Tanks and Wells of New South Wales, Water Supply and Irrigation.

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The necessity for a liberal consideration of the question of water supply for the dry districts is of such rapidly increasing importance to those districts and to the Colony generally, that the time has arrived for active steps to be taken to obtain, by actual survey and observation, the data necessary to determine the best means to be adopted to conserve and distribute, in an economical and effective manner, that portion of our rainfall now carried off by our river systems and discharged into the ocean, conferring but little benefit on its course; though running through districts where the soil only requires its invigorating agency to produce in abundance any vegetable growth suited to the climate.

In framing this paper I have divided the subjects to be dealt with into two sections:

I.—Water supply for stock routes.

II.—Water supply for irrigation.

This course is advisable for two reasons: because the works to be dealt with, that have up to the present time been carried out by the Government, have been solely for the improvement of the stock routes; and because the important works necessary on these routes cannot generally be brought within the scope of any scheme having irrigation as its main object. Isolated cases may occur where watering-places could be provided for in this way, but as a rule it will be found that the supply for this purpose must be obtained from works complete in themselves, and constructed solely with a view to meet the requirements of stock traffic. This is a necessary consequence, inasmuch as stock routes are laid out to afford the best and shortest practicable connection between the terminal points, and without any reference to those differences of level that would prevent their being introduced into a general scheme of water supply. Cases might occur where points on such routes could be supplied from the irrigation channels, but such points might not be suited to the general division of the watering stages along that route.

The stock routes of the Colony have an important bearing on pastoral industry, and deserve greater attention and expenditure in opening and improving them than they have hitherto received. Much may have been done, but very much more remains to be done before they can be considered efficient in facilitating the transmission of stock. They are the only avenues from the pastoral districts to the consumer, and from one pastoral district to another. Properly watered and managed they would be invaluable as affording a certain outlet to the markets, and also as a means of reducing to some extent the enormous losses that so often overtake the sheep-farmer during dry seasons; for at such times he would have the chance of removing some portion of his stock to more favoured localities for water and feed. It has unfortunately been the case that, even when improved, these routes have not been of as much service as is desirable. This is to be attributed to the long intervals separating many of the works that have been constructed for watering purposes; to the defective maintenance of many of those works; and to the defective conditions regulating grazing on the stock routes. When it has been determined to water any stock route, arrangements should be made to construct all the works necessary to complete the chain of communication, instead of constructing watering-places that, until that chain is complete, can only be rendered available at considerable loss and injury to travelling stock, or when the long intervals separating them are bridged by natural supply, at which time there is but little need for the water that has been artificially conserved. It is unfortunately often the case that many of these routes are practically closed, by want of feed, even when plenty of water is obtainable; and it is a matter of great importance that this evil should be remedied as far as is practically possible, and measures adopted to make the stock routes of sufficient width, to withdraw them from lease, and protect them from being grazed on by other than travelling stock.

In the year 1869, the Government first practically recognized the necessity for constructing watering stations on the stock roads, and a sum of £5,000 was then voted by Parliament for works on the Booligal and Wilcannia Road, and handed over to the Roads Department for expenditure. At that time no works of a similar nature had been carried out by the Government; and this, combined with an imperfect knowledge of the character of the country to be dealt with, led to a course of action being adopted which, however suitable it might have proved under different circumstances, required considerable modification to adapt it to the existing conditions of the question. The primary object was to obtain water by sinking, and with this view a boring plant,
consisting of the ordinary rods and bits, was sent on to the ground, to test the nature and depth of the strata and the quality of the water to be procured.

The preliminary borings were commenced on the 1st October, at the Jumping Sandhill, about 30 miles north of Booligal, and were completed at Mount Monahra, about 120 miles from the same place, in January 1870. The camp was then broken up, as there was no water on the "Death Track" between there and Wilcannia, a distance of 80 miles. To have carried out the works along that line would have necessitated a very heavy expenditure for haulage of water. In addition to this there were other reasons for suspending operations, chief of which were the difficulties experienced in obtaining and keeping efficient men; the high cost of labour, and the comparatively small depth to which the borings had to be carried. This latter cause had a most important bearing on the question, for it was found that the time occupied in shifting a large camp and plant from one site to another, and in making the preparatory arrangements for boring, raised the cost of the work to a great extent; had the drifts that were tested been deeper seated, the borings could have been carried out at a proportionally less cost per foot. The experience gained during the work was wanting at the outset; but, though it can now be seen where mistakes were made and unnecessary expenditure incurred, it must not be forgotten that the Department acted for the best and carried out the work under very considerable difficulties, further, that the experience gained, though perhaps rather costly, has been of much value and an eventual source of economy.

Looking back at those early efforts, there can be little doubt but that the better plan to have adopted would have been to have made a preliminary examination of the district in the first place, ascertaining how far it had been tested by works carried out by the Crown lessees, gaining information as to the depth and character of springs in existing wells, their positions, and the cost and character of works best adapted to the object in view. Sites could then have been determined, and tenders at once invited for sinking wells where there was a reasonable probability of obtaining suitable water. Where existing works proved that wells were not advisable, arrangements could have been made for works to conserve storm waters; and in case of the surface features being unfavourable for tanks, the locality could have been tested for an underground supply by letting trial shafts, and possibly boring from the bottom of them for deeper seated springs, if considered necessary. Day labour would have been avoided in every possible way, for all the drawbacks connected with it in the settled districts were very much intensified in that back country. The works would then have been completed much sooner, and, as the
cost of preliminary operations and of supervision would have been considerably reduced, there would have been a larger amount left for opening the road.

When the explorations were concluded, tenders were invited for the works determined on, and the following tanks and wells were at once put in hand, and completed in 1872:

Well near the Willandra, at Mossgiel.
Well at Ivanhoe.
Tank at Boonoornoo.
Well at Mount Monahra.
Tank at Forty-eight-mile Swamp.

Since these were completed, further sums were voted, which have been expended as shown in the following list:

- Deniliquin to Hay—Pine Ridge—Dam.
- The Gums—Tank.
- Hay to Booligal—One-tree—Tank.
- Quondong—Tank.
- Booligal to Wilcannia—Jumping Sandhill—Well.
- Holy Box—Well.
- Twelve-mile Swamp—Tank.
- Thirty-five-mile Swamp—Tank.
- Wilcannia to Hungerford—Copargo—Dam.
- Peri Sandhill—Tank.
- Nipper’s Creek—Tank.
- Warramurtie—Tank.
- Gambolara—Tank.
- Balranald to Ivanhoe—Box Creek—Tank.
- Youhl Plains—Tank.
- Till-Till—Tank.
- Cobar to Nyngen—Booroomugga—Tank.
- Muriel—Tank.
- Hermitage—Tank.
- Cobar to Bourke—Cobar (Stock)—Tank.
- Cobar (Town)—Tank.
- Nullima—Tank.
- Tindary—Tank.
- Curraweena—Tank.
- Corilla—Tank.
- Two Water-holes—Tank.
- Cobar to Louth—Cutty-gullaroo—Tank.
- Bourke to Ford’s Bridge—Tank.
- Walgett to Bangett—Boro Water-holes—Tank.
- Lightning Ridge—Tank.
- Barwon to Narran—Cumborah—Tank.
- Narrabri to Moree—Galathera—Tank.
- Boggy Creek—Tank.
- Wagga Wagga to Bland—Junee—Dam.
- Wallace Town—Dam.
- Wagga Wagga to Cootamundra—Hurley’s—Dam.
- Albury to Tocumwall—Major’s Water-hole—Dam.

In 1882 a sum of £50,000 was granted for tanks and wells, and arrangements were made for its expenditure on the different stock routes recommended by the Mining Department. This amount was so much in excess of any previous grants which had hitherto
been of a desultory and intermittent character, that it was considered advisable to frame and adopt a more systematic course of action; and with this view, type drawings and specifications were prepared, embodying the results of the experience gained by the officers of the department during the time they were engaged on this duty. This course was considered all the more necessary, as the increase on previous grants indicated a recognition of the growing importance of the question; a recognition which will probably be followed by a development of present operations, so as to include the more important works connected with a general scheme of water supply for irrigating portions of the rich but arid districts of the Colony. A further sum of £53,800 was voted on this year's estimates, which with the amount granted last year, is being expended on tanks and wells as rapidly as possible; but great difficulties have been experienced in getting contracts for their construction taken up, the seasons having been exceptionally unfavourable for these operations. This has in many cases considerably increased the cost of the work; but it was considered advisable in the more urgent cases to carry out their construction at once, even at an increased outlay, rather than delay it to a more favourable season.

The works by which the stock routes have been supplied, or partially supplied, with water, may be divided into the following classes:

1. Wells,
2. Tanks,
3. Dams,
and it will be advisable to deal with them in this order, describing the nature of the conditions surrounding each class, and the operations that have been and are now being carried out by the Government, in endeavouring to construct works that, while economical in detail, will at the same time ensure a permanent supply of water both for stock and human consumption.

1. Wells.

The conditions under which drift waters are obtained, and their important bearing on the settlement of the dry districts of this Colony, give this branch of the subject as great an interest as any with which we have to deal. This interest is, in a measure, due to the difficulties surrounding a satisfactory solution of the origin of, and the varying conditions under which these waters are discovered; but still more is it due to the fact that this source of supply, when the quality of the water is suitable for stock, is at once the most certain and economical means of meeting the great want which settlers in that country have to contend against. So far our experience of the question may be considered as confined to the more shallow-seated and unfortunately non-artesian drifts;
but it is a matter for congratulation that money has been voted by Parliament, and operations commenced, for testing the great west and north-west country for a deeper seated and hoped for artesian supply; should the predictions regarding the existence of such a supply prove well founded, and the water that may be discovered, prove suitable for stock, or still further, for irrigation purposes, it will be almost impossible to estimate the increased facilities that will be offered to settlement, or to assess the increased value of that portion of our territory.

