DUTY OF DISTRIBUTARIES IN SANDY SOILS SUCH AS IN THE FEROZEPUR DIVISION OF THE SIRHIND CANAL.

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Preliminary.

Definition of "Duty."

The "duty" of water is usually understood to be the ratio between the area supplied with water, and the average supply run for a certain period.

The cusec is the unit of discharge, and the "period of flow", which is the "base" in point of time, consists of two distinct seasons, *viz.*, the Kharif from 1st April to 30th September, and the Rabi from 1st October to 31st March.

The "duty" of a channel, which is the measure of its efficiency, may thus be defined, as the area irrigated during such season (*i. e.*, Kharif and Rabi) by one cusec flowing for a certain number of days within that season, measured at the head of the channel.

Since the efficiency of this cusec is largely discounted by avoidable and unavoidable waste through absorption, evaporation, careless use, etc., the duty as obtained above does not represent the maximum obtainable or ideal, but the actual.

Duty may be expressed by the following formula, where—

D = Duty.

A = Area irrigated.

T = Sum of the daily discharges of the channel.

P = Period of flow.

$$D = \frac{A \times P}{T}$$

Delta ($\triangle$) is a term given to represent the average depth of water in feet, used during any season, over the area irrigated. It is another way of expressing the efficiency of

a channel, and is in inverse ratio to the duty. A high duty shows, a high efficiency, and a high value of delta, the reverse.

GENERAL CONSIDERATION OF THE SUBJECT.

The factors, which, it is generally agreed, govern the value of duty are :—

(*i*) State of the channel.

(*ii*) Discharge.

(*iii*) Losses in transit.

(*iv*) Area irrigated.

(*i*) *State of channel.*—It will be readily conceded that the condition of a channel largely affects its efficiency, and therefore the duty. The proper maintenance of a channel is thus of extreme importance. Weeds, silt heaps, and over-grown berms, head up supply, show a false discharge as referred to the gauge, and give upper outlets an undue share of the supply. If it is considered scientifically right to design correctly, then it is equally scientifically improper not to keep up a channel to that design, and not to work it as nearly to that design, as may be consistent with local conditions and variations.

(*ii*) *Discharges.*—A module for distributary head discharges has been designed by Mr. Kennedy and a few exist in certain channels of the Punjab, but the module does not appear to have made much headway.

A second method of gauging discharges which had a certain vogue for a time, was that by "Benton's Tables," which were based on observations of the "head" into the distributary and the area of the waterway.

The method which has been employed most consistently is that of checking discharges constantly by observation. A table is drawn up giving the discharge for every decimal of a foot of gauge reading. This is checked by observation and corrected when necessary. Discharges are recorded from an observation of the average of the morning and evening gauges.

It is clear that tables should be as correct as possible and checked frequently, as discharges referred to gauge readings are materially affected by silt deposit, scour, and undue berm growth.

If it is found that silt deposited in the bed is "obstinate," it is safest and best to remodel the section of the channel and leave the silt *in situ*. It is quite possible that the head regulator also will need remodelling. It has not always been realized to what extent the area of the waterway of the head regulator affects silting.

Since the actual discharge-run in a channel depends so largely on the demand and the available supply, it would not be either economical or possible to constantly run the designed full supply. Assuming the available supply to be ample the variation in the demand may be considerable. Rainfall is one great determining factor, for it may be heavy and general, or sporadic, in which latter case the demand would vary considerably over the whole area under command ; thus necessitating a modification in the discharge to suit requirements. Such variations in demand occur naturally during the Kharif season, in the early days of which the demand must always be slack, except where the cultivation of a densely populated district coexists with a large commanded area.

(*iii*) *Losses in transit.*—Losses in transit, *i. e.*, from the time the supply enters at the head of a channel till the fields are irrigated include : –

(*a*) Loss by absorption (in which may be included evaporation and percolation) in the distributary and subsidiary channels.

(*b*) Loss in the water-course.

(*c*) Loss dependent on the method of distribution, *i. e.*, time of flow.

(*d*) Loss dependent on the percentage of commanded area to be irrigated, *i. e.*, intensity of irrigation.

