EFFECTS OF CLEARING AND SNAGGING ON PHYSICAL CONDITIONS OF RIVERS

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Introduction

Clearing and snagging (removal of bank vegetation and large woody debris from channels) may be used for reducing the stage and duration of high frequency flooding. Environmental impacts occur because riparian vegetation and the organic debris it produces influence the stream morphology, water quality, and aquatic and terrestrial habitats.

Riparian trees and shrubs and adjacent in-channel woody debris provide important aquatic and terrestrial habitat. Furthermore, they help maintain local water quality by filtering soil eroded from uplands and shading the channel. Stumps, logs, and branches provide cover for fishes (1,2) and stable substrate for macroinvertebrates and algae. (1,3) Woody debris protects gravel and bottom-dwelling organisms from erosive flow. A moderate amount of bank vegetation and woody debris stabilizes channel planform and substrate.

At the same time, an accumulation of fallen timber and associated deposited sediments contribute significant hydraulic roughness and can impede the flow producing a greater local stage during frequent flood events than would otherwise be observed. This may also result in localized unacceptable deposition in the channel or scour of the banks. In-channel woody debris and log jams also reduce boating opportunities.

Complete clearing and snagging can have detrimental effects upon stream habitats. Thus, a balance between habitat considerations and channel conveyance is necessary. Selective removal of bank and near-channel floodplain vegetation and channel obstructions is a means of accomplishing this balance. Environmental aspects and general guidelines for selective clearing and snagging projects were presented by Shields and Nunnally. (4)

This paper describes a pilot study conducted as part of a larger research effort to develop techniques to quantify and predict incremental hydraulic and environmental effects of snag removal. The principal objective of the pilot study was to investigate effects of selective clearing and snagging on physical conditions and aquatic habitat in a sand bed river. Long-term research objectives are to relate the densities and types of woody debris in streams to: specific biotic parameters (species type and densities); conveyance (the ability of the river channel to transport water); and longitudinal dispersion (the tendency of a channel reach to trap and hold fine particulate matter).

Study Site

Pilot data were collected from a reach of the South Fork Obion River near Bradford, Tennessee, in Gibson, Weakley, and Carroll Counties. Concurrent with our study, the clearing and snagging project was in progress with construction beginning in September 1989. Implementation of the project was in strict compliance with selective clearing and snagging guidelines. (5,6) The work consisted of bank clearing and snag removal of approximately six miles of the main river channel and four miles of smaller tributaries. The work was performed by a crew of seven men using a small D-3 bulldozer with a cable and winch, chainsaws, and a small flat bottom boat with motor. Work was limited to removal of trees and large woody debris from the bottom and banks of the channel. Logs embedded in the channel were not removed if they were aligned with the flow. No rooted trees, whether alive or dead, were cut if they were leaning over the channel at an angle of 20 degrees or less off vertical unless they had severely undercut or damaged root systems. Access and material disposal was limited to one side of the channel in order to minimize disturbance or damage to the riparian habitat. Disposal materials were piled and placed in a manner to prevent re-entry into the channel. No channel excavation (i.e., sediment removal) was performed. Approximately three miles, or about one half of the main channel work, was completed during the Fall of 1989.

5. "Stream Obstruction Removal Guidelines" prepared by the Stream Renovation Guidelines Committee, a joint committee of the Wildlife Society and the American Fisheries Society in cooperation with the International Association of Fish and Wildlife Agencies, 1983.

6. "Stream Renovation and Maintenance Guidelines for the Obion-Forked Deer River System" developed by the Governor's West Tennessee Natural Resources Task Force as part of a Federal Court Agreed Order for the Obion-Forked Deer Basin Authority, 1985.

7. Platts, William S., et. al., "Methods for Evaluating Riparian Habitats with Applications to Management," General Technical Report INT-221, U.S. Dept. of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, 1987.

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11. Richards, Keith, "Rivers: Form and Process in Alluvial Channels," published by Methuen and Co., New York, N.Y., 1982.

