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Title: Incipient Motion and Particle Transport in Gravel-Bed Streams

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The incipient motion of sediment particles in gravel-bed rivers is a very important process. It represents the difference between bed stability and bed mobility. A field study was conducted in Oak Creek, Oregon to investigate incipient motion of individual particles in gravel-bed streams. Investigation was also made of the incipient motion of individual gravel particles in the armor layer, using painted gravel placed on the bed of the stream and recovered after successive high flows. The effect of gravel particle shape was examined for a wide range of flow conditions to determine its significance on incipient motion.

The result of analysis indicates a wide variation in particle shapes present. Incipient motion and general transport were found to be generally independent of particle shape regardless of particle sizes.

A sample of bed material may contain a mixture of shapes such as well-rounded, oval, flat, disc-like, pencil-shaped, angular, and block-like. These are not likely to move in identical manners during transport nor to start motion at the

same flow condition. This leads to questions about the role of shape in predicting incipient motion and equal mobility in gravel-bed streams.

The study suggests that gravel particles initiate motion in a manner that is independent of particle shape. One explanation may be that for a natural bed surface many particles rest in orientations that give them the best protection against disturbance, probably a result of their coming to rest gradually during a period of decreasing flows, rather than being randomly dumped. But even when tracer particles were placed randomly in the bed surface there was no evident selectively for initiation of motion on the basis of particle shape.

It can be concluded from analysis based on the methods of Parker et al. and Komar that there is room for both equal mobility and flow-competence evaluations. However, the equal mobility concept is best applied for conditions near incipient motion and the flow-competence concept is best applied for larger flows and general bedload transport. Furthermore, with an armored bed, such as that at Oak Creek, there is a tendency for a more-nearly equal mobility (or equivalent) for the normalized transport rates for the various size fractions when incipient motion and moderate bedload transport occurs.

Incipient Motion and Particle Transport in Gravel-Bed Streams

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LIST OF SYMBOLS

a = the length of the longest axis of the particle
a_1 = distance from center of gravity to point of support
a_2 = distance from point of support to plane of bed
b = the length of the intermediate axis of the particle
c = the length of the shortest axis of the particle
c_1 = particle volume coefficient
c_2 = particle area coefficient
d = representative particle diameter
d_8 = diameter of circumscribing sphere
d_{50} = the median particle size
d_{65} = particle size that 65 percent of all particles are smaller
d_n = nominal diameter
d_s = particle size
d_x = particle size that x percent of all particles are smaller
$F_{d,c}$ = critical drag force
F_g = gravity force
F_s = Shields parameter
g = gravitational acceleration
K = Shields parameter
L = length of reach being flushed below water source
n = Manning's roughness coefficient
q = the unit discharge (e.g., cfs/ft width)
q_b = volumetric bed load discharge per unit width
q_c = unit discharge at incipient motion
q^* = dimensionless volumetric transport rate
R = the hydraulic radius (flow area divided by wetted perimeter)
R_g' = submerged specific gravity of sediment
S = actual surface area of the object
s = surface area of sphere of the same volume of the object

S_b	=	the bed slope
S_e	=	the friction slope
T	=	the suspension half-life for any particle size
T_t	=	the particle travel time in seconds
u_*	=	shear velocity
w	=	the particle fall velocity
X	=	a correction factor for surface drag in terms of d_{65}/δ'
x	=	a reference particle size for a particular bed
y	=	the flow depth
Y	=	a correction of lift force in the transition between hydraulically rough and smooth beds, in terms of d_{65}/δ'
γ	=	specific weights of fluid
γ_s	=	specific weights of sediment
δ'	=	thickness of the laminar sublayer
ξ	=	a correction of effective flow for various particles (hiding factor)
η	=	efficiency factor = 1.0 for a long river or canal
θ	=	angle of repose of sediment
ρ	=	fluid density
ρ_s	=	sediment density
τ_o	=	the cross-sectional average shear stress at the boundary
τ_*	=	Shields stress
τ_c	=	critical shear stress
ϕ	=	slope angle of the bed
ψ	=	bed stability parameter
ψ^*	=	hydraulic stability parameter
ψ_p	=	sphericity

INCIPIENT MOTION AND PARTICLE TRANSPORT IN GRAVEL-BED STREAMS

I. INTRODUCTION

Research Need

Incipient motion of sediment particles in gravel-bed rivers is a very important process. It represents the difference between bed stability and bed mobility. This has implications for the physical composition of the bed, which may possibly be adjusting and changing slowly over a long period of time. It also has implications for the biological features and chemical quality of the bed, with relevance for aquatic organisms and such human health and aquatic health concerns as the storage of toxic substances that might otherwise cause contamination of the water. Hence, understanding of incipient motion conditions for bed material is needed for a wide variety of problem analyses and for design.

Incipient motion is one basis for analysis and design of stable river beds. One use may be for determining maximum flows at which a contaminated bed will remain stable and retain toxic substances that otherwise might contaminate the water and affect aquatic organisms and human health. Another use may be to establish "flushing flows" to maintain a clean, pervious stream bed in rivers subject to upstream discharge control. Without adequate flushing, fine-sized sediment and organic matter may accumulate in the void spaces among bed particles and cause low permeabilities. Oxygen depletion may then occur in the bed due to the presence of oxygen-using organisms and matter, causing such problems as suffocation of fish eggs buried in the gravel bed that receive oxygen from intra-gravel seepage.

Knowledge of incipient motion conditions is also needed for general sediment transport studies where rates of transport and sizes of material transported are important. The bed load transported in a river is dependent on the water discharge in a proportional but non-linear manner. However, bed load transport does not occur at small discharges. The condition of incipient motion is needed to set a lower bound on the bed load transport function.

Research attention is needed on this problem not only for the practical applications mentioned above but also for a better understanding of the problem and for general application in the scientific field of hydraulic engineering.

Research Objectives

The overall objective of this research is to develop a predictive knowledge of the incipient motion of gravel particles through increased understanding of hydraulic and sediment transport phenomena in an armored gravel-bed stream. Five specific objectives provide detail to this broader objective. They are as follows:

1. Investigate incipient motion of gravel particles in the armor layer of a gravel-bed stream in relation to water discharge;
2. Investigate flushing of small-size particles from coarse stream bed;
3. Investigate the effects of particle shape on incipient motion;
4. Investigate the probability of movement of individual coarse particles of various sizes and the associated equal-mobility theory as it applies to incipient motion and general transport; and
5. Investigate possible improved application of the

Parker et al. prediction equation for Oak Creek bed load based on newer data.

Research Scope

This research is directed towards increased understanding of the incipient motion of sediment in gravel-bed streams. Field studies were conducted in Oak Creek on incipient motion of gravel particles and bedload transport. Information from earlier studies at Oak Creek was also assembled. All the information was combined for a comprehensive analysis of incipient motion and related phenomena.

II. PROBLEMS IN DETERMINING INCIPIENT MOTION

Gaps in Understanding Particle Behavior at Flows Near Incipient Motion

Prediction of incipient motion is difficult, even for a specific river reach. Lack of precision in the definition of incipient motion is one reason. However, there are several other difficulties.

The most basic problem is that bed material in a natural river is not all uniform in size and shape. A great deal of variation occurs in terms of the particle size composition of the bed surface. Over a small area at a given place in the channel bed there will be a wide range of particle sizes present. Bed material is highly heterogenous in its composition. At a single location the bed material may contain particles that range in size from cobbles to sand. Additional difficulties arise due to the interaction of large and small particles in the bed, indicated by such conditions as particle "hiding" and the "embeddedness" of the surface. There is also spatial variation in the particle size composition of the bed because of differences in bed form and shape over small distances and variations in flow strength in different parts of the channel.

Spatial variability adds vertical, lateral and longitudinal variations to the composition of bed material in a natural river. Vertical variation is associated with an "armoring" process whereby the surface layer has relatively less of the small size fraction of bed material compared to material beneath it. Spatial variation laterally and longitudinally is due to differences in bed morphology and associated variations in flow hydraulics in different parts of the channel.

Wide variation also occurs in particle shapes. A sample of bed material may contain a mixture of well-rounded, oval, flat, disk-like, pencil-shaped, angular, and block-like particles. These are not likely to move in identical manners during transport nor to start motion at the same flow condition. This leads to questions about the role of shape in predicting incipient motion.

This variability in bed material composition makes difficult the selection of a representative size to use for describing incipient motion. It also makes it difficult to select representative sizes to use with bed-material transport equations.

The purpose of this research is an increase in our understanding of the incipient motion in gravel-bed rivers of particles that are generally in contact with the stream bottom. Such investigation brings together consideration of the dynamic behavior of the fluid and the physical behavior of the sediment being moved from a gravel-bed river. This research is mainly directed towards understanding the mechanism of incipient motion of gravel particles in terms of flow variables and particle geometry.

Proposed Research To Increase Understanding

Research at Oak Creek, Oregon over the past two decades has provided data describing bedload transport and incipient motion. The initial Oak Creek research program started in 1969 (Milhous and Klingeman, 1973) with the goal of developing concepts to help describe the nature of sediment transport in a stream when a coarse armor layer is present. In 1975 it was decided to continue the research program with changes to the sampling system. The goal of the research during 1975-1976 (Heineke, 1976) was to develop the means to sample bedload for shorter time intervals to allow improvement in understanding and predicting bedload transport relations for a stream having an armor layer.

One of the major areas of investigation for the 1969 and 1975 research programs was the relationship between the coarse armor layer and the finer gravels, sands, and silts "trapped" in and just below this armor layer. It was thought that the armor layer provided a location or reservoir for the trapping of finer materials and that little resuspension of this trapped material occurred until motion of the coarser armor layer began. It was also thought that as flows decreased after a storm peak the finer material settled out and was trapped by this coarser layer.

During 1977-78 (Saluja, 1982), sediment transport relations were investigated for total bedload and for particular sediment size ranges of the bedload in Oak Creek. Bedload sampling was done under transient conditions of storm runoff. Several bedload transportation regression equations were developed that relate bedload transport rates to the water discharge of the stream, considering all stages of the hydrograph. Statistical curve fitting techniques were used to develop the bedload equations.

The present research program has focused on the incipient motion process for bed material in gravel-bed rivers. The investigation included general bedload transport, flushing flows, sizes of dislodged particles compared to bed material sizes, and effects of particle shape on incipient motion. To accomplish the study, intensive bedload sampling was done in Oak Creek during 1988-1989 along with experiments on particle movement and shape using painted gravel. All of the previous Oak Creek data on bedload and bed material sampling were organized and incorporated into this study.

Hypotheses to Test

Two main hypotheses are involved in this research. These are that:

(1) there is equal probability of movement of particles in the armor layer, regardless of size, for incipient motion and for general transport; and

(2) initiation of movement is a function of the particle shape factor.

The hypotheses are tested by a detailed literature review followed by a series of field experiments and analysis of the resulting data. From available theory and data for incipient motion, a predictive knowledge of incipient motion behavior is developed for gravel-bed streams.

III. LITERATURE REVIEW

Incipient Motion of Particles

Incipient motion of bed material in a river due to flowing water refers to the beginning of movement of bed particles that previously were at rest. Incipient sediment motion is the condition at which these sediment particles just begin to be moved by the flow. It is implied that the particles, once disturbed, will continue to move over some unspecified distance during some unspecified time. Incipient motion is associated with changing river flow conditions. Most generally, this is due to increasing water discharge. Incipient motion is a transitory condition between bed-material stability and general bed-material transport.

Water flowing over bed material in a gravel-bottomed stream exerts forces that tend to move or entrain the particles individually and in large numbers. The forces that resist the entraining action of the flowing water differ according to particle size and to the size gradation of the bed material. For coarse material, e.g., sands and gravel, the forces resisting motion are caused mainly by the weight of the particles. Finer sediment that contains an appreciable amount of silt and clay tends to be cohesive and resist entrainment mainly by cohesion rather than by the weight of the individual particles. Vanoni (1975) states that when hydrodynamic forces acting on a grain of non-cohesive sediment or an aggregate of particles of a cohesive sediment reach a value that, if increased even slightly, will put the grain or aggregate into motion, then the critical or threshold condition is said to have been reached.

The incipient motion of individual particles in a uniform or nearly uniform bed has been studied by several investigators. Very adequate reviews of incipient motion concepts are given in Graf (1971), Vanoni (1975), and Simons and Senturk (1977).

Wang and Shen (1984) have shown that for laminar flow, the incipient sediment motion condition can be determined easily because as soon as flow exceeds this incipient condition, nearly all sediment particles are in motion. For turbulent flow, the instantaneous force acting on the particle fluctuates a great deal with time. Usually only a few sediment particles may be moved by the flow near incipient motion conditions.

In his work, Milhous (1973) observed that small amounts of fine sediment do move around and among the armor particles when the armor particles are not moving.

The subjectivity in deciding when motion of the bed has begun, together with bed material heterogeneity and bed morphology variability, make it difficult to determine the exact incipient motion condition with turbulent stream flow. This would explain why different incipient motion values and criteria have been proposed by various investigators.

The physical processes involved at the beginning of sediment motion have been studied by many investigators since the 18th century. The most significant modern work in this area was carried out by Shields in 1930s as reported by Vanoni (1975).

The general form of the governing equations can be derived by evaluating the forces acting on a particle of non-cohesive sediment resting in a bed of similar material. These forces include the gravitational force of the submerged weight of the particle and the hydrodynamic forces of lift normal to the bed and drag parallel to the bed. This is depicted schematically in Figure 1 with ϕ as the slope angle of the bed, θ as the angle of repose of the submerged sediment, and τ_c as the critical shear stress when incipient motion begins. The gravitational force, F_g, is:

$$F_g = c_1 (\gamma_s - \gamma) d_s^3 \tag{1}$$

where F_g = gravity force;
c_1 = particle volume coefficient;
γ_s = specific weight of sediment;
γ = specific weight of fluid;
d_s = particle size; and
$c_1 d_s^3$ = volume of the particle;

The sediment particle size d_s is often taken as the median particle size, d_{50}.
The critical drag force is:

$$F_{d,c} = c_2 \, \tau_c \, d_s^2 \tag{2}$$

where $F_{d,c}$ = critical drag force;
c_2 = particle area coefficient;
τ_c = critical shear stress; and
$c_2 d_s^2$ = effective area of the particle.

Since the lift and drag forces are both functions of the same variables, and since the constants in the theoretical equations are experimentally determined, the lift term is often not separated out in the formulation. If the moments of the governing forces about a point are equated and the resulting equation is rearranged, the analysis yields:

$$\tau_c = \frac{c_1 a_1}{c_2 a_2} (\gamma_s - \gamma) \, d_s \cos\phi \, (\tan\theta - \tan\phi) \tag{3}$$

where a_1,a2 = distances as specified in Figure 1;
θ = angle of repose of sediment; and
ϕ = slope angle of the bed.

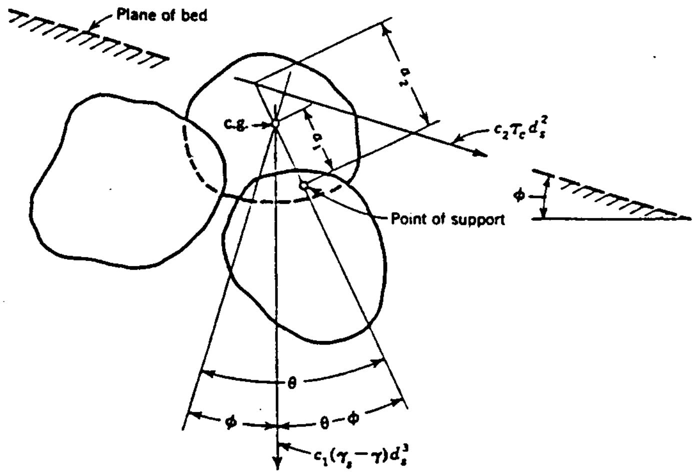


Figure 1 Forces on sediment particle in bed of sloping stream (Source: Gessler, 1971)

For the relatively small bed angles associated with natural streams, the equation takes the form:

$$\tau_c = K(\gamma_s - \gamma) d_s \tag{4}$$

where K = Shields parameter.

The parameter K is commonly referred to as the Shields parameter. The above analysis assumes that the inertial forces are large relative to the viscous forces (fully turbulent flow). In this case, K is approximately constant. However, for relatively large viscous forces (small Reynolds numbers), the Shields parameter will not be constant. The Shields diagram for this parameter, depicted in Figure 2, shows the variation of this parameter with the boundary Reynolds number.

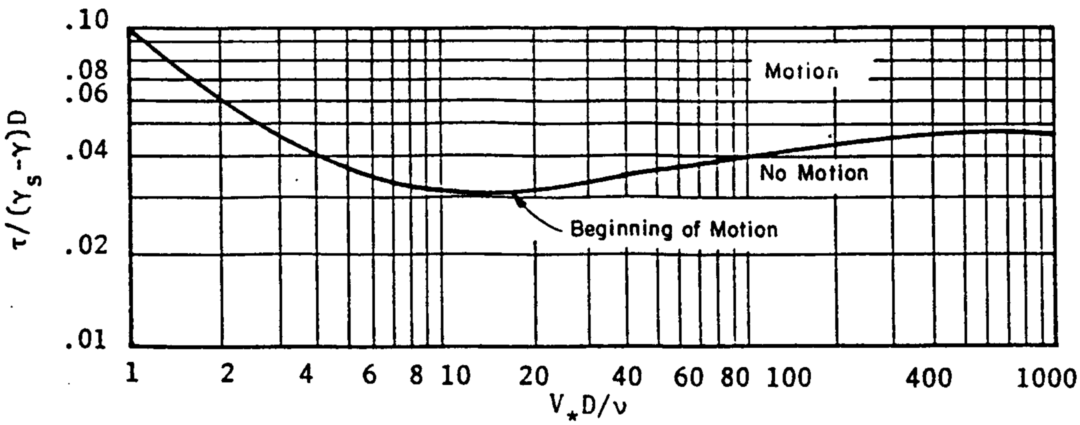


Figure 2 Modified Shields relationship for beginning of motion (Source: Gessler, 1971)

Shields (Gessler, 1971) obtained his results by measuring the bed load at various values of $\tau / (\gamma_s - \gamma)d$, with all values of τ being at least twice the critical value (τ_c). He then extrapolated his findings down to the point of zero bed load. With this technique, he avoided the problem of defining the exact point where motion of the bed begins. Gessler points out, however, that Shields did not differentiate between losses due to bed form and those due to grain roughness. Consequently, he overestimated the Shields parameter at incipient motion by as much as 10 percent. The diagram shown in Figure 2 has been adjusted by Gessler to reflect this correction.

Shields' results are in a dimensionless form that is difficult to interpret in physical terms. If the density of the bed material is assumed to be constant and the fluid is assumed to be fresh water, the Shields diagram can be transformed into a diagram of critical shear stress versus grain size as depicted in Figure 3.

The investigations that led to the development of the Shields diagram were based on the use of uniform particle materials. The armor layer of a gravel bed stream or river is composed of non-uniform material. Hence, the particle size distribution of this armor layer has been studied by several other investigators, including Gessler (1971), Little and Mayer (1972), Kellerhals and Church (1977), Shen and Lu (1983), and Odgaard (1984).

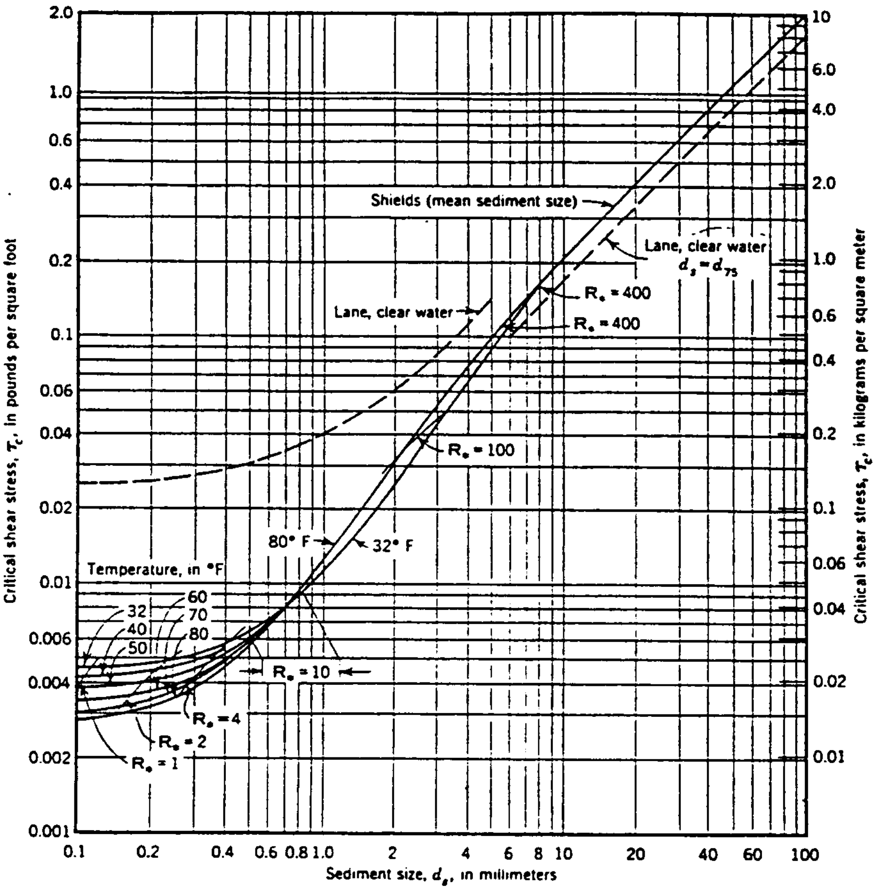


Figure 3 Critical shear stress for quartz sediment in water as a function of particle size (Source: Vanoni, 1975)

Recent investigations suggest that, for the same median particle size, the turbulence intensity at the bed increases with increased size of the largest particles in the bed. As a result, the effective Shields parameter is reduced. Rakoczi (1975) concluded that the d_{10} of the material (material for which 10 percent is finer by weight) is appropriate in the Shields relationship for gravel-sized particles, while Shen and Lu (1983) recommend the use of d_{30}

of the material, along with a modification of the Shields diagram to give the "armor layer Shields curve" for non-uniform bed materials using the median particle size, d_{50}, of the material.

Figure 4 illustrates the Shields parameter for nonuniform bed sediment. This figure indicates that the Shields parameter could be as low as 0.02 for gravel sized material. However, this curve is based on very little data.

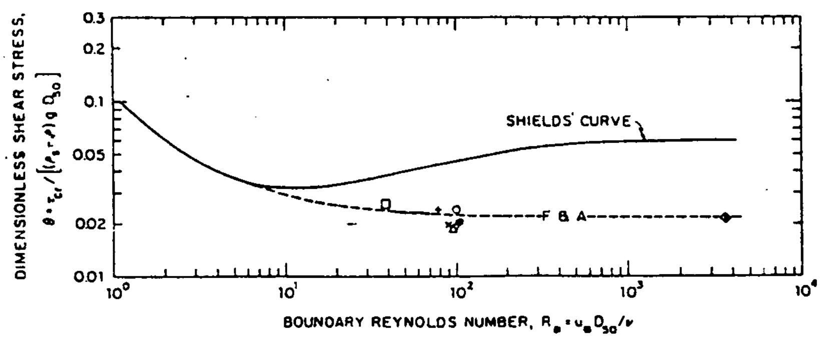


Figure 4 Shields factor for non-uniform bed sediment (Source: Odgaard, 1984)

Parker (1979) developed a bed-load transport function using extensive data from gravel-bed streams. Included in his transport function is a threshold shear stress parameter (Shields parameter) of 0.03. Andrews (1983) found from investigations of 24 self-formed gravel-bed rivers in Colorado that the mean critical dimensionless shear stress relative to the median particle diameter (d_{50}) was 0.033. Consequently, a Shields parameter of about 0.03 appears to be appropriate for the mobilization of gravel bed streams.

Therefore, for particles larger than about 0.2 inches (6 mm) in water, the modified Shields relationship for gravel-bed rivers can be given as:

$$\tau_c = 0.03 \ (\gamma_s - \gamma) \ d_{50} \tag{5}$$

where τ_c = the critical shear stress; and
d_{50} = the median particle size.

The channel boundary shear stress that is required to mobilize the bed can be expressed in terms of mean channel flow properties. A commonly used form is:

$$\tau_o = \gamma R S_e \tag{6}$$

where τ_o = the cross-sectional average shear stress at the boundary;
R = the hydraulic radius (flow area divided by wetted perimeter); and
S_e = the friction slope.

for steady uniform flow, the friction slope S_e is equivalent to the mean channel bed slope, S_o.

Care must be taken when using this relationship because the slope term (S_e) refers to the energy losses associated with the bed roughness, and not the bed form (ripples or dunes) or channel alignment. Generally, however, neither ripples nor dunes form in gravel bed streams (although the bed morphology causes other bed forms to occur). If the stream is relatively wide (width/depth > 10) and has a flat bed, the hydraulic radius may be approximated by the flow depth, and the bottom shear in equation (6) can be expressed as:

$$\tau_o = \gamma y S \tag{7}$$

where: y = the flow depth.

Channel shear velocity can also be used as an alternative way of considering shear stress in the velocity equations. The shear velocity can be expressed as:

$$u_* = \sqrt{\frac{\tau_0}{\rho}} \tag{8}$$

where: u_* = shear velocity; and
ρ = fluid density.

Manning's friction equation for a wide channel can be expressed in terms of unit width of channel as:

$$q = \frac{1.486}{n} S^{\frac{1}{2}} y^{\frac{5}{3}} \tag{9}$$

where q = the unit discharge (e.g., cfs/ft width); and
n = Manning's roughness coefficient.

If Manning's equation is solved for y and substituted into equation (7), the bed shear stress can be expressed, in U.S. customary units, as:

$$\tau_o = \gamma \left[\frac{n\, q}{1.486\, S^{\frac{1}{2}}} \right]^{\frac{3}{5}} \tag{10}$$

where 1.486 = conversion factor (= 1.00 in S.I. metric units).

Analysis of data from many rivers, canals, and flumes (Anderson et al. 1968) indicates that the Manning's roughness coefficient can be predicted (with U.S. customary units) by the equation:

$$n = 0.04\, d_{50}^{\frac{1}{6}} \tag{11}$$

where d_{50} is the median particle size given in feet.

The average boundary shear stress for steady uniform open channel flow, τ_o , was given in equation (6) with S_e as the slope of the energy grade line along the channel. At the critical bed shear stress, τ_0 becomes equal to τ_c , and one can write:

$$\tau_c = \gamma R S_e \tag{12}$$

Furthermore, if the stream is relatively wide and has a flat bed this can be rewritten (in a manner similar to equation 7) as:

$$\tau_c = \gamma y S_e \tag{13}$$

If equation (11) is substituted into equation (10), the bed shear in equation (10) is equated to the critical shear stress in equation (5), and specific gravity is assumed to be 2.65, then the required discharge for mobilizing the bed can be expressed as a function of the particle size and the friction slope. In U.S. customary units this becomes:

$$q_c = 0.25 \frac{d_{50}^{\;1.5}}{S^{1.17}} \tag{14}$$

where q_c = the unit discharge at incipient motion (cfs/ft) (flow needed for bed mobilization).

The relationship in equation (14) is shown in Figure 5 as a set of curves of unit discharge versus grain size for various channel bed slopes.

Figure 5 provides a means to estimate the stream discharge that is required to mobilize the bed and initiate motion. For example, for a stream in which the d_{50} is 2.0 inches and the channel slope is 0.005, a flow of about 8 cfs/ft of stream width would be required. If the average channel width is 25 ft, this then equates to a required flow of about 200 cfs.

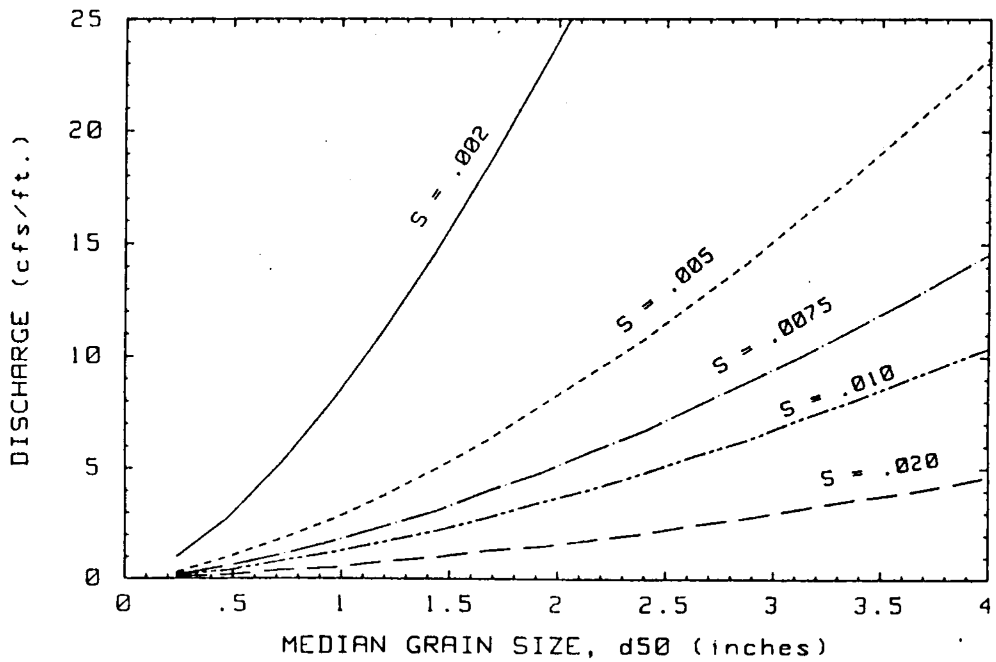


Figure 5 Critical unit discharge for bed mobilization as function of particle size and channel slope, based on Shields entrainment function (Source: Reiser and Ramy, 1985)

However, the analysis leading to the development of these curves is an over-simplification of the incipient motion process in a natural stream. Such realistic conditions as the embedding of the stream gravels in fine sized material or the imbrication of the gravels can change the flow required for mobilization. The estimated discharge is also sensitive to the Shields parameter. For instance, a commonly used value for the Shields parameter is 0.047, as suggested by Gessler (1971) and Meyer-Peter and Muller (1948). An increase from 0.03 to 0.047 in the value of this parameter, for the relationships presented, would more than double the discharge required for incipient motion to occur.

Additional complications in determining the flow required to mobilize the bed are associated with the selection of an appropriate d_{50} and an appropriate frictional slope for the stream. In particular, a non-linear channel alignment or a non-planar bed make this latter parameter difficult to assess.

Critical Velocity and Shear Stress

The basic concept of a critical shear stress is that when the forces on the particle due to flowing water overcome the weight of the particle, then the particle will move (Gessler, 1971). The incipient motion of particles is governed by the probabilistic character of fluid shear stress in a turbulent flow. As observed as early as 1936 by Shields, the process of initiation of motion is statistical in nature. The method of estimating the critical shear stress used by Shields (i.e., extrapolation downward to zero motion from transport conditions) implied that there is no movement of a uniform bed material at the critical shear stress.

Another definition of critical shear stress (Paintal,1969) identifies the critical shear stress as that at which 3% of the surface particles are moved during every hour. Paintal's definition implies that the time rate of particle movement is an important factor in the determination of the critical shear stress. Gessler (1965, 1970) defined the critical shear stress for a particle to be the time-averaged shear stress at which the "probability of being eroded equals the probability of remaining at rest."

Helland-Hansen (1971) studied the effect of time upon the definition of incipient motion. He states "bedload transport is a statistical phenomenon where random velocity fluctuations are responsible for the dislodgement of gravel particles". Hence, the determination of a threshold value of shear stress or velocity to define a scour criterion should involve time as a variable. In his long-term experiments with a fairly uniform gravel mixture (D_{50} = 1 inch) the gravel bed was continuously exposed to a gradually decreasing flow. Gravel particles transported out of the bed were periodically sampled in a downstream collector, avoiding the need for visual assessment of the first displacement of particles. Time rate of transport versus average discharge resulted in a straight-line relationship, extending into the range of flow strength where the most common bedload formulas and scour criteria predict zero movement. The size-gradation curve of the transported material resembled the original bed gradation, but shifted continuously toward the smaller size fractions as the flow strength dropped.

In his study, Helland-Hansen (1971) observed that the particle size distribution curves show the selectiveness of the flow in dislodging particles under gradually decreasing discharge. It is of interest that the flow not only flushes out the medium-sized particles, but transports the larger ones also as long as the flow is sufficiently turbulent.

Neill (1968) considered Gessler's definition to be incomplete because the definition did not include a period of time over which the probability of remaining stationary equals the probability of moving. Egiazaroff (1965) proposed a method for determining the incipient motion for a particle in a non-uniform sediment, but only for a particle seated on a common datum with adjacent particles. This orientation rarely or never occurs in nature.

Because of the statistical nature of the entrainment process, there is no truly critical condition for initiation of motion for which motion begins suddenly as the condition is reached. Shih and Komar (1990a) reviewed the work by Kramer in the mid-1930s in which three intensities of motion of sand near the critical or threshold condition were given: weak, medium, and general movement. These are defined as:

> "1. Weak movement indicates that a few or several of the smallest sand particles are in motion in isolated spots in small enough quantities so that those moving on 1 cm^2 of the bed can be counted.
>
> 2. Medium movement indicates the condition in which grains of mean diameter are in motion in numbers too large to be countable. Such movement is no longer local in character. It is not yet strong enough to affect bed configuration and does not result in appreciable sediment discharge.
>
> 3. General movement indicates the condition in which sand grains, up to and including the largest, are in motion and movement is occurring in all parts of the bed at all times."

Despite controversies among investigators in defining the critical condition, there seems to be reasonable agreement among published results from several sources. Therefore, one can conclude that the incipient motion of a particle is related to a "critical" shear stress applied to the particle by flowing fluid. The average bed shear stress for steady uniform open channel flow, τ_0 , is given by equation (6).

The dimensionless Einstein hydraulic stability parameter, ψ, for a hydraulically rough bed can be written as:

$$\psi = \frac{(\gamma_s - \gamma)d}{\gamma R S_e} \tag{15}$$

where ψ = bed stability parameter; and

d = representative particle diameter.

Since $\gamma = \rho g$, this equation can be rewritten as:

$$\psi = \left(\frac{\rho_s - \rho}{\rho}\right) \frac{d}{RS_e} \tag{16}$$

where: g = gravitational acceleration; and
ρ, ρ_s = fluid and sediment densities, respectively.

Substituting equation (12) in equation (15) yields:

$$\psi = \frac{(\gamma_s - \gamma)d}{\tau_c} \tag{17}$$

But

$$\psi = \frac{1}{F_s} \tag{18}$$

where F_s is called herein the Shields parameter and can be written as

$$F_s = \frac{\tau_c}{(\gamma_s - \gamma)d} \tag{19}$$

By rearrangement of equation (19), one can obtain the general solution for the critical shear stress when the flow is hydraulically rough (i.e., non-flat bed surface):

$$\tau_c = F_s(\gamma_s - \gamma)d \tag{20}$$

Values of F_s given in the literature indicate that F_s ranges from 0.017 to 0.076. Vanoni (1975) stated that Shields in 1936 indicated a value of 0.06. Other values of Shields parameter are given in Graf (1971). As an alternative method of measuring critical shear stress, Milhous (1973) has suggested successive increases in flow over a bed until particles are observed to move, as he reviewed 1964 work done by McNeil. Andrews (1984) concluded that most particles are entrained within a relatively narrow range of discharges.

From the critical shear stress analysis, one can conclude that there is a critical shear associated with the particle size distribution. Milhous and Klingeman (1973) have observed that particles having a wide range of sizes are found in the armor layer and many of the particles are small enough that they could be transported by flows of less than the critical discharge if they were not protected by the larger particles. In other words, the smaller particles are hidden from the hydraulic forces of the stream by large stable particles.

The hidden position of a particle is related to the uniformity of the bed material. If d_{50} and standard deviation are large, small particles in the bed surface mixture may be "hidden" by larger particles. Thus, the critical shear stress to disturb these hidden particles will be larger than that for the same size of particles when present in a uniform bed (hence, not hidden).

For calculating the rate of bed material movement, Einstein (1964) has defined a hiding factor, ξ. This has been incorporated into his hydraulic stability parameter as follows:

$$\psi* = \xi \, Y \left[\frac{\log 10.6}{\log 10.6 \frac{Xx}{d_{65}}} \right]^2 \left[\frac{\rho_s - \rho_f}{\rho_f} \right] \frac{d}{RS} \tag{21}$$

where:

ψ^* = hydraulic stability parameter;

ξ = a correction of effective flow for various particles (hiding factor);

Y = a correction of lift force in the transition between hydraulically rough and smooth beds, in terms of d_{65}/δ';

X = a correction factor for surface drag in terms of d_{65}/δ';

x = a reference particle size for a particular bed;

d_{65} = particle size that 65 percent of all particles are smaller;

δ' = thickness of the laminar sublayer;

Einstein (1950) states that for a uniform rough bed, $\xi = 1$ and $Y = 1$. Furthermore, $X = 1.0$, $x = 0.77\ d_{65}/\ \delta'$. Thus:

$$\left[\frac{\log 10.6}{\log 10.6\ \frac{Xx}{d_{65}}}\right]^2 = 1 \qquad (22)$$

and $\psi^* = 0.66\ 1/F_s$

This reduces, ψ^* to becoming proportional to $1/F_s$. Therefore, the Einstein hiding factor appears to be an appropriate way of handling smaller particles in an armor layer. By using the concept above, the stability parameter can be expressed as

$$\psi^* = (\xi)\left(\frac{1}{F_s}\right) = f\left(\xi\ ,\ \frac{1}{F_s}\right) \qquad (23)$$

Milhous (1973) states that the stability of a particle increases as its size in a heterogeneous bed decreases below $0.69\ d_{65}$.

Most investigations of incipient motion have considered only shear stress as being the most influential parameter, while lift force is often ignored completely. Vanoni (1975) stated that work done by Einstein and El-Samni in 1949 and Apperly in 1968 are the main researchers who made quantitative observations of lift forces on sediment in a bed. Einstein and El-Samni showed that lift near the bed may be due to: (a) pressure differences because of the large velocity gradient, and (b) upward velocity components caused by turbulence. Yalin (1963) showed that a lift-force analysis can yield the Shields relation.

The distribution of instantaneous lift force observed by Apperly (1968) indicated that there was a predominance of negative values, but there were infrequent bursts of large positive lift forces. These large lift forces are apparently the ones that entrain particles.

Particle Shape and Incipient Motion

Particle shape and orientation affect particle mobility (Bluck, 1967; Butler, 1977). Particle shape describes the general form of a particle. Particle imbrication offers a particularly stable orientation, with flat-shaped particles resting on each other and inclined in the downstream direction. This creates an artificially smooth bed surface which resists entrainment (O'Brien, 1984). Imbricated particles sheltered by neighboring particles, often in the turbulent wake of large particles, require larger shear stress to induce motion (Baker and Ritter, 1975) than for equivalent individual, randomly-oriented particles.

The shapes of objects may be classified in many ways. Some involve comparisons with standard geometric shapes, such as spheres, cubes, prisms, cylinders or cones. At best, most sediment particles only roughly approximate these regular solid shapes.

One approach to particle shape analysis commonly used to study the settling velocity of grains in water is to measure three mutually perpendicular axes. From these a shape factor can be determined. This is given by:

$$SF = \frac{c}{\sqrt{(a\ b)}} \tag{24}$$

where a = the length of the longest axis of the particle;

b = the length of the intermediate axis of the particle; and

c = the length of the shortest axis of the particle.

This definition is essentially that proposed by Krumbein (Kumbein, 1941).

Ideally, the property of sphericity might be measured by the following equation (Simon, 1977):

$$\psi_p = [(\frac{b}{a})^2 \frac{c}{b}]^{\frac{1}{3}} = \frac{s}{S} \quad (25)$$

where: ψ_p = sphericity;

S = actual surface area of the object; and

s = surface area of sphere of the same volume of the object.

This ratio is 1 for a sphere. For all other solids the ratio has a value less than one. Because of the difficulties of measuring the surface area of irregular solids, the sphericity may also be expressed as d_n/d_8, where d_n is the nominal diameter (diameter of a sphere of the same volume as the object) and d_8 is the diameter of the circumscribing sphere (generally the long diameter). As before, a sphere has a sphericity of 1 and other objects have values less than 1.

In a sample of sand or gravel, each fragment or particle will have its own sphericity value. Some, however, will be disk-shaped or notably flat and elongated in two directions, shortened in the third. Others will be elongated in one direction only and will be "roller-shaped". Both such shapes yield a low sphericity value (Krumbein, 1941). In some instances it is important to distinguish between the two. The sphericity index as defined above fails to do so.

Distinction between such shapes, however, is possible by means of diameter ratios. Zingg has shown (Simon, 1977) that if the ratios b/a is plotted against c/b (where a, b, and c are length, breadth, and thickness, respectively) particles can be made to define four shape classes (Krumbein, 1941). To class I belong the oblate or disk-shaped pebbles; to class II, the equiaxial or nearly spherical objects; to class III, the triaxial pebbles; and to class IV belong the prolate, rod-like or roller-shaped forms. Their relation to the Zingg and sphericity indices is shown in Figure 6. The curves represent lines of equal sphericity as shown is Figure 6.

Terms to indicate side similarity, such as prismoidal, bipyramidal, pyramidal, wedge-shaped, parallel-tabular, may be used. This latter classification, however, is qualitative and does not, as a rule, bear any relation to the dynamical behavior of these objects during transportation. Instead, a single-number index of shape is preferred which is amenable to mathematical manipulation and by means of which a shape distribution or frequency curve can be constructed.

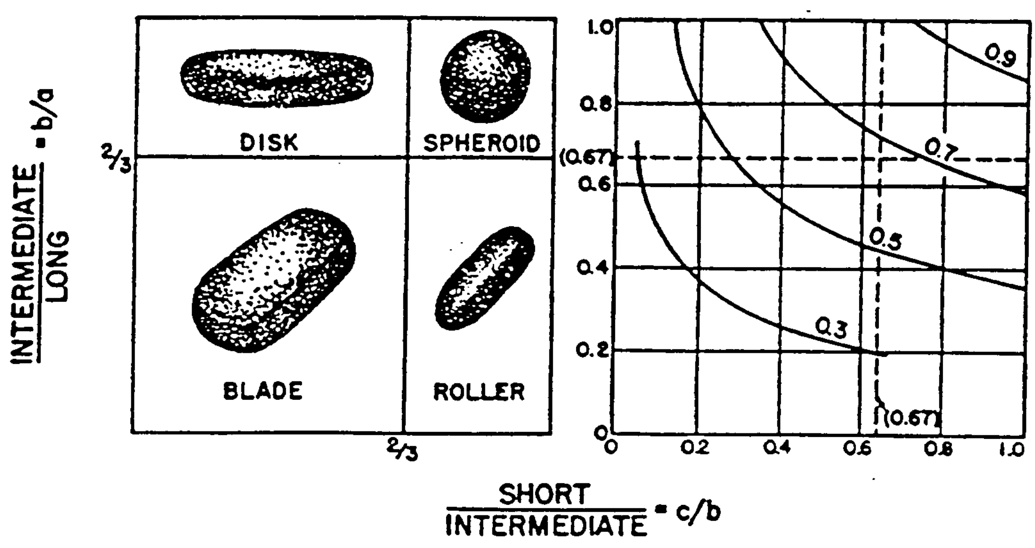


Figure 6 Zingg's classification of pebble shapes (Source: Krumbein, 1941)

To set up such an index of shapes, some standard of reference is needed. The sphere may be taken as such a standard. This tends to be the limiting shape developed by many rock and mineral fragments upon prolonged abrasion. Furthermore, the sphere has certain unique properties which make it a useful standard of reference. Of all possible shapes for a given volume, the sphere has the least surface area. Consequently, the sphere has the greatest settling velocity in a fluid of any possible shape (volume and density being the same). Under conditions of suspension transport, the more spherical particles tend to become separated from others of the same size and density but of less spherical form. The more spherical particles are deposited, whereas those less spherical are carried away.

The reverse situation prevails under conditions of traction transport. In this case, of two particles of the same volume and density, the less spherical will remain behind and the more spherical will roll away.

Flat, disc-like particles have been observed to be imbricated, whereby one grain rests against and on another, with one end tilting up in the direction of flow. Mantz(1980) suggests that flat, imbricated grains have increased bed stability and lower transport rates relative to non-imbricated grains for the same flow conditions. Komar and Li (1986) attribute their increased stability near threshold conditions to higher pivot angles exhibited by imbricated and flat grains. Pivoting angle is defined as the angle formed by particle contact points with an underlying particle. Similarly, Lane and Carlson (1954) found that disc shaped grains are less susceptible to motion than spherical particles of equal weight. Ashworth and Ferguson (1989) noticed that spherical particles moved farther than flatter particles, which indicates lower transport rates for discs. Carling, et al. (1992) found lower particle velocities for discs than for spheres at low flow velocities; however, at higher flow velocities the trend was reversed. In contrast, Magalhaes and Chau (1983) concluded that flat, low-density shale particles have lower resistance to initial motion. The shale sediments had critical shear stresses 15% lower than those gives by the Shields diagram and 40- 50% lower than those recommended by the U.S. Bureau of Reclamation for the design of channels.

A study of the effect of particle shape on bedload transport in Piceance Creek, Colorado by Moore (1994) indicates that the reference transport critical shear stress for the median surface particle size (τ_{r50}), for flat-shaped particles, is approximately 2.5 times higher than those for more spherical-shaped particles. This indicates a lower susceptibility of disc-like particles to initial entrainment and lower transport rates for given flow conditions than more rounded particles.

A single-number index of shape is required which is amenable to mathematical manipulation and by means of which a shape distribution or frequency curve can be constructed. In order to set up such an index of shapes, some standard of reference is needed. The sphere may be taken as such a standard. The sphere is the limiting shape assumed by many particles upon prolonged abrasion. Also, of all possible shapes for a given volume, the sphere has the least surface area. Under conditions of bedload transport of two particles of the same volume and density, the less spherical particle will remain behind and the more spherical particle will roll away (Moore, 1994).

Accumulation and Flushing of Fines in Gravel Beds

Problems

Several problems arise when fine sediment is present in a coarse streambed. Such problems include suffocation of eggs in spawning habitat, reduction of bed infiltration rate by accumulation of fine material, and change in river regime and aquatic habitat impacts (e.g., see Klingeman and MacArthur, 1990). These are briefly described in the following paragraphs.

While buried in the gravels of streams for several weeks to months, fish eggs and larvae are subjected to various environmental factors that can cause mortality. The fate of eggs deposited at some depth in the gravel streambed depends in part upon the amount of dissolved oxygen in the intragravel water and the availability of pore space within the gravel. The term "intragravel" refers to interstitial spaces within the streambed. The amount of dissolved oxygen content and rate of the flow of intragravel water are main factors that affect buried eggs and larvae (Wickett, 1954). These conditions are directly influenced by the amount of fine sand deposited in gravel pore spaces.

Fine sediments can significantly affect fish habitat and other instream biota (Gibbons and Salo, 1973; Meehan and Swanson, 1977). Fine sand particles in the gravel create a physical barrier and thus reduce the permeability of the gravel bed. This prevents stream water from moving into and flowing within the gravel. This phenomenon could result in the suffocation of eggs or entrapment of the larvae and lead to the elimination of preferred spawning habitat. Therefore, a sand-free streambed is one of the most important factors which contribute to the usability of spawning habitat.

A major problem in groundwater recharge occurs due to the reduction in the infiltration rate caused by accumulation of sediment and other fine material on the bottom and banks of streams. Clogging is primarily caused by settling of sediment and straining of suspended material as water moves through the surface sediment layer and into the soil. Clogging eventually tends to cause the greatest relative reduction of infiltration rate if the bottom soil is coarse sand and the suspended sediment is fine sand. Flushing and removal of the fine sediment from the top layer of the clogged recharge zones is necessary to again increase the rate of infiltration of water.

Hydropower and other diversion schemes change river flow patterns. Sediment, including fine sediment, is usually excluded from the diverted water and is instead transported and deposited downstream of the hydropower system. This condition tends to change the river regime and aquatic habitats in the river (Klingeman and MacArthur, 1990). Activities that involve flushing and exclusion of fine particles from the streambed farther downstream will further alter the bed material texture in the stream.

From the above examples, it is apparent that the periodic removal of fine sediment from gravel beds has biological significance. How this removal can be achieved forms the underlying basis for the determination of flushing flow requirements.

The Intrusion of Fines

The process by which deposition of fine particles occurs could be best described from seasonal hydrograph characteristics in terms of hydrograph shape and flow duration. According to O'Brien (1984), deposition is generally observed on the rising limb when sands are deposited in the cobble interstices. This differs from the observation of Milhous (1973), who noted that the gravel void spaces were filled with sand on the recession limb of storm hydrographs. O'Brien further indicates that when cobbles move, the sand is washed from the interstices but rearrangement of the cobbles will result in a more stable and possibly imbricated armor layer.

Beschta and Jackson (1979) have shown that sediment deposition and intrusion into the gravels involves two principal mechanisms: (1) the transport and deposition of sand particles into the surface voids of the gravel bed, and (2) the settling of the particles into deeper gravel voids. The settling process occurs primarily under the influence of gravitational forces, but seems assisted by the turbulent pulses at the gravel surface. Einstein (1968) found that the fine particles which are carried in suspension from upstream and settle out of suspension into a gravel bed have a tendency to filter slowly down through the pores of the gravel. The silt does not deposit on the top of any gravel, but instead, slowly settles down to the bottom of the gravel bed, gradually building up a deposit there, filling the pores from the bottom up while leaving the upper layers of gravel relatively clean. Observations by Beschta and Jackson (1979) indicate that most deposition and intrusion occurs within the upper 5-10 cm of the gravel.

Flushing From a Stable Bed

The laboratory studies of Beschta and Jackson (1979) indicated that upon the elimination of a source of fine sediments, a given flow can flush fines out of the gravels to a depth of about 0.4 inches (1 cm). The gravel bed in those experiments was composed of material having a mean diameter of about 0.6 inches (1.5 cm). Such findings agree with those of O'Brien (1984), who found that fine material could be cleaned from a cobble channel bed to a depth of about 0.5 - 1.0 of the average cobble diameter. However, results of both investigations indicated that further flushing of fines requires mobilization of the stream bed.

Natural high flow events on unregulated streams normally provide the necessary level of stream bed mobilization to flush fine sediments. Regulated streams, however, differ in two major ways from unregulated systems. First, upstream dams can cut off the major supply of streambed gravel sediments to downstream reaches. Second, the regulation of flows may eliminate the periodic high flows which would normally set the channel bed in motion and flush the fine material from the gravels. Thus, as previously noted, the provision of a flushing flow can have both positive and negative effects on fish habitat. A positive effect would be the removal of fine sediments from important spawning and rearing habitat; the negative effects could be manifest in channel morphology changes including the downstream movement of the spawning gravels with no replacement from upstream.

Magnitude of Flushing Flow

It should be noted that when flushing flows are needed, the magnitude of the require discharge may vary depending upon the bed morphological features under consideration (i.e., spawning riffles or rearing pools). Reiser and Bjornn (1979) noted that streamflow changes generally influence flow velocities and area of riffles more than area of pools. Kraft (1972) and Wesche (1974) both demonstrated that velocity versus depth was the most dynamic parameter with respect to varying flows. The most dramatic changes in velocities are, therefore, likely to manifest themselves in riffle areas. Intuition and observation show that higher flows are required to remove surface sediments from pool areas than riffle areas. However, even higher flows are needed to flush fines from below an armored layer in a riffle. An armor layer forms whereby finer material is held in place by coarse material. An excellent graphical presentation of the relative magnitude of these flows is provided in Bjornn et al. (1977) and depicted in Figure 7.

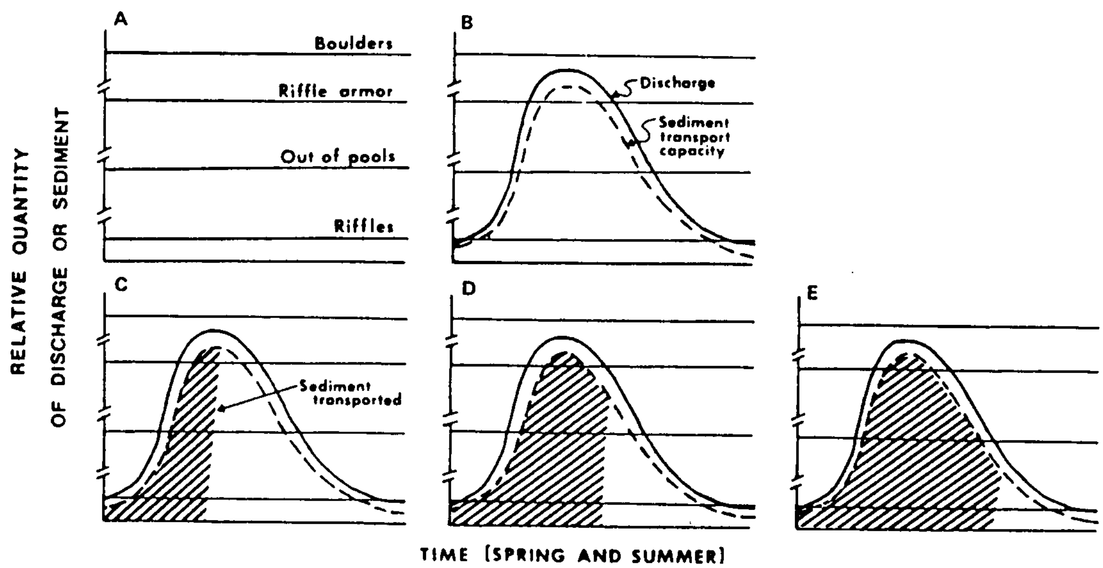


Figure 7 Relative discharges for transport of sediment across riffles, out of pools, out of armored riffles, and out of substrate armored by boulders for a given section of stream (As modified from Bjornn et al., 1977 by Reizer and Ramy, 1985)

As described by Bjornn et al. (1977), Figure 7A displays (in increasing magnitude) the critical discharges needed for transporting coarse and fine sediments across riffles, out of pools, out of riffles after dislodging the armor layer, and out of the substrate after moving large boulders. The amount of coarse and fine sediments capable of being transported through a given reach of stream is a function of flow (Figure 7B).

Figure 7 further demonstrates three potential conditions of sediment transport in an unregulated stream. In Figure 7C, a condition of above-average discharge is presented. In this condition, the flows are capable of mobilizing the armor layer on the riffles, and the fine sediment within the riffles can be transported downstream. As indicated, essentially all such sediment has been transported out of the system before the flows begin to recede. Thus, very little sediment would be redeposited at the lower flows.

The condition in Figure 7D is representative of a stream which is still transporting fine sediments after the flows have declined below the level which mobilizes the armor layer on riffles. In this situation, the riffles would be refilled with sediment. Figure 7E depicts a stream which is still transporting fine sediments after flows have fallen below levels which remove fines from pools. Thus, the pools would be refilled with sediments. It should be noted that if no armored layer is present in a stream, sediment transport from riffle areas would be occurring in all but the lowest flow conditions depicted.

The conditions displayed in Figure 7 were for an unregulated stream which exhibits distinct runoff events. In regulated systems, a much flatter hydrograph may result with peaks in flow being of relatively short duration. Nevertheless, the same general patterns and principles apply. That is, the magnitude and duration of the required flushing flow depend on the extent and characteristics of the sediment problem.

Under some conditions, sufficient flushing may be achieved through a relatively rapid increase and decrease in flows (a quick "pulse" of flow). Such may be the case if flushing is targeted at very fine sediments within a short unarmored riffle section located immediately below a water development project. In this case, a brief increase in flow may be sufficient to effectively transport the material. In contrast, the flushing of extensive sediment deposits within pools or within armored riffles may require bed mobilization only achieved by the sustained release of substantially higher flows. Methodologies which have been used for assessing flow requirements are reviewed in the following section.

Beschta and Jackson (1979), in evaluating the process of fine sediment intrusion into gravels, also assessed the mechanism and timing of flushing flows in small streams. They concluded that flushing of fines can only occur during periods of relatively high flows that disrupt the channel bed and cause bedload transport. From field measurements made in Oregon Coast Range streams, it was determined that the general transport of bed material smaller than sand size occurs after flows exceed about 13.7 cfs/mi^2 drainage area (0.15 m^3/Sec/km^2). Beschta and Jackson (1979) determined from a frequency analysis of daily flows that this level was exceeded on a mean basis about 20 days each year. This would represent the flow which is equalled or exceeded 5 percent of the time. Based on the above, it can be estimated, for example, that a stream with a drainage area of 100 mi^2 would need a flow of about 1,370 cfs to flush fines from the stream bed.

Although Beschta and Jackson (1979) do not formally suggest using this approach for determining flushing flow requirements, its potential value should not be dismissed. It may be that similar relationships exist for drainage basins having similar characteristics to the ones originally measured during the investigation (i.e., small coastal headwater streams). Wesche et al. (1977) used the assumption of drainage basin similarity in making flushing flow recommendations for two different systems in Wyoming.

To ensure applicability of this approach, detailed information of the respective drainage basin characteristics is required. Flow records are needed to determine exceedance levels. This approach should probably be reserved for planning-level studies. This technique offers no consideration of the timing or duration of flows.

In 1980, Water and Environment consultants (WEC, 1980), used an adaptation of the Meyer-Peter & Muller transport formula and the Manning equation to assess flushing flows on 18 headwater streams in southeast Wyoming. The methodology was focused on predicting the incipient motion of a specific size sediment, rather than on the entire channel bed. Field data collected at each site included bed material samples, stream bed and water surface slopes, water velocities, and general watershed and river characteristics. Data analysis was performed using the Meyer-Peter & Muller transport formula and tractive force theory. Because of the steep slopes and armored nature of the channels studied, WEC (1980) assumed that a hydraulically rough boundary existed. Thus, a flushing flow was defined as the discharge which produces critical shear stress on a particle of a given size on a rigid boundary. This approach is applicable for removing superficial fines but would not result in the mobilization of the bed, which some investigators indicate is required to flush interstitial fines. The flows determined were recommended for a 72-hour duration and were to coincide with the natural spring runoff period.

O'Brien (1984) conducted a study in Yampa River in the Dinosaur National Monument, designed to assess the minimum streamflow regime for preserving the processes and natural conditions vital to the channel morphology and aquatic life systems of the river. The particular concern was the provision of channel conditions conducive to the maintenance of the endangered Colorado River squawfish. The study included both field and laboratory tests designed to investigate sediment transport and streamflow relationships. Suspended sediments, bed load and various physical and hydraulic parameters for the study area (velocity, depth, slope, substrate particle size) were measured in the field.

A physical model of one study reach was constructed in an experimental flume to aid in the evaluation of sediment transport dynamics. The study resulted in the development of a synthetic hydrograph for the maintenance of channel morphology and existing aquatic systems. Flushing flows, defined in terms of effective discharge and bankfull discharge, were integrated into the hydrograph. As noted by O'Brien (1984), the effective discharge is the flow that transports the most sediment over a long period of time. It is the product of the magnitude of the sediment transported by a given discharge and the frequency of occurrence of that discharge. In the Yampa River, the effective discharge was computed as 11,500 cfs with a return period of about 1.5-2 years.

The bankfull discharge, which is often equated with the dominant discharge, is usually considered the flow event which controls channel morphology. Indeed, the dominant discharge has been recommended and used as a flushing flow by other investigators (Wesche et al., 1977; McLaughlin, 1977). However, these have generally been associated with alluvial streams where, as noted by Rosgen (1982), the bankfull discharge has an average return period of 1.5 to 2.0 years. This frequency makes the discharge an effective channel-forming event. For the Yampa River, however, O'Brien (1984) determined the bankfull discharge to be about 21,500 cfs and to have a recurrence interval of 20 years. He noted that the Yampa River was not an alluvial stream, but an incised river. Thus, channel adjustment flows are limited to infrequent events.

O'Brien (1984) used both the effective discharge and the bankfull discharge in recommending flushing flows for the Yampa River: the 48-hour discharge that equals or exceeds 11,500 cfs (effective discharge) but is less than 21,000 cfs (bankfull discharge). The effective discharge was recommended as a flushing flow for retarding vegetation encroachment, replenishing beach and bar areas with sand,

and scouring areas of sand deposition in the cobble reach. Flow up to the bankfull discharge would serve to rework and maintain cobble bars and prevent changes in channel morphology.

The approach used by O'Brien (1984) is perhaps the most thorough method reviewed for deriving flushing flow recommendations. The technique included both office and field studies, and the actual physical modeling of one stream reach. This approach should be applicable to implementation studies, especially where the release flows have a high economic value.

Duration of Flushing Flows

As previously discussed, the gravel bed must be mobilized in order to release fine sediment for transport. Parker (1982) and Andrews (1983) both indicated that different particle sizes in gravel bed streams commence motion within a very narrow band of discharges. Consequently, once the bed begins to mobilize, most of the fine material should be entrained rather quickly. If the flushing flows cease, however, the bed will stop moving and the fine sediments will again begin to settle into the gravel.

Einstein (1968) derived an expression for the half-life for a fine particle to remain suspended in the flowing water. The expression is:

$$T = \frac{0.692\, y}{w\, \eta} \tag{26}$$

where: T = the suspension half-life for any particle size;

y = the water depth;

w = the particle fall velocity; and

η = efficiency factor = 1.0 for a long river or canal.

Using a medium silt sized particle of 0.0008 inches (0.02 mm) in water of 3.28 feet (1.0 m) depth, the half-life is approximately 40 minutes. Consequently, with the exception of clay sized material, it appears that flushing must continue until the material from the uppermost portion of the reach travels through the entire section of stream.

Vanoni (1975) reported a bedload relationship developed by Kalinske (1947) based on the ratio of the mean grain velocity to the water velocity. Figure 8 shows this ratio as a function of the ratio of the bed material's critical shear stress (τ_c) compared to the bed shear stress (τ_o). If the bed shear stress is assumed to be just sufficient to mobilize the gravel bed, then the ratio of the diameters of the fine material to the gravel material provides an estimate of τ_c/τ_o. Since this ratio is less than about 0.2 for most conditions of interest, the particle travel velocity should be at least 70 percent of the water travel velocity (from Figure 8). Consequently, a particle travel time of about 1.5 times the water travel time appears to be a reasonable estimate of the required flushing time.

An equation for determining the travel time for a particle can be derived using a similar method to that used to estimate the water velocity at incipient bed motion. The equation assumes that the fine material particle travel velocity is set at 70% of that water velocity. The equation is:

$$\frac{T_t}{L} = \frac{0.3\ S_b^{\frac{1}{2}}}{d_{50}^{\frac{1}{2}}} \tag{27}$$

where T_t = the particle travel time in seconds;

L = length of reach being flushed below

water source (ft);

S_b = the bed slope (ft/ft); and

d_{50} = the median particle size (ft).

This relationship is shown graphically in Figure 9 and provides an estimate of the time required to flush fine sediments from the stream (in hours per mile of stream) as a function of the gravel bed d_{50} for various channel slopes. This figure appears to imply that a stream with a steeper slope will require a longer flush time. However, the magnitude of the flow required for flushing is far less for the steeper gradient stream (see Figure 5); thus, a longer duration of flow would be needed.

Using this figure, the required duration of a flushing flow for a stream with a median grain size of 2.0 inches (50.8 mm) and a slope of 0.005 would be 0.45 hours/mile of stream. If the stream were 20 miles (32 km) long, it would require a flow duration of 9 hours.

The above analyses are oversimplifications of the process of flushing fine material from gravel beds. Some comparison with field data would be necessary before any confidence could be placed in the methodology.

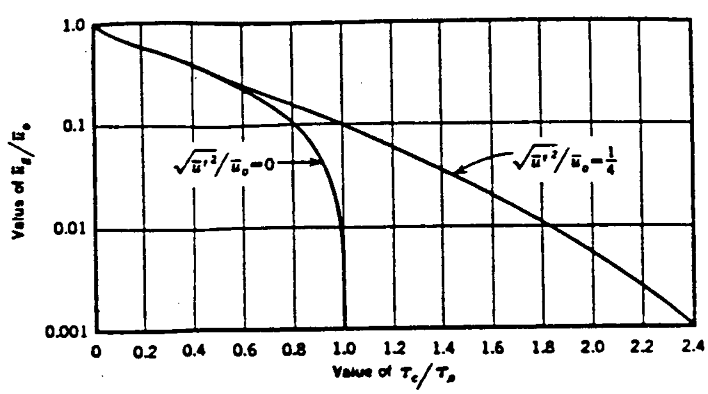


Figure 8 Kalinske's 1947 relation for mean particle velocity as a function of critical shear stress (Source: Vanoni, 1975)

Kalinske's work (Vanoni, 1975) was based on the use of uniform grain sized material. Thus, the application of his results to the flushing of fine sediments from gravel beds may not be appropriate. The above analysis also neglects the random process involved when an individual particle is mobilized, embedded in the gravels, and then re-mobilized. In actuality, any material flushed from one location along a stream would be found scattered along the channel downstream of the original location, as Einstein (1950) found in flume experiments. The location of these sediment particles should be described by a time-varying distribution function. Consequently, a probabilistic approach to the problem should be considered. The random nature of the phenomenon explains the reason why a longer duration of flushing will remove a greater percentage of the fine material as well as the reason why sections of stream nearer the flushing source would be cleaned better than those farther downstream.

The flushing duration indicated by Figure 9 may provide a reasonable estimate if the fine material is carried primarily as suspended load (mainly silt and clay sizes). However, for sand-sized fine material, the flushing time is probably greatly underestimated.

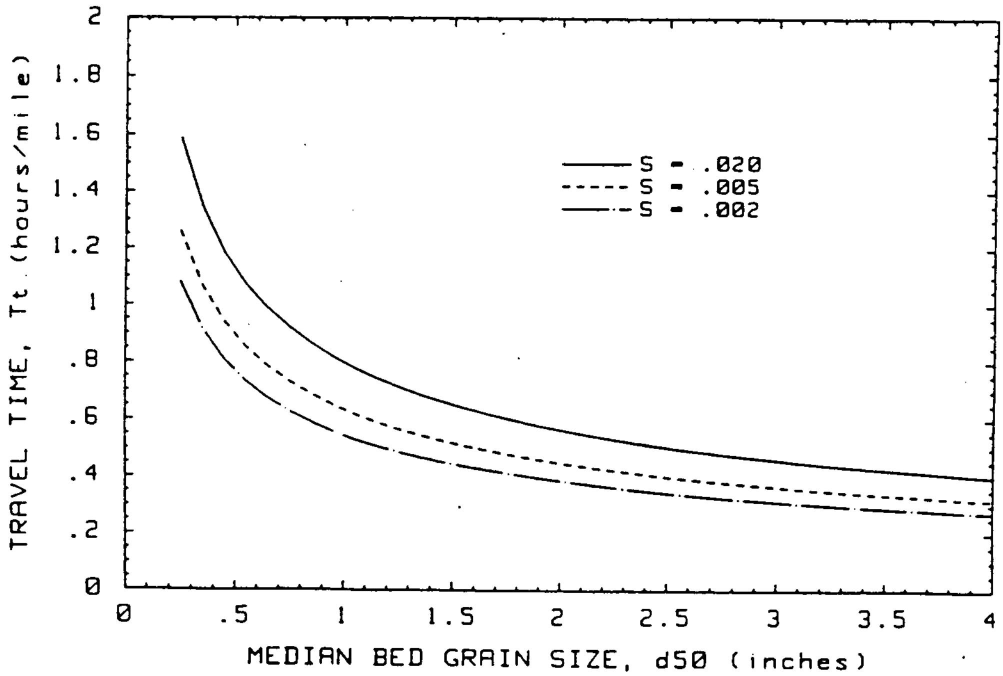


Figure 9 Time required to flush fine sediments as function of median bed particle size and channel slope (Source: Reiser and Ramy, 1985)

Summary of Parker et al. Bedload Prediction Equation

Parker (1978; 1979) developed a bed-load function which pertains specifically to gravel-bed streams. Using 278 experimental and field data sets, Parker fitted the data by eye to the relationship:

$$q^{*}=11.2\left[\frac{\tau_{*}-0.03}{\tau_{*}^{3}}\right]^{4.5} \tag{28}$$

where:

$$q^{*}=\frac{q_b}{(d_{50}\sqrt{R_g'\,d_{50}})} \tag{29}$$

where: q^{*} = dimensionless volumetric transport rate;

q_b = volumetric bed load discharge per unit width;

R_g' = submerged specific gravity of sediment (1.65); and

τ_* = Shields stress.

This particular form of Shields stress is defined by Parker as:

$$\tau_* = \frac{\tau}{(\rho R'_g \, d_{50})} \tag{30}$$

Equation (28) is plotted in Figure 10 along with the data used to derive it. Although this equation has not had widespread use, it has the advantage that it was derived specifically for gravel bed streams.

The study of Parker et al. (1982) was based primarily on a reanalysis of the bedload samples collected by Milhous (1973) in Oak Creek. The approach of Parker et al. (1982) was to analyze 10 grain-size ranges governed by sieve intervals, and attempt to correlate the bedload transport rates of each range with the flow stresses. They used only those measurements of Milhous (1973) obtained during conditions of broken armor, that is when most of the grain sizes in the armor are represented in the bedload.

Parker et al. (1982) have hypothesized that the existence of a bed armor regulates the entrainment of particles by the stream, resulting in their being approximately equal in mobility, that is, all grain sizes are entrained at about the same flow discharge and are transported at rates in proportion to their presence in the bed material. This has come to be known as the equal-mobility hypothesis.

Several subsequent studies have supported this hypothesis. Utilizing data from several streams, Andrews (1983) and Andrews and Erman (1986) examined variations in the largest particle sizes found in bedload samples at different flow stages.

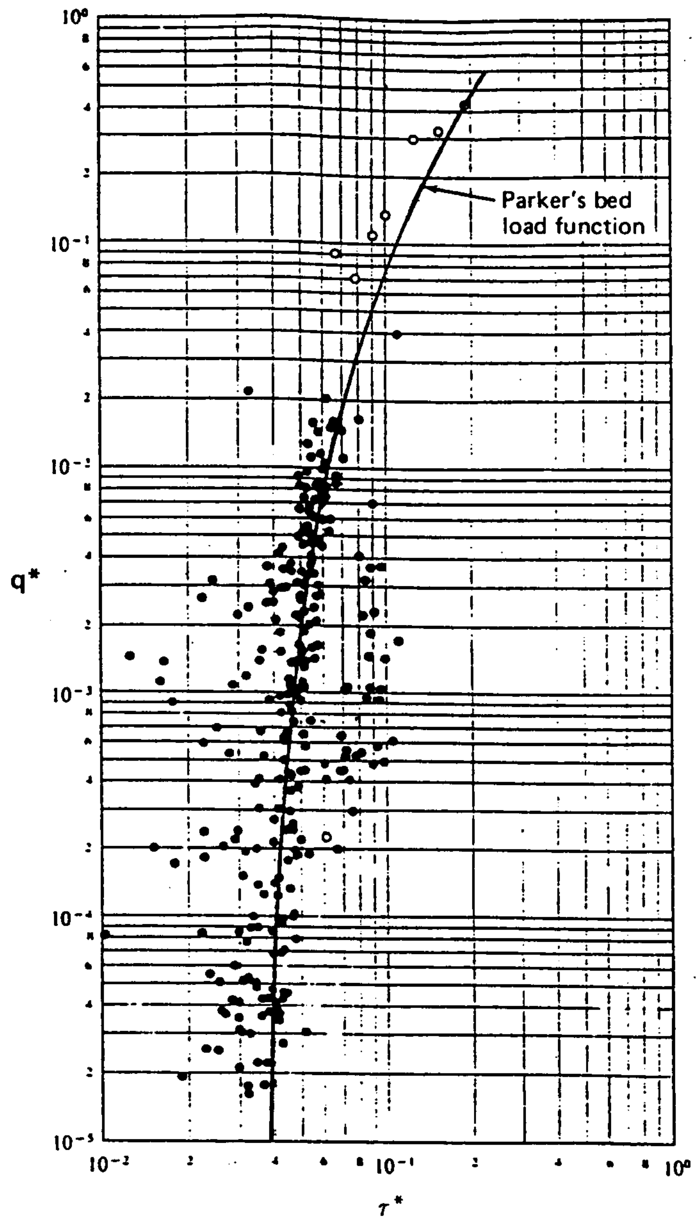


Figure 10 Parker bedload relation for gravel-bed rivers (Source: Parker, 1978 by Reiser and Ramy, 1985)

They concluded that the maximum particle size undergoes almost no change over a range of flow discharges or bed stresses. Wilcock and Southard (1988) have undertaken flume experiments involving bed sediments of mixed sizes, and concluded that " all fractions in a size mixture begin moving at close to the same value of bed shear stress during steady-state transport conditions". A theoretical foundation for the hypothesis has been provided by the analysis of Wiberg and Smith (1987). The collective impact of these studies has been to "prove" the equal mobility or near-equal mobility of gravel entrainment and transport in streams.

A distinctly different approach was taken by Shih and Komar (1990a, 1990b) to evaluate transport rates of the particle-size fractions in Oak Creek. It was first established that there is a systematic evolution of the bedload particle-size distributions, demonstrating that the distributions progressively become coarser and more skewed with increasing flow stage (Komar & Shih, 1992).

In their studies, Komar and Shih (1992) have indicated that Parker et al. (1982) made an assumption of equal mobility as a first-order approximation in developing relationships for evaluating bedload transport rates of the particle-size fractions in Oak Creek. That assumption yielded reasonable results in determinations of gravel transport rates, but did not account for observed variations in bedload particle-size distributions at different flow stages.

As discharges and bed stresses increase in Oak Creek, the bedload grain sizes become significantly coarser and their distributions are increasingly skewed as they approach the distribution of the bed material (armor plus subarmor). These changing bedload particle sizes demonstrate that there is a marked departure from equal particle entrainment and transport bedload in Oak Creek. Higher order solutions for predicting transport rates, those which do not assume equal mobility, have been developed by Diplas (1987) and Shih and Komar (1990a, 1990b). These advanced analyses provide predictions of changing bedload particle sizes and also yield improved calculations of transport rates.

Various lines of evidence have been offered in support of the equal-mobility hypothesis. A series of publications have analyzed the relationship between the largest particles found in bedload samples and flow discharges or bed stresses. Rather than demonstrating that the bedload grain-size distributions are nearly constant at all flow stages, which should prevail with equal mobility, those studies show that there are rapid changes in grain sizes as reflected by the largest particles in the bedload samples. It can be argued that these data represent a transitional stage during which the grain-size distributions of bed load samples are approaching the size distributions of the bed material, and that the faster this transition the closer the conformity with the equal-mobility hypothesis. This interpretation constitutes a broader view of equal mobility in a stream than the specific conditions to which the bed load transport analyses of Parker et al. (1982) apply. There are problems with this broader interpretation in that comparisons between data from Oak Creek (well-developed armor) and Great Eggleshope Beck (absence of a armor) by Komar (1986) imply that the latter stream comes closer to equal mobility, in spite of the expectation that the armor layer in Oak Creek should tend to equalize grain mobility. It is clear from this comparison that factors other than the presence of an armor layer are important to sorting processes, leading to variations in bedload particle sizes and the relative transport rates of different size fractions.

Shih (1989), in his study of differential bedload transport rates in Oak Creek, indicated that the strong support for equal mobility appears to go well beyond the original intention of Parker et al. (1982) when they formulated the hypothesis. The objective of their work was to develop a method for calculating transport rates of different size fractions, and an assumption of equal mobility served as a first-order approximation. However, a corollary of perfect equal mobility is that with varying flow discharges there should be no change in the grain-size distributions of the bedload samples, including no shifts in the maximum particle size.

Parker et al. (1982) based their analysis on the data of Milhous (1973) from Oak Creek, Oregon, and noted that there actually are significant variations in bedload particle sizes that represent a departure from their assumption of perfect equal mobility. With that recognition, they were the first to attempt the development of a higher-order analysis that would account for varying bedload particle-size distributions.

As seen in Figure 11, the analysis provides a reasonable comparison between predicted and measured transport rates of gravel sieve-size fractions in Oak-Creek for the equal-mobility analysis of Parker et al. (1982), the modified higher order solution of Diplas (1987), and the grain-size distribution approach of Shih and Komar (1990b). However, it should be recognized that in sediment transport predictions an acceptable result in one where the predicted and measured values are within a factor of 5 or less. From that standpoint, the first-order solution (Parker et al., 1982) would be acceptable in most applications. Therefore, the analysis has been a success in terms of predicting gravel transport rates.

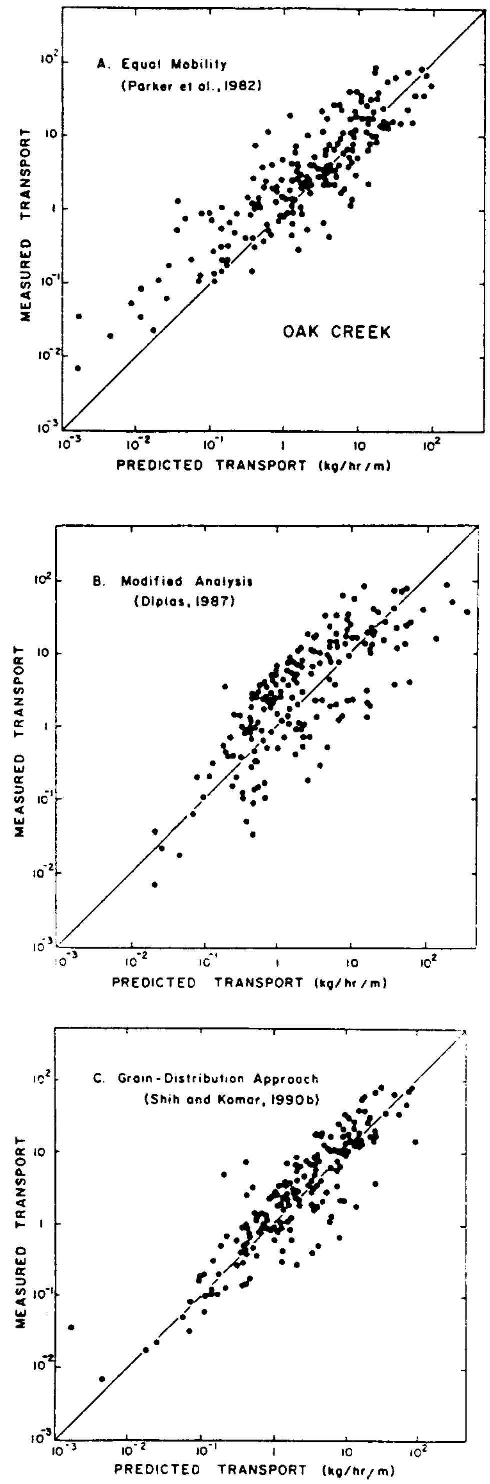


Figure 11 Measured versus predicted transport rates of sieve-size fractions in Oak Creek (Source: Komar & Shih, 1990b)

IV. RESEARCH APPROACH AND METHODOLOGY

Overall Approach for Hypothesis Testing

The complex nature of incipient motion and particle transport has made experimental studies a necessity to improve knowledge and engineering practice. The intensive field study of a gravel-bed river is used here to explore the basic sediment transport process related to the stated research objectives. The field measurements provide several insights to incipient motion processes. This study offers the advantage of realism by using natural river conditions for the large number of variables involved in the incipient motion process.

To verify or disprove the proposed hypotheses, a series of new experiments were used along with previous work done by other researchers at Oak Creek. Figure 12 shows a schematic diagram of Oak Creek data collection, processing, and analysis for this study. Table 1 shows how the research objectives, test hypothesis, and research activities are combined.

To examine the equal mobility hypothesis, painted gravel particles were buried in the armor and subarmor layer of the bed at different locations laterally and longitudinally along a reach of Oak Creek. Bedload samples were collected during each storm runoff to capture painted particles and develop the relation of transported particles with discharge.

Particle shape was measured to examine its effect on incipient motion and test the particle shape hypothesis. Particle weight was measured to assist in developing the relationship among particle shape, equivalent size, and incipient motion. Other data (i.e., velocity, cross section surveying, bedload rate) were also measured.

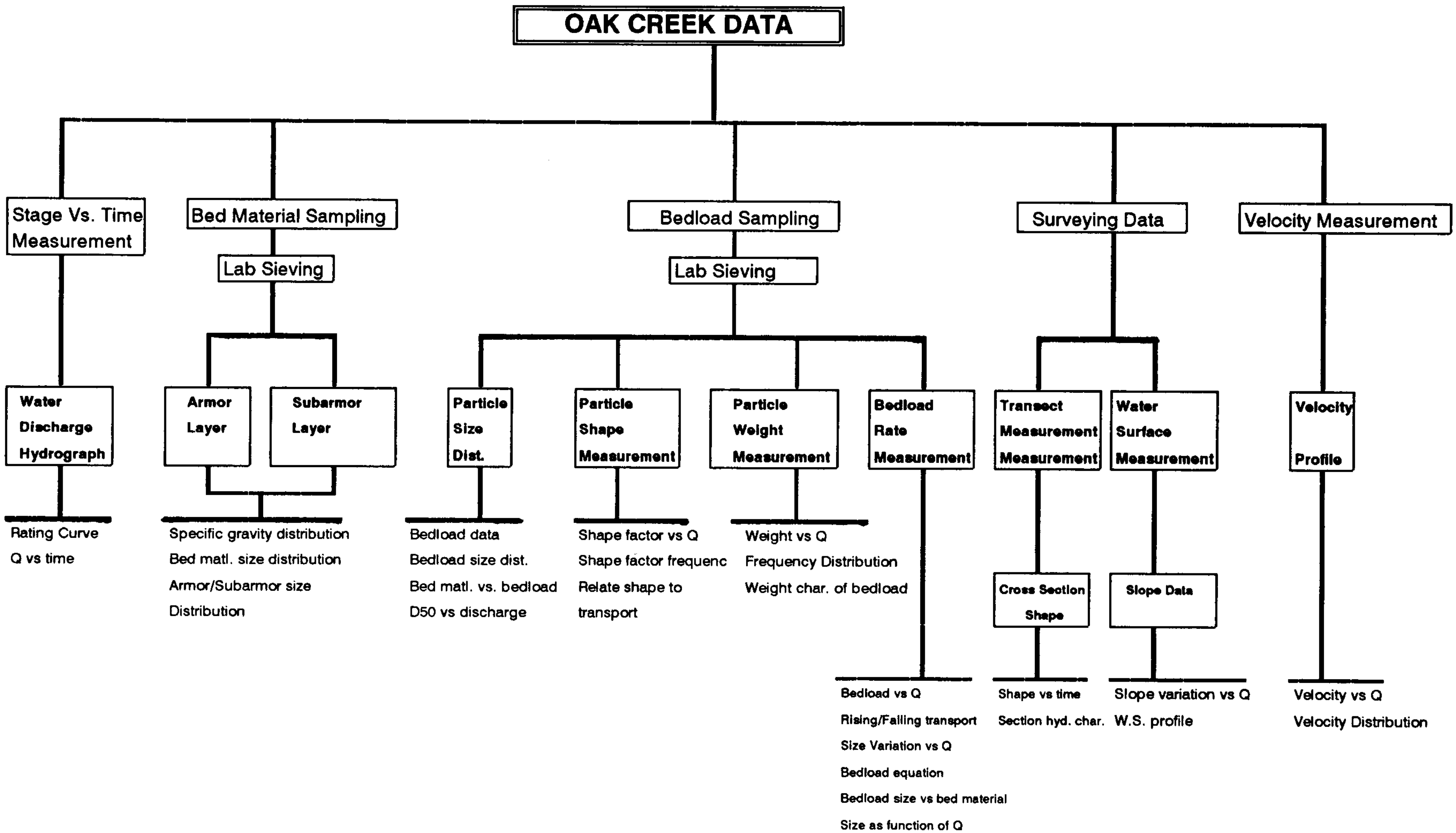


Figure 12. Oak Creek data collection Schematic diagram

Table 1 Research approach to improve predictive knowledge of incipient motion and particle transport

Research Objective	Hypothesis to Test	Research Approach
1. Incipient motion of armor particles in relation to water discharge	H1. There is an equal probability of movement of armor-layer particles, regardless of size	a, b, c, d Analysis of all data Tracer particles
2. Flushing of small particles from armor layer	Affected by H1 and H2	a, b, c Velocities Analysis of data for small sizes
3. Effect of particle shape on incipient motion	H2. Initiation of motion is a function of particle shape	a, b, c Tracer particles Velocities near bed
4. Probability of movement for various particle sizes at incipient motion and for general transport	H1 and for general transport	a, b, c, d
5. Bedload transport prediction improvements for Oak Creek bed material	Application of H1 and H2	Combination of all of the above

a = water stages and discharges over time

b = bed material characteristic

c = bedload sampling over time

d = channel transect/ survey data

The information available was used to develop a more general form of incipient motion and bedload transport relationship for Oak Creek, based on the available theories and experimental relationships.

