OPEN CHANNEL PROFILING HANDBOOK

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OPEN CHANNEL PROFILING

SCOPE

This handbook contains the instructions on how to measure the velocity profile and calculate the flow of open channels. The velocity profile is measured using a handheld velocity meter. Flow is calculated with the continuity equation ($Q = \overline{U} \times A$) where Q is flow, $\overline{U}$ is mean velocity and A is cross-sectional area.

Section I describes mean velocity, cross-sectional area, site selection, profiling and methods of determining the mean velocity. Section II describes methods of calculating the instantaneous flow rate. Section III is a case study with the MMI Model 2000 being used to determine $\overline{U}$.

CONTENTS

SECTION I PROFILING

MEAN VELOCITY ($\overline{U}$) DEFINITION

A particle of water near the conduit wall will not move as fast as a particle toward the center. To understand this, we need to look at the molecules of moving liquids. The first layer of molecules stick to the wall of the conduit. The next layer will move by sliding across the first layer. This happens throughout the flow with each successive layer moving at a faster velocity. The change in velocity is greater near the conduit wall than it is toward the center. If velocity measurements of each layer could be taken, a velocity profile similar to the one in Figure 1-1 would be produced. Notice that the velocity decreases near the surface. Since most flows fit this profile, this is called the typical profile. There are, however, situations which will cause other profile shapes and it is usually more difficult to calculate flow with these shapes.

To calculate flow, an average or mean of all the varying velocities must be determined. Since it is not practical to measure the velocity of each layer of molecules, methods have been developed by which a mean velocity ($\overline{U}$) can be determined from velocity measurements taken at a number of positions in the flow.

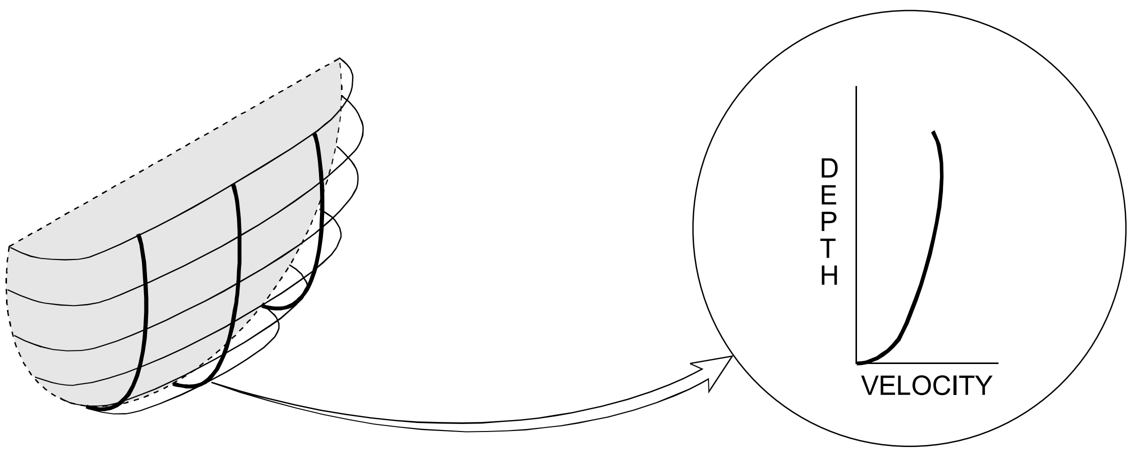

Figure 1-1. Typical Profile

CROSS-SECTIONAL AREA

The cross-sectional area of the flow is determined from a level measurement and the channel shape. It is important that the mean velocity measurement and the level measurement is done at the same location in the channel.

SITE SELECTION

A site that produces the typical profile shape will give the most accurate results. In a majority of the cases, problem sites can be identified by a visual inspection. Site inspection guidelines are as follows:

- The channel should have as much straight run as possible. Where the length of straight run is limited, the length upstream from the profile should be twice the downstream length.
- The channel should be free of flow disturbances. Look for protruding pipe joints, sudden changes in diameter, contributing sidestreams, outgoing sidestreams, or obstructions. Clean any rocks, sediment, or other debris that might be on the bottom of the pipe.
- The flow should be free of swirls, eddies, vortices, backward flow, or dead zones. Avoid areas that have visible swirls on the surface.
- Avoid areas immediately downstream from sharp bends or obstructions.
- Avoid converging or diverging flow (approach to a flume) and vertical drops.
- Avoid areas immediately downstream from a sluice gate or where the channel empties into a body of stationary water.

