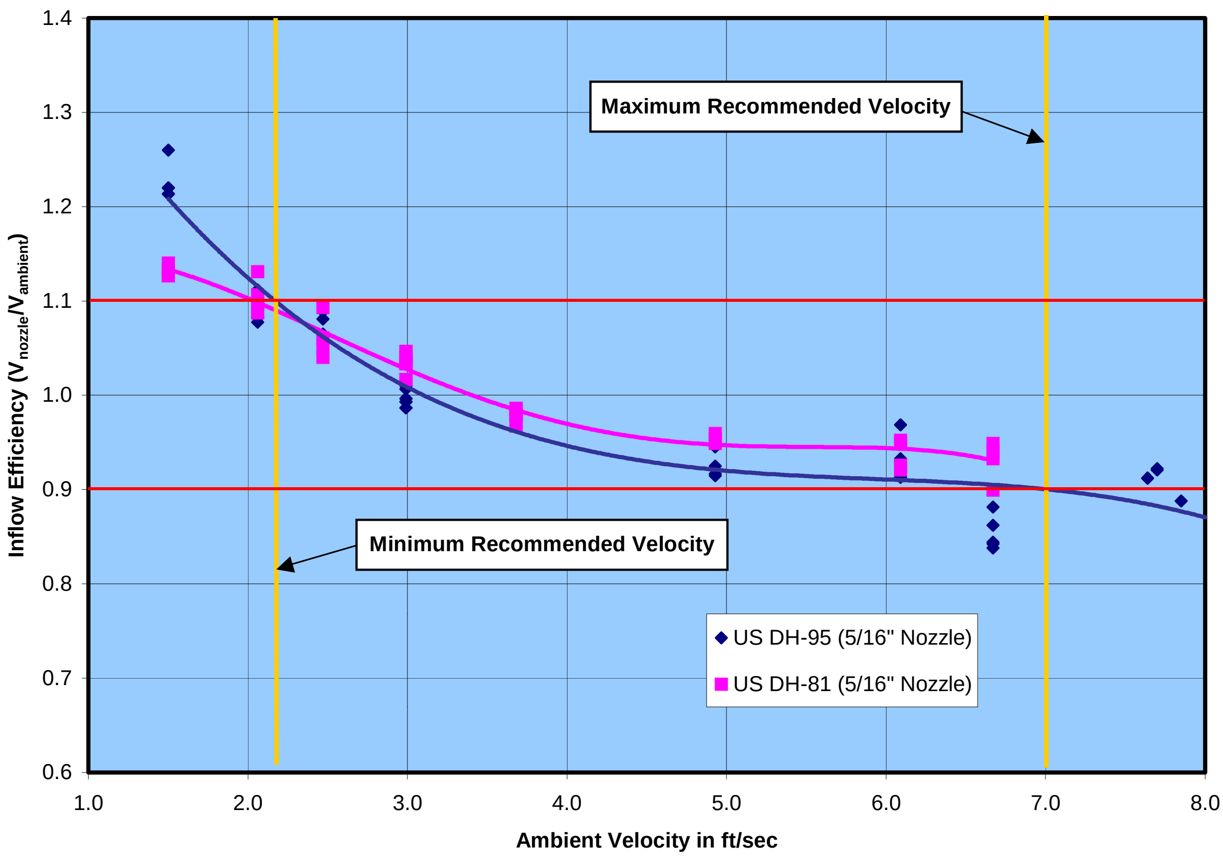


Figure 5. Inflow Efficiency, US DH-95, 5/16-inch Nozzle

