The area of land under irrigable culture throughout the world is rapidly on the increase. In Egypt, India, and the United States of America, alone, the area irrigated annually amounts to over 60 millions of acres, and on all sides there are further extensions involving millions of acres.

India probably furnishes the most rapid cases of development, canal colonies of a million acres growing up within ten years' time on land originally worthless; in fact, in arid regions, where irrigation is an essential to cultivation, progress appears to be most rapid, no legislation being in that case necessary to induce people to use water once it is provided.

In semi-arid regions progress is at first hindered, for there cultivation more or less profitable is possible without irrigation and moderate results are obtained from the natural rainfall.

The advantages gained by the use of irrigation in addition to rainfall, however, are sufficient to ensure the extension of irrigation to these lands eventually, and the possession of a moderate rainfall, although at first apparently a hindrance to progress is bound to prove advantageous ultimately.

To whatever class the land to be irrigated belongs, whether it is entirely dependent on irrigation or whether irrigation is to be resorted to in order to supplement a deficient or uncertain rainfall, the main questions which concern the engineer are “How much water is available?” and “To what area of land can it be profitably applied?”

This knowledge is required as a basis for planning the works of irrigation systems, without it the design is largely dependent on conjecture, and recent investigations show how little value can be placed on conjecture, especially as to the amounts of water either used or required for irrigation.

The amount of water available, either with or without artificial storage must be ascertained, and it will generally be found that it is water, not land, which limits the extension of irrigation systems.

To what area of land can the available water be profitably applied? is a most important question. In this connection many authorities use the term, “Duty of Water” and the impression of
what the term is intended to convey is generally vague. The duty of a stream of one cubic foot per minute may be stated as either two acres or four acres, but in order to ascertain from this the amount of water used, the length of the irrigating period must also be known. The length of the irrigating periods vary with the locality, and also with the seasons, hence the statement of duties in this way leads to confusion. For this reason probably, standard works, or works containing accurate information on this subject, now usually, in referring to amount of water used, simply give this as so many inches in depth over the whole area irrigated, and also refer to the length and frequency of the irrigating periods.

This method of stating the duty conveys its meaning much more clearly to the engineer, and is in a form more readily applicable to practice.

Statements of the amount of water used, when put in this form are very easily compared, and the comparisons are interesting. For example, the following taken from the "Annual Reports of the United States Department of Agriculture for 1900," representing American experience, and the figures given in "Buckley's Irrigation Works in India for 1889-90," representing Indian experience.

**AMERICAN IRRIGATION.** — Amount of water diverted, including losses in main channels, 5.47 feet; including losses in laterals only, 2.37 feet; supplied at margins of fields, 1.34 feet.

These figures are averages based on measurements taken at stations representing an area equivalent to one-third of the United States of America, and represent the average amount of water used in addition to an average rainfall of .45 feet. Depths of water are stated as over whole area watered.

**INDIAN EXPERIENCE.** — The amount of water used for all distributories of the Ganges Canal, 1889-90, 2.8 feet.

These figures are interesting as averages, but in examining the details from which the averages are compiled, great variations in the individual cases are noticeable; thus accentuating the necessity of an accurate knowledge of the circumstances before deciding as to the actual requirements in any individual case.

**LOCAL EXPERIENCE.** — Mildura. — For the last three seasons in Mildura 1902-3, 1903-4, 1904-5, an accurate record has been kept of area watered and amount of water used. The results, together with the circumstances affecting them, are now stated in as concise a form as possible.

In order to make the references more readily understood, the following short description of the Mildura irrigation system is given:

Mildura at present contains roughly 9500 acres of land under irrigable culture, 8000 acres of this amount being in a fairly compact area, the balance, 1500 acres, being scattered. The irrigation water is lifted by pumps from the River Murray into the channels for distribution. The channel system consists of 70 miles of mains and 100 miles of lateral channels, and over 100 miles of head ditches in the various lands under irrigation. Of the mains 10 miles are lined with concrete, and of the laterals 40 miles, the balance being in fairly retentive
soil. There are usually four or five pumpings in the season, which begins July 1st and ends June 30th. The dates of the pumpings are arranged to suit the nature of the planting, and vary slightly according to the season. To expedite the watering each block of land is assigned a certain order on the roster or watering list. The roster is arranged at the beginning of the season, and is rigidly adhered to.

With a dry winter, usually five pumpings are required during the season; when the winter is wet four pumpings are sufficient. Each block is allowed to water once during each pumping, but the average number of waterings actually taken is about four during the seasons, when five pumpings are run, while the average is nearly three when four pumpings are given.

The water rate, except for special crop watering, is so much per annum, independent of the amount of water used. Each irrigator is allowed to take what is considered sufficient, no limit being assigned to the quantity of water taken, so long as there is not any apparent waste. This fact of course tends to increase the amount of water used. Still, irrigators are aware of the fact that, although just sufficient water is good, too much is harmful, and the tendency of late years has been towards economy in the use of water.

For instance, on the light, sandy soil of the pine ridges it used to be the habit to water heavily on every opportunity, and an immense amount of water was poured into the soil. A great part of this water disappeared into the subsoil only to reappear at lower levels charged with impure salts, the result being destruction of trees and vines. This fact has since been recognised, and the tendency now is to give soil of this nature not more than two or three good waterings in the season, and preserve the moisture in the intervals by keeping the soil well cultivated.

Mildura lands, as a rule, are well cultivated, the prevailing opinion being that to water not too frequently but deeply, and to cultivate well in the intervals, gives the most economical results as regards irrigating. That this opinion is held in other localities may be concluded from the following extract from the “Report of Irrigation Investigations in Arizona 1900.” “The application of water through furrows wherever practicable saves the loss of water by evaporation from the surface. The application of small amounts of water at one irrigation is ordinarily wasteful. The smaller the amount supplied at one time, the larger will be the percentage of loss by evaporation. If, for example, only the upper two or three inches of the soil are moistened, nearly all the water will escape without passing through the plants growing in the soil. If the upper foot is moistened, probably one-half the water applied will pass through the plants. The objects of all methods of irrigation is to get as much of the irrigating water as possible to pass through the plants, and let as little of it as possible escape by seepage or evaporation.”

As regards the advantages of frequent cultivation, the following example taken from the same source will fully bear witness:—“A certain area of land was irrigated, part was afterwards cultivated and part allowed to go uncultivated; after a period of 80 days the state
of the soil was ascertained, and it was found that as regards moisture the first five feet in depth of the cultivated soil still retained 62 per cent. of the moisture, while the first five feet in depth of the un-cultivated soil contained only 45 per cent. of the moisture.

In Mildura considerable economy is exercised in the use of water and efficient cultivation is the rule. Over-watering is recognised as harmful, so that the figures given herein represent fairly good practice. Rigid economy, however, cannot be expected under a system of charging independently of the amount used. American experience indicates that when water is sold by measure the resultant saving is from 20 to 25 per cent. of the amount of water originally used. This is part of what is known as the preventible waste inside areas irrigated.

Having briefly described the Mildura system and indicated the probable extent of economy practised in the use of water therein, the following particulars which influence the amounts of water used will be given:

(1) Classification of soil.
(2) Nature of planting.

Following this will be given the records for seasons 1902-3, 1903-4, 1904-5, including dates and duration of irrigation, amount of water used, and amount of rainfall for the corresponding periods.

Classification of Mildura Soils.—Pine, 1682 acres, more or less sandy; Belar, 1281 acres, more or less sandy; Mallee, 3818 acres, more or less stiff; bluebush, 2559 acres, more or less stiff. Total, 9340 acres. The planted area is classed as above:

The pine soil is loose and sandy, being the soil of the well-known pine ridges. The soil being very loose absorbs any rain which may fall, and, being easily worked, the surface can be kept in such a condition that the moisture is retained. On this class of soil water can be used most economically, and cases are on record of vines planted on pine soil going through the season on only one good irrigation.

The belar soil is heavier than the pine, it contains some sand, and, when well worked, is fairly retentive. The Mallee and bluebush soils are of a heavier class. The Mallee soil absorbs water readily, but unless well worked, very shortly after being irrigated, loses the greater part of its moisture. The bluebush soil is the heaviest of all, least retentive of moisture, and requires more frequent waterings.

In regard to the comparative amounts of water used on different soils for seasons 1902-3, it may not be out of place to mention the following:—1161 acres, mostly Mallee, averaged 2.66 feet of water; 1624 acres, mostly pine, averaged 2.61 feet of water.

It was until recently assumed that the pine soils, being sandy, took considerably more water than the Mallee soils which are stiff, but the measurements lately obtained do not bear this out. When the water is economically used, the loose pine soils require probably less water than the stiffer Mallee soil, though the loose soil offers greater possibility in the way of either of waste or economy than stiff soils, into which the water cannot be induced to soak so freely.
NATURE OF PLANTING.—The planting is given for seasons 1902-3 and 1904-5. The figures show that the area under vines is considerably more than one-half the planted area—viz., 5500 acres. The Citrus family above 800 acres. Deciduous trees about 1000 acres. Lucerne about 500 acres, and hay crops about another 500 acres. It is interesting to note that in season 1902-3, the last year of the drought, the area under hay crop was double the present area.

PLANTED AREA RETURN—MILDURA.

