4/6

D. T. Mitchell.

1886.

NEW SOUTH WALES.

ROYAL COMMISSION—CONSERVATION OF WATER.

FIRST REPORT

OF THE

COMMISSIONERS.

ABRIDGED EDITION.

SYDNEY: THOMAS RICHARDS, GOVERNMENT PRINTER.

12*e* 34—86

1886.

[1*s*.]

INDEX.

SUMMARY OF MEETINGS OF COMMISSIONERS.

Number of meetings held.	W. J. Lyne, President.	R. Barton.	J. B. Donkin.	F A. Franklin.	F. B. Gipps.	R. L. Murray.	D. M'Mordie.	R R. Machattie.	G. W. Townsend.	W. S. Targett.
Commission: Meetings to 10 Dec., 1885; number held, 99.	57†	58	76	72	87	62	88	1	16‡	17§
Subcommittee:* Meetings to 11 June, 1885; number held, 7	4	...	...	5	7	...	7	...	...	...

---

* Consisting of the President and Messrs. Franklin, Gipps, and M'Mordie.

† The President, on accepting office as Minister for Public Works, found it impossible to attend any further meetings of the Commission.

‡ Left Sydney in September, 1884, in connection with Colo survey.

§ Appointed as a member of the Commission, May, 1885.

1886.

NEW SOUTH WALES.

ROYAL COMMISSION—CONSERVATION OF WATER.

FIRST REPORT OF THE COMMISSIONERS.

To His Excellency the Right Honourable CHARLES ROBERT, BARON
CARRINGTON, Knight Grand Cross of the Most Distinguished Order
of Saint Michael and Saint George, Governor and Commander-in-Chief of the Colony of New South Wales and its Dependencies,
&c., &c., &c.

MAY IT PLEASE YOUR EXCELLENCY,—

We, your Commissioners, appointed on the 10th day of May, 1884, "to make a diligent and full inquiry into the best method of conserving the rainfall, and of searching for and developing the underground reservoirs supposed to exist in the interior of this Colony, and also into the practicability, by a general system of water conservation and distribution, of averting the disastrous consequences of the periodical droughts to which the Colony is from time to time subject," have the honour to submit this our First Report:—

Meetings.

We have held ninety-nine meetings, and examined 137 witnesses, minutes of whose evidence are appended.*

Experience of other countries.

At the outset of our inquiry we caused letters to be sent to the Chief Secretaries of the Australian Colonies, the Governors of some of the Western States in the American Union, and, by the courtesy of your Excellency's predecessor, Lord Augustus Loftus, and the Foreign Office of the Imperial Government, to the Departments of European countries and the Presidencies of India in which works for the conservation and distribution of water have been carried out; and those communications have in a large measure placed at the service of this

---

* The Minutes of evidence will be found in the original edition of the Report.

Colony a knowledge of the methods employed by other countries for the conservation and distribution of water and the experience which has been gained in respect to them. Much of this information is necessarily of a technical nature, having reference to constructive details; but many of the plans and other particulars with which we have been supplied will be found to be extremely valuable when similar works are entered upon in New South Wales.

Information from pastoralists and surveyors.

We have also sent circulars with skeleton county and parish maps to the whole of the Government surveyors, and to all the principal landholders and other persons resident in different parts of the Colony from whom we had reason to hope information might be obtained respecting the watersheds of the districts in which they reside, the general fall of the surface, the flow of underground water, the number, position, and character of the wells, tanks, and dams, the amount of rainfall and evaporation, irrigation where practised, and other information of the like nature. The number of circulars already issued is 560, and they have been accompanied by 5,040 maps. 108 answers have been received, and, as a great number of others are expected to come in, it is not possible to embody this information in the present Report. It is expected to be voluminous and important, and the information is being carefully compiled as it is received, and we anticipate that, when the whole of the replies are received and tabulated, the accumulated experience and knowledge of pastoralists and others, scattered over a wide area, who have expended large sums in sinking wells and conserving water will be of great value in aiding future efforts for the discovery of underground supplies of water and in indicating localities most suitable for the construction of storage works and distributing channels.

Engineer.

By the smallness of the appropriations made by Parliament for the purposes of the Commission, taken in connection with the fact that the services of surveyors and engineers employed under Government have not been available to the Commissioners, we have been precluded from undertaking an instrumental examination of the different catchment areas of the Colony, so essential for the proper consideration of water conservation and distribution to the best advantage; but it was nevertheless necessary that, in the prosecution of our inquiries, we should have the assistance of an Engineer, for the purpose of making flying surveys and reporting on particular points, and we accordingly selected a gentleman for that office.

Levels, gauges, river sections, and discharges.

Information as to the levels of different parts of the Colony existed in some of the Government offices, particularly in that of the Engineer-in-Chief for Railways; and it was one of the earliest duties of the Engineer to compile all known levels and to connect them with the river systems of the Colony. This has been so far completed as to give a fairly accurate idea of the slope of different parts of the Colony, and to show the directions in which canals or other distributaries may be practicable. He has also devoted attention to the ascertainment of accurate sections and discharges of the rivers Murray, Murrumbidgee, Macquarie, and Darling; the localities selected for the purpose being Albury, Dora Dora, Gundagai, Dubbo, Warren, Bourke, Brewarrina, and Walgett. Gauges have been fixed at all these places, and (with the exception of those at Dora Dora and Warren) they have been connected with the railway levels. The gauges, are, therefore, now connected with sea-level, and the foundation has been laid for the compilation upon uniform data of the discharges of the principal rivers—information which it is essentially necessary to procure before any large works for the storage and distribution of water can be safely entered upon.

Visits of the Commission to the country.

For the purpose of inspecting localities of proposed or possible works for water conservation, as well as to make ourselves better acquainted with the interior of the Colony, and to suit the convenience of important witnesses whose evidence we could not otherwise have obtained, we made the following tours :—

1st. To the Yanko and Colombo Creeks, taking evidence at Narrandera and Jerilderie on subjects specially referred to us by the Honorable the Colonial Secretary.

2nd. To Tamworth, Gunnedah, Narrabri, Walgett, Brewarrina, Bourke, Goonery Springs, Nyngan, and Dubbo, holding meetings and taking evidence at all these places in the order mentioned.

3rd. To Hay, Corrong Station, aud Tupra Station.

In addition to these tours made by the Commission, we, on two occasions, deputed one of our number (Mr. F. B. Gipps, C.E.) to report on proposed sites of works for water conservation. The first of these visits of inspection was to the Namoi River, and the second to the Upper Murray. The reports of these inspections will be found in the Appendix.

Diversion of Snowy River into Murrumbidgee.

At an early sitting of the Commissioners, the Surveyor-General of this Colony stated in his evidence that he believed a large supply of water could be diverted from the Snowy River to supplement the discharge of the Murrumbidgee, and evidence was also obtained that water could probably be stored on the Upper Murrumbidgee on an extensive scale, sufficient to assist materially in equalizing the flow in that river. In consequence of these opinions, we deputed a surveyor to make an instrumental examination of the Tantangara basin on the Upper Murrumbidgee, and also to level from the Snowy River to the watershed between it and the Murrumbidgee. The surveyor's report on the Tantangara basin, with our Engineer's remarks thereon, are included in the Appendix. The report on the levels in the Snowy River basin has not yet come to hand.

Tantangara basin.

Subjects for future examination

In this our first report we have dealt with the questions submitted to us so far as the time and means at our disposal have permitted ; but connected directly with the subject of our inquiry there are several very important points which we have not yet had opportunity of investigating. Foremost amongst these are the terms on which an equitable settlement of intercolonial rights in the waters of the Murray River can be made. The Government of Victoria has for many years been collecting valuable statistics regarding the Murray and its tributaries in that Colony ; but, excepting the records of the height of the Murray maintained by Mr. Russell, Government Astronomer, no corresponding information is available in New South Wales. It is highly desirable that a definite understanding on this subject should be arrived at as soon as possible, and with that end in view we propose to obtain the necessary data on which to base a satisfactory intercolonial agreement. To prepare the way for such an agreement we have arranged to confer with the Royal Commission on Water Supply in Victoria. Other points which merit full and careful inquiry, and to which we propose to devote our attention, are :—

(*a*) The examination of the northern tributaries of the Darling, with special reference to the storage of flood-water in the upper portions of their basins, and to irrigation in the plains.

(*b*) A similar examination of the basins of our coastal rivers.

(*c*) The practicability of storing flood-water, on an extensive scale, in lakes and in all depressions of large capacity on the western plains, and in particular in the lakes near the Lower Darling and in Lakes Cargelligo and Urana.

(*d*) The problem of the underground supplies of water, especially as to their sources, direction of flow, and extent.

In addition to pursuing our inquiries on these subjects, we are prepared to deal promptly with the works for which surveys are herein recommended, provided the necessary funds are placed at our disposal.

Scope of present inquiry.

For the systematic consideration of the subjects which have been included within the scope of our inquiry up to the present, as well as for the purpose of furnishing a comprehensive abstract of the evidence obtained, we have classed the various questions under the following heads :—

Under the first head the general characteristics of the Colony are dealt with, and particularly those having an influence on the rainfall and on the available supply of water; while in the second, third, and fourth divisions, the amount of the rainfall and the proportion of it lost by evaporation and percolation are discussed.

In parts 5 to 8 inclusive, the methods which have been, or can be, adopted for utilizing the available supply of water are described, and reference is made to the practice of other countries, especially in regard to irrigation.

The question of navigation is dealt with in part 9, and its position and importance relatively to irrigation are briefly referred to.

Under the 10th heading we have divided the Colony into principal drainage basins and groups of drainage areas, and have calculated the area and the mean rainfall of each basin or group of basins. This arrangement enables us to place the information bearing on water conservation and supply, and especially that portion of the subject bearing on the rainfall, in a clear light and in a condensed form. With the aid of the rainfall returns of the Government Astronomer, the county and parish maps prepared by the Survey Department, and the evidence we have taken, the information regarding both the rainfall and the drainage area has been made as complete as possible, and is the closest approximation at present obtainable.

In the 11th division we have discussed the question of riparian rights, and have submitted a draft of the legislation which we recommend. This question is one of pressing importance, and one which must be dealt with before any national system of water conservation can be properly initiated. It will be seen that the main features of the proposed administrative machinery for developing water conservation and supply are—

(*a*) A permanent Board, acting directly under a Minister who will be able to devote a large portion of his attention to this and cognate questions ; and

(*b*) The establishment of a system of local Trusts, which will generally construct and manage works for water conservation and supply.

Under the 12th heading, the conclusions arrived at by the Commission on subjects other than legislation are embodied in a series of recommendations.

(1.) PHYSICAL FEATURES.

Great Dividing Range.

The Great Dividing range, trending, roughly speaking, almost parallel with the coast, forms the principal watershed of the Colony; and, with the spurs which run out from its eastern and western slopes, determines the direction of surface flow. The Muniong and the Snowy Ranges, in the southern portion of the Colony, are the only mountains upon which snow rests for any considerable time ; and although snowstorms occasionally visit Ben Lomond and the higher altitudes of the range, they are not of sufficient frequency and the quantity of snow precipitated is not large enough to form any very important factor in estimating the sources of water supply. The Murray, the Murrumbidgee, and the Snowy River are the only streams whose volume is augmented to any considerable extent by the melting of the snow, and these all take their rise in the Snowy Mountains. The loftiest peaks in Australia occur in this part of the country, and their summits are more than 7,000 feet above sea-level, and double the height of the Great Dividing Range viewed as a whole.

Coast rivers.

The rain-clouds which come from the Pacific Ocean with the east and south-east winds strike the shoulders of the eastern slopes of the Dividing Range, when the rain is precipitated and often flows down their steep slopes in torrents, and is carried to the sea by the Moruya, Clyde, Shoalhaven, Hawkesbury, Hunter, Manning, Hastings, Macleay, Clarence, Richmond, and other rivers. The coast district, embracing an area of 50,000 square miles, whose western boundary is the summit of the mountains, and running back from the sea to distances varying from 30 to 150 miles, has a heavier and more regular rainfall than that of the country west of the Dividing Range.

Western waters

The spurs which run out upon the western face of the main range, although not so precipitous as on its eastern declivity, are nevertheless sufficiently bold to direct the flow of water into well-defined channels for short distances from their base; nearly all, with the exception of the Lachlan (whose general course resembles that of the Darling), trending for a long distance of their flow in a north-westerly direction until they unite with the Barwon or the Darling, whose sluggish and tortuous course south-westerly and south lies through wide-reaching plains of level and for the most part rich country. The principal tributaries of the Darling are the Macintyre, the Gwydir, the Namoi, the Castlereagh, the Macquarie, and the Bogan, each in its turn being fed by numerous creeks, and the whole outflow of the western watershed (including the Murrumbidgee and the Murray) converges upon Wentworth, whence it flows west and south to the sea near Adelaide. The area and principal facts respecting the different basins, in so far as information has been available, will be referred to further on when we come to consider the characteristics and capabilities of particular districts for water storage.

Transcontinental range.