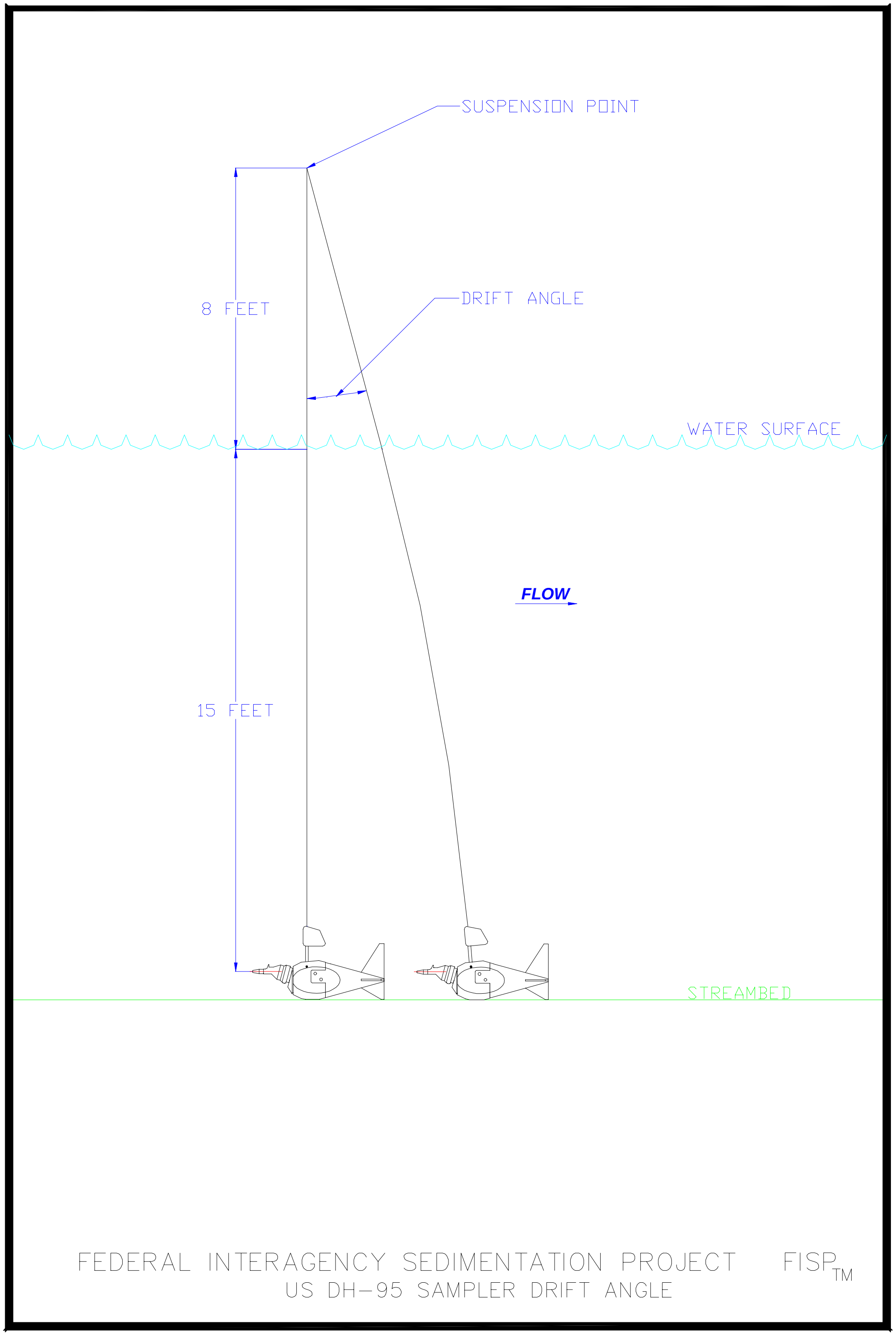


Figure 6. US DH-95 Drag Induced Drift Angle Diagram