<table>
<thead>
<tr>
<th></th>
<th>Season 1902-3</th>
<th>Season 1904-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gordos</td>
<td>2509 acres</td>
<td>2380 acres</td>
</tr>
<tr>
<td>Sultanas</td>
<td>2114 acres</td>
<td>2382 acres</td>
</tr>
<tr>
<td>Currants</td>
<td>299 acres</td>
<td>581 acres</td>
</tr>
<tr>
<td>Wine</td>
<td>58 acres</td>
<td>46 acres</td>
</tr>
<tr>
<td>Oranges</td>
<td>861 acres</td>
<td>351 acres</td>
</tr>
<tr>
<td>Lemons</td>
<td>587 acres</td>
<td>468 acres</td>
</tr>
<tr>
<td>Apricots</td>
<td>596 acres</td>
<td>527 acres</td>
</tr>
<tr>
<td>Peaches</td>
<td>181 acres</td>
<td>146 acres</td>
</tr>
<tr>
<td>Figs</td>
<td>79 acres</td>
<td>71 acres</td>
</tr>
<tr>
<td>Unenumerated</td>
<td>207 acres</td>
<td>194 acres</td>
</tr>
<tr>
<td>Lucerne</td>
<td>448 acres</td>
<td>588 acres</td>
</tr>
<tr>
<td>Crop</td>
<td>1109 acres</td>
<td>588 acres</td>
</tr>
<tr>
<td>House Garden</td>
<td>194 acres</td>
<td>218 acres</td>
</tr>
<tr>
<td>Vacant and Seepage</td>
<td>621 acres</td>
<td>1010 acres</td>
</tr>
<tr>
<td>Total</td>
<td>9340 acres</td>
<td>9593 acres</td>
</tr>
</tbody>
</table>

Following the “Classification of Soils” and “Nature of Planting,” the records of the irrigations for the three seasons mentioned will now be given.

The dates of irrigating are shown diagrammatically on the enclosed sheet, together with the monthly rainfall record for seasons 1902-3, 1903-4, 1904-5.

The dates of watering depend to a certain extent on the seasons, but not so much as might be expected. With a heavy rain at any particular time, a pumping is sometimes dispensed with, but in fruit growing there are particular periods at which it is necessary for the trees to receive water, and these periods mainly determine the dates of pumping.

As the cost of pumping and distribution in Mildura, is, roughly, £50 per day, the opportunity of dispensing with an irrigation, when that occurs, is eagerly availed of. Thus with a wet winter, as in 1904-5, no winter waterings were given, while in 1902-3 and 1903-4 the July waterings were about the heaviest of the season. The July or winter watering, when given, is almost general—vines, trees, crops and lucerne all being watered. The summer waterings, October to January, are also fairly general, two out of the three being usually taken on all land under cultivation. The March watering is mainly
used for citrus, and for the purpose of growing peas, beans, etc., for future ploughing in as green manure.

The amount of water used for seasons 1902-3, 1903-4 and 1904-5 has been measured and kept on record. The depths of water used, as given in the accompanying tables, marked A and B, include all losses in distribution, seepage from channels and evaporation. These losses are generally estimated at about 25 per cent. The channels as previously mentioned are partly concrete lined, all the worst places are lined, the balance being in fairly retentive soil. Although the estimate of loss is probably near the truth, the exact loss in distribution will not be ascertained until a large number of additional measurements are made of the water supplied at the margins of the fields irrigated. At present actual measurements are on record of the total amount of water pumped, including losses in channels, for three seasons, and actual measurements in three cases, representing 70 acres, of the amount of water supplied at the margin of the land irrigated. It is interesting to compare these latter figures with the actual amount pumped, but before the loss in distribution can be more accurately stated, these individual measurements will have to be considerably extended. The few cases of which records have been kept are not sufficient to warrant a general statement—in fact, the amount of water used in one of the cases measured is considerably above the average amount pumped.

Table B, already referred to, shows the average amount of water pumped over the whole area irrigated in Mildura. Seasons 1902-3, 1903-4, 1904-5, including losses in channels.

Table A shows each pumping in detail, but refers to a part of Mildura only. Roughly, 7800 acres out of the 9500.

The third set of results are of a different nature, and are measurements taken at margins of fields irrigated for season 1904-5. A liberal multiplication of these measurements would enable an accurate estimate to be made of loss during distribution, but the results are of value in themselves, as they show accurately the actual amount of water used under known conditions.

**AMOUNT OF WATER USED IN INDIVIDUAL CASES (MILDURA).—Case 1: 10 acres of Gordo vines, on bluebush soil. Case 2: 10 acres of Gordo vines on pine soil. Case 3: 50 acres of Gordo, sultanas, currants, apricots, on mallee and bluebush soil.**

### DEPTH OF WATER USED IN INCHES

<table>
<thead>
<tr>
<th>Waterings</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>Extra</th>
<th>4th</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sept.-Oct., 1904.</strong></td>
<td><strong>Nov.-Dec., 1904.</strong></td>
<td><strong>January, 1905.</strong></td>
<td><strong>January, 1905.</strong></td>
<td><strong>March, 1905.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>8.08</td>
<td>4.00</td>
<td>2.50*</td>
<td>5.21</td>
<td>—</td>
<td>19.79</td>
</tr>
<tr>
<td>(2)</td>
<td>10.00</td>
<td>5.37</td>
<td>3.32</td>
<td>—</td>
<td>—</td>
<td>18.69</td>
</tr>
<tr>
<td>(3)</td>
<td>10.03</td>
<td>7.91</td>
<td>7.12</td>
<td>—</td>
<td>—</td>
<td>25.06</td>
</tr>
</tbody>
</table>

* 1.50 inches of rain fell at the same time.*
The individual measurements (1), (2), (3), show results of actual amount of water supplied, varying from 18 to 25 inches per annum, or from 3 1/3rd to 10 inches per watering, while the average for the whole of Mildura for the same season shows 24.73 inches per annum, or 7.85 inches pumped per watering, including losses in distribution.

COMPARATIVE STATEMENT OF AMOUNTS OF WATER USED.—The average for America, including losses in distribution, is given as 2.37 feet; ditto for India, 2.80 feet; ditto for Mildura (average for three seasons), 2.16 feet. The American figure for average amount delivered, 1.34 feet. Assuming losses in distribution 25 per cent., the Mildura average would be 1.62 feet, while for individual cases we have 1.56, 1.65, and 2.09 feet.

The average amount of water actually used for the irrigation of horticultural land, stated at 1.62 feet per acre per annum, agrees closely with the American average, and, although it leaves room for economy, the amount can hardly be considered excessive.

The legal water right for Mildura lands is 2.03 feet of water diverted from the river; the allowable loss in distribution, 20 per cent.; giving legal quantity of delivery, 1.62 feet, while the averages for the last three seasons gives diversion from river 2.16 feet, and, assuming 25 per cent. loss in distribution, 1.62 feet delivered. This calculation is based on net area watered. If gross area in occupation, including land casually watered, is taken, then the diversion is equal to 2.03 feet, which is exactly the amount of water right, and the amount delivered 1.52 feet, or slightly less than the water right provides for.

Although the average amount of water diverted per annum may not be considered excessive, individual waterings of 10 inches may be regarded with surprise.

Take, for instance, case (3), already quoted, where 50 acres of vines and trees on mallee and bluebush soil received three waterings, as follows:—September-October, 1904, 10.03 inches; November-December, 1904, 7.91 inches; January, 1905, 7.12 inches.

In this particular case the subsoil was porous; the mallee soil was overlying a bed of limestone, which gave natural under drainage of a most perfect character. The land before watering was well ploughed and cultivated, and three rows of irrigation furrows were run between each row of vines or trees. The whole land was heavily watered, and the amount of water used above the average, owing, no doubt, to the porous nature of the subsoil.

In cases (1) and (2) we have lighter waterings—4 inches, 5 inches, and 3 1/3 inches. The land before watering was well worked, and the lighter waterings were given by running fewer furrows. In one case, only one furrow was run between each row of vines, while in another only one furrow was run for each two rows of vines, the vines being spaced about 10 feet apart. This course is adopted on account of the lateral and downward soakage from the furrows being so free in well cultivated land. Before ploughing, of course, land would take less water, and uncultivated grass lands could be given waterings of, say, three inches; but in horticultural land, kept well
ploughed and cultivated, the difficulty is to give a light watering evenly distributed. Another factor which tends to increase the amount of water required for irrigation is evaporation—not so much from the water surface of the channels, which is a comparatively small area, as from the surface of the land being irrigated. Any person who has had experience in the dry lands north of the Dividing Range is well aware of the excessive evaporation from the surface of a canvas water bag, and the condition of horticultural land under irrigation is much the same. The water is run down the furrows, and soaks into the dry, porous ground. The temperature of the ground is high, and in the warm seasons, during which most of the irrigating is done, the temperature of the wind passing over is high also, and the air itself almost devoid of moisture, so that the evaporation is excessive. During hot winds it is a common occurrence to find the water receding in the furrows during daytime, and advancing only at night, when the evaporation is much less.

The resultant figures, referring to the average amount of water pumped for whole area watered and amount of water delivered in actual cases having been given, it may be of interest to members of the Institute to have an outline of the methods adopted in obtaining these results. The first set of figures—i.e., the average depth of water provided for whole areas irrigated, were obtained by keeping a record of the total amount of water pumped and area of land supplied. The record of the flow of water in the main channel was kept by an automatic register, which shows the depth of water flowing over a weir. For this purpose a clear overfall was out of the question on account of the flat grade in the channel, and a submerged weir has been used, a continuous record of water heights being taken by means of the automatic register referred to. The register consists of a cylinder revolved by a clockwork; the cylinder carries a sheet of metallic paper, on which pencils attached to floats trace the rise and fall of the water above and below the weir.

The formula used for the submerged weir is that of J. B. Francis, as given in the "Transactions of the American Society of Civil Engineers, 1884."

\[ Q = \frac{C}{2} \sqrt{2g} \left( H'' - H''' \right) + C' L \ H'' \sqrt{2g} \left( H'' - H''' \right) \]

Where \( Q \) equals quantity of water discharged in cubic feet per sec.
\( L \) equals length of weir in feet.
\( H'' \) equals height of still water above crest up stream side.
\( H''' \) equals height of still water above crest down stream side.
\( g \) equals gravity.
\( C \) equals co-efficient for weir.
\( C' \) equals co-efficient for orifice.

