



Government of Bombay
Public Works Department

Technical Paper No. 20

Note dated November 1927

on

Model Experiments to ascertain the
effect of Partial Lining of the Malegaon
Cut in miles 38 and 39 of the Nira
Left Bank Canal

BY

C. C. INGLIS, B.A.I., M.INST.C.E.,
Executive Engineer, Special Irrigation Division

AND

D. V. JOGLEKAR, B.E.,
Assistant Engineer

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ERRATA

Page 3—

In paragraph 1, line 15, *for* the figure "8-20" *read* "8·20".

In paragraph 2, line 1, *for* the word "conclusions" *read* "conclusion".

In paragraph 3, line 8, *insert* a hyphen at the end.

Page 4—

In paragraph 7, line 9, *for* $Q=CA\sqrt{RS}$ *read* $Q=CA\sqrt{\overline{RS}}$.

Page 8—

In line 9, *for* the words "were removed" *read* "was removed".

In Figure 6, *for* the word "Projection" *read* "Projections".

Page 9—

Delete the word PLAN below Figure No. 8.

Page 10—

In the 5th line from the bottom, in the equation against the first N,
for $\frac{.033 \times 22.0 + .014 \times 6.4}{28.4}$ *read* $\frac{.039 \times 22.0 + .014 \times 6.4}{28.4}$.

Page 11—

In line 3, against the letter N *for* the equation $\frac{.039 \times 10.9 + .014 \times 17.6}{28.4}$
read $\frac{.039 \times 10.9 + .014 \times 17.4}{28.3}$.

In lines 13-15, cancel the portion against (a), (b) and (c) and *substitute—*

$$(a) G.2-4, N = \frac{.039 \times 9.0 + .014 \times 19.1}{28.1} = .022 \text{ against } .021.$$

$$(b) G.4-6, N = \frac{.033 \times 9.5 + .014 \times 18.7}{28.2} = .0204 \text{ against } .025.$$

$$(c) G.2-6, N = \frac{.036 \times 9.2 + .014 \times 18.9}{28.1} = .0212 \text{ against } .022.$$

In Statement VI, item (iv), column 2, *for* "0.236" *read* "0.0236".

In Statement VI, item (v), *for* "0.236" in column 2 *read* "0.022" and
for "0.022" in column 6 *read* "0.0212".

In paragraph 16, line 2, *for* the word "is" *read* "was".

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Note dated November 1927, on "Model experiments to ascertain the effect of partial lining of the 'Malegaon Cut' in miles 38 and 39 of the Nira Left Bank Canal,"
by C. C. Inglis, B.A.I., M.Inst.C.E., with D. V. Joglekar, B.E.,
Assistant Engineer

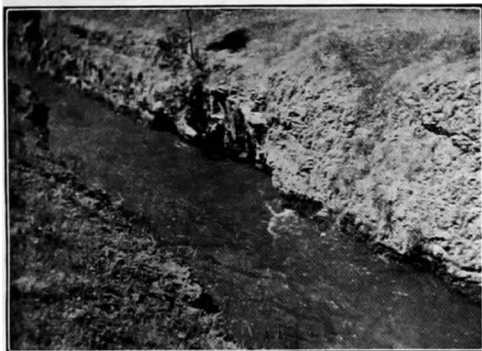
I N D E X

Photos.

1. Object of experiment.
2. The conclusions drawn from calculations made by the Executive Engineer, Nira Left Bank Canal Division.
3. Objections to proposals.
4. Alternatives to raising the banks.
5. The relative scales and dimensions of the model.
6. Method of ascertaining water levels in the model.
7. Difficulties.
8. Selection of formula to be used.
9. Equivalent discharge to be passed through the model.
10. Effect of velocity of approach on results.
11. Exaggeration of the surface slope in the model.
12. Mean velocity and mean wetted perimeter.
13. Experiments.
14. Summary of results.
15. Consideration of results.
16. Reliability of results.
17. Calculations of the effect of lining on water levels and afflux in the Malegaon Cut under different conditions.

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- Plate 1. Longitudinal and Cross Sections of Malegaon Cut.
Plate 2. Nomogram for Manning's formula.
Plate 3. Water levels in Malegaon Cut for different amounts of lining.

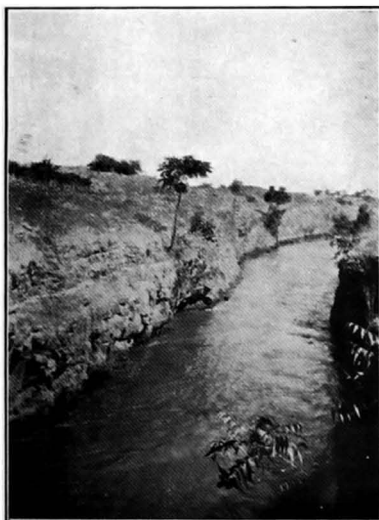
Malegaon Cut in Miles 38, 39, Nira L. B. Canal



Malegaon Cut—Shows the formation of eddies caused by the very rough sides



Malegaon Cut—Looking upstream from lower end of Cut



Malegaon Cut—Lower end of cut looking downstream

Malegaon Cut Model at Distributary No. 5, Mutha Right Bank Canal



Malegaon Cut looking downstream when the present full-supply discharge of 452 cusecs was passing; showing the depth of the cut, roughness of the sides, etc.



The view of the model after the bed and sides had been lined



Discharge of 0.83 Cusecs equivalent to 620 Cusecs; new F.S.Q. looking downstream. The view also shows the pointer plate arrangement to observe water levels



New F.S.Q. passing through the Model looking upstream

Note dated November 1927 on "Model experiments to ascertain the effect of partial lining of the 'Malegaon Cut' in miles 38 and 39 of the Nira Left Bank Canal," by C. C. Inglis, B.A.I., M.Inst.C.E., with D. V. Joglekar, B.E., Assistant Engineer

1. *Object of experiment.*—Prior to remodelling, the full supply discharge of the Nira Left Bank Canal was 452 cusecs where it passed through the deep, narrow, Malegaon Rock Cut. The conditions will be seen from Photos 1 to 4 and Plate No. 1.

On page 68 of the Nira Valley Development Project it was proposed to line the cut with concrete from mile 37-4228 to mile 38-1729 ft.; later, however, the length to be lined was reduced and altered to mile 38 to mile 38-1800. It was also proposed to splay the entrance and exit for about 150 ft., to join on to the natural section, *vide* report on afflux in the Malegaon Cut, dated 14th June 1926, by the Executive Engineer, Poona Irrigation Division (now Nira Left Bank Canal Division). It was estimated that as a result of this lining, a discharge of 636 cusecs would flow with a depth of 8.25 ft. of water, the mean surface fall being equivalent to 7'-6" per mile.

Under the old conditions—with no lining—the maximum depth of water in the Cut was 8-20 ft. at Gauge No. I (Mile 38-170) which corresponded with a discharge of 452 cusecs.

The depth of water was not, however, uniform throughout the length of the Cut, being comparatively shallow at the lower end; so in 1915 six gauges were fixed at intervals of approximately 400 ft. in connection with experiments carried out to ascertain the value of 'N' in Kutter's Formula—and the value of 'N' has recently been worked out in detail for each 400 ft. section.

A discharge curve for Gauge 7—below the Malegaon Cut—has also been worked out, and the depth necessary to pass 636 cusecs discharge extrapolated.

2. *The conclusions drawn* (by the Executive Engineer, Nira Left Bank Canal Division) from the calculations made was that 636 cusecs could be passed with an increased depth of 2.23 ft. at Gauge 2A, equivalent to 1.90 ft. at Gauge I where lining is to begin and that a freeboard of 2.5 ft. could be maintained.

