STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

January 1996

Summary of Technical Testimony in the Colorado Water Division 1 Trial

The Colorado Water Division 1 Water Rights trial was one of the most significant federal reserved instream flow water rights cases to occur since the Supreme Court of the United States ruled in the case of United States v. New Mexico in 1978. In Water Division 1, the United States filed federal claims for channel maintenance instream flows based on the Organic Act interpretation of favorable conditions of water flows. These claims to instream flows were challenged by the State of Colorado and water conservancy districts in northern Colorado that divert water from national forests.

The United States claimed it needed to keep a certain amount of water in the headwater streams of the Laramie and South Platte Rivers on the Arapahoe, Roosevelt, Pike, and San Isabel National Forests to protect stream channels and timber. Opponents feared future development of water storage projects within the National Forests would be nearly impossible if channel maintenance instream water rights were granted.

The case, which began in 1976, went to trial in 1991 and was decided in 1993. During the year-long trial the judge heard from 49 expert witnesses and evaluated 1,500 exhibits. The case was unusual in that more than one half of the testimony dealt with the highly technical sciences of hydrology, geomorphology, and sediment transport.

A recent publication by the Rocky Mountain Station (General Technical Report RM-GTR-270), *Summary of the Technical Testimony in the Colorado Water Division 1 Trial*, summarizes the technical data and information pertaining to the disciplines of geomorphology, hydrology, and sediment transport mechanics presented to the court.

Nancy Gordon, senior co-author of the book *Stream Hydrology: An Introduction for Ecologists*, read more than 15,000 pages of court transcripts to prepare the summary.

A major purpose of the document is to

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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, limited to two pages in length. Graphics and tables are encouraged.*

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summarize the large amount of technical testimony about fluvial geomorphology, hydrology, and sediment transport mechanics. The summary discusses channel formation and maintenance, as viewed by scientists with differing opinions, and allows readers to form their own judgment about the technical merit or validity of differing viewpoints.

The publication is also intended to help managers and scientists understand how one experienced water court judge viewed the testimony and technical evidence presented. By highlighting some of the strengths and weaknesses, readers can learn important lessons and hopefully use that knowledge to make future instream flow quantification efforts more understandable and compelling in a legal framework.

The technical summary is prepared in two parts:

1. An *Executive Summary* (RM-GTR-270a, 4 pages) intended primarily for managers which summarizes the history of federal reserved water rights, outlines the major issues argued in the case, and presents the court's decision.

2. The S*ummary of Technical Testimony in the Colorado Water Division 1 Trial* (RM-GTR-270, 140 pages) intended for those interested in a detailed understanding of the case and its technical arguments. It includes sections about:

- History and policy issues
- Theories on channel formation and maintenance
- The character of streams in Water Division 1
- Field data collection and analysis
- Sediment transport in mountain streams
- The United States quantification procedure.

In his ruling, Judge Behrman recognized that reserved water rights of the United States include channel maintenance purposes. However, with respect to specific claims, Judge Behrman concluded that the United States failed to show that the reserved water rights claimed are necessary to preserve the timber or to secure favorable water flows for private and public uses under state law and that the United States failed to establish the minimum amount of water needed.

The court, however, granted the United States reserved water rights for administrative sites and fire-fighting purposes and suggested that the Forest Service use its special use permitting authority to control water diversions within the National Forests in lieu of obtaining water rights.

Copies of *Summary of Technical Testimony in the Colorado Water Division 1 Trial* (RM-GTR-270, 140 pages) are available from STREAM upon request. Send electronic requests via Data General (S28a), E-mail (/s=stream/ou1=s28a@mhs-fswa.attmail.com), or FAX (970-498-1660).

Stream Habitat Quantification by Use of the Froude Number

Robert J. Danehy
James M. Hassett

The analysis of aquatic habitats in streams has been the subject of much research during the past 40 years. The traditional visual classification of pool and riffle categories has been modified to include numerous descriptive classes. However, visual classification schemes are qualitative and subjective and do not allow for objective quantification and statistical comparisons across a range of stream habitat types. Use of the Froude number provides an objective way to classify and analyze habitat units.

The Froude number (*Fr*) is used by hydraulic engineers to describe types of flow. *Fr*, derived from a force balance on an element of incompressible fluid, can be expressed as

$$Fr = \sqrt{\frac{V^2}{gy}} \qquad (1)$$

where Fr = the Froude number
V^2 = the average cross sectional velocity (V=Q/A)
y = the hydraulic depth
g = the acceleration due to gravity.

