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Standard Guide for Sampling Fluvial Sediment in Motion[1]

This standard is issued under the fixed designation D4411; 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 This guide covers the equipment and basic procedures for sampling to determine discharge of sediment transported by moving liquids. Equipment and procedures were originally developed to sample mineral sediments transported by rivers but they are applicable to sampling a variety of sediments transported in open channels or closed conduits. Procedures do not apply to sediments transported by flotation.

1.2 This guide does not pertain directly to sampling to determine nondischarge-weighted concentrations, which in special instances are of interest. However, much of the descriptive information on sampler requirements and sediment transport phenomena is applicable in sampling for these concentrations, and 9.2.8 and 13.1.3 briefly specify suitable equipment. Additional information on this subject will be added in the future.

1.3 The cited references are not compiled as standards; however they do contain information that helps ensure standard design of equipment and procedures.

1.4 Information given in this guide on sampling to determine bedload discharge is solely descriptive because no specific sampling equipment or procedures are presently accepted as representative of the state-of-the-art. As this situation changes, details will be added to this guide.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 12.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

D3977 Test Methods for Determining Sediment Concentration in Water Samples

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology D1129.

3.1.1 *isokinetic, adj*—a condition of sampling, whereby liquid moves with no acceleration as it leaves the ambient flow and enters the sampler nozzle.

3.1.2 *sampling vertical, n*—an approximately vertical path from water surface to the streambed. Along this path, samples are taken to define various properties of the flow such as sediment concentration or particle-size distribution.

3.1.3 *sediment discharge, n*—mass of sediment transported per unit of time.

3.1.4 *suspended sediment, n*—sediment that is carried in suspension in the flow of a stream for appreciable lengths of time, being kept in this state by the upward components of flow turbulence or by Brownian motion.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *concentration, sediment, n*—the ratio of the mass of dry sediment in a water-sediment mixture to the volume of the water-sediment mixture. Refer to Test Methods D3977.

3.2.2 *depth-integrating suspended sediment sampler, n*—an instrument capable of collecting a water-sediment mixture isokinetically as the instrument is traversed across the flow; hence, a sampler suitable for performing depth integration.

3.2.3 *depth-integration, n*—a method of sampling at every point throughout a sampled depth whereby the water-sediment mixture is collected isokinetically to ensure the contribution from each point is proportional to the stream velocity at the point. This method yields a sample that is discharge-weighted over the sampled depth. Ordinarily, depth integration is performed by traversing either a depth- or point-integrating

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

sampler vertically at an acceptably slow and constant rate; however, depth integration can also be accomplished with vertical slot samplers.

3.2.4 *point-integrating suspended-sediment sampler, n*—an instrument capable of collecting water-sediment mixtures isokinetically. The sampling action can be turned on and off while the sampler intake is submerged so as to permit sampling for a specified period of time; hence, an instrument suitable for performing point or depth integration.

3.2.5 *point-integration, n*—a method of sampling at a fixed point whereby a water-sediment mixture is withdrawn isokinetically for a specified period of time.

3.2.6 *stream discharge, n*—the quantity of flow passing a given cross section in a given time. The flow includes the mixture of liquid (usually water), dissolved solids, and sediment.

4. Significance and Use

4.1 This guide is general and is intended as a planning guide. To satisfactorily sample a specific site, an investigator must sometimes design new sampling equipment or modify existing equipment. Because of the dynamic nature of the transport process, the extent to which characteristics such as mass concentration and particle-size distribution are accurately represented in samples depends upon the method of collection. Sediment discharge is highly variable both in time and space so numerous samples properly collected with correctly designed equipment are necessary to provide data for discharge calculations. General properties of both temporal and spatial variations are discussed.

5. Design of the Sampling Program

5.1 The design of a sampling program requires an evaluation of several factors. The objectives of the program and the tolerable degree of measurement accuracy must be stated in concise terms. To achieve the objectives with minimum cost, care must be exercised in selecting the site, the sampling frequency, the spatial distribution of sampling, the sampling equipment, and the operating procedures.