3. There seemed to be several objections to this proposal:—

(a) The afflux would have been considerable up to the Pandara Rock Cut, about $1\frac{1}{2}$ miles upstream—because the fall in the canal in this reach is exceedingly small—less than 6 ins. per mile—in places.

(b) Even in the past, breaches have been frequent in this length;

(c) Losses would be doubled, being proportional to the square of the depth; so that the additional loss would have been of the order of three-quarters of a cusec or more; which, capitalised at 5 per cent.—putting a cusec year at the very low valuation of Rs. 2,000—would have been equivalent to a capitalised value of Rs. 30,000.

Hence it was considered desirable to see how the water level could best be kept at, or near, 147.95 at Gauge No. 1—its original Full Supply level.

4. Alternatives to raising the banks were:—

(1) Widening;

(2) Full, or partial, lining.

As the value of 'N' for the Rock Cut was known, it was possible to estimate the widening required and its cost, but the effect of partial lining was difficult to calculate or predict; so permission was obtained to carry out model experiments, and a model of the Cut was constructed in the Bascule Flume at the Hydraulic Testing Station at Distributary No. 5, Mutha Right Bank Canal—as shown in Photos 5, 6 and 7.

5. The relative scales and dimensions of the Model were as under:—

Depth and width = $\frac{1}{12}$ th those of the Malegaon Cut.

Length = $\frac{1}{180}$ th that of the Malegaon Cut.

The total length of the model was only 15 ft. and the length from Gauge No. 1 to Gauge No. 7 was 13.28 ft., equivalent to 2,400 ft. of the Cut.

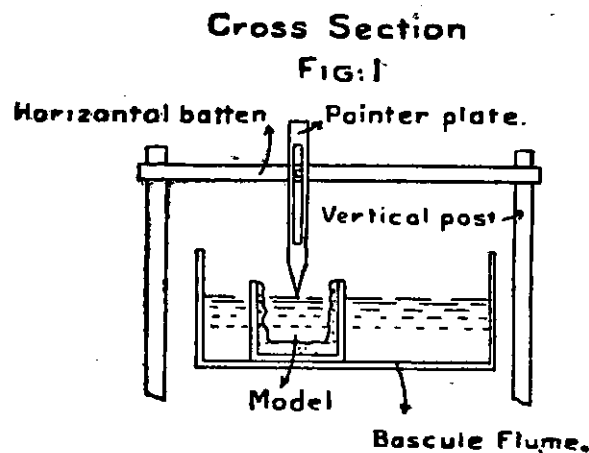
Cross sections of the Malegaon Cut were observed at distances of 50 ft. apart from Mile No. 38 to 38-2700 ft., and the model sections were based on these.

The positions of the gauges of the Cut were as under :—

Gauge No.	..	..	Mile
1	..	..	38-170
2	..	..	38-570
3	..	..	38-980
4	..	..	38-1370
5	..	..	38-1770
6	..	..	38-2160
7	..	..	38-2570

The model gauges were fixed in the same relative positions—to the scale 1 : 180. The sides and bed of the model were of wood, and wire nails were driven into the sides, so that the distance between the ends of the wire nails corresponded to the cross sections of the Cut. Cement concrete was then filled in between the nails, so that the cross sectional area of the model was 1/144 that of the Cut.

6. *Method of ascertaining water levels in the model.*—The Bascule flume can be tilted, by means of a jack, to make it possible to obtain any desired slope ; and as the flume had to be tilted from time to time, relative water levels could not be measured from gauges fixed on the flume. Vertical posts were therefore built into the ground on either side of the flume at the seven gauges and horizontal battens were fixed on the top of these and pointer plates attached (see Figure I). The battens were all fixed at the same level—to simplify readings—and slots were made in the pointer plates, so that they could be moved up and down as required, and clamped.



7. *Difficulties—Roughness of the model.*—The first difficulty was to make each section of the model of exactly the same roughness as the Malegaon Cut. This could only be ascertained by carrying out a large number of experiments of the trial and error variety ; but *eventually* the desired degree of roughness was obtained.

At first glance one might expect to get dynamic similarity provided the model were exactly to scale in all dimensions. In that case the full scale discharge would be (Scale)^{2.5} times the model discharge. It must be pointed out, however, that $Q = AV$ and $V = C \sqrt{RS}$ or $Q = CA \sqrt{RS}$; the discharge ratio will not, therefore, equal (Scale)^{2.5} unless C remains constant ; and as C is a function of the wetted perimeter this had to be taken into account. A consideration of Manning's formula shows this at a glance ; because his value of C is $\frac{1.4868}{N} \sqrt{R}$; in other words $V = \frac{1.4868}{N} R^{2/3} S^{1/2}$.

The alternatives therefore were to reduce the roughness in the model or allow for a reduction in discharge proportional to \sqrt{R} . The latter was adopted in this experiment.

8. *Selection of the formula to be used.*—(a) Comparison of the coefficient of roughness by Manning's and Kutter's Formulas:—

In the calculation done by the Nira Left Bank Canal Division, Kutter's formula was used, in which

$$C = \frac{41.6 + \frac{1.811}{N} + \frac{.00281}{S}}{1 + (41.6 + \frac{.00281}{S}) \frac{N}{\sqrt{R}}}$$

$$\& Q = A.V. \& V = c\sqrt{R.S.}$$

where R = hydraulic mean depth.

S = surface slope measured from gauge to gauge.

& A = Sectional area

$$\text{Manning's formula is } C = \frac{1.486}{N} R^{\frac{1}{6}}$$

& hence :

$$Q = \frac{1.486}{N} A.R^{\frac{2}{3}} S^{\frac{1}{2}}$$

The difference in the value of 'N' by the two formulas was entirely negligible for the Malegaon Cut—as will be seen from the comparative statement below:—

Statement I

Gauge No.	Kutter's 'N'	Manning's 'N'	Remarks
1-2 .. .. .	.0349	.0345	
2-3 .. .. .	.0366	.0366	
3-4 .. .. .	.036	.036	
4-5 .. .. .	.0372	.0373	
5-6 .. .. .	.0277	.0272	
6-7 .. .. .	.033	.0329	
2-4 .. .. .	....	.037	
4-6 .. .. .	....	.034	
2-6 .. .. .	....	.0355	

but for the model there was a considerable divergence:—

Statement II

Gauge No.	Kutter's 'N'	Manning's 'N'	Remarks
2-4 .. .. .	.0178	.020	
4-6 .. .. .	.024	.031	

(b) *Manning's formula adopted.*—One had only to compare the model with the results to see that Manning's values were much more nearly correct for the model—assuming 'N' to take into account relative scale as well as superficial roughness.

This was Ganguillet and Kutter's avowed intention, as they wrote: "the coefficient 'N' must indicate not merely the roughness of the material of the sides and bottom of the channel; but also irregularities of profile and generally the conditions causing retardation of flow." This and many other causes such as the degree of turbidity of the water, eddies rising from the bottom—in short all causes of retardation of the flow—as well as mere roughness of the wetted surface, are covered by our 'N' (vide page 98-99 of Hering & Trautwine's translation).

The meaning of 'N' is a question on which there is much confusion of thought. In text-books, 'N' is generally shown for various surfaces, such as planed wood, cement plaster, earthen channels in good order, etc., and most people have adopted that meaning. The above quotation shows, however, that that was not Kutter's intention and actually we know from long experience that 'N' varies inversely as the size of the channel. Thus 'N' in the river Indus at Sukkur is about 0.017; whereas for large canals 'N' is about 0.0225 and for small channels 0.025. In practice, therefore, Kutter's 'N' is not a surface coefficient, nor is it a regime coefficient—because small channels in equally good regime give higher values of 'N.' So it should be looked on as a measure of relative roughness, not

of absolute roughness. The point for consideration therefore was as to whether Kutter's formula took scale sufficiently into account. For low values of 'N' it seems to do so; but for high values of 'N', it does not.

