BUREAU OF WATER SUPPLY AND WASTEWATER MANAGEMENT

Wastewater Treatment Plant Operator Training

Module 25: Introduction to Flowmeters

Topical Outline

Unit 1 – Introduction

I. Introduction
   - A. Definitions

II. Why Use Flowmeters?
   - A. Regulatory Requirements
   - B. Process Control

III. Data Output
   - A. Instantaneous Flowmeters
   - B. Continuous Recording

IV. Flow Hydraulics
   - A. Types of Conditions
   - B. Factors Affecting Flow Rate
   - C. Q = AV

Unit 2 – Flowmeter Technologies

I. Open Channel
   - A. Accuracy
   - B. Primary Hydraulic Control Element
   - C. Measuring Devices

II. Closed Pipe
   - A. Flow Measuring Components
   - B. Installation Considerations

Unit 1 – Introduction

Learning Objectives

- Explain why flow is measured.
- List two types of data output.
- Describe four factors that affect flow rates.
- Calculate flow when given area and velocity.

This is a very basic course that contains minimal theory. It covers the basic concepts needed to understand flowmetering in collection systems and small wastewater treatment plants (WWTP). As a result, both open channel and closed pipe flows are discussed; however, open channels are covered in much more detail. The “Advanced Flowmeters” course builds on concepts covered in this course, and focuses on more complex flowmetering applications and larger facilities.

Definitions

Area is a measure of the surface of a specific two dimensional object. Although the object may be a square, rectangle, or circle, the units are expressed in square units, such as square inches (sq. in.) or square feet (sq. ft.).

Flow is a measure of fluid passing a given point over a given time period. Flow is determined by multiplying area times velocity. This may be expressed as cubic feet per second (cfs), gallons per minute (gpm), millions of gallons per day (MGD), cubic meters per second (m^3/s), etc.

Flowmetering is the task of measuring a quantifiable volume over a defined time, such as million gallons per day, gallons per minute, liters per minute, or cubic meters per day.

Infiltration is the extraneous flow entering the wastewater collection system caused by the percolation of rain water and short-term rise of the groundwater table during and shortly after a storm event. This extraneous flow enters through such sources as defects in manholes, mainline, and lateral sewers.

Inflow is the extraneous flow entering the wastewater collection system during or immediately after a storm event through sources which are directly connected to the system, including, but not limited to, roof leaders/downspouts; basement, yard, and area drains; drains from springs and swampy areas; manhole covers; and cross connections from storm sewers and catch basins.

Velocity is the distance traversed (length) by a body divided by the time it took to travel the distance. Therefore, a fluid moving 10 feet in 10 seconds has a velocity of 1 foot per second (fps).

One of two factors dictates flowmetering:

- Regulatory requirements.
- Process control.

If a regulation requires flowmetering, there is no option but to comply. If flowmetering will establish a more stable treatment process, then flowmeters may be installed for process control even though they are not required by a regulation.

Regulatory Requirements

Section 64.8 of the Domestic Wastewater Facilities Manual-10/97

- Devices should be installed in all plants to indicate flow rates of raw wastewater or primary effluent, return sludge, and air to each tank unit.
- Plants designed for flows of 100,000 gallons per day (gpd) or more should totalize and record flow.

National Pollutant Discharge Elimination System (NPDES) Permit

- The NPDES Permit requires flow-paced composite sampling of Wastewater Treatment Plant (WWTP) effluent.
  - Part A of most NPDES Permits contains the following verbiage under "Composite Sample:" *The composite must be flow-proportional; either the volume of each individual sample is proportional to discharge flow rates, or the sampling interval is proportional to the flow rates over the time period used to produce the composite.*
    - Automatic flow-paced composite sampler. This is a sample that is interfaced with the flowmeter.
    - A discreet sampler and the use of a strip chart showing hourly flows. This requires a sample that collects discreet samples into individual bottles and the operator removes a measured portion.

PADEP Chapter 94 Requirements

- Section 94.12. Annual report.

  The report shall include the following:

  (5) A discussion of sewer system monitoring, maintenance, repair and rehabilitation, including routine and special activities, personnel and equipment used, sampling frequency, quality assurance, data analyses, infiltration/inflow monitoring, and, where applicable, maintenance and control of combined sewer regulators during the past year.

- Section 94.13. Measuring, indicating, and recording devices.

  Flow measuring, indicating, and recording equipment shall be calibrated **annually**.

- See Appendix A: PADEP Chapter 94 – Municipal Wasteload Management.

Potential Requirements

If there have been previous flow problems at a facility, certain actions may be required. Such actions may include the implementation of infiltration/inflow reduction programs.

A municipality conducting Infiltration/Inflow (I/I) work must know several parameters for their system:

- The base flow is attributed only to the domestic flow.
- A maximum flow rate in a system will be composed of the peak domestic flow and the effects of I/I.

Process Control

Practical Requirements:

- Able to adjust process equipment or ensure adequate pumping capacity is available.
- Able to control downstream chemical feed systems.
- Able to determine when you are reaching the capacity of a system (sewer line, pumping station, or treatment unit).

Flowmeter data can be read when needed using an instantaneous flowmeter, or the data can be recorded continuously on a continuous recording flowmeter.

Instantaneous Flowmeters

- May be the only flowmeter used by small facilities.
- Less expensive than continuous recording flowmeters.
- Used to spot-check permanent flowmeters (calibration).

Figure 1.1 – In-line flowmeter[1]

Figure 1.2 - Volumetric weir[2]

Continuous Recording

- To meet regulatory requirements, continuous recording flowmeters are used by WWTPs that have flows greater than 100,000 gpd.

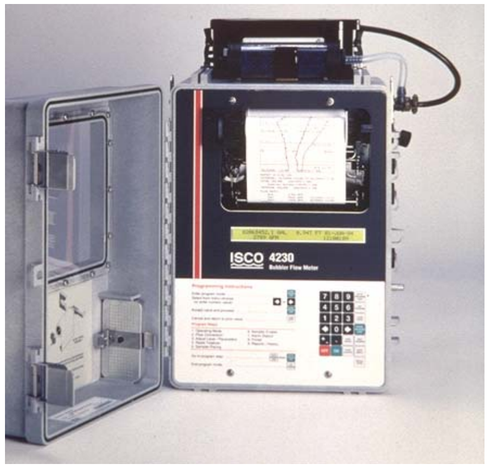


Figure 1.3 – Example Continuous Recording Device[3]

Types of Conditions

- Open Channels/Pipes
  - Pipes include gravity sewers or channels.
- Closed Pipes (flowing full)
  - Pipes include sewer lines running full or force mains.

Factors Affecting Flow Rate

- Approach and Departure Conditions—The hydraulic conditions prior to the flowmeter and leaving the flowmeter are important, especially for open channel flows.
- Channel Shape—Normally the shape of the channel must be uniform.
- Liquid Depth—All metering devices have a minimum and maximum depth in which they can function.
- Liquid Velocity—There is a minimum and maximum velocity at which meters can function.

Q = AV

Q = AV
▶ Q = the volume through a system
▶ A = the area of the system
▶ V = the velocity in the system

- The most fundamental equation to understanding flow in a system—pipe or open channel.
- All units in the equation must be the same.
- Example:

  If the area of a system is 1.5 square feet and the velocity is 2.3 feet per second, what is the volume?

  Q = AV
  Q = 1.5 sq ft x 2.3 fps
  Q = 3.45 cubic feet per second (cfs)

  How much would this be in gallons per second?

  Q = 3.45 cfs x 7.48 gallons per cubic feet
  Q = 25.8 gallons per second

Calculation

1. If you have a channel that is 1 foot wide, the flow is 6 inches deep, and the velocity is 2.5 feet per second (fps), what is the volume in cubic feet per second and gallons per minute?

2. If you have an 8 inch diameter pipe and the velocity is 2.5 fps, what is the volume? (Hint: $A = \pi r^2$)

3. Given a flow of 0.87 cfs conveyed in a 12 inch diameter sewer line, what would be the velocity?

[1] USABlueBook. Flowmeter – For Sch 40 x 1" (5-40 GPM). Retrieved on January 28, 2005, from https://usabluebook-onramp.com/cgi-bin/onramp.exe?custnum=&password=&pgm=itemnum.bbx&itemnum=67600&button=Submit

[2] USABlueBook. 6" Volumetric Weir. Retrieved on January 28, 2005, from https://usabluebook-onramp.com/cgi-bin/onramp.exe?pgm=itemdet.bbx&id=26411&custnum=&password=

[3] Courtesy of Isco, Inc.

Unit 2 – Flowmeter Technologies

Learning Objectives

- Define an open channel.
- Describe the purpose of the primary hydraulic control element.
- List two open channel primary hydraulic control elements.
- List four open channel measuring devices for measuring depth.
- List three types of flowmeters used on closed pipes.
- Identify two installation considerations for closed pipes.

An open channel implies free air space above a gravity conveyed liquid. Thus, an open channel may be a visible channel, or it may be a closed pipe that is **not** flowing full.

An open channel flowmeter has two primary components:

- Primary hydraulic control element (PHCE).
- Measuring device.

Accuracy

Flowmeter instrumentation is normally expressed as plus or minus (±) a certain percentage of actual flow rate.

- For closed pipes, the flowmeter reading may be within 2% - 4% of the actual flow, or it may vary from 4% - 8% of the actual flow.
- The reading may vary more with open channels. Accuracy depends on the hydraulic control conditions and the type of meter selected.

Primary Hydraulic Control Element

- The purpose of the hydraulic control element is to change the characteristics of the channel to reduce the area and generate an increase in velocity past a given point.
- The ideal location for the primary hydraulic control element in a sewer line is an approach with a moderate slope and a steeper slope on the discharge side.
- It should not be located at the end of a long steep run. A steeper discharge reduces the potential for backwater affecting the velocity through the hydraulic control element.
- Two common primary hydraulic control elements are weirs and flumes.
- A weir is almost like a dam with a small section cut out from the front, which causes a decrease in area for the water to flow through.
- A flume normally has the width decreased, which causes a higher velocity.

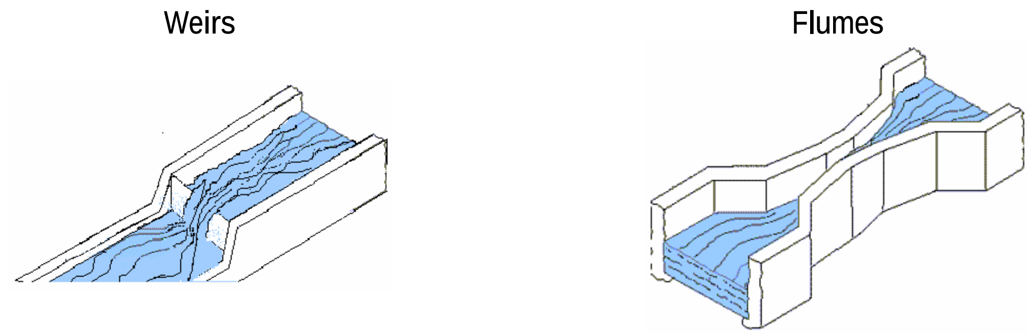


Figure 2.1 – Primary Hydraulic Control Elements[1]

Weir

A **Weir** is a controlled obstruction that is usually a sharp-crested, thin plate. Wastewater cascades over the top of the weir and air is added into the nappe.

Sharp-Crested

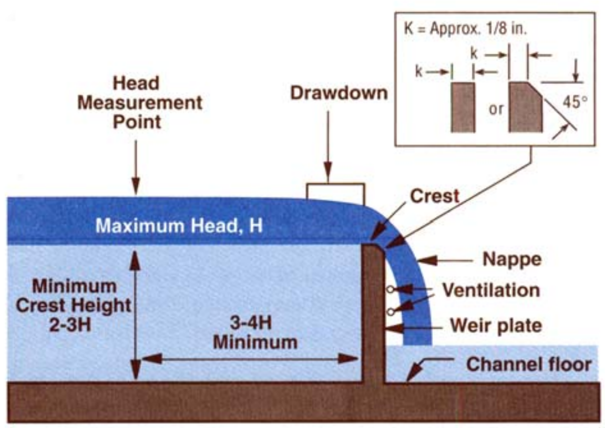


Figure 2.2 – Sharp-Crested Weir[2]

- The location of the measuring point is very specific and cannot be altered. The diagram above shows the proper location of the head measurement point.

- It is a very common weir. It is simple but effective in the **proper** circumstances and with adequate maintenance.

V-Notch Weir

- The degree of a V-notch can vary.
    - The degree of a V-notch weir is determined by the angle of the notch. The V-notch may range from a small angle such as 22½ degrees or 30 degrees, through sizes of 45 degrees to 60 degrees. The widest v-notch weirs are 90 and 120 degrees (90 degree v-notch weirs are the most common).

☑ Exercise/Activity

We have an effluent flow that ranges from 10 gpm to 1,500 gpm from a well-operated WWTP. We do not anticipate an unacceptable amount of solids. What are possible V-notch weir options? Use Appendix D - ISCO Table 5-3A.

Rectangular Weir

- There are two types (a contraction is the notch cut in the top of the weir plate):
    1. With end contractions.
    2. Without end contractions.

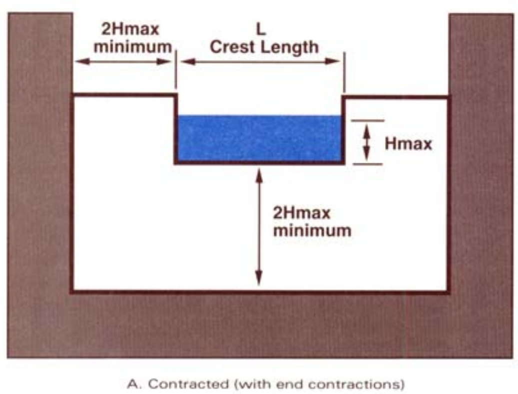


Figure 2.3 – Rectangular Sharp-Crested Weir with End Contractions[3]

Figure 2.4 – Rectangular Weir[4]

Exercise/Activity

If we have a 2 ft rectangular weir without end contractions and the depth is 0.33 feet, what is the flow? Use Appendix D - ISCO Table 11-3.

Flume

A **Flume** is a *specially shaped open channel* flow section that restricts the channel area and/or changes the channel slope, resulting in an increased velocity and a change in the level of the liquid flowing through the flume.

- A flume should have enough velocity so that solids do not accumulate in the primary hydraulic control element. Flumes have a greater resistance to accumulation of solids than weirs.

Parshall Flume

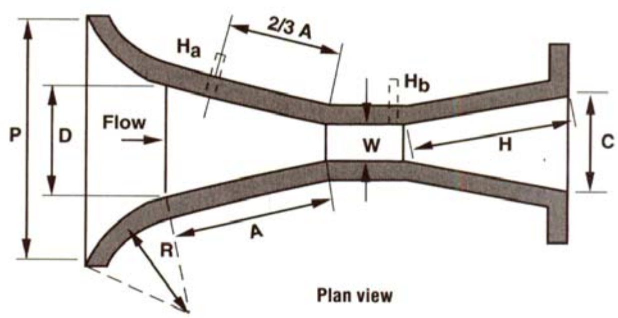


Figure 2.5 – Parshall Flume[5]

- Originally developed for monitoring irrigation flows.
- Can be formed from many different materials.
- Commonly installed in wastewater treatment plants for flow monitoring. It is characterized by:
  - Accurate results.
  - Low maintenance.
- Because the channel is rectangular and a head drop of at least 70 mm is required for free flow, it is difficult to install a Parshall flume into existing sewers.
- The Parshall flume has a range of flow variations of about 20 to 1.

Palmer-Bowlus Flume

- Commonly used in the retro-fit of a manhole to create a metering manhole.
- The shape is similar to a round pipe but it has either a slightly narrowed channel wall or a slightly raised floor.

Trapezoidal Flume

- Very few clogging problems.
- Wide range of capability, especially accurate at low flows.

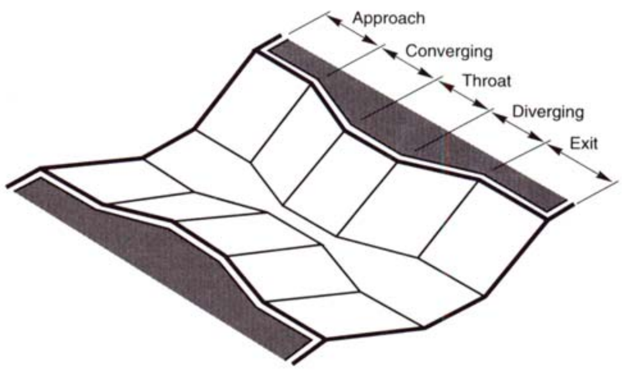


Figure 2.6 – Elements of a Trapezoidal Supercritical Flow Flume[6]

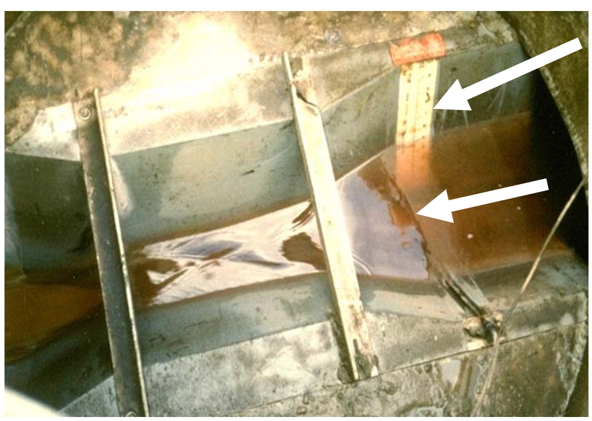


Figure 2.7 – Trapezoidal Flume[7]

Weirs vs. Flumes

Advantages	Disadvantages
Weirs • Low cost • Easy to install	**Weirs** • High head loss • Periodic cleaning • Not suitable for flows with solids • Accuracy affected by excessive approach velocities
Flumes • Self cleaning • Lower head loss • Accuracy less affected by approach velocity than a weir	**Flumes** • High cost • Difficult to install

Quick Comparison	
1' Rectangular Weir with end contractions (ISCO Flow Handbook) • 128.4 GPM = 0.20' H • 475.7 GPM = 0.50' H	1' Parshall Flume (ISCO Flow Handbook) • 53.96 GPM = 0.10' H • 7,240 GPM = 2.50' H

Measuring Devices

Measuring devices can be used to determine depth or velocity. In open channels, the measuring device determines the depth of flow within the primary hydraulic control element. The device is measuring the depth of flow from some fixed reference point. For example, from the bottom of the channel.

Depth

- To obtain accurate readings, it is important to measure the depth of flow at the specified measuring point.

Bubbler System

- Depth measurement is based on the amount of back pressure. The pressure required to force air through the system determines the depth measurement.

Advantages of Bubblers	Disadvantages of Bubblers
• Suitable for small channels • Not affected by wind, steam, foam, turbulence, temperature, lightning • Only bubble tube contacts flow • Very accurate • Maintains level calibration (can be 10 times more accurate than an ultrasonic)	• Plugging • Greater power consumption • Desiccant maintenance

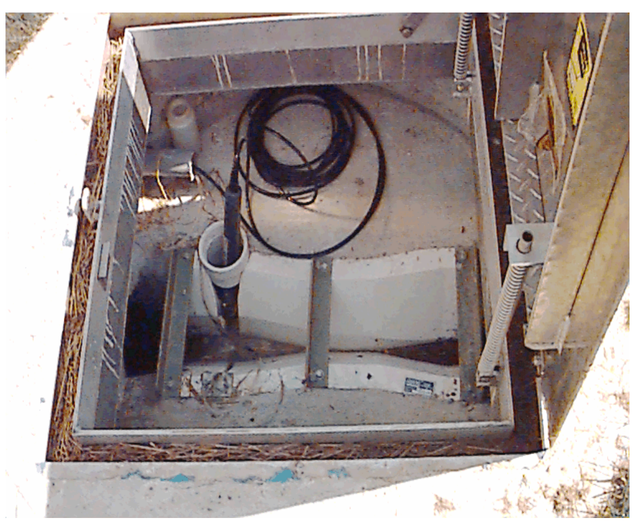


Figure 2.8 – Typical Bubbler Installation[8]

Ultrasonic

- Sends out an electronic beam that reflects off the water surface and back to a sensor. This checks the water level; it does **not** measure a change in velocity like a Doppler meter on a closed pipe.

Advantages of Ultrasonics	Disadvantages of Ultrasonics
• Non-contact sensing • Easy to install • Maintenance free • No contact with chemicals in stream • Not affected by grit and dirt on the bottom	• Surface foam and turbulence can cause false signals

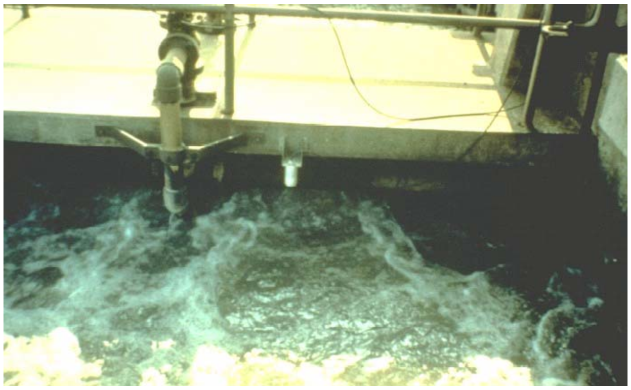


Figure 2.9 – Turbulence[9]

A reflector plate may be used on an ultrasonic meter for two different purposes:

- It keeps the sensor above the water level and can protect it if the manhole surcharges.
- A more common use is when high humidity is a problem and moisture could condense on the lens of the sensor. For example, metering flow from an industry where the wastewater has an elevated temperature.

