STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid In Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station **April 2004**

Rapid Evaluation of Sediment Budgets

Researchers and land managers are increasingly interested in the response of erosion and sedimentation to changes occurring on watershed hillslopes or in stream channels. Managers need to predict how land use will alter erosion and sedimentation rates and the relative importance of different sediment sources in order to assign priorities for erosion control. They also must anticipate where sediment will be deposited, how long it will be stored, and how it will be re-mobilized. Sediment budgets are a useful tool for address these management problems.

Land managers and researchers often assume that sediment budgeting is a time consuming exercise suitable only for long-term studies. In the book ***Rapid Evaluation of Sediment Budgets,*** **Leslie Reid**, USDA Forest Service, Pacific Southwest Research Station, and Thomas Dunne, University of California at Santa Barbara, School of Environmental Sciences and Management, argue that sediment budgets can be constructed for a variety of applications using an approach that usually requires no longer than two months of fieldwork and analysis.

Rapid Evaluation of Sediment Budgets is intended as a guide for land managers who are contemplating the use of sediment budgets. It is not intended as a how-to manual for budget construction, although the book describes useful techniques that geomorphologists and hydrologists already involved in sediment budgeting might find useful. Although the methods of budget construction are relatively uncomplicated, they require that users have extensive backgrounds in geomorphology and hydrology if the methods are to be used appropriately.

A sediment budget is an accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin (figure 1). In its full form, a sediment budget accounts for rates and processes of erosion and sediment transport on hills and in channels; for temporary storage of sediment in bars, alluvial fans, and other sites; and for weathering and breakdown of sediments while in transport or storage. Although complete sediment budgets are of scientific interest, they are frequently more detailed than is necessary to address problems encountered in resource management.

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The *PRIMARY AIM* is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.

CONTRIBUTIONS are voluntary and will be accepted at any time. They should be typewritten, single-spaced, and limited to two pages. Graphics and tables are encouraged.
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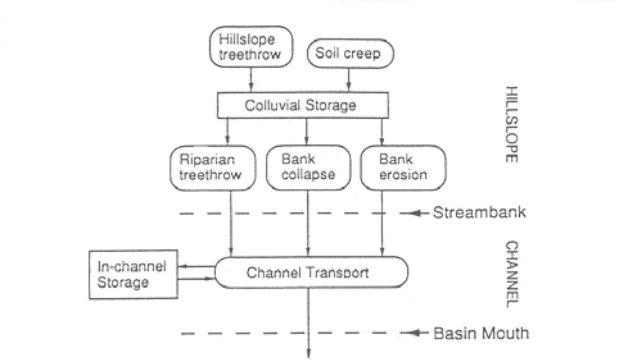

Figure 1. Simple flowchart of sediment transport on hillslopes and in channels. In this case, treethrow and soil creep intermittently transport sediment downslope to the channel bank, where it is eventually delivered to the channel by channel-side treethrow, bank collapse, and bank erosion. Sediment is then alternately stored and transported by the channel to the watershed mouth. Processes are noted as ovals, storage elements as rectangles, and transfers as arrows; the streambank appears as a dashed line.

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Sediment Budget Construction Procedure

The construction of approximate sediment budgets proceeds most smoothly if it follows a consistent 7-step process:

Step 1: Carefully define the problem

Step 2: Acquire background information

Step 3: Subdivide the area

Step 4: Interpret aerial photographs

Step 5: Conduct fieldwork

Step 6: Analyze the data

Step 7: Check results.

For most applications, some combination of the following information is required:

- the type and location of major natural and management-related sources of sediment,
- the approximate amount of sediment contributed by each type of source,
- the grain-size distribution of sediment contributed from each source,
- the approximate volumes and grain sizes of sediment in storage along streams,
- the approximate transport rate of sediment through stream channels and valley floors.

The information that is relevant depends on the problem posed, and answers to the first three points often suffice.

Misconceptions

Reid and Dunne point out that there is a persistent misconception among both land managers and researchers that the construction of sediment budgets is a time-consuming, academic exercise that is impractical for addressing the goals of land-use planning or short-term research. Although sediment budgeting often uses long-term measurements, budgets can also be constructed using rapid measurements and estimates to provide results at a level of precision adequate for most management needs. Sediment budgets are mistakenly viewed as impractical for short-term analyses in part because the utility of approximate budgets is often overlooked.

