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An American National Standard

Standard Guide for Operation of a Gaging Station[1]

This standard is issued under the fixed designation D 5674; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The guide covers procedures used commonly for the systematic collection of streamflow information. Continuous streamflow information is necessary for understanding the amount and variability of water for many uses, including water supply, waste dilution, irrigation, hydropower, and reservoir design.

1.2 The procedures described in this guide are used widely by those responsible for the collection of streamflow data, for example, the U.S. Geological Survey, Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Department of Agriculture, Water Survey Canada, and many state and provincial agencies. The procedures are generally from internal documents of the preceding agencies, which have become the defacto standards used in North America.

1.3 It is the responsibility of the user of the guide to determine the acceptability of a specific device or procedure to meet operational requirements. Compatibility between sensors, recorders, retrieval equipment, and operational systems is necessary, and data requirements and environmental operating conditions must be considered in equipment selection.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1129 Terminology Relating to Water[2]

D 1941 Test Method for Open Channel Flow Measurement of Water with the Parshall Flume[2]

D 3858 Practice for Open-Channel Flow Measurement of Water by Velocity-Area Method[2]

D 5129 Test Method for Open Channel Flow Measurement of Water Indirectly by Using Width Contractions[2]

D 5130 Test Method for Open-Channel Flow Measurement of Water Indirectly by Slope-Area Method[2]

D 5242 Test Method for Open-Channel Flow Measurement of Water with Thin-Plate Weirs[2]

D 5243 Test Method for Open-Channel Flow Measurement of Water Indirectly at Culverts[2]

D 5388 Test Method for Indirect Measurements of Discharge by Step-Backwater Method[2]

D 5389 Test Method for Open Channel Flow Measurement by Acoustic Velocity Meter Systems[2]

D 5390 Test Method for Open Channel Flow Measurement of Water with Palmer-Bowlus Flumes[2]

D 5413 Test Method for Measurement of Water Levels in Open-Water Bodies[2]

D 5541 Practice for Developing Stage-Discharge Relation for Open-Channel Flow[2]

2.2 *ISO Standards:*[3]

ISO 1100 Liquid Flow Measurement in Open Channels—Part I: Establishment and Operation of a Gauging Station

ISO 6416 Measurement of Discharge by Ultrasonic (Acoustic) Method

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *control*—the physical properties of a channel, which determine the relationship between the stage and discharge of a location in the channel.

3.2.2 *datum*—a level plane that represents zero elevation.

3.2.3 *discharge*—the volume of water flowing through a cross-section in a unit of time, including sediment or other solids that may be dissolved in or mixed with the water; usually cubic feet per second (f^3/s) or metres per second (m/s).

3.2.4 *elevation*—the vertical distance from a datum to a point; also termed stage or gage height.

3.2.5 *gage*—a generic term that includes water level measuring devices.

3.2.6 *gage datum*—a datum whose surface is at the zero elevation of all of the gages at a gaging station. This datum is

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Measurement of Liquid Flow in Open Channels*, ISO Standards Handbook 16, 1983. Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

often at a known elevation referenced to the national geodetic vertical datum (NGVD) of 1929.

3.2.7 *gage height*—the height of a water surface above an established or arbitrary datum at a particular gaging station; also termed stage.

3.2.8 *gaging station*—a particular site on a stream, canal, lake, or reservoir at which systematic observations of hydrologic data are obtained.

3.2.9 *national geodetic vertical datum (NGVD) of 1929*—prior to 1973 known as mean sea level datum, a spheroidal datum in the conterminous United States and Canada that approximates mean sea level but does not necessarily agree with sea level at a specific location.

3.2.10 *stilling well*—a well connected to the stream with intake pipes in such a manner that it permits the measurement of stage in relatively still water.

4. Summary of Guide

4.1 A gaging station is usually installed where a continuous record of stage or discharge is required. A unique relationship exists between water surface elevation and discharge (flow rate) in most freely flowing streams. Water-level recording instruments continuously record the water surface elevation, usually termed stage or gage height. Discharge measurements are taken of the stream discharge to develop a stage-discharge curve. The discharge data are computed from recorded stage data by a stage-discharge rating curve.

5. Significance and Use

5.1 This guide is useful when a systematic record of water surface elevation or discharge is required at a specific location. Some gaging stations may be operated for only a few months; however, many have been operated for a century.