Mr. C. S. Wilkinson (the Geological Surveyor) and other geologists are of opinion that at some earlier epoch there existed a dividing range of primary rocks running nearly at right angles with the coast range, and he has traced it across from the Flinders Range in South Australia to Wilcannia, curving round to Cobar, Parkes, and Orange, so that it forms the watershed between this portion of the Darling and Lachlan basins. The rocks forming the roots of this range may be traced near the surface, and Mount Murchison is regarded as portion of the range, which, by denudation, has in the lapse of ages now almost wholly disappeared.

Cretaceous basin.

The country to the north of this lost range, on the Gulf of Carpentaria and perhaps Port Darwin, is supposed by Geologists to have been submerged by the sea at one time as a deep basin, and that its present condition is due partially to upheaval and partially to the enormous denudation of the mountain chains of Australia. From these premises deductions have been drawn having an important bearing upon the probable existence of underground water, which will call for further reference.

Lakes.

If we except lakes which are estuaries of the sea, such as Lake Macquarie, the principal lakes of New South Wales are shallow, and are also untrustworthy in regard to the permanency of their supply. In many cases they are merely large depressions connected with rivers, and depending for their supply on occasional floods in those rivers. Lake George, situated on the eastern side of the dividing range, and at an elevation of about 2,200 feet above the sea, is the best known, and one of the most important lakes of the Colony. In dimensions it is about 19 miles by 6, and is supplied from several intermittent creeks, but has no outlet. As might be expected under these circumstances, the water in the lake is strongly impregnated with salts. Lake George has been known to fail entirely, as also has Lake Bathurst, ordinarily about 15 miles in circumference, situate in the same district, and its bed to be dry for considerable periods; but these lakes have never been known to overflow. Of the other lakes of the Colony the most important are Yantara, Cobham, and Salt Lakes, near the extreme north-west of the Colony; Poopelloe, Pamamaroo, Menindie, Cawndilla, and Tandou Lakes, along the course of the Darling; Lake Victoria, near the Lower

Murray, Cowal Lake, and Lake Cargelligo, which are fed from the Lachlan, and the Narran Lake, in which the river of the same name is lost. There are many other lakes of less importance, but similar in their description to those mentioned. Of the lakes situated near the course of the Lower Darling there are three having each an area of more than 60 square miles. The great capacity of these lakes is evidenced by the fact that when rapid falls in the Darling occur, it is estimated by the captains of the river steamers that the outflow from the lakes to the Darling keeps the river navigable for ten days or a fortnight longer than it otherwise would be. This is an important point, especially when it is considered that the outlets from the Darling to the lakes are in their natural state, and that, with few exceptions, no attempt has been made either to increase the supply flowing into the lakes or to regulate the outflow. In the case of the lakes east of the Darling, in the county of Livingstone, an almost permanent supply is maintained, through the construction of a dam across the Tallywalka Creek. This was done by the lessees at their own expense, the cost amounting to £3,000 or £4,000; and, as stated by Mr. Mair, "the effect of that dam was to throw the water into a series of lakes extending north and south a distance of 80 miles, and I should think giving several hundred miles of almost permanent water frontage." The figures stated by Mr. Mair show at a glance the remarkably profitable character of the dam referred to. "Several hundred miles of almost permanent water frontage," acquired at an expense of "£3,000 or £4,000," is a statement which requires no comment.

Cowal Lake.

Lake Cargelligo.

Cowal Lake and Lake Cargelligo occupy with regard to the Lachlan a position similar to that occupied by the Menindie and other lakes with reference to the Darling; Lake Cargelligo, with its area of 11½ square miles, presenting unusual facilities for storing large supplies of flood-water. Special surveys to ascertain what can be done in this respect have been made under the direction of Mr. Adams, Surveyor-General, and with most encouraging results. The question has not escaped the notice of the lessees of the land surrounding the lake, as they have constructed a dam on the creek leading from the lake to the river Lachlan, and by that means they retain a large portion of flood-water. The improvement of this dam, and the construction of sluice-gates in it, as suggested by Mr. Moriarty, Engineer-in-Chief for Harbours and Rivers, would produce very beneficial effects at a very moderate expense.

Lake Urana.

Cowal Lake and Lake Urana, though large in point of area, scarcely deserve the name of lakes, as they are merely shallow depressions, which obtain an uncertain supply from occasional floods. Surveys may, however, show that they are capable of being very much improved.

Lake Yantara.

Cobham Lake.

The lakes in the extreme north-west of the Colony, Lake Yantara and Cobham Lake in particular, have large catchment areas; and from their position, in a very dry district, remote from any permanent river, must be looked on as possessed of very considerable importance. Before the heavy rain of January last, Cobham Lake was almost, if not quite, dry; but after the flood of that month, there was a sheet of water 8 miles in length, and in some places as much as 27 feet in depth.

Facilities for canals.

The general configuration of the country, as exemplified in its mountain system, is so well known that a detailed description of the great barrier, whose elevation varies from 2,000 to upwards of 7,000 feet, seems unnecessary; but the rise and fall of the country westward is not, perhaps, so commonly understood. The levels of the country lying between the Murray and the Murrumbidgee show that it is singularly well adapted for the construction of canals, and the capabilities of its soil for agricultural production can hardly be surpassed. Over a large portion of the area there is a gentle inclination north-west from the Murray, and south-west from the Murrumbidgee, and our investigations justify the expectation that water from these rivers can be led over a large portion of its surface. The country between the Lachlan and the Murrumbidgee is more irregular ; but the enormous area lying between the Lachlan and the Darling, which appears as a blank in the general maps of the Colony, has been ascertained to possess some well-defined features. So level is the southern portion of this area that there is every reason to believe water may be conducted through the whole of it; in fact, in high floods the waters of the Lachlan and the Darling—ordinarily separated by an interval of 200 miles—have spread out to within a distance of about 30 miles of each other. North of the Willandra Billabong there are depressions wherein there is reason to hope considerable bodies of water may be stored in this arid region ; but the information available, which at present is very limited in extent, does not disclose any specially favourable features in the contour of the country for distributing channels. North of the Bogan, and west of the Great Dividing Range, the country is irregular until it leaves the spurs from the range ; but the fall thence to the Darling is remarkably uniform, and offers great facilities for the distribution of water through artificial channels.

Levels : Newcastle to Walgett.

Starting at only 2 feet above high-water mark at Newcastle, the Great Northern Railway runs up the Valley of the Hunter, and is carried over the Liverpool Range, at an elevation of 2,070 feet ; it then descends at the rate of 85 feet per mile for 8 miles, and at the rate of nearly 40 feet per mile until the Werris Creek is reached, at an elevation of 1,245 feet. Taking a north-westerly course across the basin of one of the principal tributaries of the Namoi, the level falls 371 feet in the first 41 miles, the elevation at Gunnedah being 874 feet, and 177 feet in the 46 miles to Narrabri, where it is 697 feet. From Breeza to a point 70 miles north-west of Narrabri, following the line of railway survey, the fall of the country, with few and unimportant exceptions, is 3 feet per mile, the distance being 152 miles ; thence to Walgett, 43 miles, at the junction of the Namoi and the Barwon, the fall is scarcely 15 inches per mile.

Sydney to Bourke.

The configuration of the country between Sydney and Bourke is seen from an examination of the railway-levels between those termini. Starting at Sydney at 64 feet above the sea the Great Western Line crosses the Valley of the Nepean at about 90 feet, and reaches the summit of the Main Range at the Clarence siding at an elevation of 3,658 feet. Descending the spurs of the western slope into the valley of the Macquarie, Bathurst is passed at an elevation of 2,153 feet, and in the next 40 miles it ascends nearly 700 feet to a point near Orange, from which locality the descent to the western plains begins. Dubbo, 278 miles from Sydney, is situate on the eastern margin of the plains, and its elevation is 865 feet. Beyond Dubbo there are some low ridges and slight undulations, which influence the grades considerably over short lengths, but for the whole distance (225 miles) to Bourke the fall is remarkably steady, averaging about 2¼ feet per mile. The valley of the Macquarie is first crossed at 145 miles from Sydney, the watershed dividing the Macquarie from the Lachlan at 186 miles, the valley of the Macquarie again at a distance of 248 and 278 miles, and the Bogan, at Nyngan, at 377 miles. Between Dubbo and Nyngan there is a mean fall of about 3 feet per mile. The first of the low ridges which occur beyond Nyngan is at 397 miles, and its elevation at the place crossed is 622 feet, the lowest ground between that point and Nyngan being at 546 feet above sea-level. Girilambone, at 405 miles, is situate on the next ridge, its elevation being 639 feet; and of the series of ridges which follow, the highest is 781 feet, at 414 miles. Cobar Road, 424 miles, marks another ridge of 747 feet, and in the next 8 miles there is a fall of 170 feet, or more than 21 feet per mile; the next 23 miles show a fall at the rate of 4 feet per mile, and the next 46 miles about 18 inches per mile. The black-soil country begins near this point, and the surface is very level on to Bourke, but with a slight fall-away from the river, the elevation at 491 miles being 343 feet, while that at Bourke (503 miles) is 346 feet.

Bourke to Mount Brown.

No levels by an instrumental examination of the country beyond the Darling have been obtained, but a section prepared by the Superintendent of Drills goes to show that there is an undulating rise from the Darling to the Mount Brown Range. This range is shown as having an elevation of more than 1,000 feet above sea-level, becoming gradually lower and less defined as it extends south. The range appears to trend west of south until it passes into South Australia. The fall of the country north-west of the Darling to that river is so slight that no water except in times of heavy rain would reach it.

Wallerawang to Walgett.

The country along the route of the railway proposed to be constructed from Mudgee to Walgett (428 feet) resembles in its general character that along the line to Bourke. The railway line from Wallerawang to Mudgee follows as far as Ilford the course of the Dividing Range, which here recedes further from the coast than at almost any other point. The respective elevations at Wallerawang, Ilford, and Mudgee are 2,928, 2,450, and 1,635 feet. The levels of the survey between Mudgee and Walgett show to within 40 miles of Coonamble an undulating country, whose average elevation ranges between 1,100 and 1,200 feet. The ridge between the Talbragar and the Castlereagh would be crossed at an elevation of 1,660 feet, and another ridge 41 miles to the northward at 1,560 feet. The plain country begins at a point distant from Sydney 293 miles and to the south of Coonamble 40 miles. It falls with gentle undulations for 10 miles to a level of 918 feet, and the fall for the next 30 miles to Coonamble is a fairly regular one of 11 feet per mile. The fall for the first 15 miles beyond Coonamble is at the rate of about 3½ feet per mile, and thence to Walgett (66 miles) it is slightly over 1 foot per mile.

Dubbo to Coonamble.

The surveys made between Dubbo and Coonamble show that the country is higher and more ridgy than on the opposite side of the Macquarie. While at Dubbo the elevation is 865 feet, at 28 miles from Dubbo in the direction of Coonamble it is 1,100 feet; 9 miles of undulating country brings the level down at Marthaguy Creek to the same as Dubbo, and from the creek to Coonamble there is a fairly regular fall of a little more than 6 feet per mile.

Between Bourke and Walgett.

Comparing the line from Dubbo to Bourke with the surveys from Dubbo to Walgett and Coonamble, it will be seen that while on the former the plains begin at or slightly to the west of Dubbo, on the last-named route the undulating country goes to about 39 miles north of Dubbo. The levels also go to show that while the fall of the rivers is towards the north-west, there is also in this part of the colony a fall in the land towards the south-west.

Nyngan to Cobar.

Nyngan is situated on the east bank of the Bogan, at an elevation of only a few feet above the flood-level of that river. 58 miles to the west the railway surveys show that the line to Cobar will have to be taken across a ridge at an elevation of 1,045 feet above sea-level, or 473 feet above Nyngan and 255 feet above Cobar. The position of this ridge corresponds with that of the mountain chain described by the Government Geologist as one which probably formed the southern coast-line of the ocean, whose waters in the cretaceous period covered most of the area now lying northwards to the Gulf of Carpentaria and Port Darwin. Comparing the levels at Cobar with those of the portion of the survey which has been made between Condobolin and Wilcannia, it is found that the former are about 450 feet higher than the latter. Cobar appears to be on the side of the range referred to, while the line from Condobolin follows the low undulating country about 130 miles to the south and south-west.

Forbes to Wilcannia.

The Forbes to Wilcannia route, from Condobolin to the north-west, shows an irregular succession of undulations until the top of the Guagong Range is reached, the pass through which is lower than Condobolin, the respective heights being 660 feet and 618 feet. In the county of Blaxland the country continues ridgy, but there is still a fall in a southerly and in a westerly direction. Booberoy Creek which, like the Willandra Billabong, is an effluent from the Lachlan, is crossed at 36 miles from Condobolin, and at an elevation of 530 feet. Passing beyond the branches of the creek there is a gradual ascent to the top of a ridge, which is crossed at an elevation of 654 feet, and at a distance of 70 miles from Condobolin. The route for the next 164 miles is through an undulating incline to the north-west, the height above sea-level at that point (234 miles beyond Condobolin) being 264 feet, and for the remaining distance (35 miles) to Wilcannia the surveyed line extends through plains country. Along the first 234 miles from Condobolin to Wilcannia many extensive depressions are met with, several of which appear to become marshes or lakes after heavy rains, and some of which could probably be utilized for the storage of large supplies of water. After passing the Guagong Range, 28 miles from Condobolin, there is every reason to believe that in the undulating country extending from that place to within 35 miles of the Darling, no portion of the rainfall ever reaches either that river or the Lachlan. A large proportion of the plains country is subject to inundation, particularly after crossing the first ana-branch of the Darling, at a distance of 22 miles from Wilcannia.