Now for low values of 'N' and normal conditions Manning's and Kutter's formulas give almost identical results; but for high values of 'N' this experiment has shown that Kutter's formula does not take relative roughness sufficiently into account and that Manning's formula, under these conditions, is decidedly better; and this probably holds for most model work. This formula has the further enormous advantages of being simple in form; clear as regards the relative effect of factors; and capable of easy mathematical treatment.

Hence Manning's formula has been adopted for all calculations in this Paper.

It is not, of course, disputed that for large rivers, Kutter's formula, which takes the slope factor into account, is still the best formula to use. It should not be imagined, however, that Kutter's formula is correct, and that other formulas are mere simplifications and approximations to Kutter's. All formulas, including Kutter's, are mere approximations.

9. *Equivalent discharge to be passed through the model.*—By Manning's formula:

$$Q_1 \text{ of the model} = \frac{A}{144} \frac{1.486}{N} \left(\frac{R}{12}\right)^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$= \frac{Q \text{ of the Cut}}{144 \times 12^{\frac{5}{2}}}$$

(provided N and S are the same in both).

The correct discharge equivalent to 452 cusecs was thus 0.6 of a cusec (see Plate 2 for velocities by Manning's formula).

10. *Effect of velocity of approach on results.*—In a channel of uniform section the velocity is constant and the fall in the water levels in any length is due to loss of head caused by roughness; or in other words:

Slope = fall in water-level \div distance;

$$\text{or } S = \frac{h}{L};$$

but in a channel of varying section, the velocity is not constant, and we must allow for the velocity of approach, *i.e.*, the fall in the water surface between the upper and lower sections is due to two causes:

- (a) the head lost in overcoming friction; and
- (b) the head lost in creating velocity.

The effect of (b) in the case of Malegaon Cut is almost negligible as compared to the friction head; but in the case of the model the friction head is relatively reduced—due to the longitudinal scale being reduced, whereas the velocity head remains the same and hence is relatively considerable. So the total drop required was:

$$h_v + h_n,$$

where h_v = head required to create velocity

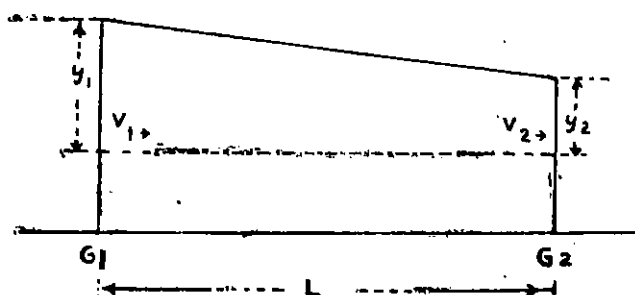
and h_n = head required to overcome friction.

The drop in surface had therefore to be worked out by Bernoulli's theorem:

$$\text{or } S = \frac{\left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)}{L}$$

where y_1 and y_2 are the heights of water surface above a datum level; and V_1 , V_2 the velocities at the two gauges—see Figure 2..

FIG: 2



As stated above, 'N' for the Malegaon Cut, obtained by this method, differed very little from 'N' obtained when the head required to create a velocity of approach was ignored—*vide* Statement III below.

Statement III

Gauge No.	Manning's 'N' when $S = \frac{h}{L}$	Manning's 'N' when $S = \frac{\left(y_1 + \frac{V_1^2}{2g}\right) - \left(y_2 + \frac{V_2^2}{2g}\right)}{L}$
G. 1-2	·0345	·032
G. 2-3	0·0366	·0355
G. 3-4	0·036	·0365
G. 4-5	·0373	·0374
G. 5-6	·0272	·030
G. 6-7	·0328	·0327

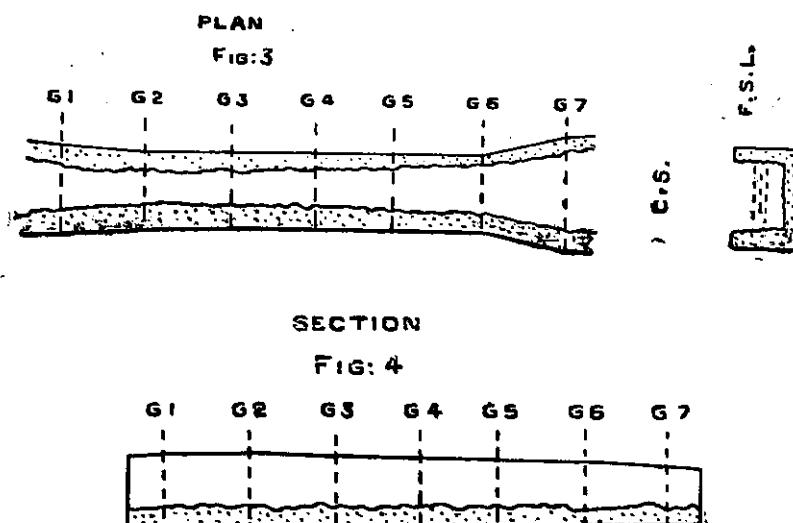
11. *Exaggeration of the surface slope in the model.*—When a discharge of 0·6 cusec (equivalent to 452 cusecs) was passed, the fall in the water surface between Gauges Nos. 1 and 7 was only about ·025 ft.; so it was very difficult to observe the difference in water levels between gauges with sufficient accuracy—despite precautions being taken to get steady flow conditions,—because as a result of the roughness of the sides of the model, fluctuations in the water surface could not be eliminated. Hence to make the measurements of 'h' easier, the surface slope was increased to four times the original slope and later to nine times—the corresponding discharges being double and three times the original. This increased the velocity and hence the head required to create the velocity.

It was found that when 'S' was increased nine times, surface undulations developed,—due to the velocity approximating to the critical velocity—and hence these observations had to be rejected.

As already explained, the distance between gauges in the model was only 2·2 ft.; so that 'h' in each gauge length—even with the exaggerated slope—was small; consequently a slight experimental error caused a considerable error in 'N.' It was therefore decided to calculate 'N' for the gauge lengths 2 to 4 and 4 to 6.

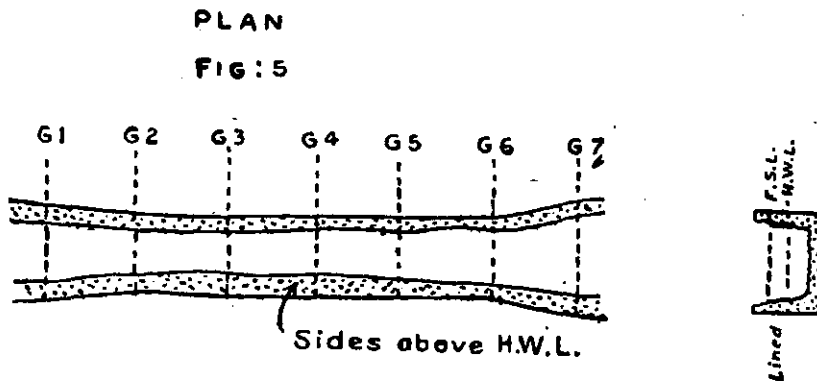
12. *Mean velocity and mean wetted perimeter.*—As the section varied considerably, mean velocities and hydraulic mean depth of the sections were worked out from measurements of three cross sections in each gauge length and arithmetic means were adopted for \bar{V} & \bar{R} .