A second misunderstanding arises because erosion and transport rates are difficult to measure precisely, accurately, and consistently. Erosion is perceived as being intractably variable and complex, and lengthy measurement periods are assumed to be necessary if monitoring is to produce a meaningful average erosion rate. However, it is possible to design simple sampling schemes that account for seasonal and local variations in process rates if the reasons for these variations are understood. In addition, most management applications require only that the order of magnitude or the relative importance of process rates be known.

A third misconception centers around the notion that sediment budgeting implies construction of detailed maps of erosion processes. Management problems usually involve areas that are too large to permit thorough examination either in the field or on aerial photos, so comprehensive mapping is impractical and sediment budgeting is thus assumed to be impossible. However, construction of budgets for large areas merely requires a modification of techniques. Large areas are divided ("stratified") into subunits of similar soils, bedrock, vegetation, topography, and land use, and each subunit is characterized by budgets constructed for representative areas within it.

Conclusions

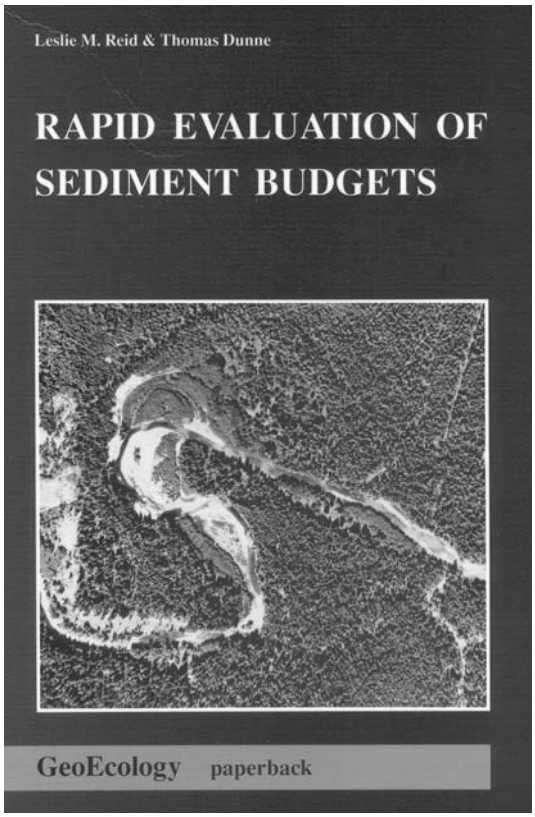
The 164 page book, ***Rapid Evaluation of Sediment Budgets,*** does not pretend to be a complete guide to sediment budget construction, but it provides a comprehensive overview of strategies and tools useful for understanding sediment production and transport in watersheds. The validity of a sediment budget then depends on how wisely these methods are employed.

Effective construction and interpretation of sediment budgets requires a sound understanding of erosion and sedimentation processes, experience in field mapping and in the measurement and analysis techniques to be used, and above all, good professional judgment. Each area represents its own difficulties and opportunities, so analysts must have a strong enough background in geomorphology and hydrology to take advantage of the peculiarities of the area to be evaluated, and they must be creative and open-minded in their approach.

An insufficient number of sediment budget studies exists to allow statistical evaluation of the accuracy and reproducibility of the general approach. However, Reid and Dunne have found that when several trained geomorphologists are asked to evaluate a process rate, results agree relatively closely, and certainly to well within an order of magnitude. Because many sediment budget applications require only approximate estimates, this level of accuracy is thought to be adequate.

Construction of sediment budgets is more difficult in some areas than others. At sites where sediment input is dominated by large, infrequent events, rates must be evaluated using as long a period of record as possible. In such cases, land use may cause small changes in process frequencies which can strongly affect long-term sediment yields, but which may not be observable over the time frame available for analysis.

The most difficult aspects of a sediment budget to quantify are those involving transport and storage of sediment in channels. In areas where these components are particularly important, sediment budgets can often reveal the process interactions that control channel response, the types of changes a channel may undergo, and the likely location of those changes, even if rates cannot be quantified.