Choosing the Method

All profiling methods can be used in a site that produces a typical profile and has sufficient level to measure three point velocities. If you cannot avoid sites with nontypical profiles or low flows, the following guidelines will help in choosing a method that will give the best results. Keep in mind that choosing the method will become easier as you gain experience in profiling.

Low flows - The 0.9 x Umax method is recommended in flows of less than two inches.

Rapidly Changing Flows - A flow that is changing more than 10% in three minutes or less can be classified as rapidly changing. The 0.9 x Umax or 0.4 methods take the least amount of time. However, these methods usually require a typical profile shape for accurate results.

Comment:

Check the level several times during the profiling procedure. If the level has changed, but the change is less than 10%, average the level measurements and use the average in the flow calculation.

Asymmetrical flow - The 2-D method is recommended for asymmetrical flows. An asymmetrical flow will have a difference of 30% or more between the right and left side velocities.

Vertical drop (outfalls)	-	The 2-D method is recommended for outfalls. Remember to measure the level on the same plane as the velocity profile. Outfalls should be avoided wherever possible.
Nontypical profile shape	-	If you suspect a profile shape may not be typical, use the 2-D method.

PROFILING CHECKS

For best possible results, you should:

- Check the inside diameter of the conduit. Also, measure the horizontal and vertical diameters. If there is a difference, then average the diameters.
- Check for symmetry of flow.
- Check level several times during the procedure.
- Check the invert for rocks, sediment, and other debris.

CALCULATING $\overline{U}$

PROFILING METHODS

0.9 x Umax Method

- Take a series of point velocity measurements throughout the entire flow.
- Identify the fastest velocity. In most cases, this is usually located in the center just beneath the surface.
- Multiply the fastest velocity by 0.9 for $\overline{U}$.

2, .4, .8 of Depth Method

- Measure depth of flow (Page 1-5).
- Calculate the positions on the centerline by:

  0.2 x depth
  0.4 x depth
  0.8 x depth

- At the .2, .4, and .8 positions, measure and record the velocities (Figure 1-2).

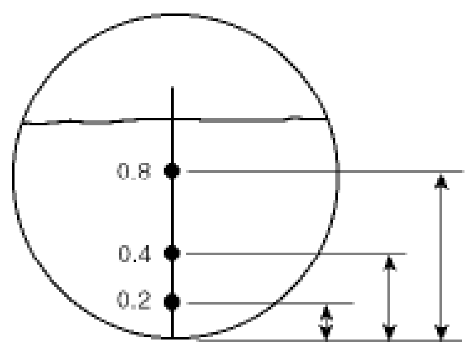

Figure 1-2. (.2, .4, .8) Velocity Positions

Comment:

In manmade channels, measure the .2, .4, and .8 positions from the bottom.

- Average .2 and .8 velocities.
- Average the .4 velocity with the .2 and .8 average for the $\overline{U}$.

.4 Method

A simplified version of the .2, .4, .8 method is to measure the velocity at the .4 position and use this as $\overline{U}$. This method is probably the least accurate because it uses only one data point and assumes that a logarithmic profile exists. This is also called the 60% of depth method.

2-D Method

- Locate the center line of the flow.
- Locate vertical velocity lines (VVL) halfway between the center line and the side walls of the conduit. This is measured at the widest part of the flow.
- Take at least seven velocity measurements at different depths along the center line.
- Take velocity readings at different depths on the VVL. The distance between these depths should be the same as those on the center line.

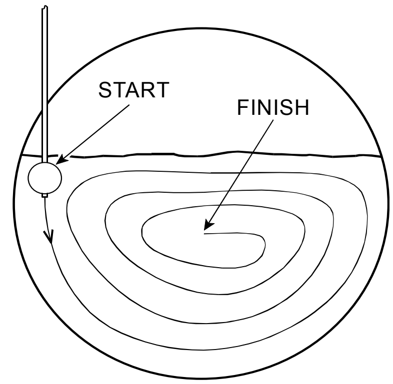

Figure 1-3. 2-D Velocity Positions

- Take final point velocity readings at the right and left corners of the flow.
- Check the data for any outliers. If a best fit curve of the velocity profile were plotted, an outlier would lie outside the best fit curve region. See Figure 3-1 on Page 3-2.
- Average all measurements except outliers for $\overline{U}$. Remember to include the corner measurements.