(*a*) *Absorption and percolation.*—Either of these terms is generally used to express the action of both ; absorption is, however, the more usual expression. Mr. J. S. Beresford * well differentiates their respective action. He considers "absorption" as an action of capillarity, and "percolation" as an action dependent on the same principle as govern the flow of water through pipes. He says with reference to absorption that "the interstices become so small that they act in the same way as capillary tubes, the water being retained in the cavities with a *greater force* than that due to the hydrostatic head in pressing it through."

* Vide Punjab Irrigation Branch Paper No. 10.

There is no rule whereby the quantity of water lost by absorption may be determined. The following empirical formulæ are however given :—

(i) Mr. Beresford states * that under ordinary conditions the loss by absorption between the head of a distributary and any point L miles downstream, can be approximately ascertained by the formula :
Loss $= AL^x$.

When A = actual loss observed in the first mile and x the power to which L is raised, varying from $\frac{5}{6}$ to $\frac{6}{7}$.

(ii) In Mr. T. Higham's formula †

$$P = C\sqrt{D} \times \frac{W.\ L.}{1{,}000{,}000}$$

When P = Loss by absorption in any reach in cusecs.

C = Constant usually taken as 3·5.

D = Depth of supply in feet.

W = Width of water surface in feet.

L = Length of reach.

(iii) Mr. R. G. Kennedy also works out the absorption for the Upper Bari Doab Canal with reference to the surface width, in the case of distributaries not running constantly, at one cusec for every 170,000 square feet of water surface (W. L. in Higham's formula).

Absorption has generally been accepted as being a function of the wetted area, and depth; and it would only be in very wide shallow channels that the surface area would approximate to the wetted area. In Mr. Higham's formula it would appear that *C* should be a variant and not a constant, as it would vary with every class of soil.

The writer made some experiments about eighteen years ago on the Sirsa Branch of the Western Jumna Canal, when that canal had only been running for two years, and got as a result an absorption of 11·3 and 10·5 cusecs per million square feet of wetted area, during the months of June and

* Punjab Irrigation Branch Paper No. 10.

† Punjab Irrigation Branch Paper No. 7.

November, respectively. The formula worked out from this was $C \sqrt{D} =$ absorption, where C varied between 3·8 and 4·1 during two seasons.

Percentages of loss as given by Mr. R. G. Kennedy (I) from experiments on the Upper Bari Doab Canal and by Mr. J. H Ivens, (2) from experiments on the Ganges Canal are respectively :—

	(1)	(2)
	Per cent.	Per. cent.
In the distributary itself	... $7\frac{1}{2}$	8
In watercourses	... $26\frac{1}{4}$	26
In various ways	... $31\frac{1}{4}$	32
	65	66

Thus the water actually utilized in those days varied from 34 per cent. to 35 per cent. of the supply entering the distributary.

(*b*) *Losses in water-courses.*—These results are very close, but it is doubtful if the loss of 31 to 32 per cent. is all actual loss to the crops. Many experiments have been made in the Punjab with reference to wheat requirements ; but it cannot be said to have been yet determined beyond a doubt that just so much water is necessary and no more for a crop. In ordinary cultivation the zamindar cannot always get his share at the crucial moment, hence he takes all he can so as to guard against a lengthy period of uncertain supply. The loss by evaporation must be great in the fields themselves, but there is nothing to show that that evaporation is real loss. Such evaporation is probably an aid to the health of the crops when water is not available. Mr. J. S. Beresford considered that the evaporation in the fields might total twenty per cent. of the supply in the watercourse, or eighteen per cent. of the supply entering the distributary. This might be considered " unavoidable loss," if loss it be, and the rest of the " loss in various ways," namely, thirteen per cent. to fourteen per cent., should be considered as due to wasteful modes of irrigation.

Losses are shown to be greatest in watercourses. There are several reasons for this ; chief amongst them being the mode

of internal distribution ; and the size and number of watercourses on any channel. When remodelling schemes were started all over the Punjab, watercourses were combined and outlets reduced in number and enlarged in size. The discharge of these outlets vary between two and four cusecs, but the latter size appears to be too large, and even two cusecs are too much in many cases for the cultivators to handle.

