

# A SYSTEM OF CONTROL AND DISTRIBUTION OF WATER IN SUGAR CANE IRRIGATION.

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No system of irrigation can be considered efficient which does not provide means for the complete control of the water throughout the processes of distribution, for the elimination of undue losses through seepage, and for the total prevention of erosion throughout the scheme. Distribution in this connection being taken to include not only the transmission of water in bulk along the furrows, but also its subdivision into smaller streams as it leaves the furrow, to be led to the different portions of the fields, and its actual application to the soil among the cane lines; while erosion can be chiefly thought of as occurring in the fields.

The scarcity of water available for irrigation purposes along the sugar belt of Natal, and the cost incurred in raising it to the level of the irrigable lands, make it so valuable that every possible means should be adopted to economise and use wisely the existing supply.

The first step towards economy in the present instance is the water-proofing of all furrows. Losses by seepage, which are always great in unlined earth furrows, are increased enormously by the necessary intermittance of the flow in the great majority of furrows used for cane irrigation.

The seepage losses in well made and properly maintained furrows, carrying a constant flow of water, have been measured by direct experiment in many countries, and the averages of figures published at different times may be summarised as follows, in terms of losses in cusecs per mile of earth furrow over a wetted perimeter of 5 feet:—

In good clay . . . .	0.10
In loam . . . . .	0.20
In gravel . . . . .	1.00

Those figures have been found to agree well with the losses obtained by direct gauging under various conditions of a permanent flow furrow existing on the North Coast. They are, however, totally inadequate to express the losses where furrows carrying an intermittent flow are concerned, and it is not too much to estimate at certainly more than one cusec per mile the losses in a furrow of 5 feet wetted perimeter constructed through average so called "hard soils;" through light soils and sand the losses are of course much heavier.

Those excessive losses are caused not only by the rapid absorption of water by the dry banks but also by direct leakage through the fissures occurring in furrows, which have been left out of use for fairly long periods.

Two factors contribute towards increasing the seepage in earth furrows in comparison with the volume of water carried. On the one hand the velocity of flow has to be kept at a low figure to

avoid the scouring of the banks, on the other hand, the inclination of the banks to the horizontal must be small to avoid their rapid deterioration and collapse; the two considerations leading in the design, to larger figures being adopted for the cross section and the wetted perimeter than would otherwise be essential. Those factors, of course, assume a greater importance in light than in heavy soils.

The high losses of water in earth furrows render them altogether uneconomic if their length has to be fairly extensive, for, with the rapid changes in the type of soils met with in restricted areas along the coastal belt it is probable that a stretch of light soil will soon intervene that will cripple an otherwise well laid out scheme. Further, there is another aspect to those heavy losses. The water thus liberated from the furrows percolates through the soil towards the lower parts of the neighbouring fields and creates the necessity of heavy drainage to avoid water-logging.

Again, fields over which actual application of water has been stopped in order to allow the cane to mature, receive, through seepage, an undue amount of water whose effect is to reduce the possible sucrose.

In fact, no irrigation scheme is at all possible if at least the main furrow, which ensures the transmission of the bulk of the water to and across the fields, is not rendered water-proof.

The chief deterrent to the lining of furrows is the cost of the process; but as no great success can be derived out of a system based on unlined furrows, the expenditure incurred in lining them must be taken into account as part and parcel of any proposed scheme and not considered as a superfluous extra.

Properly carried out, the lining of a furrow is not extremely costly. Of the several possible ways of lining a furrow one, which is largely used and gives very good results, consists in applying cement plaster to wire netting stretched along the inner surfaces of the furrow.

To carry out the process the usual routine is followed of excavating along a line of pegs placed at fairly small intervals along the ground and giving the required grade for the furrow. During this first excavation the proposed shape of the furrow is roughly formed, the final shaping to a template being carried out after pegs have been placed inside the furrow and at the correct grade, the template itself, made of hard wood, being used as a scraper. The wire netting is then dropped into position and the plastering done, care being taken

to allow a thickness of at least  $\frac{3}{8}$  of an inch of mortar to pass below the netting.

Good results have been obtained by using ordinary  $\frac{1}{2}$  inch mesh galvanised wire netting and a mortar made of a mixture of 1 part of cement to 4 of sand by volume. It is indispensable that the sand be coarse and gritty and free from organic matter.

Certain precautions are necessary, however, to ensure success in the carrying out of this method. The first is that the slope of the banks to the horizontal should not exceed the angle of repose of the soil through which the furrow is being constructed. This will make the lining safe from any upward pressure during periods of high rain.

To avoid cracks in the lining, expansion joints have to be formed at prescribed short intervals along the plastering. An easy way of obtaining those is for the plasterer to cut across the freshly applied mortar with the edge of his trowel in a direction perpendicular to the length of the furrow; each cross cut going right through the plaster to the wire netting.