2-D Method Alternate

Another way to do the 2-D profile is with the FPA (fixed point average) feature of the Model 2000 Flo-Mate. The Flo-Mate sensor is moved at a constant velocity in a pattern across the flow that covers the cross-sectional area. The velocity displayed by the Flo-Mate at the end of the FPA period is the mean velocity.

Comment:

It may take several attempts to get the FPA time set so that the end of the FPA period coincides with the end of the sensor motion.

- Set the FPA time to the appropriate number of seconds.
- Place the sensor at the start position and wait for a few seconds.
- Press <ON/C> and start moving the sensor.

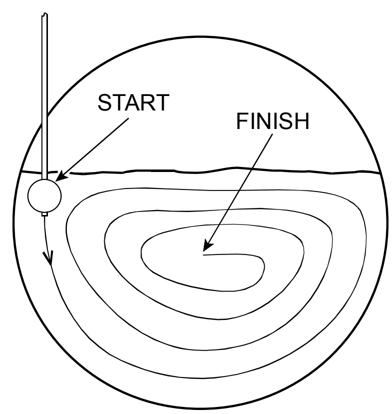

Figure 1-4. 2-D Method Alternate

VPT Method

The Velocity Profiling Technique (VPT) was first described by N. T. Debevoise and R. B. Fernandez in the November 1984 issue of the WPCF Journal. With this method, a series of point velocity measurements are taken at different depths along the centerline of the flow. These measurements along with level are input into a VPT computer program which calculates the flow. This is one example of the more advanced profile integration techniques which are possible.

MEASURING LEVEL

Circular Conduits

- Measure the inside diameter of the conduit.
- Measure distance D (Figure 1-4).
- Subtract D from the inside diameter of the conduit for the depth of flow. This eliminates the problem of the ruler interfering with the liquid.

Comment:

The level measurement and the velocity profile must be on the same plane for proper application of the continuity equation.

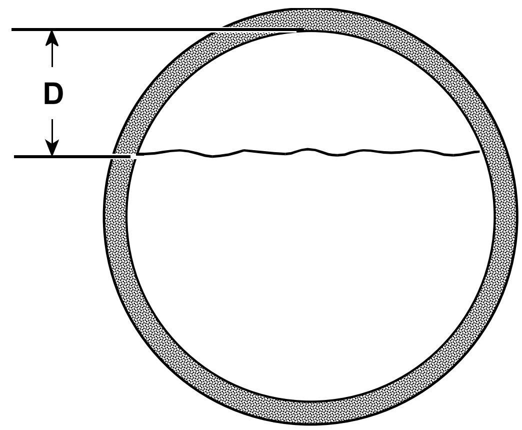

Figure 1-5. Level Measurement

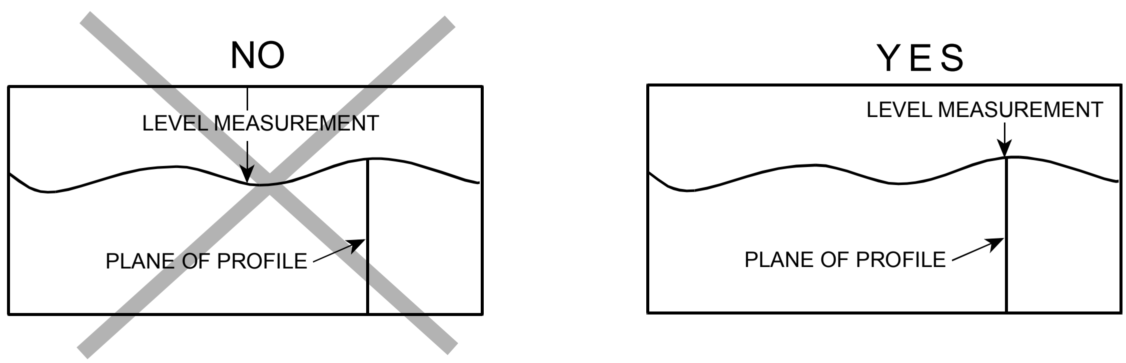

Figure 1-6. Location of Level Measurement

SECTION II CALCULATING FLOW

CIRCULAR CONDUITS

To calculate flow in circular conduits you need:

- The mean velocity $\overline{U}$ from Section I.
- The depth of flow at the time of profile.
- The inside diameter of the conduit.

Outline

Calculating flow is outlined as follows:

- Calculate the level to diameter ratio (L/D).
- Identify the flow unit multiplier (K) (Table I, Pages 2-3 and 2-4).
- Square the diameter in feet.
- Calculate flow.