Oak Creek Research Facilities

The Oak Creek hydrologic and sediment transport research facilities were used in this study. The facilities are located in the McDonald State Forest on the western edge of the Coast Range nine kilometers northwest of Oregon State University, Corvallis, Oregon (Milhous and Klingeman, 1973; Klingeman, 1979; Klingeman, Milhous and Heinecke, 1979). Figure 13 shows the general location of Oak Creek watershed and research facilities.

Mean annual precipitation is about 1250 mm, most of which falls between November and March. Mean annual discharge is on the order of 3.5 cfs (0.10 m^3/sec) (Milhous, 1973). Elevations in the drainage area above the research facilities range from 75 to 665 feet. Oak Creek drains about 2.6 mi^2 (6.7 km^2) at the gaging station. The watershed is covered primarily with Douglas fir forest. Timber harvest and road construction have resulted in a mosaic of forest ages.

Alder and other deciduous trees form a closed canopy over the stream. Their roots buttress the banks and provide channel alignment stability. They contribute a large amount of organic matter to the Creek, ranging from leaves to large branches and fallen trees. Beavers have also modified sections of the Oak Creek upstream of the gaging station.

There is strong hillslope control on valley form. The channel gradient near the sedimentation facilities is about 1 percent. Channel width is about 12 feet and banks are 3 to 5 feet high. The dominant bed particles are gravel and small cobbles.

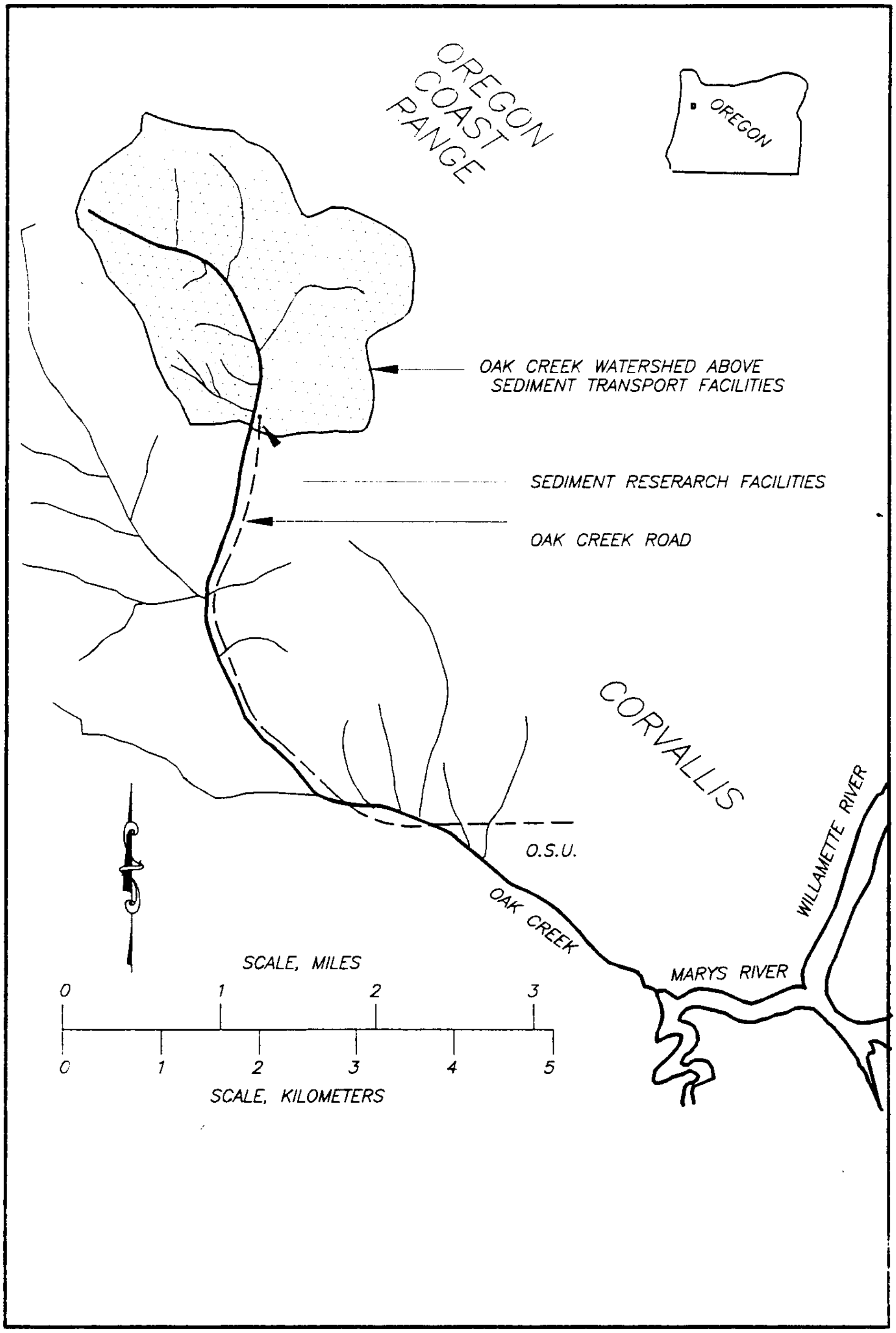


Figure 13 General location map, Oak Creek watershed (Source: Klingeman, 1979)

A vortex-tube system for measuring bedload transport was developed for Oak Creek and began operation in 1969. It was subsequently modified in 1975. The sediment transport research facility mainly consists of a vortex tube sampler, a sediment trap, a weir structure and an off-channel stilling well in an instrument house. The vortex trap is incorporated into the broad-crested weir, which acts as a control for water level at the nearby stilling well to provide a stable-stage-versus discharge relationship. The stilling well is connected to the stream by two pipes buried slightly below the bed surface. Water level recorders are mounted over the stilling well to collect stage data. A staff gauge is also located on the upstream end of the weir. Typically two Leopold and Stevens Type F automatic water level recorders are used continuously to record the short term (2 day) and intermediate-term (8 day) hydrographs during data collection seasons. Each is set at a different scale for water stage so that the 8-day charts show general hydrograph characteristics and the 2-day charts provide detailed stage changes over short periods.

The Oak Creek research facilities and a schematic arrangement of sediment sampling facilities are shown in Figures 14 and 15, respectively. Photos of the research facilities are shown in Figures 16.

The sampler develops a vortex flow to move bedload through a flume embedded in the floor of the weir structure. The bedload and a portion of the stream flow are removed to an off-channel pit, where the bedload sample is collected. Water returns to the creek downstream of the structure. The weir structure is 3.6 m wide and 0.9 m high, similar to bankfull creek dimensions. The flume is 0.3 m deep and 0.46 m wide, with semicircular sides and a flat bottom. The flume extends diagonally across the floor of the weir structure and is open to the flow over the full weir width. Control sluice gates are used to divert streamflow to the off-channel pit and

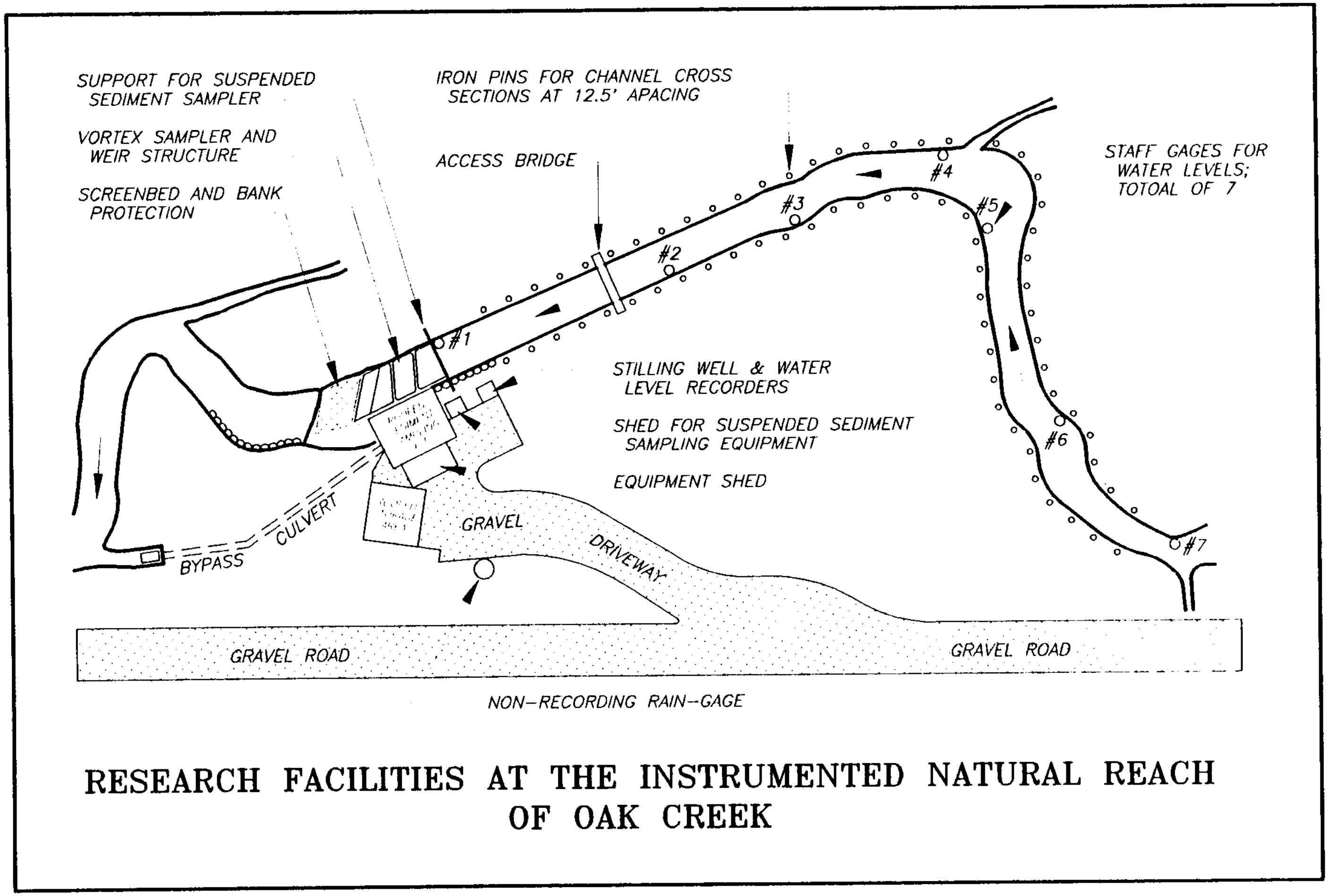


Figure 14 Research facilities at instrumented natural reach of Oak Creek (Source: Klingeman, 1979)

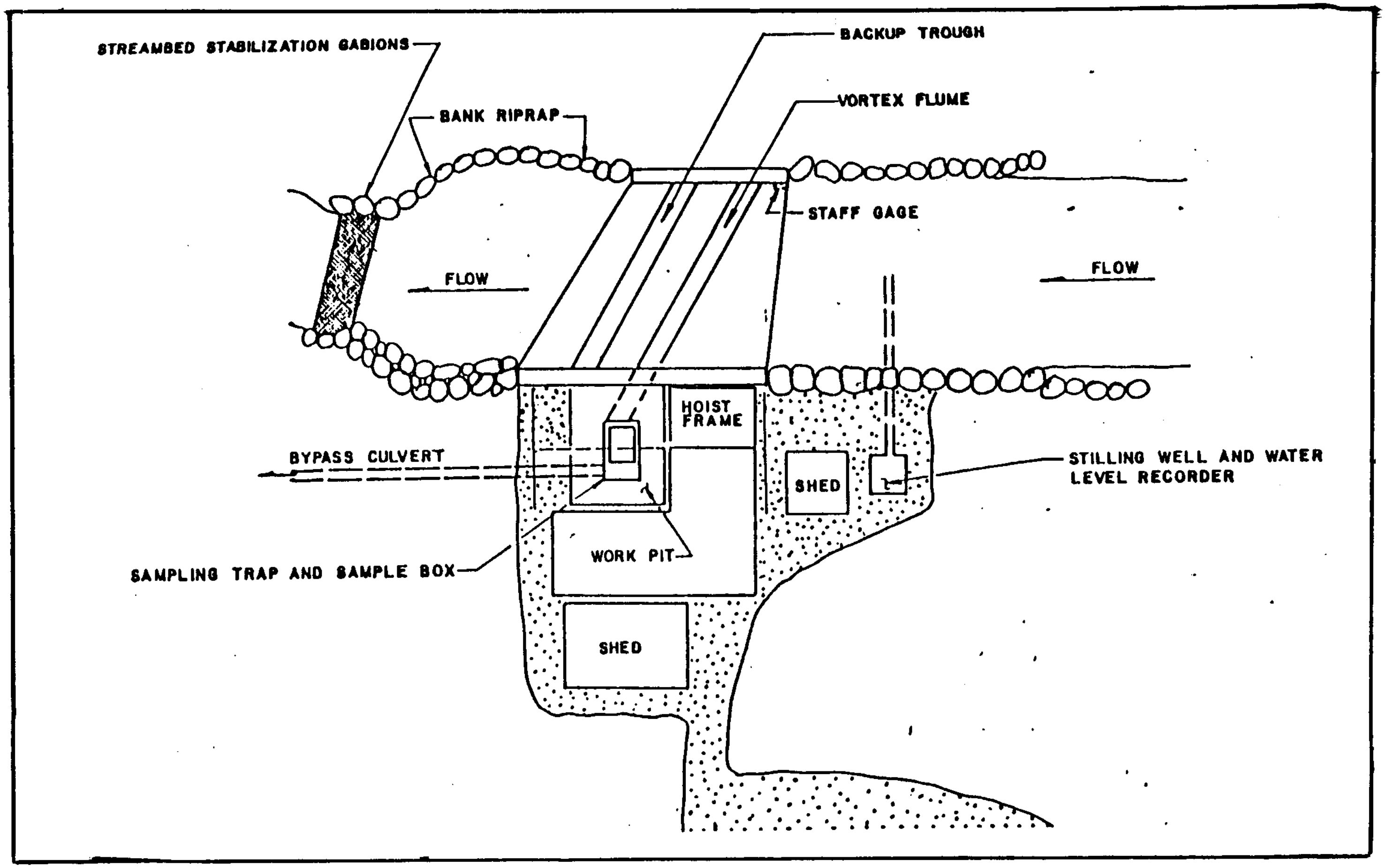
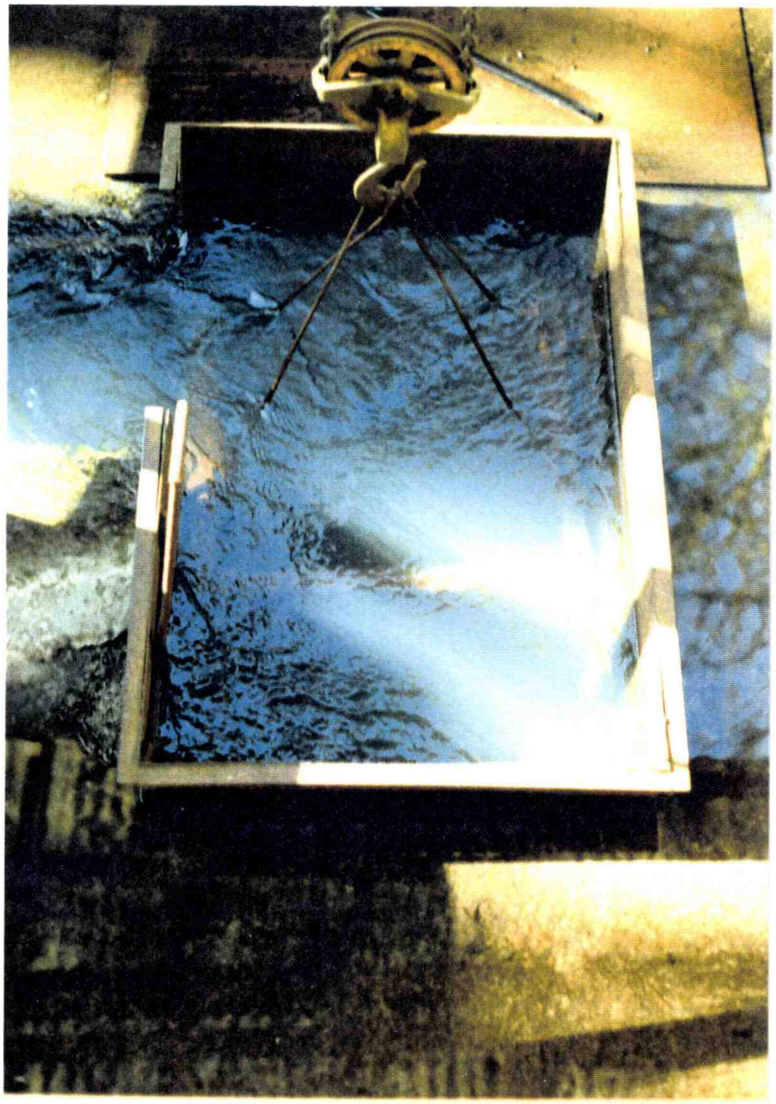


Figure 15 Schematic arrangement of Oak Creek sediment sampling facilities (Source: Klingeman, 1979)

A.

B.

Figure 16 Oak Creek bedload sampling facilities



c.

Figure 16 Continued

regulate its return to the stream. A rectangular sample box, suspended in the sampling pit from an overhead hoist frame, fits beneath the lip of the flume to collect the bedload. A short, removable flume can be placed across the pit to allow the bedload to return to the stream without collection. Such continuous operation of the vortex flume prevents its clogging with sediment at large discharge. This sampling system permits continual or intermittent sampling of the transported bedload (Klingeman and Emmett, 1982).

Field Procedures

Bedload Sampling Program

A total of 63 bedload samples were collected on a continuous basis during winter, spring and fall of 1988 (January to May and November to December) and winter and spring of 1989 (January to April). Samples were taken on rising, falling and fluctuating stages of the hydrograph. Data collected during each sampling period included the water surface elevations at the start and end of bedload sampling, water temperature, duration of sampling, and total bedload transport.

The vortex-tube sampler was used to capture the total bedload transport along Oak Creek. Part of the water discharge is also diverted to carry sediment to a trap area. This prevents re-entrainment of the trapped bedload. The trapping efficiency of the Oak Creek installation was at least 95% at typical bedload transport rates (Milhous, 1973). A second trough was placed two feet downstream of the vortex flume in order to act as backup trough; however, it captures almost no additional sediment, providing further evidence for the high efficiency of the vortex system.

At larger discharges, and hence greater gravel transport, short time intervals were used for the bedload samples collected. At the highest transport rates, sampling intervals were less than 30 minutes, whereas the average sampling interval was about 3 hours. At the very lowest discharges, sampling continued over intervals of several days.

Many of the bedload samples collected in the vortex trap, especially those obtained at higher discharges, weighed over 100 pounds. These were processed in the field by first passing them through a 3/8 inch sieve. The coarser fraction was then wet sieved in the field, whereas a split sample of the finer material was taken to the laboratory for oven drying and separate sieving. Combined, a very wide range of sieve series was used for the bedload samples, so that sieving yielded 17 size fractions and well-defined particle size distributions.

Painted Gravel Experiments

A series of experiments was conducted during the study to obtain information on the movement of individual particles in the stream. This was done in order to better understand, by use of tracer particles, the complexities of sediment movement when the stream bed is armored. The painted tracer particles used in the various experiments on armor layer behavior ranged in size from 4 inches to 3/4 inch. The particles used to study sub-armor behavior ranged from 4 inches to 0.485 inch (#4 sieve, or 4.76 mm size). Photos in Figure 17 illustrate the location of painted gravel in the stream bed.

The basic procedures followed in conducting the painted gravel experiments were as follows:

* Obtain representative samples of the armor and sub-armor bed material.

* Sort the material down into various sizes by dry sieving.
* Paint (yellow, orange, or white), number and weigh individual gravel particles within the size range of 4 inches to #4 sieve.
* Place painted particles for armor layer in the top 3 inches of bed surface (several locations used).
* Place painted particles for sub-armor layer in the second 3 inches of bed surface (one location used).
* Locate the longitudinal and lateral positions of painted rock placement with respect to an access bridge across the Creek.
* During and after each high water period, search bedload samples for presence of any painted particles, retrieving all such particles for identification.
* After each high water period, search the stream downstream of the points of particle placement and locate the place where each visible painted particle is found, note particle's identification number, but leave the particle in place.
* Air dry each painted particle found in bedload samples. Weigh each particle and compare the measured weight to the pre-placement weight (the numbers on transported particles become unreadable due to abrasion, such that particle weight provides the next best identification).
* Measure longest, intermediate, and shortest axis of each painted particle found so that shape factor can be calculated.
* Repeat the above steps after each successive storm.

A.

B.

Figure 17 Painted gravel locations in Oak Creek

C.

D.

Figure 17 Continued

Cross Section Surveying

Measurements of cross sections were repeated three times after three major storms during the study period to investigate any variation of shape of the Creek's cross section over time. A plan view of the study reach upstream of the bedload sampling station and locations of cross section survey markers are shown in Figure 18. A total of 12 of these cross sections were used. The sequential changes in cross sectional shape at each section were studied to determine whether the stream discharges were adequate to move the armor layer and alter the bed morphology.

Bed and water surface elevations were also measured at each cross section during each cross section survey. These data were used to evaluate water surface and channel bed slopes. This information was for computation of critical shear stress.

Velocity Measurements

Periodic velocity measurements at the bridge cross section upstream of the vortex-tube sampler (cross section 3 in Figure 18) were made during 1990, using a pygmy current meter. Simultaneous stage observations were made at the staff gage downstream of the bridge. Depth of water and point velocities at 0.2 and 0.8 depth below the water surface were measured at several points along the cross section. These data were used in developing a velocity-stage-discharge relationship. The velocity-stage-discharge relationship were used for the evaluation of channel shear velocity.

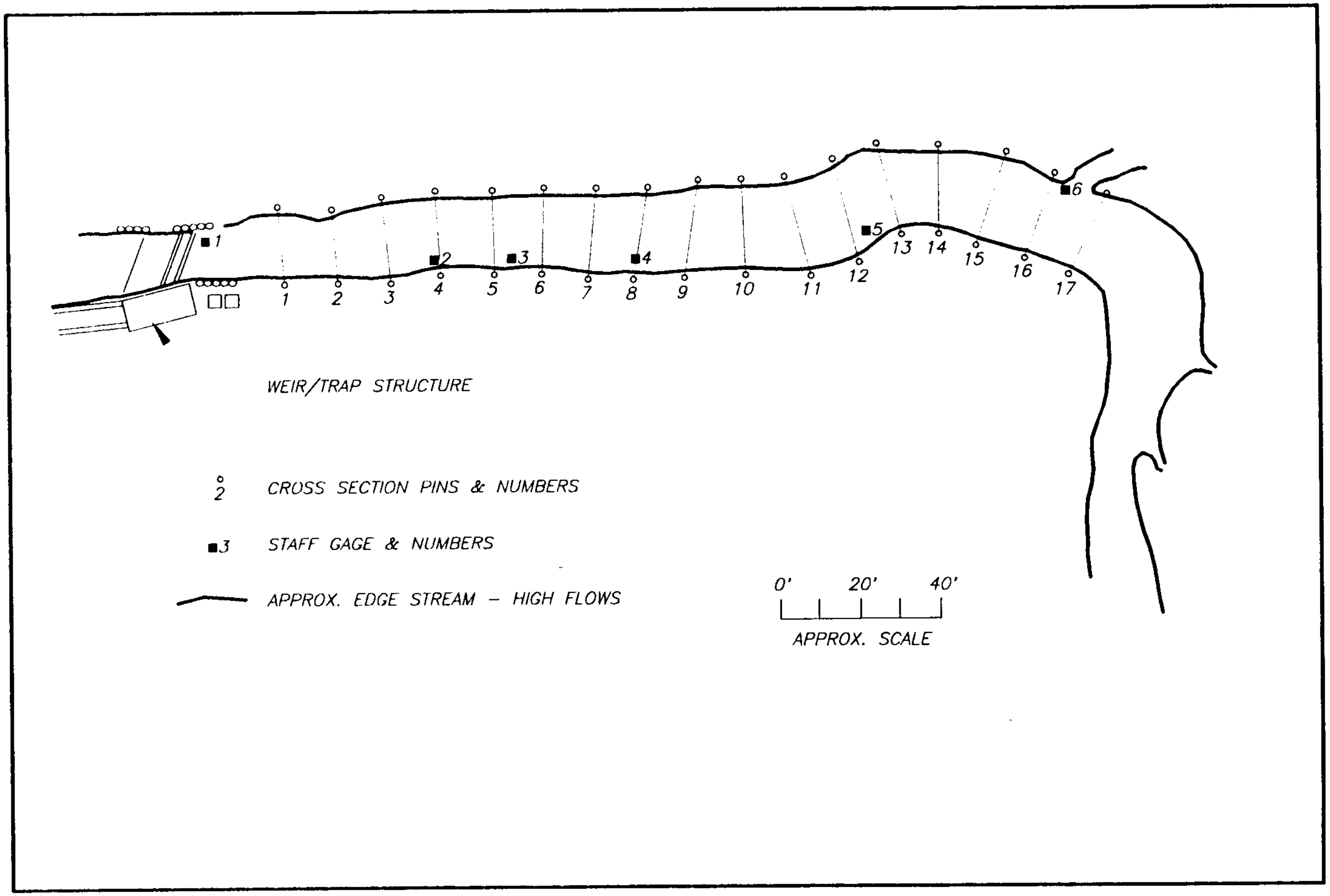


Figure 18 Oak Creek cross-section station and staff gage Locations (Source: Milhous, 1973)

Laboratory Sediment Measurements

Particle Size Analysis

In the laboratory, the samples were allowed to air-dry for a few days by spreading them out on flat trays. These air-dried samples were then placed in an oven at a temperature of 105° C for 24 hours, after which easily removable organic matter was discarded. The dried bedload samples were then passed through a set of mechanical sieves in a Rotap shaker for 15 minutes. The amount of sample retained on each sieve was weighed.

Particle Shape Measurements

Particle shape measurements were made for 35 bedload samples for use in particle shape analysis. These measurements were made for particle sizes greater than 3/8" in each bedload sample. At least 10 particles in each sieve size range were measured. A micrometer was used for measurement of longest (a), intermediate (b), and shortest (c) axis of each particle. The "a" axis measurement was the longest axis. The "b" axis was the longest axis in the widest plane perpendicular to the "a" axis. The "c" axis was measured as the shortest axis perpendicular to "b".

Computer Compilation of Prior Data

Data collected systematically in the mid-1970's on bed material size characteristics was assembled and compiled for use in this investigation. This includes armor layer samples (to a depth of the larger particles found in the surface --

about three inches) and subarmor samples (the next equivalent depth below the armor layer). Results are summarized in Appendix C. Field sampling techniques and laboratory analyses have been described elsewhere (Milhous, 1973; Klingeman and Emmett, 1982).

Previous specific gravity measurements are also compiled in Appendix C. Material from several bed material and bedload samples had been saved by size fraction. These spanned the size range from 4 inches down to #100 sieve (0.149 mm opening). Samples from each size fraction were weighed in air and submerged to obtain the weights and volumes from which specific gravities could be calculated.

V. PRESENTATION OF EXPERIMENTAL RESULTS

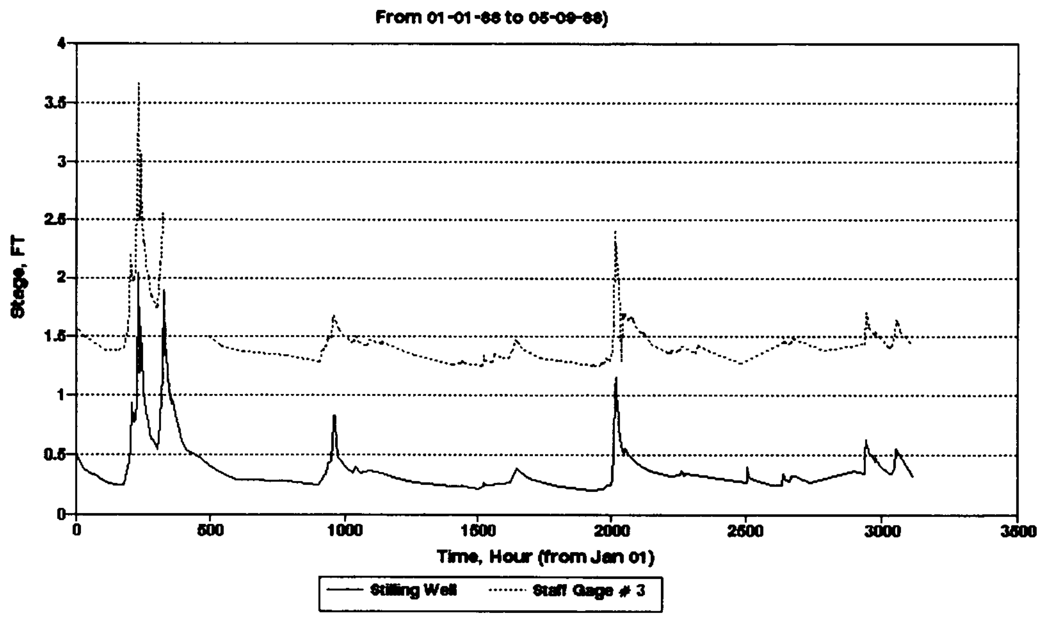
Discharge Hydrographs

Discharge hydrographs were developed for all bedload sampling periods. These were based on the measured variation of stage versus time using the staff gage data at the vortex sampler. Figure 19 illustrates stage variations during 1988-1989 bedload sampling period. Figure 19 also shows staff gage data for an auxiliary staff gage located 170 feet upstream and set to the same elevation datum. The concurrent differences in water stage provide data for water surface slope. The Oak Creek rating curve at the vortex bedload sampler was later used to convert these stage records to a discharge-versus-time relationship.

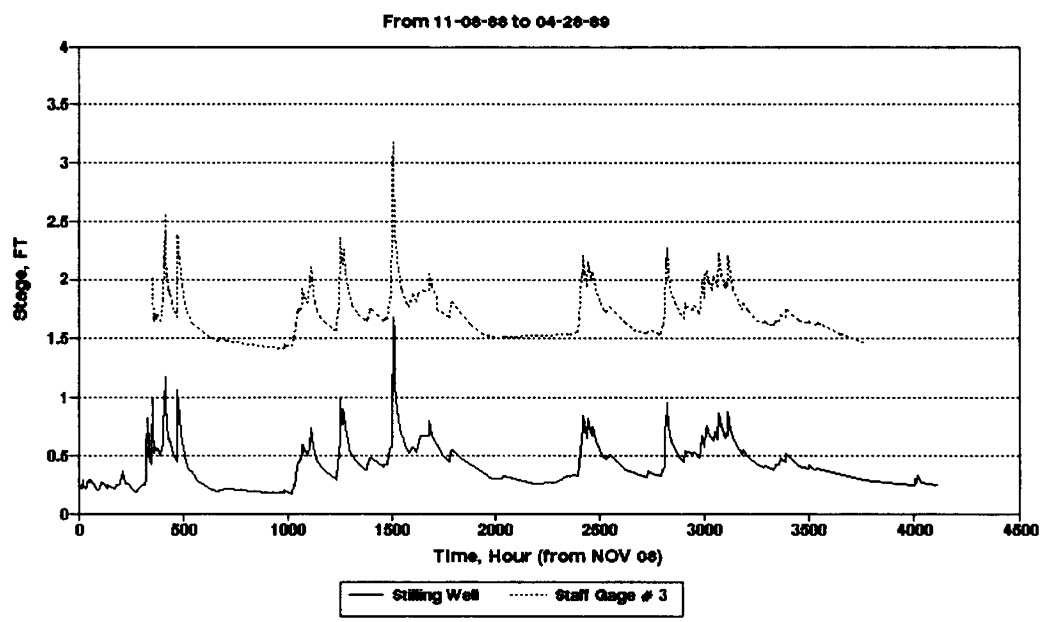
Figure 20 shows discharge hydrographs for data collected by Milhous in 1971, Saluja in 1978, and Matin in 1989. The hydrographs are "lagged" rather than being consecutive over time for the three periods. The measured discharge varies from 0.70 to 120 cubic feet per second. The discharge data were used to develop bedload and particle size relationships with discharge. Appendices A and B show the Oak Creek stage hydrographs and the Oak Creek rating curve, respectively.

Bed Material Size Characteristics

To evaluate bed material characteristics, bed material size gradation data for Oak Creek collected by Heinecke in 1975 and by Choquette and Hammond (unpublished data) were compiled for the both armor and subarmor layers. Twenty-one sites were chosen for bed material sampling upstream of the Oak Creek bed load sampler. The locations for these are shown



A. Winter/spring runoff season 1988



B. Fall/winter/spring runoff season 1988-89

Figure 19 Oak Creek stage hydrographs for 1988-89

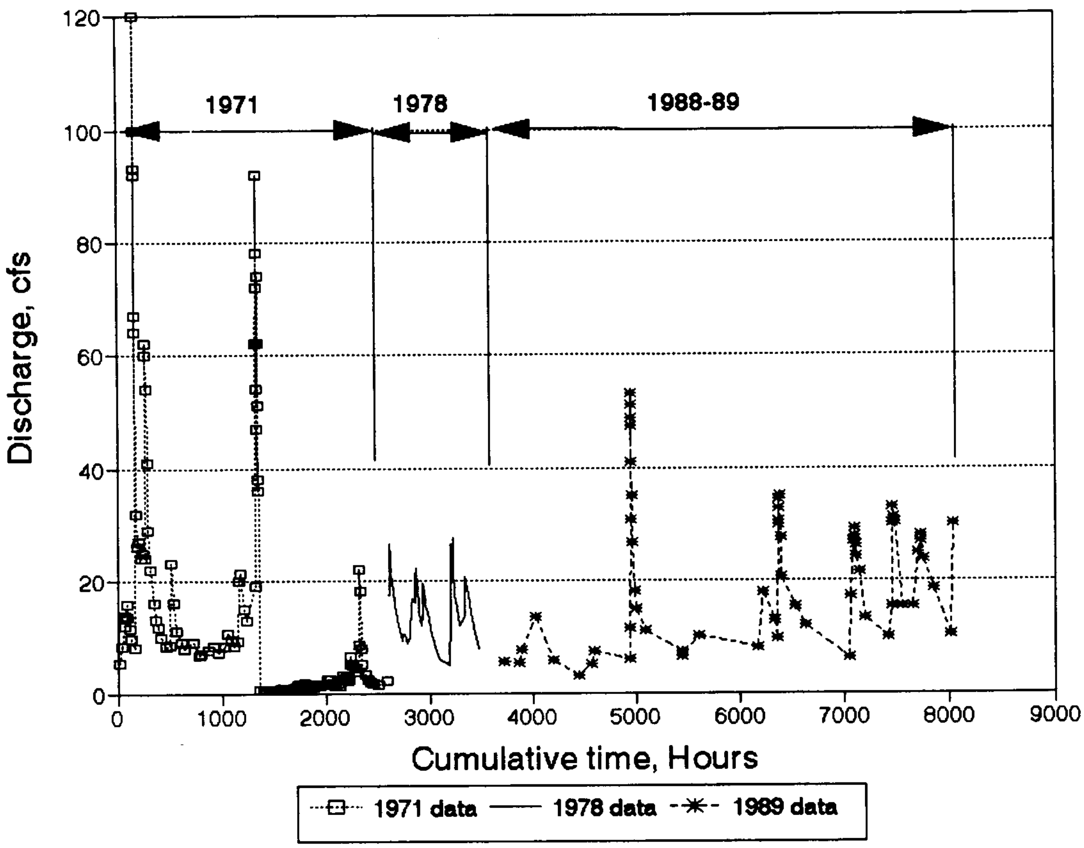


Figure 20 Oak Creek discharge hydrographs for all data collection periods

in Appendix C and cover the channel between the bed load sampler and section 12 upstream (see Figure 18). The sites were selected to represent a wide range of bed-surface particle size conditions.

The sample location identification numbers used and shown in Appendix C correspond to numbered reference pins along the banks (see Figure 18) and to transverse positions at cross sections between paired pins. The transverse positions are based upon the water's edge at an intermediate flow (about 20 cfs) when string lines and tags were placed over the stream between all paired reference pins. The mid-distance between water's edge was designated as centerline (CL) and the one-quarter points and one-eighth points for this width of stream were also identified with tags. These tags provided the reference points used for bed material sampling in November 1978. When sampling the bed material, great care was taken to collect all sizes present, from the largest cobbles encountered down to the smallest sand grains retainable on a #200 sieve (0.074 mm).

Two samples were collected at each of the 21 sampling sites: one of the armor-layer bed material and one of the sub-armor-layer bed material. The two were distinguished from each other for sample collection purposes in a convenient, arbitrary manner, as follows (Klingeman, personal communication):

> The armor layer is considered to have a coarser texture than the remainder of the stream bed because of the washing-away of smaller particles from the exposed surface. Hence, for sampling purposes the armor later was taken to be that surface zone extending deep enough into the bed to include the full vertical depth of penetration of the largest surface-exposed rock. When removed, such particles leave indentations in the surface that can be used to define the bottom of the surface layer. All material found in this zone was collected as part of the armor layer. Consequently, the size of the armor material sample collected varied from location to location along the stream, due to variable surface texture of the bed.
>
> The sub-armor layer is all that material found in the bed beneath the armor layer. Hence, for sampling purposes an estimate was made at the outset for the size of the largest bed particle likely to be found. This size (about 15 cm) was used to establish the vertical depth of sampling of the sub-armor material. Consequently, the size of the sub-armor material sample collected was relatively constant from location to location along the stream. However, when the sizes present at a sampling site were distinctly smaller than generally found

elsewhere, the sampling depth and sample size were decreased somewhat.

Bed material data were used in analysis of bed material composition in relation to bedload size gradation. Table 2 gives a statistical summary of size gradation data for bed material samples. Figure 21 shows the representative size gradations of composite armor and subarmor layers for the 21 bed material samples. A summary of laboratory analyses and a location map for samples are presented in Appendix C.

Table 2 Representative gradation data for Oak Creek armor and subarmor bed material (1978 data)

Characteristic Size	Armor Layer Mean Size (mm)	Armor Layer 95% Conf.	Subarmor Layer Mean Size (mm)	Subarmor Layer 95% * Conf.	Combined Mean Size (mm)	Combined 95% Conf.
D_{100}	101.7	35.4	92.9	14.8	97.3	26.4
D_{90}	86.6	34.8	63.0	14.1	74.7	26.3
D_{84}	78.7	32.8	53.7	13.9	66.2	25.1
D_{75}	69.9	31.9	42.5	11.8	56.2	24.0
D_{65}	62.6	31.7	31.8	9.1	47.2	23.3
D_{60}	58.8	31.2	27.7	8.5	43.2	22.9
D_{50}	47.5	22.0	20.0	7.2	33.7	16.4
D_{35}	33.8	17.2	10.7	5.3	22.3	12.7
D_{25}	26.7	15.6	6.6	4.0	16.3	10.9
D_{16}	19.8	13.6	3.7	2.3	11.8	9.7
D_{10}	13.8	11.2	2.2	1.5	8.0	8.0
D_{5}	8.2	8.6	1.2	0.8	4.7	6.1

* +/- confidence interval for the range of mean values

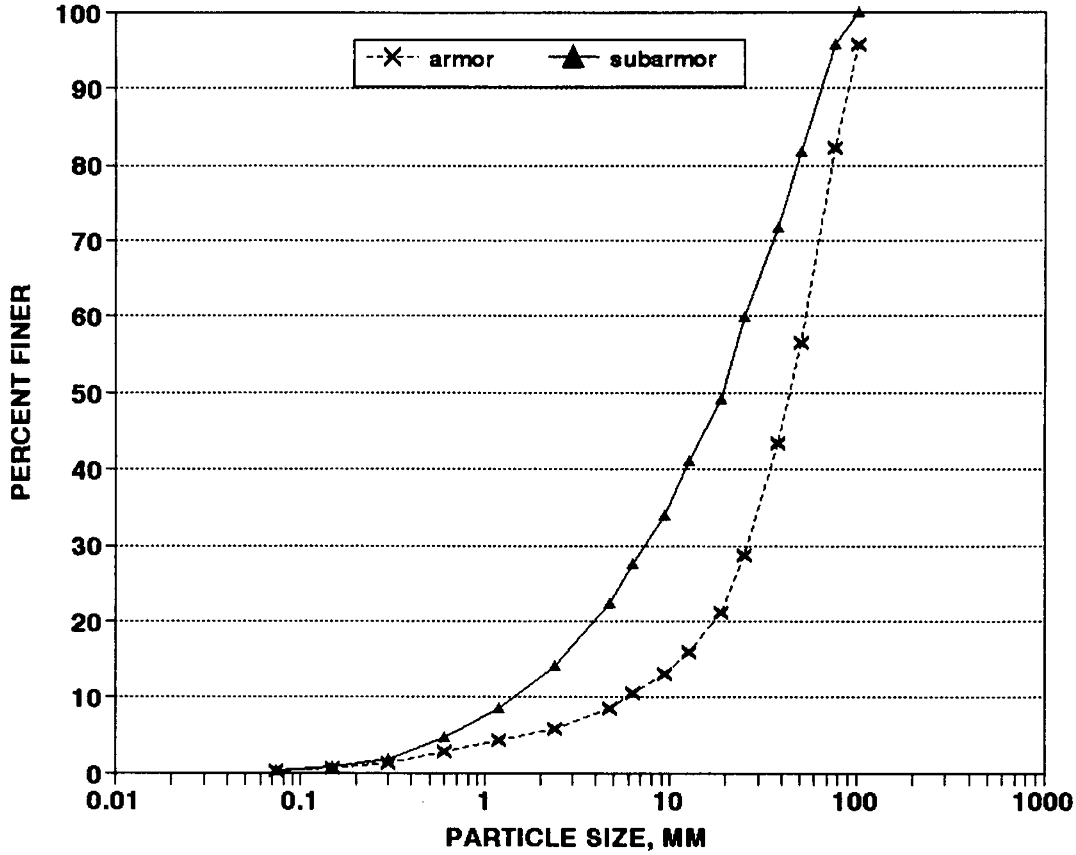


Figure 21 Representative Oak Creek armor and subarmor bed material (1978 data)

Specific Gravity Analysis

The measurement of specific gravity for sediment involves the determination of particle weights and volumes and the comparison of the weight-to-volume ratio with that for water at a standard temperature such as 4°C.

Particle weight can be determined by its direct measurement. However, there is choice as to whether the particles are oven dried or remain saturated (from past submergence in the bed) but with their surfaces dry. This choice determines whether a dry specific gravity or saturated-surface dry specific gravity is determined for the particles. With slight numerical differences in values the direct measurement of particle volumes for irregular-shaped sediment is impractical. Therefore, indirect means of determining volume are used. For large particles, one technique is to use a graduated cylinders to determine the volume of water displaced by fully immersing the particles. Another choice is to weigh the particles fully submerged (usually with a beam balance supporting a wire basket in a large water container), compare this with their weight in air, determine the resulting buoyant force due to displacement of water, and convert this force to the corresponding displacement volume.

For small-sized sediment, the weight/water-displacement technique is facilitated with a pycnometer bottle of known constant volume. First, the pycnometer bottle is filled with distilled water of known temperature to fill the known volume. The filled bottle is then weighted. Next, some of the water is removed, the sediment is added, and water is added to reestablish the known volume. The bottle with water and sediment is then weighed. The difference in these weights is the submerged weight of the particles. The obtained values are adjusted to standard water temperature. The sediment is then dried and weighed. Finally, the results of individual steps are combined to give the specific gravity.

Specific gravity measurements made by Milhous (1970) and Klingeman, Choquette and Hammond (December 1978 unpublished data) were used to determine the variations in specific gravity for bed material and bedload data. A summary of results are presented in Appendix C. Figure 22 shows specific gravity variations with particle size. An average value of 2.90 was selected for Oak Creek bedload and bed material. Figure 22 also indicates that the average value of specific gravity is larger for gravel than for sands in Oak Creek bed material and bedload.

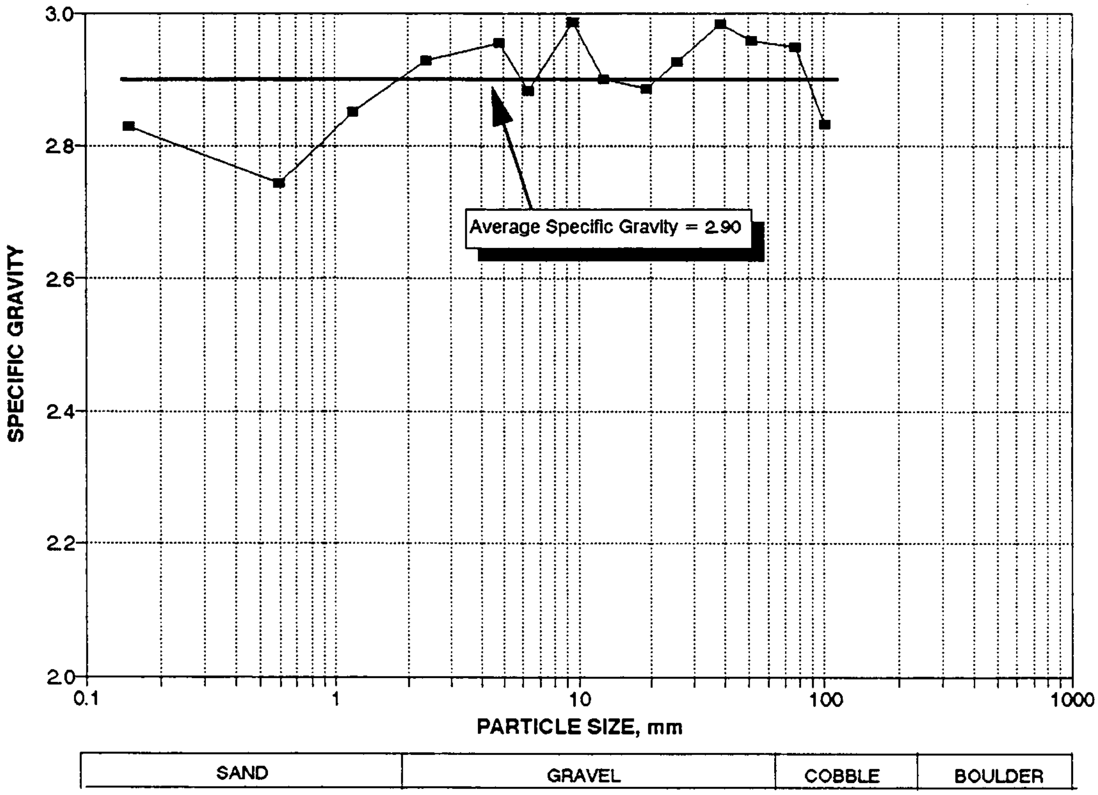


Figure 22 Oak Creek composite specific gravity for bed material and bedload

Bedload Data

A total of 239 bedload samples were collected during Oak Creek bedload sampling for the period of 1971 to 1989. Of these, 119 samples were collected by Milhous in 1971, 59 by Saluja in 1978, and 60 by Matin in 1988-1989. An additional sample was collected in January, 1990 and is also included in the Matin bedload data.

The complete bedload data are given in Appendix D. Table 3 illustrates the data summarized for each size gradation for 1989 data set. Summaries of bedload data for 1971 to 1989 samples are presented in Tables 4 to 6.

Table 3 Example of Data summary for Oak Creek bedload samples

SAMPLE NUMBER: 88-1

Date/Time :	Start:	01/23/88-18:15	End:	02/02/88-14:00	Delta Time:	240.75 hrs
Stage, ft :	Start:	0.351	End:	0.283	Delta W.S.:	-0.068 ft
Average Temperature:		7 C			Mean Stage:	0.317 ft

LAB DATA

Total Wt. (gr): 253.08 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	4.11	1.62	1.62	98.38
1/4"	6.350	5.22	2.06	3.69	96.31
# 4	4.760	6.13	2.42	6.11	93.89
# 8	2.380	19.52	7.71	13.82	86.18
# 16	1.190	34.21	13.52	27.34	72.66
# 30	0.590	58.70	23.19	50.53	49.47
# 50	0.297	67.00	26.47	77.01	22.99
# 100	0.149	40.87	16.15	93.16	6.84
# 200	0.074	13.49	5.33	98.49	1.51
# 230	0.064	1.94	0.77	99.25	0.75
Pan	-----	1.89	0.75	100.00	-0.00

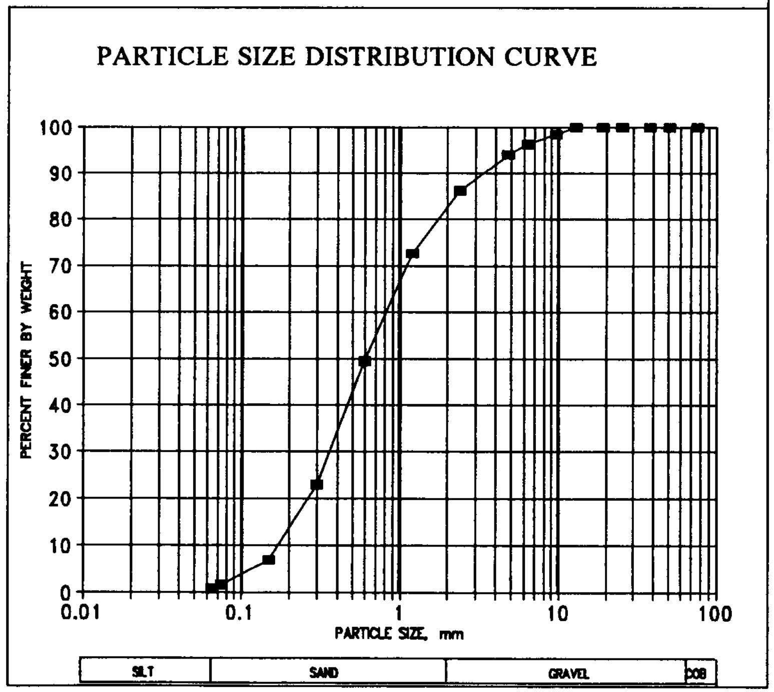


Table 4 Oak Creek bedload data for samples obtained during fall/winter 1971

Sample	PERCENT FINER, mm								Total	Duration	Discharge	Largest	slope	Water
No.	D10	D16	D35	D50	D65	D84	D90	Dmax	Weight,kg	hrs	Qavg, cfs	Particle	ft/100ft	Temp (C)
71-1	0.32	0.40	0.72	1.16	2.37	8.13	11.94	11.94	0.195	27.4	5.4	58.5	0.83	
71-2	0.19	0.26	0.63	0.93	1.39	3.88	5.48	9.52	0.530	21.2	8.4	3.4	0.84	
71-3	0.25	0.34	0.61	0.95	1.52	4.32	7.14	9.52	0.410	22.8	11.9	6.7	0.86	
71-4	0.25	0.36	0.74	1.11	2.06	5.91	8.37	9.52	0.394	4.8	13.8	5.3	0.83	
71-5	0.07	0.07	0.37	0.72	1.17	4.11	12.40	25.4	2.240	16.0	15.8	62.1	0.87	5.0
71-6	0.34	0.46	0.86	1.23	2.12	5.00	7.85	25.4	0.403	7.2	13.5	56.7	0.86	5.0
71-7	0.20	0.28	0.54	0.87	1.37	3.52	5.41	9.52	0.365	20.3	11.4	8.0	0.86	3.9
71-8	0.25	0.35	0.70	1.15	2.28	11.06	19.52	19.52	0.200	21.7	9.7	21.6	0.85	3.3
71-9	0.20	0.29	0.52	0.80	1.15	3.12	4.89	25.4	0.128	29.8	8.0	62.5	0.84	3.3
71-10	5.47	9.68	19.41	24.89	33.04	48.43	58.63	76.2	326.910	0.5	92.0	944.0	0.97	5.0
71-11	2.97	4.82	10.51	16.98	23.88	40.13	50.29	76.2	261.360	0.5	92.0	1259.0	0.97	5.0
71-12	3.35	4.38	11.62	19.29	27.32	44.88	53.85	76.2	148.960	0.4	93.0	1732.0	0.97	5.0
71-13	2.80	4.99	18.41	26.45	35.23	53.70	64.59	76.2	354.200	0.9	100.0	1455.0	0.98	5.0
71-14	6.20	9.41	18.85	24.50	32.71	47.83	70.91	76.2	640.140	0.5	120.0	1185.0	0.99	5.0
71-15	1.36	2.19	7.24	13.21	19.97	31.75	37.04	76.2	146.450	1.5	67.0	944.0	1.00	6.7
71-16	1.39	2.01	4.78	8.45	14.81	26.25	33.58	50.8	88.270	1.0	64.0	424.0	1.00	6.7
71-17	0.73	0.99	2.02	3.51	6.38	16.43	21.57	25.4	16.388	6.8	32.0	107.0	0.98	6.1
71-18	0.51	0.69	1.28	1.99	3.37	8.45	13.15	25.4	4.953	12.7	26.0	66.0	0.97	5.0
71-19	0.49	0.70	1.38	2.15	4.03	10.49	16.99	25.4	2.277	6.9	27.0	53.0	0.97	6.1
71-20	0.43	0.62	1.17	1.86	2.96	8.07	13.50	19.05	2.730	21.0	24.0	45.0	0.97	6.1
71-21	0.48	0.68	1.28	1.98	3.35	8.91	15.69	38.1	4.925	19.7	25.0	127.0	0.97	6.7
71-22	0.51	0.70	1.30	2.02	3.43	8.58	12.99	25.4	4.640	29.0	24.0	75.0	0.97	6.7
71-23	0.95	1.33	2.93	5.83	12.72	27.89	35.36	50.8	64.130	1.2	62.0	434.0	1.00	6.7
71-24	0.86	1.16	2.25	4.04	7.82	22.13	29.39	50.8	21.000	1.0	60.0	223.0	1.00	7.2
71-25	0.76	1.01	1.87	2.91	4.98	16.14	23.52	50.8	35.040	2.9	54.0	324.0	1.00	7.2
71-26	0.66	0.85	1.51	2.11	3.40	8.61	16.14	50.8	46.250	12.5	41.0	630.0	0.99	7.2
71-27	0.46	0.62	0.97	1.34	2.14	4.22	6.14	25.4	5.074	8.6	29.0	643.0	0.98	7.2

Table 4 (Continued)

Sample	PERCENT FINER, mm								Total	Duration	Discharge	Largest	slope	Water
No.	D10	D16	D35	D50	D65	D84	D90	Dmax	Weight,kg	hrs	Qavg, cfs	Particle	ft/100ft	Temp (C)
71-28	0.39	0.54	0.95	1.32	1.86	3.21	4.34	19.05	2.652	20.4	22.0	24.3	0.97	7.2
71-29	0.34	0.45	0.81	1.10	1.61	2.38	3.62	19.05	1.325	27.6	16.0	7.5	0.96	6.7
71-30	0.27	0.37	0.66	0.96	1.33	2.21	3.03	9.52	0.499	22.7	13.0	2.1	0.96	6.1
71-31	0.28	0.36	0.59	0.84	1.09	1.93	2.27	9.52	0.865	20.6	11.7	1.9	0.96	5.6
71-32	0.31	0.41	0.74	1.04	1.58	3.06	4.37	19.05	0.931	26.6	10.0	12.2	0.95	5.6
71-33	0.29	0.38	0.69	1.00	1.49	2.71	3.87	25.4	0.506	50.6	8.2	62.8	0.95	5.6
71-34	0.21	0.30	0.54	0.84	1.20	2.27	3.21	4.76	0.270	38.6	8.5	0.8	0.95	5.0
71-35	0.25	0.34	0.60	0.89	1.17	2.19	3.12	9.52	1.904	5.6	23.0	5.2	0.97	5.6
71-36	0.30	0.39	0.69	0.98	1.39	2.29	3.44	9.52	0.937	21.3	16.0	4.1	0.96	5.6
71-37	0.34	0.44	0.87	1.41	2.34	10.04	15.24	38.1	0.309	22.1	11.0	143.0	0.96	5.6
71-38	0.34	0.44	0.83	1.20	2.04	4.89	7.51	25.4	0.239	55.5	8.9	49.2	0.95	6.1
71-39	0.34	0.43	0.77	1.10	1.74	3.90	9.80	9.80	0.138	29.9	7.8	8.7	0.94	6.7
71-40	0.31	0.41	0.79	1.18	2.20	8.47	12.48	12.48	0.484	86.4	8.9	36.7	0.95	7.2
71-41	0.41	0.52	1.00	1.55	2.25	4.36	10.35	19.05	0.472	50.8	6.8	4.6	0.94	7.2
71-42	0.44	0.60	1.21	2.02	3.56	7.89	9.97	50.8	0.430	21.5	7.0	6.7	0.94	7.8
71-43	0.28	0.39	0.80	1.18	2.04	6.46	9.89	38.1	0.114	71.5	7.7	120.0	0.94	6.7
71-44	0.23	0.33	0.63	0.98	1.74	4.51	7.98	9.52	0.262	49.5	8.3	8.1	0.94	6.7
71-45	0.40	0.51	0.91	1.27	1.96	4.30	6.47	9.52	0.133	51.0	7.2	3.1	0.94	7.2
71-46	0.39	0.58	1.47	2.59	4.85	14.85	19.05	19.05	0.372	64.2	8.4	27.0	0.94	5.6
71-47	0.39	0.52	1.04	1.70	2.66	5.85	7.97	9.52	0.495	27.5	10.6	11.6	0.96	4.4
71-48	0.34	0.46	1.03	2.01	4.65	14.52	19.17	25.4	0.294	24.5	9.5	61.7	0.95	3.9
71-49	0.41	0.56	1.22	2.19	4.35	12.63	18.84	19.05	0.300	25.0	8.2	29.3	0.94	4.4
71-50	0.22	0.32	0.67	1.05	1.68	3.33	4.35	9.52	0.157	43.5	9.3	1.5	0.95	4.4
71-51	0.16	0.21	0.41	0.65	1.14	3.45	6.64	25.4	3.225	7.5	20.0	56.0	0.97	4.4
71-52	0.33	0.44	0.77	1.02	1.42	2.35	3.95	9.52	2.112	19.2	21.2	6.8	0.97	4.4
71-53	0.24	0.33	0.59	0.94	1.50	4.19	8.55	9.52	0.316	26.3	14.8	6.2	0.96	5.0
71-54	0.20	0.30	0.57	0.93	1.49	3.96	7.43	9.52	0.150	24.2	12.8	7.3	0.96	5.0

Table 4 (Continued)

Sample No.	PERCENT FINER, mm								Total Weight,kg	Duration hrs	Discharge Qavg, cfs	Largest Particle	slope ft/100ft	Water Temp (C)
	D10	D16	D35	D50	D65	D84	D90	Dmax						
71-55	0.49	0.67	1.17	1.88	3.33	24.42	45.80	76.2	80.840	94.0	19.0	1789.0	0.97	5.0
71-56	0.58	0.81	1.68	2.86	7.01	40.64	61.38	76.2	43.000	1.0	62.0	1033.0	1.00	5.6
71-57	0.75	1.07	2.61	7.42	23.28	49.53	68.79	76.2	90.000	1.0	72.0	1307.0	1.01	5.6
71-58	2.12	3.93	15.51	25.66	35.23	55.14	63.04	63.04	1056.000	2.2	92.0	2393.0	1.02	5.6
71-59	3.28	5.13	12.33	19.49	27.40	43.23	51.08	76.2	598.600	0.4	78.0	1046.0	1.08	5.6
71-60	1.50	2.15	5.34	9.52	17.60	32.22	38.89	76.2	152.100	1.2	54.0	715.0	1.05	5.6
71-61	1.38	2.15	6.53	11.74	18.55	31.97	38.89	50.8	126.000	2.0	47.0	497.0	1.04	5.6
71-62	1.04	1.49	3.41	5.97	9.57	20.17	25.31	50.8	112.100	5.9	36.0	310.0	1.02	5.6
71-63	0.95	1.33	2.99	5.37	9.52	21.11	26.79	50.8	50.400	2.8	38.0	462.0	1.02	5.6
71-64	1.27	1.92	5.54	10.36	17.81	30.98	37.55	50.8	188.760	2.4	51.0	601.0	1.00	5.6
71-65	1.86	2.88	7.99	16.04	25.68	45.39	54.99	76.2	304.200	1.2	62.0	1222.0	1.00	5.6
71-66	2.62	4.45	13.70	22.50	32.40	49.75	60.96	76.2	392.250	0.8	74.0	1447.0	1.00	5.6
71-67	0.13	0.21	0.47	0.73	1.07	2.15	3.15	4.76	0.019	24.0	0.7	0.4	0.94	10.6
71-68	0.14	0.21	0.40	0.54	0.86	2.25	5.74	5.74	0.017	23.2	0.7	1.2	0.94	11.1
71-69	0.23	0.37	1.03	2.25	5.43	10.58	13.76	19.05	0.039	24.5	0.7	24.2	0.94	12.2
71-70	0.21	0.34	0.78	1.43	3.47	6.91	7.89	7.89	0.026	23.5	0.7	1.4	0.94	11.7
71-71	0.40	0.57	1.64	4.30	7.64	13.27	15.44	15.44	0.034	24.3	0.7	6.5	0.94	11.1
71-72	0.07	0.11	0.26	0.41	0.57	1.08	1.55	4.76	0.050	24.0	0.7	0.2	0.94	13.3
71-73	0.14	0.24	0.50	0.92	3.13	13.36	15.49	15.49	0.009	24.5	0.7	2.3	0.94	13.3
71-74	0.08	0.15	0.32	0.44	0.56	1.05	1.42	2.38	0.008	23.5	0.7	0.1	0.94	12.2
71-75	0.07	0.11	0.35	0.51	0.76	1.53	2.22	4.76	0.006	24.0	0.7	0.4	0.94	11.1
71-76	0.07	0.09	0.25	0.40	0.52	0.93	1.14	2.38	0.006	25.0	0.7	0.0	0.94	10.6
71-77	0.11	0.19	0.46	0.78	1.34	3.83	5.15	5.15	0.018	21.5	0.8	0.6	0.94	10.0
71-78	0.07	0.11	0.34	0.52	0.89	2.23	4.90	4.90	0.007	25.5	0.8	0.7	0.94	8.9
71-79	0.07	0.11	0.32	0.48	0.70	1.16	1.92	2.38	0.006	24.0	0.8	0.1	0.94	7.8
71-80	0.16	0.23	0.40	0.52	0.73	1.16	1.19	1.19	0.002	24.0	0.8	0.0	0.94	7.8
71-81	0.19	0.24	0.40	0.52	0.70	1.10	1.37	9.52	0.017	24.0	1.1	4.1	0.94	8.9

Table 4 (Continued)

Sample No.	PERCENT FINER, mm D10	D16	D35	D50	D65	D84	D90	Dmax	Total Weight,kg	Duration hrs	Discharge Qavg, cfs	Largest Particle	slope ft/100ft	Water Temp (C)
71-82	0.38	0.47	0.94	1.71	3.51	8.59	12.95	19.05	0.456	24.0	1.4	19.8	0.94	10.0
71-83	0.15	0.22	0.45	0.82	3.31	12.30	9.52	9.52	0.020	24.2	1.0	2.5	0.94	10.0
71-84	0.15	0.23	0.46	0.70	1.39	4.08	5.49	5.49	0.005	23.4	0.9	0.6	0.94	8.9
71-85	0.11	0.16	0.35	0.50	0.84	3.03	4.76	4.76	0.030	24.7	1.8	1.0	0.94	8.3
71-86	0.15	0.21	0.39	0.54	0.94	3.22	5.15	19.05	0.049	24.4	1.3	31.2	0.94	7.8
71-87	0.26	0.37	0.93	3.54	7.37	13.09	15.33	15.33	0.028	23.2	1.0	2.1	0.94	6.7
71-88	0.23	0.36	1.71	4.81	8.61	14.19	16.01	16.01	0.034	24.0	1.0	6.0	0.94	7.8
71-89	0.57	1.29	6.59	9.34	12.24	15.94	17.11	17.11	0.041	24.0	1.5	3.2	0.94	7.8
71-90	0.17	0.24	0.46	0.75	2.34	10.81	13.90	13.90	0.014	23.9	1.5	2.5	0.94	6.1
71-91	0.42	0.75	7.22	11.65	16.89	21.87	23.20	23.20	0.056	24.5	1.3	16.4	0.94	4.4
71-92	0.44	0.70	2.70	5.61	8.73	14.16	16.00	25.4	0.049	24.5	1.4	36.7	0.94	5.0
71-93	0.44	0.67	3.64	9.89	15.36	21.32	22.85	22.85	0.052	23.8	1.5	13.2	0.94	6.7
71-94	0.20	0.60	1.99	4.40	8.68	14.31	16.09	16.09	0.048	24.0	2.3	3.7	0.94	7.2
71-95	0.25	0.40	1.05	2.10	4.76	11.58	9.52	9.52	0.043	23.8	2.5	5.6	0.94	7.8
71-96	0.30	0.43	0.97	1.80	3.50	7.63	9.16	9.52	0.040	23.8	1.6	3.6	0.94	6.7
71-97	0.33	0.46	1.04	1.93	4.61	10.94	9.52	9.52	0.029	24.2	1.4	4.2	0.94	7.2
71-98	0.45	0.70	2.65	9.65	12.47	16.04	9.52	9.52	0.039	24.2	1.7	9.5	0.94	6.7
71-99	0.51	0.83	3.51	11.35	17.07	21.99	19.05	19.05	0.058	24.1	1.3	17.8	0.94	5.0
71-100	0.41	0.63	1.97	3.92	6.93	12.72	9.52	9.52	0.056	24.2	3.1	6.9	0.94	5.6
71-101	0.29	0.37	0.62	1.03	1.93	5.51	8.02	38.1	0.170	24.0	2.6	139.0	0.94	6.7
71-102	0.29	0.39	0.73	1.08	1.73	3.69	4.89	25.4	0.040	23.8	2.1	39.0	0.94	6.7
71-103	0.25	0.38	0.89	1.72	3.70	11.46	9.52	9.52	0.058	9.3	2.5	6.4	0.94	7.8
71-104	0.13	0.28	1.05	2.41	4.66	8.61	9.52	9.52	0.090	14.5	5.1	6.2	0.94	8.9
71-105	0.21	0.33	0.77	1.43	2.99	7.68	9.52	9.52	0.069	8.0	6.5	3.2	0.94	8.9
71-106	0.22	0.32	0.74	1.41	2.41	5.43	6.96	9.52	0.045	16.2	5.0	1.6	0.94	8.9
71-107	0.41	0.68	2.65	5.19	7.99	13.36	9.52	9.52	0.065	24.1	4.4	4.9	0.94	8.9
71-108	0.29	0.44	1.34	2.60	4.65	8.12	9.22	9.52	0.055	23.9	3.8	4.6	0.94	8.3

Table 4 (Continued)

Sample No.	PERCENT FINER, mm								Total Weight,kg	Duration hrs	Discharge Qavg, cfs	Largest Particle	slope ft/100ft	Water Temp (C)
	D10	D16	D35	D50	D65	D84	D90	Dmax						
71-109	0.60	0.95	2.63	5.43	10.85	20.65	19.05	19.05	0.275	8.6	8.5	35.4	0.94	8.3
71-110	0.84	1.27	3.37	6.44	15.96	42.47	50.8	50.8	17.600	5.5	22.0	883.0	0.94	8.3
71-111	0.64	0.89	1.96	3.85	7.60	17.35	23.42	50.8	3.400	10.0	18.0	351.0	0.94	8.3
71-112	0.44	0.59	1.11	1.89	3.20	7.16	9.31	9.52	0.035	7.2	7.9	2.8	0.94	8.3
71-113	0.46	0.62	1.50	3.39	9.01	19.91	19.05	19.05	0.340	17.0	5.2	25.8	0.94	7.8
71-114	0.37	0.50	1.26	2.37	4.50	11.79	9.52	9.52	0.089	24.0	3.3	5.2	0.94	7.8
71-115	0.39	0.52	1.12	2.08	4.32	10.34	9.52	9.52	0.110	23.9	2.4	4.9	0.94	7.8
71-116	0.31	0.40	0.77	1.22	2.28	8.18	9.52	9.52	0.048	23.8	2.0	1.7	0.94	6.7
71-117	0.27	0.39	0.79	1.18	1.96	4.58	6.97	9.52	0.036	24.2	1.8	1.5	0.94	7.2
71-118	0.50	0.77	2.21	4.15	8.49	14.30	9.52	9.52	0.109	54.5	1.6	8.9	0.94	7.8
71-119	0.37	0.54	1.20	2.27	4.33	12.18	9.52	9.52	0.126	89.8	2.1	9.7	0.94	7.8

Table 5 Oak Creek bedload data summary for samples obtained during winter 1978

Sample	Percent Finer, mm							Total	Duration	Hyd.	Discharge, cfs			Water
No.	D10	D16	D35	D50	D65	D84	D90	Weight, gr	hrs	Trend	Qavg	Qmin	Qmax	temp(C)
78-1	0.40	0.59	1.20	1.80	3.00	8.32	10.00	896.1	6.00	F	17.30	16.67	17.77	8.3
78-2	0.32	0.46	0.90	1.50	2.40	6.66	8.00	5603.4	13.33	R	17.30	15.87	23.54	8.2
78-3	0.62	0.95	2.00	4.00	6.50	11.44	13.00	13573.8	2.00	R	25.78	23.54	25.99	8.1
78-4	0.60	0.91	1.90	3.30	5.50	10.44	12.00	15928.8	2.05	C	26.48	24.76	25.99	
78-5	0.62	0.93	1.90	3.30	5.50	9.68	11.00	16665.4	5.15	F	24.01	21.76	24.76	
78-6	0.60	0.91	1.90	3.00	5.00	8.80	10.00	6783.8	6.05	F	21.54	20.02	21.76	
78-7	0.70	0.96	1.80	2.80	4.20	7.85	9.00	5631.1	10.17	FL	19.42	19.45	20.30	
78-8	0.60	0.84	1.60	2.20	3.40	6.90	8.00	2962.6	9.17	F	18.36	16.67	19.45	
78-9	0.60	0.74	1.20	1.60	2.50	5.24	6.10	1974.0	15.83	F	15.54	14.04	16.67	
78-10	0.35	0.49	0.95	1.20	1.70	3.83	4.50	779.1	37.42	F	12.01	10.61	14.04	
78-11	0.34	0.46	0.82	1.10	1.50	2.94	3.40	775.8	35.25	FL	9.18	9.23	10.61	
78-12	0.39	0.51	0.90	1.40	1.00	4.42	5.50	241.6	6.00	FL	10.24	9.23	10.84	
78-13	0.60	0.89	1.80	3.40	11.00	19.36	22.00	1092.3	22.50	FL	10.24	9.68	11.08	8
78-14	0.60	0.89	1.80	3.40	32.00	43.40	47.00	532.5	26.50	F	8.83	8.13	9.68	8.3
78-15	0.55	0.71	1.20	1.80	2.60	5.18	6.00	578.1	19.75	R	9.89	8.13	11.08	8.5
78-16	0.35	0.46	0.80	1.10	1.60	3.04	3.50	136.6	8.17	R	10.59	9.68	13.53	8.4
78-17	0.34	0.48	0.92	1.50	2.30	5.11	6.00	2770.8	8.58	R	15.54	13.53	16.67	8.3
78-18	0.50	0.69	1.30	1.90	3.40	7.66	9.00	4904.6	6.00	FL	16.60	16.14	17.22	8.3
78-19	0.40	0.57	1.10	1.80	3.00	6.12	7.10	9734.6	22.83	FL	16.07	15.60	18.04	8.2
78-20	0.40	0.53	0.95	1.30	2.00	5.04	6.00	2712.1	4.00	R	17.66	15.87	19.45	
78-21	0.58	0.75	1.30	2.20	4.00	8.56	10.00	7041.4	2.58	R	20.48	19.45	22.94	7.2
78-22	0.60	0.84	1.60	2.60	4.20	8.61	10.00	12851.5	5.68	F	22.25	21.17	22.94	7.2
78-23	0.60	0.79	1.40	2.10	3.10	6.75	7.90	4699.3	9.98	F	18.36	16.67	21.17	7.2
78-24	0.52	0.66	1.10	1.50	2.20	5.09	6.00	1827.8	11.55	F	15.54	15.08	16.67	8.9
78-25	0.50	0.61	0.95	1.30	1.80	3.62	4.20	660.3	12.62	F	14.12	12.53	15.08	8.8
78-26	0.38	0.50	0.90	1.40	1.90	3.65	4.20	927.4	24.58	FL	12.01	11.08	14.04	8.7
78-27	0.50	0.64	1.10	1.40	2.00	4.20	4.90	251.7	4.50	R	14.12	13.53	14.56	8.7

Table 5 (Continued)

Sample	Percent Finer, mm							Total	Duration	Hyd.	Discharge, cfs			Water
No.	D10	D16	D35	D50	D65	D84	D90	Weight, gr	hrs	Trend	Qavg	Qmin	Qmax	temp(C)
78-28	0.60	0.74	1.20	1.90	3.00	6.04	7.00	1621.4	2.87	R	19.42	14.56	19.45	8.6
78-29	0.51	0.65	1.10	1.90	3.00	6.80	8.00	13729.2	15.17	F	18.71	16.67	22.35	7.8
78-30	0.58	0.73	1.20	1.80	2.50	5.08	5.90	846.4	8.13	F	15.54	14.82	16.67	7.6
78-31	0.48	0.59	0.92	1.20	1.80	3.47	4.00	633.3	17.92	F	14.12	12.04	14.82	7.3
78-32	0.40	0.54	1.00	1.60	2.10	5.06	6.00	398.7	47.67	F	10.24	8.56	12.04	6.6
78-33	0.65	0.88	1.60	2.20	3.00	5.28	6.00	313.4	48.08	F	7.42	6.26	8.56	6.6
78-34	0.38	0.48	0.80	1.20	2.20	6.08	7.30	90.0	22.00	F	6.00	5.87	6.26	6.8
78-35	0.50	0.81	1.80	3.50	12.00	16.18	17.50	74.2	74.50	F	5.30	4.38	5.87	6.9
78-36	0.20	0.34	0.80	1.30	2.80	8.12	9.80	29.7	20.25	FL	4.94	4.74	5.11	7.1
78-37	0.68	1.04	2.20	3.40	5.00	8.80	10.00	148.8	3.30	R	6.36	5.11	9.23	7.4
78-38	0.62	0.90	1.80	2.80	4.00	7.04	8.00	325.9	4.78	R	12.01	9.23	12.04	7.6
78-39	0.50	0.61	0.97	1.70	2.30	5.87	7.00	3380.5	3.72	R	17.30	12.04	15.60	7.8
78-40	0.55	0.68	1.10	2.00	3.40	8.57	10.20	17645.2	2.62	R	26.48	15.60	27.24	7.7
78-41	0.60	0.84	1.60	2.50	4.00	9.17	10.80	6225.7	1.67	F	25.78	24.15	27.24	7.7
78-42	0.55	0.71	1.20	2.00	3.20	7.99	9.50	21491.9	8.33	FL	24.01	23.54	25.37	7.8
78-43	0.65	0.88	1.60	2.50	4.00	8.26	9.60	7347.4	4.67	F	22.95	22.94	25.37	7.8
78-44	0.52	0.68	1.20	2.00	3.20	7.61	9.00	8880.6	4.83	FL	22.25	21.17	25.37	7.9
78-45	0.64	0.92	1.80	3.10	5.20	10.52	12.20	13323.5	1.67	R	27.54	25.37	27.88	7.9
78-46	0.60	0.82	1.50	2.30	3.80	8.89	10.50	14048.4	6.25	F	25.78	24.15	27.88	7.8
78-47	0.50	0.62	1.00	1.50	2.50	5.92	7.00	4297.3	8.42	F	21.54	18.88	24.15	8.1
78-48	0.56	0.71	1.20	2.00	3.00	6.04	7.00	833.6	9.43	F	17.30	16.14	18.88	8.6
78-49	0.50	0.64	1.10	1.80	2.80	7.51	9.00	779.4	15.20	F	15.18	13.28	16.14	8.5
78-50	0.33	0.42	0.70	0.97	1.30	3.20	3.80	367.3	22.00	F	12.01	11.56	13.28	8.4
78-51	0.45	0.57	0.95	1.20	1.90	3.88	4.50	1224.8	45.17	FL	13.42	10.84	15.60	8.5
78-52	0.53	0.69	1.20	1.80	2.50	5.39	6.30	2084.2	3.17	R	19.42	14.56	21.76	8.4
78-53	0.50	0.64	1.10	1.80	2.70	6.35	7.50	4515.2	4.43	F	20.48	20.02	21.76	8.6
78-54	0.52	0.68	1.20	2.00	3.20	6.47	7.50	12073.4	19.15	F	19.77	19.16	20.88	8.4

Table 5 (Continued)

Sample No.	Percent Finer, mm D10	D16	D35	D50	D65	D84	D90	Total Weight, gr	Duration hrs	Hyd. Trend	Discharge, cfs Qavg	Qmin	Qmax	Water temp(C)
78-55	0.40	0.52	0.90	1.30	2.00	4.58	5.40	1722.8	8.08	F	18.36	17.77	19.45	8.1
78-56	0.61	0.78	1.30	2.00	3.10	6.67	7.80	1237.0	18.67	F	17.30	15.08	17.77	8.1
78-57	0.52	0.76	1.50	2.20	3.20	5.71	6.50	516.1	20.50	F	14.12	12.53	15.08	7.2
78-58	0.15	0.26	0.60	0.95	1.50	3.40	4.00	145.0	27.50	F	10.59	9.68	12.53	6.6
78-59	0.22	0.34	0.70	1.10	1.60	5.70	7.00	102.0	44.17	F	7.94	7.07	9.68	6.2

Table 6 Oak Creek bedload data for samples obtained during fall to spring 1988-89

Sample	Percent Finer								Total	Duration	Hyd.	Discharge			Water
No.	D10	D16	D35	D50	D65	D84	D90	Dmax	Weight, gr	hrs	Trend	Qavg	Qmin	Qmax	Temp(C)
88-1	0.18	0.23	0.43	0.60	0.99	2.19	3.56	9.52	253.1	240.75	F	5.67	4.44	6.96	7
88-2	0.28	0.40	0.87	1.42	2.24	4.41	5.66	9.52	316.9	147.00	R	5.32	4.44	6.24	7
88-3	0.31	0.47	1.09	1.94	3.50	7.05	9.83	12.70	299.6	23.75	R	7.65	6.24	9.13	9
88-4	0.22	0.32	0.77	1.27	2.06	4.31	5.83	12.70	1073.6	141.25	FL	13.43	6.92	32.42	8
88-5	0.28	0.40	0.80	1.18	1.88	3.91	5.61	12.70	305.0	169.00	F	5.74	3.90	7.79	7
88-6	0.29	0.44	1.10	1.92	3.91	19.63	21.80	19.05	162.0	256.75	F	3.14	2.47	3.90	8
88-7	0.23	0.34	0.74	1.12	1.87	4.55	6.89	12.70	211.2	118.00	R	5.06	3.35	6.96	9
88-8	0.19	0.31	0.78	1.28	1.95	4.01	5.40	9.52	184.4	28.08	R	7.50	6.35	8.58	6
88-9	0.33	0.53	1.27	1.88	2.69	4.86	5.92	9.52	223.2	339.17	F	6.10	5.86	6.35	6
88-10	0.22	0.32	0.80	1.50	2.73	5.58	7.38	9.52	783.8	3.75	R	11.41	5.86	17.99	7
88-11	0.60	0.77	1.45	2.44	4.39	9.82	12.64	38.10	59844.3	2.75	R	30.82	17.99	45.55	8
88-12	0.75	0.94	1.91	3.57	6.31	12.67	20.15	76.20	69009.4	1.50	R	47.41	45.55	49.37	8
88-13	0.58	0.83	1.81	3.17	5.53	11.94	17.83	50.80	118799.5	1.75	R	51.11	49.37	52.85	8
88-14	0.61	0.82	1.67	2.67	4.91	10.47	14.70	50.80	104894.9	1.50	R-PEAK	53.03	52.85	53.22	8
88-15	0.55	0.77	1.62	2.75	5.03	10.82	14.53	50.80	94803.4	2.33	F	48.71	44.36	53.22	8
88-16	0.52	0.73	1.47	2.18	3.70	7.40	10.18	19.05	24082.0	2.42	F	41.04	37.86	44.36	8
88-17	0.38	0.47	1.34	3.26	4.85	6.29	8.94	25.40	9754.4	3.00	F	35.02	32.23	37.86	8
88-18	0.41	0.60	1.25	1.86	2.62	4.71	6.09	19.05	22755.2	8.00	F	26.80	21.77	32.23	8
88-19	0.23	0.33	0.71	1.25	1.87	3.44	4.38	12.70	1155.1	16.50	F	18.10	14.68	21.77	9
88-20	0.26	0.38	0.82	1.25	1.95	4.08	5.36	12.70	750.1	25.75	F	14.88	14.68	15.08	9
88-21	0.20	0.30	0.61	0.95	1.39	2.29	3.43	9.52	514.9	70.25	F	11.08	7.50	15.08	8
88-22	0.21	0.31	0.83	1.43	2.19	4.28	5.15	9.52	525.1	360.25	F	7.42	4.00	9.00	7
88-23												6.45	5.59	7.34	9
88-25	0.35	0.51	1.01	1.55	2.22	4.44	5.74	19.05	41772.0	162.00	FL	10.03	3.66	19.91	
88-26	0.28	0.41	0.93	1.55	2.33	4.96	6.44	19.05	5211.6	568.50	FL	8.04	1.26	17.99	
88-27	0.30	0.41	0.79	1.12	1.76	3.34	4.30	19.05	31193.2	50.00	FL	17.84	13.14	18.53	
88-28	0.52	0.70	1.24	1.82	2.45	4.63	5.82	19.05	8503.8	118.50	F	12.88	5.55	21.88	

Table 6 (Continued)

Sample No.	Percent Finer								Total Weight, gr	Duration hrs	Hyd. Trend	Discharge			Water Temp(C)
	D10	D16	D35	D50	D65	D84	D90	Dmax				Qavg	Qmin	Qmax	
88-29	0.37	0.52	1.14	2.12	3.96	8.25	10.34	12.70	929.9	16.25	R	9.76	5.55	14.63	
88-30	0.46	0.66	1.21	1.82	2.52	4.84	6.31	25.40	52653.1	8.25	FL	32.74	14.63	43.10	
88-31	0.84	1.21	2.58	4.39	6.47	11.56	15.11	38.10	56063.3	3.50	F	30.56	27.52	33.70	
88-32	0.61	0.83	1.63	2.36	4.05	7.98	10.85	25.40	17161.0	3.42	R	29.88	27.52	32.29	
88-33	0.62	0.83	1.57	2.23	3.68	6.36	8.84	25.40	28563.7	2.67	R	34.43	32.29	37.00	
88-34	0.64	0.85	1.61	2.27	3.74	6.63	9.05	25.40	37480.4	3.67	F	35.12	33.70	36.54	
88-35	0.59	0.77	1.35	1.90	2.61	4.93	6.32	25.40	19192.8	10.58	F	27.71	22.16	33.70	
88-36	0.64	0.89	1.97	3.54	5.65	10.19	12.18	25.40	3654.8	6.00	F	20.48	18.79	22.16	
88-37	0.31	0.45	0.86	1.19	1.79	3.09	4.11	12.70	1332.8	126.92	FL	15.43	7.96	27.10	
88-38	0.29	0.40	0.77	1.09	1.67	3.21	4.45	12.70	2454.1	97.75	FL	11.95	9.00	19.46	
89-39	0.30	0.45	1.01	1.73	2.85	5.90	8.74	12.70	871.8	425.75	FL	6.35	3.59	11.57	
89-40	0.27	0.39	0.84	1.35	2.31	8.52	12.80	38.10	4587.6	7.50	R	17.12	11.57	23.28	
89-41	0.50	0.71	1.33	1.95	3.06	7.13	10.60	25.40	46602.0	26.25	FL	27.04	21.60	33.70	
89-42	0.94	1.38	3.57	6.51	10.64	17.67	21.74	50.80	185061.7	12.50	FL	29.14	26.02	31.78	
89-43	1.32	2.04	5.44	8.83	12.02	20.55	23.42	38.10	27787.3	2.08	F	27.93	27.71	28.14	
89-44	0.56	0.75	1.40	2.06	3.57	8.76	11.40	25.40	9439.5	3.08	F	26.35	25.00	27.71	
89-45	0.64	0.84	1.55	2.21	4.04	9.52	11.80	25.40	7820.9	5.42	F	24.26	23.56	25.00	
89-46	0.60	0.78	1.37	1.90	2.58	4.93	6.41	25.40	29443.1	42.50	FL	21.54	15.13	27.10	
89-47	0.45	0.65	1.49	2.74	5.79	11.61	14.65	25.40	3105.2	46.08	FL	13.19	11.72	15.13	
89-48	0.74	1.12	3.75	6.54	10.09	16.59	20.50	38.10	7975.9	215.17	F	9.90	6.16	14.12	
89-49	0.44	0.66	1.53	2.79	5.75	11.61	14.98	25.40	10525.2	48.67	R	15.38	6.16	26.80	
89-50	0.69	0.93	1.87	3.24	5.71	11.87	16.03	38.10	65712.1	2.67	R	30.19	26.80	33.70	
89-51	0.63	0.82	1.53	2.23	4.18	9.92	12.59	25.40	12560.3	1.25	F	33.06	32.42	33.70	
89-52	0.68	0.87	1.62	2.32	4.66	11.19	15.93	50.80	34691.2	3.00	FL	31.14	29.26	34.36	
89-53	0.74	1.01	2.00	3.85	7.74	16.68	20.99	50.80	246840.7	18.08	FL	30.44	20.76	40.30	
89-54	0.48	0.69	1.39	2.25	4.92	12.44	18.41	25.40	5777.9	74.50	FL	15.23	10.79	20.76	
89-55	0.39	0.54	0.94	1.34	2.06	5.82	9.94	25.40	12152.6	94.25	FL	15.33	12.43	25.60	

Table 6 (Continued)

Sample No.	Percent Finer								Total Weight, gr	Duration hrs	Hyd. Trend	Discharge			Water Temp(C)
	D10	D16	D35	D50	D65	D84	D90	Dmax				Qavg	Qmin	Qmax	
89-56	0.55	0.73	1.26	1.89	2.88	7.28	10.88	38.10	106691.3	47.75	FL	25.00	19.91	28.02	
89-57	0.70	0.97	2.09	4.13	7.39	14.91	18.41	50.80	191871.3	22.50	FL	26.86	21.04	35.02	
89-58	0.51	0.68	1.13	1.70	2.31	5.31	8.41	19.05	11449.7	7.00	F	28.11	25.48	30.82	
89-59	0.65	0.84	1.61	2.36	5.01	11.43	14.81	25.40	12054.9	16.67	F	23.78	22.16	25.48	
89-61	0.44	0.60	1.01	1.45	2.03	4.12	5.61	19.05	8240.0	103.25	F	18.55	11.29	26.80	
89-62	0.36	0.49	0.98	1.59	2.55	8.02	11.26	19.05	1452.0	167.17	FL	10.25	8.17	14.38	
90-4	0.90	1.15	1.87	2.57	4.30	9.48	13.17	25.40	6440.0	21.25	F	30.16	22.78	38.19	

Particle Shape Analyses

The results of laboratory measurements of particle shape are shown in Appendix E. Individual samples were divided into size fractions. The measurement data are for individual particles selected from each sieved size fraction. The data include individual particle weights, the lengths of the three longest mutually perpendicular axes, the particle shape factor based on these axis lengths, and four additional ratios of axis lengths for use in shape characterization.