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15. Petryk, S., and Bosmajian, G., III, "Analysis of flow through vegetation," Journal of the Hydraulics Division, ASCE, Vol. 101, No. HY7, July, 1975, pp. 871-884.

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17. Lovera, Federico, and Kennedy, John F., "Friction-Factors for Flat-Bed Flows in Sand Channels," Journal of the Hydraulics Division, ASCE, Vol. 95, No. HY4, July, 1969, pp. 1227-1234.

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19. Hauer, F. Richard, "Organic Matter Transport and Retention in a Blackwater Stream Recovering from Flow Augmentation and Thermal Discharge," Regulated Rivers: Research and Management, Vol. 4, No. 4, Nov-Dec., 1989, pp. 371-380.

20. Shields, F. Douglas, et. al., "Hydraulic and Environmental Effects of Channel Stabilization, Twentymile Creek, Miss.," Draft Technical Report, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS., Feb., 1990.

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Based upon inspection of the pilot study reaches, it was apparent that detailed counting, measurement, and mapping of snags would have prohibitive manpower and cost requirements. Due to the dense overbank forest, access along the top of banks was very limited. In addition, the turbid water conditions would make it difficult to count or estimate the submerged snags. These conditions are typical of most southern alluvial streams. Therefore, a method was needed where snag density could be estimated visually via a small boat and crew in a few days time.

For the purposes of this pilot study, large woody debris formations (Figure 2) were described using the National Marine Fisheries Service (7) classification system supplemented with our size criteria as follows:

<u>Blockage Type Categories</u>

Type A - Streambank Trees
Large leaning tree(s) (both alive and dead) with stable root systems in the side of the bank(s) with some portion of the roots, trunk, or limbs submerged in water and obstructing the "in-bank" flow.

Type B - Bridge
Large tree(s) that have fallen across the stream with "in-bank" flows occurring under the blockage.

Type C - Collapsed Bridge
Large tree(s) that have fallen across the stream with section(s) of the tree(s) leaning against the bank(s) and with "in-bank" flows going under or over portions of the blockage.

Type D - Ramp
Large tree(s) blocking a portion of the stream and leaning against one bank with "in-bank" flows going under or around one end of the blockage.

Type E - Drift
Large tree(s) and woody debris blocking a portion of the stream with "in-bank" flows occurring freely around both ends of the blockage.