13. *Experiments.*—(i) In Series IV (Figures 3 and 4), 'N' was observed before any lining was carried out with 1·2 cusecs equivalent to 452 cusecs with slope exaggerated four times and was found to be ·039 and ·033 between Gauges 2-4 and Gauges 4-6 respectively.

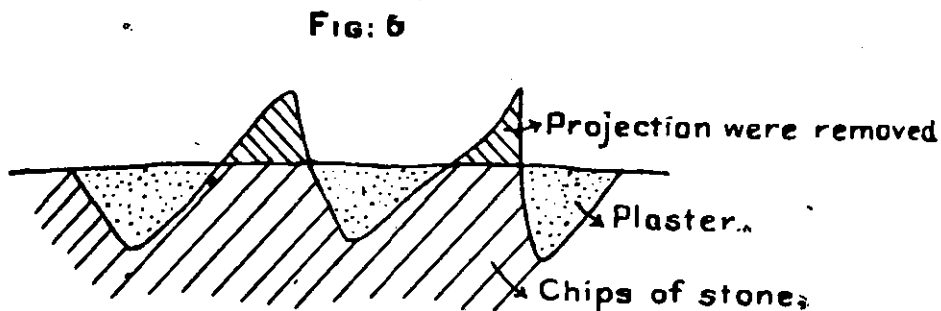


(ii) *Series V.*—In this series the water levels were observed when discharges of 0·83 and 0·40 cusec (equivalent respectively to the new F. S. Q. of 620 cusecs and H. W. Q. of 300 cusecs) were passed through the unlined model. The water level at Gauge No. 7 was maintained so that the depth of water corresponded to 6·5 ft. and 3·9 ft., as these were the downstream levels anticipated for F. S. and H. W. discharges. The water lines were then marked and recorded.

(iii) *Series VI.*—The sides between Full Supply Level and Hot Weather Levels were then lined—as this was one of the proposals for lining (Figure 5).



In making the sides smooth, half the length of projecting chips were removed and then a plaster coat of half the height of chips was added as shown in Figure 6.



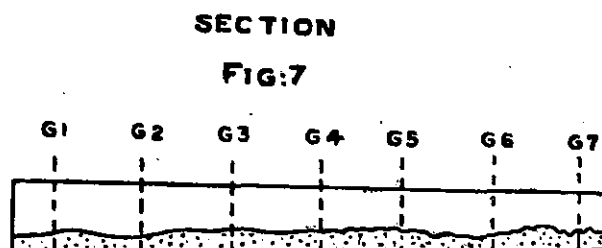
Measurements of the sections after lining were made and tables of area and wetted perimeter prepared. A discharge of 1·5 times 0·83 cusec or 1·25 cusecs was used to exaggerate the slope 2·25 times.

The effect of lining the sides between F. S. L. and H. W. L. was found to be very little, and certainly not worth the trouble and expense which would be involved:—

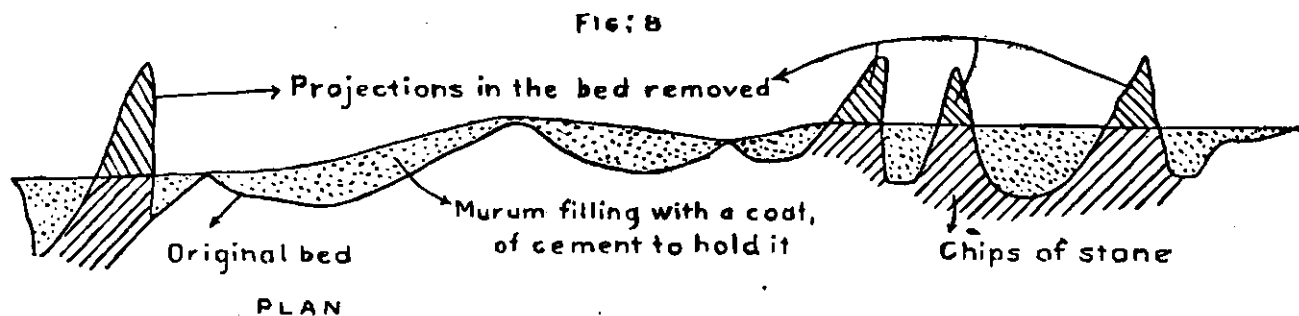
Statement IV

Series No.	—	N		
		G·2—G·4	G·4—G·6	G·2—G·6
Series IV	Unlined	0·039	0·033	0·036
Series VI	Sides between F. S. L. and H. W. L. lined ..	0·037	0·027	0·032

(iv) *Series VII.*—In this experiment, the bed was lined from Gauge No. 1 to Gauge No. 4 only, the portion of the bed from Gauge 4 to Gauge 7 being left rough (see Figure 7).



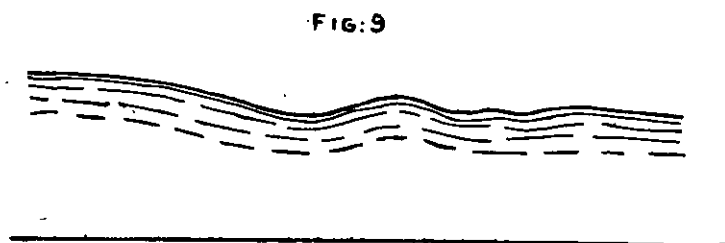
In lining the bed, care was taken to see that the wavy unevenness was maintained—as would actually be the case if the Malegaon Cut were lined—but projecting points were removed and the hollows in the bed (see figure 8) were filled in with murum with a rough binding coat of cement put on the murum to hold it; because without this the murum could not withstand the high velocity.



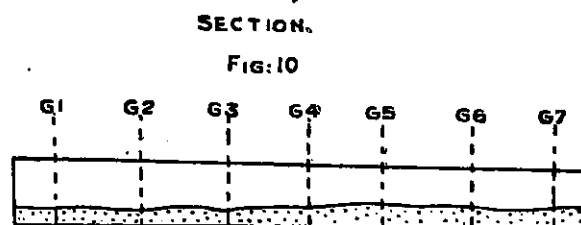
Discharges equal to $1\frac{1}{2} \times 0.83$ and 2×0.83 cusecs (0.83 being equivalent to full supply discharge of 620 cusecs) were passed through the model. It was found that with 1.66 cusecs undulations formed as shown in figure 9.

Only the results for 1.25 cusecs could, therefore, be used for comparison.

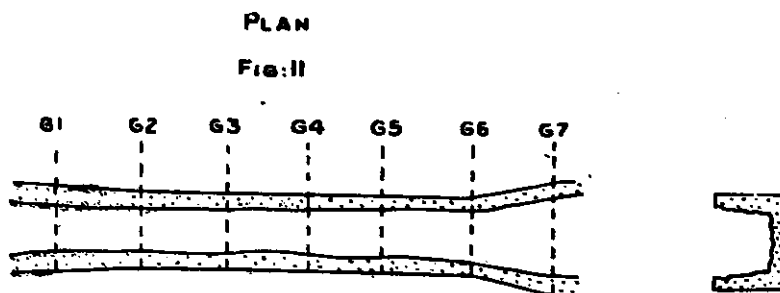
This showed a reduction of 'N' in the upper half—where the bed and sides above H. W. L. were lined—from 0.037 to 0.020.



(v) *Series VIII.*—The lining of the bed was then completed from Gauge 1 to Gauge 7 (Figure 10) and values of 'N' were worked out with a discharge of 1.25 cusecs, and for the whole length (G. 2-6) 'N' was 0.022.