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Several examples of rapidly constructed sediment budgets are provided by the authors. Anyone interested in constructing sediment budgets for management applications should find this book useful as a guide to specific analysis techniques and as a source of ideas for applying those techniques to management problems.

References

Reid, Leslie M. and Thomas Dunne, 1996. ***Rapid Evaluation of Sediment Budgets.*** Reiskirchen: Germany, Catena Verlag (GeoEcology paperback), 164 p.

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National Weather Service
Precipitation Frequency Data on the Web

The rainfall frequency atlases and technical papers published by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) serve as de-facto national standards for rainfall intensity at specified frequencies and durations in the United States. Civil engineers and hydrologists have always used these probabilistic estimates of rainfall intensities for particular durations and locations for the design of a wide range of hydraulic structures. More recently their use has been extended to include a broad array of environmental management and analysis.

In 1953, the NWS began publishing general rainfall-intensity-frequency-duration values or "precipitation frequency estimates" (Weather Bureau Technical Paper 24, 1953). These estimates were produced by the NWS at the request of other Federal, state, and local agencies because the NWS is the primary Federal agency with the required meteorological and hydrometeorological expertise required to develop the estimates and NWS is an independent agency which does not regulate or design based on the estimates. The values have become de-facto national standards by inclusion or reference in the design and planning standards of a wide variety of

