Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Wastewater Flow Measurement**	
Effective Date: August 27, 2015	**Number:** SESDPROC-109-R4
Authors	
Name: Louis Salguero Title: Environmental Engineer Signature: [signature]	Date: Aug 26, 2015
Approvals	
Name: John Deatrick Title: Chief, Field Services Branch Signature: [signature]	Date: 8/26/15
Name: Hunter Johnson Title: Field Quality Manager, Science and Ecosystem Support Division Signature: [signature]	Date: 8/26/15

Revision History

The top row of this table shows the most recent changes to this controlled document. For previous revision history information, archived versions of this document are maintained by the SESD Document Control Coordinator on the SESD local area network (LAN).

History	Effective Date
SESDPROC-109-R4, *Wastewater Flow Measurement*, Replaces SESDPROC-109-R3 **Cover Page:** SESD's reorganization was reflected in the authorization section by making John Deatrick the Chief of the Field Services Branch. The FQM was changed from Liza Montalvo to Hunter Johnson. **Revision History:** Changes were made to reflect the current practice of only including the most recent changes in the revision history. **Section 2.4:** First Paragraph – Omitted the following sentence "This flow measurement device should be set up as close as possible to the facility's flow measurement equipment and in the same water or wastewater stream." Added "This flow measurement device should be set up at the appropriate head measurement point. Second Paragraph – Omitted the "The accuracy of the primary flow device…" and added "The accuracy of the secondary system…" **Section 2.6.1:** Second Paragraph – Added "Where C is the discharge coefficient, L is the length of the weir, and H is the hydraulic level at the time of measurement." and "This is due to the variation of the C value when the H value changes." **Section 4:** Third Paragraph – Added "A limited number of primary devices are maintained by SESD."	August 27, 2015
SESDPROC-109-R3, *Wastewater Flow Measurement*, Replaces SESDPROC-109-R2	August 12, 2011
SESDPROC-109-R2, *Wastewater Flow Measurement*, Replaces SESDPROC-109-R1	June 13, 2008
SESDPROC-109-R1, *Wastewater Flow Measurement*, replaces SESDPROC-109-R0	November 1, 2007
SESDPROC-109-R0, Wastewater Flow Measurement, Original Issue	February 05, 2007

TABLE OF CONTENTS

1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when conducting flow measurement during field investigations.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when conducting flow measurement in the field. On the occasion that SESD field personnel determine that any of the procedures described in this section are inappropriate, inadequate or impractical and that another procedure must be used to obtain flow measurement data, the variant procedure will be documented in the field logbook, along with a description of the circumstances requiring its use. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD local area network (LAN). The Document Control Coordinator is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 References

1. Water Measurement Manual, U.S. Department of the Interior, Bureau of Reclamation, Most Recent Edition.

2. National Pollutant Discharge Elimination System (NPDES) Compliance Inspection Manual, U.S. Environmental Protection Agency, Most Recent Version.

3. SESD Operating Procedure for Hydrological Studies, SESDPROC-501, Most Recent Version.

4. King, H. W., and E. F. Brater, Handbook of Hydraulics, Sixth Edition, McGraw-Hill; New York, 1976.

5. Davis, C. V., and K. E. Sorenson, Handbook of Applied Hydraulics, Third Edition, McGraw-Hill: New York, 1969.

6. Stevens Water Resources Data Book, Stevens Water Monitoring Systems, Inc., Portland, Oregon, Most Recent Edition.

7. ISCO® Open Channel Flow Measurement Handbook, Teledyne ISCO, Inc., Lincoln, Nebraska, Most Recent Edition.

8. "Discharge Measurements at Gaging Stations," Chapter 8 of Book 3, Section A, U.S. Department of Interior, U.S. Geological Survey, Reston, Virginia, 2010.

9. "Sewer Flow Measurement: A State-of-the-Art Assessment," Municipal Environmental Research Laboratory, Office of Research and Development, U. S. Environmental Protection Agency: Cincinnati, Ohio, 600-275027.