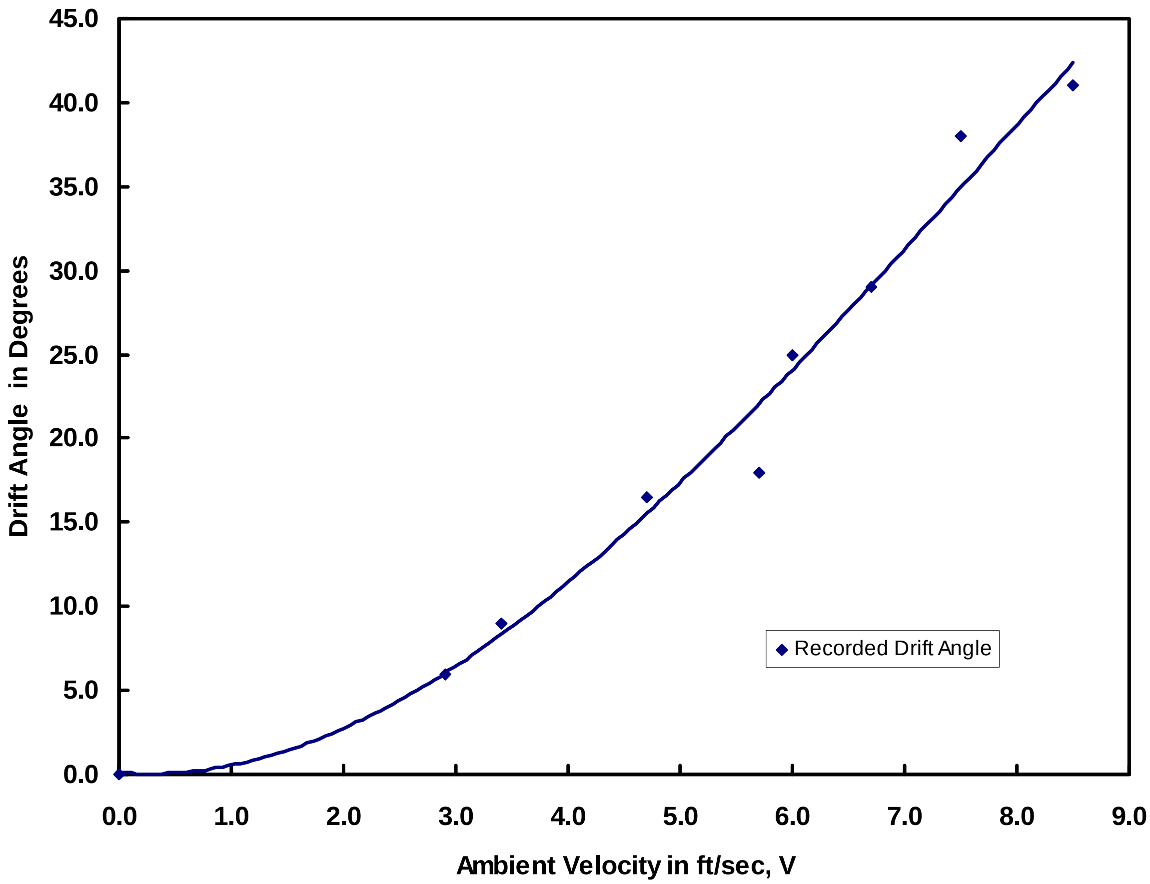
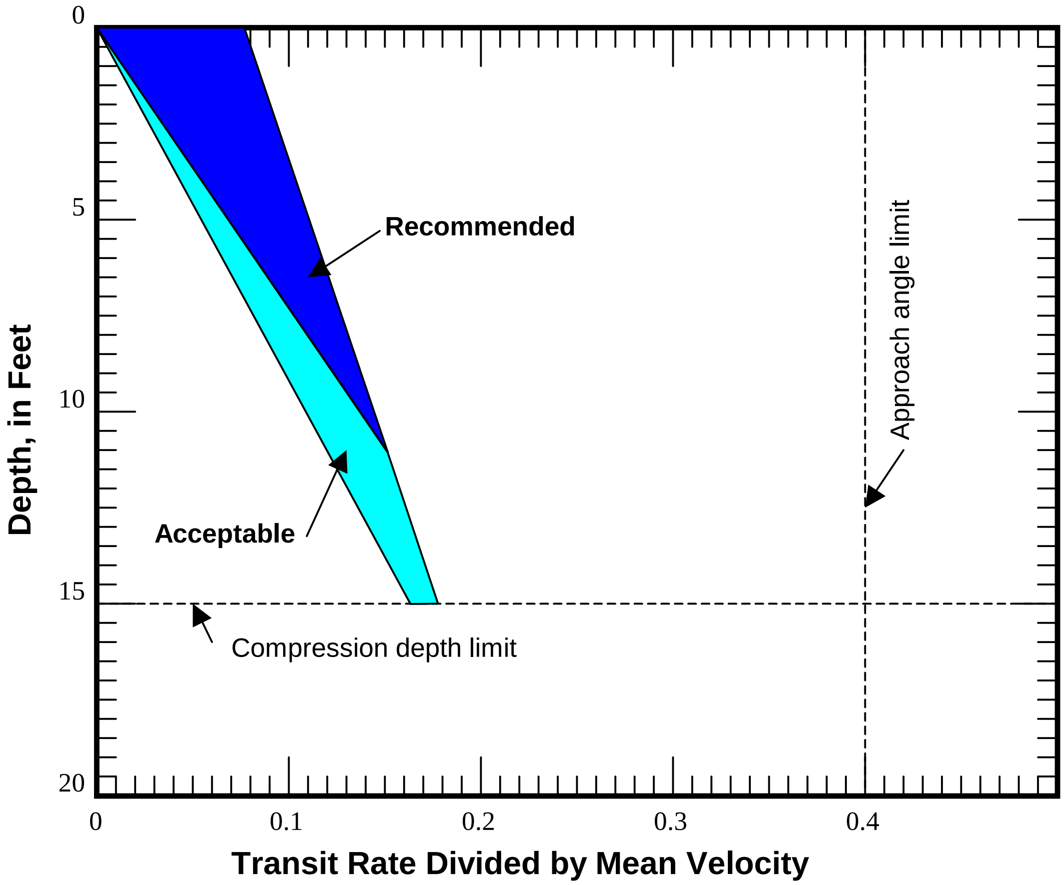
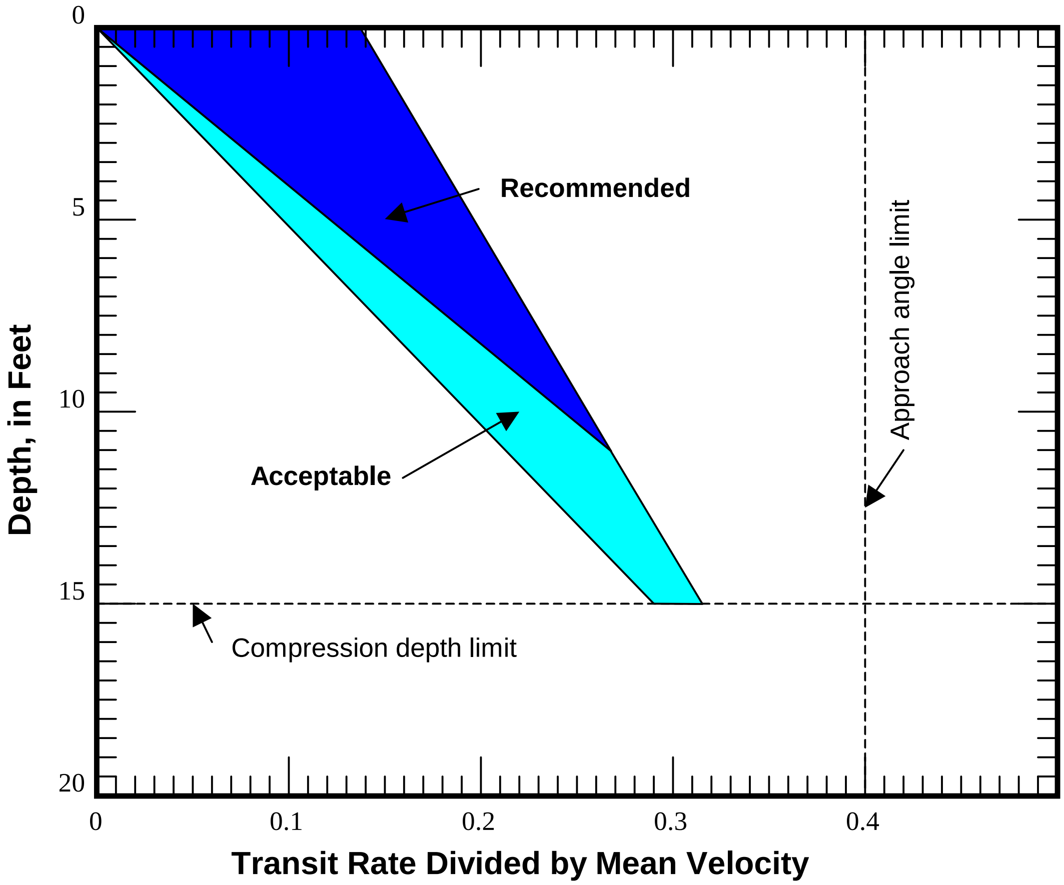