Whether the predictions are likely to be realized appears to be a question that can only be satisfactorily settled by the boring rods. Theorising, though much has been indulged in, has so few well ascertained data on which to build hopes of an ever-flowing, inexhaustible supply, and is opposed by so many ascertained facts proving the uncertainties connected with the discovery of water in the shallower drifts, that we may, if hopeful, wisely be doubtful, till all room for doubt is disposed of by actual test.

Many reasons have been advanced by the advocates of an artesian supply to support their views; amongst others, the mud springs between the Darling and the Paroo, and the height to which water has risen in some of the deeper wells north of the Darling. These are facts, but whether they are entitled to the wide interpretation given to them—whether they indicate general and not merely local conditions—remains to be proved.

The Government Astronomer, in his "Rain and River Observations," for 1880 and 1881, has published some very interesting reports bearing on this question; but it may possibly be found that the deductions he has drawn may be capable of very considerable modification when the conditions connected with the rainfall on the Darling basin are investigated. In his report for 1880 he writes—"Since the rain measures of 1880 and the river measures for the same period are more complete than they have ever been before, it will be worth while to test one by the other. I have before endeavoured to prove that the water passing down the Darling in an average year is only a very small portion of the rainfall, and is in fact very much less than must be available for that purpose after every allowance that can be made for evaporation and vegetation. For 1880 we have the means of testing this question by observations more complete than any which have previously been taken over the best part of the watershed of the Darling, that is the western slopes of the Main Range, where, from the abundance of rivers and creeks, it is obvious that the rain water readily runs off the soil. There are forty-five rain stations, and the mean rainfall derived from these is 20.74 inches; the area included is about 110,000 square miles: all the drainage from this country passes Bourke, in the river Darling, and at this point a daily record of the height of the river is kept, and the mean
result shows that the river has averaged throughout the year 6' 8" above the summer level. The width of the river at Bourke is 180 feet, and the velocity when in flood is rather less than one mile per hour. A few figures which I need not give here suffice to prove that \( \frac{1}{4} \) of an inch of rain over the watershed, or \( \frac{1}{5} \) part only of the rainfall, represents all the water that passed Bourke during the whole year. When full allowance is made for the power of evaporation in a dry year, and for all other circumstances which might prevent the rain-waters reaching the rivers, it is certain that a very much greater proportion than \( \frac{1}{5} \) becomes running water. In such country as that under discussion common experience would give \( \frac{1}{3} \) of the rainfall as the available water, but for the sake of being on the safe side, we will assume that only \( \frac{1}{5} \) of the rainfall becomes running water, and it still represents a quantity sufficient to supply eight rivers like the Darling for the whole year.

"It therefore seems impossible to doubt that an unlimited supply of water passes away underground, more in fact than would suffice to make the whole of the western districts a well-watered country, and all that is wanted to make this supply available is a judicious use of the boring rod."

"In his report for 1881 Mr. Russell further states:—"The evidence is conclusive that the annual supply from rain finding its way into this great natural storehouse is perfectly inexhaustible; it is also certain that as much must find its way out as in, every year, under natural conditions, and the few wells that have been sunk prove that the outlet is so situated that the water is under pressure in the reservoir, and will rise up to or above the surface when wells are sunk into it."

Mr. Russell speaks with no uncertain voice, and as his views have an important bearing on the question of water supply for those districts, both as regards wells and surface conservation, they are well worth our serious consideration.

The rainfall over the Darling basin above Bourke having been determined with more or less accuracy during 1879, 80 and 81, and the mean level of the river at Bourke having been also ascertained for the same years, we are enabled to make a rough comparison of the fall and discharge.

1879.—Mean rainfall... 33'24 inches. Mean river level ... 29'08 feet. 1880. 1881.

1879. 1880. 1881. 1880. 1881. 1881.

The proportional difference between the rainfall and the river discharge for these years is so great that it necessary to try and discover a reason for the discrepancies, and then, if possible, show the connection this may have with the general question—that the enormous proportion of the rainfall, mentioned by Mr. Russell, disappears underground and feeds our waterbearing drifts.
In 1880 and 1881 it will be seen that the rainfall was very nearly the same, yet in the latter year the discharge, which, if there were no disturbing elements, ought to correspond, was only \( \frac{1}{3} \) of what it was in 1880. Again, in 1879, the rainfall, which was 80 per cent. in excess of 1881, was accompanied by a discharge thirty-eight times as great. There must be some reasons for these differences, and as they have an important bearing on the estimated loss by a deep soakage it will be well to consider how they can be accounted for.

In the first place the mean rainfall must be considered, and by referring to the rain maps there appears to be a possibility that this has been over-estimated. These maps show that there are a greater proportional number of observing stations on the eastern side of the watershed than there are on the levels occupying the central and more westerly sections; and as the rainfall is greater on the eastern side, any preponderance of observing stations there must give an excess on the true mean, unless the area composed by each station is made an element in the calculation.

The discharge of the Darling at Bourke also appears to have been incorrectly estimated and to be less than the actual discharge. The estimate is based on the velocity of the river in its normal state, that is, on the velocity when there are no disturbing influences, as when the river is in flood and full for a considerable distance above and below the point of observation. This velocity is estimated at nearly one mile an hour, and, with the cross section of the river waters at their mean level, forms the basis on which the discharge is calculated. If we examine the river curves at Bourke, we find that the floods are in many cases of short duration, forming a series of waves succeeding one another at longer or shorter intervals. This being the case, the normal velocity can scarcely be considered a satisfactory factor, as it should have an increased value when the river is at its higher levels and the water coming down in a wave. This is borne out by Mr. Russell's statement that a flood in November, 1881, travelled from Bourke to Wilcannia in three days—this gives a velocity of seven miles an hour.

The proportion of rainfall likely to become running water must to a great extent be dependent on the features of the watershed. On the eastern side, which is bounded by the coast range, the proportion must be much greater than it is on the levels, where but a very small percentage finds its way into the main channels; and when the rainfall is greatest on the eastern side of the shed, we must expect to find that a larger proportional quantity finds its way into the river, than when contrary conditions prevail. This was decidedly marked in 1879, when there was such a great discrepancy between the supposed mean rainfall and the river discharge, as compared with the two other years quoted. The
conditions under which the rainfall occurs must also have an important influence; the heaviness of the fall, that is, the quantity measured by the time; the intervals separating different falls; and the state of the ground at the time of the fall, whether dried and cracked by summer suns and capable of absorbing largely; or with a close saturated surface capable of throwing off the maximum proportion of the rainfall. Account must also be taken of the enormous bodies of water brought down by the rivers that are intercepted and diverted in filling lagoons, warrambools, swamps and lakes; and that in heavy floods, are thrown back over the level country for scores of miles, and largely retained there when the floods in the rivers recede; retained in shallow creek beds and swamps, when the evaporation is enormous.

These causes—over-estimated rainfall—under-estimated discharge—enormous evaporation on the levels which form the largest proportion of the area of the basin—the loss in filling secondary channels, &c.—and the surface soakage—all taken together, may probably materially modify the results arrived at by Mr. Russell.

It may be advanced that the "surface soakage" just alluded to is the great source of loss, that, percolating to the lower drift beds, is their main supply; but the soakage referred to is of a very different character, and that it takes place to an enormous extent is known to all who are acquainted with the country under consideration. The dry, parched soil, seamed with cracks and fissures, hungrily drinks in the water falling on it, but the impermeable clay beds prevent its descent to any great depth, and the burning summer heats and dry thirsty winds rapidly evaporate the water lying on the surface of the ground, dry the soil, and the moisture carried away from the surface layers is replaced from below by capillary attraction, and exposed to evaporation under conditions which reduce it to vapour much more rapidly than it can take place from a water surface.

That there may be places where large quantities of water find its way underground, to supply the lower drift beds, cannot be positively denied; but that such wholesale percolation takes place generally is very improbable; and if the conditions advanced fail to support the view that this enormous loss by percolation does not take place, then it would be interesting to ask how this large body of water is disposed of; and how far our knowledge of the conditions under which water-bearing drifts are discovered in that country sustains or disproves the assumption that they are so lavishly supplied from the surface.

The geological bearings of the case I leave for those more conversant with that science than I am, but en passant, it would be interesting to ask this question. Where is the subterranean outlet for the enormous proportion of the rainfall that has been and is being absorbed on the Darling watershed above Bourke, if Mr.
Russell's assumption is correct? Is not its escape to the ocean barred by the older rocks that crop up through the alluvial deposits, and that extend from the dividing range between the Lachlan and Darling near Gilgunnia, through Cobar, and running north-erly with some surface breaks, cross the Darling on to the Warrigal? It appears very probable that these older formations must cut off the alluvial deposits to the east of this line from those to the west, and therefore from the ocean, and that consequently the assumed percolation on the Darling basin should be stored locally, and that the increasing storage should show itself in an increasing rise in well waters in that district or in surface springs. But this is not the case. Again, assuming that this rock barrier does not exist, and that the drift beds are continuous to the ocean, we are met by as great a difficulty in reconciling such a discharge to the conditions of the case. A thousand miles of drift must oppose an insurmountable obstacle to a free discharge of water; and assuming that it has an existence, there should be a very perceptible rise in the levels of well waters, more particularly towards the eastern side of the shed and during wet seasons; this is however not the case.