The first part of the formula being the theoretical formula for the weir, and the second part for the orifice. The formula used for the weir adopted for the Mildura measurements was—

\[ Q = 3.33 L \left( H'' - H''' \right)^{\frac{3}{2}} + 4.6 \ L \ H'' \sqrt{(H'' - H''')} \]
L in the first factor being corrected for end contractions, but velocity of approach neglected, as it was only 50 feet per minute.

In connection with this it may be mentioned that much confusion is caused by the use of an abbreviation of the above formula,

\[ Q = 3.33 \times L \sqrt{(H^2 - H'\prime^2) (H^2 + 0.381 H'\prime^2)} \]

given as a simpler form for computing. The formula appears algebraically deducible from the one immediately preceding, but it must be remembered that when the co-efficient 3.33 is used, L in the first factor is the length of crest corrected for end contractions, while when the co-efficient (4.6) is used in the second factor, the L, by which it is multiplied, is the length of crest, the necessary correction being made when multiplying by the experimental co-efficient (4.6).

The misuse of the formula leads to errors too great to be neglected in cases usually occurring.

The submerged weir was adopted for the purpose of measurement in Mildura on account of the fact that to obtain a clear overfall would have necessitated the actual lifting of the water another foot in height, and this was not allowable.

Hamilton Smith, Junior, in his work on "The Flow of Water Over Weirs," treats of this subject very fully. Therein he refers to the original experiments by Poncelet and Lesbros, the experiments of Lesbros in 1832 and 1852, the Lowell hydraulic experiments conducted by J. B. Francis (Past President American Society of Civil Engineers in 1868), and further experiments by Fteley and Stearns, made during construction of waterworks for Boston, and recorded in the "Transactions of the American Institute, 1883." J. B. Francis, and Messrs. Fteley and Stearns deal fully with the subject of submerged weirs, but Mr. Hamilton Smith does not attach much value to this method of measurement, and his summary regarding it is to the effect that "Submerged weirs afford a most imperfect method of gauging the flow of water, due to the impossibility of correctly measuring the lower head, and also to the fact that small errors in the determination of the head above and below the weir may largely affect the deduced values—when the depth of the canal is quite large in proportion to the difference of head above and below the weir, so that the velocity of approach is not great, then the discharge may be roughly determined."

However, in many cases, and in the particular case we have in Mildura, where the pumps discharge into practically level channels, and it is not desirable to place an extra foot of head on the pumps, a clear fall is not obtainable, and the close agreement of results given by the formula of several authorities makes it probable that, under suitable conditions and with careful measurements of the head above and below the weir, the results are fairly accurate, and can be relied on.

In support of this there is the opinion of Messrs. Fteley and Stearns, who are probably the most reliable authorities on this sub-
ject, that "In practice this form of weir may be found useful in cases where, on account of the slight fall available, it would be impossible to erect a weir of ordinary form, and the results can be rendered reliable by arranging so that the velocities of approach to and exit from the weir are small, the discrepancy in results being occasioned by inaccurate corrections for these velocities."

With the Mildura weir the velocity of approach is reduced to 50 feet per minute, the correction for which may be neglected; the measurements of the up stream and down stream heads are made from water admitted to wells through a small pipe, the surface of the water in the wells being therefore free from disturbance.

Such, then, is the method adopted for obtaining the total amount of water pumped into the main channels and distributed over the whole area under cultivation. The measurement of the amount delivered to the individual blocks involved another problem. The grades of the channels, including the laterals and minor distributaries, were too flat to admit of the amount of supply to the individual blocks being measured over weirs; flume measurement, as practised in America, involved the assumption that the discharge varied with the depth of water in the flume, and for each depth of flow there was a corresponding discharge. This may hold where the grade of the channel is sufficient to prevent any rise of the water in the flume due to obstructions placed down stream, but does not hold in Mildura, where the grades are flat. Backing up of the water in the lead ditch increases the depth of flow in the flume, but diminishes the discharge, inasmuch as the hydraulic grade is reduced. For this reason flume methods of measuring were abandoned, and a meter specially designed to meet the requirements.

As will appear from the diagram, the apparatus used is an inferential meter, fitted on a vertical spindle, supported above water at its upper end, on ball bearings. The fan blades, four in number, are adjustable, and so designed that each cubic foot of water passing through the circular horizontal orifice can be made to produce one revolution of the fan. Thus the dial, connected with a counter attached to the spindle, is made to show the number of revolutions, and consequently the number of cubic feet of water discharged. The whole is built into a double-brick pit, with inlet and outlet gratings. The meter is specially suitable for use in flat channels, where there is not sufficient fall available to allow of the satisfactory use of weirs. A fall of less than three inches is all that is necessary for the purpose of accurate registration by this appliance.

For streams of different sizes, both the diameter and number of orifices may be varied, so that flows of all dimensions may be accommodated.

For streams of the size usually handled in watering a ten-acre block (up to 100 cubic feet a minute), one 12 inch orifice is sufficient. Two 12 inch orifices are ample for streams up to 200 cubic feet a minute, one 2 foot orifice for streams up to 400 cubic feet a minute, and a 3 foot orifice for streams up to 900 cubic feet per minute, while an arrangement of four 3 foot orifices would accom-
moderate a stream of 3600 cubic feet per minute, which in Mildura is
the size of stream handled for the irrigation of 8000 acres.

The accuracy obtained in tests under working conditions is within
2 per cent. of actual measurements into a concrete-lined tank, while
a meter manufactured and placed in the channel for the first time
read within 5 per cent. of direct measurement without any adjust-
ment.

By means of the submerged weir the total amount of water pumped
was recorded, and by means of the water meter described above the
amounts used in individual cases were measured.

Eventually it is hoped that a sufficient number of individual meas-
urements will be taken to ascertain exactly the average amount of
water entering the fields. Then, and not until then, will the actual
loss in distribution be known.

Should the system of sale by measure be established, it would en-
sure economical use of the water, and at the same time a complete
balance-sheet of the water lifted could be presented. An accurate
knowledge of the facts as they exist could only result in a more
economical use of the water.

In Victoria the summer flow of the rivers would be severely taxed
with any considerable extension of irrigation involving summer water-
ings.

Storage of water involves expenditure, therefore it is all the more
necessary to use every drop of water to the best advantage, and it
is only by accurate knowledge of facts as regards requirements that
rigid economy can be enforced, and the best use made of our avail-
able water supply.

All information of this nature is of interest to the engineer, and
it is with the object of placing local experience on record for com-
parsion with the experience of other districts that the results of
measurements to date are now laid before Members of the Institute.

NOTE.—The author of this paper is indebted to the Chairman and
Commissioners of the First Mildura Irrigation Trust for their cour-
tesy in allowing the Trust records to be used. Permission was given
on the understanding that the information was to be placed before
the members of the Victorian Institute of Engineers.
Diagram of Meter.
### RECORD OF LAND WATERED IN MILDURA.

*Table "A" refers to Part Area—7800 Acres.*

<table>
<thead>
<tr>
<th>Date of Watering from</th>
<th>July 8</th>
<th>Oct. 6</th>
<th>Nov. 18</th>
<th>Jan. 4</th>
<th>March 9</th>
<th>July 22</th>
<th>Nov. 16</th>
<th>Jan. 11</th>
<th>March 15</th>
<th>Sept. 12</th>
<th>Nov. 17</th>
<th>Dec. 28</th>
<th>March 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;&quot; to &quot;&quot; Hours run at Pumping Station</td>
<td>Aug. 22</td>
<td>Nov. 9</td>
<td>Dec. 16</td>
<td>Feb. 3</td>
<td>April 4</td>
<td>Aug. 29</td>
<td>Dec. 28</td>
<td>Feb. 4</td>
<td>March 27</td>
<td>Oct. 22</td>
<td>Dec. 18</td>
<td>Jan. 31</td>
<td>March 30</td>
</tr>
<tr>
<td>Average Stream in Channel</td>
<td>1,007</td>
<td>3,920</td>
<td>3,500</td>
<td>3,250</td>
<td>3,550</td>
<td>3,550</td>
<td>3,650</td>
<td>3,750</td>
<td>3,750</td>
<td>3,750</td>
<td>3,750</td>
<td>3,750</td>
<td>3,750</td>
</tr>
<tr>
<td>Volume of Water Pumped in Cubic Ft.</td>
<td>23,661,000</td>
<td>174,326,000</td>
<td>131,625,000</td>
<td>121,415,000</td>
<td>127,415,000</td>
<td>120,215,000</td>
<td>211,500,000</td>
<td>171,441,000</td>
<td>205,012,000</td>
<td>171,441,000</td>
<td>205,012,000</td>
<td>171,441,000</td>
<td>205,012,000</td>
</tr>
<tr>
<td>Area Irrigated in Acres</td>
<td>6,788</td>
<td>6,532</td>
<td>6,319</td>
<td>6,011</td>
<td>5,819</td>
<td>6,976</td>
<td>6,632</td>
<td>5,118</td>
<td>5,118</td>
<td>6,976</td>
<td>6,632</td>
<td>5,118</td>
<td>5,118</td>
</tr>
<tr>
<td>Depth of Water Pumped in Inches</td>
<td>0-49</td>
<td>7-35</td>
<td>6-23</td>
<td>6-91</td>
<td>10-88</td>
<td>7-63</td>
<td>8-75</td>
<td>6-96</td>
<td>9-80</td>
<td>8-08</td>
<td>7-53</td>
<td>7-09</td>
<td>9-29</td>
</tr>
<tr>
<td>Number of Days Run</td>
<td>46</td>
<td>35</td>
<td>29</td>
<td>26</td>
<td>26</td>
<td>36</td>
<td>41</td>
<td>21</td>
<td>12</td>
<td>40</td>
<td>31</td>
<td>29</td>
<td>23</td>
</tr>
</tbody>
</table>

Number of Days for the Season—Season 1902-1903, 162; Season 1903-1904, 115; Season 1904-1905, 125.