Oak Creek bed material was analyzed for its particle shape characteristics. This was done for all grain size fractions from that retained on a 4-inch sieve down to that retained on a 3/8-inch sieve. All of the available particles coarser than 3 inches were analyzed whereas 10 randomly selected particles were analyzed from each group of particles retained on the 3", 2", 1-1/2", 1", 3/4", 1/2", and 3/8" sieves. No particles smaller than 3/8-inch in sieve size were analyzed for shape because of the difficulties encountered in making such measurements accurately on small particles. Each particle was individually weighed after previous oven drying. The lengths of the three mutually perpendicular axes were then measured using calipers and a scale.

Every particle was weighed and measured according to Krumbein's method (Krumbein, 1941), where a is the length of the longest axis, b is the length of the intermediate axis, and c is the length of the shortest axis. These values were averaged according to size range. Calculations were then made of the shape factor, relative lengths, Zingg's ratio, and nominal diameter.

VI. ANALYSIS AND INTERPRETATION OF RESULTS

Oak Creek Bed Material Characteristics Analysis

Previous unpublished measurements of bed material samples from 1978 (see Appendix C) were used in analysis of bed material characteristics. This was done to characterize the source material for bedload transport. Bed material samples were collected from 21 locations in a 160-foot reach of Oak Creek, immediately upstream of the vortex bedload sampler, representing the range of material normally found in the bed. Armor material and subarmor material were separately collected. Laboratory particle size analyses were made for all samples. Comparison of individual and composite samples revealed a definitely coarser composition for armor material than for that beneath, with d_{50} values of 47.5 and 20.0 millimeters (mm) for composited armor and subarmor samples, respectively (see Table 2). The d_{50} values for individual armor samples ranged from 16.3 to 98.1 mm whereas the d_{50} values for subarmor samples varied from 6.3 to 35.4 mm (values interpolated from data in Appendix C).

In sediment transport studies the d_{65} size is often considered to be representative of the bed and the d_{35} size as representative of the material being transported. The ratio of the d_{65} size to the d_{35} size is often used as a measure of the uniformity of the bed material from the view point of the hydraulic properties of the bed. A uniform material has a ratio of one, the ratio increases as the material become more non-uniform. This ratio (d_{65}/d_{35}) is called the "hydraulic uniformity ratio" (Senturk, 1977). The larger the ratio, the less uniform or more varied is the material.

A graph of the d_{50} of armor and subarmor layer versus hydraulic uniformity ratio for individual sampling points shows that the uniformity ratio has less fluctuation for armor layer material than subarmor layer material (see Figure 23).

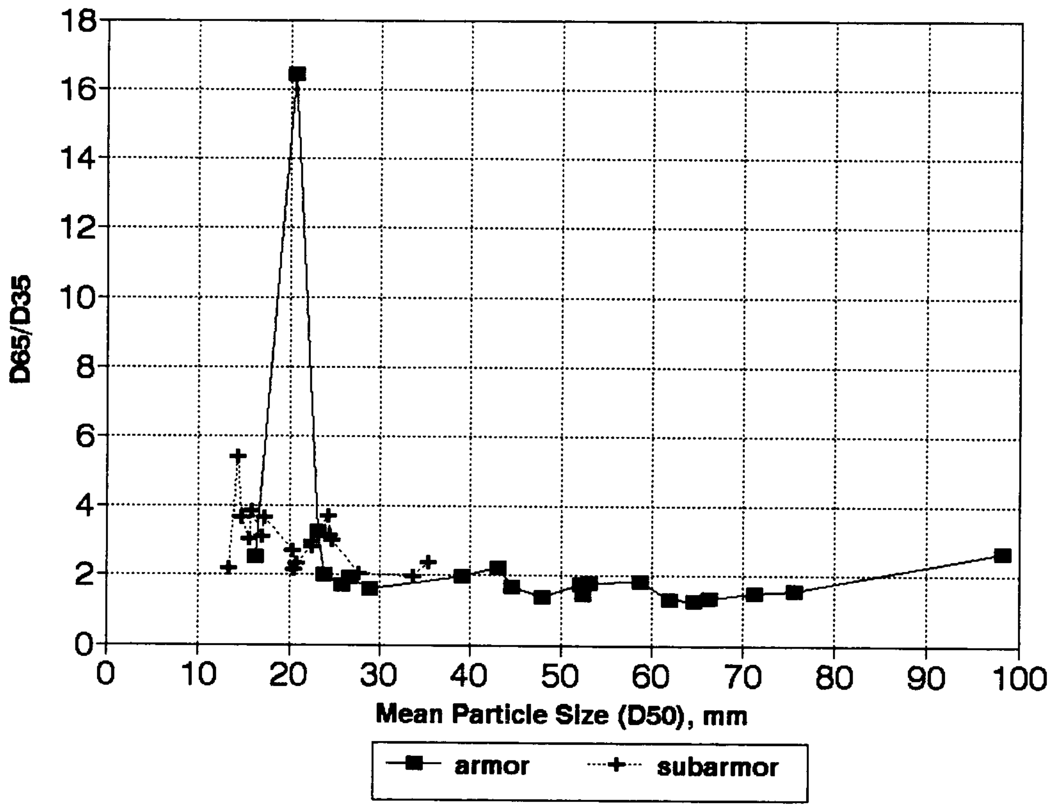


Figure 23 Hydraulic uniformity variation with d_{50} based on difference in size distributions of the armor and subarmor layers

Analysis of Oak Creek bed material data indicates that the average hydraulic uniformity ratio of the armor layer has a value of 1.92, which is less than the value of 3.08 for the subarmor layer. Thus, the armor layer is more uniform than the subarmor layer.

The review of size gradation data indicates a strong vertical variation between the armor and subarmor layer. The ratio of $d_{50\text{-armor}} / d_{50\text{-subarmor}}$ was 2.27, evidence of moderately strong armoring. Winnowing of fines from the surface layer, perhaps combined with hydraulic sorting when the streambed is largely mobilized, may account for the difference in size distributions of the armor and subarmor layers. Trask in mid-1930's defined a bed material sample sorting coefficient as square root of d_{75}/d_{25}. Bed material sorting coefficient was used to evaluate the bed material sampling variation along the study reach. A well sorted material has a sorting coefficient close to one and poorly sorted material (wider range of sizes present) has a larger coefficient. Figure 24 illustrates the differences in the degree of sorting in Oak Creek for armor and subarmor layer. There is better sorting for the armor layer than for the subarmor layer.

Bedload and Bed Material Size Relationship

The analysis of bedload data indicates that there is a critical discharge below which the armor layer is relatively stable and above which a considerable amount of armor-size bed material is found in the bedload samples of the vortex trap. Milhous (1973) estimated this critical discharge at approximately 40 cfs (1.1 m^3/sec) for Oak Creek. Milhous also noted that above 70 cfs (2.0 m^3/sec) "the whole bed seemed to be in motion".

Frequency distribution analyses for composite bedload and bed material particle sizes were performed for several discharge groups. As illustrated in Figure 25, bed material is mono-modal, with armor material distinctly skewed to the coarsest particle sizes. The bedload size distribution at small flows is mono-modal but with sizes much smaller than the armor. The bedload size distribution is bi-modal for discharges greater than 50 cfs, with a strong skewness toward coarse particles in the armor layer for discharges above 90 cfs.

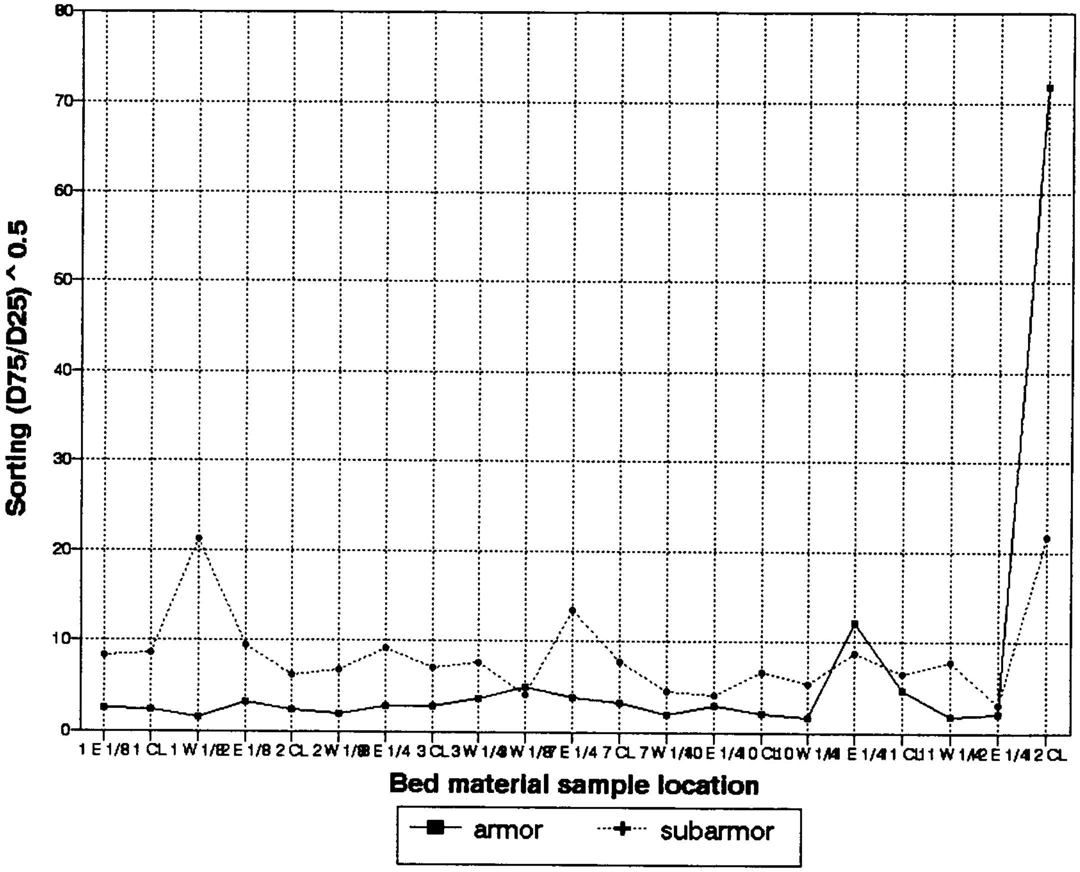


Figure 24 Sorting variation along sampling reach

Skewness variation with discharge for transported bedload samples is shown in Figure 26. A trend is evident with bedload particle size distributions becoming more negatively skewed at higher flows.

Representative gravel-size distributions of transported material collected in the vortex bedload sampler for several discharge groups are given in Figures 27-29. Each covers part of the range of discharges and compares the bedload distributions with bed material armor and subarmor. It is apparent from these grain-size distributions that there were pronounced variations in sizes of gravel transported over the range of experienced discharges. The shift in grain

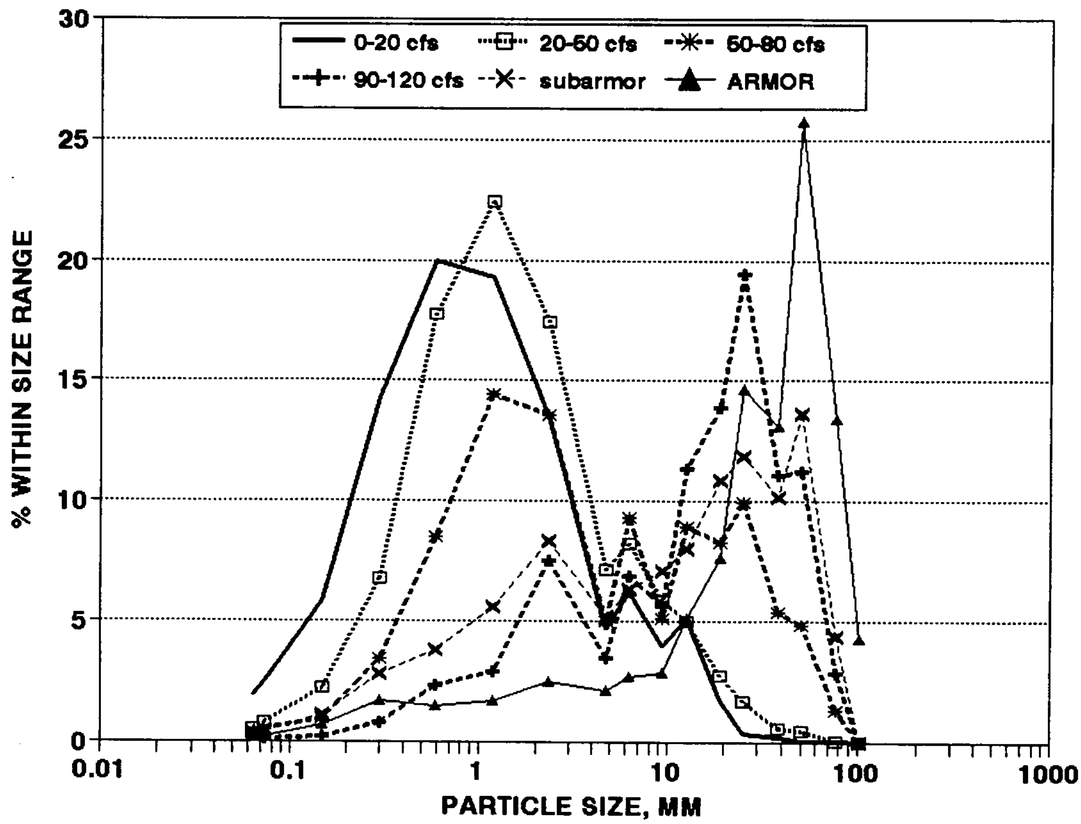


Figure 25 Oak Creek composite bed material and bedload variations, 1971-1989 data

sizes with increasing discharge affects the entire distribution and is reflected in the shifting median sizes (d_{50}) of the bedload.

The largest change in d_{50} is seen to occur during the increase in discharge from the group for 20-25 cfs to the group for 51-78 cfs (Figure 28). This range represents the breakup of the armor layer. There is nearly a fourfold increase in the median transported size during that transition, whereas a further increase in discharge to 120 cfs triples d50 from about 8 mm to 24 mm.

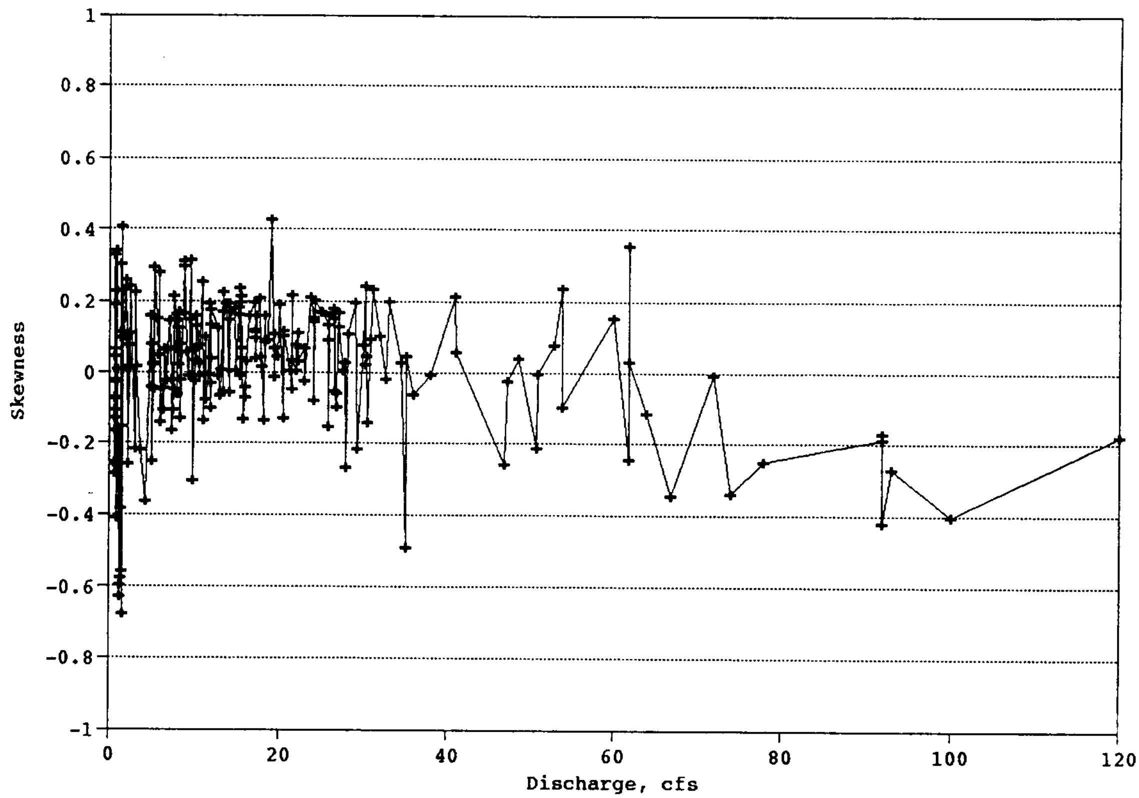


Figure 26 Bedload skewness variation with discharge

The distributions shown in Figures 27-29 also demonstrate that the median sizes of transported materials during low flow stages are sizes that are at the small end of the size range for both the armor and subarmor (Figure 27). This is true up to the 20-25 cfs discharge group. Above this flow range, the bedload size coarsens (see Figure 28). Such a shift seems more appropriate as critical discharge for the beginning of armor breakup is reached. At the discharge group of 91-93 cfs, the size distribution has become roughly similar to that of the subarmor (see Figure 29). Reasonable trends of progressively changing particle sizes with discharge can be seen from the bedload size distributions in Figure 27-29. These show that in Oak Creek the sizes of the transported gravel do increase with increasing discharge. The trends are most distinct above a discharge group of 25-30 cfs, the estimated critical

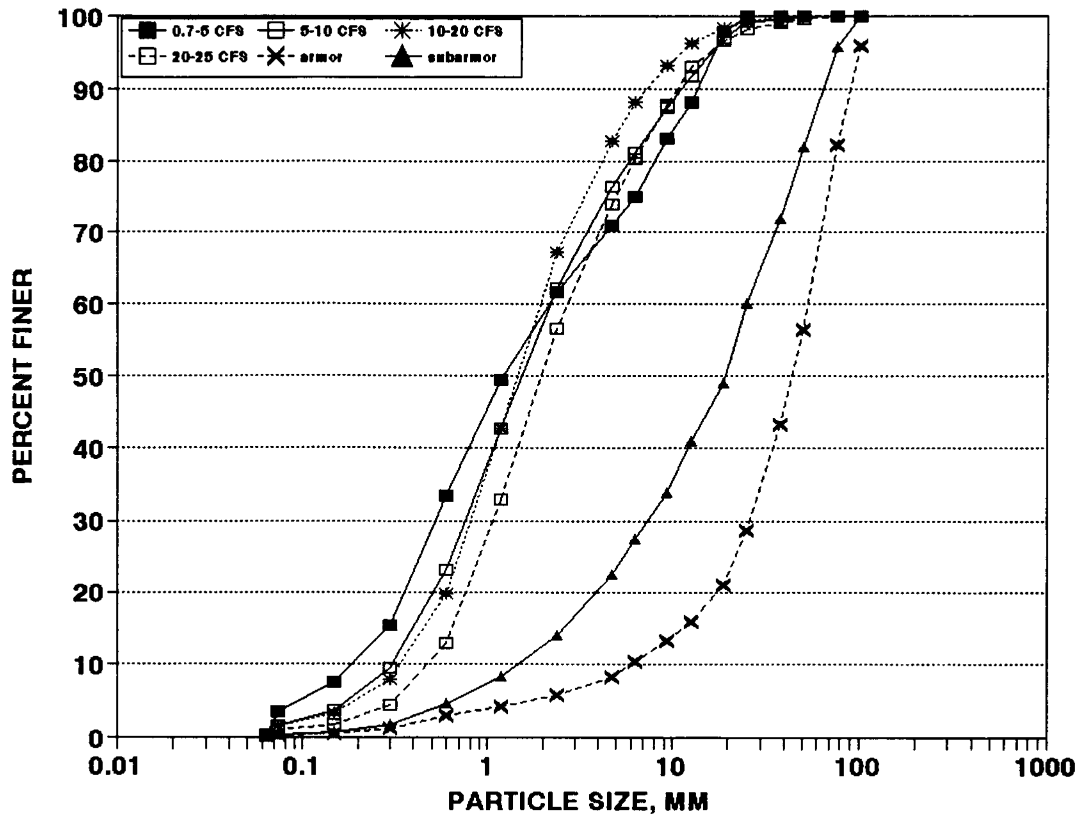


Figure 27 Composite bedload particle size distribution for 0.7 - 25 cfs discharge groups

discharge for breakup of the armor layer. Below that discharge, there is a noticeable increase in scatter of the data for particle size distributions.

In Oak Creek the bedload distributions become progressively coarser with increasing flow and become systematically more skewed as they approach the distribution of the bed material. It can be estimated from Figures 27-29 that agreement between bedload and bed-material distributions is not achieved until discharges exceed about 120 cfs, with bedload becoming similar to subarmor in size distribution at about 100 cfs.

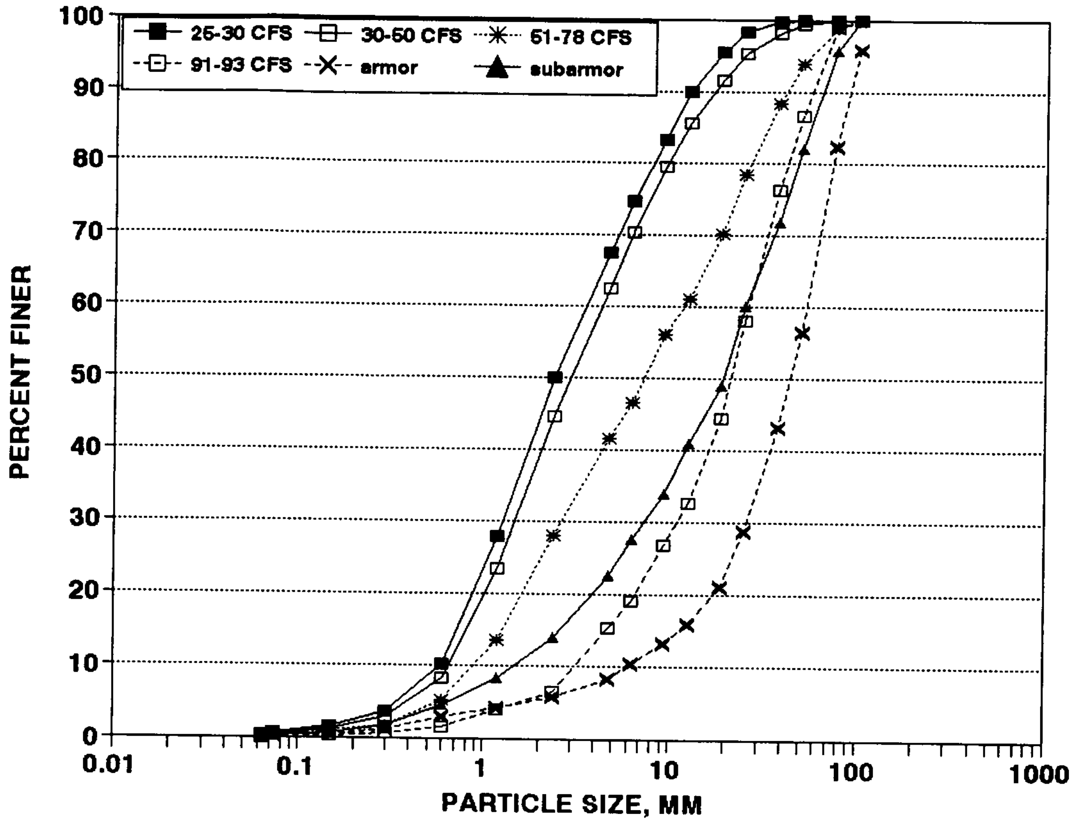


Figure 28 Composite bedload particle size distribution for 25-91 cfs discharge groups

The systematic shifts in the nature of the bedload size distributions in Oak Creek demonstrate that the particle-entrainment processes must be complex and depend on flow stage. At high discharges, nearly all sizes of materials in the bed are mobilized by massive non-selective entrainment, so that the resulting particle size distribution of bedload reflects the bed-material source. This is apparent in Figure 29 for bedload size distributions at high discharges. At lower discharges, the bedload distributions are more nearly Gaussian (but with some skew and biomodality) and no longer mimic the bed-material distributions. It may be that the distribution of bed shear stresses exerted by the stream

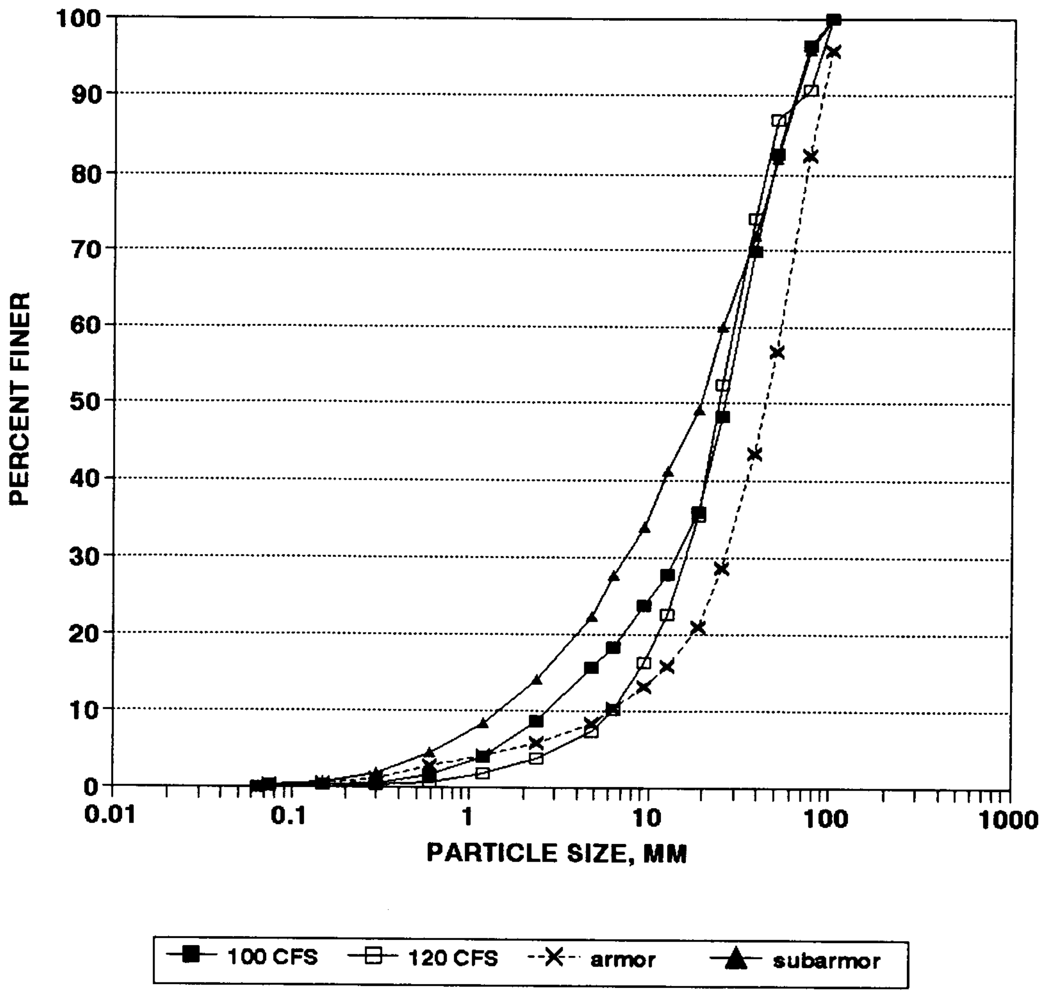


Figure 29 Composite bedload particle size distribution for 100-120 cfs discharge groups

flow at these smaller discharges is more important for the particle-by-particle entrainment, the bed no longer being fully mobilized. Grass (1971) showed that temporal variations in bed stresses are approximately Gaussian distributed. Therefore, it is possible that the resulting size distributions of randomly entrained particles similarly end up Gaussian in character.

It is seen that there is considerable variation in the sizes of the transport gravel. There are systematic changes in the relatives amounts of the several sieve fractions with discharge, the overall effect being an increase in the particle sizes within the bedload at the higher discharges. Figures 30 and 31 illustrate the size variations of bedload samples with discharge for three representative particle sizes. The trends of changing sizes are particularly evident at discharges greater than 25 cfs, the flow stage at which the armor pavement begins to break up. In addition to these shifts in sizes of particles being transported, it is apparent that the overall character of the distribution varies with discharge. This can be justified on the basis that when fine particles are moved from gravel interstitial spaces, bigger particles become more available to transport. This may be as a result of changes in hiding factor effect for smaller particles as discharge increases.

The presence of bimodality was seen in samples at discharge groups of 50-80 cfs and 90-120 cfs, that is near completion of the break up of the armor layer and its full mobilization. This suggests that the finer mode might represent part of the matrix fill from within the subarmor. It is possible that the second mode represents a release of finer-sized particles from the bed material matrix. The origin of this second mode in the size distributions of the trap samples caught at the vortex sampler cannot be resolved at present.

It should be recognized that the changing particle-size distributions seen in Figures 27-29 reflect the relative transport rates of the different size fractions, not their absolute transport rates. Accordingly, as the discharge increases, all sizes that can be moved by the flow are transported at progressively higher rates, as shown by the analyses of Parker et al. (1982) and Diplas (1987). This is also true of the smaller size fractions, even though their frequencies in the particle-size distributions of the bedload samples decrease with increasing discharge.

At discharges below the estimated incipient motion flow (25 cfs), the d_{50} of particles are in the sand range size, varying between 1.3 - 2.0 mm. The analysis also indicates

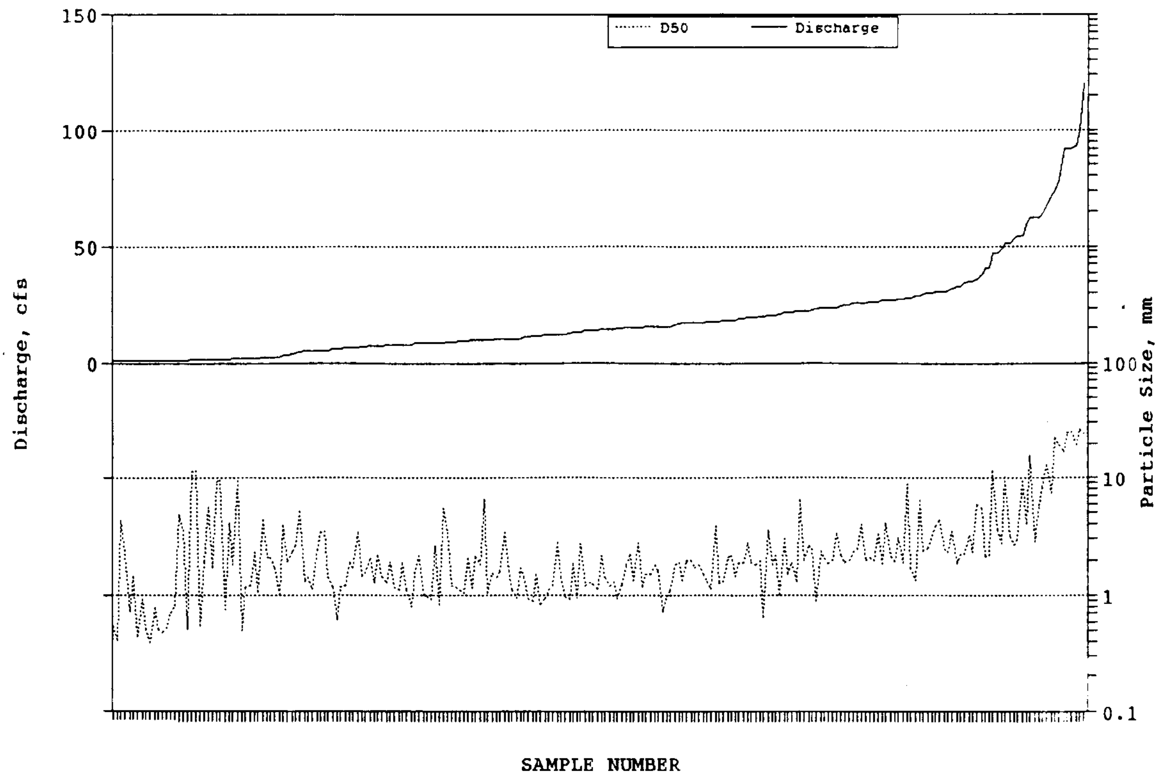


Figure 30 Bedload d_{50} size variations with discharge

that d_{90} of particles for range of discharges below incipient motion does not show a specific pattern in size variation. The d_{90} size range varies between 7 - 15 mm. Figures 32-34 illustrate chronological variations of d_{90} and d_{50} of the bedload particle size with discharge for the 1971, 1978, and 1989 data sets.

Variations of mean particle size, d_{50}, with discharge were also analyzed using all the bedload data. Appreciable scatter of data is shown in Figure 35. Yet it is shown in Figure 35 that there is a good correlation between d_{50} particle size with discharge for discharges above 24 cfs. This trend does not exist at lower discharges. The best fit line on Figure 35 indicates a quick increase in median particle size with discharge above the estimated incipient motion flow range (e.g., 20-25 cfs).

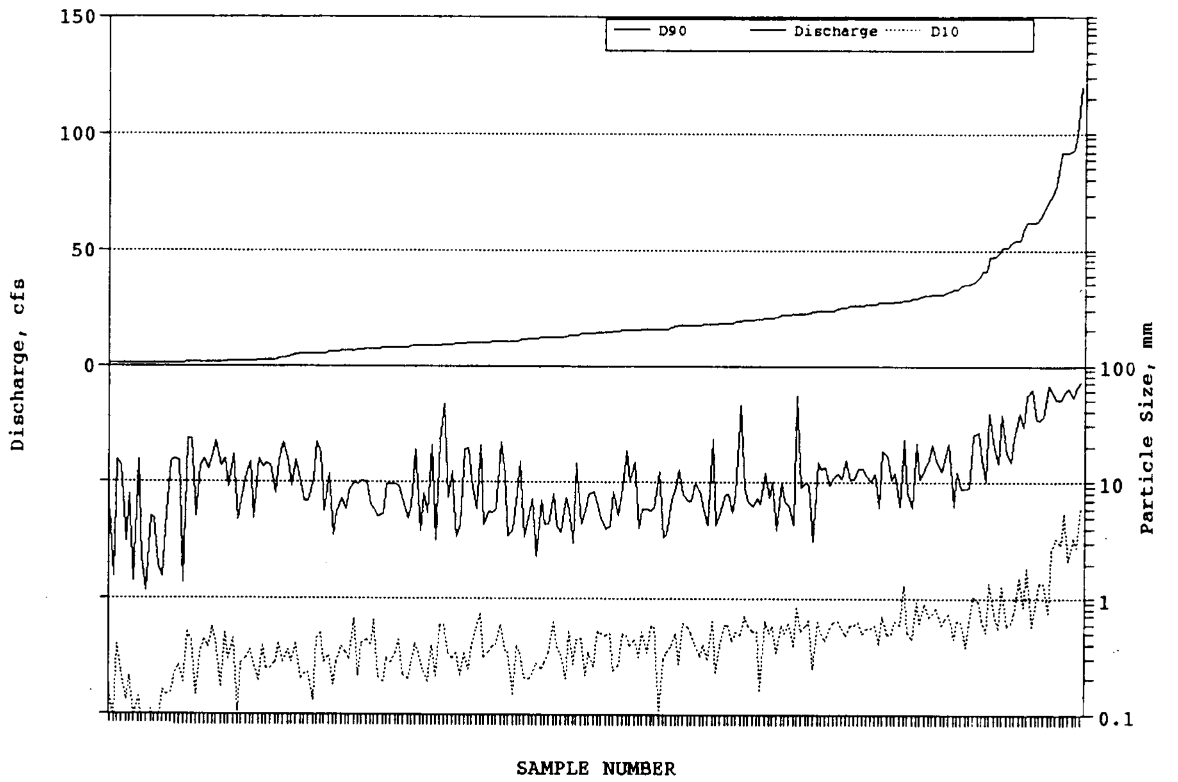


Figure 31 Bedload d_{10} and d_{90} size variations with discharge

To further evaluate particle size variation with discharge, the samples categorized by whether collected on the rising limbs or falling limbs of hydrographs. Results of the analyses using median particle size (d_{50}) are shown in Figures 36 and 37. The comparison between d_{50} size variations for rising and falling limbs of hydrographs is shown in Figure 38, along with limited results for samples collected at steady flows. Results indicate higher values of d_{50} for the rising limbs of hydrographs compared to d_{50} values for falling limbs, for discharges approximately above 18 cfs. This trend is reversed for discharges below 18 cfs. One reason for this difference may be the smaller number of samples for rising-limb events compared to falling-limb events for the discharge range of 0-20 cfs.

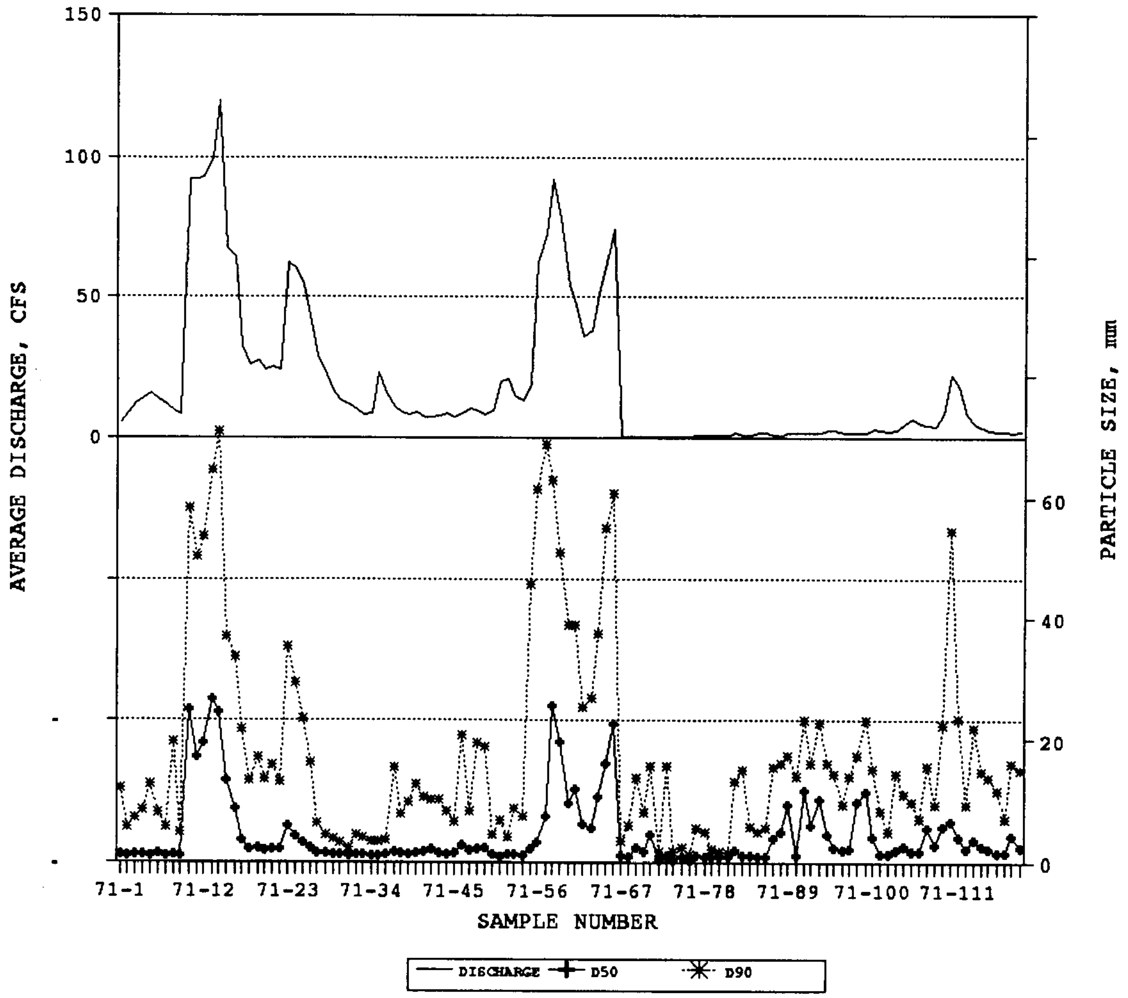


Figure 32 Chronological representative particle size variation with discharge, 1971 data

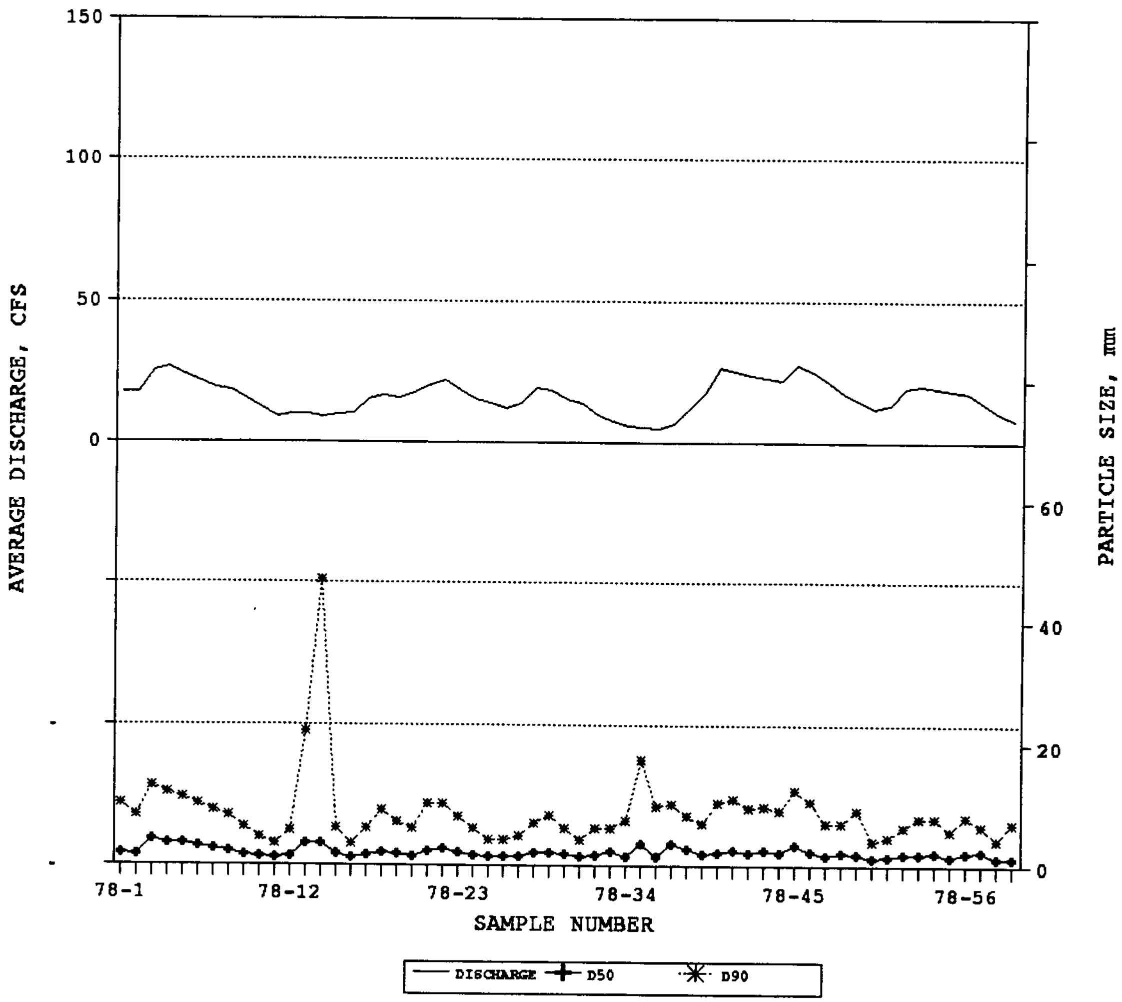


Figure 33 Chronological representative particle size variation with discharge, 1978 data

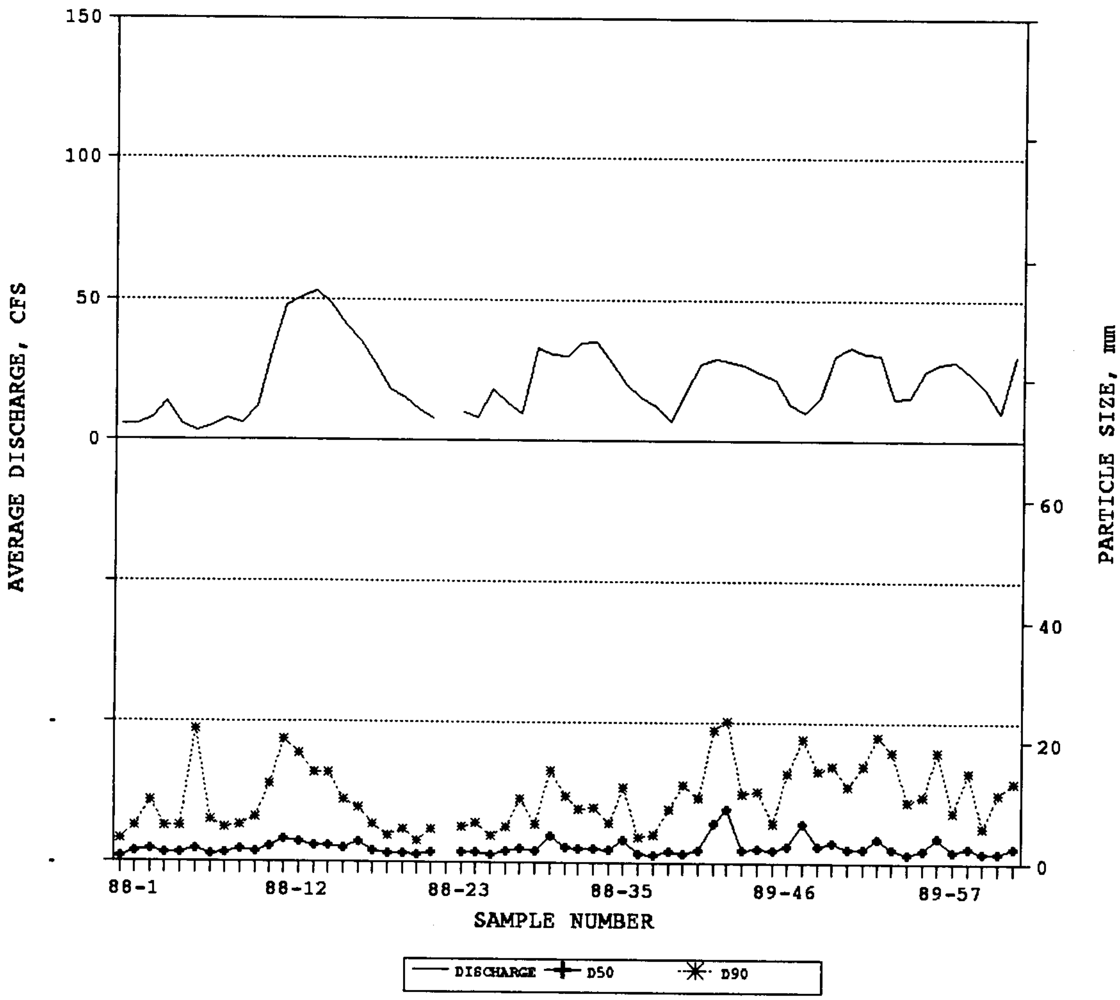


Figure 34 Chronological representative particle size variation with discharge, 1989 data

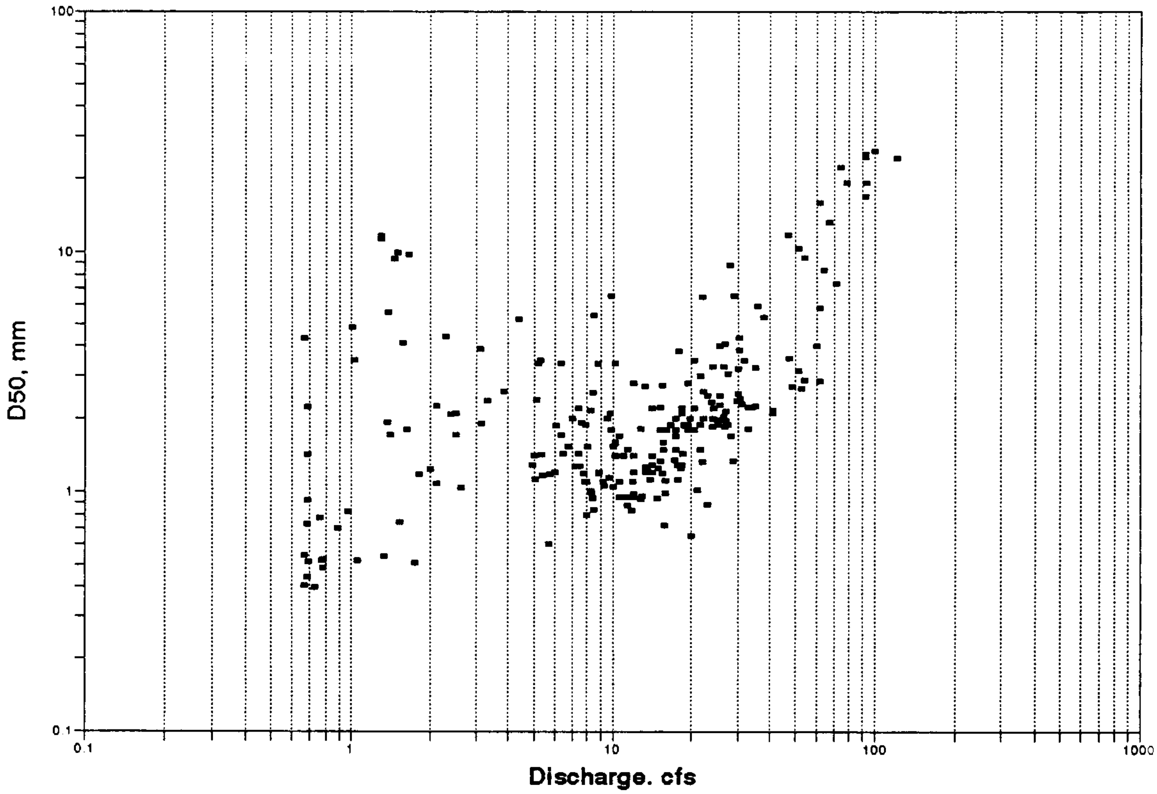


Figure 35 Median particle size variation with discharge, 1971-1989 data

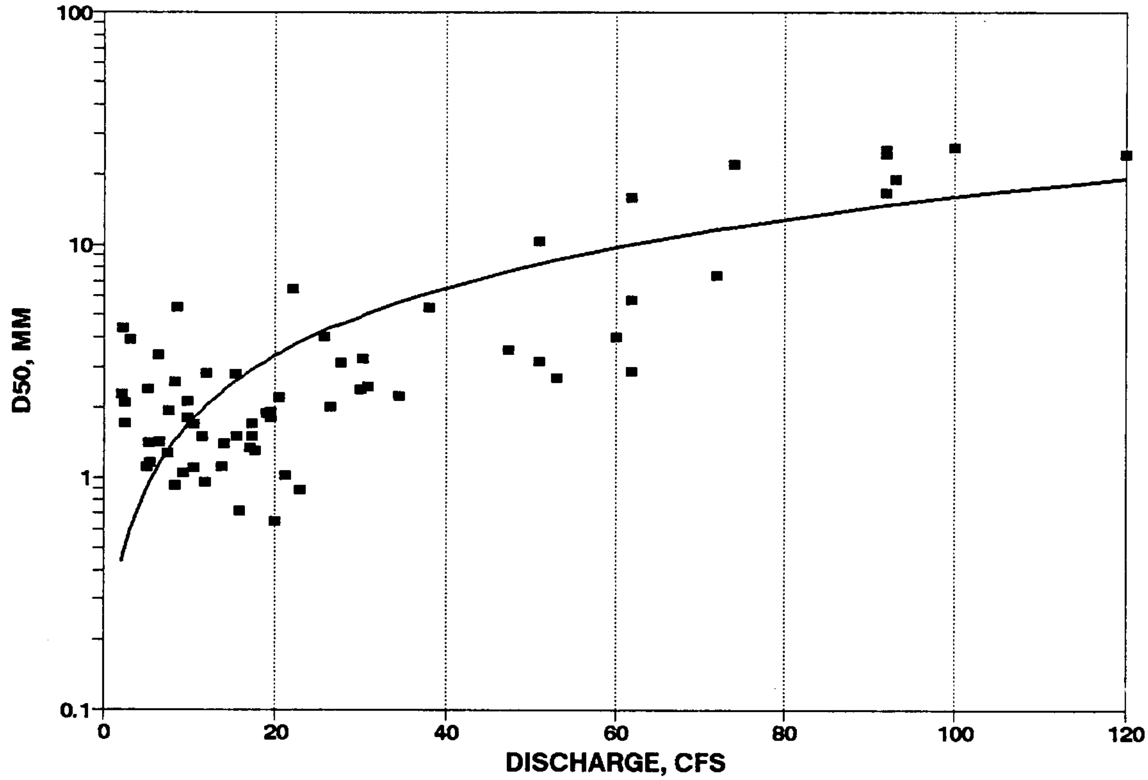


Figure 36 Median particle size variation with discharge for rising limbs of hydrographs, 1971-1989 data

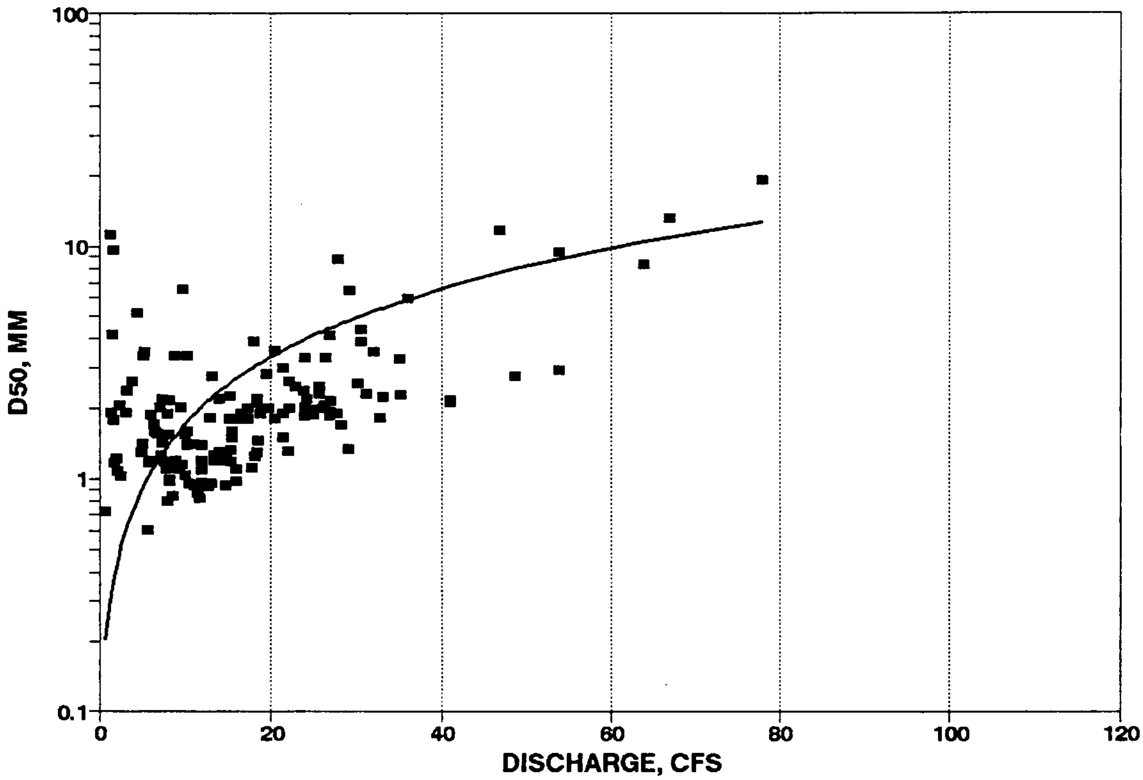


Figure 37 Median particle size variation with discharge for falling limbs of hydrographs, 1971-1989 data

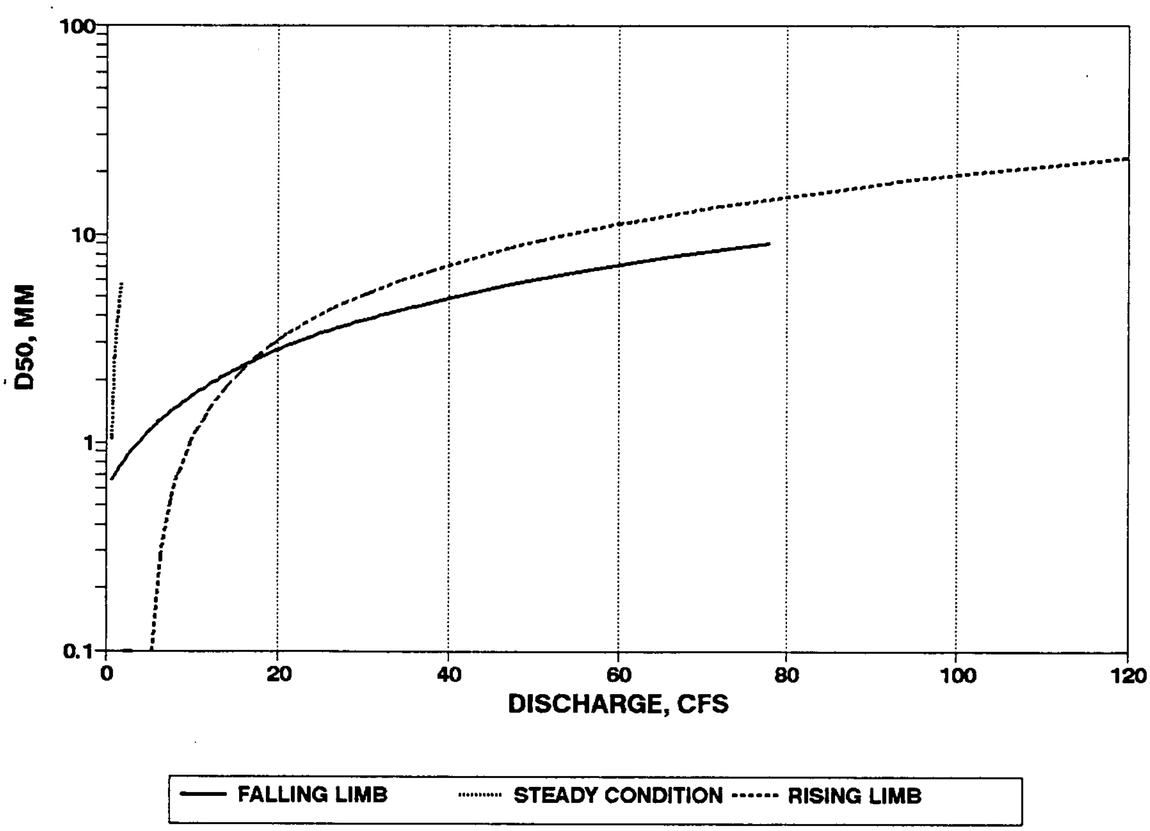


Figure 38 Median particle size variation with discharge for rising and falling limbs of hydrographs,1971-1989 data

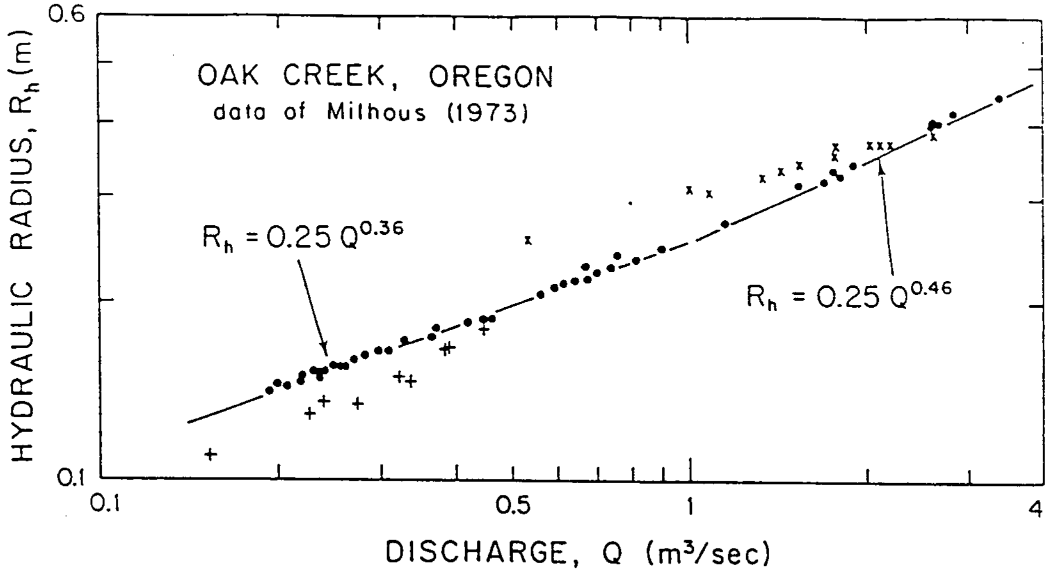
Shear Stress Evaluation

The hydraulics of the flow in the study reach of Oak Creek was reviewed to understand the relationship between flow stresses and discharge. The hydraulic information provided by Milhous(1973) was analyzed to satisfy this objective. The hydraulic radius and mean velocity were plotted as a function of discharge. Figure 39 illustrates the relationships obtained by Komar (1989) for Oak Creek. As the discharge increases, the hydraulic radius and mean velocity both increases. These relationships were used later in evaluation of shear stress and Shield entrainment function.

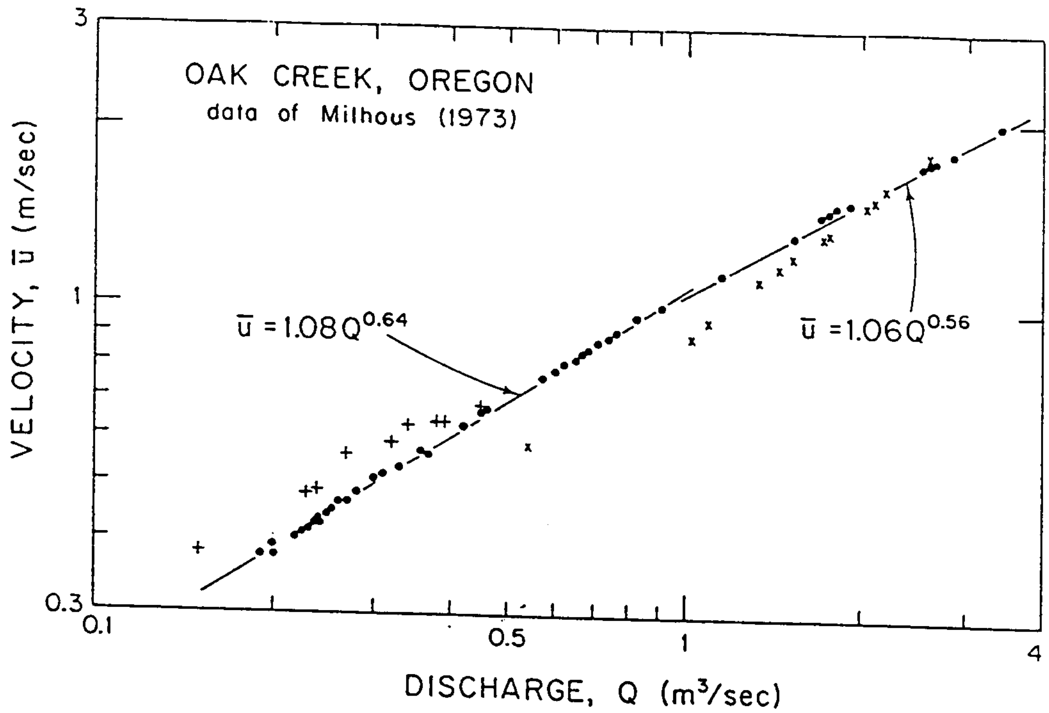
As the discharge increases, the d_{90} size of samples collected in the vortex bedload trap ranged from about 6 mm to 70 mm. This range of sizes is adequately represented in the armor surface, which is the likely source of particles which govern the flow-competence evaluations. Because larger particles were collected in samples during the winter 1971 than for the composite size of d_{90}, it can be assumed that the flow-competence evaluations undertaken with this data were not affected by limitations in the availability of large sizes.

It appears that the concept of flow competence is valid for Oak Creek. However, simple correlations between sizes of transported particles and discharges cannot serve as the basis for general relationships for competence evaluations which might apply to other river systems (Komar, 1989).

Some improvement in generality is provided by Figure 40. This relates particle size to the mean flow shear stress required to entrain and transport individual particles from the deposit of mixed sizes found on the bed of Oak Creek. The stresses were calculated using the bed shear stress relationship recommended in equation (6).



A. Hydraulic radius variation



B. Mean velocity variation

Figure 39 Hydraulic radius and mean velocity variation as function of discharge based on 1971 data (Source: Komar, 1989)

A "least squares" fit of the data yields the following relationship:

$$\tau = 41.6\ (d_{90})^{0.34} \tag{31}$$

where the stress units are dynes/cm^2 and the diameter units are cm. This is a selective entrainment relationship, an evaluation of the flow stress required to entrain an individual particle of diameter d_{90} from a deposit of mixed sizes. In that this diameter (d_{90}) is also the representative particle size that the flow can move, equation (31) can be used as a flow-competence relationship for Oak Creek. From a process standpoint, the diameter D_{90} depends on the shear stress of the flow. However, in equation (31) the stress is given as the dependent variable, a form used for application to competence evaluations where a flood stress is to be calculated from the largest particle transported (Komar, 1989).

The diameters in Figure 40 were evaluated from the size distribution analysis for bedload data. As before, the trend in Figure 40 is seen to be strongest at the higher flow stages, that is for stresses which occur when discharges are greater than that required for breakup of the armor.

Figure 40 also contains a similar plot of the flow stress versus the median diameter d_{50} of transported bedload captured in the vortex bedload trap. There is a relatively strong correlation which yields

$$\tau = 110\ (d_{50})^{0.23} \tag{32}$$

for the critical stage associated with breakup of the armor. It is apparent that the scatter of data at these higher stages is less than scatter of data that depends on the d_{90}

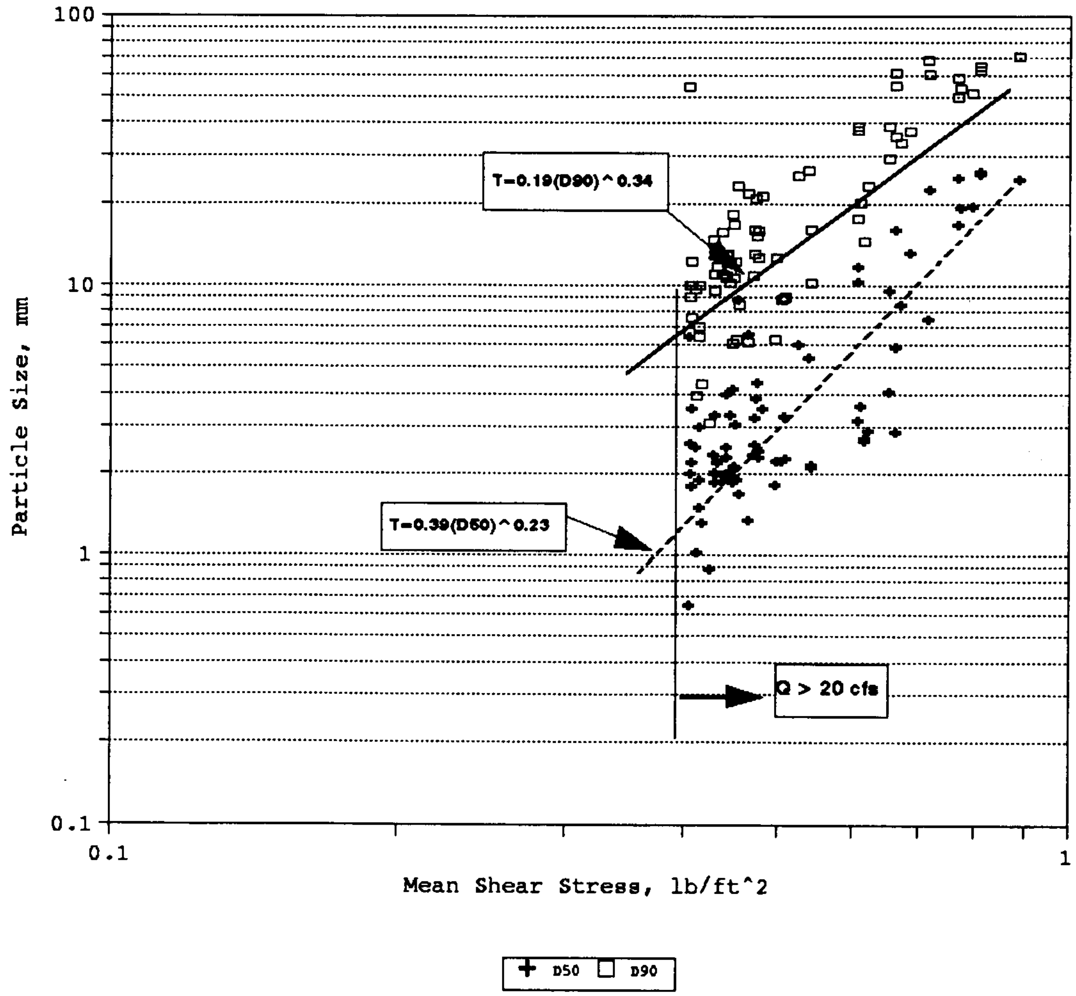


Figure 40 Representative particle size variation with mean shear stress for discharges greater than 20 cfs, 1971-89 bedload data

particle size transported. Undoubtedly, this is because the median d_{50} is based on as few as ten to as many as thousands of particles (depending on the transporting rate), whereas the d_{90} represents a much smaller number of particles.

On the other hand, the dependence of the flow stress on d_{90} is much stronger than on d_{50}, evident in the respective exponents of the two empirical relationships (0.34 versus 0.23). For this reason, it is still preferable to base flow-competence evaluations on the d_{90} rather than on the median size. However, using both computations would provide more confidence in the resulting estimates of the flow's hydraulic conditions. The shear stress relationship with particle size at lower flows shows a wide scatter of data, with no obvious trend. Figure 41 illustrates shear stress variation with particle size for all of the data.

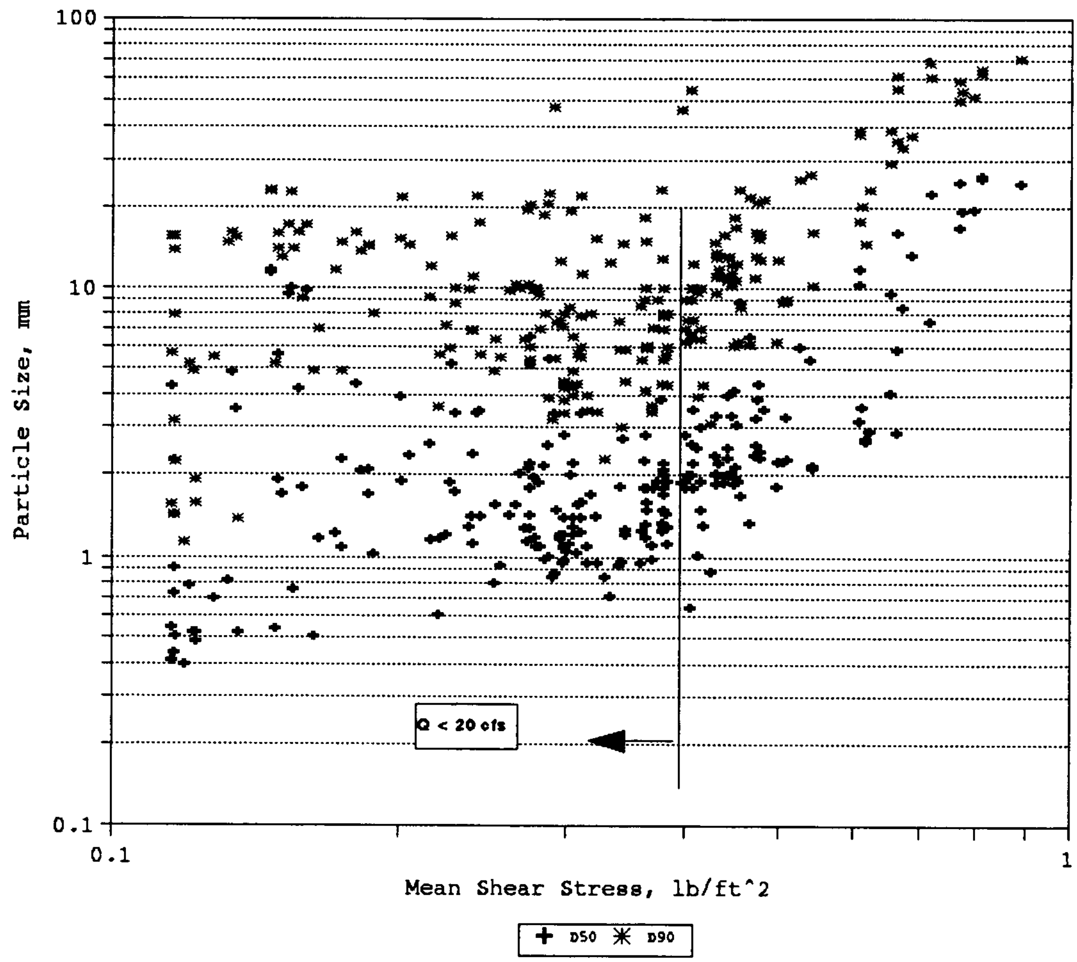


Figure 41 Representative particle size variation with mean shear stress, 1971-89 bedload data

Bed Material Stability Function Evaluation

In prior Oak Creek research, the stability of the bed material was studied by using the simplified Einstein Bedload function (Einstein, 1964). This approach was used assuming that the effects of the particle size distribution of the bed could be represented by a single representative particle size. The simplified method is also more applicable when no suspension occurs. However, the simplified function was used to obtain a general idea of how the observations compared to the function and to obtain some idea of the importance of the armor layer. The stability and bed load functions were calculated using the following equations:

$$\Phi = \frac{q_s}{G_s\ (d_r)^{\frac{3}{2}}\ \sqrt{G_s-1}} \qquad (33)$$

$$\psi = \frac{(G_s-1)\ d_r}{R\ S} \qquad (34)$$

where Φ = bedload transport function;
q_s = bedload transport per unit width;
G_s = specific gravity of solids (2.90);
d_r = representative particle size; and
ψ = bed stability function.

d_{35} is typically taken as the representative particle size (d_r) for use in both the stability function and the transport function. Einstein's function is plotted in Figure 42, for all bedload data during 1971-89. The following assumption was made with the data analysis of 1971-89, which was also made by Milhous (1973) in analyzing his data:

"If one assumes that the stability of the bed material is due to the armor layer, the characteristic particle size used in the stability function should be related to just the armor layer. Consequently, a separate characteristic size could be used for each function".

A good fit was achieved with the data when the d_{35} size was used for the armor layer in the stability function and the d_{50} size of the material below the bed surface was used for the transport function. Figure 42 shows the results of using the d_{35} size for the armor layer and the d_{50} size of the bed material below, as done by Milhous (1973).

The data points fall below the Einstein curve. A similar trend occurs in the 1969-72 data, but not to the same extent. This suggests that for some given stability function, the actual transport is less than expected by Einstein's theory. One possible reason for the values falling below the Einstein curve is that the armor layer is located on top of the material below it and any finer-sized material located within the armor layer is protected by the large particles until a high percentage of the armor layer is in motion. This may mean that the transport function gives too high of value for an armored stream. The material is not as free to move and is more protected from the flow than if the armor layer did not exist. A "hiding" factor to address this, was used in the complete Einstein relation. He stated that the lift exerted may be less on small particles which are between or under the larger ones, and therefore the stability function is greater. For the bed load, his charts are not applicable to the simplified equations, but using larger values for the stability function would cause a better fit of the data.

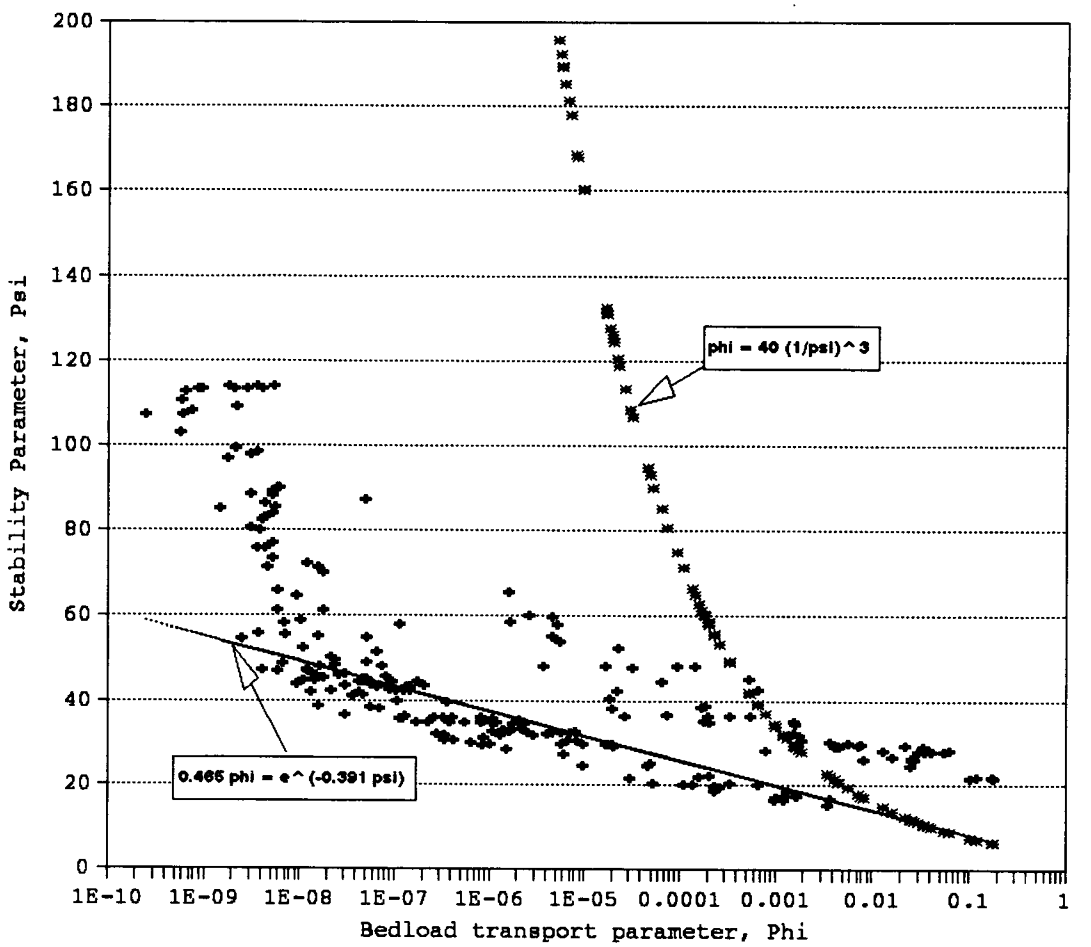


Figure 42 Comparison of bedload data to Einstein bedload function, 1971-89 data

The second possible reason for the values falling below the Einstein curve is that considerable suspended material is present. The simplified Einstein approach does not consider the effects for this factor. Some of the stream's energy may be dissipated in maintaining the smaller material in suspension. This could lessen the amount of energy available to help move the coarser material. Therefore, the transport function might again be too large with suspended material present. If much bed load transport is occurring, this is probably not extremely significant.