Liverpool to Wentworth.

Skirting the valley of George's River and crossing that of the Nepean, the Great Southern Line ascends the Dividing Range to Mittagong, from which place to Breadalbane it traverses the table-land, whose elevation varies from 2,000 to 2,300 feet above the sea. This plateau constitutes an important portion of the gathering ground for the Shoalhaven River and its tributaries in the south, and for the Wollondilly and its tributaries on the north. Beyond Bredalbane there is a descent through hilly country, and in the catchment area of the Lachlan till the basin of the Murrumbidgee is reached near Yass, where the country is still hilly, the elevation at Yass being 1,657 feet. Beyond this point the gathering ground of the Murrumbidgee is traversed, but at only a short distance from the watershed between that river and the Lachlan. At Junee the elevation is 985 feet, and thence to the Murrumbidgee at Narrandera the country may be classed as undulating, but with a fall of nearly 7 feet per mile. From Narrandera to Hay the course of the river is followed along open plains, having a mean fall of 2½ feet per mile. The height above sea-level at Hay is 305 feet, while that at the junction of the Murrumbidgee with the Murray is about 190 feet, which gives a fall in a direct line of about 15 inches per mile. From the junction of the Murray and Murrumbidgee to Wentworth the fall is only 70 feet, while the direct distance is about 85 miles.

(2.) RAINFALL.

Causes of abnormal rainfall

The quantity of rain which falls in any given locality depends on many circumstances, chief among which are temperature, distance from the ocean, configuration of the country, and position relatively to prevailing winds. Concurrence of several favouring causes produces abnormally high rainfall, while concurrent absence of such causes will have the reverse effect. Thus, at Cherra Pungi, on the Lower Himalayas, the mean annual rainfall during the years 1859 and 1860 reached the enormous amount of 615 inches. There the vapour-laden clouds carried by the south-west monsoons from the Bay of Bengal strike the mountains at an elevation of 4,500 feet and discharge their contents in torrents of rain. On the other hand, in that portion of Central Asia extending along the northern side of the Himalayas rain is almost unknown. For the week ending 18th June, 1885, the rain-gauge at Yowai (33 miles due east of Cherra Pungi) registered a fall of 64·79 inches, of which 51½ inches fell in forty-eight hours. Although 40 inches in twenty-four hours have been measured at Cherra Pungi, it is believed that 50 inches in two days is higher than any previous rainfall on record. In one of the islands of the Hawaiian group rain is said to fall every day on one side of the mountain, while it is alleged that rain has never been known to fall on the other.

Rain records.

Parliament made provision for the establishment of the Observatory in the year 1856; but, although meteorological science has a most important bearing on the prosperity of the Colony, it was not until the appointment of Mr. H. C. Russell, B.A., to the office of Government Astronomer, in 1870, that any systematic effort was made to collect information of the rainfall of New South Wales, and its great progress since then is mainly due to his labours. Finding only five observing stations in existence, he at once took steps to add others—with what success may be seen from the fact that the number of observers who sent in statistics of rain-measures during 1884 was 496. Notwithstanding the importance which is now attached to the subject, a map of Australia would show nearly one half of its area a total blank (if the overland telegraph line be excepted), so far as meteorology is concerned; and data based upon observations made over a much wider field than that which has yet been occupied will have to be accumulated before the course of storms can be accurately traced, or generalizations affecting the rainfall of the continent can be safely made.

Decrease of annual mean.

The fact that the Astronomer's records of rainfall came from only five observers in 1870, and that until 1878 Mr. Russell had very great difficulty in enlisting co-operation of others in this department of his work, seems to justify the opinion that the average of recorded rainfall for those years would be extremely fallacious if taken as the average of the rainfall of the Colony for the same period, or if looked upon as anything more than the most approximately accurate mean obtainable of that of the coast district. Indeed, the only method of obtaining useful practical results from the rainfall observations, as far as water conservation is concerned, is to ascertain the mean rainfall as nearly as possible in each river basin. This has now been done, and the results are stated in connection with the various drainage areas.

Cause of apparent decrease of rainfall.

With the exception of the years 1878 and 1879, the latter of which was phenomenally wet, the averages of the years since 1874 disclose an almost uniformly regular decrease in the rainfall. This is no doubt partly attributable to the series of very dry years which have proved so disastrous to the principal producing interests of the Colony. A diminished rainfall of 50 per cent. has at times desolated particular districts, but the records of the Astronomer have proved that droughts are not of equal severity throughout the Colony—that while one part of the country suffers from a diminished rainfall, other parts have an average supply, and others again may be favoured with an abundant fall. As the "dry" districts occupy a far larger area than those which may be regarded as humid, and as the quantity of rainfall there is of more pressing importance, it is not surprising that the number of observing stations in the former is much greater than that in the latter. A glance at the rainfall map of 1878—the first year in which it was published—shows that observing stations were then few, and widely separated throughout the Colony, to the west of the Main Range; while in that for the year 1884, that portion of the Colony, in common with the coast districts, was thickly studded with collectors of meteorological statistics. Rain from thunder-storms is often extremely local. It was found on a single run, where six rain-gauges were kept in various parts of it, that the record of the rainfall ranged from 19·81 inches to 27·75 inches.

Coast districts.

An idea of the rainfall along the coast may be formed from the records of the following observing stations, the first column showing the main rainfall for each year during which records have been kept, the second showing the average number of rainy days, and the third the number of years of which the preceding columns are the average :—

	Mean rainfall. Inches.	Wet days.	Years in mean.
Eden...	35·78	115	14
Sydney	49·61	163	14
Port Macquarie	60·59	131	14
Clarence Heads	45·06	87	8
Antony	63·85	155	4

Table-land.

The like information applicable to the following stations on the table-land is :—

	Mean rainfall. Inches.	Wet days.	Years in mean.
Tenterfield	29·99	72	14
Armidale	29·76	78	14
Tamworth	25·64	69	7
Mount Victoria	36·65	89	12
Goulburn	25·84	87	14
Cooma	18·38	78	14
Kiandra	61·16	103	6

Darling.

Records from the following stations on the Darling show these results :—

	Mean rainfall. Inches.	Wet days.	Years in mean.
Walgett...	15·76	40	5
Brewarrina	20·04	...	12
Bourke	16·01	42	10
Louth	11·40	30	4
Menindie	7·37	33	4
Wentworth	11·14	70	14

Rain sections.

Commencing on the coast, and following as nearly as possible the parallels of latitude, there is, as a rule, a steady decrease in the rainfall. This is exemplified in the case of the three lines passing in this manner from the coast towards the western boundary of the Colony through the following stations :—

A.

Name of Station.	Approximate distance from the coast.	Mean annual rainfall.	Mean number of rainy days.	Number of years reckoned.	Remarks.
	miles	inches			
Clarence Heads ...	0	45·06	87	8	
Grafton	20	33·57	81	13	
Glen Innes... ...	96	33·03	104	3	
Myall Creek ...	160	27·18	78	6	
Dungalear	300	15·08	31	4	
Warraweena ...	420	14·93	32	8	
Nocoleche	540	12·19	39	6	
Mount Poole ...	680	7·13	20	6	

B.

Sydney	0	49·61	163	14	
Carcoar	120	26·14	79	3	
Lake Cowal	220	13·97	47	5	
Naradhan	280	17·15	47	5	Probably influenced by the Cocoparra Range.
Culpotaro	400	12·35	42	6	
Lake Victoria	560	9·50	27	3	

C.

Cape Saint George	0	51·67	108	14	
Queanbeyan	60	22·56	70	14	
Wagga Wagga	150	22·12	74	13	
Wangonilla	300	14·20	45	7	
Murrray Downs......	370	15·58	51	14	

New South Wales compared with other countries.

The rainfall of New South Wales as compared with some other countries does not support the idea of those who regard this Colony as peculiarly arid ; and it could be shown that droughts, which are the great scourge of the country, are common to almost every part of the habitable globe. It is true that the diminished rainfall is not so disastrous in its consequences in more temperate climates as it is in Australia ; but the meteorological records of England show that during the period between 1740 and 1750 there was only 71 per cent. of the average rainfall. In some parts of Europe—Sweden and Russia—the rainfall is as low as 15 inches per annum ; the average for twenty years at Marseilles was 12·8 inches, and at Alicante the total for the year has fallen as low as 7·1 inches. In so exceptionally favoured a country as Great Britain the distribution in different parts is very unequal, the average falling as low as 20 to 28 inches on the east, and running up to 75 inches in the lake districts. The precipitation of rain is in many countries more immediately caused by the existence of mountain ranges which intercept the rain-clouds as they are swept up from the sea. The rain-bearing winds from the Bay of Bengal pass over the wide tract of swampy plains, and striking the Himalayas near Darjiling discharge their contents in torrents along the face of the mountains, while the south-west moonsoon deluges the Western Ghats with from 100 to 250 inches in a year, the fall in each case becoming less inland as the clouds are exhausted of their moisture. Cape Colony, whose climate and physical features greatly resemble that of New South Wales, has a heavy rainfall precipitated on its eastern slopes by the winds which blow from the Indian Ocean; and, while the rainfall of the Colony as a whole is reported to be 24 inches, the average declines to about 12 inches in the western districts. This is much the same as that which occurs in the more remote interior of New South Wales and Queensland and in the northern areas of Victoria, the rain-clouds in each Colony being largely intercepted by the mountain ranges. The mean rainfall in the southern portion of South Australia, where there are no high coast ranges to arrest the drift of the clouds, is as low as 20 inches at Adelaide, and 8 inches at Port Augusta, at the head of Spencer's Gulf. California is a country which for the larger portion of its area is extremely arid, and its rainfall intermittent, periods of heavy flood and extreme drought alternating with each other. During the interval from 1850 to 1872, the yearly rainfall at San Francisco ranged from 7·4 inches to 49·27. On the coast to the north of San Francisco the rainfall becomes heavy, while to the south, at San Diego, it diminishes to 10 inches, and at Fort Yuma it is little more than 3 inches. In some districts, however, abundant supplies of artesian water have been discovered ; and on the summits of the Sierra Nevada they have a snow-field to draw upon, of which the only approach to a counterpart in New South Wales is the Snowy Mountains.

Rain-winds

The rainfall of the Colony is brought chiefly by the winds which come from the south-east and east. Much of the rain with which they are charged is precipitated in the coast district or on the eastern slopes of the main range. The moisture which remains in the clouds after they have passed the summits of the mountains falls in quantities which diminish almost in direct proportion to the distance from the range. This rule is, however, correct only within certain limits, which can be plainly traced in Mr. Russell's rainfall map. On referring to this map, it will be observed that in passing towards the north-west of the Colony the rainfall diminishes till the district bordering on the Darling is reached, and that not only does the diminution cease there, but there seems to be a slight increase towards the Queensland border. This is due to the fact that the heaviest rains in that part of the Colony come from the north-west, and that they diminish in their south-easterly course, till the supply of moisture finally becomes exhausted. The cause of the great rain-storms which traverse a large portion of the Colony from north-west to south-east is not well understood, owing to the want of a sufficient number of observing stations in Queensland and in South Australia.

Influence of forests on rainfall.

An opinion which has obtained some acceptance is that the rainfall of different parts of the globe is to a great extent modified and determined by the forests; and a large body of facts has been collected in reference to India, Spain, the Mauritius, and elsewhere, to show that the denudation of the forests has diminished the rainfall, and caused in large measure the sterility of certain tracts of country. This generalization appears to have had its origin in a deduction by Humboldt, who, when travelling in South America, observed that in a district where trees had been cut down the waters of the lake dried up, and that after the growth of the semi-tropical vegetation indigenous to the region the bed of the lake again became filled with water. Mr. Russell, however, brings indisputable evidence to show that the waters of Lake George, which, when moderately full, is 20 miles long, and 7 miles wide, was dry in 1836, and was for a short time used as a cattle and sheep run, and that the drying up of the immense body of water which it had before contained could not by any possibility be attributed to the cutting down of trees. The reason in each case was a decrease in the rainfall affecting the whole world. He regards the trees as the result of the rain, and not the rain as the result of the trees. On the other hand, the Government Astronomer of this Colony points to the rain records of England from 1726 to 1882—to those of France, extending back to 1688—to those of the United States of America, for a period of sixty-six years—and to those of this Colony for forty-three years, all of which show an increase, not a decrease, in the rainfall, notwithstanding the enormous amount of forest destruction which has taken place. And American observations show that the magnificent forests which extend from Minnesota to Maine have a rainfall identical with that of the nearly treeless plains which extend westward of Chicago.

Effect of ring-barking on surface flow.