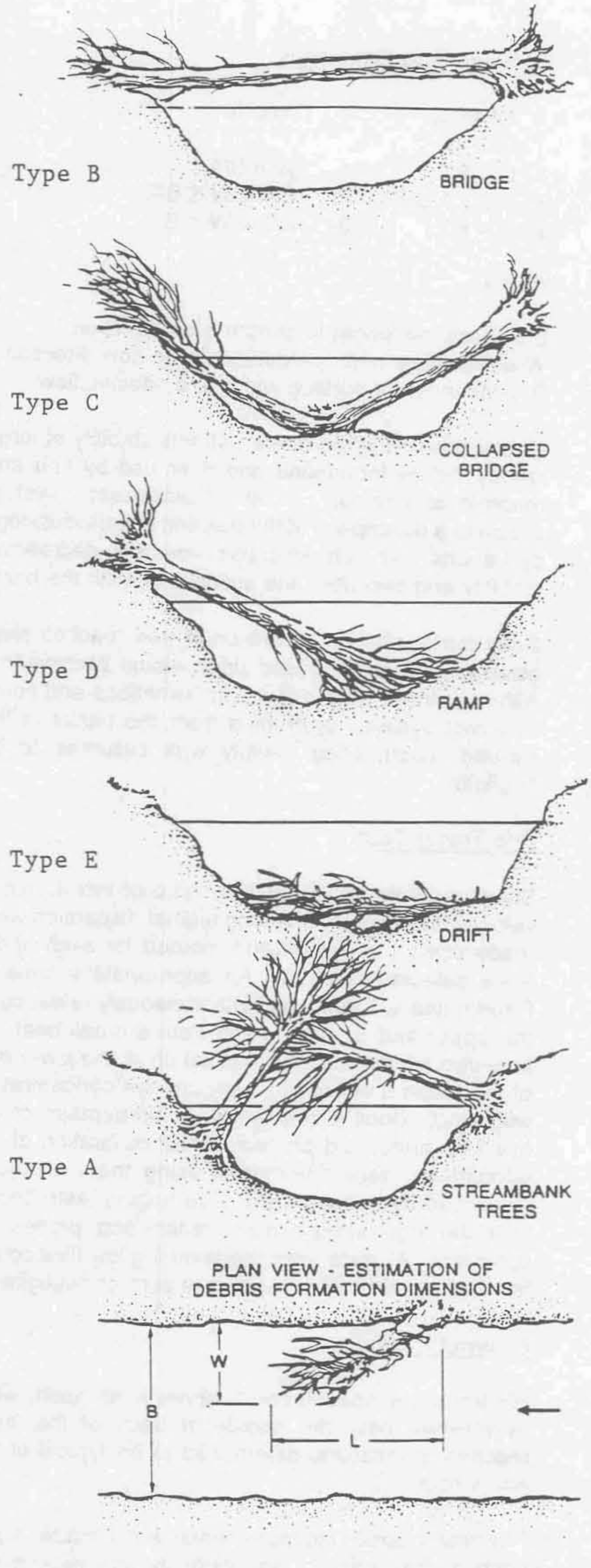

Figure 2: Large Woody Debris Formations

between the three selected reaches. The dispersion variance indices for the uncleared reaches were about twice as large as for the cleared reach. Values of the longitudinal dispersion coefficient (D_{LP}) computed from hydraulic parameters compare reasonably with values computed from the dye curves.

Values of hydraulic resistance factor (Darcy-Weisbach f) computed using snag density were in close agreement with measured f only for the cleared reach. However, reach lengths (approximately one mile) that were necessary for determination of a representative snag density were probably too long for direct application of a simple uniform flow resistance equation (measured f).

Physical Habitat Data

Frequency histograms (Figure 4) were plotted for each of the four physical habitat variables. Descriptive statistics and Shannon diversity indices for each of the three reaches are shown in Table 2. Histograms, ANOVA, and Shannon indices all indicated higher levels of physical diversity associated with snags.