A single "critical" discharge value is often assumed to apply to incipient motion and bed stability. Such values form part of most bed load formulas. However, differences in such values have been found for several runoff hydrographs in sequence, even with enough intervening time for full bed stability to be achieved. Apparently there are differing residual effects from past events, causing a range of "critical" discharges to occur over time. Therefore, a representative value may be a central value in this range. Figure 43 illustrates the variation of Shield parameter with Einstein parameter. The data indicate two separate lines of fit to the data.

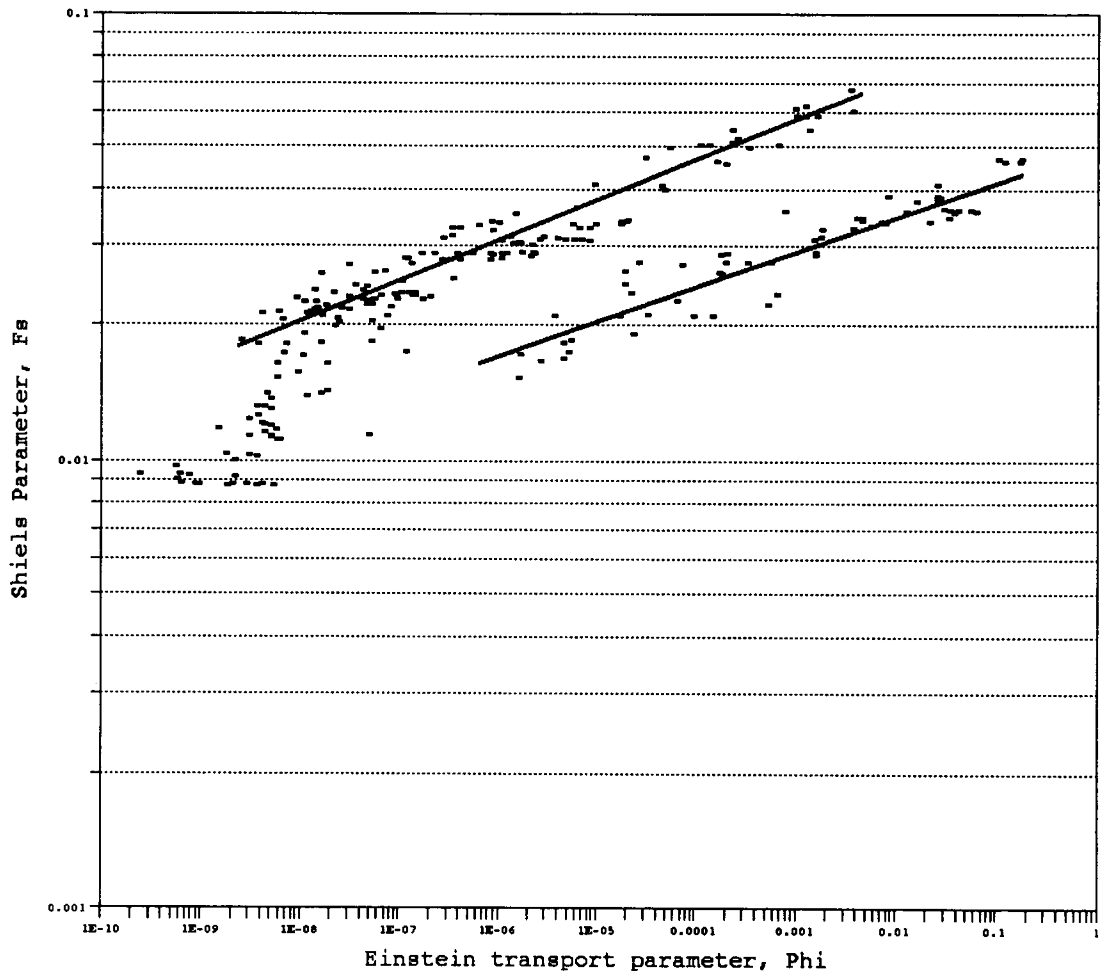


Figure 43 Shields parameter versus Einstein parameter, 1971-89 bedload data

Figure 43 also indicates that transport is possible at very low values of Shield parameter. It is clear that there is some probability of sediment transport at all levels of bed shear stress and, in the words of Paintal (1969), " this probability is never zero except in still water".

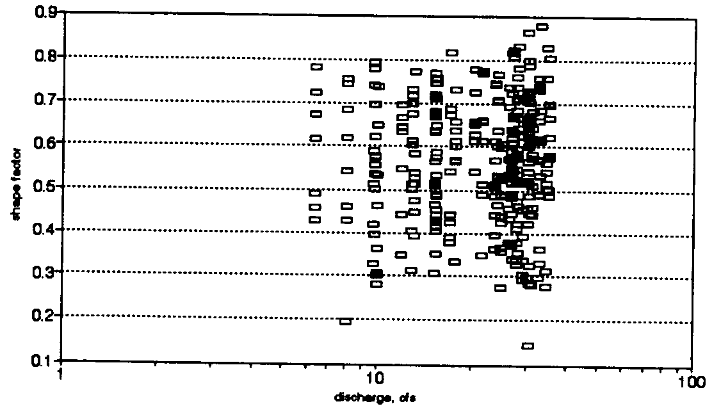
Particle Shape Characteristics

Most of the studies on incipient motion are based on nearly spherical, uniform particles. Bedload transport relationships do not specifically account for the effects of particle shape on particle motion.

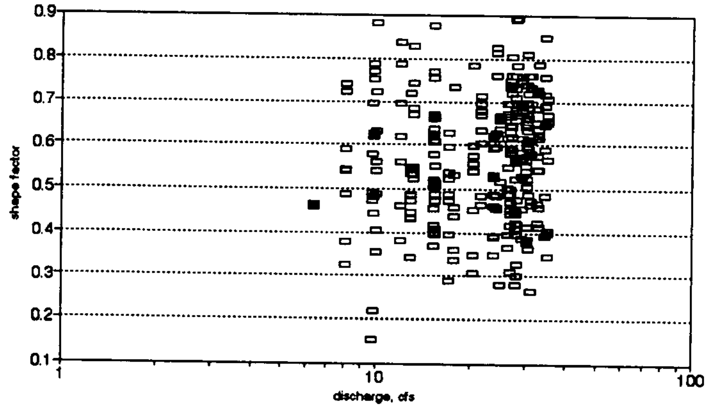
These effects were studied for several particle size ranges (3/8" to 2") in Oak Creek gravel-bed with an armored layer. Particle shape may be quantified by using the Zingg classification or the Corey shape factor (Krumbein, 1941).

To relate the effect of particle shape to transport, the particle shape factor for bedload samples in each size category (3/8" to 2") was plotted versus flow discharges. Figure 44 illustrates particle shape variation with discharge. The analysis of data indicates a wide variation in particle shape factor at every flow discharge for each size fraction. The variation of shape factor is between 0.2 and 0.9.

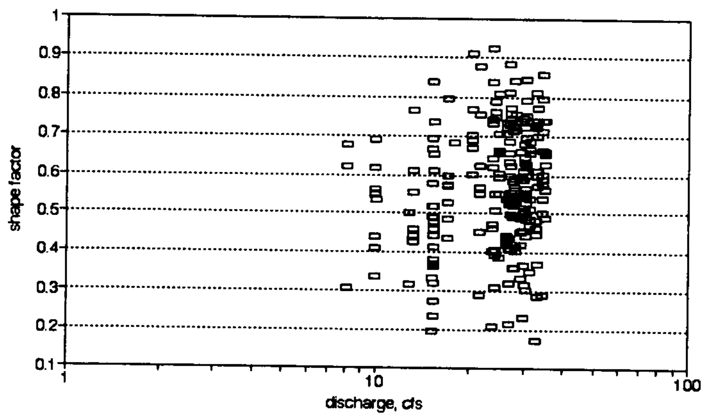
Particle shape factor frequency analysis was conducted for all the measured particles. The result of analysis suggests a variation between 0.5 and 0.7 for most of particles, with an average shape factor of about 0.6. Figure 45 illustrates shape factor frequency distribution for all particles in all size fractions. Most size fractions roughly follow a normal Gaussian distribution for the shape factor. A skew toward higher shape factor for the 1-1/2" size fraction of particles is thought to be mainly a



A. All particles (3/8")

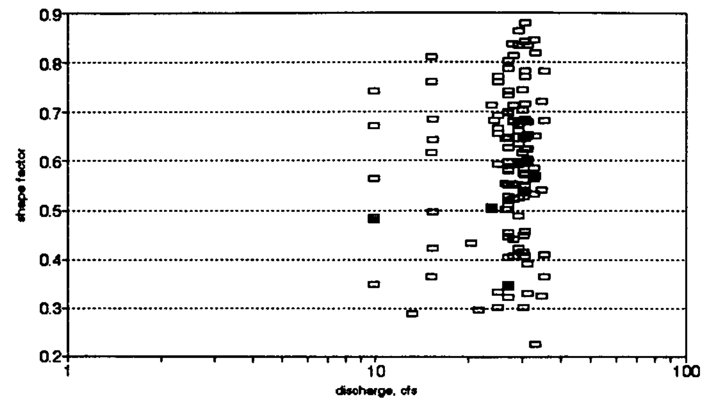


B. All particles (1/2")

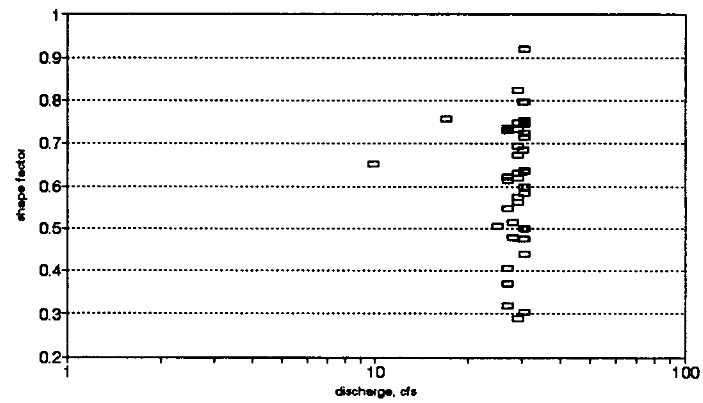


C. All particles (3/4")

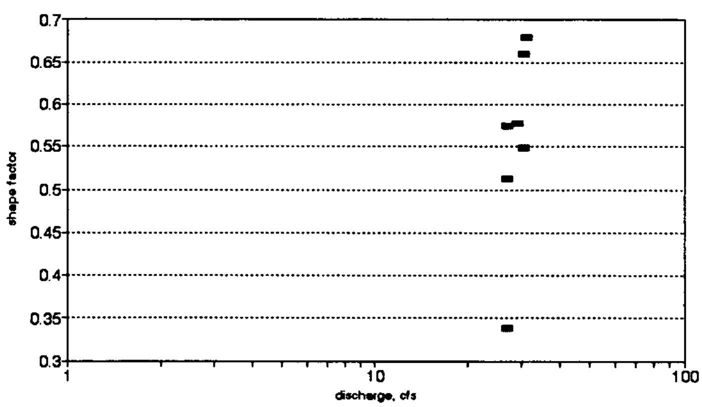
Figure 44 Particle shape factor variation with discharge, by size class, 1989 bedload data



D. All particles (1")



E. All particles (1 1/2")



F. All particles (2")

Figure 44 Continued

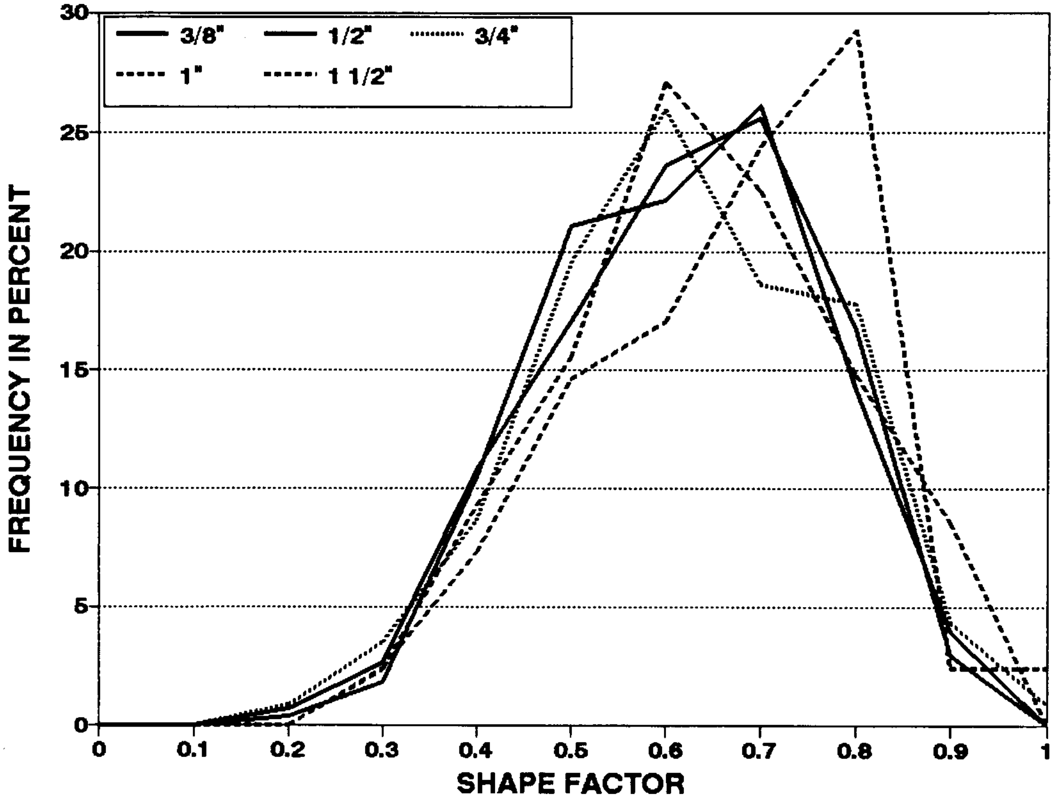


Figure 45 Particle shape factor frequency distribution, by size class, 1989 data

result of having fewer particles available for analysis in that size range compared to the other particle size fractions.

A graph of particle shape variation with discharge is shown in Figure 46. This shows more clearly than in Figure 44 that particle shape factor is independent of discharge and of size fraction.

Zingg's classification analysis was also performed to categorize particle shapes and to evaluate if increases in discharge and particle size have any effect on particle shape class. Such a classification, however, is considered to give a qualitative description that does not, as a rule, bear any relation to the dynamic behavior of these particles during transportation. Figure 47 illustrates relationship between particle Zingg ratios and relative length for particle size ranges 3/8" to 2". Zingg shape classification showed very little difference in shape for the size ranges examined.

The relationship of particle shape factor to sphericity was also analyzed for different particle sizes. Figure 48 illustrates the relationship between particle shape factor and sphericity for each particle size range. The result of analysis indicates a linear relationship between these two factors for each particle size. The numerous data points on each graph indicate the associated flow discharge values. From prior discussion and as it is observed in Figure 48, the increase in sphericity is independent of the flow discharge. These relationships may be used in evaluation of particle sphericity.

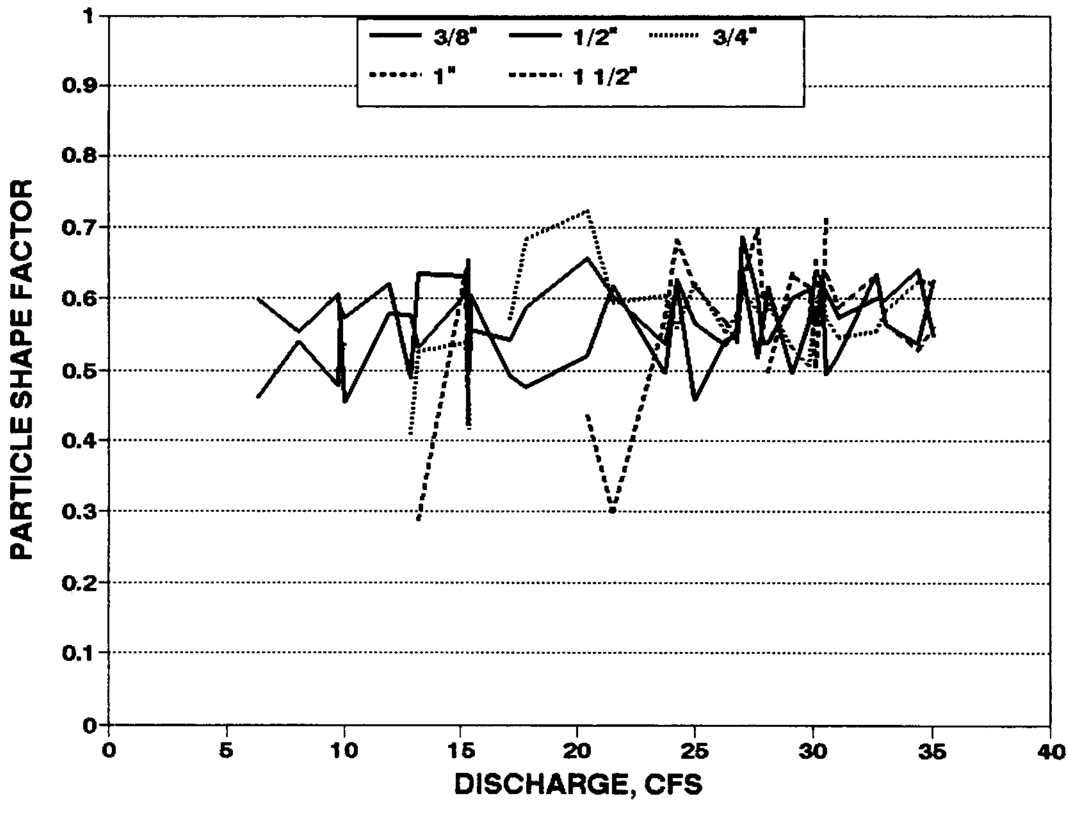
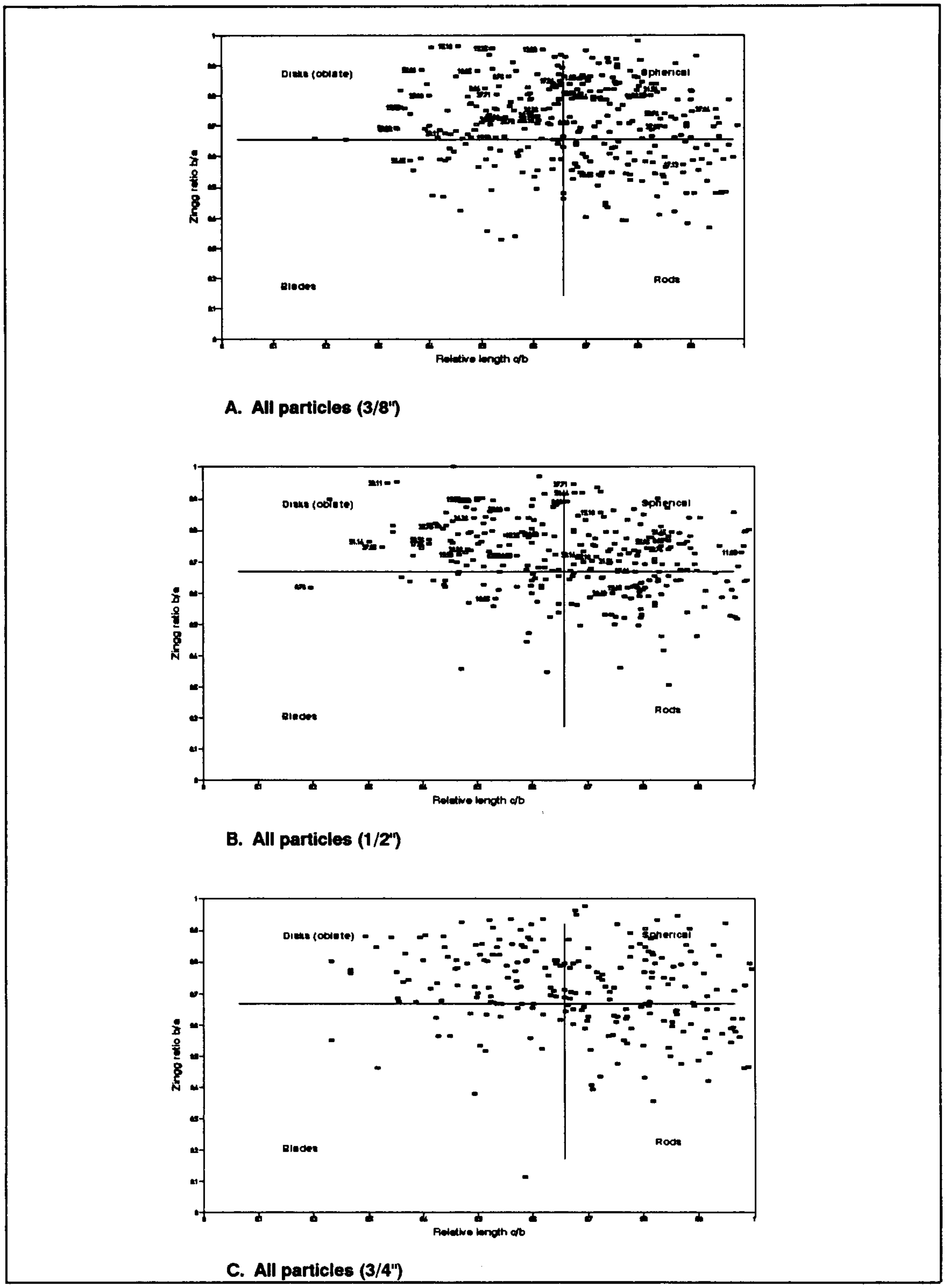


Figure 46 Particle shape factor variation with discharge, by size class, 1989 data

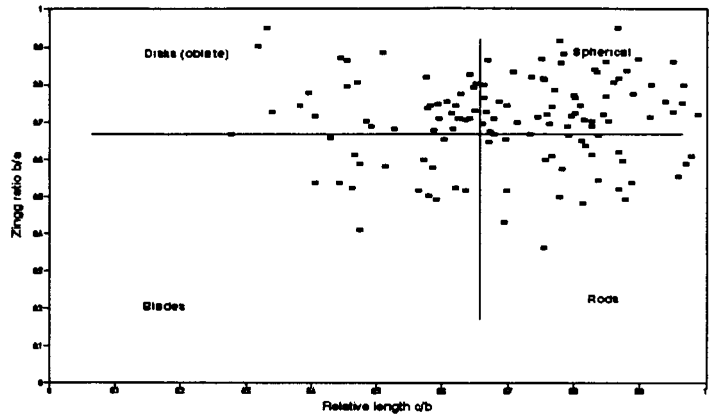


A. All particles (3/8")

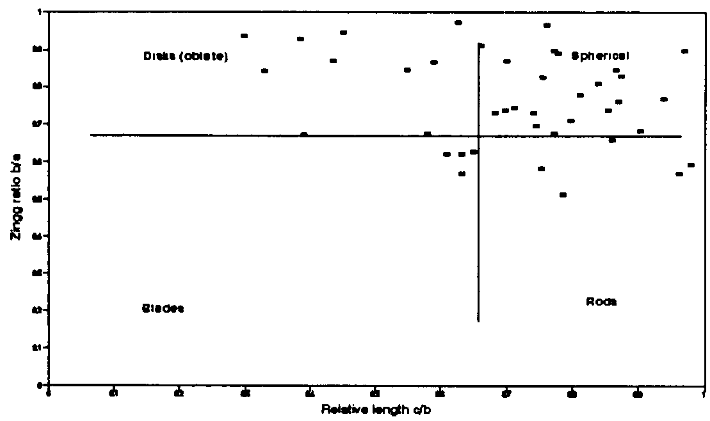
B. All particles (1/2")

C. All particles (3/4")

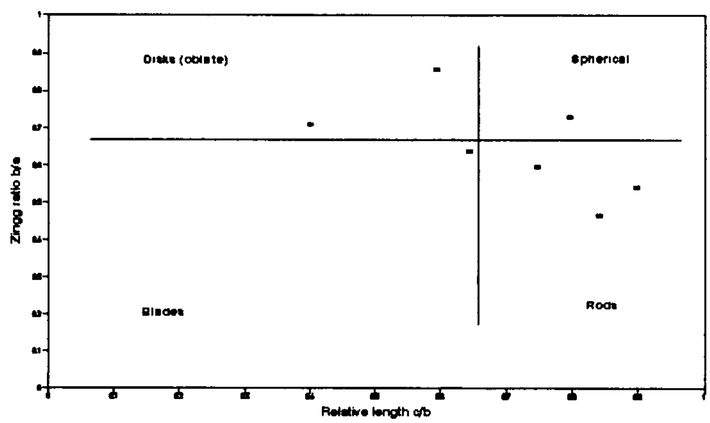
Figure 47 Ratio of Zingg classification versus relative length, by size class, 1989 data



D. All particles (1")



E. All particles (1 1/2")



F. All particles (2")

Figure 47 Continued

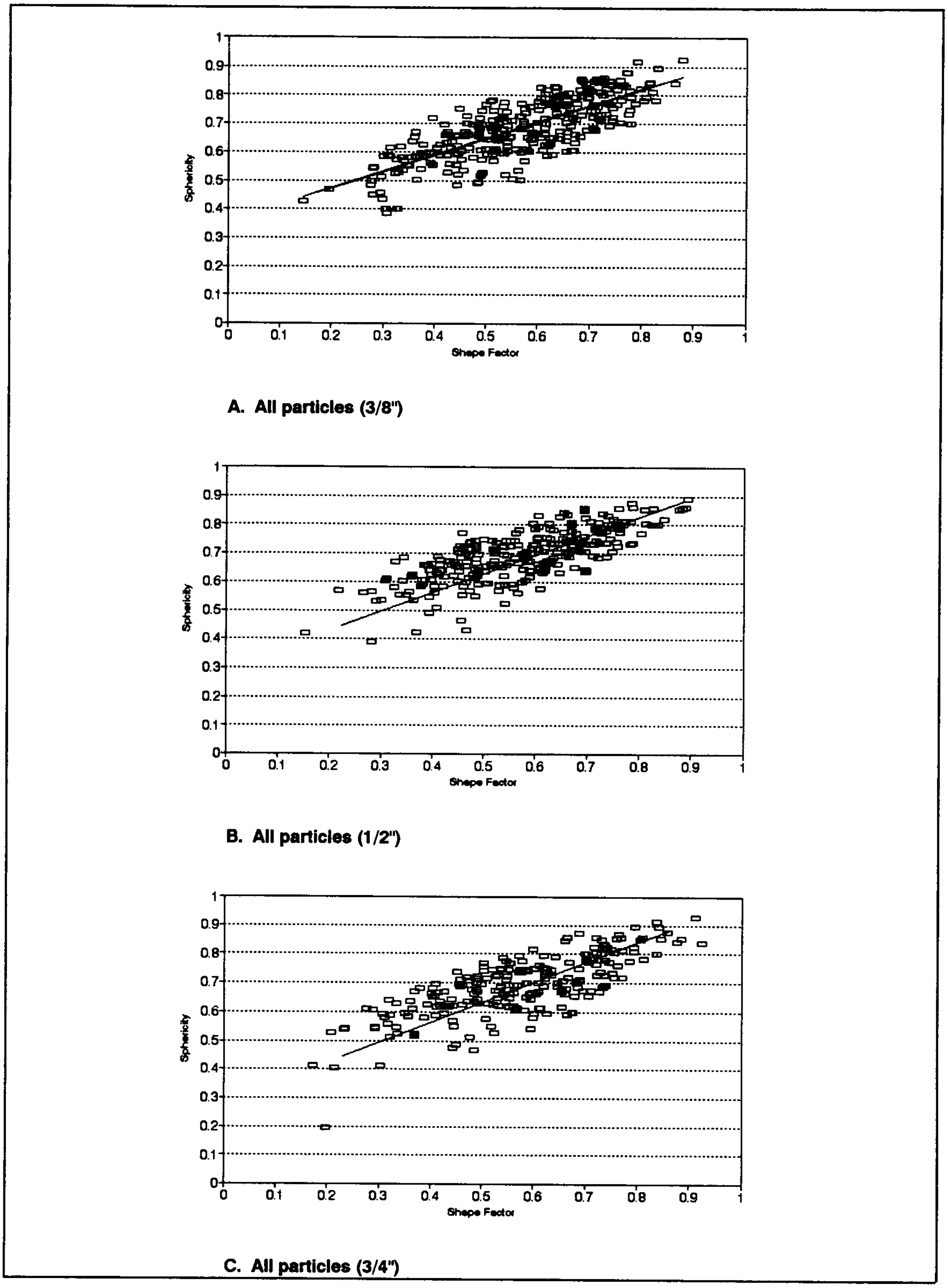
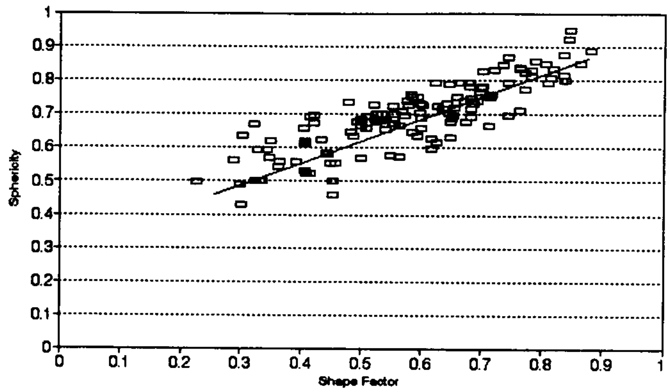
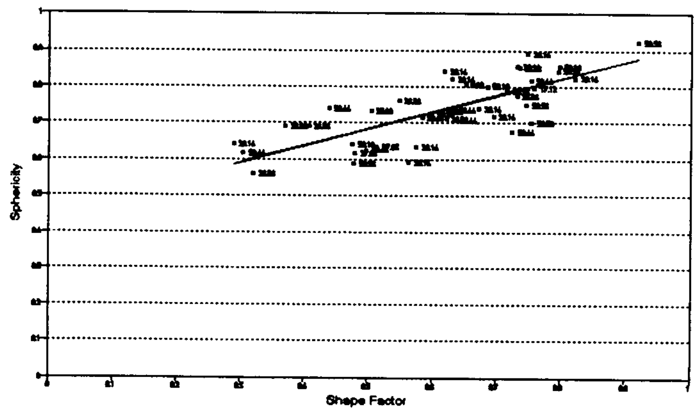


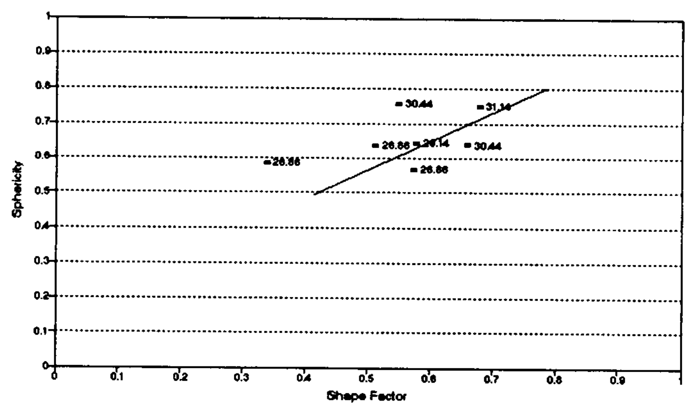
Figure 48 Particle sphericity variation with shape factor, by size class, 1989 data



D. All particles (1")



E. All particles (1 1/2")



F. All particles (2")

Figure 48 Continued

In general, from the foregoing analysis, gravel particles were found to initiate motion in a manner that is independent of particle shape. One explanation for this independency of particle shape to discharge may be that for a natural bed surface many particles rest in imbrication-like orientations that give them the best protection against disturbance, probably a result of their coming to rest gradually during a period of decreasing flows, rather than being abruptly or randomly redeposited from motion. But even when painted particles were placed randomly in the bed surface, there was no evident selectivity for initiation of motion based on particle shape.

The investigation of particle shape relationships provides a better understanding of the effects of particle shape on bedload transport. It appears that particle shape does not have a significant effect on bedload transport relationships for gravel bed streams. However, the shape effect can be incorporated into current bedload transport relationships with a more homogeneous bed of a particular shape (e.g., disc-shaped) such as described by Moore (1994), to better understand bedload transport rates.

Particle Weight Distribution

The effect of particle weight on bedload transport was also analyzed. A total of 989 particles in the size ranges of 3/8 inches to 2 inches were weighted. Table 7 illustrates the variation of particle weight for each size range. Figure 49 shows a wide variation of particle weight with discharge for each particle size. A frequency analysis was performed for each size class of particles. The results of this analysis are shown in Figure 50 as cumulative frequency distributions. As shown there, a particular measured weight may occur in more than one size class. This may be justified on the basis that particles in each size class cover a wide range between the two defining sieves for that size class. Hence, two particles in adjacent size classes may have similar median diameters but different shapes, such that the particle with the smaller median diameter can actually be heavier. Another possibility may be variation in the specific gravity of particles, although it has been shown elsewhere that the variation is small.

Figure 51 illustrates the average values of particle weight for each group of particles in a size class at each observed discharge. The horizontal lines of best fit suggest equal mobility of particles within each class, rather than moving the smaller ones at lower discharge and the larger ones at higher discharge.

Table 7 Weight data summary for measured particles, 1989 data

Size Range (inches)	Number of Particles	Measured Weight (gr)		
		Minimum	Average	Maximum
3/8 - 1/2	305	1.68	2.50	3.31
1/2 - 3/4	276	4.25	6.74	10.24
3/4 - 1	231	9.45	17.58	26.83
1 - 1 1/2	129	32.30	48.76	76.87
1 1/2 - 2	41	99.00	120.68	142.90
2 - 3	7	290.50	354.45	418.40

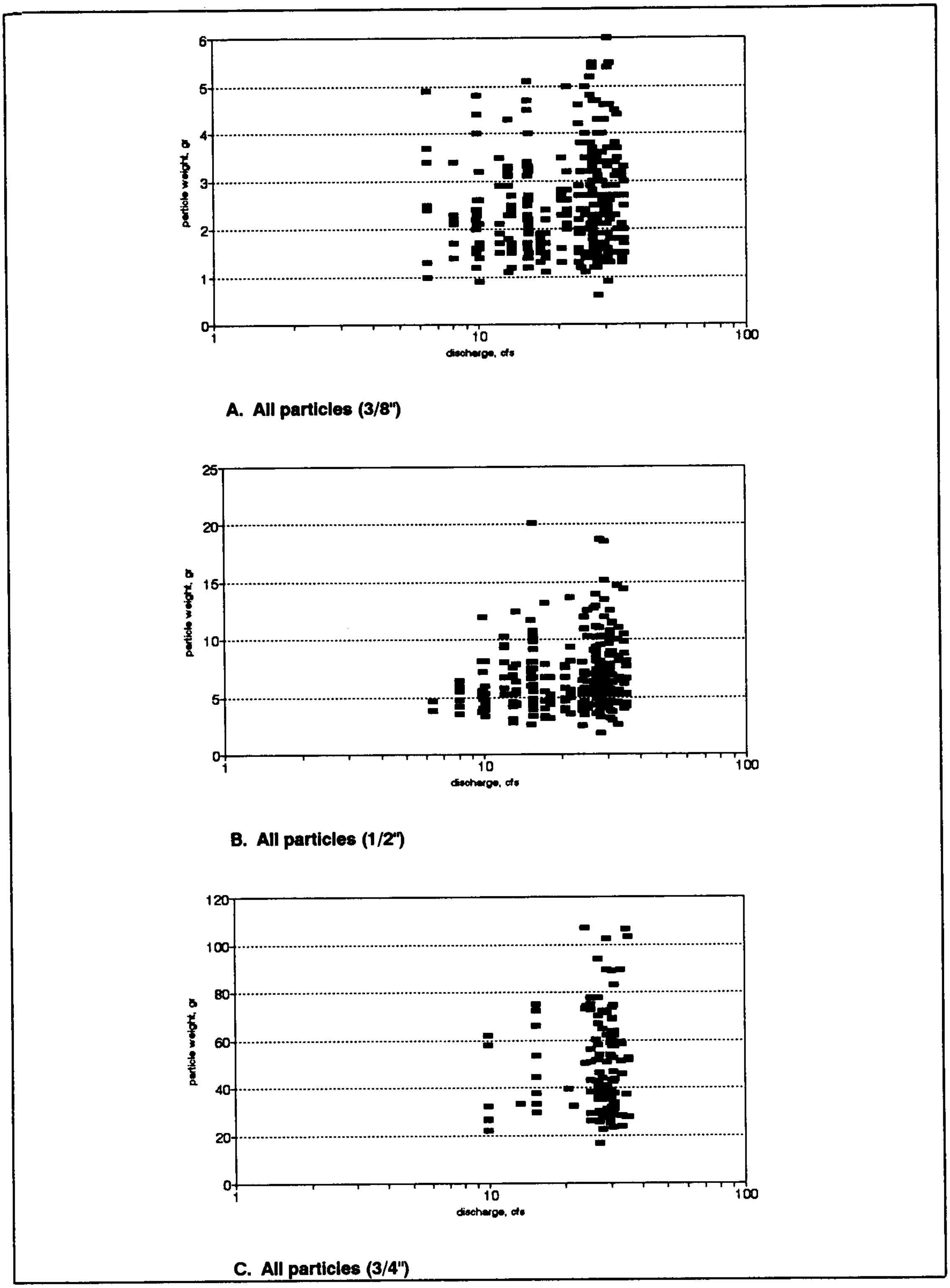
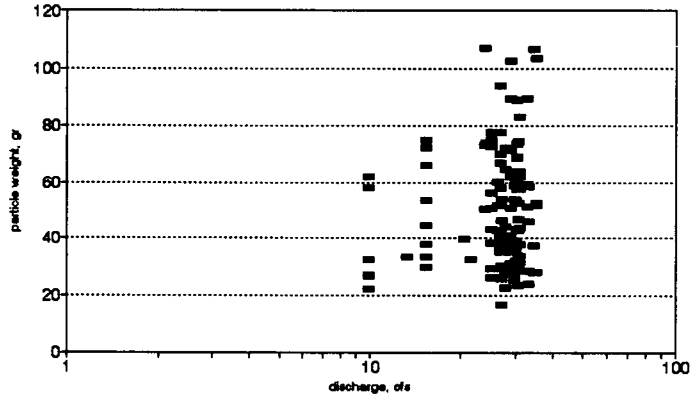
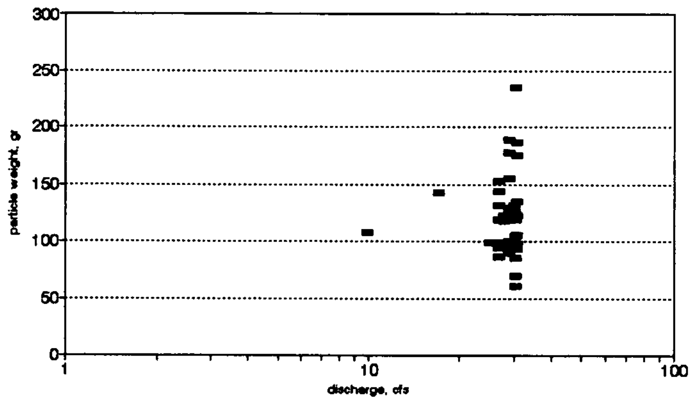


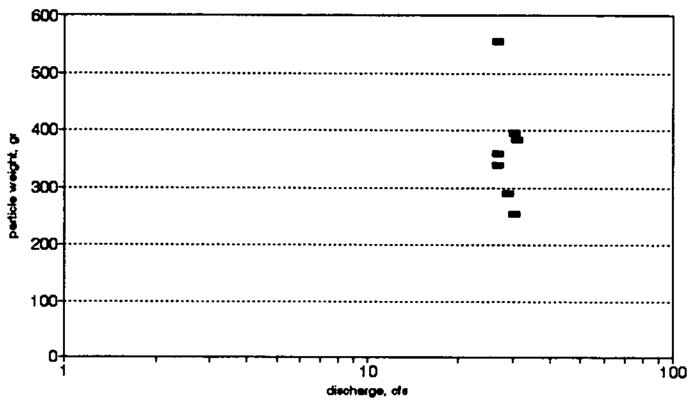
Figure 49 Particle weight variation with discharge, by size class, 1989 data



D. All particles (1")



E. All particles (1 1/2")



F. All particles (2")

Figure 49 Continued

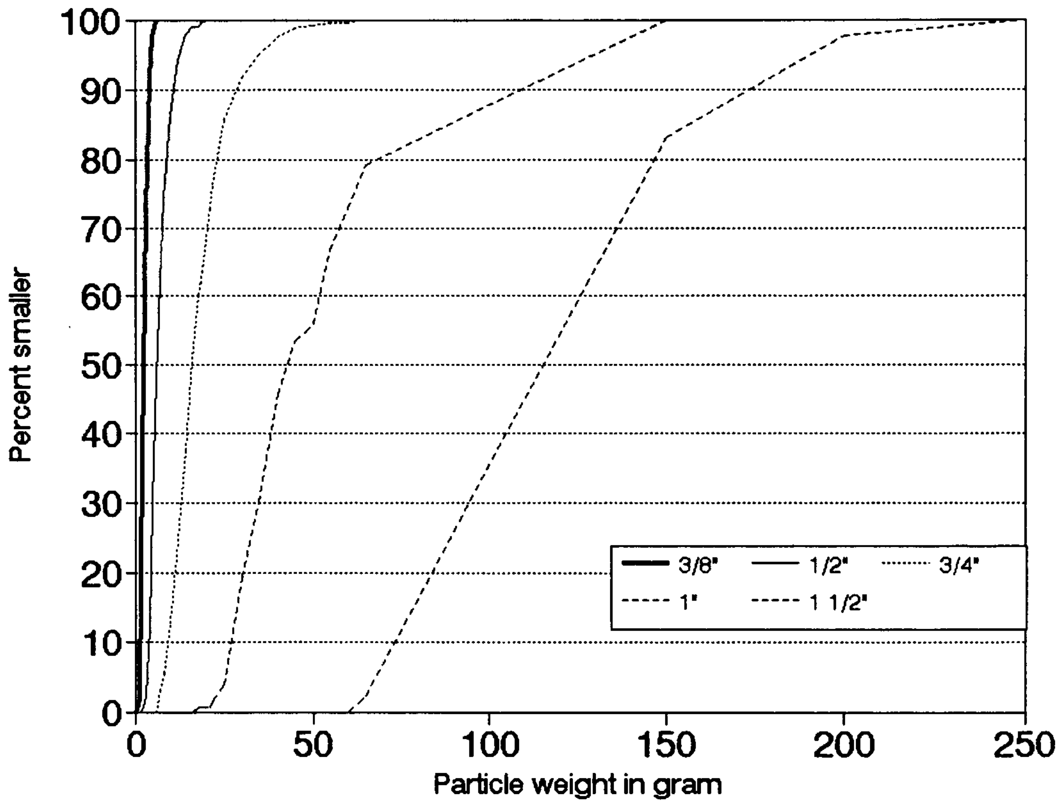


Figure 50 Particle weight frequency distribution, by size class, 1989 data

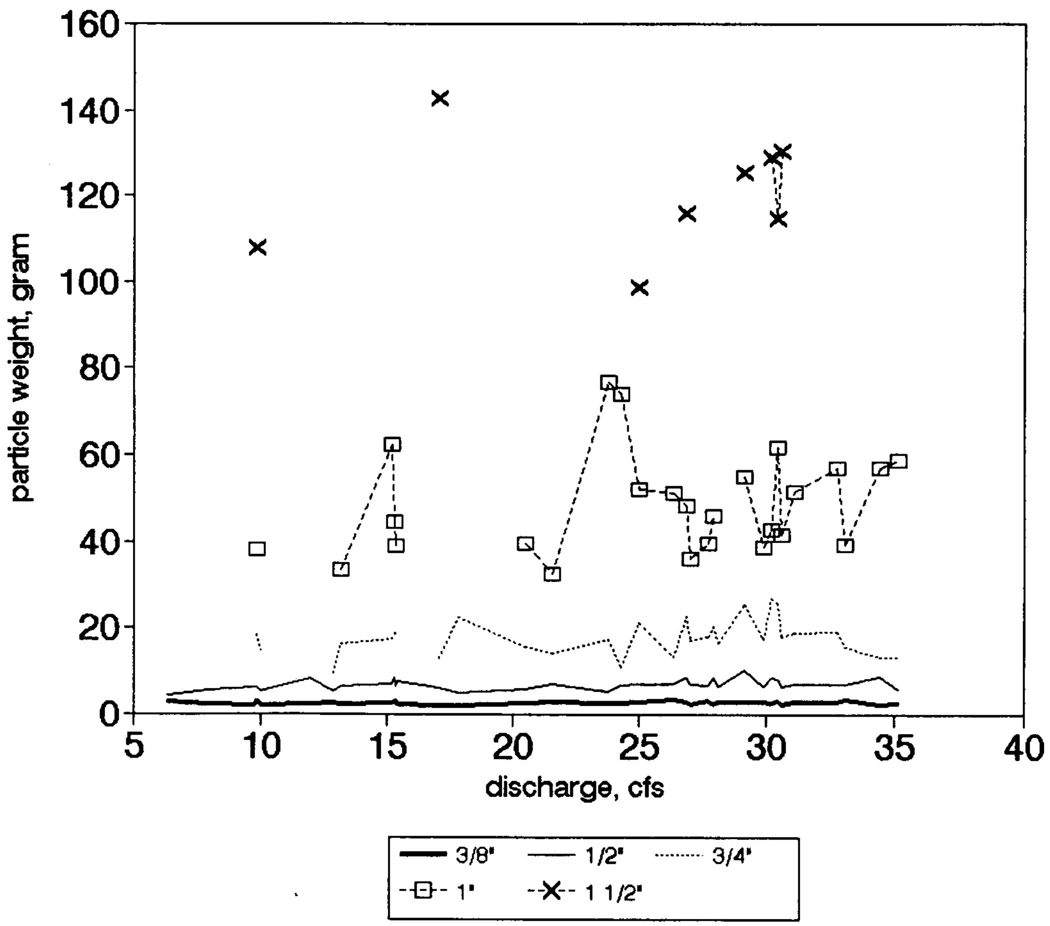


Figure 51 Average particle weight variation with discharge, by size class, 1989 data

Bedload Relationship

A problem in developing bedload-transport relationships is that the sediment characteristics are highly variable and difficult to describe analytically. Most researchers have assumed that the bed material follows a log-normal or Gaussian distribution, and use one or two grain-size parameters such as the median size or some coarser percentile to characterize the sediment as a whole.

Komar (1990a) stated that in many fluvial systems the bed material is not log-normally distributed, but instead is bimodal or highly skewed. Bedload equations based on a single sediment parameter will be inadequate in such streams, and will give inconsistent results from one stream to another which may have the same median grain size but differ in their overall distributions of bed-material sizes. The bimodality in bedload particle size distribution was also observed in Oak Creek (see Figure 25).

When general bedload transport occurs, the total calculated amount of bed material moved will be relatively unaffected by the exact choice of discharge selected as "critical" to incipient motion under such circumstances. However, when runoff events involve only moderate increases in discharge, the critical discharge used to be calculate bedload transport and the duration of time when discharges exceed the selected critical value become very important in determining the total amount of bed material that is transported.

Many investigators have pointed out the important interaction between the armor layer and the movement of material as bedload (e.g., Milhous, 1973; Klingeman and Emmett, 1982; and Parker et al., 1982) they have shown that of the existing bed load equations is made quite tenuous when an armor layer exists. The armor layer is the single most important factor in limiting the availability of stream bed sediment and in controlling the relationship of stream flow and sediment load in a gravel-bottomed stream. The armor layer controls the sediment transport system by regulating the reservoir of sand and finer particles in the stream bed and by protecting the bed material from entrainment in the flow. At high flows the armor layer controls the rate of release of material to the bed load and suspended load of the stream; at intermediate flows it prevents fine sand in the bed from being entrained in the flow; at low flows it filters out fine material.

The behavior of the "fines" reservoir for different portions of the runoff hydrograph was perhaps first described by Milhous in 1973. He stated that at a particular flow no bed material is being deposited as the void space available is already filled. As the flow increases, some material is scoured, but below the critical point where motion of the bed material starts, the majority of the finer material is held in this "reservoir". If the flow continues to increase, incipient motion of the armor layer may be reached and exceeded. This armor material starts to move, exposing the finer material to the flow and to transport as suspended load or bed load. This may cause a measurable increase in the suspended load. Assume that the flows are high enough to empty the voids reservoir. As the flow recedes, the armor layer reforms and progressively becomes more stable and acts as a trap for sands and fines until the void spaces are again filled. Then once the reservoir is full and no longer acting as a trap, more small-sized sediment will be transported along the stream instead of being trapped in the bed. This process could begin and end with a partially full or a partially empty voids reservoir, depending upon the flow conditions that occur.

Bed-material transport in gravel-bed rivers is initiated most commonly during runoff events. At other times, the bed is stable for all but a few days or a short season each year (Klingeman and Mcarthur, 1990). This is because the bed material sizes are large enough to withstand the stresses imposed by the flow most of the time. Transport initiation processes require larger flows that must exceed the incipient-motion values.

Figure 52 illustrate typical Oak Creek bedload hydrographs during runoff events. The lower graph is for a period in 1971 and the upper graph is for an event in 1989. As it can be seen, the bedload hydrograph follows the same trend as the discharge hydrograph in each case.

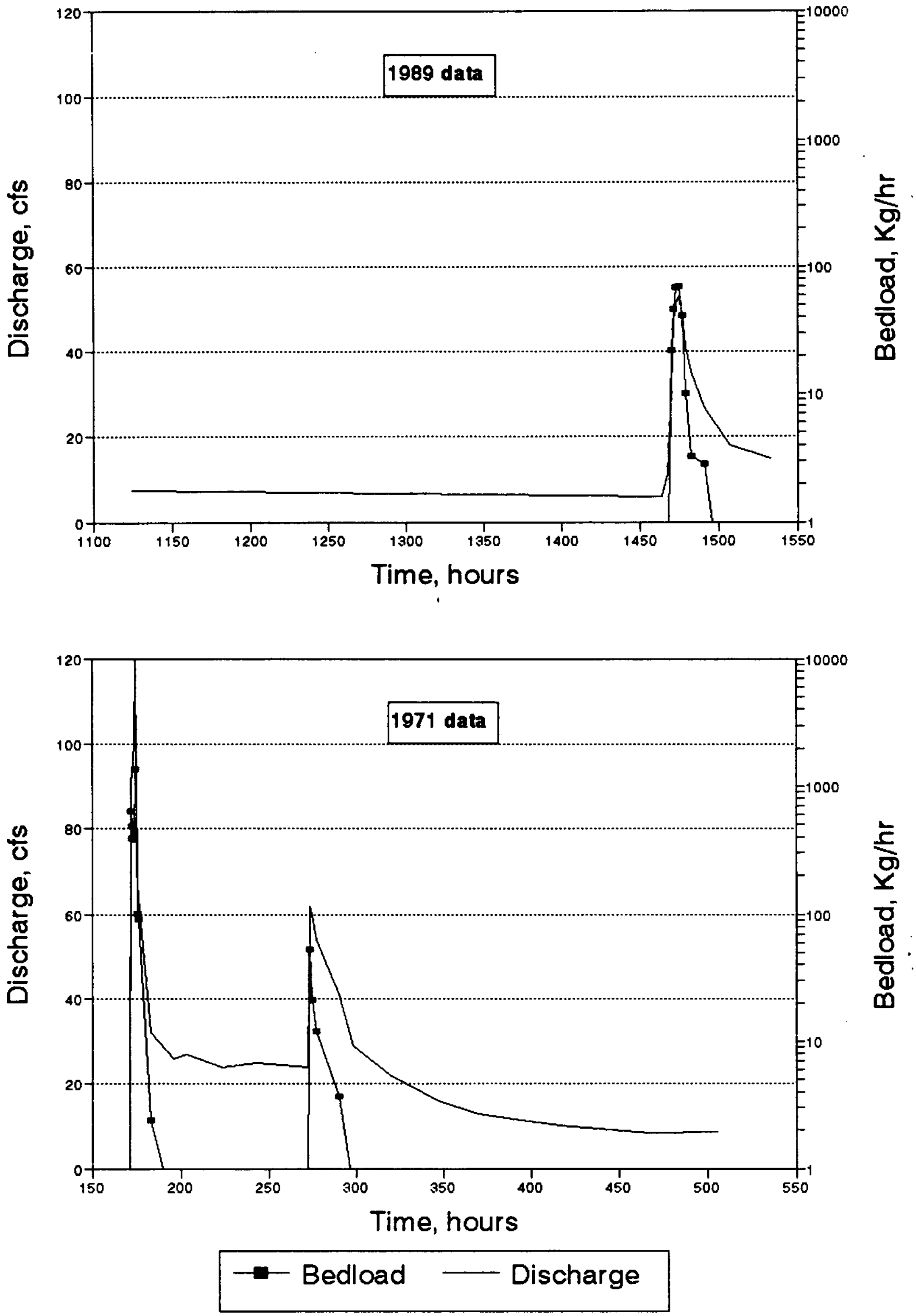


Figure 52 Typical bedload transport during runoff events

To evaluate the bedload transport rate in Oak Creek, all of the bedload data for the period of 1971 - 1989 were sorted with flow discharge. A discharge of 24 cfs was selected as a break point in the trend of data as shown in Figure 53.

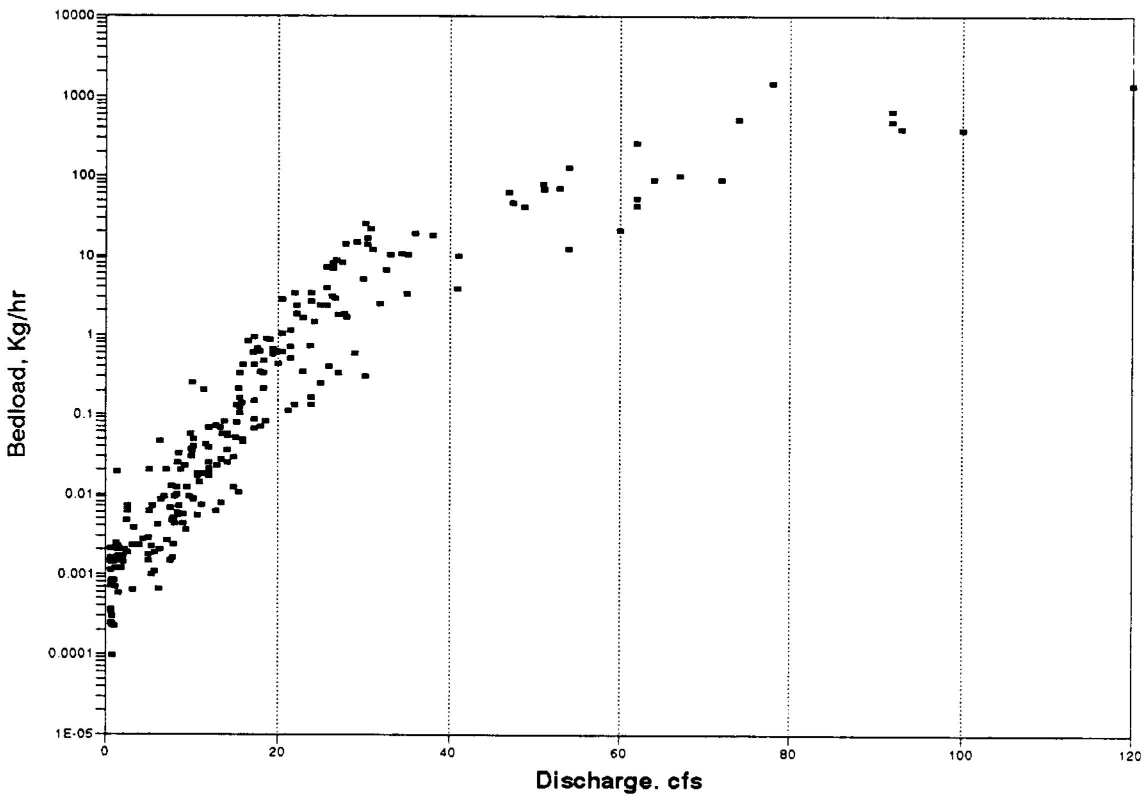


Figure 53 Variation of bedload transport with discharge

All samples collected during 1971-89 were analyzed by statistical curve fitting techniques to find how best their transportation rate could be related to water discharge. Figure 53 illustrates bedload rate variation with discharge for all of the data. As it can be seen, there is a significant change in trend of data at approximately 24 cfs (incipient motion flow).

To further analyze this change in trend of data a more detailed analysis were performed. The bedload data were divided into two groups. Group one included all bedload data for discharges less than 24 cfs and group two included all bedload data greater or equal to than 24 cfs. Figures 54 and 55 illustrate the bedload variation with discharge for these groups. As it can be seen in Figure 54 there is a wide variation of bedload transport for discharges below 10 cfs. An increase of discharge from 10 to 20 cfs, the bedload rate increased by approximately two log cycles. However, it should be noted that the bedload rates at discharges below 24 cfs are minimal (approximately 1 kg/hr for a discharge of 20 cfs).

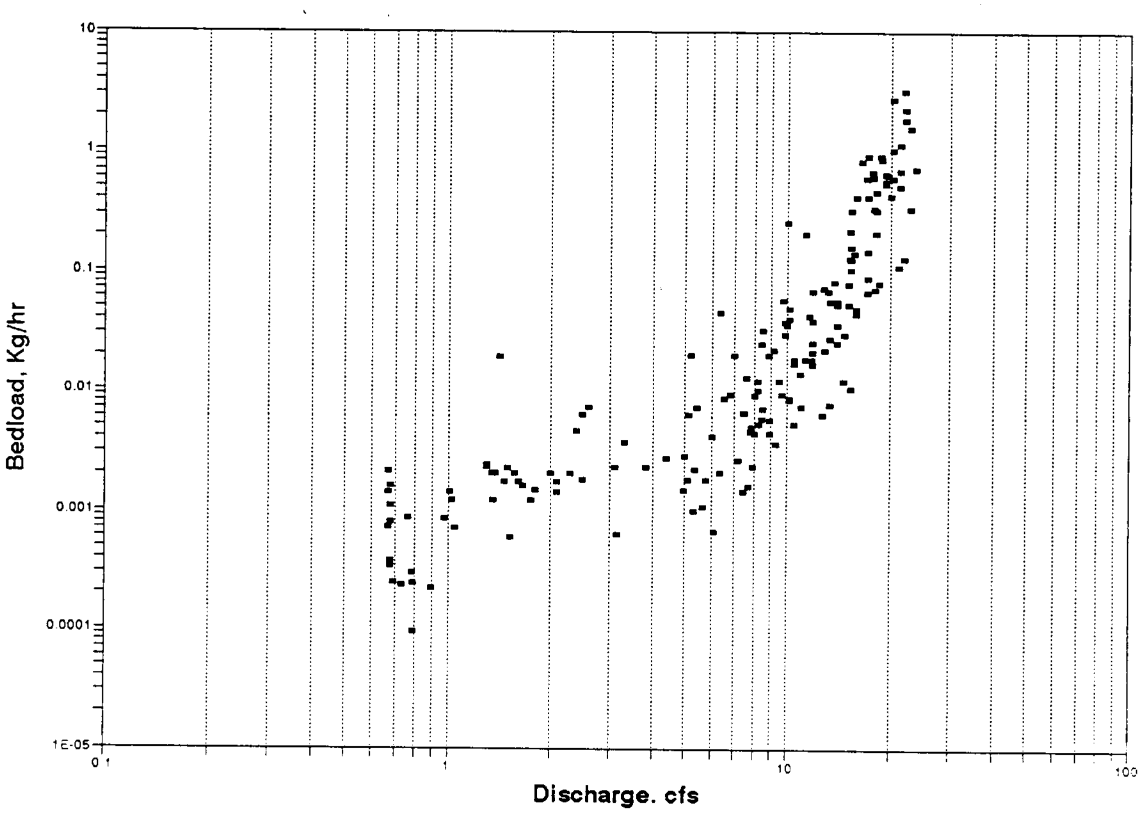


Figure 54 Bedload variation with discharge for Q < 24 cfs

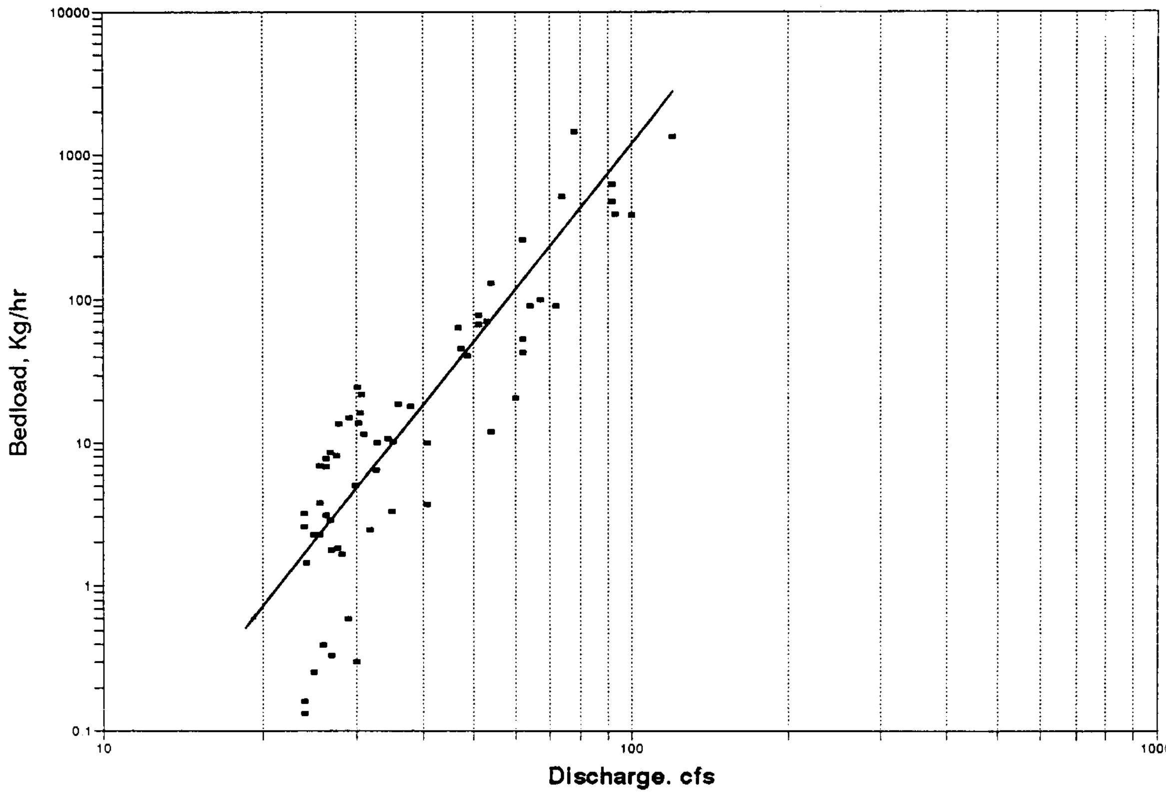


Figure 55 Bedload variation with discharge for Q > 24 cfs

In contrast, for flows above 24 cfs a well defined trend was observed in the bedload relationship with discharge. Figure 55 illustrates the best line fit for these data.

The bedload transport rates were subdivided in four different rates for four constituent sediment sizes: coarse gravel, fine gravel, coarse sand and fine sand. The dividing sizes used to separate these graphs were greater than 9.52 mm, 2.38-9.52 mm, 0.297-2.38 mm, and 0.074-0.297 mm, respectively.

Analyses of these constituent sediment transport relations showed that coarse sand had the highest percentage transport overall for nearly all discharges. However, the relative percent of coarse sand was reduced rapidly as the discharge increased to the critical discharge for break-up of armor layer.

Figure 56 illustrates the variation of each size group as discharge increases.

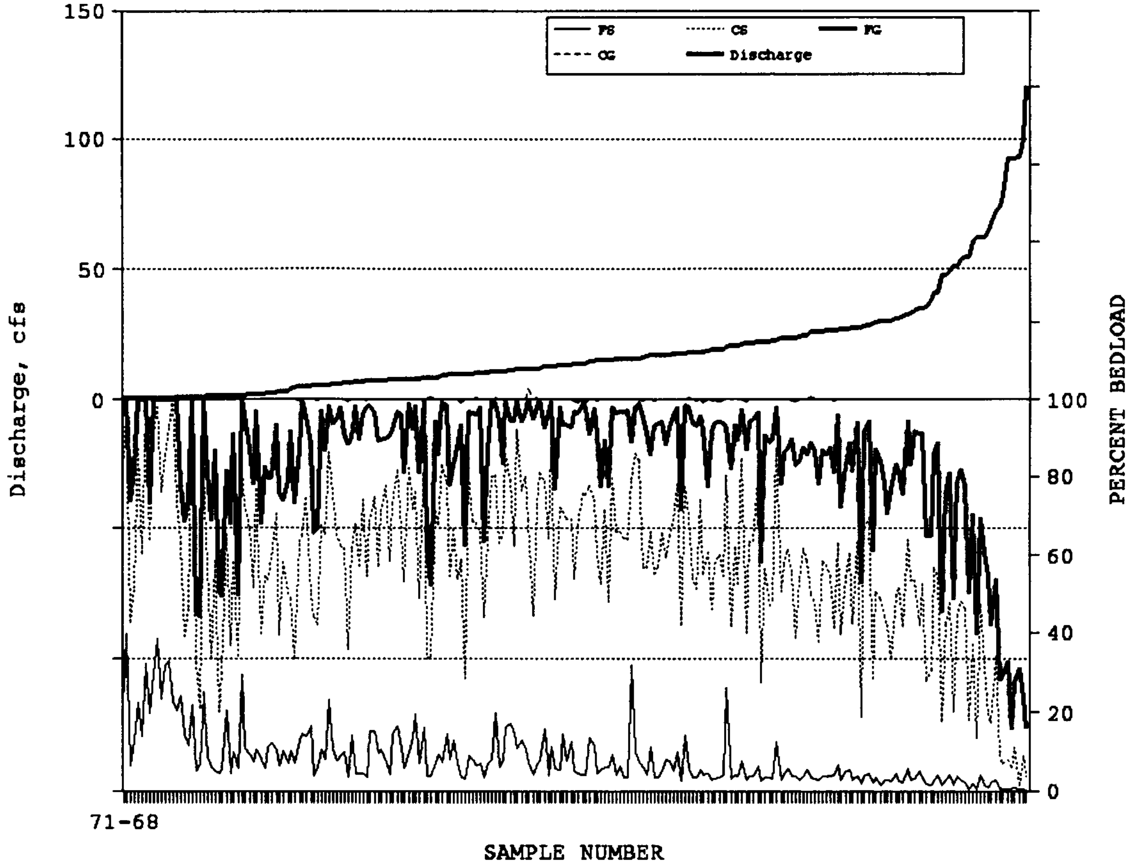


Figure 56 Percent variation of constituent sediment with discharge for all data, 1971-89

As it can be seen there is a random increase in percentage of coarse gravel at very low discharges. The percent of coarse gravel increases rapidly as flow exceeds incipient motion. It is interesting to note that even these extremely low transport rates seem to be functionally related to the strength of flow (here described by discharge). This behavior strengthens the probabalistic theory of particle motion by random turbulence, since the degree of turbulence is recognized to be related to the flow strength. It furthermore points out the weakness of the concept of a single threshold of movement.

The rapid increase in transport of coarse gravel at larger flows, as shown in Figure 56, may be an indication of the selectiveness of the flow in dislodging particles at lower discharges. It is of interest here that the flow does not only flush out the medium-sized particles as described by Neill (1968), but transports the larger ones also as long as the flow is sufficiently turbulent. This sequence of events may conform to what one might expect from a statistical viewpoint.

Figures 57 illustrates the above analysis when done separately for rising limbs and falling limbs of hydrographs. No significant differences were observed for these conditions in the relative transport of the four constituent sizes. Figure 58 shows 5-discharge moving average for both rising and falling limbs of hydrographs.

The changes in total bedload transport rate for rising and falling limbs of hydrographs were also studied. The rising limbs would include the initial movement of a high percentage of the bed material (incipient motion). Data taken during the falling limbs would indicate the flow rates at which the majority of the bed load transport stopped. The time and stream discharge would be known for various bed load transport rates. Figures 59 and 60 illustrate the variation for rising and falling limbs of hydrographs, respectively.

All of the available bedload data were used to develop the curves for bedload relationships with discharge for falling and rising limbs of hydrographs. Variations in the value is enough to make one wonder if these two "individual" curves actually represent a different bed load relationship, but perhaps rather just a slightly different range of data values. Figure 61 illustrates the bedload relationship for different stages of the hydrograph.

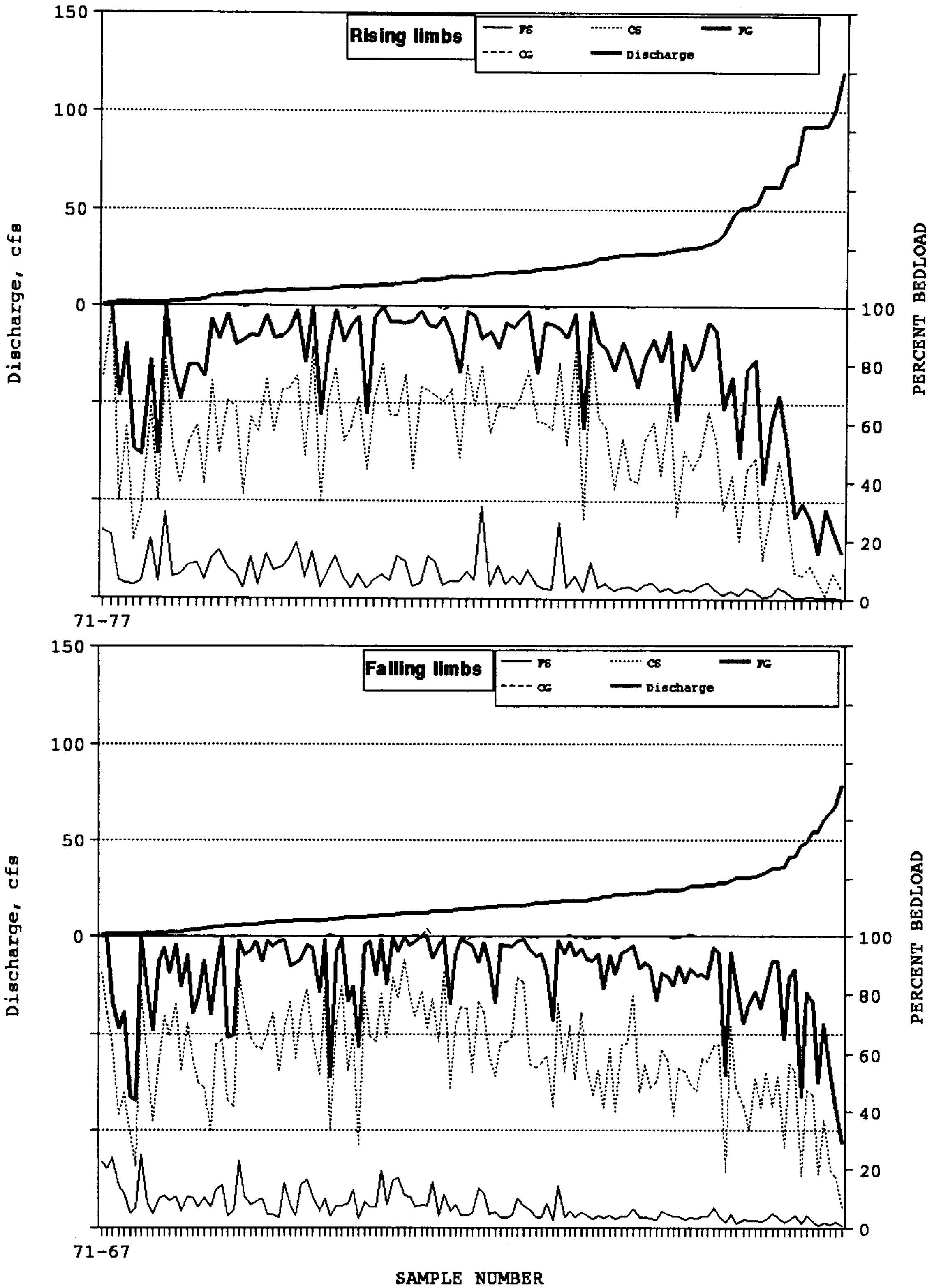


Figure 57 Percent variation of constituent sediment with discharge for rising/falling limbs of hydrographs

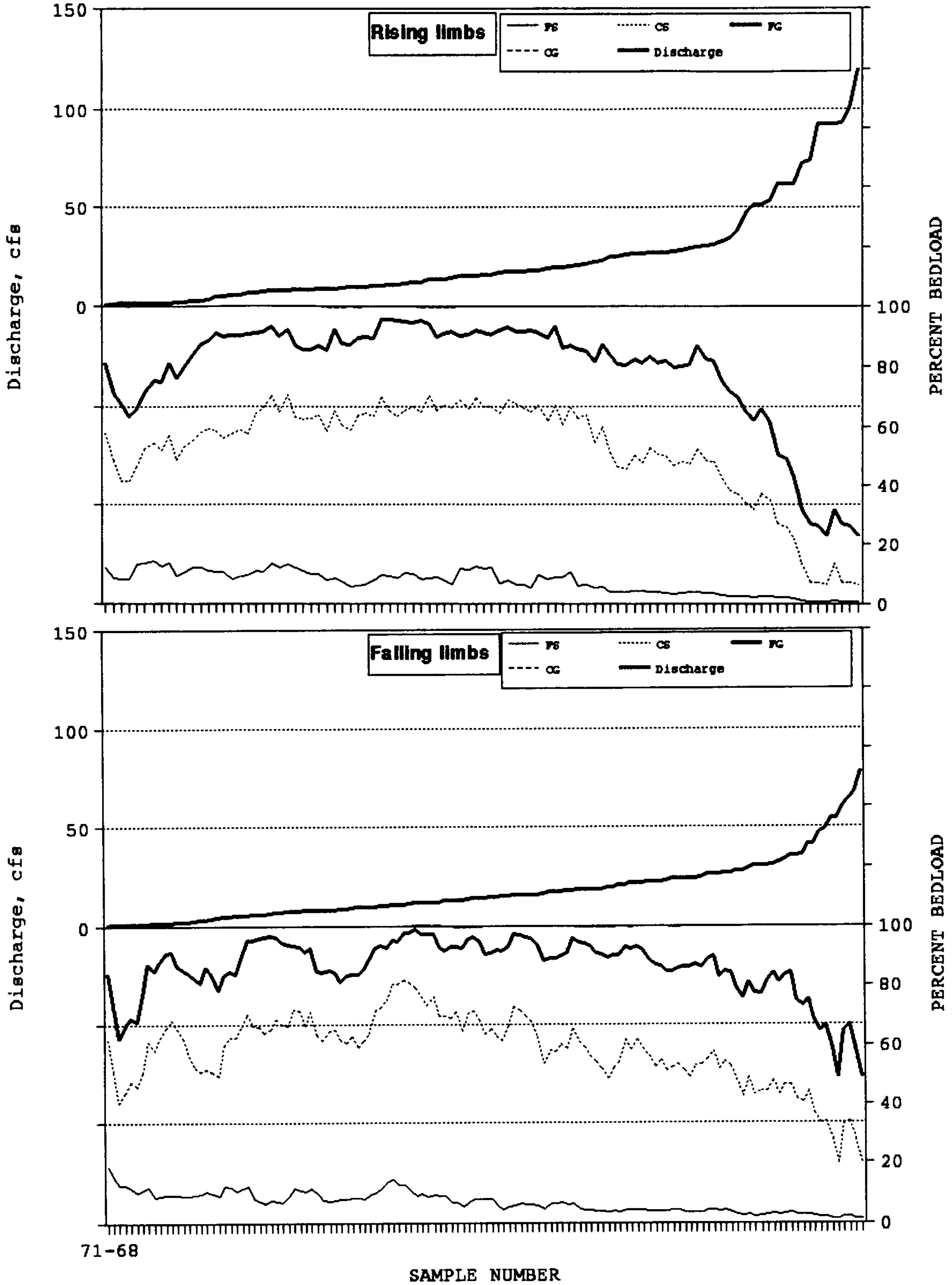


Figure 58 Percent variation of constituent sediment with discharge (5-discharge moving average)

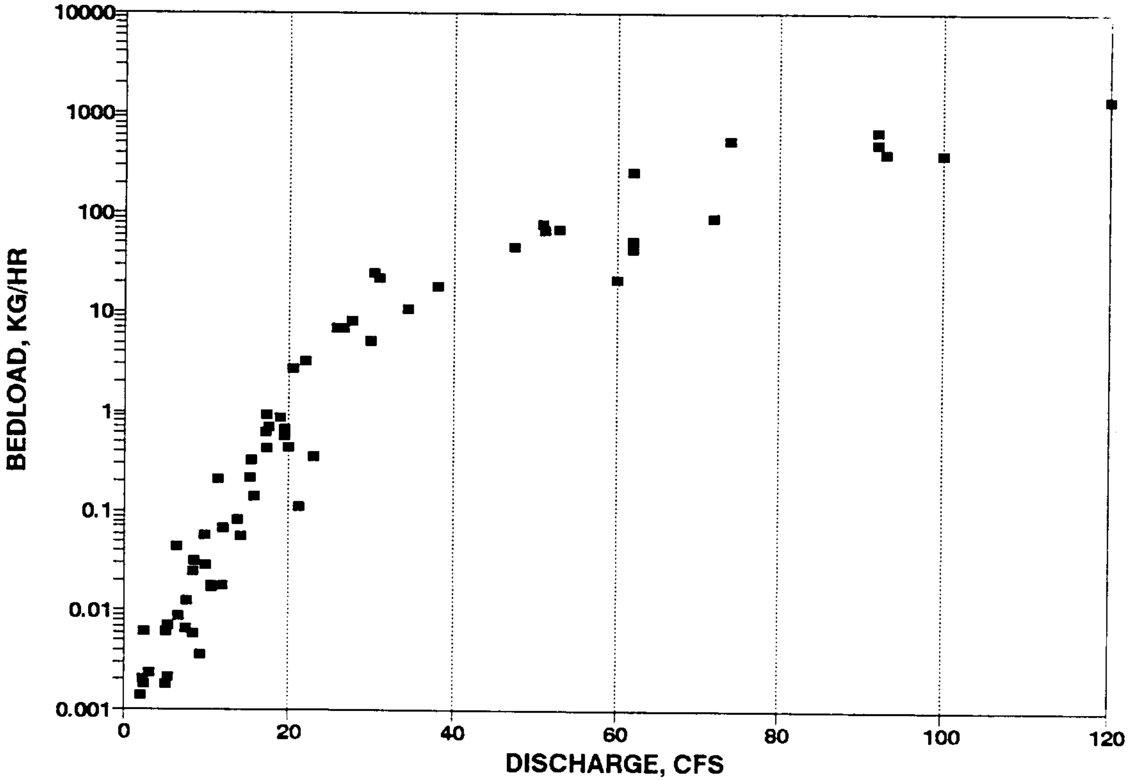


Figure 59 Bedload transport variation with discharge, rising limbs of hydrographs

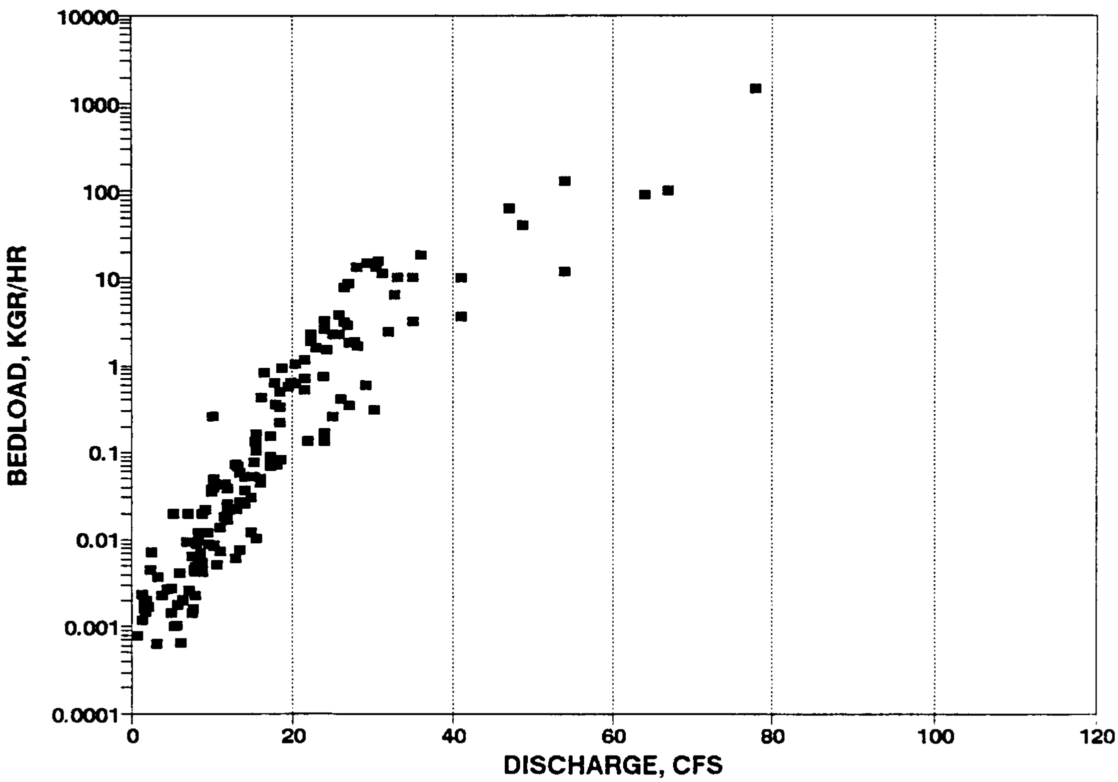


Figure 60 Bedload transport variation with discharge, falling limbs of hydrographs

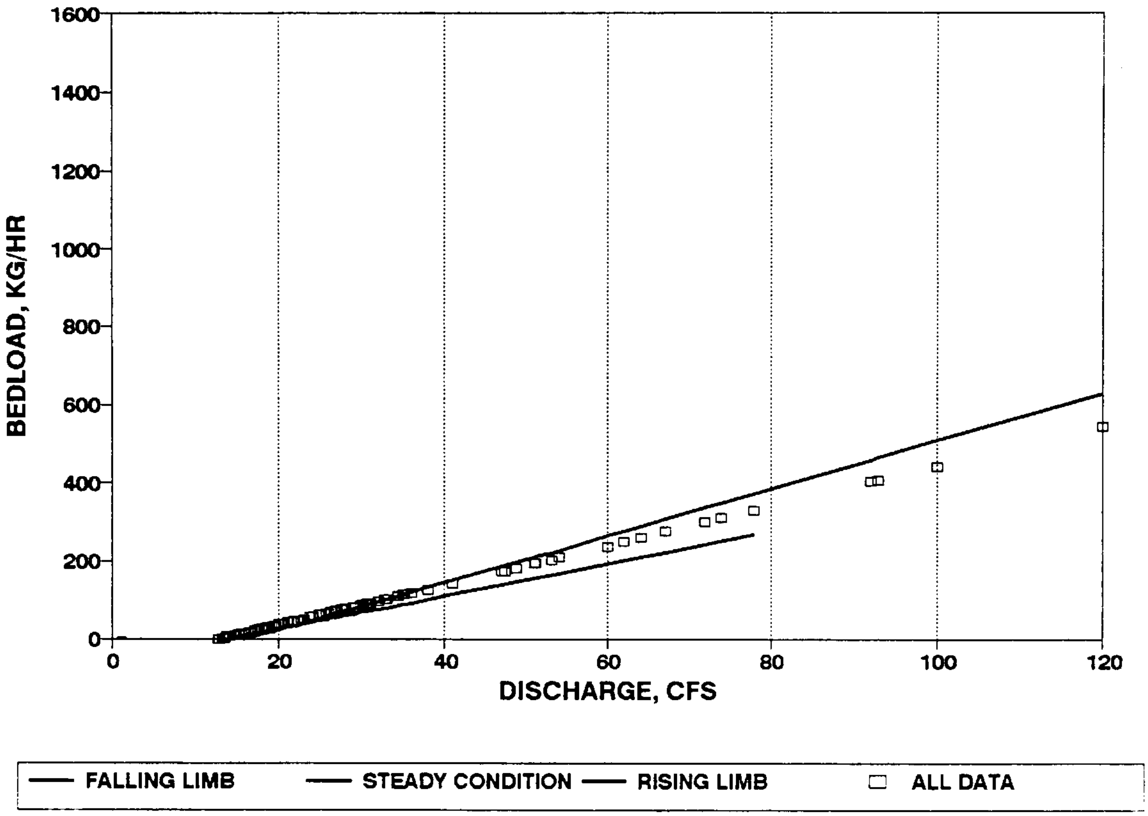


Figure 61 Bedload transport relation with discharge for all stages of hydrographs

VII. CONCLUSIONS AND RECOMMENDATIONS

The primary objective of the research was to investigate incipient motion of gravel particles in the armor layer of a gravel-bed in relation to water discharge and to develop a better understanding of the sediment transport system for a stream with an armor layer. An investigation was also made of the relation between stream discharge and bedload to improve the prediction of bedload equation for Oak Creek. These objectives have been accomplished in a qualitative and partially quantitative way.