Calculate the Level/Diameter Ratio (L/D)

Ratio = L ÷ D

Where:

L is depth of flow in inches at time of profile.

D is inside diameter in inches.

L/D is the level/diameter ratio.

Identify Flow Unit Multiplier K

K ⇢L/D Ratio in Table I on Pages 2-3 and 2-4.

Where:

K is the flow unit multiplier.

Find the appropriate L/D ratio in the L/D column and move to the right to the desired units column to get the proper flow unit multiplier.

Comment:

The flow unit multiplier in Table I is only for circular conduits measured in feet. The multiplier was derived using a one foot per second flow in a one foot diameter conduit as the model.

Convert the Diameter to Feet and Square

D^2 = (Diameter in inches ÷ 12)^2

Where:

D^2 is in feet diameter squared. The diameter needs to be converted to feet because the velocity is in feet per second.

Calculate the Flow

K x D^2 x $\overline{U}$ = flow

Example:

What is the flow in millions of gallons per day (MGD) of a 10-inch diameter conduit with a 6-inch level? The $\overline{U}$ has been calculated to be 1.5 ft/sec.

Calculate Level/Diameter Ratio L/D

Level ratio L/D = 6 inches/10 inches = 0.6

Identify K

K = 0.6 → 0.3180 from Table I

Calculate D^2

D^2 = (10 in ÷ 12)^2 = (0.833 ft)^2 = 0.694 ft^2

Calculate flow

K x D^2 x $\overline{U}$ = MGD = 0.3180 x 0.694 ft^2 x 1.5 ft/sec = 0.331 MGD

Table I Flow Unit Multiplier

L/D	K (Flow Unit Mulitiplier)					
	MGD	GPM	CFS	CMM	CMD	LPM
.01	.0009	.5966	.0013	.0023	3.2522	2.2585
.02	.0024	1.6824	.0037	.0063	9.1709	6.3687
.03	.0044	3.0814	.0069	.0117	16.7986	11.6644
.04	.0068	4.7296	.0105	.0179	25.7811	17.9036
.05	.0095	6.5894	.0147	.0249	35.9190	24.9438
.06	.0124	8.6351	.0192	.0327	47.0701	32.6876
.07	.0156	10.8475	.0242	.0411	59.1295	41.0621
.08	.0190	13.2113	.0294	.0500	72.0148	50.0103
.09	.0226	15.7143	.0350	.0595	85.6585	59.4851
.10	.0264	18.3460	.0409	.0694	100.0039	69.4471
.11	.0304	21.0975	.0470	.0799	115.0022	79.8627
.12	.0345	23.9609	.0534	.0907	130.6108	90.7020
.13	.0388	26.9294	.0600	.1019	146.7919	101.9388
.14	.0432	29.9967	.0668	.1135	163.5116	113.5497
.15	.0477	33.1571	.0739	.1255	180.7393	125.5134
.16	.0524	36.4056	.0811	.1378	198.4467	137.8102
.17	.0572	39.7374	.0885	.1504	216.6081	150.4223
.18	.0621	43.1480	.0961	.1633	235.1995	163.3330
.19	.0672	46.6334	.1039	.1765	254.1985	176.5267
.20	.0723	50.1898	.1118	.1900	273.5844	189.9892
.21	.0775	53.8135	.1199	.2037	293.3373	203.7064
.22	.0828	57.5012	.1281	.2177	313.4387	217.6657
.23	.0882	61.2496	.1365	.2319	333.8710	231.8548
.24	.0937	65.0555	.1449	.2463	354.6172	246.2619
.25	.0992	68.9161	.1535	.2609	375.6613	260.8759
.26	.1049	72.8286	.1623	.2757	396.9880	275.6861
.27	.1106	76.7901	.1711	.2907	418.5825	290.9823
.28	.1163	80.7982	.1800	.3059	440.4305	305.8545
.29	.1222	84.8503	.1890	.3212	462.5182	321.1932
.30	.1281	88.9439	.1982	.3367	484.8325	336.3892
.31	.1340	93.0767	.2074	.3523	507.3605	352.3337
.32	.1400	97.2464	.2167	.3681	530.0894	368.1176
.33	.1461	101.4507	.2260	.3840	553.0071	384.0327
.34	.1522	105.6875	.2355	.4001	576.1017	400.0706
.35	.1583	109.9546	.2450	.4162	599.3618	416.2234
.36	.1645	114.2500	.2545	.4325	622.7757	432.4831
.37	.1707	118.5715	.2642	.4488	646.3325	448.8419
.38	.1770	122.9172	.2739	.4653	670.0208	465.2922
.39	.1833	127.2851	.2836	.4818	693.8301	481.8265
.40	.1896	131.6733	.2934	.4984	717.7501	498.4375
.41	.1960	136.0797	.3032	.5151	741.7607	515.1178
.42	.2023	140.5026	.3130	.5319	765.8788	531.8603
.43	.2087	144.9400	.3229	.5487	790.0673	548.6578
.44	.2151	149.3902	.3328	.5655	814.3250	565.5034
.45	.2215	153.8512	.3428	.5824	838.6420	582.3902
.46	.2280	158.3212	.3527	.5993	863.0080	599.3111
.47	.2344	162.7985	.3627	.6163	887.4133	616.2592
.48	.2409	167.2811	.3727	.6332	911.8480	633.2277
.49	.2473	171.7673	.3827	.6502	936.3024	650.2100
.50	.2538	176.2553	.3927	.6672	960.7664	667.1989