Apart from these views, there are several other considerations that have an important bearing on the case, and that are difficult to reconcile with Mr. Russell's views. Those who have conducted boring operations or have sunk shafts in that country, or those who have watched and noted the work carried out by others, must be aware that in the alluvial country it is very rarely that water is missed at the ordinary depths of the shallower seated drifts underlying those districts; they must also be aware that there are thick beds of stiff impermeable clays passed through before water is obtained; that the water when struck rises to a greater or lesser extent, and then retains that level, independent of either long continued dry or wet seasons. The conclusions to be drawn from these works, which at intervals are pretty well scattered over that country, is that the water-bearing drifts and overlying clays are general. This being the case, how can the extensive soakage assumed to exist in accounting for the small discharge of the Darling as compared with the rainfall on its basin, be accepted as reasonable? Again, if instead of admitting general loss by soakage, we admit that it may occur on a large scale in certain localities, we have to face the same difficulty in reconciling a varying head of supply with a constant level in the wells tapping these drifts. If it is said that this uniformity is due to the fixed level of the discharge of the drifts beds it does not relieve us from the difficulty, for whether the level of discharge is regulated by the ocean level or whether that discharge takes place before reaching it, there must be such an enormous length of drift to be travelled by the water before obtaining an outlet that the back
pressure would be virtually equivalent to a seal. Again, if this constant feeding and escape of water is going on now it must have been going on for ages past, and it therefore appears strange that, as it had been found that brackish surface drifts improve by being worked, that all the brackish elements have not long since been washed out of the deeper drifts by the constant assumed flow through them. The objections now raised naturally point to an old supply for these drift beds—a supply which has remained stagnant and locked up for ages—a supply that is exhaustible with time and pumping plant, and which is so inconsistent with the views held by those who have fondly dreamed of a perpetual artesian flow, that it is not at all likely to be kindly received by them. They have, however, the pleasure of knowing that their theories are opposed only by theory, and this shows the necessity that exists for obtaining, by systematic effort, data connected with this question; until this is done, all efforts to arrive at a satisfactory solution of the apparent inconsistencies which are constantly cropping up will be futile. Mr. P. K. Abbott collected many facts relating to wells in the Liverpool Plains district, and, in a very interesting paper read before this Society, in November 1880, gives much valuable information bearing on the question in that locality. The observations commenced by this gentleman should be followed up in other parts of the Colony, the positions of all works of this character being determined and marked on a map; the level of the drift containing the water and the level to which that rises in the bore or shaft being shown in each case, and the levels reduced to a uniform datum. The strength of supply and quality of the water, with the influence of long continued droughts or wet seasons should also be noted. In the course of time, when the level, above alluded to had been determined over a large area of country it might be possible, if there is any underground flow, to plot a curve giving a value to the head of supply, and the back pressure in these drifts. The general information, when a sufficient amount of it has been collected, might enable the courses of the drift channels to be traced, and save much loss of time and capital in uselessly sinking upon salt-water leads.

In the works constructed by the Government for reaching, lifting, storing, and distributing underground waters, the shafts are slabb'd right through, and divided into two compartments, each 2 feet 6 inches square, by a brattice extending from the top to the bottom of the shaft. The lifting appliances consist of a whim and gearing working two self-acting buckets, which discharge into a timber-framed, iron-lined service tank communicating with the troughing for watering the stock. In carrying out these works, great care has to be taken to have the slabbing thoroughly fitted, and clay well puddled into all spaces at the back of same. Care
must also be taken in having the shaft carried down truly and
having the runners properly fixed, as the smooth working of the
buckets is dependent on attention to these points; while all rough-
ness or jarring in their travel very soon loosens the slABBing and
increases the cost of maintenance. Some of the water-bearing
drifts are very troublesome and difficult to deal with, and in such
cases if the water has a considerable rise, with a strong supply, it
will often be found advisable not to sink to the drift, but to stop
some few feet above it and then put down a carefully tubed bore
to tap the water. Boring can also be advantageously resorted to
in some cases, to avoid the necessity of puddling back water of
bad quality—often a difficult and expensive operation—when it is
underlaid by good water having a sufficient rise to give the
required supply in a shaft sunk to within a few feet of the former.

When these works were just initiated several modifications of
the type adopted were considered by the Department, and amongst
these were:

1. Brick-stein ing in lieu of slabbing. The objections to this
proposal were based chiefly on the increased cost, and on the
difficulty, which in some cases amounted to a practical impossibility,
of obtaining labour and material for the purpose. A modification
of this proposal was also considered, to stone the lower portion of
the well in this way to protect the water from the effects of the
timber slabbing, but it was not adopted, as a composite system
would have been awkward on account of the change in the shape
and dimensions of the shaft that would have been necessary.
The cost and difficulties before alluded to were also, at the time
prohibitory.

2. The employment of masonry and of puddle for service tanks
was also considered, but at the time framed timber lined with
galvanized iron was adopted as being more certain and better
adopted for the purpose than either of the others. Stone is often
far more difficult to procure than timber, and lime or cement
becomes very expensive on account of the cost of carriage.
Masonry service tanks are now being constructed in a few cases
where timber is very scarce and stone procurable close to the
work. Earthen puddle tanks require great care in their con-
struction and in their maintenance; they should never be allowed
to run dry, as if they do they soon begin to lose water; but
where they are attached to wells where a constant supply of water
is available to keep them full, they would, if attended to, prove
more economical than either the framed or masonry tanks; and
as their use would allow of a large storage at a small cost, wells
having a weak but steady supply could in many cases be utilized.
Iron-framed, buckled plate tanks are now being tried, and should
prove more lasting and economical than any other type yet
adopted.
3. The use of pumps in lieu of the primitive whim was also considered and abandoned, as at the time, it would have been difficult to effect necessary repairs, and this might have caused great loss to stock dependant on watering-places where the pumping gear was out of order. The conditions surrounding these works have however altered so much since they were initiated that it is now well worth while considering whether water cannot be raised in a more economical manner than by the use of the whim, which under favourable conditions fails to utilize more than 50 per cent. of the horse power. The application of this power to pumping gear would give better results, and would not only be more economical in itself, but would very considerably lessen the cost of the shaft; for when double buckets were dispensed with the size could be very much reduced, lessening the outlay on both sinking and slabbing; the latter too would not be subjected to the same strains as with buckets working either on runners or with bumpers; strains, that in bad ground, especially running drifts, often lead to great expense for repairs and, in some cases, total abandonment of the work. The use of the horse as a motive agent, even when applied to improved gear should however be avoided as much as possible, as in bad seasons there are elements of uncertainty attached to it even as there are to its more economical rival wind. This agent has up to the present time not been tried by the Government on these works, and for the same reason that prevented it, years ago, adopting improved pumping gear; but the time has arrived when the primitive machinery of the past can be abandoned and more perfect appliances adopted, and in future works of this class, where the conditions are favourable, windmills and pumps will be provided instead of the whims now used for the purpose. Objections have been urged against the use of windmills for these works, on the ground that the wind might fail at the very time when a lot of travelling stock required water. This objection is perfectly valid; but the evil can be met by constructing larger service tanks, which, as there would always be water in them, might be made of puddled clay walls and bottom, which would without any increased cost provide a much larger surface storage to meet any sudden demand.

Before concluding these remarks on wells, it may be advisable to draw attention to the use that could in many cases be made of drainage shafts in localities in the dry districts where drifts are known to exist within from ten to twenty feet of the surface, are also known to have a limited area and to be influenced by the local rainfall. In such cases the power of storage could be very much increased by sinking shafts to tap these drifts in places where the surface features favoured the collection of either standing or running water, which would then discharge down
these shafts and be rapidly stored under favourable conditions as to temperature and evaporation, and at a depth from which it could be economically raised to the surface as required.

2. Tanks.

Most of the works for supplying the stock routes with water come under this head; and before describing the different types of tanks that have from time to time been adopted, it may be as well to give a short sketch of the conditions under which surface waters should be collected and conserved, and under which stock using these works should be supplied with water. In selecting a site for a tank the main points to be attended to are—that the area of the watershed will suffice, under the conditions of rainfall, to fill the tank and keep up the supply necessary to meet loss by soakage and evaporation and the demands made by stock traffic; that the nature of the surface of the shed allows of a sufficient proportion of the rainfall being available for storage, this being materially assisted by a proper system of gathering drains, by the fall of the country towards the tank, and by the consolidation of the surface by stock or otherwise; that the soil in which the tank is to be excavated is of a retentive nature; and in estimating this latter condition it must be borne in mind that many tanks which when first constructed lose water subsequently become thoroughly watertight, this result being due to the deposit of clayey silt brought off the catchment by the rains. Advantage should if possible be taken of the features of the locality to provide for a storage of water above the surface of the ground. This course, when it can be carried out, materially lessens the cost of the work, as a much smaller amount of excavation will suffice than where the whole of the storage is below the natural surface. This super-surface conservation may be effected either by gravitation or by pumping over the embankment enclosing the excavation. In the former case, which is of course the more preferable, there must be rising ground near the tank site, with a sufficient catchment above the level of the embankment to allow of the enclosed area of the tank being either wholly filled, or filled to a sufficient extent to warrant the expense of fluming. In the latter case the features, though not suitable for an over-bank discharge, must allow of a collection of water at the tank site which, after filling it to the same level through an inlet pipe, can then be pumped over the embankment into the tank.

When tanks are constructed in watercourses, the plan adopted by the Department is to make an embankment below the excava-
tion; and in cases where the channel is shallow and the fall of the bed considerable, this dam is carried above the level of the creek banks, and flanking embankments carried on the same level as dam are continued up each side of the creek until they cut the
natural surface of the ground. In other cases, where the fall of the bed is inconsiderable, a dam is constructed both above and below the excavation, and these if raised above the level of the creek banks are joined by lateral embankments; an inlet pipe is laid under the upper dam, which allows water to gravitate into the excavation and enclosed space until it reaches the level of the water outside; a valve is then closed, and if necessary the outside water is pumped over the embankment into the reservoir. This plan, while giving a greater depth of water, at the same time shuts off the tank supply from that in the shallow reach above it, and considerably reduces the loss by evaporation and soakage. In all works of this character great care must always be taken to provide an adequate bye-wash, and, wherever it is possible, the work should be located to allow of a natural channel being used for this purpose.

The system to be adopted in watering stock at these works involves two questions of great importance; that of the economical use of the water; and the preservation of its purity as far as is practically possible when it is gathered off what must be to a great extent a camping ground. It may be laid down as a broad principle that, to attain these ends, stock must not be allowed to water in the reservoir; for the amount of water carried away by sheep in their fleeces, the amount of silt carried by them into the tank, and the pollution of the water by all kinds of stock when drinking are all so great that no arguments are necessary to support this view; and it was fully recognized by the Department when the first works were constructed. These tanks provided for independent watering, but subsequently many departures were made from the original design. These modifications, which will be presently described, were made to reduce the cost and to simplify the details as much as possible; the latter course being rendered all the more necessary on account of the heavy outlay that had to be incurred in repairing the older works which had been very inefficiently maintained.

