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HYDROSTATIC UPLIFT PRESSURES UNDER DAMS ON PERVIOUS EARTH FOUNDATIONS

by

D. J. HEBERT, JUNIOR ENGINEER

Denver, Colorado
May 25, 1934

UNITED STATES

DEPARTMENT OF THE INTERIOR

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MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: HYDROSTATIC UPLIFT PRESSURES UNDER DAMS ON PERVIOUS EARTH FOUNDATIONS.

By D. J. HEBERT, JUNIOR ENGINEER

Under direction of

E. W. LANE, RESEARCH ENGINEER

TECHNICAL MEMORANDUM NO. 384

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HYDROSTATIC UPLIFT PRESSURES UNDER DAMS ON PERVIOUS FOUNDATIONS

The purpose of this study is to investigate the existing methods of estimating the magnitude of uplift pressure, due to a head of water, under masonry structures on porous foundations. A comparison of the various methods is made on the basis of a collection of observed pressures under a number of existing structures on porous foundations. Pressures at significant points under the structure are computed from each of the methods and then these values are compared with actual measured pressures under the dam.

The most definite conclusion that can be drawn from this study is that none of the methods investigated for computing uplift is satisfactory in its present form. The empirical methods are admittedly only approximations and while they give fair results for some portions of any one dam they are considerably in error for the remaining portions. The curve comparing theoretical and actual pressures indicate that the plain creep theory of Bligh can be discarded in favor of the weighted creep method. From a consideration of safety it seems advisable to assume that the horizontal creep is one-third as effective as the vertical creep. This is the weight proposed by E. W. Lane in Tech. Memo No. 303, U. S. Dept. of Interior, Bureau of Reclamation. The electric analogy method, which is the most attractive as a basis for rational design, was found to give results at considerable variance with the measurements on the dams analized. Until it is made more elastic to take care of the variable factors in the problem, it is no better than the empirical method of weighted creep.

The desirability of having a method for predicting pressures with a reasonably high degree of accuracy is readily apparent. It is possible to insure masonry dams on porous foundations against some of the various ways of possible failure by using large factors of safety. Besides being uneconomical, designs of this kind may still fail due to a condition which was not taken into consideration. The most desirable theory for design purpose is, of course, one which will give a structure that is safe against any method of failure. This theory should also evaluate pressures to a sufficient degree of accuracy that large safety factors need not be used. The scope of this paper does not allow an attempt to set up any new theory. It includes only an analysis of present design theories as well as the proposed electric analogy theory.

The basis for the analysis and comparison of these methods, used in design, was a collection of pressure pipe observations under actual structures. A graphical picture of the comparison is shown for each dam on Figs. 1 - 13. The data as received consisted of readings of water levels in pressure pipes placed in various positions under the dams. These were expressed in terms of lost head. To any point the head lost is the difference in head between the point of entry and the point under consideration. This loss was found by subtracting, from the upstream water level, the water level in a piezometer pipe rising from the point in the sub-soil. The loss of head was then expressed in percentage of the total head on the dam. The pressure expressed this way was assumed to be constant at any point. From Darcy's Law for flow in the soil we have

$$V = K\frac{h}{l} \text{ or } h = \frac{Vl}{K}$$

Since l/K is constant for any point in a homogeneous subsoil, (h) is directly proportional to velocity (V). (V) in turn depends on the total head (H) which causes flow. When (H) increases (V) also increases and causes a greater loss due to friction. Finally we say that (h) increases as H increases keeping the ratio of the two theoretically constant. By expressing the loss in this way, the effect of fluctuations in head water and tail water were eliminated.

Creep distance which is defined as the distance of travel along the under surface of the dam, is divided into two classes for this report - creep as computed for Bligh's method and called herein plain creep and a second class called weighted creep. The second one arises from the assumption that creep along a vertical plane is more effective for dissipating head than is creep along a horizontal surface. Therefore a factor is applied to the horizontal creep distance to give equivalent vertical creep. This method of weighting was used in the report although the same result can be obtained by evaluating vertical in terms of horizontal creep. Creep to any point under the dam is expressed in percent of the total creep.

All the data was reduced to the same basis and expressed in the same terms. To make the comparison between theoretical pressures and observed pressures a graph was plotted for each dam. For this graph the percentage- creep was plotted along the abscissa and the percentage-head-lost along the ordinate. The values at the various observation pipes were connected by straight lines. In order to compute the percentage plain creep for locating the pipes along the abscissa it was necessary to fix the point where creep would be considered to end. The determination of this point is complicated by the fact that tail water potential must be assumed to exist at the end of creep. Due to the presence of weep holes, long downstream aprons, grouted and ungrouted rubble work, the beginning of tail water potential or creep end could not be located rigidly.

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An analysis of toe conditions and the assumed location of creep end are given for each dam.

Colorado River Dam. Fig. A-1.

In this case the last pressure pipe was located 29'-3" upstream from point A. Downstream from the pressure pipe there was no way of telling what the pressure was. The location of the actual tail water was not given. Beyond A the water can escape freely to the tailwater so pressure corresponding to tail water elevation was assumed to exist from section A-A downstream. The weep hole was assumed to be too small to release the residual pressure under it so it was not taken for the creep end point.

Percha Dam. Fig. A-2.

For this dam an analysis was made and curves drawn using two different points of creep end. For the first case the end point was taken at point B. It was thus assumed that the rubble concrete with the weep holes thru it offered enough resistance to retain some of the uplift pressure beneath it.

In the second case the creep end was taken at the first weep hole, point A. If the tail water pressure is taken at A instead of B the total creep is shortened horizontally (30 minus 8') = 22' and vertically by 17'. In order for tail water pressure to exist under the first weep hole it must be rather large so that the subsoil water can pass thru it freely.

Kabo Headworks. Fig. A-3.

End of creep for this dam was taken at A. The original data did not indicate the location of tail water potential. The observations of water levels in this pipe however indicated that the pressure at (d_5) was greater than the amount equal to tail water elevation. The brick pitching was then being subjected to uplift and the creep end was assumed at the end of this pitching.

Deoha Barrage. Fig. A-4.

The end point for this dam is pretty well fixed. Both in this report and in the computations accompanying the original data the point A was used.

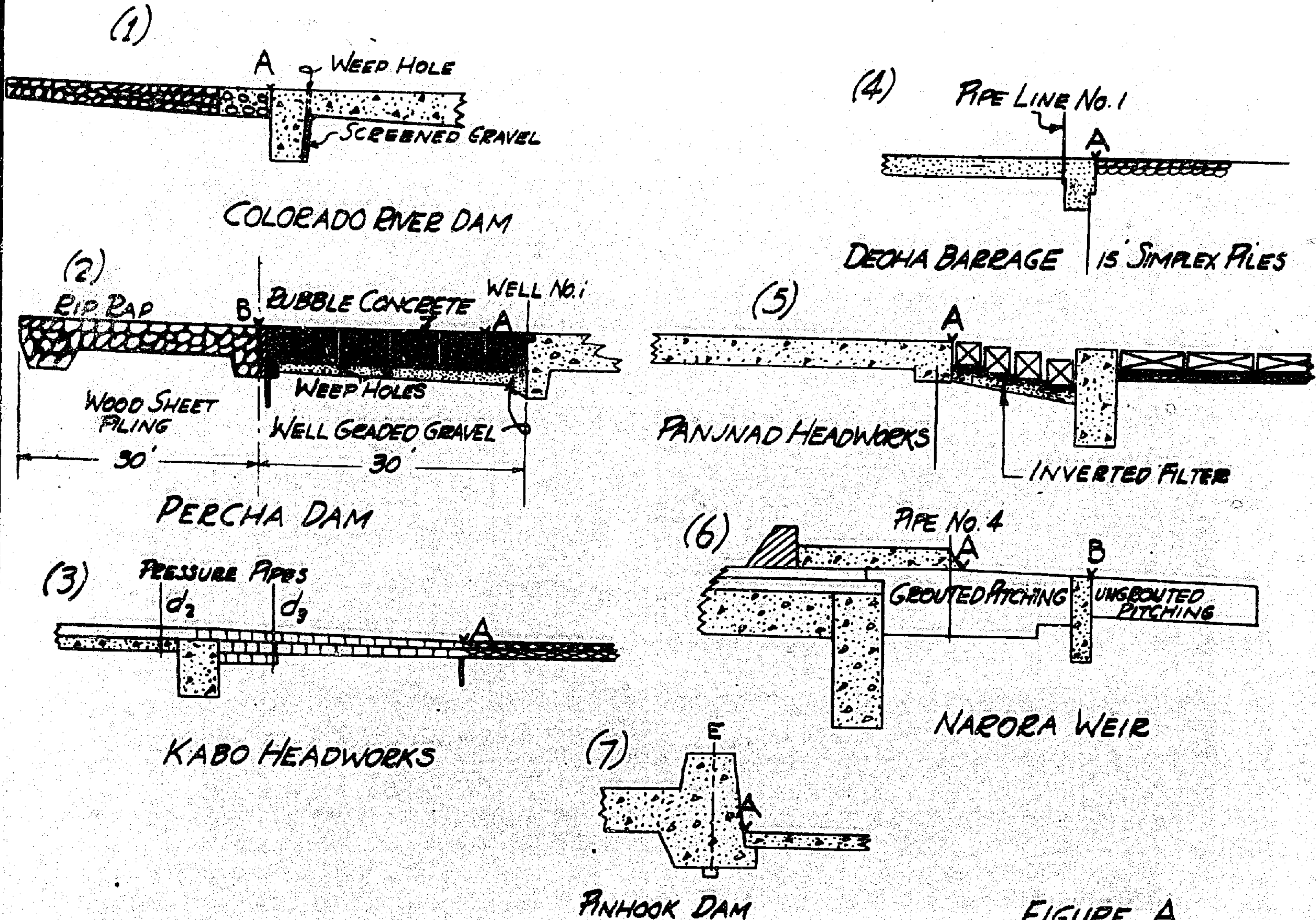


FIGURE A

X-D-1035

Panjnad Head Works. Fig. A-5.

In the computation for creep the beginning of the filter at point A was taken as 100 per cent creep. A residual head remains at this point of about 9.4% of total head. This decreases to 7.4% of the head at the end of the filter but increases again to 8.2% at the beginning of the downstream rip-rap. The reason for this action of the pressures is probably that the stream lines divide after they pass under the sheet piling. One part of the line goes up thru the filter and the other continues on to go under the downstream well. There is probably a layer of clay at or near the surface which keeps this residual pressure under it. This layer is shown in a geological section of other parts of the subsoil and can no doubt be assumed to exist at this section.

Narora Weir. Fig. A-6.

In this case the analysis accompanying the data made the assumption that the creep ended at point A. Although the sketch shows grouted pitching at this point there was no way of telling what condition it was in. So the same creep end was used in the computation for Fig. 5A. Then the pitching was assumed to be tight and the end of creep was taken at point B for Fig. 5b.

Pinhook Dam. Fig. A-7.

The end of creep was taken at point ... the beginning of the downstream apron. Then it was assumed that the apron restricts flow enough to maintain a head under it and the end of the apron was used for creep end. The change of creep end changes the gradient especially at the toe of the apron.

Method of drawing Curves.

As has been explained before the actual and theoretical uplift pressure were plotted on the same graph. Three different theories were used to evaluate the uplift pressures. The first one is the well known Bligh Line of Creep Method which assumes the loss of head proportional to the creep distance which has been called herein plain creep. The line of pressures for this method shows as a straight line from zero to one hundred per cent. This is because of the method of plotting. The second theory is the Weighted Creep Theory proposed by Mr. E. W. Lane, in the Tech. Memo referred to previously. This method assumes the horizontal creep to be only one-third as effective as vertical creep. All slopes greater than 45° were called vertical and less than 45° were called horizontal. To determine this line points were taken at critical places such as breaks in the under surface profile. The loss of head is assumed to be proportional to the weighted creep. The points along the abscissa remain the same and the percentage weighted creep is plotted as the percentage loss of head. The third theoretical line is one that is measured by means of an electric-analogy set up. The underlying theory for this method and the set-up used for this study are as follows.

The analogy is based on the assumption that Darcy's Law for flow in soils holds rigidly. This law, as has been stated hitherto, establishes the velocity to be directly proportional to the loss of head. The law has been checked by numerous experimenters since it was first set up by Darcy. The equation of flow, from this law, is the equation of viscous or laminar flow and has the same form as Ohm's Law for flow of electricity in a conductor, viz. $I = (1/R)E$. Therefore, the flow of electricity can be considered analogous to the flow of water thru soils. Thus, by simulated hydraulic conditions in an electrical set up, a measurement of potential will by analogy give head.

A sketch of the analogy set up is shown on page 1 App. For a conductor a salt solution was used. The exact strength of the solution is not known as it was merely tap water which contained enough salt to carry the current. The models used were constructed from pyralin, a non-conductor, and the boundary conditions were set up by means of putty. Putty was also tried as a material for the model dam but difficulty was encountered in getting it to stand vertically even when most of the oil had been removed. The pyralin models were constructed to various scales from 1" = 15' to 1" = 40' and were all approximately 8" inlength. Two copper strip electrodes, under a voltage of about 50 volts were used to simulate potential acting on the dam. These strips were placed at the planes where water ould enter and leave the subsoil.

The procedure used was as follows. The dam was placed between the electrode with the various cut-offs and walls sealed to the glass to prevent any flow under them. The voltage was then applied from an "110-volt" line thru a bank of lights. The probe was placed at critical points and the resistance slider moved along the resistance wire until the hum of a voltage difference stopped at the percentage loss corresponding to that of the probe position. The accuracy of this point depends on the amount of potential difference that can be detected by a set of head phones on an amplifier with loud speaker. The sensitivity of the amplifier and speaker is about four times greater than that of the head phones alone. The head phones can detect nothing less than .002 volt while the amplifier can pick up a difference of only .0005 volt. An amplifier was used in all the experiments performed. The resistance wire was divided into a hundred parts which makes the slider reading equal to the percentage drop for plotting the curve of pressure.

By changing the procedure slightly an entire flow net can be drawn. Place the resistance slider at some percentage point and then locate the equi-potential line in the model by moving the probe along the line of silence in the model. As a means for facilitating the transfer of the equi-potential line to a sheet of paper, a pantograph was used. The usual pencil insert was replaced by a copper probe needle insulated from the metal arm. To complete the flow net the electrode and the boundaries are interchanged. With the same procedure as outlined, the stream lines can now be drawn. Only one complete flow was plotted in this study and it was under the Panjnad Weir located in Punjab, India. For the other dams only the ends of the potential lines, at the under surface, were located. The flow net taken is shown on Figure 7 - c. The model of this dam was considerably larger than the others with the result that much shorter electrodes had to be used. The effect of the shorter electrodes is apparent from the figure. There is a crowding of the stream lines with a corresponding velocity increase at the entrance and exit of the subsoil. This represents a false condition as the actual planes of entrance and exit are practically unbounded. The condition was remedied by the use of smaller models and longer electrodes, and the results, using the smaller models, were used for the comparison diagrams. It will be noted that in the set-up to take a complete flow net for this weir the downstream well was neglected. When the same dam was run with the smaller model, the well was included and very little difference in results was observed.

Although the curves for each dam are almost self explanatory, there are a few points on which possible confusion can be forestalled by a few words about each dam.

Colorado River Dam Grand Valley Project - Fig. -1-

The observations which were very numerous for this dam covered a wide range of variation. They were divided into six groups chronologically. A mean was computed from the readings in each group and this mean value was plotted as representing conditions within its particular time interval. A special condition exists at this dam. While the water can enter the soil, under the upstream apron, across the entire width, it can only escape through a constricted section directly under the weir proper. This condition causes a a decreased pressure in the section by the same action as a constriction in a pipe. Because of this control section variations are likely to be magnified in front of the section since no compensating action within the soil can relieve the variations in the pressures. It will be noted that in this case as in others where vertical creep distances are a small part of the total creep, the plain creep and the weighted creep line fall close together throughout their lengths.

Percha Dam, Rio Grand Project - Fig. 2.

In this plate, there are three observation lines which fall out of line with the rest. One of these lines represents the first set of observations taken and the other two represent the final two sets. In the case of the first one, the small loss of head may have been the result of the smaller thickness of silt on the bed which upon the increase in thickness increased the resistance to flow from free water to pipe number one. The last two were taken after a summer flood which probably disturbed the silt bed and this changed the resistance to a value apprching that for the first observation. In order to show the effect on the curves of varying the position at the end of . creep, another plate was made - Plate No. 2A. For this plate the end of creep was taken at the first weep hole. Then a mean observation line drawn on plate 2 was transferred to plate 2A where a comparison of theoretical pressures, computed by using the new end of creep, is made with the probable mean of the observations.

Pinhook Dam, Marquoketa, Iowa. Fig. -4

Two sets of curves were made up for the Pinhook Dam - figs. 4 and 4A. Fig. 4 used the beginning of the long downstream apron as creep end while Fig. 4A uses the end of the apron. The true end of creep no doubt lies somewhere between these two extremes. The dates of the observations are shown on the curves. The first four lines represent conditions before any appreciablesilt deposit had accumulated over the bottom of the reservoir. The fifth line represents measurements after a good deposit had formed.

Kabo Head Works. Fig.-6

Pressure pipes were installed along three different cross sections labelled in the original data as Shwebo Canal Side, Ye-U Canal Side and Center line. The sections differ only slightly in their dimensions so only one electrical set up was used. Plates 6 and 6a show pressure curves for all three cross sections. The higher pressures at U1, U2 and U3 on the center line are due to a ridge of clay under the center line of dam. Because of the restricted passage the pressures are built up in advance of the restriction.

Deoha Barrage, Sarda Canal. Fig. - 3

A great many pressure pipes were installed in this dam and numerous observations are available. By taking the mean reading along a line of pipes normal to flow a representative picture of the flow across the whole section of sub-soil is obtained. A disturbing element was present in this dam in the form of a thirty foot cut-off of Universal Sheet piling which had openings ¾ inch along the joints. The effect of the leaky piling is evident in the curves Fig. 3. The restriction of flow increases the loss and reduces the pressure at pipe line number 8. Creep distances were computed both considering the piling effective and also neglecting it. Curves are shownfor both cases.

Narora Weir, Lower Ganges Canal. Fig. - 5

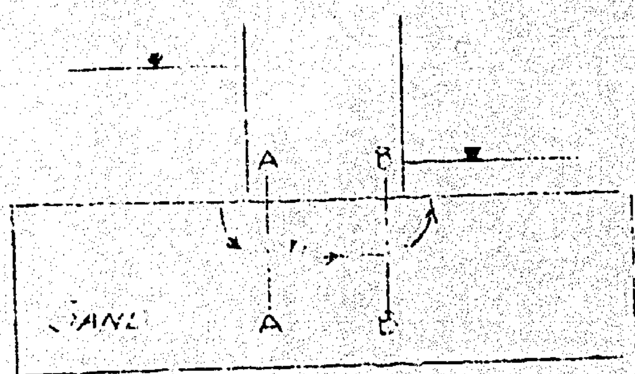
This dam failed due to upward pressures of such magnitude under the downstream apron, that portions were actually lifted allowing material to be washed from the subsoil. Unfortunately only very few measurements are available before the failure. In reconstructing the dam pressure pipe were placed and the observations on these pipes were used in the analysis. Only the cross-section at chain 32 was used in plotting the curves because this section was a typical one and had the most complete set of observations.

Panjnad Headworks, Punjab, India. Fig. - 7

This set of observations at Panjnad is a very comprehensive one and has already been subject to a considerable amount of analysis by Indian engineers. The pipes are so placed that a rough flow net can be drawn from the observations. A copy of a flow net drawn by A. N. Khosla of the Panjab Irrigation District is shown on Fig. 7c along with the flow net plotted by electric analogy. In computing the creep distances the end point of the filter was used as was explained previously. From a study of the geological section of the subsoil, it seems quite possible that the layer of clay at the surface extendsat least to the section which contains the observation pipes. The geological sections included only the bays from No. 2 to No. 32. Since the section containing the pipes was at Pier 44 the above statement about the clay layer is merely an assumption. A great number of measurements were taken on this dam under a wide variation in head. Based on the assumption that the percentage of head lost to any pipe remains constant, the observed values were plotted against head for each pipe. The slope of a mean line thru the point gives the percent head left at the pipe and by subtracting from 100% the head lost is obtained. The original data was worked up in this way and the percentages referred to were used in this present study. In addition to the regular analogy set up, one wwas made using a tipped tray giving a varying depth of electrolyte of 1/8" per inch of tray width. Some idea of the variable permeability in the underground may be gained from a study of the flow not drawn from the observations. For perfectly homogeneous subsoil the rectangles, formed by the intersections of stream and potential lines, have a constant ratio of length to width. The degree that this ratio departs from a constant quantity as it does in Khosla's flow not may be taken as a measure of non-homogenoity.

Discussion:

In all of the curves the pressure line as measured by electric analogy takes very much the same form., There is a steep slope at the entrance and exit while the middle portion is rather flat with one or more points of inflection depending on the profile of the under surface. That this form is the shape which the curve must take can be seen by analizing the following simple case.



With a simple structure on a porpus foundation as shown in the figure, the stream line (n) will take the form shown. This shape can be shown mathematically to be an ellipse with foci at the toe and heel of the structure. Loss of head occurs along the stream line. In the portion ahead of Section A-A and behind Section B-B the length of the stream line per unit horizontal distance is greater than between the two sections where the laminar flattens out. So, therefore, the curve of head loss will have two steep portions connected by a much flatter section as all the curves show.

The analogy curve of pressures indicates that comparatively large losses are to be expected at the entrance and exit. A steep gradient is indicated at the toe which is not apparent in the curve of actual pressures. It must be kept in mind, however, that due to the difficulty of fixing the creep end the gradient shown by the measured pressures is rather indefinite.

After an analysis by the electric analogy method to confirm the mathematical development the problem of computing uplift pressures is by no means solved. As a preliminary to any such method as the electric analogy, which allows of a very nice degree of refinement, a study of measurements under actual dams should be made. Having done this, the investigator can interpret his analogy results for what they are worth. With such a clear cut method as the electrical set up it is always a temptation to lose sight of the true weight of the results and to proceed beyond any justifiable limit. An indication of the limits can be obtained directly from experiments with hydraulic models. A comparison between the results of these experiments and analogy measurements on the same dam profile should give a better agreement than can be obtained with actual measurements.

Before entering a discussion of this method of establishing the existence of laminar flow an examination of the observed data will be made with the same end in view. With strictly laminar flow the loss to any point expressed as a percentage of the total head would remain constant. This fact follows directly from the construction of a flow net which remains the same regardless of the magnitude of the head. The data from four of the dams was drawn up in graphic form Figs. 8 - 10A. Time was measured along the abscissa and upstream level, downstream level, head, and percentage head lost were plotted along the ordinate for each pipe. In the case of Nathare Escape Head the tail water elevations were not available so the variation in head could not be shown. There seems to be no relation between upstream level and uplift pressures. In the case of the Colorado River Dam it is difficult to note any features of the variation in the percentage lines as compared with the variation of head because of the long interval between observations. It is always possible for a fluctuation in head to occur within one interval and not show its effect until the next interval when a new head is recorded. In the instance of the Deoha Barrage curves, a few of the pipes seem to follow the head water but the others show no such relationship. Here again the intervals between observations were too great to be of much value in this particular analysis. Of the four dams shown, Kabo Headworks is the most consistent. The observations plotted were taken within a period of 4 days. The percentage lines do not follow the curve of head at first but become constant when the head remains constant.

The decided variation in the percentage loss lines is a very disturbing factor unless it can be explained on the basis of the flow under the dam shifting and changing the flow lines at any particular section. The non-existence of steady percentage drops is a way of saying that the flow net for the section has changed. A flow not can always be drawn when the flow is definitely laminar and remains constant as long as conditions of the medium remain constant.

The experiments with hydraulic models which have already been referred to have been of two types. In one type the pressures under the model dam are measured in the same way as those existing under an actual dam. A model of a dam is set up on screened sand with piezometer tubes installed for reading pressures. The model is then subjected to a head of water and the piezometer levels are read. The most complete set of experiments of this type is that of Colman, a record of which may be found in the Transactions Amer. Soc. Civ. Engineers, Vol. 80, p.421, 1916. A series of experiments using electric analogy was made on the same dam shapes by the U. S. Bureau of Reclamation. A comparison of these results with those of Colman is given in Tech. Memo. 303, Security of Masonry Dams on Earth Foundations by E. W. Lane. The results do not check and on the basis of these experiments the electric analogy method would have to be seriously restricted in its use.

The second type of experiments mentioned before are those in which the actual stream lines are traced under a structure by means of dyes introduced into the seepage water. These experiments show very clearly that the water does flow in laminas. The dyes travel very definite curves and thus seem to contradict the work of Colman.

In order to reconcile the two sets of experiments a neglected source of error must be found in one of the two types. From the standpoint of actual pressures existing under dams, which can cause failure, the experiments of Colman would seem to be the more directly applicable of the two types. He used two samples of sand referred to as sand A and sand B. Sand A was a natural sand varying from large pebbles to fine grains with very little clay. Sand B was obtained by screening A thru a $\frac{1}{2}$" square mesh sieve which removed about 35% of the larger pebbles. The experiments using Sand B were used by Mr. Lane in showing the comparison with analogy results. Colman in his set-up did not take any particular precaution to insure uniform distribution of his foundation material. Since the range of size in his material was considerable and since no provision was made for uniform distribution, it is difficult to say how much more nearly homogeneous his material is than the material of an actual dam sub-soil.

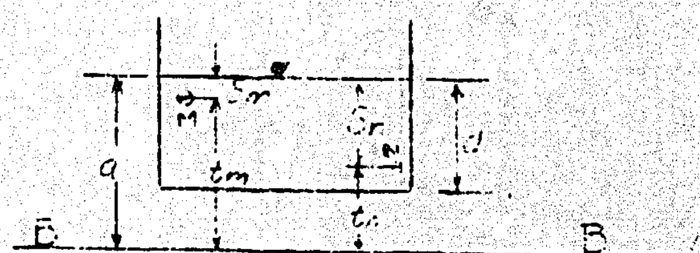
Khosla states that the electric analogy is only applicable under the following conditions:

a. "If gravity were absent."

b. "If the transmission constant for flow in the vertical direction were exactly the same as in the horizontal."

He attributes (b) to stratification or to some other causes which have as yet been undetermined. He goes to some length in an analysis of the Panjnad observations to establish a factor by means of which indicated pressures are corrected for gravity. This corrected pressure he calls the value after the hydro-dynamical pressure. The observations at two pressure pipes Nos. 28 and 29 are used to establish the existence and magnitude of this correction. However, two other pipes Nos. 14 and 15, which are equally well situated for showing this correction, fail to indicate its existence. After computing the correction, Khosla neglects it because it is very small.

The questions of pressure with regard to laminar flow is apt to be very confusing. It should be remembered that in hydrodynamics only potential is considered as causing flow. By potential is meant the inherent ability of a body by reason of its position, to accomplish work. In hydraulics potential may be said to consist of two parts, pressure and position. Pressure can be defined in terms of potential thus: it is the potential of a point with reference to a datum thru the point. From the definition of potential given it is obvious that there must be a datum or plane of reference. When every point in an hydraulic system is referred to some common plane, the potential of each point relative to the datum is accomplished. As a simple illustration of the difference between potential and pressure a tank of water is used.



The pressure at two points, in the tank, such as M. and N. is equal in each case to the weight of the water column above the point. Unit pressure can be set equal to the height of the column multiplied by the unit weight of the liquid. Thus the pressure expressed as head of liquid is S_m for point M and S_n for point N. Since S_m and S_n are different the pressures are different. The potential of point M referred to Plane B-B is equal to the pressure plus the difference in elevation. The potential there equals S_m plus t_m or (a). Likewise for point S_n the potential equals S_n plus t_n or (a). So M and N have the same potential although they are under different pressures. Potential is measured usually by means of a piezometer tube. The elevation of the water surface in the tube is a measure of the potential. In measuring uplift under a dam, the datum for determining piezometer elevation is usually taken as the tailwater and the difference in elevation is called head.

In dealing with subsoil flow the velocity is usually so small that total energy can be measured by means of potential. The necessity of superimposing an electrical field to represent gravity in the electrical analogy method is very questionable. The electric potential at a point is certainly analogous to the potential of water measured in the manner described here if the flow is laminar. If the resistances are strictly analogous in the sub-soil and in the analogy set up, the flow will be similar.