10. A Guide to Methods and Standards for the Measurement of Water Flow, U.S. Department of Commerce, National Bureau of Standards, NBS Special Publication 421, 1975.

11. Wells, E. A. and H. B. Gotaas, "Design of Venturi Flumes in Circular Conduits," American Society of Civil Engineers, 82, Proc. Paper 928, April 1956.

12. American Society of Testing Materials, 1985 Annual Book of ASTM Standards, Volume 11 - Water, American Society of Testing Materials: Philadelphia, Pennsylvania, 1985.

13. US EPA Region 4 Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), November 2001.

14. SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version.

15. SESD Operating Procedure for Control of Records, SESDPROC-002, Most Recent Version.

16. US EPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Region 4 SESD, Athens, GA, Most Recent Version.

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when collecting flow measurement data. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy (SHEMP) Manual and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear and gloves.

1.5.2 Procedural Precautions

The following precautions should be considered when collecting flow measurement data:

- Special care must be taken when walking around open flow channels.
- A safety harness is required when the danger of falling into a large volume of fast moving water presents a life threatening situation.
- Always watch footing and use hand rails at the facility to minimize accidents during walk-through of the facility.
- Watch for overhead power lines when installing flow measurement equipment.
- Wear personal protection equipment when appropriate.
- Watch for uncovered grating during walk-through.

2 Wastewater Flow Considerations

2.1 Introduction

The U.S. Department of the Interior (USDOI) Water Measurement Manual (1) is a standard reference for details on checking the installation of primary open channel flow devices. Basic guidance for making wastewater flow measurements and a basic description of all acceptable wastewater flow measurement systems are given in the EPA National Pollutant Discharge Elimination System (NPDES) Compliance Inspection Manual (2). This manual will be used by SESD field investigators as guidance for such measurements.

2.2 Site Selection

It is the field investigator's responsibility to ensure that the facility's influent or effluent wastewater flow measurement system or technique used measures the total wastewater discharged (described by the NPDES permit, if applicable). The location of influent wastewater flow measurement equipment should be prior to all recycled wastewaters streams.

2.3 Flow Measurement Systems

Flow may be measured on an instantaneous or a continuous basis. A typical continuous system consists of a primary flow device, a flow sensor, transmitter, flow recorder, and totalizer. Instantaneous flow measurements can be obtained by using the primary flow device. Techniques which are described later in this Section are available for measuring instantaneous flows with portable equipment.

The heart of a typical continuous flow measurement system is the primary flow device. This device is constructed to produce predictable hydraulic responses which are related to the flow rate of water or wastewater through it. Examples of such devices include weirs and flumes which relate water depth (head) to flow, Venturi and orifice type meters which relate differential pressure to flow, and magnetic flow meters which relate induced electric voltage to flow. These standard primary flow devices, if installed and built according to established standards, have proven to be accurate.

A flow sensor is required to measure the particular hydraulic responses of the primary flow measurement device and transmit the responses to the recording system. Typically, sensors include ultra-sonic transmitters, floats, pressure transducers, capacitance probes, differential pressure cells, electromagnetic cells, etc. The sensor signal is generally converted using mechanical, electro mechanical or electronic systems into units of flow which are recorded directly on a chart or transmitted into a data system. Systems which utilize a recorder are generally equipped with a flow totalizer which displays the total flow on a real time basis.

An important consideration for the investigator during wastewater studies is to obtain continuous flow data at a facility where only instantaneous flow data are being taken. If an open channel primary flow device is utilized for making instantaneous measurements, only the installation of a portable field sensor and recorder is necessary. If, on the other hand, the facility being investigated does not utilize a primary flow device, and a continuous flow record is desired, a Son Tek Argonaut-SW® current flow meter can be used or a portable primary flow device will have to be installed. Field investigators have open channel equipment available for field use. These devices should be installed according to the manufacturer's instructions.