The first departure made from the original design was to introduce a separate tank with flattish slopes for stock to water in; this being connected with the main tank by a pipe with a valve, so that the inflow of water to the drinking slopes could be regulated to the demand. The advantages claimed for this design are——economy in first cost, economy in maintenance, and simplicity of detail. The disadvantages, which overbalance the benefits are thus set forth by Mr. Bruce, the Chief Inspector of Stock (report for 1888):——"That a great deal of the water, as now supplied from them, is liable to be polluted and carried away by the stock wading into it, especially by sheep; that they are liable to be crushed and injured in crowding down into the drinking-tank;
and that the waste of water by evaporation is greatly increased by its being allowed to run into and stand in the drinking-tank.”

Mr. Bruce might have added too, that the inlet pipe from the main tank to the drinking-tank is very liable to be silted up and rendered inoperative.

On the Cobar to Nyngen Road the tanks are simple open excavations, in which all stock water direct. This is undoubtedly the simplest and, in first cost, the cheapest form, but it is open to the objections previously urged as to waste and pollution of water, the latter too in an aggravated form which is very marked when the water is low. These tanks were constructed to meet the urgent wants of the Cobar township and mine, and to secure the trade from that important district for the Sydney market.

The last type of tank to be noticed is that adopted in the Bourke district, which, with a separate drinking slope, has an open communication with the main reservoir, through a box drain. This plan nullifies any advantages that might be claimed for the separate drinking-tank system as already described, and aggravates all the objections to it, reducing it in fact to a level with the open single excavations on the Cobar to Nyngen Road, with the added disadvantages, that the first cost—for equal contents—is greater, and the exposed areas for soaking and evaporation much increased.

The experience gained in carrying out these works has led to the conclusion that the system first adopted is that which, considering the greater facilities that now exist for obtaining skilled labour, and for transporting and repairing the necessary plant, should be adopted in all future works; and type drawings have been prepared which, while showing some alterations in detail, embody the same principles that were followed in the first works of this class carried out by the Department.

The main alteration in the details of construction is the employment of pumping gear in lieu of the M'Comas water lift. This avoids the necessity for a lot of submerged timber-work, which, in addition to being very expensive, is always an element of weakness; it also lessens much of the annoyance and inconvenience due to silting, which chokes the M'Comas lift but is avoided with our pumping appliances, by a floating suction pipe. Another alteration is the construction of a service tank to supply the troughing instead of connecting it direct with the pump. This gives stock a much steadier supply when they are watering, and provides a reserve to meet any sudden demand when the pumps are under repair.

The use of pumps for increasing the storage by lifting water over the embankments, in cases where it collects outside the works, has been considered and approved, but the power to be employed
has not been determined. In all cases where the conditions are favourable windmills should be employed; and in forming an opinion on this point it must be remembered that, as they are slower and more uncertain in their action than steam, they can only be advantageously used for feeding the main tank when there is a considerable collection of water outside the embankments. When this is not the case, more rapid pumping will be necessary, and then steam should be employed if fuel is procurable within a reasonable distance. Pumping appliances should be erected at each work, and used for filling the service tank, in addition to pumping water over the embankments for storage. This course is preferable to having a portable engine and centrifugal doing duty at the tanks along one or more lines; for in many instances fuel would be too distant from the sites to be economically used; the stages would be too long, and the delay as between one tank and another would mean the loss of the outside water, which if it collected in sufficient quantities to admit of such delay, should be pumped into the tank by wind-power.

Windmills, though they have not received much attention, and have been but little used in those districts, are destined to be extensively employed in lifting water both for stock and irrigation. When it is considered that there are very few days in the year during which good work could not be obtained from a well constructed mill—that the first cost is comparatively small—and that the after cost for work done is confined to the expenses for maintenance—it seems very strange that attempts have not been more generally made to utilize this power. When its value has been practically tested and the results are presented in a tangible form, there is little doubt but that it will be extensively used by all who are interested in the adoption of a cheap means of raising water, whether from wells or tanks, whether for stock watering or irrigation purposes.

Great difficulties are often experienced in letting these works, more particularly during dry seasons, when the want of water and feed within a reasonable distance of the tank site render it absolutely impossible to carry them out; and in other cases, somewhat less unfavourable, has increased the cost of excavation from 30 to 40 per cent. above the price for which it could have been done in good seasons. This is the necessary consequence of employing animal power in ploughing and scooping—though this system has very much reduced the cost of excavating and has almost entirely superseded manual labour. Attention has consequently been directed to steam power, and Fowler's ploughing and scooping plant has been successfully used for some time in South Australia. More recently the Messrs. Edols at Burrawang purchased and worked a similar plant on their property, where I saw it in operation in May last. The following extracts from my
report to the Department explain, from my point of view, the relative advantages of steam and animal power under varying conditions:

"This plant consists of two 16 h.p. traction engines, with horizontal winding drums for working a double, three-furrow balance plough and an earth scoop. There is also an 8 h.p. traction engine for drawing water and firewood, and for assisting the main plant when travelling from one site to another. The cost of this on the station was about £5,000."

"The advantages claimed for this machine are"—

"1. That it is independent of the seasons, and able to work under conditions that would prohibit the use of bullocks or horses.

"2. That it is much quicker and more economical than animal power.

"3. That it is easily transported from one locality to another, and through country where bullocks would die for want of water and grass.

"In practice I think it will be found that these advantages are not fully realized, and that there are very important modifying influences to be considered.

1. Though it can work under conditions that would prohibit the use of bullocks or horses, it is not fully independent of the seasons, inasmuch as it consumes about 1,800 gallons of water per diem, which is equivalent to what would be consumed by about 120 bullocks. Herbage or grass is of course not needed, and so far this plant is independent and is in a position to do work where animal power could not be applied; but firewood and water are as necessary for the engines as are grass and water for bullocks; and where these requisites are scarce, and have to be hauled from any considerable distance, the limit for the application of this machinery is very soon reached. In favourable country for running the traction engine I consider, from what I saw at Burrawang, that 20 miles would be about the limiting distance for haulage of wood and water; but in unfavourable country, that is, where the ground was loose and sandy or where it was boggy, the limiting distance would be much reduced, for in such ground the traction engine is unable to work, or works under such difficulties that its normal efficiency would be very much lessened.

2. The claim for superior speed and economy can only be partially sustained. In bad seasons, when animal power could not be applied on account of there being no feed, and in places where firewood and water were within a reasonable distance by a sound track, the steam plant commands the situation; but in good seasons the work could be more rapidly carried out by bullock plants if the same capital was invested in them, but not at the same price, though even on this score there is not much to
be advanced in favour of the steam plant, as will be seen by reference to the following figures showing the cost of excavation by both systems:

"Cost of steam plant ... ... ... ... £5,000
Weekly expenses—

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 engineer and manager</td>
<td>£4</td>
</tr>
<tr>
<td>3 drivers</td>
<td>4</td>
</tr>
<tr>
<td>1 steersman</td>
<td>2</td>
</tr>
<tr>
<td>1 scooperman</td>
<td>1</td>
</tr>
<tr>
<td>1 clearer (for rope)</td>
<td>1</td>
</tr>
<tr>
<td>2 woodcutters</td>
<td>2</td>
</tr>
<tr>
<td>1 cook</td>
<td>1</td>
</tr>
<tr>
<td>10 rations</td>
<td>0</td>
</tr>
<tr>
<td>Interest @ 8 per cent.</td>
<td>8</td>
</tr>
<tr>
<td>Depreciation @ 12 per cent.</td>
<td>12</td>
</tr>
</tbody>
</table>

Total ... ... ... £42

"The work done in a week is equivalent to about 2,500 cubic yards, which makes the cost 4d. per cubic yard.

"This estimate of cost is based on the supposition that there are no stoppages and that there is no delay between one tank and another; but, as a matter of fact, there are many stoppages and much delay in transporting plant. This latter element of loss increases to a great extent in sandy country or in wet seasons, when the bullock plant is most favoured. Taking these disturbing elements into consideration, we must fix the price of the work done at a much higher rate. I estimate that only thirty-four weeks in each year can be relied on for work, the balance being required to cover the various unavoidable delays. This affects the estimate of cost to a considerable extent; for with a plant of this character, requiring trained men to work it, no reduction can be made in the weekly expenses during the time it is idle; consequently we have fifty-two weeks' wages, &c., at £42, representing thirty-four weeks' work at 2,500 cubic yards a week, or 85,000 cubic yards, costing £2,184, being at the rate of 6d. per cubic yard.

"Cost of bullock plant... ... ... ... £1,300
Weekly expenses—

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 manager</td>
<td>£3</td>
</tr>
<tr>
<td>5 bullock-drivers</td>
<td>7</td>
</tr>
<tr>
<td>2 ploughmen</td>
<td>3</td>
</tr>
<tr>
<td>5 scoopermen</td>
<td>7</td>
</tr>
<tr>
<td>1 tailor</td>
<td>1</td>
</tr>
<tr>
<td>1 cook</td>
<td>9</td>
</tr>
<tr>
<td>15 rations</td>
<td>2</td>
</tr>
<tr>
<td>Interest @ 8 per cent.</td>
<td>2</td>
</tr>
<tr>
<td>Depreciation @ 10 per cent.</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Total ... ... ... £37

"A strong plant like this could excavate about 1,500 cubic yards in a week, which would cost 6d. per cubic yard.
This estimate, like that for the steam plant, requires modification, as the bullocks could not, for various reasons, be constantly worked. Estimating the same loss of time, which taking the average run of the reasons is I think equitable, and we have—

<table>
<thead>
<tr>
<th>Work Type</th>
<th>Hours</th>
<th>Rate (£)</th>
<th>Total (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 weeks' work</td>
<td></td>
<td>37.5</td>
<td>1,266.10</td>
</tr>
<tr>
<td>18 weeks' idle time</td>
<td></td>
<td>18.0</td>
<td>324.00</td>
</tr>
</tbody>
</table>

£1,590 10 0

This amount represents thirty-four weeks at 1,500 cubic yards a week, or 51,000 cubic yards, and the cost per yard is about 7½d.