Fr can be thought of as the ratio of kinetic energy (proportional to V^2) to potential energy (proportional to gy). *Fr* values greater than 1 describe supercritical or shooting flow; *Fr* values less than 1 describe subcritical or tranquil flow.

In field practice, *Fr* can be calculated as

$$Fr = \sqrt{\frac{TWQ^2}{gA^3}} \qquad (2)$$

where TW = top width
Q = discharge
A = cross sectional area.

Equation (2) is exactly equivalent to equation (1). Consequently, the Froude number can be computed by measuring channel width, cross sectional area, and discharge at specific stream cross sections.

Biologists have recently begun to use this tool in the analysis of habitat. Heede and Rinne (1990) suggested that a hydraulic approach to aquatic habitat analysis could improve our understanding of the relationship between fish and flow. Statzner and Higler (1986) used hydraulic character to describe patterns of aquatic insect distribution. Jowett (1993) analyzed 1,112 stream sites in New Zealand and showed *Fr* values for pools to be less than 0.18 and *Fr* values for riffles to be greater than 0.41.

Danehy (1994) examined aquatic habitat in a small (116 km^2) central New York watershed. Stream flows and 31 cross-sections one bankfull width apart were obtained at 13 sites during summer low flow conditions. *Fr* (for each cross section) and *Fr* variance (for each site) were calculated using equation 2.