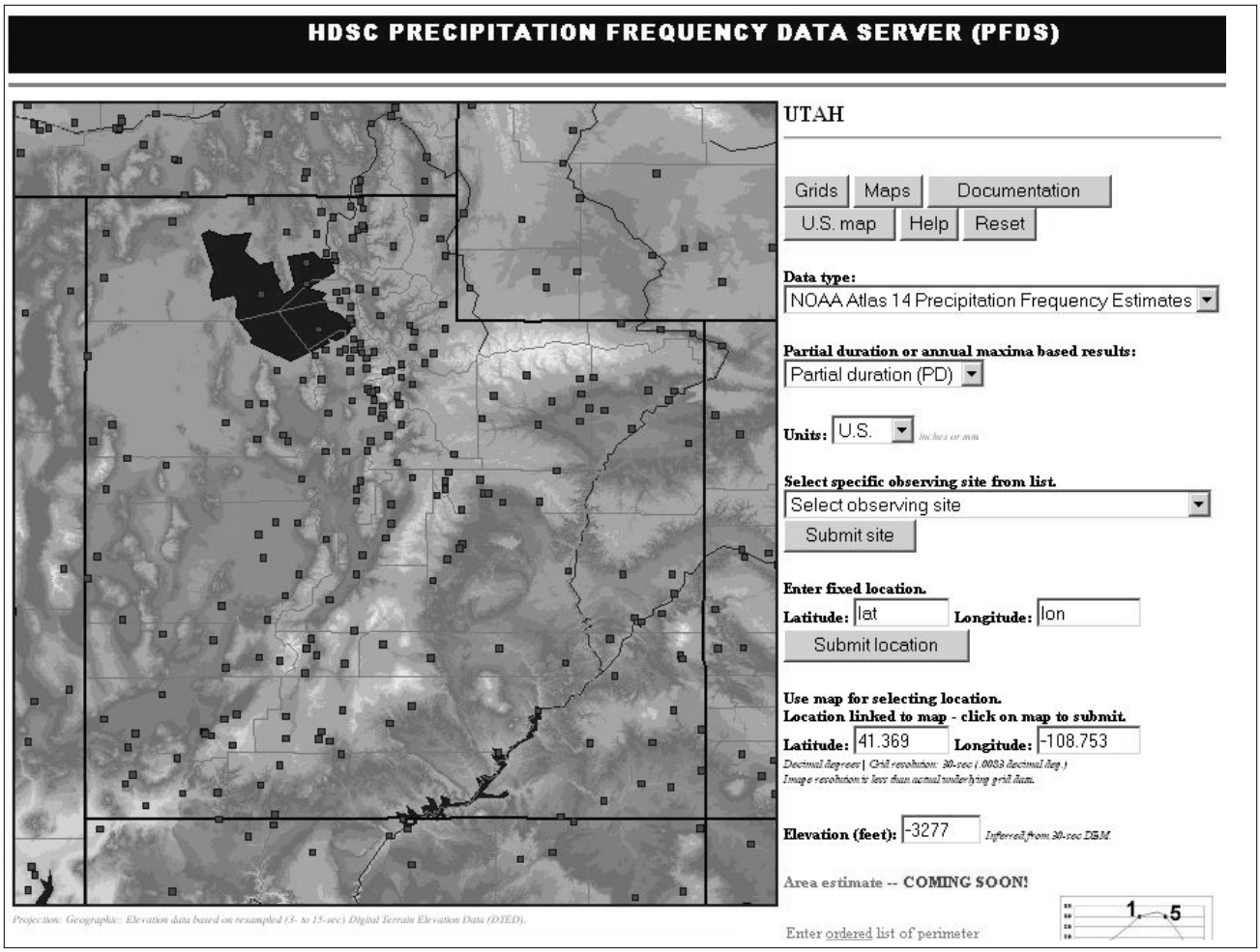

Figure 1. An example of the Precipitation Frequency Data Server screen for the State of Utah.

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agencies at Federal, state, and local levels.

Precipitation frequency estimates are developed by using statistical hydrometeorological techniques that have evolved over time and which have been the subject of extensive research and discussion in peer reviewed, scientific literature. The general approach is to examine time series of annual maximum (or partial duration) values and determine appropriate underlying probability distribution functions that can be used to interpolate or extrapolate estimates at a variety of frequencies and durations. The resulting point estimates are then spatially interpolated to regular grids from which cartographic quality maps are derived.

NWS precipitation frequency estimates have traditionally been delivered in the form of Weather Bureau Technical Papers and Memoranda as well as NOAA Atlases, all hard copy documents. With the advent of the World Wide Web, these documents have been scanned and made available via web pages. The National Weather Service specifically developed the Precipitation Frequency Data Server (figure 1) as the primary web portal to precipitation frequency estimates and associated information. Recent updates to NWS precipitation frequency estimates are being delivered entirely in digital rather than hard copy form in order to make the estimates more widely available to the public and to provide the data in a broader and more accessible range of formats.

While the primary audience for precipitation frequency estimates consists of civil engineers, hydrologists, agriculture interests, environmental planners, and floodplain managers, the general public also maintains a general interest in the estimates. The presentation formats accessible through the Precipitation Frequency Data Server include:

- the Atlases and associated documentation of the underlying development methodology, including tables and maps, in Portable Document Format (PDF),
- downloadable tables and graphs of precipitation frequency estimates at any user-selected location (figure 2), and
- grids in a variety of formats including Federally mandated GIS formats.

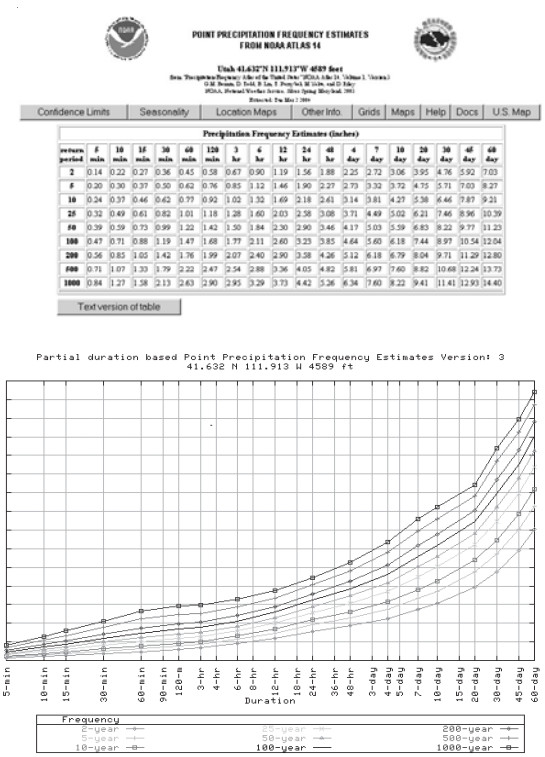

Figure 2. Example tabular and graphical displays of precipitation frequency estimates for a location in Utah.

