STREAM GAGING CONTROL STRUCTURE FOR THE RIO GRANDE CONVEYANCE CHANNEL NEAR BERNARDO, NEW MEXICO

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PRELIMINARY REPORT

Hydraulic Model Studies

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INTRODUCTION

Early in 1961 the U. S. Bureau of Reclamation began a 5-year water salvage study on the Bernardo to San Acacia reach of the Rio Grande in New Mexico. In this reach a conveyance channel is used to transport part of the river flow (fig. 1). The Rio Grande conveyance channel is designed to transport all river flows up to 2000 cfs. River water not carried in the conveyance channel flows down the old river channel now used as a flood way. In order to properly evaluate their study involving the effects of eradicating the salt cedar growths accurate stream flow records are necessary on the conveyance channel.

Presently a gaging station is located on the downstream side of a highway bridge 5 miles downstream from the diversion structure. The top width of the channel ranges from 80 to 95 feet and the bottom width from 75 to 85 feet (fig. 2). Flows greater than 100 cfs occupy the full width of the channel. Those flows less than 100 cfs meander on the stream bed. The channel bed is composed of fine sand with a median fall diameter of 0. 24 mm. Discharge measurements are made once or twice a week. Wading measurements are made in the vicinity of the gage for discharges less than 500 cfs and all other discharges are measured from a cable way 80 feet upstream from the bridge. These measurements indicate that two different stage-discharge relationships exist, one for a dune bed and slow velocities (lower flow regime) and one for a plane bed and fast velocities (upper flow regime) (figs. 2 and 3). The shift from lower regime to upper regime flow usually occurs between 500 cfs and 1200 cfs but dune bed conditions have existed for flows as large as 2000 cfs. Measurements numbered 968 to 975 on figures 2 and 3 were made between March and May 1961, and indicates flow and channel conditions at the present time. Discharge measurements at the gaging station indicate a 4-foot range in mean bed elevation (figs. 4 and 5), thus complicating the problem even more. The low bed elevation is considered to be at 1.0-foot gage height. Bankfull stage is at 9.5 feet. Flow duration curve (fig. 6) indicates that the median flow is 280 cfs with flows exceeding 1000 cfs 16 percent of the time.

An agreement was made between the Bureau of Reclamation and the U. S. Geological Survey to design and build a control structure for improving the discharge records by creating an accurate stage-discharge relationship. The Geological Survey was to conduct a model study for determining the most suitable structure and the elevation at which the structure should be set. The findings of the model study were to be presented to the Bureau and a final decision made on the structure through joint consultation between the two agencies. The Bureau of Reclamation is to finance and construct the control.

A preliminary reconnaissance for selecting the control site was made by personnel of the U.S.G.S. and U.S.B.R. on February 8, 1961. A location about 1000 feet downstream from the present gage site was chosen (fig. 2) and an auxiliary gage installed to correlate with gage heights at the present site. The reach of channel selected for the control is illustrated in figures 7 and 8.

The objectives of the model studies were to design a control that would have the following characteristics within the limitations of site conditions:

1. Pass the sand being transported in the channel without an appreciable affect on the stage-discharge relation.
2. Determine a satisfactory position for a bubble gage orifice to measure stage.
3. Provide a stable rating with less than 1.5% change in discharge for a 0.1 foot change in stage.
4. Create a rating from which discharge records with a 5% overall accuracy would be obtained.
5. Determine the proper location and elevation of the structure in the channel.
6. Consider possibility of a suitable discharge measuring section on or near the structure.
7. Consider the possibility of measuring total sediment load.
8. Design and position a simple but effective energy dissipator.
9. Will not restrict the design capacity of the channel (2000 cfs).

The site conditions present many problems in meeting the control objectives. The major problems are:

1. The change in the bed elevation.
2. The variable bed form.
3. The low bankfull stage.
4. The location of the headgates only 5 miles upstream.
5. The fine grained nature of the bed material.

The elevation of the control must be located above the maximum bed elevation to be stable and sediment free. However, the low bankfull stage limits how high above the bed the crest may be placed. Also, the changing bed form creates a problem in locating the crest elevation in that a control crest located too high may result in a rougher dune bed form upstream with greater resistance to flow and consequent larger flow depths. Larger flow depths would restrict the maximum flow capacity of the channel either because of over bank flow or backwater at the diversion structure. If the control crest is located too low above maximum bed elevation then submergence is a problem. The problem of submergence is further complicated in that the changing bed form and bed elevation downstream will result in variable submergence.

The fine grained bed material scours easily creating a problem in designing the energy dissipator and probably will require some riprapping for protection. Also, because the sands erode so easily the amount of horizontal constriction to obtain the desired control sensitivity is limited.

PROPOSED CONTROL

Based on the model studies (see Experimental Procedures and Equipment) conducted in the hydraulic laboratory at Colorado State University, the following control structure (Type K) is proposed for installation at the Rio Grande conveyance channel near Bernardo, New Mexico.

Recommended Control Design

A perspective drawing and cross sections for the recommended control are shown in figures 9 and 10. Model studies indicated that a crest 16 feet wide with a longitudinal slope of 16:1 and transverse slope of 35:1, an approach apron slope of 2:1, and a downstream apron slope of 3:1 would provide a stable control structure body under all but the most severe bed conditions. The transverse crest slope creates a low "V" to provide a higher degree of rating accuracy and to concentrate the low flows. A "V" with a 40:1 lateral slope was found to give a change in discharge, 1.5% or less for 0.01 foot change in gage height at 400 cfs and above (fig. 11). Below 400 cfs the change in discharge for 0.01 foot change in stage increases gradually so that it is 7% at 30 cfs. A transverse slope of 35:1 is recommended for the proposed control. Additional convergence or installation of a sharper "V" notch in the control tends to create an irregular water surface condition and also creates additional scour problems.

A set of baffles mounted on the upstream edge of the crest apron (fig. 10) served to keep the low part of the "V" clear of sand under all model conditions. A small teardrop shaped mounting provided a means of keeping the bubbler gage orifice above any layers of sand that encroached downstream toward the crest. The teardrop was located with its top 0.05 foot below the crest at a point 4 feet upstream from the crest (fig. 10). Based on the water surface profiles (fig. 12) auxiliary orifices could be placed at points 5 feet and 8 feet upstream from the crest. Orifices placed any further than 5 feet upstream from the crest could be affected by a small surface wave or by sand encroachment. Sand intrusion on the control crest outside the baffle zone did not seem to create any unusual water surface conditions or adversely affect the rating.

An energy dissipator sill 1.5 foot high located 16.5 feet horizontally downstream and 4 feet vertically under the crest prevented excessive scour downstream from the control. However, rock riprap on the bed and banks for short distance downstream from the dissipator may be needed. Riprapping along banks in the vicinity of and upstream from the control may also be necessary.

Recommended Control Position

It is recommended that the elevation of the control be located 4.50 feet below bankfull stage. Locating the crest of the control this distance below bankfull stage would position the crest at a gage height of 5.0 foot present gage datum, or 1.3 foot auxiliary staff gage datum at proposed installation site. Discharge measurements, made this spring as plotted on figures 2, 3, and 13, indicate lower regime flow with large depths, low velocities and maximum gage height. Thus, the auxiliary staff gage should indicate maximum water surface conditions. A 1.3 foot elevation of the control crest would correspond to approximately 1.5 foot above the mean bed elevation. However, the control would be located only 0.5 foot above the maximum bed elevation measured in 1958 and would be 0.25 foot lower than the maximum bed elevation measured in 1957. A higher crest elevation is not recommended because of the unknown effects of the control on the bed configuration. That is, the control may change the bed configuration pattern such that resistance to flow would be greater resulting in an increase in depth so that the channel would not operate at design capacity.

The elevation of the control was determined from the model study that indicated that at 2,000 cfs and 100 percent submergence, the upstream water surface elevation would be 4.0 feet above the crest of the control (fig. 14). Subtracting 4.0 feet from the maximum tailwater elevation at 2,000 cfs (fig. 13) gives a crest elevation of 5.25 feet. However, allowing

0.5 foot freeboard from bankful stage (9.5 feet) gives a crest elevation of 5.00 feet. This latter elevation was the one selected for the control.

With the control set at 5.00 feet gage height elevation, the data from the present gaging station indicates free fall for flows below 300 cfs under maximum tailwater conditions. However, at average tailwater conditions free fall should prevail up to 1100 cfs. To indicate possible measurement scatter resulting from variable submergence, the rating curves shown in figures 15 and 16 were constructed. Figure 15 was constructed considering the crest located at 1.3 foot auxiliary gage height. Figure 16, for a 1.8 foot crest auxiliary gage height, indicates the improvement in the rating if the control height is increased 0.5 foot. The curves show the maximum scatter that would be anticipated resulting from variable submergence. From the flow duration curve (fig. 6) it can be seen that free fall conditions could be expected 50 percent of the time under maximum submergence conditions and 87 percent of the time under average submergence conditions.

Discharge Measurements on the Control

Vertical velocity curves taken at a cross section 9 feet upstream from the control crest are shown in figures 17 and 18. Slight velocity irregularities are indicated directly downstream from the baffles. However, reasonably good mean velocities could be obtained in the baffle area by using the three point method (Corbett and others). Outside the baffle area, or from 8 feet either side of the crest to the banks there is indication that 0.6 foot depth readings would provide a velocity as close or closer to the true mean than the 0.2 foot and 0.8 foot depth method. Small horizontal angles may exist downstream from the baffles, although the model study indicates that the angles are negligible.

The vertical velocity curves are actually plotted to model velocities. By multiplying by the factor 3.15 to convert to prototype velocities it is evident that velocities exceeding 8 feet per second are possible for free fall conditions at 2,000 cfs. Actually the control should be in submergence at the higher flows so it is unlikely that the velocities would exceed 6 feet per second. Because of the longitudinal and transverse crest slope, care must be used in sounding and positioning the meter that the true depth and velocity are measured. This may require heavier sounding weights than are normally used.

Sediment Sampling from the Control

A curb 0.2 foot high installed at a position 0.5 foot vertically below the crest on the downstream apron (fig. 10) provides a means of taking total sediment load samples. The design and location of the curb was derived from a study made in conjuction with the energy dissipator. The horizontal fillet upstream from the curb eliminated excessive water surface disturbance on the apron and improved the vertical distribution of the sediment. The curb, in addition to improving the sediment distribution, provides a satisfactory means of sampling the total flow depth by providing a means for the sample nozzle to touch the apron floor. The curb was was located 0.5 foot below the crest to eliminate any possibility of it affecting the depth-discharge relation. It was not located any lower to eliminate the possibility of the bed covering the sampling point under adverse conditions. Samples could be obtained from the curb under low-flow conditions by wading on the control and reaching downstream to sample the flow. Naturally, care would have to be used, when sampling in this method, not to disturb the flow upstream of the sampler. Sampling under high flow conditions would have to be accomplished using a guide to position the sampler. It is suggested that a channel iron be bolted to the apron and the area between the apron and the upstream leg filled with cement. The area between the upstream and downstream legs of the channel left open to serve as guide rod supports. Another possibility would be to use the angle between the apron and the horizontal fillet as guide rod supports.

Accomodations could be provided for the piping from the pump sampler to be mounted either in the curb fillet or downstream from the lower leg of the channel iron. If a pump sampler is used, it is recommended that two nozzles be installed. One nozzle downstream from the low point in the control and the other nozzle downstream from the 1/3 position. The baffle clearing effect in the center of the control should be considered when obtaining pump samples. By proper calibration of the two nozzles accurate total sediment load samples should be obtained.

Suggestions for Contruction and Operation

A control built of loosely grouted rock to a depth of 11 feet below bankfull stage or 2.5 feet below low bed elevation should provide a stable structure. Cut off walls of sheet piling at or near the upstream and downstream toes of the weir would add to the stability. A 3 to 5 inch concrete cap should be placed over the control. A smooth crest surface would decrease backwater and the possibility of large sand deposits as was indicated in baffle studies. Possible exposure of the bare rocks on the downstream apron may be useful for added dissipation of energy.

Discussions with personnel associated with the Dunning flume (Benedict and others) indicate that baffles constructed of sheet steel welded to angle irons would be superior to the mounting used for the Dunning installation. Bolts could be set in the proper position on the control apron and the welded angle iron baffles installed or removed as was needed.

Installation of a simple tailwater gage at a point 60 feet downstream from the control crest (this distance provided representative tailwater readings in the model studies) would provide submergence information. A small well and shelter with continuous recorder would be adequate. Low water record at this tailwater gage would be unnecessary since submergence would only occur at the higher flows.

EXPERIMENTAL PROCEDURES AND EQUIPMENT

The model study was broken down into three phases. First, two-dimensional models were tested in the 2-feet by 60-feet flume to determine the most suitable design. This design was then checked and modified by a three-dimensional model in the 8-feet by 150-feet flume. The third phase was the development of an energy dissipator to decrease downstream scour.

In order to simulate the different bed forms that occur in the prototype in the 2-feet flume, the slope of the flume was varied. With a slope of 1.0%, a plane bed existed for all model discharges. With a slope of 0.7%, a plane bed existed for discharges larger than about 1000 cfs and dune bed form below. With a slope of 3%, dune bed existed for all discharges. Ratings were established for each control for the different flume slopes.

Flume slope was not changed in the 8-feet flume. Instead the vertical position of the control was changed to create the various bed conditions.

Flumes

The 2-feet wide flume used in the two-dimensional study was 60 feet long and 2.5 feet deep. The walls were plexiglass and the bottom was metal. The flume was equipped with a 12-inch centrifugal pump that recirculated sediment and flows up to 7.5 cfs. The discharge was regulated by a gate valve and measured by a calibrated orifice in the discharge line. The slope of the flume could be changed automatically.

The 8-feet wide flume used for the three-dimensional study was 150 feet long and 2 feet deep. The walls were plexiglass and plywood and the bottom was plywood. The flume was equipped with a 12-inch and a 19-inch recirculating pump system with a discharge capacity of up to 21 cfs. The discharge was regulated by valves and measured by calibrated orifice meters in discharge lines from each pump. In this study either a 12-inch or a 19-inch recirculating pump was used. They were never used in combination. To model the control structure, it was installed 12 feet from the downstream end. To study the effect of submergence an adjustable gate at the downstream end of the flume was used to create backwater. To study the energy dissipator for control K it was moved upstream 60 feet to obtain a sufficient length of sand bed to determine the limits of scour.

Sediment

The sediment used in the 2-feet flume was quartz sand having a median fall diameter of 0.33 mm with a 2.65 specific gravity. The material in the 8-feet flume was quartz sand with a median fall diameter of 0.19 mm and a specific gravity of 2.65. The sediment in both flumes was about 0.5 foot deep.

Weir Models

Models were made of 3/4 inch plywood with some variations made with sheet metal and molding plaster. Various models were tried but all were designed using the basic dimensions found most favorable in the Del Rio Studies, Karaki, 1961. All models had a downstream apron slope of 3:1 and an upstream apron slope of 2:1.

Model Scales

A scale of 1:8 was chosen for the two-dimensional studies. This scale was chosen to amplify more detail of the basic structure shape than would appear in the 8-feet flume. This scale related only to the structure and the fluid flow, and not to the sand grain size or dune heights. The following relationships apply:

$$L_r = \frac{L_p}{L_m} = 8$$

$$q_r = \frac{q_p}{q_m} = (L_r)^{3/2} = 22.6$$

$$Q_p = 22.6\ q_m \times 70$$

$$V_r = \frac{V_p}{V_m} = (L_r)^{1/2} = 2.83$$

A scale of 1:10 was used in the 8-feet flume. This was a convenient ratio because the average prototype channel width is 80 feet, hence 0.1 on the model represents 1 foot on the prototype. The following relationships apply on the 8-feet flume models:

$$L_r = \frac{L_p}{L_m} = 10$$

$$q_r = \frac{q_p}{q_m} = (L_r)^{3/2} = 31.6$$

$$V_r = \frac{V_p}{V_m} = (L_r)^{1/2} = 3.16$$

$$Q_p = 31.6\ q_m \times 80$$

EXPERIMENTAL RESULTS AND DISCUSSIONS

Weir A

The weir A, figure 19, was a modification of Karaki's (1961) type G control. A transverse slope to create a slight "V" shape was incorporated into the downstream control lip to create better accuracy and to confine the low flows. It was found that an undesirable wave was created just upstream from the lip at flows over 900 cfs.