From this it will be seen that the same amount of capital invested in bullock plant would give a much larger output while at work, but at an increased cost of 1½d per cubic yard. Could the seasons be relied on, there is little doubt that animal power would be preferable to this form of steam plant, as the extra cost by bullocks is fairly balanced by the risk of breaking down, &c., which in the out of the way places where this machinery would be employed, would entail great loss of time and money, and very soon cover the small margin of difference in favour of steam.

When, during long continued droughts, it is impossible to employ animal power, and when water and fuel are available for steam, then this plant comes to the front and offers the only practical means of tank excavation.”

Another excavating machine, invented by Mr. Waugh, is now at work near Sydney; and though it does not avoid the necessity for employing horses and drays to remove the material, promises to very greatly reduce the cost of “getting.” It has the advantage of being less cumbersome than the ploughing and scooping machinery, is much less costly, but is far more limited in its application. The patentee is perfecting the machine, which, being constructed on a new principle, has naturally exhibited some defects. When these are remedied, it promises to be a valuable addition to the resources at our command for reducing the cost of excavation either in tanks or canals.

II.—WATER SUPPLY FOR IRRIGATION.

There are few questions of such importance, few questions with which the future prosperity of this Colony is so intimately interwoven as that of irrigation; and considering the extent to which works of this character will promote settlement and mitigate the uncertainties that now attend both pastoral and agricultural occupation, it seems strange that no steps have been taken to ascertain to what extent and at what cost the rainfall of this Colony can be conserved and distributed over the waterless areas of our western sheds, where a rich soil now lying fallow, only waits its invigorating influence to yield returns that, with the climate we possess, would convert it into a mine of wealth. Surveys that will require
years to complete, and that are essentially necessary to assist in framing a comprehensive scheme, are not even commenced, and the time must be far distant when we shall be able to lay claim to having taken the first great step towards developing the wonderful resources of our lands. It cannot be said that attention has not been drawn to the advantages to be derived from such works, for seventeen years ago, when giving evidence before the Board appointed to inquire into the Moama and Deniliquin railway scheme, Mr. W. C. Bennett, Commissioner and Chief Engineer for Roads, drew attention to the yearly waste of water brought down by our western rivers, and the practicability of employing it for irrigation purposes. The Commissioners appointed to inquire into a water supply for Sydney and suburbs, in their report thus allude to the subject:—“Although our commission limits us to an inquiry into the supply of Sydney and suburbs, we have not been unmindful of the great desirability of obtaining such a plentiful command of water as would permit of its free use in irrigation; not only in the immediate neighbourhood of Sydney, but also over some considerable portion of the county of Cumberland. We feel convinced that this question of irrigation ought no longer to be neglected. Our comparatively dry climate, coupled with the very unequal and uneven distribution of rainfall, point imperatively to the necessity for making provision for storing up the superabundance of rain that occasionally falls, that it may afterwards be dispersed to the thirsty soil as required, and thus secure fertility and plenty in all seasons.” Time after time have letters and leading articles appeared in the public journals drawing attention to what has been done and gained by such works in other countries, and showing the necessity of action if we intend to avail ourselves of the latent wealth at our feet; but in even plainer language and with practical force has Nature herself indicated what water can do in the dry districts, and how readily, if conserved and at our disposal, it can be distributed over the face of the country. In proof of this I instance the spread of the flood-waters of the Murrumbidgee, Lachlan, and Darling, in 1871; the network of connections between the Bogan, the Macquarie, and the Castle-reagh Rivers, in the counties of Clyde, Leichhardt, Gregory, &c.; the water circulation in North Gipps, which, with many other instances, point in no unmeaning manner to the facilities offered by the natural features of the country for distributing the supply brought down by our rivers, and for pouring living streams of water over the thirsty plains. Yet notwithstanding all this, season after season as it rolls by shows us our rivers, fed from the higher lands by the greater rainfall, by melting snows and by springs, carrying the life-blood of the country through the very districts where its fertilizing agency is a necessity to success, to discharge it to waste in the ocean; while those who have eyes to see, and must
see the incalicable advantages that would accrue from utilizing it
look on and abuse Nature rather than exert the powers they possess
and assist her to assist them.

The conditions surrounding this problem in this country are
widely different to those which had to be dealt with in India and
Southern Europe; there a teeming population made it necessary
that increased and certain returns should be obtained from the
soil, and there as soon as the facilities for obtaining water were
afforded they were immediately taken advantage of, and thus,
both by direct and indirect returns, enterprise in this direction was
couraged. In the former country, though much remains to be
done, it is almost impossible to over-estimate the blessings that
irrigation works have conferred on the people, improving both
physical and moral tone, and to a great extent mitigating the evils
that in a densely populated country attend a failure of the crops
that form the great staple of life. In this country, instead of
having a large population settled on the soil requiring the assist-
ance offered by such works to meet their wants, we have an
immense territory possessing a soil capable of growing any
products suited to the climate, which is now little better than a
huge sheep-walk, but which is capable of being converted into
great agricultural districts capable of supporting thousands where
now it is difficult to count tens. This paucity of population
has been urged as an argument against such works being under-
taken, the inference being that population must precede irriga-
tion. This means that irrigation will never be carried out on
the great western plains, for I maintain that in the Riverina
districts irrigation works must precede settlement, that is, settle-
ment on any but a pastoral basis. To those acquainted with these
districts this must be obvious, for without water agriculture is
impossible, and except in certain confined and favoured localities,
it is impossible for irrigation to be applied to any agricultural
holding by ordinary private enterprise. The pastoral tenant—the
sheep farmer—can provide all the water he requires for his
flocks by local conservation in tanks and by wells; but the large
quantities of water required for crops cannot be locally conserved
in the flat country, while to obtain it from distant sources means
an expenditure of capital far beyond the abilities of any agricul-
turist, and far in excess of any returns that could possibly
obtain from individual holdings. Maintaining these views, I fail
to see how the hopes entertained as to settlement on a large scale,
following on the liberal railway policy pursued in these districts,
can possibly be realized; I fail to see how, unless water is at
our command, the lines constructed, being constructed, and those
proposed, more particularly the latter, can ever carry much
besides pastoral produce. Whether railways through these dist-
릭ts will pay under such conditions remained to be proved; but
that they would do so were a population settled on the country, actively engaged in cultivating the soil, does not admit of a doubt, any more than does the fact that, taken in connection with a water supply, they would have an important bearing on settlement in such improved districts, by the facilities they would give for distributing produce grown in those districts.

Believing as I do, that in those districts, the construction of the main channels for distributing water must precede settlement, it follows, that for some time after their construction they will have a more important bearing on pastoral than on agricultural occupation; and though, even from this narrowed view of the question, they will be of immense importance, it cannot be expected that they will prove remunerative until they are utilized for the more comprehensive objects for which they were constructed. The advantages to be derived from such works by the sheep-farmer are manifold, and in themselves well worth consideration. Prominent amongst these are—the direct facilities that would be afforded for watering stock by giving new frontages along the arterial channels, while the benefits from this source could be much increased by cutting distributing channels to feed tanks off the main lines, and by turning surplus waters into the many natural hollows existing in those districts. A great saving of feed would result from this, by allowing of a more equable distribution of stock and by lessening the distances they would have to travel between feed and water. Such channels would also aid in keeping communication open in all seasons, and thus allow, should occasion arise, of the transfer of stock from less to more favoured districts, and materially lessen the enormous losses to which pastoralists are liable during droughts. Nor must it be forgotten that these channels would in their districts afford the means of mitigating to a greater or lesser extent the evils attending droughts, by the facilities they would give for growing artificial crops, which being stored during good seasons would materially assist in meeting the wants of stock during bad seasons.

One of the first steps to be taken or that, judging by the benefits that are likely to be derived from a comparatively small expenditure, should be taken, is to assist Nature where she has defined the course of the waters during flood-times, and improve the régime of the overflow channels from our rivers, such as the Merowie, Middle Billabong, and Willandra from the Lachlan; the numerous creeks leading from the Macquarie to the Bogan; the various channels forming a natural system of distribution in North Gipps; and many other cases, all of which are capable of being made of immense service to their respective districts. These watercourses should be straightened and improved, so as to admit of an inflow at a lower flood-level, and to allow of a larger body of water being carried down them during the comparatively short periods when
the rivers afford a gravitation supply: these periods should also be lengthened by the construction of weirs. Branch channels should be cut to divert flood-waters from the rivers and overflows into the numerous lakes, swamps, and natural depressions found in those districts, which could in many cases be utilized, not only for the benefit of the adjoining lands, but also as reservoirs to make good the loss from various causes in the overflows, &c. The advisability of carrying out this latter work would of course be greatly dependent on the advantages to be derived as compared with the cost of cutting the feeders, but as these could be utilized along their courses, the distances of these natural reservoirs from the point of diversion becomes a matter of less importance. Sluices would necessarily be required to regulate the waters and to prevent a back flow when the rivers fell. Private efforts have been made in some few instances to attain these ends; inlets have been cut from the rivers to these secondary channels, which, generally speaking, are more imperfectly defined where they leave the rivers than they are further on in their course; but most of these efforts have failed to fully realize the expectations of the promoters—failed because, though admitting the river waters at a lower level, the channels below the inlet improvements were left unaltered and only capable of carrying the water forward at the velocity due to their natural régime, this velocity being very small, on account of the sinuous course of these creeks through a comparatively level district giving a much lesser fall than that of the country on the general direction of flow. Much could be done in this direction by judiciously planned works—done, too, with a very moderate outlay; and though these improvements would have a limited application to irrigation, they would yet assist in that direction and would be of immense benefit to the pastoral industry, and would greatly increase the value of the Crown Lands and the rents that ought to be derived from them; and when, later on, they were connected with a more perfect scheme, they would be as valuable to the agriculturist as in their earlier stages they were to the sheep-farmer.