5.2 Gaging station records are used for many purposes:

5.2.1 Resource appraisal of long-term records to determine the maximum, minimum, and variability of flows of a particular stream. These data can be used for the planning and design of a variety of surface water-related projects such as water supply, flood control, hydroelectric developments, irrigation, recreation, and waste assimilation.

5.2.2 Management, where flow data are required for the operation of a surface-water structure or other management decision.

6. Site Location

6.1 The general location of the station will be dependent on the purpose for which the station is established. Location constraints for a resource appraisal-type station may be quite broad, for example, between major tributaries. Constraints for a management-type station may require a location just below a dam, contaminant discharge point, or other point at which discharge information is required specifically.

6.2 *Site Requirements*—Certain hydraulic characteristics of the stream channel are desirable for collecting high-accuracy data of minimal cost. Hydraulically difficult sites can still be gaged; however, accuracy and cost are affected adversely. Desirable conditions include the following:

6.2.1 The general course of the river should be straight for approximately 300 ft (100 m) above and below the gage.

6.2.2 The flow is confined to one channel at all stages.

6.2.3 The stream bed is stable, not subject to frequent scour and fill, and is free of aquatic growth.

6.2.4 The banks are sufficiently high to contain flow at all stages.

6.2.5 A natural feature such as ledge rock outcrop or stable gravel riffle, known as a "control," is present in the stream. It is necessary and practical in some cases to install a low-head dam or artificial control to provide this feature. Additional information on man-made structures is given in Test Methods D 1941, D 5242, and D 5390.

6.2.6 A pool is present behind the control where water-level instruments or stilling well intakes can be installed at a location below the lowest stream stage. The velocity of water passing sensors in a deep pool also eliminates or minimizes draw-down effects on stage sensors during high flow conditions.

6.2.7 The site is not affected by the hydraulic effects of a bridge, tributary stream entering the gaged channel, downstream impoundment, or tidal conditions.

6.2.8 A suitable site for making discharge measurements at all stages is available near the gage site.

6.2.9 There is accessibility for construction and operation of the gage.

6.3 *Site Selection*—An ideal site is rarely available, and judgement must be exercised when choosing between possible sites to determine that meeting the best combination of features.

6.3.1 *Office Reconnaissance*—The search for a gaging station begins with defining the limits along the stream at which the gage must be located on topographic maps of the area. The topographic information will indicate approximate bank heights or overflow areas, general channel width, constrictions, slope, roads, land use, locations of buildings, and other useful information so that promising locations can be checked out in the field.

6.3.2 *Field Reconnaissance*—If the range of possible gage locations is large, flying over the stream at a low altitude in a small aircraft is an efficient way of checking for promising sites. The view from the air on a clear day is much more helpful than peering off of a few highway bridges. Traversing the channel in a canoe or small boat is an alternative method. Field reconnaissance is best performed during low flow conditions; however, additional reconnaissance at high flow conditions and under ice-covered conditions for northern streams adds data that result in improved site selection.

6.3.3 *Logistical Reconnaissance*—Once a site has been selected that meets hydraulic considerations, and before design or construction begins, the following should occur:

6.3.3.1 Property ownership must be ascertained and legal permission secured to install and maintain the gage. This may include multiple landowners, especially if a cableway is required from which to make discharge measurements.

6.3.3.2 Necessary permits must be obtained from applicable governing agencies for, but not limited to, building and excavation, stream bank permits, and FAA notification for cableways or other local requirements.

6.3.3.3 Where electrical or phone service is required for operation, the availability of this service should be verified.