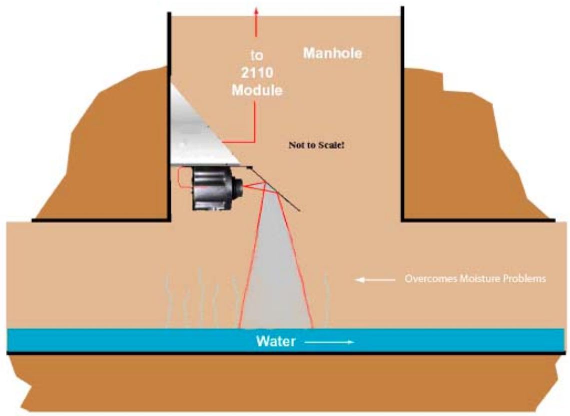


Figure 2.10 – Horizontal Reflector Plate Mount "Wall Mount"[10]

Submerged Pressure Transducer

- ▶ Since the sensor is located on the bottom of the channel, it is good for flows where winds, steam, or foam exist.

Advantages of Submerged Pressure Transducers	Disadvantages of Submerged Pressure Transducers
• Suitable for small channels • Not affected by wind, steam, foam, or turbulence • Senses pressure through silt and sand	• Flow stream chemicals can damage the sensor • Flowing debris can foul the sensor • Changing flow stream temperatures can affect sensor readings • Lightning can damage the sensor

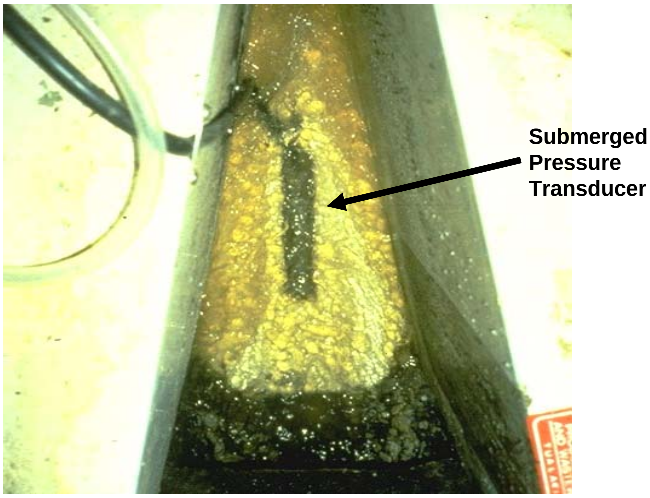


Figure 2.11 – Submerged Pressure Transducer in Flume[11]

Float

- When using a float, depth is normally measured by using a stilling well that is connected to the side of the nozzle.

- It is highly desirable to keep the float out of the flow stream so that it does not collect rags or affect the flow pattern.

Advantages of Floats	Disadvantages of Floats
• Simple to install • Easy to understand where levels activate the control system • Inexpensive	• Grease or other debris can accumulate on floats and cause problems • In a turbulent wet well, floats can become tangled • Take up more space in a wet well than other control systems

Portable Meter

Portable meters are small, compact, self-contained flowmeters used in remote locations; or they are used for spot-checking flows.

- Portable meters have a self-contained power supply but may still use the same technology as permanent meters. Because of this, most portable meters will check the flow rate at a programmed time interval.

- Instantaneous types are often inserted into a pipeline when performing spot-check flowmetering studies.

Advantages of Portables	Disadvantages of Portables
• Useful for spot-checking a flow • Used where electric power may not be available • Some new meters are having a solar panel option that is mounted on a nearby utility pole, to decrease battery maintenance • New telemetering technology options allow for wireless communication in certain circumstances • Useful for sewer flow studies for Act 537 plan update, infiltration/inflow analysis, determination of capacity in sewer line for future flows • Initial capital cost may be $3,000 to $10,000 depending on selected options • Some portable meters have an option to interface with a portable sampler	• Battery life is dependent on the time interval the flow is checked • Operator must be fully aware of hydraulic conditions and ensure acceptable conditions • Operator must program meter for each application • Normally, the operator must go to the location and download the data • Ongoing expense/requirement for battery charging or replacement

Velocity

- In addition to measuring depth, some measuring devices are used to measure flow velocity in an open channel.

Area Velocity

- Used where submerged, surcharged, or full pipe conditions exist.

Figure 2.12 – Area Velocity Meter[12]

Flow Measuring Components

Primary Hydraulic Control Element

- The **pipe** controls the hydraulic conditions.
- The **pipe material** affects the hydraulic conditions inside the pipe.

Measuring Device

- Measuring devices for closed pipes measure velocity.
- There are various types of flowmeters used on closed pipes:
  - Ultrasonic.
  - Doppler.
  - Transit-Time.
  - Magnetic.
- The measuring devices must be selected and calibrated for the type of pipe as well as other factors.
- Measuring devices for closed pipes are covered in more detail in the Advanced Flowmeters course.

Installation Considerations

Because closed pipes are pressurized, there are more installation options available than there are for open channels which rely solely on gravity.

Orientation

- **Vertical Orientation**—An example location is a pumping station force main.
- **Horizontal Orientation**—There is an increased chance of sediment accumulation in the pipe.

Separation Distances

- Separation distance is necessary to have proper flow through the meter.

  This means no valves, elbows, or tees near the meter.

- Depends on specific requirements for each meter, but typically requires straight pipe runs of 10 D upstream and 5 D downstream of the meter (D = diameter of pipe). If in doubt, increase the distance between the meter and valves, elbows, or tees.

Calculation

If we have a pipe of 4 inch diameter, using the separation distance guidelines, what is the absolute minimum distance of straight pipe that is needed (excluding the width of the meter)?

Calculation

Look at Appendix D and use Table 9-5 (90 degree V-notch weir). Compare how ½ inch makes a difference in flow reading. Compare 6 inch (0.50 feet) with 6.5 inch (0.54 feet).

[1] Courtesy of Isco, Inc.

[2] Douglas M. Grant and Brian D. Dawson, *ISCO Open Channel Flow Measurement Handbook,* Fifth Edition, (P.O. Box 82531, Lincoln, NE 68501-2531, 2001), p. 27.

[3] Douglas M. Grant, p. 35.

[4] Courtesy of Isco, Inc.

[5] Douglas M. Grant, p. 67.

[6] Douglas M. Grant, page 97.

[7] Courtesy of Isco, Inc.

[8] Courtesy of Isco, Inc.

[9] Courtesy of Isco, Inc.

[10] Courtesy of Isco, Inc.

[11] Courtesy of Isco, Inc.

[12] AmericanSigma.com. Sigma 910 Area Velocity Flowmeter. Retrieved on February 8, 2005, from http://www.americansigma.com/products/910flowmeter.cfm.

Unit 3 – Calibration

Learning Objectives

- List two flowmeter calibration techniques.
- Describe how to identify the correct location for a sensor.
- Discuss two techniques for calibrating a flowmeter using measured volume.
- Calculate known volumes for comparison to meter readings.

Calibration of a flowmeter ensures that it is providing accurate data. Having a flowmeter that is not calibrated can be worse than not having a flowmeter installed at all. Using incorrect data from a flowmeter can lead to incorrect assumptions, more expensive operations, and possibly personal injury.

- Calibration on process control meters should be done at least annually.
- Larger facilities should calibrate their meters at least annually, if not more often.
- Meters used to generate reports for regulatory agencies may be calibrated annually, if not more often, as a requirement.
- For open channels, the depth of flow at the correct location on a primary hydraulic control element can be used to verify a flowmeter by comparing the measurement with a look-up table.

Open Channel

- Clean the area before calibration.
  - Clean the walls of any algae.
  - Verify there is no sediment on the bottom.
  - Check for spider webs that may interfere with the signal.
- Verify that it is an open channel installation (i.e. pipe not flowing full).

Closed Pipe

- If the system has been designed properly, the only site condition of concern is to verify the pipe is always full.

Open Pipe or Channel

- The sensor point is critical to proper measurement.
  - All weirs and flumes have a designated point that is used to determine head differential in associated hydraulic conditions in the primary control element section (weir or flume).
  - Each hydraulic control element has its designated point for measurement. That point is dependent not only on the type of control element but also the size.
  - The figure below shows the head measurement point. This is the location where depth of flow is determined for a weir type application.

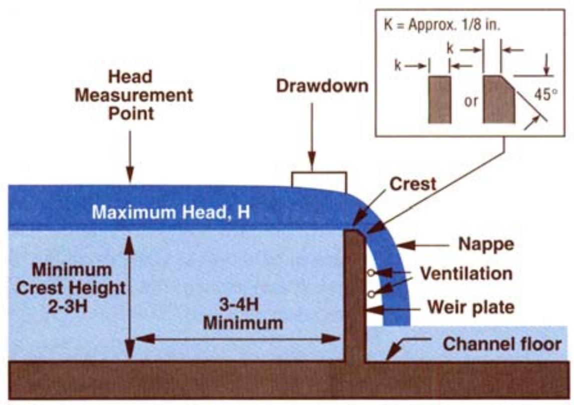


Figure 3.1 – Sharp-Crested Weir[1]

  - The figure below shows the location where flow is measured for a Parshall Flume (H_a).

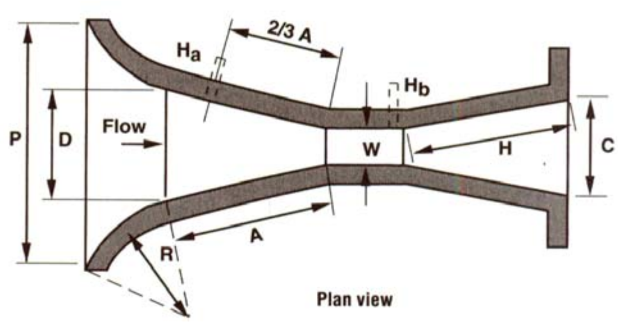


Figure 3.2 – Parshall Flume[2]

Closed Pipe

- Each manufacturer will specify where and how the sensor is to be located.
- Some sensors must be installed with a specific orientation to the pipe.
- Once installed properly, the location and orientation of the sensor should not be altered.
- Once the sensor is installed properly and working, the downstream or upstream conditions must not be altered.

Open Channels

- Vary the flow through the flowmeter and measure with a device that is more accurate than the flowmeter itself.
- Distribute a known volume of liquid through the channel.
- Have an electronic calibration procedure performed by a qualified instrumentation company on-site.
- Use a ruler to measure the depth of flow at the proper location.

Closed Pipes

- Vary the flow through the flowmeter and measure with a device that is more accurate than the flowmeter itself.
- Distribute a known volume of liquid through the pipe.
- Have an electronic calibration procedure performed by a qualified instrumentation company on-site.
- In extreme cases, remove and return the meter to the factory for calibration.

Measured Volume

The following two calibration options can be used for open channels or closed pipes.

Bucket and Stopwatch Method

- There may be locations or situations when flowmetering is not provided but it is desirable to know the flow rate. An example may be a chemical feed system. It is possible to use a stopwatch to time how long it takes to fill either a 1 gallon or 5 gallon bucket.
- This assumes the flow rate is not large and you can safely access the discharge point. It is best if 2 people do this to prevent problems. If the flow rates are very large, you would use a much larger receptor for the liquid being pumped, such as a 55 gallon drum, liquid sludge tanker, or treatment unit such as primary clarifier.

    1. You should not alter the flow rate during the test.

2. If anything besides water is being pumped or measured, take necessary safety precautions for the substance, such as goggles and gloves.

3. One person starts the stopwatch as the other person places the bucket under the discharge point. Be careful because a 5 gallon bucket filled with water will weigh about 42 pounds. If you are using another chemical such as alum or sodium hypochlorite, it will weigh more because of its density. You may want to tie a rope to the bucket to prevent dropping it into a tank.

4. As the bucket is filled, the second person stops the watch and records the time in seconds.

5. It is desirable to perform the test about three times and average the results.

6. The average results are then divided into the volume of 5 gallons, which yields an answer in gallons per second. Multiply by 60 seconds to convert to gallons per minute. Multiply gallons per minute by 60 minutes to convert to gallons per hour. Multiply gallons per hour by 24 hours to convert to gallons per day. Or reference the table in Appendix B (we only provided in five second increments up to 3 minutes).

7. If the flow is very low, you may want to use a 1 gallon bucket; however, the larger the volume, the more accurate the results. Perform the necessary calculations to convert to gallons per day.

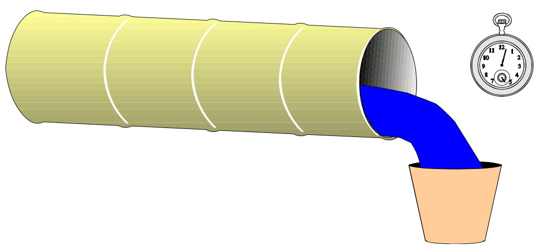


Figure 3.3 – Bucket and Stopwatch[3]

Discharge Into a Known Size Tank (Tanker, WWTP Tank)

- This calibration test requires discharge into a tank of known volume (the size of the tank must be known).
- Recording of the elapsed time is critical.
- Hydraulic characteristics cannot be altered for the test.
- Record the time it takes to fill the tank.
- Perform the necessary calculations to convert to gallons per day.

Weirs

- Flowmeter readings from weirs are based on depth of flow. These readings are not taken directly at the weir.
  - The depth of the flow is either used in a lookup table or put into a formula that has a variable for such factors as shape of weir, size, or with or without end contractions.
  - Use of a lookup table is easier than using the formulas.
- The shape and size of the weir is critical to determining accuracy limits.
  - V-Notch—to identify which table to use to look up accuracy limits, the shape of the weir must be known.
  - Rectangular is the most common weir in use—to identify which table to use to look up accuracy limits, the length of the weir must be known. It is also important to know the shape of the upstream channel, and if it is with or without end contractions.
  - Cipolletti—to identify which table to use to look up accuracy limits, the shape of the weir must be known.

☑ Exercise/Activity

1. We want to meter the effluent flow from a small wastewater treatment system that serves the community of King Village of approximately 200 homes. It is assumed that each home uses approximately 250 gpd, for a total daily flow of approximately 50,000 gpd. The discharge is temporary stored within the system and discharged with a pump during a 12 hour period instead of continuously over a 24 hour period. Use Appendix D and look at tables 9-1 through 9-5 to select a V-notch weir which would be appropriate and state why. Do not allow more than a maximum of 1 foot of head over the weir.

2. Having taken this course, a WWTP operator measured the following depths at the proper location upstream of a 1 foot rectangular weir without end contractions. What are the flows? Use Appendix D - ISCO Table 11-1.

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm)	Reading (mgd)
2.40	0.200		
2.52	0.210		
2.76	0.230		
3.00	0.250		
3.60	0.300		
4.32	0.360		
4.92	0.410		

Flumes

- The shape and size of a flume is critical to determining accuracy limits.
- The following equation is for single point measurement of a Parshall Flume.

Table 3.1 – Rate of Flow Equation for a Single Point Measurement of a Parshall Flume

For widths less than ½ foot	$Q = 4.12\ H^{1.58}$
	Q = rate of flow in cubic feet per second L = width of throat in feet H = head in feet at designated point in flume

☑ Exercise/Activity

The WWTP staff was able to measure the depth of the flow in a 6 inch Parshall flume at Ha with good accuracy and they determined the following depths. What are the flows? Should an instrumentation person be contacted to inspect the flume?

Measured Depth (inches)	Calculated Depth (feet)	Reading (gpm) See ISCO Table 13-4
1.2	0.10	
3	0.25	
4.5	0.38	
6	0.50	
7.5	0.62	

[1] Douglas M. Grant and Brian D. Dawson, *ISCO Open Channel Flow Measurement Handbook,* Fifth Edition, (P.O. Box 82531, Lincoln, NE 68501-2531, 2001), p. 27.

[2] Douglas M. Grant, p. 67.

[3] Courtesy of American Sigma.

Unit 4 – Maintenance

Learning Objectives

- Name two considerations for sensor maintenance.
- List three site conditions that affect the performance of a flowmeter.
- Discuss two maintenance considerations for portable flowmeters.

To properly maintain sensors, it is important to:

- Avoid excessively abrasive cleaning agents.
- Follow the manufacturer's guidelines.
- Determine if sensor maintenance is needed on closed pipes.
- Ensure conditions inside the pipe are suitable.
    - Pig the line if unusual encrustaceans exist.
    - Flush the line if solids build up.

There are several site conditions that affect the performance of a flowmeter:

- Humidity
  - Humidity control is critical for bubbler type systems. These systems need the air tank purged on a regular schedule. Purging should be more frequent in the summer because the air has a higher moisture content.
- Solids deposition
  - It is important to clean a V-notch weir on a regular basis to remove algae and debris.
- Foaming problems
  - Foam can cause incorrect readings, especially if the sensor is becoming fouled. Periodically ensure that foam levels are acceptable and sensors are clean.
- Primary hydraulic control element—is it level?
  - It is critical that the weir or flume be level and perpendicular to the flow.

☑ Exercise/Activity

What potential problem exists in this picture? Which types of sensors would this problem affect?

Figure 4.1 – Potential Problem?[1]

Considerations

Portable flowmeters serve a number of purposes in a variety of settings. Below are some portable flowmeter considerations:

- Portable flowmeters tend to require more maintenance because they are generally installed in less than ideal conditions.
- It is important to store portable flowmeters in a clean and dry environment. Storing portable flowmeters in the corner of a dirty garage as an example, will allow dust to enter the control panels and otherwise adversely affect the life of the unit.
- Batteries play an important role in the operation of portable flowmeters, and in some cases, an internal battery may be a part of a permanent unit. Be sure to replace batteries with the correct type.

[1] Courtesy of Isco, Inc.

Unit 5 – Problems/Troubleshooting

Learning Objectives

- Name two ways a sensor can become fouled.
- List three post-installation problems inside the pipe that create meter inaccuracies.
- Describe three common problems associated with the use of a V-notched weir.

Improper Initial Flow Estimates

Improper Initial Flow Estimates

- When selecting a flowmeter, it is important to consider the estimated minimum, average, and maximum flow rates to ensure the correct meter is utilized.

☑ Exercise/Activity

Assume a 120 degree v-notch weir, with an average flow of 500 gpm. After initial operation, it was recognized that the flow could range from 20 gpm to 900 gpm. Is there a better v-notch weir for this application? Use Appendix D - ISCO Tables 9-3, 9-5, and 9-6.

Sensor Fouling

Sensor fouling can negatively impact the operation of a flowmeter.

- Open channels provide easy access to most sensors.
    - Silt can build up in front of the sensor. Periodically remove the sensor to allow solids to be flushed out.
    - Rags can accumulate and shield the sensor.
    - During high flows, the sensor may become dislodged and flushed down the pipe.
- If you have an ultrasonic meter that is suspended over a flume or a weir, check to make sure that spider webs have not accumulated in the cone.

Power Source

All flowmeters require a dependable power source.

- If the flowmeter is dependent on batteries, replace the batteries within the recommended timeframe.

Other Common Problems

There are various problems that can develop after a flowmeter has been installed.

- Encrustation in a pipe
  - If encrustation develops inside a pipe, the encrustation should be removed. Encrustation can be removed physically or chemically.
  - When removing encrustation, care must be taken to avoid damaging the flowmeter.
- Sedimentation/silt
  - If sedimentation or silt develops, flush the line with clear flow.
  - If a v-notch weir is being used, remove the v-notch weir to flush solids out of the channel.
- Temperature fluctuations
  - If temperature changes are frequent or extreme, it may adversely affect accuracy.
- Poor housekeeping
  - It is important to maintain the area around the flowmeter. Consider the following picture. The evidence of surcharging by debris on top of the nozzle, plus the amount of debris in the grating does not give a high degree of confidence that this meter is being properly maintained.

Figure 5.1 – Evidence of Surcharging by Debris on Top of the Nozzle

- Poor installation
  - Misaligned pipe
  - Accumulation of rags on the cable leading to the sensor

Figure 5.2 – Improper Installation[1]

- Common portable flowmeter problems:
  - Debris accumulation—It is important to remove any debris that accumulates a few feet upstream of the weir or at the sensor.
  - Loss of power—Check the batteries or electrical connection.
  - Data loss—Download data on a regular basis to avoid filling the memory.

- Common v-notch weir problems:
  - Debris clogging the v-notch—Remove debris from the weir or clean away the debris with a soft brush.
  - Weir has been damaged—Purchase a replacement. The weir may be cracked.
  - Weir orientation is damaged—The weir must be level and perpendicular to the flow.

[1] Courtesy of American Sigma.

Appendices

Appendix A	PADEP Chapter 94 – Municipal Wasteload Management
Appendix B	Bucket and Stopwatch Method
Appendix C	Average Flow Chart
Appendix D	ISCO Figures and Tables

[PA] [WAT094] 094 - Municipal Wasteload Management

25 - ENVIRONMENTAL PROTECTION

PART I - DEPARTMENT OF ENVIRONMENTAL PROTECTION

SUBPART C - PROTECTION OF NATURAL RESOURCES

ARTICLE II - WATER RESOURCES

CHAPTER 94 - MUNICIPAL WASTELOAD MANAGEMENT

November 21, 1977
Last Amended: Effective September 5, 1998

GENERAL PROVISIONS

Section 94.1. Definitions.

The following words and terms, when used in this chapter, have the following meanings, unless the context clearly indicates otherwise:

Average daily organic load - The arithmetic mean of all samples of 5-day Biochemical Oxygen Demand, expressed in terms of pounds per day, collected over a calendar month.

Ban - A restriction placed by the Department on additional connections to an overloaded sewer system or a sewer system tributary to an overloaded plant and other necessary measures the Department may require to prevent or alleviate an actual organic or hydraulic overload or an increase in an organic or hydraulic overload.

Bypass - The intentional diversion of wastewater either at or after the headworks of the plant.

CAP - Corrective action plan - A plan and schedule developed by the permittee of a sewerage facility which has an existing or projected overload. A CAP establishes actions existing or projected overload. A CAP establishes actions needed and a schedule to reduce the overload and provide needed capacity.

CSO - Combined sewer overflow - An intermittent overflow, or other untreated discharge from a municipal combined sewer system (indicating domestic, industrial and commercial wastewater and stormwater) which results from a flow in excess of the dry weather carrying capacity of the system.

