INVESTIGATION OF EFFECT OF GEOMETRY ON PERFORMANCE OF GRIT COLLECTION TROUGHS

by

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I. INTRODUCTION

Grit chambers, or some other type of grit collection devices are necessary in combined sewer systems because of the large amount of grit laden storm runoff that is usually associated with them. Also, appreciable amounts of grit may be found in separate sewers. This grit may come from many sources, some of which are: waste water from bathrooms and kitchens, silt which enters sewers through openings and loose joints, washings from floors and basements, and wastes from manufacturing processes.

Removal of grit in advance of pumps and treatment units prevents wear of the machinery used in these units and the unwanted accumulation of immovable grit deposits in settling tanks and sludge digesters. This removal also facilitates the handling of sludge produced in the various treatment processes.

Channel type grit chambers for the removal of grit from domestic sewage are designed to capture particles possessing a specified settling characteristic and to pass those particles more susceptable to scour. The grit captured by such grit chambers is usually stored in collection troughs for which little information is available regarding design parameters. Ideally, these troughs would possess hydraulic scour characteristics similar to the prevailing conditions in the channel so that grit would be collected selectively without contamination by lighter fractions. The object of this thesis is the investigation of the effect of geometry on the performance characteristics of grit collection troughs that serve to collect and store grit captured by grit chambers.

Data for this investigation was obtained by using a model grit chamber made of marine plywood and interchangeable plexiglass troughs. Enough plastic troughs were made so that comparison studies could be made of each of the following factors: upstream slope, downstream slope, and depth to width ratio of the trough. The chamber was designed to settle a 0.1 mm. sand particle. An adjustable weir was provided at the discharge end of the grit chamber to enable independent investigation of depth and velocity. A perforated plate was also placed in the upstream portion of the channel to stabilize wave effects.

The research procedure consisted of the addition of a known quantity of sand of specified size to the approach channel of the grit chamber, and the quantity of sand recovered was subsequently determined after each experiment. The sand was removed by siphoning it in its subaqueous state from the water filled trough into a graduated cylinder.

As stated earlier the grit troughs were interchangeable so that their efficiencies could be compared. In addition, the troughs were transparent so that the flow pattern of the particles could be observed and described. Water was supplied by connecting a fire hose from a water main to the grit chamber. The flow in the grit chamber was calibrated by a series of comparisons between a scale showing depth in the chamber and the quantity of water flowing through the chamber in a certain period of time.

II. REVIEW OF LITERATURE

Literature reviewed for this thesis gave information which fundamentally fell into three classes: sedimentation theory, grit chamber design, and efficiency of grit chamber troughs.

The problem studied in this thesis seemed to be closely related to sediment transport and the settling of particles along the bottom of a stream, or sedimentation theory. Morris (4) describes the difficulty of solving this problem: He said that non-uniformity and unsteadiness of flow, ordinary turbulence and macroturbulence, and waves complicated the matter, in addition to the constantly changing channel characteristics, and the flow of mixtures of water and solid particles. There has been a lot of study on this matter of sediment transport, but little of a rational nature.

Sediments are usually divided into two types: sediment that is moving along the bed, called bed load, and sediment that is in suspension in the turbulently moving water, called the suspended load. According to Morris (4), "perhaps the most widely used approach in sediment studies is that based on a separate analysis of the bed load, in terms of the tractive force at the bed, and of the suspended load, in terms of turbulent transfer mechanisms, with these two increments added then to give the total load."

With respect to the bed load several formulas have been devised. The most important contributors of bed load studies are DuBoys, Straub, Kalinske, Shields, and Einstein. The main paramenters DuBoys takes into account are the grain size and shape, the bed slope, the layer thickness of the sediment on the bed, the grain density, and the friction and shear forces. He assumes that the bed load moves in a kind of laminar flow with each layer sliding over the other and with the velocity decreasing linearly with depth. However, the assumed physical mechanism in his sedimentation characteristic formula is not what actually takes place in the stream, but it is believed adequate. DuBoys' formulas are ordinarily restricted to alluvial rivers, for which the typical channel cross section is wide and relatively shallow. Straub modified DuBoys' formulas, but still they were limited to two dimensional flow. Shields' formulas are based on the Nikuradse velocity distribution equations and the analysis of drag forces on the grains. He also takes into account the velocity of the flow. Shields' formulas give good correlation although there is a considerable scatter of data. Thus, his formulas were deemed unreliable for grit chambers. A. A. Kalinske based his analysis on turbulent fluctuations in velocity at the bed, drag force, diameter and weight of the particles, and the angle of repose of the particles. He also took into account the fluctuations of the shear force and bed velocity. Kalinske found his formulas to correlate well with many experimental data if a certain term in his bed load formula corresponded with a turbulence intensity of one-fourth. Hence, too great a restriction was placed on the turbulence intensity in the grit chamber to enable utilization of his formulas. Einstein analyzed sediment transport using statistics a great deal; taking into account fall velocity, particle size and specific weight, and the hydraulic properties of flow. In his analysis, the time to move a particle along the bed becomes a function of the diameter of the particle and the settling velocity. His settling velocity is a function of gravity, particle diameter and weight, and a complicated dimensionless number that accounts for viscosity. By combining various derived formulas he arrived at a bed load formula where one of the terms must be found emperically.

Thus, it was believed that this formula would not be successful in the application to grit chambers.

Von Kårmån, Ippen, and Rouse contributed to the analysis of suspended load formulas initiated by the work of Boussinesq and Vanoni. These analyses theorize that the amount of sediment tending to fall through a unit horizontal area is a function of the settling velocity and the sediment concentration, and also that resuspension of the sediment is a function of the gradient of concentration and a diffusion coefficient. The diffusion coefficient is not constant nor dimensionless, but changes with local turbulence intensities and other transfer mechanisms. The equations for sediment transport require the knowledge of the sediment concentration at a particular point. Also, a particular type of turbulence must be assumed in order to express a velocity distribution which, in turn, permits the diffusion coefficient to be expressed. The equations used in suspended load studies also require equilibrium conditions. Due to the preceding restrictions, these formulas could not be used.

As Morris writes (4), "Thus far, it has been impossible to develop any fully rational equation for total sediment load of a stream....equations have been developed for both the bed load and the suspended load segments of the total load, but even these are far from satisfactorily settled." It is not an easy matter to add sediment and bed load, since there is no actual demarcation between the two.

It appears reasonable to assume that the total load concentration of suspended sediment should be a function of the depth and velocity of flow, the channel slope, the density, specific weight and viscosity of the fluid, and the size and specific weight of the grains. However, equations derived from a dimensional analysis standpoint have been investigated, but there is still a considerable scatter of data probably arising from the highly uncertain character of the bed roughness effect. One of the major problems comes from bed roughness changes for various conditions of the stream. In addition, even if this roughness problem were solved, the solution would apply only to steady, uniform, two-dimensional flow, so that further study would be required to make it practical.

There are two methods commonly employed in the design of grit chambers in current engineering practices: (1) the method of the designing of chambers with respect to a constant velocity in the chamber which would permit settling of the grit of a certain size and specific weight and prevent settling of the lighter fractions, and (2) the method advocated by Camp (1). Both methods will be discussed in the following paragraphs.

In the design criteria advocated by Camp, he takes full advantage of two processes at work in grit chambers.

One of the processes is the settling of grit and organics which is selective in the fact that grit will settle faster. This process is the one used solely in many designs and will be discussed more fully later. The other process is the scouring of bed load movement process of settled solids which Camp claims to be effective in separation of putrescible solids from more dense inorganic solids than sedimentation.

Camp states that a grit chamber may be designed to settle any particle whose settling velocity is greater than a certain amount. In other words, the chamber may be designed with respect to a constant velocity in the chamber that would permit the settling of a particle of one size and weight, but prevent settling of a smaller and/or heavier particle. However, Camp says that in this type of design, it must be assumed that the velocity of the sewage is the same in all parts of the chamber and that there are no eddies. But in actual grit chambers the velocity is not the same at all points and there are eddies which retard settling. Experiments show that the error due to velocity inconsistencies and eddies is of no practical significance provided the grit remains on the bottom when it reaches there. Camp states that, when the chamber is designed in this way, other things being equal, a change in the mean velocity in the channel would require a proportional change in the length to obtain the same performance. Furthermore, he says that a considerable change in chamber length and chamber velocity could be made with little effect on the performance providing particles that reached the bottom would stay there. He then states that an increase in velocity would also increase the scour of the particles and that this scouring effect determines the best chamber velocity and not the settling process. The writer agrees with Camp in the fact that both differential settling and scour velocities should be used in the design of grit chamber. But, as shown above, the settling process alone is inadequate in chamber design and, it will be pointed out later, that Camp's design on the basis of scour velocities has some shortcomings also.

Camp employed Shields' relation for the "critical tractive force" required to start scour of material of a given size and density and expressed it as follows:

$V_c = \sqrt{\frac{8B}{f} g(s-1)d}$. In the above equation:

V_c = the velocity required to start the scour of the particles whose diameter is d and specific gravity is s,

g = the acceleration due to gravity,

f = the Darcy-Weisbach "friction factor" which is suggested to be a constant equaling 0.03 for grit chambers, and

B = an experimental constant whose value was found by Shields to be about 0.04 for unigranular material, but for nonuniform sticky material like grit a value of about 0.06 was considered safe for design.

Camp felt that the mean tractive force or shear on the walls and floors of a channel is related to the mean velocity of the stream. It is noted that depth does not influence scour, although it does affect settling. From the above equation, the optimum velocity is found. Camp then suggests a method of designing a grit chamber that maintains this velocity regardless of flow rate. This method of design employs either the shaping of the cross section of the chamber in such a way that the velocity remains constant at all depths together with a downstream rectangular depth control section, or the employment of a Sutro (proportional) weir at the effluent end of the chamber.

Since Camp bases his design of grit chambers on the velocity required to start scour of particles of a certain size and specific gravity, it is appropriate to review the validity of this scour velocity equation. The equation itself is derived from the "critical tractive force" equation by Shields. Shields' equation is one that deals with the bed load movement in a stream where sediment, supposedly, completely covers its bottom. Even Shields' equation comes from Nikuradse's velocity distribution equation which deals with velocity in a pipe coated with densely packed, uniform sand grains. Shields converts Nikuradse's equation to one of a two dimensional type. Thus we go from an equation dealing with roughness elements on the inside surface of a pipe, to one with roughness elements on the bottom of a channel only. This partially explains the scatter of data in Shields' equation and also seems to imply a discrepancy in Camp's formula. In addition, Camp's equation does not take into account the suspended load in the stream, yet he does concede the fact that changes in velocities will resuspend or scour certain size particles, and these particles would be considered part of the suspended load. However, he assumes that the particles scoured will be either putrescible particles or particles smaller than those intended to be trapped. This seems to be a reasonable assumption if there is no bottom turbulences tending to increase resuspension of larger particles, but from the writer's review of sediment transport this seems to be not quite the case. The discrepancy here is more clarified when one considers the changes in cross-sectional area and shape, the sharp changes in direction of the inside surfaces of the chamber, and the transitions from one cross-section to another. The friction factor term in Camp's equation also appears to warrant some discussion. This is the Darcy-Weisbach friction factor which is a function of Reynolds Number and relative roughness. Therefore, if the Darcy-Weisbach friction factor were a constant, as suggested by Camp, then the relative roughness and the Reynolds' Number would either both have to be constants or they would have to combine with each other in such a way that the relation between the two would be constant. In the case of grit chambers, Reynolds Number is ordinarily a function of the mean velocity and the hydraulic radius of the channel, and the kinematic viscosity of the water. Therefore, it can be seen that changes in either depth, or mean viscosity, or temperature (viscosity), or any combination thereof would change the Reynolds Number. The relative roughness is normally taken to be the ratio of the effective sand grain size to the equivalent pipe diameter of the channel. If the chamber is designed to settle a certain sand grain, the effective size is seen to be a constant. The equivalent pipe diameter will also remain constant if the depth in the channel remains constant, however, the depth doesn't remain constant in practice. Therefore, it seems reasonable to assume that the friction factor would not remain constant in a grit chamber in practice. Another discrepancy arises when one considers the fact that the Darcy-Weisbach friction factor was arrived at by coating pipes with varnish and then attaching sand to its wet surface, but, in grit chambers, only the bottom-most surface contains sand or grit and this grit may be in motion, not stationary.

Metcalf and Eddy (2) imply that grit hoppers, or troughs, are usually designed with respect to cleaning efficiency and capacity, and that design procedures, in practice, are mostly based upon past experience. Their only suggestion, with respect to collection trough design criterion, is that the trough sides should be at least a 45° slope so that grit would slide down toward the bottom of the trough. Therefore, there is little rational information available to indicate the effect of trough geometry on collection efficiency.

In the literature reviewed on the efficiency of grit collection troughs, Van Natta's (7) work dealt with the problem much more explicitly. His studies dealt with sand with average sizes of 0.72, 0.36, 0.20 and 0.10 mm., but most of his investigation was with the 0.20 and 0.10 mm. sand sizes.

Three shapes of grit collection troughs were studied in Van Natta's investigation using a model grit chamber to determine the most efficient shape for the selective capture of grit. His model was made of plywood with interchangeable plastic troughs. The troughs used consisted of a 2:1 side slope and differed only in respect to length of the bottoms.

Water was run through the apparatus at varying velocities and depths. Velocities and depths of flow in the chamber were controlled by an adjustable, calibrated weir at the downstream end of the chamber and a depth measuring ruler at the downstream end of the collection trough. Grit was introduced into the chamber through a funnel as the flow entered through the approach channel. After the grit had been added, the flow was stopped and the grit was removed and measured. The measurement was compared with the amount of grit added to the chamber enabling calculation of a value of per cent passing the trough for each run. His series of experiments are divided into sections according to particle size used.

As mentioned earlier, most of Van Natta's investigation was with the 0.20 and 0.10 mm. sand fractions. The sand used was processed into these sizes using sieves, however, the maximum and minimum particle diameters varied from the average particle size by as much as 0.05 mm. for the 0.20 mm. sand fraction used, and 0.025 mm. for the 0.01 mm. sand fraction used. By using closer sieves, the experimenter would have had a more accurate knowledge of the sand added to and collected from the model grit chamber.

Van Natta plotted various graphs of his data in order to establish a trend and/or correlation that would indicate the most efficient trough. One series of curves showed the relation between the mean velocity of the chamber and the percent of grit passing the trough for each trough and weir setting. He also presented bar graphs showing the percent grit passing for each of the troughs with conditions of identical velocity conditions and weir settings. In these velocity curves and bar graphs, Van Natta was searching for an indication that one trough would trap more grit than the others within a range of velocities of flow in the chamber. The author's velocity curves showed little differentiation between troughs especially in the 0.10 mm. sand fractions and this lack of differentiation between troughs was also shown in his bar graph illustrations.

Van Natta used graphs to show the relation between the percent grit passing and several flow characteristics, namely: Reynolds Number, Froude Number, and depth expressed as a ratio with width. In these graphs of percent passing versus selected flow characteristics, the author sought to compare the variables believed to affect grit scour through the chamber for weir settings of 0.05, 0.10, and 0.15 feet respectively. He also wanted to indicate the order of importance of these variables. This series of graphs show sufficient demarcation between troughs in all instances except for 0.10 mm. sand fractions at 0.05 and 0.10 feet weir settings, and for 0.20 mm. sand fractions at the 0.10 feet weir settings. The order of variation of the three variables shown in these graphs from the parameter showing the most variation to the one showing the least was Reynolds Number, Froude Number, and the depth parameter. The author later used this analysis to decide which variables to investigate when attempting to develop a formula describing the phenomena in the chamber.

Van Natta also compared the troughs under identical scour conditions in order to show which trough exhibited the best selective settling characteristics.