After a short period the sand moved in and covered the apron upstream from the control lip. This eliminated the control from consideration.

Weir B

Weir B incorporated a longitudinally sloping crest similar to Karaki's type F control (fig. 20).

During tests of high flows the crest stayed clear but at flows below 800 cfs fingers of sand encroached to within 2 feet of the crest.

Weirs C, D, E and F

Weirs C, D, E and F (fig. 21) were tested using the same basic shape as weir B but with a longitudinal crest slope of 18:1. Also, various forms of transverse sloping crests were superimposed on the basic 18:1 longitudinal slope to concentrate the flow, to improve the rating, and to increase movement of sand over the control. Weirs C, D, and E represented varying degrees of convergence. The sand was swept across the apron for all flows 500 cfs and greater. Below 500 cfs the sand encroached to within 1 foot of the crest and was concentrated in the middle. Convergence of the flow to the center was noticeable on all three controls. Adverse waves were also present. Weir F was the same as weir E except that baffles were mounted on the upstream edge.

Three rows of baffles were used with spacing and heights similar to the turbulence flume on the Middle Loup River (Benedict and others, 1953), (see Baffle Studies). The three rows of baffles were not effective in keeping the control clear of sand and created an irregular water surface. Although these controls had some undesirable characteristics it appeared that with further modification a more suitable control would evolve. Stage-discharge curves are shown in figure 25.

Weir G

Weir G incorporated a "V"shaped apron with an longitudinal 18:1 crest slope and transverse 35:1 crest slope (fig. 22). Water surface conditions were relatively smooth throughout the various flows. At flows below 500 cfs there was a tendency for the sand to collect in the low part of the control. Deflecting baffles were tried upstream on the control and by proper positioning the sand in the "V" was eliminated (fig. 26).

Weir H

Based on the favorable results found in weir G, a new basic control called weir H was installed for further and more detailed study. This control had a 16:1 longitudinal crest slope, but no transverse slope to converge the flow (fig. 23). Rating for weir H is shown in figure 28.

Weir I

Weir I was a modification of H whereby a transverse crest slope was added. The longitudinal crest slope was 16:1, and the transverse slope was 18:1 (fig. 24). This control gave a smooth and even rating (fig. 28), except that at the 1 percent slope there was a shift in critical flow point between 1000 and 15,000 cfs. It is believed that this results from modeling technique to obtain a plane bed and will not occur in the prototype. Sand rode up the low part of the "V" to within 2 feet of the crest. A set of deflecting baffles was installed at the upstream edge of the crest. This cleared off the low part of the crest. The transverse crest slope resulted in an undesirable convergence of the flow.

Weir J

This weir was the same as weir I except that the transverse crest slope was changed to 35:1 (fig. 24). The rating for this control had the same shape control as I at the 1 percent slope (fig. 28). Baffle arrangement 2 and 9, table 1, were effective in keeping the crest free of sand as illustrated in figure 27.

Based on the favorable results obtained in the two-dimensional model study control J was selected for study in the 8-feet flume. In the 8-feet flume the longitudinal crest slope was 16:1, the transverse crest slope was 40:1, the approach apron slope was 2:1, the downstream apron slope was 3:1, and there was variable slope in the transition from the approach apron to the control crest. A comparison of the basic control (control H) and the J control as model in the 8-feet flume is given in figure 29. Also included in the figure is a comparison of the J control as modelled in the 2 and 8-feet flumes. It is obvious that the two-dimensional model study did not take into account the effect of converging the flow with the transverse slope.

A series of 40 baffles was installed at the upstream edge of the transition from the approach apron to the crest. The transition slope on the upstream end of the apron rendered the outside baffles ineffective. Also, small bits of debris collected on the closely spaced baffles.

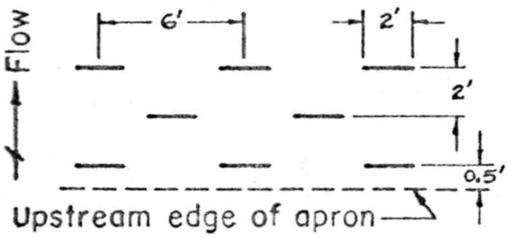
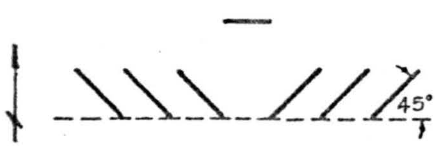
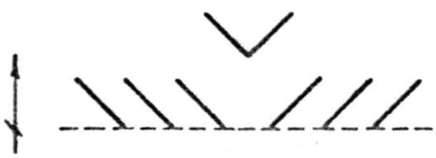
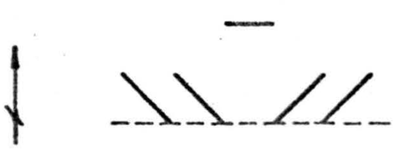
<u>Weir K</u>

Weir J was modified to obtain weir K to eliminate unfavorable water surface conditions and to simplify the control shape for easier construction. This control design was tested and recommended for installation at the proposed site (see Proposed Control). A comparison of the ratings for the J and K control in the 8-feet flume is given in figure 30.

BAFFLE STUDY

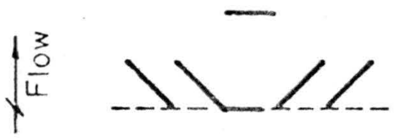
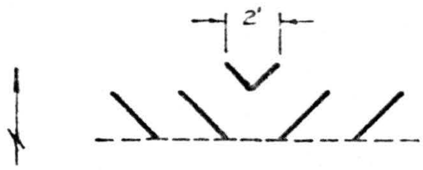
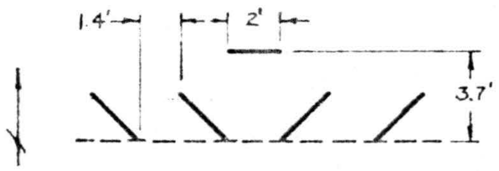
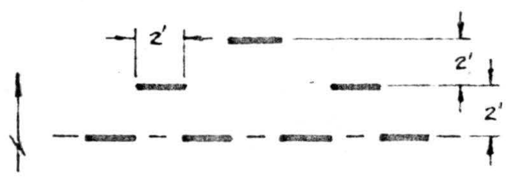
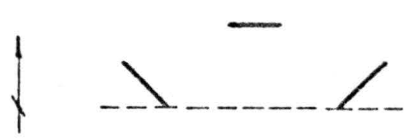
A study was made of the effectiveness of baffles located on the upstream edge of the controls in keeping the control clear of sand. The most effective system was No. 9, table. 1. This baffle arrangement kept the crest clear of sand, created less water surface disturbance, and created less horizontal angle on the crest than any other system modelled. The baffles in the upstream row were the same dimensions as those used in the Dunning flume, i.e.: 1.0 foot high and 2.0 feet wide. The downstream baffle was 0.5 foot high and 2.0 feet wide. The baffles created less water surface disturbance and were still effective when the top of the upstream row of baffles was set 0.1 foot prototype distance below the level of the control crest. However, if the baffles were set at too great a distance below crest elevation they were less effective. The baffles study is summarized in table 1.

Table I **BAFFLE MODEL STUDY**

Baffle Positioning	Water Surface	Clearing Effectiveness
 Position No. 1	Extremely rough for all flows.	Not too effective; slows down velocity so that sand will deposit on apron.
 Position No. 2	*HF: A little choppy. **LF: Pretty choppy	Very good, but would make angular flow for measuring.
 Position No. 3	HF: Fairly smooth. LF: Still a little choppy, but smoother than No. 1.	Clears sand out at high flows (1000 and up). "V" baffle not as effective at low flow.
 Position No. 4	HF: High hump at upstream baffles. LF: Creates bad wave in front of front baffle.	Not as effective at high or low flow because it seems to slow down velocity and allow sand to deposit.
 Position No. 5	Same as No. 2.	Middle 6 to 8' of apron is kept clean.

*HF = high flow
**LF = low flow

Table I **BAFFLE MODEL STUDY (Cont.)**

Baffle Positioning	Water Surface	Clearing Effectiveness
 Position No. 6	Same as No. 3.	Same as No. 3.
 Position No. 7	Same as No. 5.	Same as No. 5.
 Position No. 8	Same as No. 2, except does not cause as much turbulence.	Does not spread sand out quite as much as No. 2.
 Position No. 9	Same as No. 8 except slightly more turbulence - but less than No. 2.	Less angular flow than No. 2. Does not spread sand out quite as much as No. 2. More effective than No. 8.
 Position No. 10	Very rough.	Same as No. 1.
 Position No. 11	Smoother than Nos. 2 or 9.	Fair. Not quite as good as Nos. 2 or 9.

ENERGY DISSIPATOR STUDY

A model study was conducted to determine the most effective energy dissipator to control and minimize downstream scour.

It must be emphasized that model studies of scour can only give qualitative results not quantitative. That is, the model will indicate favorable conditions such as a reverse roller that keeps sand piled against the downstream toe of the structure and it can be presumed when comparing various designs that the design that performs best in the laboratory will also perform best in the field. For this reason the results of the test are reported in model dimensions except that for continuity discharge is given as prototype.

The study involved the use of various height sills located at various positions on the downstream 3:1 sloping apron. Also, baffles upstream from the sill were tried to determine if they would improve the jump action.

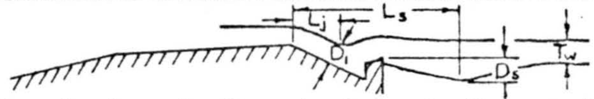
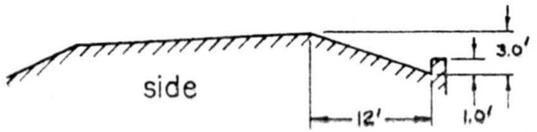
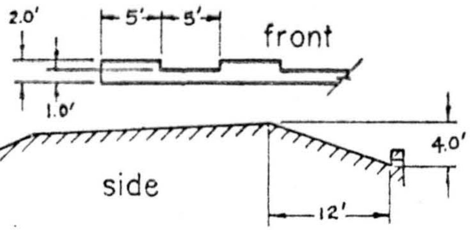
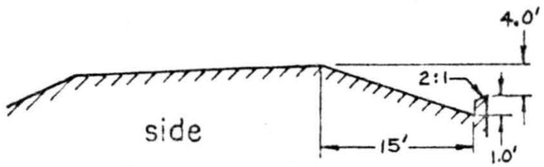
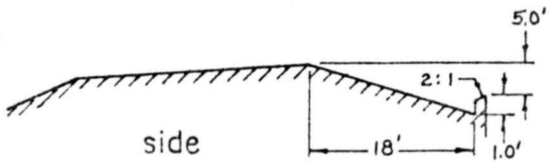
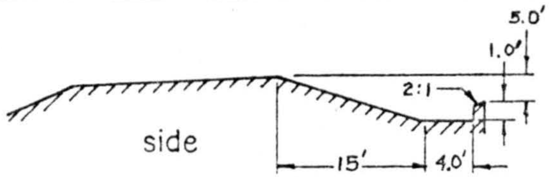
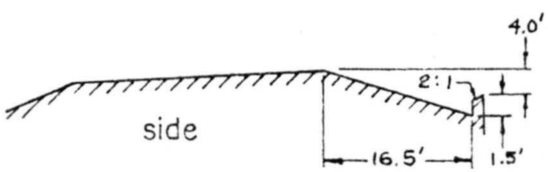
Two tail water conditions were considered in conducting the study. One was termed theoretical minimum tail water and was the tail water elevation that resulted from adding the depth of flow from figure 2 for the discharge being modeled to the low bed elevation. The other condition, termed low tail water elevation, was taken from the low gage height curve, figure 13. Low bed elevation from a study of the field data was 4 feet below the low point on the control crest. These tail water elevations in feet above low bed elevation are given in table 2.

Table 2. Tail Water Depths Above Low Bed Elevation

	Minimum		Low	
Q_p	T_{W_p}	T_{W_M}	T_{W_p}	T_{W_M}
500	1.64	.16	2.7	.27
1,000	2.47	.25	3.7	.37
1,500	3.29	.33	5.2	.52
2,000	4.09	.41	6.6	.66

The various sill heights and location studied and the results of the study are summarized in table 3. Models 1 and 2 had sills that were located too high above low bed elevation. This resulted in excessive scour downstream; as compared to the others. Model 3 had the top of the sill located at low bed elevation and as indicated in table 2 did not have excessive scour for 500 and 1000 cfs but did at 1500 and 2000 cfs when tail water was at minimum or lower. However, with low tail water the scour problem was improved. Model 4 was an attempt to decrease the scour by extending the apron length without increasing the height of the sill. This model at minimum or lower tail water worked well for the lower two flows but had added excessive scour at the higher flows. Model 5 was an attempt to decrease the scour by using a horizontal basin. This model also had excessive scour downstream from the sill. Model 6 was a slight modification of 3, whereby the sill height was increased 0.5 foot, but still keeping the sill crest at low bed elevation by extending the apron 1.5 foot. This energy dissipator performed very well at minimum tail water except at 2000 cfs. However, when the tail water was set at low tail water elevation the scour was not excessive. It is questionable if tail water elevation would ever be at the minimum theoretical elevation.

To try and improve the performance of model 6, baffles 0.03 foot high and 0.2 foot long (model distance) with the same spacing as position 1, table 1, were placed on the face of the apron. Three rows of baffles were also tried with the crest of the lowest row at the same elevation as the sill crest. Then the upper row was removed so that only two rows were on the apron. The upper row was replaced and the lowest row moved above them. No matter what position they were in, the baffles caused the flow to leave the face of the apron and override the sill with a resulting decrease in efficiency. Preliminary investigations with larger baffles indicated the same result.

Table 3 Dissipator Study Model	 Q_P	L_j	D_1	L_s	D_s	T_w	Submergence %	Remarks 1. Sand deposit against sill. 2. Extent of scour. 3. Jump conditions. } Ref. by No.
1 	730 1400			2.8 2.8	.383 .423	.244 .344	0 14.9	
2 	1200 1500 2000	- - - - - -	- - - - - -	3.8 - - 4.0	.428 Floor Floor	.300 - - .293	0 - - 0	1. Good at 1200 cfs. Poor at 2000 cfs. 2. Severe at 2000 cfs. 3. Jump contained at 1200 cfs. Passed over sill at 2000 cfs.
3 	500 1000 1500 1500 2000 2000	1.10 1.0 1.2 .40 .9 .40	.04 .06 .13 .19 .18 .23	2.7 3.2 2.75 3.2 4.1 4.2	.220 .375 Floor .287 Floor .357	.164 .212 .329 .52 .409 .60	0 0 0 41 - - 62	1. Good sand deposit. 2. Scour to floor. Extends all across flume. Scour not excessive at high flows with submergence. 3. Jump contained, all flows.
4 	500 1000 1500 2000	.9 .9 1.2 1.2	.05 .09 .12 .15	2.6 3.2 - - 4.5	.1 .20 Floor Floor	.169 .370 .400 .455	0 0 0 - -	1. In all flows - good. 2. Scour severe except at 500 cfs. 3. Jump contained, all flows.
5 	500 2000	.9 1.0	.05 .15	2.3 4.9	.1 Floor	.211 .409	0 - -	1. Good at both flows. 2. Good at 500 cfs. Severe at 2000 cfs. 3. Hydraulic jump well contained.
6 	1500 1500 2000 2000 1000	.7 .45 .9 .30 .75	.14 .18 .15 .25 .06	3.15 3.85 3.05 3.85 2.65	.271 .362 Floor .307 .116	.329 .52 .409 .66 .37	0 40.6 10.75 84.5 0	1. Good all flows. 2. Scour not excessive except at 2000 cfs with 10% submergence. 3. Jump contained, all flows.