Capacity - The rated ability of the plant to receive and effectively treat a specified load. When the term is used in reference to a pump station or sewer system, the term refers to the rated ability to effectively convey a specified load.

Clean Water Act - 33 U.S.C.A. Sections 1251, 1252, 1254 - 1256, 1259, 1262, 1263, 1281 - 1288, 1291, 1292, 1294 - 1297, 1311, 1314, 1315, 1317 - 1319, 1321 - 1324, 1328, 1341, 1342, 1344, 1345, 1362, 1364, 1375 and 1376.

Combined sewer system - A sewer system which has been designed to serve as both a sanitary sewer and a storm sewer.

Connection - The connection of a structure which generates or could generate hydraulic or organic loads to a sewer system.

Discharge - Wastewater flow which is or would be discharged to a sewer system.

Exception to a ban - An allowable connection to a sewer system even though a ban is in effect.

Extension - An addition to the sewer system to accommodate more than one connection.

Facilities of public need - Hospitals, health clinics, nursing care facilities, primary and secondary education facilities, fire and police stations and correctional institutions.

Headworks - For the purposes of this chapter, the first treatment unit or wetwell within the plant.

Hydraulic design capacity - The maximum monthly design flow, expressed in millions of gallons per day, at which a plant is expected to consistently provide the required treatment or at which a conveyance structure, device or pipe is expected to properly function without creating a backup, surcharge or overflow. This capacity is specified in the water quality management permit (Part II permit issued under Chapter 91) (relating to general provisions).

Hydraulic overload - The condition that occurs when the monthly average flow entering a plant exceeds the hydraulic design capacity for 3-consecutive months out of the preceding 12 months or when the flow in a portion of the sewer system exceeds its hydraulic carrying capacity.

Industrial user - An establishment which discharges or introduces industrial wastes into a sewerage facility.

Interference - A discharge which, alone or in conjunction with a discharge from other sources, does the following:

(i) Inhibits or disrupts the sewerage facility, its treatment processes or operations or its sludge processes, use or disposal.

(ii) Is a cause of a violation of a requirement of the sewerage facility's NPDES permit - including an increase in the magnitude or duration of a violation - or of the prevention of sewage sludge use or disposal in compliance with the following statutory provisions and regulations or permits issued thereunder - or more stringent State or local regulations:

(A) Section 405 of the Clean Water Act (33 U.S.C.A. Section 1345).

(B) The Solid Waste Disposal Act (SWDA) (42 U.S.C.A. Sections 6901 - 6987), including Title II, more commonly referred to as the Resource Conservation and Recovery Act of 1976 (RCRA).

(C) State regulations contained in a State sludge management plan prepared under Subtitle D of the SWDA, the Clean Air Act (42 U.S.C.A. Sections 7401 - 7642, the Toxic Substances Control Act (15 U.S.C.A. Sections 2601 - 2629) and the Marine Protection, Research, and Sanctuaries Act of 1972 (16 U.S.C.A. Sections 1431 - 1434; 33 U.S.C.A. Sections 1401, 1402, 1411 - 1421 and 1441 - 1445).

Load - The rate of flow and organic strength of the wastewater, including infiltration, discharged to a plant, as measured at the influent of the plant or in the sewer system or a portion of it.

Monthly average flow - The total flow received at a sewerage facility or another portion of the sewer system during any 1-calendar month divided by the number of days in that month. This value is always expressed in millions of gallons per day (mgd).

Monthly average organic loading - The total organic load received at a plant during any 1 calendar month divided by the number of days in that month. This value is expressed in pounds per day of biological oxygen demand after 5 days (BOD5).

NPDES permit - A permit or equivalent document or requirements issued by the EPA, or, if appropriate, by the Department, to regulate the discharge of pollutants under section 402 of the Clean Water Act 33 U.S.C.A. Section 1342).

Official plan - A comprehensive plan for the provision of adequate sewage systems adopted by a municipality possessing authority or jurisdiction over the provision of the systems and submitted to and approved by the Department as provided by the Pennsylvania Sewage Facilities Act (35 P.S. Sections 750.1-750.20) and Chapter 71 (relating to administration of sewage facilities planning program).

Organic design capacity - The highest daily organic load at which a sewage treatment facility or a portion thereof is expected to provide a specific predetermined level of treatment. This capacity is normally specified in the water quality management permit (Part II permit issued under Chapter 91).

Organic overload - The condition that occurs when the average daily organic load exceeds the organic design capacity upon which the permit and the plant design are based.

PPP - Pollution Prevention Plan - A written document that guides a discharger in the reduction of pollutants at their source before they reach the wastewater treatment plant. The PPP shall, at a minimum, address the following elements:

(i) An explicit statement of top management support for implementation of the pollution prevention plan.

(ii) A process characterization that identifies and characterizes the input of raw materials, outflow of products and generation of wastes.

(iii) An estimate of the amount of each waste generated.

(iv) Development of pollution prevention alternatives based on an estimate of reductions in the amount and toxicity of waste from each pollution prevention activity.

(v) An identification of pollution prevention opportunities to be implemented and an implementation timetable with interim and final milestones and periodic review of implemented recommendations.

Pass through - A discharge which exits the plant into waters of this Commonwealth in quantities or concentrations which, alone or in conjunction with a discharge from other sources, is a cause of a violation of a requirement of the plant's NPDES permit - including an increase in the magnitude or duration of a violation.

Permit - A permit required by section 202 or 207 of the act (35 P.S. Sections 691.202 and 691.207).

Permittee - A person who possesses or is required to possess a permit.

Plant - Devices, systems or other works installed for the purpose of treating, recycling or disposing of sewage.

Pollution prevention - Source reduction and other practices - for example: direct reuse or in-process recycling - that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials, energy, water or other resources, or protection of natural resources by conservation.

Pretreatment - The reduction of the amount of pollutants, the elimination of pollutants or the alteration of the nature of pollutant properties in wastewater prior to or in lieu of discharging or otherwise introducing the pollutants into a sewerage facility.

Pretreatment program - A program administered by a sewerage facility that has been approved by the EPA under 40 CFR 403.11 (relating to approval procedures for pretreatment programs and granting of removal credits).

Prohibition - A restriction placed by a permittee on additional connections to an overloaded sewer system or a sewer system tributary to an overloaded plant.

Sanitary sewer overflow - An intermittent overflow of wastewater, or other untreated discharge from a separate sanitary sewer system (which is not a combined sewer system), which results from a flow in excess of the carrying capacity of the system or from some other cause prior to reaching the headworks of the plant.

Separate sanitary sewer system - A sewer system or part thereof which is specifically designed and intended to carry sanitary sewage separate from stormwater as specified in the permit.

Sewerage facilities - The term used to collectively describe a plant and sewer system owned by or serving a municipality.

Sewer system - The pipelines or conduits, pumping stations and force mains, and other appurtenant constructions, devices and facilities used for conveying sewage to a plant.

(b) A word or phrase which is not defined in this chapter but which is defined in Chapter 92 (relating to National Pollutant Discharge Elimination System) has the meaning as defined therein.

Section 94.2. Purpose.

This chapter is intended to prevent unpermitted and insufficiently treated wastewater from entering waters of this Commonwealth by requiring the owners and operators of sewerage facilities to project, plan and manage future hydraulic, organic and industrial waste loadings to their sewerage facilities. Reductions in wastewater volume and pollutant mass loadings through the application of pollution prevention practices are encouraged to avoid hydraulic, organic and industrial wastewater overloads at sewerage facilities to accomplish the following objectives:

(1) Prevent the occurrence of overloaded sewerage facilities.

(2) Limit additional extensions and connections to an overloaded sewer system or a sewer system tributary to an overloaded plan.

(3) Improve opportunities to prevent or reduce the volume and toxicity of industrial wastes generated and discharged to sewerage facilities and where prevention and reduction opportunities have been maximized, and to recycle and reuse municipal and industrial wastewaters and sludges.

Section 94.3. Scope.

This chapter requires owners of sewerage facilities to properly plan, manage and maintain sewerage facilities in a manner which will do the following:

(1) Anticipate and prevent overloading sewerage facilities.

(2) Limit additional extensions and connections to an overloaded sewer system or a sewer system tributary to an overloaded plant.

(3) Prevent the introduction into sewerage facilities of pollutants which will interfere with the operation of the plant or pass through or otherwise be incompatible with the treatment process or sewerage facility.

(4) Improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

GENERAL REQUIREMENTS

Section 94.11. Sewer extensions.

(a) A sewer extension may not be constructed if the additional flows contributed to the sewerage facilities from the extension will cause the plant, pump stations or other portions of the sewer system to become overloaded or if the flows will add to an existing overload unless the extension is in accordance with an approved CAP submitted under Section 94.21 or Section 94.22 (relating to existing overload; and projected overload) or unless the extension is approved under Section 94.54 (relating to sewer line extension).

(b) The Department may issue a permit for the construction of a capped sewer, which would be tributary to an overloaded sewerage facility where the capped sewer would not be placed into service until adequate conveyance and treatment capacity becomes available under all of the following conditions:

(1) The proposed project is consistent with the approved official plan of the municipality.

(2) The municipality or municipal authority which owns the sewer system to which the capped sewer would connect has an approved program for providing adequate conveyance and treatment capacity within 5 years of the date of issuance of a capped sewer permit by the Department.

(3) Other Department requirements for sewer design and construction are met.

Section 94.12. Annual report.

(a) To provide for annual review of sewerage facilities and ensure that there is sufficient time to address existing operational or maintenance problems or to plan and construct needed additions, plant permittees shall submit a complete and accurate wasteload management annual report, in duplicate, by March 31 of each year to the appropriate regional office of the Department. The report shall be signed by the preparer and by the permittee of the plant and include the following:

(1) A line graph depicting the monthly average flows (expressed in millions of gallons per day) for each month for the past 5 years and projecting the flows for the next 5 years. The graph shall also include a line depicting the hydraulic design flow (also expressed in millions of gallons per day) of the plant included in the water quality management permit (Part II permit issued under Chapter 91 (relating to general provisions)).

(2) A line graph depicting the monthly average organic loading (expressed as pounds per day of BOD5) for each month for the past 5 years and projecting the monthly average organic loading for the next 5 years. The graph shall also include a line depicting the organic loading design (also expressed in pounds per day of BOD5) of the plant included in the water quality management permit (Part II permit issued under Chapter 91).

(3) A brief discussion of the basis for the projections referred to in paragraphs (1) and (2), as well as a description of the time needed to expand the plant to meet the load projections, if necessary. Data used to support those projections should be included in an appendix to the annual report.

(4) A map showing all sewer extensions constructed within the past calendar year, sewer extensions approved or exempted in the past year in accordance with the Pennsylvania Sewage Facilities Act (35 P.S. Sections 750.1 - 750.20) and Chapter 71 (relating to administration of the sewage facilities program), but not yet constructed, and all known proposed projects which require public sewers but are in the preliminary planning stages. The map shall be accompanied by a list summarizing each extension or project and the population to be served by the extension or project. If a sewer extension approval or proposed project includes schedules describing how the project will be completed over time, the listing should include that information and the effect this build-out-rate will have on population served.

(5) A discussion of the permittee's program for sewer system monitoring, maintenance, repair and rehabilitation, including routine and special activities, personnel and equipment used, sampling frequency, quality assurance, data analyses, infiltration/inflow monitoring, and, where applicable, maintenance and control of combined sewer regulators during the past year.

(6) A discussion of the condition of the sewer system including portions of the system where conveyance capacity is being exceeded or will be exceeded in the next 5 years and portions where rehabilitation or cleaning is needed or is underway to maintain the integrity of the system and prevent or eliminate bypassing, combined sewer overflow, sanitary sewer overflow, excessive infiltration and other system problems.

(7) A discussion of the condition of sewage pumping stations, including a comparison of the maximum pumping rate with present maximum flows and the projected 2-year maximum flows for each station.

(8) A report, if applicable, of industrial wastes discharged into the sewer system. This report shall include the following:

(i) A copy of any ordinance or regulation governing industrial waste discharges to the sewer system or a copy of amendments adopted since the initial submission of the ordinance or regulation under this chapter, if it has not previously been submitted. Ordinances, regulations or fee structures may provide incentives to industrial waste dischargers to use pollution prevention techniques to reduce or eliminate the generation of industrial wastewater discharges to the sewer system.

(ii) A discussion of the permittee's or municipality's program for surveillance and monitoring of industrial waste discharges into the sewer system during the past year.

(iii) A discussion of specific problems in the sewer system or at the plant, known or suspected to be caused by industrial waste discharges and a summary of the steps being taken to alleviate or eliminate the problems. The discussion shall include a list of industries known to be discharging wastes which create problems in the plant or in the sewer system and action taken to eliminate the problem or prevent its recurrence. The report may describe pollution prevention techniques in the summary of steps taken to alleviate current problems caused by industrial waste dischargers and in actions taken to eliminate or prevent potential or recurring problems caused by industrial waste dischargers.

(9) A proposed plan to reduce or eliminate present or projected overloaded conditions under Sections 94.21 and 94.22 (relating to existing overload; and projected overload).

(b) Permittees of sewer systems which contribute sewage flows to the plant shall submit information to the permittee of the plant as required to facilitate preparation of the annual report.

Section 94.13. Measuring, indicating and recording devices.

(a) A plant which receives or will receive within the next 5 years, monthly average flows exceeding 100,000 gallons per day shall be equipped to continuously measure, indicate and record the flow. The permittee of the plant shall install equipment necessary for these measurements within 6 months after the date when such a flow becomes evident.

(b) Flow measuring, indicating and recording equipment shall be calibrated annually, and the calibration report shall be included in the annual report submitted under Section 94.12 (relating to annual report).

Section 94.14. Approval of official plans and revisions.

No official plan, official plan revision or supplement will be approved by the Department or delegated agency, nor will an exemption from the planning requirements be granted under Chapter 71 (relating to administration of the sewage facilities planning program) that is inconsistent with this chapter.

Section 94.15. Pretreatment program development.

In cases where pollutants contributed by industrial users result in interference or pass through, and the violation is likely to recur, a permittee shall develop and implement specific local limits for industrial users and other users, as appropriate, that together with appropriate sewerage facility or operational changes, are necessary to ensure renewed or continued compliance with the plant's NPDES permit or sludge use or disposal practices.

ACTION ON OVERLOAD FACILITIES

Section 94.21. Existing overload.

(a) If the annual report establishes or if the Department determines that the sewerage facilities or any portions thereof are either hydraulically or organically overloaded, the permittee of the sewerage facilities shall comply with the following program:

(1) Prohibit new connections to the overloaded sewerage facilities except as approved by the permittee under the standards for granting exceptions contained in Sections 94.55 - 94.57 (relating to building permit issued prior to ban; replacement of a discharge; and other exceptions). No building permit may be issued by a governmental entity which may result in a connection to overloaded sewerage facilities or increase the load to those sewerage facilities from an existing connection. The permittee shall retain records of exceptions granted and make the records available to the Department upon request.

(2) Immediately begin work for the planning, design, financing, construction and operation of the sewerage facilities that may be necessary to provide required capacities to meet anticipated demands for a reasonable time in the future and resulting in a project that is consistent with the applicable official plans approved under the Pennsylvania Sewage Facilities Act (35 P.S. Sections 750.1 - 750.20) and the regulations thereunder in Chapter 71 (relating to administration of the sewage facilities planning program) and consistent with the requirements of the Department and the Federal Government regarding areawide planning and sewerage facilities.

(3) Submit to the Regional Office, for the review and approval of the Department, a written CAP to be submitted with the annual report or within 90 days of notification of the Department's determination of overload, setting forth the actions to be taken to reduce the overload and to provide the needed additional capacity. The written CAP shall include, but not be limited, to limitations on and a program for control of new connections to the overloaded sewerage facilities and a schedule showing the dates each step toward compliance with paragraph (2) shall be completed.

(b) Upon receipt of an acceptable CAP submitted in accordance with subsection (a)(3), the Department may modify or lift the requirement to prohibit new connections and the issuance of building permits contained in subsection (a)(1). In determining whether the requirement to prohibit new connections shall be modified or lifted, the Department will consider the extent to which the permittee plans to limit new connections; the timing for provisions of additional capacity and reduction of the existing overload; and the impact of the overload on treatment plant effluent quality, water quality degradation and public health.

(c) The Department may approve permits for extensions to overloaded sewerage facilities when the following conditions are met:

(1) The proposed extension is consistent with an acceptable CAP submitted under subsection (a)(3).

(2) The proposed extension is consistent with the applicable official plan approved under the Pennsylvania Sewage Facilities Act and the regulations adopted thereunder at Chapter 71.

(3) The additional load from the proposed extension will not have a significant adverse impact on the water quality of the receiving waters.

(4) The proposed extension is in accordance with any other applicable requirement of this title.

(5) The connections to the extension are controlled in accordance with the CAP submitted in accordance with subsection (a)(3); provided that, no connections to extension may be allowed when the approved CAP is not being implemented in accordance with the schedule contained therein.

Section 94.22. Projected overload.

If the annual report shows or if the Department determines that the sewerage facilities or any portion thereof will, within the next 5 years, become hydraulically or organically overloaded, the permittee of the sewerage facilities shall comply with the following:

(1) Submit a report or CAP to the regional office, with the annual report or within 90 days of notification of the Department's determination, setting forth steps to be taken by the permittee to prevent the sewerage facilities from becoming hydraulically or organically overloaded. If the steps to be taken include planning, design, financing, construction and operation of sewerage facilities, the facilities shall be consistent with an official plan approved under the Pennsylvania Sewage Facilities Act (35 P. S. Sections 750.1 - 750.20) and the regulations thereunder in Chapter 71 (relating to administration of the sewage facilities planning program) and consistent with the requirements of the Department and the Federal government regarding areawide planning and sewerage facilities.

(2) Limit new connections to and extensions of the sewerage facilities based upon remaining available capacity under a plan submitted in accordance with this section.

IMPOSITION OF BAN

Section 94.31. Organic or hydraulic overload.

A ban on connections will be imposed by the Department whenever the Department determines that the sewerage facilities or any portion thereof are either hydraulically or organically overloaded or that the discharge from the plant causes actual or potential pollution of the waters of this Commonwealth and, in addition, that one or more of the following conditions prevail:

(1) The Department determines that a ban is necessary to prevent or alleviate endangerment of public health.

(2) The permittee has failed to submit a satisfactory plan or has failed to implement the program as required by Section 94.21 (relating to existing overload).

Section 94.32. Public health hazard or pollution.

A ban may be imposed by the Department whenever the Department finds that such a ban is needed in order to prevent or eliminate public health hazards or pollution resulting from violations of The Clean Streams Law (35 P. S. Sections 691.1 - 691.1001) not otherwise covered by the provisions of this chapter.

Section 94.33. Notice of ban.

(a) A ban imposed by order of the Department will be addressed to the person or municipality who authorizes connection to the sewer system and who operates the sewer system or plant. The ban shall be effective immediately upon receipt of the order imposing the ban.

(b) The Department will publish the order imposing the ban in one newspaper of general circulation in the area affected by the ban beginning no later than 48 hours after the imposition of the ban or as soon thereafter as publication schedules allow. The Department will publish the order imposing the ban, following imposition of the ban, once in the Pennsylvania Bulletin, provided, however, that failure or delay in so publishing by the Department shall not in any way affect the date of imposition or validity of the ban.

(c) The Department, at the time of imposition of the ban, will give notice of the ban to a governmental entity which issues building permits in the area of the ban. No building permit which may result in a connection to the overloaded sewerage facilities or increase the load to those sewerage facilities shall be issued by a governmental entity after the ban is effective; provided, however, that failure or delay in the notification will not, in any way, affect the date of imposition or validity of the ban.

BAN MODIFICATION OR REMOVAL

Section 94.41. Elimination of overload.

A ban may be removed by the Department, in the exercise of its discretion, in accordance with the following conditions:

(1) If the permittee has demonstrated that steps have been taken which have resulted in the reduction of the actual loading to the plant to less than the capacity provided in the permit or, in the case of a sewer system, to eliminate the hydraulic overload, the ban may be removed to allow connections up to capacity.

(2) If it is affirmatively demonstrated, through the submission by the permittee and approval by the Department of an application for an amendment to the permit, that the actual capacity of the plant is in excess of the capacity provided in the existing permit and is sufficient to prevent an overload until additional capacity is made available, the ban may be removed to allow connections up to the new capacity.

Section 94.42. Reduction of overload.

(a) The Department may modify a ban to allow limited approval of connections if the permittee demonstrates that steps have been taken which have resulted in the reduction but not the elimination of the overload, that public health will not be endangered, and that downstream uses will not be adversely affected; provided that the permittee adheres to an acceptable program and schedule for eliminating the overload.

(b) Priority shall be given to connections in the following order:

(1) The elimination of public health hazards.

(2) The elimination of pollution.

(3) The connection of facilities of public need.

Section 94.51. Request for exception.

Exceptions to bans shall be requested in writing from the Regional Office of the Department for the county in which the requested exception is located and shall state with specificity the reasons why such request should be granted. No exception shall be considered granted until the applicant is so advised in writing by the Department.

Section 94.52. Limitations on exception.

The exceptions to a ban described in Sections 94.55 - 94.57 (relating to building permit issued prior to ban; replacement of a discharge; and other exceptions) are to be strictly construed and are the only exceptions the Department will allow.

Section 94.53. Transfer of exception.

The exceptions to a ban described in Sections 94.55 - 94.57 (relating to building permit issued prior to ban; replacement of a discharge; and other exceptions) are not transferable; an owner granted an exception under this title cannot transfer his right to discharge under that exception to another person or to another location, except as such transfer will result from a sale or other transfer of property for which an exception has been granted prior to the sale or other transfer of property.

Section 94.54. Sewer line extension.

Exceptions to a ban are limited to those exceptions which do not require the extension of existing sewer lines, except as needed for the elimination of public health hazards or pollution or for facilities of public need.

Section 94.55. Building permit issued prior to ban.