Table I Continued

L/D	K (Flow Unit Mulitiplier)					
	MGD	GPM	CFS	CMM	CMD	LPM
.51	.2603	180.7433	.4027	.6842	985.2306	684.1879
.52	.2667	185.2295	.4127	.7012	1009.6850	701.1701
.53	.2732	189.7121	.4227	.7181	1043.1200	718.1385
.54	.2796	194.1894	.4327	.7351	1058.5250	735.0869
.55	.2861	198.6594	.4426	.7520	1082.8910	752.0076
.56	.2925	203.1204	.4526	.7689	1107.1080	768.8945
.57	.2989	207.5706	.4635	.7857	1131.4660	785.7401
.58	.3053	212.0080	.4724	.8025	1155.6540	802.5377
.59	.3117	216.4309	.4822	.8193	1179.7630	819.2801
.60	.3180	220.8374	.4920	.8360	1203.7830	835.9605
.61	.3243	225.2255	.5018	.8526	1227.7030	852.5715
.62	.3306	229.5934	.5115	.8691	1251.5120	869.1057
.63	.3369	233.9392	.5212	.8856	1275.2010	885.5560
.64	.3431	238.2607	.5308	.9019	1298.7580	901.9149
.65	.3493	242.5560	.5404	.9182	1322.1710	918.1745
.66	.3554	246.8232	.5499	.9343	1345.4320	934.3275
.67	.3615	251.0600	.5594	.9504	1368.5260	950.3654
.68	.3676	255.2643	.5687	.9663	1391.4440	966.2805
.69	.3736	259.4340	.5780	.9821	1414.1730	982.0645
.70	.3795	263.5668	.5872	.9977	1436.7010	997.7090
.71	.3854	267.6604	.5963	1.0132	1459.0150	1013.2050
.72	.3913	271.7125	.6054	1.0285	1481.1030	1028.5440
.73	.3970	275.7206	.6143	1.0437	1502.9510	1043.7160
.74	.4027	279.6822	.6231	1.0579	1524.5460	1058.7120
.75	.4084	283.5946	.6319	1.0735	1545.8720	1073.5220
.76	.4139	287.4553	.6405	1.0881	1566.9170	1088.1370
.77	.4194	291.2612	.6489	1.1025	1587.6630	1102.5440
.78	.4248	295.0096	.6573	1.1167	1608.0950	1116.7330
.79	.4301	298.6972	.6655	1.1307	1628.1970	1130.6920
.80	.4353	302.3210	.6736	1.1444	1647.9500	1144.4090
.81	.4405	305.8774	.6815	1.1579	1667.3360	1157.8720
.82	.4455	309.3629	.6893	1.1711	1686.3350	1171.0660
.83	.4505	312.7735	.6969	1.1840	1704.9260	1183.9760
.84	.4552	316.1053	.7043	1.1966	1723.0880	1196.5890
.85	.4599	319.3538	.7115	1.2089	1740.7950	1208.8860
.86	.4644	322.5143	.7186	1.2208	1758.0230	1220.8490
.87	.4688	325.5815	.7254	1.2325	1774.7430	1232.4600
.88	.4731	328.5500	.7320	1.2437	1790.9240	1243.6970
.89	.4772	331.4135	.7384	1.2545	1806.5330	1254.5360
.90	.4812	334.1650	.7445	1.2650	1821.5310	1264.9520
.91	.4850	336.7967	.7504	1.2749	1835.8760	1274.9140
.92	.4886	339.2997	.7560	1.2844	1849.5200	1284.3890
.93	.4920	341.6636	.7612	1.2933	1862.4060	1293.3370
.94	.4952	343.8759	.7662	1.3017	1874.4650	1301.7120
.95	.4981	345.9216	.7707	1.3095	1885.6160	1309.4560
.96	.5008	347.7815	.7749	1.3165	1895.7540	1316.4960
.97	.5032	349.4297	.7785	1.3277	1904.7390	1322.7350
.98	.5052	350.8287	.7816	1.3280	1912.3650	1328.0310
.99	.5068	351.9145	.7841	1.3321	1918.2840	1332.1410
1.00	.5076	352.5112	.7854	1.3344	1921.5360	1334.4000