(vi) *Series IX.*—In this series, the sides of the model below Hot Weather Level down to the bed were also lined; so that the whole section was then lined; when 'N' fell to 0.014.



In all these series from VI to IX, the water level maintained at Gauge No. 7 was the same as that which will obtain at Gauge 7 in the Malegaon Cut with a discharge of 620 cusecs.

14. *Summary of results.*—The values of 'N' as observed are given in the tabular form below :—

STATEMENT V

Serial No.	Series	G. 2-4	G. 4-6	G. 2-6	Equivalent discharge of the Malegaon Cut	Slope exaggerated times	Remarks
(i)	IV	·039	·033	·036	452	2·25	Unlined. Sides lined from F. S. to H. W. S. Do. and upper half of bed. Do. and whole length of bed. Complete lining.
(iii)	VI	·037	·027	·032	620	"	
(iv)	VII	·020	·031	·026	"	"	
(v)	VIII	·021	·025	·022	"	"	
(vi)	IX	·014	·014	·014	"	"	

These figures showed that (i) lining the sides from F. S. L. down to H. W. L. reduced the value of 'N' by about 10 per cent. and is, therefore, not worth the cost.

(ii) Lining the bed in the first half of the Cut (G. 2—G. 4) had a very considerable effect, reducing 'N' from 0·032 to 0·026 or an additional 20 per cent; lining the lower half of the bed reduced 'N' by further 10 per cent. and complete lining reduced 'N' to 0·014 as against 0·036 unlined or a reduction of 60 per cent.

15. *Consideration of results.*—Let us consider whether the results obtained tally with an assumption that 'N' for a channel which is partly lined and partly unlined should be equal to

$$\frac{N_1 \times W P_1 + N_2 \times W P_2}{W P_1 + W P_2}$$

Where 'N₁' and W. P₁ are the coefficient of roughness and wetted perimeter for unlined conditions and 'N₂' and W P₂ for the portion lined.

If this assumption holds, then it will be simple to estimate the effect of partial lining.

As the section was not uniform, averages had to be worked out :—

	G. 2-G. 4	G. 4-G. 6	G. 2-G. 6
Average wetted perimeter	28·4"	28·4"	28·4"
Average depth of sides between F. S. L. and H. W. L.	3·2"	3·1"	3·2"
Average width	11·1"	12·7"	11·9"

Thus starting with serial No. (i) and ending with serial No. (vi) above we get the following results :—

Serial No. (iii) sides between F. S. L. and H. W. L. lined.

(a) *G. 2-4*

$$N = \frac{·033 \times 22·0 + ·014 \times 6·4}{28·4} = ·033 \text{ as against } ·037 \text{ observed.}$$

(b) *G. 4-6*

$$N = \frac{·033 \times 22·2 + ·014 \times 6·2}{28·4} = ·0288 \quad ,, \quad ·027 \quad \text{do.}$$

(c) *G. 2-6*

$$N = \frac{·036 \times 22 + ·014 \times 6·4}{28·4} = ·031 \quad ,, \quad ·032 \quad \text{do.}$$

Serial No. (iv) sides as in (2) and bed lined down to G. 4.

(a) *G. 2-G. 4*

$$N = \frac{.039 \times 10.9 + .014 \times 17.5}{28.4} = .0236 \text{ as against } .020 \text{ observed}$$

(b) *G. 4-6*

The value of 'N' actually observed was 0.031 whereas in the previous experiment it worked out to 0.029 and was observed as 0.027. At first sight one might have expected no change, as this length was not altered; but it should be borne in mind that owing to the velocity of approach being higher and depth lower—causing the proportion of unlined surface to be higher—the friction loss was necessarily greater; hence this difference was to be anticipated.

(c) *G. 2-6*, $N = \frac{.0288 + .0236}{2} = .026$ against .026.

Serial No. (v) sides between F. S. L. and H. W. L. and whole bed lined.

(a) *G. 1-4*, $N =$ same as in 3 (a), viz., .0236 against .021.

(b) *G. 4-6*, $N = \frac{.033 \times 9.5 + 18.9 \times .014}{28.4} = .0204$,, .025.

(c) *G. 2-6*, $N = \frac{.036 \times 10.1 + 18.3 \times .014}{28.4} = .0218$,, .022.

The errors in (a) and (b) cancel out and seem to indicate that G. 4 did not give a true reading—due probably to a local undulation at that point; but over the whole length the figures agreed.

Below is given a comparative statement of calculated values of 'N' and observed values:—

STATEMENT VI

Serial No.	G. 2 to G. 4		G. 4 to G. 6		G. 2 to G. 6		Remarks
	N Observed	\bar{N} Calculated	N Observed	\bar{N} Calculated	N Observed	\bar{N} Calculated	
(i)	.039	....	.033	....	.036	....	Unlined.
(iii)	.037	0.033	.027	.0288	0.032	0.031	{ Sides F. S. L. to H. W. L. lined.
(iv)	.020	0.236	.031	.0288	0.026	0.026		{ Do. and upper half of bed.
(v)	.021	0.236	.025	.0204	0.022	0.022	{ Do. and whole length of bed.
(vi)	.014	....	.014	....	0.014	....	Wholly lined.

16. *Reliability of results.*—Especially over the whole length of the model the results tally as closely as could be expected under the conditions and there is no constant plus or minus error. For the particular purpose for which the experiment was carried out the results may be considered as giving sufficiently accurate qualitative results.

17. *Conclusions on the effect of lining on water levels and afflux in the Malegaon Cut under different conditions.*—The values of 'N' (shown in Statement VII)—obtained from the model—were applied to the Malegaon Cut in working out water levels for various amounts of lining and Plate 3 and statement VII show the results.

(1) It will be seen that the total difference of water levels between Gauge 1 and Gauge 7 with 620 cusecs and no lining would be 4.99 feet and that the present depth at Gauge 1 would increase from 8.49 feet with the old Full Supply Discharge of 452 cusecs to 10.39 feet with the new Full Supply Discharge of 620 cusecs.

(2) If the sides of the Cut between Full Supply Level and Hot Weather Level were lined from Gauge 1 to Gauge 7, the depth would be reduced by 0.81 feet or 1.09 feet higher than the present Full Supply Level.

(3) If the bed only were lined from Gauge 1 to Gauge 4, the depth would be reduced by 0.95 feet; or 0.95 feet higher than the present Full Supply Level.

(4) If the bed were lined for the whole length (i.e., from Gauge 1 to Gauge 7) the depth would be reduced by 1.43 feet and the water level would be 0.47 feet higher than the present Full Supply Level.

(5) The depth would be reduced by 2·17 feet if the bed and sides were lined up to Full Supply Level from Gauge 1 to Gauge 4 only, *i.e.*, for 1,200 feet length—the remaining 1,200 feet length (from Gauge 4 to Gauge 7) being left untouched. In other words, the water level would be 0·27 feet lower than the present Full Supply Level.

(6) If the whole Cut were lined, the depth would be reduced by 3·24 feet and the water level would be 1·34 feet lower than the present Full Supply Level.

The most interesting result is that the water level with a discharge of 620 cusecs would be slightly lower at Gauge 1 than with the present F. S. Q. of 452 cusecs, if the Cut were completely lined in the upper half length of the Cut from Gauge 1 to Gauge 4.

An alternative worth considering—because the work will be much easier to carry out—will be to line the bed in its whole length. If it is considered desirable to keep the water down to its old level, the sides may also be lined for the first 600 feet—either at once or later.