The writer feels that Van Natta's accuracy in his selective sedimentation study depended largely upon his velocity and corresponding percent grit capture data. It was previously stated that this data showed little demarcation between troughs for the 0.10 mm. sand fraction. Furthermore, the velocity and percent grit trapped data in the 0.10 mm.

sand fraction showed little differentiation between weir settings using the same trough. This lack of differentiation between weir settings occurred for two of the three troughs Van Natta studied. It is the writer's belief that a better range of data and more accurate data might have been obtained if a more refined model grit chamber had been employed. From the writer's study of Van Natta's grit chamber and data, it appears that the 0.20 mm. fraction would, theoretically, be settled at all depths and velocities used in Van Natta's investigation, except the highest velocity at the 0.15 feet weir setting for the largest trough. However, for the 0.10 mm. sand fraction, Van Natta's chamber length did not seem adequate in the following experiments: (1) the experiments with the smallest trough investigated at the highest velocity used for the weir setting of 0.10 feet, and at the highest two velocities used for the weir setting of 0.15 feet; (2) the experiments with the trough with a four inch bottom length at the highest two velocities used for the weir setting of 0.10 feet, and at the highest three velocities used for the weir setting of 0.15 feet; and (3) the experiments with the largest trough investigated at all velocities used for the 0.15 feet weir setting, and for all but the lowest velocity used for the 0.10 feet weir setting. Van Natta also had trouble reading depth of flow at high velocities because of "rippling". Therefore, it appears that the lack of chamber length for capture of the 0.10 mm. sand fraction and the "rippling effect" may have influenced the accuracy of Van Natta's data.

It was also expressed in Van Natta's study that "the chamber and trough sections were considered as a unit in developing efficiencies and all grit settling in both were included in the measurement." However, it seemed to the writer that prolonged running of the chamber after all the sand had flowed through the funnel used to introduce the sand would result in less sand being trapped than when the channel flow was shut off immediately. The author's written work did not state that he took this consideration into account.

Finally, Van Natta attempted to develop a prediction equation which would describe the phenomena occurring in the chamber. However, the author was unsuccessful in this attempt.

III. METHODS AND MATERIALS

The main piece of apparatus used in this investigation was a model grit chamber which was built according to the dimensions shown in Figure 1. This grit chamber provided a means of obtaining data in the form of purely empirical values. The materials used to build this model were plywood, outdoor grade, and transparent plastic.

The grit chamber was designed to settle a 0.10 mm. particle size over the approximate maximum depth and velocity range that the chamber would be run. The grit chamber was fabricated of plywood, except for the grit collection troughs, and wood screws were used to fasten joints together. The plywood surfaces were painted with marine varnish to provide waterproofing and to prevent warping. Waterproof contact cement and waterpump grease was used as a sealer at joints; the former being utilized with the screws. The waterpump grease was found to be satisfactory for all sealing of minor leaks although it did harden and crack somewhat after a few days of exposure.

Six troughs were used in this study; these troughs are shown in Figure 3. The troughs were made of plexiglass acrylic plastic. This plastic was transparent so that the movement of the particles in the trough could be observed.

Particle observation was also aided by pasting a dark piece of paper behind each trough. Thus an observer could view the white particles of sand through the transparent trough against a dark background. Wing nuts and bolts were used to attach the troughs to the grit chamber so that they could be readily interchanged with one another.

The design of the troughs were such that each of the three trough shape variables; upstream slope, downstream slope, and length to width ratio; could be studied independently. These trough shape variables are shown in Figure 2.

In most cases, a sedimentation tank or a Parshall flume would follow a grit chamber in order to control the depth of flow. However, in this case, the flow had to be immediately channeled away, therefore, a knifeblade weir was used to control the depth of flow in the grit chamber. This weir also provided a means of measuring the quantity of flow going through the chamber. Immediately upstream of the weir was a short stabilization sections. The stabilization section was needed to help trap particles that passed over the trough, thus, helping to prevent an excessive amount of grit from washing away.

The chamber cross section, the weir, and the source of water used in this study was the same as used by Van Natta (7).

The water temperature did not vary significantly from that employed by Van Natta. Therefore, it was not deemed necessary to recalibrate the weir.

The following is a description of the weir and the calibration procedure as reported by Van Natta (7). The weir was rectangular in shape and had a piece of sheet metal fastened to the bottom edge to provide a sharp crest. The elevation of the crest of the weir was adjustable. The weir was calibrated by passing a constant flow of water through the chamber, and into a weigh tank for a measured interval of time. The weight of the water collected was converted to flow rate. Measuring the temperature of the water, thereby fixing its density, the volume of the water was subsequently found. The volume divided by the time thus gave the quantity of water which passed through the chamber in cubic feet per second.

In the calibration of the weir, two thin metal rulers were employed. One of the rulers was located on the inside face of the weir; it measured the distance from the bottom of the channel to the crest of the weir. The other ruler was placed directly behind the trough section on the inside wall on the channel. This ruler measured the depth of the water in the chamber. The difference between the readings on the two rulers was plotted against the known quantity of water flowing through the chamber on log graph paper. Van Natta's calibration points are listed in Table 1 and are plotted in Figure 4. The graph thus plotted was then used to find the flow quantities used during the experiments by merely taking the difference in the above ruler measurements and then reading the flow from the graph.

Van Natta's (7) overall model grit chamber design was improved by increasing the length of the approach channel and installing an energy dissipator.

An approach channel was made and jointed to the upper end of the grit chamber for two reasons: to direct the flow into the chamber properly and to assist in stabilizing wave effects of the flow. The writer felt that the less the quantity and the size of the surface waves, the easier it would be to measure the flow. As shown in Figure 1, the approach channel was made narrower than the grit chamber in order to prevent grit from settling in this channel before it reached the grit chamber. At first, the approach channel was only about three feet long, but an excessive amount of surface waves were present in the chamber over a large flow range. Therefore, it was lengthened by eight feet, and the surface disturbances were reduced by a very significant amount.

Another device used to stabilize the surface waves was a perforated plate placed as shown in Figure 1. This plate was made of three quarter inch yellow pine with holes drilled in it in such a fashion that the total area of the holes approximated half the total area of the plate. According to Stoker (6) such a plate would significantly smooth the profile. It was found that this energy dissipator reduced surface disturbances by as much as 50%. Thus, the long approach channel together with the energy dissipator reduced wave disturbances to such an extent that the depth in the channel was relatively easy to measure even at high flows.

Water entered the grit chamber from the upper end of the approach channel. The water was directed vertically downward through a fire hose which was connected to a town water main. The water flowed through the grit chamber, over the weir, and was immediately drained into a connected funnel to the sewer system.

A second funnel was used to introduce the grit to the flow. This particular funnel is shown in Figure 1. It was placed about three feet from the end of that part of the approach channel which was attached to the grit chamber itself. The funnel had a rubber hose and a clamp attached to its bottom. With the clamp shut, a measured quantity of saturated sand could be released into the funnel and then suspended above the flow in the approach channel until the experimenter was ready to release the sand. It was found that a water sand mixture passed through the funnel at a nearly constant rate except for a few instances. In these instances the sand poured through the funnel so fast that it was essentially dumped on the channel bottom. This presented a problem as to whether to shut the flow off and regard all the sand settled on the bottom of the channel and chamber as being trapped, or only regard the sand trapped in the chamber, or permit the flow to remain in the channel until the sand had spread out along the bottom. It became obvious that none of the above procedures would produce worthwhile results and so situations where a very rapid feed existed were disregarded and repeated. The extremely rapid feeds were largely eliminated by permitting the sand to completely settle in the funnel before releasing it to the flow.

After each experiment the grit or sand was collected in the following manner. A large baffle plate was placed immediately behind the trough after the flow was terminated. The baffle plate prevented sand from escaping past the trough during the sand collection operation. A small paint brush was then used to slowly sweep the sand from the chamber into the trough. It was believed that all sand trapped in the trough and settled in the chamber proper could be considered as the amount trapped by the trough. After all of the sand in the chamber was swept into the trough, it was siphoned into a large graduated cylinder. A plastic tube with a twelve inch glass tube attached to one end was found to be excellent for this operation, since the mouth of the glass tube could be controlled easily and could also be directed closely over the bottom and sides of the trough.

The sand used in this study averaged out to be 0.10 mm. in diameter. The vender of the sand used was the Ottawa Silica Company, Ottawa, Illinois, and their #90 SHELL MOLDING Sand was used in this investigation. This particular sand was found to have a high percentage of the size of particles needed. Grains of uniform size were obtained by passing the raw sand through a series of sieves. The most important sieve sizes used were the #140 and #170 U. S. Standard Sieves. These two sieves had a mesh size of 0.105 mm. and 0.088 mm. respectively. Thus, all particles passing through the #140 sieve and retained on the #170 sieve were used in the experiments. In other words, the sand trapped between these two sieves was considered to have sufficient uniformity and to have maximum and minimum diameter values sufficiently close to the average particle size of 0.10 mm. The specific gravity of the sand was 2.64 from ASTM designation: C128-42. Since the variance from the average particle size was so small, it was not deemed necessary to use hydraulically separated sand as "make-up" sand in the experiments.

During a standard run the weir was set at the desired elevation and a mixture of sand and water was poured into a 250 ml. graduated cylinder. This sand was allowed to settle and about two inches of water was maintained above the top of the settled sand. A constant rotation of the cylinder on a table top quickly compacted the sand to such a degree that there was no more than a two ml. additional settlement in 24 hours after the initial compaction. However, this settlement was neglected, since the sand was introduced into the chamber only a few minutes after it was measured, and the error in settlement differences between quantities added to the chamber from experiment to experiment was insignificant. Thus after the initial compaction of the sand, after rotation of the cylinder, the amount of sand was measured volumetrically in millimeters. The sand was then placed into the feed funnel with the help of a wash bottle. A valve on the water main was turned on and the desired flow in the chamber was established. The clamp on the bottom of the funnel was then released, and the mixture of sand and water permitted to drop into the flow passing through the approach channel.

Only a few minutes were required for the funnel to empty and the rate of feed of sand was essentially constant from experiment to experiment; the only exceptions being the very rapid feed rate cases as mentioned earlier. For these cases that particular experiment was repeated. When all the grit had been introduced into the flow the valve on the water main was shut off, thus the operation of the chamber was terminated. The grit was collected in a large cylinder as explained earlier. After the grit settled to the bottom of the large cylinder, the excess water was siphoned from the above sand surface. The sand was then poured into a 250 ml. cylinder with the help of a wash bottle. The grit collected was measured volumetrically in the same graduated cylinder as was used to measure the grit that was added to the funnel in the beginning of the experiment.