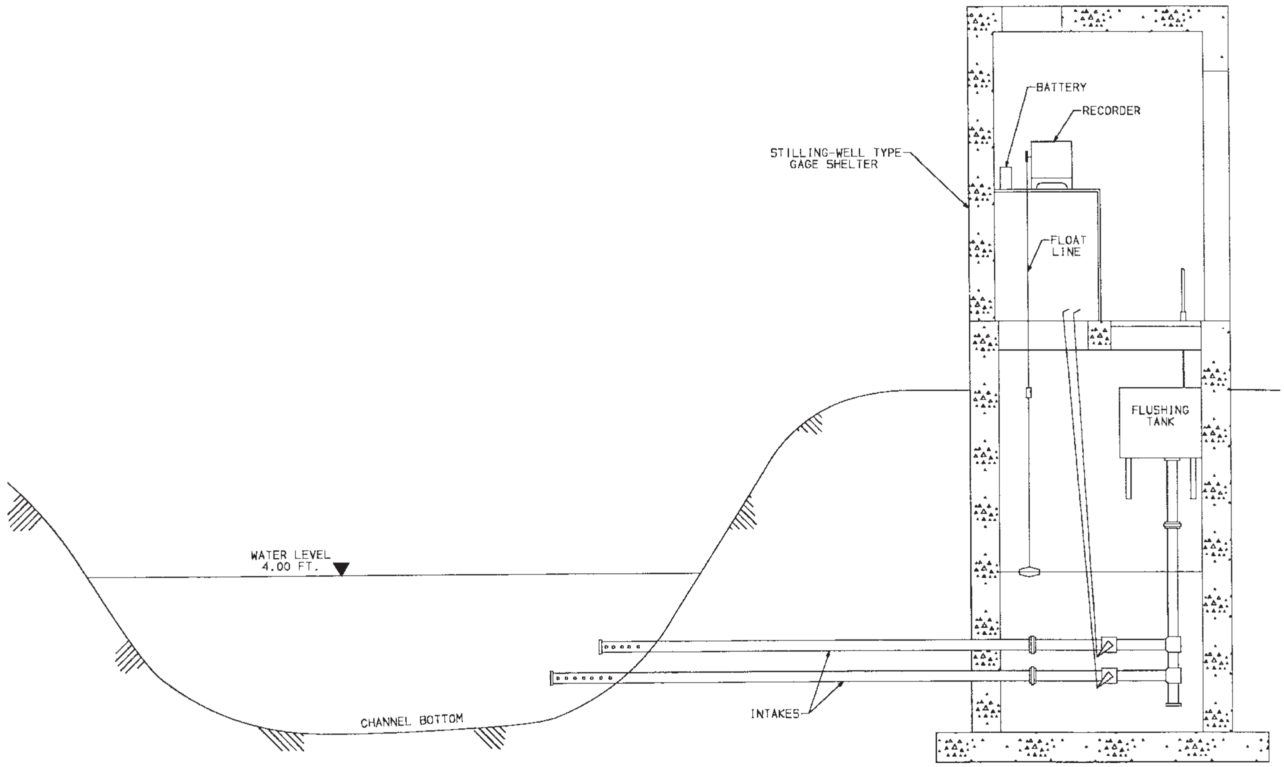

FIG. 1 Stilling Well Gage

6.3.3.4 Most gaging stations are intended to record over the range of stream stages. It is therefore important to obtain any local information available on historical flood levels and to make estimates of stage for a 100-year event using locally used flood-frequency equations. A cross-section survey of the channel should be obtained during field reconnaissance to aid in estimating high flow stage.

6.4 More detailed information is available in Refs **(1-3)**[4] and ISO-1100.

7. Types of Gaging Stations

7.1 Non-recording stations can be as simple as a permanent staff gage attached to a bridge, pier, or other structure, which is read and recorded manually in an appropriate notebook once or more each day. For details on non-recording gages, see Test Methods D 5413, ISO 1100, and Refs **(1-4)**.

7.2 Recording gages are usually nonattended installations that require a sensor in direct contact with the water that is connected mechanically or electrically to a recording device.

7.2.1 Stilling well-type gages use a vertical well installed in the stream bank with small-diameter intake pipes connecting the river to the well. In this type of installation, a float on the water surface in the well drives a recorder housed in a shelter over the well by mechanical means (Fig. 1). Stilling well gages tend to provide more reliable data because water-level sensing as well as recording components of the system are protected from direct installation in the stream. Disadvantages are locations with unstable stream channels that may move away from the intakes and higher initial cost. For details on stilling well gages, see Test Methods D 5413, ISO 1100, and Refs **(1-3, 5)**.

7.2.2 Bubbler-type gages consist of a gas supply, usually nitrogen, which is fed through a controller and tube to an orifice attached near the bed of a stream. The gas pressure is equal to the liquid head in the stream. A pressure transducer, mercury, or balance-beam manometer senses this pressure and passes this information either mechanically or electronically to a compatible recorder (Fig. 2). The advantage to this system is less expensive construction costs, which is especially desirable for short-term gages or in locations in which stilling well installations are difficult. Disadvantages are maintaining the orifice in a stable mounting on the river bed. Keeping the orifice from being buried in silty streams is also a problem. For details on bubble-gages, see Test Methods D 5413, ISO 1100, and Refs **(1-3, 5, 6)**.