The point is well made that there are factors such as stratification which disrupt the rigidity of the analogy., The questions for solution is the degree of this departure from strict analogy and the factors causing it.

From the experiments performed by Taylor and Uppal at Punjab, India, it is evident that the flow can be brought very close to the purely theoretical by controlling conditions. The sand used here was very uniform. It was of such a grade that it passed a 60 mesh sieve but was retained on an 80 mesh. This gives a range of particle size approximately from .0068" to .0087". No attempt was made to measure uplift but it is planned to do so at a later date. From the shape of the stream lines it can be expected that those measurements will check with analogy measurements.

From a comparison of electric analogy results with actual measurements and model experiments the conclusion indicated at the present stage is that any application of analogy results to problems of practical design must be made with care. I believe the analogy method has considerable value for a qualitative study of subsoil flow. It is not possible yet to make much quantitative use of the method. There are still too many factors involving the geological conditions at any dam site which elude evaluation and so cannot be simulated in an analogy set up.

I do not believe that as yet there is any conclusive evidence that flow in subsoil of a masonry dam cannot eventually be studied both qualitatively and quantitatively by means of the electric analogy. I consider no evidence conclusive which does not attack the fundamental basis for analogy. Attempts to do this have been made but the evidence upon which they rest is not convincing.

The data used in this report were drawn from the following sources:

Colorado River Dam - - - Transactions A.S.C.E. 1929, Vol. 93

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Pinhook Dam - - - - - - - " " " "

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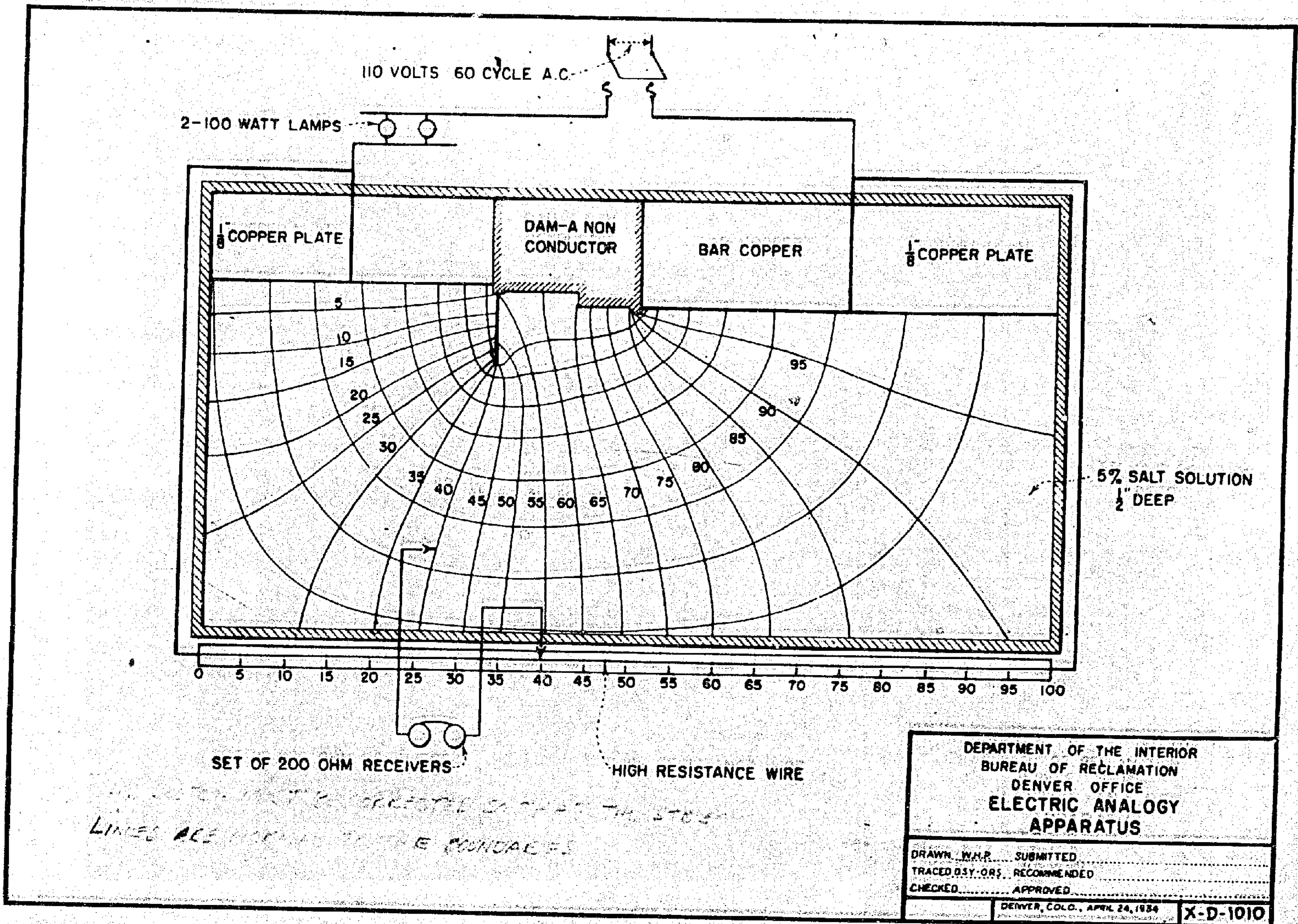
Nathaura Escape Head - - United Provinces, P.W.D. India.

Dooha Barrage - - - - - United Provinces, P.W.D. India.

Panjnad Headworks - - Punjab Engineering Congress, Paper No. 162 (1933)?

The Bureau of Reclamation is indebted to these organizations for the valuable assistance they have furnished.

APPENDIX


110 VOLTS 60 CYCLE A.C.
2-100 WATT LAMPS
1/8" COPPER PLATE
DAM-A NON CONDUCTOR
BAR COPPER
1/8" COPPER PLATE
5% SALT SOLUTION 1/2" DEEP
SET OF 200 OHM RECEIVERS
HIGH RESISTANCE WIRE
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE
ELECTRIC ANALOGY
APPARATUS
DRAWN W.H.P. SUBMITTED
TRACED D.S.Y.-O.R.S. RECOMMENDED
CHECKED APPROVED
DENVER, COLO., APRIL 24, 1934
X-D-1010

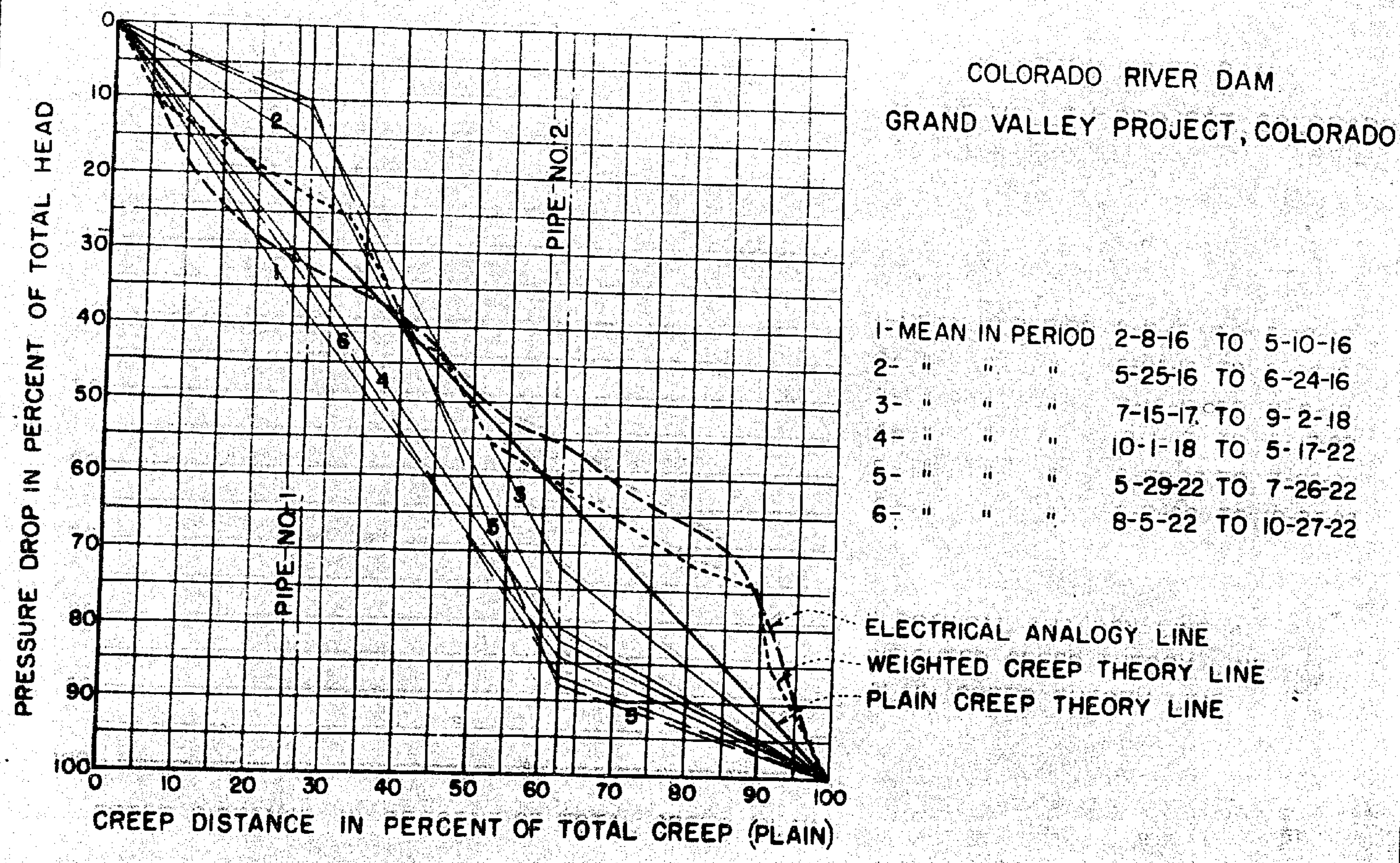

COLORADO RIVER DAM
GRAND VALLEY PROJECT, COLORADO
1- MEAN IN PERIOD 2-8-16 TO 5-10-16
2- " " " 5-25-16 TO 6-24-16
3- " " " 7-15-17 TO 9-2-18
4- " " " 10-1-18 TO 5-17-22
5- " " " 5-29-22 TO 7-26-22
6- " " " 8-5-22 TO 10-27-22
ELECTRICAL ANALOGY LINE
WEIGHTED CREEP THEORY LINE
PLAIN CREEP THEORY LINE
PIPE NO. 1
PIPE NO. 2
PRESSURE DROP IN PERCENT OF TOTAL HEAD
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)
0
10
20
30
40
50
60
70
80
90
100

FIG. 1
X-D-1036

PERCHA DAM

RIO GRANDE PROJECT

SHEET 1

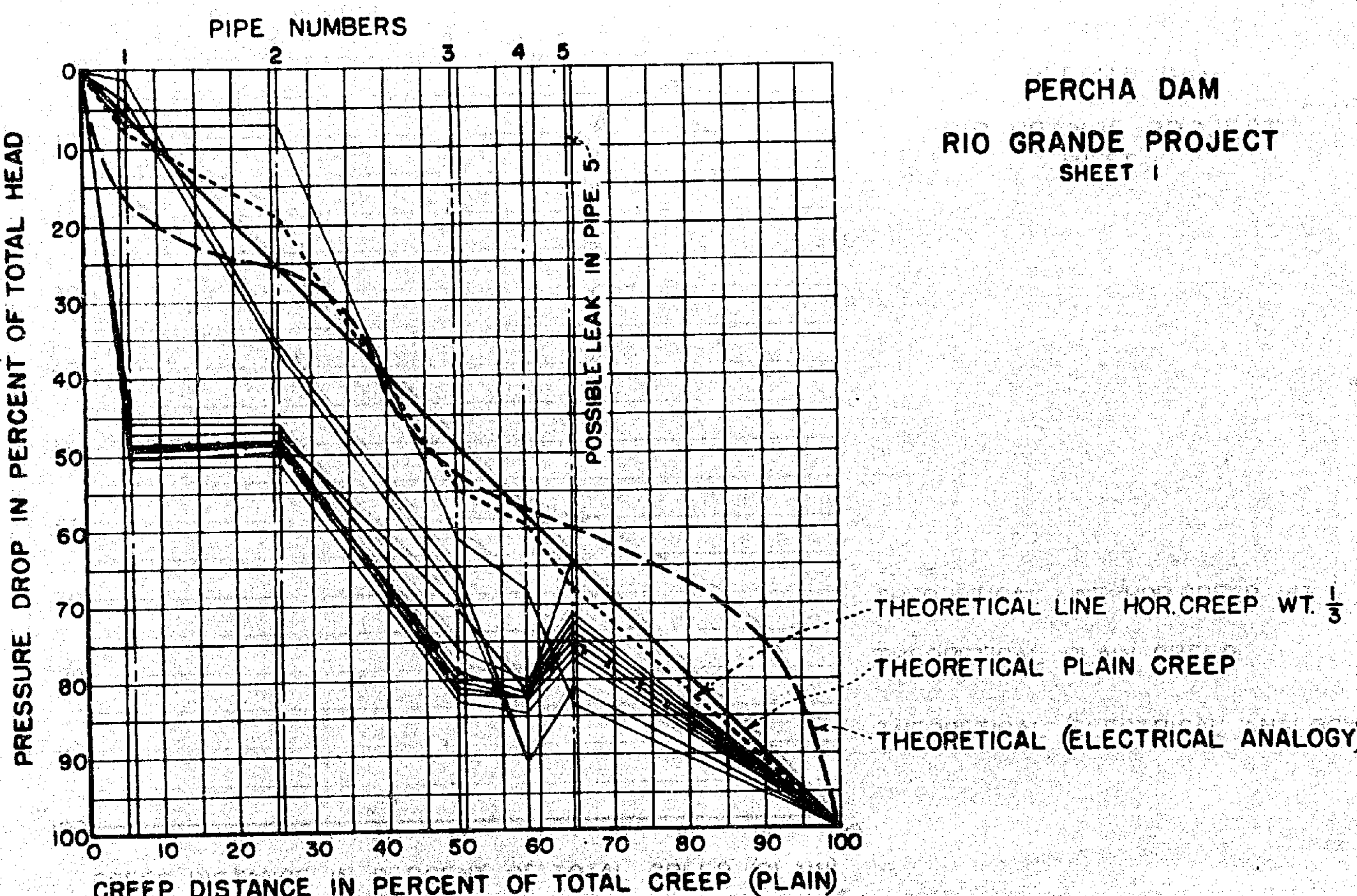
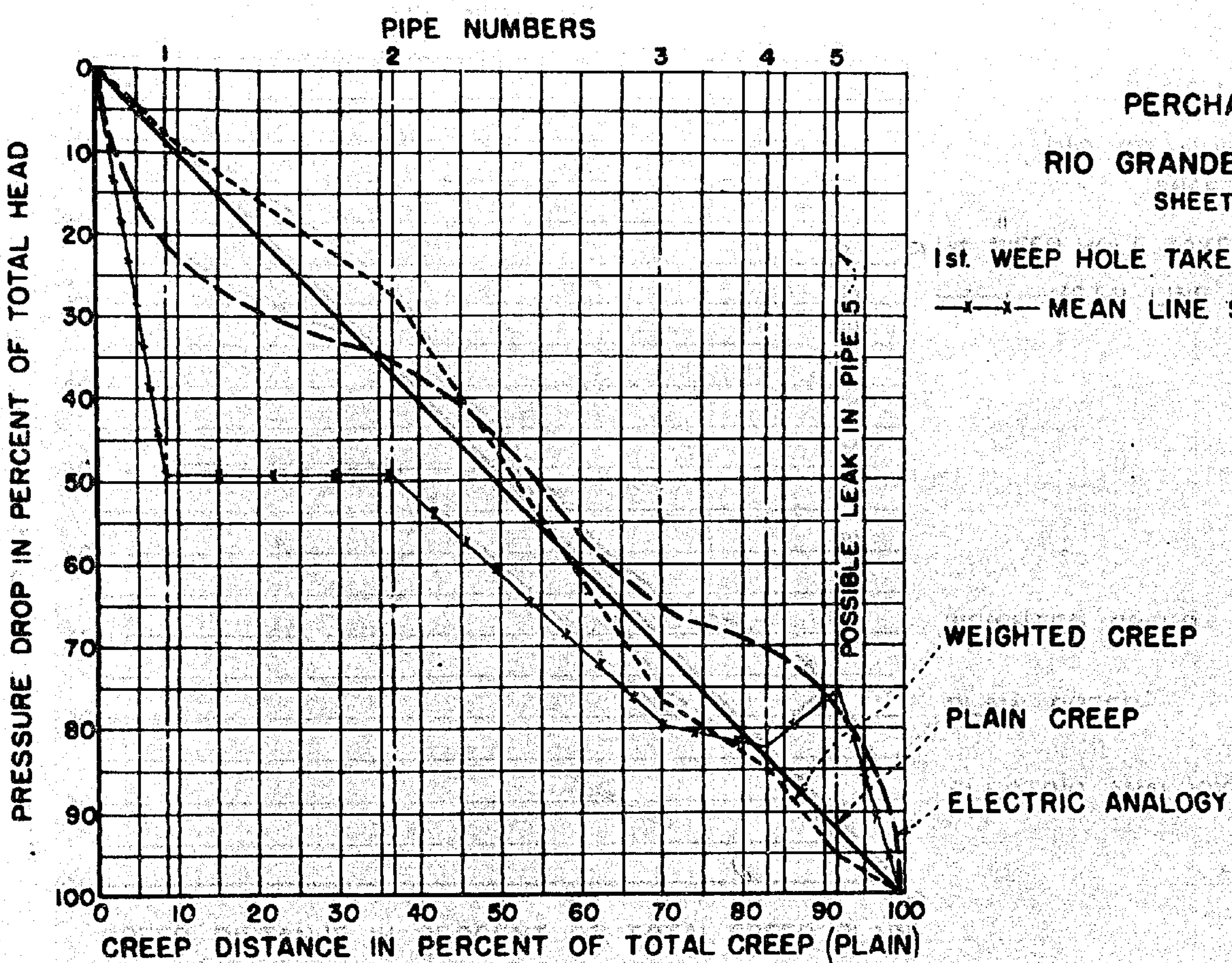


FIG. 2
X-D-1037



This plot is for the purpose of showing the effect of varying the location of the end of creep.

FIG. 2A
X-D-1038

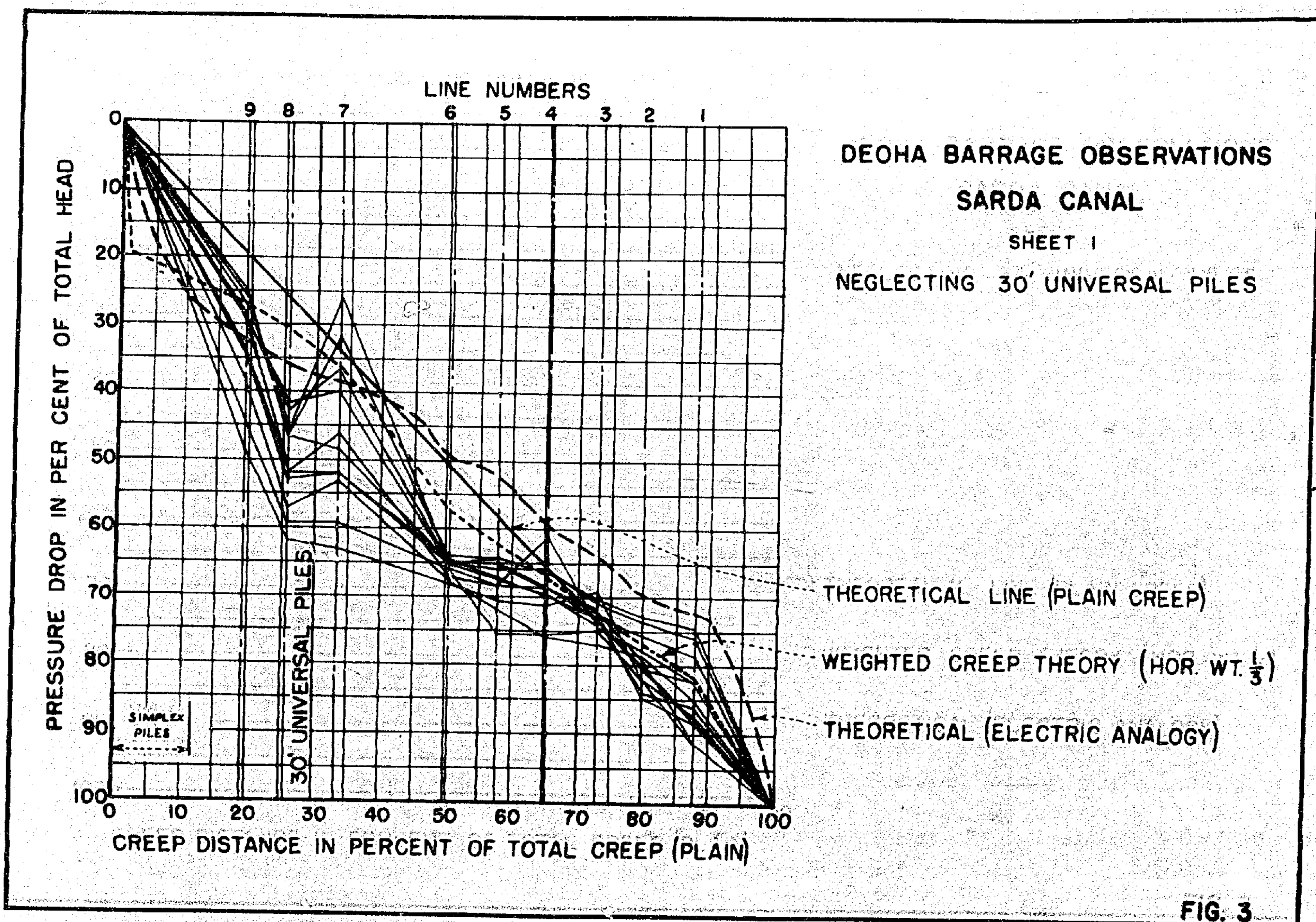

DEOHA BARRAGE OBSERVATIONS
SARDA CANAL
SHEET I
NEGLECTING 30' UNIVERSAL PILES
LINE NUMBERS
9 8 7 6 5 4 3 2 1
0 10 20 30 40 50 60 70 80 90 100
PRESSURE DROP IN PER CENT OF TOTAL HEAD
0 10 20 30 40 50 60 70 80 90 100
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)
SIMPLEX PILES
30' UNIVERSAL PILES
THEORETICAL LINE (PLAIN CREEP)
WEIGHTED CREEP THEORY (HOR. WT. 1/3)
THEORETICAL (ELECTRIC ANALOGY)

FIG. 3
X-D-1039

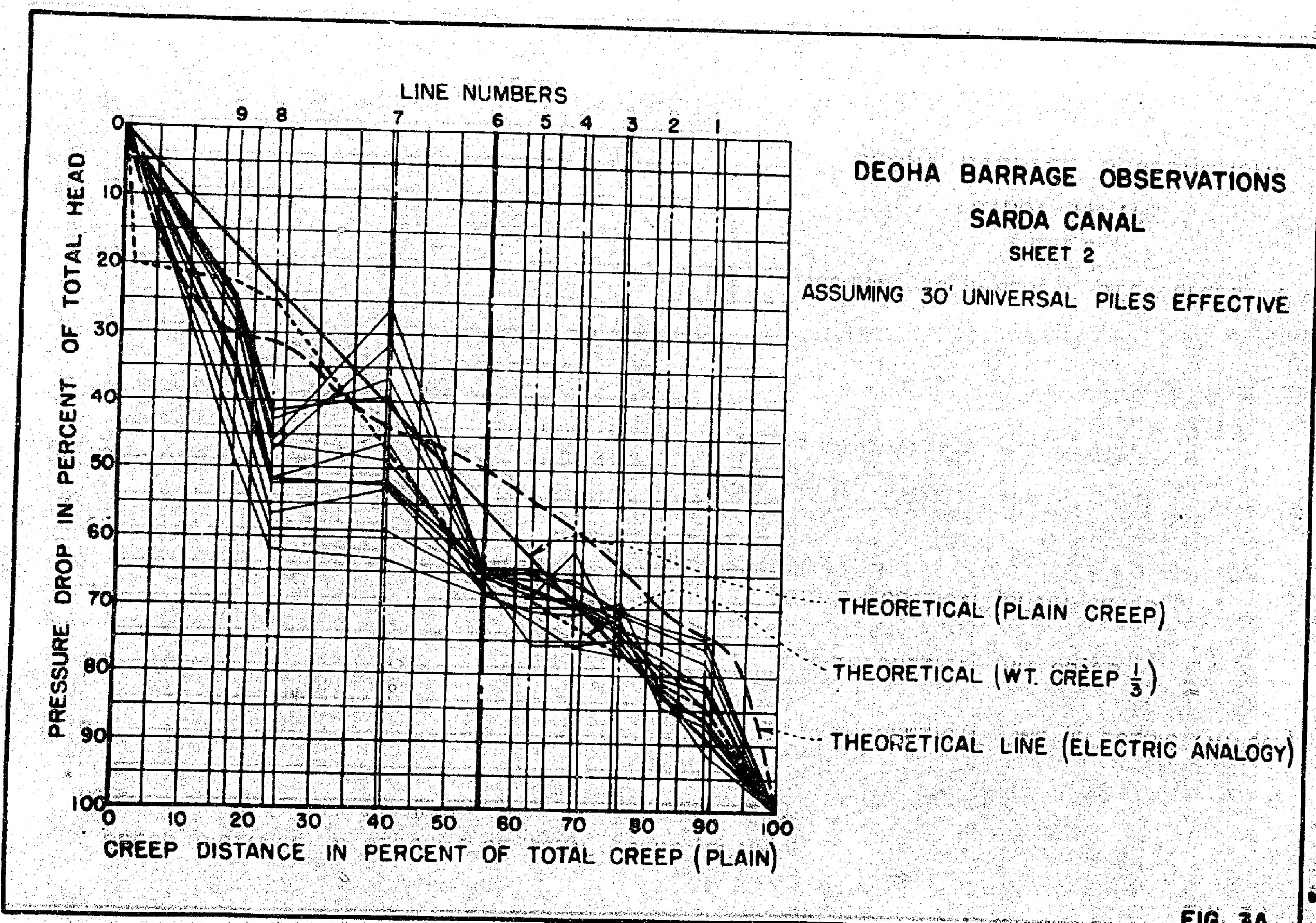


FIG. 3A
X-D-1040

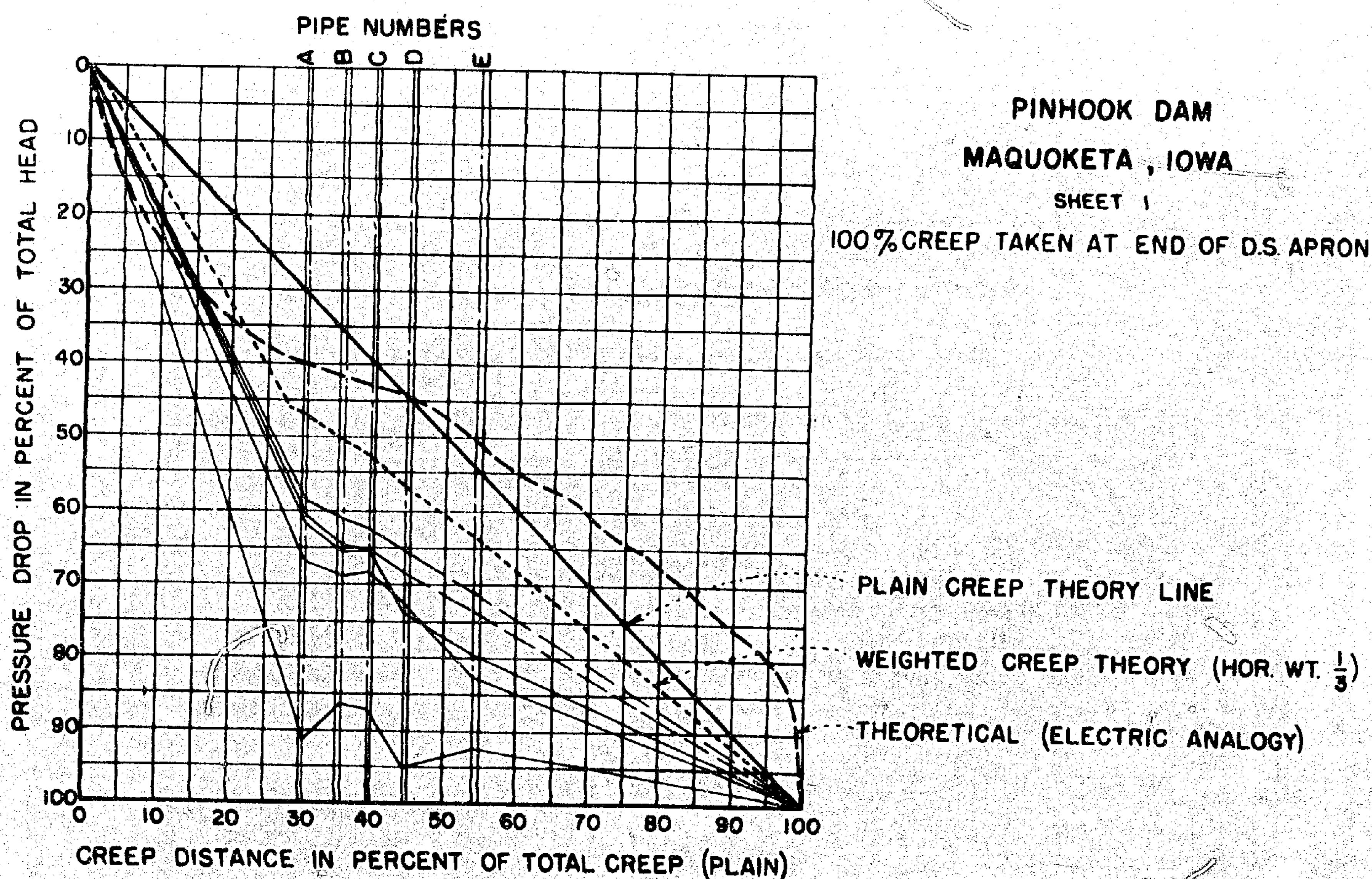

PINHOOK DAM
MAQUOKETA, IOWA
SHEET 1
100% CREEP TAKEN AT END OF D.S. APRON
PIPE NUMBERS
A B C D E
PLAIN CREEP THEORY LINE
WEIGHTED CREEP THEORY (HOR. WT. 1/3)
THEORETICAL (ELECTRIC ANALOGY)
PRESSURE DROP IN PERCENT OF TOTAL HEAD
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)
0
10
20
30
40
50
60
70
80
90
100