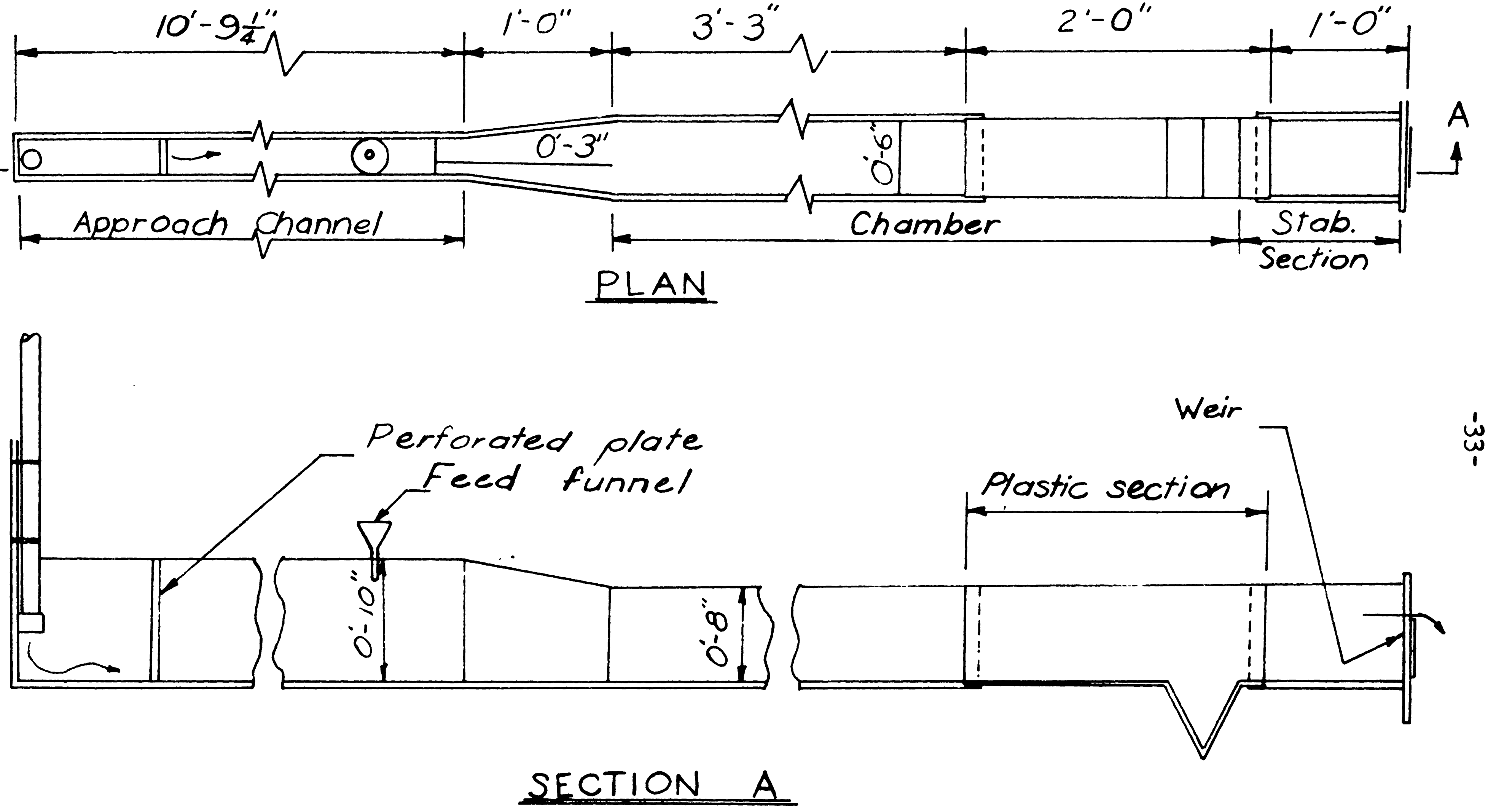


Figure 1 : Sketch of apparatus

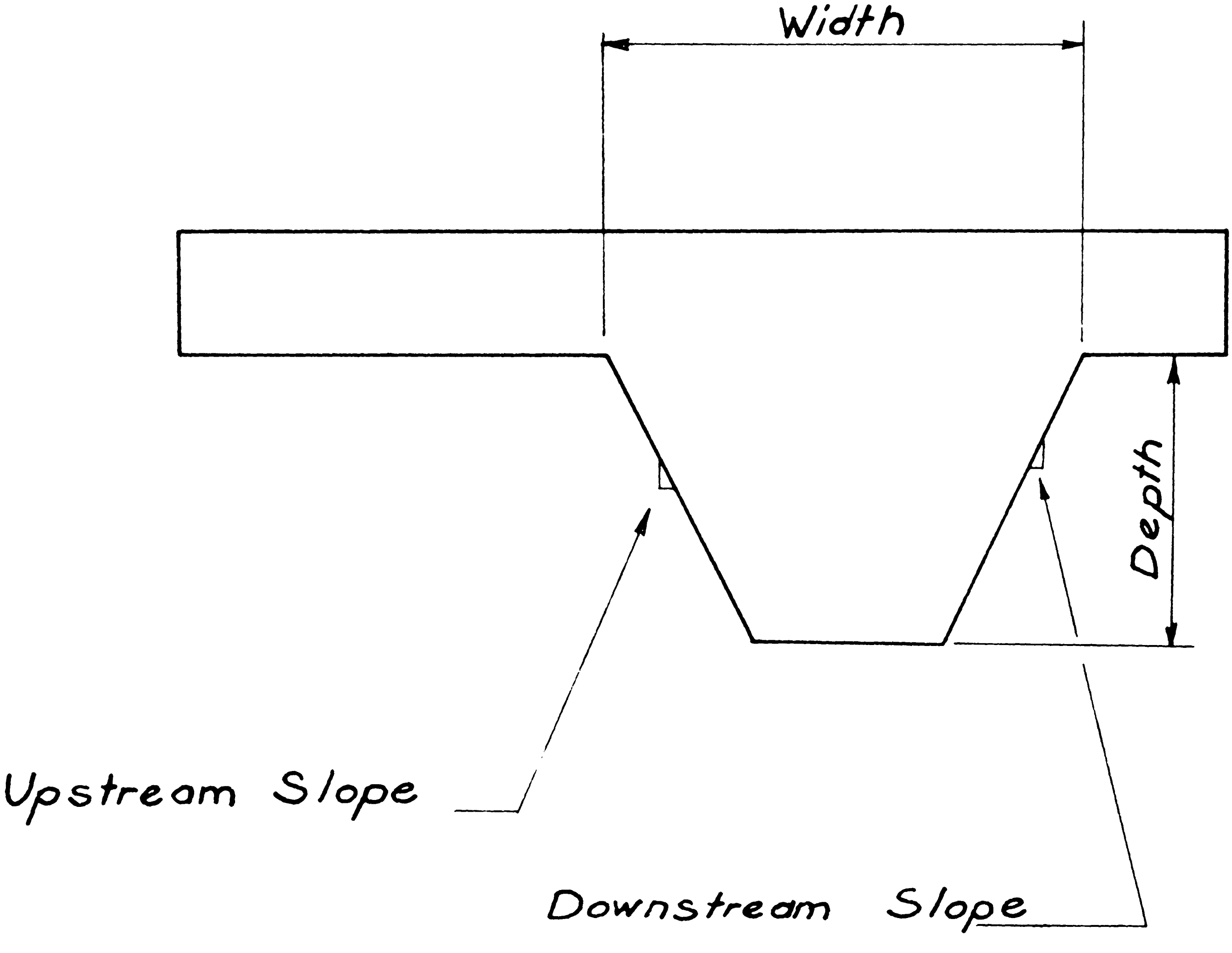


Figure 2: Typical trough showing trough shape variables

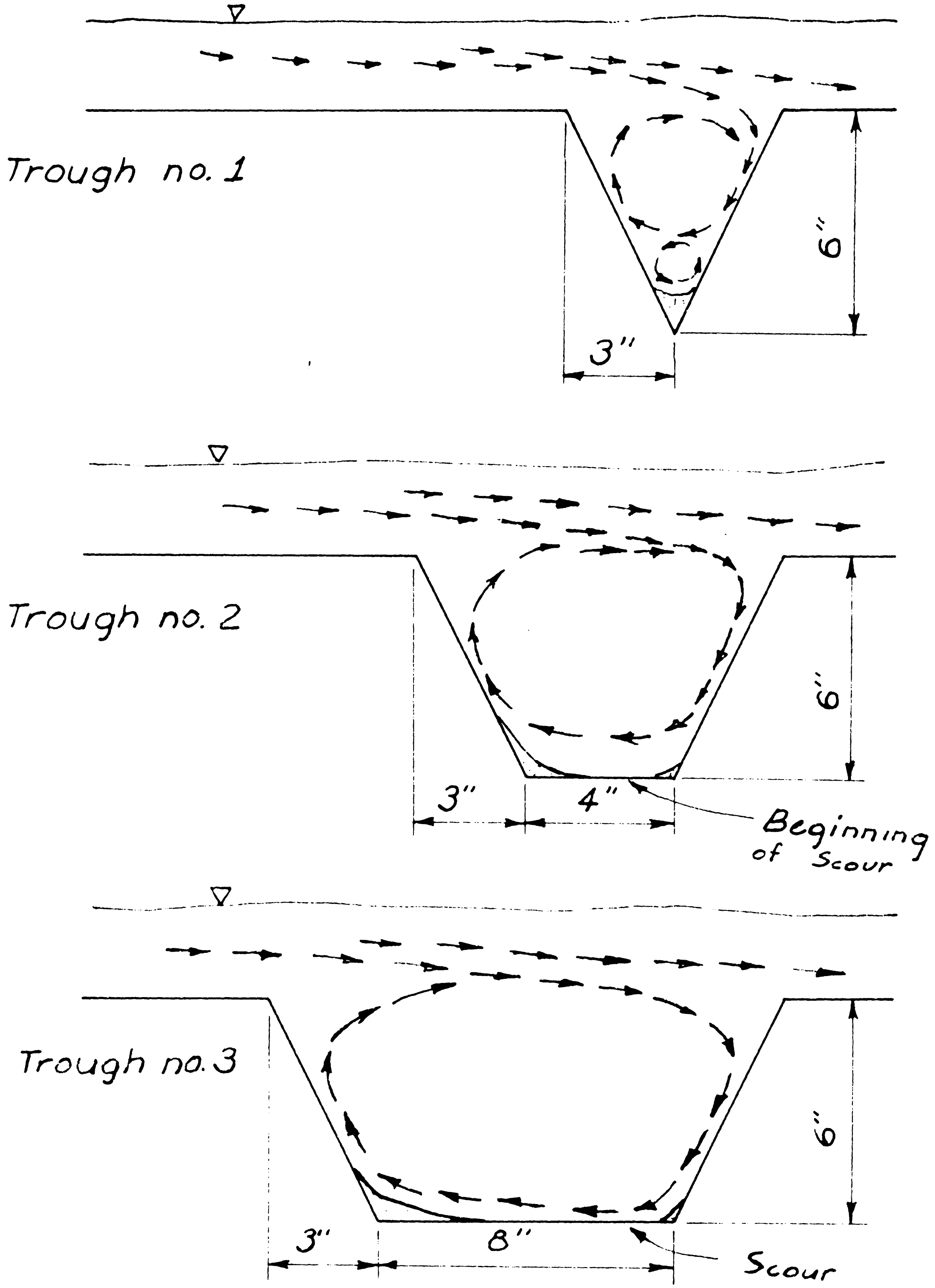
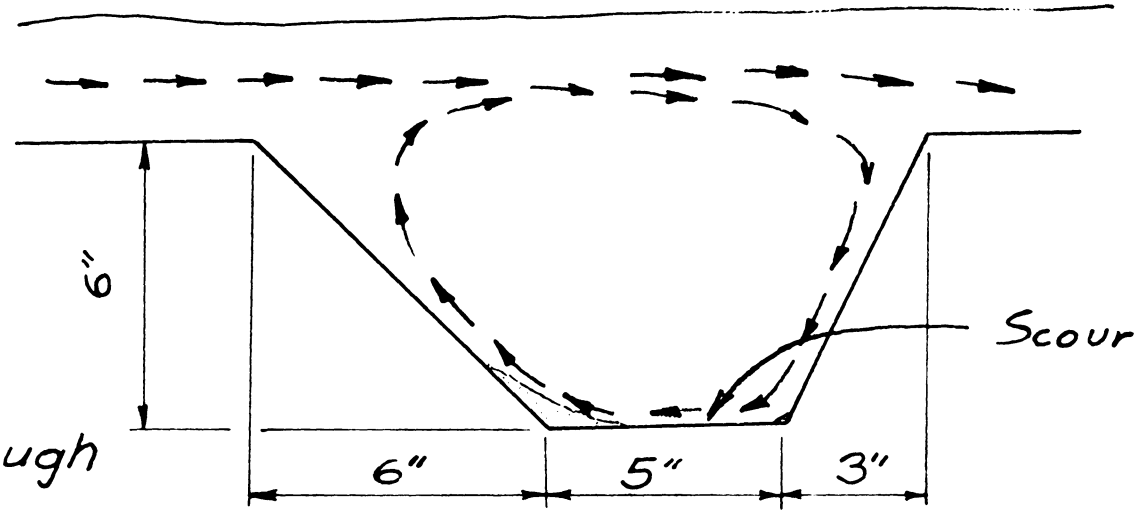
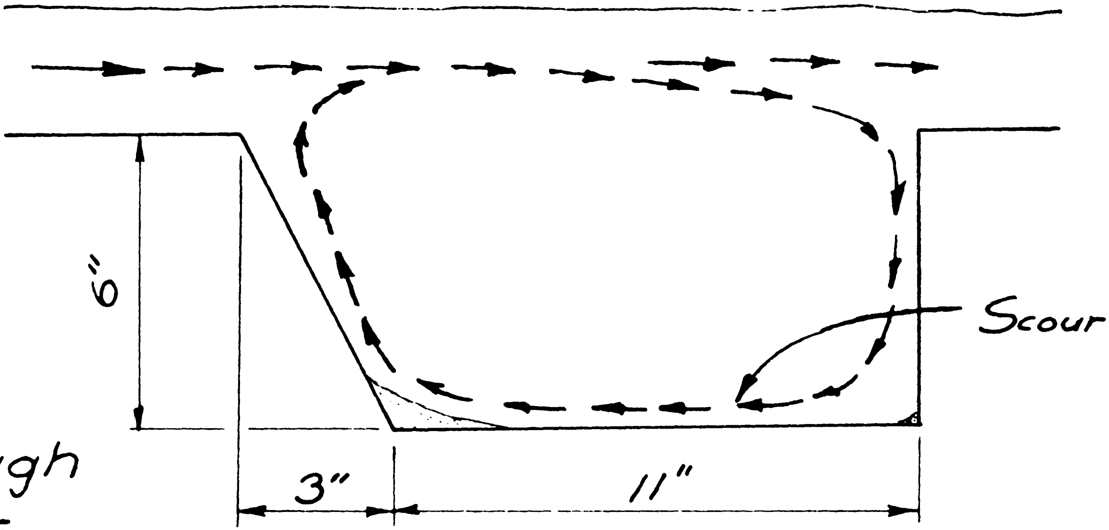


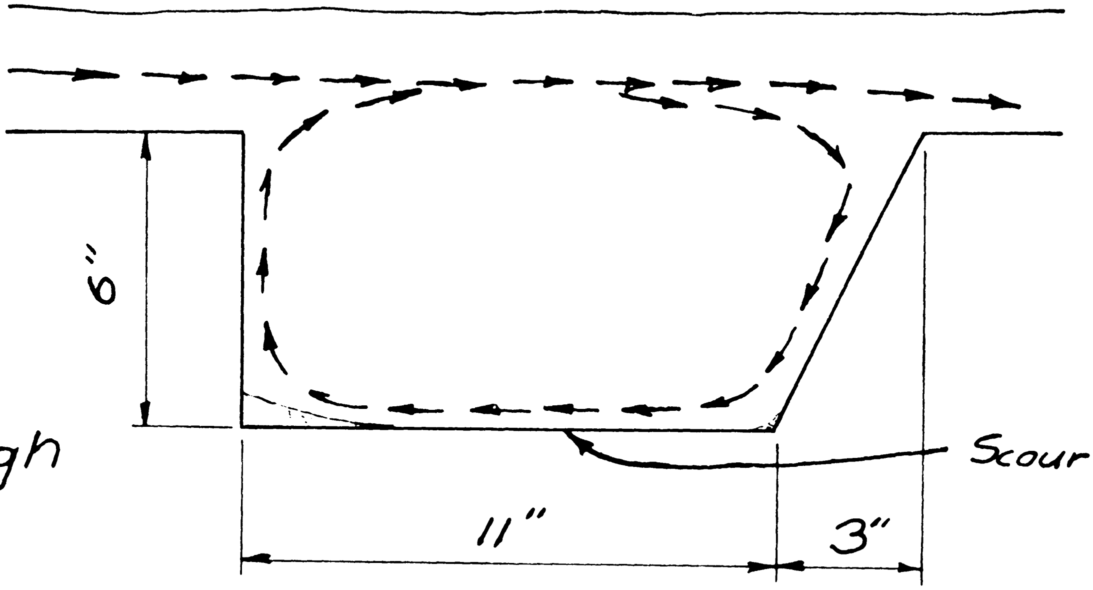
Figure 3: Trough dimensions and typical particle flow patterns



Trough no. 4



Trough no. 5

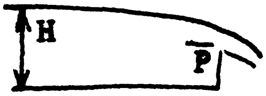


Trough no. 6

Figure 3 (continued)

TABLE I

Weir Calibration Data



Temperature of water - 23°C

Density of water at 23°C-
62.28 lbs./ft3

P ft.	H ft.	Trial	Weight lbs.	V Volume wt./62.28 cu.ft.	T Time seconds	Flow Rate V/T average cu.ft./sec.
0.10	0.225	1	500	8.028	157.5*	
0.10	0.225	2	500	8.028	137.9*	
0.10	0.225	3	500	8.028	131.9*	
0.10	0.225	4	500	8.028	129.6*	
0.10	0.225	5	500	8.028	128.9*	
0.10	0.225	6	500	8.028	127.4*	
0.10	0.225	7	500	8.028	129.0	
0.10	0.225	8	500	8.028	128.6	
0.10	0.225	9	500	8.028	129.4*	0.0623
0.10	0.208	1	400	6.423	133.5	
0.10	0.208	2	400	6.423	135.0	
0.10	0.208	3	400	6.423	135.9	
0.10	0.208	4	400	6.423	136.2	
0.10	0.208	5	400	6.423	137.3	0.0474
0.10	0.245	1	500	8.028	104.3*	
0.10	0.245	2	500	8.028	102.8*	
0.10	0.245	3	500	8.028	100.2	
0.10	0.245	4	500	8.028	100.9	0.0799
0.20	0.365	1	500	8.028	99.6*	
0.20	0.365	2	500	8.028	91.4*	
0.20	0.365	3	500	8.028	84.6*	
0.20	0.365	4	500	8.028	83.8*	
0.20	0.365	5	500	8.028	82.7	
0.20	0.365	6	500	8.028	82.5	0.0972
0.20	0.405	1	500	8.028	64.0*	
0.20	0.405	2	500	8.028	58.7*	
0.20	0.405	3	500	8.028	58.2	
0.20	0.405	4	500	8.028	57.4	0.1389

(continued)

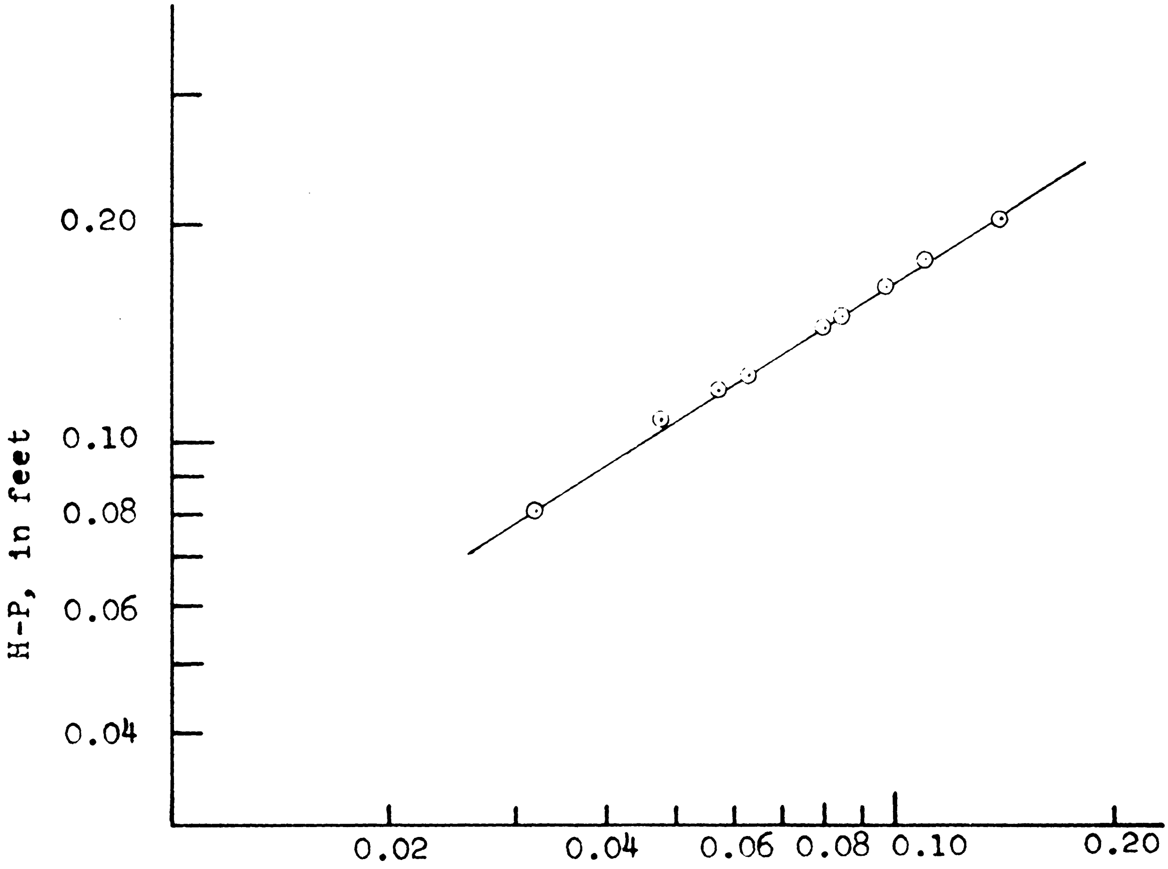
TABLE I (Continued)