The important bearing of these channels, &c., on the water supply for the districts they intersect points to the urgent necessity that exists for taking prompt measures to reserve from sale all lands adjacent to them, that, under normal conditions, can only be utilized for grazing, but that would be valuable for agricultural purposes when provided with a certain water supply. This course should also be adopted under similar conditions of settlement on all belts of country where, without survey, there is sufficient reason to think they can be brought within the scope of any general scheme of irrigation. This course will be necessary to prevent the improved areas, or the areas proposed for improvement, being alienated for purely pastoral purposes, and to ensure
that the Colony generally shall reap the full advantage of the increased value of these lands—an increased value that should be credited to these works, and which, while recouping the country for a considerable proportion of the outlay, would at the same time practically prohibit these areas being devoted purely to grazing. The increased cost of such land would also have the effect of making the holder more rapidly develop its capabilities and would ensure every advantage being taken of the irrigation works, without which the cultivator could not rely upon a return for his labour and capital, and without which these works could not be expected to prove remunerative.

In considering this question from a general point of view, it must be borne in mind that as the features of the country to be dealt with vary, so may there be room for an equal variation in the nature of the works best adapted for the object to be attained; and it will therefore be advisable to divide the subject into two main branches, dealing separately with irrigation derived from local sources, and with that derived from our great rivers; not forgetting that many cases may arise where the supply obtained from the former could be largely aided by the latter, and vice versa.

The country to be dealt with consists in the west and southwest of extensive plains, broken here and there by sand-hills and low ranges, and with a small fall in the direction of drainage, but nearly level transversely to such lines, except where watercourses and ridges are intersected. To the eastward the ranges become more frequent and of greater magnitude, gradually culminating in the coast range which divides the eastern and western watersheds. The rivers and their earlier tributaries have a considerable fall in their upper courses, but this gradually diminishes as they run westerly, till in the plain country it does not much exceed 4 inches in the mile, but as the bends give a river length roughly estimated as being three times greater than that of a direct line the fall of the country would be about 12 inches per mile.

The rainfall over these districts varies very much, being dependent to a great extent on the features of the country and on position in regard to the main coast range, where the fall is heaviest. From this range there is, with some slight local irregularities, a marked decrease of the rainfall as we advance westwards. The nature of the rainfall is not only spasmodic in its annual amount, but is equally fitfully distributed over each year. This has an important bearing on the proportion that is converted into running water, and that can be conserved for future use, as also on the loss by evaporation; this must be greatest on the low-lying western plains, where the ground has a high temperature and the winds are very dry and act very continuously. The loss from this cause must attain its maximum when the annual fall is so
distributed that the minimum of running water is formed, when, consequently, there is no concentration of rainfall off large areas to reduce the evaporation surface, and to further lessen loss by the difference in the rate of evaporation off a water surface as compared with that off the soil. In such cases I can readily understand that were the supply kept up under equally favourable conditions for the whole year, we would have fully 20 feet to record as the result. But unfortunately we have no data on this point, any more than we have as to the proportion of this evaporation that may be given back by condensation in other form than that of rain. But although these data are not at our command, and as it is consequently impossible to arrive at definite conclusions as to the exact number of inches, we must make the measure of evaporation in different localities; and although we admit that where light recurrent rains fall on a baked and heated ground surface, and are exposed to hot and thirsty winds, the evaporation must be enormous, I yet think we are justified in taking more hopeful views as to the possibilities of irrigation than has been done by those writers who have lately made a bugbear of the evaporation question, and have tried to prove that it must render any irrigation scheme impracticable. It cannot be denied that in the eastern and hill districts of this watershed the rainfall is greatest, and evaporation much less than on the plains; that the incline of the country favours a rapid concentration of rainfall, giving water surfaces of limited area for evaporative agencies to act on. In these districts the rainfall must be impounded for after distribution through artificial channels; and while so concentrated, the loss by evaporation need not trouble us here much more than it does in other dry countries, save that we have not as copious and constant a supply to draw on as other countries have had for their irrigation schemes; but when concentration ends, and the water is discharged over the surface to be irrigated, then the loss from this cause will be heavy; but it still remains to be proved whether a 2-inch watering, even admitting the rapid loss, will not produce as great a vegetable growth with the forcing climate of our plains, as the same amount of water where the heat and evaporation are less, and where the water remains longer in the soil. Judging by the wonderful effects produced by even half-an-inch of rainfall in the same country, it appears probable that the rapid loss by evaporation is in a measure made up to us by the equally rapid growth of vegetation. Should this view be incorrect, is the loss through evaporation so much in excess of what it is in other dry countries, that we should at once despair? I think not. The loss from a water surface in Bombay has been estimated at about 6 ft. per annum; in this Colony, at Bourke, Mr. H. C. Russell estimates the evaporation at about 7 ft. Presumably the evaporation off the soil, as compared with that off water, will bear the
same proportion to one another in both countries, in which case our position is very little more unfavourable than is that of India, where irrigation has been carried out on a large and most successful scale.

From the foregoing it will be seen that there are two classes of country for us to deal with: that on the middle levels, where the rainfall is, taking an average of years, fairly abundant, where the evaporation is not very great, and where the slope of the country is sufficiently marked to convert a large proportion of the rainfall into running water, which, under normal conditions, is rapidly carried away by creeks and rivers. The other class is on the level lowlands, where there is a minimum of rainfall, a maximum of evaporation, and so little incline, that under ordinary conditions of rainfall but little running water is formed.

Local conservation of rainfall for irrigation purposes can only be adopted in the hill country, where the natural features offer facilities for storage. The works for this purpose, which in India are called tanks, have been largely used in that country from time immemorial, and great benefits have been and are still being derived from improvements of this class. In the Madras Presidency, in 1853, there were, according to Capt. R. Baird Smith, no less than 43,000 tanks in use, and 10,000 more which had been allowed to get out of repair and were of no service. In forming an opinion of the amount of work involved in the construction of these reservoirs, it must be remembered that the word "tank" has a much broader significance in India than it has in this country, where they are little else than excavations, few of which contain more than 20,000 cubic yards; there, tanks are large reservoirs conserving enormous bodies of comparatively shallow water, which is impounded by embankments. The Ponnaiy tank in Trichinopoly covers an area of about 80 square miles, the embankments being 30 miles in length; while the Veranum tank has an area of 35 square miles, and embankments 12 miles long. Similar works could be constructed in this Colony, and a large proportion of the rainfall locally conserved and distributed. Dams could be thrown across valleys and basins, and, where the drainage from the watersheds naturally feeding these reservoirs was insufficient, channels could be cut to bring an extra supply from some adjacent shed, or, in many instances, could be made to divert the flood-waters from neighbouring creeks or rivers. By such means as these the evil effects of our spasmodic rainfall could be mitigated in the improved districts, and isolated areas of rich land made permanently reproductive and independent of the seasons in localities which could not be brought within the scope of a general scheme, either on account of the levels being unfavourable, or on account of much valueless land having to be traversed by the canals before the district to be irrigated could be reached. In such cases the cost of
bringing water from a distance might be prohibitory, and then the only courses open would be to take advantage of local supply, to trust to the seasons, or to abandon the ground for agricultural purposes. The first of these alternatives can only be successfully followed when the rainfall and catchment area are sufficient to provide the necessary supply, and when the natural features offer facilities for storage and distribution at a cost that will allow of the water being made commercially reproductive; the second alternative of trusting to the seasons seems to be born of the happy-go-lucky style of farming so general in this country, and which, unless in particularly favoured districts, or in favourable seasons, is as general in its failure as in its adoption. The last is often the natural sequence of the second alternative, and in far too many cases for the interests of the community has this been the result of undertaking agriculture under conditions that without artificial regulation are too unfavourable to allow of success; the consequence being that these lands, rich though they may be, revert to the Crown, or are absorbed into some large pastoral estate, the selector and would-be farmer having wasted not only his small capital but some years of labour which could have been more beneficially employed in other channels. Amongst the many advantages to be derived from local conservation, is the fact that there need be no such delay in providing the necessary supply as would be the case if the lands to be dealt with had to wait until they could be brought within the scope of a general scheme, and this advantage is increased by the fact that such works could be undertaken by district Boards, whereas the larger and more comprehensive scheme, being national in its aspect, would have to be dealt with by the central authorities. The important bearing of such local works on the welfare of the country is very forcibly shown by the concluding remarks in Captain Smith's report on irrigation in the Madras Provinces. He says: "I cannot close my report without reverting for a moment to the field of improvement presented by the Presidency of Madras in the single department of irrigation. In all parts of India, profit to the State and the people follows, as certainly as effect follows cause, the provision of an abundant supply of water for agricultural purposes, but in Madras the results go far beyond the general average. The staple of agriculture in the irrigated districts being rice, the want of water brings with it abject poverty and discontent, its abundance wealth and contentment. Every acre that is newly watered passes at once from the revenue rate of dry, to that of wet cultivation, guaranteeing to the Government an immediate return, paid with far greater ease to the cultivator of the land than the lower tax leviable before. The return is immediate, and its amount great. I have almost hesitated in adopting the data given by the Madras Commissioners of Public Works, so extravagantly large do they
appear; but they are statements founded on official returns, open to verification, and unlikely to be seriously in error. When these show returns varying from 77 to a maximum of 259 per cent. on the original cost of the works, it is inconceivable that fields paralleled only, if paralleled at all, by those of Australia and California, can be left much longer unwrought."

This description, however true it may have been in its application to the districts alluded to at the time it was written, is scarcely parallel with the conditions surrounding the question in this Colony; but after making every allowance for sparse population, high priced labour, and distant markets, there is much still left to excite hope and sustain the belief that the time has arrived when irrigation works should be initiated; and that in the years that must elapse in carrying them into complete effect, settlement will be borne steadily forward on the living streams distributed through the thirsty land; successful settlement developing the latent wealth of the Colony and ensuring a grand future of peace and prosperity.