From the model test it is believed that model 6 will protect the control and there will not be excessive scour downstream unless tail water elevation at 2000 cfs becomes much lower than the past gage height records indicate. Then a moderate amount of riprapping may be necessary. Model 3 would also be adequate but was not quite as good as 6.

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Corbett, D. M. and others, 1945, Stream-gaging Procedure: U. S. Geol. Survey Water-Supply Paper 888.

Karaki, S. S., 1961, Stream Gaging Control Structure in the Rio Grande: Colorado State University Research Foundation Report.

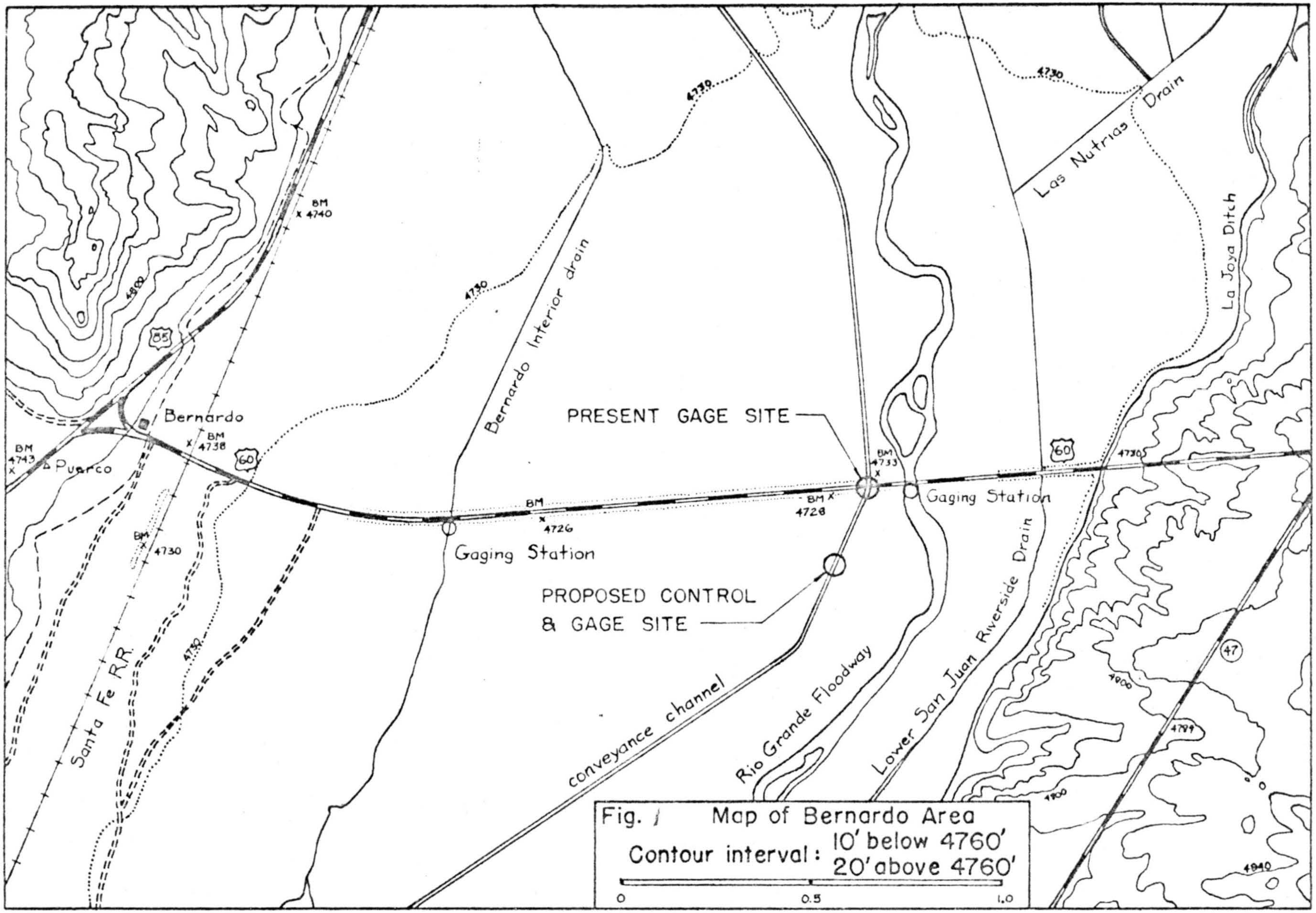


Fig. 1 Map of Bernardo Area

Contour interval: 10' below 4760'
20' above 4760'

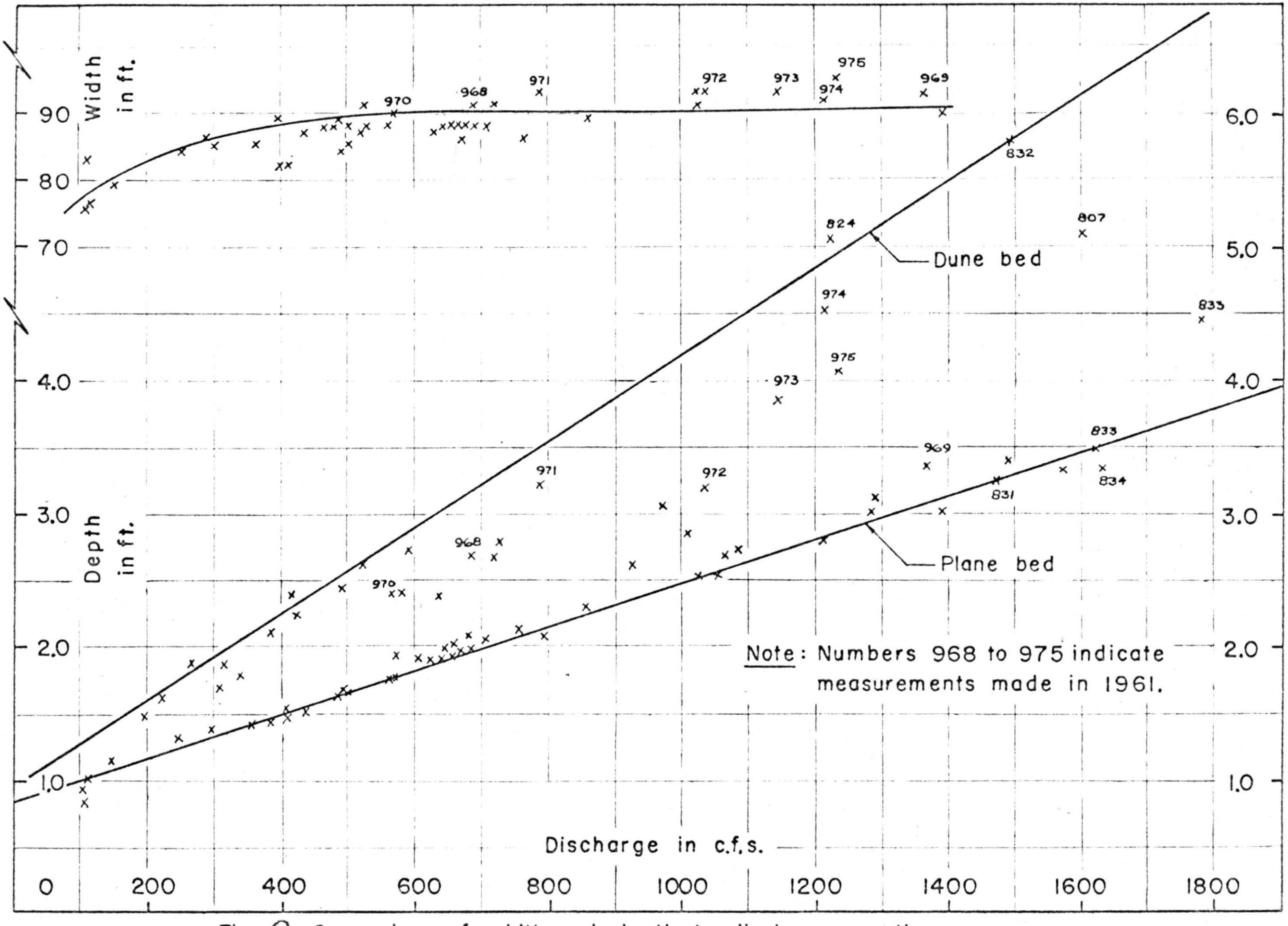


Fig. 2 Comparison of width and depth to discharge on the Rio Grande conveyance channel near Bernardo, N. Mex.

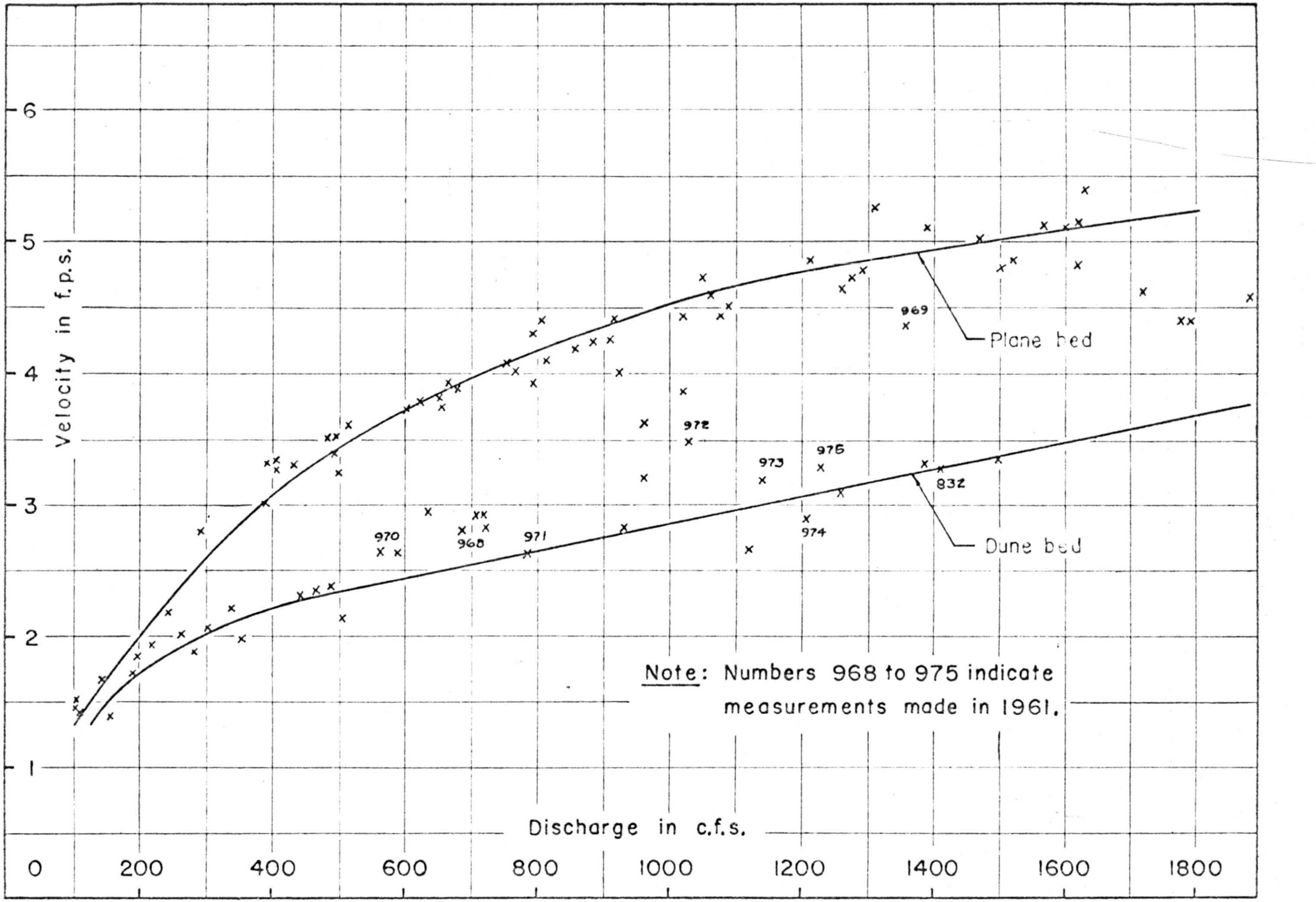


Fig. 3 Comparison of velocity to discharge on the Rio Grande conveyance channel near Bernardo, New Mexico.

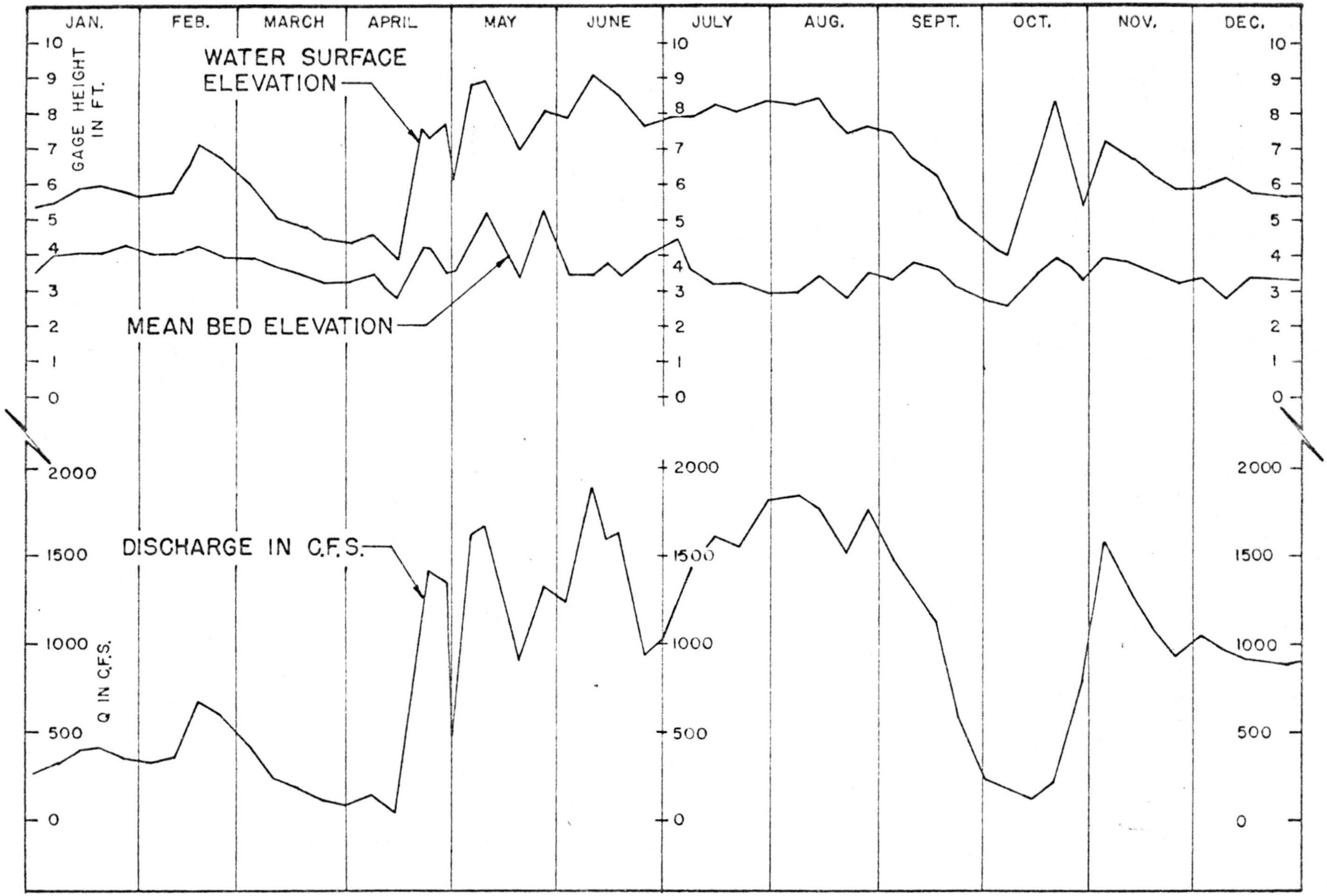


Fig. 4 Relationship of water surface elevation, bed elevation, and discharge during 1957.