Remodelling on these lines has been to some extent beneficial ; but it is not proved that the loss in watercourses has been much reduced, for sub-watercourses are still used. Everything points to the conclusion that watercourses demand first consideration in the matter of prevention of waste by absorption, and it is quite possible that when water becomes of more value than at present in the Punjab, that is to say, when the population has largely increased, and all possible extensions have been carried out, watercourses and ducts will be made pakka.

(*c*) *Method of distribution.*—It will generally be accepted that apart from the question of absorption and its remedies, economy of distribution in the distributary itself is entirely desirable.

It has gradually become the practice to run main distributary channels in rotation. The advantages of this system were probably noticed first in the *Rabi* season, when demand exceeded supply, and it was found difficult to satisfy demands without some such arrangements. Coincidently, outlet systems were remodelled, so that full supplies without *tatils* became possible. Great economy has resulted, and the system has been rightly credited with many economic administrative advantages. The principle involved would appear correct, and when a suitable module outlet has been designed to discharge correctly under varying conditions, the rotational system will be seen at its best.

(*d*) *Loss arising from reduction of percentage of area to be irrigated.*—It is clear that, if the area to be irrigated in a certain tract is reduced, say, from sixty-six per cent. to forty-four per cent. of commanded area, the main channel will have to carry a smaller supply, which will be less expeditiously conveyed to the area under command, and the duty will in consequence be materially reduced. Unfortunately it is not only the question of duty that has to be considered. The Canal Officer is bound to distribute his supply so as to produce food stuff evenly, and in due

proportion to the largest number of cultivativators possible. Moreover the question of water-logging will ever be present where irrigation is concentrated. It would appear therefore that the limit on the one hand is the spread of the supply to such an extent as would materially curtail its usefulness, and on the other hand, the intensifying of irrigation to such ar extent as to benefit only the few, and expose the tract to water ogging.

(*iv*) *Area irrigated.*—(*a*) *Method of delivery.*—So far little progress has been made in getting cultivators to their supply in bulk, though the enlargement in size, and reduction in the number of the outlets, and the rotational system, have done a great deal towards the desired end. Water-courses, except such as carry very small supplies, are still, in the main, divided off into sub-water-courses running concurrently.

It has been proved that the sub-division of large fields into suitable compartments is of great economic importance. The size considered suitable for such *kiaris* has been fixed at 70' × 70' and this does not appear to be too small, nor does it impose any special hardship. *Kiaris*, however, should have some fixed proportion to the discharge of the outlet.

(*b*) *Allotment of supply.*—In fixing the size of any outlet it is necessary to fix the correct proportionate discharge suitable to each *chak*. The discharge of a distributary can be found by dividing the net irrigable area by the discharge factor, which is fixed by a consideration of the expected duty calculated on the period of flow. Similarly the discharge of the outlets may be found ; but there are various considerations which affect the question, and due weight must be given to governing factors, such as :—

(*i*) Class of cultivators.

(*ii*) Class of crops.

(*iii*) Size and shape of *chaks*.

(*iv*) Proportion of high to low land.

(*v*) Slope of natural surface.

(*vi*) Variation in demand.

(*vii*) Actual discharge head, gauged by highest land.

(*c*) *Outlets.*—On the older canals the usual method was to give an outlet of a certain area proportionate to the gross

as that of Ferozepur, it is found that wheat occupies fifty to sixty per cent. of the irrigated area, and gram about fifteen to twenty per cent ; so that if wheat alone were considered, as it might well be in such cases, the normal discharge would suffice under this head.

(*iii*) *Size and shape of Chak.*—Where the country is fairly flat there should be no difficulty in settling the size and area of a *chak*. The shape would of course depend greatly on the boundaries in the case of old villages, and cannot always be set out so as to permit of the best results. A short wide *chak* would seem to be uneconomical, from the fact that the supply would have to be divided between two or more sub-water-courses On the other hand a long narrow *chak* is wasteful, from the fact that the water-course would have to be in constant flow. It has been suggested that a proper sized *chak* would be one where the length was approximately three times the width. Minors have of late years been more or less discounted in favour of large water-courses ; but it would seem that in sandy districts, it would be far better from an economical and administrative point of view to have minors which would cross old depressions and contour round sand hills.