5.2 A suitable site must meet requirements for both stream discharge measurements and sediment sampling (**1**).[3] The accuracy of sediment discharge measurements are directly dependent on the accuracy of stream discharge measurements. Stream discharge usually is obtained from correlations between stream discharge, computed from flow velocity measurements, the stream cross-section geometry, and the water-surface elevation (stage). The correlation must span the entire range of discharges which, for a river, includes flood and low flows. Therefore, it is advantageous to select a site that affords a stable stage-discharge relationship. In small rivers and man-made channels, artificial controls as weirs can be installed. These will produce exceptionally stable and well defined stage-discharge relationships. In large rivers, only natural controls ordinarily exist. Riffles and points where the bottom slope changes abruptly, such as immediately upstream from a natural fall, serve as excellent controls. A straight uniform reach is satisfactory, but the reach must be removed from bridge piers and other obstructions that create backwater effects.

5.3 A sampling site should not be located immediately downstream from a confluence because poor lateral mixing of the sediment will require an excessive number of samples. Gaging and sampling stations should not be located at sites where there is inflow or outflow. In rivers, sampling during floods is essential so access to the site must be considered. Periods of high discharge may occur at night and during inclement weather when visibility is poor. In many instances, bridges afford the only practical sampling site.

5.4 Sampling frequency can be optimized after a review of the data collected during an initial period of intensive sampling. Continuous records of water discharge and gauge height (stage) should be maintained in an effort to discover parameters that correlate with sediment discharge, and, therefore, can be used to indirectly estimate sediment discharge. During periods of low-water discharge in rivers, the sampling frequency can usually be decreased without loss of essential data. If the sediment discharge originates with a periodic activity, such as manufacturing, then periodic sampling may be very efficient.

5.5 The location and number of sampling verticals required at a sampling site is dependent primarily upon the degree of mixing in the cross section. If mixing is nearly complete, that is the sediment is evenly and uniformly distributed in the cross section, a single sample collected at one vertical and the water discharge at the time of sampling will provide the necessary data to compute instantaneous sediment-discharge. Complete mixing rarely occurs and only if all sediment particles in motion have low fall velocities. Initially, poor mixing should be assumed and, as with sampling any heterogeneous population, the number of sampling verticals should be large.

5.6 If used properly, the equipment and procedures described in the following sections will ensure samples with a high degree of accuracy. The procedures are laborious but many samples should be collected initially. If acceptably stable coefficients can be demonstrated for all anticipated flow conditions, then a simplified sampling method, such as pumping, may be adopted for some or all subsequent sampling.

6. Hydraulic Factors

6.1 *Modes of Sediment Movement:*

6.1.1 Sediment particles are subject to several forces that determine their mode of movement. In most instances where sediment is transported, flow is turbulent so each sediment particle is acted upon by both steady and fluctuating forces. The steady force of gravity and the downward component of turbulent currents accelerate a particle toward the bed. The force of buoyancy and the upward components of turbulent currents accelerate a particle toward the surface. Relative motion between the liquid and the particle is opposed by a drag force related to the fluid properties and the shape and size of the particle.

6.1.2 Electrical charges on the surface of particles create forces that may cause the particles to either disperse or

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

flocculate. For particles in the submicron range, electrical forces may dominate over the forces of gravity and buoyancy.

6.1.3 Transport mode is determined by the character of a particle's movement. Clay and silt-size particles are relatively unaffected by gravity and buoyant forces; hence, once the particles are entrained, they remain suspended within the body of the flow for long periods of time and are transported in the suspended mode.

6.1.4 Somewhat larger particles are affected more by gravity. They travel in suspension but their excursions into the flow are less protracted and they readily return to the bed where they become a part of the bed material until they are resuspended.

6.1.5 Still larger particles remain in almost continuous contact with the bed. These particles, termed bedload, travel in a series of alternating steps interrupted by periods of no motion when the particles are part of the streambed. The movement of bedload particles invariably deforms the bed and produces a bed form (that is, ripples, dunes, plane bed, antidunes, etc.), that in turn affects the flow and the bedload movement. A bedload particle moves when lift and drag forces or impact of another moving particle overcomes resisting forces and dislodges the particle from its resting place. The magnitudes of the forces vary according to the fluid properties, the mean motion and the turbulence of the flow, the physical character of the particle, and the degree of exposure of the particle. The degree of exposure depends largely on the size and shape of the particle relative to other particles in the bed-material mixture and on the position of the particle relative to the bed form and other relief features on the bed. Because of these factors, even in steady flow, the bedload discharge at a point fluctuates significantly with time. Also, the discharge varies substantially from one point to another.