While the information regarding the effect of forests on rainfall is, as a rule, indefinite and contradictory, the question of the effect of eucalyptus forests on surface drainage seems to be practically settled. In a paper read before the Royal Society of New South Wales, by Mr. W. E. Abbott, in 1880, the result of ring-barking forestsof eucalyptus in the Hunter River district was shown to afford conclusive evidence that such forests in their natural state have a remarkble effect in stopping the flow of surface-water. In the instance quoted by Mr. Abbott, three creeks, which before the ring-barking was done were dry, excepting after unusal rainfall, became permanent running streams. As pointed out in the paper referred to, the eucalyptus has obtained the reputation of being possessed of exceptional capabilities for absorbing water, and it has in consequence been successfully used as a means of draining swampy ground. These capabilities for absorbing moisture are strikingly shown by the gaugings which Mr. Abbott made of the supply in the creeks mentioned. After the trees had been killed, the supply flowing at ordinary times was found to be 26½ gallons per minute, while after heavy rains the quantity was too great to admit of its being gauged by the means available. In the same paper attention is called to a report by Mr. Draper, of the New York Observatory, in which it is maintained that "neither the rainfall nor the temperature of the Atlantic States of America has altered in any appreciable degree within the last century," though "these are the States in which, during the last century, a larger amount of deforestation has been done than in any other part of the world." Mr. Draper also investigated the records of the rainfall of Paris for a period of 190 years, and "found on examining them that during that time there had been a slight increase in the rainfall, not steadily, but in oscillations extending over long periods."

Effect of forests on temperature.

While there appears ample proof that forests have no appreciable effect on the rainfall, it is beyond question that they have a moderating effect on the temperature. This has been well illustrated in the case of two places in the Punjab Plains, situated at a distance of 18 miles apart, one in open country and the other in a dense forest. It is found that in the hot season the temperature at the latter is generally 6° or 8° lower than at the former.

Use of forests in preserving soil from erosion.

An important use of trees and shrubs is in preventing the erosion of the soil in hilly places by floods. The pernicious effect of completely clearing the ground of trees in hilly country when the soil is deep can be studied in the Colony at no great distance from Sydney; and in some countries the absence of trees is in this manner a source of great national loss. Moncrieff says that in Spain "the whole country is furrowed by rivers running in deep beds and fed by natural drainage lines scored over its surface, and generally dry. The slopes, entirely devoid of vegetation, can offer no resistance to the eroding action of the water, and possess no means of retaining the moisture. So, the rain-storm over, the torrents run for a few days in flood and return to their extreme dryness." The wholesale denudation of forests in mountainous country will almost inevitably be followed by the washing down of the surface soil wherever it is broken up for cultivation, and the propriety of imposing restrictions upon ring-barking on lands so situate may well engage the attention of the Government.

Other uses of forests.

The effect of forests upon rainfall is totally distinct from the question of their immense importance to the health of communities, their great value in preserving the soil of mountainous country from denudation, and their uses in the industrial arts.

Influence of conserved water upon rainfall.

It was expected that the construction of large works for the storage and distribution of water in Italy would have had an appreciable effect in increasing the humidity of the atmosphere, but experience has not confirmed that view. The impression appears to be general that the climate of the interior may be ameliorated by evaporation from an extensive water-surface, and it is thought that in the course of years the rainfall may be sensibly increased by the enlargement of water storage from year to year. Several observers have noticed that thunderstorms appear to be deflected by creeks, even in such perfectly level country as the Darling, and that the rain which falls along the course of such depressions is greater than that in other parts of the district.

(3.) EVAPORATION.

Experiments by the Government Astronomer.

From the systematic observations which the Government Astronomer has initiated, it may be expected that the amount of evaporation in different parts of the Colony will be ascertained with a close approximation to accuracy, but in the present state of knowledge upon the subject opinions vary considerably. Thus, many pastoralists have written to the Astronomer to say that in the hottest months of the summer evaporation goes on at the rate of 1 foot per month for three or four months, while others do not think that it amounts to more than 3 or 4 feet for the whole year. The Assistant Engineer for Roads, who is charged with the construction of tanks, thinks that from a tank containing 18 feet of water evaporation would not exceed 4 or 5 feet (Q. 1571). It has been stated in our inquiries that at Gurley, in the Gwydir district, 2,000 sheep were watered for considerably more than a year from a tank 10 feet deep, and there was water in it then, although none had run in the whole time. One witness, speaking of a swamp near the north-western boundary of the Colony, into which the water brought down from Queensland by the Bulla River flows, says that the average depth of the lake was 4 feet, and that the water lasted fifteen months, when it disappeared from evaporation and soakage (Q. 3087). The conditions upon which observations are made, though in the main similar as to temperature and permeability of soil over large areas in the western districts, are nevertheless sufficiently dissimilar in different localities to account for any discrepancy in estimates of evaporation of the whole of the north-western districts, based upon observations applicable to a particular spot or to a very limited area. Hot winds, which are of comparatively rare occurrence in the coast districts (being generally underlain by the sea-breeze), and which range in temperature at Sydney from 80° to 106°, are more frequent on the western plains, where the thermometer sometimes records 130°, and for days together stands at 110° to 116°. It would be a mistake, however, to attribute this condition of wind to long periods, for the wind records show that, as compared with the coast districts, those beyond the Main Dividing Range have a comparatively tranquil atmosphere.

Evaporation under ordinary conditions.

In the course of the Government Astronomer's experiments he found that the evaporation from grass was from one and a half to two and a half times greater than that from water, and that the evaporation from soil destitute of vegetation was from two to three and a half times greater than from water. The evaporation from a water-surface at Albury was at an average rate of more than 4 inches per month for the six months October to March, and nearly 7 inches a month for the two months of December and January.

Circumstances on which evaporation depends.

The amount of evaporation depends on several circumstances, prominent among which are the temperature, the winds, and the nature of the surface from which the evaporation takes place. It has been found that evaporation is affected in an important degree by the temperature of the water acted upon, as well as by the temperature of the atmosphere. Thus, for example, in the case of the Ganges Canal, which is fed largely by snow-water, the evaporation at Roorkee, 18 miles from the head works, was found to be only one tenth of an inch per diem, while at a distance of 52½ miles from the head works it was more than one seventh of an inch per diem. With a hot wind blowing incessantly, the maximum evaporation from still water at Roorkee was found to be half an inch in twenty-four hours. In the Madras Presidency it was found by Major Mayne, R.E., that the mean evaporation from a reservoir 1,375 acres in extent was 0·165 of an inch in twenty-four hours, or 60 inches per annum. In the Bombay Presidency the evaporation has been ascertained to be 72 inches per annum.

Testing arrangements made by Mr. Russell.

We proposed, soon after the inception of our inquiry, to establish a series of observing stations, with a view to ascertain the amount of evaporation in different districts, but we found that the Government Astronomer was making arrangements for the same purpose, and we did not therefore deem it expedient to proceed further in the matter. Mr. Russell wrote :—

> Parliament having voted money for me to make experiments upon evaporation, I had arranged to carry out these at places where I have observers, viz., Bourke, Menindie, Wentworth, Hay, Albury, Young, Euabalong, Dubbo, and Lake George, and at such of the public tanks as have caretakers of sufficient intelligence to make the observations. The tanks I proposed to use are generally similar to the one in use for so many years here, viz., 4 feet diameter and 3 feet deep, made of galvanized iron, and provided with a screw gauge showing loss of water in thousandths of an inch. I desired to include Cobar, Wilcannia, and Milparinka, if observers could be obtained. As the money is only recently available, I have only taken preliminary steps in this matter, and should be willing to modify the proposals as far as possible to meet the wishes of the Commission. I would like to point out that it must take some years to get data from these experiments such as will be useful in computation, and perhaps what has been already done may serve for present use. Mr. Todd, in the dry climate of Adelaide, finds the evaporation from a tank 4 feet over, and sunk in the ground, 66 inches per annum. (Rainfall 21 inches, not much more than Bourke). In Melbourne (rainfall 25 inches) under similar circumstances it is found to be 48 inches, and in Sydney 32 inches.

Tank evaporation.

Since writing the above Mr. Russell has had evaporation tanks placed at a number of the stations mentioned and has obtained the following returns :—

EVAPORATION TABLE.—Result of Observations with the Tank Evaporation.

Month.	Bourke.	Hay.	Hillston.	Remarks.
	inches.	inches.	inches.	
March	1·579	......	......	Observations commenced on 23 March.
April	4·770	......	......	
May	3·037	......	......	
June	2·858	.....	......	
July	1·637	......	......	
August	3·793	2·762	2·074	Observations at Hillston began on 13th.
September	3·975	2·736	3·280	
October	7·552	......	......	

Narran Lakes,

Mr. W. E. Abbott estimates the area of Narran Lake or, more correctly speaking, of the two lakes which constitute what is commonly known as Narran Water, at 35,000 acres. This appears to be the area when the lake is full or nearly so. Assuming that the average area of the surface from which evaporation would take place during the whole year would be about 20,000 acres, it is an important question what quantity of water would pass off by evaporation alone. Supposing that the evaporation would be at the rate of 6 feet per annum, the quantity which would during the year be evaporated from every acre of the exposed surface would be 261,360 cubic feet. This would be equivalent to a rate of nearly half a cubic foot per minute per acre, or to nearly 166 cubic feet per second over the entire area. If it be assumed that the Narran flows only three months in the year, it would require to give a supply of 664 cubic feet per second during that period to make up the amount which would pass off by evaporation. Mr. Abbott mentions that for some distance before it reaches the lake the Narran has a width of about 40 yards. Assuming this width, it appears that, merely to supply the estimated amount evaporated, the river at the inlet with a mean velocity of 1½ feet per second must have a mean depth of 3 feet 9 inches if flowing for three months in the year. The Narran is very irregular in its flow, and it seems highly improbable that such a large supply as 489 cubic feet per second would pass down to the lake for three months continuously. If the assumed period of flow be shortened, a greater depth and a larger volume of water would be required in the river to meet the call of evaporation. With regard to the large supply which is said to flow into the Narran in times of flood, the great capacity of the lake affords a ready explanation for the fact that no water flows out again. Taking the total area of the lake as stated by Mr. Abbott, namely, 35,000 acres, and supposing a flood to occur when the lake is empty, or nearly so, a very simple calculation shows that if the mean depth of the lake be 10 feet, it will require a flow of 4,000 cubic feet per second for forty-four days to fill the lake. This would be equal to a river 120 feet wide and nearly 17 feet deep, flowing with a velocity of 2 feet per second. It will thus be seen that, after allowing for evaporation, there can be comparatively very little water left to be accounted for by soakage to the underground strata. The Narran is a type of several other intermittent streams, particularly those flowing southwards from Queensland.

Evaporation from shallow depressions.

Evaporation from a broad, shallow depression such as Narran Lake is much greater in proportion to the water surface exposed than from tanks such as are commonly excavated for stock purposes. This is due to three causes. In the first place the larger surface affords a greater scope for the action of the wind. The second cause is the extent to which the temperature of shallow water is affected by the sun's rays. The third cause is due to the action of capillary attraction in maintaining a strip of land around the lake in a state of saturation. This last is a point which is frequently overlooked, though it is one of great importance, especially when it is considered in the light of Mr. Russell's experiments already referred to on the relative rates of evaporation from a water surface and from earth.

Lake George.

Early in the present year the Government Astronomer had a self-registering evaporation-gauge placed in Lake George. The primary object in fixing the gauge there was to ascertain the evaporation from such a large body of water, the conditions at that lake being very favourable for such an investigation. The following tabular statement is a summary of the results obtained :—

Date.	Evaporation.		Rainfall.	Total Loss by Evaporation.	
	Reading of Gauge.	Loss.			
1885.	inches.	inches.	inches.		Months of
March 1	2·8	......	......	......	
April 1	6·8	4·0	0·44	4·44	March.
May 1	7·7	0·9	1·54	2·44	April.
June 1............	8.8	1·1	1·92	3·03	May (very windy).
July 1............	6·7	gain. 2·1	3·42	1·32	June.
August 1	5·0	gain. 1·7	1·82	0·12	July.
September 1 ...	5·4	loss. 0·4	1·06	1·46	August.
October 1	7·9	2·5	1·15	3·65	September.
October 31......	10·7	2·8	1·74	4·54	October.
8 months... ..	......	7·9	13·09	20·99	

In connection with this table the Government Astronomer adds the following explanatory note :—

It will be observed that I have added only the rain which fell on the lake, taking the mean of the two rain-gauges, one at each end. That is, I have assumed that no water runs from the hills into the lake, but I have done so because the gauge shows the rise in the lake when the heaviest rain fell to be only equal to the measured rainfall. For instance, on the 12th June the rain measured was 1·02, and the lake rose just 1 inch. I have no record of the state of the creeks leading to the lake, but it may be stated that the rains have been very light and the season dry, so that it is not likely much, if any, would run after an inch rainfall in one day, the heaviest record.