RECTANGULAR CHANNELS

Flow in rectangular channels is calculated by the following:

- Determine $\overline{U}$ with the .2, .4, .8 method as described on Page 1-3. For channel widths of six feet or larger, use the .2, .6, .8 method as described on Page 2-6 for rivers and streams. Velocity units must be in ft/sec.
- Calculate the cross-sectional area in ft^2 by:
  [(Depth of Flow) in. ÷ 12] x [(Channel Width) in. ÷ 12]
- Calculate flow by:
  $\overline{U}$ x (Cross-sectional Area)

The result should be a flow rate in ft^3/sec (CFS). You can convert this to other flow units with the flow unit conversion multipliers in Table III on page 2-7.

Example:

What is the flow in a channel 24 inches wide with a 10-inch deep flow?

Solution:

- Velocity measured at
  .2 = 1.5 ft/sec
  .4 = 1.7 ft/sec
  .8 = 1.8 ft/sec
- (1.5 + 1.8) ÷ 2 = 1.65 ft/sec
- $\overline{U}$ = (1.65 + 1.7) ÷ 2 = 1.67 ft/sec
- From Table II on Page 2-5, 10 in = 0.83 ft
- Area = 0.83 ft x 2 ft = 1.66 ft^2
- Flow = 1.67 ft^2/sec x 1.66 ft = 2.77 ft^3/sec

From Table III on Page 2-7.

.64632 x 2.77ft^3/sec = 1.7903 MGD

Table II Inch to Feet Conversion

IN	**0.50**	**1.00**	**1.50**	**2.00**	**2.50**	**3.00**	**3.50**	**4.00**
FT	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33
IN	**4.50**	**5.00**	**5.50**	**6.00**	**6.50**	**7.00**	**7.50**	**8.00**
FT	0.37	0.42	0.46	0.50	0.54	0.58	0.62	0.67
IN	**8.50**	**9.00**	**9.50**	**10.00**	**10.50**	**11.00**	**11.50**	**12.00**
FT	0.71	0.75	0.79	0.83	0.87	0.92	0.96	1.00

You will need to divide the width of the channel into equal segments (Figure 2–1). Then do a velocity profile and calculate the flow for each segment. Sum the segment flows for the total flow. The procedure for calculating flows in rivers and streams is as follows:

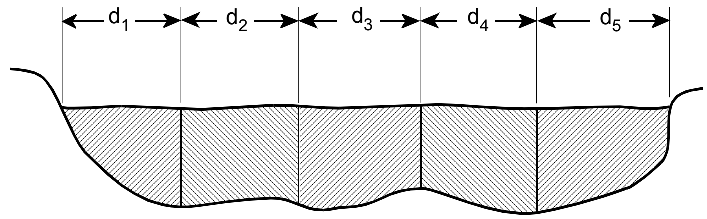

Figure 2-1. Segment Length

Comment:

The smaller the segment the better the result. If you find that the difference in mean velocity between two adjacent segments is greater than 10%, the segments should be smaller.

- Divide the channel width into segments of equal length (d) (Figure 2-1).
- Locate the center line of each segment at $\frac{1}{2}$d (Figure 2-2).
- Measure segment depth on the segment center line.

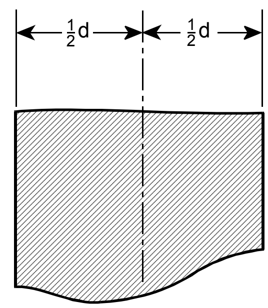

Figure 2-2. Segment Centerline

Comment:

The .2, .6, and .8 positions for rivers and streams are measured from the surface. All depth and velocity measurements must be on the same plane.