(*iv*) *Proportion of high ground to low.*—The importance of knowing as nearly as possible the relative areas that are high and low in each *chak*, is obvious, and the knowledge is needed to enable a correct estimate to be made of the probable " head. " It is desirable also to have some conception of the general slope of the natural surface in each *chak*. The longitudinal section is not of very much use for the purpose. If the land is high near the channel and slopes off rapidly, cultivators, particularly in times of stress, will lower the bed of their water-courses, and carry off an undue proportion of the water. If on the other hand the land is generally high, and the natural surface-slope small, the water-course must silt, and silt badly. Corrections must therefore bemade for extreme cases, because the discharge of a water-course is materially affected by the fall or slope in its upper reach.

As it is practically impossible to command the highest land in every case, it would be better to eliminate such areas from the *chak* altogether, till such time as, by process of gradual evolution, the water levels in the distributary were automatically raised. It would be better then to eliminate small patches of high land than to allow separate lift outlets, which are liable to abuse

(*v*) *Variations in demand.*—The demand for water is never constant throughout the year, nor even throughout a single season. During the *Kharif* the early demand is usually slack, as cultivators are engaged in cutting winter crops and in other agricultural pursuits. At such periods the supply at the head of a distributary is small and low, and in excess towards the tail. Then again, heavy or scattered rainfall causes an unequal and varying demand, with large variations in the water level from the normal, and consequently in the "head" of discharge for various outlets. Again in the *Rabi* the demand is uniformly constant and strong, unless there be heavy general rain. During the closures villagers clean out their water-courses, and deepen them as much as possible, so that outlets draw off an excessive supply, and the tails suffer. It will be seen that among other causes the water gradient varies with the demand, and short of constructing a true module no ordinary outlet can fully cope with such variations; but an allowance can be made in the "head" which would reduce the effect of such variations to a considerable extent.

(*vi*) *Discharge head.*—Both theoretically and in practice, the "head" is the chief factor in governing the discharge from an outlet of given size. All other factors merely modify the discharge at each outlet. The root of the whole question is in arriving at a suitable "head" for each outlet, which will as far as possible be constant, or at all events be an average of important variation. Too small a head will lead to too loose outlets, and the attendant evils of future difficulty and waste. Too great a head reduces the size of the outlet. Of the two evils, the tight outlet is the lesser, for it is always difficult to reduce an outlet, as it leads to a great deal of heartburning.

When making allowances a point to be kept in view is that unless a channel has been correctly designed, silt may deposit in the bed, raising the supply level and the discharge of the outlets in the upper reaches. Outlets that are too loose are bound to have the effect of reducing the duty by heavy waterings.

SPECIAL CONSIDERATION OF THE SUBJECT.

The Jaitu major distributary, which takes out at mile 72 of the Abohar Branch of the Sirhind Canal, has been taken for the purpose of an illustration. It is typical in many ways of most of the channels in the Ferozepur Division, running through a tract,

sand blown, and at one time dotted with numerous shifting sand dunes.

The remodelling of this channel was completed in 1909, and the irrigation and duty statistics from that time will show to what extent such remodelling was sufficient, and wherein it failed, to some extent, of attaining the main object, namely a better and more evenly distributed supply

The plan shows the general lie of the country, and the several curves mean so many sand hills which had to be negociated. The longitudinal section depicts very clearly the difficult ground encountered, and the difficulties that must have been overcome in fixing suitable *chaks* and outlets. The Jaitu might well have been made only half its length, considering the narrow width of country taken up. But seemingly lines of depression, which would now be boldly crossed, were formerly held to be the most fitting boundaries of irrigation.

An extremely interesting statement is attached which will well repay careful study. It is a statement of outlets, showing sizes, and discharges actually observed, as well as those theoretically calculated from actual heads observed. Columns are also included giving commanded areas, average irrigation for the years 1910-11 to 1912-13, and the average percentage of commanded area irrigated for each water-course ; also the duty and percentage of loss.