FIG. 4
X-D-1041

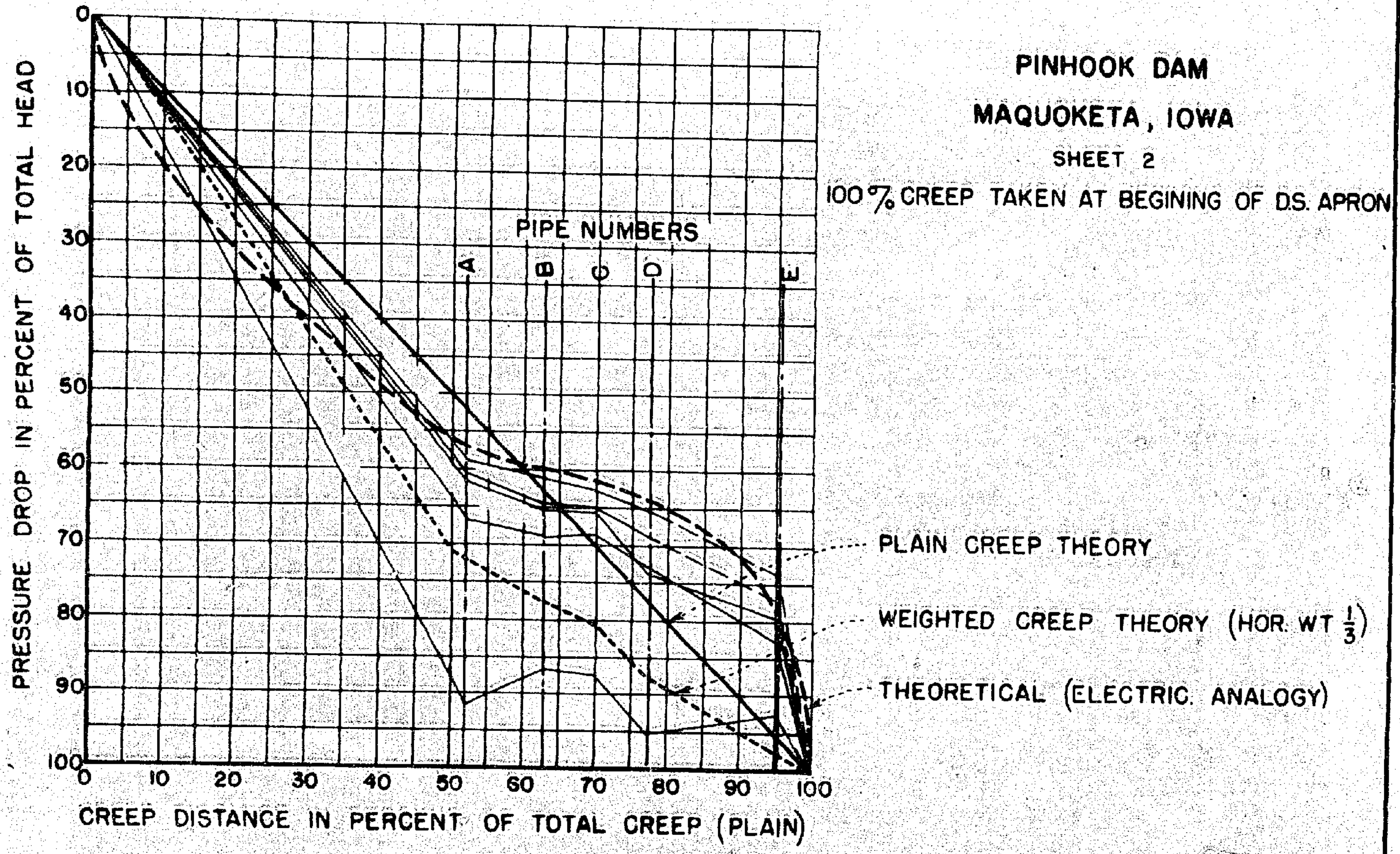


FIG. 4A
X-D-1042

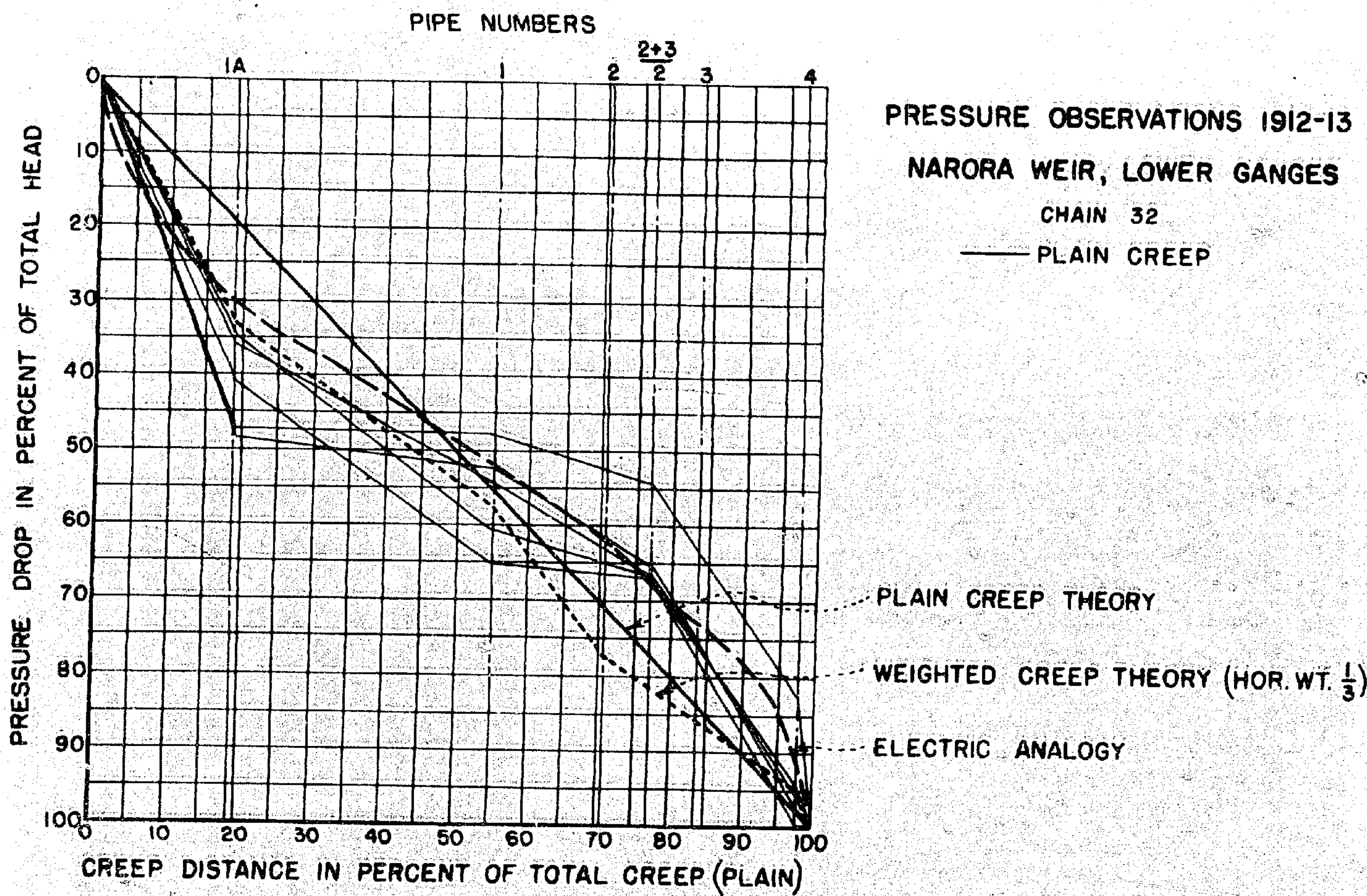

PIPE NUMBERS
1A
1
2
(2+3)/2
3
4
0
10
20
30
40
50
60
70
80
90
100
PRESSURE DROP IN PERCENT OF TOTAL HEAD
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)
PRESSURE OBSERVATIONS 1912-13
NARORA WEIR, LOWER GANGES
CHAIN 32
—— PLAIN CREEP
PLAIN CREEP THEORY
WEIGHTED CREEP THEORY (HOR. WT. 1/3)
ELECTRIC ANALOGY

FIG. 5
X-D-1043

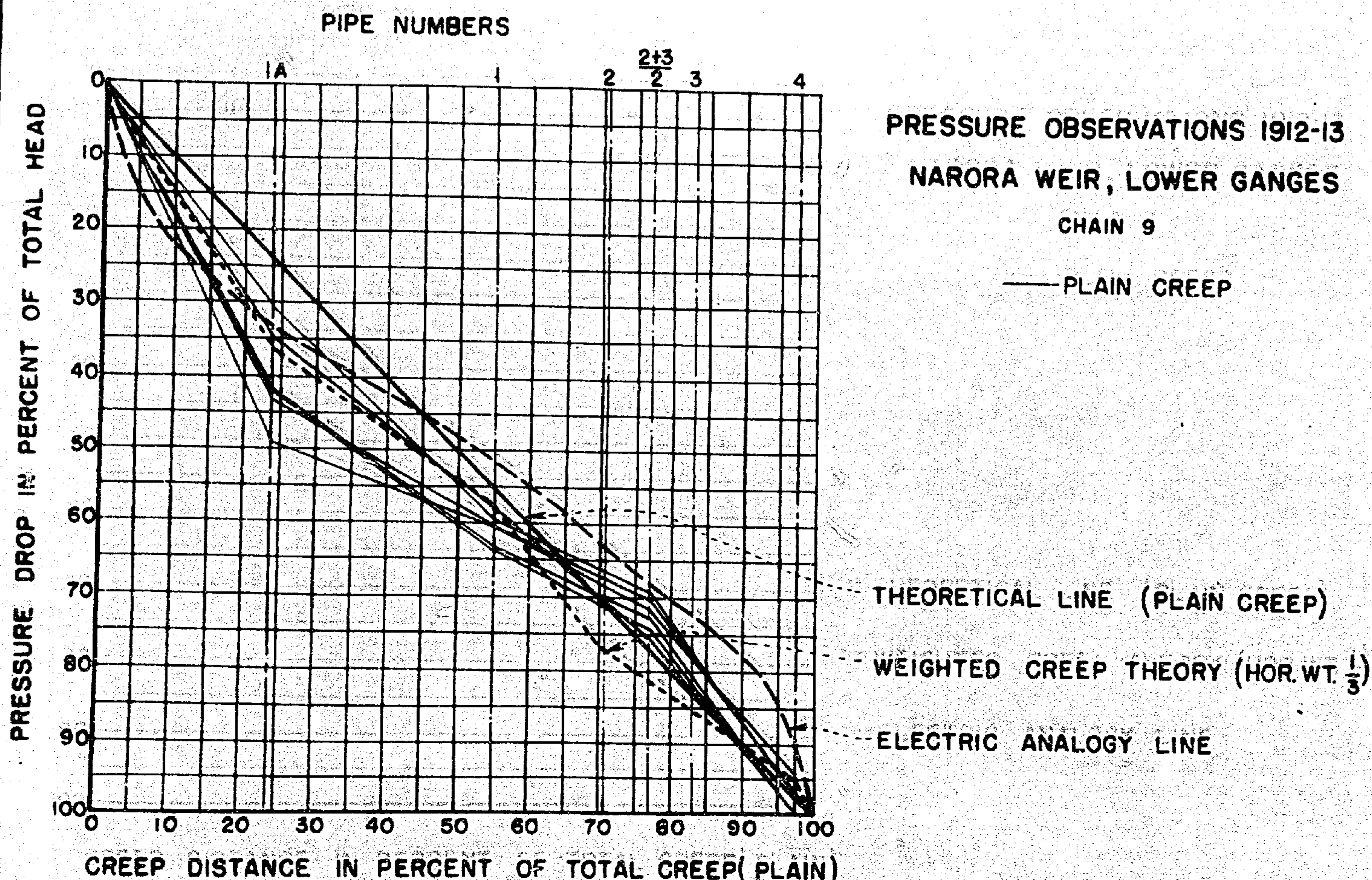


FIG. 5A
X-D-1044

PRESSURE OBSERVATIONS 1912-13

NARORA WEIR, LOWER GANGES

CHAIN 32

Showing the effect of placing creep end at end of downstream grouted pitching.

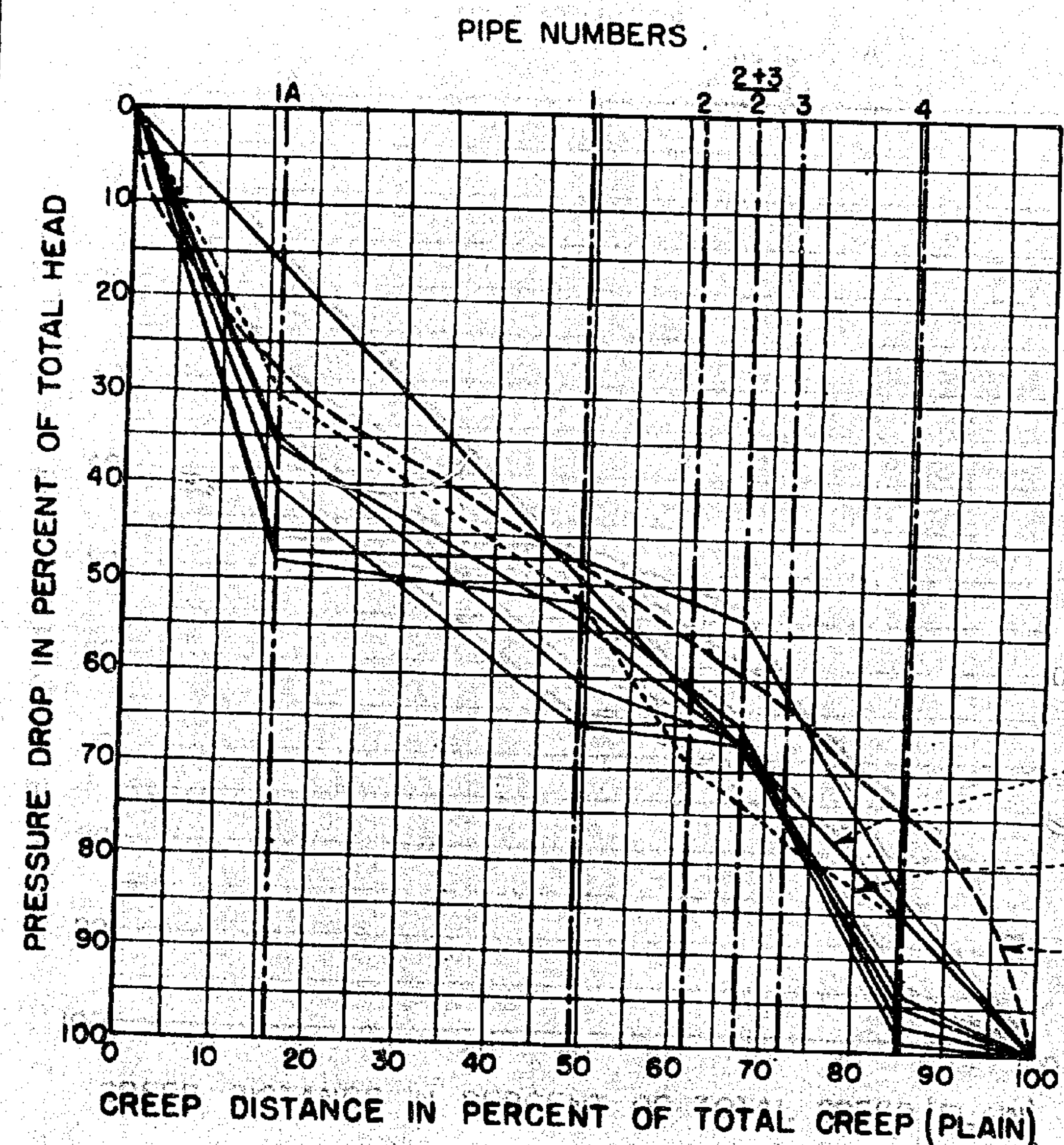


FIG. 58

X-D-1045

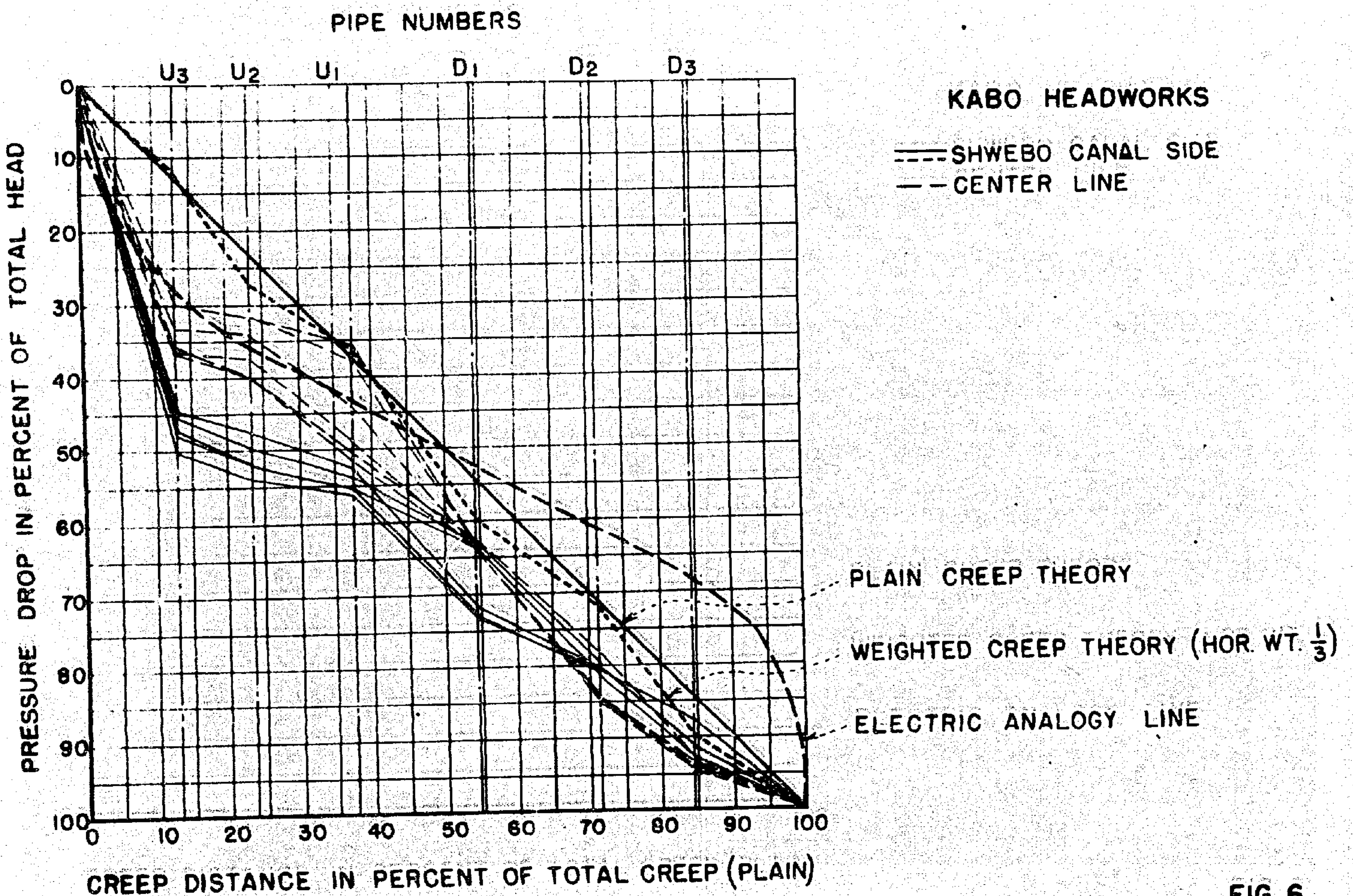

PIPE NUMBERS
U3
U2
U1
D1
D2
D3
KABO HEADWORKS
SHWEBO CANAL SIDE
CENTER LINE
PLAIN CREEP THEORY
WEIGHTED CREEP THEORY (HOR. WT. 1/3)
ELECTRIC ANALOGY LINE
PRESSURE DROP IN PERCENT OF TOTAL HEAD
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)

FIG. 6
X-D-1046

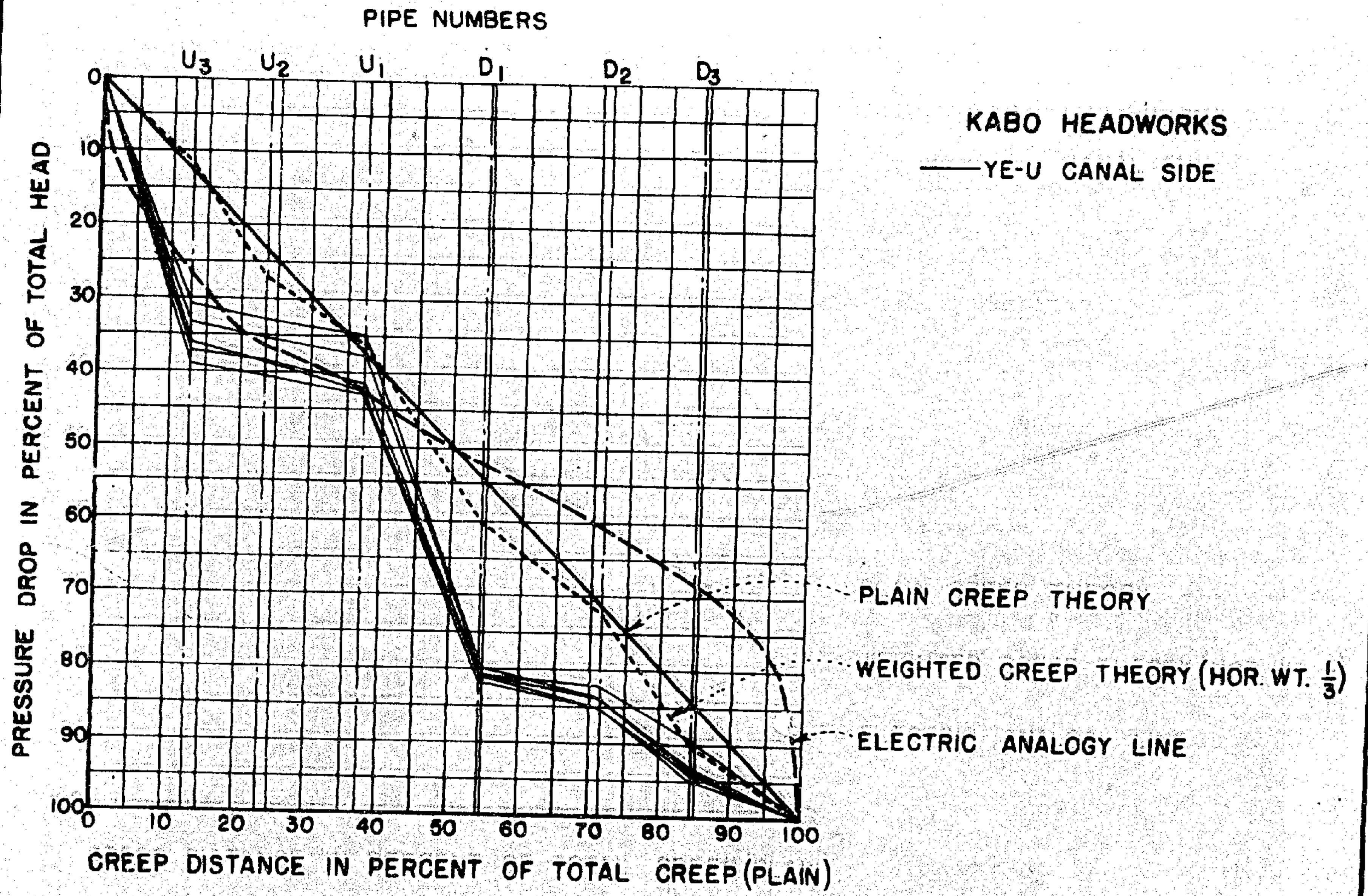


FIG. 6A
X-D-1047

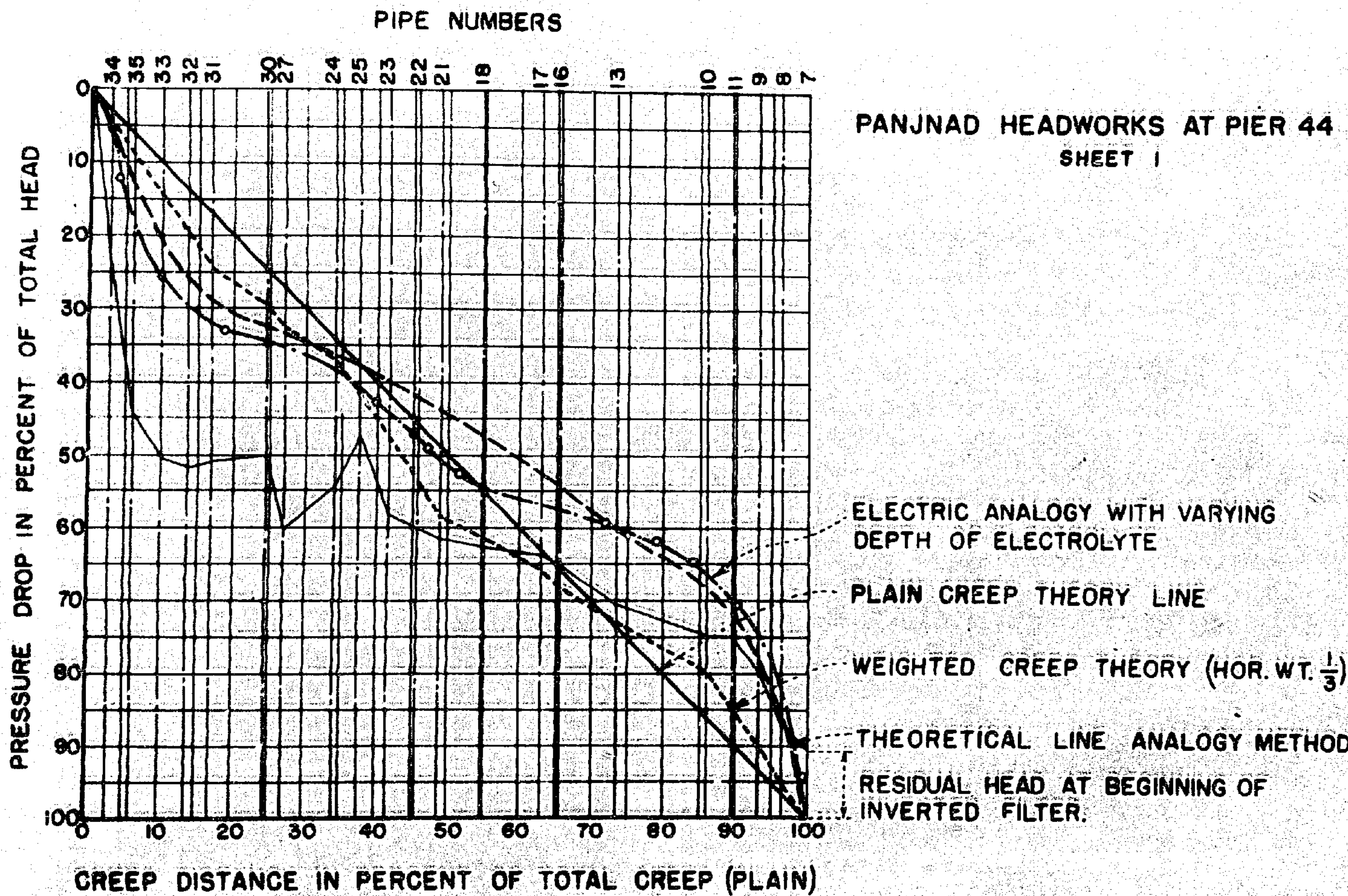

PANJNAD HEADWORKS AT PIER 44
SHEET 1
PIPE NUMBERS
34 35 33 32 31 30 27 24 25 23 22 21 18 17 16 13 10 11 9 8 7
PRESSURE DROP IN PERCENT OF TOTAL HEAD
0 10 20 30 40 50 60 70 80 90 100
CREEP DISTANCE IN PERCENT OF TOTAL CREEP (PLAIN)
ELECTRIC ANALOGY WITH VARYING DEPTH OF ELECTROLYTE
PLAIN CREEP THEORY LINE
WEIGHTED CREEP THEORY (HOR. WT. 1/3)
THEORETICAL LINE ANALOGY METHOD
RESIDUAL HEAD AT BEGINNING OF INVERTED FILTER.