6.1.6 Within a river or channel, the sizes of the particles in transport span a wide range and the flow condition determines the mode by which individual particles travel. A change in flow conditions may cause particles to shift from one mode to the other.

6.1.7 For transport purposes, the size of a particle is best characterized by its fall diameter because this describes the particle's response to the steady forces in the transport process.

6.2 *Dispersion of Suspended Sediment:*

6.2.1 The various forces acting on suspended-sediment particles cause them to disperse vertically in the flow. A particle's upward velocity is essentially equal to the *difference* between the mean velocity of the upward currents and the particle's fall velocity. A particle's downward velocity is essentially equal to the *sum* of the mean velocity of the downward currents and the particle's fall velocity. As a result, there is a tendency for the flux of sediment through any horizontal plane to be greater in the downward direction. However, this tendency is naturally counteracted by the establishment of a vertical concentration gradient. Because of the gradient, the sediment concentration in a parcel of water-sediment mixture moving upward through the plane is higher than the sediment concentration in a parcel moving downward through the plane. This difference in concentration produces a net upward flux that balances the net downward flux caused by settling. Because of their high fall velocities, large particles have a steeper gradient than smaller particles. Fig. 1 (**2**) shows (for a particular flow condition) the gradients for several particle-size ranges. Usually, the concentration of particles smaller than approximately 60 µm will be uniform throughout the entire depth.

6.2.2 Turbulent flow disperses particles laterally from one bank to the other. Within a long straight channel of uniform cross section, lateral concentration gradients will be nearly

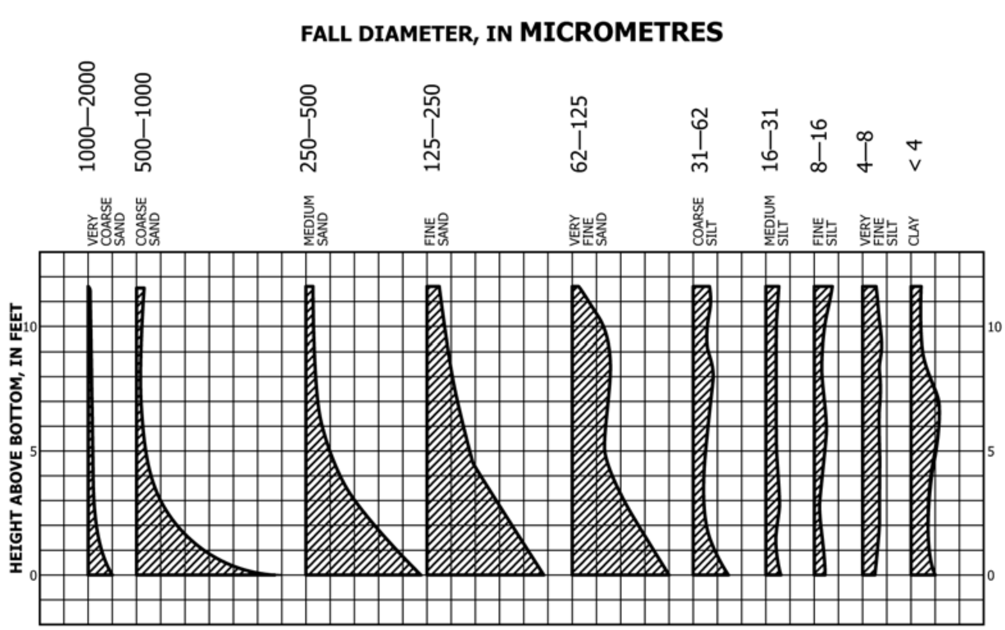

FIG. 1 (**2**) Vertical Distribution of Sediment in the Missouri River at Kansas City, MO