A discharge which the Department determines will result from a structure for which a valid building permit had been issued within 1 year prior to the date of imposition of the ban shall constitute an exception to the ban.

Section 94.56. Replacement of a discharge.

A new source of discharge which replaces a source of discharge forever eliminated as a result of demolition, destruction, accident, act of God or act of government shall constitute an exception to the ban if the Department determines that the following conditions are met:

(1) The new source of discharge is contained in a structure on the same property as the source of discharge which it has replaced.

(2) The new source of discharge will not generate a greater volume of wastewater flow or organic content than the source of discharge it has replaced.

Section 94.57. Other exceptions.

Connections which are necessary to eliminate a public health hazard or which are necessary for the operation of a facility of public need as the term is defined in Section 94.1 (relating to definitions) shall constitute an exception to a ban.

Sections 94.61 - 94.64. [Reserved]

Use of Bucket and Stopwatch Method to Calculate Flow Rate

Bucket and stopwatch method

Assume use of a 5 gallon bucket					Assume use of a 1 gallon bucket				
Seconds	Gals/ sec	Gals/ min	Gals/ hr	Gals/ day	Seconds	Gals/ sec	Gals/ min	Gals/ hr	Gals/ day
5	1.000	60.0	3,600	86,400	5	0.200	12.0	720	17,280
10	0.500	30.0	1,800	43,200	10	0.100	6.0	360	8,640
15	0.333	20.0	1,200	28,800	15	0.067	4.0	240	5,760
20	0.250	15.0	900	21,600	20	0.050	3.0	180	4,320
25	0.200	12.0	720	17,280	25	0.040	2.4	144	3,456
30	0.167	10.0	600	14,400	30	0.033	2.0	120	2,880
35	0.143	8.6	514	12,343	35	0.029	1.7	103	2,469
40	0.125	7.5	450	10,800	40	0.025	1.5	90	2,160
45	0.111	6.7	400	9,600	45	0.022	1.3	80	1,920
50	0.100	6.0	360	8,640	50	0.020	1.2	72	1,728
55	0.091	5.5	327	7,855	55	0.018	1.1	65	1,571
60	0.083	5.0	300	7,200	60	0.017	1.0	60	1,440
65	0.077	4.6	277	6,646	65	0.015	0.9	55	1,329
70	0.071	4.3	257	6,171	70	0.014	0.9	51	1,234
75	0.067	4.0	240	5,760	75	0.013	0.8	48	1,152
80	0.063	3.8	225	5,400	80	0.013	0.8	45	1,080
85	0.059	3.5	212	5,082	85	0.012	0.7	42	1,016
90	0.056	3.3	200	4,800	90	0.011	0.7	40	960
95	0.053	3.2	189	4,547	95	0.011	0.6	38	909
100	0.050	3.0	180	4,320	100	0.010	0.6	36	864
105	0.048	2.9	171	4,114	105	0.010	0.6	34	823
110	0.045	2.7	164	3,927	110	0.009	0.5	33	785
120	0.042	2.5	150	3,600	120	0.008	0.5	30	720
125	0.040	2.4	144	3,456	125	0.008	0.5	29	691
130	0.038	2.3	138	3,323	130	0.008	0.5	28	665
135	0.037	2.2	133	3,200	135	0.007	0.4	27	640
140	0.036	2.1	129	3,086	140	0.007	0.4	26	617
145	0.034	2.1	124	2,979	145	0.007	0.4	25	596
150	0.033	2.0	120	2,880	150	0.007	0.4	24	576
155	0.032	1.9	116	2,787	155	0.006	0.4	23	557
160	0.031	1.9	113	2,700	160	0.006	0.4	23	540
165	0.030	1.8	109	2,618	165	0.006	0.4	22	524
170	0.029	1.8	106	2,541	170	0.006	0.4	21	508
175	0.029	1.7	103	2,469	175	0.006	0.3	21	494
180	0.028	1.7	100	2,400	180	0.006	0.3	20	480

Average Flow Chart

Commercial					
		Flowrate, gal/unit•d		Flowrate, L/unit•d	
Source	**Unit**	**Range**	**Typical**	**Range**	**Typical**
Airport	Passenger	3-5	4	11-19	15
Apartment	Bedroom	100-150	120	380-570	450
Automobile service station	Vehicle served	8-15	10	30-57	40
	Employee	9-15	13	34-57	50
Bar/cocktail lounge	Seat	12-25	20	45-95	80
	Employee	10-16	13	38-60	50
Boarding house	Person	25-65	45	95-250	170
Conference center	Person	6-10	8	40-60	30
Department store	Toilet room	350-600	400	1300-2300	1500
	Employee	8-15	10	30-57	40
Hotel	Guest	65-75	70	150-230	190
	Employee	8-15	10	30-57	40
Industrial building (sanitary waste only)	Employee	15-35	20	57-130	75
Laundry (self-service)	Machine	400-550	450	1500-2100	1700
	Customer	45-55	50	170-210	190
Mobile home park	Unit	125-150	140	470-570	530
Motel (with kitchen)	Guest	55-90	60	210-340	230
Motel (without kitchen)	Guest	50-75	55	190-290	210
Office	Employee	7-16	13	26-60	50
Public lavatory	User	3-5	4	11-19	15
Restaurant:					
Conventional	Customer	7-10	8	26-40	35
With bar/cocktail lounge	Customer	9-12	10	34-45	40
Shopping center	Employee	7-13	10	26-50	40
	Parking space	1-3	2	4-11	8
Theater	Seat	2-4	3	8-15	10

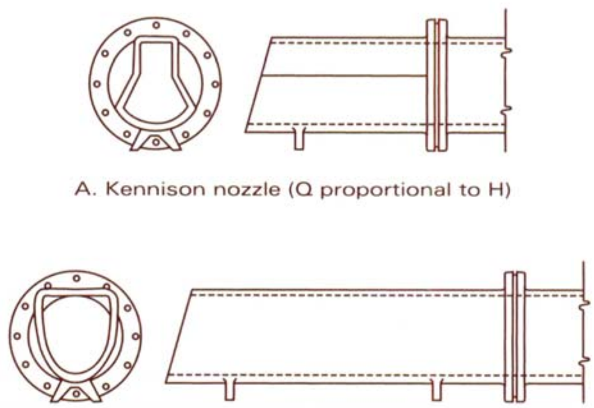
Institutional					
		Flowrate, gal/unit•d		Flowrate, L/unit•d	
Source	**Unit**	**Range**	**Typical**	**Range**	**Typical**
Assembly hall	Guest	3-5	4	11-19	15
Hospital	Bed	175-400	250	660-1500	1000
	Employee	5-15	10	20-60	40
Institutions other than hospitals	Bed	75-125	100	280-470	380
	Employee	5-15	10	20-60	40
Prison	Inmate	80-150	120	300-570	450
	Employee	5-15	10	20-60	40
School, day:					
With cafeteria, gym, and showers	Student	15-30	25	60-120	100
With cafeteria only	Student	10-20	15	40-80	60
School, boarding	Student	75-100	85	280-380	320

Recreational						
		Flowrate, gal/unit•d		Flowrate, L/unit•d		
Facility	**Unit**	**Range**	**Typical**	**Range**	**Typical**
Apartment, resort	Person	50-70	60	190-260	230
Cabin, resort	Person	8-50	40	30-190	150
Cafeteria	Customer	2-4	3	8-15	10
	Employee	8-12	10	30-45	40
Camp:					
With toilets only	Person	15-30	25	55-110	95
With central toilet and bath facilities	Person	35-50	45	130-190	170
Day	Person	15-20	15	55-76	60
Cottages, (seasonal with private bath)	Person	40-60	50	150-230	190
Country club	Member present	20-40	25	75-150	100
	Employee	10-15	13	38-57	50
Dining hall	Meal served	4-10	7	15-40	25
Dormitory, bunkhouse	Person	20-50	40	75-190	150
Fairground	Visitor	1-3	2	4-12	8
Picnic park with flush toilets	Visitor	5-10	5	19-38	19
Recreational vehicle park:					
With individual connection	Vehicle	75-150	100	280-570	380
With comfort station	Vehicle	40-50	45	150-190	170
Roadside rest areas	Person	3-5	4	10-19	15
Swimming pool	Customer	5-12	10	19-45	40
	Employee	8-12	10	30-45	40
Vacation home	Person	25-60	50	90-230	190
Visitor center	Visitor	3-5	4	10-19	15

Adapted from Metcalf & Eddy (1991), Salvato (1992), and Crites and Tchobanoglous (1998).

ISCO Figures and Tables

Figures and tables taken with permission from Douglas M. Grant and Brian D. Dawson, *ISCO Open Channel Flow Measurement Handbook,* Fifth Edition, (P.O. Box 82531, Lincoln, NE 68501-2531, 2001).



A. Kennison nozzle (Q proportional to H)

B. Parabolic nozzle (Q proportional to H^2)

Figure 3-9: Open Flow Nozzles

Table 3-8:
Dimensions and Approximate Capacities for Kennison Nozzles

Nozzle diameter		Nozzle length		Approximate maximum capacity				
inches	mm	inches	mm	CFS	GPM	MGD	l/s	m^3/hr
6	150	12	300	0.45	200	0.29	13	45
8	200	16	410	0.71	320	0.45	20	73
10	250	20	510	1.2	560	0.80	35	130
12	300	24	610	1.9	850	1.2	54	190
16	410	32	810	4.2	1900	2.7	120	430
20	510	40	1020	6.9	3100	4.5	200	700
24	610	48	1220	12	5200	7.5	330	1200
30	760	60	1520	19	8500	12	540	1900
36	910	72	1830	31	14,000	20	880	3200

Table 3-9:
Dimensions and Approximate Capacities for Parabolic Nozzles

Nozzle diameter		Nozzle length		Approximate maximum capacity				
inches	mm	inches	mm	CFS	GPM	MGD	l/s	m^3/hr
6	150	30	760	0.40	180	0.26	11	41
8	200	35	890	0.89	400	0.55	25	91
10	250	40	1020	1.8	800	1.2	50	180
12	300	47	1190	2.5	1100	1.5	69	250
14	360	53	1350	3.6	1600	2.5	100	360
16	410	59	1500	4.7	2100	3.0	130	480
18	460	68	1730	5.8	2600	4.0	160	590
20	510	75	1910	8.3	3700	5.3	230	840
24	610	84	2130	16	7000	10	440	1600

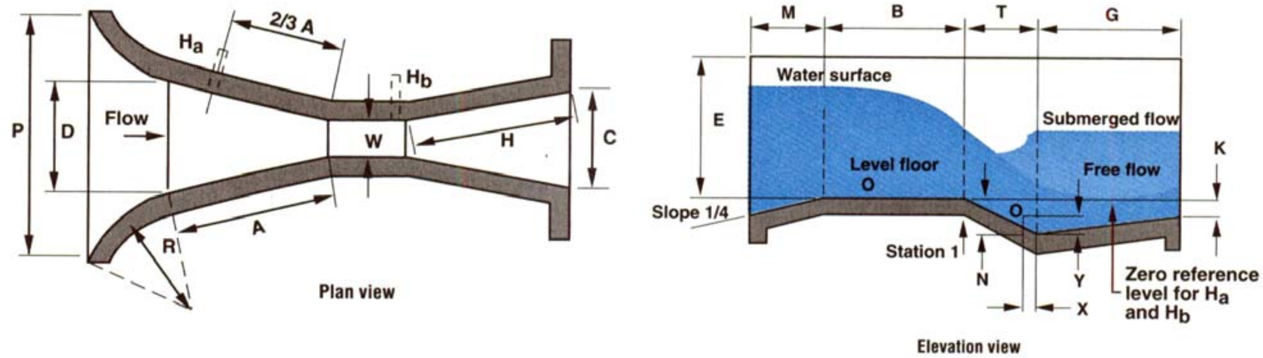


Table 4-1 A: Parshall Flume Dimensions in Inches and Feet for Various Throat Widths, W

W	A	⅔A	B	C	D	E	T	G	H	K	M	N	P	R	X	Y
1"	1' 2-9/32"	9-17/32"	1'2"	3-21/32"	6-19/32"	6" to 9"	3"	8"	8-1/8"	3/4"		1-1/8"			5/16"	1/2"
2"	1' 4-5/16"	10-7/8"	1' 4"	5-5/16"	8-13/32"	6" to 10"	4-1/2"	10"	10-1/8"	7/8"		1-11/16"			5/8"	1"
3"	1' 6-3/8"	1' 1/4"	1' 6"	7"	10-3/16"	1' to 1' 6"	6"	1'	1' 5/32"	1"		2-1/4"			1"	1-1/2"
6"	2' 7/16"	1' 4-5/16"	2'	1' 3-1/2"	1' 3-5/8"	2'	1'	2'		3"	1'	4-1/2"	2' 11-1/2"	1' 4"	2"	3"
9"	2' 10-5/8"	1' 11-1/8"	2' 10"	1' 3"	1' 10-5/8"	2' 6"	1'	1' 6"		3"	1'	4-1/2"	3' 6-1/2"	1' 4"	2"	3"
1'	4' 6"	3'	4' 4-7/8"	2'	2' 9-1/4"	3'	2'	3'		3"	1' 3"	9"	4' 10-3/4"	1' 8"	2"	3"
1' 6"	4' 9"	3' 2"	4' 7-7/8"	2' 6"	3' 4-3/8"	3'	2'	3'		3"	1' 3"	9"	5' 6"	1' 8"	2"	3"
2'	5'	3' 4"	4' 10-7/8"	3'	3' 11-1/2"	3'	2'	3'		3"	1' 3"	9"	6' 1"	1' 8"	2"	3"
3'	5' 6"	3' 8"	5' 4-3/4"	4'	5' 1-7/8"	3'	2'	3'		3"	1' 3"	9"	7' 3-1/2"	1' 8"	2"	3"
4'	6'	4'	5' 10-5/8"	5'	6' 4-1/4"	3'	2'	3'		3"	1' 6"	9"	8' 10-3/4"	2'	2"	3"
5'	6' 6"	4' 4"	6' 4-1/2"	6'	7' 6-5/8"	3'	2'	3'		3"	1' 6"	9"	10' 1-1/4"	2'	2"	3"
6'	7'	4' 8"	6' 10-3/8"	7'	8' 9"	3'	2'	3'		3"	1' 6"	9"	11' 3-1/2"	2'	2"	3"
7'	7' 6"	5'	7' 4-1/4"	8'	9' 11-3/8"	3'	2'	3'		3"	1' 6"	9"	12' 6"	2'	2"	3"
8'	8'	5' 4"	7' 10-1/8"	9'	11' 1-3/4"	3'	2'	3'		3"	1' 6"	9"	13' 8-1/4"	2'	2"	3"
10'		6'	14'	12'	15' 7-1/4"	4'	3'	6'		6"		1' 1-1/2"			1'	9"
12'		6' 8"	16'	14' 8"	18' 4-3/4"'	5'	3'	8'		6"		1' 1-1/2"			1'	9"
15'		7' 8"	25'	18' 4"	25'	6'	4'	10'		9"		1' 6"			1'	9"
20'		9' 4"	25'	24'	30'	7'	6'	12'		1'		2' 3"			1'	9"
25'		11'	25'	29' 4"	35'	7'	6'	13'		1'		2' 3"			1'	9"
30'		12' 8"	26'	34' 8"	40' 4-3/4"	7'	6'	14'		1'		2' 3"			1'	9"
40'		16'	27'	45' 4"	50' 9-1/2"	7'	6'	16'		1'		2' 3"			1'	9"
50'		19' 4"	27'	56' 8"	60' 9-1/2"	7'	6'	20'		1'		2' 3"			1'	9"

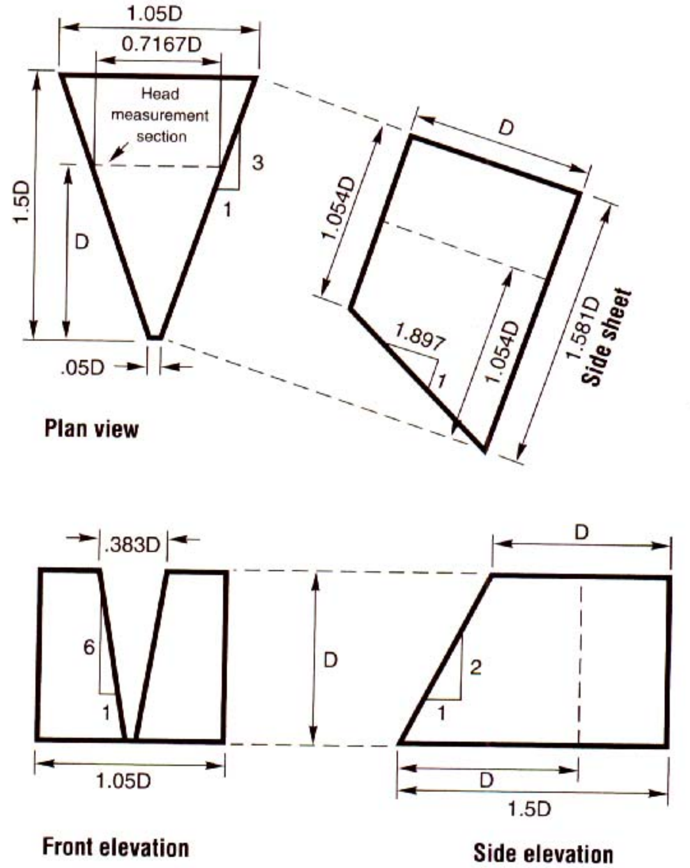
Table 4-2 A:
Minimum and Maximum Recommended Flow Rates for Free Flow through Parshall Flumes with Head in Feet

Throat width, W	Min. head, feet	Minimum flow rate			Max. head, feet	Maximum flow rate		
in./ft.		CFS	GPM	MGD		CFS	GPM	MGD
1 in.	0.10	0.010	4.28	0.006	0.70	0.194	87.3	0.126
2 in.	0.10	0.019	8.55	0.012	0.80	0.478	215	0.309
3 in.	0.10	0.028	12.6	0.018	1.10	1.15	516	0.743
6 in.	0.10	0.054	24.3	0.035	1.50	3.91	1750	2.53
9 in.	0.10	0.091	40.7	0.059	2.00	8.87	3980	5.73
1 ft.	0.10	0.120	54.0	0.078	2.50	16.1	7240	10.4
1½ ft.	0.10	0.174	78.0	0.112	2.50	24.6	11,000	15.9
2 ft.	0.15	0.423	190	0.273	2.50	33.1	14,900	21.4
3 ft.	0.15	0.615	276	0.398	2.50	50.4	22,600	32.6
4 ft.	0.20	1.26	567	0.816	2.50	67.9	30,500	43.9
5 ft.	0.20	1.56	698	1.01	2.50	85.6	38,400	55.4
6 ft.	0.25	2.63	1180	1.70	2.50	103	46,400	66.9
8 ft.	0.25	3.45	1550	2.23	2.50	140	62,600	90.2
10 ft.	0.30	5.74	2570	3.71	2.75	199	89,200	128
12 ft.	0.33	7.93	3560	5.13	3.50	347	156,000	224

Table 4-2 B:
Minimum and Maximum Recommended Flow Rates for Free Flow through Parshall Flumes with Head in Meters

Throat width, W		Min. head, meters	Minimum flow rate		Max. head, meters	Maximum flow rate	
in./ft.	meters		l/s	m^3/hr		l/s	m^3/hr
1 in.	0.0254	0.03	0.263	0.948	0.20	4.98	17.9
2 in.	0.0508	0.03	0.526	1.90	0.25	14.1	50.7
3 in.	0.0762	0.03	0.778	2.80	0.35	34.8	125
6 in.	0.152	0.03	1.50	5.39	0.45	108	389
9 in.	0.229	0.03	2.50	9.01	0.60	245	882
1 ft.	0.305	0.03	3.32	12.0	0.75	446	1610
1½ ft.	0.457	0.03	4.80	17.3	0.75	678	2440
2 ft.	0.610	0.045	11.7	42.0	0.75	915	3290
3 ft.	0.914	0.045	17.0	61.2	0.75	1390	5010
4 ft.	1.22	0.06	34.9	125	0.75	1880	6750
5 ft.	1.52	0.06	42.9	155	0.75	2360	8510
6 ft.	1.83	0.075	72.6	261	0.75	2860	10,300
8 ft.	2.44	0.075	95.2	343	0.75	3850	13,900
10 ft.	3.05	0.09	158	570	0.85	5750	20,700
12 ft.	3.66	0.10	223	801	1.05	9580	34,500

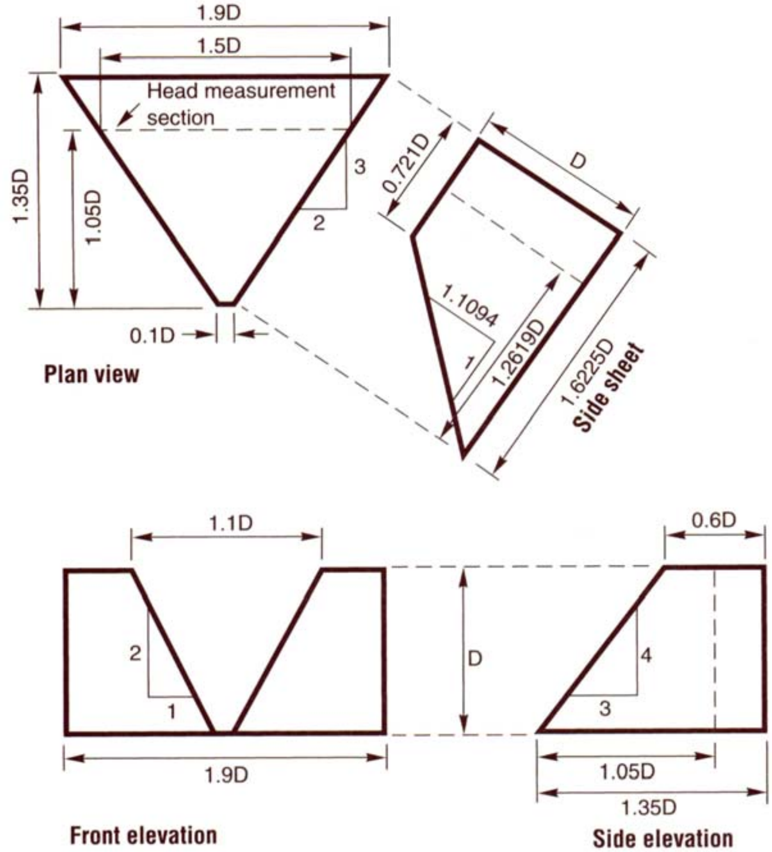
Depth D	
feet	meters
0.4	0.122
0.6	0.183
0.8	0.244
1.0	0.305



HS Flume

Figure 4-11 A: Dimensions of H-type Flumes

Depth D	
feet	meters
0.5	0.152
0.75	0.229
1.0	0.305
1.5	0.457
2.0	0.610
2.5	0.762
3.0	0.914
4.5	1.37

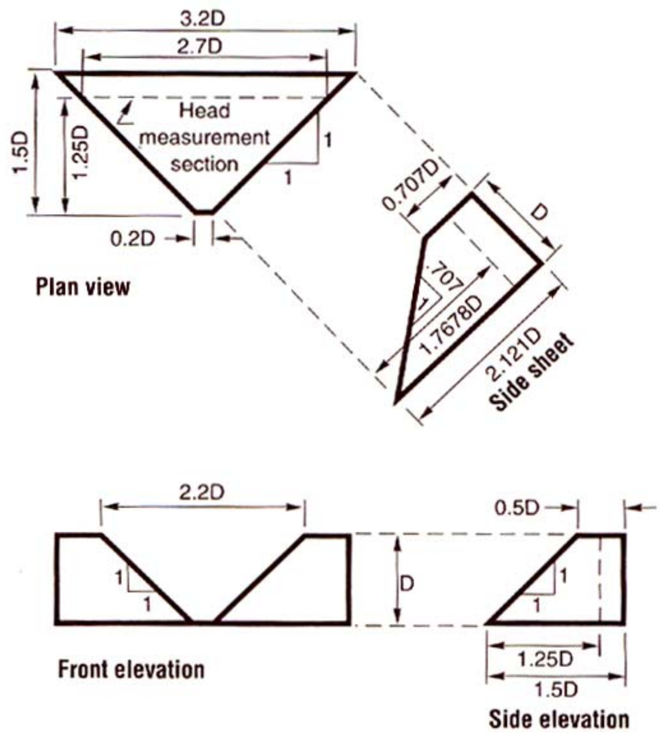


H Flume

Figure 4-11 B: Dimensions of H-type Flumes

Depth D	
feet	meters
2.0	0.610
2.5	0.762
3.0	0.914
3.5	1.07
4.0	1.22

Note: Only the 4.0 foot (1.22 m) HL flume is recommended because smaller flows are measured more accurately with an H flume.