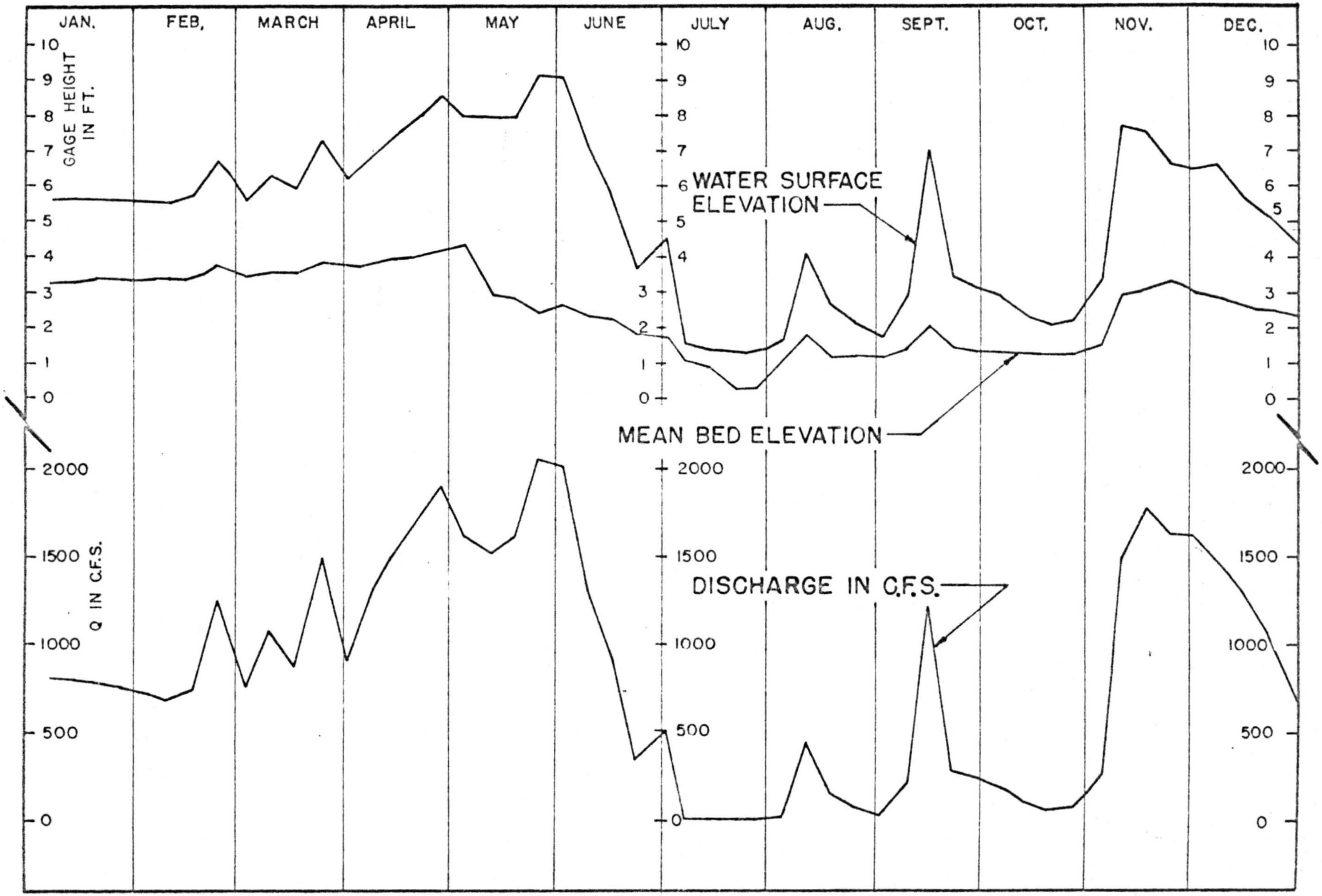


Fig. 5 Relationship of water surface elevation, bed elevation, and discharge during 1958.

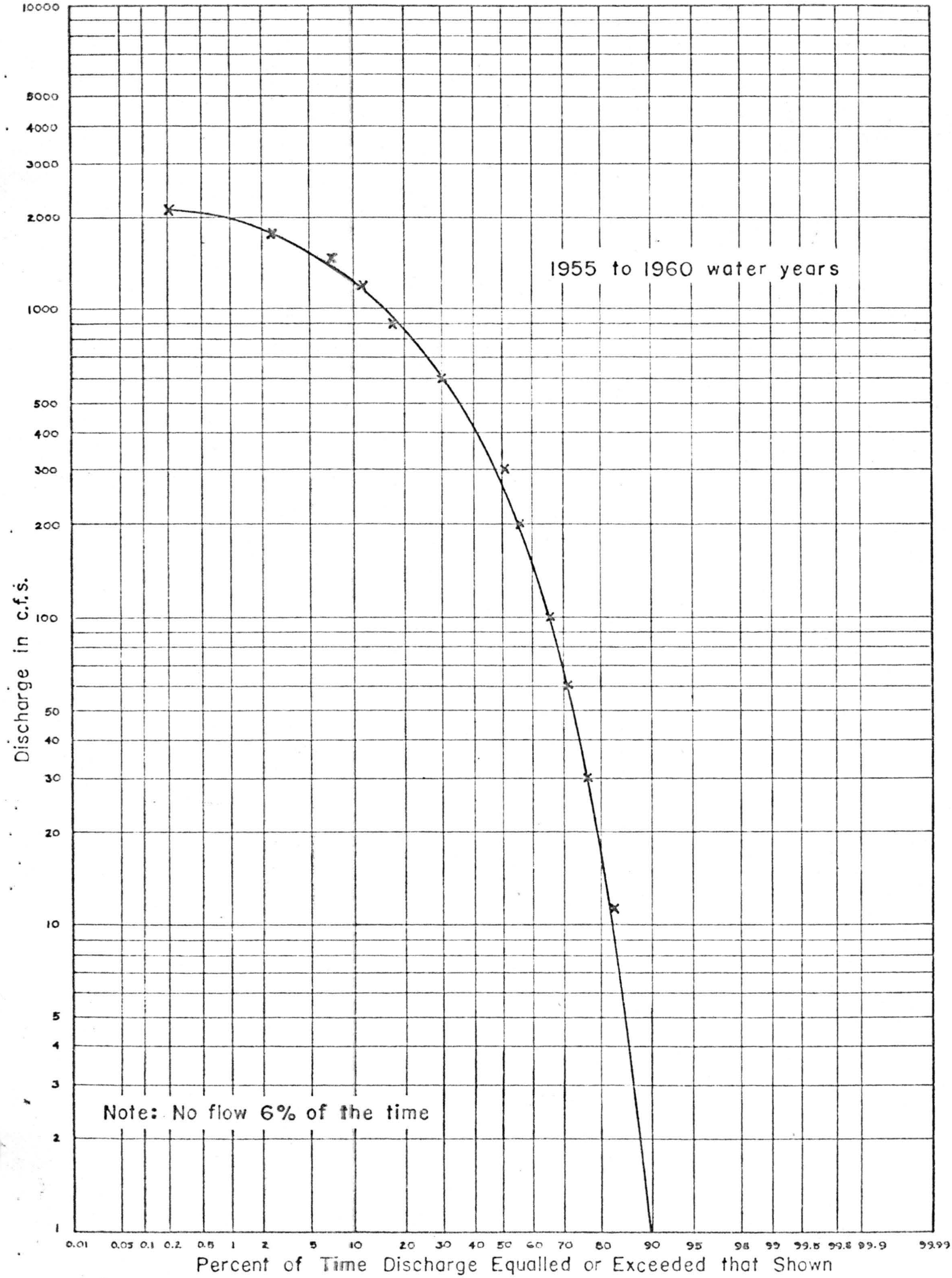


Fig. 6 Duration curve of daily flow, Rio Grande conveyance channel near Bernardo, N. Mex.

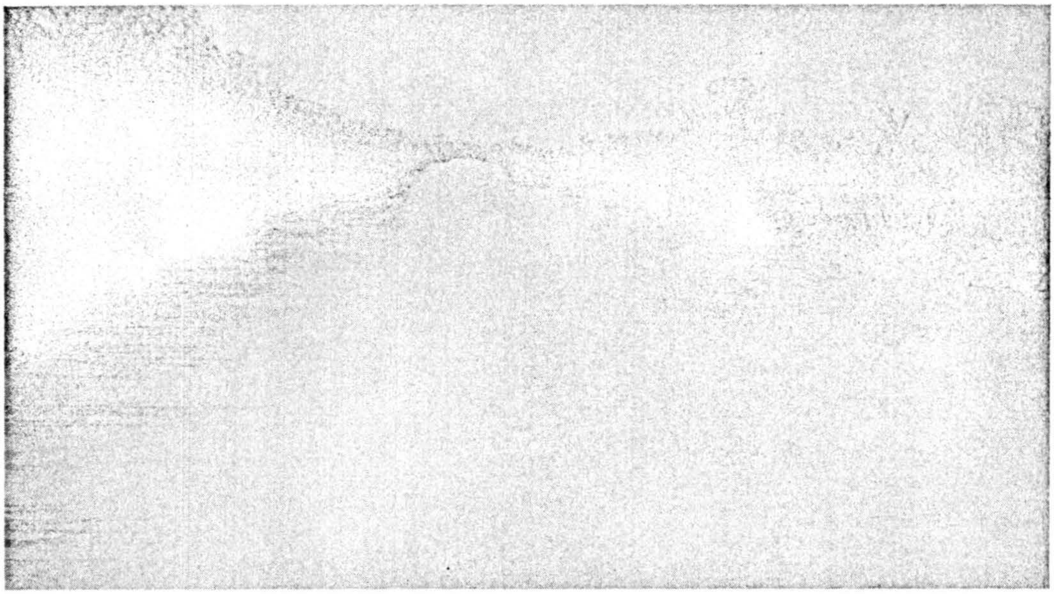


Fig. 7. Rio Grande conveyance channel near Bernardo with a flow of 700 cfs. Looking downstream toward proposed control site.

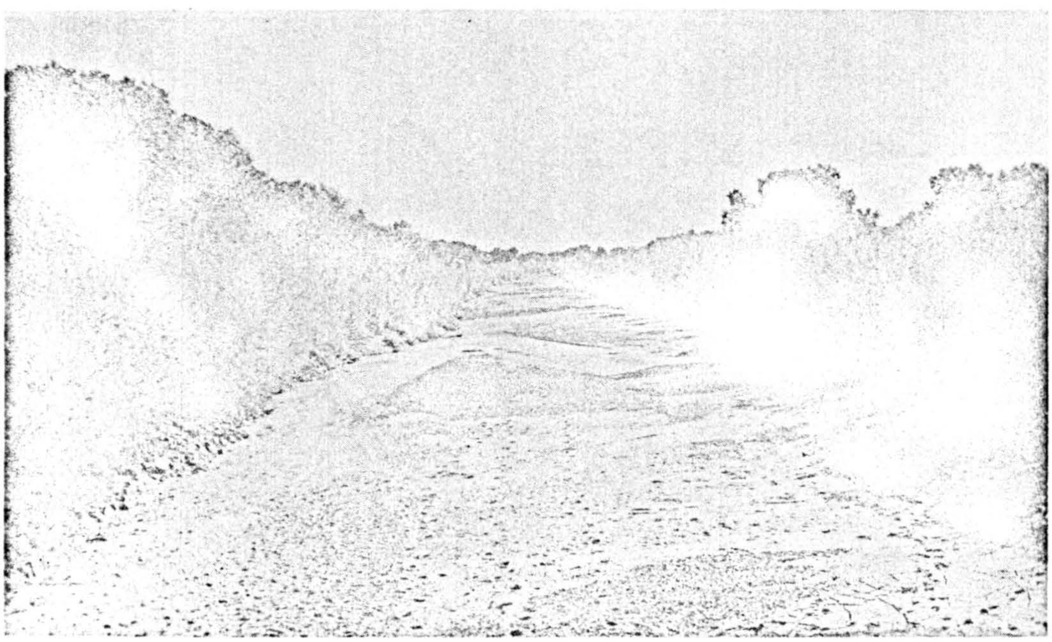


Fig. 8. Same reach as above without flow.