Hypotheses were tested on the effect of particle shape on incipient motion and on the equal-mobility theory for motion of particles in the armor layer.

The analyses undertaken here of the gravel-transport data in Oak Creek indicate that with an armor layer there is a tendency to produce an equal mobility of particle-size fractions within the bedload. It was also found that there is a progressive increase in the median sizes of the bedload and especially in the sizes of the larger particles involved in the transport as water discharge increases. A final line of the evidence is that with increasing discharge, the bedload samples mimic the distribution of the bed material, including the high degree of skewness and progressive reduction of frequencies of the smaller size fractions present.

It is important to note that the grain size distributions of bedload show the selectiveness of the flow in dislodging particles at flows above the that needed for armor break-up. At flows below the critical flow, the flow not only flushes out the small size particles, but transports the larger ones also as long as the flow is sufficiently turbulent (see Figures 30, 31, and 56). This sequence of events conforms to what one might expect from a statistical viewpoint. It should be noted that possible human and animal effects on stream conditions should be taken into consideration as affecting experimental results (producing scatter) for small-size samples.

As it is shown in Figure 43, it is important to note that even at extremely low transport rates, transport seem to be functionally related to the strength of flow. This behavior strengthens the probabalistic theory of particle motion due to random turbulence. It furthermore points out the weakness of the concept of a sharp threshold of movement.

The observations from painted gravels experiments indicate that when the larger particles are moved they probably move further in each step because there are few "hiding" places in the bed for the larger sizes. In contrast, the smaller sizes can find hiding spots in the bed and are probably not moved as far as the largest particles. Observations further indicate that due to transport there is considerable interchange of particles between the bed material below the armor layer and the armor layer, with some particles being "stored" in the bed for a relatively long time. The movement of individual particles is intermittent, with periods of rest even during times of appreciable bed material movement, individual particles being deposited and scoured in a non-uniform and unsteady manner.

The results of analysis of the effect of particle shape on incipient motion disprove the hypothesis that initiation of movement is a function of particle shape for gravel bed streams. In general, gravel particles were found to initiate motion in a manner that is independent of particle shape. One explanation may be that for a natural bed surface many particles rest in imbrication-like orientations that give them the best protection against disturbance. Even when painted particles were placed randomly in the bed surface, there was no evident selectivity for initiation of motion based on particle shape.

The analysis of particle weight distributions suggest equal mobility of particles within each size class, rather than movement of the smaller ones at lower discharge and of the larger ones at higher discharge.

Good relationships were found between the large particle sizes transported and both the flow discharge and the Shields parameter for the discharges above armor break-up flows (about 24 cfs).

The bedload is directly related to the stream discharge when the stream discharge is greater than the critical discharge for the armoring material. The rate of bedload transport is related to the critical discharge because both are related to the size of the particles in the armor layer. The bedload discharge can be calculated using Einstein's simplified bed load functions if the representative size used is the D_{35} size of the armor layer for the stability function and the D_{50} size of the material below the armor for the transport function. The critical shear stress can be determined using the D_{90} size of the armor layer.

The armor layer is the most important single factor in limiting the availability of stream bed sediment and in controlling the relationship between stream flow and bedload discharge. The armor layer controls bedload transport at flows large enough to move the armor layer and can cause a considerable shift in relationship of the bedload transport versus stream power. Vertical variations in the bed material composition of gravel-bed rivers are not important for incipient motion, even though significant to general bed-material transport. This is because the flow only "sees" the surface when the bed is stable. Therefore, care must be taken to sample only the bed surface for use in predicting incipient motion.

Review of the Parker et al. bedload equation indicates that it does not account for changing bedload particle sizes and it is a first-order solution to bedload transport. As it is shown by Komar (Figure 11), the Parker analysis provides a reasonable comparison between predicted and measured transport rates of gravel sieve-size fractions in Oak Creek.

It should be also noted that in sediment transport predictions an acceptable result in one where the predicted and measured values are within a factor of 5 or less. From that standpoint, the Parker prediction would be acceptable in most applications. Therefore, the analysis is a success in terms of predicting gravel transport rates. The differential transport rates of bedload relations developed by Komar is more directly applicable to the physical processes of particles entrainment and transport as reflected in the bedload particle sizes.

The main conclusion of the research is that the armor layer acts as a "valve" and a "reservoir" in the sediment transport system of a gravel-bed stream. The armor layer removes material from the system at small flows which is again released at larger flows. The armor layer also prevents bed material beneath it from getting entrained in the flow on a rising hydrograph, but does supply fines to the flow from its sediment reservoir. On the falling limb of a hydrograph, when the armor is again stable, sand can be entrained in the flow.

The research in this dissertation brings out the fact that a stream is a very dynamic system and varies considerably in both time and space. Consequently, an understanding of the natural sediment system requires the development of considerable basic concepts in the field based on analytical and laboratory studies.

In summary, the major conclusion is that the sediment transport system along a reach of a gravel-bed stream is unsteady and non uniform. Time is an important factor in that the past history of flows in the stream is important to the understanding of the dynamics of gravel-bottomed streams. Sediment movement and the dynamics of the stream bed are very complex and very multi-dimensional. The bed materials in a reach are related to the past history of high flows as well as to the material available.

Future work should include examination of whether sampling efficiencies of the vortex trap could have affected the grain-size distributions of the samples to an extent that might have produced the increasing skewness at higher discharges. Presently, it is assumed that sampling efficiencies are high for all sizes but fine sand at most low to moderate flows, based on only limited verification.

It is also recommended that future efforts be focused on the actual normalized transport rates of the various size fractions rather than attempts to further establish equal mobility by focusing on the Parker et al. equation.

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APPENDICES

APPENDIX A

OAK CREEK STAGE HYDROGRAPHS

1. Winter-Spring Runoff Season 1988
2. Fall-Winter-Spring Runoff Season 1988-1989

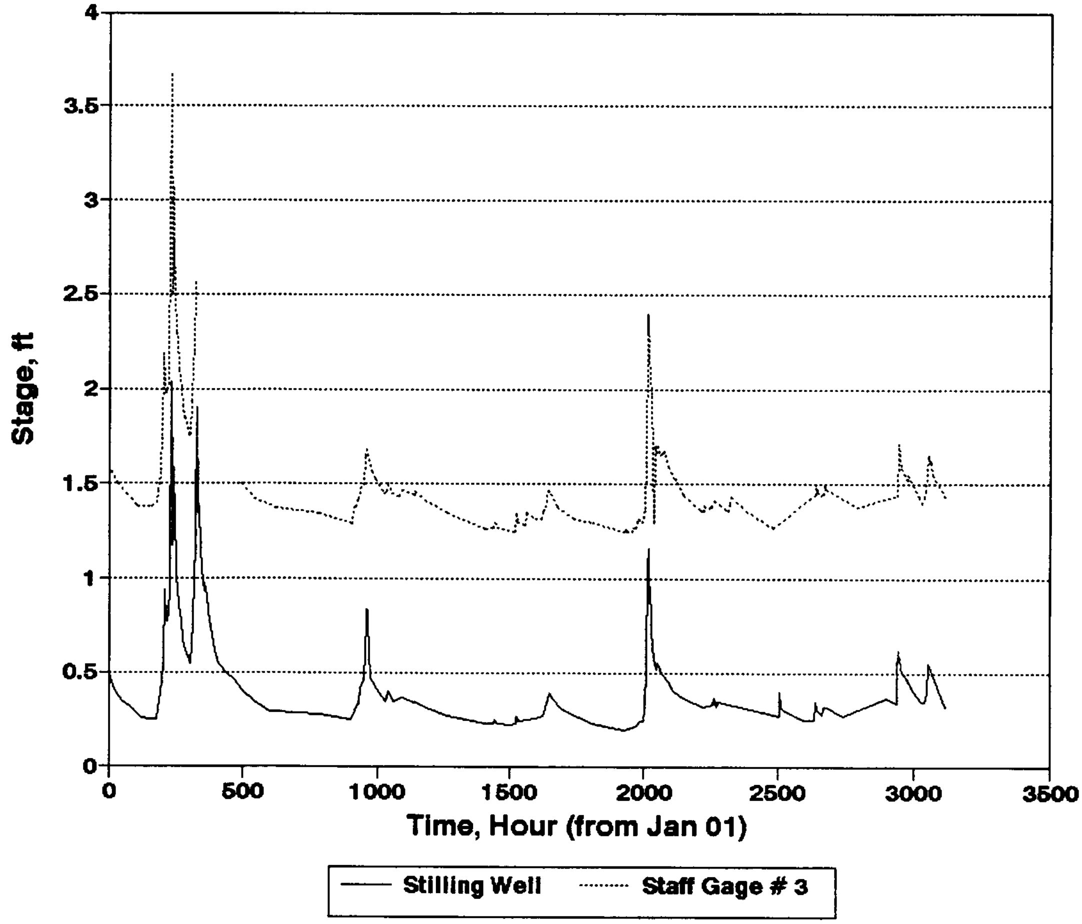


Figure 62 Oak Creek Stage Hydrographs
(Jan. 1, 1988 - May 9, 1988)

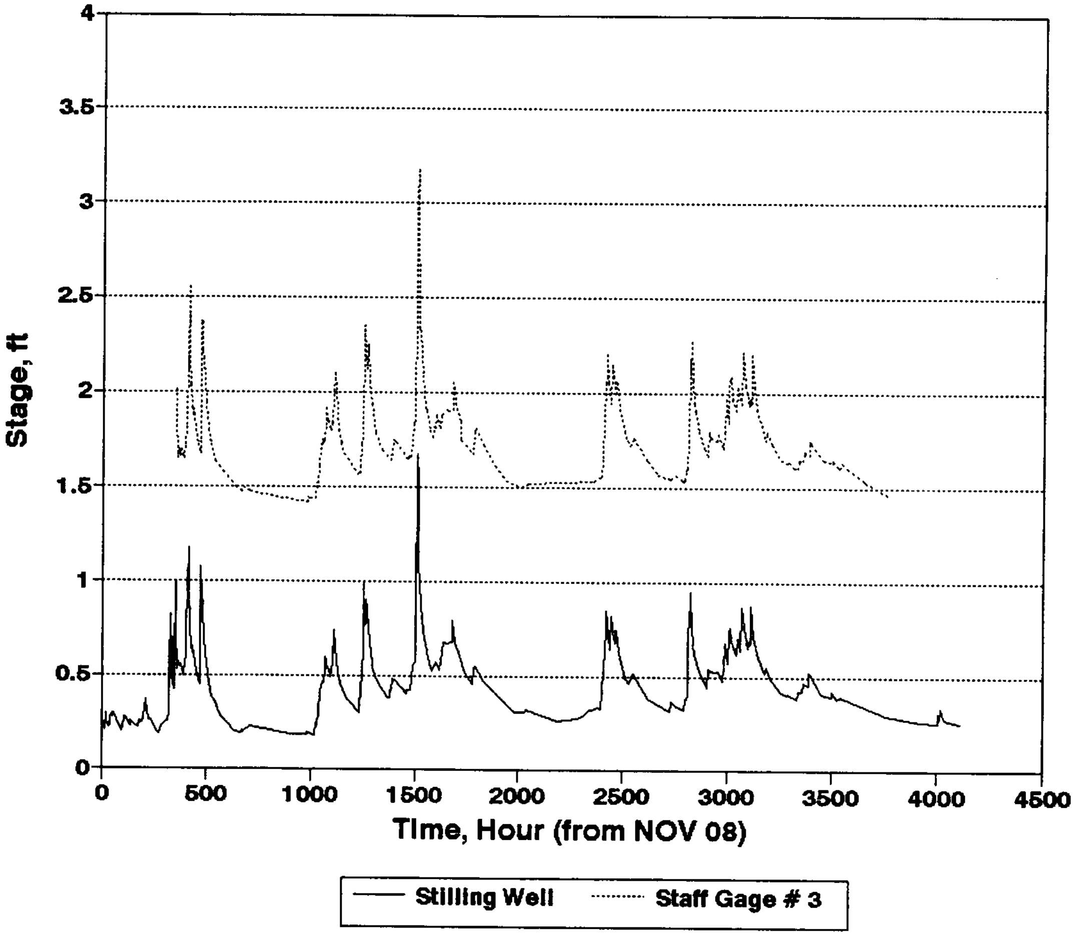


Figure 63 Oak Creek Stage Hydrographs (Nov. 8, 1988 - Apr. 28, 1989)

APPENDIX B

OAK CREEK RATING CURVE AT VORTEX BEDLOAD SAMPLER

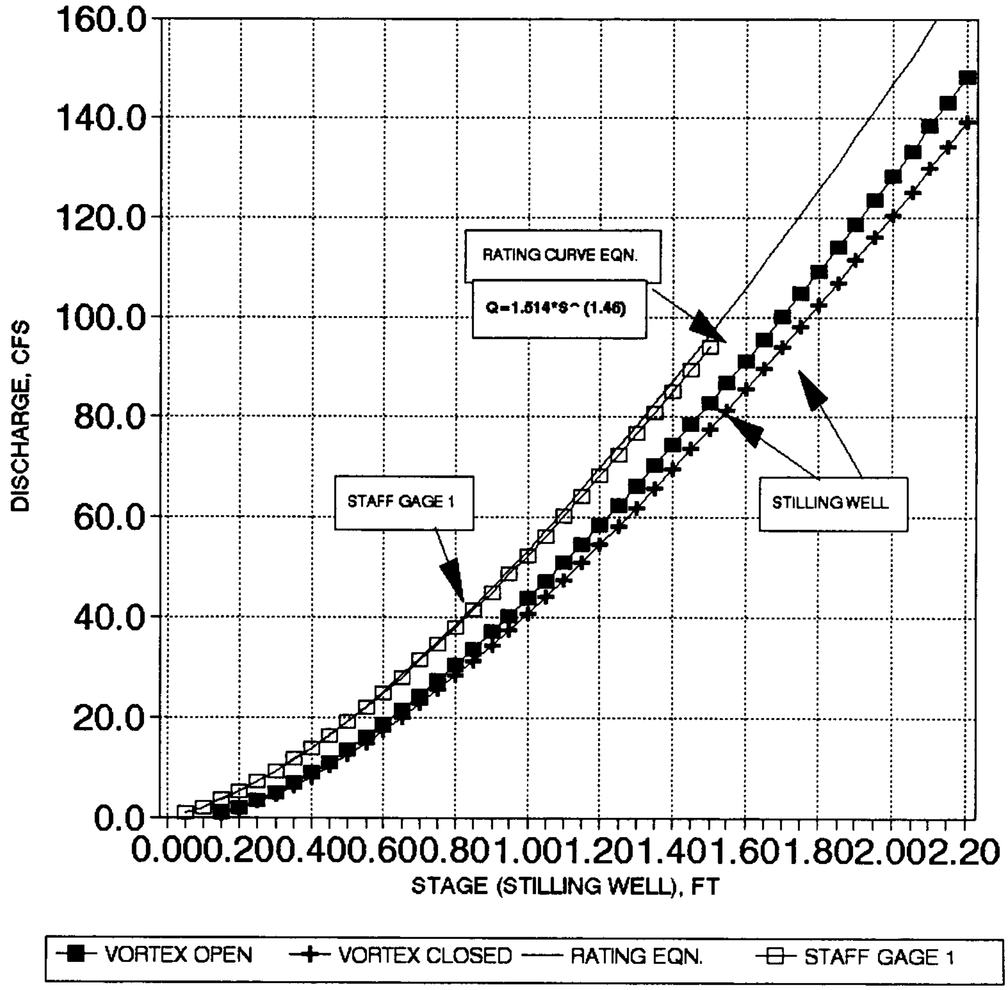


Figure 64 Oak Creek Rating Curves

APPENDIX C

OAK CREEK BED MATERIAL SAMPLE DATA

Choquette-Hammond 1978 Size Gradation Data Set
Specific Gravity Data Set

Table 8 Armor layer gradation data for bed material samples, 1978

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 8 / mm 203.	6" 152.4	4" 101.6	3" 76.2	2" 50.8	1-1/2 38.1	1" 25.4	3/4" 19.05	1/2" 12.7	3/8" 9.525	1/4" 6.35	# 4 4.76	# 8 2.380	# 16 1.19	# 30 0.59	# 50 0.29	# 100 0.14	# 200 0.07	Pan ----
1 E 1/8	100.00	100.00	******	******	82.45	70.90	42.14	27.59	20.49	16.94	14.13	11.36	7.35	4.39	2.29	0.93	0.42	0.22	0.00
1 CL	100.00	100.00	******	******	47.10	42.05	20.69	14.50	7.74	5.54	3.55	2.69	1.60	0.86	0.46	0.24	0.13	0.07	0.00
1 W 1/8	100.00	100.00	******	72.11	23.12	11.42	3.17	1.94	1.36	0.90	0.65	0.52	0.42	0.32	0.23	0.14	0.06	0.03	0.00
2 E 1/8	100.00	100.00	******	******	84.65	78.57	49.00	35.34	27.63	21.76	18.55	16.01	12.42	10.09	7.64	3.89	1.43	0.57	0.00
2 CL	100.00	100.00	******	86.32	57.79	41.67	20.83	14.28	9.49	7.77	5.64	4.06	3.39	1.96	1.02	0.45	0.22	0.10	0.00
2 W 1/8	100.00	100.00	******	84.81	47.58	26.88	16.38	9.88	5.68	3.44	3.06	1.38	0.69	0.38	0.22	0.11	0.05	0.02	0.00
3 E 1/4	100.00	100.00	******	79.84	46.83	36.87	24.10	16.67	11.76	9.40	6.80	5.15	2.92	1.49	0.71	0.34	0.17	0.08	0.00
3 CL	100.00	100.00	81.43	63.19	43.92	28.80	18.88	12.53	9.38	7.70	5.80	4.47	2.75	1.48	0.73	0.29	0.14	0.06	0.00
3 W 1/4	100.00	100.00	******	******	100.00	82.54	53.10	41.25	31.09	25.09	18.71	14.06	8.23	4.46	2.17	0.87	0.44	0.23	0.00
3 W 1/8	100.00	100.00	******	******	89.16	80.47	68.51	54.59	44.04	35.44	24.53	16.92	8.52	5.29	3.56	1.84	0.80	0.37	0.00
7 E 1/4	100.00	100.00	******	79.58	53.46	47.76	31.80	24.80	17.26	14.26	10.72	7.81	3.00	1.06	0.46	0.22	0.11	0.05	0.00
7 CL	100.00	100.00	******	******	100.00	63.78	48.36	32.79	24.55	17.94	13.70	10.99	7.38	4.71	2.57	1.01	0.48	0.22	0.00
7 W 1/4	100.00	100.00	******	92.15	55.88	29.19	18.69	12.93	8.67	6.72	5.11	4.08	3.00	2.28	1.56	0.82	0.38	0.18	0.00
10 E 1/4	100.00	100.00	******	******	65.87	48.53	35.51	23.26	16.93	14.22	10.80	6.09	2.48	1.17	0.59	0.19	0.07	0.04	0.00
10 CL	100.00	100.00	83.71	50.49	31.70	17.54	8.39	4.58	1.99	1.30	0.57	0.31	0.12	0.05	0.03	0.02	0.02	0.01	0.00
10 W 1/4	100.00	100.00	******	76.04	29.30	17.01	4.85	4.17	1.91	1.26	0.62	0.29	0.06	0.02	0.01	0.00	0.00	0.00	0.00
11 E 1/4	100.00	100.00	******	******	83.50	66.01	53.73	43.34	36.50	33.05	29.76	26.86	22.81	18.44	12.80	5.78	2.47	1.24	0.00
11 CL	100.00	51.30	51.30	41.80	29.29	25.02	14.68	8.65	6.21	4.71	3.46	2.64	1.59	0.99	0.60	0.29	0.14	0.06	0.00
11 W 1/4	100.00	100.00	******	64.56	27.01	18.63	10.54	8.03	6.02	5.07	3.32	2.47	0.85	0.38	0.22	0.12	0.07	0.03	0.00
12 E 1/4	100.00	100.00	93.21	54.77	30.20	19.41	7.06	2.21	0.73	0.41	0.20	0.09	0.05	0.04	0.04	0.04	0.04	0.02	0.00
12 CL	100.00	100.00	******	82.31	58.50	58.50	53.17	48.99	45.56	42.84	39.49	37.25	32.94	28.13	20.24	5.98	1.68	0.89	0.00
AVERAGE	100.00	97.68	95.70	82.28	56.54	43.41	28.74	21.06	15.95	13.13	10.44	8.36	5.84	4.19	2.77	1.12	0.44	0.21	0.00

Samples collected by Choquette and Hammond, 1978
Notation following sample numbers: E = east; W = west; CL = centerline
1/4 = quarter-point; 1/8 = eighth-point

Table 9 Subarmor layer gradation data for bed material samples, 1978

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																		
	in 8	6"	4"	3"	2"	1-1/2	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	Pan
	mm 203.	152.4	101.6	76.2	50.8	38.1	25.4	19.05	12.7	9.525	6.35	4.76	2.380	1.19	0.59	0.29	0.14	0.07	----
1 E 1/8	100.00	100.00	******	86.97	70.93	62.99	51.43	42.69	39.94	29.65	24.00	19.26	12.26	7.25	3.73	1.42	0.52	0.23	0.00
1 CL	100.00	100.00	******	79.67	71.49	68.35	55.34	44.08	35.72	29.23	23.44	18.56	10.56	5.24	2.37	0.92	0.36	0.11	0.00
1 W 1/8	100.00	100.00	******	******	92.81	86.22	71.89	61.74	54.18	47.92	42.19	37.95	30.84	24.26	16.30	7.92	3.23	1.48	0.00
2 E 1/8	100.00	100.00	******	******	88.64	81.70	73.05	62.75	53.93	45.25	37.66	31.52	22.85	15.96	9.24	3.59	1.21	0.55	0.00
2 CL	100.00	100.00	******	******	89.99	74.68	59.34	47.56	38.61	31.68	25.74	20.53	11.98	6.03	2.61	0.92	0.41	0.22	0.00
2 W 1/8	100.00	100.00	******	97.53	78.63	67.64	55.09	44.31	37.01	29.59	23.95	19.39	12.74	7.91	4.17	1.50	0.53	0.23	0.00
3 E 1/4	100.00	100.00	******	******	86.57	72.60	61.95	52.32	44.11	38.27	31.91	26.57	16.19	8.05	3.38	1.13	0.41	0.19	0.00
3 CL	100.00	100.00	******	96.62	76.66	62.04	51.46	42.14	34.78	29.08	23.83	19.09	10.93	5.99	2.73	0.89	0.33	0.15	0.00
3 W 1/4	100.00	100.00	******	96.16	78.52	73.93	62.83	52.73	44.12	36.25	29.10	22.65	12.92	6.67	3.00	1.10	0.44	0.21	0.00
3 W 1/8	100.00	100.00	******	******	97.18	89.46	76.13	62.63	48.53	36.14	26.25	17.94	8.85	5.09	3.12	1.63	0.76	0.35	0.00
7 E 1/4	100.00	100.00	******	89.72	74.07	67.76	61.76	54.52	48.48	42.86	36.53	30.29	16.05	6.13	2.51	0.98	0.40	0.19	0.00
7 CL	100.00	100.00	******	******	90.51	80.37	67.44	56.27	44.94	38.34	31.75	26.95	18.84	10.58	4.17	1.25	0.58	0.31	0.00
7 W 1/4	100.00	100.00	******	96.56	85.19	75.77	59.20	46.52	34.84	27.54	20.28	16.00	11.25	8.22	5.51	2.69	1.12	0.48	0.00
10 E 1/4	100.00	100.00	******	92.70	77.49	64.48	47.04	35.12	26.69	20.00	14.27	10.50	5.09	2.64	1.35	0.44	0.16	0.07	0.00
10 CL	100.00	100.00	******	94.67	74.21	63.74	51.00	41.90	34.44	27.98	22.59	18.44	11.02	5.29	2.11	0.74	0.31	0.15	0.00
10 W 1/4	100.00	100.00	******	91.61	65.84	52.31	41.35	31.91	26.87	22.57	17.94	13.96	6.98	3.09	1.61	0.65	0.25	0.11	0.00
11 E 1/4	100.00	100.00	******	******	88.79	79.44	66.46	55.35	47.43	40.70	34.40	28.87	18.61	10.36	5.14	2.00	0.95	0.55	0.00
11 CL	100.00	100.00	******	94.29	83.39	70.10	65.65	45.24	37.21	30.86	24.61	19.54	10.92	6.20	3.55	1.42	0.54	0.23	0.00
11 W 1/4	100.00	100.00	******	99.58	83.18	68.30	61.53	53.53	46.52	39.04	29.00	20.09	6.14	2.61	1.59	0.72	0.28	0.07	0.00
12 E 1/4	100.00	100.00	******	92.20	72.12	55.31	40.30	27.03	17.68	12.49	9.09	6.16	2.70	1.18	0.65	0.37	0.21	0.10	0.00
12 CL	100.00	100.00	******	******	95.49	90.17	77.33	69.35	65.75	56.33	50.06	44.83	35.80	26.74	17.13	4.65	1.30	0.64	0.00
AVERAGE	100.00	100.00	******	95.63	81.99	71.78	59.88	49.03	41.04	33.89	27.55	22.34	13.98	8.36	4.57	1.76	0.68	0.32	0.00

Samples collected by Choquette and Hammond, 1978

Notation following sample numbers: E = east; W = west; CL = centerline

1/4 = quarter-point; 1/8 = eighth-point

Table 10 Specific gravity data for Oak Creek bed material and bedload, 1970 and 1978

SPECIFIC GRAVITY DETERMINATIONS

Sieve Size	Opening mm	Dry Sample Size kg	Specific Gravity @ 4 C		
			Weighted Oven Dry Basis	Weighted Sat.Surf. Dry Basis	Displacement Sat. Surf. Dry Basis
February 1970 :					
2"	50.80	5.51	2.93	2.84	
1 1/2"	38.10	6.74	2.94	2.87	
3/4"	19.05	25.88	2.88		
1/2"	12.70	10.52	2.96	2.81	
3/8"	9.52	15.55	3.00		
4	4.76	4.57	2.98		
8	2.38	0.68	2.83		
16	1.19	1.03	2.85		
30	0.59	0.64	2.74		
100	0.15	0.41	2.83		
December 1978 :					
4"	101.60	12.62	2.83	2.80	2.75
3"	76.20	26.94	2.95	2.86	2.81
2"	50.80	12.99	2.97	2.90	2.90
1 1/2"	38.10	3.61	3.06	2.86	2.88
1"	25.40	3.35	2.93	2.83	2.83
3/4"	19.05	3.26	2.91	2.79	2.75
1/2"	12.70	3.31	2.90	2.76	2.74
3/8"	9.52	2.94	2.90	2.78	2.75
1/4"	6.35	2.87	2.88	2.73	2.69
4	4.76	1.98	2.88	2.70	2.62
8	2.38	2.33	2.96	2.65	2.57

RESULTING COMPOSITE SPECIFIC GRAVITY

Sieve Size	Opening mm	Specific Gravity @ 4 C		
		Weighted Oven Dry Basis	Weighted Sat.Surf. Dry Basis	Displacement Sat. Surf. Dry Basis
Individual Size Ranges				
4"	101.60	2.83	2.80	2.75
3"	76.20	2.95	2.86	2.81
2"	50.80	2.96	2.88	2.90
1 1/2"	38.10	2.98	2.87	2.88
1"	25.40	2.93	2.83	2.83
3/4"	19.05	2.89	2.81	2.75
1/2"	12.70	2.90	2.76	2.74
3/8"	9.52	2.99	2.78	2.75
1/4"	6.35	2.88	2.73	2.69
4	4.76	2.95	2.70	2.62
8	2.38	2.93	2.65	2.57
16	1.19	2.85		
30	0.59	2.74		
100	0.15	2.83		
Cumulative Size Fractions				
> 1"	25.40	2.93	2.85	2.83
> 1/2"	12.70	2.92	2.83	2.81
> 1/4"	6.35	2.92	2.81	2.79
> #4	4.76	2.93	2.80	2.77
> #8	2.38	2.00	2.79	2.75
> #100	0.15	2.88		
< 1/2"	12.70	2.86		
< #4	4.76			

* Values shown for specific sieve sizes were adjusted on basis of weight from data for 1970 and 1978. Combined data near bottom of table are arithmetically averaged from data shown above in table.

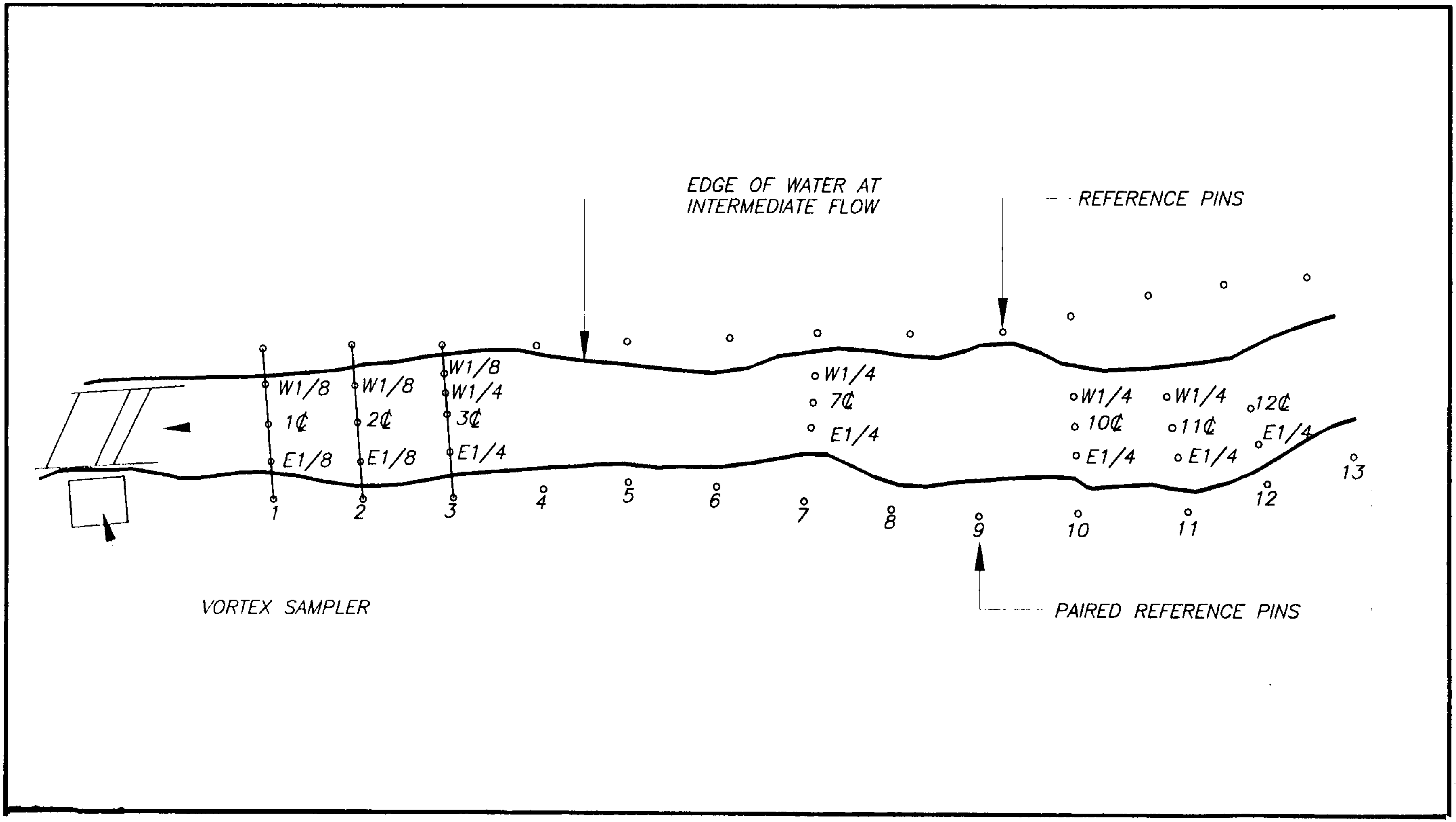


Figure 65 Oak Creek bed material sampling sites, 1978

APPENDIX D

OAK CREEK BEDLOAD SAMPLE DATA

Milhous 1971 bedload data set
Saluja 1978 bedload data Set
Matin 1988-1989 bedload data Set

Table 11 Gradation data for bedload samples, 1971 data

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
71-1						100.00	91.07	86.60	80.67	77.70	65.10	51.00	30.80	8.20	2.00	0.80	0.00	
71-2						100.00	98.93	98.40	91.81	88.50	76.30	62.70	33.10	19.30	6.30	1.90	0.00	
71-3						100.00	96.20	94.30	88.57	85.70	76.40	60.60	34.20	12.80	4.10	1.60	0.00	
71-4						100.00	95.20	92.80	85.07	81.20	69.40	53.00	29.30	12.30	4.20	1.40	0.00	
71-5				100.00	97.20	93.00	90.13	88.70	86.70	85.70	79.50	65.50	45.90	31.50	23.40	18.40	0.00	
71-6						100.00	95.67	93.50	86.84	83.50	69.30	49.30	23.20	7.60	2.50	1.00	0.00	
71-7						100.00	96.27	94.40	91.00	89.30	79.10	62.50	38.90	17.30	6.10	2.10	0.00	
71-8					100.00	89.20	85.07	83.00	79.94	78.40	66.30	51.50	31.40	12.70	4.90	2.20	0.00	
71-9						100.00	97.93	96.90	92.17	89.80	81.40	66.80	41.20	16.60	6.30	2.70	0.00	
71-10	100.00	98.30	86.30	74.00	51.40	34.00	21.81	15.70	11.24	9.00	5.80	3.00	1.20	0.50	0.20	0.10	0.00	
71-11	100.00	98.50	90.30	82.80	68.20	54.80	40.07	32.70	21.45	15.80	8.10	3.20	1.10	0.50	0.30	0.20	0.00	
71-12	100.00	98.80	88.80	78.50	62.60	49.50	37.11	30.90	22.44	18.20	1.30	4.40	1.30	0.40	0.20	0.10	0.00	
71-13	100.00	96.40	82.40	69.90	48.20	35.80	27.80	23.80	18.34	15.60	8.80	4.00	1.50	0.50	0.30	0.20	0.00	
71-14	100.00	90.80	86.96	74.30	52.40	35.40	22.61	16.20	10.27	7.30	3.80	1.70	0.60	0.30	0.20	0.10	0.00	
71-15	100.00	99.40	96.30	91.20	76.80	63.00	48.87	41.80	32.34	27.60	17.40	8.80	3.90	2.10	1.30	0.70	0.00	
71-16		100.00	97.20	93.70	83.30	73.50	60.77	54.40	41.41	34.90	19.60	8.10	2.60	0.90	0.40	0.20	0.00	
71-17				100.00	94.10	87.30	79.30	75.30	64.91	59.70	41.30	20.50	6.80	2.00	0.60	0.10	0.00	
71-18				100.00	98.70	95.20	89.60	86.80	78.54	74.40	58.30	33.00	12.60	3.90	1.30	0.50	0.00	
71-19				100.00	95.70	91.90	86.04	83.10	74.11	69.60	54.50	31.30	12.90	4.90	1.80	0.50	0.00	
71-20					100.00	93.90	89.44	87.20	80.21	76.70	61.20	35.80	15.20	5.60	2.20	0.80	0.00	
71-21			100.00	97.50	95.70	92.50	87.77	85.40	78.07	74.40	58.50	33.10	13.10	5.10	2.30	1.20	0.00	
71-22				100.00	97.70	96.30	89.70	86.40	78.34	74.30	57.60	32.80	12.40	4.40	1.60	0.60	0.00	
71-23		100.00	96.60	92.20	82.00	73.50	64.97	60.70	51.51	46.90	31.40	13.90	4.10	1.40	0.70	0.30	0.00	
71-24		100.00	98.20	95.90	87.30	80.90	73.77	70.20	60.48	55.60	37.20	16.50	4.80	1.50	0.70	0.30	0.00	
71-25		100.00	99.00	95.70	91.30	86.90	80.57	77.40	68.74	64.40	45.90	20.30	6.20	2.10	0.90	0.30	0.00	
71-26		100.00	96.50	95.80	94.00	91.80	87.87	85.90	79.31	76.00	56.70	26.90	7.90	2.60	1.20	0.70	0.00	
71-27				100.00	98.70	97.20	95.33	94.40	90.27	88.20	69.60	47.20	14.70	4.40	1.40	0.30	0.00	
71-28					100.00	98.20	97.13	96.60	93.67	92.20	79.60	46.40	18.00	6.40	2.20	0.80	0.00	
71-29					100.00	99.40	99.00	98.80	96.54	95.40	84.10	54.60	23.60	7.50	2.40	0.60	0.00	
71-30						100.00	99.53	99.30	97.37	96.40	87.60	62.00	31.50	11.40	3.40	1.30	0.00	

Table 11 (Continued)

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
71-31						100.00	99.87	99.80	98.87	98.40	91.90	71.20	35.60	11.00	3.10	1.00	0.00	
71-32					100.00	98.70	97.49	96.88	93.50	91.80	80.90	57.10	28.00	8.90	3.10	1.10	0.00	
71-33						100.00	99.27	98.90	96.04	94.60	82.30	59.10	30.60	10.10	3.70	1.20	0.00	
71-34								100.00	98.34	97.50	86.00	64.80	39.60	16.00	5.30	0.80	0.00	
71-35						100.00	98.80	98.20	96.40	95.50	87.50	66.10	34.60	12.60	4.10	1.10	0.00	
71-36						100.00	98.87	98.30	96.17	95.10	85.90	60.90	30.30	9.90	3.40	1.00	0.00	
71-37					100.00	94.40	87.07	83.40	79.34	77.30	65.70	46.40	24.90	7.60	2.60	1.20	0.00	
71-38						100.00	96.40	94.60	87.34	83.70	71.20	49.80	25.50	7.40	2.70	1.30	0.00	
71-39						100.00	93.14	89.70	88.30	87.60	77.60	54.10	27.10	7.30	2.70	1.40	0.00	
71-40						100.00	90.34	85.50	80.97	78.70	67.70	50.30	27.40	9.30	3.60	1.40	0.00	
71-41					100.00	89.20	95.33	98.40	91.01	87.30	67.70	42.20	19.60	4.40	1.10	0.40	0.00	
71-42						100.00	93.00	89.50	78.78	73.40	56.80	34.60	15.80	4.40	1.60	0.60	0.00	
71-43						100.00	93.07	89.60	83.81	80.90	70.90	50.20	27.10	10.60	4.40	2.10	0.00	
71-44						100.00	94.80	92.20	87.67	85.40	71.90	59.10	33.70	13.70	5.30	2.10	0.00	
71-45						100.00	97.60	96.40	89.74	86.40	74.10	48.20	20.40	4.40	1.20	0.70	0.00	
71-46					100.00	86.60	82.67	80.70	70.04	64.70	48.60	30.90	16.50	7.10	3.50	1.50	0.00	
71-47						100.00	96.27	94.40	85.41	80.90	62.90	40.30	19.30	5.80	2.10	0.90	0.00	
71-48					100.00	89.80	81.67	77.60	69.54	65.50	54.60	39.80	22.30	8.20	3.20	1.20	0.00	
71-49					100.00	90.20	84.07	81.00	72.01	67.50	53.00	34.60	17.60	5.50	1.90	0.80	0.00	
71-50						100.00	98.93	98.40	94.40	92.40	78.40	55.50	32.10	14.50	6.20	1.70	0.00	
71-51				100.00	95.70	94.40	93.00	92.30	89.77	88.50	80.30	66.60	48.20	26.40	8.70	0.90	0.00	
71-52						100.00	98.27	97.40	94.34	92.80	84.60	60.30	24.60	7.90	2.30	0.60	0.00	
71-53						100.00	94.00	91.00	87.74	86.10	77.40	60.60	35.20	13.40	4.60	1.20	0.00	
71-54						100.00	95.00	92.50	88.70	86.80	78.50	60.50	36.40	15.80	6.70	2.50	0.00	
71-55	100.00	95.50	91.30	88.00	84.40	81.80	78.80	77.30	73.64	71.80	60.50	35.70	13.10	4.70	2.00	0.80	0.00	
71-56	100.00	95.60	86.00	83.50	79.00	75.50	71.70	69.80	63.74	60.70	47.30	26.30	10.30	4.00	1.70	0.50	0.00	
71-57	100.00	92.10	84.90	75.90	66.80	61.40	56.34	53.80	48.07	45.20	33.90	18.30	7.00	2.60	1.20	0.60	0.00	
71-58		100.00	80.70	69.50	49.60	39.50	31.44	27.40	21.47	18.50	11.30	5.40	2.20	1.00	0.60	0.40	0.00	
71-59	100.00	99.10	89.90	80.00	62.20	49.10	35.77	29.10	19.64	14.90	7.00	2.50	0.90	0.40	0.20	0.00	0.00	
71-60	100.00	99.50	96.00	89.60	77.50	67.70	55.91	50.00	38.61	32.90	18.10	7.20	2.00	0.60	0.20	0.00	0.00	

Table 11 (Continued)

Sample No.	in 4 / mm 101.	3" / 76.2	2" / 50.8	1-1/ / 38.1	1" / 25.4	3/4" / 19.05	1/2" / 12.7	3/8" / 9.52	1/4" / 6.35	# 4 / 4.76	# 8 / 2.38	# 16 / 1.19	# 30 / 0.59	# 50 / 0.29	# 100 / 0.14	# 200 / 0.07	# 230 / 0.06	Pan / ----
	Sieve Size and Cumulative Percent Finer by Weight																	
71-61		100.00	96.00	89.60	78.00	66.10	52.11	45.10	34.38	29.00	17.80	8.50	3.00	1.30	0.80	0.50	0.00	
71-62		100.00	98.40	96.00	90.10	82.70	70.84	64.90	51.58	44.90	27.50	12.10	3.80	1.50	0.80	0.40	0.00	
71-63		100.00	99.00	94.90	89.40	81.40	70.47	65.00	53.55	47.80	30.60	14.00	4.00	1.10	0.40	0.10	0.00	
71-64		100.00	96.00	90.50	78.90	67.50	54.71	48.30	37.71	32.40	20.20	9.30	3.00	1.20	0.80	0.50	0.00	
71-65	100.00	98.60	88.30	78.20	64.70	54.80	44.67	39.60	30.08	25.30	13.50	5.50	1.70	0.60	0.30	0.10	0.00	
71-66	100.00	97.50	85.00	72.90	55.30	43.70	33.37	28.20	20.74	17.00	9.20	3.90	6.40	0.60	0.40	0.30	0.00	
71-67								100.00	97.27	95.90	87.20	70.40	43.90	22.50	11.30	5.60	0.00	
71-68								100.00	91.61	87.40	84.90	76.80	55.40	25.00	10.50	5.00	0.00	
71-69						100.00	88.01	82.00	68.81	62.20	51.40	38.60	25.50	12.70	6.70	3.50	0.00	
71-70								100.00	80.55	70.80	60.10	47.50	29.50	13.90	7.00	3.80	0.00	
71-71						100.00	82.41	73.60	59.08	51.80	42.50	30.50	17.00	6.50	3.00	1.00	0.00	
71-72										100.00	95.80	87.50	67.80	39.50	20.80	10.40	0.00	
71-73						100.00	82.14	73.20	69.34	67.40	63.90	56.90	41.80	19.70	10.50	3.50	0.00	
71-74										100.00	97.10	88.30	69.40	32.00	16.00	9.40	0.00	
71-75								100.00	95.27	92.90	91.40	81.00	58.60	29.40	20.60	12.00	0.00	
71-76										100.00	98.30	91.40	74.20	38.00	27.70	12.00	0.00	
71-77								100.00	92.74	89.10	76.00	63.40	44.10	23.50	13.00	7.50	0.00	
71-78								100.00	93.14	89.70	85.50	73.90	56.50	31.80	18.80	13.50	0.00	
71-79										100.00	93.10	85.10	60.80	32.60	20.00	12.70	0.00	
71-80											100.00	85.40	59.00	22.50	9.00	4.40	0.00	
71-81										100.00	99.80	88.20	60.20	21.70	6.00	1.90	0.00	
71-82					100.00	95.70	89.77	86.80	77.21	72.40	58.30	43.50	23.50	5.00	1.50	0.50	0.00	
71-83						100.00	84.94	77.40	71.41	68.40	62.80	57.40	45.60	24.00	9.50	4.00	0.00	
71-84								100.00	92.14	88.20	73.50	63.30	47.00	20.50	10.20	4.00	0.00	
71-85								100.00	93.21	89.80	81.80	73.40	59.10	29.40	14.50	6.80	0.00	
71-86								100.00	92.74	89.10	81.20	71.40	56.00	25.00	10.20	4.00	0.00	
71-87						100.00	82.94	74.40	60.55	53.60	46.60	39.60	29.10	11.60	4.40	1.50	0.00	
71-88						100.00	79.08	68.60	56.08	49.80	39.00	31.90	22.00	14.40	5.30	2.40	0.00	
71-89						100.00	67.35	51.00	33.68	25.00	20.20	15.60	10.50	4.50	1.60	0.30	0.00	
71-90						100.00	87.67	81.50	74.57	71.10	65.20	59.30	46.70	20.50	8.00	3.00	0.00	

Table 11 (Continued)

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
71-91					100.00	71.20	53.01	43.90	31.65	25.50	21.30	19.40	14.80	6.70	2.40	0.80	0.00	
71-92						100.00	79.21	68.80	53.55	45.90	33.30	23.60	14.40	6.00	2.80	1.00	0.00	
71-93					100.00	75.10	57.71	49.00	42.74	39.60	29.80	23.00	15.00	5.50	1.50	0.00	0.00	
71-94						100.00	78.54	67.80	57.21	51.90	39.50	25.70	16.00	8.00	14.00	1.60	0.00	
71-95						100.00	86.41	79.60	69.88	65.00	53.50	38.40	24.20	11.50	6.50	2.70	0.00	
71-96						100.00	94.27	91.40	79.01	72.80	58.10	41.60	23.50	10.00	4.50	2.40	0.00	
71-97						100.00	87.47	81.20	70.81	65.60	56.30	39.50	22.10	8.60	3.40	0.80	0.00	
71-98						100.00	66.22	49.30	45.90	44.20	33.80	24.40	14.10	5.50	1.80	0.40	0.00	
71-99					100.00	70.20	53.54	45.20	40.34	37.90	32.40	22.00	12.00	4.80	2.50	0.90	0.00	
71-100						100.00	83.94	75.90	62.58	55.90	39.20	26.90	15.40	6.50	2.70	0.90	0.00	
71-101						100.00	95.74	93.60	86.01	82.20	70.50	56.00	34.10	10.50	3.00	0.90	0.00	
71-102						100.00	98.07	97.10	92.24	89.80	76.90	55.00	29.00	10.50	3.90	1.20	0.00	
71-103						100.00	86.61	79.90	73.24	69.90	58.90	42.90	27.00	12.10	5.50	3.40	0.00	
71-104						100.00	92.20	88.30	73.25	65.70	49.80	37.20	28.10	16.50	10.80	7.00	0.00	
71-105						100.00	93.20	89.80	79.81	74.80	61.60	47.00	30.00	14.40	6.50	3.00	0.00	
71-106								100.00	87.61	81.40	64.80	46.70	31.40	14.50	5.60	2.00	0.00	
71-107						100.00	82.14	73.20	56.22	47.70	33.40	23.60	14.70	7.00	3.00	0.60	0.00	
71-108						100.00	94.40	91.60	74.42	65.80	48.40	33.00	22.40	10.40	4.80	1.90	0.00	
71-109					100.00	78.60	68.07	62.80	52.88	47.90	33.50	20.00	10.00	3.70	1.40	0.40	0.00	
71-110		100.00	88.20	81.80	73.90	68.40	61.40	57.90	49.78	45.70	27.40	15.20	6.40	2.30	1.10	0.50	0.00	
71-111				100.00	91.50	86.70	76.64	71.60	60.68	55.20	41.60	23.10	8.90	2.30	0.70	0.20	0.00	
71-112						100.00	93.74	90.60	81.74	77.30	58.50	37.90	16.10	4.00	0.90	0.20	0.00	
71-113					100.00	81.50	71.04	65.80	60.81	58.30	43.90	31.80	15.40	3.80	1.40	0.50	0.00	
71-114						100.00	86.01	79.00	70.88	66.80	50.10	34.10	20.00	7.00	2.70	1.00	0.00	
71-115						100.00	88.34	82.50	72.44	67.40	54.40	37.20	19.50	5.70	2.00	1.00	0.00	
71-116						100.00	91.47	87.20	79.61	75.80	66.50	49.50	28.90	9.20	3.60	1.60	0.00	
71-117						100.00	97.27	95.90	88.57	84.90	72.80	50.50	27.70	10.90	5.00	2.50	0.00	
71-118						100.00	78.61	67.90	58.98	54.50	36.80	24.20	12.60	4.50	1.50	0.60	0.00	
71-119						100.00	85.21	77.80	71.27	68.00	51.50	34.80	18.10	7.50	3.60	1.50	0.00	

Table 12 Gradation data for bedload samples, 1978 data

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
78-1				100.00	95.35	95.35	92.50	88.20	81.40	74.89	59.17	33.96	16.59	8.18	3.73	1.89	0.00	
78-2				100.00	99.19	99.19	97.18	93.07	86.69	80.31	65.21	39.50	16.61	7.90	4.12	2.24	0.00	
78-3					100.00	97.54	89.96	78.10	63.40	52.96	37.35	20.53	7.28	2.83	1.40	0.80	0.00	
78-4				100.00	99.14	97.20	91.10	80.92	68.57	58.63	41.24	24.71	9.98	4.17	2.08	1.26	0.00	
78-5					100.00	99.28	93.07	83.47	69.94	58.55	38.87	21.97	8.76	3.75	1.83	1.07	0.00	
78-6						100.00	95.56	87.41	74.88	62.73	40.32	19.43	6.57	2.65	1.30	0.78	0.00	
78-7					100.00	99.09	97.93	92.22	81.72	69.33	45.78	22.80	7.01	2.79	1.41	0.86	0.00	
78-8						100.00	98.44	93.45	84.75	74.04	51.39	26.31	8.17	3.61	1.95	1.12	0.00	
78-9						100.00	99.65	97.12	91.90	83.67	63.77	33.20	8.83	3.36	1.61	0.85	0.00	
78-10						100.00	99.05	97.18	94.84	90.43	76.02	44.49	16.55	8.03	3.78	1.88	0.00	
78-11							100.00	99.47	97.61	94.54	83.08	54.29	20.73	7.45	2.58	1.31	0.00	
78-12							100.00	95.63	92.02	85.41	67.96	43.07	17.38	6.14	2.01	0.99	0.00	
78-13				100.00	93.20	82.25	68.87	63.14	58.52	53.91	43.95	24.71	8.87	3.53	1.75	0.95	0.00	
78-14			100.00	72.52	60.20	60.20	58.47	58.32	57.22	54.03	42.73	24.16	9.24	3.39	1.09	0.55	0.00	
78-15						100.00	99.20	94.24	86.69	79.40	59.21	32.54	11.12	3.48	1.39	0.60	0.00	
78-16								100.00	98.60	94.27	80.48	51.76	21.06	8.06	3.05	1.60	0.00	
78-17						100.00	99.03	96.84	91.35	84.85	65.93	40.47	15.13	6.49	3.19	1.75	0.00	
78-18				100.00	98.63	98.23	95.78	91.51	85.01	76.03	56.62	34.92	11.92	4.22	2.41	1.42	0.00	
78-19					100.00	99.71	98.17	95.61	88.06	78.65	56.61	35.47	13.60	5.83	3.16	1.88	0.00	
78-20						100.00	98.20	95.65	91.52	85.29	68.96	45.09	16.32	4.71	1.64	0.85	0.00	
78-21				100.00	99.62	99.13	96.15	89.27	80.32	71.06	52.33	30.33	10.68	3.79	1.86	1.06	0.00	
78-22					100.00	99.38	95.90	89.11	78.59	68.50	46.86	26.91	9.37	3.60	1.90	1.17	0.00	
78-23						100.00	98.04	93.68	86.06	77.35	53.94	27.02	8.89	3.49	1.86	1.11	0.00	
78-24						100.00	98.88	96.37	91.99	85.78	66.09	36.76	12.21	4.19	1.74	0.91	0.00	
78-25							100.00	98.98	96.86	92.45	75.08	41.61	13.12	4.02	1.25	0.41	0.00	
78-26						100.00	99.39	98.13	95.68	91.48	72.89	43.17	18.15	7.14	2.44	1.19	0.00	
78-27							100.00	97.71	94.95	89.54	68.25	35.58	12.48	4.70	1.87	1.00	0.00	
78-28						100.00	97.57	94.11	88.06	79.01	57.74	30.91	10.02	3.14	1.30	0.72	0.00	
78-29					100.00	99.78	97.51	92.99	85.38	77.51	55.91	33.97	12.61	4.36	1.98	1.13	0.00	
78-30						100.00	99.42	96.66	92.14	86.33	64.36	34.45	11.06	3.42	1.35	0.61	0.00	

Table 12 (Continued)

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
78-31							100.00	98.88	96.71	92.89	75.69	43.24	13.86	4.14	1.59	0.80	0.00	
78-32							100.00	98.32	92.14	85.71	66.00	38.20	17.26	7.10	2.70	1.35	0.00	
78-33							100.00	98.78	90.45	83.00	54.63	26.01	9.13	3.42	1.50	0.80	0.00	
78-34							100.00	95.00	85.82	80.54	65.24	46.48	22.66	7.69	1.96	0.81	0.00	
78-35						100.00	77.40	66.57	61.66	55.35	41.82	25.20	13.26	6.16	2.38	0.99	0.00	
78-36							100.00	87.15	76.61	73.19	63.52	47.97	26.13	12.91	4.90	2.47	0.00	
78-37						100.00	92.68	88.75	76.06	62.26	35.93	18.88	8.66	3.36	1.33	0.77	0.00	
78-38						100.00	98.28	94.93	82.41	70.53	44.34	20.90	9.25	4.25	1.78	0.89	0.00	
78-39					100.00	99.64	97.93	94.13	88.92	82.81	65.78	39.70	14.89	4.83	1.82	0.94	0.00	
78-40					100.00	98.35	94.19	87.67	79.71	72.06	54.52	33.78	12.58	3.89	1.42	0.73	0.00	
78-41				100.00	98.92	98.08	93.92	86.42	77.12	68.00	47.25	26.92	9.46	3.22	1.52	0.88	0.00	
78-42				100.00	99.76	99.17	95.43	90.03	82.57	74.80	55.45	32.82	12.02	3.64	1.43	0.78	0.00	
78-43					100.00	98.91	96.10	89.53	80.61	70.91	48.46	26.39	9.23	3.21	1.55	0.89	0.00	
78-44				100.00	99.69	98.96	95.73	90.98	84.02	75.77	56.10	32.46	11.87	3.48	1.25	0.64	0.00	
78-45				100.00	99.47	97.41	90.59	81.32	71.10	61.80	42.20	23.02	8.25	2.69	1.24	0.72	0.00	
78-46					100.00	98.88	94.26	88.11	79.88	71.00	49.24	27.35	9.91	3.24	1.42	0.77	0.00	
78-47					100.00	99.24	97.65	94.19	88.58	82.10	63.06	36.93	14.03	3.97	1.45	0.79	0.00	
78-48							100.00	93.93	88.23	79.88	57.03	29.63	10.63	3.62	1.57	0.89	0.00	
78-49					100.00	97.90	96.77	91.22	85.69	79.46	59.58	33.09	12.97	4.56	1.89	0.99	0.00	
78-50								100.00	98.11	94.77	80.85	55.85	26.33	7.91	2.26	1.13	0.00	
78-51						100.00	99.80	98.19	95.03	91.17	72.08	40.17	15.06	5.25	2.17	1.11	0.00	
78-52					100.00	99.12	97.65	94.80	89.76	82.21	60.18	32.66	11.66	3.56	1.47	0.79	0.00	
78-53					100.00	99.76	97.45	93.60	87.66	80.28	61.87	36.88	14.47	4.15	1.43	0.73	0.00	
78-54					100.00	99.83	98.38	94.18	86.59	77.69	54.71	32.48	12.51	4.23	1.97	1.16	0.00	
78-55						100.00	99.77	97.95	93.00	87.51	69.40	42.47	18.40	5.64	1.68	0.89	0.00	
78-56					100.00	96.48	95.63	93.21	87.33	79.23	55.28	27.15	9.55	3.27	1.34	0.70	0.00	
78-57						100.00	99.84	96.83	89.36	79.62	53.81	26.92	11.54	4.85	2.02	1.06	0.00	
78-58							100.00	98.76	96.42	92.43	80.26	55.71	34.80	19.53	9.28	3.99	0.00	
78-59						100.00	93.52	92.00	88.76	84.78	73.34	50.02	29.85	14.68	6.09	2.60	0.00	

Table 13 Gradation data for bedload samples, 1988 data

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
88-1							100.00	98.38	96.31	93.89	86.18	72.66	49.47	22.99	6.84	1.51	0.75	-0.00
88-2							100.00	96.97	92.43	86.84	67.53	45.87	25.23	10.68	2.77	0.56	0.25	-0.00
88-3						100.00	96.76	89.27	82.50	73.84	57.13	37.79	20.70	9.58	3.30	0.82	0.38	-0.00
88-4						100.00	97.18	93.61	91.47	87.01	71.05	48.52	29.35	14.66	5.77	1.75	0.91	0.00
88-5						100.00	96.92	93.41	91.17	88.64	75.68	50.51	26.48	10.67	3.75	1.51	0.95	0.00
88-6					100.00	82.38	78.77	73.60	70.57	68.83	58.15	37.23	22.11	10.40	4.24	1.77	1.18	0.00
88-7						100.00	95.88	95.15	88.94	84.93	74.28	52.84	29.20	13.92	5.83	2.61	1.72	0.00
88-8							100.00	96.66	92.58	88.24	74.79	47.94	29.05	15.32	7.91	3.74	2.39	-0.00
88-9							100.00	98.22	92.40	83.43	62.26	33.15	17.67	8.86	4.35	2.06	1.42	0.00
88-10							100.00	94.60	87.78	80.00	62.41	45.70	29.25	14.75	5.63	1.93	1.13	-0.00
88-11			100.00	97.52	96.29	93.53	90.13	83.37	74.84	67.86	49.50	30.85	9.75	4.49	1.69	0.63	0.39	0.00
88-12	100.00	98.62	97.35	96.13	93.13	89.34	84.09	75.67	65.18	57.78	42.26	23.89	4.96	2.68	1.31	0.59	0.38	-0.00
88-13		100.00	99.78	98.36	95.45	91.02	85.68	78.71	68.79	61.45	44.34	24.74	10.27	3.72	1.75	0.75	0.47	0.00
88-14		100.00	99.78	99.36	96.82	92.91	88.66	82.01	71.61	64.32	47.98	26.11	9.55	2.83	1.14	0.50	0.34	-0.00
88-15		100.00	99.73	99.29	97.68	93.56	88.56	80.85	71.57	63.63	47.52	28.03	11.02	4.20	1.72	0.83	0.49	-0.00
88-16					100.00	98.54	95.05	88.68	81.68	73.78	54.15	29.02	11.99	4.14	1.31	0.54	0.37	-0.00
88-17				100.00	98.39	97.78	95.08	91.18	84.73	63.81	41.90	33.99	23.75	4.72	0.40	0.12	0.08	0.00
88-18					100.00	99.68	99.09	96.13	91.07	84.45	62.81	33.55	15.73	6.57	2.67	1.14	0.73	-0.00
88-19						100.00	99.18	98.45	95.41	92.43	77.19	48.68	31.51	14.23	4.85	1.34	0.70	0.00
88-20						100.00	99.35	97.74	93.39	87.96	74.06	48.78	26.56	11.72	4.53	1.71	1.03	-0.00
88-21							100.00	99.57	97.41	95.33	85.81	60.68	34.34	16.13	6.37	2.30	1.37	0.00
88-22							100.00	98.55	96.48	87.93	68.65	45.19	28.09	15.25	6.00	2.42	1.56	0.00
88-23						100.00	50.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88-24																		
88-25		100.00	100.00	100.00	100.00	99.79	98.98	96.24	92.22	86.44	68.49	42.03	18.87	8.09	3.58	1.93	1.23	0.00
88-26		100.00	100.00	100.00	100.00	98.98	96.49	95.91	89.83	83.17	65.98	43.16	23.99	10.93	4.19	2.08	1.24	0.00
88-27		100.00	100.00	100.00	100.00	99.71	99.34	98.36	96.64	92.85	77.98	53.08	25.80	9.98	3.92	2.35	1.33	-0.00
88-28		100.00	100.00	100.00	100.00	99.78	99.03	96.67	92.44	85.18	64.35	33.78	11.88	3.96	1.46	0.61	0.44	0.00
88-29		100.00	100.00	100.00	100.00	100.00	96.71	87.67	78.50	70.61	53.83	36.55	18.57	7.10	2.11	0.67	0.42	0.00
88-30		100.00	100.00	100.00	99.57	98.90	97.86	94.75	90.17	83.66	63.86	34.45	13.67	5.47	2.39	1.15	0.79	0.00

Table 13 (Continued)

Sample No.	in 4 / mm 101.	3" / 76.2	2" / 50.8	1-1/ / 38.1	1" / 25.4	3/4" / 19.05	1/2" / 12.7	3/8" / 9.52	1/4" / 6.35	# 4 / 4.76	# 8 / 2.38	# 16 / 1.19	# 30 / 0.59	# 50 / 0.29	# 100 / 0.14	# 200 / 0.07	# 230 / 0.06	Pan / ----
	Sieve Size and Cumulative Percent Finer by Weight																	
88-31		100.00	100.00	98.37	96.88	93.37	87.94	76.96	64.51	53.06	33.38	15.71	5.85	2.30	1.07	0.56	0.43	-0.00
88-32				100.00	98.88	96.96	93.57	87.44	80.38	71.23	50.38	25.98	9.53	3.30	1.33	0.63	0.45	0.00
88-33				100.00	99.40	98.90	96.62	91.64	83.98	74.81	53.28	26.48	8.99	3.25	1.41	0.70	0.51	0.00
88-34				100.00	99.37	98.70	96.65	91.16	83.31	74.41	52.44	25.43	8.70	3.41	1.62	0.82	0.62	0.00
88-35				100.00	99.59	98.81	97.60	94.39	90.13	83.26	63.08	30.76	9.84	3.81	1.77	0.88	0.62	0.00
88-36				100.00	98.91	96.36	91.55	81.98	69.63	59.09	41.42	22.95	8.83	3.19	1.24	0.56	0.40	-0.00
88-37						100.00	99.44	98.22	97.17	93.86	79.82	50.08	22.54	9.27	3.33	1.24	0.80	-0.00
88-38						100.00	97.76	96.70	94.80	91.49	80.00	54.87	26.30	10.50	3.40	1.24	0.81	-0.00
89-39						100.00	99.03	91.32	85.98	78.95	61.57	40.53	21.94	9.82	4.12	1.66	1.07	-0.00
89-40			100.00	96.89	96.89	94.64	89.93	85.40	80.95	76.49	66.06	47.51	25.91	11.30	3.85	1.49	0.96	0.00
89-41				100.00	98.89	96.68	92.45	88.74	82.45	76.59	60.35	31.63	11.97	5.40	2.32	1.17	0.85	-0.00
89-42		100.00	99.84	98.79	93.91	87.12	72.77	60.77	49.43	41.42	28.54	13.64	4.84	2.03	0.95	0.47	0.35	-0.00
89-43			100.00	99.13	94.13	80.86	68.37	52.71	40.29	31.04	18.84	8.93	3.60	1.53	0.66	0.32	0.23	-0.00
89-44				100.00	98.37	96.64	93.04	85.61	78.86	72.84	57.21	30.33	10.81	3.89	1.45	0.71	0.47	-0.00
89-45				100.00	99.05	96.29	92.37	83.99	76.59	69.76	53.98	26.85	8.49	2.80	1.08	0.50	0.36	-0.00
89-46				100.00	99.89	99.22	98.03	94.93	89.91	83.31	63.36	29.92	9.51	3.93	1.82	0.87	0.63	-0.00
89-47				100.00	98.93	95.26	87.67	76.95	67.72	60.02	48.23	30.49	14.29	5.52	1.94	0.73	0.48	-0.00
89-48			100.00	98.64	95.79	88.29	77.22	62.35	49.22	39.86	28.41	17.09	7.55	2.99	1.19	0.55	0.36	0.00
89-49				100.00	98.89	94.45	87.51	77.28	67.70	60.52	47.82	29.84	14.21	5.95	2.13	1.03	0.55	-0.00
89-50			100.00	99.41	97.09	93.62	86.00	78.32	68.30	60.07	44.31	22.44	7.52	2.81	1.25	0.65	0.46	-0.00
89-51				100.00	98.75	95.86	90.24	83.11	75.77	68.84	53.21	27.64	8.61	2.82	1.16	0.55	0.39	0.00
89-52		100.00	98.89	98.89	97.11	93.34	86.53	81.20	72.35	65.62	51.40	25.77	7.33	2.42	1.03	0.51	0.38	0.00
89-53		100.00	99.71	98.49	94.13	88.18	76.97	70.19	60.95	55.01	41.85	20.18	6.47	2.59	1.26	0.68	0.50	-0.00
89-54				100.00	95.65	90.60	84.63	77.08	70.48	64.37	52.36	31.57	13.03	5.25	2.04	0.83	0.57	-0.00
89-55				100.00	99.63	96.25	93.83	89.42	85.35	81.32	71.54	47.00	18.14	6.03	2.06	0.85	0.58	-0.00
89-56			100.00	99.91	99.16	96.85	93.27	87.55	82.52	77.08	61.77	33.42	10.85	3.91	1.66	0.90	0.60	-0.00
89-57		100.00	99.35	98.48	96.06	91.11	80.20	72.00	61.58	53.76	39.54	20.91	7.48	2.89	1.36	0.73	0.53	-0.00
89-58					100.00	98.77	96.46	91.51	87.19	82.33	66.69	37.56	12.41	3.78	1.35	0.59	0.41	0.00
89-59				100.00	98.09	94.25	87.89	78.12	70.31	63.99	50.41	26.59	8.29	2.66	1.02	0.46	0.31	-0.00
89-60																		

Table 13 (Continued)

Sample No.	Sieve Size and Cumulative Percent Finer by Weight																	
	in 4	3"	2"	1-1/	1"	3/4"	1/2"	3/8"	1/4"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	# 230	Pan
	mm 101.	76.2	50.8	38.1	25.4	19.05	12.7	9.52	6.35	4.76	2.38	1.19	0.59	0.29	0.14	0.07	0.06	----
89-61					100.00	99.48	98.58	95.61	92.04	87.63	74.04	43.36	15.45	5.10	1.85	1.11	1.11	0.00
89-62					100.00	96.01	92.84	86.57	81.14	75.70	64.16	42.80	20.66	6.93	1.93	0.62	0.62	0.00
90-4				100.00	96.34	94.29	89.66	84.10	76.53	68.92	48.40	16.93	2.51	1.25	0.62	0.31	0.31	0.00

Table 14 Data summary for individual Oak Creek bedload samples, 1988-89

SAMPLE NUMBER: 88-1

FIELD DATA

Date/Time : Start: 01/23/88-18:15 End: 02/02/88-14:00 Delta Tim 240.75 hrs
Stage, ft : Start: 0.351 End: 0.283 Delta W.S -0.068 ft
Average Temperature: 7 C Mean Stag 0.317 ft

LAB DATA

Total Wt. (gr): 253.08 Analyzed by: HM Date Analyzed: 04/07/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retaine	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	4.11	1.62	1.62	98.38
1/4"	6.350	5.22	2.06	3.69	96.31
# 4	4.760	6.13	2.42	6.11	93.89
# 8	2.380	19.52	7.71	13.82	86.18
# 16	1.190	34.21	13.52	27.34	72.66
# 30	0.590	58.70	23.19	50.53	49.47
# 50	0.297	67.00	26.47	77.01	22.99
# 100	0.149	40.87	16.15	93.16	6.84
# 200	0.074	13.49	5.33	98.49	1.51
# 230	0.064	1.94	0.77	99.25	0.75
Pan	-----	1.89	0.75	100.00	-0.00

PARTICLE SIZE DISTRIBUTION CURVE

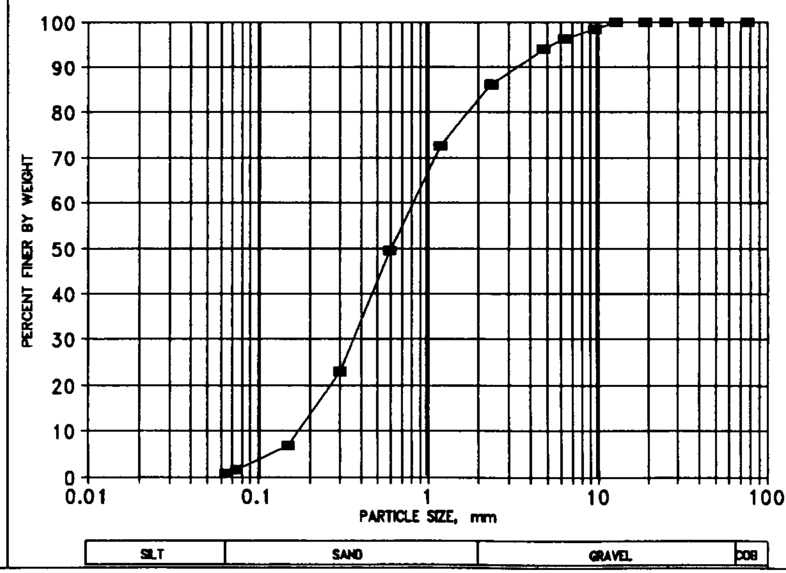


Table 14 (Continued)

SAMPLE NUMBER: 88-2

FIELD DATA

Date/Time :	Start:	02/02/88-14:00	End:	02/08/88-17:00	DT:	147.00 hrs
Stage, ft :	Start:	0.283	End:	0.332	DWS:	0.049 ft
Average Temerature:		7 C			AVG:	0.308 ft

LAB DATA

Total Wt. (gr): 316.89 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retaine	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	9.61	3.03	3.03	96.97
1/4"	6.350	14.38	4.54	7.57	92.43
# 4	4.760	17.72	5.59	13.16	86.84
# 8	2.380	61.18	19.31	32.47	67.53
# 16	1.190	68.65	21.66	54.13	45.87
# 30	0.590	65.40	20.64	74.77	25.23
# 50	0.297	46.12	14.55	89.32	10.68
# 100	0.149	25.06	7.91	97.23	2.77
# 200	0.074	7.01	2.21	99.44	0.56
# 230	0.064	0.96	0.30	99.75	0.25
Pan	-----	0.80	0.25	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

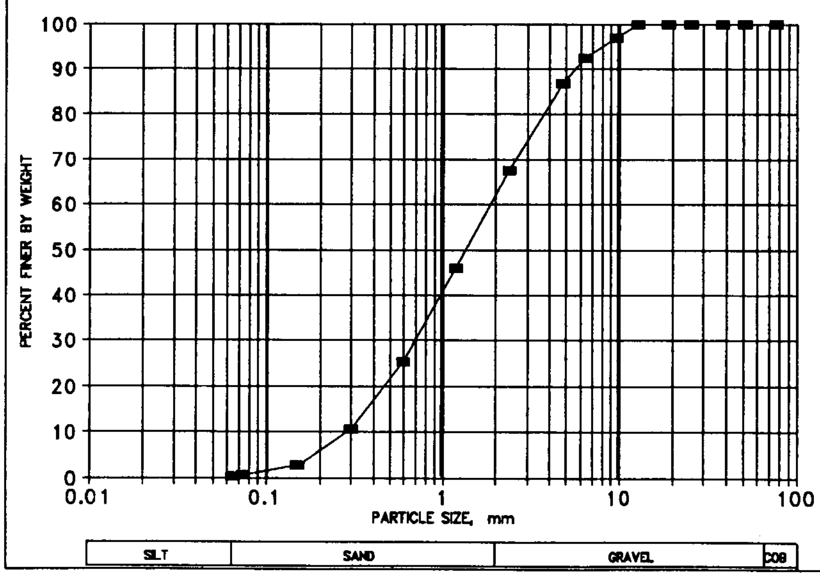


Table 14 (Continued)

SAMPLE NUMBER: 88-3

FIELD DATA

Date/Time :	Start:	02/08/88-17:00	End:	02/09/88-16:45	DT:	23.75	hrs
Stage, ft :	Start:	0.332	End:	0.403	DWS:	0.071	ft
Average Temerature:		9 C			AVG:	0.368	ft

LAB DATA

Total Wt. (gr): 299.60 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retaine	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	9.70	3.24	3.24	96.76
3/8"	9.525	22.44	7.49	10.73	89.27
1/4"	6.350	20.28	6.77	17.50	82.50
# 4	4.760	25.95	8.66	26.16	73.84
# 8	2.380	50.07	16.71	42.87	57.13
# 16	1.190	57.93	19.34	62.21	37.79
# 30	0.590	51.20	17.09	79.30	20.70
# 50	0.297	33.32	11.12	90.42	9.58
# 100	0.149	18.81	6.28	96.70	3.30
# 200	0.074	7.43	2.48	99.18	0.82
# 230	0.064	1.32	0.44	99.62	0.38
Pan	-----	1.15	0.38	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

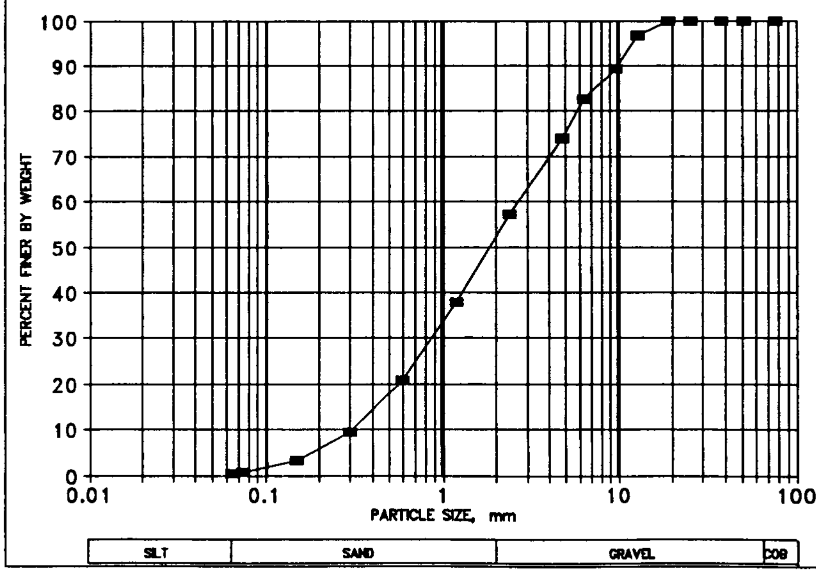


Table 14 (Continued)

SAMPLE NUMBER: 88-4

FIELD DATA

Date/Time :	Start:	02/09/88-16:45	End:	02/15/88-14:00	DT:	141.25	hrs
Stage, ft :	Start:	0.403	End:	0.363	DWS:	-0.040	ft
Average Temerature:		8 C			AVG:	0.383	ft

LAB DATA

Total Wt. (gr): 1073.60 Analyzed by: HM Date Analyzed: 04/07/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	30.24	2.82	2.82	97.18
3/8"	9.525	38.31	3.57	6.39	93.61
1/4"	6.350	23.02	2.14	8.53	91.47
# 4	4.760	47.91	4.46	12.99	87.01
# 8	2.380	171.30	15.96	28.95	71.05
# 16	1.190	241.90	22.53	51.48	48.52
# 30	0.590	205.85	19.17	70.65	29.35
# 50	0.297	157.66	14.69	85.34	14.66
# 100	0.149	95.50	8.90	94.23	5.77
# 200	0.074	43.07	4.01	98.25	1.75
# 230	0.064	9.02	0.84	99.09	0.91
Pan	-----	9.82	0.91	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

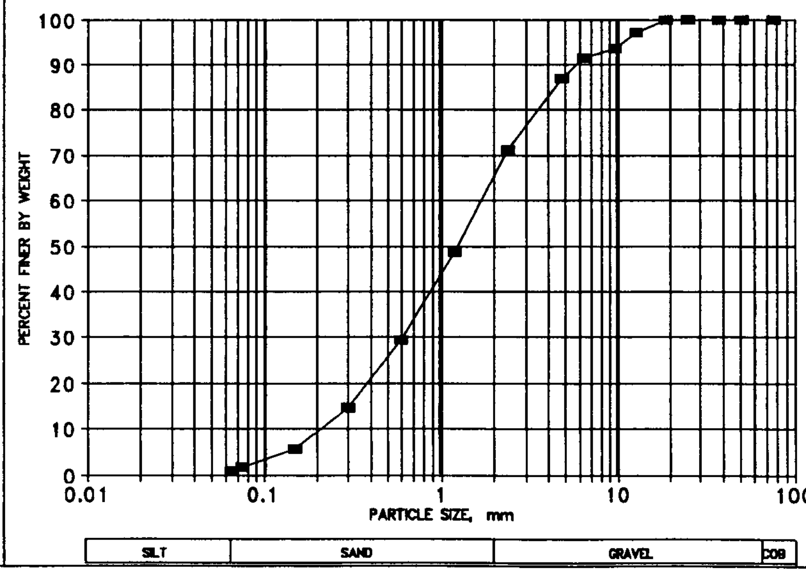


Table 14 (Continued)

SAMPLE NUMBER: 88-5

FIELD DATA

Date/Time :	Start:	02/15/88-15:00	End:	02/22/88-16:00	DT:	169.00	hrs
Stage, ft :	Start:	0.371	End:	0.267	DWS:	-0.104	ft
Average Temerature:		7 C			AVG:	0.319	ft

LAB DATA

Total Wt. (gr): 304.97 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	9.38	3.08	3.08	96.92
3/8"	9.525	10.71	3.51	6.59	93.41
1/4"	6.350	6.84	2.24	8.83	91.17
# 4	4.760	7.70	2.52	11.36	88.64
# 8	2.380	39.54	12.97	24.32	75.68
# 16	1.190	76.75	25.17	49.49	50.51
# 30	0.590	73.30	24.04	73.52	26.48
# 50	0.297	48.20	15.80	89.33	10.67
# 100	0.149	21.10	6.92	96.25	3.75
# 200	0.074	6.85	2.25	98.49	1.51
# 230	0.064	1.71	0.56	99.05	0.95
Pan	-----	2.89	0.95	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

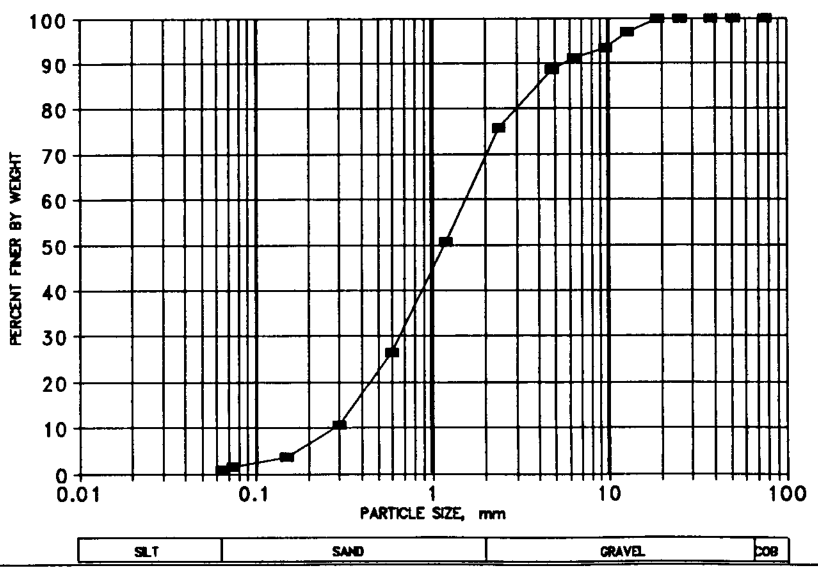


Table 14 (Continued)

SAMPLE NUMBER: 88-6

FIELD DATA

Date/Time :	Start:	02/22/88-16:00	End:	03/04/88-8:45	DT:	256.75	hrs
Stage, ft :	Start:	0.267	End:	0.221	DWS:	-0.046	ft
Average Temerature:		8 C			AVG:	0.244	ft

LAB DATA

Total Wt. (gr): 162.02 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	28.54	17.62	17.62	82.38
1/2"	12.7	5.86	3.62	21.23	78.77
3/8"	9.525	8.38	5.17	26.40	73.60
1/4"	6.350	4.91	3.03	29.43	70.57
# 4	4.760	2.81	1.73	31.17	68.83
# 8	2.380	17.30	10.68	41.85	58.15
# 16	1.190	33.90	20.92	62.77	37.23
# 30	0.590	24.50	15.12	77.89	22.11
# 50	0.297	18.97	11.71	89.60	10.40
# 100	0.149	9.98	6.16	95.76	4.24
# 200	0.074	4.01	2.48	98.23	1.77
# 230	0.064	0.95	0.59	98.82	1.18
Pan	-----	1.91	1.18	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