The Precipitation Frequency Data Server is maintained by the NWS Hydrometeorological Design Studies Center in Silver Springs, Maryland. The Center's major function is to prepare national standards for Precipitation Frequency (PF) and Probable Maximum Precipitation (PMP).

The homepage for the Center is located at http://www.nws.noaa.gov/oh/hdsc/index.html and the Precipitation Frequency Data Server can be found at http://hdsc.nws.noaa.gov/hdsc/pfds/.

The site is fairly self-explanatory, but a user's guide for the Precipitation Frequency Data Server and other older precipitation frequency publications are also directly accessible from the server. Check it out and bookmark it for future reference when you may need rainfall frequency data.

Ask DOCTOR Hydro

Dear Doc Hydro: I just ran across an EPA field manual for surveying wadeable streams that instructs observers to visually estimate substrate particles sizes and which uses larger size classes than the phi or 1/2 phi Wentworth classes commonly used during Wolman pebble counts. I've always had my field crews measure particles and tally them by size class using the more than 20 size classes of the Wentworth scale recommended by the American Geophysical Union. Visual estimates and fewer size classes would certainly speed up field work. What do you think of this idea?

Doc Hydro recognizes that visual estimates, or "ocular assessments," have been widely used in the past by biologists to estimate the sizes of substrate particles. Typically, these estimates placed particles into broad size classes, for example, "1-to-3-inch gravel" thereby making it difficult to directly compare this data with more precise particle size distribution typically collected by geomorphologists and engineers based on the Wentworth scale. Despite the continued use of visual estimates, I'm unaware of any comprehensive published studies demonstrating that visual estimates are reproducible among different observers.

Since there's no substitute for real data, Doc Hydro decided to perform a little experiment comparing visual and measurement techniques on a 100 particle sample of river rocks. Although there are only 5 replications of each technique and statistically this is less rigorous than one might wish, the results provide valuable insight into differences among the various techniques.

The 100 particles were sampled along a grid located on a large river bar using the Wolman method. The round river rocks were placed into buckets and brought to the lab for easy measurement. In the lab, Doc Hydro carefully identified the intermediate axis of each rock and measured the diameter as precisely as possible using a caliper. The size distribution from this measurement is considered to represent the "true" size distribution of the particles. The caliper measured d_{16}, d_{50}, and d_{84} sizes were 20, 42, and 83 mm, respectively.

Five different observers, ranging from very experienced to inexperienced, were asked to visually estimate the size of each particle and tally them into one of the EPA EMAP size classes (table 1). Observers were provided with a marble and a tennis ball to help them calibrate their eyes.

Next each observer measured all of the particles using a FISP SA-97 Hand-held Particle-size Analyzer, commonly called a gravel-O-meter or gravel template, and tallied particles by standard 1/2 phi Wentworth size classes. The procedure was repeated a third time using a ruler and particles were again tallied by Wentworth size classes.

Figure 1 shows the plotted particle size distributions for all of the observers for each of the measurement techniques. Table 2 shows the average d_{16}, d_{50}, and d_{84} values of the 5 observers obtained from the plotted particles size distribution curves.

It's apparent from the plots that all of the observers had

EPA EMAP Class Name	EMAP Size Classes (mm)	EMAp Description
Fine Gravel	> 2 - 16	Lady bug to marble size
Course Gravel	>16 - 64	Marble to tennis ball size
Cobbles	>64 - 250	Tennis ball to basketball size
Boulders	>250 -4,000	Basketball to car size
Bedrock	>4,000	Rock bigger than a car

Table 1. Visual estimate size classes and descriptors. From: Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. Environmental Monitoring and Assessment Program-Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C., April 2001.