(*a*) *Discharge of Outlets.*—The actual discharges and observed " head " were taken one day in December 1912 with a full supply of 221·77 cusecs entering the distributary, by Bawa Shib Singh Bedi, Sub-Divisional Officer, Ferozepur Division, to whom the writer is indebted for the figures. The differences between the " observed discharge " and the discharge as per head (columns 4 and 6) are only in a very few cases noticeable, but in a general way they show that the discharges must have been carefully observed.

Comparing the designed with the observed discharges (columns 3 and 4) the enormous differences will show at a glance that when the remodelling of this channel was carried out, no attempt whatever was made to arrive at even an approximate " head " for each outlet. In no single instance is it shown that the observed discharge of an outlet is *less* than the proposed, hence the excess taken by these outlets on the distributary itself deprived the tail of its legitimate supply.

(*b*) *Irrigated Areas.*—The percentage of commanded area allotted for irrigation by the Jaitu is forty per cent., and it will be seen that of the direct outlets, about fifty-six per cent. do more than their fair share. These were either fixed in low land, or commanded areas in the depressions. Other cases, where the observed discharge is greater than that proposed, and where the percentage irrigation done is less than designed, may be explained by the fact that the proportion of high land to low is excessive, and that at the time the discharges were observed, cultivators were irrigating in the lowest lying areas.

(*c*) *Class of cultivators.*—It will be noticed that the command according to the observed "head" is good throughout, and the natural conclusion would be that the area irrigated should be much larger ; the difference is explained by the fact that individual holdings are large and labour hard to get, so that, though the cultivators would be classed under the heading of good, they are unable or unwilling to extend irrigation, and prefer taking a large supply for small areas – that is over irrigating.

(*d*) *Soil and crops.* –Generally speaking the soil is only really sandy on the surface. A little below the surface there is light loam with intervals of good clayey soil in the various depressions. The main winter crops are wheat, barley and gram ; the first occupying about fifty-four per cent. of the irrigated area, barley about twenty per cent. and gram about twenty-two per cent. The *Kharif* main crop is the greater millet, forming about seventy-seven per cent. while Indian corn is seldom more than ten per cent. of the irrigated area, though the soil is quite suitable. Sugarcane is not grown as entailing too much labour, and cotton has been discontinued on accouut of the bol-worm which destroyed large areas some years ago. There is not, therefore, much variety in the kinds of crops sown, so that no difficultty should have arisen in making the necessary allowance for discharge.

(*d*) The variations in demand are not very great once the demand has started, though, during the early *Kharif*, cultivators are unable to do much irrigation and there are few market gardeners. '*Charrie*' greater millet) sown for fodder is fairly early, but when sown as a food stuff, it is not usually irrigated until the middle of the season. The *Rabi* demand is always constant and keen.

Column 12 gives the percentages of waste of all kinds for each direct water-course. Certain outlets apparently received more water than is shown by the observed discharges, and the results for these are therefore vitiated.

To arrive at an approximately correct idea of the supply actually used in the fields, and not the minimum, the wheat crop has been assumed to take a depth of 1·25 feet, and that of barley and gram a depth of 0·8 feet. There was only a trifling amount of "miscellaneous" which has been placed under the head of barley and gram. The depths taken above are not unreasonably high, as the actual delta for the whole channel works out to 1·4, while the delta as assumed to have been actually used, and omitting all absorption and waste, works out to one foot. Omitting the water-courses mentioned above, as showing a false discharge, we find that the percentage of waste on the water-course is in no case more than fifty. This is the percentage including waste from all causes, and the average waste is only 25·9 per cent.

If we examine the percentage of waste on the branches and minors, it is found that the highest in any individual case is 54, and the average is 22·9, while turning to the distributary as a whole it is found that the percentage of waste works out to 27·9 per cent. According to all previous experiments, the percentage ot waste should be sixty-five, and even if we take smaller depths as having been actually utilized in the fields, say 0·9 feet for wheat and 0·6 for barley and gram, we get 42·8 as the total percentage of waste.