Wastewater flow measurement systems are generally very accurate. Any continuous flow measurement system that cannot measure the wastewater flow within ±10 percent of the actual flow is considered unacceptable for use in measuring wastewater flow.

2.4 Field Investigation Procedures

During the investigation, the field investigator will verify that the facility's flow measurement system (including primary flow device) provides flow data within ±10 percent of the actual flow. The primary flow device and the secondary system will be checked to determine if they conform to recognized design and installation standards. Deviations from standard conditions will be documented. The facility chart recorder will be checked to verify that the time and scale are correct. The accuracy of the flow measurement system is checked by making an instantaneous flow measurement and comparing this reading against the facility's instantaneous flow reading. In addition, EPA flow equipment can be installed to confirm the facility's totalizer readings. This flow measurement device should be set up at the appropriate head measurement point. An instantaneous flow reading will be documented in the field book or on the flow chart recorder when possible.

The installation of systems to measure wastewater flows can be time consuming, particularly if there is no primary device. Therefore, field personnel can use existing facility primary flow devices and flow measurement systems when the accuracy of these devices and the system can be verified. The field investigator will verify that an existing facility flow measurement system (including primary flow device) utilized to measure wastewater flow conforms to recognized design and installation standards, and any deviation from standard conditions will be documented. The accuracy of the secondary system may be checked by making an independent flow measurement. If there is no usable or existing primary flow measuring device or if the device has been located in the wrong place, the investigator may, if so desired, install a portable primary flow device. The accuracy of flow sensors and recorders for open channel flow devices can be checked by making an instantaneous measurement utilizing the primary flow device and comparing this against the recorder reading. If the discharger's flow measurement system is accurate within ±10 percent of the actual flow, the investigator can use the existing system.

If non-standard primary flow devices are being used, data supporting the accuracy and precision of the methods being employed should be provided by the permittee. Deficiencies found during the inspection will be recorded by the investigator, and the permittee will be informed that the equipment should be calibrated as soon as possible.

2.5 Specific Techniques

This section familiarizes the field investigator with the most commonly used methods for wastewater flow measurements and the primary devices that will be encountered during field studies. The following methods are included only to enable the field investigator to make accurate flow estimates when necessary.

2.5.1 Volumetric

Volumetric flow measurement techniques are among the simplest and can be anaccurate method for measuring flow. These techniques basically involve the measurement of volume and/or the measurement of time required to fill a container of known size.

2.5.1.1 Vessel Volume

Vessel volume is used to obtain flow data particularly applicable to batch wastewater discharges. Accurate measurement of the vessel volume and the frequency at which it empties is all that is required.

2.5.1.2 Sump Pump

This measurement is made by observing the sump levels when the pumps cut on and off and calculating the volume contained between the two levels. This volume, along with the number of pump cycles, will give a good estimate of the daily wastewater flow. The inspector must also account for the quantity of wastewater that flows into the sump during the pumping cycle.

2.5.1.3 Bucket and Stop Watch

The bucket and stop watch technique is particularly useful for the measurement of small wastewater flows. It is simple to use. The only equipment required to make this measurement is a calibrated container (bucket, drum, tank, etc.) and a stop watch. A minimum of 10 seconds to fill the container is recommended. Three consecutive measurements should be made, and the results should be averaged.

2.5.2 Dilution Methods

Dilution methods for water and wastewater flow measurements are based on the color, conductivity, fluorescence, or other quantifiable property of an injected tracer. The dilution methods require specialized equipment, special attention to detail by the investigator, and are time consuming. Dilution methods are described in SESD Operating Procedure for Hydrological Studies (SESDPROC-501). (3)

2.6 Open Channel Flow Measurements

Measurement of wastewater flow in open channels is the most frequently encountered situation during field investigations. An open channel is defined as any open conduit, such as a channel or flume, or any closed conduit, such as a pipe, which is not flowing full. The most commonly encountered methods in measuring open channel wastewater flows are described in this section.