FIG. 7
X-D-1048

PANJNAD HEADWORKS PIER 44

SHEET 2

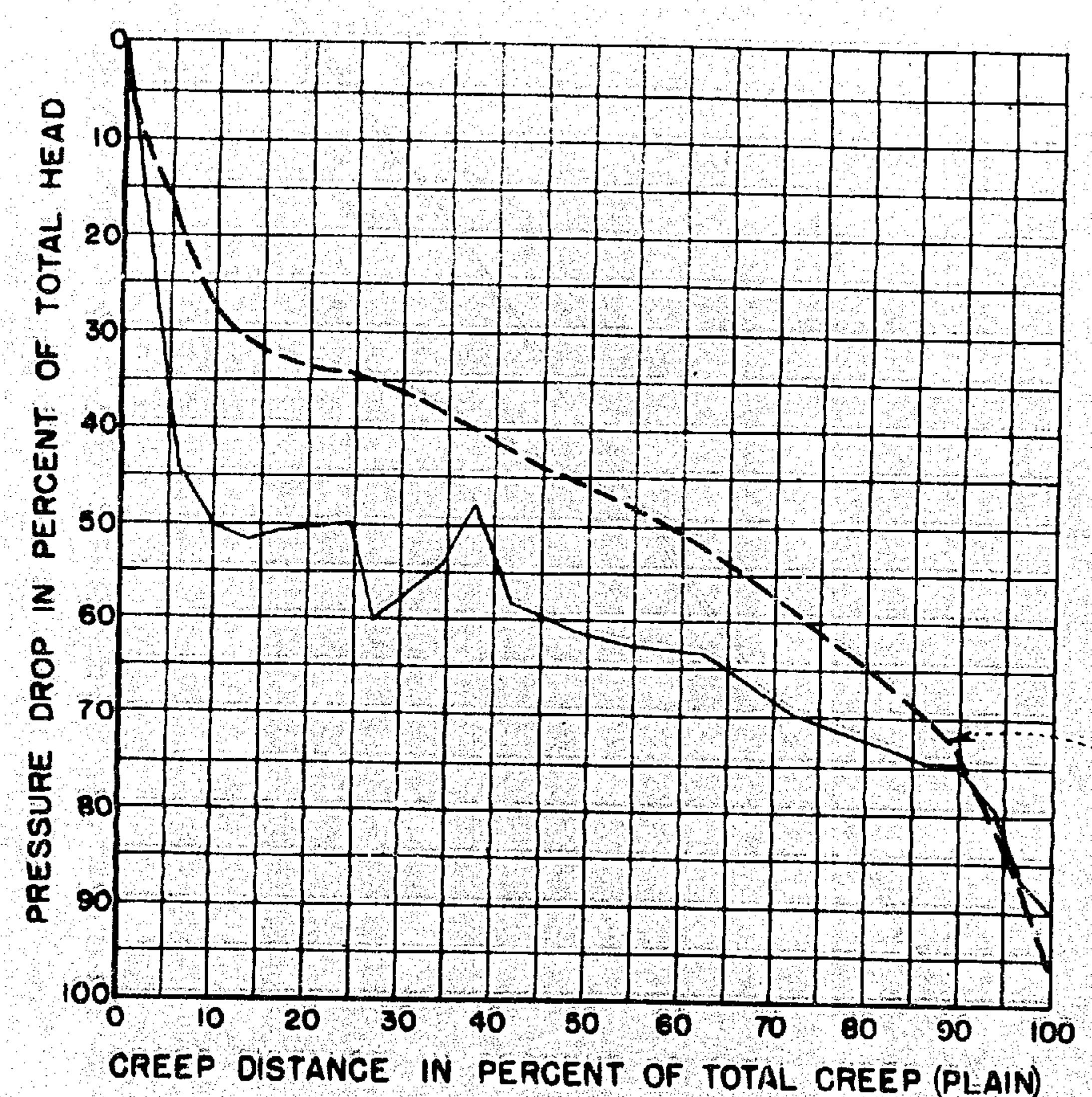


FIG. 7A
X-D-1049

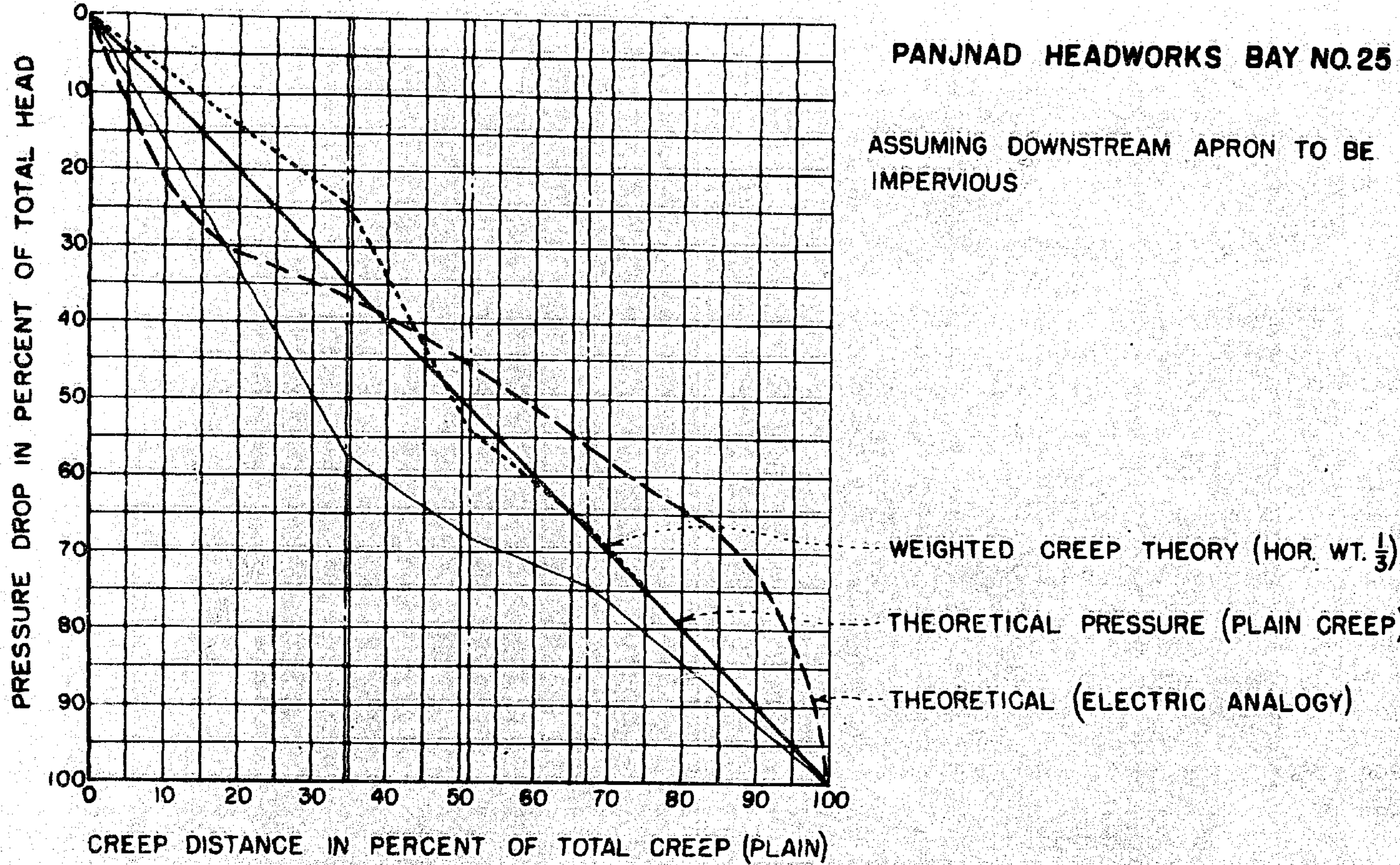
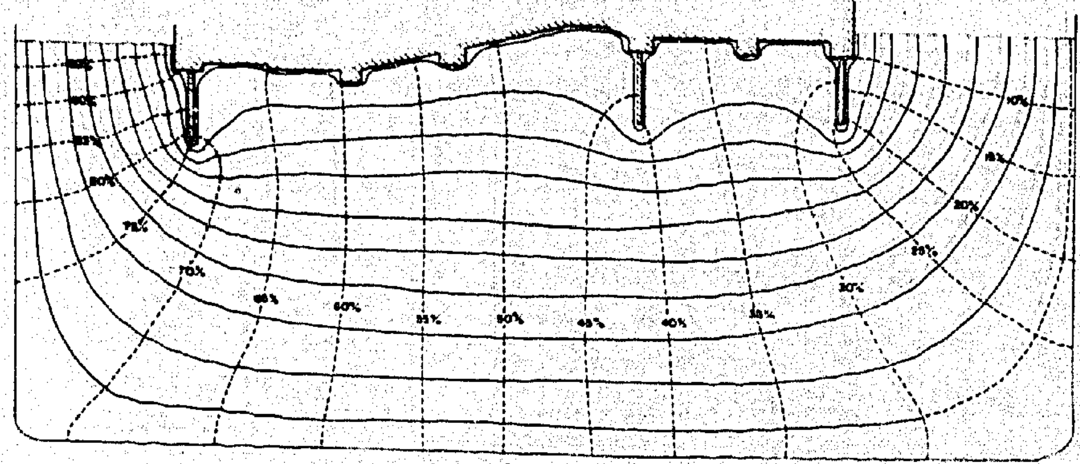
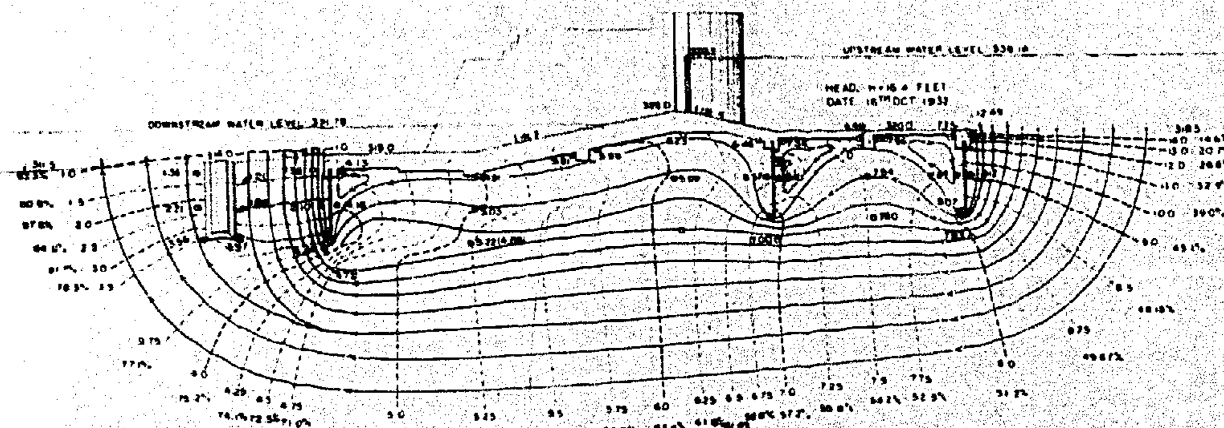


FIG. 7B
X-D-1050

FIG. 7c



PIER 44
PANJNAD HEAD WORKS
FLOW NET PLOTTED
BY ELECTRIC ANALOGY
SCALE 1"=15'



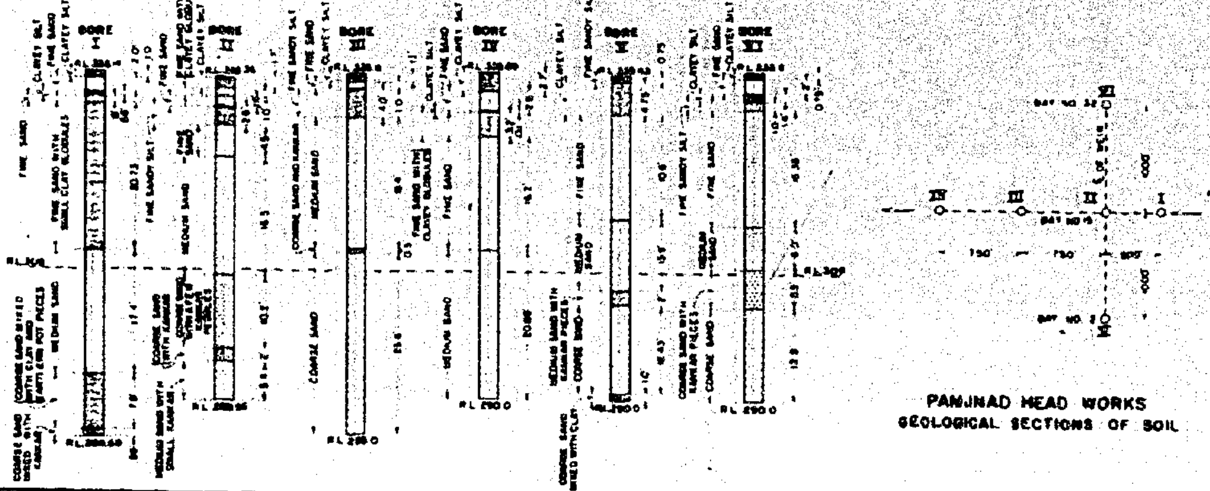
NOTES

○ INDICATES TOP OF STRAINER WHERE INDICATED PRESSURE (P) IS ASSUMED TO ACT.

NUMERALS AGAINST ○ DENOTE VALUES OF P AT THAT POINT FOR H=16.4

PERCENT FIGURES DENOTE % LOSS OF HEAD LINE

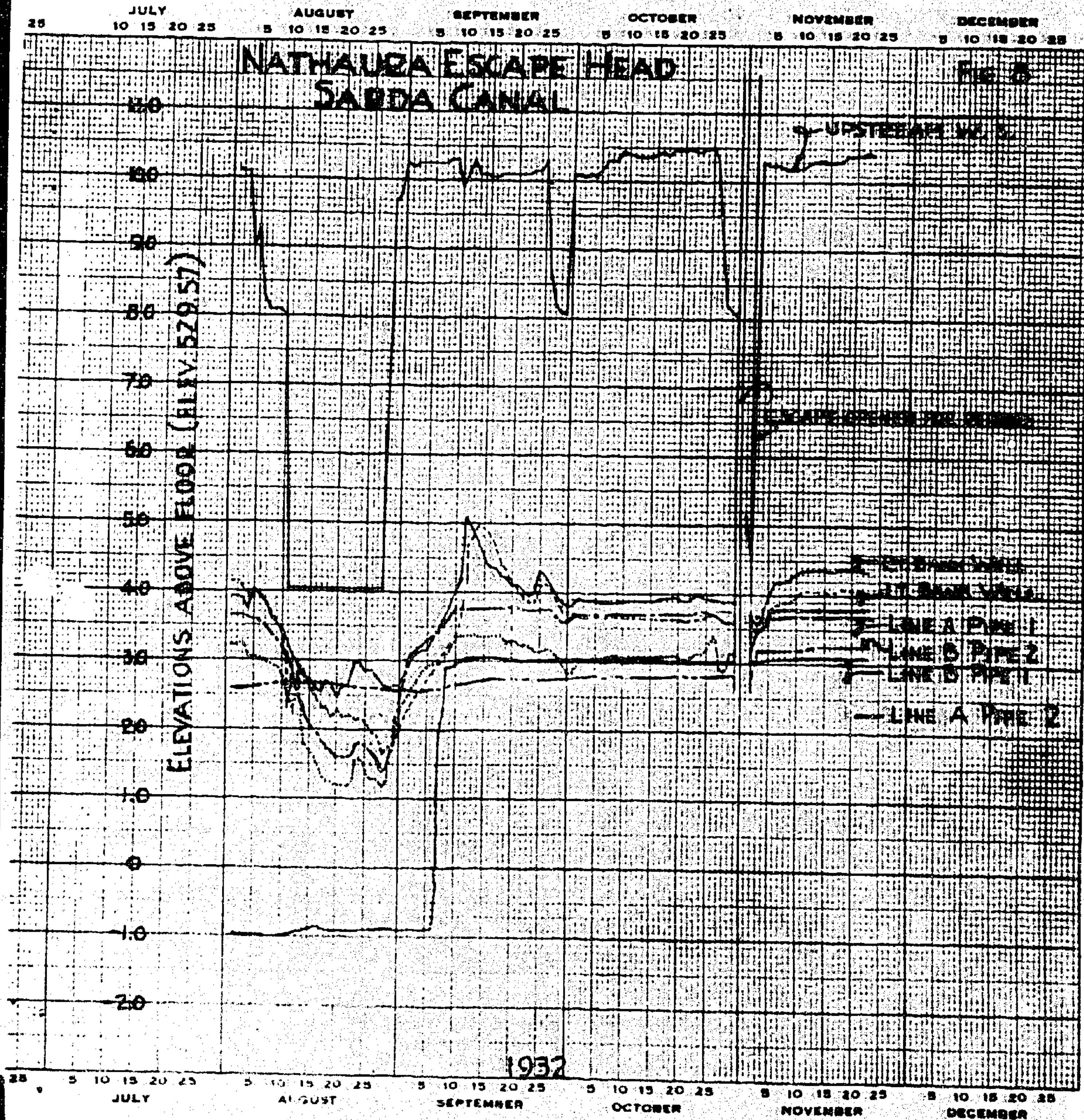
PIER 44
PANJNAD HEAD WORKS
STREAM LINES AND PRESSURE CONTOURS
H=16.4
SCALE 1/250



PANJNAD HEAD WORKS
GEOLOGICAL SECTIONS OF SOIL

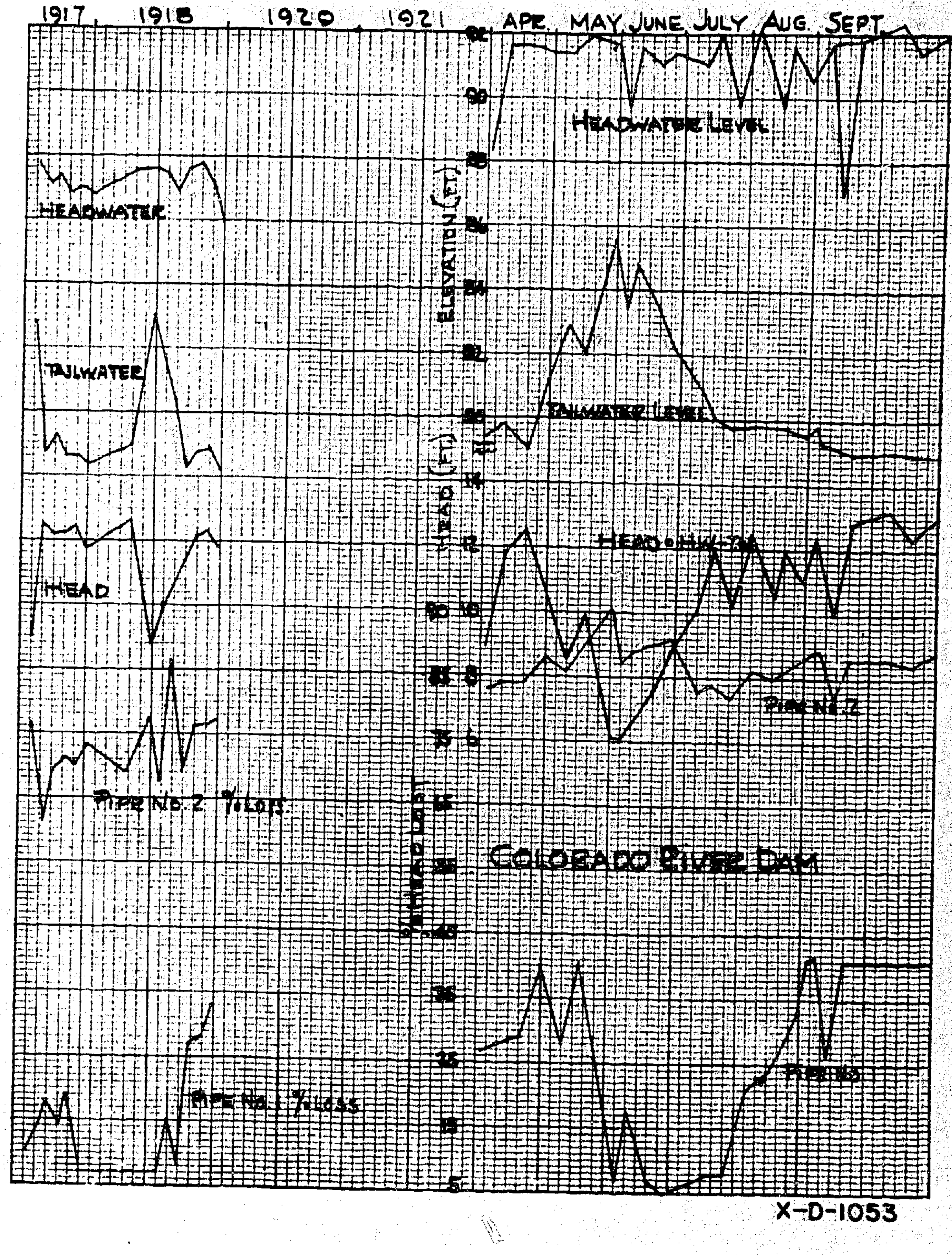
X-D-1051

RECORD SHEET



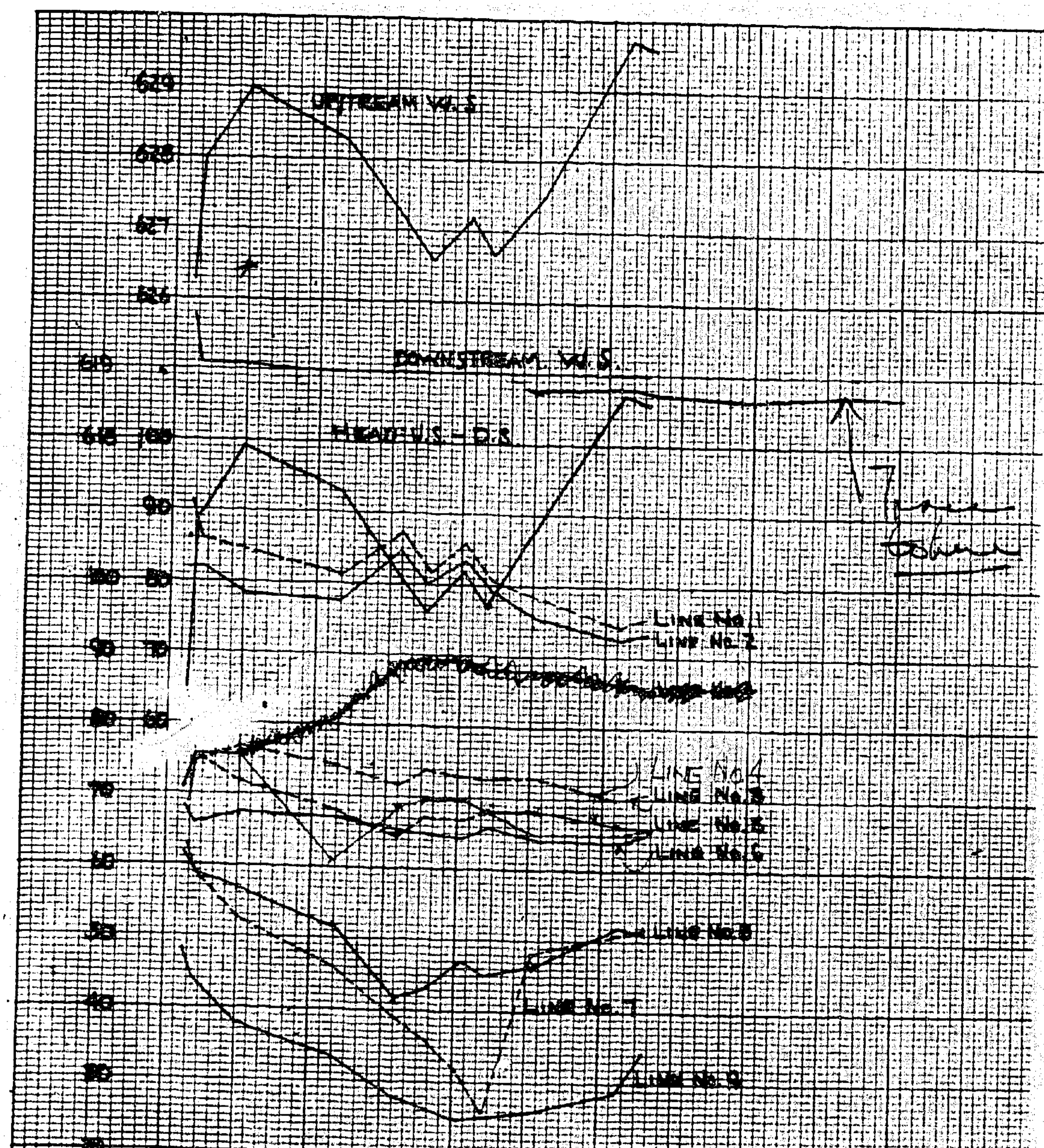
X-D-1052

FIG. 9


1917
1918
1920
1921
1922
APR. MAY JUNE JULY AUG. SEPT.
HEADWATER LEVEL
HEADWATER
ELEVATION (FT.)
TAILWATER
TAILWATER LEVEL
HEAD (FT.)
HEAD
PIPE NO. 2
PIPE NO. 2 % LOSS
COLORADO RIVER DAM
PIPE NO. 1 % LOSS