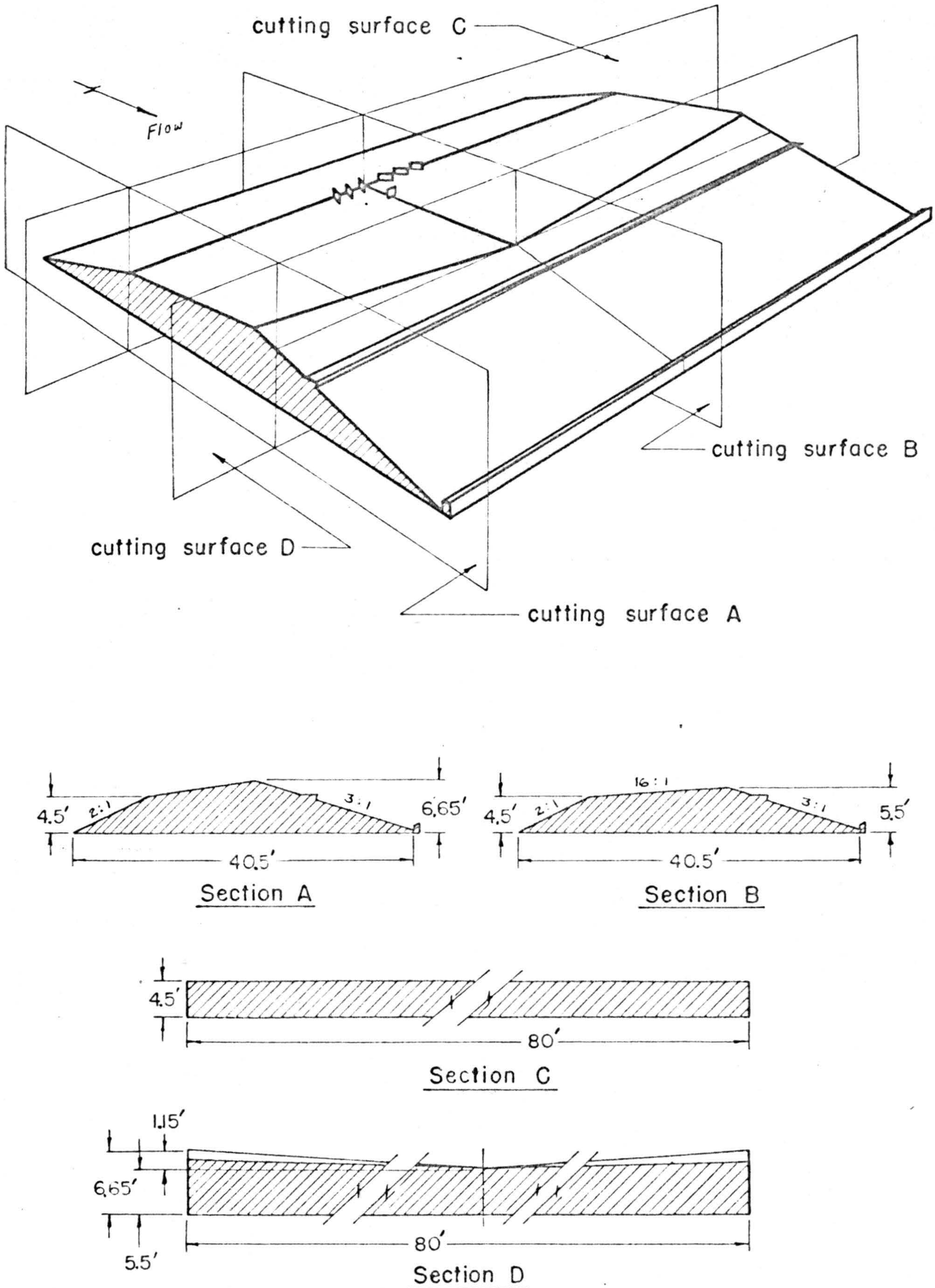
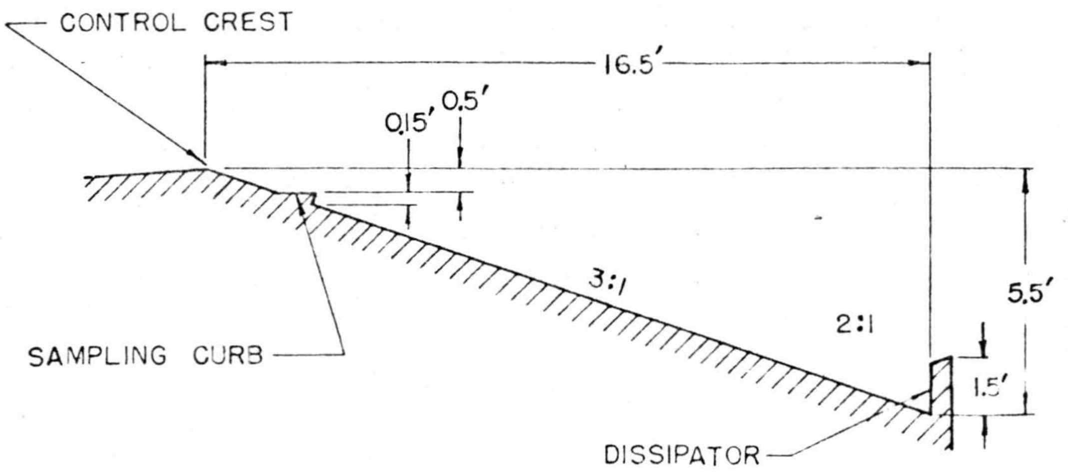
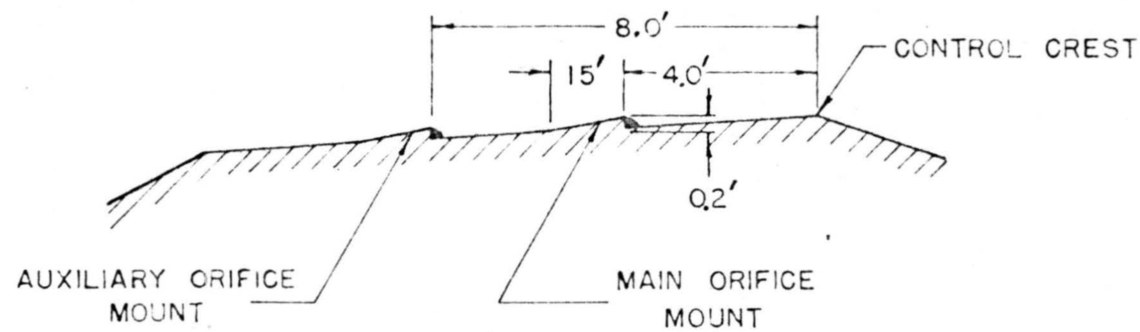


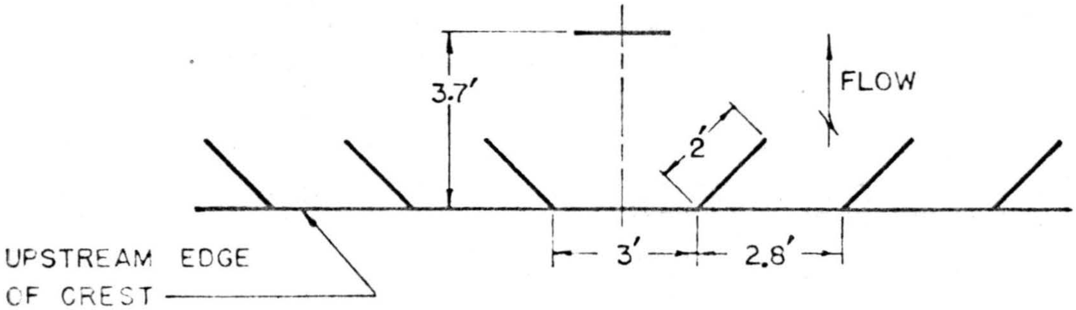
Fig. Proposed control details



Cross section of downstream apron showing energy dissipator and sampling curb.



Proposed orifice positioning



Baffle positioning

Fig. [illegible] Control accessories

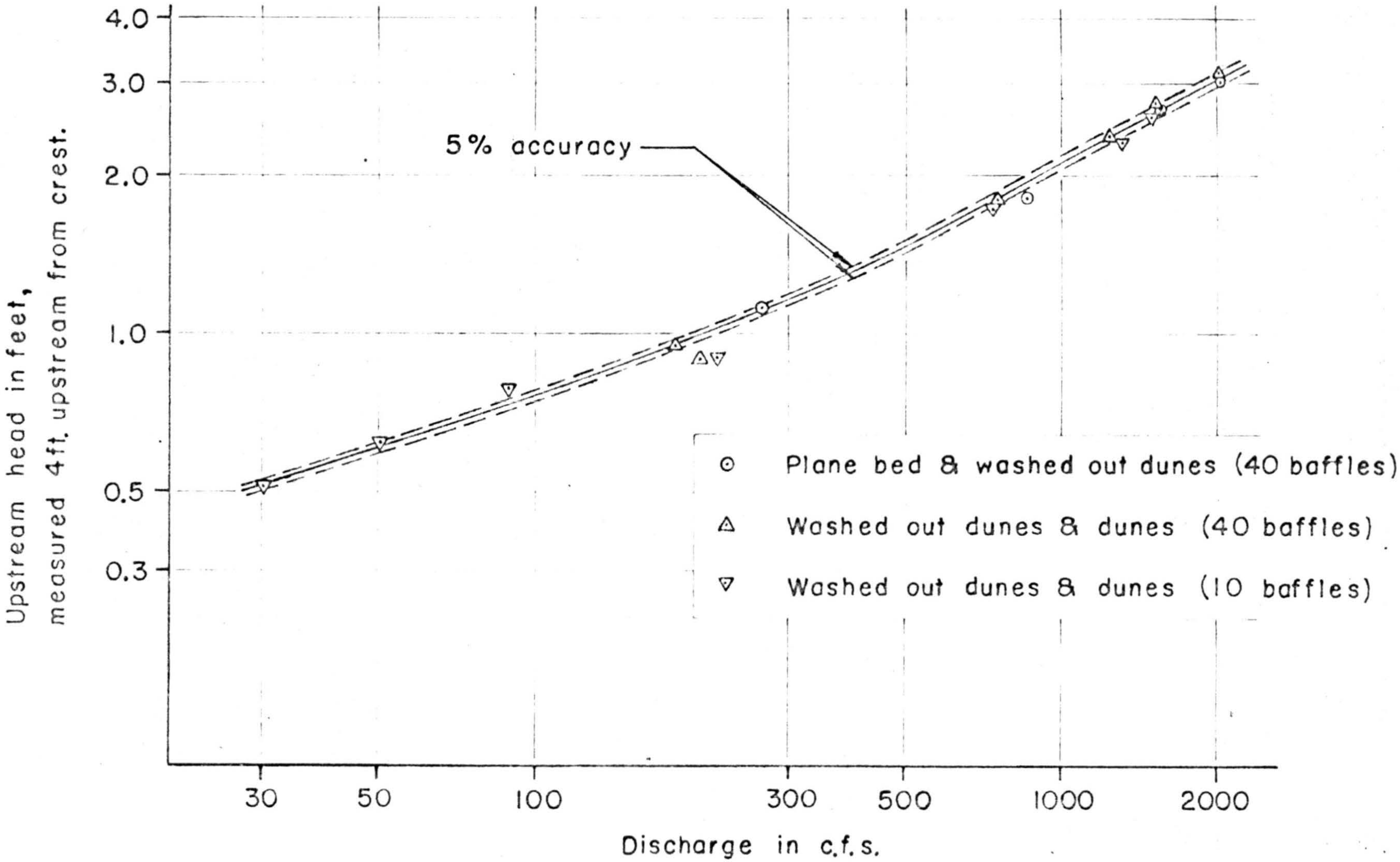


Fig. 11 Stage discharge relationship for control K taken at a point 4 ft. upstream from crest.

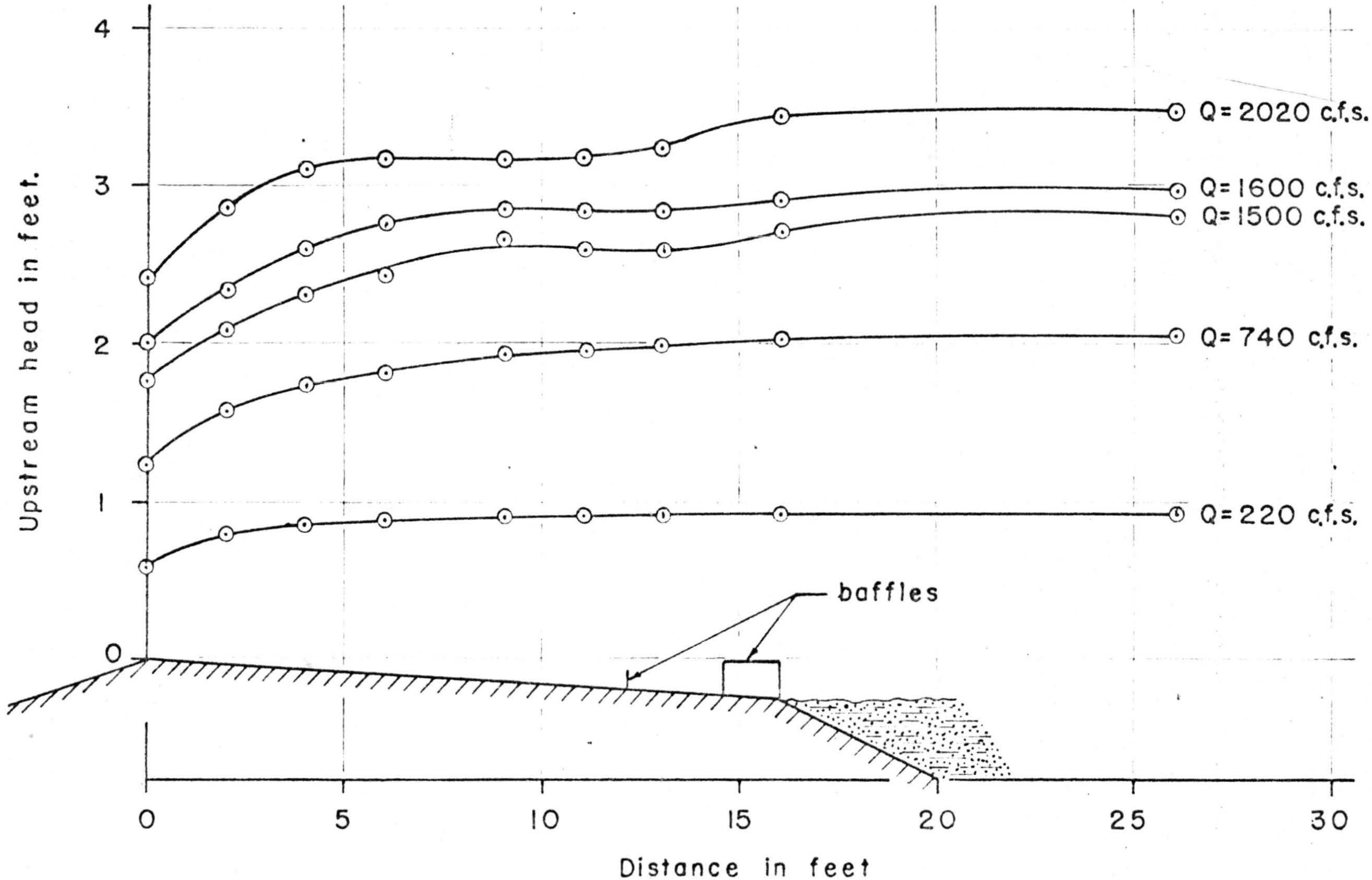


Fig. 12 Water surface profiles for K control (free-fall conditions).

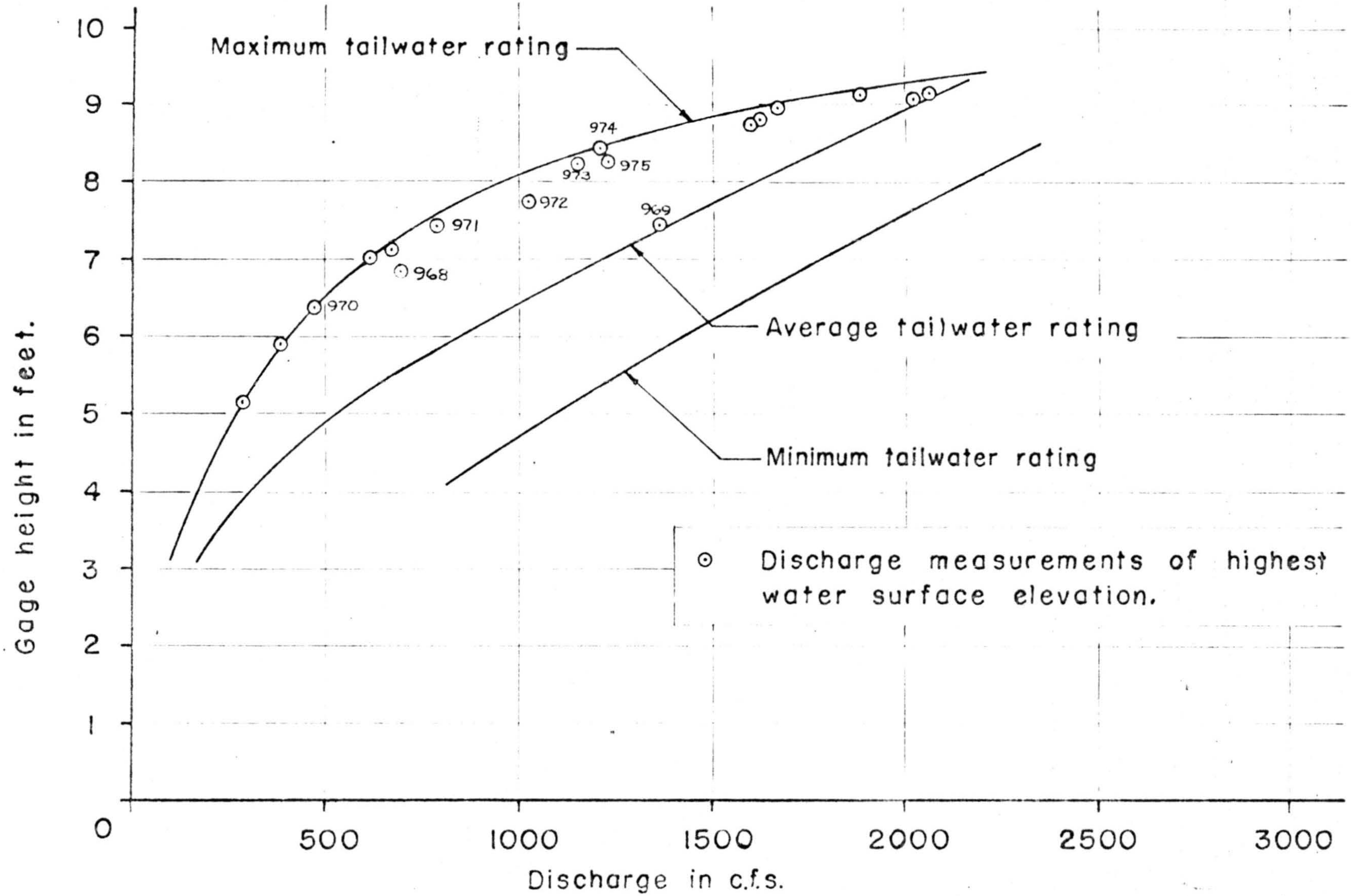


Fig. 15 Stage-discharge relationship for maximum and average tailwater levels based on field data.