- Calculate the .2, .6, .8 velocity positions on the segment centerline by:

  .2 x Depth
  .6 x Depth
  .8 x Depth

- Measure the velocity at the .2, .6, and .8 positions.
- Average the .2 and .8 velocities.
- Average the .6 velocity with the average of the .2 and .8 velocities for $\bar{U}$.
- Calculate segment areas (Figure 2-4).
- Calculate the flow of each segment by:
  Segment Area x $\bar{U}$.
- Sum the flow of the segments for total flow.

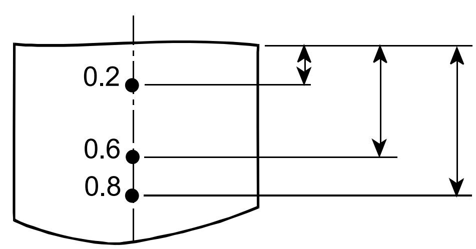

Figure 2-3. Velocity Profile

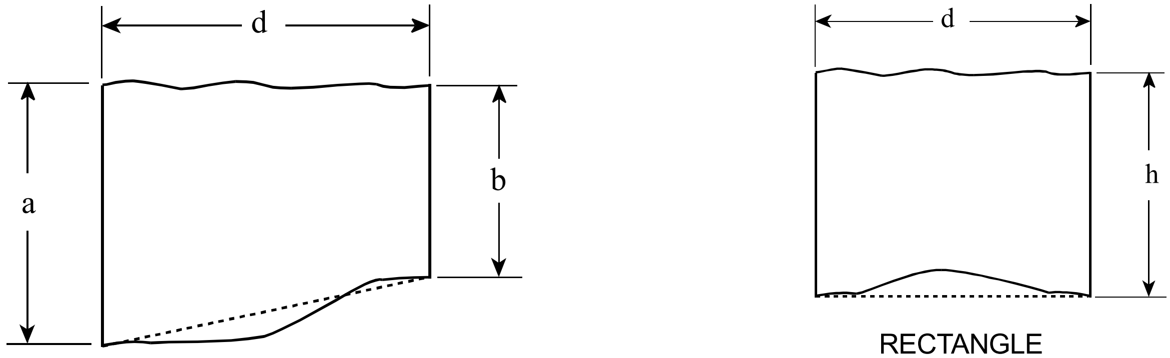

Figure 2-4. Segment Area

Flow Unit Conversion

To convert flow units, locate the appropriate flow unit conversion factor in Table III. Then multiply the existing unit's conversion factor to get the new unit's.

Table III Flow Unit Conversion Factors

EXISTING UNITS ↓ / NEW UNITS →	CFS	MGD	GPM	CMD	CMM
CFS	1	0.64632	448.831	2446.576	1.69901
MGD	1.54723	1	694.44	3785.412	2.62876
GPM	0.002228	0.00144	1	5.45099	0.0037854
CMD	0.000408	0.0002642	0.18345	1	0.0006944
CMM	0.5885	0.380408	264.172	1440	1

Example:

Convert 20 ft^3/sec (CFS) to millions of gallons per day (MGD).

Solution:

From: Table III, conversion factor = 0.64632

Then: 20 ft^3/sec x 0.64632 = 12.9264 MGD

Table IV Flow Units

MGD - Millions of Gallons per Day	CMM - Cubic Meters per Minute
GPM - Gallons per Minute	CMD - Cubic Meters per Day
CFS - Cubic Feet per Second	LPM - Liters per Minute

SECTION III
A PROFILING EXAMPLE
USING THE MMI MODEL 2000

This section illustrates how to collect and analyze data from circular conduits and achieve the best possible accuracy. The data shown in this section is actual field data that was collected with a MMI Model 2000 in a normal flow.

Comment:

A 2-D profile is used to collect the field data since this method provides the most point velocity measurements. A centerline profile is plotted and a best fit curve is drawn. This permits all profiling methods described in Section I to be utilized with one set of velocity measurements.

Collecting Field Data With the Model 2000
The 2-D Method

We start the 2-D profile on the vertical center line at the invert or bottom of the conduit. The first velocity measurement with the Model 2000 is at 0.75 inches or 1.9 cm from the invert. This is because the electrodes, which measure the point velocity, are 0.75 inches from the bottom of the sensor. If the sensor is moved up 0.25 inches for the second velocity measurement, this will put the electrodes one inch from the invert. The sensor can then be moved at even-inch or half-inch increments. Five to ten velocity measurements between the bottom and the surface are recommended. After the vertical center line is profiled, the level is measured and recorded.

Next the right and left vertical velocity lines are profiled and recorded. Then the right and left corner velocity measurements are taken and recorded. Finally the level is measured and recorded. We now have the necessary data to calculate flow.