Figure 7. US DH-95 Drag Induced Drift Angle Chart



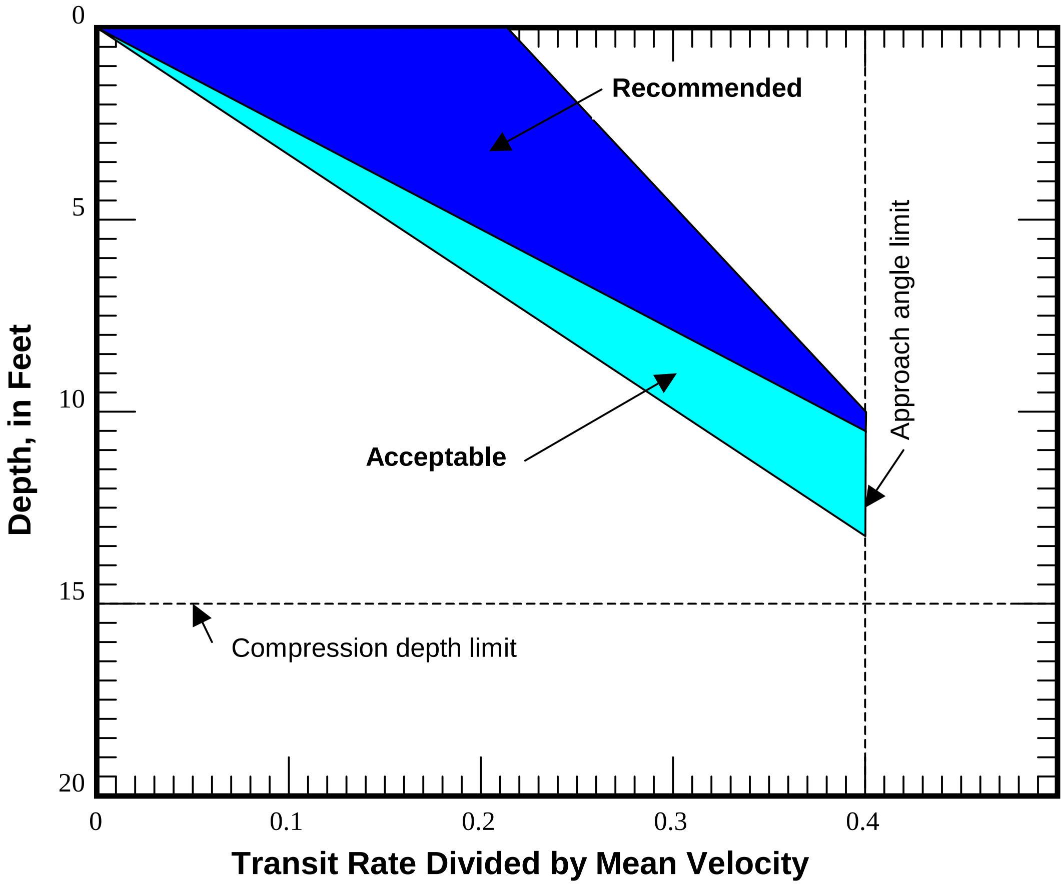
Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1215 mL, which includes a polypropylene bottle and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 8. Transit Rate Diagram for US DH-95, 3/16-inch Plastic Nozzle