2.6.1 Weirs

A weir is defined as an overflow structure built according to specific design standards across an open channel to measure the flow of water. Equations can be derived for weirs of specific geometry which relate static head to water flow. Weirs are classified into two general categories, broad crested and sharp crested.

Broad crested weirs take the following form; Q=CLH3/2. Where C is the discharge coefficient, L is the length of the weir, and H is the hydraulic level at the time of measurement. Values for the coefficient C are given in hydraulic handbooks (4, 5). Broad crested weirs can only be used to calculate instantaneous flows. This is due to the variation of the C value when the H value changes.

Sharp crested weirs are constructed in a wide variety of shapes and the most commonly encountered are V-notch, rectangular, and Cipolletti weirs. If such weirs are constructed as outlined in the USDOI Water Measurement Manual (1), they are considered standard primary flow devices.

All weirs should be inspected to determine if the weir installation and construction conform to the conditions given in the USDOI Water Measurement Manual (1), and provide a uniform influent flow distribution, and that the weir is placed squarely across the channel perpendicular to the direction of flow. Useful tools for checking weir construction and installation include a carpenter's level, a framing square, a measuring tape, a staff gage, or surveyor's level and rod. Problems observed during the inspection or study should be noted in the field records or logbook.

A set of weir tables is necessary for calculating the flow. Some sources of these tables are: the USDOI Water Measurement Manual (1), the Stevens Water Resources Data Book (6), and the ISCO® Open Channel Flow Measurement Handbook (7).

2.6.2 Flumes

There are several types of flumes (e.g., Palmer-Bowlus, Cutthroat, H, and Trapezoidal) but the most widely used is the Parshall flume. The Parshall flume is considered a standard primary flow device when constructed and installed as outlined in the USDOI Water Measurement Manual (1).

All flumes should be inspected to determine if entrance conditions provide a uniform influent flow distribution, the flume dimensions conform to those given in the USDOI Water Measurement Manual (1), the floor of the flume at the throat section is level, and the throat section walls are vertical. Useful tools for checking the construction and installation of Parshall (and other) flumes include a carpenter's level, a framing square, and a measuring tape. The flume should be closely examined to determine if it is discharging freely. If there is any question about free discharge, the downstream head (Hb) should be measured and compared to the head at the proper location (Ha) in the converging section. A staff gage is useful for making head measurements. Any problems observed during the inspection or study should be noted in the field logbook.

A set of flume tables is necessary for calculating flows. Some sources of these Tables are: the USDOI Water Measurement Manual (1), the Stevens Water Resources Data Book (6), and the ISCO® Open Channel Flow Measurement Handbook (7). The explanatory material accompanying these tables should be read and understood before they are used. Tabulated flow values are given for measured head values to determine accuracy.

2.6.3 Open Flow Nozzles

Open flow nozzles such as parabolic or Kennison nozzles are factory calibrated and are ordinarily supplied as part of a flow measurement system. Calibration and installation information for each nozzle should be supplied by or obtained from the manufacturer. The accuracy of these devices is reported to be often better than ± 5 percent of the indicated flow. A volumetric flow measurement may be used to check accuracy of this device if flow volumes are not excessive.

2.6.4 Velocity-Area Method

The basic principle of this method is that the flow in a channel (cubic feet/second) is equal to the average velocity (feet/second) times the cross sectional area (square feet) of the channel. SESD has two methods for determining flow using the area velocity method. The first method uses an ISCO® area-velocity flow meter in which the probe senses velocity and water depth and converts these readings to a flow rate. In the second method, the velocity of the water or wastewater is determined with an Argonaut-SW® current flow meter (which can also calculate cross-sectional area changes) or a current meter. The area of the channel is either measured or calculated using an approximation technique. Refer to SESD Operating Procedure for Hydrological Studies (SESDPROC-501) (3) for Surface Water Flow Measurements.