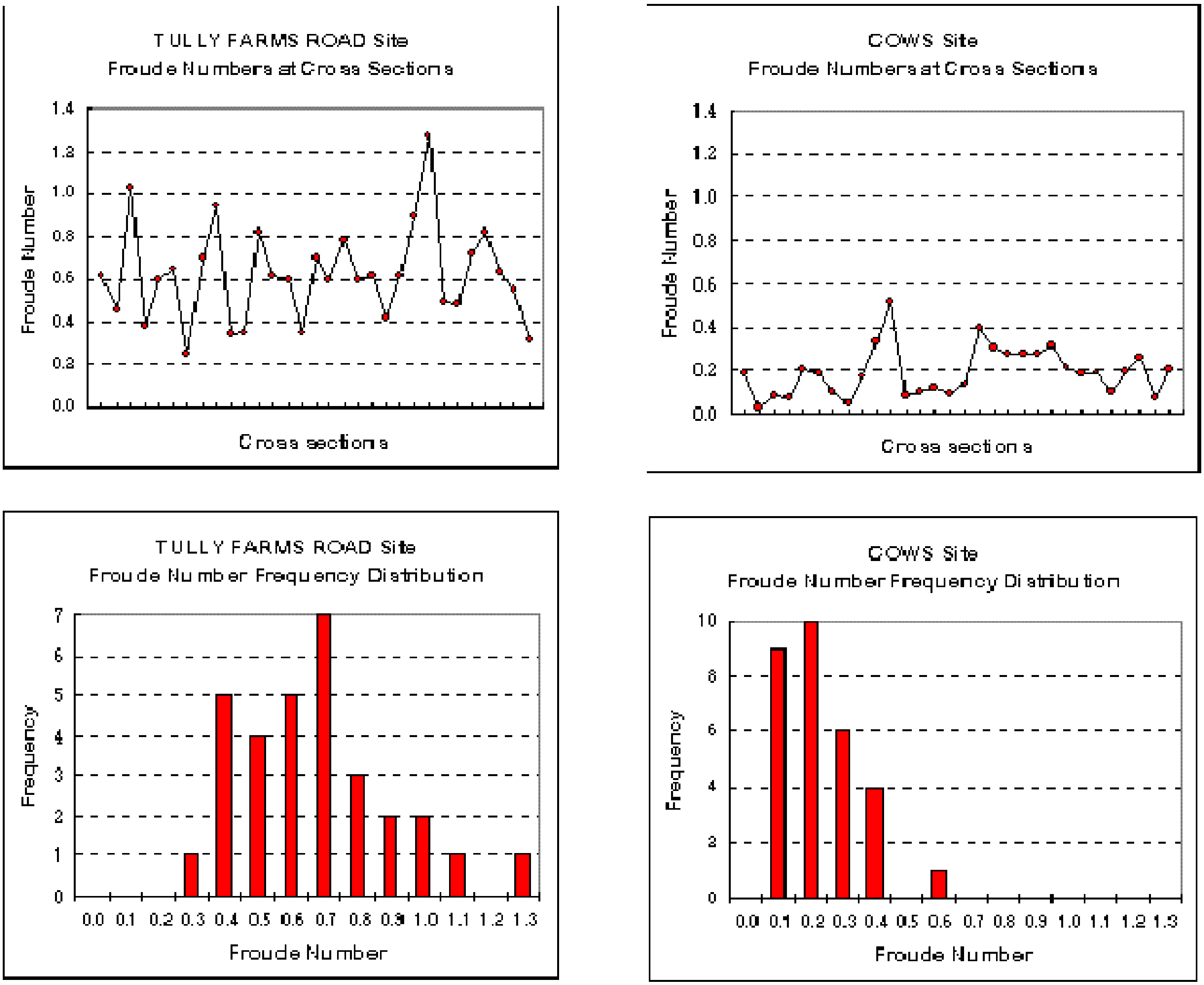

Figure 1. Froude number longitudinal and frequency distributions at 31 cross sections at two sites on Onondaga Creek, Tully, New York.

Figure 1 is a comparison of two sites by longitudinal and frequency distribution of *Fr*. The lower *Fr* values at the Cows site indicate the predominant pool habitat while the higher values at Tully Farms Road describe a more riffle dominate environment. The distribution and size of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) reflect those differences with much larger brown trout found at the Cows site predominated by pools while brook trout were found only at the Tully Farms Road site containing more riffles.

A comparison of the means of the 13 sites (Table 1) separates the sites into distinct groups. Mean *Fr* ranged from 0.13 to 0.47. Using Jowett's criteria, a single site (Webster

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i,Ú°s	i,Ú°s f,	i,Ú°s f,
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i, ˇs ÇˇRattlesn	i, ˇs	i, ˇs Çˇ
i,~ˇs ÒˇSnavlin	i,~ˇs	i,~ˇs Òˇ
i,Òˇs d	i,Òˇs	i,Òˇs
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i,ö s Table 1. Waller-Duncun mult
i, s | comparison of Froude numbers at 14 s
i,| s ● within the Onondaga Creek waters
i,Ï s _ Sites with the same letter are not statistic
i,_ s " different at the = 0.05 1

Rd) had a mean in the pool range and three sites (Rattlesnake 1, Woodmancy, and Emerson) had means in the riffle range. The rest of the sites fell between these extremes.

Fr alone does not tell the entire story with respect to fluvial fish habitat. *Fr* variance for a reach provides additional important information. High variance indicates heterogeneous habitat which should be reflected in more diverse communities. In Danehy (1994) *Fr* variance differences between pool-riffle channels from higher gradient step-pool channels were evident. Pool-riffle channels had a *Fr* variance of less than 0.50 whereas the more complex step-pool channels had a *Fr* variance > 0.50.

While mean *Fr* is a measure of habitat type, *Fr* variance is a measure of habitat complexity.

The Froude number can be an important addition to the aquatic ecologist's tool box. The ability to describe habitat quantitatively is a clear improvement over the many qualitative approaches that have been proposed. From a more practical standpoint, stream restoration projects are frequently managed by an engineer. The ecologist who can express habitat concerns in terms meaningful to the engineer is more likely to be heard.

References

Danehy, R.J., 1994. Geomorphic, hydrologic, and hydraulic determinants of fish and macroinvertebrates in a small watershed. Ph. D. Dissertation, SUNY College of Environmental Science and Forestry, Syracuse, NY, 158 pp.

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Ask DOCTOR Hydro

Dear Doc Hydro: It seems like there are many different ways to classify particle sizes. Is there a particle size classification standard that is widely accepted?

High particle size variability is a common trait of many natural rivers. The range of particle sizes in a river may span five orders of magnitude. Consequently, the properties of an individual particle are largely irrelevant, and the behavior and characteristics of groups of particles takes on increased significance. For this reason, it is both necessary and convenient to group sediments into different size classes.

As a result, numerous classification systems have developed. Most are essentially arbitrary and can be found in the engineering, geologic, and fisheries literature. Most are based on the metric system; however, a few early classification approaches used English units.

The table on the following page shows some of the most commonly used particle size classification systems and allows ready comparison among them. Note that there is a remarkable degree of similarity between the various systems especially with respect to size class breaks. Most differences are related to nomenclature. This can be a problem, especially when people use the same words but mean something different.

The most common classification system used in stream studies in the United States is that proposed by the American Geophysical Union (AGU) (Lane, 1947). While there is no official standard in the strict sense, the vast majority of professional practitioners use the AGU system.

The AGU system, which is an extension of the Wentworth scale, is widely used because size classes vary by doubling of the lower class (e.g., 2, 4, 8, 16, 32, etc.) and the sizes correspond closely to United States standard sieve mesh openings.