*Table "B" refers to Whole Area.*

<table>
<thead>
<tr>
<th>Gross Area of Planted Land</th>
<th>9,340 acres</th>
<th>9,297 acres</th>
<th>9,555 acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net</td>
<td>8,936 &quot;</td>
<td>8,447 &quot;</td>
<td>8,843 &quot;</td>
</tr>
<tr>
<td>Number of Water Acres Supplied</td>
<td>34,303</td>
<td>24,317</td>
<td>27,883</td>
</tr>
<tr>
<td>Average Number of Waterings on Gross Area</td>
<td>3-73</td>
<td>2-59</td>
<td>2-91</td>
</tr>
<tr>
<td>&quot;&quot; Net Area</td>
<td>3-69</td>
<td>2-81</td>
<td>3-15</td>
</tr>
<tr>
<td>Average Depth of Water Acre</td>
<td>7-92 inches</td>
<td>7-99 inches</td>
<td>7-95 inches</td>
</tr>
<tr>
<td>Average Depth of Water on Gross Area</td>
<td>20-54</td>
<td>20-69</td>
<td>22-95</td>
</tr>
<tr>
<td>&quot;&quot; Net Area</td>
<td>20-31</td>
<td>22-45</td>
<td>24-73</td>
</tr>
</tbody>
</table>
| Rainfall During Season     | 11-72 "     | 14-77 "     | (Incomplete) 12-70 " + May and June, 1905."
### DATES OF IRRIGATIONS

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1903-1904</td>
<td>161 days</td>
<td>105 days</td>
<td>18th</td>
<td>22nd</td>
<td>23rd</td>
<td>28th</td>
<td>17th</td>
<td>27th</td>
<td>22nd</td>
<td>16th</td>
<td>6th</td>
<td>9th</td>
</tr>
<tr>
<td>1904-1905</td>
<td>115 days</td>
<td>1904-5</td>
<td>23rd</td>
<td>25th</td>
<td>22nd</td>
<td>16th</td>
<td>28th</td>
<td>3rd</td>
<td>3rd</td>
<td>3rd</td>
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</tr>
</tbody>
</table>

### MONTHLY RAINFALL RECORD

<table>
<thead>
<tr>
<th>Month</th>
<th>1902-3</th>
<th>1903-4</th>
<th>1904-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan.</td>
<td>182</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>Feb.</td>
<td>85</td>
<td>46</td>
<td>47</td>
</tr>
<tr>
<td>Mar.</td>
<td>38</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>Apr.</td>
<td>49</td>
<td>49</td>
<td>48</td>
</tr>
<tr>
<td>May</td>
<td>101</td>
<td>135</td>
<td>136</td>
</tr>
<tr>
<td>Jun.</td>
<td>158</td>
<td>162</td>
<td>147</td>
</tr>
<tr>
<td>July</td>
<td>195</td>
<td>159</td>
<td>152</td>
</tr>
<tr>
<td>Aug.</td>
<td>128</td>
<td>136</td>
<td>177</td>
</tr>
<tr>
<td>Sept.</td>
<td>135</td>
<td>173</td>
<td>243</td>
</tr>
<tr>
<td>Oct.</td>
<td>136</td>
<td>243</td>
<td>274</td>
</tr>
<tr>
<td>Nov.</td>
<td>159</td>
<td>243</td>
<td>274</td>
</tr>
<tr>
<td>Dec.</td>
<td>159</td>
<td>173</td>
<td>195</td>
</tr>
</tbody>
</table>

Showing Troughs: 1902-3, 11.30; 1903-4, 14.27.
DISCUSSION.

The President stated that £50 per day seemed a large sum for the pumping required for the comparatively small area of Mildura, although the soil was largely of a non-retentive character.

The paper bore out the general experience of engineers that a large quantity of water was used that might be conserved. His own observation led to the conclusion that better results followed the use of less water.

The means used to measure the water were interesting and ingenious. When the difference of levels was too low for weir measurement the meter should be of much use. Until more accurate methods were brought into use, irrigation would not be the success it should be.

Perhaps other members might wish to say something pending the fuller discussion to follow—Mr. Craven, for instance.

Mr. A. W. Craven said that until the printed matter was available at next meeting, the subject was difficult to deal with.

Prof. Kernot desired to know whether Mildura was extending. Would it ultimately grow along the branches of the Murray and Murrumbidgee, for miles? The Railway Commissioners had given extra facilities to permit of communication with the city.

The President thought it satisfactory that it had retained its position.

Mr. A. C. Mountain thought it had rather fallen back somewhat.

Mr. J. M. Coane quoted from the paper to show that there was an increase in the area under raisins, and vines generally; but that, excepting lucerne, other products were decreasing. He did not think that the export markets paid.

Prof. Kernot, resuming, said that was a one year’s comparison, and too much weight should not be placed upon the deductions. If the figures were for twelve years, something might be learned from them.

It would be an advantage if the statistics were “diagrammed.” There were agitations for running the river waters miles into the desert for irrigation, but why were the banks of the river itself not cultivated? On the Nile, there was simply a narrow strip along either side under cultivation.

Mr. A. W. Craven thought Prof. Kernot had brought out some important information. As a member of the Parliamentary Railway Standing Committee, he had visited Mildura before it was fully developed, and a reason urged for the necessity for railway construction was that the settlement could not progress until the first fruits could be got to market expeditiously. He had thought that getting the early fruit—much earlier than from anywhere else—to Melbourne, would have enabled the producers to secure the market and cash returns, a matter of importance to the settlement. But now that
they had the railway, the extraordinary thing was that quite an opposite result had followed.

Mr. M. Elliot thought that the author had advanced in a direction that was absolutely required—namely, towards the accurate measurement of water. It had always been a difficulty with him, in his irrigation projects, to know what quantity of water he was using.

He would ask whether the figures referred to “furrow” or “flush” irrigation. If it was furrow irrigation, then it could not be directly compared with irrigation in country districts, where there was no control over check banks. He had seen these so placed that the farmers used much more water than was necessary.

The paper was valuable in so far as it contained accurate information of what was being done.

As to Prof. Kernot’s remarks: In the first place, the settlers took up the land and cultivated it upon wrong lines. After planting oranges and lemons, they had to dig up all their trees and start afresh. It had been a case of experimental irrigation. The settlers had done great work, and good work, but much time had been taken in finding out what was the exact crop suitable to the locality. Now they had found the most suitable lines to work on.

In other places the farmers had found that the best returns were derived from cultivating for dairy purposes.

The President pointed out that the figures were for three years—1902 to 1905—not for one year. Still, it was desirable to go further back than that. Before the products could be utilised to any great extent, he thought it would be necessary to work for export.

Mr. J. M. Coane said, in regard to the question whether the irrigation were “furrow” or “flooding,” what he had seen at Mildura led him to believe that the vines were on the furrow method, and the lucerne on the flooding.

When trees and vines were flooded the reflection of the sun from the water burnt the bark; therefore it was the system to prevent large water surfaces. With the older trees there were two furrows on each side; with the younger, one.

As to extension, he thought it would be on two lines—irrigation for export goods, and irrigation for Australian consumption.

Unless they could by a suitable preferential tariff secure the English canned and dried fruit market, large areas would be devoted to the purpose of fattening cattle, and producing butter, cheese, etc., for export. Those would then be the most suitable products for the gravitation areas, but it would hardly be possible to make the trade pay with pumping costing as much as that at Mildura.

As to heat and hot winds, he thought all irrigated countries were subject to these. Last January fully one-third of the Mildura crops, and one-fifth of the Goulburn Valley crops, were destroyed by an excessive wave of heat. Even the water became extremely hot and injured the plants. Irrigation must be maintained continuously, night and day; if water is to be economised, cessation during the night generally means a great loss.

He did not think members generally were aware of the extent of lucerne
irrigation in Victoria. He knew of one property where 2000 acres were irrigated three or four times during the season by gravitation, and six sheep could be kept per acre during that period.

The President asked how the measurements were effected where weirs were not used.

Mr. Coane said that the principal irrigation trust—Rodney—assumed three inches to be the average irrigation. That was the basis of the charge.

Mr. M. Elliot asked whether that was not a guess?

Mr. Coane said that as the result of a number of gaugings that he had conducted, he thought that, with the Northern Plains soil, three inches would be a fair average. It depended upon whether the land was properly graded. He did not think that the possibilities with different crops were anything like exhausted.

The President said that the possibilities in Victoria seemed to be almost unlimited. There was the fact that the rainfall did not average more than 11 inches over a large part of the country, and that was not nearly enough to maintain vegetation commercially.

Irrigated lucerne would enable much more stock to be carried than at present, and the outlet for frozen mutton, cheese, etc., seemed, to him, to be very good.

Mr. G. H. Grant, on behalf of the Institute of Surveyors, returned thanks for the invitation issued to members from that Institute, and would be pleased if it could be extended to the next meeting also.

His brother (Mr. C. J. Grant) would, he believed, be able to attend at the continued discussion, and as he had been Resident Engineer at Mildura for nine years, doubtless he would be able to deal with the points raised.
The President said Mr. Grant's paper on "Irrigation in Mildura," was open for discussion. The subject was of special interest and value, as it dealt with a subject which, he thought, had greater hope of success, and indicated better prospects for the future prosperity of Victoria, than any other subject could have. He was very glad to notice in the paper that Mr. Grant was hopeful of the ultimate success of irrigation in Victoria, and he spoke as one not only having practical experience, but as having had special facilities and opportunities for studying its working in the centre where it had been most extensively practised so far. The more one thought of irrigation, and the more one read about it, the more one was impressed with the importance of endeavouring to have it undertaken in Victoria, coupled, as far as possible, with a system of educating the farmer up to its use. Unless the cultivator had the controlling factors and figures at his fingers' ends, he was not likely to be very successful. Take, for instance, the question of the absorption of water, and the retention of water in the soil, to which a prominent place had been given in the paper. Dr. Maxwell, Queensland, had made some very careful experiments in that respect, and had shown that the absorption of soils varied to an enormous degree—as much at 300 per cent. in different samples. This was very largely due to the percentage of nitrogen present in the soil. Taking an average of 50 samples, containing .163 of nitrogen, 6 per cent. of water was retained at the end of five months; another average of 50 samples, containing .647 per cent. of nitrogen, 20 per cent. of moisture was retained at the end of five months. That might explain to some extent what Mr. Grant pointed out on page 47—the difference between blue soil and sandy ridge soil, as probably the latter carried more vegetation.