It must be pointed out that in furrows lined in this way fairly high velocities of water are possible owing to the smoothness of the sides and to their resistance to scouring. These high velocities naturally bring about smaller cross sections in the design, although a technically economic section cannot usually be adopted on account of the limitation of the slope of the banks imposed by the angle of repose of the soil.

A properly lined furrow can be made to serve a purpose very different from that of just transmitting water. It can be used to conserve water, a function which in the majority of cases would not only add considerably to its utility but also help towards the solution of many difficulties.

As the process of distribution to the fields progresses, the point along the main furrow at which the water is withdrawn gradually increases in distance from the place at which the furrow receives its supply of water; and, usually, the supply is interrupted during such times as no actual distribution takes place. When the water is restored to the furrow after any such interruption, an interval of time is required for the stream to reach from the higher end of the furrow down to the place at which it will be used. The period of time increasing with the length of furrow involved, and very often amounting to several hours on account of the small velocities of transmission used in irrigation work.

As a rule it is possible to allow exactly for that interval and to arrange for the men who are going to do the watering to arrive at the field almost simultaneously with the water; but mistakes may be made which cause a loss of water or of time, according as to whether the water is early or late

in reaching its destination, whereas with a furrow that could be left full of water at the end of the daily operations, the task of resuming work in the morning would be straightforward, and would be accompanied by no waste either of water or of time. Again, it may not be convenient to start a pump early enough in the day to allow a suitable interval for the progress of the water and then leave enough daylight for the men to do a full 10 hour shift.

When the supply of water is obtained by diversion from a river, the spot at which the water is available may not be at all suitable for the construction of a dam to conserve the water not immediately required; further, the cost of building a dam is sometimes high, while its rapid silting up is often a danger.

These obstacles to efficient work can be removed to a large extent by turning the furrow, on lining it, into a reservoir.

This is accomplished by altering the usual routine of furrow construction which results in a constant sloping channel of which the grade and the cross section are designed to accommodate the flow required during working hours. In the reservoir type, the channel is made up of long stretches of level furrow, each subdivision of the whole furrow being lower in level than that immediately preceding it; the usual uniform grading being thus altered to a regular stepping down of the channel at definite intervals. This maintains, over the whole length of the furrow, a gradient that will ensure the necessary flow. Those successive level stretches can then be completely filled and kept from overflowing, while the supply is still on, by automatic valves, placed at the end of each section: those are adjusted to close when the water in the lower section next to them reaches a definite safe level: the interruption of the flow causing the water to accumulate in the next higher section. The system being entirely automatic in so far as the control of levels is concerned, the filling up of the furrow proceeds until the highest level section is reached and filled, at which time the source of supply is turned off.

Once the furrow is so filled, water may be drawn from it at any point of its length, the full amount stored up between the point of discharge and the highest stage of the furrow being available for use, as each of the automatic valves opens, as soon as the level of the water in the lower section next to it begins to drop, and allows the flow to establish itself along the channel. Water can be drawn off simultaneously at several places along the furrow, provided the total amount drawn does not exceed that supplied to the furrow.

With this system in action, the longer the furrow, the larger is the amount of water it can store and the more efficient is the control and timing of all operations.

Further, the cross section of the furrow has no longer to be limited to suit the flow of water available during working hours for, with the possibility of conserving water in the furrow itself, the total supply available during 24 hours or that fraction of it considered necessary to the scheme constitutes, with the cost of the undertaking, the limiting factors to the cross section adopted. Moreover, any lined furrow is susceptible of transformation into such a temporary reservoir.

No reference has been made so far to side gates or valves for releasing the water from the furrow and turning it to the fields. Such gates and valves can in fact be dispensed with entirely on furrows used for the immediate distribution to the fields, their place being taken advantageously by portable syphons.

These are easily turned out of 2 inch steel piping shaped to straddle the lower edge of the furrow, the discharge end of the syphon being made to reach one foot lower in level than the end dipping in the furrow.

A larger diameter might be adopted but would have the disadvantage of not being easy to handle and to prime. The end of a 2 inch pipe can easily be closed with the hand for priming purposes while a larger pipe would need a special stopper or some form of priming gear.

With such a small diameter the task of bending the pipe is simple and inexpensive, and the weight of the apparatus enables it to be carried about with ease, one man taking four of them at a time on short journeys.

The maximum amount of water than can be removed from a furrow by one of those pipes amounts to 0.16 of a cusec when a free pressure head of 1 ft. is available. Under average conditions the flow is usually found to be approximately 0.10 of a cusec.