7.2.3 Acoustic Velocity Meter (AVM) stations directly sense and record the velocity observed between two transducers at fixed elevations in the channel cross section. The AVM gages are used in locations in which stage-discharge relations are unreliable, usually in deep, slow-moving channels or where tidal or bidirectional flow occurs. Additional information is given in Test Method D 5389.

8. Gaging Station Structures

8.1 *Stilling Well Functional Requirements*—A stilling well must provide a water surface at the same elevation as that of the stream at any point in time, dampen out the effect of surface waves, and provide a sensor, usually a float and recording system.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

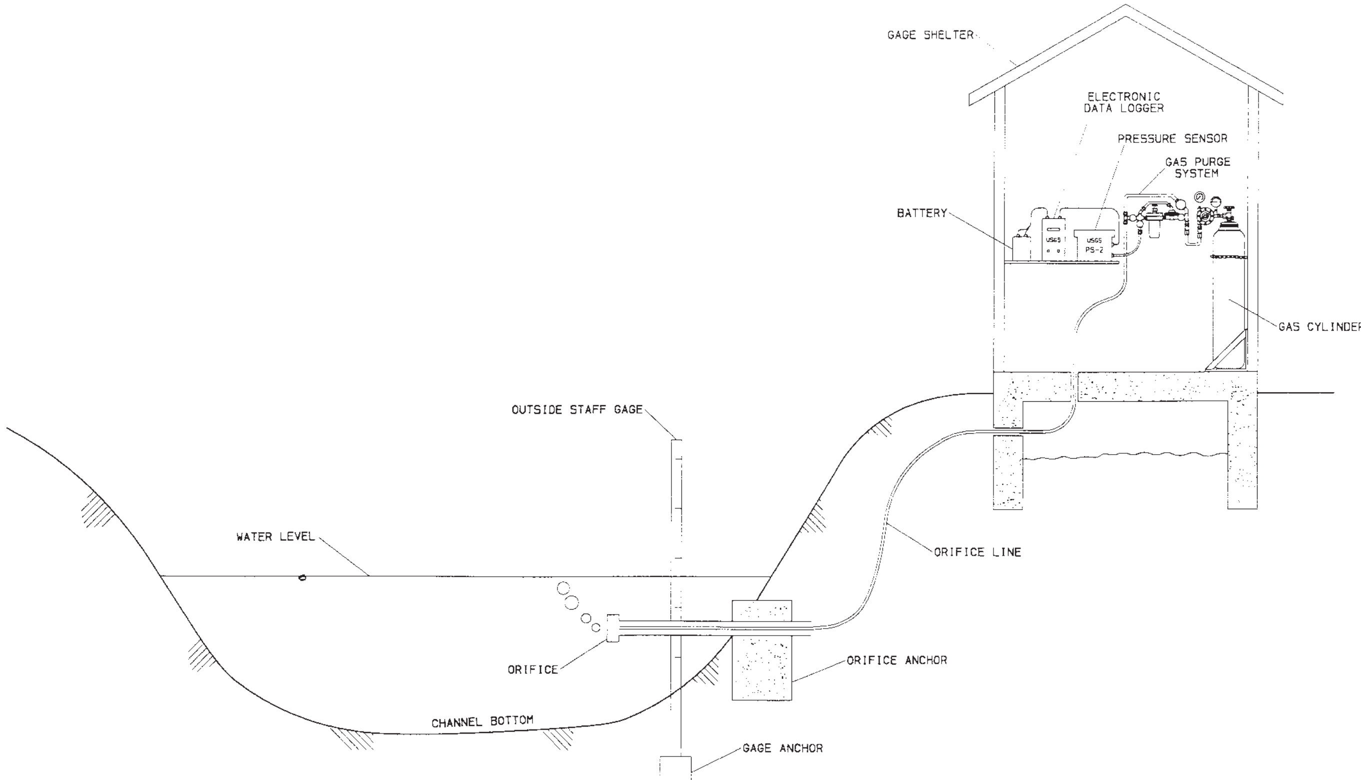

FIG. 2 Bubble Gage

8.1.1 The stilling well must be sufficiently long to cover the entire range of stages that might occur reasonably.

8.1.2 The stilling well can be any shape in plan view; however, most are either round or square. Permanent long-term gages should have a large enough area to allow personnel to work inside them for servicing; the most common size is approximately 4 by 4 ft (1.2 by 1.2 m). Some semipermanent stilling wells may be as small as 1 ft (0.3 m).

