Duty of Water in Irrigation under the Major Irrigation Works, North-Central Province

By ALEXANDER PROVAN WEIR, A.M. Inst. C. E. (Irrigation Dept., Ceylon.)

The "duty" of water is the number of acres of crop which can be matured by one cusec of water flowing continuously for a defined period of time. This defined period of time is termed the base of the duty and is the number of days during which the supply of one cusec flows continuously in order to mature the crop.

Owing to losses by percolation, seepage, evaporation, wastage, and lack of system in distribution, the duty measured in acres per cusec increases as the water flows down the irrigation channels from which it is distributed to the fields. If one cusec issued from the tank sluice is reduced by losses to only half a cusec when gauged at the fields; and if that discharge from the tank sluice is sufficient to irrigate thirty acres, then the duty of the paddy field is 60 acres per cusec, but that the tank is only 30 acres per cusec.

During the last twelve months, the Author inspected some 95 miles of supply and waste channels in all stages of flow, and has examined the rainfall returns and the records of water issues for cultivation during the last twenty years from the larger of the Irrigation Tanks in the North-Central Province. Experiments carried out as a result of these inspections and analyses appear to indicate that stabilization in the quantity of supply of water for irrigation purposes substantially reduces the cost of maintenance of the supply systems and does not materially deplete the volume of water available for irrigation.

RAINFALL RETURNS.

Between April 1st and August 31st, the ten rainfall stations within, or adjacent to, the 080
square miles of catchment of the tanks analysed record an average rainfall of 13.86 inches on 23 wet days.

<table>
<thead>
<tr>
<th>Station</th>
<th>Average Rainfall</th>
<th>Number of wet days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anuradhapura</td>
<td>14.44</td>
<td>31</td>
</tr>
<tr>
<td>Dambulla</td>
<td>14.21</td>
<td>28</td>
</tr>
<tr>
<td>Galawela</td>
<td>17.17</td>
<td>38</td>
</tr>
<tr>
<td>Kalawewa</td>
<td>12.72</td>
<td>22</td>
</tr>
<tr>
<td>Maradankadawela</td>
<td>15.91</td>
<td>25</td>
</tr>
<tr>
<td>Mihintale</td>
<td>13.62</td>
<td>20</td>
</tr>
<tr>
<td>Minneri</td>
<td>13.13</td>
<td>18</td>
</tr>
<tr>
<td>Nachchaduwa</td>
<td>13.67</td>
<td>19</td>
</tr>
<tr>
<td>Sigiriya</td>
<td>12.39</td>
<td>17</td>
</tr>
</tbody>
</table>

Apart from their catchments, the average rainfall at the tanks adjoining the fields during the same period is 13.54 inches on 22½ days, which is almost identical with the average for the whole area.

In this Province, the Yala cultivation season under the Major Tanks commences on April 15th and the last date of water issue is August 14th and these dates are fixed by law. During this shorter period, the average rainfall is 9.86 inches and the number of wet days are 17 within, or adjacent to, the paddy field areas.

**CULTIVATION PROCEDURE.**

There are two methods of cultivation adopted in Ceylon for paddy growing under Irrigation:—Surface Irrigation and Standing Water Irrigation. Surface Irrigation entails saturation of the soil at relatively long intervals. The Standing Water method is accomplished by ensuring that the crop is constantly immersed in water, any losses from saturation or evaporation being made good as they occur.

Unlike the farmers in the Southern Province, the Eastern Province and parts of the North-Western Province, the N.-C. P. cultivators, with very few exceptions, do not take advantage of the beneficial effects obtained by aeration of the soil: a phenomenon produced when the land on which the crops are grown is allowed to dry out and crack between waterings, when surface irrigation is
adopted. Instead, they grow their crops by the standing water method. In consequence, the daily loss during the Yala cultivation, except on wet days, is never less than $\frac{1}{2}$", and, until the seedlings appear, the loss greatly exceeds this amount, as water is deliberately run to waste.

Less water is used when surface irrigation is employed than when the more primitive standing water method is adopted, but, owing to the varying time intervals between waterings, it is a matter of difficulty to reduce the duties under the different systems to the same base for purposes of comparison.

On April 15th, at the termination of the Maha-Yala close season, the fields commence to receive a supply of water. The plots are gradually flooded until immersed in about six inches of water and this level is maintained for a maximum of 14 days. Water is then reduced to 3" depth and the first mudding starts. As soon as the field is muddied (trampled by buffaloes) the water level is again increased to 6" with the object of choking or drowning the weeds uprooted by the trampling. Owing to the scarcity of buffaloes, or man-power, or for other reasons, about three weeks elapse from the commencement of water issue until the second mudding starts. The water is again reduced to 3" depth, as buffaloes cannot trample successfully in deeper water, and the second (and final) mudding takes place. On completion of this process, the plots are drained off and roughly levelled or smoothed over. The seed is then sown broadcast.