Weir Calibration Data

P ft.	H ft.	Trial	Weight lbs.	V Volume wt./62.28 cu.ft.	T Time seconds	Flow Rate V/T average cu.ft./sec.
0.20	0.350	1	500	8.028	92.7*	
0.20	0.350	2	500	8.028	94.3	
0.20	0.350	3	500	8.028	95.5	
0.20	0.350	4	500	8.028	95.8	
0.20	0.350	5	500	8.028	94.7	0.0844
0.20	0.319	1	500	8.028	139.5	
0.20	0.319	2	500	8.028	140.4	
0.20	0.319	3	500	8.028	142.5	
0.20	0.319	4	500	8.028	162.7*	
0.20	0.319	5	500	8.028	140.2	0.0571
0.20	0.281	1	200	3.211	118.5*	
0.20	0.281	2	200	3.211	93.5*	
0.20	0.281	3	200	3.211	98.4	
0.20	0.281	4	200	3.211	100.6	
0.20	0.281	5	200	3.211	109.8*	
0.20	0.281	6	200	3.211	102.4	
0.20	0.281	7	200	3.211	97.9	
0.20	0.281	8	200	3.211	103.6	0.0319
0.20	0.380	1	500	8.028	81.6*	
0.20	0.380	2	500	8.028	78.3*	
0.20	0.380	3	500	8.028	76.2*	
0.20	0.380	4	500	8.028	75.3*	
0.20	0.380	5	500	8.028	73.4*	
0.20	0.380	6	500	8.028	73.0	
0.20	0.380	7	500	8.028	73.0	0.110

*Values not used in computing T. average

(After Van Natta)



FLOW, IN CUBIC FEET PER SECOND

FIGURE 4: WEIR CALIBRATION CURVE

(After Van Natta)

VI. RESULTS

The results of this study will be divided into two segments. The first segment of the results will be the evaluation of the efficiency of the collection troughs used, and the second segment of the results will be the evaluation of Camp's scour relation.

In the investigation of collection troughs, the object of the experiments was to find which of the collection troughs used would collect the most grit relative to the other troughs, and to attempt to find the reason for this grit collection superiority with respect to its scour characteristics and shape. The experiments were divided into six series, the difference between each series being that a different trough was used in each case. The experimental procedures were carried out according to the methods described in Section III... Methods and Materials, and the unit described in this section was employed to determine the effectiveness of the different troughs.

From each experiment, data was obtained in the form of weir height, depth of flow, the amount of grit added, and the amount of grit collected. The weir settings used were 0.05, 0.10, and 0.15 feet. The depth of flow and weir height enabled the experimenter to read the flow in the chamber from Figure 4, and the percent grit trapped was calculated from the amount of grit added to and collected from the trough. The values of velocity, Reynolds Number, using depth of flow, Reynolds Number, using hydraulic radius, Froude Number, friction factor, and critical velocity were then calculated because these parameters were thought to either directly or indirectly affect grit settling and trapping. The results of the six series of experiments are presented in Tables II through VII.

Data was obtained for the widest range of velocities which was physically practical for each experiment. At the highest velocity for each series of experiments and for each weir setting, there was almost no grit settling to the bottom of the chamber. As the velocities decreased from experiment to experiment more and more grit would settle in the chamber before reaching the trough.

Surface waves were insignificant except at the highest velocities, but even at these velocities the waves were relatively small as compared to the experiences reported for Van Natta's (7) chamber.

Except for a few instances where the sand flowed through the feed funnel at a rate that piled it on the channel bottom, which made it necessary to repeat the experiment, the feed rate was practically constant for each experiment and amounted to about one drop of the water-sand mixture per second.

The patterns of particle flow observed in the troughs are shown in Figure 3. The troughs used are numbered one through six, a notation used throughout this study. A double vortex was formed in Trough 1 during the experiments. The smaller vortex appeared to rotate faster than the larger one, but it did not seem to produce any scouring effect upon the collected sand under it. In Trough 2, grit collected in the corners and there was only one vortex observed. The vortex in Trough 2 produced some scour, as shown in Figure 3, but not as much as the other troughs mentioned later. This vortex pushed most of the grit scoured toward the upstream corner of the trough. Troughs 3, 4, 5, and 6 one vortex was found that scoured the particles toward the upstream corner of the trough, as shown in Figure 3, and the scour in these troughs were significantly more than the scour in Trough 2.

It was observed that the grit was trapped in the troughs in three ways. Firstly, most of the grit trapped fell into the trough by being washed along the bottom of the chamber until finally sliding down the upstream slope of the trough. Only a small percentage of grit would be picked up at the edge of the trough and carried into the vortex. Secondly, the vortex in the trough would throw a certain portion of the grit against the downstream slope of the trough and the grit would slide down to the bottom. Thirdly, the vortex in the trough would transport grit within the boundaries of the trough, and the heaviest particles would be pushed along the bottom of the troughs which exhibited scour, whereas, the lightest particles would travel around within the vortex until they eventually entered the main flow in the chamber, thereby washing through. Some particles, transported within the boundaries of the vortex, were just heavy enough to settle in the trough. These "border-line" particles would be carried by the vortex to the bottom of the trough, but would turn to the outside of the vortex and fall back as the vortex made its upward sweep.

In order to show the most efficient trough with respect to performance and velocity, the curves in Figures 5, 6, and 7 were plotted for each trough for weir settings of 0.05, 0.10, and 0.15 feet, respectively. Troughs 1 and 3 showed only average performance with respect to velocity. Troughs 2 and 5 indicated the worst performance with respect to velocity as shown by Figures 5, 6 and 7, however, the performance of Trough 5 was decidedly better at the 0.05 feet weir setting. Troughs 4 and 6 appeared to exhibit the best overall performance with respect to velocity with Trough 6 being the better of the two. Figures 5, 6, and 7 did not give any clear indication about the efficiency of the troughs studied due to the scatter of data, but they did indicate general trends.

A graph showing the relation between the Reynolds Number, using depth of flow, and the percent grit trapped was plotted for each trough from the data in Tables II through VII. These graphs were meant to show the relative efficiency between the troughs with respect to Reynolds Number. The plotted values indicated a straight line in each case, therefore, using the theory of least squared (5) a straight line was calculated for each series of experiments. Using a test of the slope of the curves (5), and with a confidence of 99%, these straight line curves were the curves of best fit for the data. The curves were used to eliminate the data that fell furthest from the representative curves, in order to compare average values of the troughs on an equal basis. This type of comparison will be discussed later. Each statistically derived curve of percent grit trapped versus Reynolds Number was copied on a single sheet of paper. The result of copying the graphs on a single sheet of paper enabled a quick comparison between troughs to be made. This series of curves is shown in Figure 8. Figure 8 indicates that Trough 1 and 5 have only average performance efficiencies with respect to Reynolds Number, using depth of flow. These curves also show that the performance of Troughs 2 and 3 were the worst, and Troughs 4 and 6 were the best, with respect to Reynolds Number, using depth of flow.

A similar series of curves shown as Figure 9 was made for the Reynolds Number, using the hydraulic radius of the channel cross-section. The data indicated a straight line configuration, so curves which approximated the data were plotted without the aid of statistics. The same relative performance was indicated in this series of curves as the series of curves showing the relation between Reynolds Number, using depth of flow, and the percent grit trapped.

It was desired to show the relative efficiency of the troughs with respect to Froude Number. Therefore, a series of curves was made showing the relation between Froude Number and percent grit trapped for weir settings of 0.05, 0.10, and 0.15 feet, respectively. Straight lines were plotted to the data. The lines of percent grit trapped versus the Froude Number are shown in Figure 10. The curves of Figure 10 are divided into three distinct groups according to the weir setting. This grouping of curves is not unusual, since the weir height governs the range of the depths of flow; and since Froude Number is inversely proportional to depth. Figure 10 shows that Troughs 2 and 3 exhibit the worst performance with respect to Froude Number, Troughs 1 and 5 exhibit average performance, and Troughs 4 and 6 exhibit the best performance with respect to the Froude Number.

It was decided to compare troughs using average values of velocity, Reynolds Number, Froude Number, and percent grit trapped; but every series of experiments did not contain the same number of observations. Therefore, in order to compare average values on the same basis, the writer felt that the same number of observations should be used for each series of experiments. This meant the elimination of the extra data by some method. The method employed was that of plotting curves statistically and eliminating those data points which fell furthest from the representative curve. The series of curves used, as mentioned earlier, are those showing the relation between Reynolds Number and percent grit trapped, as shown in Figure 8.

The procedure for eliminating data was for every high value discarded a low value was also discarded. For the series of experiments where Troughs 1 and 2 were used, there was an odd number of values obtained, therefore, a high and a low value was discarded, but the average of the total number of values was added. This procedure tended to shift the average values toward the median values, thereby making the average values more representative of the relative trough performance.

The values of Reynolds Number, Froude Number, velocity, and percent grit trapped, that were not eliminated, were averaged and are shown in Table VIII. Bar graphs could now be made of the adjusted average values of Reynolds Number, Froude Number, percent grit trapped, and velocity. These bar graphs were made in such a way that comparisons could be made between the troughs; they are found in Figure 12 and 13. Troughs 4 and 6 have the highest adjusted average Reynolds Number, Froude Number, and velocity. Trough 3 had the highest adjusted average percent grit trapped, aside from Trough 1.

Also shown in Figure 12 was a bar graph showing comparisons between troughs using median values of percent grit trapped for all experiments performed. This was done to obtain another measure of their relative performance. Table IX shows the array and median values of percent grit trapped, and trough grades for medians. The trough grades are meant to show the relative performance of each trough, the lowest grade indicating the best trough. Table IX shows that Troughs 1 and 5 have the best median values of percent grit trapped, whereas, Troughs 2, 3, and 6 have intermediate values, and Trough 4 has the worst value with respect to median values of percent grit trapped. The bar graph showing median values of percent grit trapped of all the experiments indicated Troughs 1 and 5 as the best, Troughs 2 and 3 as the worst, and Troughs 4 and 6 as intermediate with respect to performance. In comparing Table VIII with Table IX, it is seen that the adjusted median and adjusted average values of percent grit trapped very closely match, and for this reason it was decided not to show adjusted median values of velocity, Reynolds Number, and Froude Number in these particular experiments.

Figure 11 presents curves representing the percent grit trapped versus the calculated scour velocity for all troughs investigated. Camp (1) defines scour velocity as that velocity required to start the scour of particles. The calculated scour velocity came from Camp's scour relation and will be discussed later. The series of curvesin Figure 11 show Troughs 4 and 6 to exhibit the highest calculated scour velocities, and Trough 2 to exhibit the lowest calculated scour velocities. Data necessary to plot the curves in Figure 11 can be found in Tables II through VII.

In order to determine the overall relative performance of the troughs studied, a rating chart was made to rank the troughs using all the variables or parameters mentioned thus far. This rating chart is shown in Table XIII. The troughs were graded for each parameter or variable, the smallest grade indicating the best trough. It will be noticed that there are grades for the troughs for scour velocity and

Reynolds Number, using hydraulic radius; the basis for these grades are found in the notes on Tables XI and XII respectively. As shown in Figure 13, the rankings of the troughs show that Trough 6 is first, Trough 4 is second, Trough 5 is third, Trough 1 is fourth, Trough 3 is fifth, and Trough 2 is sixth in order of their performance from the best to the worst.

The second segment of this section will be the evaluation of Camp's scour relation (1). Camp based his design of grit chambers upon the scour velocity in the chamber; a discussion of his design procedures and scour relation can be found in Section II....Review of Literature. Camp's scour velocity is that velocity required to induce scour of particles of a certain size and density. His formula shows the relation between the scour velocity, specific weight and diameter of the particle, and the Darcy-Weisbach "friction factor". The "friction factor" is a function of Reynolds Number, using hydraulic radius, and the relative roughness, using the ratio of particle diameter to four times the hydraulic radius or the equivalent pipe diameter.

The data obtained in the writer's study enabled "friction factors" and critical velocities to be found in each experiment. And it was noted that the results obtained may have application for the evaluation of the Camp relation, therefore, the data was analyzed to ascertain the degree of agreement.

Camp employed Shield's relation for the "critical tractive force" required to start the scour of material of a given size and density, and expressed it as follows: $V_c = \sqrt{\frac{8B}{f} g(s-1)d}$. The terms in the equation are defined in Section II....Review of Literature. Camp implies that all the terms under the radical are constant when the grit size, weight, and cohesiveness are known. He suggested that the Darcy-Weisbach "friction factor" be considered as a constant for grit chambers and that the term "B" also be considered a constant. Camp implied that "B" depends upon the cohesiveness and uniformity of the material.

From the data obtained from the experiments the writer was able to calculate the Reynolds Number and the relative roughness for each experiment. The Reynolds Number used in this particular case was the velocity of flow in the channel multiplied by four times the hydraulic radius of the channel cross-section divided by the kinematic viscosity of the water. The relative roughness used was the actual sand size divided by four times the hydraulic radius of the channel cross-section. The Reynolds Number and the relative roughness made it possible to find the "friction factor" from Moody's curves for each experiment (3). Using the corresponding "friction factor" derived for each experiment, the scour velocity was subsequently calculated. Tables II through VII show the "friction factors" and scour velocities thus calculated. From the calculated scour velocities, a series of curves were plotted showing the relation between the calculated scour velocities for each experiment and the percent grit trapped. This series of curves is shown in Figure 11. It should be noted that the range of scour velocities is relatively small which gives an indication of the selective sedimentation properties of the troughs because velocities below or above the scour velocities would either trap the particles used in the experiments or reject them respectively. Therefore, the range of scour velocities indicated that the Camp expression was satisfactory.

It was subsequently decided to find out what the "friction factors" would be if they were derived from a scour velocity that was actually picked from the velocities in the experiments. The scour velocity decided upon was one that trapped 80% of the particles. From the percent grit trapped versus velocity curves of Figures 5, 6, and 7, a velocity was read for each trough and weir setting used, and the corresponding "friction factor" was calculated in each case. The data obtained was tabulated in Table X.

From the curves of Figure 11 and the data in Tables II through VII, and Table X, the writer was now able to determine whether there was any agreement with Camp's scour relation.

The "friction factors" shown in Tables II through VII vary from 0.0240 to 0.0350. This variation in the values of the "friction factors" is due to the method employed to obtain it. The method employed to find the "friction factor" was to calculate the Reynolds Number and relative roughness and the "friction factor" corresponding to these two parameters is obtained from the Moody diagram (3). Therefore, as shown in Tables II through VII, if the relative roughness and the Reynolds Number changes, then the "friction factor" would change also, and, in turn, the scour velocity would change. In other words, as the depth and velocity changes in a grit chamber, the scour velocity will also change. And this change in scour velocity will make a change in the percent grit captured in the grit chamber. As shown in Figure 11, small change in scour velocity will bring large changes in the amount of grit trapped. In conclusion, it does not seem appropriate to assume a constant "friction factor" of 0.03 when using Camp's scour relation when designing a grit chamber.