8.1.3 Stilling wells may be fabricated from poured concrete, concrete blocks, galvanized steel, concrete culvert pipe, or other suitable material. The well must have a sealed bottom to preclude the interchange of water from the stream and ground water.

8.1.4 Stilling wells are usually installed in a stream bank for protection and to minimize freezing in northern climates. They may be attached to bridge piers or wing walls in some applications but must be protected from damage by floating debris and must not interfere with flow patterns in the channel.

8.1.5 Intake pipes are required to connect the stilling well to the stream when the well is buried in the stream bank. Holes in the well usually suffice when installed on a bridge pier or wing wall.

8.1.5.1 Intake pipes must be sized to allow the water surface in the well to be at the same level as that in the stream, but they limit the effect of wind- or boat-generated waves or other transitory or artificial fluctuations of stream water levels. Intake pipes are typically 2 to 4 in. (50 to 100 mm) in diameter. Long or small-diameter intakes may cause a lag in response in the stilling well. The following relation can be used to predict the intake pipe lag for a given rate of change of stage **(1)**.

$$\Delta h = \frac{0.01}{g} \frac{L}{D} \left(\frac{A_w}{A_p}\right)^2 \left(\frac{dh}{dt}\right)^2$$

where:

Δh = lag, ft (m),
g = acceleration of gravity, ft (m)/s/s,
L = intake length, ft (m),
D = intake diameter, ft (m),
A_w = area of stilling well, ft^2(m^2),
A_p = area of intake pipe, ft^2(m^2), and
dh/dt = rate of change of stage, ft (m)/s.

8.1.5.2 Two or more intakes are usually installed, one vertically above the other, in case an intake is damaged or silted shut.

8.1.5.3 The invert elevation of the lowest intake should be at least 6 in. (150 mm) below the lowest expected stream level. The intake should be at least 1 ft (300 mm) above the floor of the stilling wall to allow for the storage of silt that may enter the structure.

8.1.5.4 Drawdown in the stilling well can occur where stream velocity past the intake is high. Drawdown can be reduced by installing a static tube to the streamward end of the intake pipe. A typical static tube is a piece of perforated pipe with the capped end attached to the intake pipe with a 90° elbow so that it points downstream.

8.1.6 Stilling wells located in cold climates require special procedures to prevent the freeze-up of water in the well or intake pipes, or both.

8.1.6.1 Stilling wells in cold climates are usually installed in stream banks where much of the well is ground covered. Wells should be constructed of nonconductive materials or insulated with an insulating material on the well's exterior. Intake pipes should be installed lower to prevent freezing.

8.1.6.2 Stilling wells with good ground cover can be kept ice-free by installing insulated subfloors at ground level. Subfloors must be above normal winter water levels to be effective. Typical subfloors will be attached rigidly to the stilling well and have holes slightly larger than instrument floats to allow the floats to pass through at high water events. These holes can be covered with light-weight insulating materials such as foam insulating board that will either float on top of instrument floats or float out of place during high water events.

8.1.6.3 Electric or propane heaters can be used to prevent freezing. Electric heat bulbs hanging in the center of the well under an instrument shelf can be quite effective for heating the air above the water surface. Submergible heaters can be placed in the well to heat the water. Heat tape can be installed in intake pipes, if necessary.

8.1.6.4 Bubbler systems, allowing a gas, usually nitrogen, to be bubbled from an open-ended tube placed on the well floor under recorder floats, will circulate warmer water from the bottom and prevent surface ice formation.

8.1.7 Instrument shelters can vary from large walk-in shelters installed on large stilling wells to small weatherproof boxes attached on small-diameter pipe wells. The shelter's functional requirements depend on the type and quantity of instrumentation, climate, and environmental and security conditions. Walk-in shelters with a 4 by 4-ft (1.2 by 1.2-m) minimum are desirable for installations with complex equipment, which require lengthy servicing during inclement weather. Some shelters are equipped with electricity, phones, telemetry, and other operational support systems.