To sum up, we get out of every hundred cusecs entering the head of the Jaitu Distributary during the *Rabi* of 1912-13, and according to the depth assumed as having been used on the fields :—

(1)	Loss in the distributary itself ...	4·8
	Loss in water-courses and branches ...	23·1
	Utilized	72·1
		—— 00·00
(2)	Loss in distributary itself ...	4·8
	Loss in water-courses and branches ...	38·0
	Utilized	57·2
		——100·00

These figures, if there is truth in them, are startling, and appear to go far towards modifying the previously accepted theory that the total loss on a distributary amounted to sixty-five per cent. It may be, and possibly is, correct to assume that within the last quarter of a century, since the time the theory of waste was first propounded, we have gone far towards reducing waste

by remodelling, and adjusting suppplies to the areas commanded. It is not pretended that the results obtained in the present case are strictly accurate. To arrive at accurate figures, the discharge of the water-course would have to be as accurately gauged as that of the distributary itself. There are figures to show the minimum depths needed for a good wheat crop ; but these would somewhat exaggerate the actual so-called waste.

It will be seen from the statement that while the discharge at the head of the distributary was 221·77 cusecs, the total loss was 10·6 cusecs :—*i.e.*,

Branches and Minors	...	116·95.
Outlets	... ...	94·22.

211·17 against 221·77 full supply.

The wetted area is 3,930,000 sq.ft. and water surface is 3,201,000 sq.ft.

Now let these figures be applied to the formula given by Sir T. Higham :—

$$P = \text{Total loss} = C \sqrt{D} \times \frac{W\ L}{1{,}000{,}000}$$

$$C = 3{\cdot}5$$

$$\sqrt{D} = \sqrt{3{\cdot}8} = 1{\cdot}95.$$

$$\frac{W\ L}{1{,}000{,}000} = \frac{3{,}201{,}000}{1{,}000{,}000} = 3{\cdot}2 \text{ say}$$

Therefore the total loss $= 3{\cdot}5 \times 1{\cdot}95 \times 3{\cdot}2 = 21{\cdot}6$ cusecs against the observed absorption of 10·6 cusecs.

It would seem, therefore, that the above formula would perhaps be more suitable for large channels, and that it is hardly applicable to distributaries. In this particular instance the constant C would work out to 1·7 nearly.

Again taking Mr. Kennedy's figures* where he gives one cusec to every 170,000 s.ft. on distributaries not running constantly.

Therefore the total absorption $= \frac{3{,}201{,}000}{170{,}000} = 18{\cdot}8$ cusecs against 10·6 observed.

* Punjab Irrigation Branch Paper No. 10, page 27.

Taking the total discharge of branches and minors, as observed (column 4), and the discharge of outlets as calculated from "heads" (column 6) we get :—

Total Jaitu discharge ...	...	... 221·77.
Total branches and main ...	116·95	
Total outlets as calculated ...	90·32	... 207·27.
Absorption ...	...	... 14·50.

If the discharges calculated from the observed "heads" are accepted as more likely to be correct than the observed discharges, a total absorption of 14·5 cusecs against the previously shown 10·6 cusecs is obtained, and 14·5 would seem to be a more likely figure. Further, the usually accepted absorption per million cubic feet of wetted area is taken as eight cusecs for such a channel. In this particular case, taking absorption as varying somewhere between 10·6 and 14·5 cusecs, it is found that with a wetted area of 3,931,587 s. ft., the absorption per million square feet varies between $(\frac{10·6}{3·93})$ say 3 cusecs and $(\frac{14·5}{3·93})$ say 3·8 cusecs. Unfortunately no observations for absorption in the first mile were taken, and consequently the value of Mr. Beresford's formula A L* cannot be tested in the light of the figures given above.

The Jaitu Distributary was in flow for 103 days during the *Rabi* of 1912-13 ; but the main canal was in flow for 168 days, and the latter figure has been taken as the "base."

Omitting the outlets mentioned above, and two others with small duties of 96 and 98 respectively, it will be seen that the duties of the water-courses range from 156 to 290. These large variations from the average appear to point to the fact that the various governing factors, discussed in the first part of this paper, were not closely studied when remodelling was carried out in 1909. Taking the direct water-courses alone we find that the average duty works out to 238.

Turning to the average duty of branches and minors, it is found that the duty is 256. Ordinarily, it might be expected that the duty of direct water-courses would be higher than that of a minor or branch ; and the result in this case may possibly

* Punjab Irrigation Branch Paper No. 10,

be due to the branches and minors being unduly favoured by the subordinate staff.