Apart from doing away with the necessity either of installing expensive gates or of leaving gaps in the lining of the furrow those syphons provide safe and cheap outlets at any point along a furrow at which, as occasion demands, it may be necessary to draw water. Further, they provide a handy way of measuring the amounts drawn at different points. The total volume of water supplied to a furrow being known, it is easy by counting the number of syphons in use to determine by simple division the amount discharged through each of them. Conversely, if the usual minimum discharge of 0.10 cusec per syphon is kept in mind it is easy to estimate the number of syphons to be put in use at any time.

The common mistake of leaving a side gate open or of neglecting to patch up one of the gaps serving as outlets to the furrow can no longer occur with the use of those syphons, the mere fact of remov-

ing them to a safe place of storage at the end of a day's work immediately doing away with any such possible cause of waste and delay whenever the water is again sent along the furrow.

As it is necessary to check the flow of the water and prevent it from travelling further along the furrow than is required for the day's work, the cuts made into the plaster come in handy for holding into position a light wooden baffle lined with thin galvanised iron, the edges of which slide into the slits and provide quite a good joint.

From the time the water leaves the syphon until it is disposed of along the cane lines, it has to be guided along two main directions which may be described in general as perpendicular and parallel respectively to the course of the main furrow.

In its course at right angles to the furrow, the water is following the natural slope of the ground and this, considering the topography of the hills on which our cane fields are situated, is usually very steep. The water soon acquires a high velocity which would cause rapid erosion of the soil if special measures were not taken to protect the ground surface. Such free travel on the ground would also involve losses by seepage.

To eliminate both seepage and erosion, at this stage of the distribution, a system of portable semi-circular flumes is used. Those flumes generally 6 ft. in length and 9 inches in diameter are made of 22 gauge galvanised iron and stiffened by turning over the straight edges. Light and easy to handle they constitute an excellent way of guiding the water down hill. They carry approximately half a cusec of water. No special means are necessary to make the joints between the successive lengths water-tight, as the velocity of the water causes it to pass over the simple lap joints with scarcely any loss. This makes them very useful for the frequent shifting about and the quick setting and lining up which is necessary at times. No preparation whatever of the ground is required before a stretch of those flumes is fixed up ready for use. The flumes also afford the great advantage of taking the water clean over the shallow ditches in which the canes stand and over any drain that may be met along their course.

The displacement of the water along directions approximately parallel to the furrow takes place chiefly along the cane lines themselves: which should be planted either exactly along contour lines or else along lines of fairly small gradient.

Each of the two systems of planting offers advantages and disadvantages, which will not be fully entered into here, in so far as lay out and water distribution is concerned.

The system of accurate contouring wherever it is applicable, requires a large amount of surveying as the contouring of one line cannot usually be reproduced in successive ones spaced out from it,

and the exercise of great care in following with the furrowing plough the lines marked out by the surveyor. Any mistake made by the ploughman, altering the contours to a series of ups and downs, constituting obstacles which the normal flow of water cannot overcome.

On the other hand, good contour planting will enable the water to be led to either side of the down hill flume, thus reducing the number of displacements of the flumes by half as compared with those required by the second system of planting.

The other system of planting, that of furrowing for the cane lines along gentle slopes, calls for very little surveying for grades, only a few guiding lines being required to avoid serious mistakes. The grades obtained are not constant from line to line, but a good lay-out will always give a general inclination in one direction to all the lines in fairly extensive areas. With this method of planting, the water can be led to one side only of the down hill flume.

To remove the water from the flumes and turn it into the lines, which they intersect practically at right angles, two methods are in use. At the lower end of the fluming the velocity of the water is destroyed in great part through checking the flow and turning it off at right angles by means of a plate of galvanised iron, a piece of sacking, or one of the flumes placed along the direction of the cane line. But, as the flume usually carries more water than is needed for one cane line, fractions of the flow are removed higher up by placing in the flume one end of a bent piece of piping placed with its opening facing up the flume. The speed of the water is always large enough to cause that part of it which penetrates the pipe to swerve round along the bend and fall out of the flume into a cane line.

To distribute water over the whole of the field, the fluming has to be shifted as soon as the area directly irrigable from one of its positions has been covered. This shifting is not a very exacting task, being carried out gradually, as the distribution goes on. The application of the water begins at the lowest cane line reached by the flumes and as it proceeds upwards from line to line, lengths of fluming are naturally left out, and are from time to time taken across in small bundles to the next position in which the fluming will be required and there assembled. When the highest cane line is reached the last few lengths of fluming are removed together with the syphons that were supplying them with water and in the course of the following few minutes the fluming is again complete in its new position, ready for use.

The necessity of altering the position of the whole length of the line of fluming can be avoided, when irrigating in hard soils, by introducing so-called level ditches, which assist in distributing the water in directions approximately parallel to the main furrow. These level ditches are small unlined

water furrows approximately 14in. wide by 8in. deep, constructed on the level, with no grade at all, and are spaced at intervals of 80 to 100 feet measured along the slope of the ground.