Until the seed germinates and the seedlings appear, the surface is flooded on alternate days, and this is the only period when water is not allowed to remain on the land. About one week after sowing two inches of water is retained and constantly replenished until the shoots are sufficiently tall to stand a deeper immersion, i.e., until about one month after germination. The danger stage is now passed, and as it is impracticable in most cases to ensure uniform replenishment, the depth of water is increased to 3" or 4" and replenishment takes place weekly or at shorter intervals. (Where aeration is adopted under the surface irrigation system, the plots are replenished at 10-day or
even fortnightly intervals.) Water is required until a fortnight after the plants flower.

If, as not usually happens, the crop is attacked by the caterpillar pest, it is usual to flood the plots to a depth of 9" or more in an effort to wash off the insects or at least to localize the affected area.

The overall issue of water extends from April 15th to August 14th and very frequently after the latter date if sowing is delayed, and the replenishment necessary averages $\frac{9}{2}$" per day for about 120 days, as it is not necessary to keep the plants immersed in water whilst the paddy is ripening. The compensation afforded by rain during this period is off-set by the increased issues necessary at different stages of cultivation and the defensive measures taken against the caterpillar pest, and one acre of paddy, therefore, requires about $120 \times \frac{9}{2} = 60$ inches of water in four months which represents approximately a duty of $47\frac{1}{2}$ acres per cusec to a four months' base in the field, as one cusec of water flowing for 24 hours will flood one acre of land 1.08 feet deep.

This Standing Water method of irrigation precludes to a great extent rotational issues to the branch channels supplied by the main channel as the time interval between waterings is too short to permit of systematic manipulation of the planks at the various branch channel off-takes and it is, therefore, only on the small distributaries and the cultivators' field channels which irrigate individually a very small acreage that rotational issues can be adopted with success.

Where orthodox surface irrigation is adopted with its increased time intervals there is definite scope for the introduction of rotational issues which require less water and reduce wastage to a minimum.

At the present time, with the market price of paddy as low as cents 75 per bushel, one might reasonably suppose that the N.-C.P. cultivator would readily adopt a system of cultivation which, without any additional labour other than the efficient drainage of his land, may increase the productivity of the soil by as much as from fifty to one hundred per cent. and thus make the growing of paddy a profitable proposition instead of a hazardous enterprise.
So far efforts to introduce this improved system have met with practically no response, although its efficacy has been amply demonstrated on the lands under Tissawewa.

**Tank Duty.**

It has been shown that the duty in the field under the system of cultivation in vogue approximates to 47\(\frac{1}{2}\) acres per cusec to a four months' base, and that rotational issues on a large scale cannot be successfully adopted until cultivation procedure is modernized. Owing to lack of data and the dissimilarity of the various supply systems under the tanks reviewed it is not practicable to determine any approximation of the duty at any particular point on a supply system other than at the point of issue from the tank, although the probable losses in each different supply system can be computed.

Overall issues during cultivation have been calculated and, where necessary, reduced to the four months' base, and representative years have been selected where the actual extent of Yala cultivation was known in the last twenty years. Since accurate records of water levels and sluice openings are available together with the daily rainfall, in many instances it has been possible to exclude from the analyses those seasons when great extremes have occurred. Occasionally heavy replenishment in April or May has caused the tanks to spill, and the sluices have been opened fully, not for irrigation purposes, but as an additional safety precaution. Again, in years of exceptional drought, owing to the partial failure of the South-West Monsoon, it has been necessary to conserve the water in some tanks and to reduce issues to a minimum in an endeavour to sustain life in a portion of the crops under cultivation. These abnormal over- and under-issues, which do not recur in regular time-cycles, can have but little bearing on the average. The rainfall averages, with the exception of Sigiriya (10), Nachchaduwa (26), Galawela (27), and Minneri (33), are the means of more than 40 years of records. The acreages cultivated under the individual tanks are in every case substantial, and vary from 300 acres to more than 2,000 acres.
Further, in undeveloped schemes such as Minneri, where in late years a portion of the water issue has been diverted for Railway use, the analysis has not been pursued in detail, as in the absence of a technical cultivation officer to regulate issues according to requirements, the results of trial calculations selected at random indicate that divergences are so great that no reliable average could be obtained from the 300 or 400 calculations necessary if a full investigation were carried out.