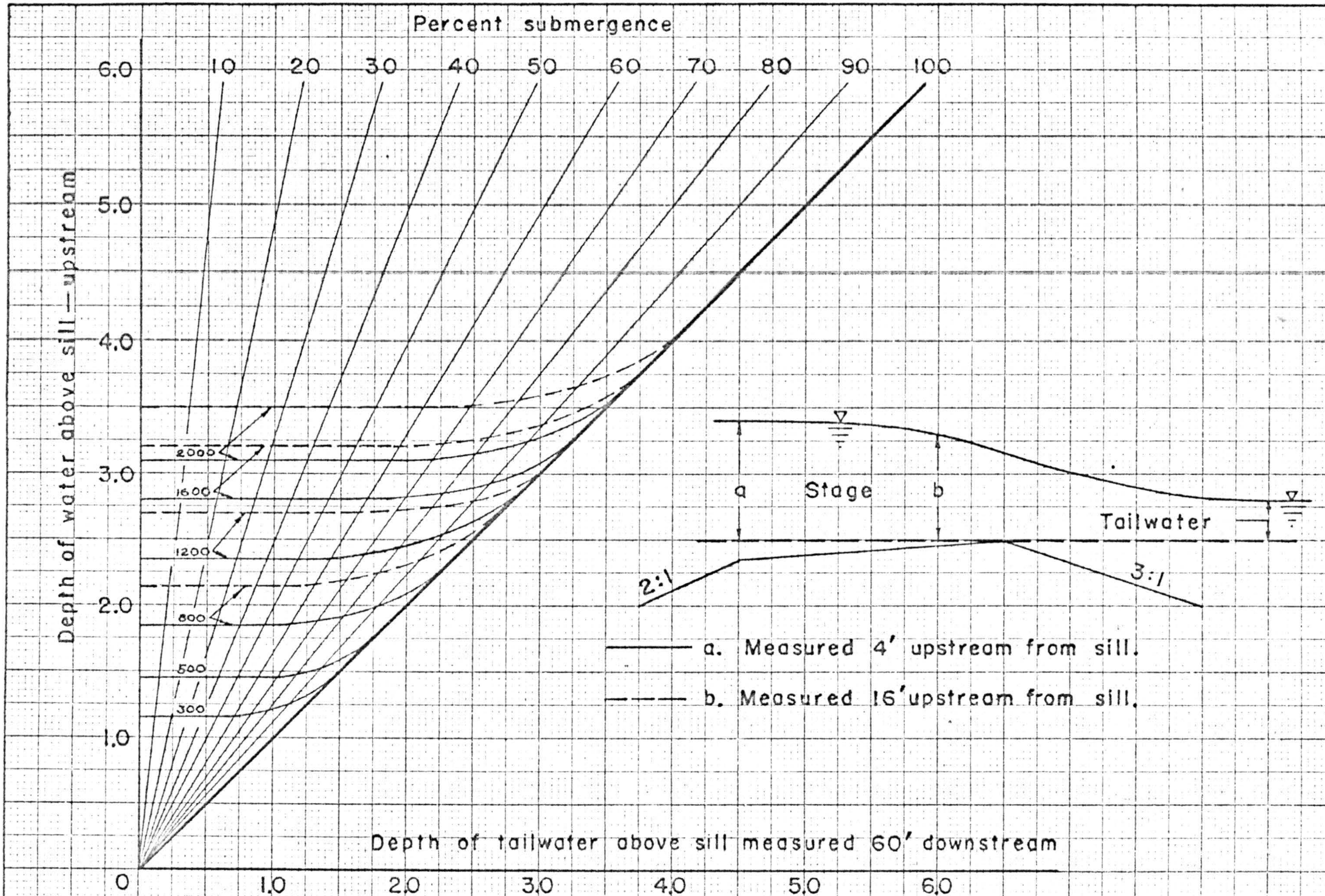


Fig. 14 Submergence curves for K control.

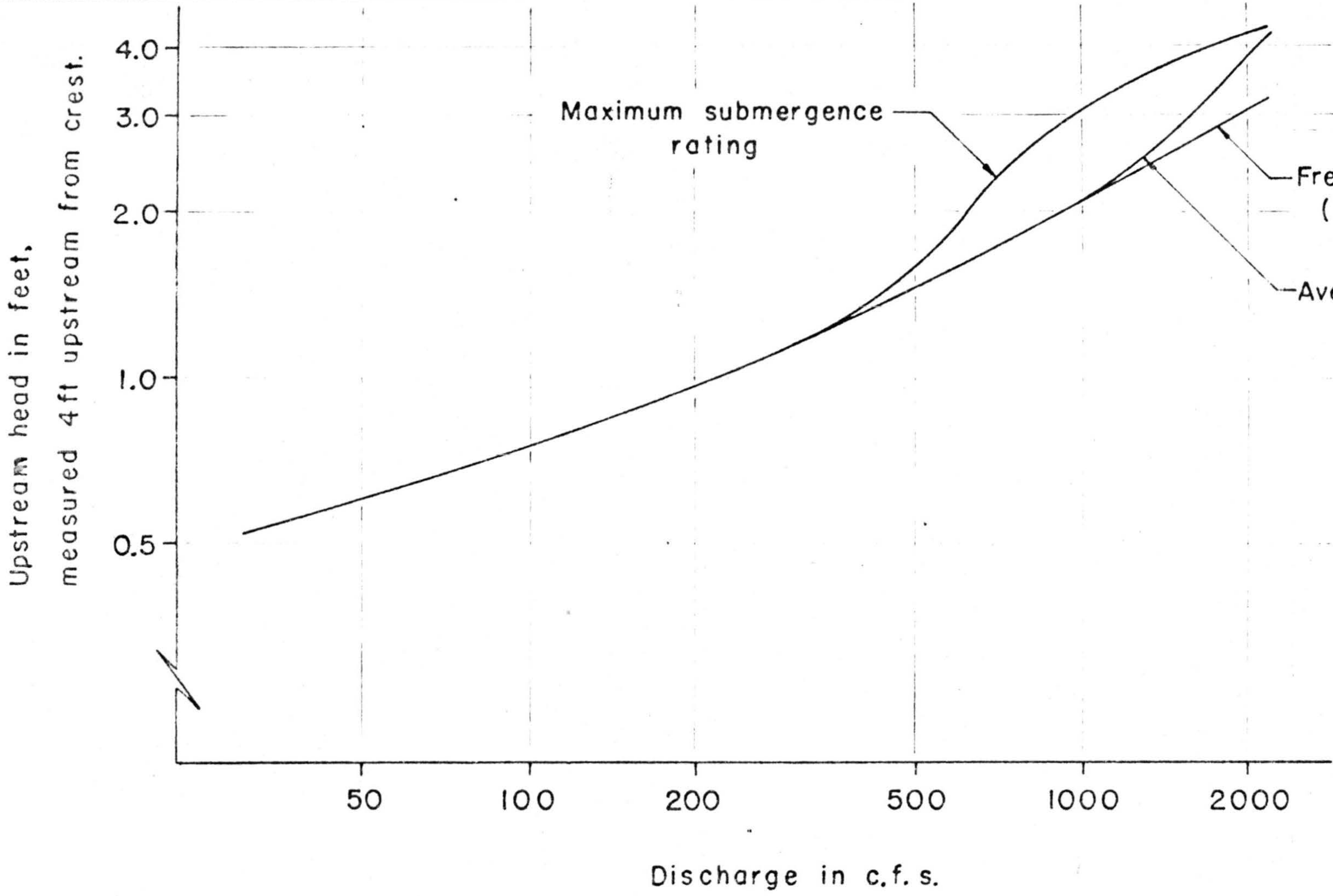


Fig. 15 Comparison of free fall, average submergence, & maximum submergence rating as indicated by model & field data for a 1.3' crest gage height. Head measured 4 ft. upstream from crest.

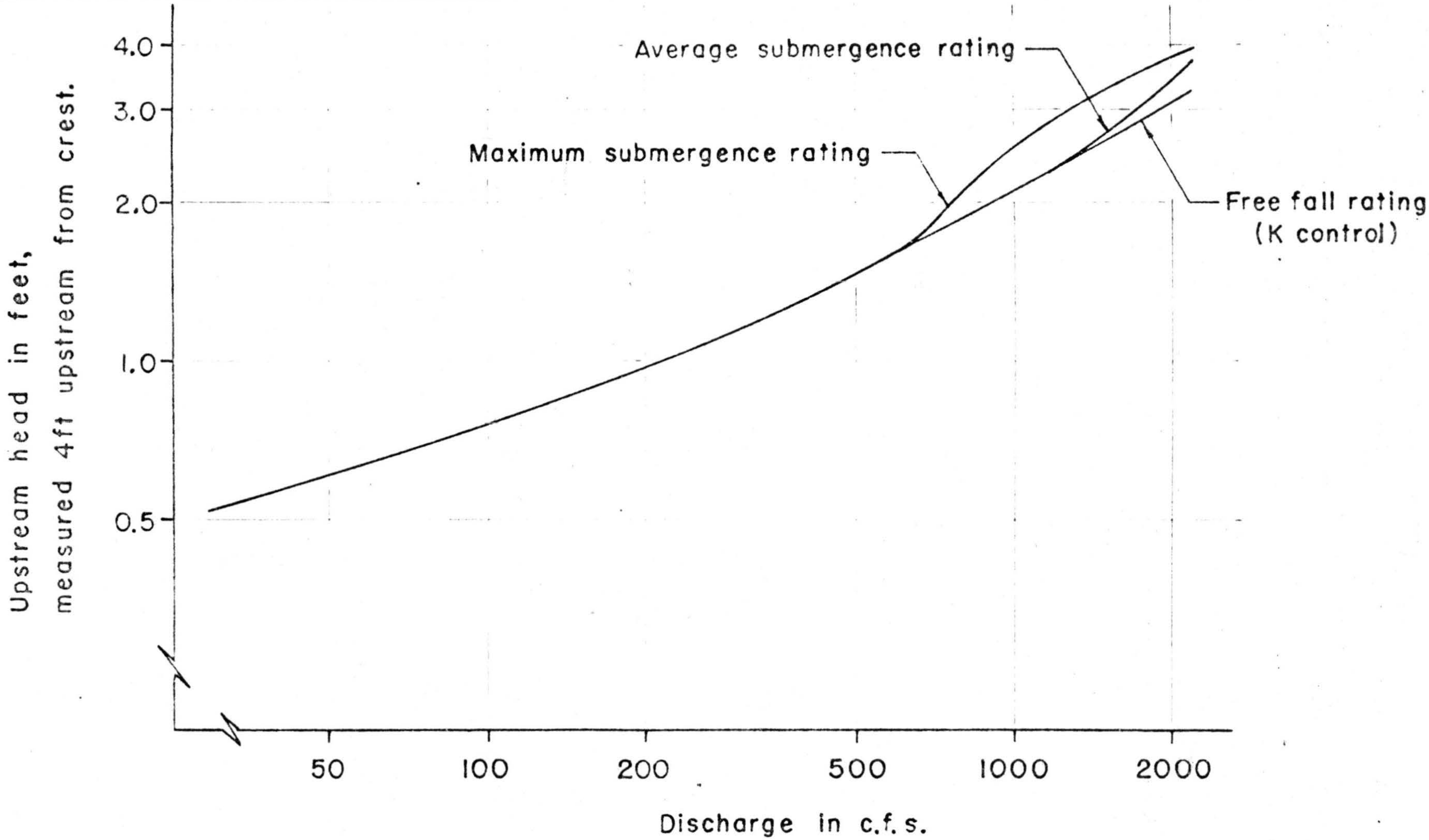


Fig. /. Comparison of free fall, average submergence, & maximum submergence rating as indicated by model & field data for a 1.8′ crest gage height. Head measured 4′ upstream from crest.

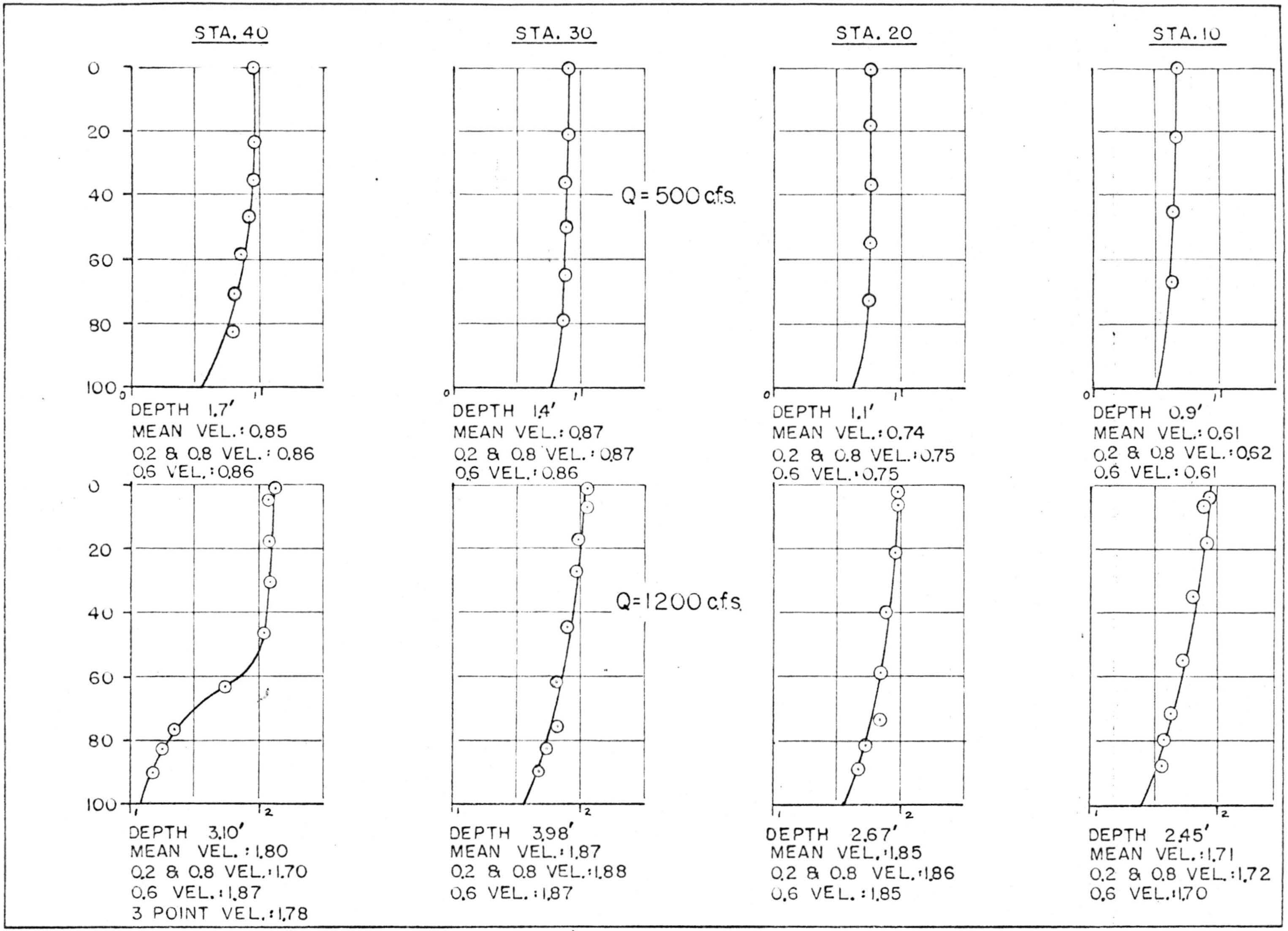


Fig. 17 Vertical velocity curves taken 9' upstream from crest. (free fall conditions)