The local conservation we have been considering, though it must have a great influence on the advancement of agriculture, is secondary in extent and importance to the supply offered by our river systems, on which we shall have to depend for irrigation in the low country, or for providing water for any comprehensive scheme; and sooner or later active steps will have to be taken to draw these waters into our service, and so utilize them that they will lessen the loss and misery attending droughts in the pastoral districts, increase the stock-carrying capacity of the country, and develop the extraordinary but latent agricultural resources of districts where an unrivalled soil and climate will yield abundant returns to reward our enterprise. To attain these desirable ends water and population are necessary. The former we possess, and it only needs capital and skill to divert it into channels where it will be at our command, a potent power in the advancement of the Colony, instead of being carried wastefully to the ocean, a practical satire on our prayers: the latter—population—must, as far as the dry districts are concerned, follow, not precede, such works; and there is little doubt that when water is obtainable for irrigation, agricultural settlement will certainly follow, more particularly as the preliminary cost of preparing the surface will be much less than what it is in many other countries, both on account of its natural evenness and on account of the small quantity of timber to be dealt with.

The few attempts at irrigation that have been made in the Riverine district have been conducted under great disadvantages, as the water has been pumped from a low level, and the cost consequently increased to a very great extent; notwithstanding this great drawback the results have been very satisfactory, and point in a most unmistakable manner to the benefits that must be derived
from the construction of works that will deliver the required supply by gravitation. The following extracts from a letter kindly written by a gentleman who is intimately connected with one of the largest pastoral properties on the Murrumbidgee, needs little comment, except to draw attention to the fact that the water was raised by steam power, and that the cost of irrigation on which the writer's opinions are based, was much in excess of what it would have been under a properly carried out scheme delivering the water by gravitation, and also much in excess of what it would have been with steam pumping, had there been weirs to raise the water level and reduce the lift. This gentleman writes as follows: “Some years ago I ploughed up about 10 acres near a lagoon on this station and sowed a portion in lucerne, a portion in prairie grass, a portion in maize, and a portion in oats.

“The soil, although rich enough, is rather stiff and clayey, and it was very imperfectly broken up when the seeds were sown; the consequence being that the crops came up very unevenly, but all the plants that did come up grew very luxuriantly.

“I irrigated the patch by pumping the water by means of a 12-inch centrifugal pump, and a 12-horse power engine from the lagoon into a raised channel carried round the higher side of the land; from which channel the water was allowed to overflow, by making breaches at intervals in the bank, spreading itself about until all the land was saturated. The ground is almost a dead level, so that there was little difficulty in distributing the water over the surface.

“I watered it about five times during the summer months, giving it on each occasion a soaking which I should think equal to 2 inches of rain or thereabouts.

“The maize crop grew well to a height of 8 or 10 feet, and the cobs of corn were of good size, but I kept no record of the quantity gathered. The lucerne and prairie grass were fed down with sheep, and the oat crop, a very fine one, was cut down for hay. The lucerne is still growing, and thrives well. The prairie grass died out last summer, when I did not irrigate it.

“The primary object of my experiment was attained in satisfying me that crops of all ordinary kinds suited to the climate can be grown in great abundance in this district by means of irrigation, but I could not pretend to give anything like an accurate estimate of the cost per acre of laying down and watering, or to speak with anything like authority as to the profitableness or otherwise of the work.

“I am inclined to think that ordinary agricultural products of a compact and easily transportable kind, such as flour, would be more cheaply purchased elsewhere, and brought down by rail, than grown here under irrigation, but that irrigation might be profitably
used for producing hay, which is bulky, and consequently expensive of carriage; or for raising potatoes or roots which are perishable, or green stuff to feed valuable stock on in time of drought.

"I think also that wine-growing might be profitably carried on under irrigation, as vines thrive very vigorously here when liberally watered, and produce grapes of great richness and flavour,

"One thing I may mention which may appear somewhat incredible to people who have seen the Murrumbidgee River only in time of flood, viz., that I think the supply of water in the summertime would sometimes be found inadequate to very extensive irrigating operations.

"The stream is frequently, from January to March, so shallow that a horse may ford it without wetting his knees, and of no great width; and from the quantity of water I have myself pumped up with one engine and pump for irrigating and sheep-washing purposes, I feel sure that if 500 or 1,000 other people were each withdrawing a similar quantity of water from the river, the stream would be found insufficient.

"This drawback could of course be obviated by the construction of weirs to impound large quantities of water in the channel and prevent it from running to waste; but this work would probably be found too expensive to be undertaken until the country becomes very much more thickly peopled than it is likely to be for many years yet."

From the foregoing extracts it will be seen that the writer only tried and only formed an opinion on the profitableness of irrigation from the results obtained with the everyday agricultural products of the Colony; but, great as would be the advantages of extending the cultivation of such products into the dry districts, they would be insignificant when compared with the returns that would be obtained from the more profitable cultivation of plants that are more particularly adapted to the Riverine climate, such as indigo, madder, chardon, hemp, limes, olives, &c.

The concluding paragraphs of the letter have an important bearing on the question; and, before proceeding further, it may be well to consider the nature of the rivers from which our supply must be drawn, and the conditions under which water can be stored and diverted for distribution. As has been previously remarked, the fall of the rivers, which is very slight in the lowlands, increases considerably as we trace them towards their sources. Another feature is, that where they have the greater fall they run through deep and comparatively narrow valleys, bounded by ranges of considerable abruptness, and generally of a rocky, barren character; that when the fall is slight, there they run in deep-seated beds through a plain country, over which the waters spread for very considerable distances during floods. The quantity of water brought down by these rains is, on account of the
spasmodic nature of the rainfall, very variable; some seasons give a full river for months at a time, while there are equally long periods during which the flow is insignificant. To meet these variations and to equalize the supply that must be provided for irrigation, impounding works are the first necessity, and there is little room for doubt that this must be carried out, not only in the comparatively level reaches of the rivers, but more particularly in the middle and upper courses of the main channels and their tributaries. Many of those who have interested themselves in the question consider that weirs in the lower courses of these rivers, impounding water on the frontages of the lands to be irrigated, will meet the requirements of the case; but a little consideration will show that any such limited supply would be quite inadequate for any broad irrigation scheme, and that the cost of the works to carry such a plan into effect would be out of proportion to the benefits derivable from it.

The quantity of water annually required may be estimated at 12 inches, being six waterings of 2 inches each. This amounts to 43,560 cubic feet per acre. Assuming the river to have an average width of 150 feet, and that the depth maintained was 20 feet, this would give a storage of 15,840,000 cubic feet per mile of river channel, and would provide for the irrigation of 360 acres, or a strip of land on each side of the river about a quarter of a mile in width. It may be said that no account has been taken of the occasional supply brought down, and which would refill the ponds; but as there are seasons when no such supply could be relied on, and as irrigation to be successful must be certain, I have left this out in my estimate. The expense of constructing weirs and, on our navigable rivers, locks, for maintaining traffic, would be out of all proportion to the advantages derived; for even then the water would have to be raised by steam or wind power. The construction of weirs in the alluvial country characterizing the lower reaches of the western rivers of this Colony would be a very costly undertaking, on account of the difficulties that would be experienced in protecting such works from scour. Exceptional cases might arise where rocky bars would be found crossing the rivers, on which such works could be securely founded, but these cases would be few and far between, and can almost be neglected in considering the subject. It may possibly be urged as against the objections now raised, that the expense of constructing such works could not be charged in its entirety to the irrigation funds, inasmuch as with locks in connection with the weirs permanent navigation would be established, and this should be debited with a portion of the outlay. This, however, cuts both ways, as it reduces the quantity of water at disposal for irrigation by the depth that would have to be maintained for navigation; but apart from this, it is worth consideration whether, if such improvements are ever considered
advisable, lateral canals would not be found preferable to improving the existing channels, with their tortuous courses; with the large supply of water required to provide for their unnecessary length and width; and with the constant difficulty of maintaining such works in flood-time. Taking all these points into consideration, such a system for irrigation supply must be discarded, though, in connection with the impounding operations that should be carried out in the upper reaches, weirs might be of modified use on the lower levels for assisting in the diversion and storage of water.

The great object to be attained is to provide a steady, certain supply that can be distributed by gravitation, and, to compass this, a sufficient body of water must be stored in the upper courses of the main rivers and their tributaries to provide a supply during the season of least rainfall, when the natural flow would be insufficient; and having made this provision, to construct canals to receive and carry into the dry districts the water so stored. The upper and middle, or upper-middle courses of the rivers to be dealt with, are far more favourably circumstanced for economical storage and diversion works than they are on the levels; for the fall, though not too great to allow of moderate impounding works throwing back the water to a great distance, is yet sufficient to allow of the water being readily diverted from the natural channels into artificial canals excavated for the purpose. The valleys through which these rivers pass are in many places very much contracted, the waters running through narrow gorges which open out above into large basins. These sites offer favourable opportunities for constructing weirs, the foundations on these sections of our rivers being of a sound character, and no difficulties likely to arise from the flanking action of scour. Enormous bodies of water could be stored in such places without any disproportionate expense being incurred, and in some cases with a very small outlay. The tributaries to these rivers would have to be similarly dealt with, means being provided in each case to allow the impounded waters to be discharged as required, so that any surplus over what would be needed for merely local wants could be passed down to supply the lower ponds where the water was being drawn off by the main canals, and those ponds still lower down where, either by steam or wind, water was being raised for irrigation along the rivers.

The preceding remarks are necessarily of a merely general character, for the data at our command are of such a very meagre nature that it is a matter of impossibility to formulate any scheme. Before this can be done, careful observations must be made of the discharge of our rivers at different points, and extensive and accurate surveys prepared, showing the quantity of water we can command and the cost of the works for conserving and distributing it. Until this is done any views on this question must be vague and ill-defined; but we know enough of the conditions
under which irrigation will have to be carried out in this country, and under which it has been carried out in other countries, to enable us to take a practical view of the question as a whole; enough to protect us from being carried away by the mad enthusiasm which pictures the whole of the dry country converted into a garden of Eden, and, at the same time, protect us from the baneful workings of those who handle our rainfall and evaporation as weapons of attack with which to rout those who earnestly desire to see this country benefited by a wise use of those blessings we have too long neglected. For the present we must wait, wait patiently but not without hope, for the first steps to be made to carry out the necessary surveys in connection with, at least, one of our rivers, and to obtain other necessary data on which to frame some tangible, practical scheme.