Another very important factor was the amount of water it took to produce a pound of dry substance of any given crop. In Queensland it took 150 lbs. of water to obtain 1 lb. of dry material of sugar-cane, and a similar determination should be made for all crops in Victoria. But the principal measurement which had to be taken was the measurement of the water itself, and he thought Mr. Grant had done good work in bringing before the Institute the device illustrated for giving a fairly accurate measurement of the water used. They must first of all ascertain the actual amount of water applied to the soil, before any other measurement could be of any value. The appliance Mr. Grant had introduced seemed to be fairly cheap, and if it gave the average result he claimed for it (within an error of 2 per cent.), there was no doubt it would be very satisfactory and
useful. Whether it was to be used as a means of charging for the water, or of giving the farmer the information he required to carry on his business, did not matter. It would be economical and instructive in any case; and economy in the use of water was absolutely necessary, for, without it, irrigation would not be successful.

Mr. J. M. Coane said he had studied Mr. Grant’s paper, and there were several things in it worthy of attention in connection with the general question of irrigation. In the first place, Mr. Grant pointed out that the difficulties of establishing irrigation were very much greater in countries where people could get along somehow without it. And in this respect he thought it would be conceded that a large part of Victoria was in the same position as California. Fair crops could be grown occasionally—perhaps two years out of four—without irrigation, but small crops were the general rule, for our average had been very low right through. Lucerne would last two or three years without irrigation, and as long as a living could be made without artificial watering, it was hard to get people to incur expense to properly prepare and irrigate their lands. At Mildura the case was quite different. There they were absolutely obliged to irrigate to do any good at all, so that the difficulties of initiation were less than in the moister parts of Australia. But the people did not thoroughly realise the benefit that would be derived from irrigation, even in the wetter parts. Very often delayed autumn rains led to late sowing, with the accompanying results of bad crops, and there was no winter grass for the cattle. It was clear that, if the water were taken advantage of more than it is, to irrigate the land before ploughing, better crops would be obtained than we had at present, and manuring would give a much better return. He had seen in the Cohuna district and elsewhere the benefit of irrigating before ploughing, so as to get an early sowing. He had also seen good results from spring irrigation when there was a dry October.

Another point was that the available water was always much less than the available land. Anyone who knew Victoria, and had studied its rivers, would agree that for every acre we could find water to irrigate, there were four acres suitable for irrigation. There were at least 1½ millions of acres of irrigable land in Northern Victoria. It was necessary to be most careful of the water from the time it fell from the heavens until it was turned on to the land to be absorbed.

The question of channels was an important one. In Mildura there were long lengths of channels, with falls of about 6 in. to the mile. They had evidently kept the fall down to the minimum, in order to save pumping. In portions of these there was concrete lining, to prevent percolation, but it seemed likely that the grades could have advantageously been made steeper. One thing that was noticeable in some of the American districts was that only a quarter of the water supplied to the main channel was delivered to the fields; the remaining three-fourths being lost. The reason for this would be readily understood, when it was mentioned that in many cases quite large lakes were filled by the water which escaped
by soakage from the main channels. That was the case with a good many of the channels in the Western States of America. It had also been found to be the case in long channels in Mildura, when they were unlined. In Central North Victoria the loss would not be nearly so great, but, going west, the difficulty would increase. Another trouble was that of keeping the channels clear, not only of vegetation, but of wind-blown sand, which drifted into them, especially in dry years. It would be a very great advantage indeed to leave wind breaks wherever possible, to prevent the wind from covering fences, filling channels, and causing general havoc. Mr. Grant did not say anything about the actual cost of raising the water, but he gathered from the figures that it would be about 2d. per 1000 cubic feet.

Mr. Grant, in reply, said it would be roughly about 2d.

The President asked what was the price of fuel?

Mr. Grant: 7s. per acre cubic feet.

Mr. Coane (continuing) said there must be a great loss in fuel and management by having so many pumping stations. This would be largely avoided if the power were distributed by electricity. It seemed that one of the troubles at Mildura was the soakage through the subsoil. It was a decided advantage in many cases in the Goulburn Valley to subsoil before planting trees, vines, or lucerne, in order to let the water down smartly, and allow the roots to spread more freely.

With regard to sandy soil, not requiring so much water, his experience had been the same as that of Mr. Grant. He found that sandy soil lost much less water by capillary action than the hard land. The dew also was much more beneficial in sandy ground. He had seen three-year-old vines, unirrigated, growing on sand hills, in the Wimmera district, with stems 4 in. in diameter. In coarse sand there was comparatively little evaporation under about 2 ft. below the surface. Mr. Grant had put down the amount of water used for the year at 2 ft. If they gave 1 ft. to the ground for the year, in the Goulburn Valley, they would consider that they were irrigating pretty freely, but Mildura had a more pervious subsoil, and a hotter climate, and so lost more water by soakage and evaporation.

But the most important question mentioned in the paper was the provision for the measurement of the water. Up to the present there had been, so far as he knew, no really satisfactory device for the measurement of the water used by the farmers. But the meter described in the paper met the case. The principal point seemed a meter in which the upward flow nearly balanced the weight of the fan and spindle, and reduced the friction to a very small amount. There should be no difficulty in increasing the size of the meter. A large one should not be much more difficult to erect and manage than a small one. He thought it would be better if they could be made with fixed blades, requiring no adjustment at all, but designed with sufficient accuracy at first to give a good result. But in view of the fact that the world had been searching for centuries for a practical self-registering device for measuring water supplied to irrigators, it was gratifying to learn that this meter had fulfilled its
mission so well up to the present. He was sure the members of the Institute were glad to hear from Mr. Grant, that by its use they could get within 2 per cent. of the truth, the results having been checked by tank measurement. The chief benefit that should be derived from the meter was that farmers would learn to be more economical. The water would be made to go much further. On badly graded land, a part of the crop was ruined by over-watering, while other parts got no water at all. Bad grading, or no grading, generally caused an expenditure of more money and labour in the application of the water than if the land had been properly graded, so that a good preparation of the land would result in economy, not only to the supplier of the water, but also to the user. It seemed to him that this development was a valuable one, and would, in the near future, have an important influence on irrigation, wherever it could be put into use.

Mr. M. Elliot said Mr. Grant had given some definite knowledge of the amount of water required for the effective irrigation of land at Mildura, which was a step towards acquiring information on a very important part of the system of irrigation.

From the figures submitted, it appeared that at Mildura 2½ ft. per acre irrigated were pumped into the channels during a period varying from 115 days to 162 days during the year. This meant that each cubic foot per minute in channel was capable of providing sufficient water for 1.5 acres in the shorter period, and 2.1 acres in the longer period.

It appeared to him that the figures given in Table A meant that stream in-channel of one cubic foot per minute was capable of irrigating 2 acres during the winter months and half an acre during the summer months. It might be assumed that the plants required no more moisture in the summer than they did in the winter, and that the difference was caused by the excessive evaporation caused by the summer heat.

He was not quite able to follow the tables, as it was stated Table A showed each pumping in detail, while Table B showed the average amount of water pumped over the whole irrigated area. In Table B, on page 56, the average stream in the channel was set down at about 3500 cubic feet, in July and October. The area irrigated was about 6000 acres therefore the ratio was about 2 acres to every cubic foot of water per minute. In the season 1903-4 the average was only half an acre in the summer months. The third set of results were of a different nature. He presumed these were the results tabulated in the statement at the foot of page 49.

Mr. Grant explained that the table on page 49 referred to particular cases on some allotments of 10 acres to 50 acres. This was identical with the third set of results on page 56.

Mr Elliot (continuing) was also at a loss to know the meaning of the vertical divisions in the table of dates of irrigation given on page 57, and would like to know if the plants received only one watering per month or thereabouts, and if such were sufficient.

From Mr. Grant’s figures it appeared that about 25 per cent. of
water was lost in transit, and as Mildura was a fairly compact area, and as the channels were partly coated with concrete, this percentage would be under the loss common in irrigation areas.

It would be interesting to follow up these investigations, so as to put the results in some form to apply to general use.

He presumed that the irrigation carried out at Mildura was chiefly furrow irrigation, and that the figures stated would not apply to flush irrigation, with check banks placed anywhere. In which case the consumption of water would be considerably increased.

Mr. Grant advocated a system of supply by measurement, which had much to commend it, and only one disadvantage—viz., the cost. For general information the cost of the meters and the cost of constructing the pits should be given. It was evident that only sufficient meters would be required to go round. The saving in disputes and cost of administration would be considerable, and the saving in consumption of water would be very remarkable. The measurement system would also place all users on an equal footing, and necessitate the greatest economy to be used in irrigation.

Mr. Grant had mentioned that the cost of pumping at Mildura amounted to £50 per day. It would be interesting to know how the amount was made up, as Mr. Grant gave the impression that the cost was in proportion to the days worked. No doubt this was so, but it would not make a difference of £50 per day whether the pumps were worked or not. The cost, as remarked by the President, appeared to be high, and required some explanation. It would also be interesting to know the cost of bringing the land at Mildura into an irrigable state, and the working cost per annum, also the cost of planting and working a specified area, and the average return from such area.

He was afraid this information was not exactly within Mr. Grant's sphere, and therefore he did not press the questions. He would be glad of the information if it were available.