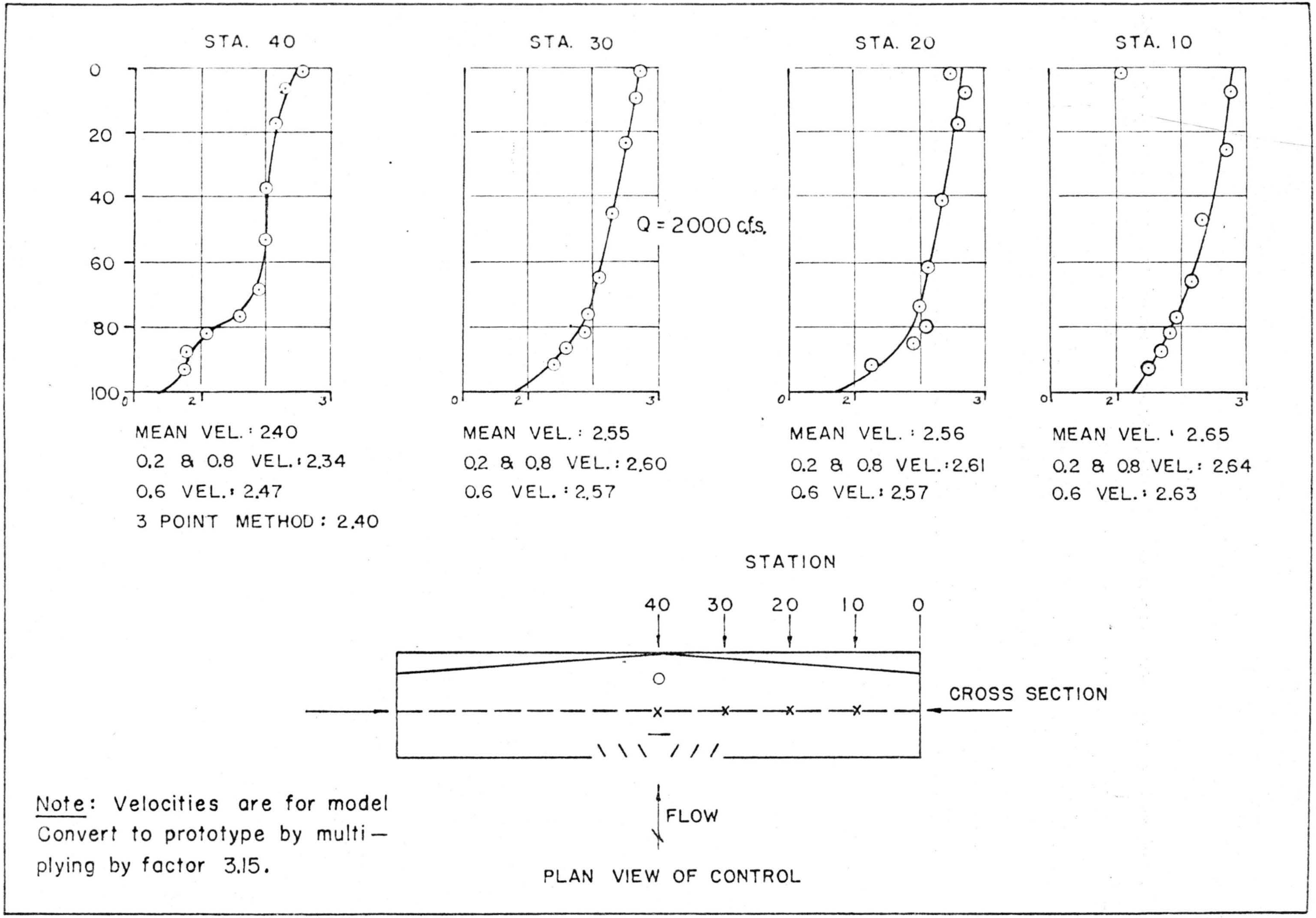


Fig. 18 Vertical velocity curves taken 9 upstream from control crest. (free fall conditions)

CONTROLS USED IN MODELING

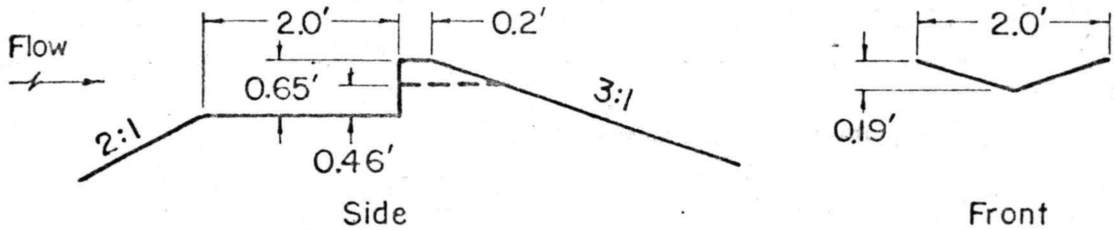


Fig. [illegible] Weir A

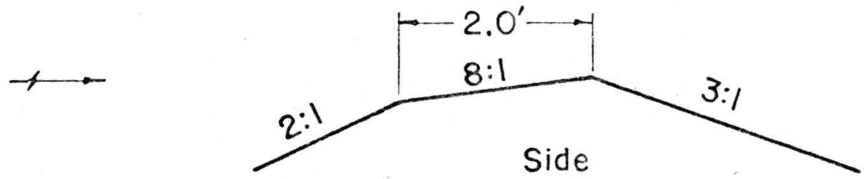


Fig. [illegible] Weir B

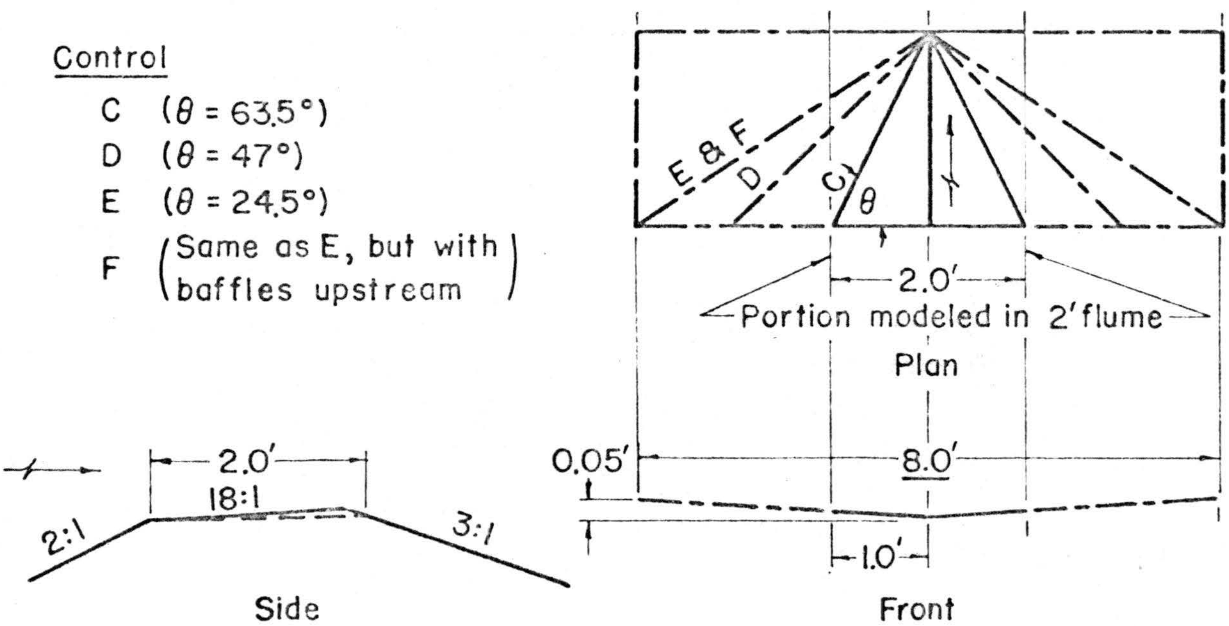
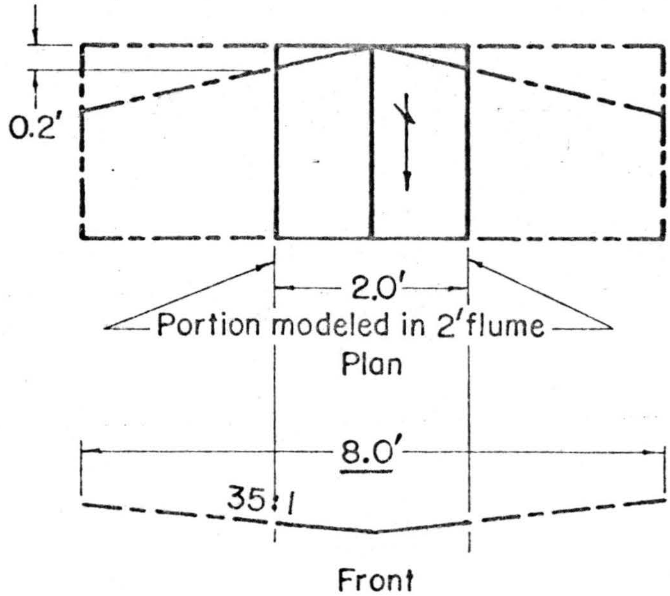


Fig. 21 Weirs C, D, E, & F

CONTROLS USED IN MODELING (cont.)

Note: Made of sheet metal.



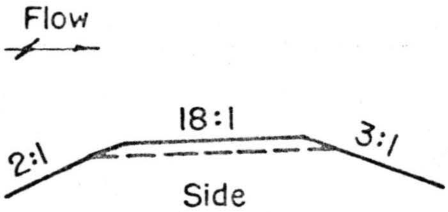


Fig. 22 Weir G

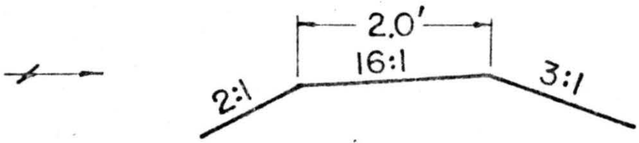
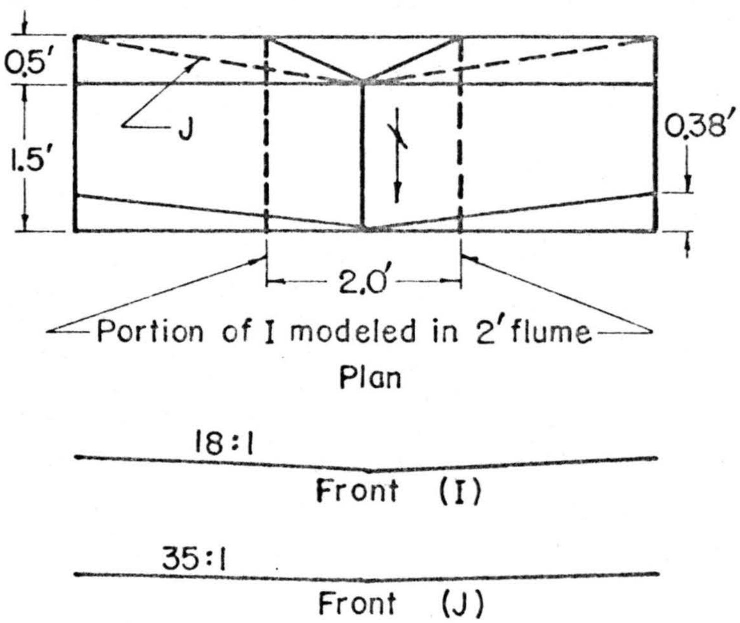


Fig. Weir H (basic structure flat surface)

Note: Weir I & J used same basic structure as H but with converging apron.



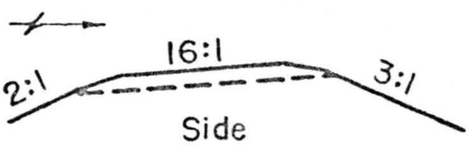


Fig. Weirs I & J

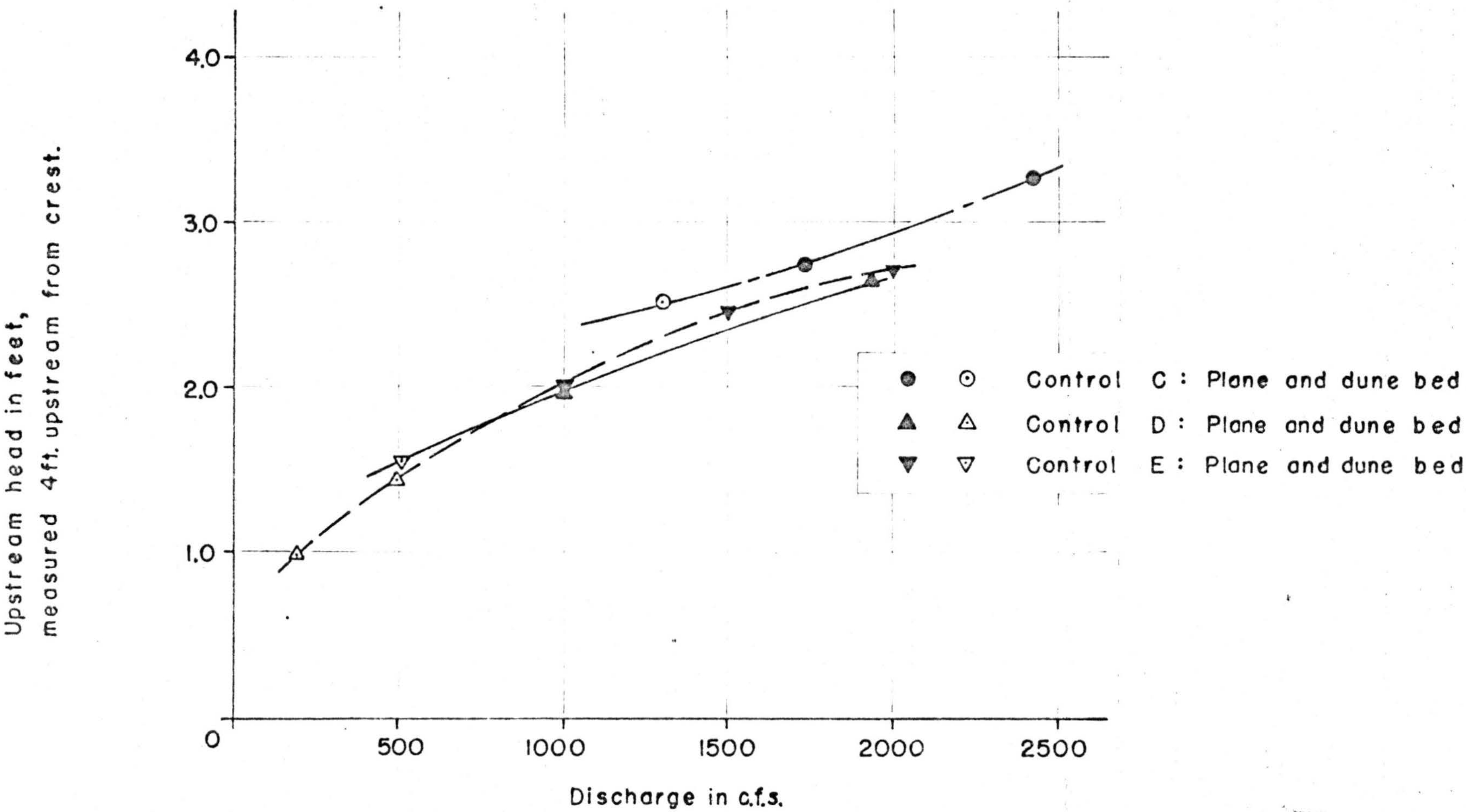


Fig. 25 Stage-discharge relationship for controls C, D, & E, (taken at a point 4 ft. upstream from the crest) (2 ft. flume data)