Finally taking the duty of the channel as a whole, we get 236·5 which is exceedingly good, even for the *Rabi*. The result is curious when compared with the average duty obtained on the water-courses and on the branches and minors, and shows that the loss in the distributary itself is very small.

Comparing the duties obtained on the Jaitu with twenty-one distributaries at the tail of the Upper Bari Doab Canal, we get :—

	JAITU.			AVERAGE OF 21 CHANNELS.		
Year.	Kharif.	Rabi.	Total.	Kharif.	Rabi.	Total.
1909-10	116	200	316	114	203	317
1910-11	86	184	270	176	210	386
1911-12	133	315	448	137	281	408

The average of the Jaitu=344 acres per cusec against 370 of the Upper Bari Doab Canal, and compares very favourably with those obtained for channels in the Bari Doab Canal, which for the same three years averaged 370 acres.

Conclusions.

The conclusions that one may draw from what has gone before may be summarized as follows :—

(*i*) That absorption in a distributary running through a sandy district is not excessive.

(*ii*) That after a few years of flow, absorption is not greater in such light loamy soils than in more clayey soil.

(*iii*) That a very high duty is obtainable in such soils, as the crops sown are such as do not ordinarily need heavy waterings, since sandy soils, though taking heavier waterings, are able to stand longer periods of non-irrigation than more clayey soil.

(*iv*) That evaporation in the fields need not necessarily be counted as loss.

(*v*) That, where holdings are small, cultivators are likely to be of the better class, and supply is likely to be utilized to the best advantage, and duty consequently enhanced.

(*vi*) That in remodelling old outlets or designing new, the head discharge at site is of the utmost importance, being only slightly modified by some other considerations set forth, also that loose outlets mean reduction of duty.

(*vii*) That by a system of closures the best duty may be obtained in any given channel.

(*viii*) That intensification of irrigation, though resulting in a smaller absorption and better duty, finds its limitations in the question of water-logging, and the needs of the people in general.

(*ix*) That the prevention of loss by absorption in a watercourse is of far more importance from the point of view of duty than the prevention of absorption in a distributary.

Statement showing Outlets, Discharges, etc., Jaitu Distributary, Rabi 1912-13.

Serial No.	Area of outlet in square feet.	Designed Discharge.	Observed Discharge.	Head.	Discharge as per Head.	Commanded Area.	Average irrigation last 3 years.	Percentage of commanded area irrigated.	Average Discharge.	Irrigated areas, Rabi 1912-13.	Duty for Rabi 1912-13.	Percentage of Loss.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	0·3	1·2	2·52	1·76	2 06	660	372	67	1·54	345	224	29·3
2	0·3	1·2	2·02	2·57	2·51	782	382	49	1·24	345	278	12·3
3	0·3	1·2	2·90	2 19	2 31	1,000	507	51	1·78	371	208	34·5
4	0·4	1 6	1·97	0·78	1·95	653	399	61	1·21	283	...	24·5
5	0·1	·4	0·45	0·53	0·35	204	30	15	0 27	...	...	73·9
6	0·7	2·7	2·95	0·73	2·88	1,415	528	37	1·81	404	223	31·1
7	0·3	1·2	2 11	1·28	1·78	562	318	57	1·29	329	255	17·6
8	0·12	·8	1·53	1·59	2·26	1,038	505	48	0 93	224	200	25·5
9	0·12	·8	0 93	1·39	1·18				0·57	341	...	...
10	0·14	1·6	2·02	0·53	1·45	970	513	53	1·24	506	408	...
11	0·14	1·6	1·61	0·63	1·75	974	329	34	0·98	195	199	38 9
12	0·3	1·2	1·22	1·19	1·70	835	363	43	0·75	266	355	...
13	1·12	4·8	5·81	1·05	6·20	3,066	1,211	39	3·56	946	266	19·5
14	0·16	2·4	4·93	1·65	4·96	1,043	882	61	3 02	665	220	27 5
15	0·1	·4	1·08	2·84	0·83	232	90	39	0·66	65	98	67·4
16	0·4	1·6	1·9	0·97	2·18	763	503	66	1·16	385	332	...