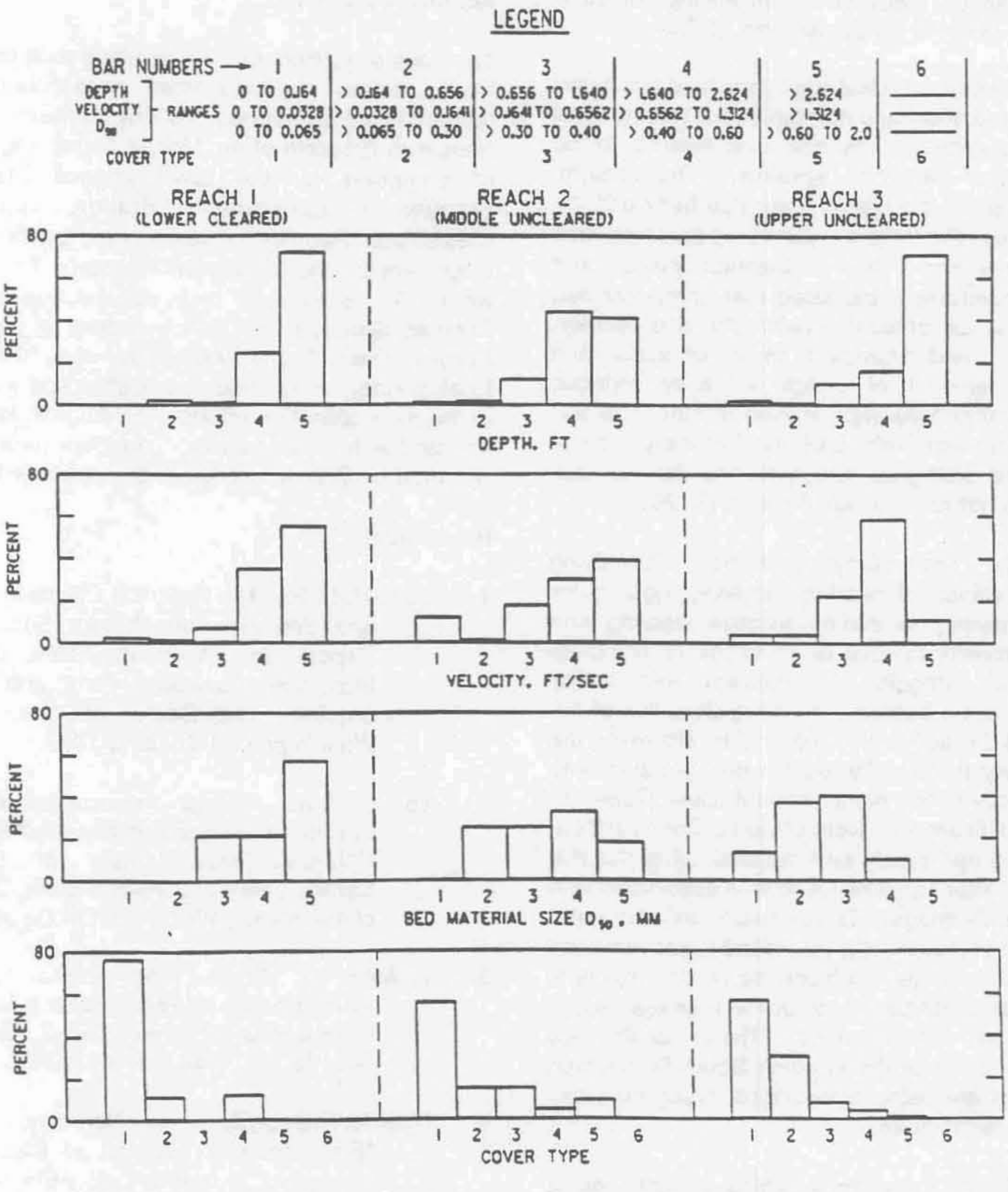

Figure 4: Physical Habitat Frequency Histograms

$\bar{t}$ = mean retention time (i.e., time of travel)
σ_t = variance of retention time distribution
DI = dispersion variance index = $\sigma_t^2 / \bar{t}^{-2}$

The time of travel for a reach was defined as the total time between the dye release or injection point at the upstream end of the reach to the centroid of the dye curve measured at the downstream end of the reach. The mean velocity, $\bar{V}$, for the reach was calculated as:

$$\bar{V} = \frac{\text{Reach Length}}{\text{Time of Travel}} = L/\bar{t}$$

The stream discharge, Q, was calculated (11) as:

$$Q = K \frac{(S_D C_i - C_b) V_o}{\int_{t=0}^{\infty} (C_d - C_b) dt}$$

where

Q = stream discharge in cfs
V_o = volume of dye in liters
C_i = concentration of dye = 0.20
C_b = background concentration
S_D = specific gravity of dye = 1.20
K = 5.886×10^5 (conversion factor to change l/min to ft^3/sec)

and the integral in the denominator is equal to the area under the dye curve.

The mean cross-sectional area in the reach was calculated as

$$\bar{A} = Q / \bar{V}$$

The mean water surface width, B, was determined as the average of several field measurements within the reach. The mean hydraulic depth and hydraulic radius was then calculated as:

$$\bar{h} = \bar{R} = \bar{A} / B$$

The water surface slope, S_w was determined by reading gages installed at each end of the reach. The reach resistance factor, Darcy-Weisbach f, was then calculated as:

$$f = 8 g \bar{R} S_w / \bar{V}^2$$

Gross longitudinal mixing is manifested in the dye tracer curve by the spread of the base of the curve. The dispersion variance index is a dimensionless number that measures the amount of mixing occurring. A high value for this index, DI, indicates a wide spread of flow-through times. Also, because of continuity, a high value indicates that a large fraction of the flow exits the reach earlier than $\bar{t}$.