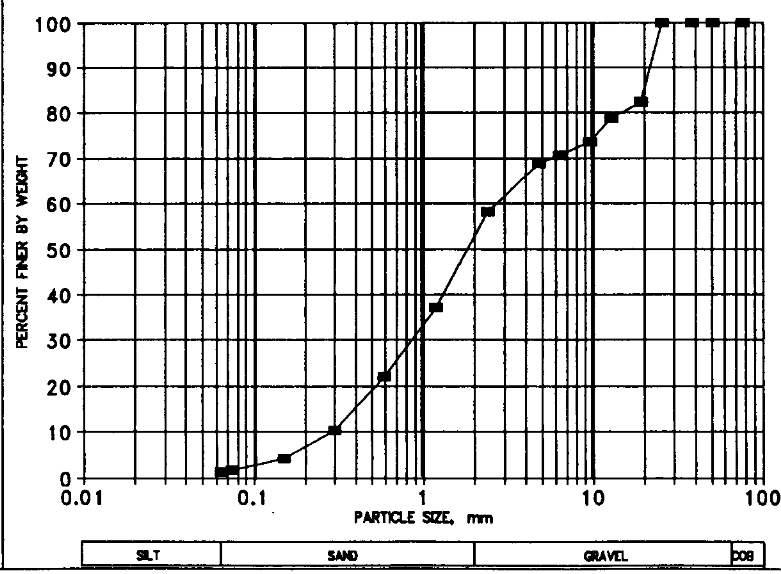


Table 14 (Continued)

SAMPLE NUMBER: 88-7

FIELD DATA

Date/Time :	Start:	03/04/88-8:45	End:	03/09/88-6:45	DT:	118.00	hrs
Stage, ft :	Start:	0.251	End:	0.351	DWS:	0.100	ft
Average Temerature:		9 C			AVG:	0.301	ft

LAB DATA

Total Wt. (gr): 211.16 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	8.70	4.12	4.12	95.88
3/8"	9.525	1.55	0.73	4.85	95.15
1/4"	6.350	13.10	6.20	11.06	88.94
# 4	4.760	8.47	4.01	15.07	84.93
# 8	2.380	22.50	10.66	25.72	74.28
# 16	1.190	45.27	21.44	47.16	52.84
# 30	0.590	49.92	23.64	70.80	29.20
# 50	0.297	32.26	15.28	86.08	13.92
# 100	0.149	17.07	8.08	94.17	5.83
# 200	0.074	6.81	3.23	97.39	2.61
# 230	0.064	1.88	0.89	98.28	1.72
Pan	-----	3.63	1.72	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

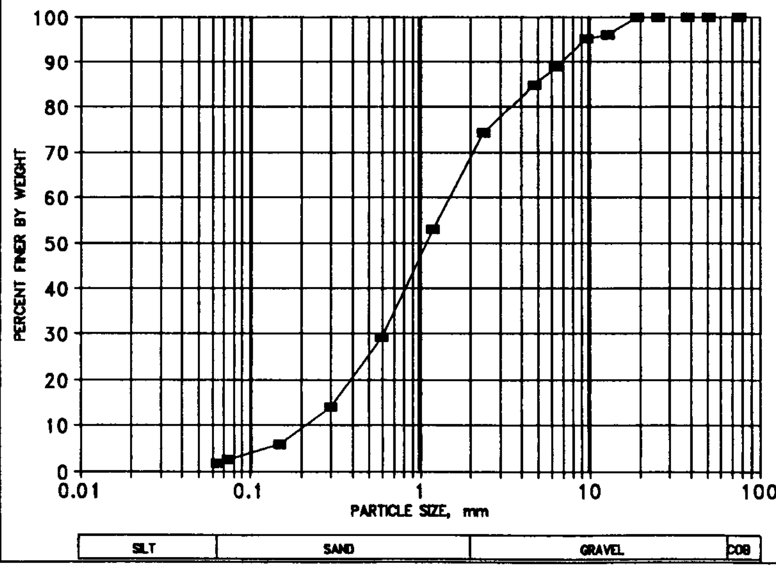


Table 14 (Continued)

SAMPLE NUMBER: 88-8

FIELD DATA

Date/Time :	Start:	03/09/88-6:45	End:	03/10/88-10:50	DT:	28.08	hrs
Stage, ft :	Start:	0.351	End:	0.335	DWS:	-0.016	ft
Average Temerature:		6 C			AVG:	0.343	ft

LAB DATA

Total Wt. (gr): 184.38 Analyzed by: HM Date Analyzed: 04/07/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	6.15	3.34	3.34	96.66
1/4"	6.350	7.53	4.08	7.42	92.58
# 4	4.760	8.00	4.34	11.76	88.24
# 8	2.380	24.80	13.45	25.21	74.79
# 16	1.190	49.50	26.85	52.06	47.94
# 30	0.590	34.84	18.90	70.95	29.05
# 50	0.297	25.31	13.73	84.68	15.32
# 100	0.149	13.67	7.41	92.09	7.91
# 200	0.074	7.68	4.17	96.26	3.74
# 230	0.064	2.50	1.36	97.61	2.39
Pan	-----	4.40	2.39	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

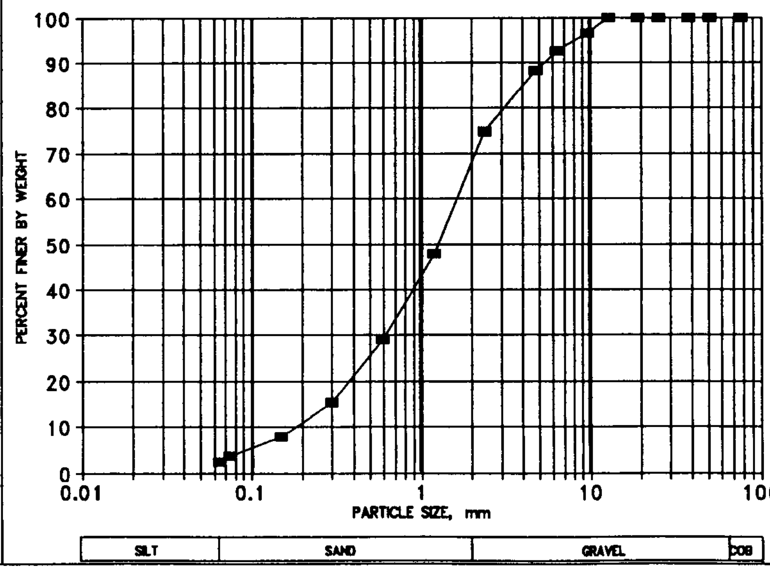


Table 14 (Continued)

SAMPLE NUMBER: 88-9

FIELD DATA

Date/Time :	Start:	03/10/88-10:50	End:	03/24/88-14:00	DT:	339.17	hrs
Stage, ft :	Start:	0.335	End:	0.322	DWS:	-0.013	ft
Average Temerature:		6 C			AVG:	0.329	ft

LAB DATA

Total Wt. (gr): 223.17 Analyzed by: HM Date Analyzed: 04/07/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	3.97	1.78	1.78	98.22
1/4"	6.350	13.00	5.83	7.60	92.40
# 4	4.760	20.00	8.96	16.57	83.43
# 8	2.380	47.26	21.18	37.74	62.26
# 16	1.190	64.95	29.10	66.85	33.15
# 30	0.590	34.55	15.48	82.33	17.67
# 50	0.297	19.67	8.81	91.14	8.86
# 100	0.149	10.07	4.51	95.65	4.35
# 200	0.074	5.11	2.29	97.94	2.06
# 230	0.064	1.43	0.64	98.58	1.42
Pan	-----	3.16	1.42	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

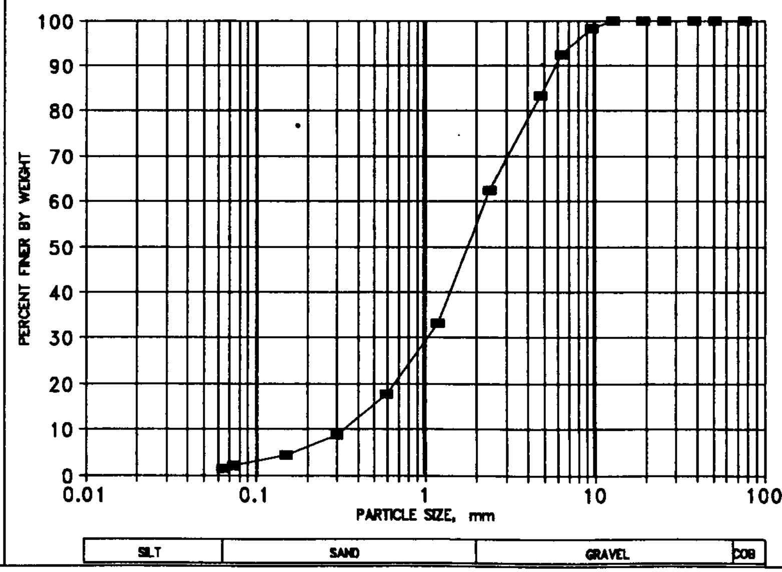


Table 14 (Continued)

SAMPLE NUMBER: 88-10

FIELD DATA

Date/Time :	Start:	03/24/88-14:00	End:	03/24/88-17:45	DT:	3.75	hrs
Stage, ft :	Start:	0.322	End:	0.585	DWS:	0.263	ft
Average Temerature:		7 C			AVG:	0.454	ft

LAB DATA

Total Wt. (gr): 783.86 Analyzed by: HM Date Analyzed: 04/06/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	42.33	5.40	5.40	94.60
1/4"	6.350	53.43	6.82	12.22	87.78
# 4	4.760	61.00	7.78	20.00	80.00
# 8	2.380	137.89	17.59	37.59	62.41
# 16	1.190	131.00	16.71	54.30	45.70
# 30	0.590	128.90	16.44	70.75	29.25
# 50	0.297	113.70	14.51	85.25	14.75
# 100	0.149	71.50	9.12	94.37	5.63
# 200	0.074	29.00	3.70	98.07	1.93
# 230	0.064	6.24	0.80	98.87	1.13
Pan	-----	8.87	1.13	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

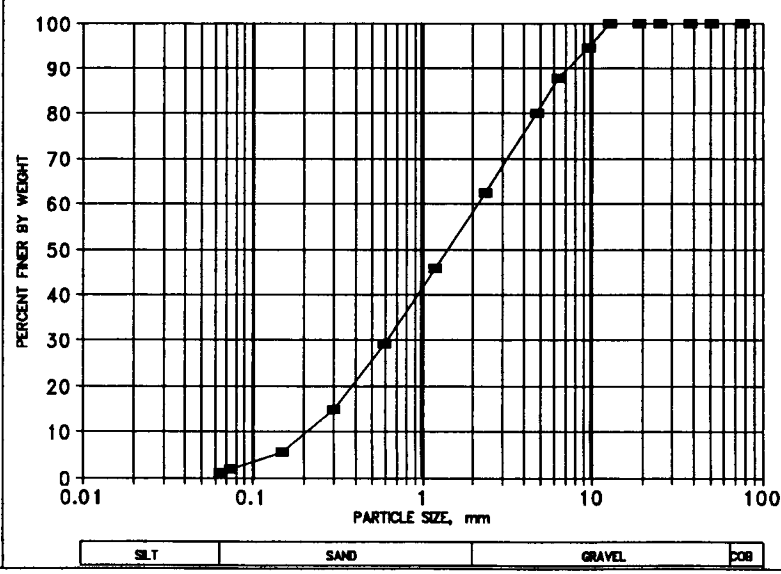


Table 14 (Continued)

SAMPLE NUMBER: 88-11

FIELD DATA

Date/Time :	Start:	03/24/88-17:45	End:	03/24/88-20:30	DT:	2.75	hrs
Stage, ft :	Start:	0.585	End:	1.025	DWS:	0.440	ft
Average Temerature:		8 C			AVG:	0.805	ft

LAB DATA

Total Wt. (gr): 12114.28 Analyzed by: HM Date Analyzed: 04/02/88

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	300.50	2.48	2.48	97.52
1"	25.4	149.32	1.23	3.71	96.29
3/4"	19.05	334.04	2.76	6.47	93.53
1/2"	12.7	411.62	3.40	9.87	90.13
3/8"	9.525	819.67	6.77	16.63	83.37
1/4"	6.350	1032.70	8.52	25.16	74.84
# 4	4.760	845.71	6.98	32.14	67.86
# 8	2.380	2224.12	18.36	50.50	49.50
# 16	1.190	2258.86	18.65	69.15	30.85
# 30	0.590	2556.54	21.10	90.25	9.75
# 50	0.297	637.26	5.26	95.51	4.49
# 100	0.149	339.58	2.80	98.31	1.69
# 200	0.074	127.73	1.05	99.37	0.63
# 230	0.064	28.95	0.24	99.61	0.39
Pan	-----	47.68	0.39	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

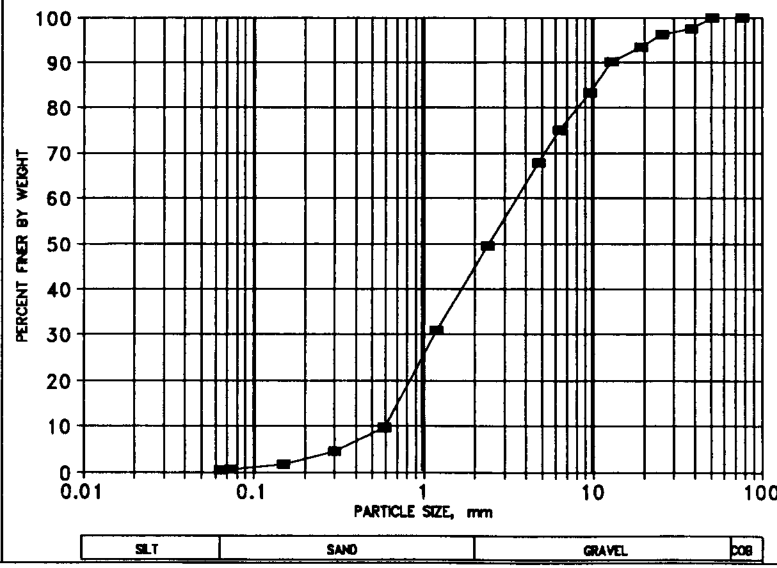


Table 14 (Continued)

SAMPLE NUMBER: 88-12

FIELD DATA

Date/Time :	Start:	03/24/88-20:30	End:	03/24/88-22:00	DT:	1.50	hrs
Stage, ft :	Start:	1.025	End:	1.078	DWS:	0.053	ft
Average Temerature:		8 C			AVG:	1.052	ft

LAB DATA

Total Wt. (gr): 17404.66 Analyzed by: HM Date Analyzed: 04/02/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2	240.10	1.38	1.38	98.62
2"	50.8	220.85	1.27	2.65	97.35
1-1/2"	38.1	212.98	1.22	3.87	96.13
1"	25.4	520.98	2.99	6.87	93.13
3/4"	19.05	660.23	3.79	10.66	89.34
1/2"	12.7	913.90	5.25	15.91	84.09
3/8"	9.525	1465.78	8.42	24.33	75.67
1/4"	6.350	1825.58	10.49	34.82	65.18
# 4	4.760	1288.69	7.40	42.22	57.78
# 8	2.380	2700.51	15.52	57.74	42.26
# 16	1.190	3197.25	18.37	76.11	23.89
# 30	0.590	3294.76	18.93	95.04	4.96
# 50	0.297	395.78	2.27	97.32	2.68
# 100	0.149	239.38	1.38	98.69	1.31
# 200	0.074	125.81	0.72	99.41	0.59
# 230	0.064	36.33	0.21	99.62	0.38
Pan	-----	65.77	0.38	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

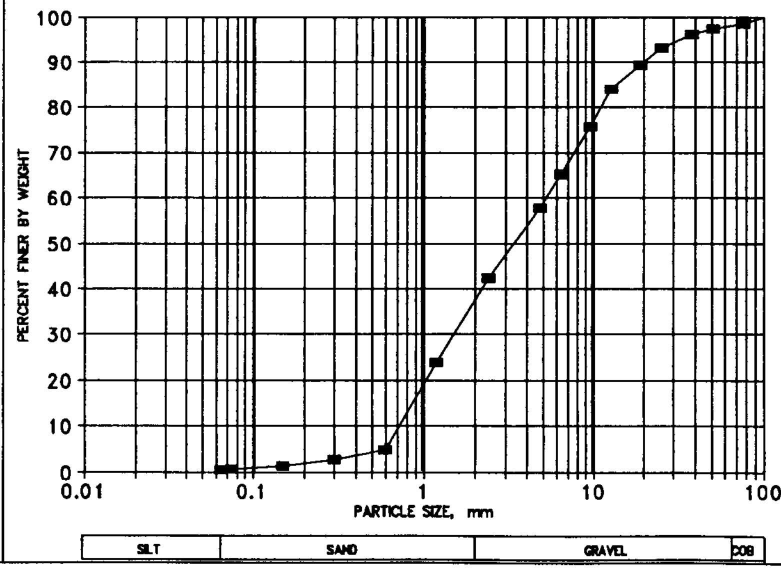


Table 14 (Continued)

SAMPLE NUMBER: 88-13

FIELD DATA

Date/Time :	Start:	03/24/88-22:00	End:	03/24/88-23:45	DT:	1.75	hrs
Stage, ft :	Start:	1.078	End:	1.125	DWS:	0.047	ft
Average Temerature:		8 C			AVG:	1.102	ft

LAB DATA

Total Wt. (gr): 19848.32 Analyzed by: HM Date Analyzed: 04/02/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	44.07	0.22	0.22	99.78
1-1/2"	38.1	282.33	1.42	1.64	98.36
1"	25.4	577.60	2.91	4.55	95.45
3/4"	19.05	877.52	4.42	8.98	91.02
1/2"	12.7	1061.73	5.35	14.32	85.68
3/8"	9.525	1383.03	6.97	21.29	78.71
1/4"	6.350	1969.23	9.92	31.21	68.79
# 4	4.760	1455.61	7.33	38.55	61.45
# 8	2.380	3395.70	17.11	55.66	44.34
# 16	1.190	3891.92	19.61	75.26	24.74
# 30	0.590	2870.77	14.46	89.73	10.27
# 50	0.297	1301.22	6.56	96.28	3.72
# 100	0.149	389.67	1.96	98.25	1.75
# 200	0.074	199.62	1.01	99.25	0.75
# 230	0.064	54.36	0.27	99.53	0.47
Pan	-----	93.94	0.47	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

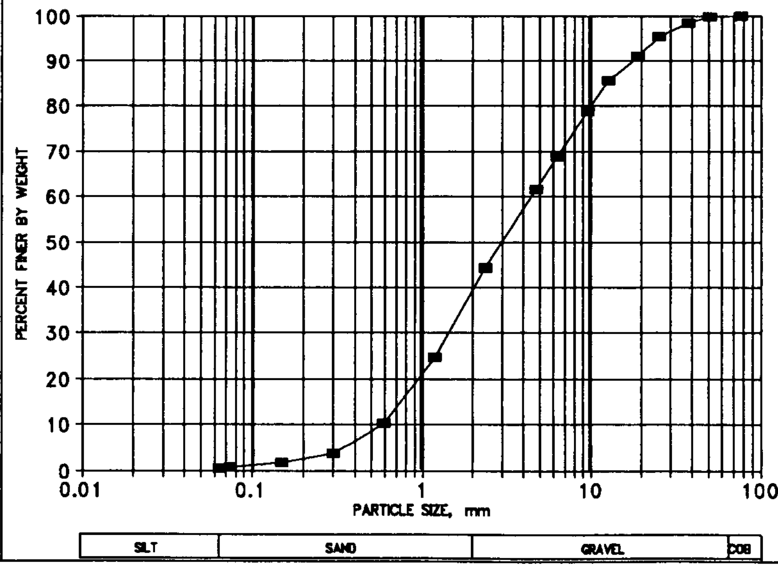


Table 14 (Continued)

SAMPLE NUMBER: 88-14

FIELD DATA

Date/Time :	Start:	03/24/88-23:45	End:	03/25/88-1:15	DT:	1.50	hrs
Stage, ft :	Start:	1.125	End:	1.13	DWS:	0.005	ft
Average Temerature:		8 C			AVG:	1.128	ft

LAB DATA

Total Wt. (gr): 17783.73 Analyzed by: HM Date Analyzed: 04/02/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	38.37	0.22	0.22	99.78
1-1/2"	38.1	74.72	0.42	0.64	99.36
1"	25.4	452.10	2.54	3.18	96.82
3/4"	19.05	695.55	3.91	7.09	92.91
1/2"	12.7	755.95	4.25	11.34	88.66
3/8"	9.525	1182.41	6.65	17.99	82.01
1/4"	6.350	1849.08	10.40	28.39	71.61
# 4	4.760	1296.52	7.29	35.68	64.32
# 8	2.380	2906.35	16.34	52.02	47.98
# 16	1.190	3890.08	21.87	73.89	26.11
# 30	0.590	2945.13	16.56	90.45	9.55
# 50	0.297	1194.78	6.72	97.17	2.83
# 100	0.149	299.70	1.69	98.86	1.14
# 200	0.074	114.84	0.65	99.50	0.50
# 230	0.064	28.21	0.16	99.66	0.34
Pan	-----	59.94	0.34	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

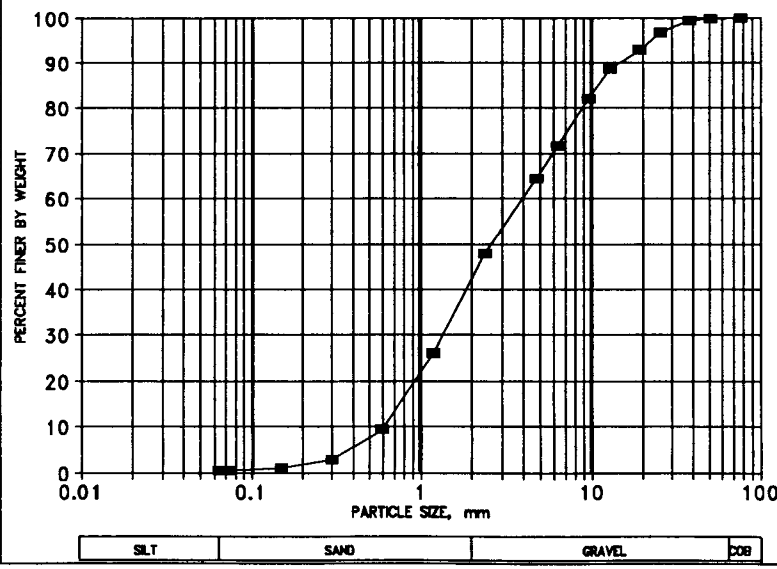


Table 14 (Continued)

SAMPLE NUMBER: 88-15

FIELD DATA

Date/Time :	Start:	03/25/88-1:15	End:	03/25/88-3:35	DT:	2.33	hrs
Stage, ft :	Start:	1.13	End:	1.008	DWS:	-0.122	ft
Average Temerature:		8 C			AVG:	1.069	ft

LAB DATA

Total Wt. (gr): 16248.14 Analyzed by: HM Date Analyzed: 04/02/88

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	43.60	0.27	0.27	99.73
1-1/2"	38.1	71.35	0.44	0.71	99.29
1"	25.4	262.62	1.62	2.32	97.68
3/4"	19.05	668.82	4.12	6.44	93.56
1/2"	12.7	812.88	5.00	11.44	88.56
3/8"	9.525	1252.70	7.71	19.15	80.85
1/4"	6.350	1507.95	9.28	28.43	71.57
# 4	4.760	1289.36	7.94	36.37	63.63
# 8	2.380	2617.37	16.11	52.48	47.52
# 16	1.190	3167.86	19.50	71.97	28.03
# 30	0.590	2762.66	17.00	88.98	11.02
# 50	0.297	1108.53	6.82	95.80	4.20
# 100	0.149	402.98	2.48	98.28	1.72
# 200	0.074	145.29	0.89	99.17	0.83
# 230	0.064	53.76	0.33	99.51	0.49
Pan	-----	80.42	0.49	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

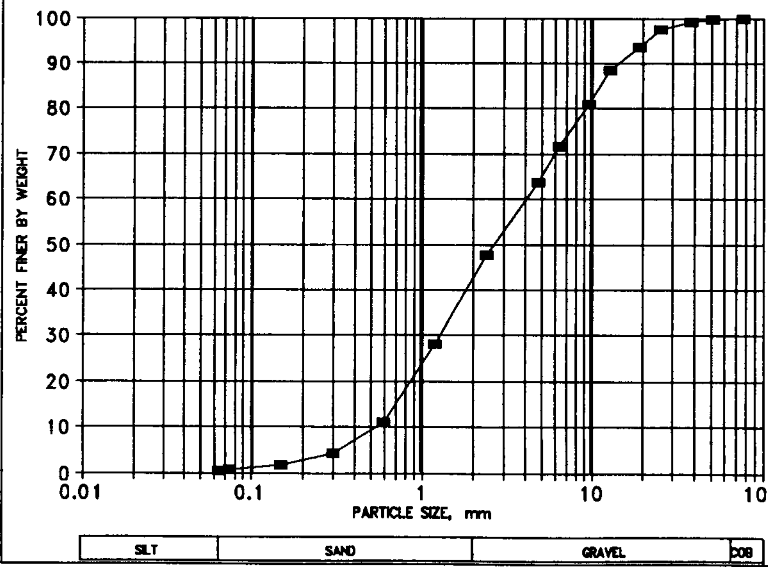


Table 14 (Continued)

SAMPLE NUMBER: 88-16

FIELD DATA

Date/Time : Start: 03/25/88-3:35 End: 03/25/88-6:00 DT: 2.42 hrs
Stage, ft : Start: 1.008 End: 0.913 DWS: -0.095 ft
Average Temerature: 8 C AVG: 0.961 ft

LAB DATA

Total Wt. (gr): 5986.50 Analyzed by: DK/ Date Analyzed: 06/30/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	87.50	1.46	1.46	98.54
1/2"	12.7	208.90	3.49	4.95	95.05
3/8"	9.525	381.50	6.37	11.32	88.68
1/4"	6.350	418.80	7.00	18.32	81.68
# 4	4.760	473.00	7.90	26.22	73.78
# 8	2.380	1175.40	19.63	45.85	54.15
# 16	1.190	1504.10	25.12	70.98	29.02
# 30	0.590	1019.60	17.03	88.01	11.99
# 50	0.297	470.00	7.85	95.86	4.14
# 100	0.149	169.20	2.83	98.69	1.31
# 200	0.074	45.90	0.77	99.46	0.54
# 230	0.064	10.20	0.17	99.63	0.37
Pan	-----	22.40	0.37	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

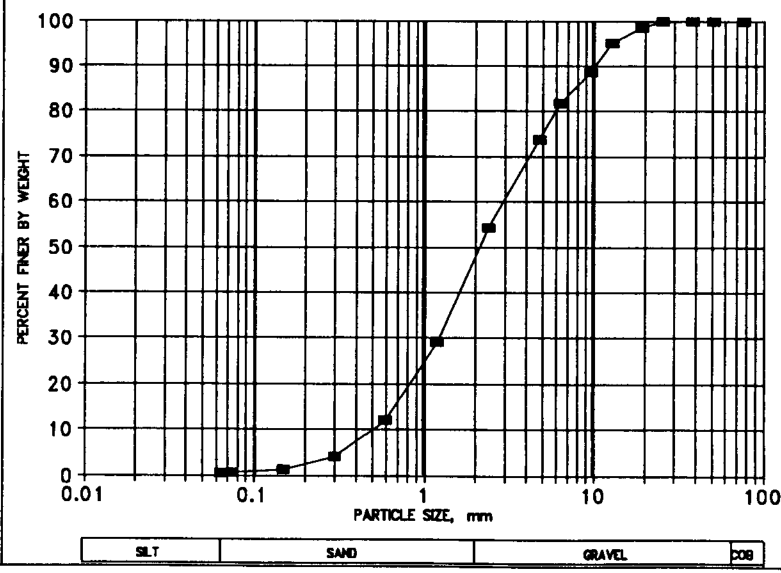


Table 14 (Continued)

SAMPLE NUMBER: 88-17

FIELD DATA

Date/Time : Start: 03/25/88-6:00 End: 03/25/88-9:00 DT: 3.00 hrs
Stage, ft : Start: 0.913 End: 0.827 DWS: -0.086 ft
Average Temerature: 8 C AVG: 0.870 ft

LAB DATA

Total Wt. (gr): 2329.80 Analyzed by: DK/ Date Analyzed: 06/30/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	37.50	1.61	1.61	98.39
3/4"	19.05	14.30	0.61	2.22	97.78
1/2"	12.7	62.90	2.70	4.92	95.08
3/8"	9.525	90.80	3.90	8.82	91.18
1/4"	6.350	150.30	6.45	15.27	84.73
# 4	4.760	487.40	20.92	36.19	63.81
# 8	2.380	510.40	21.91	58.10	41.90
# 16	1.190	184.30	7.91	66.01	33.99
# 30	0.590	238.50	10.24	76.25	23.75
# 50	0.297	443.50	19.04	95.28	4.72
# 100	0.149	100.60	4.32	99.60	0.40
# 200	0.074	6.40	0.27	99.88	0.12
# 230	0.064	1.00	0.04	99.92	0.08
Pan	-----	1.90	0.08	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

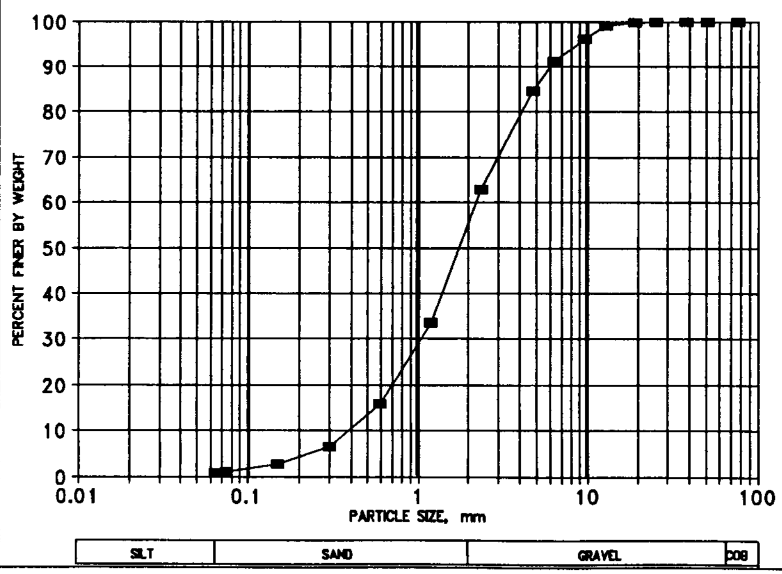


Table 14 (Continued)

SAMPLE NUMBER: 88-18

FIELD DATA

Date/Time :	Start:	03/25/88-9:00	End:	03/25/88-17:00	DT:	8.00	hrs
Stage, ft :	Start:	0.827	End:	0.653	DWS:	-0.174	ft
Average Temerature:		8 C			AVG:	0.740	ft

LAB DATA

Total Wt. (gr): 5563.20 Analyzed by: DK/ Date Analyzed: 05/27/88
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	17.90	0.32	0.32	99.68
1/2"	12.7	32.80	0.59	0.91	99.09
3/8"	9.525	164.70	2.96	3.87	96.13
1/4"	6.350	281.60	5.06	8.93	91.07
# 4	4.760	368.10	6.62	15.55	84.45
# 8	2.380	1203.90	21.64	37.19	62.81
# 16	1.190	1627.80	29.26	66.45	33.55
# 30	0.590	991.20	17.82	84.27	15.73
# 50	0.297	509.90	9.17	93.43	6.57
# 100	0.149	216.90	3.90	97.33	2.67
# 200	0.074	84.80	1.52	98.86	1.14
# 230	0.064	23.00	0.41	99.27	0.73
Pan	-----	40.60	0.73	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

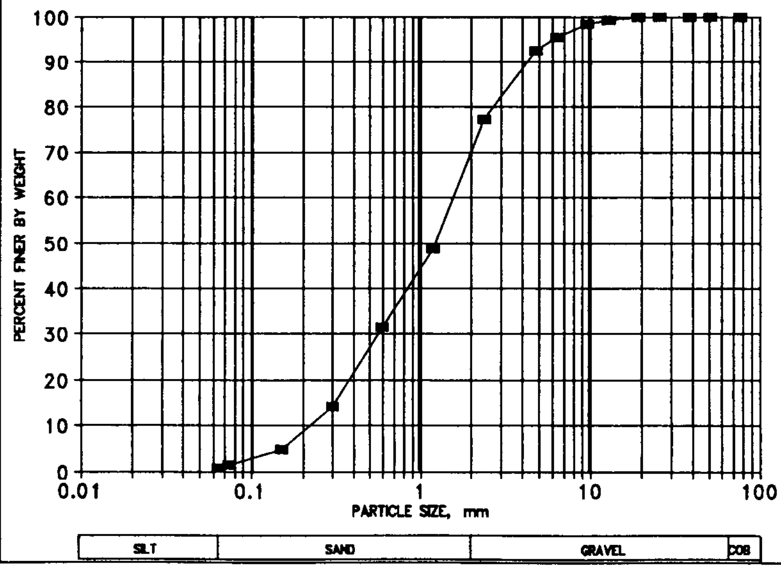


Table 14 (Continued)

SAMPLE NUMBER: 88-19

FIELD DATA

Date/Time :	Start:	03/25/88-17:00	End:	03/26/88-9:30	DT:	16.50	hrs
Stage, ft :	Start:	0.653	End:	0.521	DWS:	-0.132	ft
Average Temerature:		9 C			AVG:	0.587	ft

LAB DATA

Total Wt. (gr): 1155.06 Analyzed by: HM Date Analyzed: 04/07/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	9.48	0.82	0.82	99.18
3/8"	9.525	8.42	0.73	1.55	98.45
1/4"	6.350	35.07	3.04	4.59	95.41
# 4	4.760	34.50	2.99	7.57	92.43
# 8	2.380	176.00	15.24	22.81	77.19
# 16	1.190	329.30	28.51	51.32	48.68
# 30	0.590	198.35	17.17	68.49	31.51
# 50	0.297	199.60	17.28	85.77	14.23
# 100	0.149	108.37	9.38	95.15	4.85
# 200	0.074	40.48	3.50	98.66	1.34
# 230	0.064	7.37	0.64	99.30	0.70
Pan	-----	8.12	0.70	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

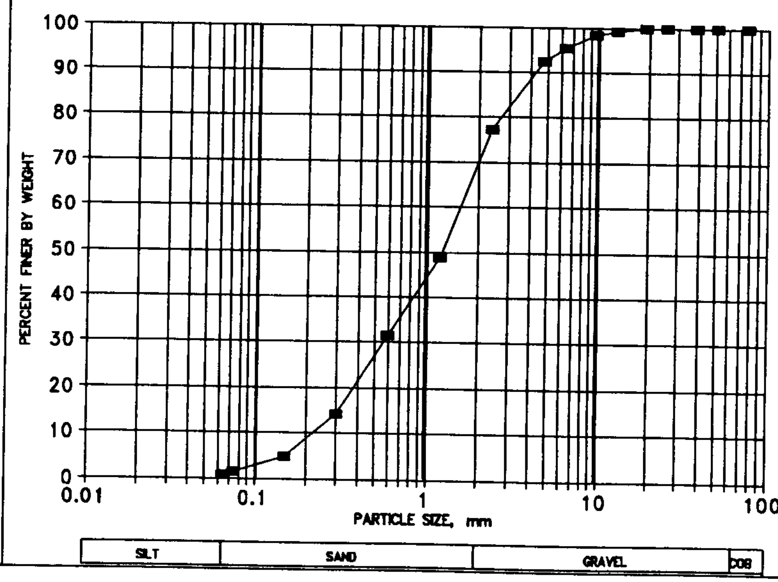


Table 14 (Continued)

SAMPLE NUMBER: 88-20

FIELD DATA

Date/Time :	Start:	03/26/88-9:30	End:	03/27/88-11:15	DT:	25.75	hrs
Stage, ft :	Start:	0.521	End:	0.529	DWS:	0.008	ft
Average Temerature:		9 C			AVG:	0.525	ft

LAB DATA

Total Wt. (gr): 750.05 Analyzed by: HM Date Analyzed: 04/06/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	4.86	0.65	0.65	99.35
3/8"	9.525	12.08	1.61	2.26	97.74
1/4"	6.350	32.64	4.35	6.61	93.39
# 4	4.760	40.70	5.43	12.04	87.96
# 8	2.380	104.30	13.91	25.94	74.06
# 16	1.190	189.60	25.28	51.22	48.78
# 30	0.590	166.67	22.22	73.44	26.56
# 50	0.297	111.30	14.84	88.28	11.72
# 100	0.149	53.91	7.19	95.47	4.53
# 200	0.074	21.15	2.82	98.29	1.71
# 230	0.064	5.14	0.69	98.97	1.03
Pan	-----	7.70	1.03	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

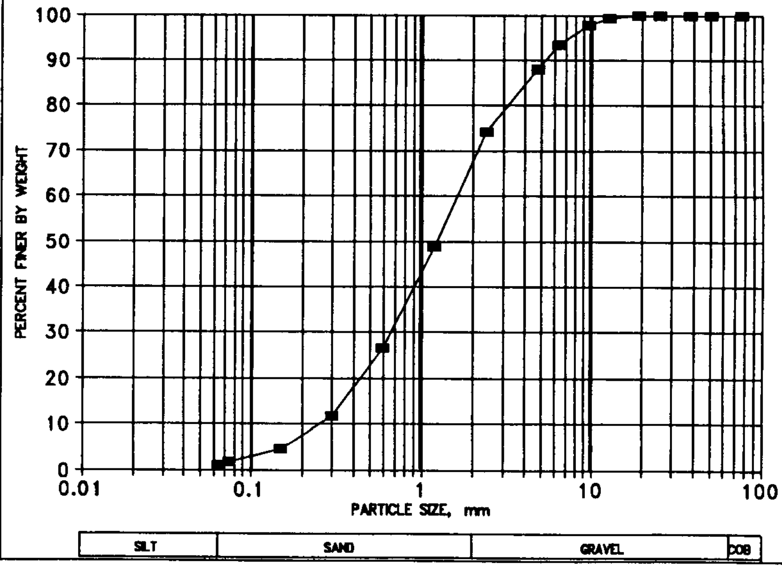


Table 14 (Continued)

SAMPLE NUMBER: 88-21

FIELD DATA

Date/Time : Start: 03/27/88-11:15 End: 03/30/88-9:30 DT: 70.25 hrs
Stage, ft : Start: 0.529 End: 0.364 DWS: -0.165 ft
Average Temerature: 8 C AVG: 0.447 ft

LAB DATA

Total Wt. (gr): 514.86 Analyzed by: HM Date Analyzed: 04/06/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	2.22	0.43	0.43	99.57
1/4"	6.350	11.10	2.16	2.59	97.41
# 4	4.760	10.70	2.08	4.67	95.33
# 8	2.380	49.06	9.53	14.19	85.81
# 16	1.190	129.37	25.13	39.32	60.68
# 30	0.590	135.63	26.34	65.66	34.34
# 50	0.297	93.73	18.20	83.87	16.13
# 100	0.149	50.25	9.76	93.63	6.37
# 200	0.074	20.94	4.07	97.70	2.30
# 230	0.064	4.82	0.94	98.63	1.37
Pan	-----	7.04	1.37	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

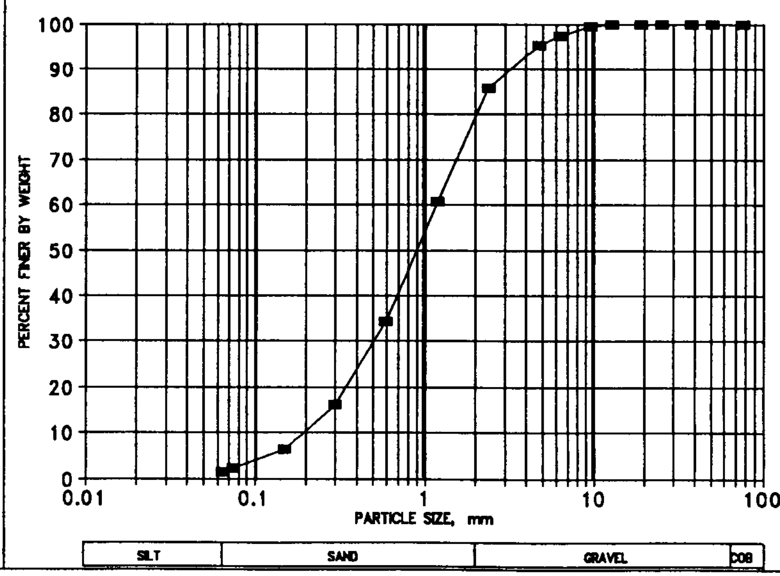


Table 14 (Continued)

SAMPLE NUMBER: 88-22

FIELD DATA

Date/Time :	Start:	03/30/88-9:30	End:	04/14/88-9:45	DT:	360.25	hrs
Stage, ft :	Start:	0.364	End:	0.36	DWS:	-0.004	ft
Average Temerature:		7 C			AVG:	0.362	ft

LAB DATA

Total Wt. (gr): 525.10 Analyzed by: DK/ Date Analyzed: 06/27/88

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7		0.00	0.00	100.00
3/8"	9.525	7.60	1.45	1.45	98.55
1/4"	6.350	10.90	2.08	3.52	96.48
# 4	4.760	44.90	8.55	12.07	87.93
# 8	2.380	101.20	19.27	31.35	68.65
# 16	1.190	123.20	23.46	54.81	45.19
# 30	0.590	89.80	17.10	71.91	28.09
# 50	0.297	67.40	12.84	84.75	15.25
# 100	0.149	48.60	9.26	94.00	6.00
# 200	0.074	18.80	3.58	97.58	2.42
# 230	0.064	4.50	0.86	98.44	1.56
Pan	-----	8.20	1.56	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

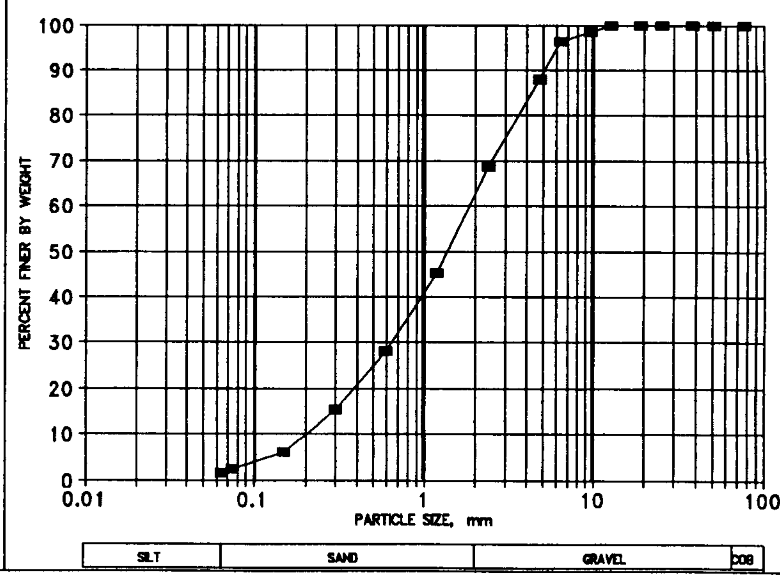


Table 14 (Continued)

SAMPLE NUMBER: 88-23

FIELD DATA

Date/Time :	Start:	04/14/88-9:45	End:	04/19/88-23:00	DT:	121.25	hrs
Stage, ft :	Start:	0.36	End:	0.315	DWS:	-0.045	ft
Average Temerature:		9 C			AVG:	0.338	ft

LAB DATA NOTE: DISCARDED BECAUSE OF ORGANICS

Total Wt. (gr): 21.60 Analyzed by: DK/ Date Analyzed: 06/27/88
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	10.60	49.07	49.07	50.93
3/8"	9.525	11.00	50.93	100.00	0.00
1/4"	6.350		0.00	100.00	0.00
# 4	4.760		0.00	100.00	0.00
# 8	2.380		0.00	100.00	0.00
# 16	1.190		0.00	100.00	0.00
# 30	0.590		0.00	100.00	0.00
# 50	0.297		0.00	100.00	0.00
# 100	0.149		0.00	100.00	0.00
# 200	0.074		0.00	100.00	0.00
# 230	0.064		0.00	100.00	0.00
Pan	-----		0.00	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

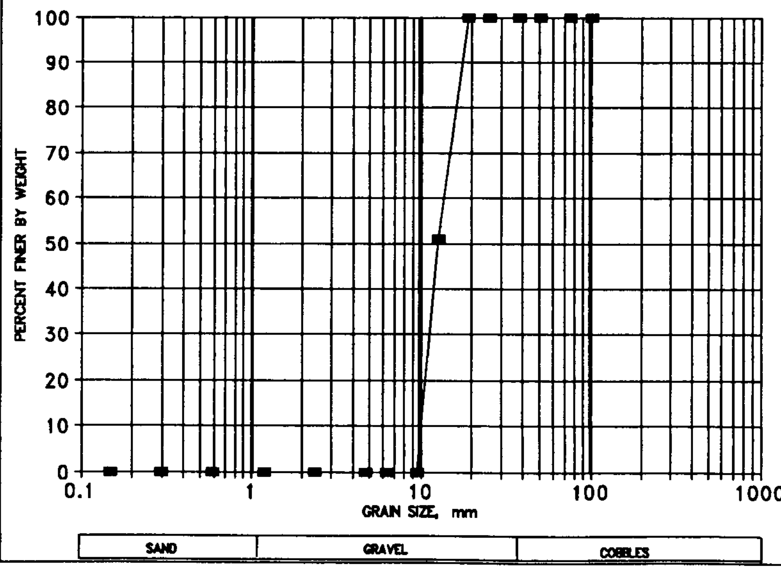


Table 14 (Continued)

SAMPLE NUMBER: 88-25

FIELD DATA

Date/Time :	Start:	05/02/88-14:30	End:	05/09/88-8:30	DT:	162.00	hrs
Stage, ft :	Start:	0.563	End:	0.260	DWS:	-0.303	ft
Average Temerature:		9 C			AVG:	0.412	ft

LAB DATA

Total Wt. (gr): 3470.75 Analyzed by: MP/ Date Analyzed: 05/09/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	7.25	0.21	0.21	99.79
1/2"	12.7	28.20	0.81	1.02	98.98
3/8"	9.525	94.95	2.74	3.76	96.24
1/4"	6.350	139.55	4.02	7.78	92.22
# 4	4.760	200.70	5.78	13.56	86.44
# 8	2.380	622.90	17.95	31.51	68.49
# 16	1.190	918.50	26.46	57.97	42.03
# 30	0.590	803.80	23.16	81.13	18.87
# 50	0.297	374.20	10.78	91.91	8.09
# 100	0.149	156.50	4.51	96.42	3.58
# 200	0.074	57.10	1.65	98.07	1.93
# 230	0.064	24.40	0.70	98.77	1.23
Pan	-----	42.70	1.23	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

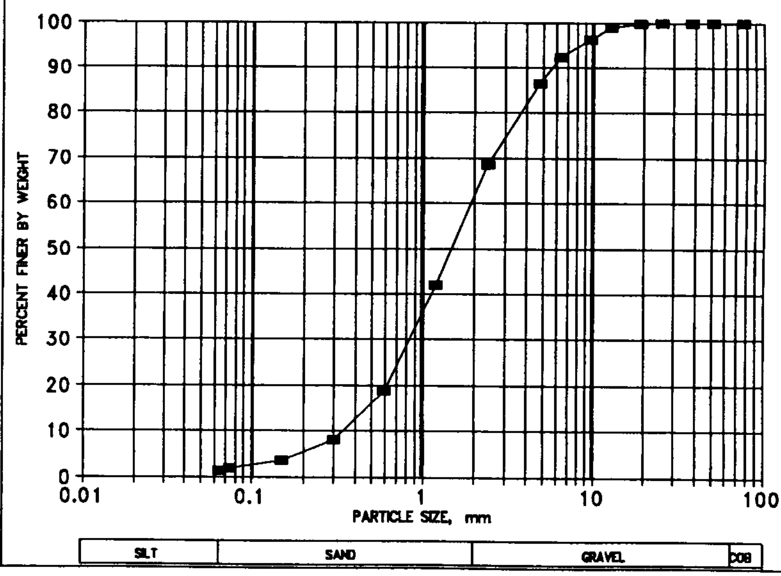


Table 14 (Continued)

SAMPLE NUMBER: 88-26

FIELD DATA

Date/Time :	Start:	11/28/88-17:00	End:	12/22/88-9:30	DT:	568.50	hrs
Stage, ft :	Start:	0.585	End:	0.525	DWS:	-0.060	ft
Average Temerature:		9 C			AVG:	0.555	ft

LAB DATA

Total Wt. (gr): 2592.50 Analyzed by: MP/ Date Analyzed: 05/06/89

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	26.45	1.02	1.02	98.98
1/2"	12.7	64.65	2.49	3.51	96.49
3/8"	9.525	15.05	0.58	4.09	95.91
1/4"	6.350	157.55	6.08	10.17	89.83
# 4	4.760	172.50	6.65	16.83	83.17
# 8	2.380	445.80	17.20	34.02	65.98
# 16	1.190	591.60	22.82	56.84	43.16
# 30	0.590	496.90	19.17	76.01	23.99
# 50	0.297	338.70	13.06	89.07	10.93
# 100	0.149	174.80	6.74	95.81	4.19
# 200	0.074	54.60	2.11	97.92	2.08
# 230	0.064	21.70	0.84	98.76	1.24
Pan	-----	32.20	1.24	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

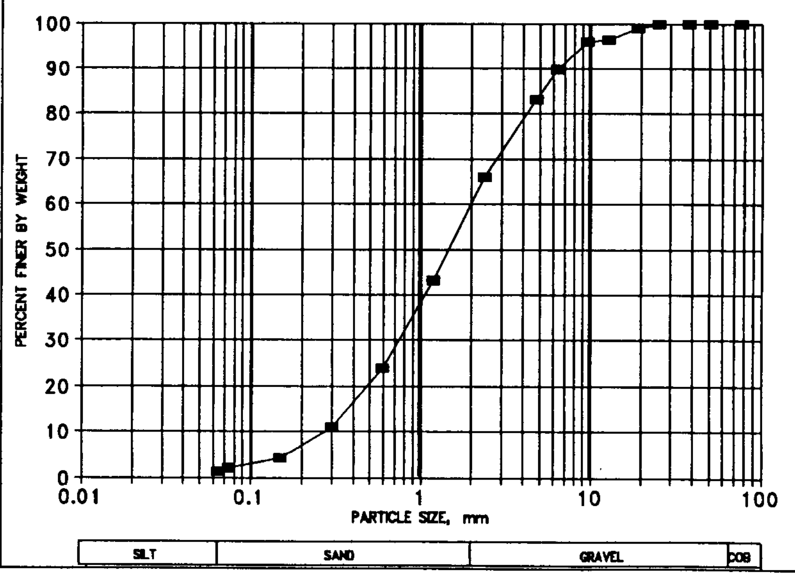


Table 14 (Continued)

SAMPLE NUMBER: 88-27

FIELD DATA

Date/Time :	Start:	12/22/88-9:30	End:	12/24/88-11:30	DT:	50.00	hrs
Stage, ft :	Start:	0.525	End:	0.655	DWS:	0.130	ft
Average Temerature:		9 C			AVG:	0.590	ft

LAB DATA

Total Wt. (gr): 3921.95 Analyzed by: MP/ Date Analyzed: 05/31/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	11.20	0.29	0.29	99.71
1/2"	12.7	14.50	0.37	0.66	99.34
3/8"	9.525	38.75	0.99	1.64	98.36
1/4"	6.350	67.30	1.72	3.36	96.64
# 4	4.760	148.70	3.79	7.15	92.85
# 8	2.380	583.30	14.87	22.02	77.98
# 16	1.190	976.60	24.90	46.92	53.08
# 30	0.590	1069.60	27.27	74.20	25.80
# 50	0.297	620.40	15.82	90.02	9.98
# 100	0.149	237.90	6.07	96.08	3.92
# 200	0.074	61.70	1.57	97.65	2.35
# 230	0.064	39.90	1.02	98.67	1.33
Pan	-----	52.10	1.33	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

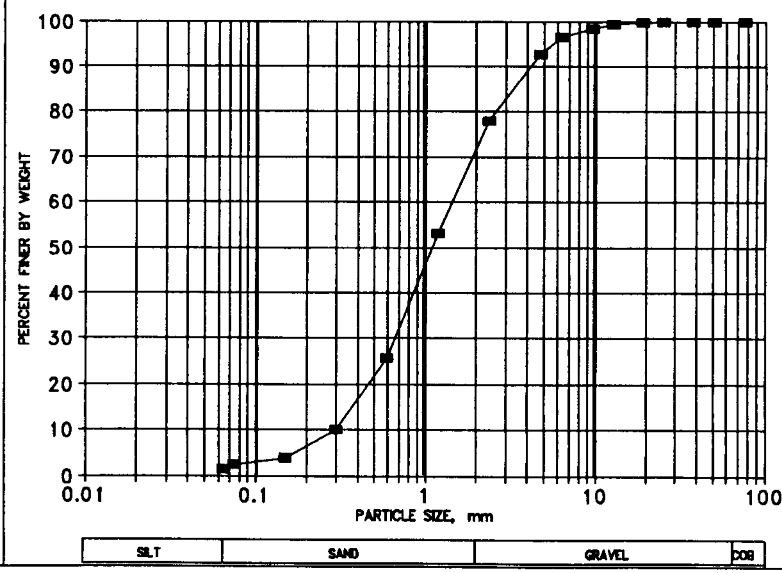


Table 14 (Continued)

SAMPLE NUMBER: 88-28

FIELD DATA

Date/Time :	Start:	12/24/88-11:30	End:	12/29/88-10:00	DT:	118.50	hrs
Stage, ft :	Start:	0.655	End:	0.314	DWS:	-0.341	ft
Average Temerature:		9 C			AVG:	0.485	ft

LAB DATA

Total Wt. (gr): 2837.53 Analyzed by: MP/ Date Analyzed: 05/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	6.23	0.22	0.22	99.78
1/2"	12.7	21.30	0.75	0.97	99.03
3/8"	9.525	67.07	2.36	3.33	96.67
1/4"	6.350	120.03	4.23	7.56	92.44
# 4	4.760	206.00	7.26	14.82	85.18
# 8	2.380	591.00	20.83	35.65	64.35
# 16	1.190	867.40	30.57	66.22	33.78
# 30	0.590	621.40	21.90	88.12	11.88
# 50	0.297	224.80	7.92	96.04	3.96
# 100	0.149	71.00	2.50	98.54	1.46
# 200	0.074	23.90	0.84	99.39	0.61
# 230	0.064	4.90	0.17	99.56	0.44
Pan	-----	12.50	0.44	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

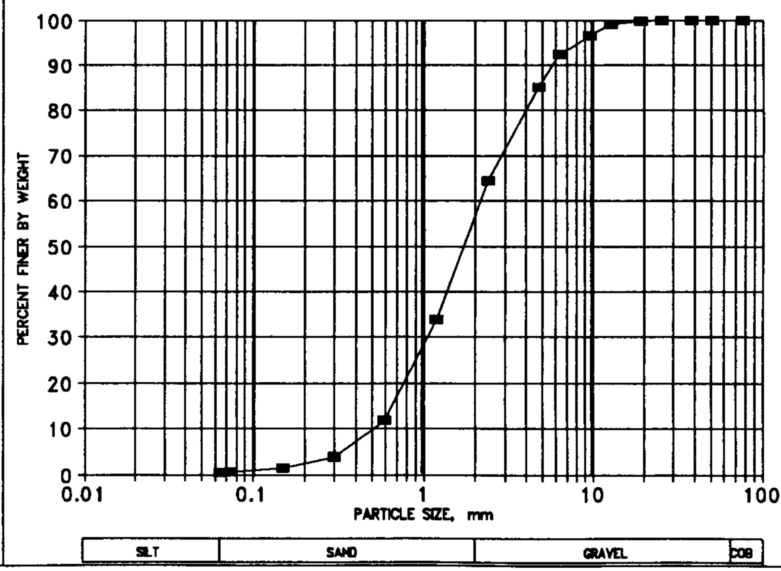


Table 14 (Continued)

SAMPLE NUMBER: 88-29

FIELD DATA

Date/Time : Start: 12/29/88-10:00 End: 12/30/88-2:15 DT: 16.25 hrs
Stage, ft : Start: 0.314 End: 0.520 DWS: 0.206 ft
Average Temerature: 9 C AVG: 0.417 ft

LAB DATA

Total Wt. (gr): 929.90 Analyzed by: HM Date Analyzed: 03/29/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	30.60	3.29	3.29	96.71
3/8"	9.525	84.10	9.04	12.33	87.67
1/4"	6.350	85.20	9.16	21.50	78.50
# 4	4.760	73.40	7.89	29.39	70.61
# 8	2.380	156.00	16.78	46.17	53.83
# 16	1.190	160.70	17.28	63.45	36.55
# 30	0.590	167.20	17.98	81.43	18.57
# 50	0.297	106.70	11.47	92.90	7.10
# 100	0.149	46.40	4.99	97.89	2.11
# 200	0.074	13.40	1.44	99.33	0.67
# 230	0.064	2.30	0.25	99.58	0.42
Pan	-----	3.90	0.42	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

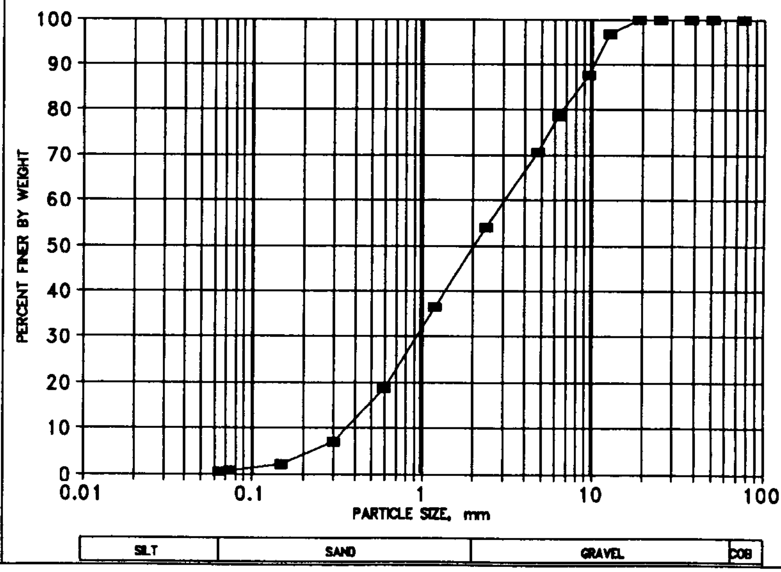


Table 14 (Continued)

SAMPLE NUMBER: 88-30

FIELD DATA

Date/Time :	Start:	12/30/88-2:15	End:	12/30/88-10:30	DT:	8.25	hrs
Stage, ft :	Start:	0.520	End:	0.850	DWS:	0.330	ft
Average Temerature:		9 C			AVG:	0.685	ft

LAB DATA

Total Wt. (gr): 8758.82 Analyzed by: HM/ Date Analyzed: 04/21/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	38.05	0.43	0.43	99.57
3/4"	19.05	57.92	0.66	1.10	98.90
1/2"	12.7	91.10	1.04	2.14	97.86
3/8"	9.525	273.15	3.12	5.25	94.75
1/4"	6.350	400.50	4.57	9.83	90.17
# 4	4.760	570.70	6.52	16.34	83.66
# 8	2.380	1734.10	19.80	36.14	63.86
# 16	1.190	2575.90	29.41	65.55	34.45
# 30	0.590	1819.70	20.78	86.33	13.67
# 50	0.297	718.60	8.20	94.53	5.47
# 100	0.149	269.50	3.08	97.61	2.39
# 200	0.074	108.50	1.24	98.85	1.15
# 230	0.064	31.80	0.36	99.21	0.79
Pan	-----	69.30	0.79	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

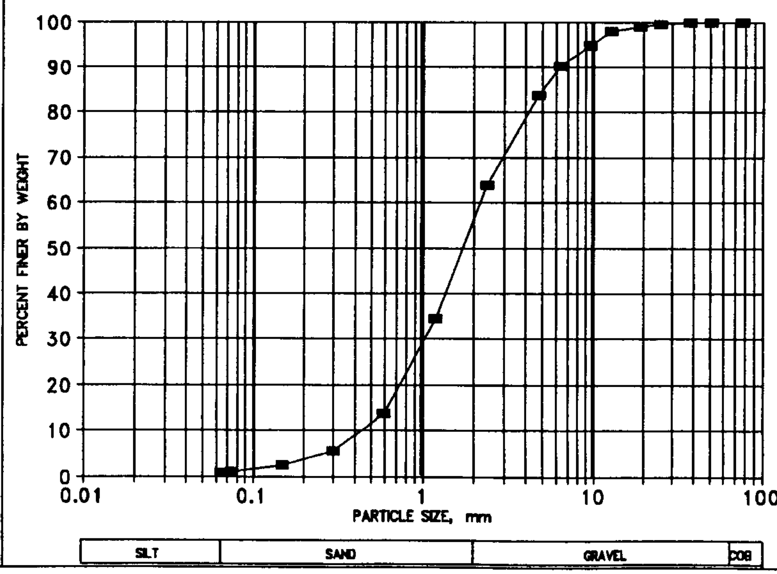


Table 14 (Continued)

SAMPLE NUMBER: 88-31

FIELD DATA

Date/Time :	Start:	12/30/88-10:30	End:	12/30/88-14:00	DT:	3.50 hrs
Stage, ft :	Start:	0.850	End:	0.752	DWS:	-0.098 ft
Average Temerature:		9 C			AVG:	0.801 ft

LAB DATA

Total Wt. (gr): 9336.58 Analyzed by: HM/ Date Analyzed: 03/23/89

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	152.45	1.63	1.63	98.37
1"	25.4	138.97	1.49	3.12	96.88
3/4"	19.05	327.93	3.51	6.63	93.37
1/2"	12.7	506.90	5.43	12.06	87.94
3/8"	9.525	1025.17	10.98	23.04	76.96
1/4"	6.350	1161.97	12.45	35.49	64.51
# 4	4.760	1069.10	11.45	46.94	53.06
# 8	2.380	1837.60	19.68	66.62	33.38
# 16	1.190	1649.90	17.67	84.29	15.71
# 30	0.590	920.60	9.86	94.15	5.85
# 50	0.297	331.20	3.55	97.70	2.30
# 100	0.149	114.60	1.23	98.93	1.07
# 200	0.074	47.80	0.51	99.44	0.56
# 230	0.064	11.90	0.13	99.57	0.43
Pan	-----	40.5	0.43	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

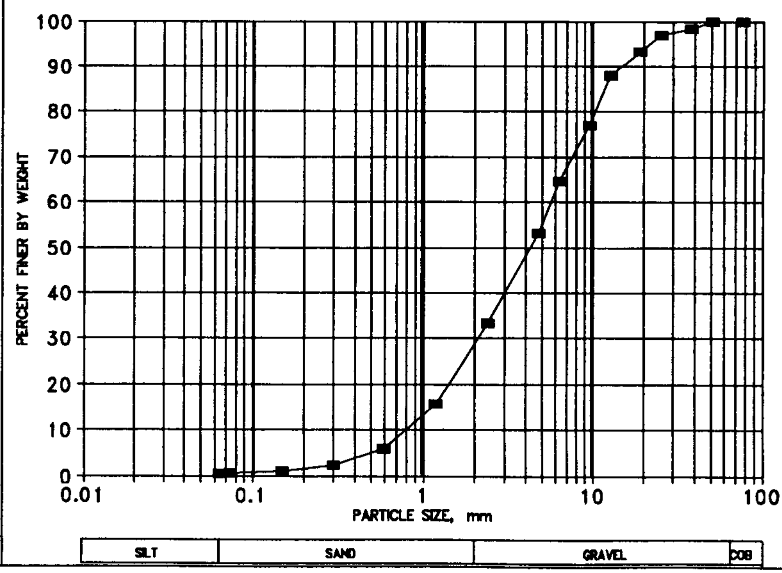


Table 14 (Continued)

SAMPLE NUMBER: 88-32

FIELD DATA

Date/Time :	Start:	12/30/88-14:00	End:	12/30/88-17:25	DT:	3.42 hrs
Stage, ft :	Start:	0.752	End:	0.828	DWS:	0.076 ft
Average Temerature:		9 C			AVG:	0.790 ft

LAB DATA

Total Wt. (gr): 5714.43 Analyzed by: HM/ Date Analyzed: 03/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	64.27	1.12	1.12	98.88
3/4"	19.05	109.73	1.92	3.04	96.96
1/2"	12.7	193.67	3.39	6.43	93.57
3/8"	9.525	350.27	6.13	12.56	87.44
1/4"	6.350	403.30	7.06	19.62	80.38
# 4	4.760	522.70	9.15	28.77	71.23
# 8	2.380	1191.40	20.85	49.62	50.38
# 16	1.190	1394.50	24.40	74.02	25.98
# 30	0.590	939.90	16.45	90.47	9.53
# 50	0.297	356.00	6.23	96.70	3.30
# 100	0.149	112.90	1.98	98.67	1.33
# 200	0.074	39.80	0.70	99.37	0.63
# 230	0.064	10.40	0.18	99.55	0.45
Pan	-----	25.60	0.45	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

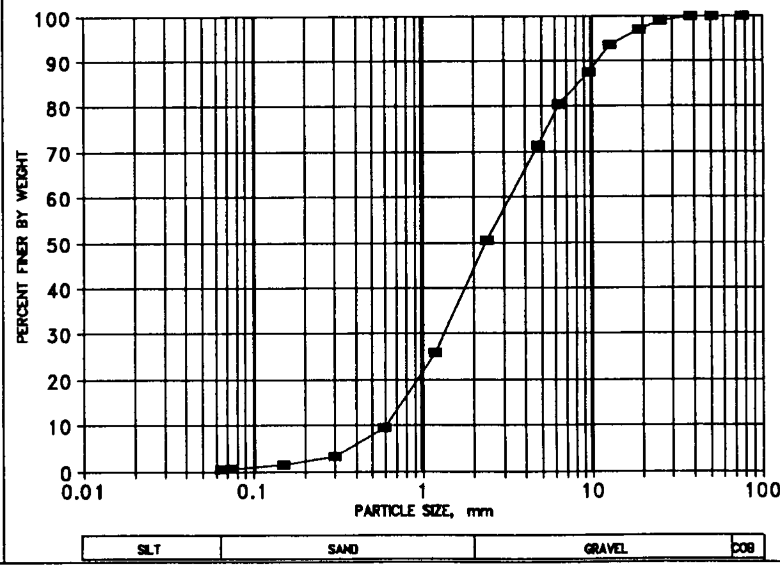


Table 14 (Continued)

SAMPLE NUMBER: 88-33

FIELD DATA

Date/Time :	Start:	12/30/88-17:25	End:	12/30/88-20:05	DT:	2.67	hrs
Stage, ft :	Start:	0.828	End:	0.893	DWS:	0.065	ft
Average Temerature:		9 C			AVG:	0.861	ft

LAB DATA

Total Wt. (gr): 5708.14 Analyzed by: HM/ Date Analyzed: 03/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	34.36	0.60	0.60	99.40
3/4"	19.05	28.60	0.50	1.10	98.90
1/2"	12.7	130.18	2.28	3.38	96.62
3/8"	9.525	283.94	4.97	8.36	91.64
1/4"	6.350	437.56	7.67	16.02	83.98
# 4	4.760	523.40	9.17	25.19	74.81
# 8	2.380	1228.90	21.53	46.72	53.28
# 16	1.190	1529.60	26.80	73.52	26.48
# 30	0.590	998.50	17.49	91.01	8.99
# 50	0.297	327.80	5.74	96.75	3.25
# 100	0.149	104.60	1.83	98.59	1.41
# 200	0.074	40.80	0.71	99.30	0.70
# 230	0.064	10.80	0.19	99.49	0.51
Pan	-----	29.10	0.51	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

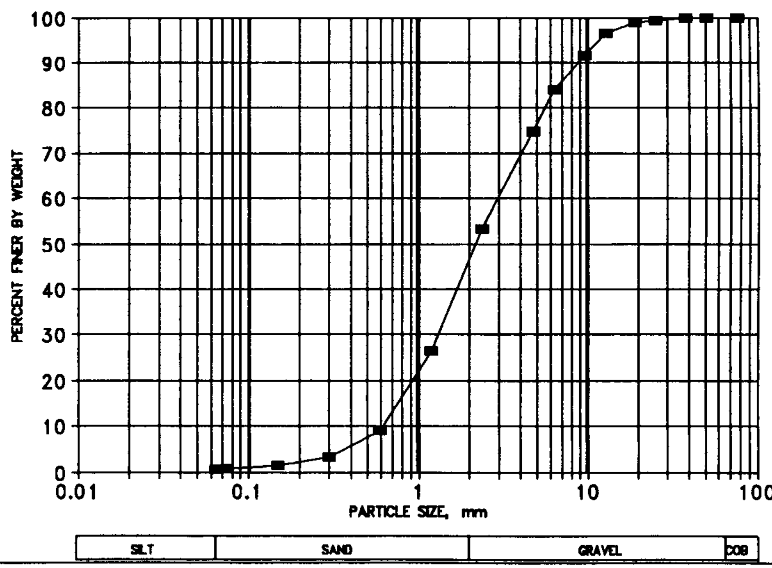


Table 14 (Continued)

SAMPLE NUMBER: 88-34

FIELD DATA

Date/Time :	Start:	12/30/88-20:05	End:	12/30/88-23:45	DT:	3.67 hrs
Stage, ft :	Start:	0.893	End:	0.850	DWS:	-0.043 ft
Average Temerature:		9 C			AVG:	0.872 ft

LAB DATA

Total Wt. (gr): 6243.03 Analyzed by: HM/ Date Analyzed: 03/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	39.38	0.63	0.63	99.37
3/4"	19.05	41.58	0.67	1.30	98.70
1/2"	12.7	128.28	2.05	3.35	96.65
3/8"	9.525	342.75	5.49	8.84	91.16
1/4"	6.350	490.13	7.85	16.69	83.31
# 4	4.760	555.50	8.90	25.59	74.41
# 8	2.380	1371.60	21.97	47.56	52.44
# 16	1.190	1686.40	27.01	74.57	25.43
# 30	0.590	1044.40	16.73	91.30	8.70
# 50	0.297	330.40	5.29	96.59	3.41
# 100	0.149	111.70	1.79	98.38	1.62
# 200	0.074	49.80	0.80	99.18	0.82
# 230	0.064	12.50	0.20	99.38	0.62
Pan	-----	38.60	0.62	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

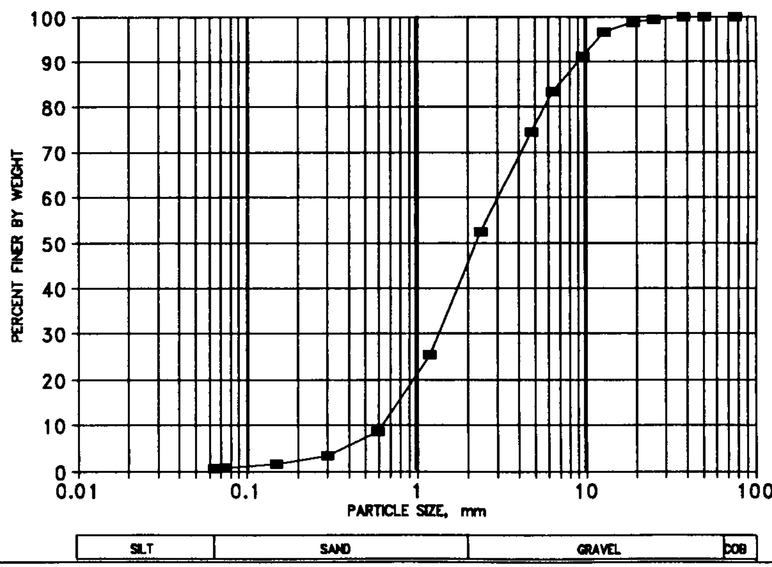


Table 14 (Continued)

SAMPLE NUMBER: 88-35

FIELD DATA

Date/Time :	Start:	12/30/88-23:45	End:	12/31/88-10:20	DT:	10.58	hrs
Stage, ft :	Start:	0.850	End:	0.660	DWS:	-0.190	ft
Average Temerature:		9 C			AVG:	0.755	ft

LAB DATA

Total Wt. (gr): 3836.96 Analyzed by: HM/ Date Analyzed: 03/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	15.86	0.41	0.41	99.59
3/4"	19.05	29.94	0.78	1.19	98.81
1/2"	12.7	46.40	1.21	2.40	97.60
3/8"	9.525	123.16	3.21	5.61	94.39
1/4"	6.350	163.50	4.26	9.87	90.13
# 4	4.760	263.60	6.87	16.74	83.26
# 8	2.380	774.20	20.18	36.92	63.08
# 16	1.190	1240.10	32.32	69.24	30.76
# 30	0.590	802.70	20.92	90.16	9.84
# 50	0.297	231.30	6.03	96.19	3.81
# 100	0.149	78.40	2.04	98.23	1.77
# 200	0.074	33.90	0.88	99.12	0.88
# 230	0.064	10.20	0.27	99.38	0.62
Pan	-----	23.70	0.62	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

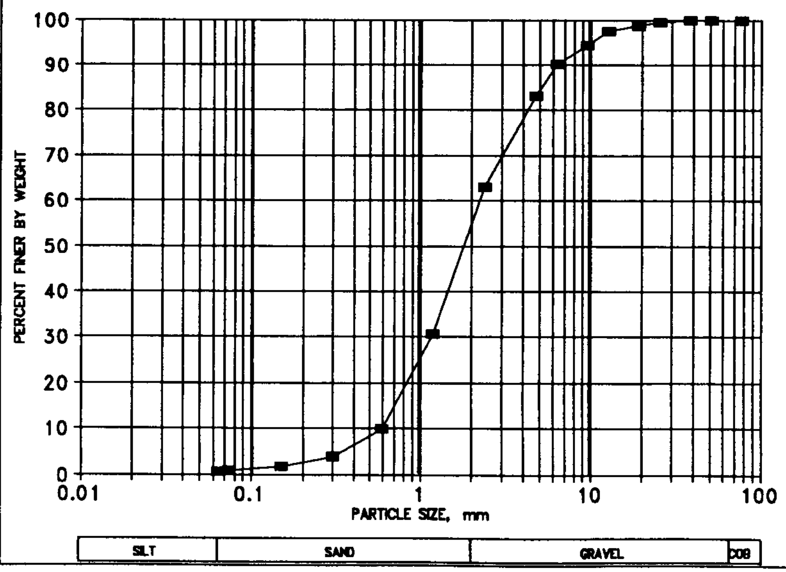


Table 14 (Continued)

SAMPLE NUMBER: 88-36

FIELD DATA

Date/Time :	Start:	12/31/88-10:20	End:	12/31/88-4:20	DT:	6.00	hrs
Stage, ft :	Start:	0.660	End:	0.600	DWS:	-0.060	ft
Average Temerature:		9 C			AVG:	0.630	ft

LAB DATA

Total Wt. (gr): 3654.80 Analyzed by: HM Date Analyzed: 03/29/89

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	39.80	1.09	1.09	98.91
3/4"	19.05	93.40	2.56	3.64	96.36
1/2"	12.7	175.60	4.80	8.45	91.55
3/8"	9.525	349.80	9.57	18.02	81.98
1/4"	6.350	451.40	12.35	30.37	69.63
# 4	4.760	385.00	10.53	40.91	59.09
# 8	2.380	645.90	17.67	58.58	41.42
# 16	1.190	675.20	18.47	77.05	22.95
# 30	0.590	515.90	14.12	91.17	8.83
# 50	0.297	206.20	5.64	96.81	3.19
# 100	0.149	71.40	1.95	98.76	1.24
# 200	0.074	24.90	0.68	99.44	0.56
# 230	0.064	5.80	0.16	99.60	0.40
Pan	-----	14.50	0.40	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

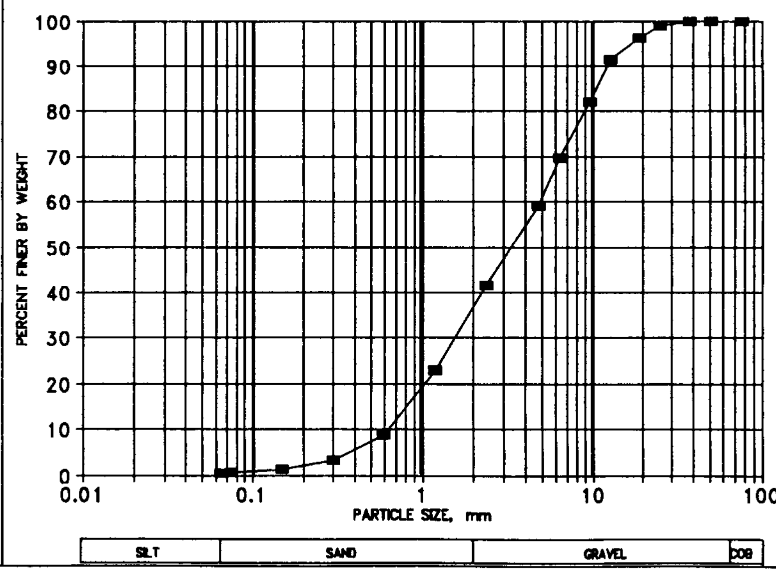


Table 14 (Continued)

SAMPLE NUMBER: 88-37

FIELD DATA

Date/Time :	Start:	12/31/88-4:20	End:	01/05/89-11:15	DT:	114.92	hrs
Stage, ft :	Start:	0.600	End:	0.475	DWS:	-0.125	ft
Average Temerature:		9 C			AVG:	0.538	ft

LAB DATA

Total Wt. (gr): 1332.80 Analyzed by: HM/ Date Analyzed: 04/07/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	7.50	0.56	0.56	99.44
3/8"	9.525	16.20	1.22	1.78	98.22
1/4"	6.350	14.00	1.05	2.83	97.17
# 4	4.760	44.10	3.31	6.14	93.86
# 8	2.380	187.10	14.04	20.18	79.82
# 16	1.190	396.50	29.75	49.92	50.08
# 30	0.590	367.00	27.54	77.46	22.54
# 50	0.297	176.90	13.27	90.73	9.27
# 100	0.149	79.10	5.93	96.67	3.33
# 200	0.074	27.90	2.09	98.76	1.24
# 230	0.064	5.90	0.44	99.20	0.80
Pan	-----	10.60	0.80	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

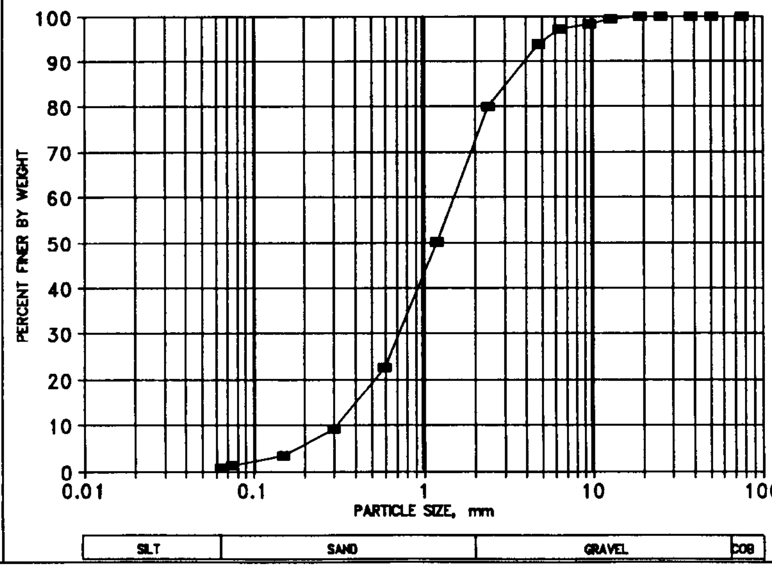


Table 14 (Continued)

SAMPLE NUMBER: 89-38

FIELD DATA

Date/Time :	Start:	01/05/89-11:15	End:	01/09/89-13:00	DT:	97.75	hrs
Stage, ft :	Start:	0.475	End:	0.612	DWS:	0.137	ft
Average Temerature:		9 C			AVG:	0.544	ft

LAB DATA

Total Wt. (gr): 2454.10 Analyzed by: HM/ Date Analyzed: 04/07/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	55.00	2.24	2.24	97.76
3/8"	9.525	26.10	1.06	3.30	96.70
1/4"	6.350	46.40	1.89	5.20	94.80
# 4	4.760	81.30	3.31	8.51	91.49
# 8	2.380	282.10	11.50	20.00	80.00
# 16	1.190	616.70	25.13	45.13	54.87
# 30	0.590	701.10	28.57	73.70	26.30
# 50	0.297	387.80	15.80	89.50	10.50
# 100	0.149	174.10	7.09	96.60	3.40
# 200	0.074	53.10	2.16	98.76	1.24
# 230	0.064	10.60	0.43	99.19	0.81
Pan	-----	19.80	0.81	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

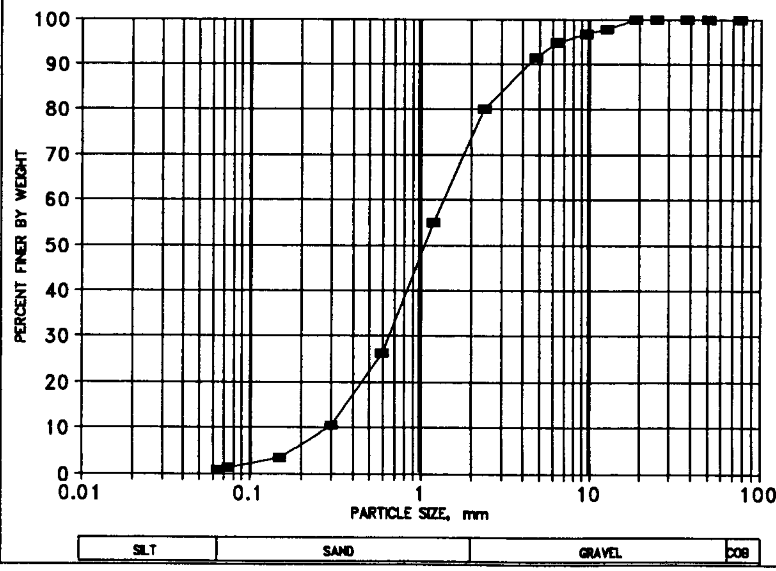


Table 14 (Continued)

SAMPLE NUMBER: 89-39

FIELD DATA

Date/Time :	Start:	01/29/89-15:00	End:	02/16/89-8:45	DT:	425.75	hrs
Stage, ft :	Start:	0.300	End:	0.457	DWS:	0.157	ft
Average Temerature:		9 C			AVG:	0.379	ft

LAB DATA

Total Wt. (gr): 871.80 Analyzed by: HM/ Date Analyzed: 04/07/89

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05		0.00	0.00	100.00
1/2"	12.7	8.50	0.97	0.97	99.03
3/8"	9.525	67.20	7.71	8.68	91.32
1/4"	6.350	46.50	5.33	14.02	85.98
# 4	4.760	61.30	7.03	21.05	78.95
# 8	2.380	151.50	17.38	38.43	61.57
# 16	1.190	183.50	21.05	59.47	40.53
# 30	0.590	162.00	18.58	78.06	21.94
# 50	0.297	105.70	12.12	90.18	9.82
# 100	0.149	49.70	5.70	95.88	4.12
# 200	0.074	21.40	2.45	98.34	1.66
# 230	0.064	5.20	0.60	98.93	1.07
Pan	-----	9.30	1.07	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