34·5

17	0·1	0 4	0·8	2·36	0·77	176	136	77	0·49	96	196	34·5
18	0·4	1·6	2·39	1·36	2·58	843	355	42	1·46	276	190	40 8
19	0·4	1·6	2·60	1·56	2·75	867	545	63	1·59	373	234	19·6
20	0·4	1·6	2·1	0·82	1·94	805	293	36	1 28	224	175	48 8
21	0·1	0·4	0·5	1·46	0·6	262	62	24	0 30	48	160	46·1
22	0 4	1·6	2·87	1·75	2·34	1,075	661	62	1·76	438	249	19 4
23	0·6	2·4	3·48	1·23	3 37	1,256	736	59	2·13	597	280	14 3
24	0·5	2 0	2 96	0·82	2·22	1,461	501	35	1 81	308	170	48·2
25	0·5	2 0	3·50	1·42	2 95	1,539	783	51	2 14	458	214	31·2
26	0·7	2·8	3·69	0·8	3 05	1,752	618	35	2·26	485	215	31·0
27	0·5	2 0	2 43	0·74	2·10	658	320	49	1·49	268	180	43·4
28	0·5	2 0	3·32	1·20	2 72	1,374	470	34	2 03	385	190	42·6
29	0·3	1·2	2·15	1·20	1 69	674	261	39	1·32	206	156	50 6
30	0 2	0·8	1·7	2 05	2·20	716	274	38	1·09	176	161	50·2
31	0·2	0·8	1·12	1·37	1·18	675	266	39	0·68	202	297	5·2
32	0·2	0 8	1·32	1·0	1·0	467	234	50	0·81	156	192	36·9
33	0·3	1·2	2·48	1·7	2 02	1,012	546	54	1·52	347	288	27·2
34	0·4	1·6	2·80	1·7	2·79	1,276	815	64	1·76	588	334	8 5
35	0·3	1·2	2·19	1·9	2·14	803	587	73	1·34	362	270	20·1
36	0·4	1·6	2·21	1·1	2·25	1,036	597	58	1·35	451	334	5·5
37	0·3	1·2	2·4	1·3	1·76	951	571	60	1·47	388	264	18·4
38	0·4	1 6	2·62	2·0	3·03	1,098	596	55	1·61	465	288	12·6
39	0·5	2·0	2·69	0·9	2·38	959	321	33	1·65	310	188	44·7
40	0·8	3·2	3·87	0·8	3·56	1,611	569	36	2·37	448	190	46·0
Total	...	...	94·22	...	...	...	...	...	57·76	13,751	238	25· 9

Branches and Minors.

Serial No.	Area of outlet in square feet.	Designed Discharge.	Observed Discharge.	Head.	Discharge as per Head.	Commanded Area	Average irrigation last 3 years.	Percentage of commanded area irrigated.	Average Discharge.	Irrigated areas Rabi 1912-13	Duty for Rabi 1912-13	Percentage of Loss.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	...	11·8	16·17	...	...	6,629	3,863	58	10·1	3,189	315	...
2	...	10·4	11·72	...	...	4,747	2,559	54	7·2	1,860	258	17·0
3	...	6·4	8·89	...	...	3,159	1,848	59	5·45	1,468	269	15·5
4	...	3·6	6·39	...	...	1,722	850	49	3·9	557	143	54·1
5	...	20·2	20·21	...	...	9,479	2,249	24	12·4	2,186	176	49·2
6	...	6·4	8·58	...	...	3,757	1,699	45	5·18	1,290	249	26·1
7	...	12·6	9·42	...	...	5,090	1,146	23	5·7	1,040	182	46·1
8	...	0·0	35·30	...	...	22,341	7,617	38	21·6	,739	315	8·8
Totals	...	...	116·95	...	...	...	...	...	71·7	18,389	256	22·9

NOTE.—Daily Dischargs of distrtbutary at head was 221·77 cusecs.
Average Discharge do. do. was 135·96 ,,
Total Irrigation was 32,146 ,,
Duty was 236·5 ,,
Percentage of waste varies between 27·9 and 42·8 according to the depths assumed to have been actually