A little history of Mildura would be valuable, as it appeared to him that the whole system of cultivation had been changed since the inception of the colony. It appeared to be somewhat of a mystery to some why Mildura had not made greater progress. The colony was a bold step in the first instance. To establish a horticultural colony by aid of irrigation, in the position of Mildura, having hardly any access to markets, was an act hard to understand. It was evident the colony had had a hard, uphill struggle, and they deserved every encouragement.

To establish closer settlement by irrigation in Victoria was no mean task. The difficulties against cultivation by irrigation were seldom mentioned; but they were by no means inconsiderable. The system was the antithesis of that under which agriculture was usually carried out. If irrigation could be carried out from the back of a horse going at a good pace it would be more popular. Such individuals as undertook the work had to find out their own methods and work out their own system. After ten years' experience the irrigationists were beginning to understand how to go to work.
Beside the want of knowledge and previous experience on the part of the people themselves, there was no definite path marked out as to what was to be grown by the water, as the local markets were decidedly limited, and there was a long journey to others. He thought, with Professor Kernot, that the public were entitled to know something of the position. One would think that after so much money had been spent it would be possible to say what would be the probable return from 100 acres of land. At the Irrigation Conference held in Melbourne in 1890, he had recommended that areas in each district be worked as model areas by experts, from which exact information could be obtained. Nothing had been done in the matter, and anyone intending to irrigate had to pick up information as best he could.

So far as one could judge from outside views, the prospects of Mildura were very much improved, and but for the unfortunate hot winds of last year the outlook would have been bright.

If Mr. Grant could supply them with the cost of the meter, and the cost of measuring outlet, it would be an advantage, because any system of irrigation would only require sufficient meters to go round. If the meter system in Melbourne were abandoned, he did not think the Yan Yean supply would hold out a single season. He had known, in the case of country towns, the water supply go up to a consumption of 300 or 400 gallons per head per day. The supply of the meter to irrigation systems would have the same effect as in household consumption. He thanked Mr. Grant for the trouble he had taken, and wished him every success in his endeavour to establish a system of accurate measurement of water.

Mr. Garson said he had read with much interest Mr. Grant's instructive paper on "Irrigation in Mildura." He thought Mr. Grant was much to be commended for the great care with which he had prepared his statistics. It was most unsatisfactory to find that so little had been done to systematise irrigation results, both in this country and America. Mr. Grant had submitted figures which showed the average depth of water used for each irrigation to be about 8 in., including loss in channels, or about 6 in. actually used on the fields. This, he thought, would compare favourably with irrigation in any part of Victoria. No doubt with a careful system of measurement, it would be improved upon. It might be reduced to 4 in. in the Goulburn Valley and other parts of the Murray River Basin. The introduction of a general system of accurate measurement was urgently required, and Mr. Grant was to be congratulated on having introduced what appeared to be a serviceable meter. It possessed two great advantages—1st, that it worked with a very small loss of head, about 2 in. only; and, 2nd, that it recorded directly the quantity of water delivered, and thus obviated the necessity for making computations. Besides economy in water, the direct result of accurate measurement would necessarily be that more attention would be devoted to the question of how much water was actually required, and it would be applied more scientifically.

The paper also referred to the subject of proper cultivation.
There was no doubt that this was an extremely important matter in connection with irrigation. This, and the preparation of the land for irrigation, were matters which had been very much neglected. He spoke more particularly of gravitation areas. He had not had an opportunity of seeing Mildura methods, but in other parts of Victoria little or no attempt had been made to prepare the land for irrigation. The character of the soil, the crops to be matured, and the moisture in the ground at the time of applying the water, were all factors to be considered when determining the quantity to be applied. At present the method was haphazard. The main object of irrigation seemed to be to get their land well covered. He had seen as much as 2 ft. of water on a field, where 6 in. would have given better results. A powerful stimulus to improved methods would be given by the allotment to irrigable lands of water rights of stated volumes at stated prices. The farmer would then have to get the most he could for his money. As Mr. Coane had remarked, probably only about one-fourth of the irrigable land of Victoria could be irrigated. It was evident, therefore, that strict economy should be practised to enable the largest possible area to be brought under irrigation. Water rights, of the character mentioned, appeared to him to be the basis of all advance in economy. There would be a strong inducement to make water go as far as possible, if a man knew he could only have a certain quantity. So long as water was applied, as at present, without measurement, it would be used wastefully, and to little advantage. Labour skilfully directed was the key to success in irrigation, as in all departments of business. The irrigation engineer could, by bringing his skill to bear on the subject, do a great deal to assist irrigation. Besides constructing works, and attending to the proper distribution of the water in the channels, so that it shall be supplied to the irrigator in the most convenient manner, and without waste, he could point out the best methods of applying water, advise as to the quantity to be used, and generally assist in placing the whole practice of irrigation on a more scientific basis. In a country like Australia, with its limited water supply, economical methods were more necessary than in countries where water was more abundant. He had no misgivings about the future of irrigation, though its progress might be slow. The main thing was to go on sound lines. One of the directions undoubtedly was the systematic and careful measurement of all water supplied for irrigation, and the recording of results, so that we might have a more reliable basis of facts to go upon than at present.

Mr. R. T. McKay, Secretary of the recent Royal Commission on the Murray waters, was introduced by the President, and said that he had arrived from Sydney that day, and had much pleasure in accepting Mr. Coane's invitation to be present at the meeting. He had come to the meeting to listen, and regretted that he did not have an opportunity of reading the paper, especially as he had taken considerable interest in the questions of irrigation and Inter-State rights in connection with river waters. Mr. Grant had done a great deal in regard to the question of measurement, and the meter he had
invented would be of great benefit to those who desired to practise economy in the use of water. When the Inter-State Commission was dealing with the matter, they endeavoured to get information from the farmers of Victoria and South Australia, regarding the quantity of water used, but nothing of a definite character could be obtained. The farmers knew they flooded the land, but could not say whether they applied six inches or six feet; in fact, their ideas were very vague indeed. Many of the Trust engineers had also very little information on this important point.

On the passing of the "Water Rights Act" of New South Wales in 1896, the right to the use, flow and control of all streams, whether perennial or intermittent, flowing in a natural channel, became vested in the Crown, with the reservation that the occupiers should have the right to use the water on their frontage for domestic or stock purposes, or for gardens up to five acres in extent. He had observed that Mr. Swinburne's Bill contained a somewhat similar provision.

In glancing through the paper since coming into the room he noticed that Mr. Grant stated "the legal water right for Mildura lands is 2.03 feet of water diverted from the river." Seeing that we on the other side of the border claim the whole of the Murray River, from its source to the South Australian boundary, to be within the territory of New South Wales, he was at a loss to understand how a legal right could be conveyed to the people of Mildura. He hoped it would not be long before the politicians settled the Murray question in some definite form on a satisfactory basis to the States concerned, because the longer it was delayed, the more complicated it became.

Victoria is apparently solving the problem to her own satisfaction by making full use of the river waters. She is establishing certain prescriptive rights, and when the matter is ultimately decided, it will be well nigh impossible to deprive the irrigators of the rights they have enjoyed for so many years.

He fully appreciated the manner in which Victoria was going on with her works, while the New South Wales people were talking about it. The Murrumbidgee scheme, involving the construction of a reservoir at Barren Jack, would shortly be submitted to Parliament, and he trusted that it would not be many years before New South Wales was making full use of her Murrumbidgee waters. They had also some splendid irrigable land fronting the Murray, but the matter was one involving Inter-State politics, because a storage reservoir which would submerge lands in New South Wales and Victoria must necessarily be the result of joint action between those States.

Although Victoria was much ahead of the other States in regard to water supply, mistakes had undoubtedly been made in connection with Trust administration and other matters, and New South Wales would be able to profit by such experience. Mr. Garson had spoken of the great extent of irrigable land in Victoria, and, of course, that also applied to New South Wales and South Australia. There were 43,000,000 acres of irrigable land in the three States, and it would be impossible to supply water to more than a very small portion of
such land. In the projected Murray and Murrumbidgee schemes they could not hope to supply irrigation to more than one acre in seven. Some provision would necessarily be made to provide a minimum of irrigation during dry periods, and the drought years of 1902 and 1903 had quite upset all calculations as to what should be done.

The great difficulty in any scheme where abnormal conditions must be considered would be to know the time to stop the maximum supply, and to give the irrigators the minimum quantity of water. A great hardship might be inflicted on the people just at the time water was needed most. A delicate adjustment would be necessary to place this matter on a satisfactory basis.

Some time ago he had been much impressed by the value of sub-irrigation at North Yanko. Sir Samuel McCaughey's orchard was excavated to a depth of about 5 feet, and about 18 inches of river sand placed in the bottom of the excavation. The earth was then replaced, and the orchard completed. Although the trees have only been planted about three years, they have shown wonderful growth, and the other day Sir Samuel gave him some navel oranges, larger and finer than anything he had seen in Australia. Surface irrigation is not permitted, the moisture being supplied to the sand beneath the orchard.

It would be interesting if experiments were made in Australia to know the least quantity of water necessary to produce certain crops. He thought they must go to California to see the greatest economy practised in the use of water, the valuable commodity being handled with the greatest care. During the dry seasons of 1897 and 1900 orchards were maintained by proper tillage, in an efficient condition, on the minimum supply of 7 inches per annum. This figure was very different from the quantity of water supplied to the Mildura irrigators.

Mr. Grant had referred to the classification of the land. It was important that the fullest information be obtained in connection with the soils of any area proposed to be placed under irrigation. He thanked the President for the opportunity of being present and taking part in the discussion.

Mr. J. A. Smith asked, in connection with the meter itself, if Mr. Grant had tried the effect of adjusting the meter with its axis in a horizontal direction. It would necessitate a small pair of mitre wheels, but if there were no conditions that prohibited it being placed in that position, it would simplify the construction considerably. It would do away with the diaphragm of brickwork, and also the pit shown in the illustration, a simple perforated plate across the channel being substituted. Perhaps there was some reason why this might not be admissible. If so, it would be interesting to have it.