RESULTS OF ANALYSES.

Reduced to a four months' base, Tissawewa Yala cultivation requires a tank duty of 36.4, but one abnormal duty was about 29.

Nuwarawewa lands require an average duty of 30.5.

Nachchaduwa duty is 26. (This scheme is only partly developed and the wastage is considerable.)

Bassawakkulam duty averages out at 28.

The lands directly irrigated by the Balalu and Goda sluices of Kalawewa Tank have duties of 37 and 34 respectively.

It will be noted that the average tank sluice duty varies between 37 acres to the cusec and only 26 acres to the cusec and undoubtedly under all schemes a great deal of water is wasted. It is somewhat difficult to decide what should be an average economic tank duty during the Yala cultivation by the Standing Water method, although fortunately in the N.-C.P. the rainfall distribution is so remarkably uniform that the problem is not so indeterminate as in other Provinces.

Tank duty can only equal field duty if there are no losses en route, but since the channel beds are not impermeable, tank duty can never approach 47½. It should not be less than 40, although this figure has not been sustained for any appreciable period during the issues reviewed.

It is probably advisable at this stage to reiterate that duty at the head (tank sluice duty) is different from duty at the field, because at first sight it might appear that, although a discharge of one cusec issued from a tank sluice is only capable of irrigating 40 acres, yet when one cusec flows onto the fields it is capable of irrigating 47½ acres, and
in such circumstances one might be inclined to believe in miracles. Actually, however, if a duty of 40 is considered sufficient at the head, one acre of land will require an issue of 0.025 cusecs from the tank sluice, but on the field, one acre requires only 0.021 cusecs and the difference of 0.004 cusecs represents the loss en route, which, in this instance, amounts to 16% of the issued water.

In the period under review, losses en route have greatly exceeded this percentage; the most favourable comparison being the Balalu Channel losses which have averaged 22.2%, with Tissa a close second with a channel loss of 23.8%. At the other end of the scale owing, mainly to under development, the Nachchaduwawa Channel losses are as much as 45% of the sluice issues.

Efforts are now being made to stabilize these losses, and an average loss of only 20% is being aimed at as a first step in the more rigid control of cultivation issues. This represents a tank issue of 0.02625 cusecs per acre cultivated or a duty at the tank sluice of 38. If these efforts are entirely successful, and experiments carried out at Bassawakkulam during the recent drought indicate that the issue is not unreasonable and no appreciable inconvenience is caused, it may be possible to reduce the issue still further in future years. The issue is given continuously throughout the cultivation period, the tank sluice being manipulated to give the necessary discharge calculated according to the depth of water in the tank.

As Yala is the principal cultivation in the district, the annual acreage sown for this crop does not appreciably alter from year to year under the various tanks, except in the few instances where active development is taking place, or where storage for a full crop is likely to be inadequate, but in any case the extent to be sown is decided by the proprietors in advance of the cultivation season so that the required issue can be computed before the first mudding takes place.

As almost all the sluice outlets discharge above the tail channel supply level, the sluice discharge is calculated from the simple formula \( Q = 5 \times A \times H \) where "A" is the area of the sluice opening in square feet and "H" the effective upstream head
of water. The effective head is assumed to be the total head above invert level of the sluice less half the amount the sluice is opened.

Calculations have been simplified by the preparation of a nomogram which gives the discharges of rectangular sluices and by the use of a table of constants for determining the segmental areas uncovered when circular sluices are opened. The nomogram and table are annexed to this Paper.

TANK EVAPORATION.

As the quantity of water discharged from the different tank sluices had been calculated, it was found possible to deduce the amount of water lost in evaporation without much additional computation.

In the first place, periods of drought extending for seven or eight days were selected in each month, and the last five days' total diminution in tank water level noted and the amount translated into acre-feet from the capacity curves of the tanks.

The sluice discharges in cusecs were converted into acre-feet, and the nett loss due to evaporation and seepage through tank bund ascertained. The two- or three-day interval at the commencement of the five-day period analysed was provided to guard against the effect of belated catchment run-off after a period of rain. The equivalent depth of tank water decrease in the five-day period was then read off the capacity graph and the result multiplied by 6 to give the equivalent decrease in level during one month (30 days). Since the tanks had water surface areas of between 100 and 5,000 acres, no effort was made to separate the comparatively minute seepage loss from evaporation loss, and the total loss from tank capacity has been assumed to be the latter.

The process was then repeated, but the total diminution in water level at each tank during the whole month, exclusive of sluice issues, was computed. This amount included replenishment.