Table X shows the "friction factors" obtained from the experiments using a scour velocity corresponding to 80% of the grit trapped. It is noted that the friction factor in the chamber may not agree with that calculated. In other words, when comparing the calculated scour velocities corresponding to the experiments with the actual velocities obtained in the experiments, shown in Tables II through VII, one can see, in Table X, that the "friction factors" corresponding to actual scour velocities do not match with the "friction factors" corresponding with the calculated scour velocities. Therefore, we see that the Darcy-Weisbach "friction factor" is not representative of what is actually happening in the grit chamber. However, if we accept Camp's scour velocity expression, and if we use the Darcy-Weisbach "friction factor" of 0.03 in Camp's expression, knowing that it may not be representative of the phenomena in the chamber; then the term "B" must be a constant that not only accounts for the uniformity and cohesiveness of the particles, but also accounts for the discrepancy between the Darcy-Weisbach "friction factor" and the actual friction in the chamber.

In calculating the scour velocities, the constant "B" was taken, as Camp suggested, as 0.04 for uniform cohesionless particles.

It was now decided to re-evaluate the term "B" in the Camp relation in order to attempt to make the Camp scour velocity match the actual or calculated scour velocities in the chamber. Table XIV shows the values of "B" that would have to be used in the Camp relation. As shown in Tables XIV the "B" term is averaged and has the value of about 0.05 for this particular group of experiments.

TABLE II

RESULTS OF EXPERIMENTS - TROUGH NO. 1

(Note: v = kinematic viscosity in ft.^{2}/sec. and R_H = hydraulic radius in ft.)

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R = \frac{VH}{\nu}$	Reynolds Number $N_R = \frac{4R_H V}{\nu}$	Froude Number $NF = \frac{V^2}{gH}$
0.120	0.280	0.671	1.223×10^4	2.305×10^4	0.0501
0.120	0.250	0.536	0.855×10^4	1.745×10^4	0.0358
0.100	0.300	0.893	1.743×10^4	3.170×10^4	0.0828
0.100	0.275	0.785	1.405×10^4	2.675×10^4	0.0698
0.100	0.250	0.680	1.106×10^4	2.215×10^4	0.0576
0.100	0.225	0.560	0.819×10^4	1.725×10^4	0.0434
0.100	0.200	0.445	0.579×10^4	1.287×10^4	0.0308
0.100	0.175	0.320	0.364×10^4	0.858×10^4	0.0182
0.050	0.265	1.094	1.886×10^4	3.660×10^4	0.1407
0.050	0.250	1.072	1.743×10^4	3.495×10^4	0.1431
0.050	0.225	0.960	1.405×10^4	2.959×10^4	0.1275
0.050	0.200	0.850	1.106×10^4	2.545×10^4	0.1124
0.050	0.170	0.694	0.767×10^4	1.829×10^4	0.0882
0.050	0.150	0.593	0.579×10^4	1.448×10^4	0.0730
0.050	0.120	0.417	0.325×10^4	0.880×10^4	0.0450
0.150	0.335	0.704	1.535×10^4	2.622×10^4	0.0461
0.150	0.310	0.606	1.223×10^4	2.183×10^4	0.0369
0.150	0.285	0.505	0.936×10^4	1.753×10^4	0.0279
0.150	0.245	0.331	0.527×10^4	1.063×10^4	0.0139

TABLE II (Continued)

RESULTS OF EXPERIMENTS - TROUGH NO. 1

Grit Added, ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score/Velocity, V_c, ft./sec.
152.0	51.0	33.55	0.0269	0.455
92.0	69.0	75.00	0.0283	0.443
90.0	20.0	22.21	0.0254	0.468
69.0	26.0	37.70	0.0263	0.460
78.0	36.0	46.15	0.0270	0.454
98.0	64.0	65.30	0.0285	0.442
58.0	52.0	89.70	0.0300	0.431
64.0	59.0	92.25	0.0335	0.408
76.0	8.0	10.52	0.0248	0.474
52.0	11.0	21.15	0.0248	0.474
71.0	18.0	25.37	0.0256	0.466
79.0	30.0	38.00	0.0265	0.458
56.0	34.0	60.75	0.0281	0.445
65.0	45.0	69.25	0.0295	0.434
68.0	65.0	95.60	0.0337	0.406
86.0	26.0	30.22	0.0260	0.463
63.0	34.0	54.00	0.0270	0.454
49.0	32.0	64.30	0.0282	0.444
58.0	48.0	82.80	0.0315	0.420

TABLE III

RESULTS OF EXPERIMENTS - TROUGH NO. 2

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R = \frac{VH}{\nu}$	Reynolds Number $N_R = \frac{4R_H V}{\nu}$	Froude Number $NF = \frac{V^2}{gH}$
0.150	0.345	0.742	1.665×10^4	2.800×10^4	0.0497
0.150	0.320	0.644	1.340×10^4	2.350×10^4	0.0403
0.150	0.290	0.524	0.988×10^4	1.832×10^4	0.0295
0.150	0.275	0.458	0.819×10^4	1.560×10^4	0.0238
0.150	0.240	0.313	0.488×10^4	0.996×10^4	0.0127
0.100	0.300	0.893	1.743×10^4	3.166×10^4	0.0828
0.100	0.280	0.804	1.463×10^4	2.764×10^4	0.0718
0.100	0.260	0.723	1.223×10^4	2.400×10^4	0.0626
0.100	0.235	0.613	0.936×10^4	1.932×10^4	0.0497
0.100	0.210	0.490	0.670×10^4	1.597×10^4	0.0357
0.100	0.190	0.395	0.488×10^4	1.111×10^4	0.0255
0.050	0.255	1.098	1.821×10^4	3.610×10^4	0.1472
0.050	0.235	1.004	1.535×10^4	3.170×10^4	0.1336
0.050	0.215	0.916	1.281×10^4	2.757×10^4	0.1215
0.050	0.200	0.850	1.182×10^4	2.458×10^4	0.1124
0.050	0.180	0.749	0.871×10^4	2.022×10^4	0.0958
0.050	0.160	0.644	0.670×10^4	1.632×10^4	0.0806
0.050	0.140	0.538	0.488×10^4	1.252×10^4	0.0638
0.050	0.115	0.387	0.289×10^4	0.724×10^4	0.0405

TABLE III (Continued)

RESULTS OF EXPERIMENTS - TROUGH NO. 2

Grit Added, ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score/Velocity, V_c, ft./sec.
54.0	12.0	22.21	0.0256	0.466
68.0	24.0	35.30	0.0268	0.456
47.0	26.0	55.35	0.0280	0.446
39.0	28.0	71.80	0.0291	0.437
49.0	38.0	72.55	0.0316	0.420
28.0	12.0	42.85	0.0253	0.469
38.0	12.0	32.90	0.0260	0.463
61.0	21.0	34.41	0.0278	0.447
40.0	16.0	40.00	0.0279	0.447
58.0	40.0	69.00	0.0291	0.437
48.0	40.0	83.30	0.0315	0.420
40.0	8.0	20.00	0.0248	0.474
40.0	9.0	22.50	0.0255	0.467
42.0	12.0	28.57	0.0260	0.463
42.0	16.0	38.10	0.0266	0.457
42.0	18.0	42.85	0.0277	0.448
36.0	26.0	72.25	0.0293	0.436
42.0	34.0	80.95	0.0310	0.424
48.0	47.0	98.00	0.0350	0.399

TABLE IV

RESULTS OF EXPERIMENTS - TROUGH NO. 3

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R = \frac{VH}{\nu}$	Reynolds Number $N_R = \frac{4R_H V}{\nu}$	Froude Number $N_F = \frac{V^2}{gH}$
0.050	0.250	1.072	1.743×10^4	3.490×10^4	0.1431
0.050	0.235	1.004	1.535×10^4	3.170×10^4	0.1336
0.050	0.210	0.895	1.223×10^4	2.662×10^4	0.1188
0.050	0.200	0.850	1.106×10^4	2.459×10^4	0.1124
0.050	0.180	0.740	0.871×10^4	2.025×10^4	0.0958
0.050	0.160	0.644	0.670×10^4	1.633×10^4	0.0806
0.050	0.140	0.536	0.488×10^4	1.252×10^4	0.0638
0.100	0.320	0.975	2.029×10^4	3.561×10^4	0.0925
0.100	0.300	0.893	1.743×10^4	3.165×10^4	0.0828
0.100	0.275	0.785	1.405×10^4	2.680×10^4	0.0698
0.100	0.250	0.760	1.236×10^4	2.475×10^4	0.0719
0.100	0.230	0.583	0.871×10^4	1.817×10^4	0.0459
0.100	0.200	0.445	0.579×10^4	1.288×10^4	0.0308
0.100	0.175	0.320	0.364×10^4	0.858×10^4	0.0182
0.150	0.355	0.789	1.821×10^4	3.010×10^4	0.0545
0.150	0.340	0.724	1.600×10^4	2.711×10^4	0.0479
0.150	0.320	0.644	1.340×10^4	2.350×10^4	0.0403
0.150	0.300	0.567	1.106×10^4	2.012×10^4	0.0333
0.150	0.280	0.479	0.871×10^4	1.643×10^4	0.0255
0.150	0.260	0.396	0.670×10^4	1.315×10^4	0.0188
0.150	0.240	0.313	0.488×10^4	0.996×10^4	0.0127
0.150	0.220	0.227	0.325×10^4	0.692×10^4	0.0073

TABLE IV (Continued)

RESULTS OF EXPERIMENTS - TROUGH NO. 3

Grit Added, ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score/Velocity, V_c, ft./sec.
45.0	3.0	6.67	0.0249	0.473
32.0	4.0	12.50	0.0255	0.467
46.0	12.0	26.10	0.0265	0.458
66.0	17.0	25.77	0.0266	0.457
44.0	17.0	38.65	0.0278	0.447
44.0	25.0	56.80	0.0290	0.438
53.0	41.0	77.40	0.0310	0.424
40.0	8.0	20.00	0.0248	0.474
40.0	9.0	22.50	0.0255	0.467
38.5	12.0	31.18	0.0260	0.463
55.0	23.0	41.80	0.0265	0.458
40.0	27.0	67.50	0.0280	0.446
45.0	36.0	80.00	0.0302	0.429
37.0	31.0	83.75	0.0280	0.446
41.0	10.0	24.40	0.0251	0.471
31.0	10.0	32.25	0.0259	0.463
42.0	14.0	33.35	0.0267	0.456
41.0	19.0	46.35	0.0275	0.450
40.0	24.0	60.00	0.0288	0.440
40.0	32.0	80.00	0.0300	0.431
46.0	40.0	87.00	0.0321	0.416
40.0	40.0	100.00	0.0350	0.399

TABLE V

RESULTS OF EXPERIMENTS - TROUGH NO. 4

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R = \frac{VH}{\nu}$	Reynolds Number $N_R = \frac{4R_H V}{\nu}$	Froude Number $NF = \frac{V^2}{gH}$
0.150	0.345	0.748	1.678×10^4	2.820×10^4	0.0505
0.150	0.335	0.704	1.535×10^4	2.625×10^4	0.0461
0.150	0.315	0.622	1.275×10^4	2.257×10^4	0.0383
0.150	0.290	0.524	0.988×10^4	1.831×10^4	0.0295
0.150	0.270	0.437	0.767×10^4	1.475×10^4	0.0220
0.150	0.250	0.356	0.579×10^4	1.160×10^4	0.0158
0.100	0.290	0.848	1.600×10^4	2.962×10^4	0.0772
0.100	0.270	0.763	1.340×10^4	2.578×10^4	0.0671
0.100	0.250	0.680	1.106×10^4	2.213×10^4	0.0576
0.100	0.230	0.583	0.871×10^4	1.821×10^4	0.0459
0.100	0.210	0.490	0.670×10^4	1.460×10^4	0.0357
0.100	0.310	0.935	1.886×10^4	3.370×10^4	0.0879
0.050	0.270	1.156	2.029×10^4	3.905×10^4	0.1539
0.050	0.250	1.072	1.743×10^4	3.490×10^4	0.1431
0.050	0.230	0.983	1.470×10^4	3.065×10^4	0.1307
0.050	0.210	0.895	1.223×10^4	2.662×10^4	0.1188
0.050	0.190	0.800	0.988×10^4	2.250×10^4	0.1048
0.050	0.170	0.694	0.767×10^4	1.825×10^4	0.0882

TABLE V (Continued)

RESULTS OF EXPERIMENTS - TROUGH NO. 4

Grit Added, ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score/Velocity, V_c, ft./sec.
32.0	10.0	31.22	0.0256	0.466
28.0	12.0	42.90	0.0260	0.463
27.0	13.0	48.15	0.0269	0.455
31.0	20.0	64.55	0.0280	0.446
34.0	26.0	76.50	0.0292	0.437
20.0	20.0	100.00	0.0319	0.418
26.0	8.0	30.77	0.0255	0.467
19.0	8.0	42.10	0.0265	0.458
26.0	13.0	50.00	0.0271	0.453
18.0	12.0	66.67	0.0280	0.446
36.0	28.0	77.80	0.0295	0.434
23.0	6.0	26.08	0.0252	0.470
28.0	4.0	14.30	0.0242	0.479
28.0	5.0	17.85	0.0241	0.480
20.0	7.0	35.00	0.0249	0.473
26.0	10.0	38.45	0.0261	0.462
30.0	15.0	50.00	0.0270	0.454
23.0	18.0	78.30	0.0281	0.445

TABLE VI

RESULTS OF EXPERIMENTS - TROUGH NO. 5

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R=\frac{VH}{\nu}$	Reynolds Number $N_R=\frac{4R_HV}{\nu}$	Froude Number $NF=\frac{V^2}{gH}$
0.150	0.355	0.789	$1.821X10^4$	$3.010X10^4$	0.0545
0.150	0.320	0.644	$1.340X10^4$	$2.350X10^4$	0.0403
0.150	0.325	0.665	$1.405X10^4$	$2.442X10^4$	0.0423
0.150	0.300	0.567	$1.106X10^4$	$2.012X10^4$	0.0333
0.150	0.280	0.479	$0.871X10^4$	$1.645X10^4$	0.0255
0.150	0.260	0.396	$0.670X10^4$	$1.315X10^4$	0.0188
0.150	0.240	0.313	$0.488X10^4$	$0.997X10^4$	0.0127
0.100	0.310	0.935	$1.886X10^4$	$3.375X10^4$	0.0879
0.100	0.290	0.848	$1.600X10^4$	$2.961X10^4$	0.0772
0.100	0.270	0.763	$1.340X10^4$	$2.678X10^4$	0.0671
0.100	0.225	0.560	$0.819X10^4$	$1.725X10^4$	0.0434
0.100	0.250	0.680	$1.106X10^4$	$2.210X10^4$	0.0576
0.100	0.200	0.445	$0.579X10^4$	$1.288X10^4$	0.0308
0.050	0.260	1.115	$1.886X10^4$	$3.706X10^4$	0.1489
0.050	0.240	1.025	$1.600X10^4$	$3.268X10^4$	0.1363
0.050	0.220	0.936	$1.340X10^4$	$2.850X10^4$	0.1240
0.050	0.200	0.850	$1.106X10^4$	$2.455X10^4$	0.1124
0.050	0.170	0.694	$0.767X10^4$	$1.828X10^4$	0.0882
0.050	0.185	0.778	$0.936X10^4$	$2.152X10^4$	0.1019
0.050	0.150	0.593	$0.579X10^4$	$1.448X10^4$	0.0730

TABLE VI (Continued)

RESULTS OF EXPERIMENTS - TROUGH No. 5

Grit Added, ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score Velocity, V_c, ft./sec.
30.0	8.0	26.65	0.0251	0.471
40.0	14.0	35.00	0.0267	0.456
32.0	10.0	31.25	0.0264	0.459
44.0	24.0	54.55	0.0275	0.450
27.0	17.0	62.95	0.0289	0.439
27.0	22.0	81.50	0.0300	0.431
36.0	30.0	83.35	0.0321	0.417
22.0	4.0	18.18	0.0250	0.472
30.0	8.0	26.65	0.0256	0.466
28.0	8.0	28.55	0.0262	0.461
36.0	22.0	61.10	0.0287	0.440
24.0	13.0	54.15	0.0270	0.454
30.0	25.0	83.30	0.0305	0.427
36.0	3.0	8.33	0.0245	0.476
36.0	8.0	22.21	0.0252	0.470
33.0	8.0	24.22	0.0260	0.463
23.0	10.0	43.50	0.0265	0.458
30.0	18.0	60.00	0.0281	0.445
34.0	19.0	55.90	0.0280	0.446
36.0	30.0	83.30	0.0295	0.434