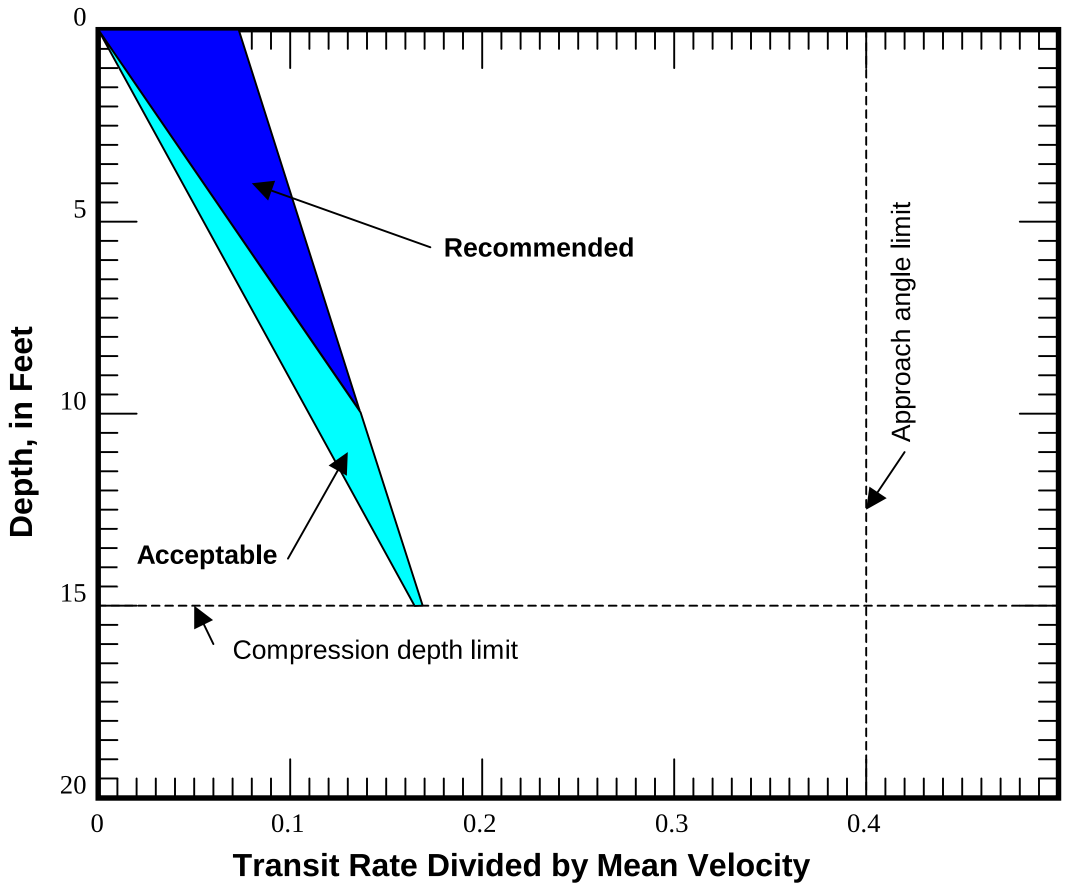
Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1215 mL, which includes a polypropylene bottle and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 9. Transit Rate Diagram for US DH-95, 1/4-inch Plastic Nozzle



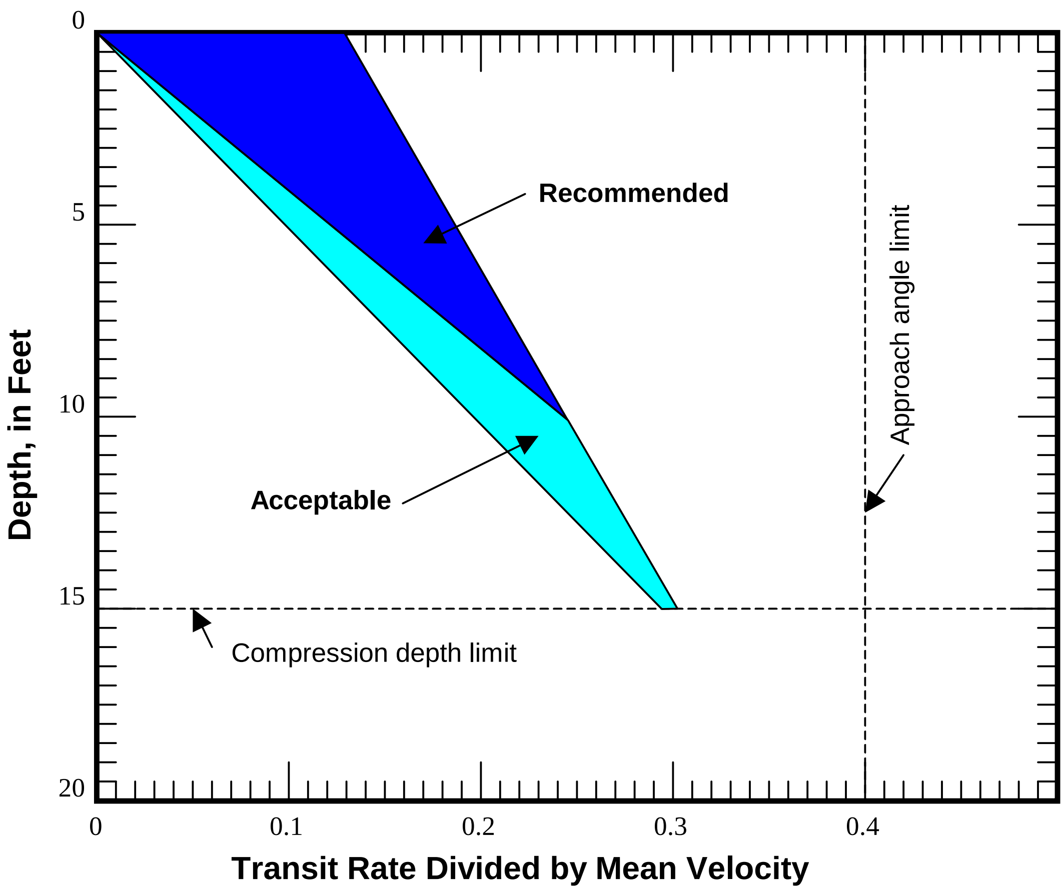
Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1215 mL, which includes a polypropylene bottle and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 10. Transit Rate Diagram for US DH-95, 5/16-inch Plastic Nozzle