HL Flume

Figure 4-11 C: Dimensions of H-type Flumes

Table 5-3 A: Useful Flow Rate Range of Various Types of Weirs in Feet

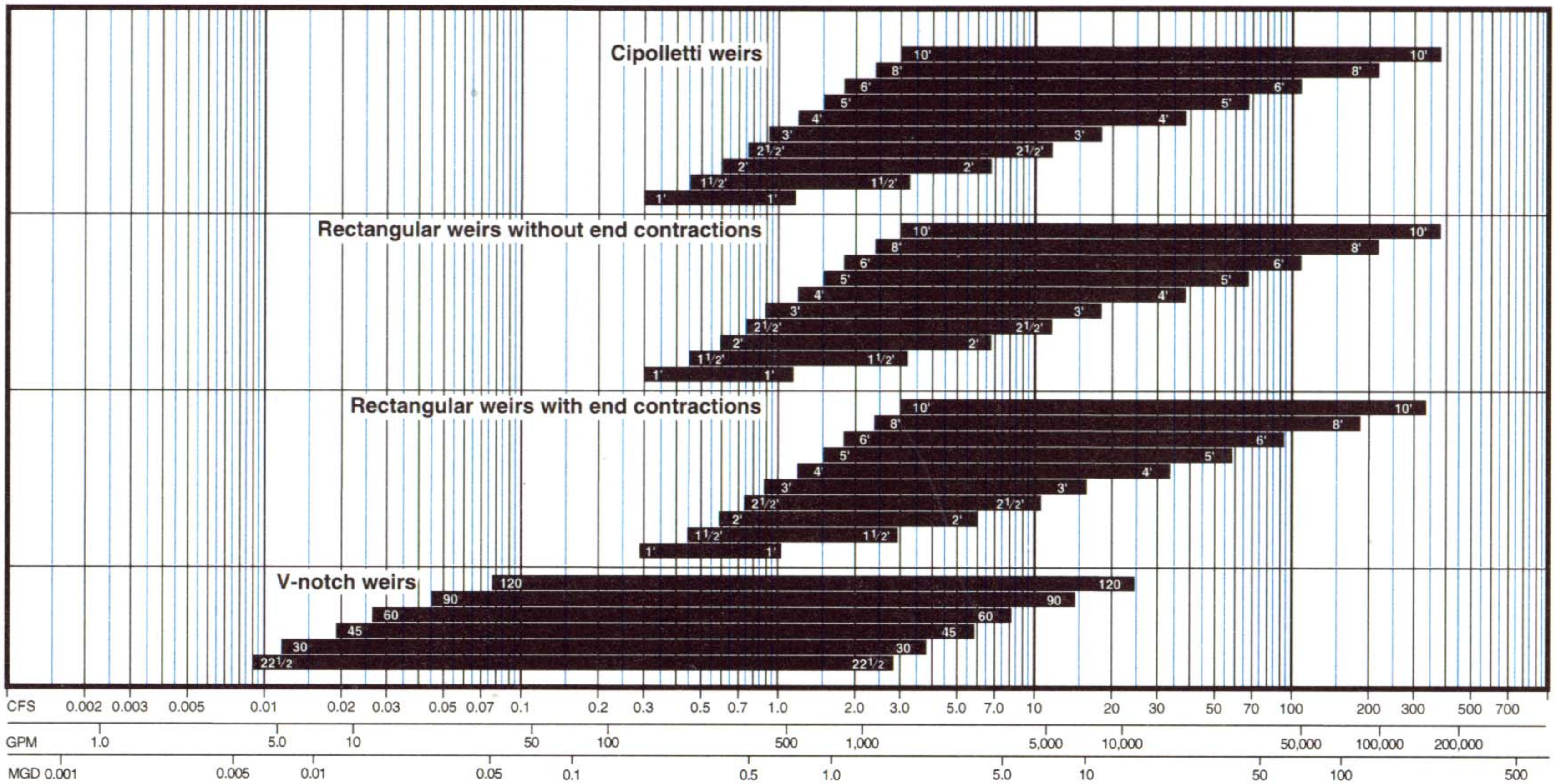


Table 5-3 B: Useful Flow Rate Range of Various Types of Weirs in Meters

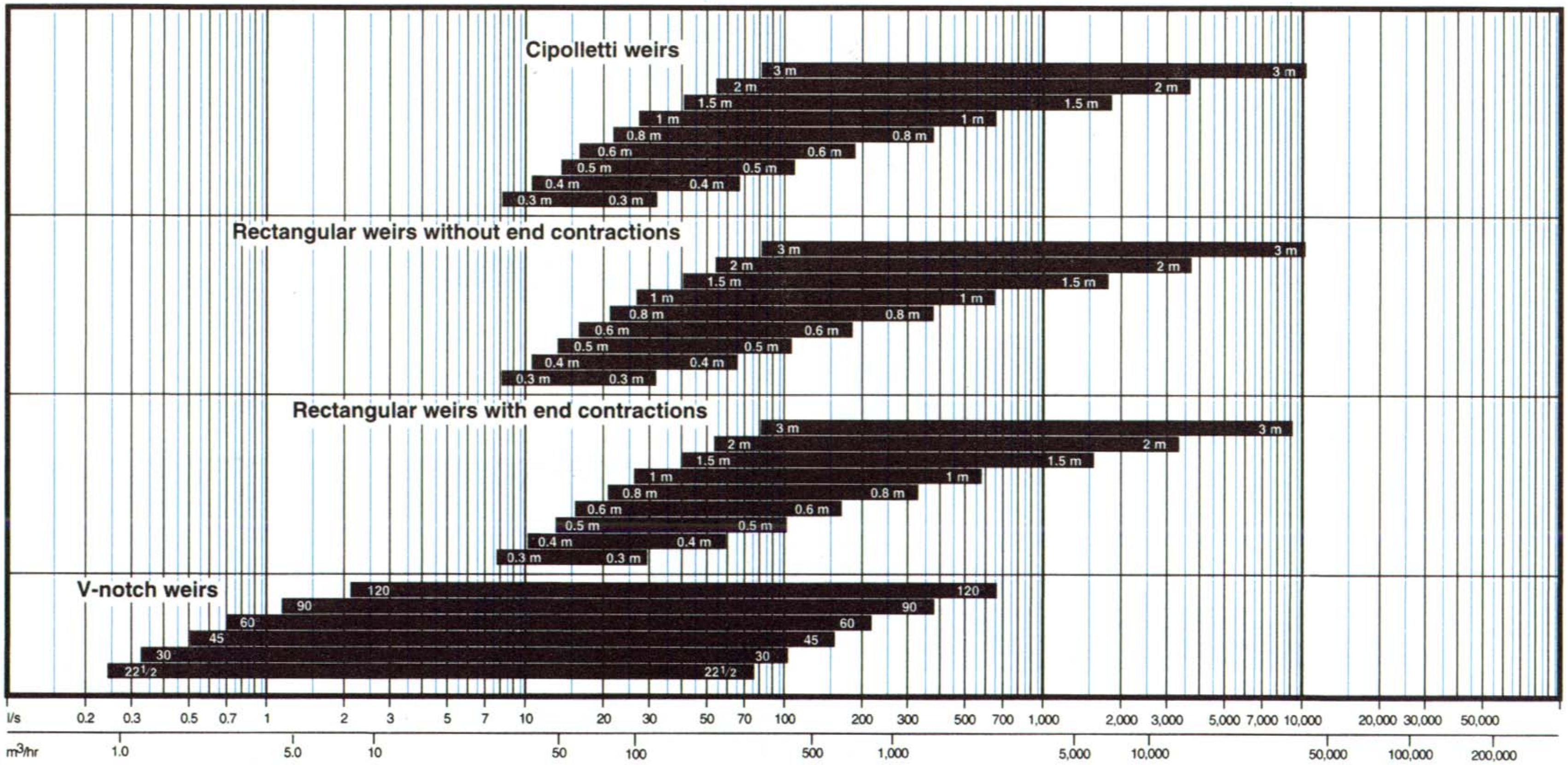


Table 5-4: Useful Flow Rate Range of Various Types of Flumes

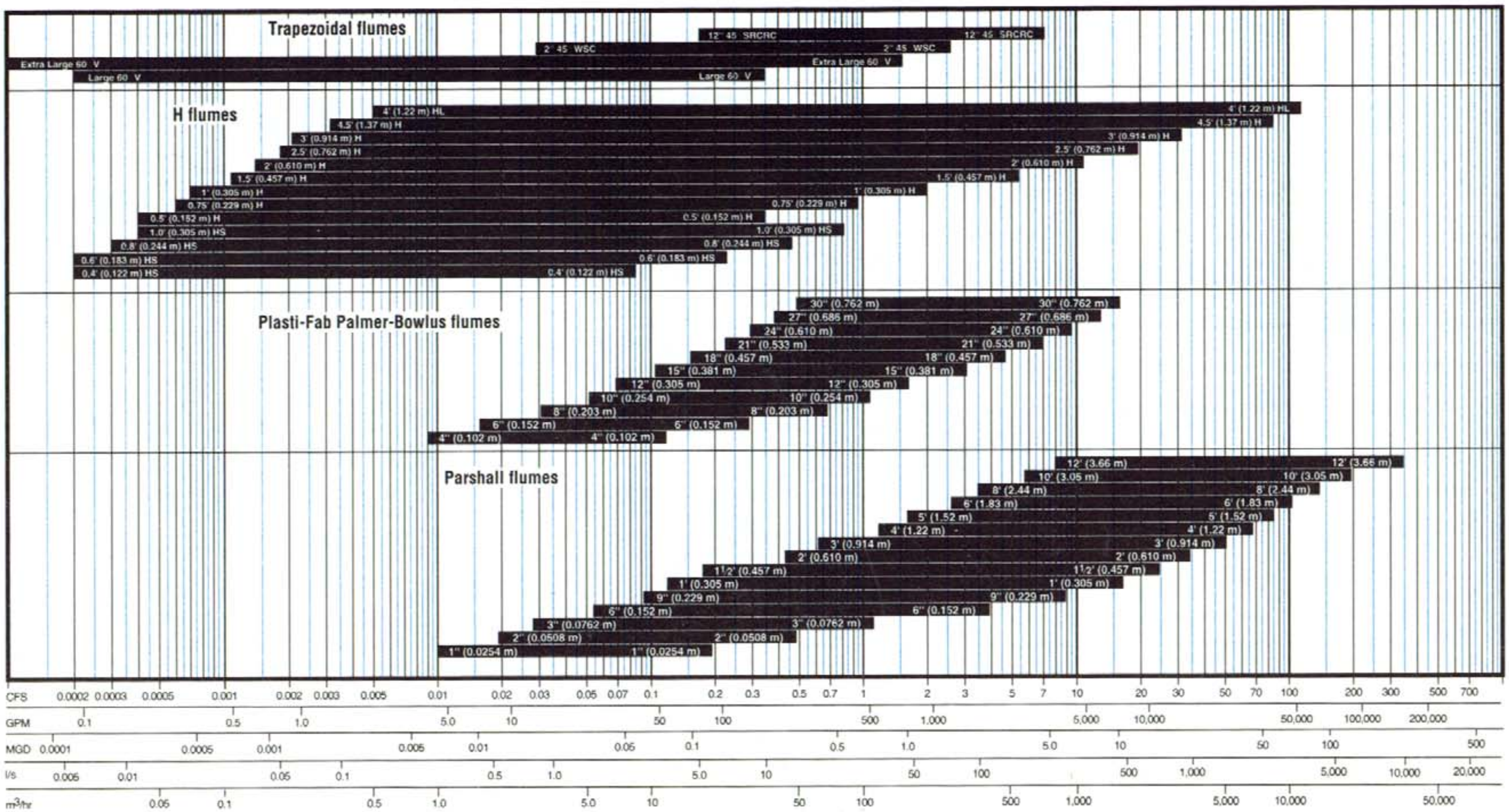


Table 6-1:
Manning Roughness Coefficient "n" for Various Channel Configurations and Conditions

Description of channel	Min.	Norm.	Max.
I. Closed conduit—partly full			
A. Metal			
1. Steel			
a. Lockbar and welded	0.010	0.012	0.014
b. Riveted and spiral	0.013	0.016	0.017
2. Cast Iron			
a. Coated	0.010	0.013	0.014
b. Uncoated	0.011	0.014	0.016
3. Wrought Iron			
a. Black	0.012	0.014	0.015
b. Galvanized	0.013	0.016	0.017
4. Corrugated			
a. Subdrain	0.017	0.019	0.021
b. Storm drain	0.021	0.024	0.030
B. Nonmetal			
1. Acrylic	0.008	0.009	0.010
2. Glass	0.009	0.010	0.013
3. Wood			
a. Stave	0.010	0.012	0.014
b. Laminated, treated	0.015	0.017	0.020
4. Clay			
a. Common drainage tile	0.011	0.013	0.017
b. Vitrified sewer	0.011	0.014	0.017
c. Vitrified sewer with manholes, inlets, etc.	0.013	0.015	0.017
5. Brick			
a. Glazed	0.011	0.013	0.015
b. Lined with cement	0.012	0.015	0.017
6. Concrete			
a. Culvert, straight and free of debris	0.010	0.011	0.013
b. Culvert with bends, connections, and some debris	0.011	0.013	0.014
c. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
d. Unfinished, steel form	0.012	0.013	0.014
e. Unfinished, smooth wood form	0.012	0.014	0.016
f. Unfinished, rough wood form	0.015	0.017	0.020
7. Sanitary sewers coated with sewage slimes	0.012	0.013	0.016
8. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
9. Rubble masonry, cemented	0.018	0.025	0.030

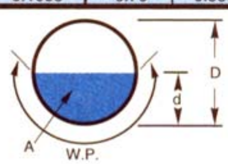
continued on the next page

Table 6-1:
Manning Roughness Coefficient "n" for Various Channel Configurations and Conditions *(continued)*

Description of channel	Min.	Norm.	Max.
II. Lined or built-up channels			
A. Metal			
1. Smooth steel surface			
a. Painted	0.011	0.012	0.014
b. Unpainted	0.012	0.013	0.017
2. Corrugated	0.021	0.025	0.030
B. Nonmetal			
1. Cement			
a. Neat surface	0.010	0.011	0.013
b. Mortar	0.011	0.013	0.015
2. Concrete			
a. Trowel finish	0.011	0.013	0.015
b. Float finish	0.013	0.015	0.016
c. Finished, with gravel on bottom	0.015	0.017	0.020
d. Unfinished	0.014	0.017	0.020
3. Wood			
a. Planed, untreated	0.010	0.012	0.014
b. Planed, creosoted	0.011	0.012	0.015
c. Unplaned	0.011	0.013	0.015
d. Plank with battens	0.012	0.015	0.018
4. Brick			
a. Glazed	0.011	0.013	0.015
b. In cement mortar	0.012	0.015	0.018
5. Masonry			
a. Cemented rubble	0.017	0.025	0.030
b. Dry rubble	0.023	0.032	0.035
6. Asphalt			
a. Smooth	0.013	0.013	—
b. Rough	0.016	0.016	—
7. Vegetal lining	0.030	—	0.500
III. Excavated or dredged			
A. Earth, straight and uniform	0.016	0.022	0.035
B. Earth, winding and sluggish	0.023	0.030	0.040
C. Rock cuts	0.030	0.040	0.050
D. Unmaintained channels	0.040	0.070	0.140
IV. Natural channels (Minor streams, top width at flood 100 ft.)			
A. Fairly regular section	0.030	0.050	0.070
B. Irregular section with pools	0.040	0.070	0.100

Table 6-2: Area and Hydraulic Radius for Various Flow Depths

d / D	A / D²	R / D	d / D	A / D²	R / D	d / D	A / D²	R / D
0.01	0.0013	0.0066	0.36	0.2546	0.1978	0.71	0.5964	0.2973
0.02	0.0037	0.0132	0.37	0.2642	0.2020	0.72	0.6054	0.2984
0.03	0.0069	0.0197	0.38	0.2739	0.2061	0.73	0.6143	0.2995
0.04	0.0105	0.0262	0.39	0.2836	0.2102	0.74	0.6231	0.3006
0.05	0.0147	0.0326	0.40	0.2934	0.2142	0.75	0.6318	0.3017
0.06	0.0192	0.0389	0.41	0.3032	0.2181	0.76	0.6404	0.3025
0.07	0.0242	0.0451	0.42	0.3130	0.2220	0.77	0.6489	0.3032
0.08	0.0294	0.0513	0.43	0.3229	0.2257	0.78	0.6573	0.3037
0.09	0.0350	0.0574	0.44	0.3328	0.2294	0.79	0.6655	0.3040
0.10	0.0409	0.0635	0.45	0.3428	0.2331	0.80	0.6736	0.3042
0.11	0.0470	0.0695	0.46	0.3527	0.2366	0.81	0.6815	0.3044
0.12	0.0534	0.0754	0.47	0.3627	0.2400	0.82	0.6893	0.3043
0.13	0.0600	0.0813	0.48	0.3727	0.2434	0.83	0.6969	0.3041
0.14	0.0668	0.0871	0.49	0.3827	0.2467	0.84	0.7043	0.3038
0.15	0.0739	0.0929	0.50	0.3927	0.2500	0.85	0.7115	0.3033
0.16	0.0811	0.0986	0.51	0.4027	0.2531	0.86	0.7186	0.3026
0.17	0.0885	0.1042	0.52	0.4127	0.2561	0.87	0.7254	0.3017
0.18	0.0961	0.1097	0.53	0.4227	0.2591	0.88	0.7320	0.3008
0.19	0.1039	0.1152	0.54	0.4327	0.2620	0.89	0.7384	0.2996
0.20	0.1118	0.1206	0.55	0.4426	0.2649	0.90	0.7445	0.2980
0.21	0.1199	0.1259	0.56	0.4526	0.2676	0.91	0.7504	0.2963
0.22	0.1281	0.1312	0.57	0.4625	0.2703	0.92	0.7560	0.2944
0.23	0.1365	0.1364	0.58	0.4723	0.2728	0.93	0.7612	0.2922
0.24	0.1449	0.1416	0.59	0.4822	0.2753	0.94	0.7662	0.2896
0.25	0.1535	0.1466	0.60	0.4920	0.2776	0.95	0.7707	0.2864
0.26	0.1623	0.1516	0.61	0.5018	0.2797	0.96	0.7749	0.2830
0.27	0.1711	0.1566	0.62	0.5115	0.2818	0.97	0.7785	0.2787
0.28	0.1800	0.1614	0.63	0.5212	0.2839	0.98	0.7816	0.2735
0.29	0.1890	0.1662	0.64	0.5308	0.2860	0.99	0.7841	0.2665
0.30	0.1982	0.1709	0.65	0.5404	0.2881	1.00	0.7854	0.2500
0.31	0.2074	0.1755	0.66	0.5499	0.2899			
0.32	0.2167	0.1801	0.67	0.5594	0.2917			
0.33	0.2260	0.1848	0.68	0.5687	0.2935			
0.34	0.2355	0.1891	0.69	0.5780	0.2950			
0.35	0.2450	0.1935	0.70	0.5872	0.2962			



A = Area of flow

R = Hydraulic radius

$= \frac{A}{W.P.}$

TABLE 6-4
Characteristics of flow-metering devices used in wastewater treatment facilities[a]

Metering device	Range[b]	Accuracy,[b] percent of actual rate	Repeatability[b] percent of full scale	Straight upstream run in pipe diameters
For open channels				
Head/area				
Flume	10:1–75:1[c]	±5–10[d]	±0.5	
Weir	500:1	±5	±0.5[g]	
Other				
Magnetic (insert type)	10:1	±1–2[e]	±0.5	
Velocity-head				
For closed conduits				
Head/pressure				
Flow tube	4:1	±.3	±0.5	4–10[f]
Orifice	4:1	±1	±1	±5[g]
Pitot tube	3:1	±3	±1[g]	10[g]
Rotameter	10:1	0.5–10	1[g]	5[g]
Venturi meter	4:1	±1	±0.5	4–10[f]
Moving fluid effects				
Magnetic (tube type)	10:1	±1–2[e]	±0.5	5
Magnetic (insert type)	10:1	±1–2[e]	±0.5	5
Target	10:1	±5	1[f]	20
Ultrasonic (Doppler)	10:1	±3	±1	7–10
Ultrasonic (transmission)	10:1	±2	±1	7–10
Vortex shedding	15:1	±1	±0.5	10
Positive displacement				
Propeller	10:1	±2	±0.5	5
Turbine	10:1	±0.25	±0.05	10[h]

[a] Based on industry practice and engineering judgement.