Mr. Russell also writes:—

During the last fourteen years the lake has lost by evaporation 12 feet, and in May, 1878, the railway survey carried down the western side showed that the lake was then 6 feet below its 1871 level, or 2,225 feet above the sea. It appears, therefore, that in seven years, 1871 to 1878, the lake lost 6 feet; and again, from May, 1878, to February, 1885, say seven years, the lake again lost 6 feet by evaporation; and this of course in addition to all the rain which fell during that period. Taking the records at Goulburn and Gungahleen, near the lake, the average rainfall for the first seven years was 27·95 inches, and during the next seven years 23·68 inches. One would expect to find more evaporation during the dry years, but this is not borne out by observations. From the rainfall and recorded evaporation, the lake therefore lost by evaporation at least 3 feet per annum. I say at least, because some rain-water must have run into the lake in addition to that which fell into it directly, but this amount cannot be determined. In future the recording gauge will determine this, and perhaps then we may apply the experience gained to estimating how much ran in during the last fourteen years. That the gauge will serve this purpose is proved by what it has already done. On March 11th a strong northerly wind came on, and in three days the lake lost by evaporation 1½ inch. On April 14th and 15th 1·10 inch rain fell, with a strong wind, and by the 17th the lake had lost all the rain by evaporation, and was at the same level as on the 13th. On the other hand, in calm or almost calm weather three and even four days pass without any loss by evaporation. It should be stated that the rain on 14th and 15th April, though 1·70 inch fell at Douglass, only 0·77 fell at the north end of the lake, and the rise in the water due to it was 1⅓ inch, so that it would appear but little of that rain-water came down the hills into the lake.

The evaporation on the lake on a windy day shows to what extent the wind affects it. No doubt its effect on a large body of water is much greater than on a small one, because on the lake in calm weather the lower air must get to a certain extent saturated with moisture, and there being no wind to carry it away, evaporation practically ceases; but where small quantities of water are placed to test evaporation, there are abundant means for the evaporated water to get away in the surrounding air which is not saturated. Evidence is accumulating that the evaporation from large tanks is not so great as has been supposed. The heat is no doubt very great, but the total absence of wind in the interior for considerable periods is obviously, from what has been shown, an important condition for the saving of water. At Bourke recently I was very much struck with the absence of wind, especially on the surface of the ground, and the self-registering anemometer which I erected there in March last bears important and measurable testimony on this point. The recording parts are so easily moved that they work satisfactorily with a velocity of 1 mile per hour. Taking the total number of miles of wind recorded at Bourke, by an anemometer placed 25 feet above the ground during thirty days, I find it is 2,350 miles, or about 78 miles a day only. The strongest wind in that period shows 50 miles of wind in 5½ hours, and the smallest record for a day is 25 miles, little more than a mile per hour. In Sydney during the same period 7,050 miles of wind were recorded, and it is not uncommon to record in Sydney in three days as much wind as was recorded in Bourke in thirty days.

(4.) SUBTERRANEAN WATER.

Flow from surface.

The quantity of rain-water which will flow off the surface into the rivers depends upon the extent of the rainfall and the slope and character of the surface; and as these vary in different localities and at different seasons, it is obvious that no general rule can be applicable. It may be stated generally that the proportion varies from 0 to 75 per cent. It has been found that in the upper portion of the river Garonne the proportion is 65 per cent., and in the case of the Po, 75 per cent. The discharge of the Seine is equal to only 23½ per cent. of the rainfall, while in the case of other rivers it is only from 10 to 15 per cent. The proportion which is drained off by the streams in the San Joaquin Valley is about one third. A large proportion of the heavy rain which is precipitated upon the steep declivities and impermeable strata of the Great Dividing Range may be expected to flow into the rivers, while very little of that which falls upon the porous surface-soil of the plains which extend on either side of the Darling would drain off the level land. The flooded land in that district has been known to extend for a distance of 70 miles across, and there are parts so flat that when the whole ground is covered by water it is often impossible to detect any current. Where the trampling of sheep takes place in lines which follow the general fall of the country, it will be found that the water will collect into channels and be conducted to the rivers. When it is borne in mind that the average quantity of rain at Bourke during eleven years has been only 16·18 inches per annum, and that the average number of days in each year upon which rain fell was forty-two, it will probably be apparent that much of the rain comes in such very fine showers as would be insufficient to create any flow, and that when, after the lapse of long intervals of dry weather, heavy rain does fall, the numerous gaping fissures which traverse the plains absorb a large proportion of it. A case is mentioned (*Evidence*, p. 85) where a torrent, such as a horse could not safely cross, descended from the Wanarang Mountains for forty-eight hours, and was nearly all absorbed by the open ground. Similar facts have been noticed in various parts of the Colony. Little more than 9½ inches (9·67) of rain is recorded to have fallen at Bourke during 1884, and this small quantity was distributed over thirty-six days. The heaviest fall for any month was 1·43 inch, and the only months in which the rainfall exceeded 1 inch were April (1·10), May (1·30), June (1·43), September (1·12), and December (1·37). It must be apparent that the discharge into the Darling in the locality of Bourke must have been so small as not to be measurable. A contrast to this condition of circumstances may be found in the measured discharge into the Darling in the locality of the Nepean and Cataract Rivers, which is found to be about 44 per cent. of the total rainfall. Mr. Russell computes the discharge of the Murray for 1883 at 36 per cent., and for 1884 at 25 per cent.

Subterranean flow.

Referring to the supplies of water which have been struck by miners beneath the basalt at Cope's Creek and other mining centres, the Principal Government Geologist states that these deep leads are old river-channels, which have been filled up by sand, clays, and basalt, and that they carry the underground drainage of the country. Their course is westerly, and they must continue right to the plains. He has seen evidence of these subterranean river-beds all along the flanks of the Dividing Range. At irregular intervals great tracts of basalt are to be found. The lava has flowed down and filled up some of the old valleys, and now forms the floor of portion of the plains, so that we cannot indicate exactly under the plains where the leads occur. All that is known is, that the old drainage system, which was in existence prior to the basaltic outbursts, has been covered up by lava in some places. He also states that the western limit of the basaltic outbursts may be described approximately by a line drawn from Albury to where the 149th meridian crosses the Macintyre River. He is, therefore, of opinion that much of the water which falls between the western summits of the Dividing Range and that line flows under the surface. The evidence given before us in reference to the Namoi, the Macquarie, and other rivers, also corroborates the theory that there is a considerable amount of percolation. We defer more specific reference to other facts bearing upon this part of the subject until we come to direct attention to the drainage areas of the different rivers and the more salient facts which have come to our knowledge respecting them.

Supposed outlet to the sea.

Supposing the amount of percolation to be as great as he estimates from the data at his command, Mr. Russell is of opinion that the underground drainage must flow to the sea; for, on the assumption that there was no outlet to the ocean, no extent of subterranean storage for water which is conceivable as existing could hold the vast accumulations which it is supposed has for ages been flowing downwards. In whichever direction the subterranean water may be supposed to flow, it must percolate through several hundred miles of strata. The mud springs found in some places in the west of this Colony tend to show that such underground flow exists; but the evidence furnished by these mud-springs, and also by wells and borings, though both interesting and valuable, is too fragmentary in its character to enable us to arrive at definite conclusions regarding the source or the extent of the underground supplies. The base of the denuded range, extending from Orange to South Australia, through or near Cobar and Wilcannia, would naturally have the effect of diverting the course of underground streams from the north, and to some extent those from the north-east.

Underground flow near Mount Gambier.

At question 963, the Government Geologist expresses the opinion that the miocene formation of which he was speaking collects the underground drainage of the Barrier Range, and that it is quite possible that it extends to the coast of Victoria and South Australia. "We cannot," he says, "tell how far it does really extend to the south, but I have no doubt that the underground water escapes into the ocean. This is proved by the underground channels which exist in the Mount Gambier district, where the water in some places is said to run at the rate of 4 or 5 miles per hour. This being limestone formation, it is easily dissolved by the underground currents, and thus channels have been formed." Subsequently he states his opinion that the underground rivers near Mount Gambier, flowing in the direction of the ocean, which is not far distant, drain an immense area of country south of the Barrier Range.

Lakes in South Australia.

By the courtesy of the South Australian Water Conservation Department, we have obtained the report of the Government Geologist of that Colony on the lakes of the Mount Gambier district. The Blue Lake, whose average diameter is about half a mile, is enclosed within steep banks of 150 to 300 feet. Its surface level is about 70 feet below the town of Mount Gambier; the average depth of the lake is from 200 to 250 feet, and the bed of the lake about 190 feet below sea-level.

Other lakes to the westward of the Blue Lake appear to be connected with it. The Government Geologist (Mr. H. Y. L. Brown) states in this report that the low temperature of the water in the Mount Gambier lakes is against the theory of its being derived from any deep-seated source in connection with volcanoes. "Their principal supply is doubtless derived from the same source as the other underground water wherewith the tertiary beds of the south-east are charged, namely, from the watershed of the Murray, Darling, &c." It appears to us, however, that the available information is insufficient to show that the underground channels near Mount Gambier derive their supplies, or any considerable portion of them, from rain falling in this Colony.

Flow from Gawler Ranges.

Mr. Russell Barton, M.P., mentions that in South Australia, between the coast and the Gawler Ranges, people can tell exactly the depth at which an inexhaustible supply of water can be found. "To my knowledge," he states, "if you sink a well at a time of heavy rain in this country, the water will rush down it, bringing with it all sorts of rubbish and debris, and within ten minutes of the stoppage of that rush the water becomes perfectly clear, and remains exactly at the same height in the well. Endeavours have been made to reduce the depth of the water by means of pumps and other appliances, but it cannot be lowered a quarter of an inch. These wells may be found at intervals for a distance of 300 or 400 miles down the coast."

Artesian flow at Sale, Victoria.

The same may be said of a remarkable well at Sale, in Victoria. When water was first struck in that well it came up quite black with leaves, rubbish, aud dead timber, showing that it must have entered the soil through openings on the surface sufficiently large to allow a great deal of water to pass into the earth otherwise than by percolation, or else that the strata in which the water was tapped contained great quantities of trees and other vegetable remains. The flow of water in that condition to the surface continued for several days, and an enormous quantity of rubbish was brought up from the well. Sale is in the immediate neighbourhood of two deep and constantly flowing rivers (the Thomson and the Latrobe), and within sight of the Australian Alps, which have a rainfall of not less than 50 inches per annum.

Bearing of geological formation on theory of underground flow.

We have very briefly referred to the opinions which the Geological Surveyor in charge has formed of the strata of the north-western districts; but the important bearing which they have upon the question of underground water storage demands more than a passing allusion. The denuded mountain range whose outcrop has been traced from Orange to Cobar, Wilcannia, thence westerly into South Australia, marks the southern shore of what is considered to have been a portion of an ocean, which at the same period probably covered the entire northern portion of Australia. By a process of oscillation the bed of the ocean was gradually upheaved, and the southern portion of the continent at a late period depressed. By the upheaval of the ocean's bed on the northern portion of Australia the cretaceous formation which occurs in this Colony north and west of Cobar was brought nearer to the surface; and the miocene marine deposits extending southwards from the Barrier Ranges to the sea were lifted up at a later period.

Water in cretaceous formation.

The cretaceous formations of this Colony, so far as they have been explored, are estimated to cover an area of about 40,000 square miles, and are generally overlaid by beds of clay formed by the compression of soil washed down from the mountains. The rocks and gravel brought down by the mountain torrents would by reason of their greater specific gravity settle for the most part along the flanks of the ranges, and in the course of strong currents, while the finer particles of soil held in solution would be carried further out.

Silting up of watercourses.

The tendency of watercourses flowing through deltas is to silt up. It is no uncommon thing for the banks and sometimes even the beds of rivers flowing through deltas to be higher than the adjacent plains; and in consequence of obstructions to their flow to cut new channels for themselves. These phenomena, so familiar to all who are acquainted with the rivers of Australia, which have their course through flat country, show what has been going on for ages; and hence, no doubt, it is that the lines of drift and gravel which remain to show the course of the drainage in former periods are found at various depths.

South Australian lakes.

The series of lakes which appear upon the maps of South Australia are situated on the margin of the cretaceous basin. In the N.E. Lakes, Frome, Blanche, Gregory, and others, the dry beds are generally incrusted with salt. There has been a period, long past, when the flood-waters of the Cooper flowed into them down the Strzelecki Valley. It seems probable, however, that a slight upheaval in the vicinity of the lakes has altered the respective levels, and now, perhaps only once in five years, the Cooper overflows into the Strzelecki, and these waters flowing for about a month seldom reach beyond the south end of Lake Blanche, when they become salt and quickly dry up.

Darling Gap.

The dip of the cretaceous basin is northwards; but, if it were otherwise, the only outlet for the drainage would be the break in the transcontinental range which occurs near Wilcannia, known as the Darling Gap. The Government Geologist says that the break in the formations is only 5 miles across, and he is of opinion that the depression there is very shallow. (Q. 944.) The strata to the south of this gap is, moreover, impermeable. While therefore it is probable that this gap may have served to drain off some of the water from the northern sea after the upheaval of its bed, and before the miocene beds to the south of it were lifted up, it is also probable that if there were now any underground flow through the Darling Gap, the fact would be made apparent by springs or flowing water on the surface in the locality, where after passing through the Gap its further progress southward would be arrested by the impermeable strata.

Water discovered below sea-level.