In principle, the shape of a concentration distribution (dye curve) is uniquely determined if the infinite series of moments of the distribution is known. It is not practical to calculate all of the moments, and most previous investigators have limited using only the first four (zero through third). It is also necessary to assume that the distributions are similar, i.e., that they may be estimated from a similarity function whose area, centroid, variance and skewness are determined by the calculated moments. The Pearson Type III (PT=III) distribution has been found to be the best similarity function by several previous investigators. (12,13)

The mathematical expression for the PT=III distribution as a concentration distribution may be stated as:

$$C = \frac{M_o}{a_p \Gamma(b_p)} \left[\frac{t - g_p}{a_p}\right]^{(b_p - 1)} \exp - \left[\frac{t - g_p}{a_p}\right]$$

where

$b_p = (2/S_t)^2$

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with M_o = the zeroth moment (area of dye curve), $\bar{t}$ = the centroid, σ_t^2 = the variance, and S_t = the skew coefficient. The DYECON computer program was used to calculate the moments and coefficients for a PT=III distribution for each of the three dye curves.

Data from dye tracer tests was also used to determine longitudinal dispersion coefficients, D_L. This coefficient reflects all of the longitudinal mixing processes or contributing mechanisms, including irregularity of channel shape and cross section, pool and riffle sequences, effects of temporary storage, etc. The longitudinal dispersion coefficient was determined using mean velocity, dye curve variance, and time of travel as follows:

$$D_L = \bar{V}^2 \sigma_t^2 / 2\bar{t}$$

Several empirical methods have been presented in the literature for estimating D_L from stream hydraulic parameters instead of from dye curves. However, these methods have not been found to be widely applicable and can only give predicted values within a factor of 2.5 to 10 or greater in accuracy. One of

The boundary friction factor f_b depends primarily on the type of bed material and suspended sediment. Miller and Wenzl (16) reported a simulation study conducted on low flow hydraulics in alluvial channels. In comparing observed vs predicted values of f_b, they concluded that of several methods available for computing the flow resistance in sand bed streams, the Kennedy-Alam-Lovera (17, 18) method yielded the lowest standard error of estimate and highest positive correlation coefficient. They noted, however, at the riffle sections the Kennedy curves may become ineffective if used for low flow conditions in streams with pool-riffle sequences. They concluded that under low-flow conditions, the total energy loss should include an additional term for local or eddy losses due to abrupt expansions and contractions. They also noted that as the discharge increased, the local losses became less significant in accurately predicting the flow characteristics. Finally, they concluded that adequate representation of the pool-riffle sequence geometry is essential for accurate modeling of low flow conditions.

In the Kennedy-Alam-Lovera procedure for sand-bed channels:

$$f_b = f' + f''$$

where

f' = friction factor attributed to sand grain roughness.

f'' = friction factor attributed to the effects of bed forms, channel irregularities, sediment load, etc.

Using dimensional analysis for the important variables, they constructed curves for the flat bed resistance f' and the bed form resistance f'' as follows:

$$f' = \phi\left[\frac{\bar{V}\bar{R}}{v}, \frac{\bar{R}}{D_{50}}\right]$$

and

$$f'' = \phi\left[\frac{\bar{V}}{g D_{50}}, \frac{\bar{R}}{D_{50}}\right]$$

where

$\frac{\bar{R}}{D_{50}}$ = relative depth ratio

$\frac{\bar{V}\bar{R}}{v}$ = Reynold's number, (v = kinematic viscosity of the water)

$\frac{\bar{V}}{(g D_{50})^{1/2}}$ = sand particle Froude Number

Values of f_b for each of the three pilot study reaches were calculated using the Kennedy curves based upon the reach hydraulic parameters determined from the dye tracer tests and the median sand grain diameter determined from the sieve analyses. Values for f_s were then calculated using the estimated snag density for the two uncleared reaches.

Results And Discussion

Snag Density

Computed values of snag density (Table 1 and Table 2) in the two uncleared reaches of this pilot study were essentially the same.

Literature reporting measured values for snag density is limited. However, at least three references were found containing data for similar streams and although the method of measuring snag density used in this study was crude, the resulting values were in rough agreement with the data presented in these studies.