Comment:

If there is a sudden drop in velocity at any position, check the sensor for debris.

FIELD DATA

CONDUIT DIAMETER = 24.25 INCHES

POSITION AS MEASURED FROM THE INVERT	CENTERLINE FT/SEC	RIGHT VVL FT/SEC	LEFT VVL FT/SEC
0.75	5.2	5.2	4.9
1.0	5.4	5.5	5.2
2.0	5.4	5.5	5.5
3.0	4.3	5.5	5.5
4.0	5.5	5.1	5.2
5.0	5.4	4.2	4.8
6.0	5.2	4.0	4.2
6.5	4.0		
LEVEL DURING PROFILE 7 INCHES 6 7/8 INCHES 7 1/8 INCHES	AVERAGE LEVEL 7 INCHES	RIGHT CORNER VEL 4.0 FT/SEC	LEFT CORNER VEL 4.8 FT/SEC

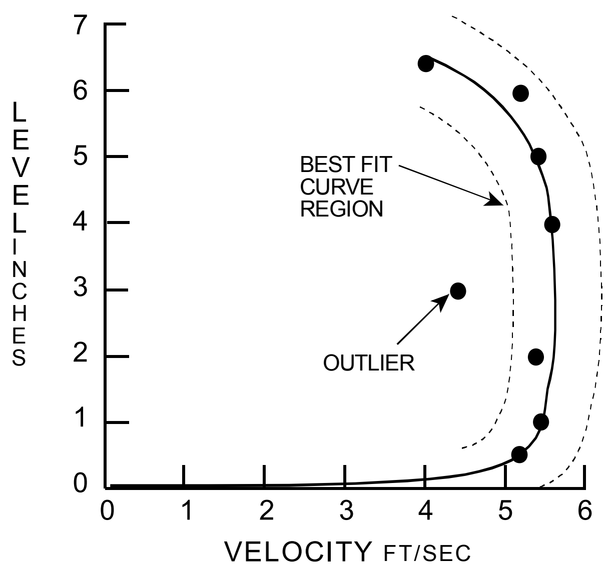

Figure 3-1. Best Fit Curve

Comment:

The 4.3 ft/sec velocity at the 3-inch position is outside the best fit curve region and is ignored. This is called an outlier

The .2, .4, .8 Method

POSITION		VELOCITY
.2 x 7" = 1.4"	.	5.4 ft/sec
.4 x 7" = 2.8"	.	5.5 ft/sec
.8 x 7" = 5.35"	.	5.35 ft/sec

(5.4 + 5.35) ÷ 2 = 5.37 ft/sec
$\overline{U}$ = (5.37 +5.5) ÷ 2 = 5.44 ft/sec

The .4 Method

The velocity at the .4 position = 5.5 ft/sec.
$\overline{U}$ = 5.5 ft/sec.

The 0.9 x Vmax Method

Vmax = 5.5 ft/sec.
$\overline{U}$ = 0.9 x 5.5 = 4.95 ft/sec

The 2-D Method

Average all velocity measurements. Remember to include the two corner measurements and discard any outliers.

$\overline{U}$ = 4.8 ft/sec

The VPT Method

This method requires a computer program. If you have this program, enter the velocity measurements from the center line profile. Discard any outliers.

$\overline{U}$ from VPT program = 5.32 ft/sec

Average $\overline{U}$

An overall $\overline{U}$ can be calculated by averaging the values from the different methods.

(5.44 + 5.5 + 4.95 + 5.0 + 5.32) ÷ 5 = 5.24 ft/sec

Comment:

If the profile is not symmetrical, then the results from the .9 x Vmax and 2-D methods may vary greatly from the VPT; .2, .4, .8; and .4 methods.

% OF DEVIATION

We calculate the % of deviation between the average and high $\overline{U}$, and the average and low $\overline{U}$. We discard any $\overline{U}$ that has a deviation greater than 10% from the average $\overline{U}$.

% of Deviation Between High $\overline{U}$ (5.5 ft/sec) and Average $\overline{U}$

$$\% \text{ deviation} = \frac{(5.5 - 5.2)}{5.24} \times 100 = 5.7\%$$

% of Deviation Between Low $\overline{U}$ (4.8 ft/sec) and Average $\overline{U}$

$$\% \text{ deviation} = \frac{(5.2 - 4.8)}{5.2} \times 100 = 7.7\%$$

Since the no deviation is greater than 10% from the average $\overline{U}$, all the values are useable.