X-D-1053

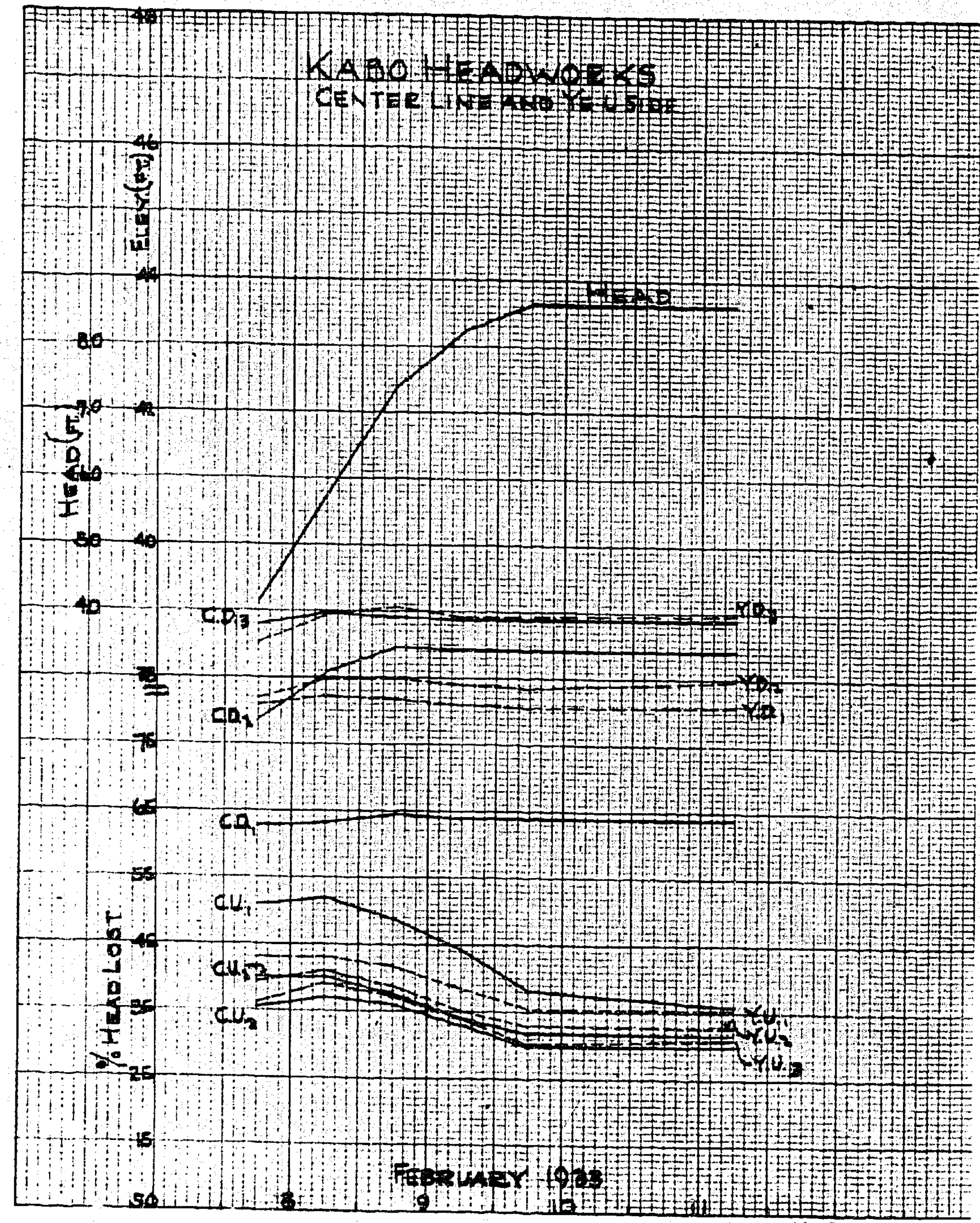
FIG. 9A



DEOHA BARRAGE OBSERVATIONS (MEANS)

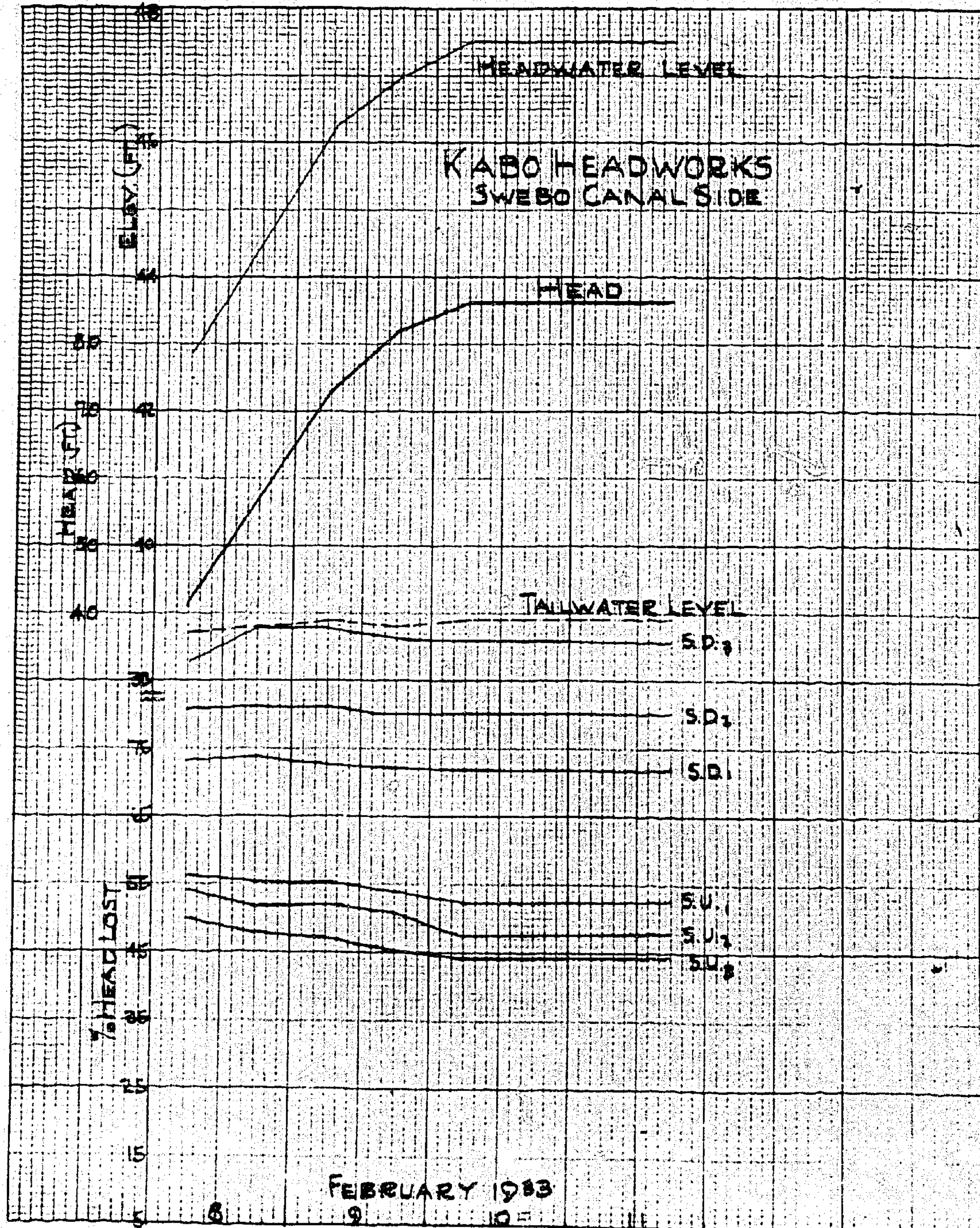
X-D-1054

FIG. 10



X-D-1055

FIG. 10A



X-D-1056

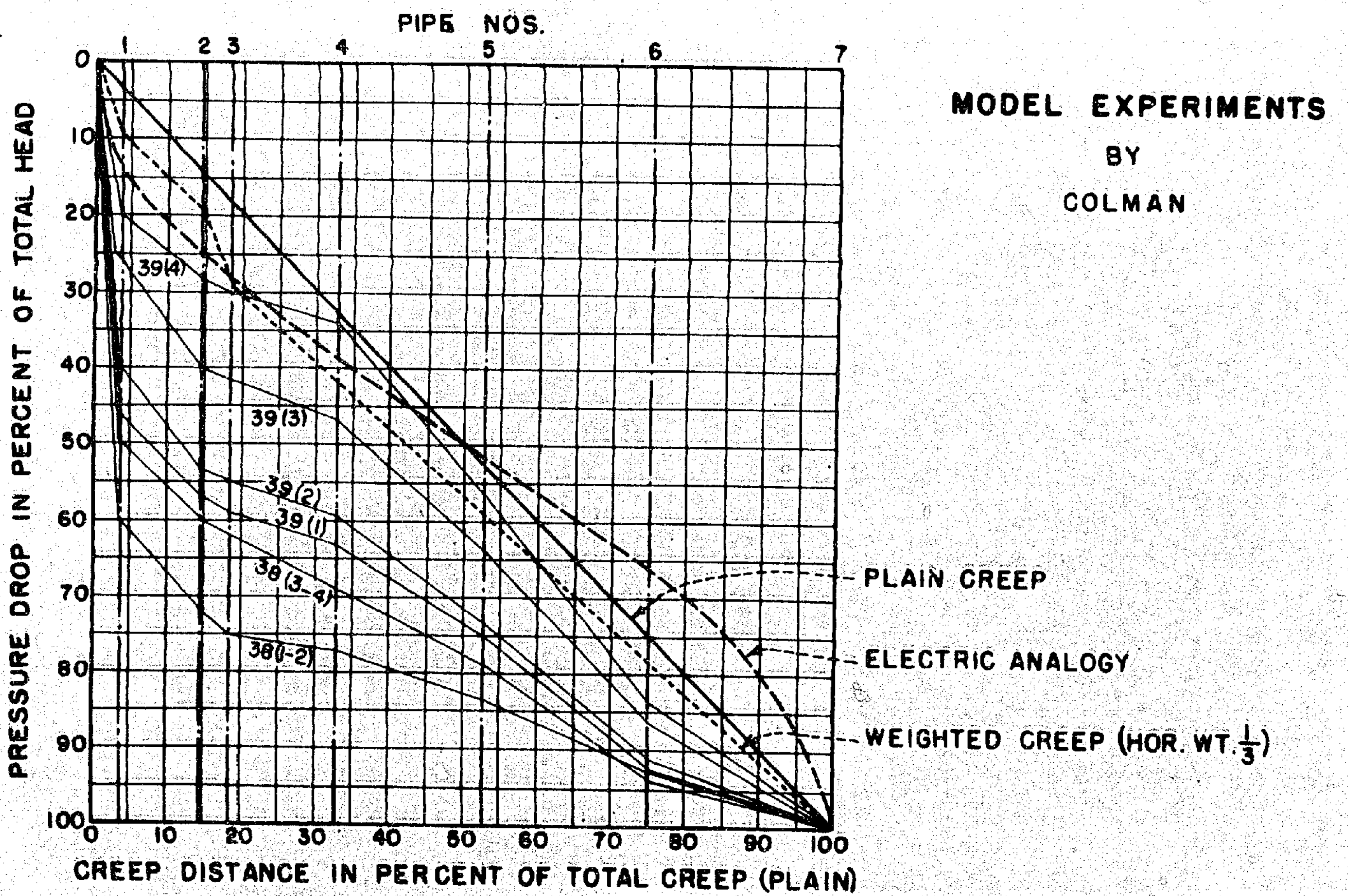


FIG. 11

X-D-1057

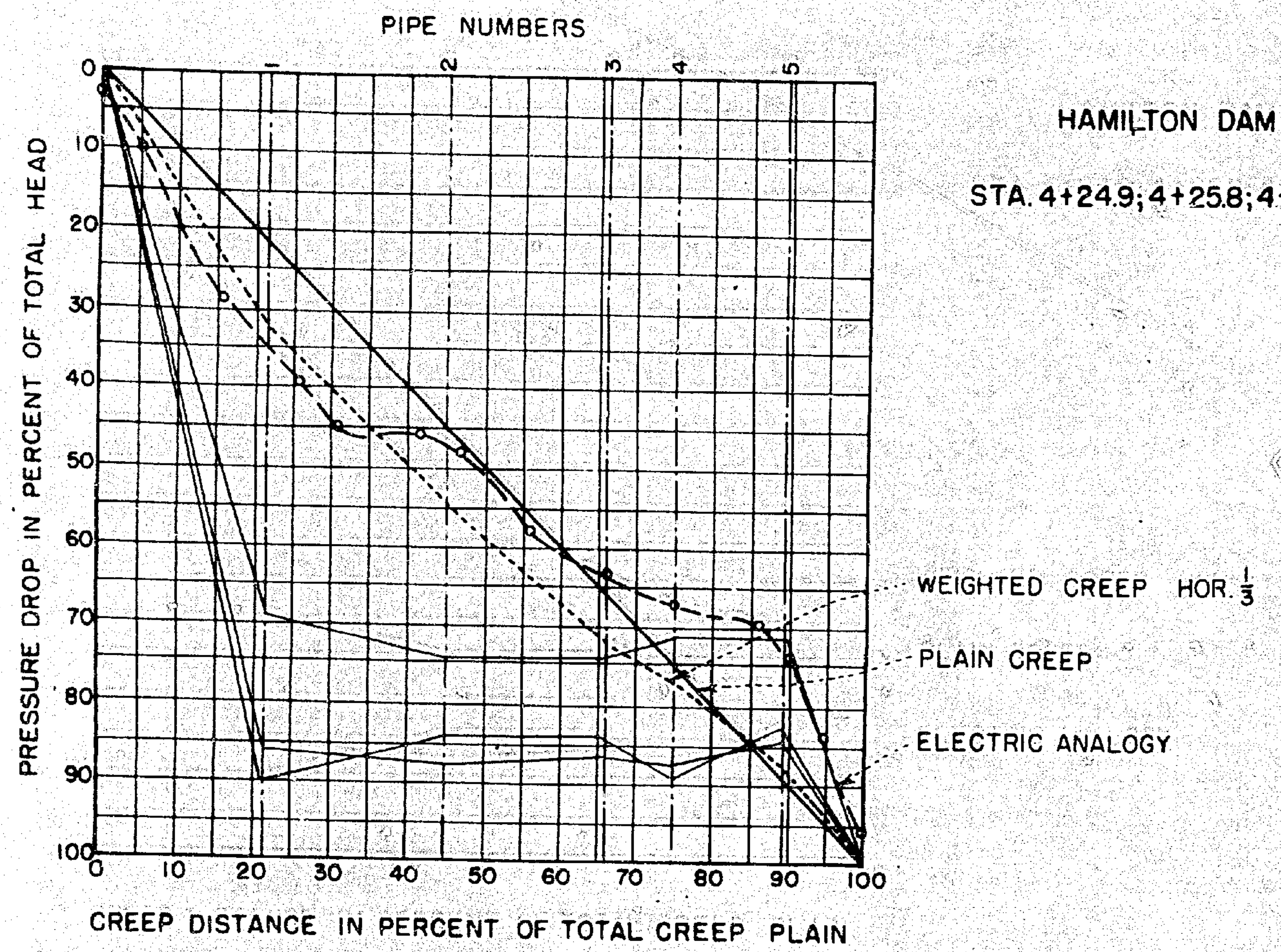
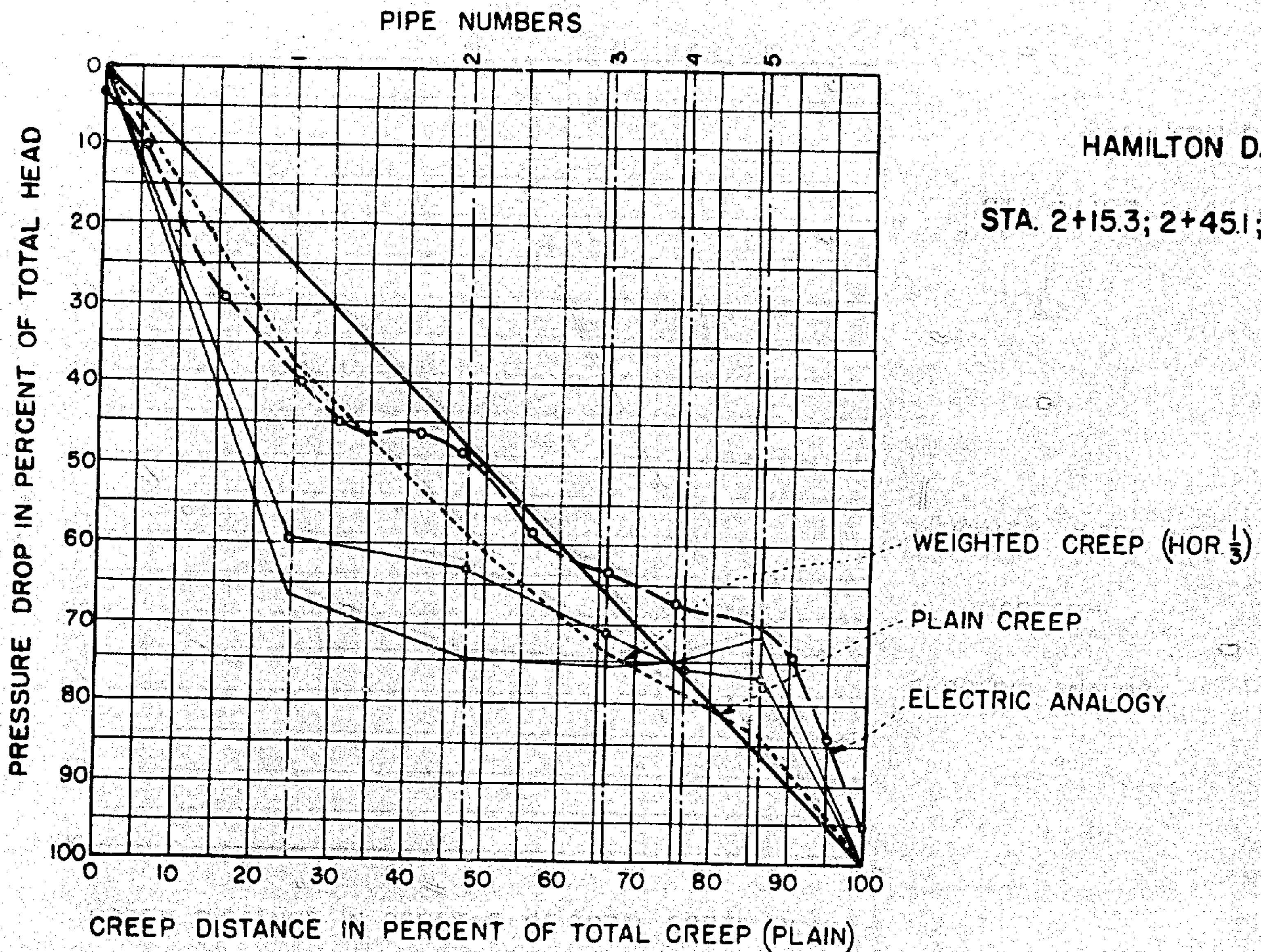


FIG. 12
X-D-1058



HAMILTON DAM

STA. 2+15.3; 2+45.1; 6+26.0

FIG. 12 A

X-D-1059

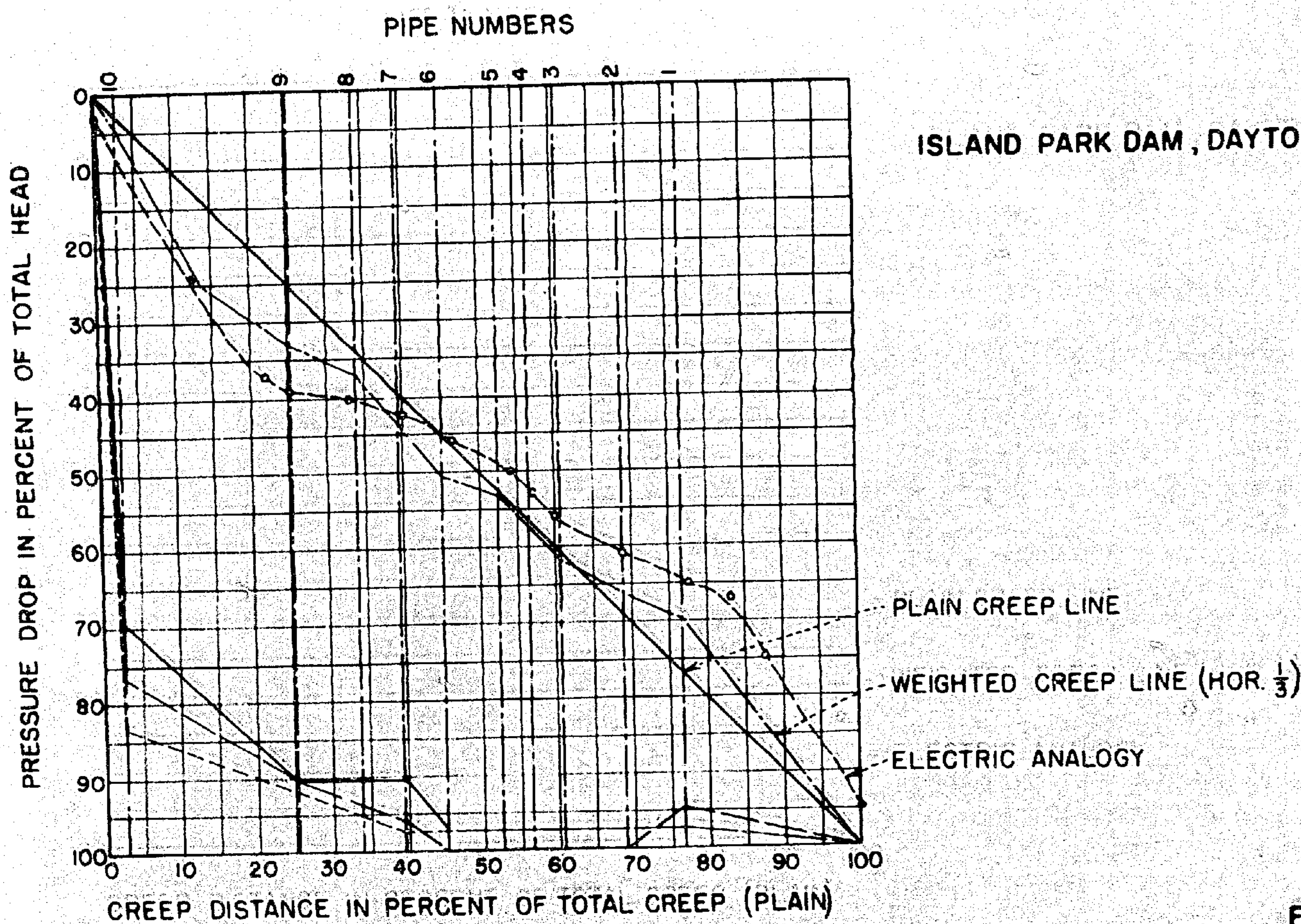


FIG. 13

X-D-1060

NAME OF DAM: Colorado River Dam or Grand Valley Dam LOCATION: Grand Valley Project, Colorado SOURCE OF DATA: Proceedings of the Am. Soc. of Civil Eng March, 1928, part

Pipe No. or Letter		1		2		END																Remarks
Creep	Hor.	27		33		72																
	Vert.	10.5		55.8		55.5																
	Total	37.5		88.8		127.5																
Plain Creep		26.4		62.5		100.0																
Weighted Creep Vertical Wt. 3		22.7		61.4		100.0																
Weighted Creep Vertical Wt.																						
% Drop by Electric Analogy		32.0		55.5		100.0																
Date / Pressure Drop		Meas. Drop	% of Total	Meas. Drop	% of Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
2-8-16 to 5-10-16			38		84		100															
5-25-16 to 6-24-16			16		80		100															
7-15-17 to 9-2-18			11		72		100															
10-1-18 to 5-17-22			32		82		100															
5-29-22 to 7-26-22			10		88		100															
8-5-22 to 10-27-22			34		87		100															

X-D-1008

NAME OF DAM: *Percha Dam* LOCATION: *Rio Grande Project, New Mexico* SOURCE OF DATA: *Proc. A.S.C.E. March 1928 part 1; Transactions A.S.C.E. 1929.*

Pipe No. or Letter	1		2		3		4		5		END										Remarks
Creep — Hor	1		27		29		41		43		73										
Creep — Vert.	7		7		36		36		42		59										
Creep — Total	8		34		65		77		85		132										
Plain Creep	6.06		25.75		49.25		58.4		64.4		100										
Weighted Creep Vertical Wt. 3	8.76		19.2		54.9		59.7		67.6		100										
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy	17		26		53		58		60		100										
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
3-18	0.55	7.5	0.55	7.5	4.55	61.9	5.05	68.7	6.15	83.7	7.35	100									
4-20	5.87		6.02		7.85		7.97		7.47		—										
3-20	5.57		5.57		7.34		7.56		7.37		—										
20	4.79		4.69		6.69		6.99		5.79		—										
10-21	4.69	50.1	4.59	49.0	7.69	82.2	7.74	82.7	6.0	64.1	9.36	100									
11-21	4.75	49.5	4.65	48.5	7.75	80.8	7.96	83.0	7.24	75.4	9.59	100									
11-21	4.56	46.2	4.56	46.2	7.56	76.6	7.97	80.8	7.05	71.5	9.86	100									
11-21	4.70	47.6	4.7	47.6	7.0	71.0	8.11	82.2	7.14	72.4	9.87	100									
11-21	4.78	51.7	4.78	51.7	7.73	83.7	7.84	84.8	7.17	77.6	9.24	100									
11-21	4.77	50.7	4.67	49.6	7.67	81.5	7.78	82.6	6.96	73.9	9.41	100									
10-23	0.38	4.2	3.48	37.7	7.33	79.5	8.38	90.9	7.48	81.1	9.22	100									
10-23	0.18	2.0	3.33	36.1	7.23	78.4	8.38	90.9	7.48	81.1	9.22	100									

X-D-1006

NAME OF DAM: Percha Dam LOCATION: Rio Grande Project New Mexico SOURCE OF DATA: Trans. A.S.C.E. 1929

Pipe No. or Letter		1	2	3	4	5	END					Remarks
Creep	Hor.	1	27	29	41	43	85					New end of creep taken
	Vert.	7	7	36	36	42	8					
	Total	8	34	65	77	85	93					
Plain Creep		8.6	36.6	70	82.8	91.4	100					
Weighted Creep Vertical Wt. 3		7.0	27.2	76.3	84.8	95.0	100					
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy												

Date / Pressure Drop	Meas Drop	% of Total	Meas. Drop	% of Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	

Observations same as preceeding sheet

X-D-1008

NAME OF DAM: *Deoha Barrage* LOCATION: *Sarda Canal, Duni, India* SOURCE OF DATA: *Note by M.L. Garga, Ass't Reasearch Officer, United Provinces, P.W.D.*

Neglecting 30' Universal piles

Pipe No. or Letter		9	8	7	6	5	4	3	2	1	END	Remarks
Creep	Hor.	17	36	55.5	76	97	117	138	157	179	186	
	Vert.	38	38	40.5	68.5	68.5	69.5	71	72	72	100	
	Total	55	74	96.0	144.5	165.5	186.5	209	229	251	286	
Plain Creep		19.2	25.9	33.6	50.5	57.8	65.2	73.0	80.0	87.8	100	
Weighted Creep Vertical Wt. 3		27.0	30.9	36.4	52.7	62.2	67.0	72.2	76.7	81.3	100	
Weighted Creep Vertical Wt.												
% Drop by Electric Anology												