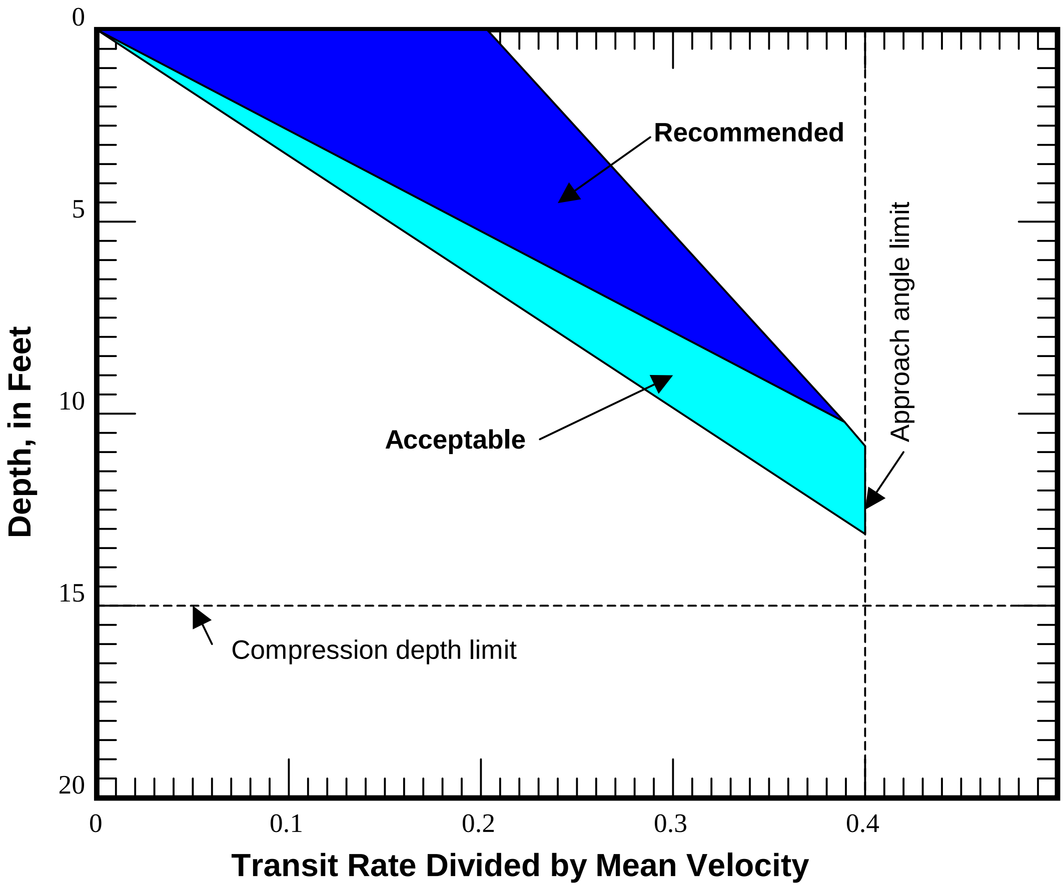
Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1265 mL, which includes a Teflon bottle, bottle adapter and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 11. Transit Rate Diagram for US DH-95, 3/16-inch Teflon Nozzle



Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1265 mL, which includes a Teflon bottle, bottle adapter and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 12. Transit Rate Diagram for US DH-95, 1/4-inch Teflon Nozzle



Note: The following configuration and volumes were used to produce this diagram. The total volume of the sampler container is 1265 mL, which includes a Teflon bottle, bottle adapter and US D-77 cap. The maximum recommended sample volume is 800 mL. The maximum acceptable sample volume is 1000 mL.