[b] Based on both the primary element and primary conversion device.

[c] Depends on the type of flume.

[d] Parshall flumes ±5%, Palmer-Bowlus flume ±10%.

[e] Of full scale.

[f] Depends on the type of flow-disturbing obstruction.

[g] Estimated.

[h] Assuming that flow straightening is used (25 to 30 pipe diameters, otherwise).

Table 9-1:
22½° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 0.4970\ H^{2.5}$ $MGD = 0.3212\ H^{2.5}$
$GPM = 223.1\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.0923	41.44	0.0597
0.02				0.52	0.0969	43.50	0.0626
0.03				0.53	0.1016	45.62	0.0657
0.04				0.54	0.1065	47.81	0.0688
0.05				0.55	0.1115	50.05	0.0721
0.06				0.56	0.1166	52.36	0.0754
0.07				0.57	0.1219	54.73	0.0788
0.08				0.58	0.1273	57.16	0.0823
0.09				0.59	0.1329	59.65	0.0859
0.10				0.60	0.1386	62.21	0.0896
0.11				0.61	0.1444	64.84	0.0933
0.12				0.62	0.1504	67.53	0.0972
0.13				0.63	0.1566	70.28	0.1012
0.14				0.64	0.1629	73.11	0.1053
0.15				0.65	0.1693	75.99	0.1094
0.16				0.66	0.1759	78.95	0.1137
0.17				0.67	0.1826	81.98	0.1180
0.18				0.68	0.1895	85.07	0.1225
0.19				0.69	0.1966	88.23	0.1270
0.20	0.0089	3.991	0.0057	0.70	0.2038	91.46	0.1317
0.21	0.0100	4.509	0.0065	0.71	0.2111	94.76	0.1364
0.22	0.0113	5.065	0.0073	0.72	0.2186	98.14	0.1413
0.23	0.0126	5.660	0.0081	0.73	0.2263	101.6	0.1462
0.24	0.0140	6.295	0.0091	0.74	0.2341	105.1	0.1513
0.25	0.0155	6.972	0.0100	0.75	0.2421	108.7	0.1565
0.26	0.0171	7.690	0.0111	0.76	0.2503	112.3	0.1617
0.27	0.0188	8.451	0.0122	0.77	0.2586	116.1	0.1671
0.28	0.0206	9.255	0.0133	0.78	0.2671	119.9	0.1726
0.29	0.0225	10.10	0.0145	0.79	0.2757	123.8	0.1782
0.30	0.0245	11.00	0.0158	0.80	0.2845	127.7	0.1839
0.31	0.0266	11.94	0.0172	0.81	0.2935	131.7	0.1897
0.32	0.0288	12.92	0.0186	0.82	0.3026	135.8	0.1956
0.33	0.0311	13.96	0.0201	0.83	0.3119	140.0	0.2016
0.34	0.0335	15.04	0.0217	0.84	0.3214	144.3	0.2077
0.35	0.0360	16.17	0.0233	0.85	0.3311	148.6	0.2140
0.36	0.0386	17.35	0.0250	0.86	0.3409	153.0	0.2203
0.37	0.0414	18.58	0.0267	0.87	0.3509	157.5	0.2268
0.38	0.0442	19.86	0.0286	0.88	0.3610	162.1	0.2333
0.39	0.0472	21.19	0.0305	0.89	0.3714	166.7	0.2400
0.40	0.0503	22.58	0.0325	0.90	0.3819	171.4	0.2468
0.41	0.0535	24.01	0.0346	0.91	0.3926	176.2	0.2537
0.42	0.0568	25.50	0.0367	0.92	0.4035	181.1	0.2608
0.43	0.0603	27.05	0.0389	0.93	0.4145	186.1	0.2679
0.44	0.0638	28.65	0.0412	0.94	0.4258	191.1	0.2752
0.45	0.0675	30.31	0.0436	0.95	0.4372	196.2	0.2825
0.46	0.0713	32.02	0.0461	0.96	0.4488	201.5	0.2900
0.47	0.0753	33.79	0.0486	0.97	0.4606	206.7	0.2976
0.48	0.0793	35.61	0.0513	0.98	0.4725	212.1	0.3054
0.49	0.0835	37.50	0.0540	0.99	0.4847	217.6	0.3132
0.50	0.0879	39.44	0.0568	1.00	0.4970	223.1	0.3212

Table 9-1:
22½° V-notch Weir Discharge Table with Head in Feet *(continued)*

Formulas: CFS = 0.4970 $H^{2.5}$ MGD = 0.3212 $H^{2.5}$
GPM = 223.1 $H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
1.01	0.5095	228.7	0.3293	1.51	1.393	625.1	0.8999
1.02	0.5222	234.4	0.3375	1.52	1.416	635.5	0.9149
1.03	0.5351	240.2	0.3458	1.53	1.439	646.0	0.9300
1.04	0.5482	246.1	0.3543	1.54	1.463	656.6	0.9453
1.05	0.5615	252.0	0.3629	1.55	1.487	667.3	0.9607
1.06	0.5749	258.1	0.3716	1.56	1.511	678.1	0.9763
1.07	0.5886	264.2	0.3804	1.57	1.535	689.0	0.9920
1.08	0.6024	270.4	0.3893	1.58	1.560	700.1	1.008
1.09	0.6165	276.7	0.3984	1.59	1.584	711.2	1.024
1.10	0.6307	283.1	0.4076	1.60	1.609	722.4	1.040
1.11	0.6452	289.6	0.4169	1.61	1.635	733.8	1.056
1.12	0.6598	296.2	0.4264	1.62	1.660	745.2	1.073
1.13	0.6746	302.8	0.4360	1.63	1.686	756.8	1.090
1.14	0.6896	309.6	0.4457	1.64	1.712	768.4	1.106
1.15	0.7049	316.4	0.4555	1.65	1.738	780.2	1.123
1.16	0.7203	323.3	0.4655	1.66	1.765	792.1	1.140
1.17	0.7359	330.3	0.4756	1.67	1.791	804.1	1.158
1.18	0.7517	337.4	0.4858	1.68	1.818	816.2	1.175
1.19	0.7678	344.6	0.4962	1.69	1.845	828.4	1.193
1.20	0.7840	351.9	0.5067	1.70	1.873	840.7	1.210
1.21	0.8004	359.3	0.5173	1.71	1.900	853.1	1.228
1.22	0.8171	366.8	0.5281	1.72	1.928	865.6	1.246
1.23	0.8339	374.3	0.5389	1.73	1.956	878.2	1.264
1.24	0.8510	382.0	0.5500	1.74	1.985	891.0	1.283
1.25	0.8682	389.7	0.5611	1.75	2.013	903.8	1.301
1.26	0.8857	397.6	0.5724	1.76	2.042	916.8	1.320
1.27	0.9034	405.5	0.5838	1.77	2.072	929.9	1.339
1.28	0.9213	413.5	0.5954	1.78	2.101	943.1	1.358
1.29	0.9394	421.7	0.6071	1.79	2.131	956.4	1.377
1.30	0.9577	429.9	0.6189	1.80	2.160	969.8	1.396
1.31	0.9762	438.2	0.6309	1.81	2.191	983.3	1.416
1.32	0.9949	446.6	0.6430	1.82	2.221	997.0	1.435
1.33	1.014	455.1	0.6552	1.83	2.252	1011	1.455
1.34	1.033	463.7	0.6676	1.84	2.282	1025	1.475
1.35	1.052	472.4	0.6802	1.85	2.314	1039	1.495
1.36	1.072	481.2	0.6928	1.86	2.345	1053	1.516
1.37	1.092	490.1	0.7056	1.87	2.377	1067	1.536
1.38	1.112	499.1	0.7186	1.88	2.409	1081	1.557
1.39	1.132	508.2	0.7317	1.89	2.441	1096	1.577
1.40	1.153	517.4	0.7449	1.90	2.473	1110	1.598
1.41	1.173	526.7	0.7583	1.91	2.506	1125	1.619
1.42	1.194	536.1	0.7718	1.92	2.539	1140	1.641
1.43	1.215	545.6	0.7854	1.93	2.572	1154	1.662
1.44	1.237	555.1	0.7992	1.94	2.605	1170	1.684
1.45	1.258	564.8	0.8132	1.95	2.639	1185	1.706
1.46	1.280	574.6	0.8273	1.96	2.673	1200	1.727
1.47	1.302	584.5	0.8415	1.97	2.707	1215	1.750
1.48	1.324	594.5	0.8559	1.98	2.742	1231	1.772
1.49	1.347	604.6	0.8704	1.99	2.776	1246	1.794
1.50	1.370	614.8	0.8851	2.00	2.811	1262	1.817

Table 9-2:
30° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 0.6760\ H^{2.5}$ $MGD = 0.4369\ H^{2.5}$
$GPM = 303.4\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.1256	56.36	0.0812
0.02				0.52	0.1318	59.16	0.0852
0.03				0.53	0.1382	62.04	0.0893
0.04				0.54	0.1449	65.01	0.0936
0.05				0.55	0.1517	68.06	0.0980
0.06				0.56	0.1586	71.20	0.1025
0.07				0.57	0.1658	74.42	0.1072
0.08				0.58	0.1732	77.73	0.1119
0.09				0.59	0.1807	81.12	0.1168
0.10				0.60	0.1885	84.60	0.1218
0.11				0.61	0.1965	88.17	0.1270
0.12				0.62	0.2046	91.83	0.1322
0.13				0.63	0.2130	95.58	0.1376
0.14				0.64	0.2215	99.42	0.1432
0.15				0.65	0.2303	103.3	0.1488
0.16				0.66	0.2392	107.4	0.1546
0.17				0.67	0.2484	111.5	0.1605
0.18				0.68	0.2578	115.7	0.1666
0.19				0.69	0.2673	120.0	0.1728
0.20	0.0121	5.427	0.0078	0.70	0.2771	124.4	0.1791
0.21	0.0137	6.131	0.0088	0.71	0.2871	128.9	0.1856
0.22	0.0153	6.888	0.0099	0.72	0.2974	133.5	0.1922
0.23	0.0172	7.697	0.0111	0.73	0.3078	138.1	0.1989
0.24	0.0191	8.561	0.0123	0.74	0.3184	142.9	0.2058
0.25	0.0211	9.481	0.0137	0.75	0.3293	147.8	0.2128
0.26	0.0233	10.46	0.0151	0.76	0.3404	152.8	0.2200
0.27	0.0256	11.49	0.0165	0.77	0.3517	157.8	0.2273
0.28	0.0280	12.59	0.0181	0.78	0.3632	163.0	0.2348
0.29	0.0306	13.74	0.0198	0.79	0.3750	168.3	0.2424
0.30	0.0333	14.96	0.0215	0.80	0.3870	173.7	0.2501
0.31	0.0362	16.23	0.0234	0.81	0.3992	179.2	0.2580
0.32	0.0392	17.57	0.0253	0.82	0.4116	184.7	0.2660
0.33	0.0423	18.98	0.0273	0.83	0.4243	190.4	0.2742
0.34	0.0456	20.45	0.0294	0.84	0.4372	196.2	0.2825
0.35	0.0490	21.99	0.0317	0.85	0.4503	202.1	0.2910
0.36	0.0526	23.59	0.0340	0.86	0.4637	208.1	0.2997
0.37	0.0563	25.27	0.0364	0.87	0.4772	214.2	0.3084
0.38	0.0602	27.01	0.0389	0.88	0.4911	220.4	0.3174
0.39	0.0642	28.82	0.0415	0.89	0.5052	226.7	0.3265
0.40	0.0684	30.70	0.0442	0.90	0.5195	233.1	0.3357
0.41	0.0728	32.66	0.0470	0.91	0.5340	239.7	0.3451
0.42	0.0773	34.68	0.0499	0.92	0.5488	246.3	0.3547
0.43	0.0820	36.79	0.0530	0.93	0.5638	253.1	0.3644
0.44	0.0868	38.96	0.0561	0.94	0.5791	259.9	0.3743
0.45	0.0918	41.21	0.0593	0.95	0.5946	266.9	0.3843
0.46	0.0970	43.54	0.0627	0.96	0.6104	274.0	0.3945
0.47	0.1024	45.95	0.0662	0.97	0.6264	281.2	0.4049
0.48	0.1079	48.43	0.0697	0.98	0.6427	288.5	0.4154
0.49	0.1136	50.99	0.0734	0.99	0.6592	295.9	0.4261
0.50	0.1195	53.63	0.0772	1.00	0.6760	303.4	0.4369

Table 9-2:
30° V-notch Weir Discharge Table with Head in Feet *(continued)*

Formulas: $CFS = 0.6760\ H^{2.5}$ $MGD = 0.4369\ H^{2.5}$
$GPM = 303.4\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
1.01	0.6930	311.0	0.4479	1.51	1.894	850.1	1.224
1.02	0.7103	318.8	0.4591	1.52	1.926	864.2	1.244
1.03	0.7278	326.7	0.4704	1.53	1.957	878.5	1.265
1.04	0.7456	334.7	0.4819	1.54	1.990	892.9	1.286
1.05	0.7637	342.8	0.4936	1.55	2.022	907.5	1.307
1.06	0.7820	351.0	0.5054	1.56	2.055	922.2	1.328
1.07	0.8006	359.3	0.5174	1.57	2.088	937.1	1.349
1.08	0.8194	367.8	0.5296	1.58	2.121	952.0	1.371
1.09	0.8385	376.3	0.5419	1.59	2.155	967.2	1.393
1.10	0.8579	385.0	0.5545	1.60	2.189	982.5	1.415
1.11	0.8775	393.8	0.5671	1.61	2.223	997.9	1.437
1.12	0.8974	402.8	0.5800	1.62	2.258	1013	1.459
1.13	0.9176	411.8	0.5930	1.63	2.293	1029	1.482
1.14	0.9380	421.0	0.6062	1.64	2.328	1045	1.505
1.15	0.9587	430.3	0.6196	1.65	2.364	1061	1.528
1.16	0.9797	439.7	0.6332	1.66	2.400	1077	1.551
1.17	1.001	449.2	0.6469	1.67	2.436	1093	1.575
1.18	1.022	458.9	0.6608	1.68	2.473	1110	1.598
1.19	1.044	468.7	0.6749	1.69	2.510	1127	1.622
1.20	1.066	478.6	0.6892	1.70	2.547	1143	1.646
1.21	1.089	488.6	0.7036	1.71	2.585	1160	1.671
1.22	1.111	498.8	0.7183	1.72	2.623	1177	1.695
1.23	1.134	509.1	0.7331	1.73	2.661	1194	1.720
1.24	1.157	519.5	0.7481	1.74	2.700	1212	1.745
1.25	1.181	530.0	0.7632	1.75	2.739	1229	1.770
1.26	1.205	540.7	0.7786	1.76	2.778	1247	1.795
1.27	1.229	551.5	0.7941	1.77	2.818	1265	1.821
1.28	1.253	562.4	0.8099	1.78	2.858	1283	1.847
1.29	1.278	573.4	0.8258	1.79	2.898	1301	1.873
1.30	1.303	584.6	0.8419	1.80	2.939	1319	1.899
1.31	1.328	595.9	0.8581	1.81	2.979	1337	1.926
1.32	1.353	607.4	0.8746	1.82	3.021	1356	1.952
1.33	1.379	618.9	0.8913	1.83	3.062	1374	1.979
1.34	1.405	630.6	0.9081	1.84	3.104	1393	2.006
1.35	1.431	642.5	0.9252	1.85	3.147	1412	2.034
1.36	1.458	654.4	0.9424	1.86	3.190	1432	2.061
1.37	1.485	666.5	0.9598	1.87	3.233	1451	2.089
1.38	1.512	678.8	0.9774	1.88	3.276	1470	2.117
1.39	1.540	691.1	0.9952	1.89	3.320	1490	2.146
1.40	1.568	703.6	1.013	1.90	3.364	1510	2.174
1.41	1.596	716.2	1.031	1.91	3.408	1530	2.203
1.42	1.624	729.0	1.050	1.92	3.453	1550	2.232
1.43	1.653	741.9	1.068	1.93	3.498	1570	2.261
1.44	1.682	755.0	1.087	1.94	3.544	1590	2.290
1.45	1.711	768.1	1.106	1.95	3.589	1611	2.320
1.46	1.741	781.4	1.125	1.96	3.636	1632	2.350
1.47	1.771	794.9	1.145	1.97	3.682	1653	2.380
1.48	1.801	808.5	1.164	1.98	3.729	1674	2.410
1.49	1.832	822.2	1.184	1.99	3.776	1695	2.441
1.50	1.863	836.1	1.204	2.00	3.824	1716	2.471

Table 9-3:
45° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 1.035 H^{2.5}$ $MGD = 0.6689 H^{2.5}$
$GPM = 464.5 H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.1922	86.28	0.1242
0.02				0.52	0.2018	90.57	0.1304
0.03				0.53	0.2117	94.99	0.1368
0.04				0.54	0.2218	99.53	0.1433
0.05				0.55	0.2322	104.2	0.1501
0.06				0.56	0.2429	109.0	0.1570
0.07				0.57	0.2539	113.9	0.1641
0.08				0.58	0.2652	119.0	0.1714
0.09				0.59	0.2767	124.2	0.1789
0.10				0.60	0.2886	129.5	0.1865
0.11				0.61	0.3008	135.0	0.1944
0.12				0.62	0.3133	140.6	0.2025
0.13				0.63	0.3261	146.3	0.2107
0.14				0.64	0.3391	152.2	0.2192
0.15				0.65	0.3526	158.2	0.2278
0.16				0.66	0.3663	164.4	0.2367
0.17				0.67	0.3803	170.7	0.2458
0.18				0.68	0.3947	177.1	0.2551
0.19				0.69	0.4093	183.7	0.2645
0.20	0.0185	8.309	0.0120	0.70	0.4243	190.4	0.2742
0.21	0.0209	9.387	0.0135	0.71	0.4396	197.3	0.2841
0.22	0.0235	10.54	0.0152	0.72	0.4553	204.3	0.2942
0.23	0.0263	11.78	0.0170	0.73	0.4712	211.5	0.3046
0.24	0.0292	13.11	0.0189	0.74	0.4876	218.8	0.3151
0.25	0.0323	14.52	0.0209	0.75	0.5042	226.3	0.3258
0.26	0.0357	16.01	0.0231	0.76	0.5212	233.9	0.3368
0.27	0.0392	17.60	0.0253	0.77	0.5385	241.7	0.3480
0.28	0.0429	19.27	0.0277	0.78	0.5561	249.6	0.3594
0.29	0.0469	21.04	0.0303	0.79	0.5741	257.7	0.3710
0.30	0.0510	22.90	0.0330	0.80	0.5925	265.9	0.3829
0.31	0.0554	24.85	0.0358	0.81	0.6112	274.3	0.3950
0.32	0.0600	26.91	0.0387	0.82	0.6302	282.8	0.4073
0.33	0.0647	29.06	0.0418	0.83	0.6496	291.5	0.4198
0.34	0.0698	31.31	0.0451	0.84	0.6693	300.4	0.4326
0.35	0.0750	33.66	0.0485	0.85	0.6894	309.4	0.4456
0.36	0.0805	36.12	0.0520	0.86	0.7099	318.6	0.4588
0.37	0.0862	38.68	0.0557	0.87	0.7307	327.9	0.4722
0.38	0.0921	41.35	0.0595	0.88	0.7519	337.4	0.4859
0.39	0.0983	44.12	0.0635	0.89	0.7734	347.1	0.4998
0.40	0.1047	47.00	0.0677	0.90	0.7953	356.9	0.5140
0.41	0.1114	50.00	0.0720	0.91	0.8176	366.9	0.5284
0.42	0.1183	53.10	0.0765	0.92	0.8403	377.1	0.5430
0.43	0.1255	56.32	0.0811	0.93	0.8633	387.4	0.5579
0.44	0.1329	59.65	0.0859	0.94	0.8867	397.9	0.5730
0.45	0.1406	63.10	0.0909	0.95	0.9104	408.6	0.5884
0.46	0.1485	66.66	0.0960	0.96	0.9346	419.4	0.6040
0.47	0.1567	70.34	0.1013	0.97	0.9591	430.4	0.6199
0.48	0.1652	74.15	0.1068	0.98	0.9840	441.6	0.6360
0.49	0.1740	78.07	0.1124	0.99	1.009	453.0	0.6523
0.50	0.1830	82.11	0.1182	1.00	1.035	464.5	0.6689