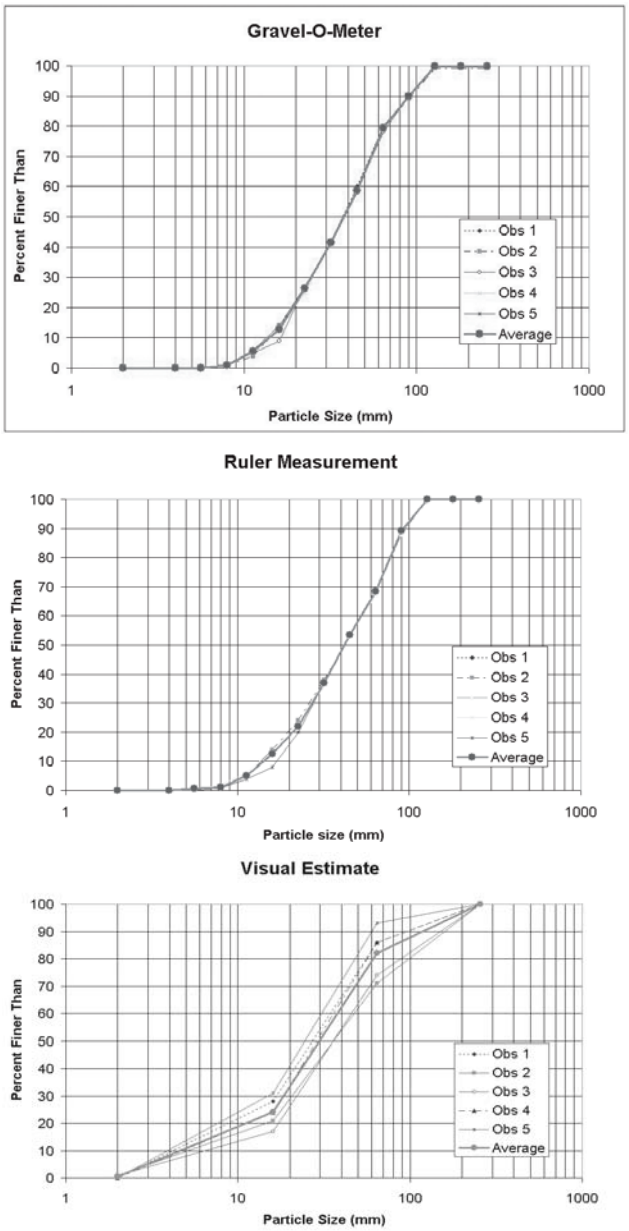

Figure 1. Plots of the particle size distributions for each of the 5 observers using the gravel-O-meter, a ruler measurement, and visual estimates. The size distributions from gravel-O-meter and ruler measurements are almost identical and tend to plot very tightly on top of each other. The particle size distributions for the visual estimates show considerably more scatter than the direct measurement techniques. For example, d_{50} values of visual estimates range from 31 to 44 mm for the 5 observers while the observers using the ruler and the gravel-O-meter consistently measured the d_{50} as 41 and 38 mm, respectively.

	d_{16}	d_{50}	d_{84}
Gravel-O--Meter	**17.2 mm (3%)**	**38.0 mm (0%)**	**72.4 mm (1%)**
Ruler Measured	**17.6 mm (8%)**	**41.0 mm (0%)**	**81.2 mm (1%)**
Visual Estimate	**9.2 mm (34%)**	**30.4 mm (18%)**	**80 mm (33%)**

Table 2. Average d_{16}, d_{50}, and d_{84} values from 5 observers using 3 different measurement techniques. Values in parenthesis are the coefficients of variation of the 5 observers.

very similar results using the gravel-O-meter and rulers since the particle size distribution curves plot almost directly on top of each other. In contrast, distribution curves from the visual estimates show considerable variability among observers.

Table 2 confirms this result with the gravel-O-meter and the ruler having almost identical d_{16} and d_{50} values and little variability (coefficients of variation zero to 8 percent). In contrast, visual estimated sizes are smaller and have coefficients of variation ranging from 18 to 34 percent indicating that different observers obtained a wide range of different size distribution statistics. Using a chi-square statistic to compare d_{16}, d_{50}, and d_{84} values to the caliper measured true values, only the visually estimated d_{16} size of 9.2 mm is statistically different from the others at the 95% confidence level.

Doc Hydro believes that the major expenditure of any field effort is getting to the field site. Once there, do the best technical job possible and take the time needed to do a quality job. Therefore, pick up the particles and measure them as accurately as you can and tally them using the standard Wentworth size classes so that the data are comparable among disciplines. Since different observers will most likely be collecting your data each year, it's especially important to reduce observer variability to the maximum extent possible. Doc Hydro recommends use of a gravel-O-meter because these measurements are less prone to observer error in identifying the intermediate axis and produce data that is comparable to sieve measurements.

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