TABLE VII

RESULTS OF EXPERIMENTS - TROUGH NO. 6

Weir Height P, ft.	Depth, H, ft.	Velocity, V, ft./sec.	Reynolds Number $N_R = \frac{VH}{\nu}$	Reynolds Number $N_R = \frac{4R_H V}{\nu}$	Froude Number $NF = \frac{V^2}{gH}$
0.050	0.270	1.156	2.024×10^4	3.901×10^4	0.1539
0.050	0.250	1.072	1.743×10^4	3.490×10^4	0.1431
0.050	0.230	0.983	1.470×10^4	3.061×10^4	0.1307
0.050	0.210	0.895	1.223×10^4	2.661×10^4	0.1188
0.050	0.190	0.800	0.988×10^4	2.245×10^4	0.1048
0.050	0.170	0.694	0.767×10^4	1.827×10^4	0.0882
0.050	0.150	0.593	0.579×10^4	1.448×10^4	0.0730
0.100	0.330	1.015	2.179×10^4	3.762×10^4	0.0972
0.100	0.310	0.935	1.886×10^4	3.375×10^4	0.0879
0.100	0.290	0.848	1.600×10^4	2.962×10^4	0.0772
0.100	0.270	0.763	1.340×10^4	2.579×10^4	0.0671
0.100	0.250	0.680	1.106×10^4	2.210×10^4	0.0576
0.100	0.230	0.583	0.871×10^4	1.818×10^4	0.0459
0.150	0.355	0.789	1.821×10^4	3.005×10^4	0.0545
0.150	0.335	0.704	1.535×10^4	2.622×10^4	0.0461
0.150	0.315	0.622	1.275×10^4	2.257×10^4	0.0383
0.150	0.290	0.524	0.988×10^4	1.830×10^4	0.0295
0.150	0.270	0.437	0.767×10^4	1.475×10^4	0.0220

TABLE VII (Continued)

RESULTS OF EXPERIMENTS - TROUGH NO. 6

Grit Added ml.	Grit Trapped ml.	Percent Grit Trapped	Darcy-Weisbach Friction Factor, f	Calculated Score/Velocity, V_c, ft./sec.
30.0	4.0	13.33	0.0243	0.478
25.0	5.0	20.00	0.0249	0.473
28.0	8.0	28.55	0.0256	0.466
27.0	10.0	37.00	0.0265	0.458
31.0	16.0	51.60	0.0261	0.462
28.0	19.0	67.90	0.0285	0.442
34.0	30.0	88.25	0.0200	0.431
31.0	6.0	19.35	0.0240	0.481
30.0	7.0	23.35	0.0248	0.474
40.0	12.0	30.00	0.0257	0.465
28.0	14.0	50.00	0.0262	0.461
35.0	20.0	57.10	0.0275	0.450
40.0	29.0	72.55	0.0283	0.443
20.0	5.0	25.00	0.0251	0.471
29.0	14.0	48.25	0.0260	0.462
34.0	20.0	58.80	0.0259	0.463
46.0	32.0	69.55	0.0280	0.446
20.0	16.0	80.00	0.0293	0.436

TABLE VIII

ADJUSTED* AVERAGE VALUES FOR TROUGHS INVESTIGATED

Trough Number	Adj. Ave. % Grit Trapped	Adj. Ave. Velocity	Adj. Ave. N_R	Adj. Ave. N_F
1	54.18	.663	1.048	.0644
2	51.542	.656	1.022	.0649
3	52.51	.627	1.014	.0581
4	49.48	.738	1.251	.0730
5	49.65	.686	1.116	.0665
6	46.70	.783	1.345	.0798

*Adjusted average = average of central values with extreme values eliminated.

TABLE IX

ARRAY OF THE VALUES OF PERCENT GRIT TRAPPED AFTER ELIMINATION OF CERTAIN DATA

1	2	3	4	5	6	Trough No.
95.60	98.00	100.00	100.00	83.35	88.25	
92.25	83.30	87.00	78.30	83.30	80.00	
89.70	80.95	83.75	77.80	88.30	72.55	
82.80	72.55	80.00	76.50	81.50	69.55	
75.00	72.25	80.00	66.66	62.95	67.90	
69.25	71.80	77.40	64.55	61.10	58.80	
65.30	69.00	67.50	50.00	60.00	57.10	
64.30	55.35	60.00	50.00	55.46	51.60	
60.75	50.68	56.00	48.15	54.55	50.00	
53.36	40.00	46.35	42.90	54.15	48.25	
46.15	38.10	41.80	42.10	43.50	37.00	
37.70	35.30	33.35	38.45	35000	30.00	
33.55	34.41	32.25	35.00	31.25	28.55	
30.22	32.90	31.18	31.22	28.55	25.00	
25.37	28.57	26.10	30.77	26.65	23.35	
22.21	22.50	22.50	26.08	22.21	20.00	
21.15	22.21	12.50	17.85	18.18	19.35	
10.52	20.00	6.67	14.30	8.33	13.33	
60.75	50.68	56.80	48.15	54.55	50.00	**Adj. Median**
54.00	42.85	41.80	48.15	54.15	50.00	**Tot. Median**
1	4	2	6	3	5	**Adj. Med. Grades**
2	5	6	4	1	3	**Median Grade**
3	9	8	10	4	8	**Tot. Med. Grade**

NOTES:

1. **Adjusted median = median of data not eliminated**
2. **Total median = median of all data**
3. **Adjusted median grade = ranking number of adjusted median**
4. **Median grade = ranking number of total median**
5. **Total median grade = sum of the adjusted median grade and median grade**

TABLE X

ACTUAL SCOUR VELOCITIES, V_o, CORRESPONDING CALCULATED SCOUR VELOCITIES, V_c, AND THEIR CORRESPONDING "FRICTION FACTORS", f, FOR EACH WEIR SETTING AND TROUGH INVESTIGATED

Trough Number	Weir Setting	V_o	f_o	V_c	f_c
1	.15	.365	.040950	.471	.0246
2	.15	.320	.05330	.47175	.02455
3	.15	.385	.03681	.46575	.02520
4	.15	.445	.02760	.47675	.02405
5	.15	.370	.03950	.47575	.02410
6	.15	.450	.02822	.4754	.02420
1	.10	.495	.02230	.471	.0246
2	.10	.430	.02950	.47175	.02455
3	.10	.445	.02760	.46575	.02520
4	.10	.470	.02475	.47674	.02405
5	.10	.445	.02760	.47575	.02410
6	.10	.510	.02100	.4754	.02420
1	.05	.5450	.01839	.471	.0246
2	.05	.5450	.01839	.47175	.02455
3	.05	.5125	.02000	.46575	.02520
4	.05	.650	.01292	.47675	.02405
5	.05	.600	.01519	.47575	.02410
6	.05	.630	.01375	.4754	.02420

TABLE XI

CALCULATED SCOUR VELOCITY GRADES

(Ref: Figure Number 10)

Trough Number	Slope	Performance	Grade
1	5	4	11
2	6	6	12
3	2	5	7
4	5	2	7
5	4	3	7
6	3	1	4

Note: The best curve should have the sleepest slope and should show the highest percentages of grit trapped.
Grade = ranking of performance of troughs.

TABLE XII

REYNOLDS NUMBER GRADES USING $D=4R_H$ IN REYNOLDS NUMBER FORMULA

Trough Number	Slope	Performance	Grade
1	5	2	11
2	6	3	12
3	2	3	7
4	5	1	7
5	4	2	7
6	3	1	4

TABLE XIII

TROUGH RATING CHART SHOWING TOTAL GRADE AND GRADES GIVEN FOR VARIABLES RATED

		Grit Trapped vs. Velocity			Grit Trapped vs. Reynolds No.	Adj. Ave. Grit Trapped	Adj. Ave. Velocity	Adj. Ave. NR	Adj. Ave. N_F	Median % Trapped
Trough Shape	Trough Number	.05	.10	.15						
	1	4	4	3	3	1	5	4	4	3
	2	5	6	6	4	3	4	6	3	9
	3	3	2	4	5	2	6	5	5	8
	4	1	3	2	2	5	2	2	2	10
	5	3	5	5	3	4	3	3	3	4
	6	2	1	1	1	6	1	1	1	8

Note: R_H = hydraulic radius; N_R = Reynolds Number; N_F = Froude Number

TABLE XIII (Continued)

TROUGH RATING CHART SHOWING TOTAL GRADE AND GRADES GIVEN FOR VARIABLES RATED

Trough Shape	Trough Number	Grit Trapped vs. Froude No.			Critical Velocity		Grit Trapped vs. N_R using R_H	Total Grade
		.05	.10	.15	Slope	Perform.		
	1	5	3	3	5	4	2	53
	2	4	5	5	6	6	3	75
	3	6	4	4	2	5	3	64
	4	1	2	2	5	2	1	42
	5	3	3	4	4	3	2	52
	6	2	1	1	3	1	1	31

TABLE XIV

VALUES OF THE CAMP CONSTANT "B" AND THEIR CORRESPONDING ACTUAL AND CALCULATED SCOUR VELOCITIES

V_L	B_L	V_C	B_O	V_O	Weir Setting
.471	.0488	.426	.0293	.365	.15
.47175	.0489	.426	.02255	.320	.15
.46575	.0477	.426	.0326	.385	.15
.47675	.0500	.426	.0436	.445	.15
.47575	.0498	.426	.08015	.370	.15
.4754	.04975	.426	.0445	.450	.15
.471	.0488	.426	.0539	.495	.10
.47175	.0489	.426	.0407	.430	.10
.46575	.0477	.426	.0436	.445	.10
.47675	.0500	.426	.0486	.470	.10
.47575	.0498	.426	.0436	.445	.10
.4754	.04975	.426	.0572	.510	.10
.471	.0488	.426	.0653	.545	.05
.47175	.0489	.426	.0653	.545	.05
.46575	.0477	.426	.0578	.5125	.05
.47675	.0500	.426	.0929	.650	.05
.47575	.0498	.426	.0792	.600	.05
.4794	.04975	.426	.0873	.630	.05

$\Sigma B_L = 88485$ $\Sigma B_O = .93810$

$\bar{B}_L = .04916$ $\bar{B}_O = .05211$ $\bar{\bar{B}} = .0506$

V_L = Calculated Scour Velocity
V_C = Camp's Scour Velocity
V_O = Actual Scour Velocity
B_L = Constant using Calculated Scour Velocity
B_O = Constant using Actual Scour Velocity
$\bar{B}$ = Average values of the Constant
$\bar{\bar{B}}$ = Average of all values of the constant

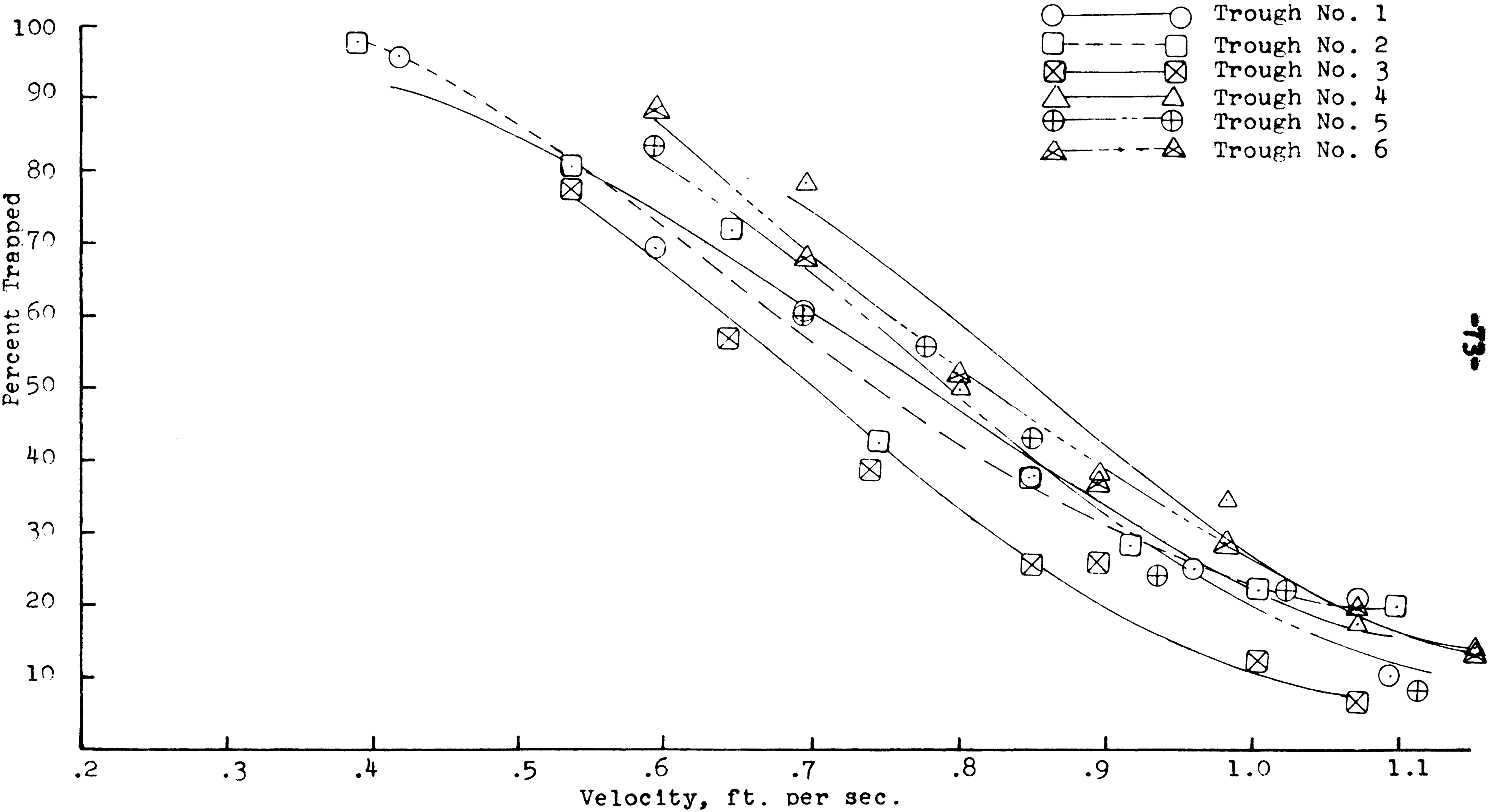


FIGURE 5. Effect of Velocity in Channel on Capture of Grit, at Weir Setting of 0.05 ft.