**Discussion.**

Mr. Russell made the following statement:—

After trying for five years to call attention to some important questions affecting the water supply of the interior, it is gratifying to me that some of those who are qualified by their professional training as engineers to take up the subject are turning their attention to it. Before making any reply to what has been said against my views, I should like to take this opportunity of saying distinctly that I do not claim to be the first to raise the question of underground water-supply. From time to time I see in the daily papers that Mr. A. started in 1868, and again that Mr. B. was first in 1876, and so on. Who was the first I will not venture to say; but from my childhood, when I heard this matter talked about in my father's house, onwards for the last forty years, I have heard one and another propounding their views on water supply for the interior, and probably the first man has now ceased to take any personal interest in the matter. I merely came forward with measures of rainfall and river discharge, and pointed out the startling difference that exists between them. I said just now that I was pleased to see professional men turning their attention to the important subject of water supply for the interior, but I must add that I am somewhat disappointed. My hope was that they would marshal the great multitude of facts now floating about in reference to our water supply into such an order as would tell us plainly many of the things the public are so anxious to know; but instead of this I am told that I am wrong in my estimate of evaporation, that it is much more active than I suppose, and that the rivers run in such impervious clay that they can lose but very little by percolation. This is no answer to what I have said—in fact it rather strengthens my position. The bulk of the rainfall on the Darling is what
may be called heavy rain, and from the nature of the country it must get into the watercourses within a few days at most, so that its loss by evaporation must be confined to the narrow limits of the channel in which it runs. Of course the two-thirds of the rainfall which I have supposed is taken up by the ground will get the full effect of evaporation from soil all over the surface, but our present concern is with the part of the rain, say one-third, which finds its way into the watercourses. What becomes of it? Does it go by evaporation? In the hottest part of summer the loss from this cause is not more than a foot per month from a water surface, and this will be the loss all over the running water, and it forms but a very small proportion of the running water in the rivers, which in flood, when the bulk of the water passes down, are often 20 and 30 feet deep. At most it comes to this,—that in the hottest part of summer the river would lose about 1 foot while the water ran from its source to Wentworth; in autumn, when the bulk of the water passes down the Darling, the actual loss would not be more than 3 or 4 inches in a month, a quantity which does not approach 1 per cent. of the rainfall for the month; and what we have lost is from 10 to 15 per cent. of the rainfall, so that evaporation has not taken it. I have been repeatedly asked why I take 30 per cent. of the rainfall as the proportion of rainfall which would get into the streams in the upper and hilly part of the Darling basin; where the rain is heavy, and the watercourses abundant, I have simply taken what seemed from experience elsewhere to be a probable quantity; and have based the calculation upon this merely to show that such an estimate was absurdly in excess of what does actually flow down the Darling. But only to mention a few authorities. Rankine, in rules and tables, gives for Britain the ratio of available total rainfall on moorland and hilly pasture as from 60 to 80 per cent. In Germany five experiments upon rivers and seven on artificial drainage boxes gave 47 per cent. In the investigation of the rivers for Sydney water supply by the Royal Commission it was shown that in a dry year 39 per cent. of the rain passed down the rivers, and in winter 54 per cent. I have heard that more recent measures gave 44 and 52 per cent. respectively. An attempt made to get this information from Lake George gave the percentage as 30. A professional man here has estimated the percentage for the best-drained parts of the Darling country as 25. It was shown by the Royal Commission on Floods in the Hunter River that in a steady rain, after the first day, 75 per cent. of the rainfall found its way into the river. Now, I may as well add, for comparison, what my figures show as the percentage of rain passing down the Darling, and they are certainly in excess of the truth. In 1880, less than 1 per cent. of the rainfall passed Bourke; in 1881, less than a tenth of 1 per cent. (0.08); and in 1882, about
1 per cent. found its way past Bourke. Let us assume that the experience of engineers in Europe and in our own coast rivers is inapplicable to rivers in the interior, the difference shown above is so great that I think there can be but one explanation of it, and that is that much of the water must get away below the surface. But let me mention a few facts from experience that seem to have a direct bearing upon this supposition. I must select from a great multitude already published, and which I hope some one will classify. Should I take some that are familiar to you, please take them simply as indicating the idea I want to bring before you, and not as facts interesting in themselves. It will be seen that we have positive evidence of deeply buried river courses and of artesian wells that show no signs of decrease after fifteen or twenty years' use. If we know of several subterranean water-courses and several artesian wells which after many years' use are as full-flowing as ever, it is surely premature to say that the water cannot flow underground, and that the wells must fail. At Laen, in the Wimmera district, Victoria, which is part of the great plain of the Murray and Darling, a bore was put down for water, and 250 feet from the surface the bore passed through a tree a distance of 6 feet, and several fruit stones were brought up in the borings, the stones being similar to plum-stones, and in some of the broken ones the kernel was recognizable; 150 feet below the tree they came upon a cement similar to that generally found in alluvial gold-fields. On Goree Station, near Yanko, when sinking a well at a depth of 80 feet, they came upon an old river bed, containing sand and gravel, and upon moving a large stone, which let in the water, a frog jumped out; it had no mouth, and was in other respects peculiar. When put in water on the surface it lived for a week, and then died. Was it covered up there when the river-bed was entombed, or was it carried there by the water usually passing in that underground channel? In building the bridge over the river at Dubbo, trees had to be cut through 85 feet below the present bed of the river. There is a well on Booroora, 15 miles west of the Mooni River. It is 40 feet deep, sunk through 9 feet of impervious clay, 26 feet of hard cement, and 5 feet loose sand, and from this the water rises to within 10 feet of the surface, coming up from the bottom in a thick stream, into which an iron rod 14 feet long was pushed and no obstruction felt. So much sand comes up with the water that the well has to be cleaned out from time to time. It takes a steam-engine and a large-sized centrifugal pump 1\frac{1}{2} day to get the water out preparatory to cleaning, and when it is empty another well into the same sand or gravel shows no less, so that it is evident that the sand hinders the flow of water, otherwise it would not be possible to empty it at all. It is remarkable that every time this well is cleaned out so that the water has free ingress, considerable quantities of rounded
charcoal in pieces about the size of a pea are brought up by the water. A somewhat similar well is found on Kallara, S.W. of Bourke; it is very much deeper, has abundance of water, which rises from the sandy drift to 26 feet above the surface, but the sand accumulates and chokes the well. Other wells in the same district find abundance of water in sandy drift. Again, west of Wilcannia a number of wells find water in a river drift a long distance from the river, and in all of them the water rises to the same heights, proving that the water is from a common supply. About 50 miles S.W. of Gunnedah, at Bomera head station, is a well only 6 feet deep; water is almost always level with the surface, and the supply practically inexhaustible, though the creek near it is frequently dry. On Garrawille station there is a well yielding 9,600 gallons per hour; near it the ground sounds quite hollow for 100 acres, and there are holes in it 3 or 4 feet deep, at the bottom of which you can see and hear the water rushing on in its subterranean course. On Cox's Creek many years ago a deep well about 80 feet was sunk to hard rock, and there was no sign of water, but as soon as they cut through the hard rock at the bottom, there came such a rush of water that they had to abandon their tools and get up the rope as fast as possible to save their lives; the water rose to within 10 feet of the surface. Years after, another well was made 80 yards from it, and next day the first well began to overflow, and has continued to do so ever since. In the valley of the Peel below Tamworth a large body of water passes down underneath the bed of the river in a gravel bed. The same sort of thing is seen in the river at Tenterfield. Ten miles south of the river at Condobolin a number of wells have been put down (about 50 feet) into what is by all considered a perfectly inexhaustible supply of good water, sufficient for irrigation and every requirement. These form just a sample of hundreds of cases that want arranging and explaining; for if there are old river beds in one part of the plains why not in another, and why may there not be an abundant drainage in such old watercourses?

Mr. T. K. Abbott, who devoted so much time to an investigation of the wells on Liverpool Plains, told me that from a study of 200 wells he was able to trace an old river bed across the plain which had abundance of water in it. Mr. W. Abbott says in most parts of the Darling country there are to be seen depressions 2 or 3 feet in depth, and sometimes 4 or 5 yards in diameter, with one or more holes in the bottom through which the surface water finds its way to lower strata; these holes exhibit no tendency to fill up—they swallow all the water that comes. For days and days a stream of water has been seen going down these holes, and one naturally asks, where to? Compared with the area of the whole Colony we have only a well here and there, and if out of these a few run over with a supply practically unlimited, and if again
these wells here and there point unmistakably to an older river system, overlaid by the present surface, would it not be better to look for it, and arrange our theory to fit the facts, and not the facts to fit the theory? In other countries it has been found advantageous to do so, for Professor Marsh, of America, says:—

"Hydrographical researches have demonstrated the existence of subterranean currents in many places where superficial geology had not suggested such a possibility. For example, the river Tiber, in Italy, loses suddenly a much larger proportion of the rainfall than can be accounted for by evaporation and the water flowing in the river; and Lombardine, than whom perhaps there can be no higher authority, satisfied himself that the quantity of water carried by these subterranean conduits and carried into the river is not less than three-fourths of the total delivery of the Tiber's basin. And we have reason to think it will be so here. To go no further than the Sydney water supply, what do we find? That rivers flowing through compact sandstone have yet running near them—that is, within two or three miles—springs which are little rivers in themselves. One such, found in the tunnel, is remarkable for the abundance of water which it furnishes. I will not detain you longer; but I think I have said enough to show that there is abundant room for investigation, and that a matter of such vital importance to the community ought to be taken up by a Royal Commission, or by some one with time and means at his disposal to carry out a complete investigation of the whole subject.

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