2.7 Closed Conduit Flow Measurements

The accuracy of closed conduit flow measuring devices may be difficult to verify. However, the accuracy can be checked by making an independent flow measurement. Two of the available procedures are the Instruments Direct® F-100-902 Ultrasonic Doppler flow meter and a dilution technique. When applying the dilution technique, please refer to SESD Operating Procedure for Hydrological Studies (SESDPROC-501) (3).

Below are some of the more commonly used closed conduit devices.

2.7.1 Venturi Meter

The Venturi meter employs a conversion of static head to velocity head whereby a differential is created that is proportional to flow. The typical accuracy of a Venturi meter is at ±1 to 2 percent (Refer to reference #9, 10, 11 and 12).

2.7.2 Orifice Meter

The orifice meter is a pressure differential device that measures flow by the difference in static head. They can be accurate, e.g., within ±0.5 percent, although their usable range is limited.

2.7.3 Flow Nozzle

The basic principle of operation is the same as that of the Venturi meter. The flow nozzle has an entrance section and a throat, but lacks the diverging section of the Venturi meter. Flow nozzle accuracies can approach those of Venturi meters (9).

2.7.4 Electromagnetic Flow Meter

The electromagnetic flow meter operates according to Faraday's Law of Induction where the conductor is the liquid stream, and the field is produced by a set of electromagnetic coils. The accuracy of the device is within ±1 percent of full scale (9).

2.7.5 Other Closed Conduit Devices

References for other closed conduit flow measurement methods such as acoustic flow meters, trajectory methods, pump curves, and water meters can be found in the EPA NPDES Compliance Inspection Manual (2).

3 Quality Assurance Procedures

The USDOI Water Measurement Manual (1), the USGS publication Discharge Measurements at Gaging Stations (8), the EPA NPDES Compliance Inspection Manual (2) and a set of weir and flume tables will be supplied to all field investigators. However, the measurements of wastewater flows require considerable experience.

Wastewater flow will be expressed in million gallons per day (mgd) or the metric equivalent (m^3/day). Time records associated with flow measurements will be kept in local time, will be made in the 2400 hour military time format, and will be recorded to the nearest five minutes. All flow measurements conducted will be documented in the field logbook for the event. All measurements will be traceable both to the individual making the measurements and the equipment utilized. All field equipment will be operated, calibrated, and maintained according to manufacturer's specifications. All equipment will be visually inspected prior to deployment to ensure proper operation.

3.1 Operational Check

A post-operation calibration check will be performed at the end of the flow measurement period according to manufacturer's specifications. It is also recommended that a calibration check be conducted at least once during the 24-hour flow measurement period, prior to the post-operation check.

4 Equipment

SESD flow measurement equipment is categorized as follows: water level/stage hardware and recorders, velocity measuring equipment and assemblies, and direct flow measurement equipment and instrumentation.

ISCO® Model 4210, 4220, and 4250 flow meters are used in conjunction with primary devices and are continuous recording systems. The Argonaut-SW® current flow meter is used to monitor current velocity and flow rates. The Argonaut-SW® can be installed in open channels and pipes without the use of primary devices. Flows in enclosed pipes can be measured using the Instruments Direct® F-100-902 Ultrasonic Doppler flow meter.

A limited number of primary devices are maintained by SESD. The following primary devices are available for installation: V-notch weir plates, rectangular weir plates, and one small Parshall flume. Staff gages are available for direct instantaneous readings. Surveying levels and rods are available for use in calculating the head. The corresponding conversion of water level to flow rate can be accomplished instantaneously from stage/staff gage readings corresponding to the primary flow device in use, or by instantaneous readings of the available recording flow meter systems.

5 Records

Information generated or obtained by the field investigator will be organized and accounted for in accordance with the SESD Operating Procedure for Control of Records (SESDPROC-002). Field notes, recorded in a bound field logbook will be generated as documentation according to the procedures found in SESD Operating Procedure for Logbooks (SESDPROC-010).