Water has been found at Tarkanina, in South Australia, 150 miles from the western boundary of this Colony in latitude 29° at a depth of 1,220 feet, or 1,040 feet below the sea-level, and it rose 20 feet above the surface; while at Hergott Springs, also in South Australia, the water was struck at a depth of 339 feet, or 193 feet below sea-level. It flows over the tubes at a height of 65 feet above the surface, and will probably rise higher if tubed. In the former case the bore was put down in the centre of the cretaceous basin, while in the latter it was near the edge, and not far removed from the watershed. Mr. Jones, Conservator of Water to the South Australian Government, writes us that the flow from the firstnamed bore does not now exceed 400 gallons per diem. The bore is only 3 inches in diameter at bottom, and the flow of water has been impeded by obstructions in it. The cretaceous clays have been found to continue below the band in which the water was struck, and it is confidently anticipated that on going a little deeper a very large supply will be met with in a pebble deposit forming the floor of the formation. The diameter of the bore at Hergott Springs is 6 inches, and the flow of water 5,000 gallons per diem. The water is of good quality, fit for domestic use, and its temperature at the bottom of the bore is 82° Fahr. At Dunlop Station, 80 miles west of Bourke, wells have been sunk, the facts in regard to which are both interesting and important. In one, a supply of fresh water was obtained at a depth of 488 feet, which rose to within 90 feet of the surface. Another well on the same station yielded an abundant supply from a depth of 573 feet, the water rising to within 15 feet of the surface. At a depth of 240 feet petrified wood, water-worn pebbles, dead fish, and marine shells were found. At 300 feet a tree 18 inches in diameter was found, and at a lower level of 143 feet a second tree was cut through. At 550 feet there were 5 feet of sandstone rock, and when the water was struck the auger dropped 2 inches into fine sand-drift. The trees found resemble those growing on the surface, that at the higher level having its branches lying to the west. No particular significance, however, can be attached to this latter circumstance, even if it can be taken as an indication of the flow of the current at the particular time when it was deposited. It is clear that the lowest level at which water was struck in these wells was considerably below the level of the sea; and that the height to which the water rose in all or both of them was above the level of the Darling Gap at Wilcannia,—the elevations of Bourke and Wilcannia above sea-level being ascertained by the railway surveys to be 346 feet and 260 feet respectively.

Employment of boring machinery.

It may be premature to accept these considerations as forming a conclusive argument against the theory of an underground river-flow to the ocean, but whatever inference may be drawn from the limited range of information at present available, the numerous facts adduced in evidence before us establish a strong presumption that there is a large quantity of water under the dry north-west country; and there is reason to hope that by the employment of boring machinery an abundant supply of good water can be made available for the use of stock.

Mud-springs.

Almost the only surface indication of the presence of water underground is to be found in the numerous mud-springs which occur to the north-west of the Darling, more particularly in the Paroo and Warrego districts, also in the southern part of Queensland. That remarkable spring at Gilgoin near Brewarrina is thought to be of this character. The proprietor of the station observing that his cattle became bogged in a slight depression, which is now the site of the spring, fenced it in and made excavations for a well. The bones of bullocks were dug out, and at lower depths were found the fossil remains of kangaroos, and bones of what are supposed to have been the diprotodon and other extinct species of animals which, in bygone ages, resorted to this treacherous ground to quench their thirst. At a depth of 28 feet the water rose in sufficient quantity to drive the men out of the well, and the supply in the shaft has always been abundant. In the case of most excavations on the site of mud-springs the muddy overflow proves so unmanageable as to be a bar to sinking by pick and shovel. The temperature of the water in the mud-springs shows that it comes from a considerable depth, and the great thickness of the overlying clay-beds through which the water is forced upwards implies strong pressure from below. Professor Stephens is of opinion that these circumstances point with certainty to the eastern ranges as the source from which this water has its origin. Mr. H. Y. L. Brown, Government Geologist, thus describes the mud-springs in his report upon artesian water :—

> There is little doubt that the mud-springs are due to water at a pressure trying to come to the surface through a bed of clay which puddles it back, the result being that the water and clay mix and come to the surface in the form of mud. Where there is a strong body of water and a large amount of pressure, it clears a passage for itself and continues flowing without any admixture of mud, the passage through the clay gradually becoming lined with fragments of sandstones, &c., from below. All the mud-springs are in the same position geologically, the water coming from below the cretaceous clay marl and shale deposit which occupies so large a portion of the country. From a comparison of the different springs and wells, and an examination of the material raised therefrom, the conclusion is that there are three geological positions in which water is found in the area under notice :
>
> 1st. Near the surface in the sand, limestone, and clay deposits of the river flats, dry lakes, old watercourses, &c., of pleistocene age. In this case, the water which falls on the sandhills and porous-clay or silt flats soaks into the ground until it meets an impervious bed of clay or other material, where it accumulates. Whether it is salt or fresh water depends upon the nature of the soil and rock in which it lies. As a rule, the water found under these conditions contains a great quantity of salt.
>
> 2nd. Between the quartzite conglomerate beds and the cretaceous marl. Water falling on the quartzite conglomerate ranges, and being absorbed by them, would collect in the hollows of the cretaceous formation, and break out as springs at the lower levels of the former.
>
> 3rd. Beneath the cretaceous deposit and on the Devonian formation below. This is the main source of water supply indicated by the mud-springs and deep wells. The newer deposits on the flanks of the Devonian sandstones, grits, and conglomerates throughout the district receive a large quantity of the rain falling on them in the joints and cracks of the rocks, and in holes and cavities in the ground, by which means the strata become charged with water, which is conducted through the cretaceous strata, and is stored there until such time as the force of gravitation, pressure of superincumbent rocks or of gas, causes it to force its way to the surface.
>
> The cretaceous rocks being formed of horizontal beds of clay-marl, mudstone, shale, and limestone, and being overlaid by hard beds of conglomerate, are liable to settle down in places by the shifting of the strata through being softened with water, or removal of limestone by dissolution. Thus the water below and the pressure above acting together would cause the forcing up of the water through any available crack or borehole, and the forming of an artesian well. The cane-swamps, so called, are depressions of this kind which seem to have been formed by a sinking of the ground. On many of them, where there are no native mud-springs, mounds may be seen which bear all the appearance of being the remains of extinct mud-springs. Pebbles and boulders of quartzite, sandstone, &c., are often found lying about on their surfaces, which may have been forced up at the same time in a similar manner to those seen at the present time at the active mud-springs.
>
> The existence of local subterranean channels containing flowing water at a moderate depth, particularly in limestone country, is very probable. In the case of the water found below the cretaceous formation, the evidence is in favour of its lying in the form of lakes in the porous strata, as it is found at different depths.

Cretaceous basin likely to afford artesian water.

There is a general concensus of opinion among geologists in this Colony whose views we have had an opportunity of learning, that the cretaceous basin will afford a supply of artesian water of good quality throughout its area ; and the Government Geologist states the maximum depth at which borings may have to be made at 700 feet. Experiments made with the boring-rods are so far confirmatory of this view not only in New South Wales, but, as we have seen, in South Australia also. This expectation of obtaining artesian water from the cretaceous basin has been entertained for some time past by the Department of Water Conservation in South Australia, and has been supported by the fact that on the south and south-west flank of the formation a very remarkable and extensive series of mud-springs exist with unlimited supplies of fairly good water, all of them, however, containing salts and lime in some degree. In the ranges, 20 miles west of Lake Frome, there are numerous springs of fresh water, the temperature of the water in one of the springs being 130° Fahr. In the Siccus Valley, south of Lake Frome several artesian wells with good water have been obtained at a comparatively shallow depth.

Water in miocene formation.

The later marine formation which underlies the alluvial deposits south of the Darling at Menindie, and which extends under a large portion of the Murray, Murrumbidgee, and the Lachlan basins, occupying in this Colony an estimated area of 22,000 square miles, is also pointed to by the Government Geologist as containing abundance of fresh water at depths varying from 200 to 500 feet. As, however, the overlying fluviatile deposits of this region are generally porous, it is not to be anticipated that water from the miocene beds will rise to the surface.

Palæozoic strata.

The map which the Government Geologist has prepared, to show approximately the extent of the different water-bearing formations, allots an area of about 22,000 square miles—chiefly along the eastern slope of the Main Dividing Range, and including the range itself—to the palæozoic rocks, in which the occurrence of a large supply of good water is exceptional; and an area of 118,000 square miles to the older alluvial deposits which form the surface of the vast plains of the Darling and the Lachlan, and which overlie the cretaceous, miocene, and palæozoic strata. In these salt water is of most frequent occurrence, but where continuous pumping is possible, thereby inducing a current, it is questionable, after experience both in this Colony and in Queensland, whether the supply would not be fresh.

Recent alluvial deposits.

Percolation.

Absorption.

Another important water-bearing formation is that of the recent alluvial deposits which occur along the course of the main rivers and creeks, although rarely at the heads of watercourses. The water passes from the beds of many of the rivers by percolation and absorption. By the former is meant the flow among the particles which constitute the subsoil; and by the latter, the capability possessed by all earths and even rocks of taking up and holding a certain proportion of water in the same manner as a sponge. To a certain extent absorption and percolation stand to one another in the relation of cause and effect. Their action is curiously illustrated by the fact that the loss from streams flowing within embankments is less than the loss from similar streams flowing in cuttings, as was proved by Mr. Beresford, Executive Engineer in the Irrigation Department of India. With regard to the rate of percolation, Mr. B. Baker ascertained that the water from the Nile flows underground in a direction at right angles to the river at the rate of 1 mile per week. The amount of loss by percolation and absorption differs widely in different cases. The mean of two experiments made on the Macquarie between Dubbo and Warren by our Engineer, Mr. H. G. M‘Kinney, showed that the loss in that river between those points from these causes is about ½ inch in depth over the wetted surface in twenty-four hours.

Percolation from the Nile.

Experiments made by Mr. H. G. McKinney

(5.) STORAGE OF WATER.

General remarks.

Having briefly reviewed some of the principal facts relating to the rainfall of the Colony, and the theory which has been formed to account for its rapid disappearance from the face of the country, it remains that we should consider what means can be adopted to utilize the rain-water to the fullest extent. It is almost superfluous to point to the fact that much of the rain which falls is almost tropical in its character, and the benefit derived from it is partial and temporary in comparison with the advantages which might be expected to follow had we the means of storing the floods of one season to supply the comparative drought of another. A fall of 1 inch in a day would be considered very heavy in Great Britain, where the rain is much lighter and more frequent; but here the Government Astronomer has preserved records of storms in which 10·610 inches of rain fell at Newcastle in two and a half hours, and at South Head, in which rain fell for upwards of twenty hours at the rate of 1 inch per hour. The amount of the rainfall is sometimes of less consequence than the period at which it comes; and a fall of 9 inches in the year over the north-western districts, divided into three falls of 3 inches each, occurring in spring, mid-summer, and autumn would, in its effect upon vegetation, be vastly more beneficial than a very much larger aggregate quantity dissipated in thin showers throughout the year, or falling at a time less favourable for the growth of herbage.

Necessity for systematic provision to avert loss to pastoral, agricultural, and mining interests, and to promote health.

Any attempt to accurately estimate the value of rainfall by a pecuniary standard must of course be illusory, although doubtless there are many who will agree with the Government Astronomer in thinking that there is good reason for the assertion that "an inch of rain over the whole Colony at the right time is worth a million of money" is not an exaggeration of the pecuniary loss which might be averted by a timely rainfall, to say nothing of the unutterable anguish of many thousands of animals, which in a period of drought perish by slow degrees from hunger and thirst. Although fully aware that the loss which results to the Colony from drought cannot be stated with arithmetical accuracy—in the case of the husbandman it is sometimes the complete frustration of his year's toil, and in that of the pastoralist the annihilation of a large part of his capital—still an attempt (even though the data should be held in some respects to be erroneous) to form a definite idea of the measure of loss from droughts is not without value. If we put the low price of 6s. 8d. per head as the value of a sheep, including wool and carcase, we see reason to suppose that the loss of the Colony from the droughts of 1881, 1882, and 1883, in sheep alone, amounted to upwards of £2,000,000 per annum. The data from which this deduction is drawn will be found in the following figures, which have been compiled by the Chief Inspector of Stock from his Official Reports:—

Number of sheep on 1st January, 1881, as per report	35,300,000
Natural increase, say 12 %	4,236,000
Total at 31st December, 1881	39,536,000
Number of sheep on 1st January, 1882, as per report	36,500,000
Loss to 1881	3,036,000
Number of sheep at 31st December, 1881	39,536,000
Natural increase, say 12 %	4,744,320
Total at 31st December, 1882	44,280,320

Number of sheep on 1st January, 1883, as per report	36,100,000
Loss to 1882	8,180,320
Number of sheep at 31st December, 1882	44,280,320
Natural increase, say 12 %	5,313,638
Total at 31st December, 1883	49,593,958
Number of sheep on 1st January, 1884, as per report	37,900,000
Loss to 1883	11,693,958
Number of sheep at 31st December, 1883	49,593,958
Natural increase, say 12 %	5,951,274
Total at 31st December, 1884	55,545,232
Number of sheep on 1st January, 1885, as per report	31,600,000
Total loss in these 4 years	23,945,232

23,945,232 sheep @ 6s. 8d. per head = £7,981,744 loss.

Loss of stock through droughts.