Figure 13. Transit Rate Diagram for US DH-95, 5/16-inch Teflon Nozzle

Table 1. Flume Test Data, US DH-95, 3/16-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
1.50	19.5	87.95	805	1.69	46.36	410	1.63
1.50	19.5	87.60	815	1.71	69.89	630	1.66
1.50	19.5	86.85	800	1.70	77.80	720	1.70
1.50	19.5	87.90	825	1.73	88.05	810	1.69
1.50	19.5	86.10	800	1.71	87.28	790	1.67
2.47	20.0	57.40	760	2.44	55.77	770	2.54
2.47	20.0	62.65	830	2.44	56.16	780	2.56
2.47	20.0	58.60	780	2.45	62.45	860	2.54
2.47	20.0	62.55	825	2.43	59.49	820	2.54
2.47	20.0	54.20	740	2.51	58.88	805	2.52
2.06	19.5	65.16	740	2.09	58.20	670	2.12
2.06	19.5	71.65	808	2.08	66.41	805	2.23
2.06	19.5	69.70	810	2.14	64.99	760	2.15
2.06	19.5	67.56	790	2.15	64.37	800	2.29
2.06	19.5	66.73	760	2.10	65.27	765	2.16
3.68	20.0	41.80	825	3.63	41.27	795	3.55
3.68	20.0	42.94	860	3.69	41.11	805	3.60
3.68	20.0	41.50	805	3.57	43.55	845	3.57
3.68	20.0	40.63	795	3.60	44.25	865	3.60
3.68	20.0	40.58	785	3.56	41.90	830	3.65
3.01	20.5	48.94	780	2.93	52.37	875	3.08
3.01	20.5	49.84	805	2.97	46.22	770	3.07
3.01	20.5	50.83	810	2.93	50.41	830	3.03
3.01	20.5	48.93	775	2.92	49.70	805	2.98
3.01	20.5	49.62	800	2.97	51.38	835	2.99
4.49	20.5	35.35	820	4.30	23.70	565	4.37
4.49	20.5	38.99	860	4.06	30.70	720	4.32
4.49	20.5	35.51	805	4.17	34.26	800	4.30
4.49	20.5	35.20	795	4.16	34.58	810	4.31
4.49	20.5	35.66	785	4.05	33.70	795	4.34
4.93	20.5	12.95	880	4.50	11.11	770	4.59
4.93	20.5	11.80	844	4.71	10.09	720	4.73
4.93	20.5	9.52	685	4.56	12.04	850	4.66
4.93	20.5	14.24	1000	4.66	13.91	965	4.62
4.93	20.5	9.37	645	4.56	10.66	755	4.67
6.67	20.0	23.41	750	5.90	16.57	550	6.10
6.67	20.0	25.97	830	5.88	18.45	630	6.29
6.67	20.0	25.09	770	5.65	22.39	750	6.16

Table 1. (continued) Flume Test Data, US DH-95, 3/16-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
6.67	20.0	21.71	655	5.56	25.47	845	6.10
6.09	20.0	27.75	830	5.51	18.53	575	5.71
6.09	20.0	26.40	790	5.51	24.12	745	5.69
6.09	20.0	28.50	875	5.65	23.05	695	5.59
6.09	20.0	29.20	890	5.61	25.34	755	5.45
6.09	20.0	28.55	885	5.71	30.13	895	5.47

Table 2. Flume Test Data, US DH-95, 1/4-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
1.50	19.5	34.06	570	1.73	46.77	750	1.66
1.50	19.5	45.34	735	1.68	47.93	775	1.68
1.50	19.5	50.56	845	1.73	50.08	810	1.68
1.50	19.5	46.62	775	1.72	50.22	825	1.70
1.50	19.5	49.95	805	1.67	50.43	815	1.67
2.47	20.0	44.81	1105	2.55	33.31	815	2.53
2.47	20.0	40.18	930	2.53	33.14	810	2.53
2.47	20.0	38.59	915	2.48	33.96	825	2.52
2.47	20.0	41.13	980	2.47	29.29	740	2.62
2.47	20.0	35.95	870	2.51	30.50	770	2.62
2.06	19.5	30.82	650	2.18	38.10	800	2.18
2.06	19.5	39.90	810	2.10	45.73	960	2.17
2.06	19.5	39.59	805	2.11	39.01	820	2.18
2.06	19.5	43.19	860	2.06	39.36	840	2.21
2.06	19.5	41.38	850	2.13	38.56	815	2.19
2.99	20.0	27.39	810	3.06	24.32	710	3.02
2.99	20.0	25.84	770	2.85	25.79	755	3.03
2.99	20.0	26.09	790	3.14	25.66	740	2.99
2.99	20.0	27.75	815	3.04	23.57	700	3.08
2.99	20.0	26.21	795	3.14	27.05	810	3.10
4.49	20.0	23.67	1025	4.53	19.50	850	4.52
4.49	20.0	24.64	1090	4.51	21.40	930	4.50
4.49	20.0	23.28	1000	4.31	20.02	860	4.45
4.49	20.0	22.77	980	4.47	21.75	980	4.57
4.49	20.0	22.30	980	4.49	21.13	895	4.39
4.93	19.5	16.25	690	4.49	15.90	695	4.53
4.93	19.5	15.49	710	4.69	15.45	725	4.86
4.93	19.5	16.26	765	4.87	17.38	820	4.89
4.93	19.5	14.50	670	4.79	17.20	805	4.85
4.93	19.5	17.45	815	4.84	16.84	765	4.71
6.67	20.0	14.13	835	6.12	10.19	615	6.25
6.67	20.0	12.75	740	6.01	11.66	680	6.04
6.67	20.0	13.38	790	6.12	11.79	740	6.50
6.67	20.0	13.54	810	6.20	11.57	685	6.13
6.67	20.0	14.42	850	6.11	12.81	770	6.23
6.09	20.5	14.27	785	5.79	12.43	695	5.79
6.09	20.5	16.49	896	5.64	14.78	820	5.75
6.09	20.5	12.75	700	5.73	14.91	840	5.84
6.09	20.5	12.44	685	5.47	12.76	720	5.85
6.09	20.5	12.79	665	5.36	15.22	830	5.65

Table 2. (continued) Flume Test Data, US DH-95, 1/4-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
7.13	20.0	11.82	725	6.35	No Data	No Data	No Data
7.07	20.0	12.55	760	6.27	No Data	No Data	No Data
7.19	20.0	11.80	740	6.50	No Data	No Data	No Data
8.26	20.0	10.57	745	7.30	No Data	No Data	No Data
8.29	20.0	9.47	680	7.44	No Data	No Data	No Data
8.47	20.0	11.37	805	7.34	No Data	No Data	No Data
7.90	20.0	7.90	795	6.86	No Data	No Data	No Data