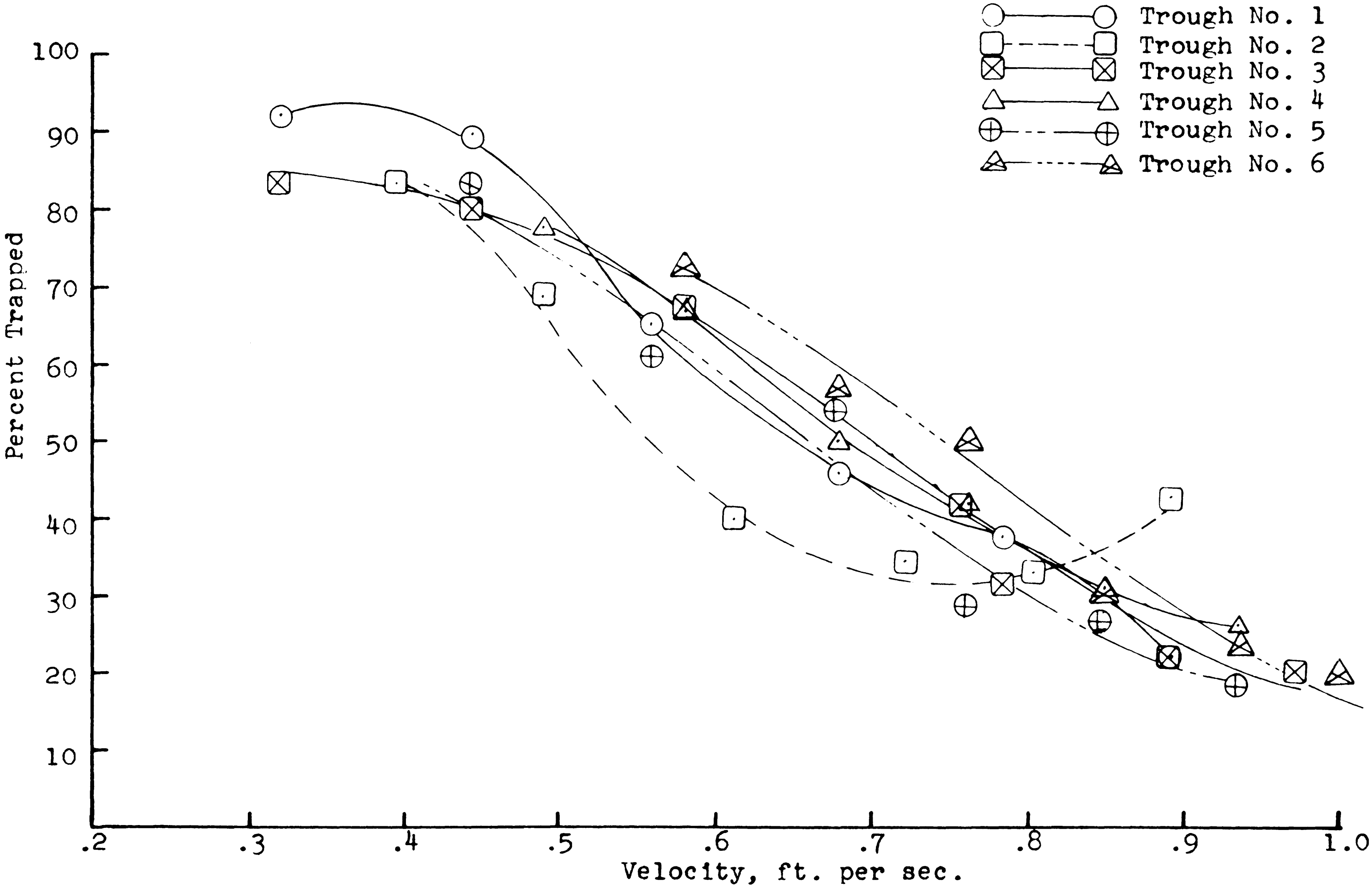


FIGURE 6. Effect of Velocity in Channel on Capture of Grit, at Weir Setting of 0.10 ft.

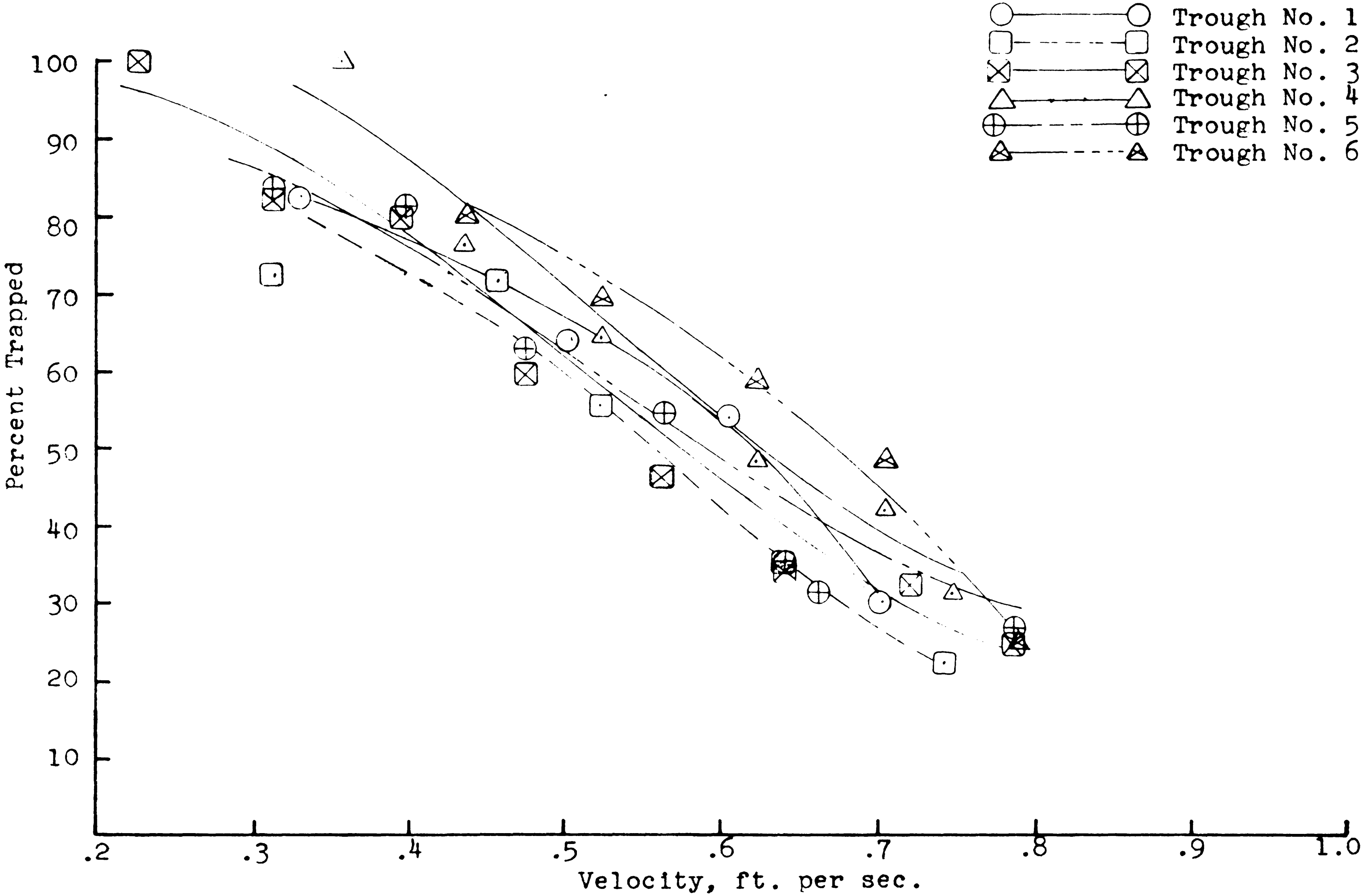


FIGURE 7. Effect of Velocity in Channel in Capture of Grit, at Weir Setting of 0.19 ft.

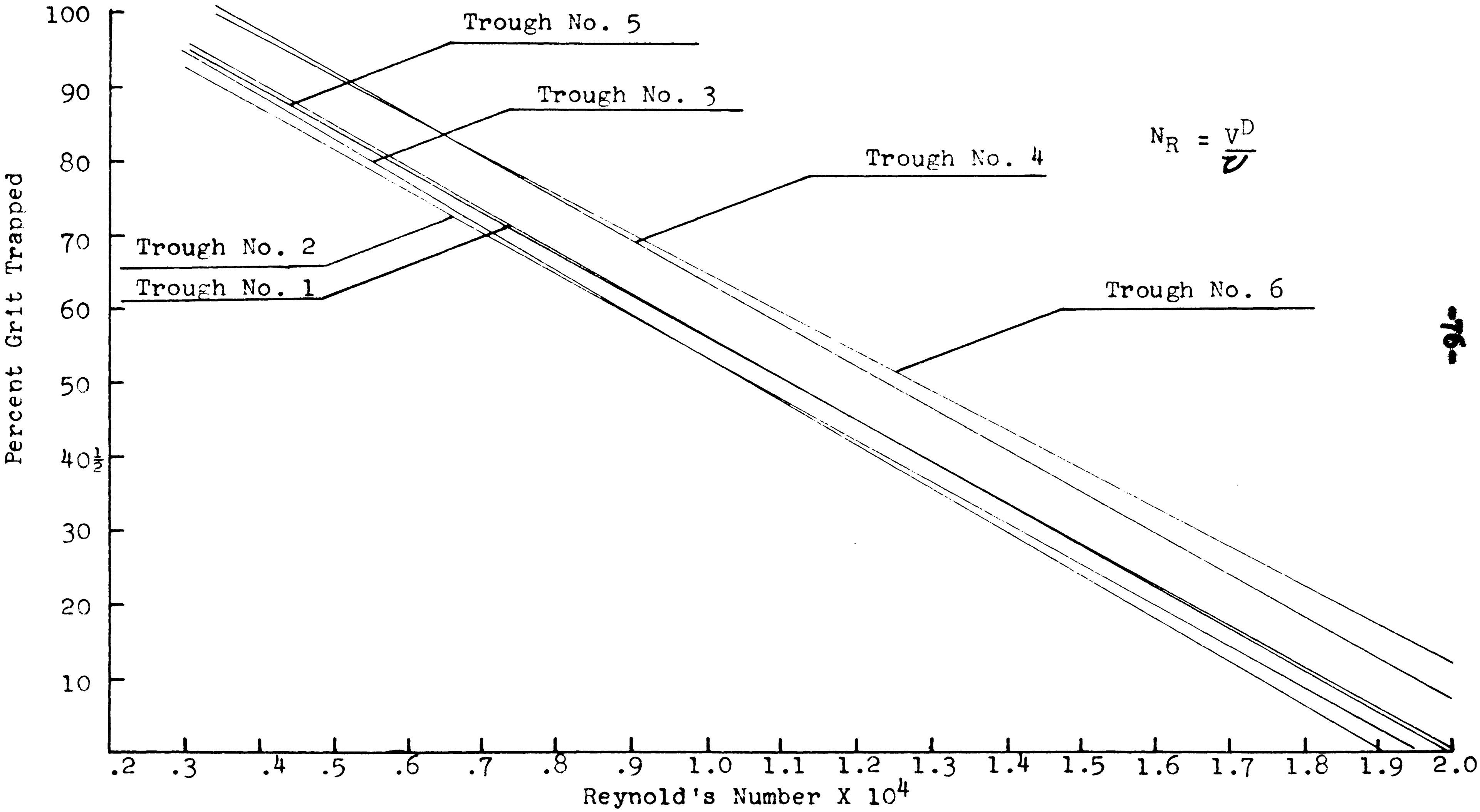


FIGURE 8. Percent Grit Trapped vs. Reynolds Number for all Weir Settings and for all Troughs

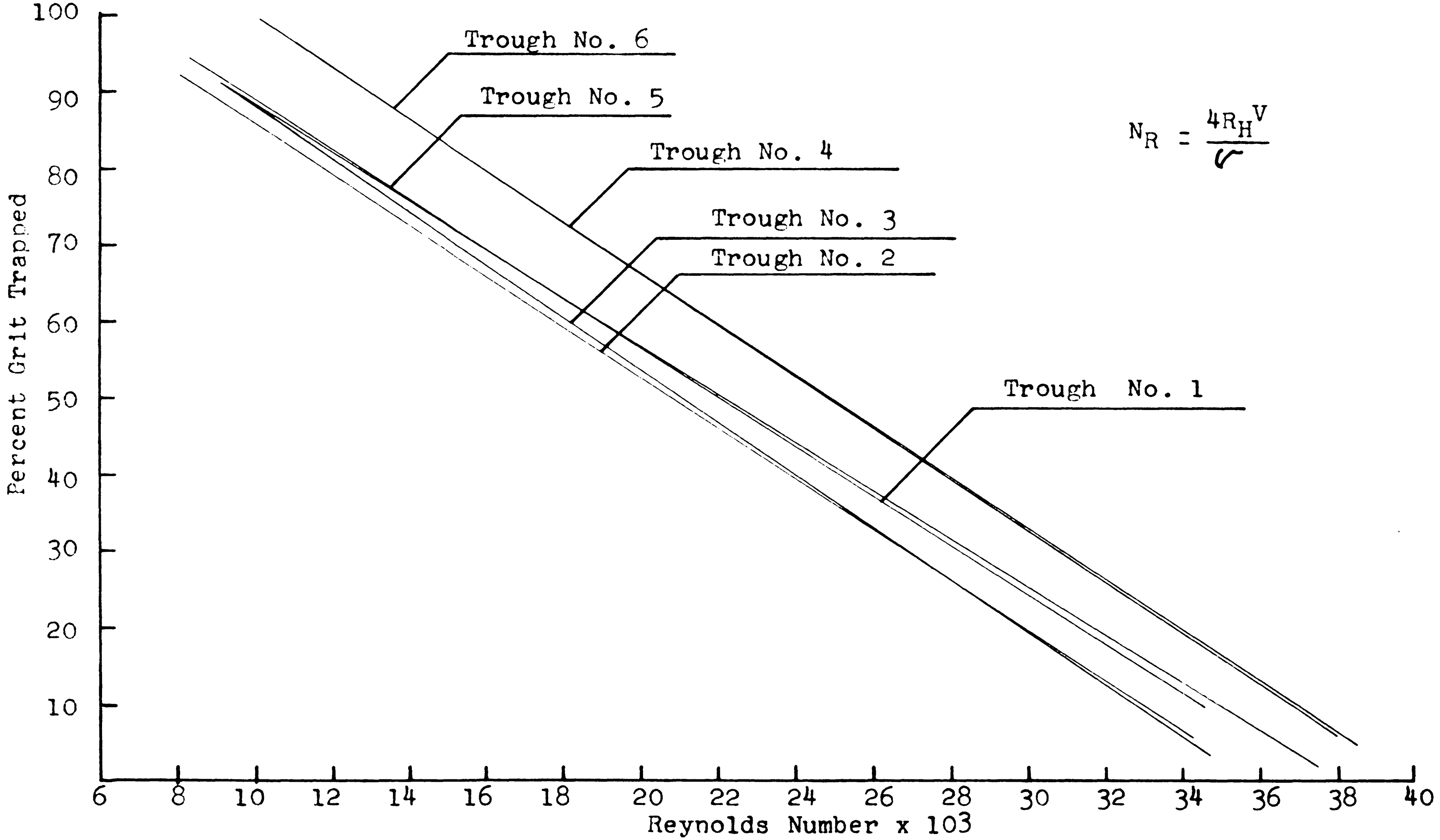


Figure 9. Percent Grit Trapped vs. Reynolds Number for all Weir Settings and for all Troughs