Date / Pressure Drop	9 Meas Drop	9 % of Total	8 Meas Drop	8 % of Total	7 Meas Drop	7 % Total	6 Meas Drop	6 % Total	5 Meas Drop	5 % Total	4 Meas Drop	4 % Total	3 Meas Drop	3 % Total	2 Meas Drop	2 % Total	1 Meas Drop	1 % Total	END Meas Drop	END % Total	Remarks
12-8-31	3.72	48.3	4.75	61.7	4.84	62.9	5.24	68.1	5.43	70.5	5.47	71.0	5.31	69.0	6.31	82	7.02	91.2	7.7	100	
12-16-31	4.2	44.2	5.62	59.2	5.6	59	6.28	66.1	7.15	75.3	7.16	75.4	7.11	74.8	7.8	82.1	8.25	86.8	9.5	100	
1-4-32	4.0	38.1	5.97	56.8	5.54	52.8	7.11	67.7	7.54	71.8	7.94	75.6	8.06	76.8	8.24	78.5	8.9	84.8	10.5	100	
2-11-32	3.38	33.5	5.22	51.7	4.7	46.0	6.76	67.0	6.87	68.0	6.14	60.8	7.49	74.2	7.84	77.6	8.2	81.2	10.1	100	
3-5-32	2.5	28	3.7	41.6	3.5	39.3	5.81	65.3	5.74	64.5	6.11	68.6	6.38	71.7	7.54	84.7	7.76	87.2	8.9	100	
3-17-32	2.26	26.7	3.64	42.8	3.09	36.6	5.49	65.0	5.68	67.2	5.86	69.4	6.23	73.8	6.77	80.2	6.92	82.0	8.45	100	
4-2-32	2.27	25	4.29	47.1	2.85	31.3	5.87	64.5	6.10	67.0	6.35	69.6	6.64	73.0	7.59	83.4	7.81	85.8	9.1	100	
4-11-32	2.18	25.3	3.92	45.6	2.22	25.8	5.66	65.8	5.86	68.2	5.86	68.2	6.24	72.6	6.82	79.3	6.97	81.0	8.6	100	
5-2-32	2.47	26.0	4.43	46.6	4.60	48.4	6.12	64.4	6.17	65.0	6.47	68.1	6.94	73.1	7.18	75.6	7.44	78.3	9.5	100	
6-7-32	3.59	28.7	6.54	52.3	6.46	51.7	8.0	64.0	8.01	64.0	8.27	66.2	8.77	70.2	9.10	72.8	9.3	74.4	12.5	100	
6-17-32	4.2	34.2	6.33	51.5	6.38	51.9	8.0	65.0	8.09	65.8	8.05	65.4	8.71	70.8	9.06	73.6	9.32	75.8	12.3	100	

X-D-1008

NAME OF DAM: *Deoha Barrage* LOCATION: *Sarda Canal Duni, India* SOURCE OF DATA: *Note by M.L. Garga Ass't Research Officer, United Provinces, P.W.D.*

Assuming 30' Universal piles to be effective

Pipe No. or Letter		9		8		7		6		5		4		3		2		1		END		Remarks
Creep	Hor.	17		36		55.5		76		97		117		138		157		179		186		
	Vert.	38		38		74.5		102.5		102.5		103.5		105		106		106		134		
	Total	55		74		130		178.5		199.5		220.5		243		263		285		320		
Plain Creep		17.2		23.1		40.6		55.6		62.4		68.8		76.0		82.2		89.0		100		
Weighted Creep Vertical Wt. 3		22.3		25.5		47.5		65.0		68.8		72.7		77.0		81.2		84.6		100		
Weighted Creep Vertical Wt.																						
% Drop by Electric Analogy		31		33		39		47		52		55		61		68		74.5		100		
Date / Pressure Drop		Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	

Observations as shown on preceeding sheet

X-D-1668

2

NAME OF DAM: Deoha Barrage (LINE No 22) **LOCATION:** Sarda Canal Duni, India **SOURCE OF DATA:** Note from Research Office P.W.D. Secretariat, Lucknow, United Provinces, India Dated October 26th 1934

Pipe No. or Letter	9		8		7		6		5		4		3		2		1		END		Remarks
Creep Hor.																					
Creep Vert.	Creep computations for both assumptions are shown on the preceeding sheets.																				
Creep Total.																					
Plain Creep																					
Weighted Creep Vertical Wt. 3																					
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy																					
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
12-2-32	—	—	—	—	—	—	—	—	—	—	6.3	67.6	6.15	66.0	6.05	64.9	6.3	67.6	9.32	100	
12-3-32	7.9	75.1	2.15	20.4	7.1	67.5	8.1	77.0	—	—	7.4	70.3	7.9	75.1	8.0	76.0	8.1	77.0	10.52	100	
12-4-32	8.3	75.3	0.0	0.0	6.9	62.6	8.6	78.1	—	—	7.6	69.0	8.2	74.4	8.35	75.8	8.55	77.6	11.02	100	
12-27-32	8.7	71.2	1.2	9.8	7.5	61.4	10.0	81.9	—	—	8.5	69.6	8.8	72.0	9.1	74.5	9.1	74.5	12.22	100	
2-15-33	—	—	—	—	—	—	5.7	67.7	—	—	6.0	71.3	6.4	76.0	6.55	77.8	6.6	78.4	8.42	100	
2-23-33	7.8	65.4	0.1	0.8	5.3	44.5	8.1	68.0	—	—	8.7	73.0	9.2	77.2	9.45	79.3	9.45	79.3	11.92	100	
6-1-33	2.05	16.4	0.1	0.8	6.6	52.8	8.3	66.3	—	—	9.1	72.7	10.35	82.7	9.9	79.1	9.85	78.7	12.52	100	
6-18-33	6.3	51.2	0.0	0.0	4.8	39.0	8.5	69.0	—	—	9.0	73.1	9.5	77.1	9.7	78.8	9.8	78.6	12.32	100	

X-D-1608

NAME OF DAM: Deoha Barrage (LINE No. 24)

LOCATION: Sarda Canal Duni, India

SOURCE OF DATA: Note from Research Office P.W.D. Secretariat, Lucknow, United Provinces, India Dated October 26, 1934

Pipe No. or Letter		9		8		7		6		5		4		3		2		1		END		Remarks
Creep	Hor.																					
	Vert.																					
	Total																					
Plain Creep																						
Weighted Creep Vertical Wt. 3																						
Weighted Creep Vertical Wt. 1																						
% Drop by Electric Anology																						
Date	Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop.	% Total	Meas. Drop	% Total	
12-2-32								6.9	74	6.95	75	7.05	75.6	6.3	67.6	7.15	76.7	7.1	76.2	9.32	100	
12-3-32		7.95	75.6	7.9	75.0	5.6	53.2	8.1	77	8.2	76	6.85	65	6.9	65.6	7.8	74.2	8.25	78.4	10.52	100	
12-4-32		8.2	74.4	8.4	76.2	4.8	43.5	8.6	78	8.25	75	7.2	65.4	7.2	65.4	8.1	73.5	8.6	78	11.02	100	
12-27-32		9.15	74.5	0.0	0.0	3.8	31.0	9.35	76.6	9.35	76.6	8.15	66.7	7.8	63.9	8.95	73.2	9.0	73.7	12.22	100	
2-15-33								5.35	63.5	5.25	62.4	5.5	65.3	6.4	76.0	6.2	73.6	6.0	71.3	8.42	100	
2-23-33						2.6	21.8	8.0	67.1	8.7	73	8.1	68	8.05	67.5	9.0	75.5	9.5	79.7	11.92	100	
6-1-33						2.7	21.6	8.25	65.9	8.7	69.5	8.5	67.9	9.35	74.7	9.4	75.1	9.85	78.7	12.52	100	
6-18-33						0.45	3.6	8.1	65.8	8.3	67.4	8.45	68.6	8.3	67.4	9.3	75.5	9.4	76.3	12.32	100	

22

X-D-1008

NAME OF DAM: Deoha Barrage (LINE No. 27)

LOCATION: Sardi Canal Duni, India

SOURCE OF DATA: Note from Research Office P.W.D. Secretariat, Lucknow, United Provinces, India. Dated October 26, 1934

Pipe No. or Letter	9		8		7		6		5		4		3		2		1		END		Remarks
Creep: Hor.																					
Creep: Vert.																					
Creep: Total																					
Plain Creep																					
Weighted Creep Vertical Wt. 3																					
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy																					
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
12-2-32	—	—	—	—	—	—	—	—	6.15	66	6.2	66.5	6.6	70.8	7.05	75.6	7.15	76.7	9.32	100	
12-3-32	8.0	76.1	7.65	72.8	2.2	20.9	—	—	6.75	64.2	6.8	64.7	7.3	69.4	7.75	73.7	8.0	76.1	10.52	100	
12-4-32	7.75	70.4	7.9	71.7	0.85	7.7	—	—	7.1	64.4	7.1	64.4	7.6	69.0	8.1	73.6	8.3	75.4	11.02	100	
12-27-32	2.3	18.8	5.0	41	0.4	3.3	—	—	8.05	66.9	7.65	62.6	8.35	68.4	8.8	72	9.05	74.1	12.22	100	
2-15-33	—	—	—	—	—	—	—	—	5.35	63.5	5.4	64.1	5.9	70.0	6.1	72.4	6.3	74.8	8.42	100	
2-23-33	4.0	33.6	5.25	44	0.5	4.2	—	—	7.85	65.8	7.85	65.8	8.5	71.3	9.0	75.5	9.25	77.6	11.92	100	
6-1-33	1.6	12.8	4.1	32.8	3.5	2.80	—	—	8.1	64.7	8.15	65	9.1	72.7	9.2	73.5	9.35	74.7	11.52	100	
6-18-33	0.0	0.0	2.2	17.8	0.0	0	—	—	7.9	64.2	8.1	65.8	8.9	72.3	9.15	74.3	9.35	75.9	12.32	100	

X-D-1068

NAME OF DAM: *Kabo Headworks Shwebo Canal Side* LOCATION: ______ SOURCE OF DATA: *Note dated May 31, 1933 by Sup't Engineer, Northern Irrigation Circle*

Pipe No. or Letter		SU3	SU2	SU1	SO1	SO2	SO3	END				Remarks
Creep	Hor.	24.25	33.92	65.42	84.3	121.7	136.0	171.0				
	Vert.	5.0	19.0	19.0	39.0	40.0	55.0	55.0				
	Total	29.25	52.92	84.4	123.3	161.7	191.0	226.0				
Plain Creep		13	23.4	37.4	54.6	71.6	84.5	100				
Weighted Creep Vertical Wt. 3		11.7	27.0	36.5	60.0	72.0	89.6	100				
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy		27	36	.43	52	61	67.5	100				

Date	Pressure Drop	SU3 Meas. Drop	SU3 % of Total	SU2 Meas. Drop	SU2 % of Total	SU1 Meas. Drop	SU1 % Total	SO1 Meas. Drop	SO1 % Total	SO2 Meas. Drop	SO2 % Total	SO3 Meas. Drop	SO3 % Total	END Meas. Drop	END % Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Remarks
2-8-33	6AM	2.03	49.9	2.21	53.9	2.30	56.1	3.0	73.2	3.3	80.5	3.59	87.6	4.1	100							
"	6PM	2.72	47.7	2.95	51.7	3.15	55.2	4.2	73.6	4.63	81.2	5.28	92.6	5.7	100							
2-9-33	6AM	3.44	47.1	3.79	51.9	4.04	55.3	5.32	72.8	5.93	81.2	6.77	92.7	7.3	100							
"	6PM	3.72	45.4	4.09	49.9	4.41	53.8	5.93	72.3	6.54	79.8	7.47	91.1	8.2	100							
2-10-33	Mean	3.81	44.3	4.09	47.5	4.51	52.4	6.17	71.7	6.91	80.3	7.81	90.8	8.6	100							
2-11-33		3.81	44.3	4.10	47.7	4.52	52.6	6.19	72.0	6.91	80.3	7.81	90.8	8.6	100							

X-D-1008

NAME OF DAM: *Kabo Headworks*
Center line of pipes

LOCATION:

SOURCE OF DATA: *Note dated May 31, 1933 by Sup't Engineer, Northern Irrigation Circle*

Pipe No. or Letter		CU3		CU2		CU1		CO1		CO2		CO3		END								Remarks
Creep	Hor.	25.5		35.5		66.7		86		123.3		138.3		170.3								
	Vert.	5.0		19.0		19.0		39		40.0		55.0		55.0								
	Total	30.5		54.5		85.7		125		173.3		193.3		225.3								
Plain Creep		13.5		24.4		38		55.5		76.9		85.8		100								
Weighted Creep Vertical Wt. 3		12.05		27.5		36.8		60.7		72.4		90.3		100								
Weighted Creep Vertical Wt																						
% Drop by Electric Analogy		Not		set up																		
Date	Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
2-8-33	6 AM	1.46	35.6	1.64	40	2.08	50.7	2.56	62.4	3.21	78.3	3.80	92.7	4.10	100							
"	6 PM.	2.09	36.7	2.27	39.8	2.96	51.9	3.60	63.1	4.86	85.2	5.37	94.2	5.7	100							
2-9-33	6 A.M	2.62	35.9	2.72	37.3	3.56	48.8	4.69	64.3	6.16	84.4	6.85	93.8	7.3	100							
"	6 PM.	2.71	33.0	2.78	33.9	3.62	44.1	5.24	63.9	6.89	84.0	7.65	93.3	8.2	100							
2-10-33	Mean	2.57	29.9	2.71	31.6	3.23	37.9	5.44	63.6	7.19	84.0	7.99	93.2	8.6	100							
2-11-33	Mean	2.57	29.9	2.70	31.4	3.09	35.9	5.46	63.5	7.21	83.9	8.04	93.6	8.6	100							

X-D-1008

NAME OF DAM: *Kaoo Headworks* LOCATION: ______ SOURCE OF DATA: *Note dated May 31, 1933 by Sup't Engineer, Northern Irrigation Circle*

Pipe No. or Letter		YU3	YU2	YU1	YO1	YO2	YO3	END				Remarks
Creep	Hor.	25.0	35.0	66.0	85.3	122.8	138.7	170.8				
	Vert.	5.0	19.0	19.0	39.0	40.0	55.0	55.0				
	Total	30.0	54.0	85.0	124.3	162.8	193.7	225.8				
Plain Creep		13.3	23.9	37.6	55.0	72.1	85.8	100				
Weighted Creep Vertical Wt. 3		11.9	27.4	36.6	60.2	72.2	90.4	100				
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy		Not set up										

Date	Pressure Drop	YU3 Meas. Drop	YU3 % of Total	YU2 Meas. Drop	YU2 % of Total	YU1 Meas. Drop	YU1 % Total	YO1 Meas. Drop	YO1 % Total	YO2 Meas. Drop	YO2 % Total	YO3 Meas. Drop	YO3 % Total	END Meas. Drop	END % Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Remarks
2-8-33	6 A.M.	1.48	36.1	1.60	39.0	1.74	42.4	3.31	80.7	3.36	81.9	3.67	89.5	4.1	100							
"	6 P.M.	2.21	38.8	2.31	40.5	2.44	42.8	4.67	81.9	4.83	84.7	5.36	94.0	5.7	100							
2-9-33	6 A.M.	2.71	37.1	2.82	38.6	3.04	41.6	5.96	81.6	6.18	84.6	6.94	95.0	7.3	100							
"	6 P.M.	2.75	33.5	2.87	35.0	3.13	38.2	6.64	81.0	6.86	83.7	7.69	93.8	8.2	100							
2-10-33	Mean	2.65	30.8	2.83	32.8	3.05	35.2	6.93	80.7	7.19	83.2	8.07	93.4	8.6	100							
2-11-33	Mean	2.64	30.7	2.81	32.7	3.03	35.3	6.91	80.4	7.17	84.3	8.04	94.3	8.6	100							

X-D-1668

NAME OF DAM: *Hamilton Dam* LOCATION: *Hamilton, Ohio* SOURCE OF DATA:

Sta. 2+15.3; 2+45.1
6+76.0

Pipe No. or Letter		1	2	3	4	5	END					Remarks
Creep	Hor.	1	9	16	22	27.5	30.5					
	Vert.	13	18	21	21	21.0	26.0					
	Total	14	27	37	43	48.5	56.5					
Plain Creep		24.8	47.8	65.5	76.2	86.0	100					
Weighted Creep Vertical Wt. 3		37.0	58.4	73.0	78.6	83.4	100					
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy												

Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total
	5.3	66.2	5.9	74	6.0	75	5.9	74	5.7	71	8.0	100								
	4.7	59	5.0	62.5	5.7	71	6.0	75	6.1	76	8.0	100								

X-D-1008

NAME OF DAM: *Narora Weir Observations 1912-13 Chain 32* LOCATION: *Lower Ganges Canal India* SOURCE OF DATA: *Engineering Conference, Simla, Vols 1 & 4, 1913*

Pipe No. or Letter		1A		1		2		2+3/2		3		4		END								Remarks
Creep	Hor	4.5		80.0		98		110.5		123.0		151.0		152.0								
	Vert.	29.5		29.5		43		43.0		43.0		43.0		47.0								
	Total	34.0		109.5		141.0		153.5		166.0		194.0		199.0								
Plain Creep		19.6		55		70.8		77.1		83.4		97.5		100								
Weighted Creep Vertical Wt. 3		33.4		57.6		77.2		81.6		85.7		94.9		100								
Weighted Creep Vertical Wt.																						
% Drop by Electric Anology		31		52		62		68		72.5		91.0		100.								
Date	Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
		1.42	35	2.48	61.2			2.7	66.7			4.03	99.4	4.05	100							
		1.69	36	2.47	54.3			3.1	67.4			4.19	94.3	4.55	100							
		2.12	41.2	3.37	65.4			3.44	66.8			4.9	95.2	5.15	100							
		3.27	48.8	3.5	52.2			4.4	65.6			6.5	97.0	6.7	100							
		4.65	47.5	4.68	47.8			5.32	54.2			8.08	82.4	9.8	100							

X-D-1008

NAME OF DAM: Narora Weir
Observ. 1912-13
Chain 18

LOCATION: Lower Ganges Canal
India

SOURCE OF DATA: Engineering Conference
Simla, Vols 1 & 4, 1913

Pipe No. or Letter		1A		1		2		2+3/2		3		4		END								Remarks
Creep	Hor.																					
	Vert.																					
	Total			CREEP DISTANCES SAME AS CHAIN 9)																		
Plain Creep																						
Weighted Creep Vertical Wt. 3																						
Weighted Creep Vertical Wt.																						
% Drop by Electric Anology																						
Date / Pressure Drop		Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
		0.2	4.8	1.6	39.5			2.34	57.9			3.35	82.6	4.05	100							
		0.35	7.7	1.8	39.5			2.45	53.8			3.65	80.2	4.56	100							
		0.82	15.9	2.0	38.8			2.74	53.2			4.1	79.6	5.15	100 — 7							
		1.60	23.9	2.95	44.0			4.01	59.8			5.77	86.2	6.7	100							
		2.85	29.1	3.95	40.4			5.58	57.0			8.37	85.4	9.8	100							
		2.97	34.9	3.49	41.1			4.94	58.1			7.02	82.6	8.5	100							

X-D-1002

NAME OF DAM: *Narora Weir Chain 9* LOCATION: *Lower Ganges Canal India* SOURCE OF DATA: *Engineering Conference Simla, Vols 1 & 4, 1913*

Pipe No. or Letter		1A	1	2	2+3/2	3	4	END				Remarks
Creep	Hor.	18	80	98	110.5	123	151	178	END OF CREEP TAKEN AT THE			
	Vert	29.5	29.5	43	43.0	43	43	50	END OF GROUTED PITCHING			
	Total	47.5	109.5	141	153.5	166	194	228				
Plain Creep		20.8	48	61.8	67.3	72.8	85.1	100				
Weighted Creep Vertical Wt. 3		32.5	51.8	69.4	73.4	77.0	85.3	100				
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy												

Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total

X-D-106

NAME OF DAM: *Narora Weir (cont.)* LOCATION: *Lower Ganges Canal* SOURCE OF DATA: *Engineering Conference Simla, Vols. 1 & 4, 1913*

Pipe No. or Letter	1A		1		2		2+3/2		3		4		End								Remarks
Creep Hor.	18		80		98		110.5		123		151		152								
Creep Vert.	29.5		29.5		43		43.0		43		43		47								
Creep Total	47.5		109.5		141		153.5		166		194		199								
Plain Creep	23.9		55.0		70.8		77.1		83.4		97.5		100								
Weighted Creep Vertical Wt. 3	36.2		57.6		77.2		81.6		85.7		94.9		100								
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy																					
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
	1.73	42.7	2.54	62.7			3.02	74.6			4.1	100	4.05	100							Mean of 2 observ.
	1.40	30.7	2.70	59.3			3.15	69.2			4.39	96.4	4.55	100							4 observ.
	1.79	34.8	2.98	57.8			3.88	75.4			5.20	100	5.15	100							
	2.81	42.0	4.27	63.7			4.87	72.7			6.85	100	6.7	100							
	4.25	43.4	5.89	60.0			6.87	70.1			9.56	97.5	9.8	100							2 observ.
	4.17	49.1	5.12	60.4			6.08	71.5			7.99	94.0	8.5	100							

NAME OF DAM: Panjnad Headworks Piers 44, 43, 46, 43 Bay 46 LOCATION: Punjab, India SOURCE OF DATA: Paper No of the Panjnad Engineering Congress by A.N. Khosla, Executive Engineer, Panjnad Division S.V.P.

SHEET 1

Pipe No. or Letter		34	35	33	32	31	30	27	24	25	23	Remarks
Creep	Hor.	0	0	2.5	3.0	4.0	24.5	27.5	48	49	51.0	
	Vert.	8	17.5	27.5	37.5	46.0	48.0	53.0	54	63.5	73.5	
	Total	8	17.5	30.0	40.5	50.0	72.5	80.5	102	112.5	124.5	
Plain Creep		2.7	5.9	10	13.5	16.7	24.3	26.9	34.1	37.5	45.5	
Weighted Creep Vertical Wt. 3		4.2	9.2	14.9	20.6	24.9	29.5	32.7	36.9	42.1	47.7	
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy		6.0	13	21	26	29	32	33.5	36	38	40	

Date / Pressure Drop	34 Meas. Drop	34 % of Total	35 Meas Drop	35 % of Total	33 Meas Drop	33 % Total	32 Meas. Drop	32 % Total	31 Meas Drop	31 % Total	30 Meas Drop	30 % Total	27 Meas. Drop	27 % Total	24 Meas Drop	24 % Total	25 Meas. Drop	25 % Total	23 Meas. Drop	23 % Total	Remarks
Pier 44 (Aver. of Obs.)		22.5		44.2		50.8		51.8		50.9		50		60.3		57.4		47.4		58.2	
45 (" ")										49.0						53.9					
46 (" ")										47.8						54.4					
Bay 46 (" ")																51.8					
Pier 43 (" ")										54.6						56.0					

X-0-1008

NAME OF DAM: Panjnad Head Works (con'd) LOCATION: SOURCE OF DATA:

SHEET 2

Pipe No. or Letter		22		21		18		17		16		13		10		11		9		8		Remarks
Creep	Hor.	52		52		70		94.5		98.5		121.5		158		160		162		162		
Creep	Vert	83.5		93		93		93.0		96.5		97.5		98.5		106.5		116.5		126.5		
Creep	Total	135.5		145		163		187.5		195.0		219.0		256.5		266.5		278.5		288.5		
Plain Creep		45.4		48.5		54.6		62.7		65.2		73.3		85.8		89.2		93.2		96.4		
Weighted Creep Vertical Wt. 3		53.2		58.1		61.2		65.7		68.2		72.8		79.8		84.3		89.9		95.2		
Weighted Creep Vertical Wt.																						
% Drop by Electric Analogy		42.0		44		47.5		53		54.5		60		68		72		77		87		
Date / Pressure Drop		Meas. Drop	% of Total	Meas Drop	% of Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
Over at Pier 44			60.0		61.2		67.4		63.5		64.7		70.6		74.7		74.7		79.1		87.1	
" " 45					60.0										71.0				79.0			
" " 46					58.5										71.4				77.4			
" " Bay 46					58.8		59.1		62.8						74.1				79.5			
" " Pier 43					61.5																	

X-D-1008

NAME OF DAM: Panjnad Head Works
Piers 44, 43 46 (concluded)

LOCATION:

SOURCE OF DATA:

SHEET 3

Pipe No. or Letter	7		4		5		6		3		2		1								Remarks
Creep Hor.	164		184.5		184.5		184.5		192.0		192.0		192.0								
Creep Vert.	135		135		142.0		150.0		150.0		158.0		166.0								
Creep Total	299		319.5		326.5		334.5		342.0		350.0		358.0								
Plain Creep	100																				
Weighted Creep Vertical Wt. 3	100																				
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy	100																				
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
Aver. Pier 44		90.6																			
" " 45		85.7																			
" " 46		(69)?																			
" " 43		89																			

X-D-1008

NAME OF DAM: Punjnad Head Works LOCATION: ______ SOURCE OF DATA: ______

Bay No. 25

Pipe No. or Letter		A		B		C		End														Remarks
Creep	Hor	109.5		112.8		162.3		233.5														
	Vert.	10.5		66.5		73.5		114.5														
	Total	120.0		179.3		235.8		348														
Plain Creep		34.4		51.5		67.8		100														
Weighted Creep Vertical Wt. 3		24.4		54.1		66.4		100														
Weighted Creep Vertical Wt.																						
% Drop by Electric Analogy		Not set up																				
Date / Pressure Drop		Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
10-16-33		4.72	54.8	11.52	65.0	12.82	72.4	17.7	100													
10-19		7.42	53.0	9.02	64.4	9.92	70.8	14.0	100													
10-20		6.67	53.6	8.07	66.8	8.97	72.3	12.1	100													
10-25		5.95	55.4	7.15	66.5	7.85	73.0	10.75	100													
10-29		5.90	59.6	6.90	69.7	7.40	74.8	9.9	100													
11-2		5.44	60.2	6.44	71.2	6.94	76.8	9.05	100													
11-5		4.43	57.8	5.83	70.8	6.23	75.7	8.24	100													
11-10		4.29	60.5	5.09	71.8	5.39	76.0	7.1	100													
11-18		3.51	60.4	4.11	70.8	4.61	79.3	5.8	100													
11-20		2.75	57.9	3.25	68.4	3.55	74.8	4.75	100													
11-22		2.21	58.0	2.51	65.9	2.81	73.8	3.8	100													
Means			57.6		68.3		74.7															

X-D-1008

NAME OF DAM: Island Park Dam LOCATION: Dayton, Ohio SOURCE OF DATA: Eng. News-Record Vol. 84, No. 21, p. 1015

Pipe No. or Letter	10		9		8		7		6		5		4		3		2		1		END Remarks
Creep Hor.	0		3		9		10		11.5		16.5		18		19.5		25.5		31.0		33.5
Creep Vert.	2		15		15		18		20.5		20.5		22		23.5		23.5		23.5		37.5
Creep Total	2		18		24		28		32.0		37.0		40		43.0		49.0		54.5		71.0
Plain Creep	2.8		25.3		33.8		39.4		45.1		52.2		56.4		60.6		69.0		76.8		100
Weighted Creep Vertical Wt. 3	4.1		33.0		37.1		43.9		50.6		53.2		57.7		61.9		66.0		69.7		100
Weighted Creep Vertical Wt.																					
% Drop by Electric Analogy																					
Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
	5	69.4	6.5	90.3			6.5	90.5	7.0	97.2					7.0	97.2	7.0	97.2	7.0	97.2	7.2 100
	5.5	76.4	6.5	90.3			6.9	95.8	7.2	100					7.2	100	7.2	100	6.8	94.4	7.2 100
	6.0	83.3					7.0	97.2	7.0	97.2			7.0	97.2	7.0	97.2	7.0	97.2	7.0	97.2	7.2 100

For observations not shown pipes were plugged.