8.2 Bubbler-type station-functional requirements basically require an instrument shelter to house pressure-sensing and recorder systems, a source of compressed gas, gas pressure regulators, and associated tubing. More information is available in Refs **(1, 6)** and ISO 1100.

8.2.1 Instrument shelter characteristics are similar to those described in 8.1.7.

8.2.2 The orifice from which the compressed gas exits into the stream must be mounted at least 6 in. (150 mm) below the lowest expected water levels. In locations at which ice cover is present, placing the orifice lower in the water column will minimize the damage caused by ice breakup or icing over of the orifice.

8.2.3 The orifice must be mounted in a stable structure that will not move in the channel. Suitable mountings include poured blocks of concrete, attachments to bridge structures, and pipes or pilings driven into the streambed.

8.2.3.1 Orifice mountings must have a reference point that can be checked periodically by differential leveling to discern whether movement has occurred.

8.2.4 Orifice positioning in moving sand-channel streams requires special techniques for obtaining satisfactory water-level data. A number of techniques have been devised to overcome these problems, such as using water well drive points and multiple orifice installations **(1, 5, 6)**.

8.2.5 A constant supply of gas is required. This is typically supplied by commercially available compressed gas cylinders.

8.2.6 A regulator mechanism is required to control and reduce the pressure between the gas source and orifice and regulate the bubble discharge rate.

8.2.7 Suitable tubing is required to connect the gas source, regulators, and orifice. Neoprene tubing with an inside diameter of ⅛ in. (3 mm) is typically used. The tubing must be protected from physical damage between the instrument shelter and orifice. It is often installed in steel pipe or conduit. It should have a downward slope, with no low spots where water can collect and freeze.

8.3 Structural supports are required for outside reference gages, such as vertical staff gages and wire-weight gages. It is impossible to describe specific requirements since each installation is different. Primary considerations include stability, protection from floating debris or ice, boat traffic, or other forms of damage or areas of hydraulic disturbance. The gage placement must be sufficiently close to the intake pipes or pressure sensor locations to represent comparable water levels.

8.4 Cableways are used frequently as a platform for obtaining high-flow discharge measurements. See Ref **(4)** for more detailed information.

9. Instrumentation

9.1 Gaging station instrumentation generally consists of water-level sensor and recorder systems. The remote transmission of data by landline, satellite, or other forms of radio transmission may also be used. It is not the purpose of this guide to describe this equipment in detail. This information is available in Test Methods D 5413 and Refs **(1-3, 5, 6)**.

9.2 A limited number of gaging stations may sense and record velocity data directly. Information on this equipment is given in Test Method D 5389, ISO 6416, and Ref **(4)**.

10. Gaging Station Datum

10.1 Each gaging station must have a datum plane as a known and constant reference for all gages and recording devices. This datum should remain unchanged throughout the life of a gaging station, even though the types of gage recorder and reference gages may change over time. The gage datum should be selected so that all readings are small, positive numbers.

10.1.1 The datum may be referred to a national datum system, usually NGVD of 1929, which is used for all national mapping activities in the United States and Canada.

10.1.2 In some cases, the datum may be tied to an independent, "local" datum maintained by a state, province, or municipal datum for specific reasons.

10.1.3 An arbitrary datum may be established for a single gaging station in some remote locations, where levels would have to be run many miles to an established datum. This may be referenced to an approximate NGVD datum by interpretation from a topographic map.

10.2 Gaging station reference marks (RMs) are permanent markers installed in the vicinity of a gaging station in order to set and maintain datum and check the various gages and recorders. The RMs are typically brass markers or bolts set in concrete posts installed in stable soil, permanent structures such as bridge abutments, cableway anchors, or large lag-bolts set in mature and stable trees. The RM locations should be selected so that they will not be destroyed or moved by activity in the area or washed away during floods. A minimum of three marks is recommended, and they should not all be in the same area or structure.

10.3 The elevations of RMs and gages are established and checked by differential leveling techniques using standard surveying equipment. Detailed leveling procedures are given in standard surveying texts and in Ref **(8)**. Levels will typically be run to all RMs and gages once per year for the first few years and then at 2- to 5-year frequencies thereafter.