Wallace and Benke (3) reported a volume of woody debris per unit channel water volume (S_{DV}) for Black Creek, Georgia, of 0.0323 as compared to a value of 0.0650 computed in this study. The volume of wood per unit area of stream bottom for Black Creek was 0.0371 ft^3/ft^2 compared to a value of 0.1680 in this study. In this study, volumes of snag blockages (i.e. considered as a mass and not as individual pieces) were based upon a visual count of all the formations in the entire reach with average sizes used for the various types. Wallace and Benke presented volumes of submerged woody debris based upon measuring individual stem diameters of snags by snorkeling along 21 transects within the study reach. Considering the difference in techniques used and that stream width and depths in this study are twice the size of Black Creek and the test reach is 1.5 times longer, it is not unreasonable that the computed values were two to four times those reported by Wallace and Benke.

Petryk and Bosmajian (15) computed values of vegetation density (S_{DA}) of 0.025-0.030 (ft^{-1}) for the Kaskaskia Mutual Dredged Channel near Bondville, Illinois. The channel section is straight, 4-10 ft deep, 330 ft long, and obstructed by trees 2-12 inches in diameter covering the side slopes. The vegetation was in full foliage, and part of the right bank was covered with large weeds and bushy willows. The photograph of the channel gives the impression that it was much more obstructed than our study reaches; therefore, the value of snag density (0.003 ft^{-1}) appears to be reasonable by comparison.

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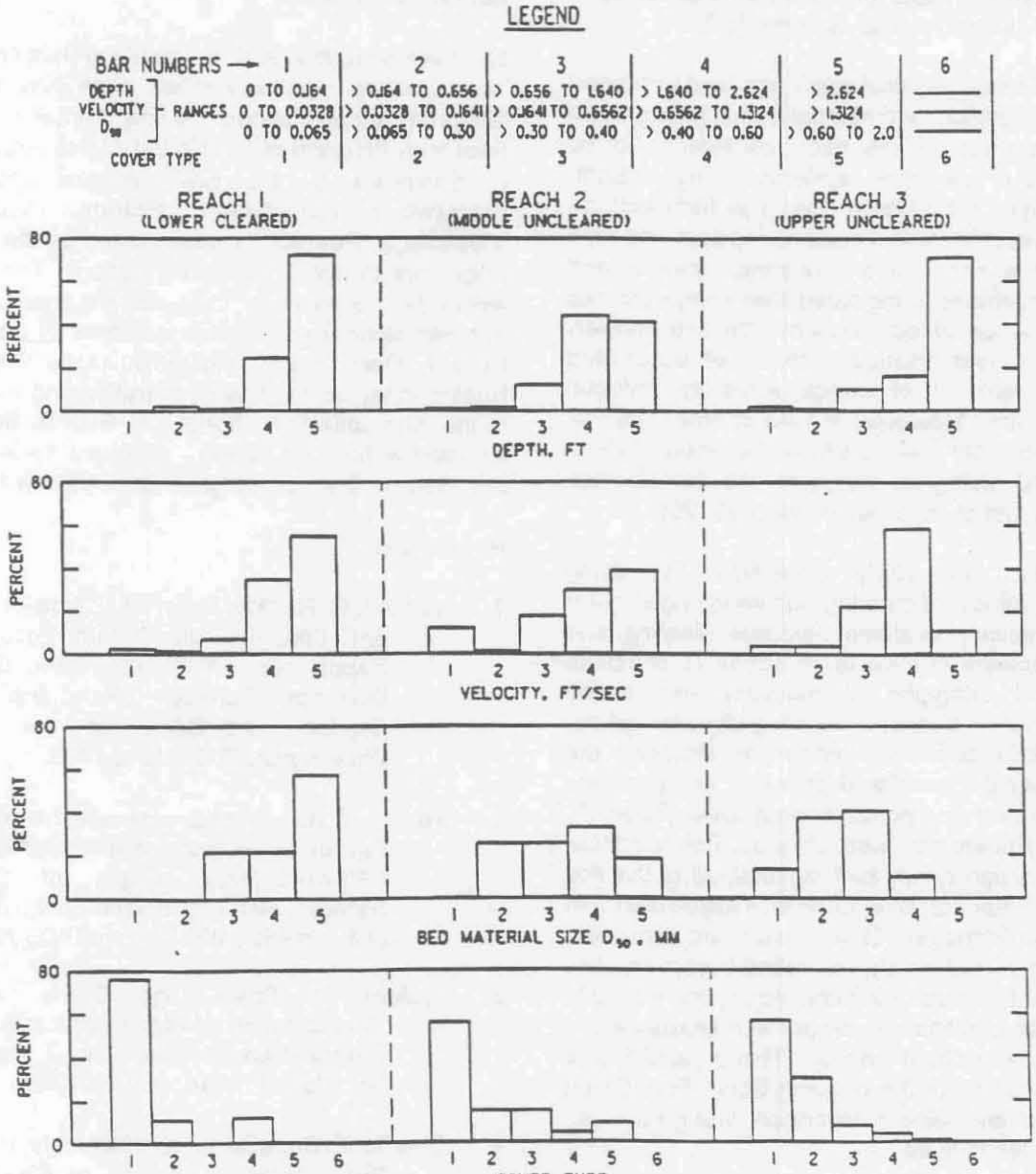