X-D-1005

NAME OF DAM: Hamilton Dam LOCATION: Hamilton, Ohio SOURCE OF DATA:

Sta 4+24.9; 4+25.8
4+54.5

Pipe No. or Letter		1	2	3	4	5	END					Remarks
Creep	Hor.	1	9	17.5	22.5	28.5	31.0					
	Vert.	11	16	19.0	19.0	21.0	24.5					
	Total	12	25	36.5	41.5	49.5	55.5					
Plain Creep		21.6	45.0	65.8	74.8	89.2	100					
Weighted Creep Vertical Wt. 3		32.5	54.6	71.8	76.7	87.6	100					
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy												

Date / Pressure Drop	Meas. Drop	% of Total	Meas. Drop	% of Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	
	5.5	69	5.9	74	5.9	74	5.7	71	5.7	71	8.0	100									
	6.9	86	7.0	87.5	6.9	86	7.0	87.5	6.7	84	8.0	100									
	7.2	90	6.7	84	6.7	84	7.1	89.0	6.6	82.5	8.0	100									

X-D-1008

NAME OF DAM: *Pinhook Dam* LOCATION: *Maquoketa, Iowa* SOURCE OF DATA: *Transactions A.S.C.E. 1929, Vol. 93*

Pipe No. or Letter		A	B	C	D	E	End (Taken at begin. of downstream apron)					Remarks
Creep	Hor	7.5	20.0	29.5	36.0	56.0	61.5					
	Vert.	61.5	61.5	61.5	65.5	67.5	68.0					
	Total	69.0	81.5	91.0	101.5	123.5	129.5					
Plain Creep		53.3	63.0	70.3	78.4	95.4	100					
Weighted Creep Vertical Wt. 3		72.3	77.4	80.6	87.6	97.7	100					
Weighted Creep Vertical Wt.												
% Drop by Electric Analogy												

Date / Pressure Drop	A Meas. Drop	A % of Total	B Meas. Drop	B % of Total	C Meas. Drop	C % Total	D Meas. Drop	D % Total	E Meas. Drop	E % Total	End Meas. Drop	End % Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Meas. Drop	% Total	Remarks
12-26-23	7.4	61.6	8.4	65.4	8.5	65.4	10.5	73.7	10.1	79.7	13.3	100									Bay 3
1-10-24	9.3	58.7	10.2	61.1	10.1	62.3	10.5	65.1	—	—	16.7										" "
2-11-24	11.5	60.6	13.1	64.4	13.3	64.9	14.2	68.3			20.8										" "
5-11-24	12.5	66.7	12.7	68.8	12.5	68.2	14.0	72.9	15.5	82.8	19.2										" "
4-22-26	22.3	91.3	21.0	86.3	20.5	87.1	22.6	95	21.8	92.5	24.1										"
12-26-23	8.3		9.1		8.6		9.0		10.5		13.3										Bay 4
1-10-24	10.0		10.2		10.4		10.8				16.7										" "
2-11-24	13.1		13.5		13.6		14.2				20.8										" "
5-11-24	13.0		13.3		13.5		14.0		16.1		19.2										" "
4-22-26	22.0		20.5		20.6		22.8		23.3		24.1										" "
12-26-23	8.4		4.4		8.9				11.2		13.3										Bay 5
1-10-24	10.0				10.6						16.7										" "
2-11-24	13.2		13.6		13.7						20.8										" "
5-11-24	12.9		13.7		13.1				16.2		19.2										" "
4-22-26	21.8		21.0		21.9		23.3		21.8		24.1										" "

Mean of 3 bays was used for computing percent drop

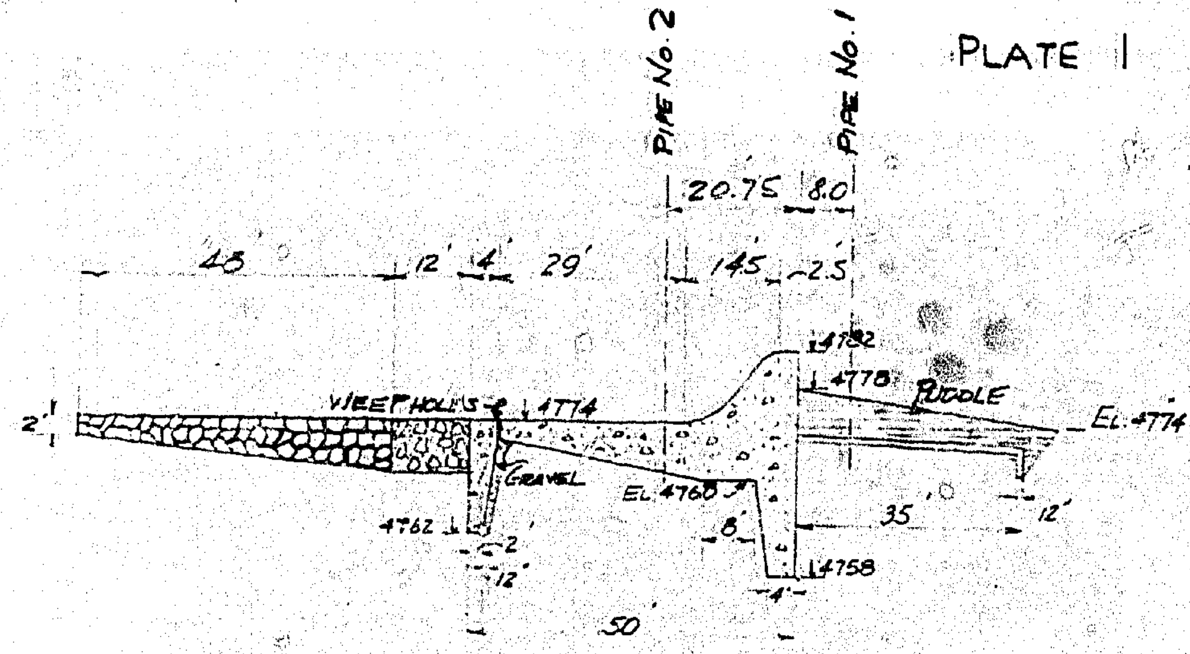
X-D-1068

NAME OF DAM: *Pinhook Dam* LOCATION: *Maquoketa, Iowa* SOURCE OF DATA: *Trans. A.S.C.E. 1929, Vol. 93*

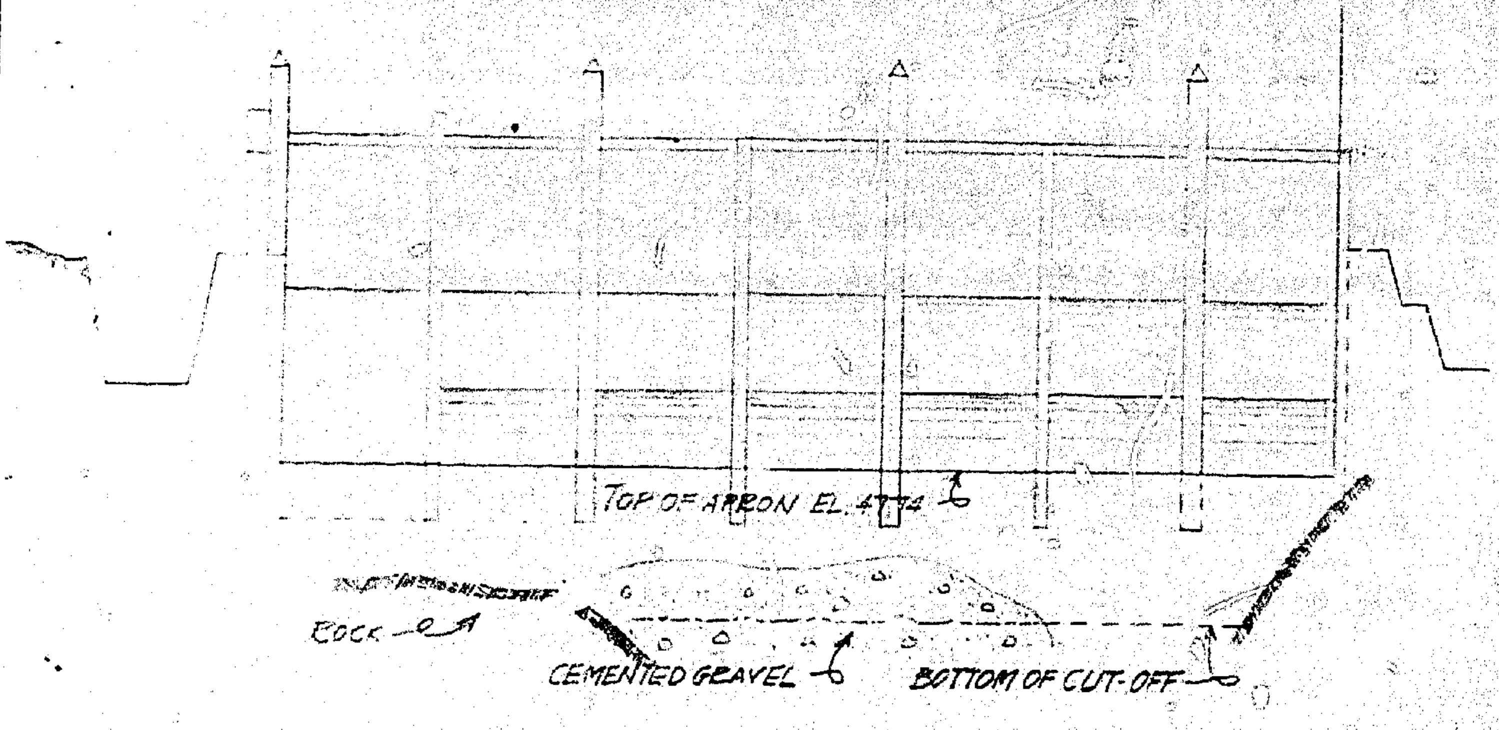
Pipe No. or Letter		A	B	C	D	E	End (taken at end of downstream apron)				Remarks
Creep	Hor	7.5	20.0	29.5	36.0	56.0	139.0				
	Vert	61.5	61.5	61.5	65.5	67.5	89.5				
	Total	69.0	81.5	91.0	101.5	123.5	228.5				
Plain Creep		30.4	35.7	39.8	44.4	54.0	100.0				
Weighted Creep Vertical Wt. 3		46.9	50.2	52.2	56.8	63.3	100.0				
Weighted Creep Vertical Wt.											
% Drop by Electric Analogy											

Date / Pressure Drop	Meas Drop	% of Total	Meas Drop	% of Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	Meas Drop	% Total	

X-D-1008



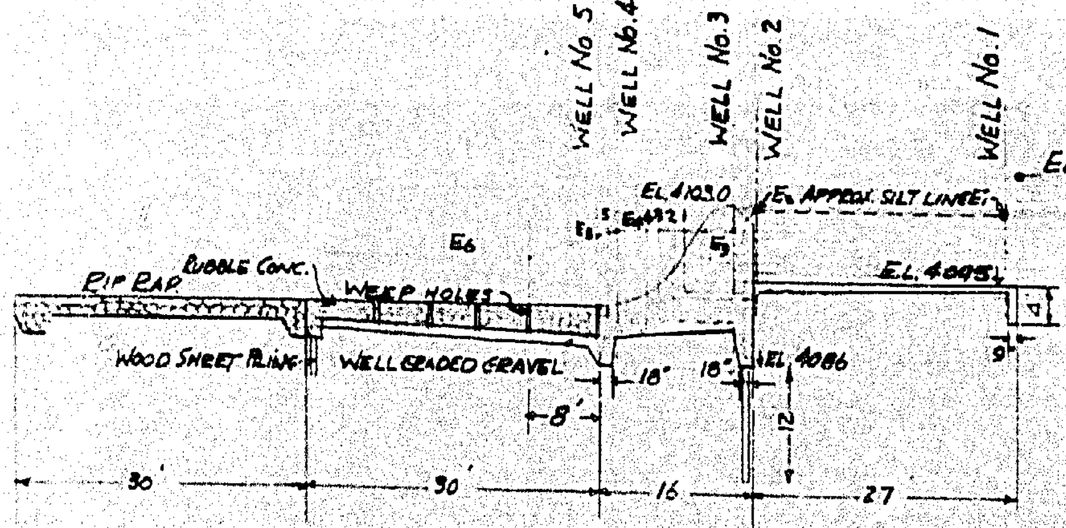
SECTIONAL VIEW
SCALE. HOR. 1"=30'
VERT. 1"=20'



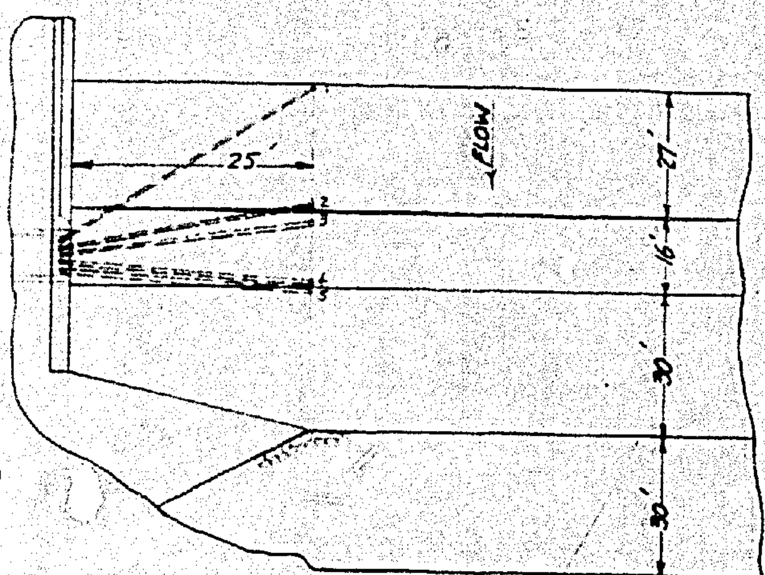
RIVER SECTION LOOKING UPSTREAM
SCALE: HOR 1"=10', VERT 1"=20'

COLORADO RIVER DAM

PLATE 2



SECTION THRU SPILLWAY
SCALE: 1"=20'



PARTIAL PLAN

PERCHA DAM, NEW MEXICO

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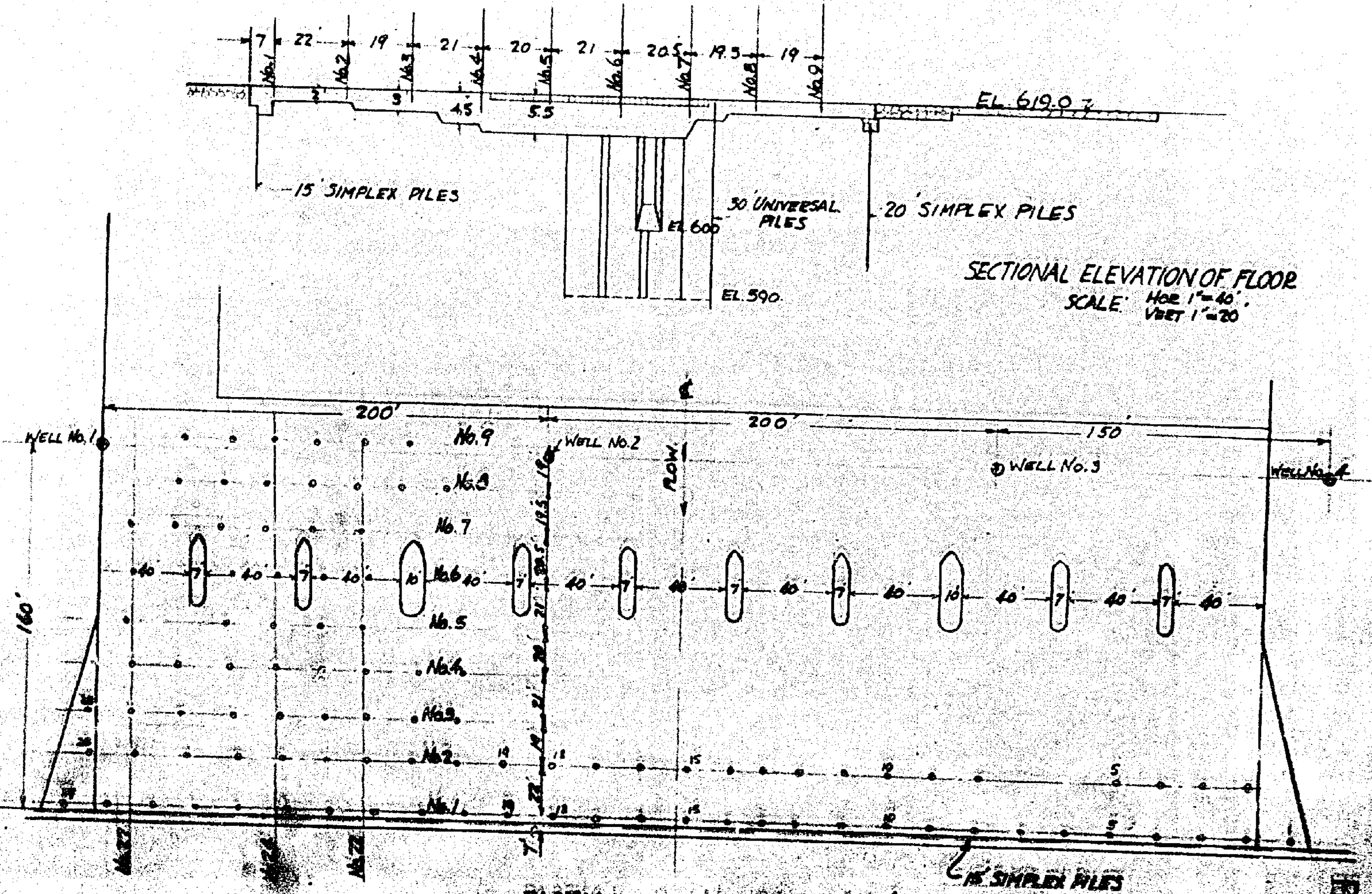
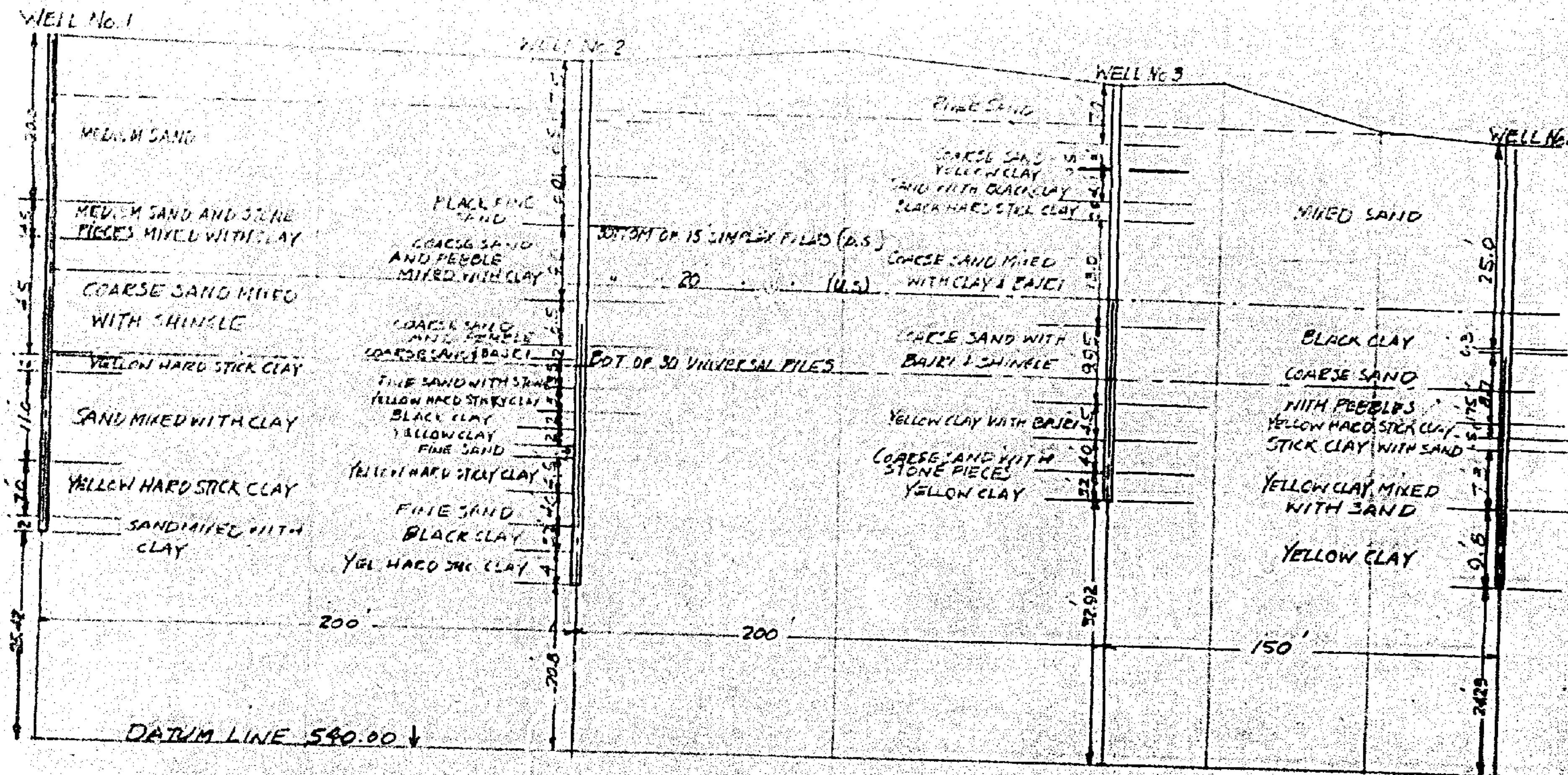


PARTIAL PLAN SCALE 1"=60'

SARDA CANAL - DEOHA BARRAGE

PLATE 3



CROSS SECTION OF DEOHA RIVER

SHOWING TRIAL BORING WELLS 1-5

SCALE: H.-1" = 60', V.-1" = 20'

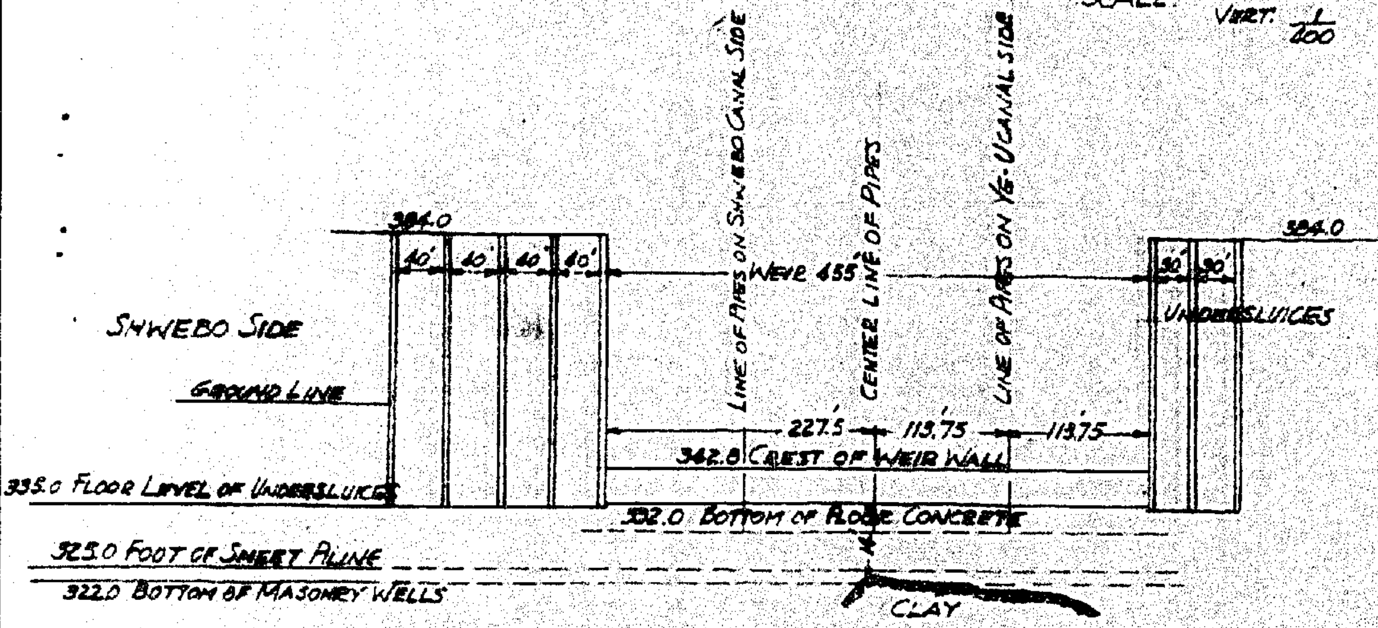
Note:

PLATE 4

PLATE 5

KABO HEADWORKS
GEOLOGICAL SECTION

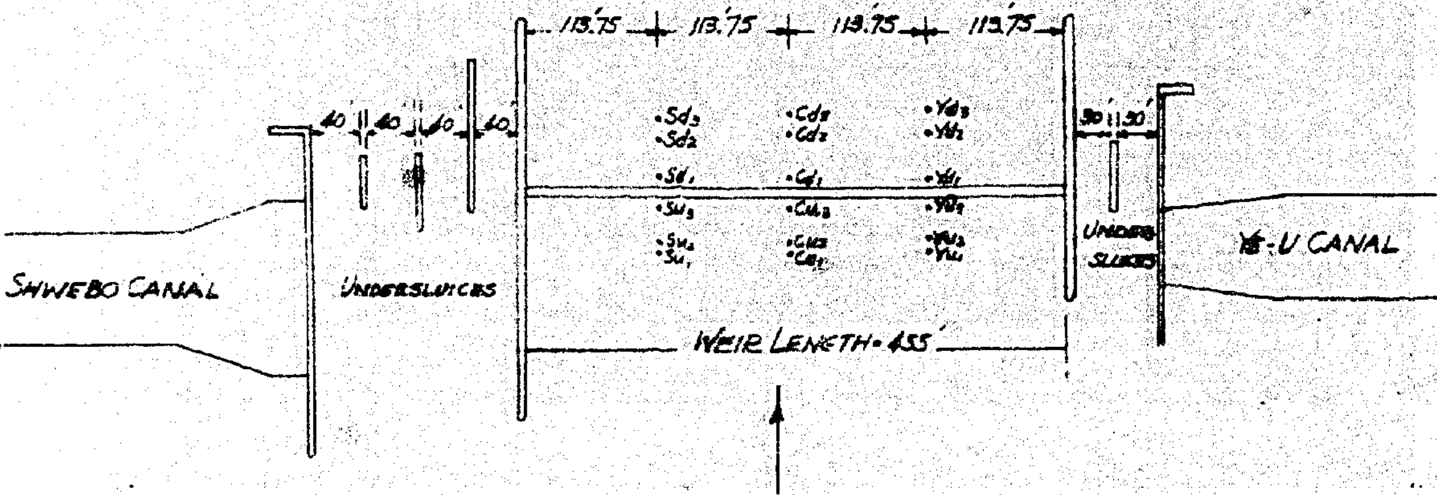
SCALE: HOR. 1/2000 VERT. 1/200

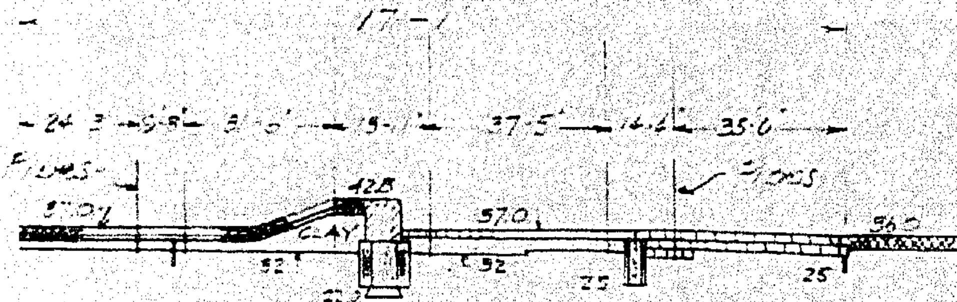


NOTE
WHEN CLAY IS NOT SHOWN
THE FOUNDATION IS SAND

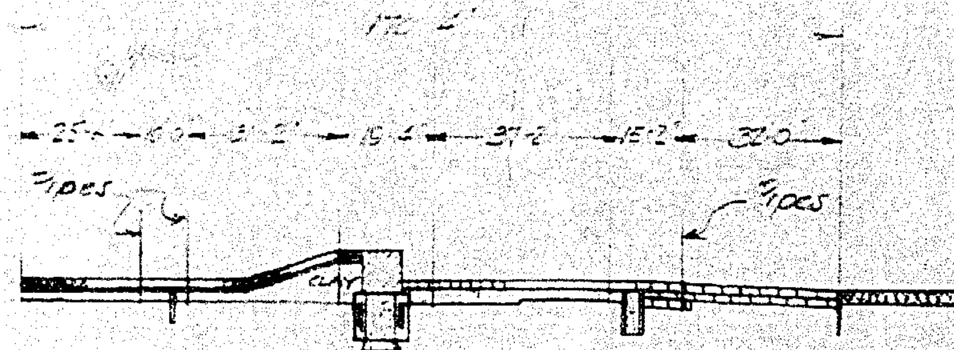
PLAN SHOWING SITE OF PIPES

SCALE: 1/2000

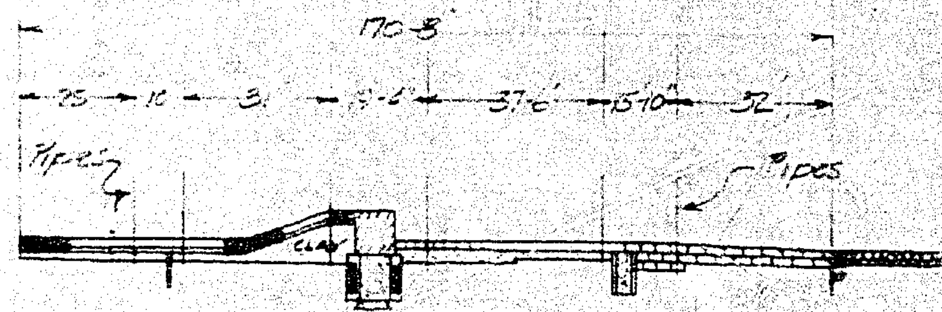




SHWEBO CANAL SIDE



CENTER LINE OF WEIR

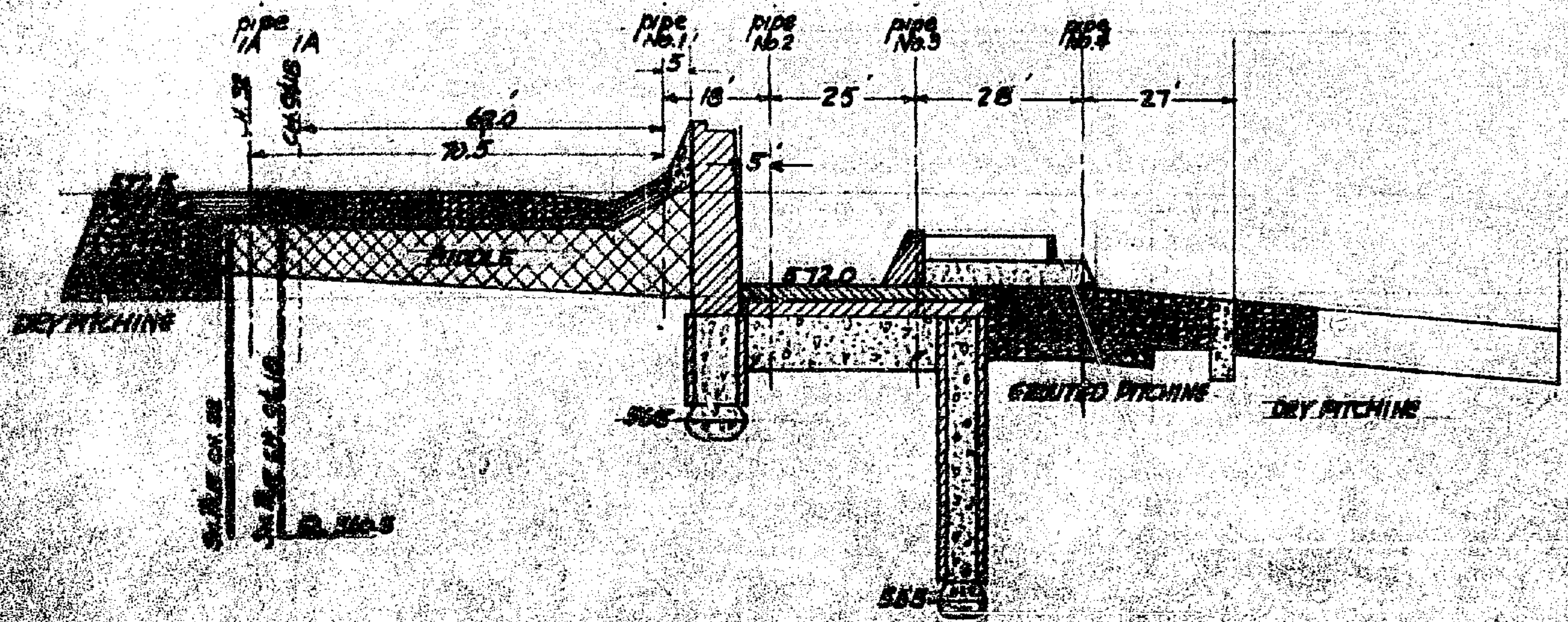


YE-U CANAL SIDE

KABO HEADWORKS

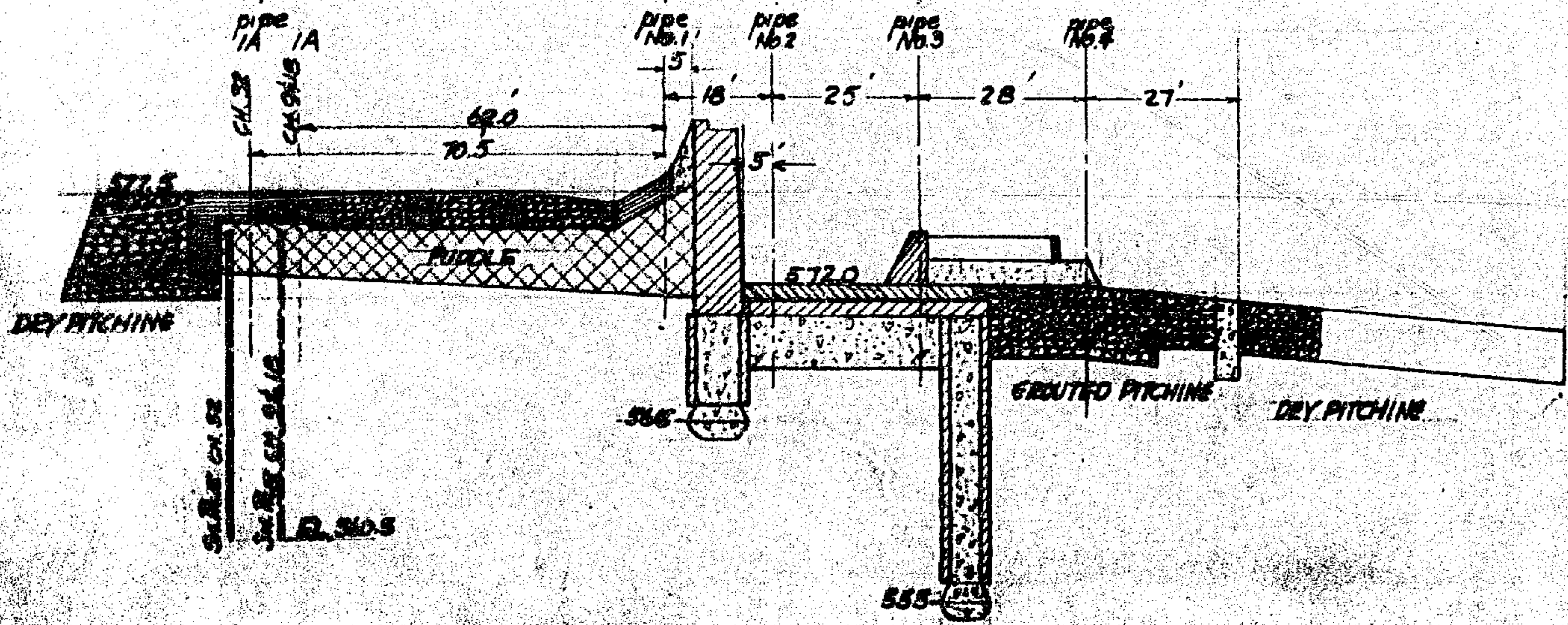
SCALE: 1"=40'

PLATE 7



NARORA WEIR AS REMODELLED

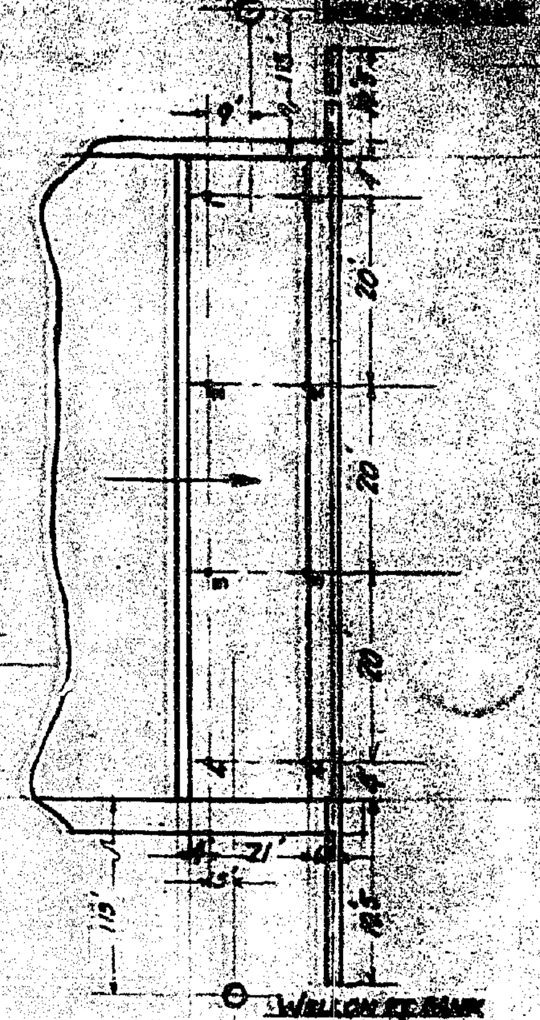
SCALE: Hor. 1" = 80'
Ver. 1" = 10'

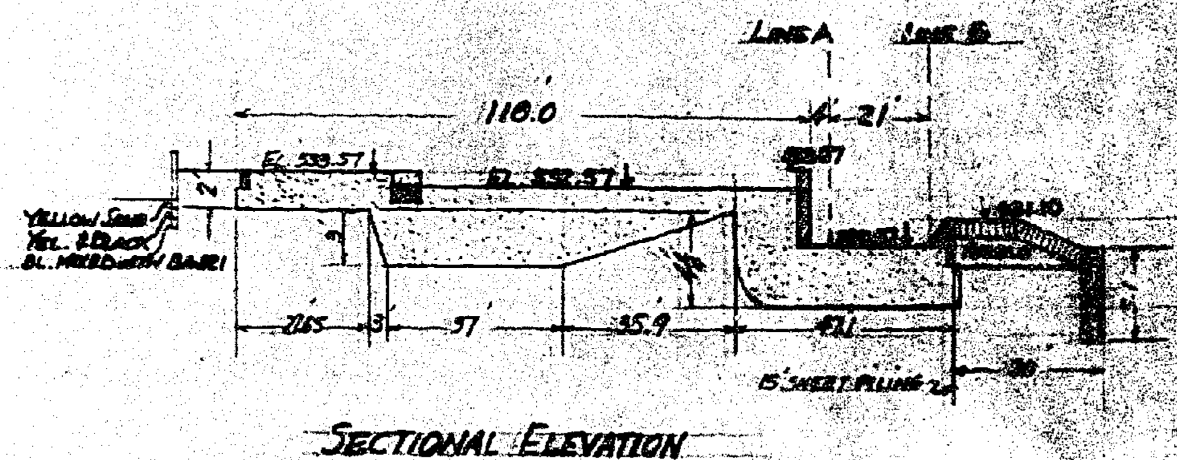


NARORA WEIR AS REMODELLED

SCALE: Hor. 1" = 30'
Ver. 1" = 10'

348





SARDA CANAL

NATHAURA ESCAPE HEAD

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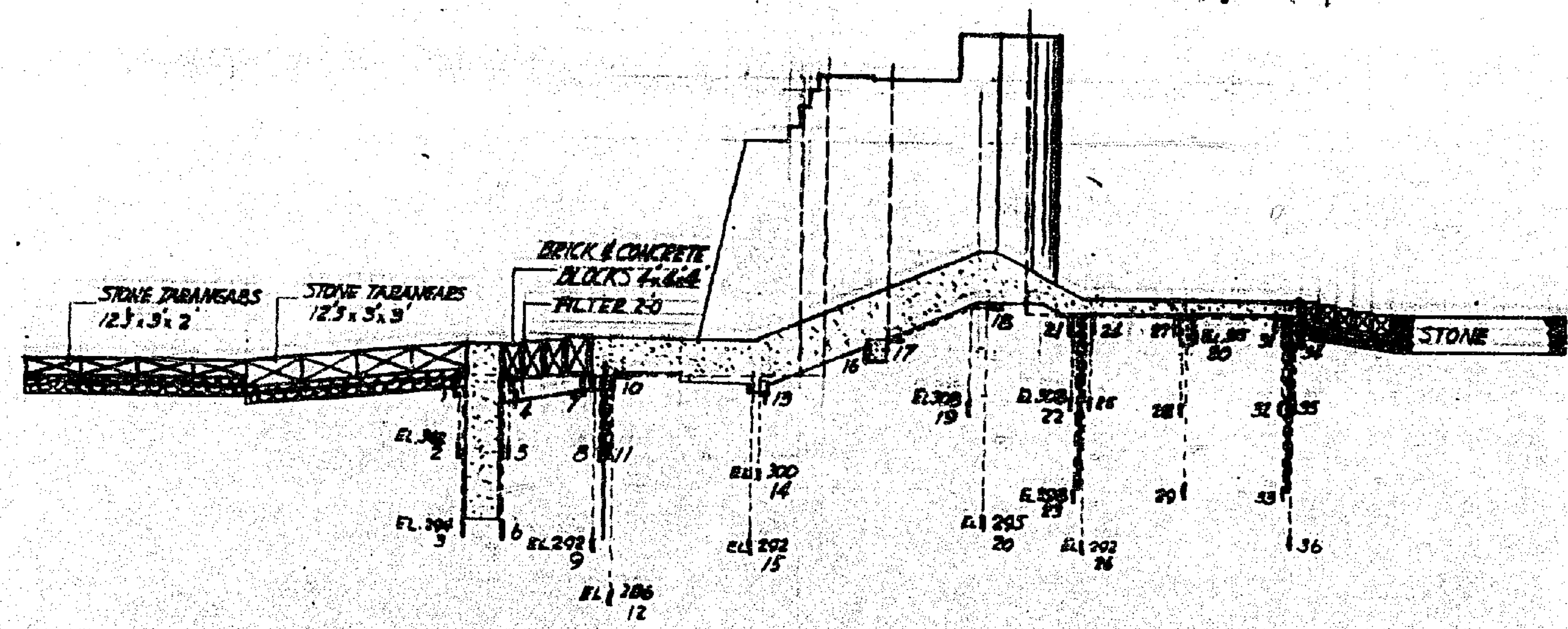

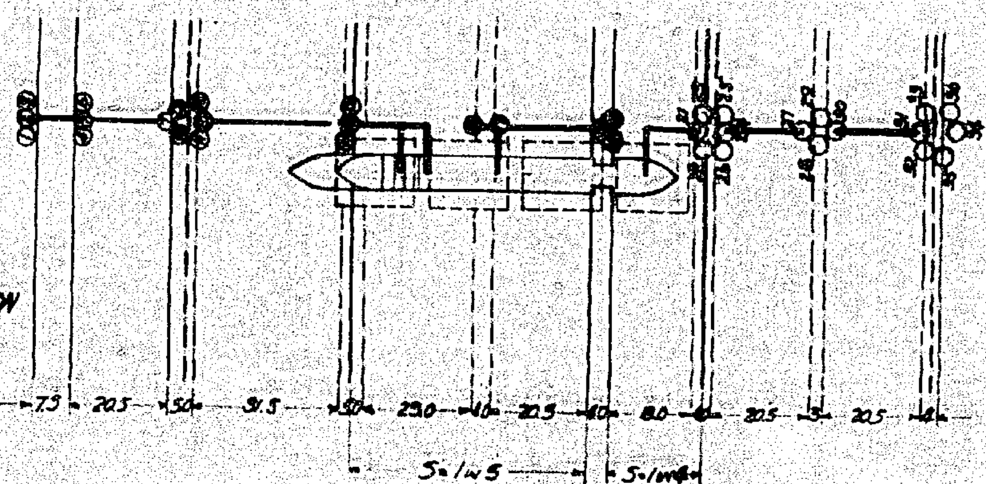

PANJNAD HEAD WORKS

SECTION OF WEIR BAYS 34 to 47

SHOWING PRESSURE PIPES IN PLAN AND SECTION

AT PIER 44

SCALE: HOR. 1" = 40'
VERT. 1" = 20'

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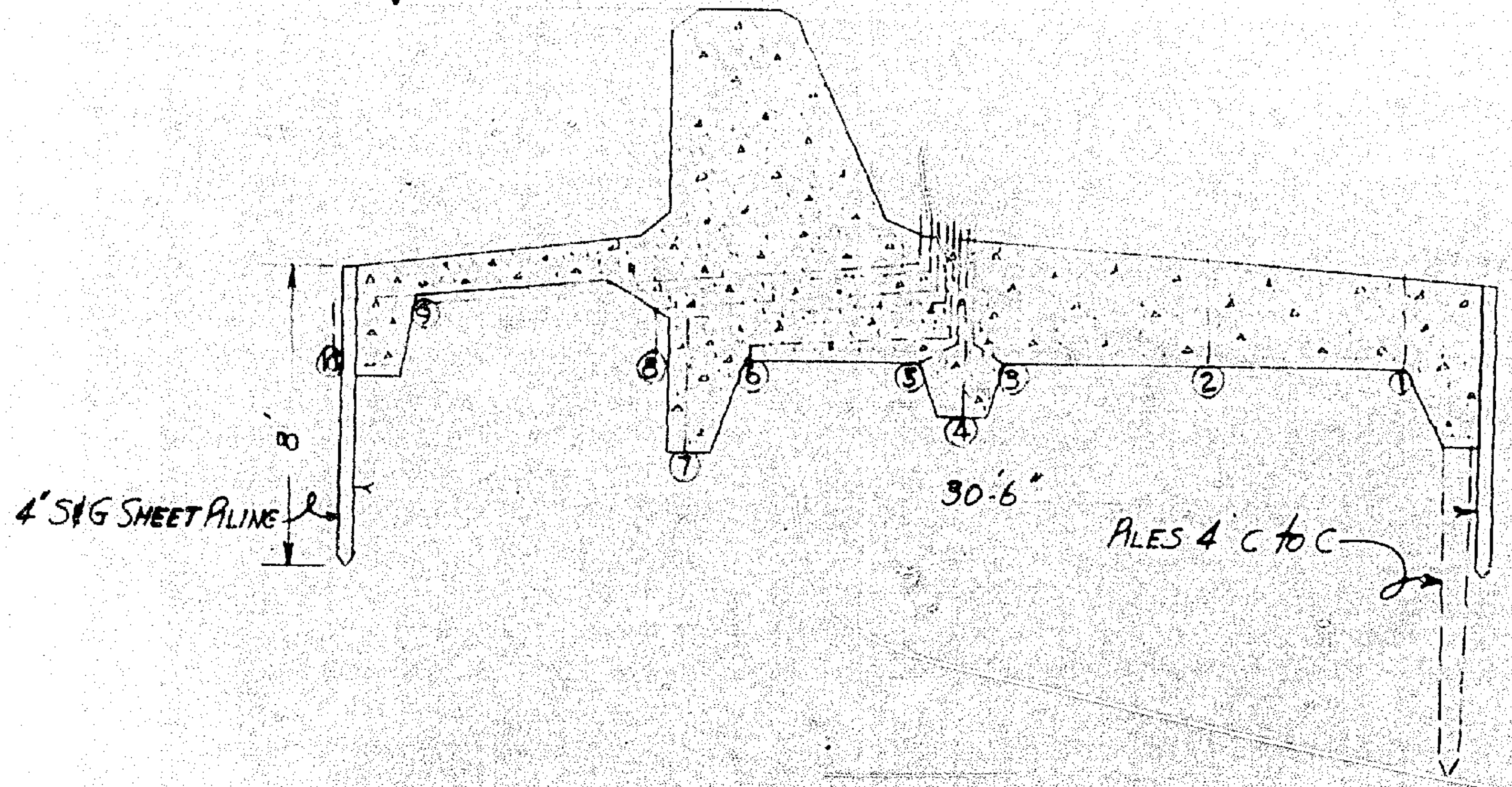
PLATE 10



ISLAND PARK DAM
SCALE: 1" = 5'

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PLATE 11

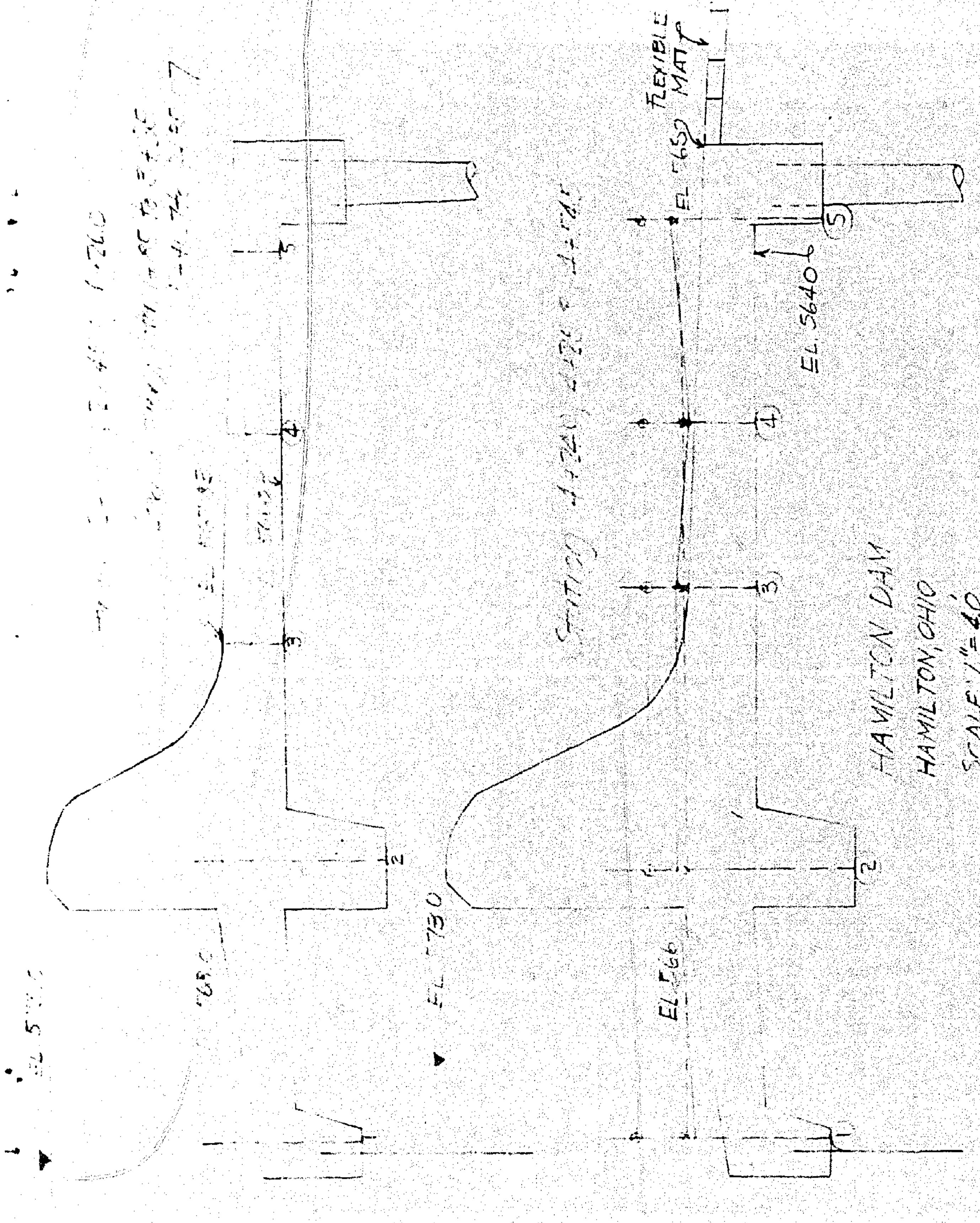
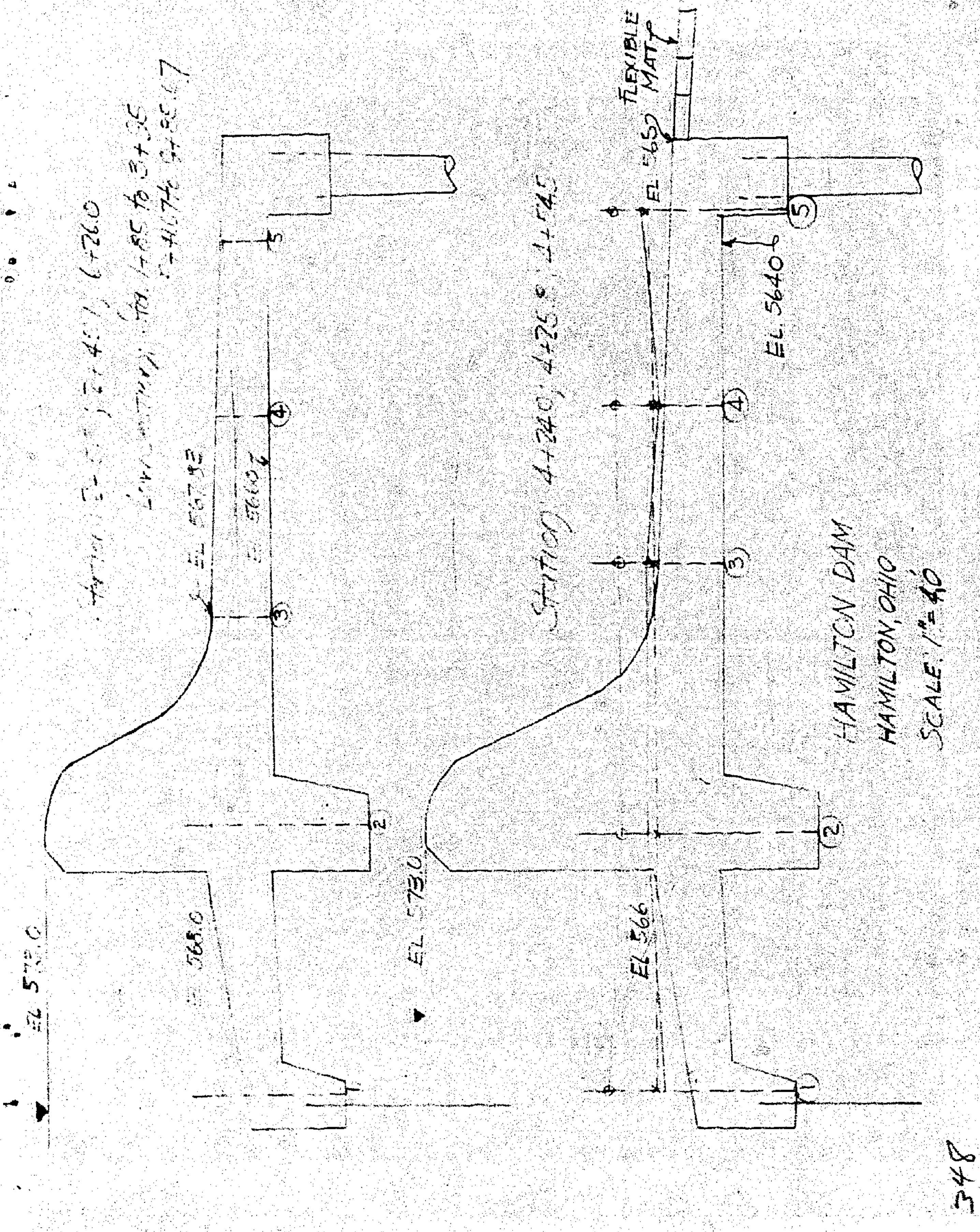

FLEXIBLE MAT
EL 5640
EL 730
HAMILTON DAM
HAMILTON, OHIO
SCALE: 1" = 40'

PLATE 11


FLEXIBLE MATT
EL 564.0
EL 573.0
EL 566
HAMILTON DAM
HAMILTON, OHIO
SCALE: 1" = 40'