This calculation assumes that the Colony is capable of depasturing 55,000,000 of sheep if efforts were made to conserve and utilize the rainfall; and we cannot suppose that this will be regarded as a too flattering estimate of our grazing resources. Each drought which afflicts the Colony may be said to be more injurious in its consequences than any of its predecessors, for the reason that there are more stock in the country to suffer. One witness states that fully one-half of the horned cattle in the Gwydir district must have died during the last four years, and a great many sheep; but that a system of water conservation would reduce the deaths to a small percentage annually (Q. 3972). Another thinks that in the late droughts the deaths of animals have been as 3 and 4 to 1 in comparison with the mortality in previous droughts (Q. 4840). Taking a radius of 100 miles from Walgett, it is given in evidence that during the last five years, taking all the runs in the district into consideration, we have lost about 60 per cent. (Qs. 4971 and 5141).

General losses through droughts.

The pastoral and agricultural interests being, in their present stage of development, wholly at the mercy of the vicissitudes of the weather, suffer more directly and severely than any other interests of the Colony from the sharp alternations of wet and extremely dry years; but inasmuch as each interest in the Colony is interwoven with every other, it is not too much to affirm that every class of the community participates in the privation and suffering which are born of adverse seasons, quite as much as in the comfort and wealth which result from bountiful harvests and the increase of flocks and herds. It would be easy to multiply instances of the loss which has overtaken mining industry, and the time when work upon the tin-mines of the northern districts, the gold-fields of Temora, the copper-mines of Cobar, and the argentiferous lodes of Silverton, had almost to be abandoned for the want of water, not simply for industrial purposes, but even for human consumption, must be still fresh in the recollection of most colonists. The greater prevalence of typhoid throughout the country during the late dry years seems to imply that the health and comfort of large numbers of the community, more particularly of those resident in the outlying districts, must have been very seriously injured by the scarcity of water—scarcity in many cases for even domestic use. The industries of the country, which are more immediately dependent on the soil, have about reached their maximum development under peresent conditions; and it will probably be admitted that if scope is to be given for the prosperous settlement of a larger rural population than that which now exists—if the stock-carrying capabilities of the country are to be increased—if agricultural activity is to be extended and made permanent—if the railways, which the Government has constructed at a cost of many millions to the State, are to be made remunerative, and to accomplish the important ends for which they have been established—it will be necessary to make the largest and most systematic provision for the conservation of water as the one element needed to give vitality to all the other possibilities of producing.

Reservoirs at head waters.

The possibility of forming storage reservoirs at the head waters of the tributaries of the principal rivers is a question which appears to have hitherto received little or no attention; but, from the partial examination of the country by the Commission, they entertain no doubt that an instrumental survey of the different river-basins will demonstrate that there are numerous sites for conserving reservoirs of very large capacity, and that by this means the easement of floods would be to some extent accomplished, and the streams of the rivers themselves controlled. As an instance of the construction of reservoirs at the heads of rivers, we may cite the dam at Campbelltown, Tasmania, which holds back 6,048 million gallons, and was constructed at a cost of £7,600.

Weirs upon effluent creeks.

Of the various methods of conserving the rainfall, that which commends itself to our judgment as producing the largest results for the smallest outlay of capital is one which Nature itself has strongly impressed upon much of the flat, dry country of the western and south-western plains. A prominent characteristic of streams subject to flood flowing through long reaches of flat country is to choke up their channels and to deposit banks of alluvium upon their edges, so that, paradoxical as it may appear, their banks are often higher than the general level of the delta through which they run. The ordinary channel not being sufficient to carry off the floods discharged upon it in times of heavy rains, the water has in many districts cut subsidiary drains through the soft soil; and the result is that there have been formed many hundreds of miles (we believe we should be within the bounds of accuracy were we to say many thousands of miles) of canals into which the waters are backed up, until such time as, upon the subsidence of the inundation, they recede into the river at the point of outflow, or run into it again at some lower part of its course. These effluent creeks, cowals, warrambools, tallywalkas, billabongs, or ana-branches, as they are variously called in different districts of the Colony, often communicate with large natural depressions capable of being formed into permanent lakes. The works required to retain the flood-waters in these creeks and lakes would in most cases be few, simple, and inexpensive, so far as impounding the higher flood-waters are concerned; and all that would be necessary, besides improving and defining the channel, to keep them permanently supplied, would be to place movable weirs across the rivers at the points of off-take, and sluice-gates in the creeks to prevent the return of the water to the main stream.

Natural depressions to be used as lakes.

Weirs across rivers.

Effluent creeks: Murray and Murrumbidgee.

A glance at the map of that portion of the Colony lying between the Murray and the Murrumbidgee, both of which are to some extent fed by snow-waters after the rains have ceased, will show from one to two thousand miles of natural channels such as those to which we refer, which it is quite within the resources of those rich districts to make available. Judging merely from the map, this part of the Colony is extremely well watered; but, for the want of systematic effort on the part of the inhabitants and of proper legal provision on the part of the State, the numerous creeks and rivers which intersect that area are nearly always dry, and the productive powers of the soil often paralyzed, while almost every year water sufficient to supply every demand for human and stock consumption and all other industrial purposes, including to a limited extent that of irrigation, is allowed to drain off to the ocean unused.

Water conservation in Victoria.

The Government of Victoria and the residents of the Swan Hill Shire in that Colony have recognized what may be done in this direction, by the enlargement of the outflow of the Murray into Gunbower Creek (a work to which this Commission has taken exception); and making provision for draining off water at the higher flood-levels into the bed of the Loddon, and thence into a numerous chain of swamps and lakes to the north-west. (Vide appendix, Secretary's Report.) It is satisfactory to observe that the fall of the country on the New South Wales side of the Murray is specially favourable for the distribution of its water in the district between that river and the Billabong, as is exhibited by the numerous effluent creeks which carry the Murray flood-waters beginning at a point near Tocumwall, and flowing north-west in the direction of Deniliquin, Baratta, on to near the junction of the Murrumbidgee.

Conservation of flood-water by private enterprise.

The works which Mr. Tyson has carried out near Oxley on the Lachlan River may be cited as a good illustration of the manner in which favorable conditions of surface-level can be turned to practical account by even individual effort. Mr. Tyson says (Q. 2834):—"I have made several cuttings from the back waters which have filled up a number of lakes, in some of which I have a supply of water for years to come. In one of these lakes the water is 50 feet deep. This cutting is from 1 to 6 miles long. I am making another cutting from Waljeers, which will be about 20 miles in length. I make use of the natural depressions so far as they follow the course which the cutting is to take, and I excavate a canal in the ground between the depressions. Where I am making the cutting it is 30 feet wide, and from 4 to 7 feet in depth. I made another cutting between Lake Bonarey and the Merowie Creek. The lake was filled, and the water lasted for seven years; but during the last three years there has been no water in it. I only wish to intercept the flood-water." As a consequence of these improvements, from 40,000 to 5C,000 sheep are depastured where not more than 20,000 could have been fed before.

Weirs on rivers. Constructive difficulties.

We are not disposed to ignore or make light of the constructive difficulties which would have to be overcome in any scheme which involved the placing of weirs across such rivers as the Darling, the Lachlan, the Murray, and the Murrumbidgee; but much of the conservation to which we have called attention could in periods of high floods be accomplished without making weirs, movable or otherwise, in the main streams below the points of off-take. In the absence of details such as can only be obtained after the preparation of plans and specifications, it would be unwise to say that the Colony is not populous enough or rich enough to place weirs across the Darling or the Murrumbidgee. That such works, placed in properly selected positions, and carried out under proper professional supervision, could be constructed there is no reason to doubt. In the absence of any special examination and study of the question by the engineers in the service of the Government, it may not be out of place to refer to the opinions of non-professional witnesses, of whom Mr. R. C. Webb may be taken as an example. He says that if a weir were well constructed on the Darling there would be nothing to prevent its standing, as there is no heavy rush of water in the river; and that even such rough and cheaply constructed dams as have been placed by private individuals across the Lachlan stand well enough until they are cut away when water is wanted (Q. 2696). The dams which have been made by private individuals in different parts of the Colony, particularly the overshot dams in the Culgoa and Birie, and weirs such as those which have been successfully constructed by the Victorian Water Trusts over the Loddon and other rivers, may be taken as a clear indication of what may be safely attempted on a somewhat larger scale, with special caution as to the accumulation of silt. This, however, is a class of work in regard to which we should proceed tentatively and with great caution; and, above all, it is of the utmost importance that no weir should be constructed in any river until after such surveys have been made and levels taken as will fully determine the effect which such weir would have on the river and on the adjacent country. The sites for weirs will require to be selected with great care. The rocky bars which are frequently found in the western rivers, and particularly in the Darling, will probably afford the best sites for weirs in those rivers. Hence, before removing or interfering with any bar, the possibility of its being required for a weir site should be well considered.

Rocky bars in rivers.

Levels suitable.

Some of the peculiar circumstances with which we have to deal are extremely favourable. Thus, for an example, in many districts the fall in the creeks is so small that for every foot in vertical height the water would be held back nearly a mile. The subsoil of the country throughout nearly the whole of the Darling basin consists of impermeable clay, and no better holding-ground for water could be desired. A similar remark applies to a great portion of the country between the Murray and the Murrumbidgee. In the case of newly excavated dams, from which the water is found to soak away rapidly, pastoralists find that that they can be easily puddled by the trampling of sheep, and in the second year form perfectly good holding-ground. Once the creeks of the district were thoroughly well saturated, the loss of water by percolation would not be excessive. It is in cases where their beds become dry and cracked by long exposure to the sun that the loss of water is so great; and it is one of the heavy drawbacks which accompany the present intermittent system of flooding, that the enormous amount of absorption from the bed of the channels until saturation point is reached prevents the waters from the rivers when in moderate flood from flowing more than half the distance which they would otherwise run; and hence it happens that the settlers who live at distances of from 50 to 100 miles from the point of off-take receive no benefit from moderate floods in such rivers as the Murrumbidgee, more particularly when the flood is of short duration. Irrespective of the great body of experience which has been obtained on this point, the opinion of the Government Geologist is assuring. He states (Q. 1027) that if canals were made on the lower part of the Darling, the soil is sufficiently impermeable to allow of the carrying of water through the country by means of canals. " For a year or so perhaps the water might percolate through, but after

Soil impervious

that the sides of the canal would become puddled; then the water would not soak away." And again (Q. 1029), "I have known races to be cut through sandy soil, and after the water has been flowing through it for a year they have become practically impermeable. In the Riverina country the water soaks away from some of the banks and dams during the first season. I think that a scheme of canalization is perfectly practicable."

Distributing channels.

Not only is the soil from its nature well adapted for the storage of water in the beds of creeks and other natural depressions, but it is extremely favourable also, as to general surface-level, for the formation of canals and subsidiary channels for the distribution of water over the plains. Throughout hundreds of miles of country the occurrence of rock or stones is phenomenal, so that the excavations necessary for this purpose can be done at a cheap rate. Excavations made by Mr. James Tyson, junr., on his stations in the Lachlan District, by means of bullocks and scoops, have been done at a cost on an average of about one shilling per yard.

(6.) TANKS AND DAMS.

Important results from tanks and dams

During the last fifteen years great waterless districts to the west and north of the Darling have been reclaimed from their normal condition, in which neither man nor beast could live, except immediately after rain, and have been made to contribute to the pastoral production of the Colony. The principal means by which this important extension of the habitable boundaries of New South Wales has been accomplished have been the excavation of tanks and the construction of dams, wherever the configuration of the Colony admitted of the latter means of storage, as on the Culgoa, Warrego, and Paroo.

Dams.

The construction of dams in the older settled and more thickly peopled districts to the south-west has, owing to the want of proper legislation, been to a large extent prevented by the risk of having them destroyed. One case may serve as an illustration of many. We quote from a communication made to us by the Hon. W. A. Brodribb (*Evidence*, p. 84).

> About the early part of 1858 a party of men went up the creek in the middle of the night and destroyed the Coree Dam, the property of Messrs. F. and G. Desailly, who repaired it, and for weeks kept armed men to prevent it being destroyed again. However, a party of twelve men went up the creek and destroyed about twenty-three dams, under the impression that their runs would be supplied with water. This destruction of property was perpetrated by men who had neglected to secure water by construction of dams when the creek flowed through the Edward River for weeks; but they were doomed to disappointment, for, having cut the dams, they found that the water did not run more than two or three miles below each dam. They came to my house on the 17th November, 1858, and told me they had burnt my upper dam by fire, there being no water in the dam at the time. They went to my house dam and cut away two panels, but there was very little water in the dam at the time. I prosecuted them before the Deniliquin Court of Petty Sessions, and three of them were committed to take their trial at the Goulburn Quarter Sessions to be holden on the tenth January, 1859. I had to go by Melbourne, thence by water to Sydney, and on by mail-coach to Goulburn; and after all the men were acquitted, and afterwards brought an action for damages against the Magistrates for committing them, and I had to attend at the Supreme Court in Sydney at a great deal of inconvenience. The case went on for sixteen days, when the men withdrew it, and they had to pay all costs. I repaired the dam after it was cut. This dam had been constructed

twenty-eight years back, and has never been empty since, and has supplied the Wanganella township with water, besides having supplied the stations on each side with water.

Tanks.

The excavation of tanks has been a work of enormous difficulty and cost, owing to the necessity of having to cart water, as well as other supplies, from the last frontier line of settlement at which the rain had been conserved. In selecting sites for tanks care has had to be taken to fix upon localities having a catchment area sufficient to supply the number of sheep to be watered at them, and where, from the slope of the surface, by means of shallow drains extending for long distances, even the smallest amount of running water might be conducted into the tank. None but those having at command a considerable capital could undertake works of the magnitude required to store water sufficient to supply the requirements of their stock for a period of from one to two years.