11. Operation of a Gaging Station

11.1 The objective of gaging station operation is to obtain a complete and accurate record of stream stage or discharge, or both. As with most scientific endeavors, the more time, attention, and experience exercised in the selection of instruments and the installation, calibration, and servicing of this equipment, the better the stream flow record will be.

11.2 Periodic visits are required at all gaging stations for the following: to verify that the system is operating properly; to make repairs if it is not; to remove the recording data; to check and reset the recording or transmitting devices, or both, if used; and to make discharge measurements for the development of a stage discharge rating.

11.2.1 Gaging station visits are usually made every 4 to 6 weeks; however, more frequent visits may be required with new or complex stations, by inexperienced personnel, or when the gaging station is known to have problems or a discharge measurement is necessary.

11.2.2 The technician should verify at each visit that the sensor and recording system is operating properly and make and record notations regarding the station status on forms developed for that purpose.

11.2.2.1 Read and record the date, watch time, and record time.

11.2.2.2 Read and record all gages, including outside gages, stage sensor, and recorder stages.

11.2.2.3 Read and record the values from other equipment, bubble rate, water quality, and temperature information.

11.2.2.4 Note conditions of the gaging station that could affect the data quality and channel and streamflow conditions, specifically the control conditions.

11.2.3 Remove the recorded information since the last visit. This may require the removal of a paper chart or electronic transfer of data by means of a personal computer or other electronic device.

11.2.4 Reset or recalibrate sensing and recording systems if not in agreement with the gage readings, if required. Make suitable notations to document for future data analysis.

11.2.5 Repeat the information noted in 11.2.2.1 and 11.2.2.2.

11.2.6 Make a discharge measurement, if required, in accordance with Practice D 3858, ISO 1100, and Refs **(1-3, 9-11)**.

11.2.7 Repeat the information noted in 11.2.2.1 and 11.2.2.2.

11.3 The AVM-type gaging stations require the performance of additional procedures, as noted in Test Method D 5389, ISO 6416, and Refs **(1, 7)**.

11.4 General maintenance is required at least once per year, usually during summer low-flow periods, to check the condition and repair or clean, as needed, the following: the stilling well and intakes, orifice attachment and lines, AVM transducers, gaging station structures, instruments, gages, cut grass, and check gages by differential levels, if applicable. Batteries and nitrogen tanks must be changed throughout the year, as required.

12. Calibration

12.1 Water-level sensing gaging stations are calibrated by making discharge measurements over the entire range of stage occurring at a particular station. A semipermanent relation will exist between stage and discharge if the station has been located carefully behind a stable control (see 6.2.5). A curve is drawn through plots of stage and discharge obtained from discharge measurements. Indirect measurements of discharge at various stages, usually from flood peak surveys, can also be used to define rating curves. See Test Methods D 5129, D 5130, D 5243, D 5388, and Refs **(1, 10-16)**. Detailed information on rating development is given in Practice D 5541, ISO 1100, and Refs **(1, 17)**.

12.2 The AVM-type gaging stations are calibrated by making discharge measurements over the entire range of flow conditions occurring at a particular station. The AVM-type stations are typically calibrated by developing a relation between the average velocity from discharge measurements and the line velocity between AVM transducers. A stage-area relation is also developed for computational purposes.

13. Computation

13.1 Present-day stream flow computations are usually performed by the input of data from paper or electronic means into a computer system that performs the basic calculations. Operators of a small number of gaging stations may find manual computations cost effective. See ISO 1100 and Refs **(1, 18)**.

13.2 Typical data requirements include mean daily gage-height or stage, mean daily discharge, instantaneous maximum and minimum stage and discharge, and stage or discharge at a particular point in time.

13.3 Datum corrections are frequently necessary to correct recorded values for slippage or damage to gages, drift, or other recorder errors. Datum corrections are based on differences between a gaging station's base gage and the recorder values observed by servicing personnel or are determined from levels to permanent RMs, indicating that a gage has moved. Datum corrections should be listed chronologically on a suitable form for a permanent record. Analysis of this listing will often indicate equipment problems that can be corrected. Datum corrections are applied to stage recordings before other calculations are performed.