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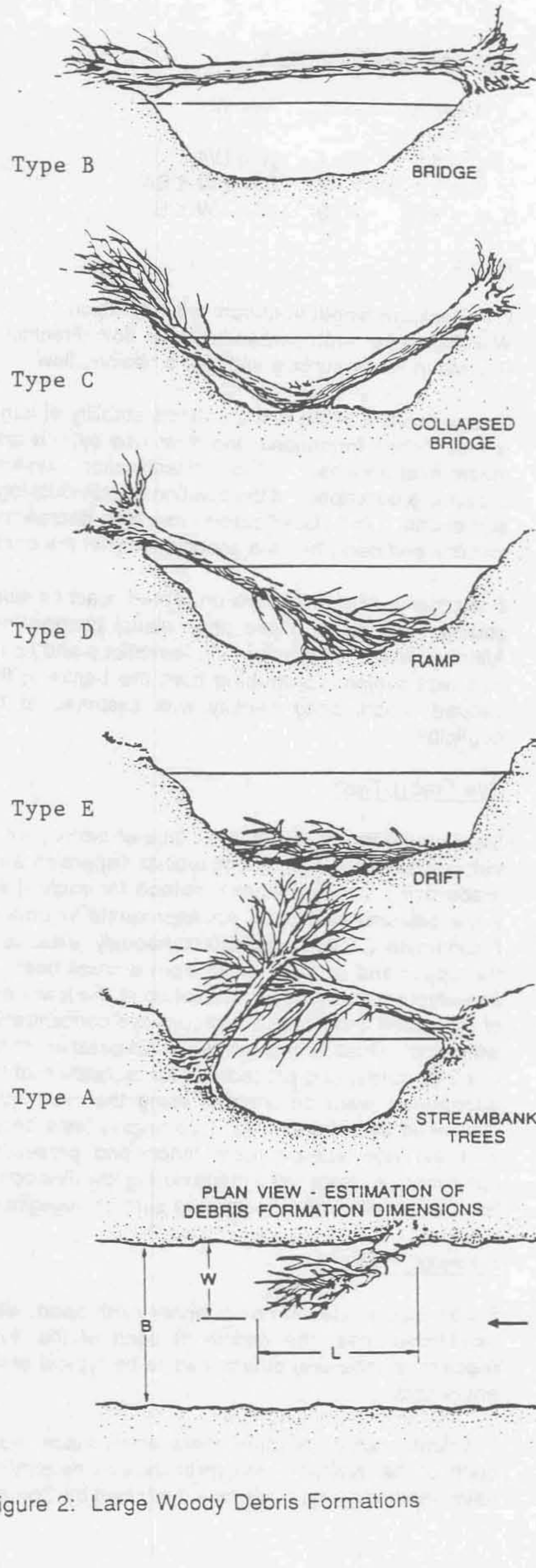

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