Table 3. Flume Test Data, US DH-95, 5/16-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
1.50	19.50	38.61	1080	1.85	29.99	775	1.71
1.50	19.50	28.54	770	1.79	32.13	820	1.69
1.50	19.50	29.76	790	1.76	35.55	915	1.71
1.50	19.50	30.02	810	1.79	28.35	725	1.70
1.50	19.50	30.17	830	1.85	32.50	830	1.69
2.47	20.00	21.81	850	2.58	24.27	960	2.62
2.47	20.00	20.73	800	2.56	20.66	800	2.57
2.47	20.00	21.99	850	2.56	24.33	990	2.70
2.47	20.00	22.20	870	2.60	20.62	815	2.62
2.47	20.00	22.04	850	2.56	25.35	990	2.59
2.06	19.50	24.91	855	2.28	30.14	1060	2.33
2.06	19.50	24.56	815	2.20	24.97	860	2.28
2.06	19.50	23.95	800	2.21	24.21	825	2.26
2.06	19.50	25.81	860	2.21	22.29	760	2.26
2.06	19.50	22.56	765	2.25	23.68	800	2.24
2.99	20.00	23.11	1055	3.03	19.11	890	3.09
2.99	20.00	26.34	1175	2.96	18.51	850	3.04
2.99	20.00	23.99	1060	2.93	18.34	860	3.11
2.99	20.00	25.19	1100	2.90	16.95	800	3.13
2.99	20.00	17.59	765	2.88	19.12	890	3.09
3.68	20.00	15.02	790	3.50	13.50	725	3.56
3.68	20.00	15.60	810	3.44	15.57	830	3.53
3.68	20.00	14.12	780	3.57	11.16	600	3.60
3.68	20.00	15.08	830	3.66	13.38	730	3.63
3.68	20.00	16.25	885	3.61	12.97	710	3.56
4.93	20.00	11.59	820	4.69	10.09	720	4.73
4.93	20.00	13.91	965	4.61	12.04	850	4.68
4.93	20.00	15.44	1115	4.79	12.12	805	4.40
4.93	20.00	12.13	820	4.48	10.66	755	4.70
4.93	20.00	11.90	795	4.43	11.86	840	4.70
6.67	20.00	10.60	985	6.11	6.93	650	6.22
6.67	20.00	9.90	910	6.09	8.66	820	6.28
6.67	20.00	10.90	1010	6.13	8.56	810	6.27
6.67	20.00	11.94	1090	6.05	8.27	790	6.33
6.67	20.00	10.72	960	5.94	7.85	710	6.00
6.09	20.50	11.65	1015	5.78	8.29	725	5.80
6.09	20.50	12.55	1065	5.63	10.89	950	5.78
6.09	20.50	11.04	975	5.86	11.47	970	5.61
6.09	20.50	8.98	750	5.54	11.01	960	5.78
6.09	20.50	10.25	875	5.66	12.04	1025	5.64

Table 3. (continued) Flume Test Data, US DH-95 5/16-inch Nozzle

		US DH-95			US DH-81		
Flume Velocity in fps	Water Temperature Degrees C	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps	Sample Time in Seconds	Sample Volume in mL	Calculated Nozzle Velocity in fps
7.09	20.00	7.70	700	6.03	No Data	No Data	No Data
7.10	20.00	7.70	715	6.15	No Data	No Data	No Data
6.97	20.00	7.85	745	6.29	No Data	No Data	No Data
6.97	20.00	7.64	715	6.20	No Data	No Data	No Data
8.58	20.00	6.99	770	7.30	No Data	No Data	No Data
8.24	20.00	7.10	770	7.19	No Data	No Data	No Data

Table 4. Filling Times for the US DH-95 Sampler

Velocity in ft/sec	Volume in mL	3/16-inch Nozzle Time in seconds	1/4-inch Nozzle Time in seconds	5/16-inch Nozzle Time in seconds
1.4	800	105	59	38
1.6	800	92	52	33
1.8	800	82	46	29
2.0	800	74	41	27
2.2	800	67	38	24
2.4	800	61	35	22
2.6	800	57	32	20
2.8	800	53	30	19
3.0	800	49	28	18
3.2	800	46	26	17
3.4	800	43	24	16
3.6	800	41	23	15
3.8	800	39	22	14
4.0	800	37	21	13
4.2	800	35	20	13
4.4	800	33	19	12
4.6	800	32	18	12
4.8	800	31	17	11
5.0	800	29	17	11
5.2	800	28	16	10
5.4	800	27	15	10
5.6	800	26	15	9
5.8	800	25	14	9
6.0	800	25	14	9
6.2	800	24	13	9
6.4	800	23	13	8
6.6	800	22	13	8
6.8	800	22	12	8
7.0	800	21	12	8
7.2	800	20	12	7
7.4	800	20	11	7
7.6	800	19	11	7

RECOMMENDED VELOCITY RANGE (3/16-inch nozzle: 67 to 24)

RECOMMENDED VELOCITY RANGE (1/4-inch nozzle: 46 to 11)

RECOMMENDED VELOCITY RANGE (5/16-inch nozzle: 24 to 8)