The figures for April were found to be valueless as almost invariably the water level in the tanks increased during that month owing to rains, and the increase in level was greater than the decrease by evaporation.
The theoretical and actual decreases in water level were approximately as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Theoretical decrease excluding replenishment</th>
<th>Actual decrease including replenishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>8&quot;</td>
<td>—</td>
</tr>
<tr>
<td>May</td>
<td>10&quot;</td>
<td>7&quot;</td>
</tr>
<tr>
<td>June</td>
<td>11&quot;</td>
<td>9&quot;</td>
</tr>
<tr>
<td>July</td>
<td>11&quot;</td>
<td>10&quot;</td>
</tr>
<tr>
<td>August</td>
<td>11&quot;</td>
<td>10&quot;</td>
</tr>
<tr>
<td>September</td>
<td>9&quot;</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

The results obtained, which can only be regarded as approximate, indicate that there is an actual net loss by evaporation of \(\frac{1}{4}\)" per day, and that in a year of drought there may be as much as \(\frac{3}{4}\) inch per day. In a few instances the peak loss recorded was 2" in five days.

Although the evaporation loss is considerable and represents a decrease of many thousands of acre-feet in the capacities of some of the larger tanks reviewed, the data is of much greater value when the capacities of village tanks in the neighbourhood are being investigated with a view to ascertaining the storage available for Yala cultivation.

As a strict cultivation programme is seldom worked to in the case of these smaller tanks, cultivation is liable to be prolonged and it follows that in an average season about 3\(\frac{1}{2}\) feet in depth of the tank water stored evaporates, reducing, in many cases, the efficiency of the small tank by as much as 50%; a strong argument in favour of the more rigid control of village tank cultivation, particularly in the case of those tanks which are not replenished by the drainage from cultivated fields in their catchments.

**Areas of opened segments of circular sluices.**

\[D = \text{diameter of sluice} \]
\[H = \text{height of opening} \]

Area of opened segment \(= D^2 \times M\)

<table>
<thead>
<tr>
<th>(H/D)</th>
<th>(M)</th>
<th>(H/D)</th>
<th>(M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.001</td>
<td>.000042</td>
<td>.125</td>
<td>.056664</td>
</tr>
<tr>
<td>.005</td>
<td>.000471</td>
<td>.15</td>
<td>.073875</td>
</tr>
<tr>
<td>.01</td>
<td>.001329</td>
<td>.175</td>
<td>.092314</td>
</tr>
<tr>
<td>D</td>
<td>H</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>---------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>.6</td>
<td>.002438</td>
<td>11.1824</td>
<td></td>
</tr>
<tr>
<td>.2</td>
<td>.003749</td>
<td>13.2273</td>
<td></td>
</tr>
<tr>
<td>.025</td>
<td>.005231</td>
<td>15.3546</td>
<td></td>
</tr>
<tr>
<td>.03</td>
<td>.006866</td>
<td>17.5542</td>
<td></td>
</tr>
<tr>
<td>.035</td>
<td>.008638</td>
<td>19.8168</td>
<td></td>
</tr>
<tr>
<td>.04</td>
<td>.010538</td>
<td>22.1341</td>
<td></td>
</tr>
<tr>
<td>.045</td>
<td>.012555</td>
<td>24.4980</td>
<td></td>
</tr>
<tr>
<td>.05</td>
<td>.014681</td>
<td>26.9010</td>
<td></td>
</tr>
<tr>
<td>.06</td>
<td>.019239</td>
<td>29.3370</td>
<td></td>
</tr>
<tr>
<td>.07</td>
<td>.024168</td>
<td>31.7981</td>
<td></td>
</tr>
<tr>
<td>.08</td>
<td>.029435</td>
<td>34.2753</td>
<td></td>
</tr>
<tr>
<td>.09</td>
<td>.035012</td>
<td>36.7710</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.040875</td>
<td>39.2699</td>
<td></td>
</tr>
</tbody>
</table>
DISCHARGE FROM RECTANGULAR SLUICES

INSTRUCTIONS:
CONNECT "LIFT" WITH "EFFECTIVE HEAD"
AND FIND POINT OF INTERSECTION ON SUPPORT A-A.
JOIN WITH "WIDTH OF SLUICE" & READ "DISCHARGE".

GATE "LIFT" OR HEIGHT OPENED:

A

DISCHARGE IN CUBIC FT

EFFECTIVE HEAD

"EFFECTIVE HEAD" = UPSTREAM HEAD ON BILL
LESS HALF THE GATE "LIFT".

WIDTH OF SLUICE

S.G. 0.3 7 34.