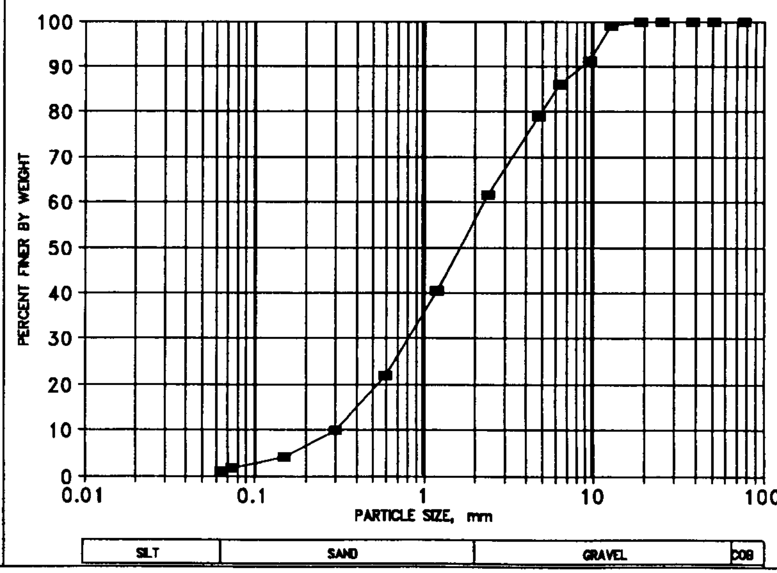


Table 14 (Continued)

SAMPLE NUMBER: 89-40

FIELD DATA

Date/Time :	Start:	02/16/89-8:45	End:	02/16/89-16:15	DT:	7.50 hrs
Stage, ft :	Start:	0.457	End:	0.680	DWS:	0.223 ft
Average Temerature:		9 C			AVG:	0.569 ft

LAB DATA

Total Wt. (gr): 4587.60 Analyzed by: HM/ Date Analyzed: 04/07/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	142.90	3.11	3.11	96.89
1"	25.4	0.00	0.00	3.11	96.89
3/4"	19.05	103.20	2.25	5.36	94.64
1/2"	12.7	215.90	4.71	10.07	89.93
3/8"	9.525	207.70	4.53	14.60	85.40
1/4"	6.350	204.10	4.45	19.05	80.95
# 4	4.760	204.70	4.46	23.51	76.49
# 8	2.380	478.50	10.43	33.94	66.06
# 16	1.190	851.10	18.55	52.49	47.51
# 30	0.590	991.00	21.60	74.09	25.91
# 50	0.297	670.10	14.61	88.70	11.30
# 100	0.149	341.60	7.45	96.15	3.85
# 200	0.074	108.40	2.36	98.51	1.49
# 230	0.064	24.20	0.53	99.04	0.96
Pan	-----	44.20	0.96	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

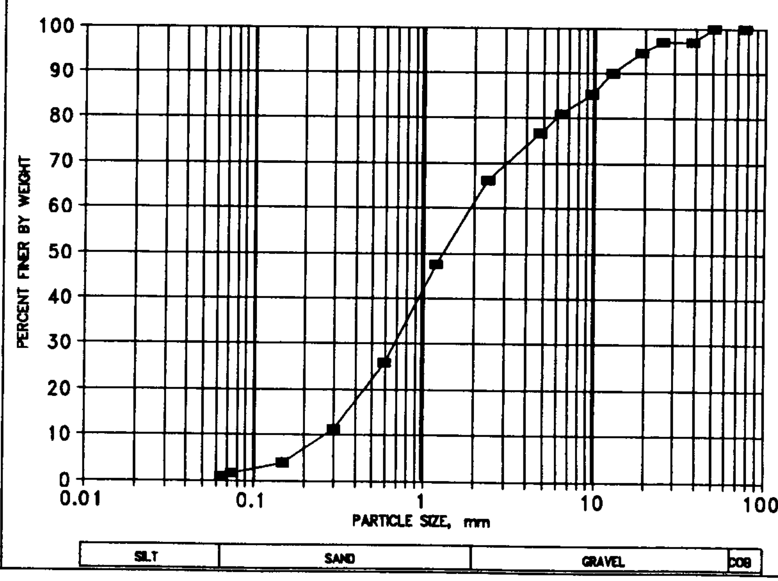


Table 14 (Continued)

SAMPLE NUMBER: 89-41

FIELD DATA

Date/Time : Start: 02/16/89-16:15 End: 02/17/89-18:30 DT: 26.25 hrs
Stage, ft : Start: 0.680 End: 0.727 DWS: 0.047 ft
Average Temerature: 9 C AVG: 0.704 ft

LAB DATA

Total Wt. (gr): 7745.90 Analyzed by: HM/ Date Analyzed: 03/24/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	86.12	1.11	1.11	98.89
3/4"	19.05	171.02	2.21	3.32	96.68
1/2"	12.7	327.55	4.23	7.55	92.45
3/8"	9.525	287.17	3.71	11.26	88.74
1/4"	6.350	487.45	6.29	17.55	82.45
# 4	4.760	453.70	5.86	23.41	76.59
# 8	2.380	1258.50	16.25	39.65	60.35
# 16	1.190	2224.10	28.71	68.37	31.63
# 30	0.590	1523.20	19.66	88.03	11.97
# 50	0.297	508.80	6.57	94.60	5.40
# 100	0.149	238.30	3.08	97.68	2.32
# 200	0.074	89.30	1.15	98.83	1.17
# 230	0.064	25.20	0.33	99.15	0.85
Pan	-----	65.50	0.85	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

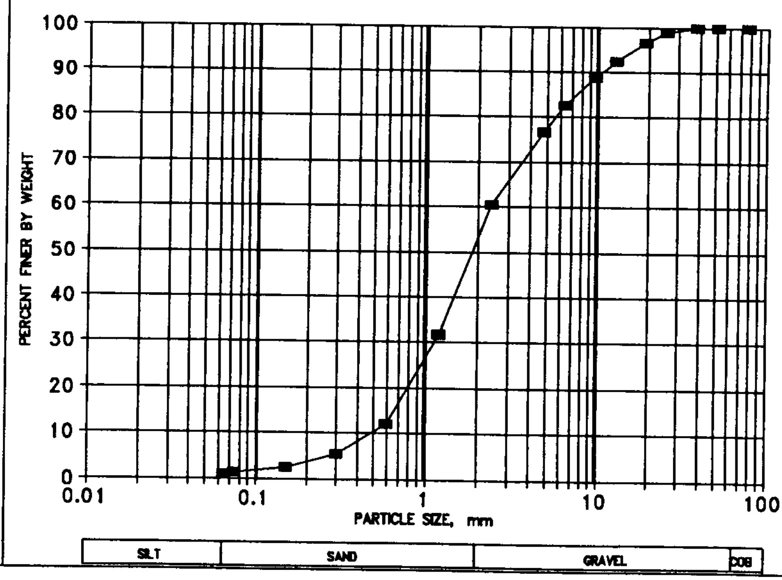


Table 14 (Continued)

SAMPLE NUMBER: 89-42

FIELD DATA

Date/Time :	Start:	02/17/89-18:30	End:	02/18/89-7:00	DT:	12.50	hrs
Stage, ft :	Start:	0.727	End:	0.762	DWS:	0.035	ft
Average Temerature:		9 C			AVG:	0.745	ft

LAB DATA

Total Wt. (gr): 31077.02 Analyzed by: HM/ Date Analyzed: 03/24/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	48.33	0.16	0.16	99.84
1-1/2"	38.1	326.45	1.05	1.21	98.79
1"	25.4	1518.83	4.89	6.09	93.91
3/4"	19.05	2107.83	6.78	12.88	87.12
1/2"	12.7	4462.33	14.36	27.23	72.77
3/8"	9.525	3728.67	12.00	39.23	60.77
1/4"	6.350	3522.57	11.33	50.57	49.43
# 4	4.760	2490.00	8.01	58.58	41.42
# 8	2.380	4004.00	12.88	71.46	28.54
# 16	1.190	4629.20	14.90	86.36	13.64
# 30	0.590	2735.20	8.80	95.16	4.84
# 50	0.297	872.40	2.81	97.97	2.03
# 100	0.149	336.80	1.08	99.05	0.95
# 200	0.074	146.80	0.47	99.53	0.47
# 230	0.064	38.40	0.12	99.65	0.35
Pan	-----	109.20	0.35	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

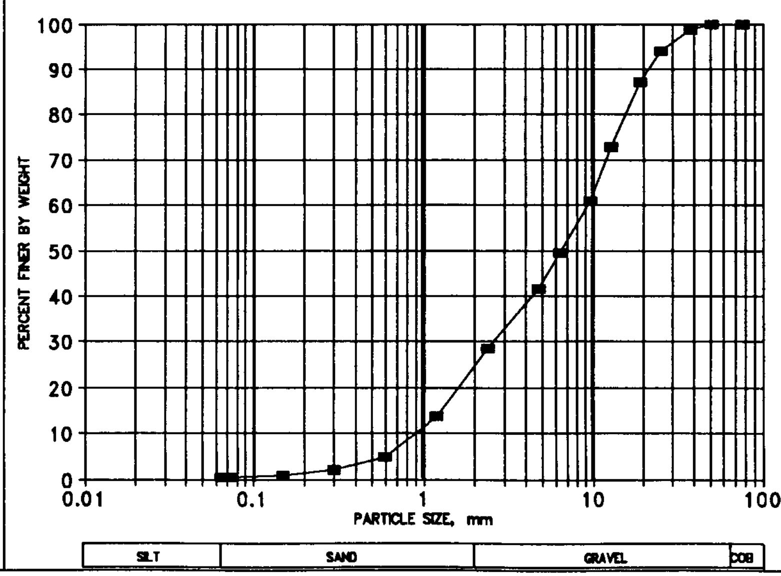


Table 14 (Continued)

SAMPLE NUMBER: 89-43

FIELD DATA

Date/Time :	Start:	02/18/89-7:00	End:	02/18/89-9:05	DT:	2.08	hrs
Stage, ft :	Start:	0.762	End:	0.755	DWS:	-0.007	ft
Average Temerature:		9 C			AVG:	0.759	ft

LAB DATA

Total Wt. (gr): 9266.13 Analyzed by: HM/ Date Analyzed: 03/23/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	80.17	0.87	0.87	99.13
1"	25.4	463.97	5.01	5.87	94.13
3/4"	19.05	1228.97	13.26	19.14	80.86
1/2"	12.7	1157.73	12.49	31.63	68.37
3/8"	9.525	1450.67	15.66	47.29	52.71
1/4"	6.350	1151.63	12.43	59.71	40.29
# 4	4.760	856.60	9.24	68.96	31.04
# 8	2.380	1130.40	12.20	81.16	18.84
# 16	1.190	918.50	9.91	91.07	8.93
# 30	0.590	494.20	5.33	96.40	3.60
# 50	0.297	191.60	2.07	98.47	1.53
# 100	0.149	81.00	0.87	99.34	0.66
# 200	0.074	31.40	0.34	99.68	0.32
# 230	0.064	8.40	0.09	99.77	0.23
Pan	-----	20.90	0.23	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

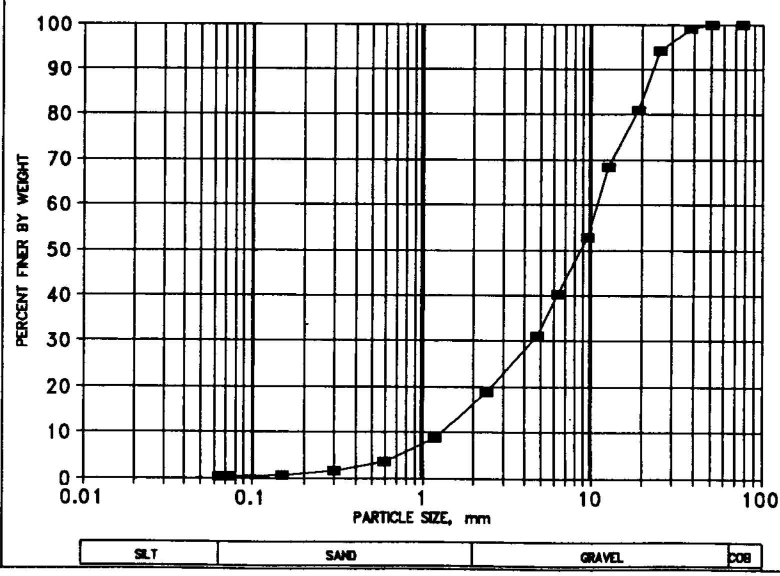


Table 14 (Continued)

SAMPLE NUMBER: 89-44

FIELD DATA

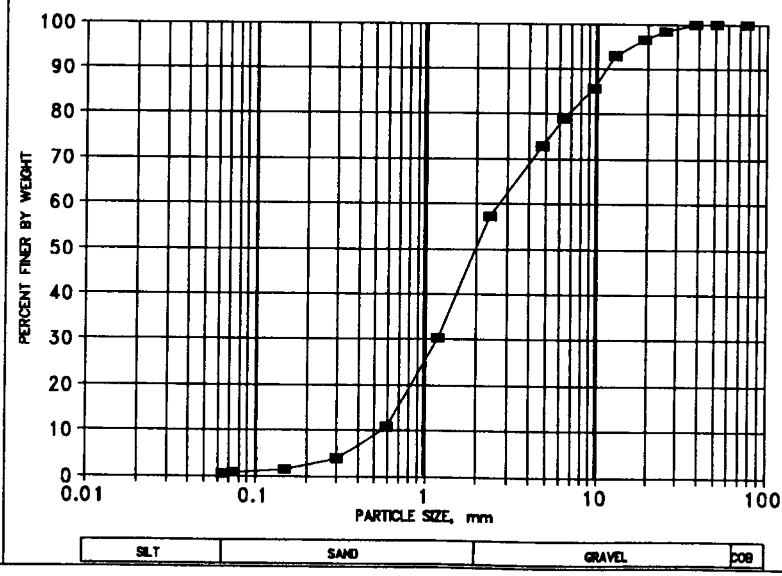
Date/Time :	Start:	02/18/89-9:05	End:	02/18/89-12:10	DT:	3.08 hrs
Stage, ft :	Start:	0.755	End:	0.710	DWS:	-0.045 ft
Average Temerature:		9 C			AVG:	0.733 ft

LAB DATA

Total Wt. (gr): 4718.35 Analyzed by: HM/ Date Analyzed: 05/11/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	77.05	1.63	1.63	98.37
3/4"	19.05	81.70	1.73	3.36	96.64
1/2"	12.7	169.50	3.59	6.96	93.04
3/8"	9.525	350.80	7.43	14.39	85.61
1/4"	6.350	318.60	6.75	21.14	78.86
# 4	4.760	283.70	6.01	27.16	72.84
# 8	2.380	737.80	15.64	42.79	57.21
# 16	1.190	1268.20	26.88	69.67	30.33
# 30	0.590	921.10	19.52	89.19	10.81
# 50	0.297	326.30	6.92	96.11	3.89
# 100	0.149	115.30	2.44	98.55	1.45
# 200	0.074	34.70	0.74	99.29	0.71
# 230	0.064	11.60	0.25	99.53	0.47
Pan	-----	22.00	0.47	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE



SAMPLE NUMBER: 89-45

FIELD DATA

Date/Time : Start: 02/18/89-12:10 End: 02/18/89-17:35 DT: 5.42 hrs
Stage, ft : Start: 0.710 End: 0.685 DWS: -0.025 ft
Average Temerature: 9 C AVG: 0.698 ft

LAB DATA

Total Wt. (gr): 3906.45 Analyzed by: HM/ Date Analyzed: 05/20/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	37.10	0.95	0.95	99.05
3/4"	19.05	107.80	2.76	3.71	96.29
1/2"	12.7	153.15	3.92	7.63	92.37
3/8"	9.525	327.45	8.38	16.01	83.99
1/4"	6.350	288.85	7.39	23.41	76.59
# 4	4.760	267.00	6.83	30.24	69.76
# 8	2.380	616.40	15.78	46.02	53.98
# 16	1.190	1059.70	27.13	73.15	26.85
# 30	0.590	717.50	18.37	91.51	8.49
# 50	0.297	222.20	5.69	97.20	2.80
# 100	0.149	67.30	1.72	98.92	1.08
# 200	0.074	22.40	0.57	99.50	0.50
# 230	0.064	5.40	0.14	99.64	0.36
Pan	-----	14.20	0.36	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

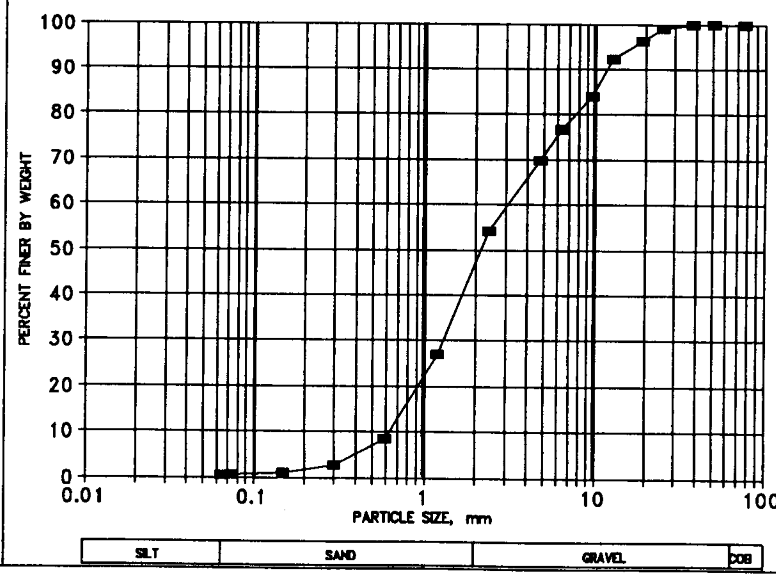


Table 14 (Continued)

SAMPLE NUMBER: 89-46

FIELD DATA

Date/Time : Start: 02/18/89-17:35 End: 02/20/89-12:05 DT: 42.50 hrs
Stage, ft : Start: 0.685 End: 0.530 DWS: -0.155 ft
Average Temerature: 9 C AVG: 0.608 ft

LAB DATA

Total Wt. (gr): 5879.82 Analyzed by: HM/ Date Analyzed: 03/22/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	6.46	0.11	0.11	99.89
3/4"	19.05	39.50	0.67	0.78	99.22
1/2"	12.7	69.62	1.18	1.97	98.03
3/8"	9.525	182.64	3.11	5.07	94.93
1/4"	6.350	295.00	5.02	10.09	89.91
# 4	4.760	387.90	6.60	16.69	83.31
# 8	2.380	1173.10	19.95	36.64	63.36
# 16	1.190	1966.40	33.44	70.08	29.92
# 30	0.590	1199.80	20.41	90.49	9.51
# 50	0.297	328.20	5.58	96.07	3.93
# 100	0.149	123.90	2.11	98.18	1.82
# 200	0.074	56.00	0.95	99.13	0.87
# 230	0.064	14.50	0.25	99.37	0.63
Pan	-----	36.80	0.63	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

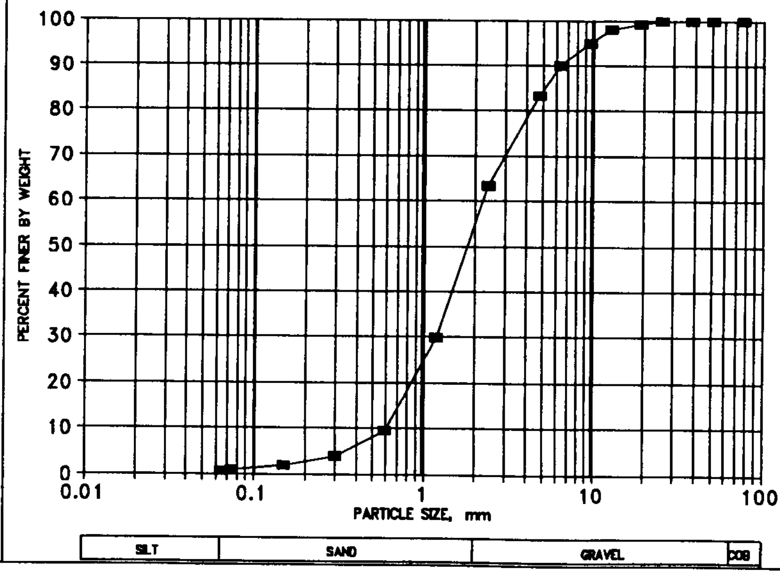


Table 14 (Continued)

SAMPLE NUMBER: 89-47

FIELD DATA

Date/Time :	Start:	02/20/89-12:05	End:	02/22/89-10:10	DT:	46.08	hrs
Stage, ft :	Start:	0.530	End:	0.510	DWS:	-0.020	ft
Average Temerature:		9 C			AVG:	0.520	ft

LAB DATA

Total Wt. (gr): 3105.20 Analyzed by: HM/ Date Analyzed: 04/07/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	33.30	1.07	1.07	98.93
3/4"	19.05	113.90	3.67	4.74	95.26
1/2"	12.7	235.80	7.59	12.33	87.67
3/8"	9.525	332.70	10.71	23.05	76.95
1/4"	6.350	286.60	9.23	32.28	67.72
# 4	4.760	239.20	7.70	39.98	60.02
# 8	2.380	366.10	11.79	51.77	48.23
# 16	1.190	550.90	17.74	69.51	30.49
# 30	0.590	503.00	16.20	85.71	14.29
# 50	0.297	272.20	8.77	94.48	5.52
# 100	0.149	111.20	3.58	98.06	1.94
# 200	0.074	37.70	1.21	99.27	0.73
# 230	0.064	7.80	0.25	99.52	0.48
Pan	-----	14.80	0.48	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

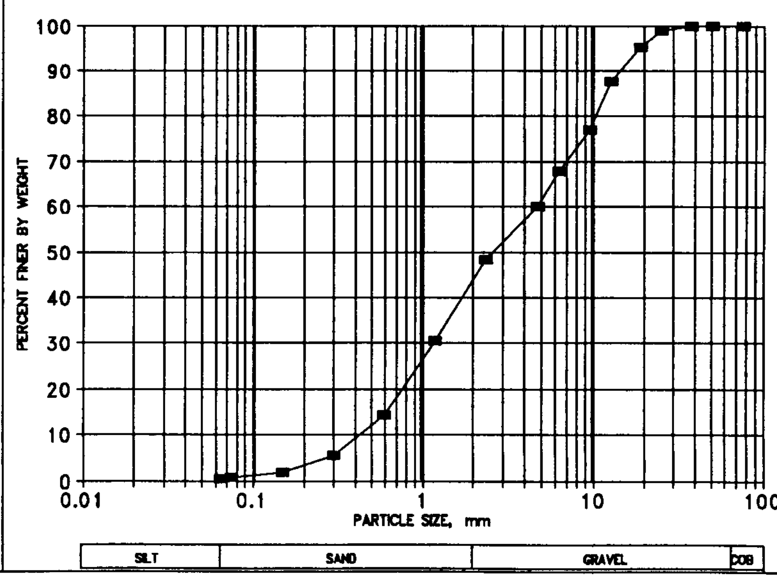


Table 14 (Continued)

SAMPLE NUMBER: 89-48

FIELD DATA

Date/Time :	Start:	02/22/89-10:10	End:	03/03/89-9:20	DT:	215.17 hrs
Stage, ft :	Start:	0.510	End:	0.330	DWS:	-0.180 ft
Average Temerature:		9 C			AVG:	0.420 ft

LAB DATA

Total Wt. (gr): 7975.90 Analyzed by: HM/ Date Analyzed: 05/10/89

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	108.10	1.36	1.36	98.64
1"	25.4	227.70	2.85	4.21	95.79
3/4"	19.05	598.50	7.50	11.71	88.29
1/2"	12.7	882.50	11.06	22.78	77.22
3/8"	9.525	1185.90	14.87	37.65	62.35
1/4"	6.350	1047.60	13.13	50.78	49.22
# 4	4.760	746.60	9.36	60.14	39.86
# 8	2.380	913.00	11.45	71.59	28.41
# 16	1.190	902.60	11.32	82.91	17.09
# 30	0.590	761.00	9.54	92.45	7.55
# 50	0.297	363.60	4.56	97.01	2.99
# 100	0.149	144.20	1.81	98.81	1.19
# 200	0.074	50.70	0.64	99.45	0.55
# 230	0.064	15.50	0.19	99.64	0.36
Pan	-----	28.40	0.36	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

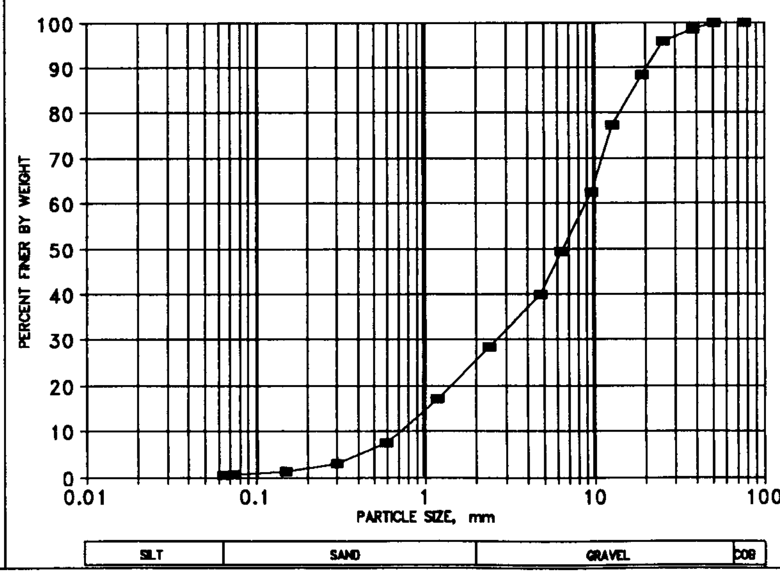


Table 14 (Continued)

SAMPLE NUMBER: 89-49

FIELD DATA

Date/Time :	Start:	03/03/89-9:20	End:	03/05/89-10:00	DT:	48.67 hrs
Stage, ft :	Start:	0.330	End:	0.740	DWS:	0.410 ft
Average Temerature:		9 C			AVG:	0.535 ft

LAB DATA

Total Wt. (gr): 3503.93 Analyzed by: HM/ Date Analyzed: 05/25/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	38.87	1.11	1.11	98.89
3/4"	19.05	155.77	4.45	5.55	94.45
1/2"	12.7	242.93	6.93	12.49	87.51
3/8"	9.525	358.63	10.24	22.72	77.28
1/4"	6.350	335.43	9.57	32.30	67.70
# 4	4.760	251.60	7.18	39.48	60.52
# 8	2.380	445.00	12.70	52.18	47.82
# 16	1.190	630.30	17.99	70.16	29.84
# 30	0.590	547.50	15.63	85.79	14.21
# 50	0.297	289.50	8.26	94.05	5.95
# 100	0.149	133.70	3.82	97.87	2.13
# 200	0.074	38.70	1.10	98.97	1.03
# 230	0.064	16.70	0.48	99.45	0.55
Pan	-----	19.30	0.55	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

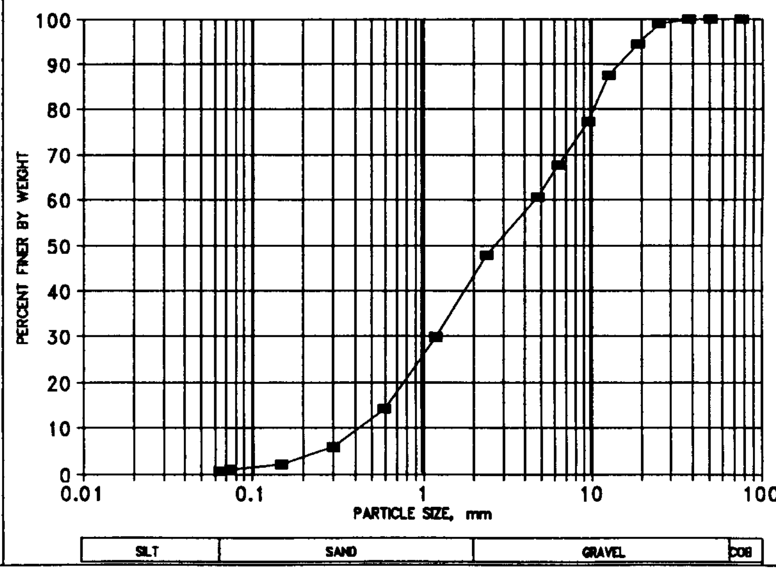


Table 14 (Continued)

SAMPLE NUMBER: 89-50

FIELD DATA

Date/Time :	Start:	03/05/89-10:00	End:	03/05/89-12:40	DT:	2.67	hrs
Stage, ft :	Start:	0.740	End:	0.850	DWS:	0.110	ft
Average Temerature:		9 C			AVG:	0.795	ft

LAB DATA

Total Wt. (gr): 16433.43 Analyzed by: HM/ Date Analyzed: 03/26/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	96.55	0.59	0.59	99.41
1"	25.4	381.95	2.32	2.91	97.09
3/4"	19.05	569.53	3.47	6.38	93.62
1/2"	12.7	1252.25	7.62	14.00	86.00
3/8"	9.525	1262.50	7.68	21.68	78.32
1/4"	6.350	1647.35	10.02	31.70	68.30
# 4	4.760	1352.40	8.23	39.93	60.07
# 8	2.380	2589.90	15.76	55.69	44.31
# 16	1.190	3594.00	21.87	77.56	22.44
# 30	0.590	2450.40	14.91	92.48	7.52
# 50	0.297	774.00	4.71	97.19	2.81
# 100	0.149	257.70	1.57	98.75	1.25
# 200	0.074	98.40	0.60	99.35	0.65
# 230	0.064	30.30	0.18	99.54	0.46
Pan	-----	76.20	0.46	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

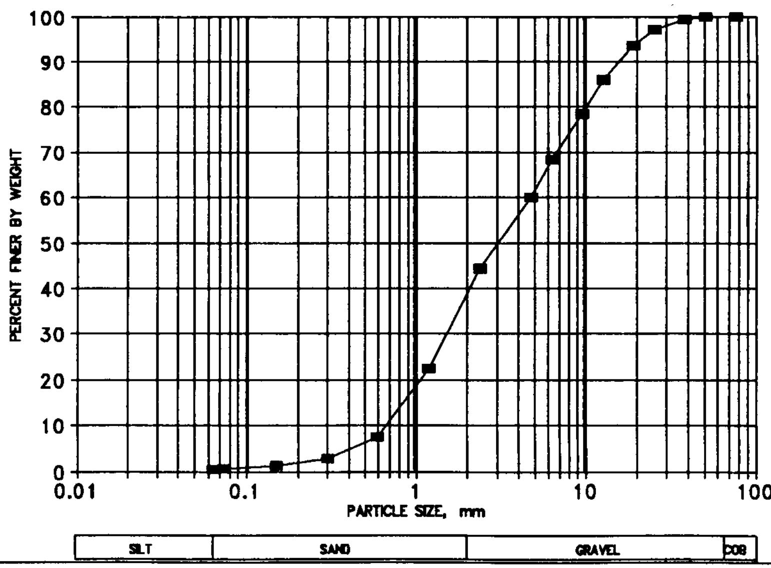


Table 14 (Continued)

SAMPLE NUMBER: 89-51

FIELD DATA

Date/Time :	Start:	03/05/89-12:40	End:	03/05/89-13:55	DT:	1.25 hrs
Stage, ft :	Start:	0.850	End:	0.830	DWS:	-0.020 ft
Average Temerature:		9 C			AVG:	0.840 ft

LAB DATA

Total Wt. (gr): 3139.95 Analyzed by: HM/ Date Analyzed: 05/06/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	39.10	1.25	1.25	98.75
3/4"	19.05	90.95	2.90	4.14	95.86
1/2"	12.7	176.55	5.62	9.76	90.24
3/8"	9.525	223.65	7.12	16.89	83.11
1/4"	6.350	230.70	7.35	24.23	75.77
# 4	4.760	217.60	6.93	31.16	68.84
# 8	2.380	490.50	15.62	46.79	53.21
# 16	1.190	803.00	25.57	72.36	27.64
# 30	0.590	597.40	19.03	91.39	8.61
# 50	0.297	181.90	5.79	97.18	2.82
# 100	0.149	52.30	1.67	98.84	1.16
# 200	0.074	19.00	0.61	99.45	0.55
# 230	0.064	5.00	0.16	99.61	0.39
Pan	-----	12.30	0.39	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

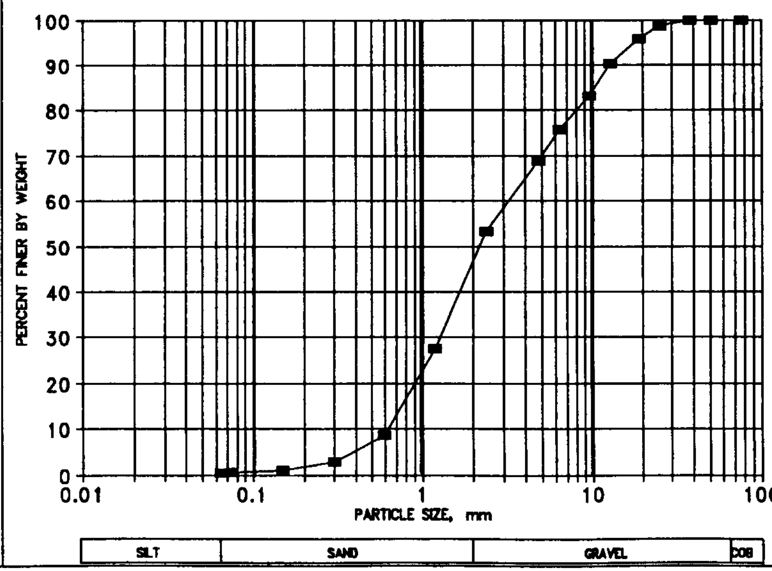


Table 14 (Continued)

SAMPLE NUMBER: 89-52

FIELD DATA

Date/Time :	Start:	03/05/89-13:55	End:	03/05/89-16:55	DT:	3.00	hrs
Stage, ft :	Start:	0.830	End:	0.860	DWS:	0.030	ft
Average Temerature:		9 C			AVG:	0.845	ft

LAB DATA

Total Wt. (gr): 5778.97 Analyzed by: HM/ Date Analyzed: 03/24/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	64.00	1.11	1.11	98.89
1-1/2"	38.1	0.00	0.00	1.11	98.89
1"	25.4	103.25	1.79	2.89	97.11
3/4"	19.05	217.48	3.76	6.66	93.34
1/2"	12.7	393.62	6.81	13.47	86.53
3/8"	9.525	308.22	5.33	18.80	81.20
1/4"	6.350	511.40	8.85	27.65	72.35
# 4	4.760	389.10	6.73	34.38	65.62
# 8	2.380	821.80	14.22	48.60	51.40
# 16	1.190	1480.70	25.62	74.23	25.77
# 30	0.590	1065.70	18.44	92.67	7.33
# 50	0.297	284.10	4.92	97.58	2.42
# 100	0.149	80.20	1.39	98.97	1.03
# 200	0.074	29.90	0.52	99.49	0.51
# 230	0.064	7.60	0.13	99.62	0.38
Pan	-----	21.90	0.38	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

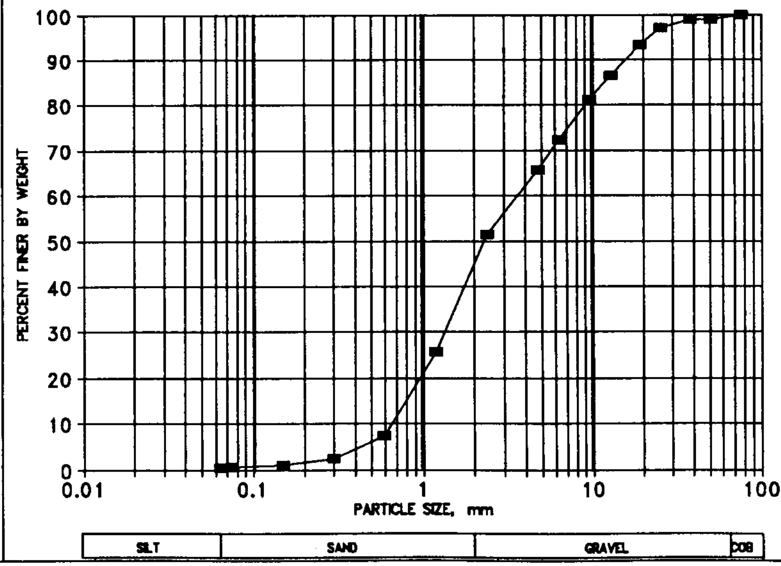


Table 14 (Continued)

SAMPLE NUMBER: 89-53

FIELD DATA

Date/Time :	Start:	03/05/89-16:55	End:	03/06/89-11:00	DT:	18.08	hrs
Stage, ft :	Start:	0.860	End:	0.635	DWS:	-0.225	ft
Average Temerature:		9 C			AVG:	0.748	ft

LAB DATA

Total Wt. (gr): 9279.93 Analyzed by: HM/ Date Analyzed: 03/26/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	27.05	0.29	0.29	99.71
1-1/2"	38.1	113.38	1.22	1.51	98.49
1"	25.4	404.21	4.36	5.87	94.13
3/4"	19.05	552.17	5.95	11.82	88.18
1/2"	12.7	1040.25	11.21	23.03	76.97
3/8"	9.525	629.54	6.78	29.81	70.19
1/4"	6.350	857.63	9.24	39.05	60.95
# 4	4.760	551.10	5.94	44.99	55.01
# 8	2.380	1221.40	13.16	58.15	41.85
# 16	1.190	2010.40	21.66	79.82	20.18
# 30	0.590	1272.80	13.72	93.53	6.47
# 50	0.297	359.20	3.87	97.41	2.59
# 100	0.149	124.00	1.34	98.74	1.26
# 200	0.074	53.70	0.58	99.32	0.68
# 230	0.064	17.10	0.18	99.50	0.50
Pan	-----	46.00	0.50	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

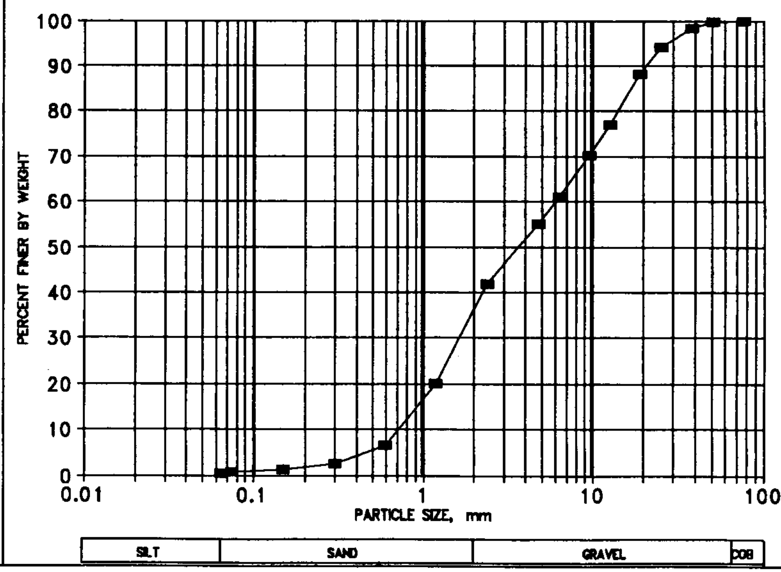


Table 14 (Continued)

SAMPLE NUMBER: 89-54

FIELD DATA

Date/Time :	Start:	03/06/89-11:00	End:	03/09/89-13:30	DT:	74.50	hrs
Stage, ft :	Start:	0.635	End:	0.526	DWS:	-0.109	ft
Average Temerature:		9 C			AVG:	0.581	ft

LAB DATA

Total Wt. (gr): 5777.90 Analyzed by: HM/ Date Analyzed: 04/07/89

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	251.40	4.35	4.35	95.65
3/4"	19.05	291.80	5.05	9.40	90.60
1/2"	12.7	345.00	5.97	15.37	84.63
3/8"	9.525	436.30	7.55	22.92	77.08
1/4"	6.350	381.10	6.60	29.52	70.48
# 4	4.760	353.20	6.11	35.63	64.37
# 8	2.380	694.00	12.01	47.64	52.36
# 16	1.190	1201.30	20.79	68.43	31.57
# 30	0.590	1070.80	18.53	86.97	13.03
# 50	0.297	449.90	7.79	94.75	5.25
# 100	0.149	185.10	3.20	97.96	2.04
# 200	0.074	69.80	1.21	99.17	0.83
# 230	0.064	15.50	0.27	99.43	0.57
Pan	-----	32.70	0.57	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

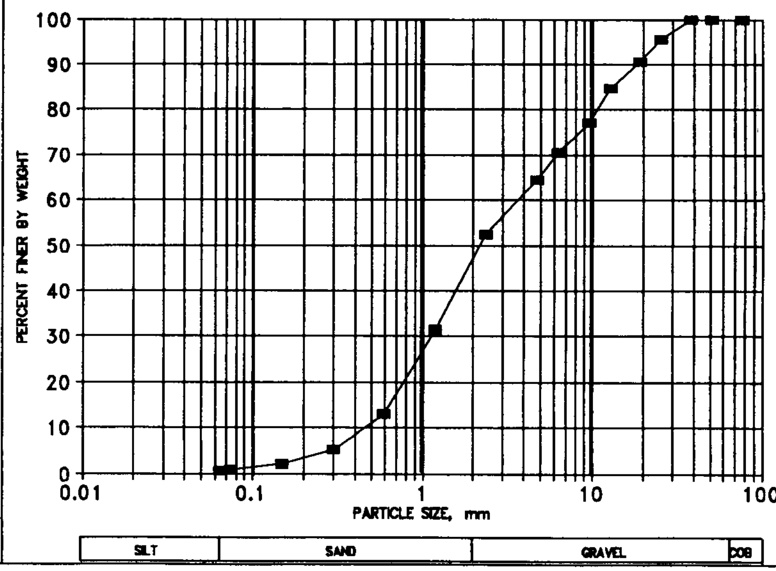


Table 14 (Continued)

SAMPLE NUMBER: 89-55

FIELD DATA

Date/Time : Start: 03/09/89-13:30 End: 03/13/89-11:45 DT: 94.25 hrs
Stage, ft : Start: 0.526 End: 0.720 DWS: 0.194 ft
Average Temerature: 9 C AVG: 0.623 ft

LAB DATA

Total Wt. (gr): 2986.28 Analyzed by: HM/ Date Analyzed: 05/15/89
Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	11.15	0.37	0.37	99.63
3/4"	19.05	100.80	3.38	3.75	96.25
1/2"	12.7	72.38	2.42	6.17	93.83
3/8"	9.525	131.48	4.40	10.58	89.42
1/4"	6.350	121.68	4.07	14.65	85.35
# 4	4.760	120.40	4.03	18.68	81.32
# 8	2.380	291.90	9.77	28.46	71.54
# 16	1.190	732.90	24.54	53.00	47.00
# 30	0.590	861.90	28.86	81.86	18.14
# 50	0.297	361.60	12.11	93.97	6.03
# 100	0.149	118.50	3.97	97.94	2.06
# 200	0.074	36.30	1.22	99.15	0.85
# 230	0.064	8.10	0.27	99.42	0.58
Pan	-----	17.20	0.58	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

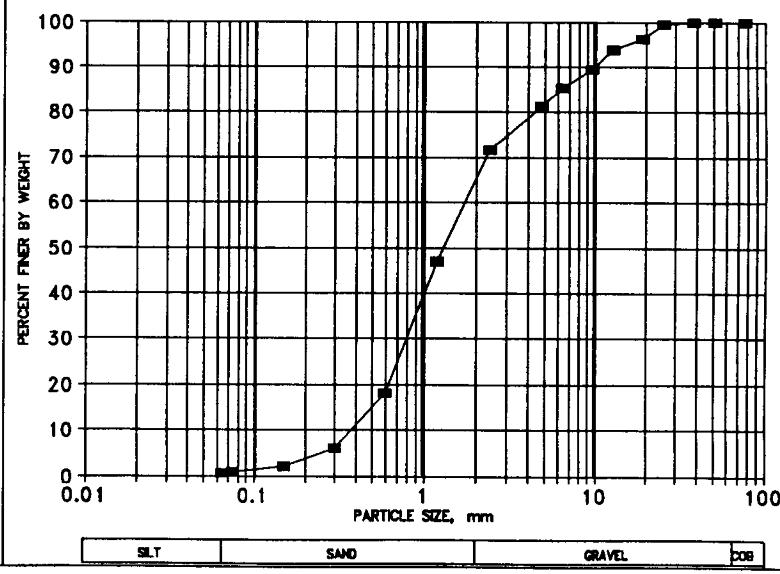


Table 14 (Continued)

SAMPLE NUMBER: 89-56

FIELD DATA

Date/Time :	Start:	03/13/89-11:45	End:	03/15/89-11:30	DT:	47.75	hrs
Stage, ft :	Start:	0.720	End:	0.700	DWS:	-0.020	ft
Average Temerature:		9 C			AVG:	0.710	ft

LAB DATA

Total Wt. (gr): 13296.91 Analyzed by: HM/ Date Analyzed: 03/22/89

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1	12.38	0.09	0.09	99.91
1"	25.4	98.85	0.74	0.84	99.16
3/4"	19.05	307.63	2.31	3.15	96.85
1/2"	12.7	475.69	3.58	6.73	93.27
3/8"	9.525	761.13	5.72	12.45	87.55
1/4"	6.350	668.85	5.03	17.48	82.52
# 4	4.760	723.40	5.44	22.92	77.08
# 8	2.380	2035.90	15.31	38.23	61.77
# 16	1.190	3769.90	28.35	66.58	33.42
# 30	0.590	3000.80	22.57	89.15	10.85
# 50	0.297	921.90	6.93	96.09	3.91
# 100	0.149	300.30	2.26	98.34	1.66
# 200	0.074	101.10	0.76	99.10	0.90
# 230	0.064	38.90	0.29	99.40	0.60
Pan	-----	80.20	0.60	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

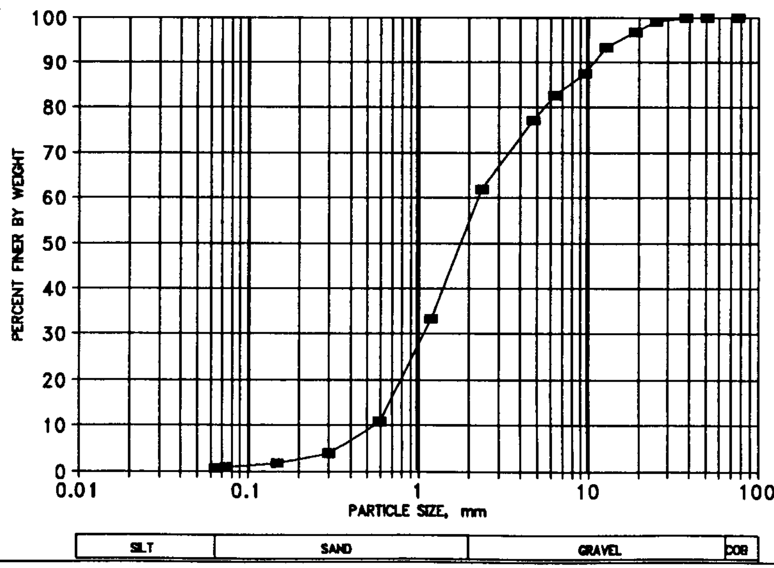


Table 14 (Continued)

SAMPLE NUMBER: 89-57

FIELD DATA

Date/Time :	Start:	03/15/89-11:30	End:	03/16/89-10:00	DT:	22.50 hrs
Stage, ft :	Start:	0.700	End:	0.805	DWS:	0.105 ft
Average Temerature:		9 C			AVG:	0.753 ft

LAB DATA

Total Wt. (gr): 19320.23 Analyzed by: HM/ Date Analyzed: 03/23/89

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8	125.52	0.65	0.65	99.35
1-1/2"	38.1	168.03	0.87	1.52	98.48
1"	25.4	467.55	2.42	3.94	96.06
3/4"	19.05	957.31	4.95	8.89	91.11
1/2"	12.7	2106.20	10.90	19.80	80.20
3/8"	9.525	1584.49	8.20	28.00	72.00
1/4"	6.350	2013.73	10.42	38.42	61.58
# 4	4.760	1510.80	7.82	46.24	53.76
# 8	2.380	2746.50	14.22	60.46	39.54
# 16	1.190	3600.60	18.64	79.09	20.91
# 30	0.590	2594.10	13.43	92.52	7.48
# 50	0.297	887.40	4.59	97.11	2.89
# 100	0.149	294.90	1.53	98.64	1.36
# 200	0.074	122.70	0.64	99.27	0.73
# 230	0.064	37.50	0.19	99.47	0.53
Pan	-----	102.90	0.53	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

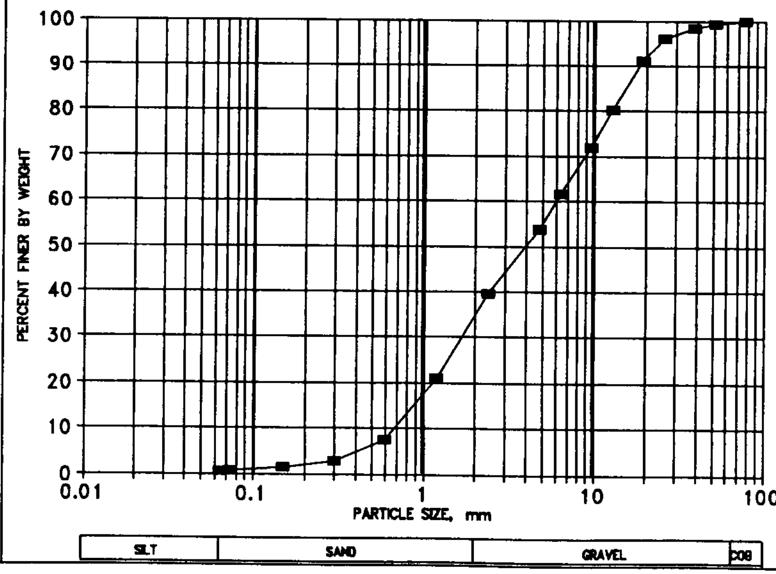


Table 14 (Continued)

SAMPLE NUMBER: 89-58

FIELD DATA

Date/Time :	Start:	03/16/89-10:00	End:	03/16/89-17:00	DT:	7.00	hrs
Stage, ft :	Start:	0.805	End:	0.718	DWS:	-0.087	ft
Average Temerature:		9 C			AVG:	0.762	ft

LAB DATA

Total Wt. (gr): 2859.80 Analyzed by: HM/ Date Analyzed: 05/20/89

Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	35.30	1.23	1.23	98.77
1/2"	12.7	65.95	2.31	3.54	96.46
3/8"	9.525	141.48	4.95	8.49	91.51
1/4"	6.350	123.68	4.32	12.81	87.19
# 4	4.760	139.00	4.86	17.67	82.33
# 8	2.380	447.20	15.64	33.31	66.69
# 16	1.190	833.20	29.13	62.44	37.56
# 30	0.590	719.20	25.15	87.59	12.41
# 50	0.297	246.80	8.63	96.22	3.78
# 100	0.149	69.30	2.42	98.65	1.35
# 200	0.074	21.80	0.76	99.41	0.59
# 230	0.064	5.20	0.18	99.59	0.41
Pan	-----	11.70	0.41	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE

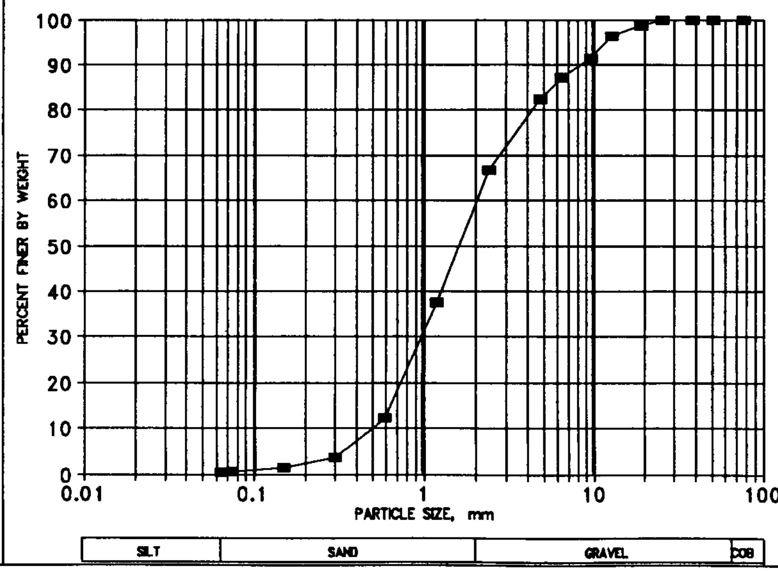


Table 14 (Continued)

SAMPLE NUMBER: 89-59

FIELD DATA

Date/Time :	Start:	03/16/89-17:00	End:	03/17/89-9:40	DT:	16.67	hrs
Stage, ft :	Start:	0.718	End:	0.660	DWS:	-0.058	ft
Average Temerature:		9 C			AVG:	0.689	ft

LAB DATA

Total Wt. (gr): 4015.07   Analyzed by: HM/ Date Analyzed: 05/19/89
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	76.87	1.91	1.91	98.09
3/4"	19.05	154.17	3.84	5.75	94.25
1/2"	12.7	255.07	6.35	12.11	87.89
3/8"	9.525	392.50	9.78	21.88	78.12
1/4"	6.350	313.57	7.81	29.69	70.31
# 4	4.760	253.50	6.31	36.01	63.99
# 8	2.380	545.30	13.58	49.59	50.41
# 16	1.190	956.30	23.82	73.41	26.59
# 30	0.590	734.80	18.30	91.71	8.29
# 50	0.297	226.10	5.63	97.34	2.66
# 100	0.149	66.10	1.65	98.98	1.02
# 200	0.074	22.30	0.56	99.54	0.46
# 230	0.064	5.90	0.15	99.69	0.31
Pan	-----	12.60	0.31	100.00	-0.00

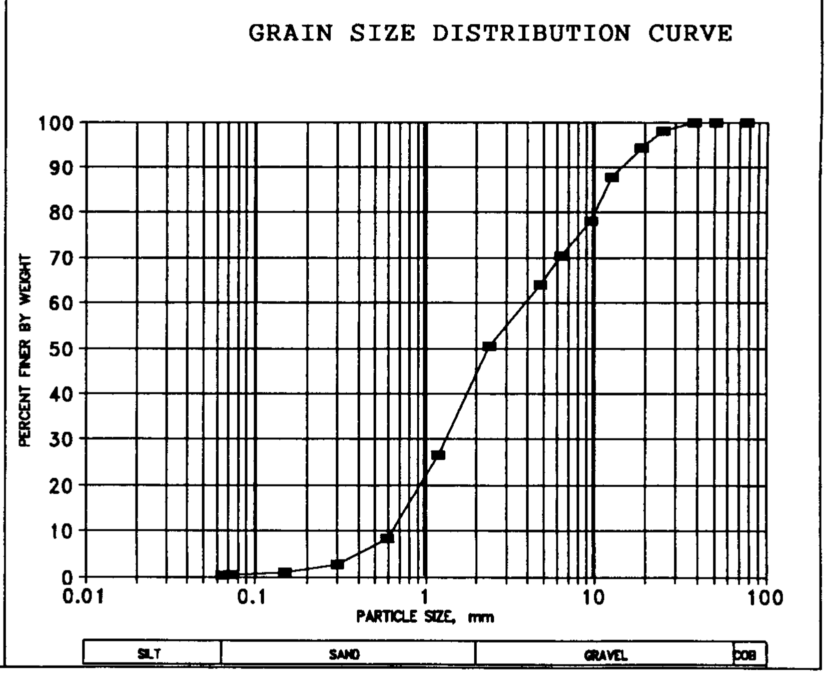


Table 14 (Continued)

SAMPLE NUMBER: 89-61

FIELD DATA

Date/Time : Start: 03/18/89-8:45 End: 03/22/89-16:00 DT: 103.25 hrs
Stage, ft : Start: 0.740 End: 0.451 DWS: -0.289 ft
Average Temerature: 9 C AVG: 0.596 ft

LAB DATA

Total Wt. (gr): 1834.00 Analyzed by: HM/ Date Analyzed: 03/09/91
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	9.60	0.52	0.52	99.48
1/2"	12.7	16.40	0.89	1.42	98.58
3/8"	9.525	54.60	2.98	4.39	95.61
1/4"	6.350	65.40	3.57	7.96	92.04
# 4	4.760	80.90	4.41	12.37	87.63
# 8	2.380	249.20	13.59	25.96	74.04
# 16	1.190	562.60	30.68	56.64	43.36
# 30	0.590	511.90	27.91	84.55	15.45
# 50	0.297	189.90	10.35	94.90	5.10
# 100	0.149	59.60	3.25	98.15	1.85
# 200	0.074	13.60	0.74	98.89	1.11
# 230	0.064	0.00	0.00	98.89	1.11
Pan	-----	20.30	1.11	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

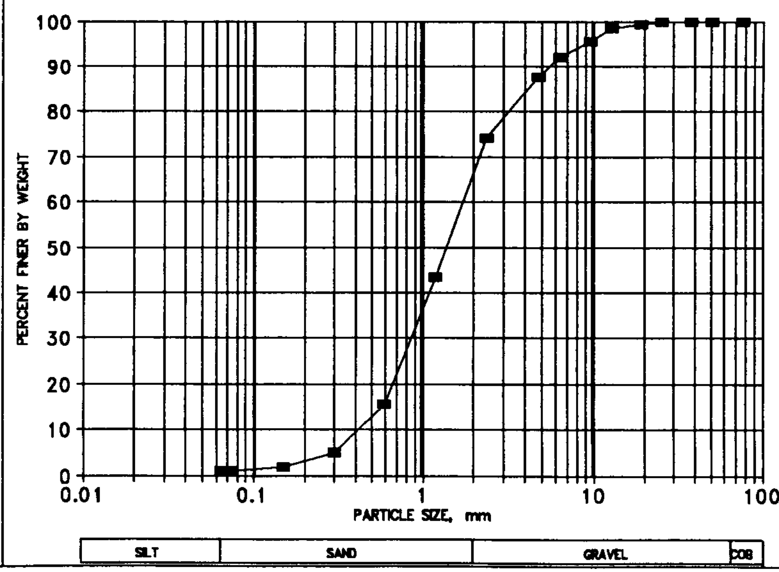


Table 14 (Continued)

SAMPLE NUMBER: 89-62

FIELD DATA

Date/Time :	Start:	03/22/89-16:00	End:	03/29/89-15:10	DT:	167.17	hrs
Stage, ft :	Start:	0.451	End:	0.515	DWS:	0.064	ft
Average Temerature:		9 C			AVG:	0.483	ft

LAB DATA

Total Wt. (gr): 1452.00 Analyzed by: HM/ Date Analyzed: 03/09/91

Was sample Split? NO

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4		0.00	0.00	100.00
3/4"	19.05	58.00	3.99	3.99	96.01
1/2"	12.7	46.00	3.17	7.16	92.84
3/8"	9.525	91.00	6.27	13.43	86.57
1/4"	6.350	78.90	5.43	18.86	81.14
# 4	4.760	79.00	5.44	24.30	75.70
# 8	2.380	167.50	11.54	35.84	64.16
# 16	1.190	310.20	21.36	57.20	42.80
# 30	0.590	321.40	22.13	79.34	20.66
# 50	0.297	199.40	13.73	93.07	6.93
# 100	0.149	72.60	5.00	98.07	1.93
# 200	0.074	19.00	1.31	99.38	0.62
# 230	0.064	0.00	0.00	99.38	0.62
Pan	-----	9.00	0.62	100.00	-0.00

GRAIN SIZE DISTRIBUTION CURVE

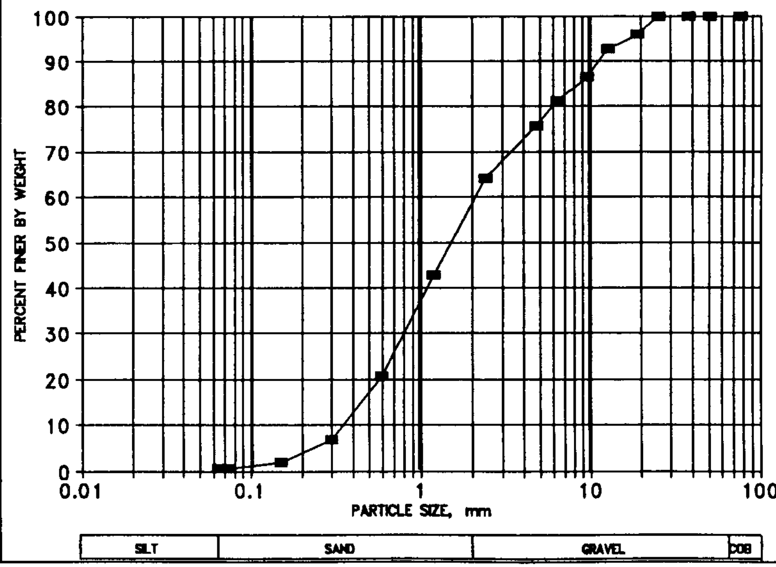


Table 14 (Continued)

SAMPLE NUMBER: 90-4

FIELD DATA

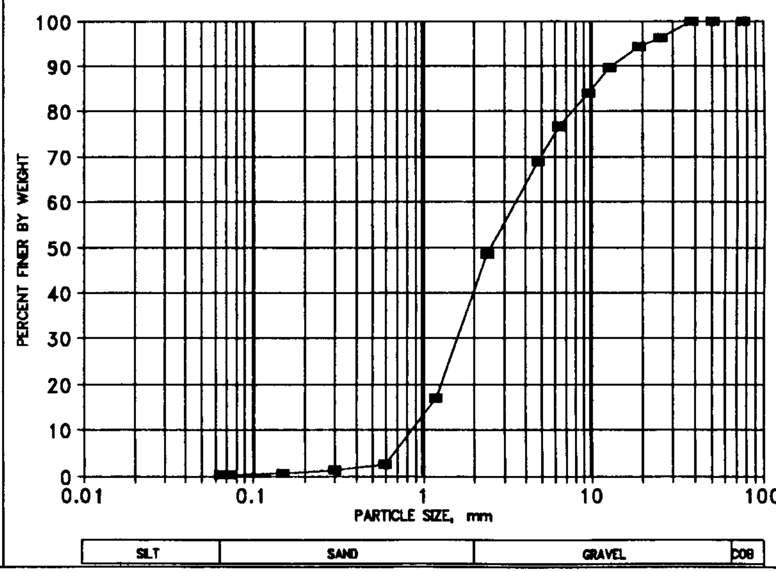
Date/Time :	Start:	01/30/90-13:30	End:	01/31/90-10:45	DT:	21.25	hrs
Stage, ft :	Start:	0.918	End:	0.671	DWS:	-0.247	ft
Average Temerature:		9 C			AVG:	0.795	ft

LAB DATA

Total Wt. (gr): 2014.78 Analyzed by: HM/ Date Analyzed: 03/09/91
Was sample Split? YES

Sieve Size US Std.	Opening mm	Sample Retained gram	Percent Retained	Cumul. Percent Retained	Cumul. Percent Finer
4"	101.6		0.00	0.00	100.00
3"	76.2		0.00	0.00	100.00
2"	50.8		0.00	0.00	100.00
1-1/2"	38.1		0.00	0.00	100.00
1"	25.4	73.80	3.66	3.66	96.34
3/4"	19.05	41.30	2.05	5.71	94.29
1/2"	12.7	93.30	4.63	10.34	89.66
3/8"	9.525	112.00	5.56	15.90	84.10
1/4"	6.350	152.50	7.57	23.47	76.53
# 4	4.760	153.20	7.60	31.08	68.92
# 8	2.380	413.52	20.52	51.60	48.40
# 16	1.190	634.05	31.47	83.07	16.93
# 30	0.590	290.61	14.42	97.49	2.51
# 50	0.297	25.32	1.26	98.75	1.25
# 100	0.149	12.59	0.62	99.38	0.62
# 200	0.074	6.25	0.31	99.69	0.31
# 230	0.064	0.00	0.00	99.69	0.31
Pan	-----	6.34	0.31	100.00	0.00

GRAIN SIZE DISTRIBUTION CURVE



APPENDIX E

OAK CREEK PARTICLE SHAPE DATA
Winter Runoff Season 1988-1989

Table 15 Oak Creek particle shape data, Winter 1989

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
88–25	10.03	3/4″	14.5	29.7	25.3	14.7	0.54	1.17	0.85	0.58	0.84
		1/2″	8.2	31.8	20.4	9.0	0.35	1.56	0.64	0.44	0.69
			6.0	23.4	18.5	11.2	0.54	1.26	0.79	0.61	0.63
			5.4	19.0	15.2	15.0	0.88	1.25	0.80	0.99	0.60
			4.3	20.0	15.0	12.5	0.72	1.33	0.75	0.83	0.56
			3.4	24.3	14.1	7.5	0.41	1.72	0.58	0.53	0.52
			4.8	25.1	15.4	12.4	0.63	1.63	0.61	0.81	0.58
			4.5	26.7	15.1	9.8	0.49	1.77	0.57	0.65	0.57
			3.9	19.4	17.0	10.2	0.56	1.14	0.88	0.60	0.54
		3/8″	2.6	27.0	12.8	5.2	0.28	2.11	0.47	0.41	0.47
			2.1	15.3	13.2	9.2	0.65	1.16	0.86	0.70	0.44
			0.9	13.8	12.2	6.0	0.46	1.13	0.88	0.49	0.33
			1.6	17.5	11.8	5.2	0.36	1.48	0.67	0.44	0.40
			1.7	29.1	9.5	5.1	0.31	3.06	0.33	0.54	0.41
			1.4	16.4	12.5	4.3	0.30	1.31	0.76	0.34	0.39
			1.4	13.7	12.5	7.0	0.53	1.10	0.91	0.56	0.39
			3.2	15.6	13.5	10.7	0.74	1.16	0.87	0.79	0.51
88–26	8.04	3/4″	21.1	32.3	28.1	18.7	0.62	1.15	0.87	0.67	0.95
			23.4	39.5	18.4	18.2	0.68	2.15	0.47	0.99	0.99
			8.4	31.6	24.2	8.5	0.31	1.31	0.77	0.35	0.70
		1/2″	4.8	27.8	18.3	8.5	0.38	1.52	0.66	0.46	0.58
			5.5	26.0	16.2	10.0	0.49	1.60	0.62	0.62	0.61
			5.6	27.3	19.6	7.5	0.32	1.39	0.72	0.38	0.61
			3.6	20.5	15.7	13.3	0.74	1.31	0.77	0.85	0.53
			6.2	27.2	15.9	11.2	0.54	1.71	0.58	0.70	0.63
			6.5	26.1	17.0	12.4	0.59	1.54	0.65	0.73	0.64
			4.2	21.1	17.7	10.5	0.54	1.19	0.84	0.59	0.56
			5.8	23.3	19.1	15.2	0.72	1.22	0.82	0.80	0.62
		3/8″	3.4	21.7	13.0	9.1	0.54	1.67	0.60	0.70	0.52
			2.2	26.0	17.1	4.1	0.19	1.52	0.66	0.24	0.45
			2.3	16.0	10.2	9.5	0.74	1.57	0.64	0.93	0.45
			2.1	14.4	13.7	9.6	0.68	1.05	0.95	0.70	0.44
			1.7	14.5	10.3	9.2	0.75	1.41	0.71	0.89	0.41
			2.1	18.6	10.2	5.9	0.43	1.82	0.55	0.58	0.44
			2.1	14.0	12.5	8.2	0.62	1.12	0.89	0.66	0.44
			1.4	15.5	12.8	6.5	0.46	1.21	0.83	0.51	0.39
88–27	17.84	3/4″	22.4	34.0	21.5	18.5	0.68	1.58	0.63	0.86	0.97
		1/2″	5.2	25.2	17.0	11.0	0.53	1.48	0.67	0.65	0.60
			4.8	25.4	16.2	6.8	0.34	1.57	0.64	0.42	0.58
			6.7	23.6	15.8	14.2	0.74	1.49	0.67	0.90	0.65
			4.6	22.9	18.1	9.3	0.46	1.27	0.79	0.51	0.57
			3.2	23.4	17.7	7.3	0.36	1.32	0.76	0.41	0.51

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			4.4	26.3	19.9	10.0	0.44	1.32	0.76	0.50	0.56
		3/8″	2.4	17.4	11.8	8.1	0.57	1.47	0.68	0.69	0.46
			2.2	16.4	12.7	8.2	0.57	1.29	0.77	0.65	0.45
			1.9	16.3	12.6	9.4	0.66	1.29	0.77	0.75	0.43
			1.7	14.0	13.0	8.6	0.64	1.08	0.93	0.66	0.41
			2.2	19.5	15.6	5.8	0.33	1.25	0.80	0.37	0.45
			1.5	15.1	10.0	9.0	0.73	1.51	0.66	0.90	0.39
			1.1	12.8	10.9	7.1	0.60	1.17	0.85	0.65	0.36
			1.4	14.3	10.2	7.4	0.61	1.40	0.71	0.73	0.39
88–28	12.88	3/4″	8.3	33.8	22.8	8.8	0.32	1.48	0.67	0.39	0.70
			10.6	25.4	23.1	12.2	0.50	1.10	0.91	0.53	0.76
		1/2″	6.7	28.8	21.4	8.5	0.34	1.35	0.74	0.40	0.65
			7.6	24.5	19.2	10.6	0.49	1.28	0.78	0.55	0.68
			5.2	23.3	16.8	10.8	0.55	1.39	0.72	0.64	0.60
			6.9	31.8	15.7	10.8	0.48	2.03	0.49	0.69	0.66
			4.5	23.6	17.3	9.0	0.45	1.36	0.73	0.52	0.57
			4.6	23.8	15.3	10.2	0.53	1.56	0.64	0.67	0.57
			2.8	19.0	17.0	8.5	0.47	1.12	0.89	0.50	0.49
			3.1	20.2	16.0	7.8	0.43	1.26	0.79	0.49	0.50
			5.2	24.0	19.0	9.2	0.43	1.26	0.79	0.48	0.60
			4.2	20.8	16.2	13.2	0.72	1.28	0.78	0.81	0.56
		3/8″	4.3	23.9	14.1	9.2	0.50	1.70	0.59	0.65	0.56
			1.8	15.1	12.6	10.1	0.73	1.20	0.83	0.80	0.42
			1.8	17.0	11.7	5.7	0.40	1.45	0.69	0.49	0.42
			3.3	19.8	13.2	10.9	0.67	1.50	0.67	0.83	0.51
			2.9	15.9	13.8	9.1	0.61	1.15	0.87	0.66	0.49
			2.3	17.6	12.7	10.7	0.72	1.39	0.72	0.84	0.45
			3.2	19.0	13.5	8.2	0.51	1.41	0.71	0.61	0.51
			3.1	23.1	17.1	6.2	0.31	1.35	0.74	0.36	0.50
			1.1	11.5	11.0	6.8	0.60	1.05	0.96	0.62	0.36
			1.1	12.0	9.6	7.5	0.70	1.25	0.80	0.78	0.36
89–29	9.76	1/2″	8.2	27.5	14.5	13.9	0.70	1.90	0.53	0.96	0.69
			8.1	26.0	18.2	12.6	0.58	1.43	0.70	0.69	0.69
			5.1	25.6	17.6	10.4	0.49	1.45	0.69	0.59	0.59
			5.5	23.8	20.0	10.3	0.47	1.19	0.84	0.52	0.61
			3.7	32.4	20.0	3.9	0.15	1.62	0.62	0.20	0.53
		3/8″	1.5	16.4	14.2	6.4	0.42	1.15	0.87	0.45	0.39
			2.2	19.7	11.6	10.5	0.69	1.70	0.59	0.91	0.45
			2.4	34.0	11.5	6.5	0.33	2.96	0.34	0.57	0.46
			2.0	14.0	10.1	8.8	0.74	1.39	0.72	0.87	0.43
			1.6	14.2	11.2	9.8	0.78	1.27	0.79	0.88	0.40
			1.2	11.7	11.5	9.2	0.79	1.02	0.98	0.80	0.37

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			1.2	13.2	11.4	6.3	0.51	1.16	0.86	0.55	0.37
			1.5	15.9	10.2	7.5	0.59	1.56	0.64	0.74	0.39
88–30	32.74	1"	89.7	53.6	35.0	24.4	0.56	1.53	0.65	0.70	1.54
			51.3	47.4	28.3	21.4	0.58	1.67	0.60	0.76	1.28
			59.4	48.2	34.0	21.6	0.53	1.42	0.71	0.64	1.34
			28.1	30.3	30.4	25.7	0.85	1.00	1.00	0.85	1.05
		3/4"	19.7	54.7	30.0	7.0	0.17	1.82	0.55	0.23	0.93
			28.4	42.5	22.2	13.7	0.45	1.91	0.52	0.62	1.05
			12.5	30.0	22.5	12.5	0.48	1.33	0.75	0.56	0.80
			18.6	33.3	22.7	16.8	0.61	1.47	0.68	0.74	0.91
			13.2	26.4	17.4	15.5	0.72	1.52	0.66	0.89	0.81
			22.8	32.2	22.8	22.0	0.81	1.41	0.71	0.96	0.98
			16.2	38.5	25.2	14.4	0.46	1.53	0.65	0.57	0.87
			22.2	34.4	19.2	18.7	0.73	1.79	0.56	0.97	0.97
		1/2"	14.7	35.5	18.5	13.9	0.54	1.92	0.52	0.75	0.84
			10.0	26.2	18.6	12.7	0.58	1.41	0.71	0.68	0.74
			5.2	25.5	17.4	8.9	0.42	1.47	0.68	0.51	0.60
			5.4	19.7	13.3	11.7	0.72	1.48	0.68	0.88	0.60
			10.0	26.4	20.0	15.0	0.65	1.32	0.76	0.75	0.74
			2.6	19.5	14.4	12.2	0.73	1.35	0.74	0.85	0.47
			4.6	20.0	15.0	8.1	0.47	1.33	0.75	0.54	0.57
			4.5	19.0	12.4	10.5	0.68	1.53	0.65	0.85	0.57
		3/8"	3.1	17.8	10.5	10.1	0.74	1.70	0.59	0.96	0.50
			4.5	31.9	13.5	6.2	0.30	2.36	0.42	0.46	0.57
			1.5	13.5	10.0	8.5	0.73	1.35	0.74	0.85	0.39
			2.9	13.7	12.1	9.5	0.74	1.13	0.88	0.79	0.49
			3.8	17.4	12.7	8.5	0.57	1.37	0.73	0.67	0.54
			3.4	18.1	10.8	10.6	0.76	1.68	0.60	0.98	0.52
			2.3	15.8	13.7	9.7	0.66	1.15	0.87	0.71	0.45
			1.8	16.8	8.8	6.9	0.57	1.91	0.52	0.78	0.42
88–31	30.56	1 1/2"	186.6	51.8	46.6	45.2	0.92	1.11	0.90	0.97	1.97
			92.9	47.7	39.5	34.5	0.79	1.21	0.83	0.87	1.56
			175.3	63.2	46.5	32.5	0.60	1.36	0.74	0.70	1.93
			134.9	81.9	46.5	29.4	0.48	1.76	0.57	0.63	1.77
			122.3	67.4	40.0	39.2	0.75	1.69	0.59	0.98	1.71
			105.0	57.9	39.5	35.7	0.75	1.47	0.68	0.90	1.63
			97.7	53.7	41.7	33.9	0.72	1.29	0.78	0.81	1.59
		1"	74.7	48.3	39.4	34.2	0.78	1.23	0.82	0.87	1.45
			52.8	43.0	31.0	26.2	0.72	1.39	0.72	0.85	1.29
			43.0	36.7	29.5	25.4	0.77	1.24	0.80	0.86	1.21
			28.9	41.3	29.3	19.9	0.57	1.41	0.71	0.68	1.06
			28.5	30.0	25.8	24.5	0.88	1.16	0.86	0.95	1.05

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			46.9	59.5	30.8	17.4	0.41	1.93	0.52	0.56	1.24
			23.4	39.3	27.6	13.4	0.41	1.42	0.70	0.49	0.99
			33.2	38.3	28.5	17.7	0.54	1.34	0.74	0.62	1.11
		3/4″	43.4	42.4	26.5	18.6	0.55	1.60	0.63	0.70	1.21
			17.8	51.0	19.2	9.5	0.30	2.66	0.38	0.49	0.90
			11.8	27.4	17.8	12.0	0.54	1.54	0.65	0.67	0.78
			11.0	30.0	17.6	13.7	0.60	1.70	0.59	0.78	0.77
			14.2	31.5	20.3	13.4	0.53	1.55	0.64	0.66	0.83
			9.0	23.2	19.6	10.5	0.49	1.18	0.84	0.54	0.72
			16.0	27.4	20.9	19.0	0.79	1.31	0.76	0.91	0.87
			20.0	28.0	18.2	17.0	0.75	1.54	0.65	0.93	0.94
		1/2″	10.8	33.4	18.6	15.3	0.61	1.80	0.56	0.82	0.76
			9.0	26.4	16.8	16.0	0.76	1.57	0.64	0.95	0.72
			4.5	19.1	14.0	9.7	0.59	1.36	0.73	0.69	0.57
			8.6	23.3	16.1	13.9	0.72	1.45	0.69	0.86	0.71
			5.2	20.0	14.0	11.5	0.69	1.43	0.70	0.82	0.60
			4.7	20.5	13.4	11.0	0.66	1.53	0.65	0.82	0.58
			3.8	18.0	15.5	8.1	0.48	1.16	0.86	0.52	0.54
			3.2	17.0	13.1	5.4	0.36	1.30	0.77	0.41	0.51
		3/8″	6.0	29.0	13.4	8.8	0.45	2.16	0.46	0.66	0.63
			2.7	13.0	11.0	8.4	0.70	1.18	0.85	0.76	0.48
			2.7	20.5	14.2	8.3	0.49	1.44	0.69	0.58	0.48
			1.5	21.2	14.0	2.5	0.15	1.51	0.66	0.18	0.39
			1.6	15.0	9.2	7.2	0.61	1.63	0.61	0.78	0.40
			0.9	10.8	8.8	6.4	0.66	1.23	0.81	0.73	0.33
			1.4	17.3	10.2	4.3	0.32	1.70	0.59	0.42	0.39
			1.9	12.8	10.4	7.0	0.61	1.23	0.81	0.67	0.43
			2.6	14.1	11.6	8.6	0.67	1.22	0.82	0.74	0.47
			0.9	14.9	10.3	3.5	0.28	1.45	0.69	0.34	0.33
88-32	29.88	1″	25.3	45.4	26.8	26.0	0.75	1.69	0.59	0.97	1.01
			58.7	60.0	29.6	26.0	0.62	2.03	0.49	0.88	1.34
			54.0	65.5	32.3	19.1	0.42	2.03	0.49	0.59	1.30
			26.4	35.0	27.0	21.6	0.70	1.30	0.77	0.80	1.03
			28.6	39.1	29.5	20.3	0.60	1.33	0.75	0.69	1.05
		3/4″	19.8	44.1	33.7	9.0	0.23	1.31	0.76	0.27	0.93
			14.2	39.0	20.8	10.5	0.37	1.88	0.53	0.50	0.83
			19.0	34.5	26.1	16.4	0.55	1.32	0.76	0.63	0.92
			34.7	40.5	21.3	18.0	0.61	1.90	0.53	0.85	1.12
			12.4	29.1	23.1	15.2	0.59	1.26	0.79	0.66	0.80
			17.8	32.4	26.6	13.4	0.46	1.22	0.82	0.50	0.90
			10.1	24.7	23.0	12.0	0.50	1.07	0.93	0.52	0.74
			12.1	26.0	18.8	16.5	0.75	1.38	0.72	0.88	0.79

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
		1/2″	7.8	28.7	13.2	11.0	0.57	2.17	0.46	0.83	0.68
			7.3	28.8	15.0	11.5	0.55	1.92	0.52	0.77	0.67
			7.4	22.0	15.2	12.7	0.69	1.45	0.69	0.84	0.67
			7.0	21.4	18.2	14.6	0.74	1.18	0.85	0.80	0.66
			6.1	23.2	13.8	11.5	0.64	1.68	0.59	0.83	0.63
			4.1	19.2	15.1	9.4	0.55	1.27	0.79	0.62	0.55
			4.6	22.0	16.2	10.2	0.54	1.36	0.74	0.63	0.57
		3/8″	4.3	19.7	13.0	10.5	0.66	1.52	0.66	0.81	0.56
			4.6	27.8	13.4	8.8	0.46	2.07	0.48	0.66	0.57
			2.7	14.1	11.1	10.8	0.86	1.27	0.79	0.97	0.48
			2.4	17.1	10.8	7.1	0.52	1.58	0.63	0.66	0.46
			2.1	13.0	12.0	9.1	0.73	1.08	0.92	0.76	0.44
			1.3	15.5	11.2	6.0	0.46	1.38	0.72	0.54	0.38
			1.7	17.5	10.4	4.0	0.30	1.68	0.59	0.38	0.41
88–33	34.43	1″	106.5	77.3	41.5	18.4	0.32	1.86	0.54	0.44	1.63
			37.5	51.7	33.5	22.5	0.54	1.54	0.65	0.67	1.15
			27.9	31.4	26.9	21.0	0.72	1.17	0.86	0.78	1.05
		3/4″	11.6	30.3	21.8	13.8	0.54	1.39	0.72	0.63	0.78
			14.8	30.5	21.4	15.0	0.59	1.43	0.70	0.70	0.85
			15.6	24.6	21.0	19.5	0.86	1.17	0.85	0.93	0.86
			13.3	26.2	20.1	16.4	0.71	1.30	0.77	0.82	0.82
			13.9	29.8	26.0	14.0	0.50	1.15	0.87	0.54	0.83
			14.5	36.7	24.7	8.8	0.29	1.49	0.67	0.36	0.84
			12.2	23.5	20.5	12.7	0.58	1.15	0.87	0.62	0.79
			18.0	35.5	21.6	18.4	0.66	1.64	0.61	0.85	0.90
			9.7	24.3	19.3	13.0	0.60	1.26	0.79	0.67	0.73
			8.9	24.3	20.5	16.5	0.74	1.19	0.84	0.80	0.71
			11.2	27.4	21.7	19.4	0.80	1.26	0.79	0.89	0.77
		1/2″	14.4	42.7	19.0	11.2	0.39	2.25	0.44	0.59	0.84
			8.8	28.6	16.8	12.9	0.59	1.70	0.59	0.77	0.71
			8.8	21.5	16.1	15.8	0.85	1.34	0.75	0.98	0.71
			10.5	27.0	19.5	14.8	0.65	1.38	0.72	0.76	0.75
			9.8	22.5	17.5	14.2	0.72	1.29	0.78	0.81	0.74
			5.4	22.5	13.8	8.5	0.48	1.63	0.61	0.62	0.60
			6.2	20.5	14.5	11.9	0.69	1.41	0.71	0.82	0.63
			4.0	17.0	13.5	11.5	0.76	1.26	0.79	0.85	0.55
		3/8″	1.3	13.4	11.0	3.8	0.31	1.22	0.82	0.35	0.38
			2.1	20.0	8.4	7.3	0.56	2.38	0.42	0.87	0.44
			1.5	13.0	9.1	9.0	0.83	1.43	0.70	0.99	0.39
			3.1	15.0	12.6	10.4	0.76	1.19	0.84	0.83	0.50
			1.4	17.2	8.7	6.3	0.52	1.98	0.51	0.72	0.39
			3.2	19.8	11.0	7.4	0.50	1.80	0.56	0.67	0.51