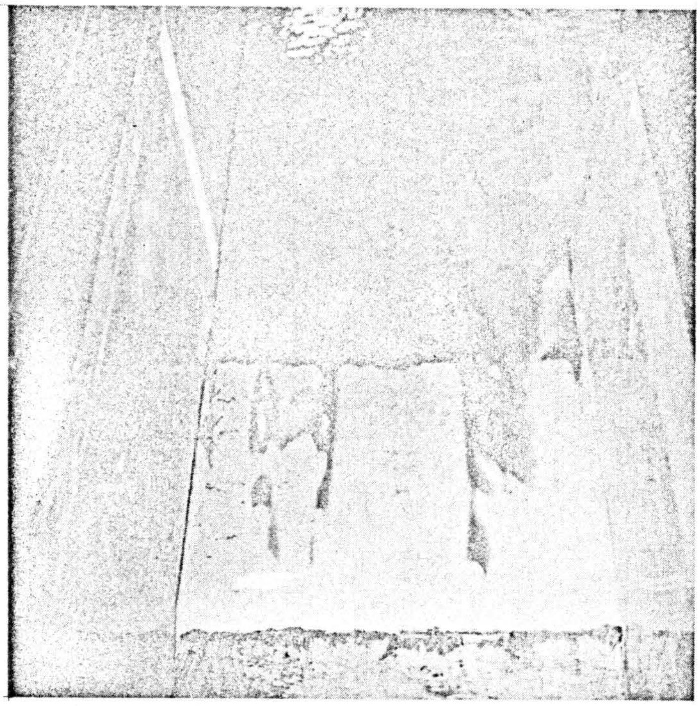


Fig. 26 Weir G in 2 ft flume showing baffle cleaning effect at flow of 300 cfs.

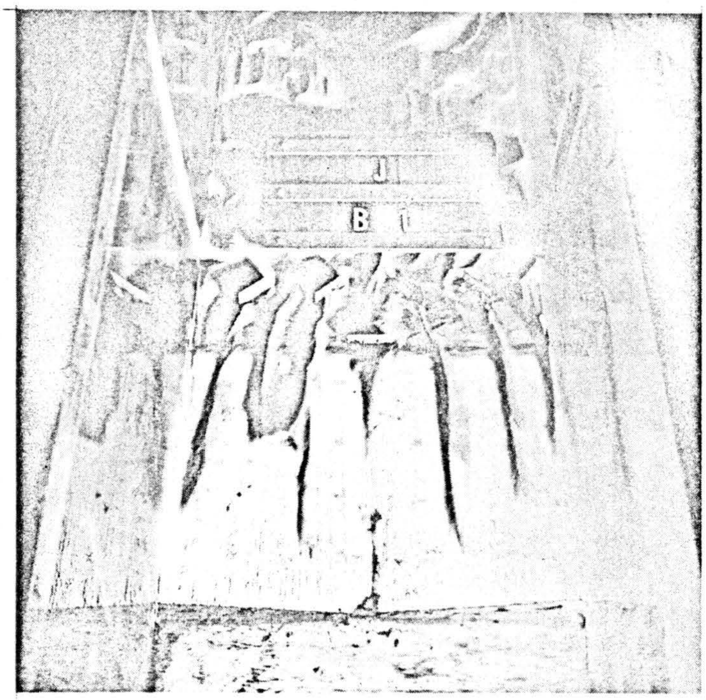


Fig. 27 Weir J in 2 ft flume showing effect of deflecting baffles.

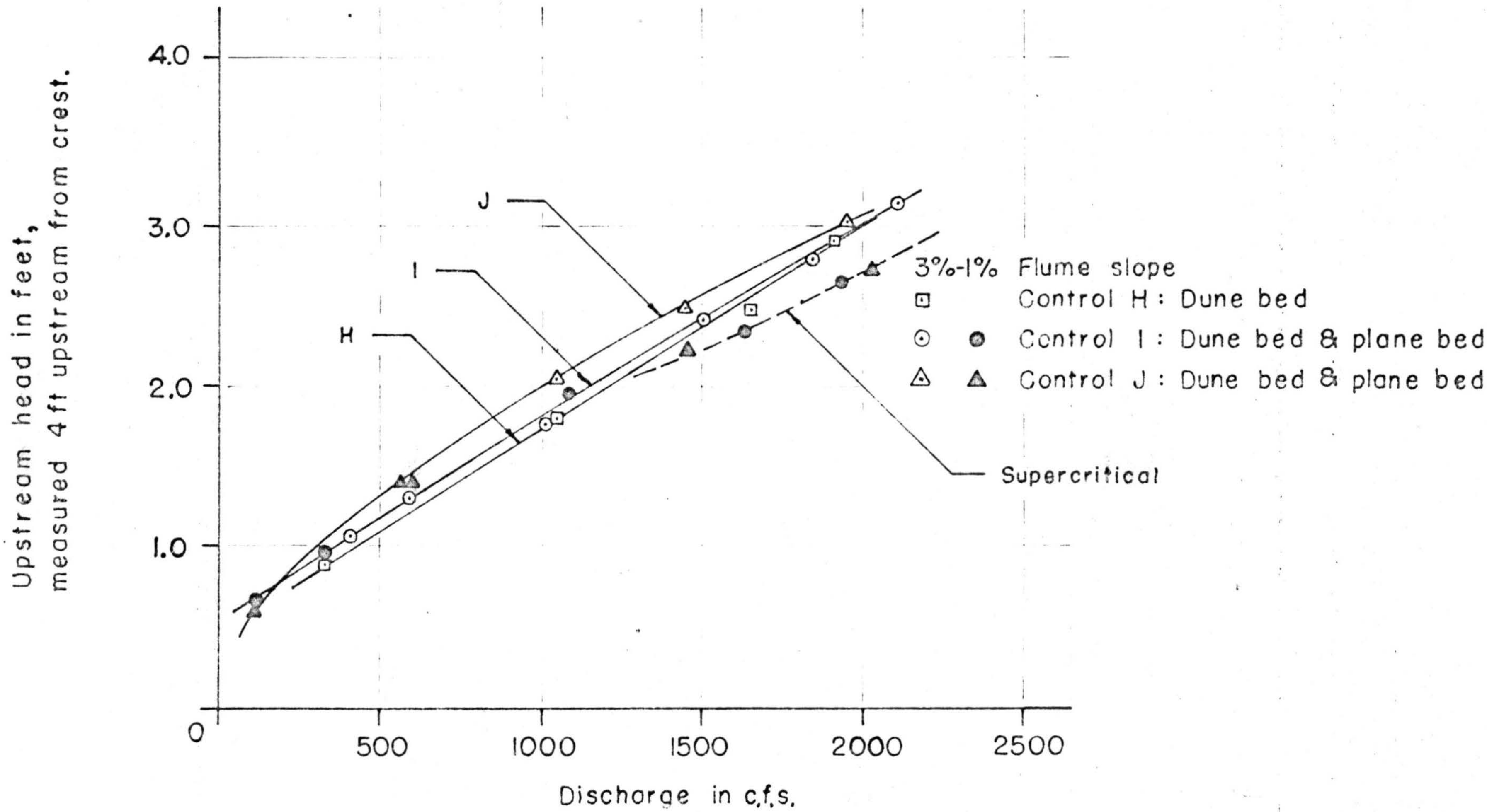


Fig. 28 Stage discharge relationship for controls H, I, & J, taken at a point 4 ft. upstream from the crest. (2 ft. flume data)

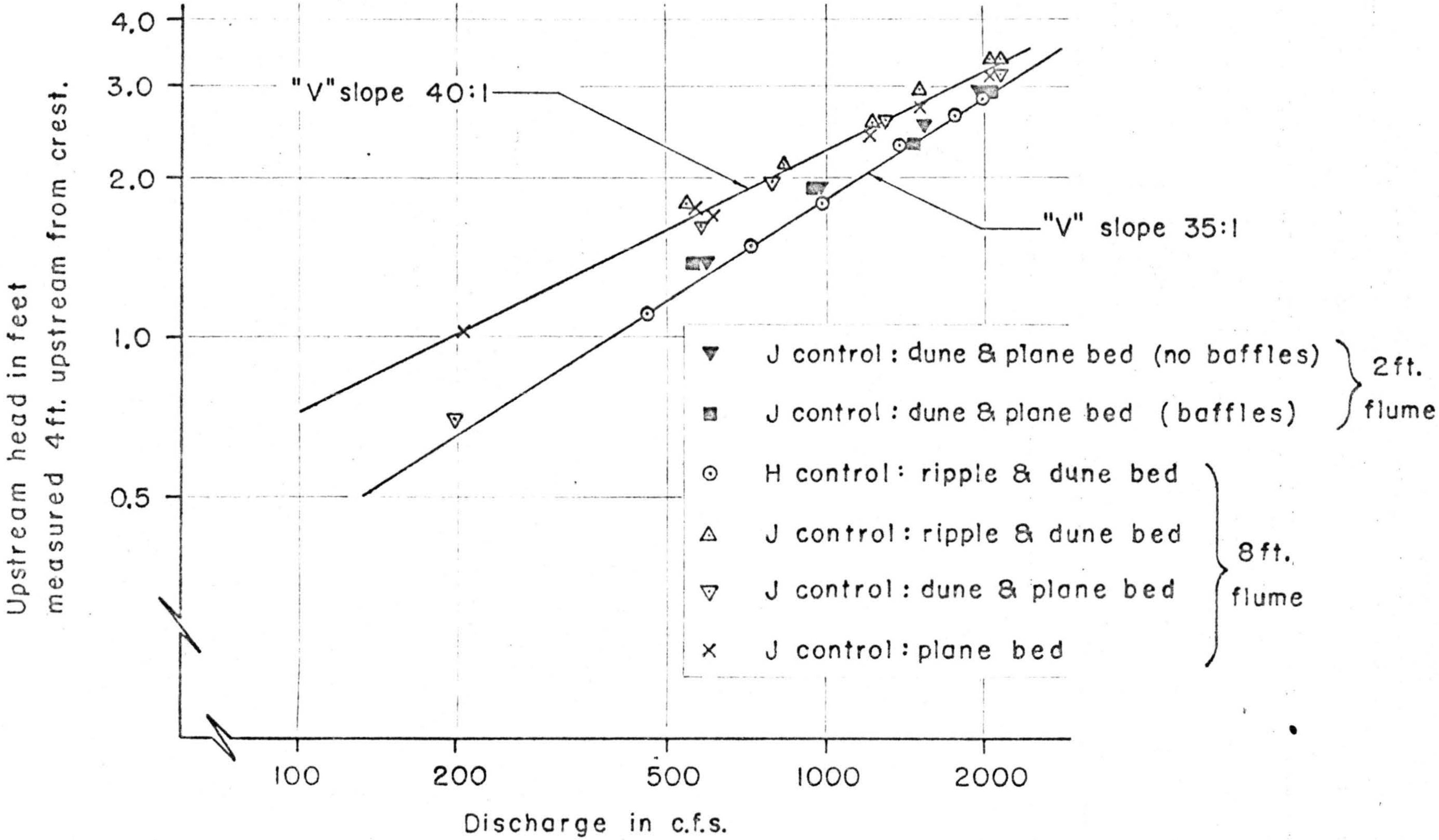


Fig. 29 Comparison of stage-discharge relationship of basic H control and J control. (2ft. & 8ft. flume)

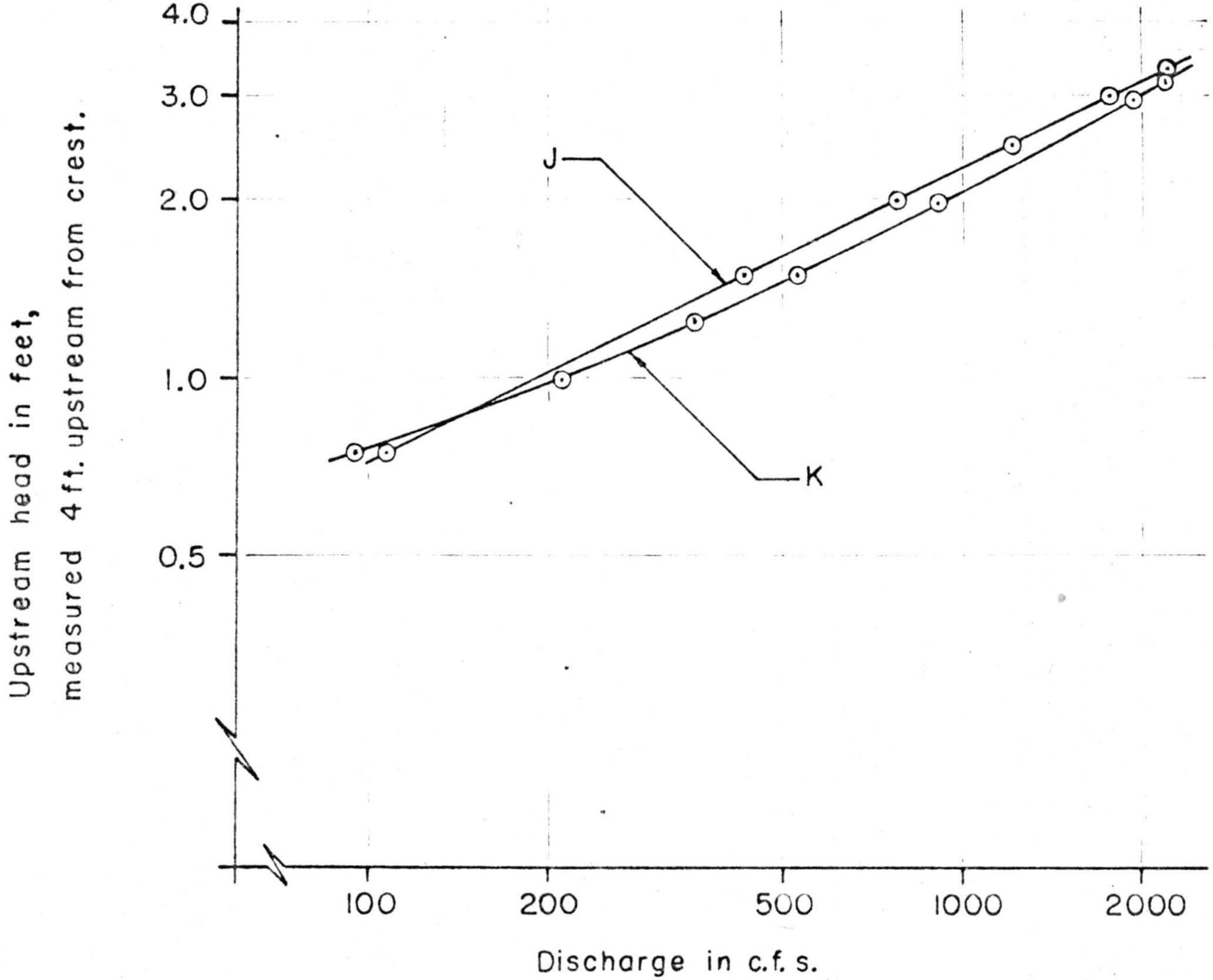


Fig. 9a Comparison of stage-discharge relationship for J & K controls.
(2 & 8 ft. flume data)