The distribution of water along the belt contained between two such successive ditches is effected exactly as already described, the ditches receiving water from the main furrow, through the usual agency of syphons and flumes.

The advantage derived from the level ditches is that they limit the length of fluming that has to be shifted at one time from one position to another: only the length needed to reach from ditch to ditch being involved in the frequent movements. The longer lines bring the water down from the main furrow to the level ditch in actual use remaining fixed in position for much longer periods and being gradually lengthened as the irrigation proceeds downwards to the successive ditches.

The system of distribution just briefly described is advantageous from many points of view. It is totally portable, extremely resisting to wear and tear. It can be exactly proportioned to the volume of water available and almost every piece of it is always in constant use. It leads to perfect control in operation, eliminates loss of water, damage caused by seepage and erosion, and does away with waste either of labour or of time.

It has the further advantage of leaving the fields open to mechanical cultivation at any period during which irrigation is not actually proceeding.

Finally, it is eminently well suited to local conditions: it has, in fact, been evolved through the necessity of overcoming difficulties peculiar to our coastal cane belt.



CHAIRMAN: We are extremely obliged to Mr. Le Roy for this very informative paper on the question of the distribution of water. It is a phase of the science of irrigation which is apt to be lost sight of. That is the actual distribution of water if you have got it actually dammed up, or pumped up, or raised to the necessary elevation. A point which Mr. Le Roy might have emphasised is that stated at the very outset of his paper—the necessity to conserve water as far as possible, because on this Natal Coast of ours, we certainly have not unlimited supplies. I remember about seven or eight years ago, when the question of irrigation was first being discussed in our Association, at one of our Conferences the very pertinent question was asked "Where are you going to get the water from?" We have a number of small coastal rivers, but for the greatest part of the year there are no rivers at all in the proper sense; they have very little water in them. Mr. Le Roy has covered a tremendous amount of ground in a short space in this paper, and although I do not like to make the sug-

gestion that he should do more work, I think the paper could be very much more easily read had Mr. Le Roy provided a few sketches and diagrams. They would have been of considerable advantage in helping a reader of the paper to follow his explanations. And I suggest that Mr. Le Roy, if he has time, before this paper is included in our proceedings, it would be an advantage if he could submit to Dr. Hedley a few crude sketches—he need not spend more time on them than is absolutely necessary—just in explanation of the text. The paper is now open for discussion.

Mr. MURPHY: Framing my question on the same lines as Mr. Owen Johnson's just now, I should like to ask Mr. Le Roy to give the approximate cost of the lining of these furrows with this netting, and also the cost of these flumes.

Mr. LE ROY: Lining of the same type which has been carried out recently under my supervision, I may say this, that the cost of lining a furrow to carry a volume of two cusecs of water is about 9d. per foot length; a furrow carrying up to five cusecs of water costs about 1/4 per foot length, and for six to eight cusecs, the work has been estimated at 1/9 per foot length. As regards other items, nine-inch diameter flumes cost about 1/3 per two yards length; six-foot unit costs about 1/3 and syphons mentioned, short ones, involving about four feet length of steel pipe, cost about 2/- each, and the longer ones 4/- each.

Mr. OWEN JOHNSON: I would like to ask Mr. Le Roy if he has used press cake in the furrows. I am told it absolutely closes up the various openings in the furrows and makes them practically water tight.

Mr. LE ROY: That has been mentioned to me, but personally I have had no experience of it.

Mr. FOWLIE: I have seen this done at Natal Estates. They quite frequently proof their furrows with press cake. Usually it is put into the furrow at some place where the water is running fairly freely, and the water seems to absorb it and make it muddy and deposit it more or less along the furrow. If there are any seepages or depressions in the furrow, it makes a most excellent lining in the furrow so long as they are kept wet. But you can understand if the furrows are left to dry out, the process requires to be repeated, so it requires time for the original press cake to get into the muddy state in the water and re-deposit to seal up the depressions, because the clayey nature of the press cake makes it crack when dry.

Mr. PALAIRET: What is the cost of the automatic valves, and what length would you make your sections, or what fall between each.

Mr. LE ROY: Automatic valves cost between £5 and £10 each, according to the capacity of the amount of water they are supposed to take. The distance between them depends on different things, but usually, say, a 3,000 foot length of furrow with a foot drop at the end of each. Of course it depends on the different conditions.

CHAIRMAN: I will ask you to accord Mr. Le Roy a hearty vote of thanks for his paper, and the trouble he has gone to in preparing it and reading it to us.

Carried.



CHAIRMAN: The next paper is "Some Notes on Varieties of Sugar Cane at the Experiment Station." I will ask Mr. Colepeper to read the paper.