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			2.0	15.9	9.3	6.6	0.54	1.71	0.58	0.71	0.43
			1.3	15.0	8.8	3.2	0.28	1.70	0.59	0.36	0.38
88–34	35.12	1″	51.8	52.5	26.4	15.3	0.41	1.99	0.50	0.58	1.28
			103.6	56.8	37.7	31.6	0.68	1.51	0.66	0.84	1.62
			52.9	56.0	34.3	16.0	0.37	1.63	0.61	0.47	1.29
			27.9	36.6	28.3	25.2	0.78	1.29	0.77	0.89	1.05
		3/4″	9.9	25.0	23.7	16.1	0.66	1.05	0.95	0.68	0.74
			10.6	30.2	18.5	15.5	0.66	1.63	0.61	0.84	0.76
			11.5	32.1	26.4	14.2	0.49	1.22	0.82	0.54	0.78
			12.7	26.1	19.4	14.1	0.63	1.35	0.74	0.73	0.80
			24.5	35.5	21.0	20.2	0.74	1.69	0.59	0.96	1.00
			9.3	26.2	18.5	12.4	0.56	1.42	0.71	0.67	0.72
		1/2″	4.2	17.1	13.6	10.0	0.66	1.26	0.80	0.74	0.56
			8.2	20.8	16.5	12.4	0.67	1.26	0.79	0.75	0.69
			7.7	28.2	18.1	14.7	0.65	1.56	0.64	0.81	0.68
			6.6	26.8	16.8	8.6	0.41	1.60	0.63	0.51	0.65
			5.3	26.1	17.0	11.9	0.56	1.54	0.65	0.70	0.60
			5.2	21.7	20.7	7.3	0.34	1.05	0.95	0.35	0.60
			4.2	21.4	17.4	7.7	0.40	1.23	0.81	0.44	0.56
			4.5	18.6	15.5	12.0	0.71	1.20	0.83	0.77	0.57
		3/8″	1.7	12.8	12.0	6.2	0.50	1.07	0.94	0.52	0.41
			1.8	14.1	11.1	7.2	0.58	1.27	0.79	0.65	0.42
			1.5	13.6	11.0	7.6	0.62	1.24	0.81	0.69	0.39
			2.0	20.0	10.4	8.4	0.58	1.92	0.52	0.81	0.43
			2.7	14.5	11.5	9.0	0.70	1.26	0.79	0.78	0.48
			2.5	16.5	14.2	10.7	0.70	1.16	0.86	0.75	0.47
			3.0	22.4	9.7	7.2	0.49	2.31	0.43	0.74	0.50
			3.3	17.2	12.3	9.7	0.67	1.40	0.72	0.79	0.51
			2.7	15.5	11.0	10.5	0.80	1.41	0.71	0.95	0.48
88–35	27.71	1″	44.2	43.7	31.8	20.7	0.56	1.37	0.73	0.65	1.22
			35.1	36.2	26.0	25.7	0.84	1.39	0.72	0.99	1.13
		3/4″	33.5	47.0	25.0	20.0	0.58	1.88	0.53	0.80	1.11
			12.6	32.5	19.6	13.2	0.52	1.66	0.60	0.67	0.80
			7.0	26.3	21.2	8.5	0.36	1.24	0.81	0.40	0.66
			13.9	28.1	21.1	17.7	0.73	1.33	0.75	0.84	0.83
			28.9	40.7	27.1	16.3	0.49	1.50	0.67	0.60	1.06
			22.3	33.8	19.3	18.2	0.71	1.75	0.57	0.94	0.97
			16.5	33.2	23.5	15.0	0.54	1.41	0.71	0.64	0.88
			6.9	20.8	19.1	14.4	0.72	1.09	0.92	0.75	0.66
		1/2″	6.2	27.4	16.7	9.0	0.42	1.64	0.61	0.54	0.63
			11.1	28.9	17.5	16.0	0.71	1.65	0.61	0.91	0.77
			6.6	22.5	16.5	13.1	0.68	1.36	0.73	0.79	0.65

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			3.7	16.3	15.4	10.4	0.66	1.06	0.94	0.68	0.53
			7.9	33.3	18.5	9.8	0.39	1.80	0.56	0.53	0.69
			6.1	22.8	17.7	10.5	0.52	1.29	0.78	0.59	0.63
			7.6	24.0	16.6	11.2	0.56	1.45	0.69	0.67	0.68
			4.8	16.2	13.0	12.9	0.89	1.25	0.80	0.99	0.58
		3/8"	4.7	18.8	15.5	9.8	0.57	1.21	0.82	0.63	0.58
			3.4	20.4	12.8	9.6	0.59	1.59	0.63	0.75	0.52
			3.2	21.2	14.0	6.5	0.38	1.51	0.66	0.46	0.51
			1.5	18.5	13.0	5.2	0.34	1.42	0.70	0.40	0.39
			3.4	19.7	9.5	9.1	0.67	2.07	0.48	0.96	0.52
			3.0	23.3	9.5	8.0	0.54	2.45	0.41	0.84	0.50
			1.2	12.7	10.2	5.4	0.47	1.25	0.80	0.53	0.37
			3.5	19.4	11.8	8.8	0.58	1.64	0.61	0.75	0.52
88-36	20.48	1"	39.7	43.8	29.8	15.7	0.43	1.47	0.68	0.53	1.18
		3/4"	22.7	34.1	26.6	20.2	0.67	1.28	0.78	0.76	0.98
			12.4	22.9	20.1	16.5	0.77	1.14	0.88	0.82	0.80
			29.6	46.7	23.3	19.8	0.60	2.00	0.50	0.85	1.07
			12.4	23.3	21.5	20.4	0.91	1.08	0.92	0.95	0.80
			7.0	25.0	19.2	15.4	0.70	1.30	0.77	0.80	0.66
			9.1	23.5	23.0	16.0	0.69	1.02	0.98	0.70	0.72
		1/2"	7.6	32.3	17.1	12.7	0.54	1.89	0.53	0.74	0.68
			5.8	26.2	20.8	7.2	0.31	1.26	0.79	0.35	0.62
			7.8	32.3	16.0	12.7	0.56	2.02	0.50	0.79	0.68
			4.7	22.3	13.8	7.9	0.45	1.62	0.62	0.57	0.58
			6.8	23.1	17.4	12.0	0.60	1.33	0.75	0.69	0.65
			4.9	19.2	15.0	13.3	0.78	1.28	0.78	0.89	0.59
			4.0	24.8	15.4	6.8	0.35	1.61	0.62	0.44	0.55
			3.8	23.5	14.1	10.5	0.58	1.67	0.60	0.74	0.54
		3/8"	3.5	18.0	14.2	10.5	0.66	1.27	0.79	0.74	0.52
			2.8	15.7	14.2	10.8	0.72	1.11	0.90	0.76	0.49
			2.3	16.2	10.8	10.3	0.78	1.50	0.67	0.95	0.45
			2.7	22.1	10.6	9.6	0.63	2.08	0.48	0.91	0.48
			2.6	22.4	12.3	9.0	0.54	1.82	0.55	0.73	0.47
			1.6	12.0	10.2	7.2	0.65	1.18	0.85	0.71	0.40
			1.3	13.7	11.5	7.7	0.61	1.19	0.84	0.67	0.38
88-37	15.43	1/2"	7.5	25.1	15.4	11.9	0.61	1.63	0.61	0.77	0.67
		3/8"	3.3	24.7	13.0	8.8	0.49	1.90	0.53	0.68	0.51
			1.2	18.9	10.2	7.4	0.53	1.85	0.54	0.73	0.37
			2.6	15.2	12.1	8.8	0.65	1.26	0.80	0.73	0.47
			2.1	17.4	13.9	6.6	0.42	1.25	0.80	0.47	0.44
			1.4	15.7	9.7	9.2	0.75	1.62	0.62	0.95	0.39
			1.9	18.5	12.7	6.2	0.40	1.46	0.69	0.49	0.43

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			1.5	12.1	10.6	8.6	0.76	1.14	0.88	0.81	0.39
			2.0	19.1	11.8	6.8	0.45	1.62	0.62	0.58	0.43
88–38	11.95	1/2"	10.3	24.9	21.5	16.1	0.70	1.16	0.86	0.75	0.75
			8.0	20.0	17.4	14.7	0.79	1.15	0.87	0.84	0.69
			9.4	24.7	20.2	12.5	0.56	1.22	0.82	0.62	0.73
			9.5	27.8	16.3	13.2	0.62	1.71	0.59	0.81	0.73
			6.7	29.0	19.3	9.0	0.38	1.50	0.67	0.47	0.65
			5.8	36.2	20.7	12.6	0.46	1.75	0.57	0.61	0.62
			5.2	19.2	14.0	13.7	0.84	1.37	0.73	0.98	0.60
		3/8"	2.9	21.7	13.8	11.5	0.66	1.57	0.64	0.83	0.49
			2.1	13.9	13.0	8.5	0.63	1.07	0.94	0.65	0.44
			1.9	15.5	12.2	8.9	0.65	1.27	0.79	0.73	0.43
			3.5	20.6	15.5	7.9	0.44	1.33	0.75	0.51	0.52
			1.7	16.5	12.5	7.9	0.55	1.32	0.76	0.63	0.41
			1.9	16.2	13.6	10.3	0.69	1.19	0.84	0.76	0.43
			1.7	18.2	11.4	5.0	0.35	1.60	0.63	0.44	0.41
			1.5	13.6	11.7	8.1	0.64	1.16	0.86	0.69	0.39
89–39	6.35	1/2"	3.8	20.6	14.8	8.1	0.46	1.39	0.72	0.55	0.54
			4.7	18.8	18.8	8.6	0.46	1.00	1.00	0.46	0.58
		3/8"	3.7	21.7	16.9	9.4	0.49	1.28	0.78	0.56	0.53
			3.4	21.8	15.8	8.5	0.46	1.38	0.72	0.54	0.52
			4.9	22.9	11.0	9.8	0.62	2.08	0.48	0.89	0.59
			2.5	18.5	12.6	9.4	0.62	1.47	0.68	0.75	0.47
			2.4	15.4	12.7	9.4	0.67	1.21	0.82	0.74	0.46
			2.5	16.4	11.0	9.7	0.72	1.49	0.67	0.88	0.47
			1.3	14.9	11.4	5.6	0.43	1.31	0.77	0.49	0.38
			1.0	13.3	7.7	7.9	0.78	1.73	0.58	1.03	0.34
89–40	17.12	1 1/2"	142.9	63.8	48.5	42.2	0.76	1.32	0.76	0.87	1.80
		3/4"	11.7	34.6	23.0	12.3	0.44	1.50	0.66	0.53	0.78
			19.3	35.9	25.0	15.8	0.53	1.44	0.70	0.63	0.92
			12.5	26.8	21.1	13.7	0.58	1.27	0.79	0.65	0.80
			8.0	24.3	22.3	13.3	0.57	1.09	0.92	0.60	0.69
			12.5	25.6	20.6	13.2	0.57	1.24	0.80	0.64	0.80
			14.6	31.1	19.5	14.7	0.60	1.59	0.63	0.75	0.84
			13.8	32.6	23.4	13.4	0.49	1.39	0.72	0.57	0.83
			10.7	23.9	22.3	18.4	0.80	1.07	0.93	0.83	0.76
		1/2"	13.2	38.2	20.4	13.2	0.47	1.87	0.53	0.65	0.81
			6.7	22.0	16.7	10.0	0.52	1.32	0.76	0.60	0.65
			5.5	17.7	16.2	10.1	0.60	1.09	0.92	0.62	0.61
			3.4	24.8	16.1	5.8	0.29	1.54	0.65	0.36	0.52
			7.9	23.7	19.8	10.5	0.48	1.20	0.84	0.53	0.69
			4.7	22.0	17.7	10.6	0.54	1.24	0.80	0.60	0.58

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			4.0	21.7	16.5	7.5	0.40	1.32	0.76	0.45	0.55
			3.2	19.9	15.4	11.0	0.63	1.29	0.77	0.71	0.51
		3/8"	1.6	15.3	11.5	5.0	0.38	1.33	0.75	0.43	0.40
			1.7	16.8	12.4	6.4	0.44	1.35	0.74	0.52	0.41
			1.5	17.5	11.8	5.6	0.39	1.48	0.67	0.47	0.39
			1.8	13.4	11.0	9.9	0.82	1.22	0.82	0.90	0.42
			1.3	16.9	9.7	8.6	0.67	1.74	0.57	0.89	0.38
			1.9	16.9	12.3	7.8	0.54	1.37	0.73	0.63	0.43
			1.7	12.4	11.5	8.2	0.69	1.08	0.93	0.71	0.41
			1.9	16.6	12.9	6.2	0.42	1.29	0.78	0.48	0.43
89–41	27.04	1"	46.5	36.5	32.1	25.2	0.74	1.14	0.88	0.79	1.24
			53.9	41.4	31.8	27.0	0.74	1.30	0.77	0.85	1.30
			30.0	33.0	27.6	24.3	0.81	1.20	0.84	0.88	1.07
			39.2	40.7	29.0	21.6	0.63	1.40	0.71	0.74	1.17
			40.0	41.0	30.5	24.7	0.70	1.34	0.74	0.81	1.18
			16.6	30.8	29.2	9.7	0.32	1.05	0.95	0.33	0.88
			25.6	34.0	29.5	22.2	0.70	1.15	0.87	0.75	1.02
			36.6	50.4	33.1	14.2	0.35	1.52	0.66	0.43	1.14
		3/4"	33.8	48.6	20.8	16.7	0.53	2.34	0.43	0.80	1.11
			17.6	37.2	21.0	15.5	0.55	1.77	0.56	0.74	0.90
			20.8	33.6	26.2	12.1	0.41	1.28	0.78	0.46	0.95
			17.4	31.5	24.3	13.8	0.50	1.30	0.77	0.57	0.89
			17.7	28.8	23.7	19.4	0.74	1.22	0.82	0.82	0.90
			11.8	26.7	20.0	14.4	0.62	1.34	0.75	0.72	0.78
			8.2	21.3	16.8	14.6	0.77	1.27	0.79	0.87	0.69
			10.1	21.5	18.8	15.3	0.76	1.14	0.87	0.81	0.74
		1/2"	7.4	28.0	15.3	12.2	0.59	1.83	0.55	0.80	0.67
			8.7	26.5	16.3	12.9	0.62	1.63	0.62	0.79	0.71
			12.9	27.0	18.5	18.0	0.81	1.46	0.69	0.97	0.81
			4.9	21.0	14.6	10.8	0.62	1.44	0.70	0.74	0.59
			6.9	23.8	13.9	13.1	0.72	1.71	0.58	0.94	0.66
			5.0	20.7	12.1	11.7	0.74	1.71	0.58	0.97	0.59
			6.5	20.8	15.1	13.5	0.76	1.38	0.73	0.89	0.64
			3.6	17.5	11.7	9.2	0.64	1.50	0.67	0.79	0.53
		3/8"	1.9	16.5	8.6	8.0	0.67	1.92	0.52	0.93	0.43
			4.7	20.7	13.2	9.0	0.54	1.57	0.64	0.68	0.58
			1.4	13.6	11.4	7.9	0.63	1.19	0.84	0.69	0.39
			1.7	13.8	10.0	9.5	0.81	1.38	0.72	0.95	0.41
			1.2	12.6	9.5	9.0	0.82	1.33	0.75	0.95	0.37
			2.5	19.9	13.2	5.5	0.34	1.51	0.66	0.42	0.47
			1.6	14.1	9.7	7.8	0.67	1.45	0.69	0.80	0.40
			2.3	17.2	8.8	7.5	0.61	1.95	0.51	0.85	0.45

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
89-42	29.14	2"	290.5	93.0	55.5	41.5	0.58	1.68	0.60	0.75	2.28
		1 1/2"	155.1	72.0	36.8	29.0	0.56	1.96	0.51	0.79	1.85
			188.7	71.0	46.5	40.0	0.70	1.53	0.65	0.86	1.98
			96.3	48.5	47.2	29.6	0.62	1.03	0.97	0.63	1.58
			89.2	54.0	50.5	15.1	0.29	1.07	0.94	0.30	1.54
			95.6	48.2	46.5	35.4	0.75	1.04	0.96	0.76	1.58
			177.7	63.5	57.9	38.3	0.63	1.10	0.91	0.66	1.94
			100.2	50.7	45.5	35.2	0.73	1.11	0.90	0.77	1.60
			128.4	63.7	45.2	36.1	0.67	1.41	0.71	0.80	1.74
			129.3	60.6	46.5	43.7	0.82	1.30	0.77	0.94	1.74
			91.3	62.2	36.2	27.3	0.58	1.72	0.58	0.75	1.55
		1"	89.8	58.4	41.3	25.8	0.53	1.41	0.71	0.62	1.54
			62.1	48.0	28.6	25.0	0.67	1.68	0.60	0.87	1.36
			71.7	39.5	34.2	30.7	0.84	1.15	0.87	0.90	1.43
			40.8	41.2	32.9	31.8	0.86	1.25	0.80	0.97	1.19
			102.6	67.2	44.0	26.5	0.49	1.53	0.65	0.60	1.61
			51.0	52.0	29.9	23.4	0.59	1.74	0.58	0.78	1.28
			36.5	44.5	27.1	20.8	0.60	1.64	0.61	0.77	1.14
			37.5	40.5	28.2	21.5	0.64	1.44	0.70	0.76	1.15
			31.2	38.4	28.4	21.8	0.66	1.35	0.74	0.77	1.08
			28.9	37.0	29.8	14.0	0.42	1.24	0.81	0.47	1.06
		3/4"	63.7	61.0	25.6	23.5	0.59	2.38	0.42	0.92	1.38
			19.2	29.2	21.8	18.6	0.74	1.34	0.75	0.85	0.92
			17.5	36.4	26.3	13.0	0.42	1.38	0.72	0.49	0.89
			19.6	34.5	27.2	15.0	0.49	1.27	0.79	0.55	0.93
			13.8	33.8	19.5	17.0	0.66	1.73	0.58	0.87	0.83
			19.6	40.5	24.6	18.5	0.59	1.65	0.61	0.75	0.93
			38.1	56.4	22.9	16.2	0.45	2.46	0.41	0.71	1.16
			19.5	34.0	21.5	13.3	0.49	1.58	0.63	0.62	0.93
			22.9	41.8	26.0	11.0	0.33	1.61	0.62	0.42	0.98
			17.9	28.8	26.9	15.1	0.54	1.07	0.93	0.56	0.90
		1/2"	13.5	28.4	18.8	17.5	0.76	1.51	0.66	0.93	0.82
			15.2	29.1	17.7	17.0	0.75	1.64	0.61	0.96	0.85
			12.0	32.2	16.0	12.0	0.53	2.01	0.50	0.75	0.79
			18.5	32.8	18.1	16.5	0.68	1.81	0.55	0.91	0.91
			7.2	24.7	17.8	9.5	0.45	1.39	0.72	0.53	0.67
			5.9	22.2	16.0	11.0	0.58	1.39	0.72	0.69	0.62
			7.8	26.4	18.4	8.5	0.39	1.43	0.70	0.46	0.68
			7.8	25.1	15.1	12.0	0.62	1.66	0.60	0.79	0.68
			7.9	23.2	20.8	12.5	0.57	1.12	0.90	0.60	0.69
			6.6	21.4	13.7	11.8	0.69	1.56	0.64	0.86	0.65
		3/8"	3.0	19.2	10.5	9.3	0.65	1.83	0.55	0.89	0.50

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			4.0	20.7	11.2	9.5	0.62	1.85	0.54	0.85	0.55
			2.6	18.4	10.2	6.2	0.45	1.80	0.55	0.61	0.47
			2.5	13.4	12.4	9.2	0.71	1.08	0.93	0.74	0.47
			3.6	23.3	11.0	4.7	0.29	2.12	0.47	0.43	0.53
			2.5	19.2	9.3	8.9	0.67	2.06	0.48	0.96	0.47
			1.6	13.2	9.7	5.9	0.52	1.36	0.73	0.61	0.40
			2.1	24.8	8.8	4.5	0.30	2.82	0.35	0.51	0.44
			2.1	18.8	11.2	4.9	0.34	1.68	0.60	0.44	0.44
			2.1	17.6	10.4	5.3	0.39	1.69	0.59	0.51	0.44
89–43	27.93	1 1/2″	118.1	69.3	43.4	28.2	0.51	1.60	0.63	0.65	1.69
			122.3	67.8	42.0	25.6	0.48	1.61	0.62	0.61	1.71
		1″	71.5	70.0	41.8	23.9	0.44	1.67	0.60	0.57	1.43
			72.2	56.9	31.5	30.2	0.71	1.81	0.55	0.96	1.43
			36.3	36.4	27.4	25.7	0.81	1.33	0.75	0.94	1.14
			64.9	51.0	35.5	23.5	0.55	1.44	0.70	0.66	1.38
			27.7	35.2	25.4	20.4	0.68	1.39	0.72	0.80	1.04
			38.4	41.0	33.4	25.2	0.68	1.23	0.81	0.75	1.16
			22.5	37.8	27.3	16.8	0.52	1.38	0.72	0.62	0.97
			34.9	45.9	31.5	15.5	0.41	1.46	0.69	0.49	1.13
		3/4″	39.1	48.1	28.3	19.7	0.53	1.70	0.59	0.70	1.17
			14.7	32.9	22.3	9.7	0.36	1.48	0.68	0.43	0.84
			11.9	25.3	22.0	13.1	0.56	1.15	0.87	0.60	0.79
			16.2	30.5	23.8	15.9	0.59	1.28	0.78	0.67	0.87
			27.6	42.2	25.8	18.0	0.55	1.64	0.61	0.70	1.04
			18.1	37.0	20.4	15.6	0.57	1.81	0.55	0.76	0.90
			16.5	24.0	21.7	19.2	0.84	1.11	0.90	0.88	0.88
			18.7	35.5	20.1	15.0	0.56	1.77	0.57	0.75	0.91
		1/2″	18.8	41.4	19.5	11.6	0.41	2.12	0.47	0.59	0.92
			6.7	21.2	15.7	13.9	0.76	1.35	0.74	0.89	0.65
			8.1	26.0	20.3	13.0	0.57	1.28	0.78	0.64	0.69
			9.6	27.2	18.1	15.0	0.68	1.50	0.67	0.83	0.73
			4.5	17.2	14.9	11.7	0.73	1.15	0.87	0.79	0.57
			3.3	20.5	15.3	5.0	0.28	1.34	0.75	0.33	0.51
			10.3	28.2	21.5	10.9	0.44	1.31	0.76	0.51	0.75
			5.3	20.5	17.9	8.6	0.45	1.15	0.87	0.48	0.60
		3/8″	3.2	20.0	12.9	8.8	0.55	1.55	0.65	0.68	0.51
			2.3	18.5	11.6	6.0	0.41	1.59	0.63	0.52	0.45
			1.4	12.1	8.9	7.9	0.76	1.36	0.74	0.89	0.39
			1.9	16.5	10.8	7.0	0.52	1.53	0.65	0.65	0.43
			2.3	20.3	14.0	5.5	0.33	1.45	0.69	0.39	0.45
			1.6	15.9	11.6	7.0	0.52	1.37	0.73	0.60	0.40
			1.3	14.5	10.1	8.6	0.71	1.44	0.70	0.85	0.38

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			1.7	12.9	10.6	8.0	0.68	1.22	0.82	0.75	0.41
			2.2	14.0	10.2	8.8	0.74	1.37	0.73	0.86	0.45
			2.3	16.0	11.4	5.7	0.42	1.40	0.71	0.50	0.45
89–44	26.35	1″	60.2	48.8	32.4	25.7	0.65	1.51	0.66	0.79	1.35
			51.5	63.0	32.5	22.7	0.50	1.94	0.52	0.70	1.28
			42.4	46.7	31.2	21.2	0.56	1.50	0.67	0.68	1.20
		3/4″	19.6	30.5	25.8	15.1	0.54	1.18	0.85	0.59	0.93
			21.9	28.5	24.4	19.4	0.74	1.17	0.86	0.80	0.96
			14.0	35.1	23.7	12.4	0.43	1.48	0.68	0.52	0.83
			12.0	31.7	17.2	16.5	0.71	1.84	0.54	0.96	0.79
			10.5	28.5	19.1	10.1	0.43	1.49	0.67	0.53	0.75
			9.2	31.5	22.7	11.8	0.44	1.39	0.72	0.52	0.72
			11.8	32.2	22.6	11.3	0.42	1.42	0.70	0.50	0.78
			7.6	26.6	19.4	16.4	0.72	1.37	0.73	0.85	0.68
		1/2″	12.7	38.3	21.7	10.5	0.36	1.76	0.57	0.48	0.80
			5.3	23.6	15.2	9.5	0.50	1.55	0.64	0.63	0.60
			6.3	25.5	19.5	8.8	0.39	1.31	0.76	0.45	0.64
			5.8	24.0	16.1	10.8	0.55	1.49	0.67	0.67	0.62
			9.1	25.2	18.5	14.5	0.67	1.36	0.73	0.78	0.72
			6.2	26.2	19.7	14.0	0.62	1.33	0.75	0.71	0.63
			4.3	23.1	16.6	9.5	0.49	1.39	0.72	0.57	0.56
			7.0	25.1	16.1	14.0	0.70	1.56	0.64	0.87	0.66
		3/8″	4.8	24.7	13.3	9.7	0.54	1.86	0.54	0.73	0.58
			3.8	23.5	15.1	7.1	0.38	1.56	0.64	0.47	0.54
			3.5	22.5	17.1	9.0	0.46	1.32	0.76	0.53	0.52
			2.9	16.5	15.0	10.9	0.69	1.10	0.91	0.73	0.49
			2.7	20.6	14.5	7.5	0.43	1.42	0.70	0.52	0.48
			1.5	12.1	9.7	8.0	0.74	1.25	0.80	0.82	0.39
			2.1	17.2	13.6	8.1	0.53	1.26	0.79	0.60	0.44
			5.2	25.6	13.9	10.8	0.57	1.84	0.54	0.78	0.60
89–45	24.26	1″	74.2	52.0	32.2	28.0	0.68	1.61	0.62	0.87	1.45
		3/4″	14.6	33.0	24.0	11.1	0.39	1.38	0.73	0.46	0.84
			10.0	25.9	21.0	17.5	0.75	1.23	0.81	0.83	0.74
			6.9	30.8	23.9	11.0	0.41	1.29	0.78	0.46	0.66
			7.4	21.1	15.0	14.0	0.79	1.41	0.71	0.93	0.67
			14.0	36.3	26.7	9.7	0.31	1.36	0.74	0.36	0.83
			13.9	30.0	24.0	13.7	0.51	1.25	0.80	0.57	0.83
			10.3	28.4	22.2	13.8	0.55	1.28	0.78	0.62	0.75
			11.3	27.4	19.0	17.4	0.76	1.44	0.69	0.92	0.77
		1/2″	5.8	19.5	14.6	13.7	0.81	1.34	0.75	0.94	0.62
			11.0	25.0	18.2	17.6	0.83	1.37	0.73	0.97	0.77
			7.2	24.8	22.4	11.4	0.48	1.11	0.90	0.51	0.67

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm			Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
				Longest a	Intermed b	Shortest c					
			4.7	23.4	17.6	12.1	0.60	1.33	0.75	0.69	0.58
			3.5	19.3	16.2	8.0	0.45	1.19	0.84	0.49	0.52
			3.6	19.0	16.1	11.0	0.63	1.18	0.85	0.68	0.53
			6.9	23.1	17.5	15.3	0.76	1.32	0.76	0.87	0.66
			12.0	43.7	15.8	12.0	0.46	2.77	0.36	0.76	0.79
		3/8″	3.8	18.6	12.3	10.7	0.71	1.51	0.66	0.87	0.54
			3.2	19.0	13.5	8.5	0.53	1.41	0.71	0.63	0.51
			2.7	17.8	12.5	10.5	0.70	1.42	0.70	0.84	0.48
			1.9	16.3	12.0	8.9	0.64	1.36	0.74	0.74	0.43
			1.5	14.6	11.8	7.0	0.53	1.24	0.81	0.59	0.39
			2.7	18.9	11.9	9.0	0.60	1.59	0.63	0.76	0.48
			2.4	15.8	13.3	11.1	0.77	1.19	0.84	0.83	0.46
			1.2	15.1	11.0	6.0	0.47	1.37	0.73	0.55	0.37
89–46	21.54	1″	32.3	56.7	30.5	12.4	0.30	1.86	0.54	0.41	1.10
		3/4″	19.3	30.0	23.5	20.1	0.76	1.28	0.78	0.86	0.92
			15.5	24.8	19.3	19.2	0.88	1.28	0.78	0.99	0.86
			9.3	25.7	23.8	11.2	0.45	1.08	0.93	0.47	0.72
			16.6	36.8	17.8	16.0	0.63	2.07	0.48	0.90	0.88
			15.2	27.9	19.6	13.3	0.57	1.42	0.70	0.68	0.85
			9.1	26.4	19.1	14.0	0.62	1.38	0.72	0.73	0.72
			19.2	32.0	28.1	16.6	0.55	1.14	0.88	0.59	0.92
			8.5	33.2	22.7	8.0	0.29	1.46	0.68	0.35	0.70
		1/2″	5.2	20.7	16.6	11.2	0.60	1.25	0.80	0.67	0.60
			5.1	18.1	14.0	10.8	0.68	1.29	0.77	0.77	0.59
			13.7	33.4	20.0	12.0	0.46	1.67	0.60	0.60	0.82
			8.2	22.0	18.5	13.5	0.67	1.19	0.84	0.73	0.69
			9.4	27.7	14.6	14.0	0.70	1.90	0.53	0.96	0.73
			3.6	21.1	14.8	11.2	0.63	1.43	0.70	0.76	0.53
			5.6	22.4	15.1	8.9	0.48	1.48	0.67	0.59	0.61
			5.0	20.5	13.8	12.0	0.71	1.49	0.67	0.87	0.59
		3/8″	2.8	16.2	11.5	9.0	0.66	1.41	0.71	0.78	0.49
			2.6	16.8	10.7	10.4	0.78	1.57	0.64	0.97	0.47
			5.0	21.8	12.0	8.3	0.51	1.82	0.55	0.69	0.59
			2.1	16.2	10.5	8.0	0.61	1.54	0.65	0.76	0.44
			3.2	19.1	11.4	9.7	0.66	1.68	0.60	0.85	0.51
			2.0	12.9	10.6	9.0	0.77	1.22	0.82	0.85	0.43
			2.3	17.8	10.5	6.7	0.49	1.70	0.59	0.64	0.45
			2.4	20.4	14.0	5.9	0.35	1.46	0.69	0.42	0.46
89–47	13.19	1″	33.3	48.8	35.4	12.0	0.29	1.38	0.73	0.34	1.11
		3/4″	22.7	37.0	26.3	17.3	0.55	1.41	0.71	0.66	0.98
			10.7	36.9	20.5	12.2	0.44	1.80	0.56	0.60	0.76
			11.8	31.8	25.2	12.1	0.43	1.26	0.79	0.48	0.78

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			11.8	23.2	21.0	16.9	0.77	1.10	0.91	0.80	0.78
			17.0	37.5	32.0	15.9	0.46	1.17	0.85	0.50	0.89
			22.8	41.4	25.9	14.0	0.43	1.60	0.63	0.54	0.98
			16.6	31.4	19.7	15.2	0.61	1.59	0.63	0.77	0.88
		1/2"	7.9	24.0	15.7	13.3	0.69	1.53	0.65	0.85	0.69
			5.6	21.8	15.1	13.5	0.74	1.44	0.69	0.89	0.61
			4.4	23.3	16.4	10.2	0.52	1.42	0.70	0.62	0.56
			12.5	34.4	18.2	13.3	0.53	1.89	0.53	0.73	0.80
			6.4	29.7	12.4	10.4	0.54	2.40	0.42	0.84	0.64
			4.3	20.3	17.4	12.6	0.67	1.17	0.86	0.72	0.56
			4.5	23.7	15.7	10.6	0.55	1.51	0.66	0.68	0.57
			5.4	19.9	16.7	15.1	0.83	1.19	0.84	0.90	0.60
		3/8"	2.5	20.0	16.1	9.5	0.53	1.24	0.81	0.59	0.47
			2.7	20.7	13.7	6.6	0.39	1.51	0.66	0.48	0.48
			2.4	13.5	12.4	10.0	0.77	1.09	0.92	0.81	0.46
			2.3	19.7	11.0	7.0	0.48	1.79	0.56	0.64	0.45
			1.7	16.0	10.6	7.6	0.58	1.51	0.66	0.72	0.41
			1.6	15.9	13.2	7.8	0.54	1.20	0.83	0.59	0.40
			1.5	14.0	10.4	6.2	0.51	1.35	0.74	0.60	0.39
			1.2	11.8	11.4	5.2	0.45	1.04	0.97	0.46	0.37
89–48	9.90	1 1/2"	108.1	55.3	48.0	33.6	0.65	1.15	0.87	0.70	1.64
		1"	58.0	50.2	35.8	28.5	0.67	1.40	0.71	0.80	1.33
			61.8	61.4	29.6	24.1	0.57	2.07	0.48	0.81	1.36
			27.2	43.6	29.6	17.4	0.48	1.47	0.68	0.59	1.04
			26.6	30.2	27.6	21.5	0.74	1.09	0.91	0.78	1.03
			32.2	38.8	34.3	17.5	0.48	1.13	0.88	0.51	1.10
			22.0	38.3	29.8	11.8	0.35	1.29	0.78	0.40	0.97
		3/4"	23.8	37.7	24.8	17.2	0.56	1.52	0.66	0.69	0.99
			17.1	31.3	28.2	16.3	0.55	1.11	0.90	0.58	0.89
			18.8	31.8	20.5	17.6	0.69	1.55	0.64	0.86	0.92
			27.8	51.3	29.0	13.0	0.34	1.77	0.57	0.45	1.04
			21.7	35.0	30.8	13.5	0.41	1.14	0.88	0.44	0.96
			14.5	33.2	21.5	14.8	0.55	1.54	0.65	0.69	0.84
			14.3	34.3	22.9	12.3	0.44	1.50	0.67	0.54	0.84
			7.4	23.0	18.0	12.6	0.62	1.28	0.78	0.70	0.67
		1/2"	4.9	25.6	23.0	5.3	0.22	1.11	0.90	0.23	0.59
			12.0	30.5	17.3	14.2	0.62	1.76	0.57	0.82	0.79
			7.2	25.1	16.0	15.8	0.79	1.57	0.64	0.99	0.67
			4.9	25.0	16.0	9.6	0.48	1.56	0.64	0.60	0.59
			4.0	20.0	17.8	11.8	0.63	1.12	0.89	0.66	0.55
			5.6	27.2	18.1	9.8	0.44	1.50	0.67	0.54	0.61
			5.4	20.0	15.8	13.7	0.77	1.27	0.79	0.87	0.60

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			5.0	19.2	15.6	13.0	0.75	1.23	0.81	0.83	0.59
		3/8″	4.8	25.9	14.0	11.0	0.58	1.85	0.54	0.79	0.58
			4.4	22.6	14.9	9.2	0.50	1.52	0.66	0.62	0.56
			4.0	19.7	16.2	11.1	0.62	1.22	0.82	0.69	0.55
			2.6	21.8	12.0	9.0	0.56	1.82	0.55	0.75	0.47
			2.6	16.4	13.9	10.5	0.70	1.18	0.85	0.76	0.47
			2.4	17.5	16.8	6.8	0.40	1.04	0.96	0.40	0.46
			2.3	18.0	12.0	7.9	0.54	1.50	0.67	0.66	0.45
			2.1	16.1	11.5	7.8	0.57	1.40	0.71	0.68	0.44
89–49	15.38	1″	53.7	49.3	35.4	26.9	0.64	1.39	0.72	0.76	1.30
			33.2	44.0	32.4	18.7	0.50	1.36	0.74	0.58	1.11
			29.8	39.8	28.1	22.9	0.68	1.42	0.71	0.81	1.07
		3/4″	38.2	56.8	24.6	17.8	0.48	2.31	0.43	0.72	1.16
			11.2	36.2	28.0	7.5	0.24	1.29	0.77	0.27	0.77
			18.2	31.4	25.8	13.6	0.48	1.22	0.82	0.53	0.91
			14.1	41.0	21.2	10.9	0.37	1.93	0.52	0.51	0.83
			24.3	38.3	30.8	14.2	0.41	1.24	0.80	0.46	1.00
			7.6	27.0	23.8	7.0	0.28	1.13	0.88	0.29	0.68
			19.4	43.3	22.7	19.2	0.61	1.91	0.52	0.85	0.93
			14.1	31.6	25.4	13.0	0.46	1.24	0.80	0.51	0.83
		1/2″	9.8	27.6	18.8	11.7	0.51	1.47	0.68	0.62	0.74
			10.3	30.8	17.2	11.7	0.51	1.79	0.56	0.68	0.75
			4.1	20.7	16.5	8.7	0.47	1.25	0.80	0.53	0.55
			4.7	20.3	16.9	10.2	0.55	1.20	0.83	0.60	0.58
			5.5	25.0	18.2	8.7	0.41	1.37	0.73	0.48	0.61
			9.2	30.7	20.3	12.2	0.49	1.51	0.66	0.60	0.72
			4.5	19.7	18.1	12.5	0.66	1.09	0.92	0.69	0.57
			3.4	21.0	15.2	7.1	0.40	1.38	0.72	0.47	0.52
		3/8″	2.2	20.8	13.8	7.3	0.43	1.51	0.66	0.53	0.45
			2.6	15.8	14.4	10.7	0.71	1.10	0.91	0.74	0.47
			3.3	20.8	14.7	7.2	0.41	1.41	0.71	0.49	0.51
			3.2	21.8	13.4	6.0	0.35	1.63	0.61	0.45	0.51
			4.0	22.3	15.5	10.7	0.58	1.44	0.70	0.69	0.55
			3.2	27.2	10.7	8.3	0.49	2.54	0.39	0.78	0.51
			2.7	22.1	14.7	8.0	0.44	1.50	0.67	0.54	0.48
			3.2	18.8	11.2	8.5	0.59	1.68	0.60	0.76	0.51
89–50	30.19	1 1/2″	129.8	59.4	49.0	37.0	0.69	1.21	0.82	0.76	1.74
			131.5	66.1	44.5	25.8	0.48	1.49	0.67	0.58	1.75
			124.9	52.3	44.3	38.4	0.80	1.18	0.85	0.87	1.72
		1″	31.7	43.0	34.5	22.5	0.58	1.25	0.80	0.65	1.09
			31.5	37.5	29.6	19.2	0.58	1.27	0.79	0.65	1.09
			35.4	43.7	31.0	19.9	0.54	1.41	0.71	0.64	1.13

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			60.5	73.8	30.0	14.2	0.30	2.46	0.41	0.47	1.35
			53.1	50.5	27.0	24.0	0.65	1.87	0.53	0.89	1.30
			39.4	42.4	36.8	16.4	0.42	1.15	0.87	0.45	1.17
			53.6	55.9	29.3	18.2	0.45	1.91	0.52	0.62	1.30
			37.1	41.1	31.0	18.8	0.53	1.33	0.75	0.61	1.15
		3/4"	48.4	50.8	26.4	18.6	0.51	1.92	0.52	0.70	1.26
			35.5	42.8	23.8	21.7	0.68	1.80	0.56	0.91	1.13
			20.0	29.8	24.0	19.3	0.72	1.24	0.81	0.80	0.94
			26.3	40.0	27.3	18.2	0.55	1.47	0.68	0.67	1.02
			30.1	35.9	23.6	18.8	0.65	1.52	0.66	0.80	1.07
			26.2	37.7	23.9	19.4	0.65	1.58	0.63	0.81	1.02
			15.2	30.4	26.7	9.1	0.32	1.14	0.88	0.34	0.85
			12.9	27.0	20.5	14.9	0.63	1.32	0.76	0.73	0.81
		1/2"	9.7	25.5	18.7	13.8	0.63	1.36	0.73	0.74	0.73
			7.4	27.7	14.5	14.0	0.70	1.91	0.52	0.97	0.67
			7.8	26.2	20.6	9.6	0.41	1.27	0.79	0.47	0.68
			10.2	24.1	21.1	13.5	0.60	1.14	0.88	0.64	0.75
			8.7	29.4	15.3	12.2	0.58	1.92	0.52	0.80	0.71
			6.4	24.2	17.3	12.4	0.61	1.40	0.71	0.72	0.64
			7.8	22.7	22.0	13.5	0.60	1.03	0.97	0.61	0.68
			7.9	28.3	19.9	9.0	0.38	1.42	0.70	0.45	0.69
		3/8"	3.4	20.2	11.8	9.6	0.62	1.71	0.58	0.81	0.52
			2.4	12.7	10.0	9.0	0.80	1.27	0.79	0.90	0.46
			1.9	15.9	12.6	8.5	0.60	1.26	0.79	0.67	0.43
			2.3	15.9	10.0	9.1	0.72	1.59	0.63	0.91	0.45
			2.4	15.6	7.5	7.1	0.66	2.08	0.48	0.95	0.46
			2.1	12.4	10.8	7.5	0.65	1.15	0.87	0.69	0.44
			2.9	19.4	11.8	8.2	0.54	1.64	0.61	0.69	0.49
			1.6	13.2	9.5	5.8	0.52	1.39	0.72	0.61	0.40
89–51	33.06	1"	58.6	48.0	34.9	23.3	0.57	1.38	0.73	0.67	1.34
			46.0	36.5	29.1	26.7	0.82	1.25	0.80	0.92	1.23
			23.8	50.8	33.9	9.4	0.23	1.50	0.67	0.28	0.99
			28.1	40.5	25.7	21.0	0.65	1.58	0.63	0.82	1.05
		3/4"	23.2	33.3	31.2	19.3	0.60	1.07	0.94	0.62	0.98
			14.0	26.4	22.0	17.8	0.74	1.20	0.83	0.81	0.83
			19.3	31.8	25.9	20.1	0.70	1.23	0.81	0.78	0.92
			15.3	35.4	29.9	9.4	0.29	1.18	0.84	0.31	0.86
			14.5	30.3	26.6	10.5	0.37	1.14	0.88	0.39	0.84
			14.4	30.3	18.8	18.4	0.77	1.61	0.62	0.98	0.84
			12.7	27.5	21.8	14.0	0.57	1.26	0.79	0.64	0.80
			9.3	24.1	19.3	13.2	0.61	1.25	0.80	0.68	0.72
		1/2"	8.5	22.4	20.2	16.7	0.79	1.11	0.90	0.83	0.70

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			4.5	20.7	15.8	13.0	0.72	1.31	0.76	0.82	0.57
			11.1	34.5	18.0	11.4	0.46	1.92	0.52	0.63	0.77
			8.1	32.0	19.8	15.5	0.62	1.62	0.62	0.78	0.69
			5.2	25.4	17.9	8.8	0.41	1.42	0.70	0.49	0.60
			6.8	27.3	17.0	13.4	0.62	1.61	0.62	0.79	0.65
			5.6	21.4	17.8	12.4	0.64	1.20	0.83	0.70	0.61
			6.5	28.0	18.3	12.3	0.54	1.53	0.65	0.67	0.64
		3/8″	3.5	19.2	13.2	10.9	0.68	1.45	0.69	0.83	0.52
			2.7	15.3	14.3	13.0	0.88	1.07	0.93	0.91	0.48
			3.2	20.8	11.3	9.4	0.61	1.84	0.54	0.83	0.51
			3.7	18.3	17.0	10.9	0.62	1.08	0.93	0.64	0.53
			3.5	18.6	16.4	9.3	0.53	1.13	0.88	0.57	0.52
			4.4	25.7	11.4	8.4	0.49	2.25	0.44	0.74	0.56
			3.2	23.0	13.5	5.8	0.33	1.70	0.59	0.43	0.51
			2.0	16.7	14.8	5.7	0.36	1.13	0.89	0.39	0.43
89-52	31.14	2″	384.0	82.4	60.0	47.8	0.68	1.37	0.73	0.80	2.50
		1″	37.7	42.0	29.4	21.0	0.60	1.43	0.70	0.71	1.16
			31.6	46.9	34.8	13.3	0.33	1.35	0.74	0.38	1.09
			57.7	43.3	35.1	26.5	0.68	1.23	0.81	0.75	1.33
			64.1	39.8	29.9	28.8	0.83	1.33	0.75	0.96	1.38
			83.5	53.2	34.5	28.0	0.65	1.54	0.65	0.81	1.51
			61.8	62.7	36.4	18.7	0.39	1.72	0.58	0.51	1.36
			43.6	37.6	32.5	21.8	0.62	1.16	0.86	0.67	1.21
			33.9	38.4	28.6	20.0	0.60	1.34	0.74	0.70	1.12
		3/4″	24.5	37.0	24.2	14.5	0.48	1.53	0.65	0.60	1.00
			13.3	30.4	18.3	16.2	0.69	1.66	0.60	0.89	0.82
			14.9	37.0	26.5	11.0	0.35	1.40	0.72	0.42	0.85
			21.5	34.5	29.5	15.0	0.47	1.17	0.86	0.51	0.96
			22.9	35.2	29.8	17.4	0.54	1.18	0.85	0.58	0.98
			20.9	38.6	23.8	15.5	0.51	1.62	0.62	0.65	0.95
			16.2	30.7	20.7	16.8	0.67	1.48	0.67	0.81	0.87
			15.4	32.7	21.6	17.5	0.66	1.51	0.66	0.81	0.86
		1/2″	11.4	32.8	17.4	13.9	0.58	1.89	0.53	0.80	0.78
			6.3	28.2	17.6	10.5	0.47	1.60	0.62	0.60	0.64
			3.7	20.7	17.0	8.7	0.46	1.22	0.82	0.51	0.53
			9.0	22.4	16.6	13.4	0.69	1.35	0.74	0.81	0.72
			11.5	30.5	18.0	14.3	0.61	1.69	0.59	0.79	0.78
			6.9	22.5	16.8	14.3	0.74	1.34	0.75	0.85	0.66
			5.3	17.2	15.2	12.3	0.76	1.13	0.88	0.81	0.60
			3.0	21.2	16.2	4.9	0.26	1.31	0.76	0.30	0.50
		3/8″	5.5	21.5	12.2	10.4	0.64	1.76	0.57	0.85	0.61
			4.6	27.4	12.9	10.8	0.57	2.12	0.47	0.84	0.57

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			1.5	14.4	10.6	6.3	0.51	1.36	0.74	0.59	0.39
			2.2	17.5	13.2	7.0	0.46	1.33	0.75	0.53	0.45
			1.8	18.6	11.2	6.4	0.44	1.66	0.60	0.57	0.42
			2.6	14.8	12.3	7.9	0.59	1.20	0.83	0.64	0.47
			2.2	16.7	9.3	8.5	0.68	1.80	0.56	0.91	0.45
			1.3	16.3	11.3	3.8	0.28	1.44	0.69	0.34	0.38
89–53	30.44	2″	394.6	96.4	52.0	46.7	0.66	1.85	0.54	0.90	2.53
			255.1	70.8	60.7	36.0	0.55	1.17	0.86	0.59	2.19
		1 1/2″	235.3	78.5	48.7	30.8	0.50	1.61	0.62	0.63	2.13
			123.3	63.5	36.1	34.7	0.72	1.76	0.57	0.96	1.72
			60.8	53.5	45.0	14.9	0.30	1.19	0.84	0.33	1.35
			121.3	60.8	44.3	30.3	0.58	1.37	0.73	0.68	1.71
			85.9	51.7	41.7	35.0	0.75	1.24	0.81	0.84	1.52
			69.2	45.3	42.8	19.3	0.44	1.06	0.94	0.45	1.41
			104.6	56.7	41.4	30.7	0.63	1.37	0.73	0.74	1.62
			119.2	55.7	37.6	29.1	0.64	1.48	0.68	0.77	1.70
		1″	89.2	45.0	37.4	26.5	0.65	1.20	0.83	0.71	1.54
			43.3	44.8	34.7	21.8	0.55	1.29	0.77	0.63	1.21
			73.9	60.5	30.2	23.5	0.55	2.00	0.50	0.78	1.45
			57.7	55.6	28.8	25.0	0.62	1.93	0.52	0.87	1.33
			69.3	44.9	35.2	27.1	0.68	1.28	0.78	0.77	1.42
			68.9	60.8	31.4	20.0	0.46	1.94	0.52	0.64	1.41
			63.7	36.8	35.0	30.3	0.84	1.05	0.95	0.87	1.38
			30.3	36.9	25.4	21.0	0.69	1.45	0.69	0.83	1.07
		3/4″	44.5	62.5	24.4	17.3	0.44	2.56	0.39	0.71	1.22
			25.8	43.8	23.6	18.2	0.57	1.86	0.54	0.77	1.02
			38.5	57.9	20.4	16.7	0.49	2.84	0.35	0.82	1.16
			33.5	38.4	24.9	22.8	0.74	1.54	0.65	0.92	1.11
			19.3	33.5	25.7	18.4	0.63	1.30	0.77	0.72	0.92
			15.7	30.5	17.7	16.2	0.70	1.72	0.58	0.92	0.86
			13.4	25.2	20.6	19.3	0.85	1.22	0.82	0.94	0.82
			14.1	32.0	20.8	16.0	0.62	1.54	0.65	0.77	0.83
		1/2″	10.1	27.3	18.9	15.2	0.67	1.44	0.69	0.80	0.74
			10.4	23.6	18.6	15.5	0.74	1.27	0.79	0.83	0.75
			4.7	17.9	16.4	11.1	0.65	1.09	0.92	0.68	0.58
			8.8	26.4	16.8	13.9	0.66	1.57	0.64	0.83	0.71
			6.4	25.9	21.3	9.0	0.38	1.22	0.82	0.42	0.64
			7.4	24.8	16.2	10.5	0.52	1.53	0.65	0.65	0.67
			12.6	33.3	22.3	14.2	0.52	1.49	0.67	0.64	0.80
			7.8	22.0	20.3	14.7	0.70	1.08	0.92	0.72	0.68
			5.7	25.0	17.0	10.4	0.50	1.47	0.68	0.61	0.62
			7.1	21.7	18.2	16.1	0.81	1.19	0.84	0.88	0.66

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
		3/8"	2.5	18.8	14.4	8.0	0.49	1.31	0.77	0.56	0.47
			5.4	33.5	12.3	11.5	0.57	2.72	0.37	0.93	0.60
			3.7	19.3	11.8	9.7	0.64	1.64	0.61	0.82	0.53
			2.4	17.6	12.3	11.6	0.79	1.43	0.70	0.94	0.46
			2.9	17.2	13.0	9.9	0.66	1.32	0.76	0.76	0.49
			3.4	22.3	13.8	7.4	0.42	1.62	0.62	0.54	0.52
			3.3	21.0	12.2	10.1	0.63	1.72	0.58	0.83	0.51
			2.3	16.3	13.0	9.3	0.64	1.25	0.80	0.72	0.45
			2.9	17.3	10.2	9.4	0.71	1.70	0.59	0.92	0.49
			2.5	19.0	11.0	10.3	0.71	1.73	0.58	0.94	0.47
89–54	15.23	1"	66.0	61.8	36.2	17.2	0.36	1.71	0.59	0.48	1.39
			72.2	52.7	32.0	31.3	0.76	1.65	0.61	0.98	1.43
			75.0	57.9	31.4	26.3	0.62	1.84	0.54	0.84	1.45
			37.8	36.8	26.7	25.4	0.81	1.38	0.73	0.95	1.16
		3/4"	25.0	37.4	32.0	18.0	0.52	1.17	0.86	0.56	1.01
			20.7	33.3	21.5	18.5	0.69	1.55	0.65	0.86	0.95
			18.3	28.5	27.4	18.6	0.67	1.04	0.96	0.68	0.91
			14.0	30.3	24.4	15.7	0.58	1.24	0.81	0.64	0.83
			14.3	34.6	28.6	10.5	0.33	1.21	0.83	0.37	0.84
			21.2	27.0	25.5	22.0	0.84	1.06	0.94	0.86	0.95
			13.9	228.6	26.0	15.2	0.20	8.79	0.11	0.58	0.83
			11.4	31.2	22.5	13.0	0.49	1.39	0.72	0.58	0.78
		1/2"	11.7	36.0	16.6	14.9	0.61	2.17	0.46	0.90	0.78
			7.5	23.0	18.3	18.0	0.88	1.26	0.80	0.98	0.67
			6.0	20.9	15.8	13.7	0.75	1.32	0.76	0.87	0.63
			6.6	21.8	15.7	12.4	0.67	1.39	0.72	0.79	0.65
			2.6	20.4	16.0	9.4	0.52	1.28	0.78	0.59	0.47
			6.6	24.7	16.6	11.7	0.58	1.49	0.67	0.70	0.65
			8.0	28.1	17.8	14.2	0.63	1.58	0.63	0.80	0.69
			7.2	29.1	20.0	9.6	0.40	1.46	0.69	0.48	0.67
		3/8"	4.7	25.1	15.8	9.3	0.47	1.59	0.63	0.59	0.58
			2.5	17.0	13.1	10.1	0.68	1.30	0.77	0.77	0.47
			3.1	16.9	13.3	9.5	0.63	1.27	0.79	0.71	0.50
			1.7	18.1	11.9	7.6	0.52	1.52	0.66	0.64	0.41
			1.4	15.5	12.0	7.7	0.56	1.29	0.77	0.64	0.39
			3.4	17.7	13.1	10.8	0.71	1.35	0.74	0.82	0.52
			1.6	13.8	12.7	10.2	0.77	1.09	0.92	0.80	0.40
			1.4	14.0	13.4	7.0	0.51	1.04	0.96	0.52	0.39
89–55	15.33	1"	44.6	46.4	40.0	18.2	0.42	1.16	0.86	0.45	1.22
		3/4"	52.0	63.5	30.1	22.7	0.52	2.11	0.47	0.75	1.29
			20.4	36.4	18.5	17.0	0.66	1.97	0.51	0.92	0.94
			22.0	35.3	23.6	12.8	0.44	1.50	0.67	0.54	0.97

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			24.8	35.8	20.7	20.0	0.73	1.73	0.58	0.97	1.00
			6.4	25.2	22.3	9.0	0.38	1.13	0.88	0.40	0.64
			10.7	36.8	27.0	11.5	0.36	1.36	0.73	0.43	0.76
			7.5	27.8	20.6	7.7	0.32	1.35	0.74	0.37	0.67
			7.0	24.0	17.7	10.1	0.49	1.36	0.74	0.57	0.66
		1/2"	20.2	41.5	23.4	15.7	0.50	1.77	0.56	0.67	0.94
			8.0	43.1	15.0	9.4	0.37	2.87	0.35	0.63	0.69
			10.8	28.4	21.3	15.2	0.62	1.33	0.75	0.71	0.76
			4.9	23.0	14.0	11.2	0.62	1.64	0.61	0.80	0.59
			6.0	23.3	17.2	13.2	0.66	1.35	0.74	0.77	0.63
			6.1	27.0	22.4	10.2	0.41	1.21	0.83	0.46	0.63
			6.7	22.8	17.4	15.3	0.77	1.31	0.76	0.88	0.65
			3.9	21.6	19.4	9.3	0.45	1.11	0.90	0.48	0.54
		3/8"	5.1	23.6	11.4	11.0	0.67	2.07	0.48	0.96	0.59
			4.5	19.9	13.9	12.4	0.75	1.43	0.70	0.89	0.57
			3.3	16.8	10.9	9.7	0.72	1.54	0.65	0.89	0.51
			2.3	15.0	12.2	10.2	0.75	1.23	0.81	0.84	0.45
			2.2	14.9	12.8	8.8	0.64	1.16	0.86	0.69	0.45
			1.2	17.1	13.0	4.6	0.31	1.32	0.76	0.35	0.37
			2.6	15.4	13.4	9.8	0.68	1.15	0.87	0.73	0.47
			1.7	14.0	12.5	9.5	0.72	1.12	0.89	0.76	0.41
89–56	25.00	1 1/2"	99.0	55.5	47.0	25.8	0.51	1.18	0.85	0.55	1.59
		1"	56.2	62.0	32.4	15.0	0.33	1.91	0.52	0.46	1.32
			50.9	44.9	36.8	27.1	0.67	1.22	0.82	0.74	1.28
			73.0	48.4	40.6	33.8	0.76	1.19	0.84	0.83	1.44
			75.0	47.2	32.5	25.7	0.66	1.45	0.69	0.79	1.45
			77.9	48.6	34.1	28.2	0.69	1.43	0.70	0.83	1.47
			43.1	35.2	29.3	24.5	0.76	1.20	0.83	0.84	1.21
			26.3	33.4	26.7	17.7	0.59	1.25	0.80	0.66	1.02
			29.4	45.2	40.8	13.0	0.30	1.11	0.90	0.32	1.06
			38.3	39.9	28.4	26.0	0.77	1.40	0.71	0.92	1.16
		3/4"	24.0	31.0	23.3	19.0	0.71	1.33	0.75	0.82	0.99
			25.5	36.0	24.0	19.3	0.66	1.50	0.67	0.80	1.01
			17.6	36.4	16.7	16.4	0.67	2.18	0.46	0.98	0.90
			31.1	44.1	27.7	20.7	0.59	1.59	0.63	0.75	1.08
			14.8	33.6	21.4	10.4	0.39	1.57	0.64	0.49	0.85
			27.7	39.7	33.0	20.0	0.55	1.20	0.83	0.61	1.04
			11.3	24.3	20.2	17.9	0.81	1.20	0.83	0.89	0.77
			16.0	34.3	21.2	16.3	0.60	1.62	0.62	0.77	0.87
		1/2"	10.3	48.8	17.4	8.2	0.28	2.80	0.36	0.47	0.75
			12.6	27.8	17.3	14.6	0.67	1.61	0.62	0.84	0.80
			7.0	21.4	17.0	11.5	0.60	1.26	0.79	0.68	0.66

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			5.5	21.0	15.5	11.5	0.64	1.35	0.74	0.74	0.61
			6.4	22.0	16.0	12.4	0.66	1.38	0.73	0.78	0.64
			5.2	21.0	14.6	11.5	0.66	1.44	0.70	0.79	0.60
			4.4	20.2	16.0	9.3	0.52	1.26	0.79	0.58	0.56
			4.0	18.9	16.4	9.1	0.52	1.15	0.87	0.55	0.55
		3/8″	3.5	17.8	12.4	8.9	0.60	1.44	0.70	0.72	0.52
			3.2	16.2	14.4	7.5	0.49	1.13	0.89	0.52	0.51
			4.0	25.8	12.7	6.6	0.36	2.03	0.49	0.52	0.55
			5.0	26.8	13.2	8.0	0.43	2.03	0.49	0.61	0.59
			2.3	14.4	11.3	6.7	0.53	1.27	0.78	0.59	0.45
			3.5	16.6	14.5	9.4	0.61	1.14	0.87	0.65	0.52
			1.4	17.4	9.3	5.6	0.44	1.87	0.53	0.60	0.39
			2.4	20.0	11.1	4.1	0.28	1.80	0.55	0.37	0.46
			2.0	14.9	11.2	6.3	0.49	1.33	0.75	0.56	0.43
			1.1	12.5	10.0	4.0	0.36	1.25	0.80	0.40	0.36
89–57	26.86	2″	556.2	117.5	74.5	48.0	0.51	1.58	0.63	0.64	2.83
			358.7	102.0	47.5	40.0	0.57	2.15	0.47	0.84	2.45
			340.4	95.2	67.5	27.1	0.34	1.41	0.71	0.40	2.41
		1 1/2″	98.5	68.7	46.2	18.0	0.32	1.49	0.67	0.39	1.59
			86.7	53.3	49.5	19.0	0.37	1.08	0.93	0.38	1.53
			153.4	53.0	47.2	36.8	0.74	1.12	0.89	0.78	1.84
			144.4	63.0	46.8	33.3	0.61	1.35	0.74	0.71	1.81
			119.1	58.8	40.9	30.5	0.62	1.44	0.70	0.75	1.70
			94.9	55.3	48.2	21.0	0.41	1.15	0.87	0.44	1.57
			99.6	55.5	48.0	28.3	0.55	1.16	0.86	0.59	1.60
			130.9	61.5	45.2	38.6	0.73	1.36	0.73	0.85	1.75
		1″	70.4	64.9	27.8	19.3	0.45	2.33	0.43	0.69	1.42
			57.9	54.9	39.3	16.0	0.34	1.40	0.72	0.41	1.33
			51.7	48.0	32.0	23.5	0.60	1.50	0.67	0.73	1.28
			26.0	34.9	30.0	25.5	0.79	1.16	0.86	0.85	1.02
			36.4	42.6	31.6	18.4	0.50	1.35	0.74	0.58	1.14
			77.8	54.5	43.2	19.6	0.40	1.26	0.79	0.45	1.47
			37.1	41.8	24.2	14.2	0.45	1.73	0.58	0.59	1.15
			29.4	42.3	30.0	18.8	0.53	1.41	0.71	0.63	1.06
			94.2	85.0	30.7	23.2	0.45	2.77	0.36	0.76	1.57
			35.8	37.2	30.4	17.5	0.52	1.22	0.82	0.58	1.14
			67.1	50.3	30.8	25.5	0.65	1.63	0.61	0.83	1.40
			34.9	37.6	28.7	23.0	0.70	1.31	0.76	0.80	1.13
			39.8	41.5	31.6	21.0	0.58	1.31	0.76	0.66	1.18
			40.6	42.3	28.5	19.2	0.55	1.48	0.67	0.67	1.18
			34.8	38.3	31.6	20.3	0.58	1.21	0.83	0.64	1.12
			42.9	46.0	34.3	20.4	0.51	1.34	0.75	0.59	1.21

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
		3/4"	40.4	43.1	25.6	21.8	0.66	1.68	0.59	0.85	1.18
			28.9	48.2	30.4	15.7	0.41	1.59	0.63	0.52	1.06
			39.1	49.4	23.5	20.4	0.60	2.10	0.48	0.87	1.17
			17.2	32.7	26.2	15.4	0.53	1.25	0.80	0.59	0.89
			21.9	32.5	23.4	17.5	0.63	1.39	0.72	0.75	0.96
			16.0	25.1	21.4	18.8	0.81	1.17	0.85	0.88	0.87
			20.8	29.1	23.1	19.0	0.73	1.26	0.79	0.82	0.95
			12.6	30.9	20.5	13.6	0.54	1.51	0.66	0.66	0.80
			29.5	35.8	25.8	20.9	0.69	1.39	0.72	0.81	1.06
			23.8	46.5	26.2	11.2	0.32	1.77	0.56	0.43	0.99
			22.6	37.5	25.8	17.0	0.55	1.45	0.69	0.66	0.97
			24.0	40.4	27.9	14.6	0.43	1.45	0.69	0.52	0.99
			13.9	30.7	21.2	13.6	0.53	1.45	0.69	0.64	0.83
			15.6	29.8	20.0	17.8	0.73	1.49	0.67	0.89	0.86
			15.1	50.9	23.4	7.4	0.21	2.18	0.46	0.32	0.85
			18.7	29.3	23.3	23.1	0.88	1.26	0.80	0.99	0.91
		1/2"	9.2	27.9	18.0	14.9	0.66	1.55	0.65	0.83	0.72
			11.2	42.5	13.0	11.0	0.47	3.27	0.31	0.85	0.77
			8.1	24.2	15.2	12.1	0.63	1.59	0.63	0.80	0.69
			9.4	28.8	19.8	10.8	0.45	1.45	0.69	0.55	0.73
			5.4	19.8	18.5	13.3	0.69	1.07	0.93	0.72	0.60
			5.2	25.0	14.5	11.3	0.59	1.72	0.58	0.78	0.60
			8.4	26.6	17.2	12.5	0.58	1.55	0.65	0.73	0.70
			5.5	23.5	15.2	9.2	0.49	1.55	0.65	0.61	0.61
			12.9	33.0	17.7	15.6	0.65	1.86	0.54	0.88	0.81
			7.3	26.4	21.5	7.4	0.31	1.23	0.81	0.34	0.67
			5.7	19.7	17.6	9.3	0.50	1.12	0.89	0.53	0.62
			14.0	25.9	20.2	17.1	0.75	1.28	0.78	0.85	0.83
			10.2	28.6	19.4	13.7	0.58	1.47	0.68	0.71	0.75
			9.2	24.6	19.2	9.6	0.44	1.28	0.78	0.50	0.72
			5.6	19.1	14.7	12.3	0.73	1.30	0.77	0.84	0.61
			4.3	20.2	14.9	7.2	0.42	1.36	0.74	0.48	0.56
		3/8"	2.8	16.2	12.8	8.3	0.58	1.27	0.79	0.65	0.49
			3.4	21.1	12.2	8.3	0.52	1.73	0.58	0.68	0.52
			2.2	18.1	12.4	5.6	0.37	1.46	0.69	0.45	0.45
			3.2	24.7	9.4	8.4	0.55	2.63	0.38	0.89	0.51
			2.0	12.5	10.2	9.2	0.81	1.23	0.82	0.90	0.43
			5.4	23.6	12.6	10.7	0.62	1.87	0.53	0.85	0.60
			2.8	16.8	9.6	7.5	0.59	1.75	0.57	0.78	0.49
			3.6	22.4	13.7	7.8	0.45	1.64	0.61	0.57	0.53
			2.7	17.0	12.0	7.6	0.53	1.42	0.71	0.63	0.48
			1.5	11.7	10.2	6.2	0.57	1.15	0.87	0.61	0.39

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			3.7	19.7	11.6	9.2	0.61	1.70	0.59	0.79	0.53
			3.3	23.0	10.3	7.6	0.49	2.23	0.45	0.74	0.51
			1.5	13.9	10.5	6.5	0.54	1.32	0.76	0.62	0.39
			5.5	27.8	10.9	8.4	0.48	2.55	0.39	0.77	0.61
			2.0	16.2	13.5	7.2	0.49	1.20	0.83	0.53	0.43
			1.8	16.8	9.5	6.5	0.51	1.77	0.57	0.68	0.42
			3.0	15.9	13.0	9.2	0.64	1.22	0.82	0.71	0.50
			2.8	15.0	12.3	9.8	0.72	1.22	0.82	0.80	0.49
			1.9	13.7	8.8	5.7	0.52	1.56	0.64	0.65	0.43
			2.1	20.7	11.7	5.8	0.37	1.77	0.57	0.50	0.44
89-58	28.11	3/4"	21.9	37.3	21.9	21.0	0.73	1.70	0.59	0.96	0.96
			27.7	41.9	26.0	25.0	0.76	1.61	0.62	0.96	1.04
			20.1	29.0	24.5	19.1	0.72	1.18	0.84	0.78	0.94
			10.3	26.3	21.2	12.5	0.53	1.24	0.81	0.59	0.75
			12.7	32.7	22.5	11.2	0.41	1.45	0.69	0.50	0.80
			6.8	26.8	21.8	9.7	0.40	1.23	0.81	0.44	0.65
		1/2"	10.2	27.4	17.4	17.1	0.78	1.57	0.64	0.98	0.75
			8.1	25.5	23.0	11.5	0.47	1.11	0.90	0.50	0.69
			1.9	20.2	21.3	6.8	0.33	0.95	1.05	0.32	0.43
			8.0	25.7	13.3	12.9	0.70	1.93	0.52	0.97	0.69
			6.7	24.5	21.0	9.3	0.41	1.17	0.86	0.44	0.65
			5.6	24.5	18.0	8.8	0.42	1.36	0.73	0.49	0.61
			4.2	25.0	15.9	6.0	0.30	1.57	0.64	0.38	0.56
			4.9	19.6	16.8	16.2	0.89	1.17	0.86	0.96	0.59
		3/8"	4.0	24.3	18.8	9.0	0.42	1.29	0.77	0.48	0.55
			4.3	23.5	17.1	9.3	0.46	1.37	0.73	0.54	0.56
			3.4	17.8	13.3	12.0	0.78	1.34	0.75	0.90	0.52
			3.1	16.0	12.8	10.4	0.73	1.25	0.80	0.81	0.50
			2.5	15.5	11.0	8.4	0.64	1.41	0.71	0.76	0.47
			0.6	15.8	10.7	4.6	0.35	1.48	0.68	0.43	0.29
			2.7	15.4	14.0	12.2	0.83	1.10	0.91	0.87	0.48
			1.4	14.1	10.5	8.6	0.71	1.34	0.74	0.82	0.39
89-59	23.78	1"	107.0	57.0	40.0	34.1	0.71	1.43	0.70	0.85	1.64
			73.4	53.5	37.8	22.5	0.50	1.42	0.71	0.60	1.44
			50.2	46.0	31.3	19.3	0.51	1.47	0.68	0.62	1.27
		3/4"	17.6	45.1	36.2	8.4	0.21	1.25	0.80	0.23	0.90
			23.2	29.5	21.9	23.5	0.92	1.35	0.74	1.07	0.98
			16.9	30.2	25.4	17.8	0.64	1.19	0.84	0.70	0.88
			31.2	39.3	31.5	16.3	0.46	1.25	0.80	0.52	1.08
			10.7	31.4	20.9	12.1	0.47	1.50	0.67	0.58	0.76
			29.3	37.0	26.1	19.3	0.62	1.42	0.71	0.74	1.06
			14.8	26.8	22.2	18.1	0.74	1.21	0.83	0.82	0.85

Table 15 (Continued)

Bedload Sample No.	Mean Discharge cfs	Particle Sieve Size (in)	Particle Weight gr.	Axis Lengths, mm Longest a	Intermed b	Shortest c	Shape Factor Sf	Relative Length a/b	Ratio for Zingg's Classification b/a	Relative Length c/b	Nominal Diameter Dn (in)
			12.8	30.9	26.2	11.5	0.40	1.18	0.85	0.44	0.81
			8.9	24.0	17.4	17.1	0.84	1.38	0.73	0.98	0.71
			8.9	23.0	20.5	15.9	0.73	1.12	0.89	0.78	0.71
		1/2"	8.0	31.7	19.8	8.7	0.35	1.60	0.62	0.44	0.69
			3.8	23.0	16.1	11.4	0.59	1.43	0.70	0.71	0.54
			4.0	21.0	18.2	9.0	0.46	1.15	0.87	0.49	0.55
			5.2	22.7	17.8	12.5	0.62	1.28	0.78	0.70	0.60
			6.5	24.3	20.4	11.7	0.53	1.19	0.84	0.57	0.64
			4.5	23.6	19.0	8.3	0.39	1.24	0.81	0.44	0.57
			5.6	24.0	18.1	10.1	0.48	1.33	0.75	0.56	0.61
			5.5	23.2	15.6	10.1	0.53	1.49	0.67	0.65	0.61
			4.5	20.1	17.7	11.4	0.60	1.14	0.88	0.64	0.57
			2.5	20.3	16.5	7.1	0.39	1.23	0.81	0.43	0.47
		3/8"	2.2	17.5	14.7	5.8	0.36	1.19	0.84	0.39	0.45
			2.7	15.3	13.0	10.5	0.74	1.18	0.85	0.81	0.48
			4.2	27.7	15.8	8.3	0.40	1.75	0.57	0.53	0.56
			4.6	27.4	11.0	7.7	0.44	2.49	0.40	0.70	0.57
			2.9	19.1	15.1	8.7	0.51	1.26	0.79	0.58	0.49
			1.6	14.1	13.5	7.0	0.51	1.04	0.96	0.52	0.40
			1.9	14.1	12.7	8.2	0.61	1.11	0.90	0.65	0.43
			2.0	16.8	11.5	7.9	0.57	1.46	0.68	0.69	0.43
			1.5	12.2	10.5	8.4	0.74	1.16	0.86	0.80	0.39
			1.3	15.1	10.8	6.2	0.49	1.40	0.72	0.57	0.38

APPENDIX F

OAK CREEK VELOCITY MEASUREMENTS, 1990
At Bridge Cross Section Upstream of
Vortex Bedload Sampler

Table 16 Oak Creek velocity measurements, 1990 data

Date	Time	Stage ft	Discharge cfs	Vortex O/C	Left Edge Sta.	Right Edge Sta.	Station	Water Depth ft	Obs. Depth	Sequential Instantaneous Velocities, ft/sec															Avg. V Vel ft/sec	Max V Vel ft/sec	Min V Vel ft/sec
1/27/90	Start 11:15	0.51	14	C	30.8	18.5	21.5	0.55	0.60																1.80	1.80	1.80
							23.0	0.55	0.60																2.20	2.20	2.20
							25.2	0.60	0.60																4.00	4.00	4.00
1/27/90	End 11:45	0.53	14.5	C			28.0	0.60	0.60																2.00	2.00	2.00
2/03/90	Start 4:10	0.95	38	C	31.1	18.3	21.0	0.90	0.60	3.0	2.9	3.0	2.8	2.6	3.2	3.4	2.9	3.2							3.00	3.40	2.60
							22.0	0.95	0.60	4.0	3.9	3.6	4.2	4.0	4.1	4.3	4.4	3.9	4.2	3.7					4.03	4.40	3.60
							22.5	1.00	0.60	3.8	3.8	4.0	3.6	4.1	3.4	3.6	3.2	3.6	3.0	3.8	3.6	3.2			3.59	4.10	3.00
							22.5	1.00	0.20	5.0	5.0	4.6	5.0	5.2	5.2	4.8	5.0	5.1	4.8	5.0	4.8	4.7	5.0	5.2	4.96	5.20	4.60
							23.0	0.90	0.60	3.8	3.6	3.8	4.2	4.0	3.6	4.3	3.5	4.0							3.87	4.30	3.50
							24.0	0.95	0.60	3.4	3.8	3.9	3.4	3.2	4.0	3.9	3.3	4.0	3.8	3.7					3.67	4.00	3.20
							24.0	0.95	0.20	4.5	4.4	5.1	4.8	4.6	4.9	5.1	5.0	5.0	4.2	4.8					4.76	5.10	4.20
							25.0	1.05	0.60	4.0	4.2	4.4	4.0	3.9	3.6	3.9	4.2	4.3	3.8	3.7	4.2				4.02	4.40	3.60
							26.0	1.05	0.60	4.0	4.2	4.1	4.2	4.3	4.4	4.2	4.2	4.1	4.3	4.4					4.22	4.40	4.00
							26.0	1.05	0.20	5.4	5.6	5.2	5.3	5.4	5.1	5.8	5.6	5.4	5.3						5.41	5.80	5.10
							27.1	1.00	0.60	3.8	4.0	4.0	3.8	3.6	3.4	3.8	3.6	3.7	3.4	3.6	3.5				3.68	4.00	3.40
							27.1	1.00	0.20	5.0	5.4	5.2	5.0	5.2	5.4	4.8	5.2	5.4	5.4	5.0					5.18	5.40	4.80
							28.0	0.90	0.60	4.0	4.2	4.2	3.6	3.7	4.0	4.2	3.6	3.8	4.0	3.6	3.6				3.88	4.20	3.60
							29.0	0.80	0.60	2.6	2.6	2.7	2.6	2.6	2.5	2.8	2.8	2.8	2.6	2.9					2.68	2.90	2.50
2/03/90	End 5:00	0.95	38	C			29.9	0.80	0.60	1.8	1.6	1.8	1.6	1.6	1.8	2.0	1.6	1.4	1.9						1.71	2.00	1.40
2/05/90	Start 2:20	0.74	25	C	30.9	18.5	20.8	0.70	0.60	2.0	2.2	2.2	2.0	1.8	2.0	2.1	2.0	2.2	2.3	2.0	2.2				2.08	2.30	1.80
							22.0	0.80	0.60	3.0	2.8	2.8	2.4	2.5	2.8	3.0	2.8	2.4	2.6						2.71	3.00	2.40
							23.0	0.80	0.60	4.0	3.6	3.7	3.8	3.9	3.8	3.4	3.4	3.6	3.6	3.6					3.67	4.00	3.40
							24.3	0.85	0.60	3.0	3.2	2.8	3.0	3.2	3.0	3.1	2.9	2.8	3.4	2.8	3.0	3.2	3.2		3.04	3.40	2.80
							26.0	0.75	0.60	3.0	3.2	3.0	3.3	3.2	3.0	2.8	2.6	3.1	2.8	3.0	2.6	3.2	3.0	2.8	2.97	3.30	2.60
							27.4	0.70	0.60	2.6	2.8	3.0	3.0	3.1	2.4	2.8	2.6	2.8	2.7	3.0	2.4	2.6			2.75	3.10	2.40
							28.1	0.70	0.60	2.4	2.4	2.2	2.6	2.4	2.2	2.4	2.5	2.1	2.6	2.6	2.4	2.2			2.38	2.60	2.10

Table 16 (Continued)

Date	Time	Stage ft	Discharge cfs	Vortex O/C	Left Edge Sta.	Right Edge Sta.	Station	Water Depth ft	Obs. Depth	Sequential Instantaneous Velocities, ft/sec															Avg. V Vel ft/sec	Max V Vel ft/sec	Min V Vel ft/sec
	End						29.1	0.50	0.60	2.2	2.0	2.2	2.0	2.2	2.1	2.0	2.0	2.0	1.8	2.1	2.0	2.2			2.06	2.20	1.80
2/05/90	2:50	0.74	25	C			30.0	0.55	0.60	1.0	1.1	1.0	1.0	1.0	1.1	1.2	1.1	1.2	1.0	1.2	1.2	1.0	1.1		1.09	1.20	1.00
	Start																										
2/10/90	12:35	1.03	43	C	31.5	18.1	19.0	0.80	0.60	1.4	1.4	1.6	1.6	1.4	1.5	1.4	1.3	1.0	1.6	1.7	1.5				1.45	1.70	1.00
							20.2	0.85	0.60	2.0	1.8	1.6	2.0	1.9	2.0	2.0	2.1	2.2	2.4	1.8	2.0	2.4	2.0	2.2	2.03	2.40	1.60
							21.1	1.00	0.60	3.8	4.0	3.8	3.6	3.3	3.4	3.8	4.0	3.6	3.8	3.7	3.8	3.6	4.0	4.1	3.75	4.10	3.30
							22.2	1.00	0.60	4.6	4.6	4.2	4.4	5.0	4.8	4.6	4.5	4.2	4.4	4.0	4.7				4.50	5.00	4.00
							22.2	1.00	0.20	5.0	4.8	5.1	5.2	5.0	5.0	5.1	5.2	5.3	5.5	5.2					5.13	5.50	4.80
							23.0	1.00	0.60	4.6	3.8	3.6	4.2	4.4	4.4	3.8	4.0	4.0	4.1	3.9	4.2	3.6	3.8	4.0	4.03	4.60	3.60
							23.0	1.00	0.20	5.2	5.0	4.8	4.8	5.4	5.0	4.6	5.4	5.3	5.4	5.0	5.4	5.6	5.0	5.4	5.15	5.60	4.60
							24.1	1.20	0.60	4.6	4.4	4.6	4.2	4.0	4.2	4.7	4.6	4.8	4.9	4.0	4.7	4.4			4.47	4.90	4.00
							24.1	1.20	0.20	4.8	5.0	5.2	5.4	5.6	5.8	5.4	5.2	5.4	5.7	5.2	5.4	5.1	5.6	5.3	5.34	5.80	4.80
							25.0	1.00	0.60	5.0	4.8	5.0	5.2	4.5	4.6	5.1	5.0	5.2	4.8	5.0	5.4	5.3	5.2	4.8	4.99	5.40	4.50
							25.0	1.00	0.20	6.4	6.2	5.8	5.8	6.0	5.8	5.9	5.8	5.7	6.0	5.4	5.8	6.0			5.89	6.40	5.40
							26.0	1.10	0.60	3.8	4.0	4.2	4.1	4.2	4.0	4.2	4.0	4.2	4.0	4.2	4.3	4.0	3.8	4.0	4.07	4.30	3.80
							26.0	1.10	0.20	5.8	5.4	5.6	5.6	5.4	5.4	5.8	5.8	6.0	5.8	5.4	5.2	5.6	5.2	5.0	5.53	6.00	5.00
							27.0	1.05	0.60	4.0	4.2	4.0	4.2	4.3	4.0	3.8	4.2	4.0	3.8	3.6	3.8	4.2	3.6	4.4	4.01	4.40	3.60
							27.0	1.05	0.20	5.2	4.8	5.0	5.2	5.0	4.8	5.0	5.3	4.6	5.1	5.0	4.9	4.8	5.0	4.7	4.96	5.30	4.60
							28.0	1.05	0.60	3.6	3.8	3.8	3.6	4.0	4.1	4.2	3.8	3.6	3.4	4.2	4.0	3.8	4.0	3.9	3.85	4.20	3.40
							28.0	1.05	0.20	4.6	4.7	4.8	4.8	4.4	4.8	4.7	4.6	4.7	4.8	5.0	5.1	4.6	4.6	4.8	4.73	5.10	4.40
	End						29.1	0.95	0.60	3.0	3.1	3.2	3.4	3.0	3.1	3.2	3.2	3.0	3.2	2.8	2.9	3.0	3.2	2.8	3.07	3.40	2.80
2/10/90	1:20	1.02	43	C			30.0	0.95	0.60	1.6	1.5	1.8	2.0	1.8	1.9	1.6	1.4	1.8	1.6	1.5	1.8	1.8	1.9		1.71	2.00	1.40
	Start																										
2/11/90	12:10	0.77	26	C	31.0	18.6	19.7	0.55	0.60	1.0	1.2	1.3	1.2	1.2	1.2	1.2	1.2	1.4	1.4	1.3	1.4				1.25	1.40	1.00
							20.9	0.55	0.60	2.4	1.8	2.0	2.2	2.4	2.4	2.0	2.2	2.3	2.4	2.3	2.1	2.0	2.3	2.3	2.21	2.40	1.80
							22.2	0.75	0.60	3.0	3.1	3.0	2.8	2.9	2.9	3.0	2.8	3.2	3.0	3.0	3.1	3.1	2.8	2.7	2.96	3.20	2.70
							23.5	0.90	0.60	3.6	3.5	3.0	2.8	3.0	3.1	3.3	3.4	3.2	3.4	3.6	3.0	3.7	3.2	3.4	3.28	3.70	2.80
							25.3	1.00	0.60	3.6	3.7	3.6	3.8	4.0	3.4	3.6	3.9	4.0	3.5	3.8	4.0	3.4	4.1		3.74	4.10	3.40
							26.3	1.00	0.60	2.8	2.6	2.6	2.9	3.0	3.0	3.0	3.2	2.4	3.2	2.8	3.3	2.4	2.8	2.4	2.83	3.30	2.40

Table 16 (Continued)

Date	Time	Stage ft	Discharge cfs	Vortex O/C	Left Edge Sta.	Right Edge Sta.	Station	Water Depth ft	Obs. Depth	Sequential Instantaneous Velocities, ft/sec															Avg. V Vel ft/sec	Max V Vel ft/sec	Min V Vel ft/sec
							27.2	0.85	0.60	3.4	3.2	3.2	2.8	3.5	3.5	3.4	3.4	3.5	3.7	3.5	3.3	3.4	3.4		3.37	3.70	2.80
							28.1	0.80	0.60	2.0	2.1	2.2	2.2	2.2	2.1	2.0	1.8	1.9	2.6	2.2	2.0	2.2	2.4	2.3	2.15	2.60	1.80
	End						29.1	0.65	0.60	2.2	2.1	2.0	2.2	2.1	2.1	2.2	2.2	2.2	2.1	2.2	2.3	2.0	1.9	2.2	2.13	2.30	1.90
2/11/90	12:35	0.77	26	C			30.0	0.70	0.60	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.3	1.2	1.6	1.4	1.3	1.4			1.35	1.60	1.20

Notes O/C = open or closed
Obs. = depth at velocity was observed