The bed can be lined with lime concrete, with a coat of cement to withstand scour. This will be comparatively cheap and very much easier to lay than lining for the sides.

As the work progresses, water—during closures—will drain away rapidly—provided the lining is done from the lower end upwards and should any repairs be required later it will always be easy to carry out the work. It is suggested, therefore, that the bed should first be lined. This should not cost more than Rs. 15,000 and if any side lining is necessary it can be done later. The value of the water saved has been shown in paragraph 3 (c) to be more than Rs. 30,000 (capitalised), so that even ignoring other advantages lining will be profitable.

18. If this experiment were to be repeated the following modifications would be made:—

(a) the model would be made at least twice as long and preferably 4 times as long—*i.e.*, the longitudinal scale should not be less than $\frac{1}{4}$ th the latitudinal and preferably not less than one-fourth.

(b) instead of making N of the model equal to N of the original, C in the formula $V = C \sqrt{RS}$ would be made the same in the model as in the original and as

$$C = \frac{1.486}{N} \sqrt[3]{R} \quad \text{or} \quad CN = K \sqrt[3]{R};$$

with C constant, N will vary as $\sqrt[3]{R}$

in other words, the model should be made relatively smoother than the original, which would be advantageous in experimental work.

The experiments and calculations were carried out by Messrs. D. V. Joglekar, Assistant Engineer, and H. V. Katakhar, Sub-Divisional Officer.

STATEMENT VII

Statement of estimated waterlevels at various gauges of the Malegaon Cut with different conditions of lining

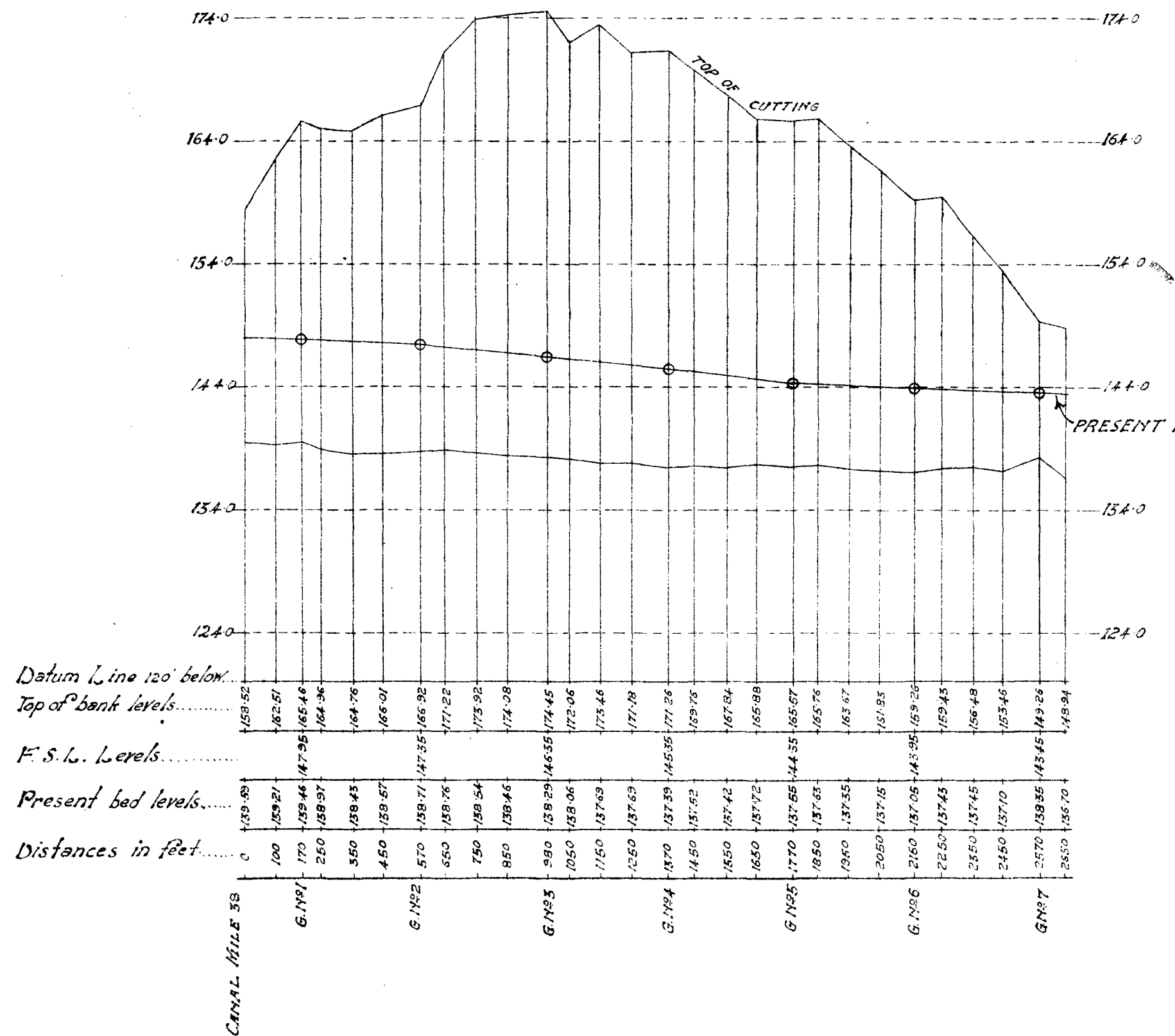
Serial No.	Conditions	Depth of water at G. 1	Water level at G. 1	Water level at G. 2	Water level at G. 3	Water level at G. 4	Water level at G. 5	Water level at G. 6	Water level at G. 7	Difference of water level between G. 1 and G. 7	Reduction in afflux	Remarks
1	W. L. for 620 Cusecs (i.e., new F. S. Q.) Cut Unlined ..	10.39	149.85	149.18	148.06	146.82	145.61	145.18	144.86	4.99	....	Estimated.
2	W. L. for 620 Cusecs lining the sides between F. S. L. and H. W. L. ..	9.58	149.04	148.41	147.24	146.26	145.39	145.00	144.86	4.18	0.81	Do.
3	W. L. for 620 Cusecs lining the bed down to G. 4 only ..	9.44	148.90	148.36	147.52	146.82	145.61	145.18	144.86	4.04	0.95	Do.
4	W. L. for 620 Cusecs lining the bed whole length ..	8.96	148.42	147.84	146.84	145.94	145.26	144.98	144.86	3.56	1.43	Do.
5	W. L. for 620 Cusecs lining the bed and sides down to G. 4 only ..	8.22	147.68	147.39	147.02	146.82	145.61	145.18	144.86	2.82	2.17	Do.
6	W. L. for 620 Cusecs lining the bed and sides whole length ..	7.15	146.61	146.19	145.61	145.27	145.02	144.91	144.86	1.75	3.24	Value obtained in — N = .014 Exp. on D. 5.
6a	Do. ..	7.59	147.30	146.57	146.02	145.49	145.14	144.96	144.86	2.44	2.55	N = .016. As per Nira Left Bank Division's Calculation.
7	W. L. for 452 Cusecs (i.e., present F. S. Q.) ..	8.49	147.95	147.35	146.35	145.35	144.35	143.95	143.45	4.50	As observed.