13.4 Shift adjustments may be used to correct for temporary changes from the stage-discharge rating curve. Those adjustments are based on the technician's visual observations and discharge measurements plotting off the rating curve. Some common causes of shifting include weed growth in the channel, debris catching on a control, backwater from a downstream stream or tributary, moss buildup on a structural control or scour, or fill of a streambed, or some combination thereof. In the case of sand or other unstable channels, shift adjustments may be necessary on a constant basis to a theoretical stage-discharge rating. Shift adjustments should be listed on a suitable form and analyzed based on changes in stream stage, experience at the site, and weather records. Shift adjustments may be applied to individual stage recordings or to mean daily (stage-computed) values, depending on the magnitude and variability of shift adjustments. Shift adjustments are always applied after datum corrections.

13.5 The calculation of daily mean discharge is accomplished as indicated by the following steps, either manually or by computer program:

13.5.1 For each gage-height recording interval (usually 5, 15, 30, and 60 min) within a day, algebraically add any applicable datum correction.

13.5.2 For each datum corrected value algebraically, add any applicable shift adjustment.

13.5.3 For each value in 13.5.2, look up discharge from the applicable stage-discharge rating curve, usually converted to a table for simplicity.

13.5.4 Add all of the incremental discharge values for the day, and divide them by the number of recorded units to obtain the mean daily discharge.

13.5.5 After completing 13.5.1-13.5.4, the data can be tabulated to meet data needs for a period of time, usually a week, month, or year. Data are typically presented by monthly columns for a yearly reporting period.

13.5.6 Daily, or instantaneous, values of stage or discharge can be extracted from the calculated values (13.5.3) to meet user requirements.

13.6 Ice buildup on the bed, edges, or surface of flowing streams, as well as ice jams, disrupts the stage-discharge relation. The computation of daily discharge during ice-affected periods is an inexact and subjective art. The most common method is based on discharge measurements, weather records, the pattern of recorded gage-heights, comparisons with other nearby gaging stations, and the experience and judgment of the analyst. More information is available in ISO 1100 and Refs **(1, 18)**.

13.7 The computation of discharge from AVM gaging stations requires a curve, constant, or equation, often referred to as "K," to relate the recorded line velocity to the mean section velocity and a stage area table. Computer computations are common; however, little standardization between programs exists presently. The basic computational requirements are given in the following:

13.7.1 For each incremental unit of recorded line velocity, look up the appropriate K, and compute the equivalent channel velocity.

13.7.2 For the corresponding recorded value of gage height, algebraically add any applicable datum correction.

13.7.3 For each value determined in 13.7.2, look up the applicable area value from the stage-area table.

13.7.4 For each increment, multiply the equivalent mean channel velocity (13.7.1) by the corresponding area (13.7.3) to obtain the incremental discharge.

13.7.5 Add all of the incremental discharge values for the day, and divide them by the number of recorded units to obtain the mean daily discharge.

13.7.6 Data summaries are the same as those described in 13.5.5 and 13.5.6.

13.8 Stage values are generally recorded to the nearest 0.01 ft (2 mm).

13.9 Discharge values are generally computed to three significant figures, except for extremely low flows, in which case two significant figures may be used.

13.10 The quality assurance (QA) of computations is usually performed by having one individual input the original data and perform the analysis and computation and having a second, more experienced person check the work independently.

13.10.1 The comparison of daily mean discharges provides some quality check where several gaging stations are operated in a region or river basin since nearby streams usually reflect similar runoff events and general trends. This is easily accomplished through the use of an on-screen or paper printout of daily discharge hydrographs.

13.11 Documentation of all aspects of the data collection, datum corrections, shift adjustments, analytical and computational methods, and the reasoning behind decisions should be provided in some written form, usually on an annual basis. The documentation should be kept indefinitely.

14. Precision and Bias

14.1 The accuracy of discharge data depends primarily on the following: (*1*) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements; and (*2*) the accuracy of observations of stage, measurements of discharge, and interpretation of records.

14.2 The precision and bias of gaging station data are difficult to evaluate in absolute terms since so many variables are involved. The evaluation of this many factors requires a large amount of judgment based largely on the experience and training of the operator. Agencies that operate large networks of gaging stations typically give subjective accuracy statements for each station for each year's data. Generally, "Excellent" means that approximately 95 % of the daily discharges is within 5 %, "good" within 10 %, and "fair" within 15 %. "Poor" means that the daily discharges have a less than "fair" accuracy.

15. Keywords

15.1 gaging station; open-channel flow; water discharge; water level

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