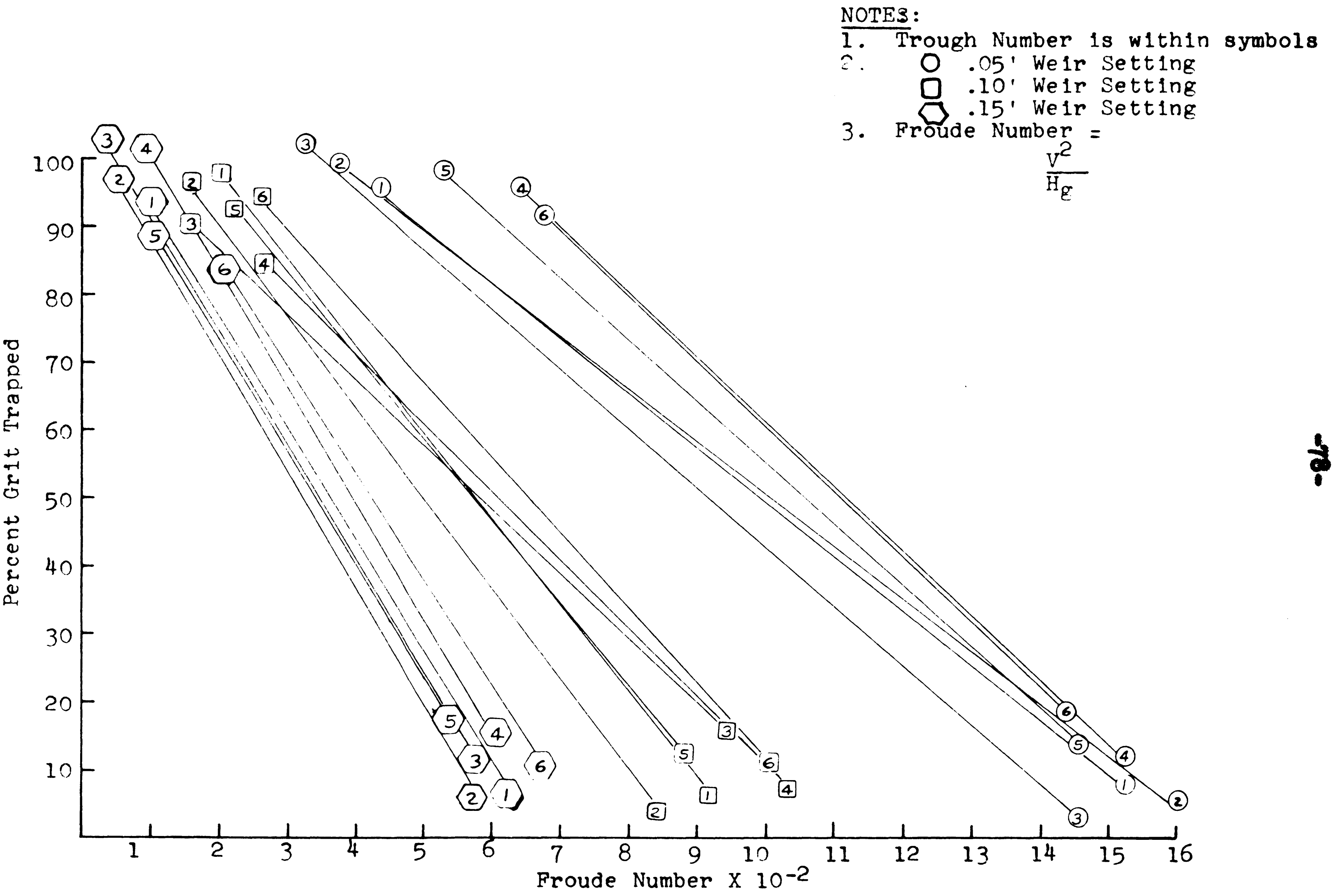


FIGURE 10. Percent Grit Trapped vs. Froude Number for all Weir Settings and for all Troughs

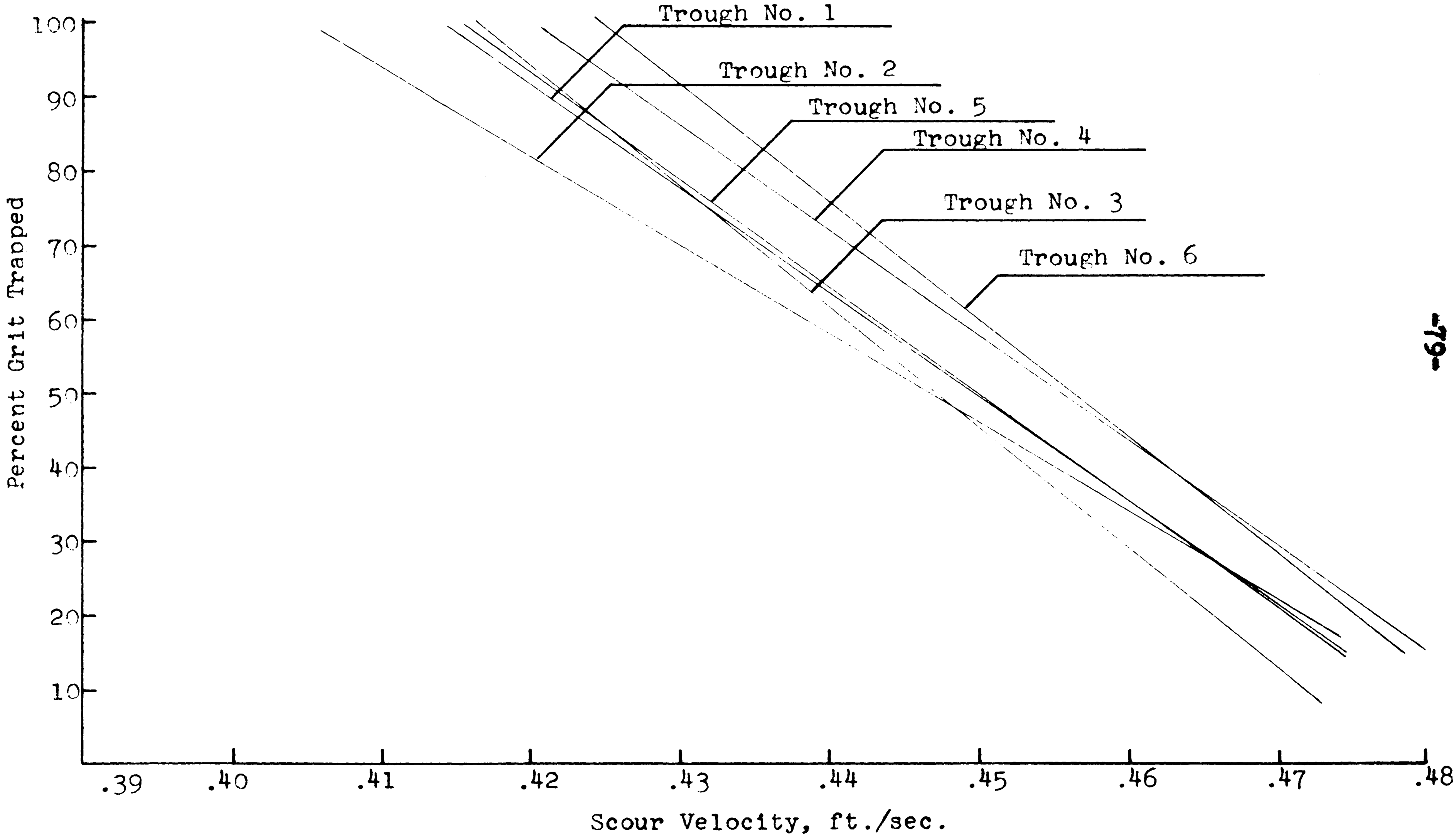


FIGURE 11. Percent Grit Trapped vs. Calculated Scour Velocity for all Troughs

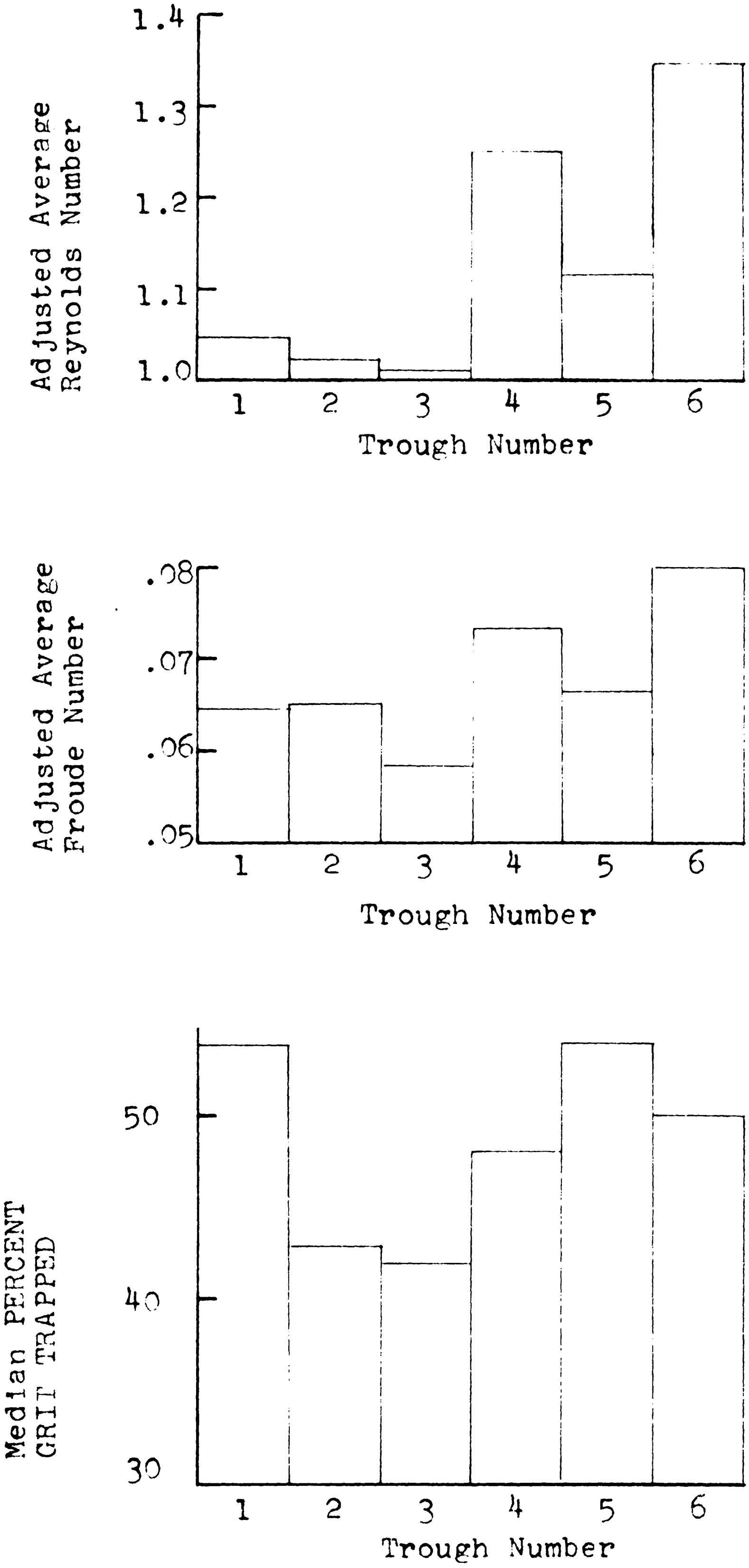


FIGURE 12. Bar Graphs of Selected Variables Showing Comparisons Between Troughs

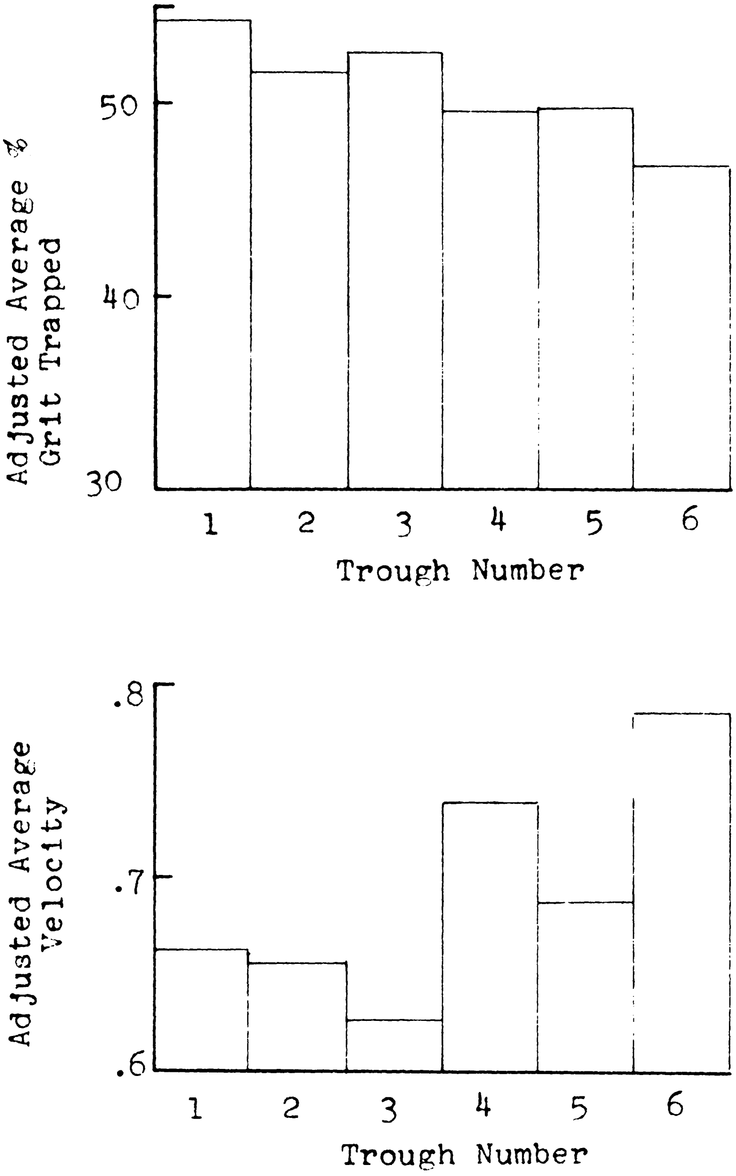


FIGURE 13. Bar Graphs of Selected Variables Showing Comparisons Between Troughs

V. CONCLUSIONS

This investigation led to the following conclusions:

1. Additional study should be made of what effect prolonged running of the grit chamber would have upon percent grit captured.

2. Additional data is needed in order to develop flow formula for grit chambers. The writer suggests that several series of additional experiments be run; one series using a constant Reynolds Number, one series using a constant Froude Number, and one series using a constant depth parameter.

3. There should be additional study of Camp's scour relation in order to find a "B" constant that would more closely describe the flow of grit in the chambers. It is suggested that more accurate scour velocities may be attained if "friction factors" were used in Camp's relation that corresponded to the actual Reynolds Number and relative roughness in the grit chamber.

4. The overall efficiency of Trough 6 seemed to have been the best, although there appeared to be no rational explanation for this finding.

The significance of this thesis was two-fold. It did indicate the complexity of the problem of grit chamber sedimentation, and it did indicate the trough shapes that seemed to be the most efficient.

VI. SUMMARY

The object of this work was to investigate the effect of geometry on the performance characteristics of grit collection troughs that serve to collect and store grit captured by grit chambers.

A model grit chamber made of marine plywood containing interchangeable plastic troughs was used to gather data. Six plastic trough shapes were constructed so that comparison studies could be made of the following trough shape factors: downstream slope, upstream slope, and depth to width ratio. Water flow of various depths and velocities was introduced from a water main into the chamber after which sand of a measured amount and specified size was added to the chamber. This procedure was used to investigate all six trough shapes.

For each experiment, performance of each trough shape was determined by halting the flow after all the sand had been added to the chamber and measuring the amount of sand captured in the chamber and trough; then finding the percent grit trapped.

The study showed that Trough 6 exhibited the best efficiency for the capture of grit. Trough 6 had a 2:1

downstream slope, a vertical upstream slope, and a bottom that was about twice as long as the depth of the trough. The study also showed that Camp's scour relation appeared to show agreement with the phenomena in the chamber.

VII. ACKNOWLEDGEMENT

The author wishes to express his appreciation to his thesis advisor, Dr. W. A. Parsons, for his advice, encouragement, guidance, and constructive criticism during the entire graduate program.

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ABSTRACT

Investigation of Effect of Geometry on Performance of Grit Collection Troughs

by

Benjamin A. Lacy

An investigation has been made to determine the effect of geometry on the performance of six collection troughs that served to collect and store grit captured by a model grit chamber. The grit employed was a 0.1mm sand fraction obtained by sieving and the width of the channel of the model grit chamber was 0.5 ft. Over a hundred experiments were performed which spanned a range of velocities of from 0.31 to 1.1 ft/sec and a range of depths of from 0.1 to 0.36 ft. The performance of the grit chamber - collection trough units was evaluated in terms of percentage grit capture under comparable flow conditions and observation of grit travel patterns.

The results indicated that the performance of the troughs was influenced by the volume, the depth to length ratio and the slope of the upstream and downstream walls. High performance appeared to be induced by large volumes, moderate depth to length ratio, vertical upstream wall slope, and a downstream slope of 2 vertical to 1 horizontal.