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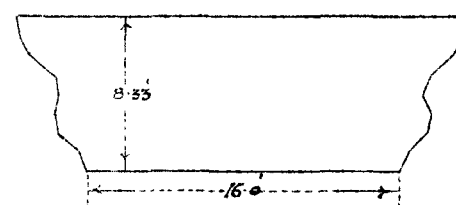
NIRA L B CANAL

LONGITUDINAL SECTION OF THE MALEGAON CUT BETWEEN MILES 38&39

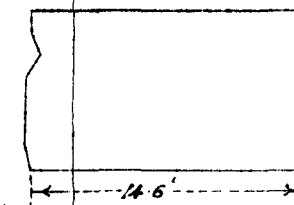
SCALE (HORI: 400' = 1"
VERT: 10' = 1")



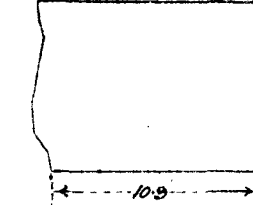
C. S. AT 0



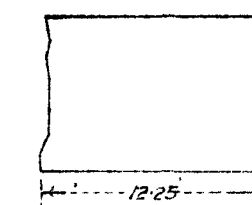
C. S. AT 170
G. M. 1.



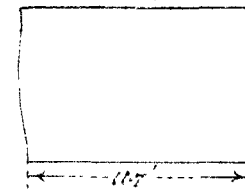
C. S. AT 570
G. M. 2.



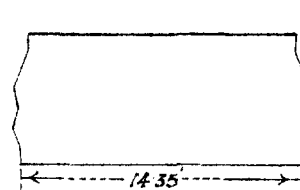
C. S. AT 980
G. M. 3.



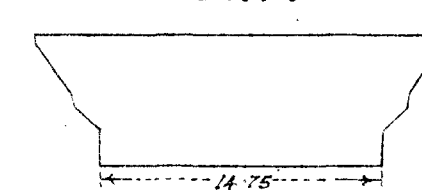
C. S. AT 1370
G. M. 4.



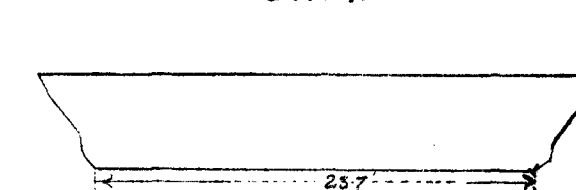
C. S. AT 1770
G. M. 5.



C. S. AT 2160
G. M. 6.



C. S. AT 2570
G. M. 7.



Note: The roughness of the bed is not shown in Cross Section, as it could not be measured being under water.

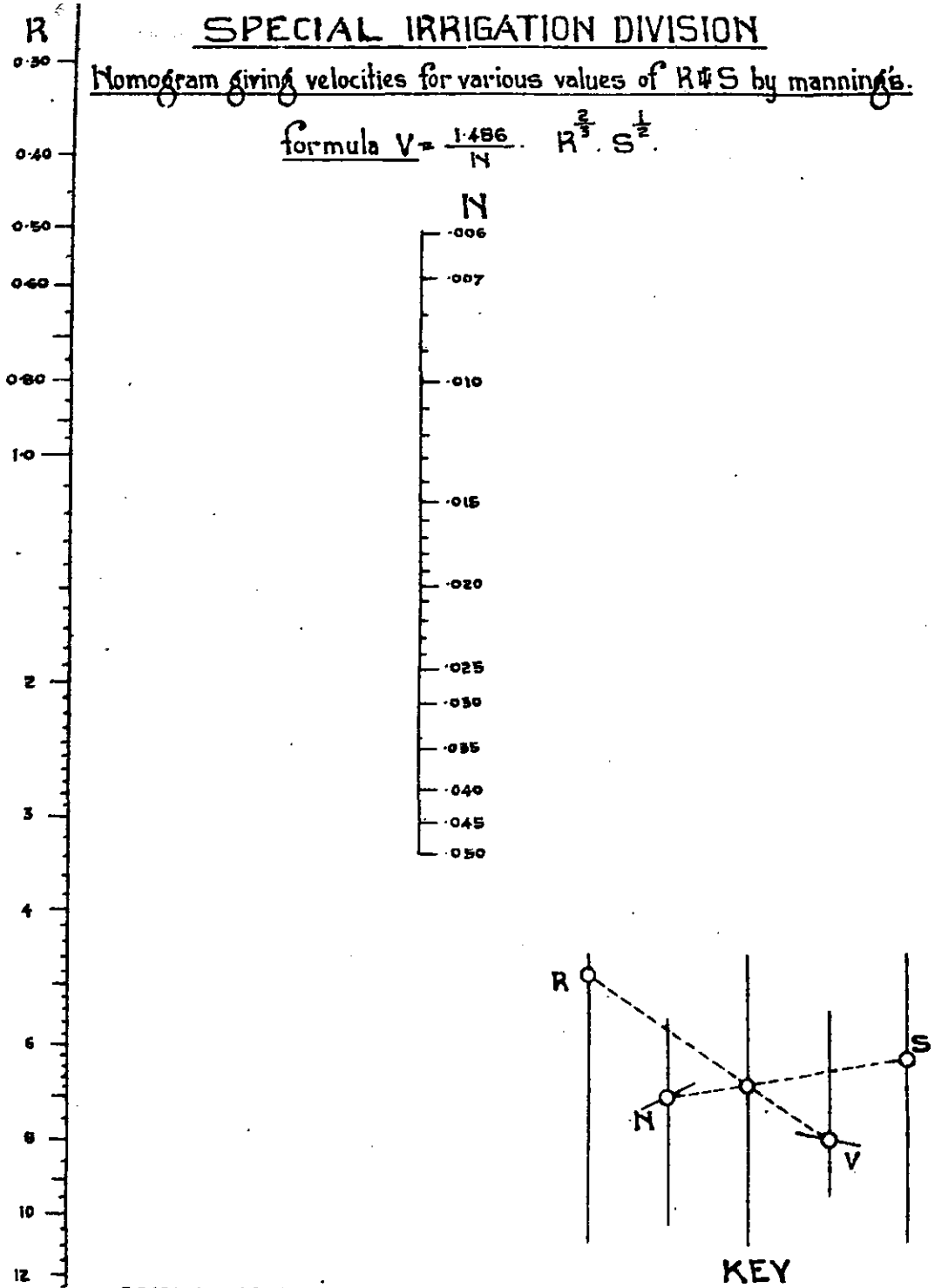
T. By: Bakshi. M.C. 22-11-27.