The actual size of particles may be based on:

(1) sieve diameter (the size of a square opening through which the particle will just pass),
(2) sedimentation diameter (based on the terminal settling velocity of a sphere), or
(3) the nominal diameter (the diameter of a sphere of the same volume as the given particle).
In practical application, the nominal diameter of large particles (generally greater than 2 mm) is estimated by measuring the intermediate axis (neither the longest nor shortest of three mutually perpendicular sides of a particle).

Particle dimensions are normally expressed in millimeters. However, in sedimentology literature, particle size (D) is often expressed in phi (ϕ) units where they are derived from the equation:

$$\phi = -\log_2 D\ (\mathrm{mm}) = -3.3219 \log_{10} D(\mathrm{mm}).$$

The minus sign was introduced so that sand sizes would have positive numbers. The phi index is useful because it normalizes particle size distributions so they can be analyzed using parametric statistics and plotted directly on arithmetic graph paper.

For detailed particle size classification, many users classify particles into 1/2 ϕ unit classes which increase by the 2 (e.g., 2, 2.6, 4, 5.6, 8, 11.3, 16, 22.6, 32, etc.) to achieve added precision.

Doc Hydro encourages use of the AGU system for consistency among those studying stream channel characteristics and systems.

The table on the following page was originally developed by staff of the USGS Hydrologic Laboratory, Denver, Colorado, and modified for this presentation.

Comparisons of Particle Size Classification Systems

U.S. Standard Sieve					230	120	60	35	18	10	5	5/16"	5/8"	1 1/4"	2 1/2"		
Phi Value						+3	+2	+1	0	-1	-2	-3	-4	-5	-6	-7	-8
Diameter (mm)	.004	.008	.016	.031	.062	0.125	0.25	0.5	1	2	4	8	16	32	64	128	>256

.0005 .001 .002 .004 .008 .016 .031 .062 0.125 0.25 0.5 1 2 4 8 16 32 64 128 >256

VF	F	M	C	VF	F	M	C	VF	F	M	C	VC	VF	F	M	C	VC	Small	Large	Small
Clay Size				Silt				Sand					Gravel					Cobbles		Boulders

AMERICAN GEOPHYSICAL UNION (Lane, 1947, AGU Transactions, v. 28, no. 6)

.0005 .001 .002 .004 .008 .016 .031 .062 0.125 0.25 0.5 1 2 4 8 16 32 64 128 >256

VF	F	M	C	VF	F	M	C	VF	F	M	C	VC	VF	F	M	C	VC	Small	Large	
Clay Size				Silt				Sand					Gravel					Cobbles		Boulders

U.S. GEOLOGICAL SURVEY (1969, Tech. of Water-Resource Investigations, Ch. C1, p. 7)

0.0039 .062 0.125 0.25 0.5 1 2 4 64

Clay	Silt	VF	F	M	C	VC	Granule Gravel	Pebble Gravel	Cobble Gravel
		Sand							

WENTWORTH SCALE (1922, Journal of Geology, v. 30, p. 377-392)

.001 .005 .074 .42 2.0 4.76 76.2

Colloids	Clay Size	Silt Size	F	M	C	Gravel	
			Sand				

AMERICAN SOCIETY FOR TESTING AND MATERIALS 1961, ASTM Standards, p. 1283)

0.002 0.05 0.1 0.25 0.5 1 2

Clay	Silt	VF	F	MC	C	VC	Gravelly, Cobbly, or Stony
		Sand					

U.S. DEPARTMENT OF AGRICULTURE (1951, Soil Survey Manual, p. 208)

Federal Interagency Sedimentation Project Technical Advisory Committee

Larry Schmidt, Program Manager, Stream Systems Technology Center, is the new Forest Service representative on the Federal Interagency Sedimentation Project Technical Advisory Committee (FISP Committee). The interagency technical committee addresses sediment instrumentation and measurement techniques.

Larry assumed the responsibility at the October meeting replacing Dr. Howard Halverson, Forest Hydrology Laboratory, Oxford, Mississippi. The Forest Service will chair the Technical Committee during FY 1996.

Editorial Policy

To make this newsletter a success, we need **voluntary contributions** of relevant articles or items of general interest. YOU can help by taking the time to share innovative approaches to problem solving that you may have developed.

Please submit typed, single-spaced contributions limited to two pages. Include graphics and photos that help explain ideas.

We reserve editorial judgments regarding appropriate relevance, style, and content to meet our objectives of improving scientific knowledge. Send all contributions to: Stream Systems Technology Center, Attention: STREAM NOTES Editor.

STREAM NOTES

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