Mr. Coane asked if hose irrigation had been introduced in Mildura. Perhaps it was not within the knowledge of many people that some of our most valuable lucerne irrigation was done by means of hoses, on the principle adopted by Bacchus Marsh. The hoses were made of calico, about 2 ft. wide, in long lengths, and these
DISCUSSION—IRRIGATION IN MILDURA.

took the water over very considerable depressions, and delivered it to high points of ground very successfully. Two gentlemen from New South Wales had recently been there, and seen the methods, and proposed to adopt them. The map of Mildura showed large undulations, and it would appear that the hose irrigation system might be of great use in the saving of water. For the Bacchus Marsh land referred to a rental was being paid of up to £8 per acre for eight months of the year. This was irrigated with calico hoses. It was the most valuable lucerne land he knew of in Australia. He would like to know if that had been done in Mildura.

The President said the system had been used in Queensland very largely. The hoses used were about 6 or 8 in. in diameter, and were used in connection with the pumping system.

Mr. Grant said that, before replying to any of the queries raised by members, he would like to say that the paper had not been written from an historical point of view. He took Mildura as it at present exists; and prominence had been given to figures in regard to the quantity of water now actually used. A good many points had been raised as to the progress of Mildura, the success of irrigation at Mildura, the cost of pumping, etc., which he had not referred to, but upon which he could supply rough figures when dealing with the questions raised.

The first query was that raised by the President, who stated that £50 per day seemed a large sum for the pumping required for the comparatively small area of Mildura, although the soil was largely of a non-retentive character.

The £50 per day mentioned in the paper did not mean an expenditure of that amount per day for 365 days in the year, but simply the pumping and distributing expenses for the number of days on which the pumps were worked. It did not include office expenses, sinking fund, or interest on loans. With regard to the cost, £50 per day covered the cost of irrigating about 200 acres, so that the figure was, roughly, 5s. per acre. The depth of an irrigation was, roughly, about 8 in., so that the cost per inch acre was something between 7d. and 8d.

The next point raised was as to whether Mildura was progressing; whether the area under cultivation was increasing, or whether Mildura was going down hill.

The diagram on the blackboard showed the acreage under cultivation. In the year 1894, about seven years after the starting of operations, the area under cultivation was 8225 acres.

From 1894 to 1899 Mildura was on the down grade. It was not until 1899, three years after the time of the formation of the Irrigation Trust, and about the time of granting of the loan by the Government, that the situation began to improve. Since then the area under cultivation had steadily increased, until the area now under cultivation, including hay crops, was 8583 acres. The largest area irrigated in one year was 8719 acres, in 1903. The increase in planting was mainly in vines. The other products had fallen off. Vines and lucerne were the only products that had increased. The re-
planting for the five years had been at the rate of 500 acres per annum; and it could be said that in 1905 there was a larger area of trees and vines under cultivation than ever before. The present increase was at the rate of about 200 acres per annum.

Mr. Craven had also raised a point in connection with this. He was a member of the Railways Standing Committee, and pointed out that Mildura people, when getting the railway, considered they would be sending down a great quantity of green fruit. Mr. Craven had probably taken the figures given in the paper to show that, as there had been a decrease in trees, there would consequently be a decrease in the amount of green fruit to be sent to Melbourne. But the decrease in trees was mainly owing to the uprooting of those planted in unsuitable soil. The amount of citrons forwarded by rail last year was 2000 tons, and a considerable quantity of fresh grapes were also sent to market. At present there were thousands of tons of citrons in Mildura, waiting for a rise in the market.

The President had referred to the power of absorption and retention of moisture by the soil. He stated that the more nitrogen the soil contained, the more efficient it became in the retention of moisture. There were very valuable figures with reference to this point in the returns of the Department of Agriculture of America; these gave a series of figures showing the total amount of water required to produce a ton weight of each kind of crop. These figures were very interesting. They could be found in the publication of four years ago; and probably have been followed up more exhaustively since then. The power of the soil to retain moisture was due to two causes. The more humus there was in the soil, the better it retained the moisture. A sandy, loose soil was also capable of being kept in a good state of tilth, which prevents evaporation from the surface. The pine soils in Mildura did not use any more water than the stiff, hard soils. In fact, the pine soil was more economical.

On the pine ridges which run through Mildura, shown on diagram, there was to be found a depth of several feet of sand, which gave
great possibilities of wasting water. In such cases large quantities of water were wasted on the land, and no damage was noticeable until, a year or two later, the water could be seen issuing from the foot of the hill lower down. In this land the water frequently percolates so deep that the vines and trees received no benefit from it. But, by using the water economically, the bulk was made use of by the plants. The capillary attraction was sufficient to draw the water up from a depth of several feet, and in this way the sandy soil was more efficient.

Mr. McKay had mentioned a case in which a minimum amount of water (about 7 in. in one year) was used on some land. He had seen a somewhat similar case quoted in the American returns, where an instance was given of dry farming. No irrigation was available, and the rainfall was only about 2 in. per annum. This, however, was assisted by the dews. The land was kept constantly cultivated, and the dews deposited on the well-tilled surface were equal to several inches of rain per annum. In Mildura he had known cases where sultana vines had carried through in one heavy watering, so that, in cases of necessity, the loose, pine soil, which was generally credited with being very extravagant in the use of water, could carry through on very little.

Mr. Garson had remarked that, before irrigation could be brought to an exact science, it was necessary to know the requirements of the soil. It should be known how much water was required, in order that the proper amount might be used. In Mildura the people were allowed to take what water they considered sufficient, with the saving clause that, if there was any decided waste, the water could be cut off. In addition to being engineer to the trust, he had control of the water distribution, and was supposed to say to any irrigator to whom he considered it necessary, "You have had sufficient water; we will shut it off." There was not a man in Mildura to whom this could be said without being contradicted. The fruit-grower would say, "You do not know as much as I do about it." The only way to educate irrigators in the proper use of water was to charge them for what they used. A clear instance of this came out in the individual measurement shown on page 49 of the paper. He (the speaker) went to read the meter in the evening. The owner of the land was there. He was asked if he considered he had had sufficient water. He replied, "No; there are some patches on my land that are not wet." The water was then allowed to run for another night. In the morning the owner said he had had sufficient water. The meter was read, and it was seen that 1 3/4 in. of water had been used over 10 acres during the night to soak the small patches which were not wet the night before.

Mr. Garson had also remarked the preparation of the land for irrigation, and attention afterwards, was an important item. That was the case. There were certain lands in Mildura which would take 10 in. in one watering at present. He could put a man on to those blocks, and water them as efficiently with 5 in., if the land were properly graded, and provided with ditches. So that the system of
Mr. Coane had referred to the extension of irrigation in dry and arid country being more easily brought about than in countries where the rainfall was sufficient to produce results of a kind. This was perfectly true. If a view were taken of all the irrigation schemes of Victoria, it would be found there were large head works. There had never been any complaint that he knew of against the efficiency of the works. From an engineering point of view, the works were probably well designed. But the irrigation did not extend, consequently the rates were not forthcoming to pay for this expenditure, the result being the writing off of enormous liabilities in connection with irrigation trusts. It was not a matter of engineering efficiency, but a question of making regulations which would compel people to take advantage of the water provided.

Mr. Coane had also referred to flat grades in connection with the Mildura channels. In Mildura, as was shown on the diagram, the water was pumped first of all into a lagoon, then into a channel on a 50 ft. level, and then a third time to a 70 ft. level, and traversed the whole country to the point indicated on the diagram. The water travelled from the river to the far end of one main channel, about 23 miles. More land was commanded by having the grades flat, but it would be more economical to lift the water another few feet, and double the grades of the channels. Flat grades added to the expenditure, especially where concrete lining was necessary. The expense, not only of lining channels, but of cleaning and maintenance, was much greater with a large channel on a flat grade. There were 170 miles of channel in Mildura. Of this about 70 miles, now on a grade of 6 in. per mile, could have been put in at 12 to 18 in. per mile, and a saving made not only in first cost of construction, but also in maintenance. The cleaning of the large channels was a very heavy item of Trust expenditure. They used to spend £850 per annum for channel cleaning. But recently it had been found that they could not continue the system of channel cleaning in vogue—viz., the work being done by hand with a shovel. They therefore tried machines, and found that the cleaning which used to cost 2s. 3d. per chain, could now be done for about 6d. They saved from £200 to £300 per annum by the use of the machines. It was a modified reaping machine. The machine ran along the bottom of the channel, and the knife cut up the slope. For the top the machine ran along the bank, and cut downward. This left a certain amount of stubble, but they found that weeds cut by the machine died off much more rapidly than when cleaned with a shovel. When cut with the machine, the second growth was weaker, and gradually died out.

Mr. Fyvie asked whether weeds or silt caused the greater trouble?

Mr. Grant said there was very little trouble from silt. For the past two years they had only spent about £50 on silt. They had some trouble with sand drift.
Mr. Coane had referred to the amount of water diverted in the American systems of irrigation. This was given as 5.47 ft. If one looked into the details of the diversions, it was no wonder that the figure was high. One of the instances given in the departmental records stated that the water in one channel was turned on, and allowed to run six months. As it had not reached the other end of the channel in that time, it was not considered good enough for use!

Another important item, and one which must certainly be brought about, was the electrification of the Mildura plant. They had at present four pumping stations. Previously to the present year they had five. But this year they had combined two lifts into one. The four stations which remained were situated almost in a straight line. The whole of them could be driven electrically from one station on the bank of the river. The pumps at present on the station could be utilised, and the driving could be done by one main wire or cable extending over the whole route from the river bank to the further station. They would have the advantage of cheaper driving, fewer men in attendance, and also cheaper fuel. To have one central station on the river bank would mean a saving in fuel of, say, Rs. 6d. per ton on 7000 tons per annum.