C. S. Englin
29/11/27
Executive Engineer
Special Irrigation Division

SPECIAL IRRIGATION DIVISION

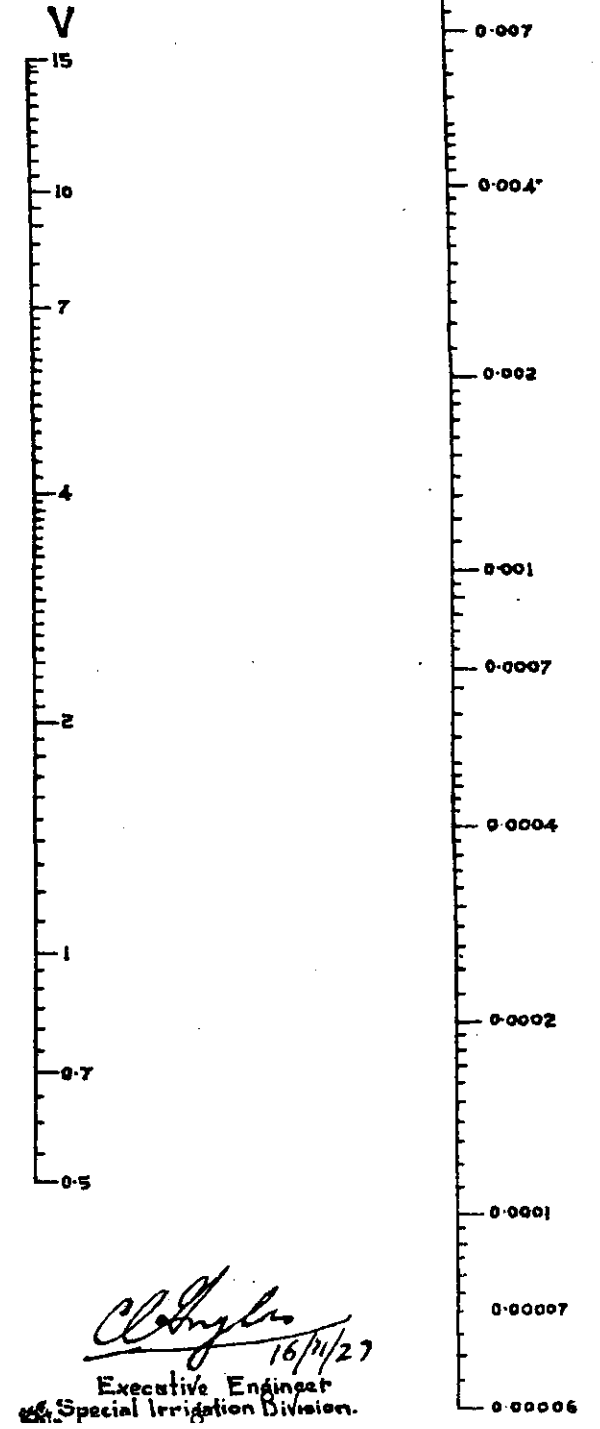
Nomogram giving velocities for various values of R & S by Manning's.

$$\text{formula } V = \frac{1.486}{N} R^{\frac{2}{3}} S^{\frac{1}{2}}$$



T BY BAKSHI. M.C. 14-11-27.

(Based on Nomogram of D. Halton-Thomson, in "Punjab Irrigation - Nomograms" by E. S. Lindley, Punjab. P.W.D.)

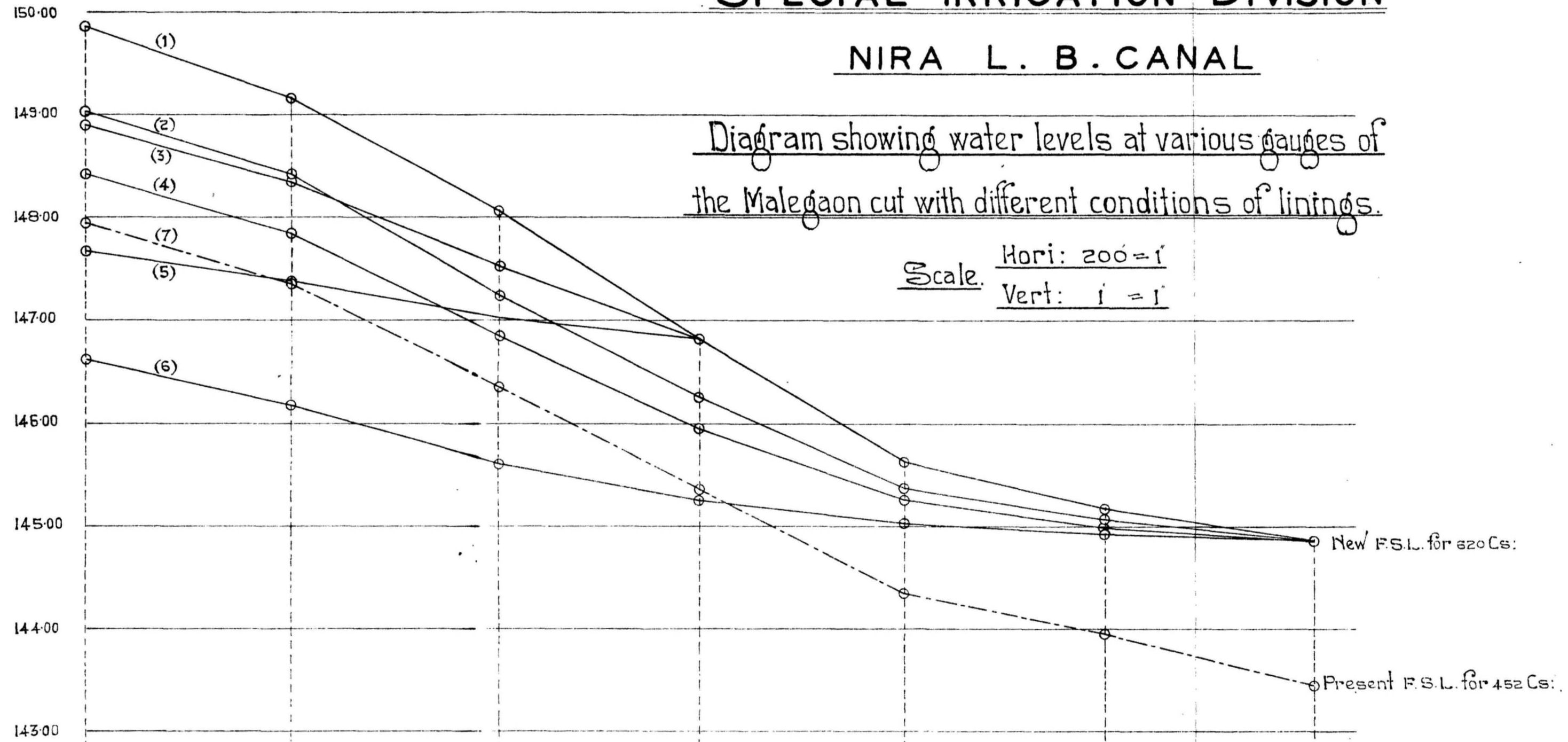


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NIRA L. B. CANAL

Diagram showing water levels at various gauges of
the Malegaon cut with different conditions of linings.

Scale. $\frac{\text{Hori: } 200 = 1}{\text{Vert: } 1 = 1}$



NOTES

Serial No.	Upper half of cut G1-G4.	Lower half of cut G4-G7.
1	Unlined	Unlined
2	Sides between F.S.L. & H.W.L. lined Bed unlined	Bed unlined
3	Bed only lined sides unlined.	Unlined.
4	Bed lined sides unlined	Bed lined sides unlined
5	Bed and sides - lined.	Unlined.
6	Bed and sides - lined.	Bed and sides - lined.
7	Unlined	Unlined.

Estimated w.L. for proposed F.S.Q. of 620 Cs: unlined.....	149.85	149.18	148.06	146.82	145.61	145.18	144.86
Estimated w.L. for 620 Cs: sides between F.S.L. & H.W.L. only lined.....	149.04	148.41	147.24	146.26	145.39	145.09	144.86
Estimated w.L. for 620 Cs: bed down to G4 only lined.....	148.90	148.36	147.52	146.82	145.61	145.18	144.86
Estimated w.L. for 620 Cs: bed only for the whole length lined.....	148.42	147.84	146.84	145.94	145.26	144.98	144.86
Estimated w.L. for 620 Cs: bed and sides down to G4 lined.....	147.68	147.39	147.02	146.82	145.61	145.18	144.86
Estimated w.L. for 620 Cs: bed and sides lined.....	146.61	146.19	145.61	145.27	145.02	144.91	144.86
Observed w.L. for present - F.S.Q. of 452 Cs: unlined.....	147.95	147.35	146.35	145.35	144.35	143.95	143.45
Present bed level.....	139.46	138.71	138.29	137.39	137.55	137.05	136.35
Distances.	0	400	800	1200	1600	1990	2400
Datum line R. L. 136.00.....	G1	G2	G3	G4	G5	G6	G7