Table 9-4:
60° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 1.443\ H^{2.5}$ $MGD = 0.9326\ H^{2.5}$
$GPM = 647.6\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD
0.01			
0.02			
0.03			
0.04			
0.05			
0.06			
0.07			
0.08			
0.09			
0.10			
0.11			
0.12			
0.13			
0.14			
0.15			
0.16			
0.17			
0.18			
0.19			
0.20	0.0258	11.58	0.0167
0.21	0.0292	13.09	0.0188
0.22	0.0328	14.70	0.0212
0.23	0.0366	16.43	0.0237
0.24	0.0407	18.27	0.0263
0.25	0.0451	20.24	0.0291
0.26	0.0497	22.32	0.0321
0.27	0.0547	24.53	0.0353
0.28	0.0599	26.87	0.0387
0.29	0.0654	29.33	0.0422
0.30	0.0711	31.92	0.0460
0.31	0.0772	34.65	0.0499
0.32	0.0836	37.51	0.0540
0.33	0.0903	40.51	0.0583
0.34	0.0973	43.65	0.0629
0.35	0.1046	46.93	0.0676
0.36	0.1122	50.36	0.0725
0.37	0.1202	53.93	0.0777
0.38	0.1284	57.65	0.0830
0.39	0.1371	61.51	0.0886
0.40	0.1460	65.53	0.0944
0.41	0.1553	69.71	0.1004
0.42	0.1650	74.03	0.1066
0.43	0.1750	78.52	0.1131
0.44	0.1853	83.16	0.1198
0.45	0.1960	87.97	0.1267
0.46	0.2071	92.94	0.1338
0.47	0.2185	98.07	0.1412
0.48	0.2303	103.4	0.1489
0.49	0.2425	108.8	0.1567
0.50	0.2551	114.5	0.1649
0.51	0.2680	120.3	0.1732
0.52	0.2814	126.3	0.1818
0.53	0.2951	132.4	0.1907
0.54	0.3092	138.8	0.1998
0.55	0.3237	145.3	0.2092
0.56	0.3386	152.0	0.2189
0.57	0.3540	158.9	0.2288
0.58	0.3697	165.9	0.2389
0.59	0.3858	173.2	0.2494
0.60	0.4024	180.6	0.2601
0.61	0.4194	188.2	0.2710
0.62	0.4368	196.0	0.2823
0.63	0.4546	204.0	0.2938
0.64	0.4728	212.2	0.3056
0.65	0.4915	220.6	0.3177
0.66	0.5107	229.2	0.3300
0.67	0.5302	238.0	0.3427
0.68	0.5502	246.9	0.3556
0.69	0.5707	256.1	0.3688
0.70	0.5916	265.5	0.3823
0.71	0.6129	275.1	0.3961
0.72	0.6347	284.9	0.4102
0.73	0.6570	294.9	0.4246
0.74	0.6797	305.1	0.4393
0.75	0.7029	315.5	0.4543
0.76	0.7266	326.1	0.4696
0.77	0.7507	336.9	0.4852
0.78	0.7754	348.0	0.5011
0.79	0.8004	359.2	0.5173
0.80	0.8260	370.7	0.5339
0.81	0.8521	382.4	0.5507
0.82	0.8786	394.3	0.5678
0.83	0.9057	406.4	0.5853
0.84	0.9332	418.8	0.6031
0.85	0.9612	431.4	0.6212
0.86	0.9897	444.2	0.6396
0.87	1.019	457.2	0.6584
0.88	1.048	470.5	0.6775
0.89	1.078	483.9	0.6969
0.90	1.109	497.6	0.7166
0.91	1.140	511.6	0.7367
0.92	1.171	525.7	0.7571
0.93	1.204	540.1	0.7779
0.94	1.236	554.8	0.7989
0.95	1.269	569.7	0.8204
0.96	1.303	584.8	0.8421
0.97	1.337	600.1	0.8642
0.98	1.372	615.7	0.8867
0.99	1.407	631.5	0.9095
1.00	1.443	647.6	0.9326

Table 9-4:
60° V-notch Weir Discharge Table with Head in Feet *(continued)*

Formulas: $CFS = 1.443\ H^{2.5}$ $MGD = 0.9326\ H^{2.5}$
$GPM = 647.6\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
1.01	1.479	663.9	0.9561	1.51	4.043	1814	2.613
1.02	1.516	680.5	0.9799	1.52	4.110	1845	2.656
1.03	1.554	697.3	1.004	1.53	4.178	1875	2.700
1.04	1.592	714.3	1.029	1.54	4.247	1906	2.745
1.05	1.630	731.6	1.054	1.55	4.316	1937	2.789
1.06	1.669	749.2	1.079	1.56	4.386	1968	2.835
1.07	1.709	766.9	1.104	1.57	4.457	2000	2.880
1.08	1.749	785.0	1.130	1.58	4.528	2032	2.926
1.09	1.790	803.3	1.157	1.59	4.600	2064	2.973
1.10	1.831	821.8	1.184	1.60	4.673	2097	3.020
1.11	1.873	840.6	1.211	1.61	4.746	2130	3.067
1.12	1.916	859.7	1.238	1.62	4.820	2163	3.115
1.13	1.959	879.0	1.266	1.63	4.895	2197	3.163
1.14	2.002	898.6	1.294	1.64	4.970	2231	3.212
1.15	2.046	918.4	1.323	1.65	5.046	2265	3.261
1.16	2.091	938.5	1.352	1.66	5.123	2299	3.311
1.17	2.137	958.9	1.381	1.67	5.201	2334	3.361
1.18	2.183	979.5	1.411	1.68	5.279	2369	3.412
1.19	2.229	1000	1.441	1.69	5.358	2404	3.463
1.20	2.276	1022	1.471	1.70	5.437	2440	3.514
1.21	2.324	1043	1.502	1.71	5.518	2476	3.566
1.22	2.372	1065	1.533	1.72	5.599	2513	3.618
1.23	2.421	1087	1.565	1.73	5.680	2549	3.671
1.24	2.471	1109	1.597	1.74	5.763	2586	3.725
1.25	2.521	1131	1.629	1.75	5.846	2624	3.778
1.26	2.572	1154	1.662	1.76	5.930	2661	3.832
1.27	2.623	1177	1.695	1.77	6.014	2699	3.887
1.28	2.675	1200	1.729	1.78	6.100	2738	3.942
1.29	2.727	1224	1.763	1.79	6.186	2776	3.998
1.30	2.781	1248	1.797	1.80	6.273	2815	4.054
1.31	2.834	1272	1.832	1.81	6.360	2854	4.110
1.32	2.889	1296	1.867	1.82	6.448	2894	4.167
1.33	2.944	1321	1.902	1.83	6.537	2934	4.225
1.34	2.999	1346	1.938	1.84	6.627	2974	4.283
1.35	3.056	1371	1.975	1.85	6.717	3015	4.341
1.36	3.113	1397	2.012	1.86	6.808	3056	4.400
1.37	3.170	1423	2.049	1.87	6.900	3097	4.460
1.38	3.228	1449	2.086	1.88	6.993	3138	4.519
1.39	3.287	1475	2.124	1.89	7.086	3180	4.580
1.40	3.346	1502	2.163	1.90	7.180	3222	4.641
1.41	3.407	1529	2.202	1.91	7.275	3265	4.702
1.42	3.467	1556	2.241	1.92	7.371	3308	4.764
1.43	3.529	1584	2.281	1.93	7.467	3351	4.826
1.44	3.591	1611	2.321	1.94	7.564	3395	4.889
1.45	3.653	1640	2.361	1.95	7.662	3439	4.952
1.46	3.717	1668	2.402	1.96	7.761	3483	5.016
1.47	3.781	1697	2.443	1.97	7.860	3528	5.080
1.48	3.845	1726	2.485	1.98	7.960	3572	5.145
1.49	3.910	1755	2.527	1.99	8.061	3618	5.210
1.50	3.976	1785	2.570	2.00	8.163	3663	5.276

Table 9-5:
90° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 2.500\ H^{2.5}$ $MGD = 1.616\ H^{2.5}$
$GPM = 1122\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.4644	208.4	0.3002
0.02				0.52	0.4875	218.8	0.3151
0.03				0.53	0.5112	229.4	0.3305
0.04				0.54	0.5357	240.4	0.3463
0.05				0.55	0.5609	251.7	0.3625
0.06				0.56	0.5867	263.3	0.3792
0.07				0.57	0.6132	275.2	0.3964
0.08				0.58	0.6405	287.5	0.4140
0.09				0.59	0.6685	300.0	0.4321
0.10				0.60	0.6971	312.9	0.4506
0.11				0.61	0.7265	326.1	0.4696
0.12				0.62	0.7567	339.6	0.4891
0.13				0.63	0.7876	353.5	0.5091
0.14				0.64	0.8192	367.7	0.5295
0.15				0.65	0.8516	382.2	0.5505
0.16				0.66	0.8847	397.1	0.5719
0.17				0.67	0.9186	412.3	0.5938
0.18				0.68	0.9533	427.8	0.6162
0.19				0.69	0.9887	443.7	0.6391
0.20	0.0447	20.07	0.0289	0.70	1.025	460.0	0.6625
0.21	0.0505	22.67	0.0327	0.71	1.062	476.6	0.6864
0.22	0.0568	25.47	0.0367	0.72	1.100	493.5	0.7108
0.23	0.0634	28.47	0.0410	0.73	1.138	510.9	0.7358
0.24	0.0705	31.66	0.0456	0.74	1.178	528.5	0.7612
0.25	0.0781	35.06	0.0505	0.75	1.218	546.6	0.7872
0.26	0.0862	38.67	0.0557	0.76	1.259	565.0	0.8137
0.27	0.0947	42.50	0.0612	0.77	1.301	583.7	0.8408
0.28	0.1037	46.55	0.0670	0.78	1.343	602.9	0.8683
0.29	0.1132	50.81	0.0732	0.79	1.387	622.4	0.8964
0.30	0.1232	55.31	0.0797	0.80	1.431	642.3	0.9251
0.31	0.1338	60.03	0.0865	0.81	1.476	662.5	0.9542
0.32	0.1448	64.99	0.0936	0.82	1.522	683.2	0.9840
0.33	0.1564	70.19	0.1011	0.83	1.569	704.2	1.014
0.34	0.1685	75.63	0.1089	0.84	1.617	725.6	1.045
0.35	0.1812	81.31	0.1171	0.85	1.665	747.4	1.076
0.36	0.1944	87.25	0.1257	0.86	1.715	769.6	1.108
0.37	0.2082	93.43	0.1346	0.87	1.765	792.1	1.141
0.38	0.2225	99.87	0.1438	0.88	1.816	815.1	1.174
0.39	0.2375	106.6	0.1535	0.89	1.868	838.4	1.208
0.40	0.2530	113.5	0.1635	0.90	1.921	862.2	1.242
0.41	0.2691	120.8	0.1739	0.91	1.975	886.3	1.277
0.42	0.2858	128.3	0.1847	0.92	2.030	910.9	1.312
0.43	0.3031	136.0	0.1959	0.93	2.085	935.8	1.348
0.44	0.3210	144.1	0.2075	0.94	2.142	961.2	1.384
0.45	0.3396	152.4	0.2195	0.95	2.199	987.0	1.422
0.46	0.3588	161.0	0.2319	0.96	2.257	1013	1.459
0.47	0.3786	169.9	0.2447	0.97	2.317	1040	1.498
0.48	0.3991	179.1	0.2580	0.98	2.377	1067	1.536
0.49	0.4202	188.6	0.2716	0.99	2.438	1094	1.576
0.50	0.4419	198.3	0.2857	1.00	2.500	1122	1.616

Table 9-6:
120° V-notch Weir Discharge Table with Head in Feet

Formulas: $CFS = 4.330\ H^{2.5}$ $MGD = 2.798\ H^{2.5}$
$GPM = 1943\ H^{2.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.8043	360.9	0.5197
0.02				0.52	0.8443	378.9	0.5456
0.03				0.53	0.8855	397.3	0.5722
0.04				0.54	0.9278	416.3	0.5996
0.05				0.55	0.9714	435.9	0.6277
0.06				0.56	1.016	456.0	0.6566
0.07				0.57	1.062	476.6	0.6863
0.08				0.58	1.109	497.8	0.7168
0.09				0.59	1.158	519.5	0.7481
0.10				0.60	1.207	541.8	0.7802
0.11				0.61	1.258	564.7	0.8132
0.12				0.62	1.311	588.1	0.8469
0.13				0.63	1.364	612.1	0.8815
0.14				0.64	1.419	636.7	0.9168
0.15				0.65	1.475	661.8	0.9531
0.16				0.66	1.532	687.6	0.9902
0.17				0.67	1.591	713.9	1.028
0.18				0.68	1.651	740.9	1.067
0.19				0.69	1.712	768.4	1.107
0.20	0.0775	34.76	0.0501	0.70	1.775	796.6	1.147
0.21	0.0875	39.27	0.0565	0.71	1.839	825.3	1.188
0.22	0.0983	44.11	0.0635	0.72	1.905	854.7	1.231
0.23	0.1099	49.29	0.0710	0.73	1.971	884.7	1.274
0.24	0.1222	54.83	0.0790	0.74	2.040	915.3	1.318
0.25	0.1353	60.72	0.0874	0.75	2.109	946.5	1.363
0.26	0.1493	66.97	0.0964	0.76	2.180	978.4	1.409
0.27	0.1640	73.60	0.1060	0.77	2.253	1011	1.456
0.28	0.1796	80.61	0.1161	0.78	2.327	1044	1.503
0.29	0.1961	88.00	0.1267	0.79	2.402	1078	1.552
0.30	0.2134	95.78	0.1379	0.80	2.479	1112	1.602
0.31	0.2317	104.0	0.1497	0.81	2.557	1147	1.652
0.32	0.2508	112.6	0.1621	0.82	2.636	1183	1.704
0.33	0.2709	121.6	0.1750	0.83	2.718	1219	1.756
0.34	0.2919	131.0	0.1886	0.84	2.800	1257	1.809
0.35	0.3138	140.8	0.2028	0.85	2.884	1294	1.864
0.36	0.3367	151.1	0.2176	0.86	2.970	1333	1.919
0.37	0.3606	161.8	0.2330	0.87	3.057	1372	1.975
0.38	0.3854	173.0	0.2491	0.88	3.146	1411	2.033
0.39	0.4113	184.6	0.2658	0.89	3.236	1452	2.091
0.40	0.4382	196.6	0.2831	0.90	3.327	1493	2.150
0.41	0.4661	209.1	0.3012	0.91	3.421	1535	2.210
0.42	0.4950	222.1	0.3199	0.92	3.515	1577	2.272
0.43	0.5250	235.6	0.3392	0.93	3.612	1621	2.334
0.44	0.5561	249.5	0.3593	0.94	3.709	1665	2.397
0.45	0.5882	263.9	0.3801	0.95	3.809	1709	2.461
0.46	0.6214	278.8	0.4016	0.96	3.910	1754	2.527
0.47	0.6557	294.3	0.4237	0.97	4.013	1801	2.593
0.48	0.6912	310.2	0.4466	0.98	4.117	1847	2.660
0.49	0.7277	326.6	0.4703	0.99	4.223	1895	2.729
0.50	0.7654	343.5	0.4946	1.00	4.330	1943	2.798

Table 11-1:
1 ft. Rectangular Weir without End Contractions
Discharge Table with Head in Feet

Formulas: $CFS = 3.330\ H^{1.5}$ $MGD = 2.152\ H^{1.5}$
$GPM = 1495\ H^{1.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.26	0.4415	198.2	0.2853
0.02				0.27	0.4672	209.7	0.3019
0.03				0.28	0.4934	221.5	0.3188
0.04				0.29	0.5200	233.5	0.3361
0.05				0.30	0.5472	245.7	0.3536
0.06				0.31	0.5748	258.0	0.3714
0.07				0.32	0.6028	270.6	0.3896
0.08				0.33	0.6313	283.4	0.4080
0.09				0.34	0.6602	296.4	0.4266
0.10				0.35	0.6895	309.6	0.4456
0.11				0.36	0.7193	322.9	0.4648
0.12				0.37	0.7495	336.5	0.4843
0.13				0.38	0.7800	350.2	0.5041
0.14				0.39	0.8110	364.1	0.5241
0.15				0.40	0.8424	378.2	0.5444
0.16				0.41	0.8742	392.5	0.5650
0.17				0.42	0.9064	406.9	0.5858
0.18				0.43	0.9390	421.5	0.6068
0.19				0.44	0.9719	436.3	0.6281
0.20	0.2978	133.7	0.1925	0.45	1.005	451.3	0.6496
0.21	0.3205	143.9	0.2071	0.46	1.039	466.4	0.6714
0.22	0.3436	154.3	0.2221	0.47	1.073	481.7	0.6934
0.23	0.3673	164.9	0.2374	0.48	1.107	497.2	0.7157
0.24	0.3915	175.8	0.2530	0.49	1.142	512.8	0.7381
0.25	0.4163	186.9	0.2690	0.50	1.177	528.6	0.7608

Table 11-2:
1½ ft. Rectangular Weir without End Contractions
Discharge Table with Head in Feet

Formulas: $CFS = 4.995\ H^{1.5}$ $MGD = 3.228\ H^{1.5}$
$GPM = 2242\ H^{1.5}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.39	1.217	546.1	0.7862
0.02				0.40	1.264	567.2	0.8166
0.03				0.41	1.311	588.6	0.8474
0.04				0.42	1.360	610.3	0.8786
0.05				0.43	1.408	632.2	0.9102
0.06				0.44	1.458	654.4	0.9421
0.07				0.45	1.508	676.8	0.9744
0.08				0.46	1.558	699.5	1.007
0.09				0.47	1.609	722.4	1.040
0.10				0.48	1.661	745.6	1.073
0.11				0.49	1.713	769.0	1.107
0.12				0.50	1.766	792.7	1.141
0.13				0.51	1.819	816.6	1.176
0.14				0.52	1.873	840.7	1.210
0.15				0.53	1.927	865.1	1.246
0.16				0.54	1.982	889.7	1.281
0.17				0.55	2.037	914.5	1.317
0.18				0.56	2.093	939.5	1.353
0.19				0.57	2.150	964.8	1.389
0.20	0.4468	200.5	0.2887	0.58	2.206	990.3	1.426
0.21	0.4807	215.8	0.3106	0.59	2.264	1016	1.463
0.22	0.5154	231.4	0.3331	0.60	2.321	1042	1.500
0.23	0.5510	247.3	0.3561	0.61	2.380	1068	1.538
0.24	0.5873	263.6	0.3795	0.62	2.439	1095	1.576
0.25	0.6244	280.3	0.4035	0.63	2.498	1121	1.614
0.26	0.6622	297.2	0.4280	0.64	2.557	1148	1.653
0.27	0.7008	314.5	0.4529	0.65	2.618	1175	1.692
0.28	0.7401	332.2	0.4783	0.66	2.678	1202	1.731
0.29	0.7801	350.1	0.5041	0.67	2.739	1230	1.770
0.30	0.8208	368.4	0.5304	0.68	2.801	1257	1.810
0.31	0.8621	387.0	0.5572	0.69	2.863	1285	1.850
0.32	0.9042	405.8	0.5843	0.70	2.925	1313	1.891
0.33	0.9469	425.0	0.6119	0.71	2.988	1341	1.931
0.34	0.9903	444.5	0.6400	0.72	3.052	1370	1.972
0.35	1.034	464.2	0.6684	0.73	3.115	1398	2.013
0.36	1.079	484.3	0.6972	0.74	3.180	1427	2.055
0.37	1.124	504.6	0.7265	0.75	3.244	1456	2.097
0.38	1.170	525.2	0.7562				

Table 11-3:
2 ft. Rectangular Weir without End Contractions
Discharge Table with Head in Feet

Formulas: $CFS = 6.660\ H^{1.5}$ $MGD = 4.304\ H^{1.5}$
$GPM = 2989\ H^{1.5}$

Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	2.426	1089	1.568
0.02				0.52	2.497	1121	1.614
0.03				0.53	2.570	1153	1.661
0.04				0.54	2.643	1186	1.708
0.05				0.55	2.717	1219	1.756
0.06				0.56	2.791	1253	1.804
0.07				0.57	2.866	1286	1.852
0.08				0.58	2.942	1320	1.901
0.09				0.59	3.018	1355	1.951
0.10				0.60	3.095	1389	2.000
0.11				0.61	3.173	1424	2.051
0.12				0.62	3.251	1459	2.101
0.13				0.63	3.330	1495	2.152
0.14				0.64	3.410	1530	2.204
0.15				0.65	3.490	1566	2.255
0.16				0.66	3.571	1603	2.308
0.17				0.67	3.652	1639	2.360
0.18				0.68	3.735	1676	2.413
0.19				0.69	3.817	1713	2.467
0.20	0.5957	267.3	0.3850	0.70	3.901	1751	2.521
0.21	0.6409	287.6	0.4142	0.71	3.984	1788	2.575
0.22	0.6872	308.4	0.4441	0.72	4.069	1826	2.629
0.23	0.7346	329.7	0.4747	0.73	4.154	1864	2.684
0.24	0.7831	351.4	0.5060	0.74	4.240	1903	2.740
0.25	0.8325	373.6	0.5380	0.75	4.326	1941	2.796
0.26	0.8829	396.3	0.5706	0.76	4.413	1980	2.852
0.27	0.9344	419.3	0.6038	0.77	4.500	2020	2.908
0.28	0.9868	442.9	0.6377	0.78	4.588	2059	2.965
0.29	1.040	466.8	0.6722	0.79	4.676	2099	3.022
0.30	1.094	491.1	0.7072	0.80	4.766	2139	3.080
0.31	1.150	515.9	0.7429	0.81	4.855	2179	3.138
0.32	1.206	541.1	0.7791	0.82	4.945	2219	3.196
0.33	1.263	566.6	0.8159	0.83	5.036	2260	3.255
0.34	1.320	592.6	0.8533	0.84	5.127	2301	3.314
0.35	1.379	618.9	0.8912	0.85	5.219	2342	3.373
0.36	1.439	645.6	0.9297	0.86	5.312	2384	3.433
0.37	1.499	672.7	0.9687	0.87	5.404	2426	3.493
0.38	1.560	700.2	1.008	0.88	5.498	2467	3.553
0.39	1.622	728.0	1.048	0.89	5.592	2510	3.614
0.40	1.685	756.2	1.089	0.90	5.686	2552	3.675
0.41	1.748	784.7	1.130	0.91	5.781	2595	3.736
0.42	1.813	813.6	1.172	0.92	5.877	2638	3.798
0.43	1.878	842.8	1.214	0.93	5.973	2681	3.860
0.44	1.944	872.4	1.256	0.94	6.070	2724	3.923
0.45	2.010	902.3	1.299	0.95	6.167	2768	3.985
0.46	2.078	932.5	1.343	0.96	6.264	2811	4.048
0.47	2.146	963.1	1.387	0.97	6.363	2856	4.112
0.48	2.215	994.0	1.431	0.98	6.461	2900	4.176
0.49	2.284	1025	1.476	0.99	6.560	2944	4.240
0.50	2.355	1057	1.522	1.00	6.660	2989	4.304