As regards the meter, Mr. Coane had raised several points. One was as to the angle of the blades, and whether those blades could not be made a fixture. In carrying out the experiments as to what accuracy could be obtained, adjustable blades were used, but for practical purposes of registration, the blades would not be made adjustable. They would be made fixtures, so that they could not be interfered with.

On the same question, Mr. Smith had asked if it would not be possible to have the fan vertical, with its axis horizontal. That would necessitate placing gear wheel under the water, and one of the main advantages claimed for the meter was that there was no driving part immersed in the water. If immersed, it would very quickly clog, owing to the dirty state of the water.

Mr. Elliott had mentioned the question of cost of establishing the meter in a system like Mildura. He could not give accurate figures as to the cost, because this depended on the size of the order. To manufacture one meter would be more expensive than to place an order for 500. To establish the system of measurement on 8000 acres, mainly in 10 acre blocks, would involve an expenditure of, roughly, about £3000. The average cost per outlet would be about £3 10s. The reason why the cost was comparatively low was that the meter was portable. Each outlet would be provided with a fixed pit, but the meters could be shifted from one stream to another. In watering Mildura, they handled a stream of 4500 cubic feet per minute. This was split into 60 irrigating heads, under six water gaugers, so that each water gauger looked after ten streams of water. If they had 20 meters in each section, these could be shifted from one pit to another, and in that way about 200 meters would be all that would be required for Mildura, with 800 outlets.
Mr. Elliott had raised a point as to the duty of water in different pumpings. They pumped a stream of 4500 cubic feet per minute. That stream irrigated 8500 acres per annum, and the number of days' pumping depended simply on the seasons. So that to state the duty of water in that way was misleading. While they pumped a stream of 4500 ft. per minute, they found the whole was required to get through the watering of 8500 acres within the period beyond which trees could not go. All products that were grown in Mildura required water at certain periods, and 5000 cubic feet per minute would be ample for an extension of Mildura to, say, 10,000 acres. He thought they might state the duty of water as two acres per cubic foot per minute. It required a considerable amount of working out to find the quantity of water used annually.

Mr. Mountain said the figures given allowed for soakage. There would not be nearly so much water required if the channels were tight.

Mr. Grant (continuing) said the quantity mentioned was the amount pumped, and included what was lost in the channels. There was a heavy loss in the channels, but it was difficult to say what the amount was. He would not be prepared to say whether it was 15 per cent or 40 per cent. The figures simply showed the total amount of water pumped, and the amount used in three cases. The information they had was not sufficient to go on, and he did not know of any case where there was sufficient evidence to say what the loss in the channels was.

The figures as to the cost of bringing the land into a fit state for cultivation he could only give roughly. Mallee or pine land might be fenced, graded, cleared, and planted and cultivated for four years for something like £50 per acre. To this must be added cost of purchase. After land had been planted for about four years, it would, at present prices, give a return of £20 to £30 per acre.

It had also been asked by Professor Kernot why there should not be a large increase in the area under irrigation. Why should there not be several Milduras established on the river bank? The reason was that the market was limited, and people could see ahead too clearly to plant to an unlimited extent in the same way that Mildura was planted. It would not do to have forty or fifty Milduras, unless we had a corresponding increase in our population, or a great diversity of products.

Mr. McKay had mentioned that the whole of the River Murray was in New South Wales land, and he could not see why the Victorian people claimed a legal right to the water. He did not know whether they had any legal claim or not, but he thought the fact that the scheme had been in existence so many years, without objection, entitled them to the water right.

Mr. McKay had enquired if any measurement had been made with a view to ascertaining the loss of water in distribution. They had found the amount pumped and the amount used in certain cases, but there was not sufficient evidence to say what the total loss was. But if the system of measurement were adopted, they could
then say what the loss was. Until then, it was merely guesswork.

The only other point raised was the question of hose irrigation. He had not seen this carried out at all. But there were several cases in which he thought the system would be of great advantage in Mildura. At present they had places where they made fills-up to 5 or 6 ft high. A good hose would stand that pressure.

In reply to a query as to the deflection of the spindle of the meter, Mr. Grant said the spindle hung vertically, and before the water reached the orifice plate there was a depth of wall which was increased with the size of the meter. In watching very closely the flow through the meter, he had noticed the water rise almost vertically. It surged up a little at the top, but there seemed very little tendency to deflection of the spindle. The flow was, as far as could be seen, truly at right angles to the orifice, and if there was any deflection at all, it was not enough to cause any inaccuracy in the registration. He thought there would be no more difficulty in the case of larger sized meters than with small ones. As to rounding off the corners of the pit, he did not consider that was necessary; the angle of the fans was fixed under known conditions, which could be reproduced in different sizes of meters.

The grating on the outlet was for the prevention of interference with the meter. The grating was made with two deflections in the angle, in order to prevent the thrusting of a stick or wire through, and thereby interfering with the meter.
DISCUSSION ON IRRIGATION IN MILDURA.

Contributed by Mr. J. T. N. Anderson.*

After congratulating Mr. Grant upon his paper, Mr. Anderson writes:

"I only regret that Mr. Grant's opportunities have evidently prevented him from giving something of the history of the Mildura Settlement, and throwing some more light on the results of the strenuous efforts which have—I trust, permanently—saved the best of the works which in 1894-5 were left by the founders (Messrs. Chaffey Bros.) to what subsequently became the first Mildura Irrigation Trust.

1st. On the question of water measurement in Mildura.

"The ordinary practical methods adopted in the irrigation States of the United States, and in most mining countries, were instituted by Messrs. Chaffey Bros. The chief reason why these were not sufficient for the needs of the settlement was not due to inaccuracy, but simply that, under the control of a popularly-elected body, methods which are economical and practical enough under individual control are often impracticable, because they depend so much on personal judgment, and, consequently, they must give place to the more expensive mechanical methods.

"On the question of accuracy, I have before me a large number of records, taken by various Mildura rangers and by myself, on the rule-of-thumb method, and I have checks on these by weir measurements, by current meter measurements, and by the constant balancing of returns, such as comparing the computed discharge of a main channel with the combined discharges given by other observers of its various distributories, and I find that the majority of these results come within the limit of accuracy Mr. Grant claims—2 per cent. This fact is the better established because, during the whole three years that I was connected with Mildura, I strenuously fought for the mechanical automatic measurement of water, and for a long time I refused to believe in the accuracy of the Chaffey's methods.

"My personal bias will be inferred from the fact that it was I who wrote the specification and made the plans for the first Galopin self-recording gauge, described by Mr. Grant on the 51st page of his paper, and that I trained others to use the current meters in accordance with the admirable system which has been so completely developed by Mr. Stuart Murray (the Chief Engineer of Victorian Water Supply) in

* Mr. Anderson's contribution arrived from New Zealand after the general discussion had been closed.—[Publication Committee.]
the gauging of the rivers and streams of the State. After the completion of my works in Mildura I encouraged Mr. Galopin to visit the settlement in connection with the matter of gauges, which has, I believe, since been successfully carried out. Under these circumstances, my admission of the accuracy of rule-of-thumb methods in the hands of competent observers will, I trust, be taken as of some weight.

2nd. Quantity of water required.

"I regret that Mr. Grant has not dealt with this, which is, after all, the most important question, in a broader and more comprehensive manner. No doubt, experience in Mildura, where there is not such a great variety of crops, and those crops which require the heaviest watering are of very limited extent, would lead one to do as Mr. Grant has done, and lay most stress on the climate and the quality of the soil as factors in determining the depth of irrigation necessary; whereas the great factor is the crop. The recognised standard works will be found to give the depth of waterings needed for such main crops as cotton, rice, and wheat.

"One of the most discouraging facts to one hoping to win kudos by closely observing the results at Mildura is to find that, after months of labour, he has got nothing more than the fact that, notwithstanding all the factors, such as a sun-heat greater than is ever recorded in the northern hemisphere, exceptionally dry winds, and sandy soil, yet the quantity of water required does not vary appreciably from the records in America, Spain, or Italy. A strong confirmation of my statement to this effect can be gathered from the 50th page of Mr. Grant's paper, where he shows that the average measured quantity of water used in Mildura is identical with that set out in the original deed, referred to by him as 'legal quantity of delivery, 1.62 feet.'


"I have naturally followed the history of the expenditure on these works with close interest. The latest return, however, which I have tabulated, was that for the year ending 30th June, 1902; but later results show that the measurements over the Galopin weir on the main channel, and the estimated result on the No. 9 pump to the 92-foot channel, the combination which gives the 8000 acres referred to by Mr. Grant, gave during the October-November watering in 1902 a depth of 7.36 inches. This, taken with Mr. Grant's returns, and the height of the river, which I had occasion to collect from the Argus, has enabled me to draw a comparison with the results obtained before the channel lining work, to which so much of the loan expenditure was devoted, and the results obtained since. The result of this comparison leads me to infer that the saving in water has been about 10 per cent. Thus the average discharge required to satisfactorily serve the 8000 acres used to be 4000 cubic feet per minute; now apparently 3600 cubic feet per minute suffices. Of course these figures do not admit of absolute comparison, because the rainfalls were different, and there was a difference in the area served. At the same time, no doubt, this fairly well represents the results of the channel lining. The estimates were
made in 1897 for the loan works, allocating £44,700 between channel lining and the improvement of machinery. It is unfortunate that the former was given the lion's share of the loan, because, while the saving estimated, and since realised, represented considerably less than 10 per centum per annum on the capital expenditure, the estimated saving on the cost of pumping, due to the alterations proposed, was over 25 per cent. per annum. With a judicious expenditure of a fair proportion of the loan on machinery, the £50 a day spent in developing barely 1600 i.h.p. for pumping should have been reduced to less than £40 per 'diem.'
Author/s:
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Title:
Irrigation in Mildura (Paper & Discussion)

Date:
1906

Persistent Link:
http://hdl.handle.net/11343/24343

File Description:
Irrigation in Mildura (Paper & Discussion)