Table 12-3

2 ft. Cipolletti Weir Discharge Table with Head in Feet

Formulas: $CFS = 6.734\ H^{1.5}$ $MGD = 4.352\ H^{1.5}$
$GPM = 3022\ H^{1.5}$

Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	2.453	1101	1.585
0.02				0.52	2.525	1133	1.632
0.03				0.53	2.598	1166	1.679
0.04				0.54	2.672	1199	1.727
0.05				0.55	2.747	1233	1.775
0.06				0.56	2.822	1266	1.824
0.07				0.57	2.898	1300	1.873
0.08				0.58	2.975	1335	1.922
0.09				0.59	3.052	1370	1.972
0.10				0.60	3.130	1404	2.023
0.11				0.61	3.208	1440	2.073
0.12				0.62	3.287	1475	2.125
0.13				0.63	3.367	1511	2.176
0.14				0.64	3.448	1547	2.228
0.15				0.65	3.529	1584	2.281
0.16				0.66	3.611	1620	2.333
0.17				0.67	3.693	1657	2.387
0.18				0.68	3.776	1695	2.440
0.19				0.69	3.860	1732	2.494
0.20	0.6023	270.3	0.3893	0.70	3.944	1770	2.549
0.21	0.6480	290.8	0.4188	0.71	4.029	1808	2.604
0.22	0.6949	311.8	0.4491	0.72	4.114	1846	2.659
0.23	0.7428	333.3	0.4800	0.73	4.200	1885	2.714
0.24	0.7918	355.3	0.5117	0.74	4.287	1924	2.770
0.25	0.8418	377.8	0.5440	0.75	4.374	1963	2.827
0.26	0.8928	400.6	0.5770	0.76	4.462	2002	2.883
0.27	0.9448	424.0	0.6106	0.77	4.550	2042	2.941
0.28	0.9977	447.7	0.6448	0.78	4.639	2082	2.998
0.29	1.052	471.9	0.6797	0.79	4.728	2122	3.056
0.30	1.107	496.6	0.7151	0.80	4.818	2162	3.114
0.31	1.162	521.6	0.7512	0.81	4.909	2203	3.173
0.32	1.219	547.0	0.7878	0.82	5.000	2244	3.232
0.33	1.277	572.9	0.8250	0.83	5.092	2285	3.291
0.34	1.335	599.1	0.8628	0.84	5.184	2327	3.350
0.35	1.394	625.7	0.9011	0.85	5.277	2368	3.410
0.36	1.455	652.8	0.9400	0.86	5.371	2410	3.471
0.37	1.516	680.1	0.9795	0.87	5.465	2452	3.532
0.38	1.577	707.9	1.019	0.88	5.559	2495	3.593
0.39	1.640	736.0	1.060	0.89	5.654	2537	3.654
0.40	1.704	764.5	1.101	0.90	5.750	2580	3.716
0.41	1.768	793.4	1.143	0.91	5.846	2623	3.778
0.42	1.833	822.6	1.185	0.92	5.942	2667	3.840
0.43	1.899	852.1	1.227	0.93	6.039	2710	3.903
0.44	1.965	882.0	1.270	0.94	6.137	2754	3.966
0.45	2.033	912.2	1.314	0.95	6.235	2798	4.030
0.46	2.101	942.8	1.358	0.96	6.334	2843	4.094
0.47	2.170	973.7	1.402	0.97	6.433	2887	4.158
0.48	2.239	1005	1.447	0.98	6.533	2932	4.222
0.49	2.310	1037	1.493	0.99	6.633	2977	4.287
0.50	2.381	1068	1.539	1.00	6.734	3022	4.352

Table 13-4:
6 in. Parshall Flume Discharge Table with Head in Feet

Formulas: $CFS = 2.060\ H^{1.580}$ $MGD = 1.331\ H^{1.580}$
$GPM = 924.5\ H^{1.580}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.7109	319.1	0.4593
0.02				0.52	0.7331	329.0	0.4737
0.03				0.53	0.7555	339.0	0.4881
0.04				0.54	0.7781	349.2	0.5028
0.05				0.55	0.8010	359.5	0.5175
0.06				0.56	0.8241	369.9	0.5325
0.07				0.57	0.8475	380.4	0.5476
0.08				0.58	0.8711	391.0	0.5629
0.09				0.59	0.8950	401.7	0.5783
0.10	0.0542	24.32	0.0350	0.60	0.9191	412.5	0.5938
0.11	0.0630	28.27	0.0407	0.61	0.9434	423.4	0.6095
0.12	0.0723	32.43	0.0467	0.62	0.9679	434.4	0.6254
0.13	0.0820	36.81	0.0530	0.63	0.9927	445.5	0.6414
0.14	0.0922	41.38	0.0596	0.64	1.018	456.7	0.6576
0.15	0.1028	46.15	0.0664	0.65	1.043	468.1	0.6739
0.16	0.1139	51.10	0.0736	0.66	1.068	479.5	0.6903
0.17	0.1253	56.24	0.0810	0.67	1.094	491.0	0.7069
0.18	0.1372	61.55	0.0886	0.68	1.120	502.7	0.7237
0.19	0.1494	67.04	0.0965	0.69	1.146	514.4	0.7406
0.20	0.1620	72.70	0.1047	0.70	1.173	526.2	0.7576
0.21	0.1750	78.53	0.1131	0.71	1.199	538.1	0.7748
0.22	0.1883	84.52	0.1217	0.72	1.226	550.2	0.7921
0.23	0.2020	90.66	0.1305	0.73	1.253	562.3	0.8095
0.24	0.2161	96.97	0.1396	0.74	1.280	574.5	0.8271
0.25	0.2305	103.4	0.1489	0.75	1.308	586.8	0.8448
0.26	0.2452	110.0	0.1584	0.76	1.335	599.2	0.8627
0.27	0.2603	116.8	0.1682	0.77	1.363	611.7	0.8807
0.28	0.2757	123.7	0.1781	0.78	1.391	624.3	0.8989
0.29	0.2914	130.8	0.1883	0.79	1.419	637.0	0.9171
0.30	0.3074	138.0	0.1986	0.80	1.448	649.8	0.9355
0.31	0.3238	145.3	0.2092	0.81	1.477	662.7	0.9541
0.32	0.3404	152.8	0.2199	0.82	1.506	675.7	0.9728
0.33	0.3574	160.4	0.2309	0.83	1.535	688.7	0.9916
0.34	0.3746	168.1	0.2421	0.84	1.564	701.9	1.011
0.35	0.3922	176.0	0.2534	0.85	1.593	715.1	1.030
0.36	0.4100	184.0	0.2649	0.86	1.623	728.5	1.049
0.37	0.4282	192.2	0.2767	0.87	1.653	741.9	1.068
0.38	0.4466	200.4	0.2886	0.88	1.683	755.4	1.088
0.39	0.4653	208.8	0.3006	0.89	1.714	769.0	1.107
0.40	0.4843	217.4	0.3129	0.90	1.744	782.7	1.127
0.41	0.5036	226.0	0.3254	0.91	1.775	796.5	1.147
0.42	0.5231	234.8	0.3380	0.92	1.806	810.4	1.167
0.43	0.5429	243.7	0.3508	0.93	1.837	824.3	1.187
0.44	0.5630	252.7	0.3638	0.94	1.868	838.4	1.207
0.45	0.5834	261.8	0.3769	0.95	1.900	852.5	1.227
0.46	0.6040	271.1	0.3902	0.96	1.931	866.8	1.248
0.47	0.6249	280.4	0.4037	0.97	1.963	881.1	1.268
0.48	0.6460	289.9	0.4174	0.98	1.995	895.5	1.289
0.49	0.6674	299.5	0.4312	0.99	2.028	909.9	1.310
0.50	0.6890	309.2	0.4452	1.00	2.060	924.5	1.331

Table 13-5:
9 in. Parshall Flume Discharge Table with Head in Feet

Formulas: $CFS = 3.070\ H^{1.530}$ $MGD = 1.984\ H^{1.530}$
$GPM = 1378\ H^{1.530}$
Where: H = head in feet

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	1.096	491.8	0.7081
0.02				0.52	1.129	506.7	0.7295
0.03				0.53	1.162	521.7	0.7511
0.04				0.54	1.196	536.8	0.7729
0.05				0.55	1.230	552.1	0.7949
0.06				0.56	1.264	567.5	0.8171
0.07				0.57	1.299	583.1	0.8395
0.08				0.58	1.334	598.8	0.8622
0.09				0.59	1.369	614.7	0.8850
0.10	0.0906	40.67	0.0586	0.60	1.405	630.7	0.9081
0.11	0.1048	47.05	0.0677	0.61	1.441	646.9	0.9313
0.12	0.1198	53.75	0.0774	0.62	1.477	663.1	0.9548
0.13	0.1354	60.76	0.0875	0.63	1.514	679.6	0.9784
0.14	0.1516	68.05	0.0980	0.64	1.551	696.2	1.002
0.15	0.1685	75.63	0.1089	0.65	1.588	712.9	1.026
0.16	0.1860	83.47	0.1202	0.66	1.626	729.7	1.051
0.17	0.2040	91.59	0.1319	0.67	1.664	746.7	1.075
0.18	0.2227	99.96	0.1439	0.68	1.702	763.8	1.100
0.19	0.2419	108.6	0.1563	0.69	1.740	781.1	1.125
0.20	0.2616	117.4	0.1691	0.70	1.779	798.5	1.150
0.21	0.2819	126.5	0.1822	0.71	1.818	816.0	1.175
0.22	0.3027	135.9	0.1956	0.72	1.857	833.6	1.200
0.23	0.3240	145.4	0.2094	0.73	1.897	851.4	1.226
0.24	0.3458	155.2	0.2235	0.74	1.937	869.3	1.252
0.25	0.3681	165.2	0.2379	0.75	1.977	887.3	1.278
0.26	0.3909	175.5	0.2526	0.76	2.017	905.5	1.304
0.27	0.4141	185.9	0.2676	0.77	2.058	923.8	1.330
0.28	0.4378	196.5	0.2829	0.78	2.099	942.2	1.357
0.29	0.4620	207.4	0.2985	0.79	2.140	960.8	1.383
0.30	0.4866	218.4	0.3144	0.80	2.182	979.4	1.410
0.31	0.5116	229.6	0.3306	0.81	2.224	998.2	1.437
0.32	0.5371	241.1	0.3471	0.82	2.266	1017	1.464
0.33	0.5629	252.7	0.3638	0.83	2.308	1036	1.492
0.34	0.5893	264.5	0.3808	0.84	2.351	1055	1.519
0.35	0.6160	276.5	0.3981	0.85	2.394	1075	1.547
0.36	0.6431	288.7	0.4156	0.86	2.437	1094	1.575
0.37	0.6706	301.0	0.4334	0.87	2.481	1114	1.603
0.38	0.6986	313.6	0.4515	0.88	2.525	1133	1.632
0.39	0.7269	326.3	0.4698	0.89	2.569	1153	1.660
0.40	0.7556	339.2	0.4883	0.90	2.613	1173	1.689
0.41	0.7847	352.2	0.5071	0.91	2.657	1193	1.717
0.42	0.8142	365.4	0.5262	0.92	2.702	1213	1.746
0.43	0.8440	378.8	0.5454	0.93	2.747	1233	1.775
0.44	0.8742	392.4	0.5650	0.94	2.793	1254	1.805
0.45	0.9048	406.1	0.5847	0.95	2.838	1274	1.834
0.46	0.9357	420.0	0.6047	0.96	2.884	1295	1.864
0.47	0.9670	434.1	0.6250	0.97	2.930	1315	1.894
0.48	0.9987	448.3	0.6454	0.98	2.977	1336	1.924
0.49	1.031	462.6	0.6661	0.99	3.023	1357	1.954
0.50	1.063	477.2	0.6870	1.00	3.070	1378	1.984

Table 14-3:
8 in. Palmer-Bowlus Flume Discharge Table with Head in Feet

Manufactured by Plasti-Fab, Inc. (Data from Plasti-Fab, Inc.)

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.26	0.1942	87.18	0.1255
0.02				0.27	0.2086	93.61	0.1348
0.03				0.28	0.2235	100.3	0.1445
0.04				0.29	0.2391	107.3	0.1545
0.05				0.30	0.2553	114.6	0.1650
0.06				0.31	0.2720	122.1	0.1758
0.07				0.32	0.2895	129.9	0.1871
0.08				0.33	0.3075	138.0	0.1987
0.09	0.0306	13.73	0.0198	0.34	0.3261	146.4	0.2108
0.10	0.0365	16.39	0.0236	0.35	0.3454	155.0	0.2232
0.11	0.0429	19.24	0.0277	0.36	0.3652	163.9	0.2360
0.12	0.0497	22.29	0.0321	0.37	0.3856	173.1	0.2492
0.13	0.0569	25.53	0.0368	0.38	0.4066	182.5	0.2628
0.14	0.0646	28.97	0.0417	0.39	0.4281	192.1	0.2767
0.15	0.0727	32.61	0.0470	0.40	0.4500	202.0	0.2909
0.16	0.0812	36.45	0.0525	0.41	0.4725	212.1	0.3054
0.17	0.0902	40.50	0.0583	0.42	0.4954	222.3	0.3202
0.18	0.0997	44.76	0.0645	0.43	0.5187	232.8	0.3352
0.19	0.1097	49.24	0.0709	0.44	0.5423	243.4	0.3505
0.20	0.1202	53.94	0.0777	0.45	0.5663	254.2	0.3660
0.21	0.1312	58.87	0.0848	0.46	0.5906	265.0	0.3817
0.22	0.1427	64.04	0.0922	0.47	0.6151	276.1	0.3975
0.23	0.1547	69.44	0.1000	0.48	0.6399	287.2	0.4135
0.24	0.1673	75.10	0.1081	0.49	0.6648	298.4	0.4297
0.25	0.1805	81.01	0.1167	0.50	0.6900	309.7	0.4459

Table 17-1:
Large 60° V Trapezoidal Flume Discharge Table with Head in Feet

Manufactured by Plasti-Fab, Inc. (Data from Plasti-Fab, Inc.)

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.29	0.0636	28.53	0.0411
0.02				0.30	0.0694	31.14	0.0449
0.03	0.0002	0.0819	0.0001	0.31	0.0755	33.89	0.0488
0.04	0.0004	0.1721	0.0002	0.32	0.0820	36.78	0.0530
0.05	0.0007	0.3060	0.0004	0.33	0.0887	39.82	0.0574
0.06	0.0011	0.4898	0.0007	0.34	0.0958	43.01	0.0620
0.07	0.0016	0.7290	0.0011	0.35	0.1033	46.35	0.0668
0.08	0.0023	1.029	0.0015	0.36	0.1111	49.84	0.0718
0.09	0.0031	1.394	0.0020	0.37	0.1192	53.50	0.0771
0.10	0.0041	1.830	0.0026	0.38	0.1277	57.31	0.0825
0.11	0.0052	2.340	0.0034	0.39	0.1365	61.28	0.0883
0.12	0.0065	2.929	0.0042	0.40	0.1458	65.41	0.0942
0.13	0.0080	3.600	0.0052	0.41	0.1554	69.72	0.1004
0.14	0.0097	4.359	0.0063	0.42	0.1653	74.19	0.1069
0.15	0.0116	5.208	0.0075	0.43	0.1757	78.83	0.1136
0.16	0.0137	6.152	0.0089	0.44	0.1864	83.65	0.1205
0.17	0.0160	7.193	0.0104	0.45	0.1975	88.64	0.1277
0.18	0.0186	8.336	0.0120	0.46	0.2090	93.82	0.1351
0.19	0.0214	9.584	0.0138	0.47	0.2210	99.17	0.1428
0.20	0.0244	10.94	0.0158	0.48	0.2333	104.7	0.1508
0.21	0.0276	12.41	0.0179	0.49	0.2461	110.4	0.1591
0.22	0.0312	13.99	0.0202	0.50	0.2592	116.3	0.1676
0.23	0.0350	15.69	0.0226	0.51	0.2728	122.4	0.1764
0.24	0.0390	17.51	0.0252	0.52	0.2868	128.7	0.1854
0.25	0.0434	19.46	0.0280	0.53	0.3013	135.2	0.1948
0.26	0.0480	21.53	0.0310	0.54	0.3162	141.9	0.2044
0.27	0.0529	23.73	0.0342	0.55	0.3315	148.8	0.2143
0.28	0.0581	26.06	0.0375	0.56	0.3473	155.8	0.2245

Table 17-2:
Extra Large 60° V Trapezoidal Flume Discharge Table with Head in Feet

Manufactured by Plasti-Fab, Inc. (Data from Plasti-Fab, Inc.)

Head (feet)	CFS	GPM	MGD	Head (feet)	CFS	GPM	MGD
0.01				0.51	0.2623	117.7	0.1695
0.02				0.52	0.2761	123.9	0.1784
0.03	0.0001	0.0671	0.0001	0.53	0.2903	130.3	0.1875
0.04	0.0003	0.1434	0.0002	0.54	0.3050	136.9	0.1970
0.05	0.0006	0.2582	0.0004	0.55	0.3201	143.7	0.2068
0.06	0.0009	0.4175	0.0006	0.56	0.3357	150.6	0.2168
0.07	0.0014	0.6268	0.0009	0.57	0.3517	157.8	0.2272
0.08	0.0020	0.8913	0.0013	0.58	0.3682	165.2	0.2379
0.09	0.0027	1.216	0.0018	0.59	0.3852	172.9	0.2488
0.10	0.0036	1.605	0.0023	0.60	0.4026	180.7	0.2601
0.11	0.0046	2.064	0.0030	0.61	0.4206	188.7	0.2717
0.12	0.0058	2.596	0.0037	0.62	0.4390	197.0	0.2836
0.13	0.0071	3.205	0.0046	0.63	0.4579	205.5	0.2958
0.14	0.0087	3.897	0.0056	0.64	0.4773	214.2	0.3083
0.15	0.0104	4.674	0.0067	0.65	0.4972	223.1	0.3212
0.16	0.0123	5.541	0.0080	0.66	0.5176	232.3	0.3344
0.17	0.0145	6.502	0.0094	0.67	0.5386	241.7	0.3479
0.18	0.0168	7.559	0.0109	0.68	0.5600	251.3	0.3618
0.19	0.0194	8.717	0.0125	0.69	0.5820	261.2	0.3760
0.20	0.0222	9.979	0.0144	0.70	0.6045	271.3	0.3905
0.21	0.0253	11.35	0.0163	0.71	0.6275	281.6	0.4054
0.22	0.0286	12.83	0.0185	0.72	0.6511	292.2	0.4206
0.23	0.0321	14.43	0.0208	0.73	0.6752	303.0	0.4362
0.24	0.0360	16.14	0.0232	0.74	0.6999	314.1	0.4521
0.25	0.0400	17.97	0.0259	0.75	0.7251	325.4	0.4684
0.26	0.0444	19.93	0.0287	0.76	0.7509	337.0	0.4851
0.27	0.0491	22.01	0.0317	0.77	0.7772	348.8	0.5021
0.28	0.0540	24.23	0.0349	0.78	0.8041	360.8	0.5194
0.29	0.0592	26.58	0.0383	0.79	0.8315	373.2	0.5372
0.30	0.0648	29.06	0.0418	0.80	0.8596	385.8	0.5553
0.31	0.0706	31.69	0.0456	0.81	0.8882	398.6	0.5738
0.32	0.0768	34.45	0.0496	0.82	0.9174	411.7	0.5926
0.33	0.0833	37.36	0.0538	0.83	0.9472	425.1	0.6119
0.34	0.0901	40.42	0.0582	0.84	0.9776	438.7	0.6315
0.35	0.0972	43.63	0.0628	0.85	1.009	452.6	0.6515
0.36	0.1047	47.00	0.0677	0.86	1.040	466.8	0.6719
0.37	0.1126	50.52	0.0727	0.87	1.072	481.2	0.6927
0.38	0.1208	54.20	0.0780	0.88	1.105	495.9	0.7139
0.39	0.1293	58.04	0.0835	0.89	1.139	510.9	0.7355
0.40	0.1383	62.05	0.0893	0.90	1.173	526.2	0.7575
0.41	0.1476	66.22	0.0953	0.91	1.207	541.8	0.7799
0.42	0.1572	70.56	0.1016	0.92	1.243	557.6	0.8027
0.43	0.1673	75.08	0.1081	0.93	1.278	573.7	0.8259
0.44	0.1777	79.77	0.1148	0.94	1.315	590.1	0.8495
0.45	0.1886	84.64	0.1218	0.95	1.352	606.8	0.8735
0.46	0.1998	89.69	0.1291	0.96	1.390	623.8	0.8980
0.47	0.2115	94.92	0.1366	0.97	1.429	641.1	0.9228
0.48	0.2236	100.3	0.1444	0.98	1.468	658.7	0.9481
0.49	0.2361	105.9	0.1525	0.99	1.508	676.5	0.9739
0.50	0.2490	111.7	0.1608	1.00	1.548	694.7	1.000