Capacity.

It is probable that there is no part of the Colony which is absolutely without rain for so long a time as two years, but the contingency which has to be provided against in some localities of the interior is practically of that nature, as the rains which fall are generally so small in quantity as to be at once absorbed by the arid surface. In 1876 it was stated, on what the Government Astronomer considered to be good authority, that on one station of the Bogan no rain had fallen for thirty months; and Mr. Licensed Surveyor Donaldson, writing from 80 miles above Gongolgan, said that "in the five years, 1864 to 1868, thirty-seven months have been absolutely without rain, unless for five or ten minutes; eleven months have been distinguished by only one or two good showers, or perhaps a day or two of light rain, leaving only twelve months in which there was good rain. The Bogan has only run through to the Darling five times in five years; and two very slight freshes have only gone part of the way down." Under such untoward conditions, tanks of small holding capacity would altogether fail; and it may be that one of the causes why so many selectors have been starved off their holdings is their inability to provide themselves with large and deep storage for water. In droughts such as those immediately referred to tanks would require to have a capacity of from 15,000 to 20,000 cubic yards, and a depth of about 20 feet.

Construction.

In the most approved form of construction the water flows through a small silt-pit previous to entering the tank. The material excavated from the tank is deposited all round the edges, where it quickly consolidates and greatly enlarges the capacity of the tank, while at the same time the banks serve to shelter the water from the play of dry winds which sweep away the moisture as quickly as it is evaporated over the water-surface, and which, in tanks not so sheltered, cause sufficient movement upon the water-surface to sensibly affect the amount of soakage from splashing against the banks. In tanks of this description, where the slope of the surface does not permit their being filled by flumes, horse-pumps, stationary engines, and windmills have been found very useful for the purpose of pumping water over the embankment, and so filling the higher levels. Where tanks are constructed in this way the quantity of silt brought into them is reduced to a minimum, and provision is made by pumping appliances for watering at troughs, thereby preventing silting and damage to the banks, and the pollution and waste of water in fleeces of sheep where the animals are allowed to drink direct from the tanks. Mr. Doyle, Stock Inspector, is of opinion that a tank having a capacity of 10,000 yards will give a supply for a longer time with pumping than one of 20,000 to which the sheep are allowed to go direct, as they carry in silt and carry out water in their fleeces. In some cases tanks 18 feet deep to which sheep have had direct access have been silted up in five years, hence the necessity of the newer mode of construction.

Number of tanks.

The conservation of water in tanks in this Colony has been more extensively carried on than that by any other means. It is applicable to a much larger area of country than that upon which dams can be made, and experience seems to have convinced pastoralists that it is far more certain and economical than the sinking of wells. If, however, the search which has been made for underground water had been made in the light of the information supplied by the Government Geologist, as to the strata in which water might be expected in different parts of the Colony, it is probable that much of the enormous loss of capital which has taken place in well-sinking would have been avoided. We observe that, in the report of the Chief Inspector of Stock for 1884, that officer, from the information supplied to him, estimates that the total number of tanks excavated in the Colony was 17,071, and that the expenditure upon them has been £3,960,472, or an average cost for each of £232. He puts down the number of dams at 8,579, and their total cost at £835,838.

Stock routes.

Of late years Parliament has made annual appropriations for providing water on the stock routes in the remote dry districts of the Colony, and upwards of £200,000 has been expended upon that object. At the beginning of this year there had been handed by the Roads Department (which constructs works for water-supply to stock in localities indicated upon the recommendation of the Inspector of Public Tanks and Wells) to the Department of Mines seven wells, four dams, ten springs, and thirty-five tanks, the aggregate of the tanks being 73,500,000 gallons, or an average of 2,450,000 each. There were twenty-one others almost ready to transfer, having a capacity of 69,000,000 gallons, or an average of 3,250,000 gallons per tank. It is expected that at the end of 1885 there will be a total of 134 watering-places in charge of the Inspector of Tanks and Wells, and taking the average standard distance apart as 15 miles, this represents provision for something like 2,000 miles of road. (Q. 3427). When the tanks are not leased they are placed in charge of caretakers, who report, through the Stock Inspector of the district, weekly, to the head of the department in Sydney. Charges are made for supplying water to stock, but the revenue derived (about £400 per annum) is less than one-tenth of the cost of supervision, so that construction and maintenance are wholly defrayed from the public revenue. The extremely dry weather during the last year or two has made it extremely difficult to obtain contractors for works of this description in the remote districts, and hence it is that larger provision has not been possible. In the event of a system of local Trusts for purposes of water-supply being called into existence, it may be expected that the Government will be in a position to hand over the tanks already made to the care of the local bodies, and so save a large proportion of the outlay for supervision and maintenance which has now to be incurred ; and that the annual appropriations made for watering stock routes will be available as subsidy to induce local bodies to make provision for supplying water to travelling stock where necessary as part of the general scheme to meet the requirements of their districts.

Railway embankments.

In Queensland the railway embankments have been used as a subsidiary means of storing water, more particularly at Rocky Creek, Tolmies Range, Wallaroo, and the 191st mile on the Central Railway, with the most satisfactory results, and the Engineer for Central Queensland, Mr. R. Ballard, states that he considers that, since the Queensland railways generally run east and west, and the flow of water is generally north and south, the system is one which should be largely adopted. There may be circumstances in which embankments may be made to serve the double purpose of railway traffic and water storage, but they are probably exceptional, and engineers generally incline to the opinion that the danger to the stability of the road would outweigh any advantage likely to be gained by such shallow storage as would be practicable.

(7.) WELLS.

Value of wells.

The pioneers of settlement have not been slow to recognize the great value of a permanent supply of water from wells, where it is stored under conditions of temperature and shelter which protect it from waste by evaporation. It is quite within the range of probability that tanks may silt up, or in the course of a long drought may have their contents exhausted by evaporation; but the supply from a good well is practically independent of the vicissitudes of the seasons. Of the total number of wells which have been sunk, a large proportion have yielded water so salt as to be unfit for use, or no water at all. Mr. James Tyson states that he has sunk a great many wells on the Lachlan to a depth of 80 feet, and that the water in all of them was perfectly salt. Out of from 150 to 200 wells sunk by Mr. R. C. Webb, of Kilfera, only two contained water which stock would drink, but not sufficiently good for human consumption. If feed be abundant, sheep will drink water which contains as much as 800 grains of salt per gallon; but in many cases the water struck contained as much as 1,200 grains per gallon. Of forty wells sunk by Mr. Fartiere, on Marfield, the water of only two could be used. Mr. F. Y. Wolsley put down thirteen bores, and the analysis proved that the water obtained contained more salt than that in the sea. Instances in which the search for pure well-water have been similarly disappointing could be multiplied almost indefinitely. There are localities in which the existence of underground water has been discovered and turned to account by means of wells; but it has happened in many cases that, of two wells sunk within a few yards of each other, one, and the deeper of the two, has been perfectly dry, while the other has passed into a water-bearing drift. Similarly, the water from one well has been found to be as salt as the sea, while that in a well a quarter of a mile distant from it has been perfectly fresh. If all the experience which has been gained by well-sinkers throughout the Colony could be plotted upon a map, deductions could be drawn which would be of great assistance to those who may hereafter sink wells; but in the absence of that information, and of anything like determinate surface indications, the sinking of wells has been found in most cases to be a very costly, and in many an almost ruinous undertaking. There are no doubt portions of the country which form an exception to the general experience; but even there it should be recollected that, in addition to the serviceable wells, there have been a large number of failures whose history and existence quickly pass into oblivion. Over a considerable area of country along the Murrumbidgee

Risk of obtaining salt water.

Murrumbidgee

an abundant supply of fresh water may be obtained at a depth of from 120 to 200 feet. A supply in less quantity, and generally somewhat brackish, is often obtainable at a depth of from 70 to 80 feet. The water which is found at the lower depth is always found in the same description of drift; and, although when struck it rushes into the well in such volume as to compel the workmen to retreat with the utmost speed—in one case rising 100 feet in three minutes—it never rises to a higher level than the first water-bearing strata, not even where tubing is used. In one well about 40 feet from the river-bank the water rose to within 80 feet of the surface, and although the flat was covered with flood-water the height of the water in the well was not increased; neither does the height of the water vary appreciably winter or summer. A witness, examined at Jerilderie (Mr. J. D. Rankin), also stated that it was very rare indeed to hear of a well being sunk on the plains near that place without water being obtained. In the Macquarie, near Dubbo, and the Castlereagh, the water from the river permeates underlying strata for a considerable area; and an abundance of good water is to be obtained in wells of moderate depth. Mr. T. K. Abbott, S.M., has contributed valuable information respecting wells in the Liverpool Plains district, extending over an area of about 100 square miles. It seems probable that a large number of the wells, of the position, depth, strata, and water of which he has obtained particulars, situate in the basins of the Cox and the Mooki, derive their supply from the soakage out of those streams; but there are several which appear to be fed by an underground flow from the spurs of the Main Dividing Range. Of eighty-nine wells in the basin of Cox's Creek and the Mooki, seventy-three bottomed in sand or gravel with an abundance of fresh water, six in clay with brackish or salt water, eight in rock with water hard to brackish, one in sand with water bitter, and one in rock with water good. The depths and situation of the wells justify the inference that water may be obtained at a moderate depth in sand or gravel almost anywhere in the county of Pottinger. Among the more remarkable wells described by Mr. Abbott is that at Bando, situate in basaltic country, near the foot of a range having an elevation of 1,600 feet higher than the well itself, which is on a slope about 150 feet above the plain. The well is 90 feet deep, and the supply, which is artesian, is at the rate of 20 gallons a minute, although, prior to the timber being sapped in the locality, it was with difficulty that a team of bullocks could be watered there. With respect to two other wells, Mr. Abbott wrote:—

Liverpool Plains.

> To the north-west of Bando there is a most remarkable spring at Garrawilla head station, and upon a recent visit I availed myself of the opportunity to measure the outflow. I found that this spring yielded the enormous quantity of 9,600 gallons per hour. I rode over the spring where it makes its first appearance, and was surprised to find the ground quite hollow for a space of upwards of 100 acres, and upon listening attentively one could hear the sound of rushing water under foot. In many places there happened to be large fissures or holes in the ground, and the water could be seen rushing along on its subterranean course at a depth of about 3 or 4 feet from the surface. A large dam has been erected below this spring, and one of the most extensive sheep-washing establishments of the Colony is supplied with water by powerful engines from this dam. The whole area of the valley in which the spring arises does not exceed 2,000 acres, and the yield per annum at the rate quoted amounts to nearly eighty-five millions of gallons of water. There can be no doubt whatever that the source of this spring is far removed from the drainage area of the valley in which it occurs.
>
> On Moredevil Station, near the source of Cox's Creek, many years ago, a well was sunk to a considerable depth. The exact depth I have been unable to ascertain, but believe it was about 80 feet. No sign of water was obtained before this level

was reached, when, as the workmen broke through some hard rock, the water rushed in so rapidly that they were compelled to abandon their tools and make good their escape by means of a rope and windlass. In a few hours the well was filled to within 10 feet of the surface. Some years ago, as the well just described exhibited symptoms of caving in, another well was sunk about 80 yards easterly from the first. This well is 100 feet deep, and is situated higher on the slope by 4 or 5 feet than the first well. When the bottom was reached the water came as rapidly as on the first, and rose to within 4 feet of the surface, and on the following morning the first well had overflown, and a strong stream amounting to upwards of 300 gallons per hour was flowing from it. This has continued ever since, through all variations of seasons, without cessation.

Underground supplies of water in old drifts.

The Government Geologist, in his evidence, refers to the large supplies of water underground with which the tin-miners of Emmaville and Cope's Creek have had to contend, and the copious flow of water which the gold-miners have had to encounter in the deep leads of Gulgong, chiefly in old river-drifts underlying basaltic rock; while Mr. Henderson, the Superintendent of Drills, describes similar experience, and tells us that, in a comparatively small area at Ballarat, from seven mines there is pumped twenty million gallons of water per diem, and that one of them has been pumped for upwards of two years and a half with little or no signs of decrease.

Upper Darling basin.

The Government Geologist regards the cretaceous formation of the Upper Darling basin as one of great importance, and he anticipates that if bores be put down to a sufficient depth, it will be found to contain water enough to supply the whole of that part of the country (Q. 1001).

It is his opinion that this supply is not derived from the local rainfall, which is evaporated from the surface or finds its way into saucerlike depressions. It is from these stagnant underground reservoirs nearest to the surface that the salt water found in such a vast number of instances throughout the alluvial plains of the interior is drawn. The abundant supply expected from the cretaceous formation is artesian. We may mention some of the facts which exemplify this theory. On the Killara Station west of the Darling, two bores have yielded an artesian supply. One known as Weewatta, discharging from a pipe 144 feet deep, delivers from 7,000 to 8,000 gallons per diem 3 feet above the surface; the other (Mullyeo, 15 miles to the north-west), 44 feet deep, supplying from 12,000 to 13,000 gallons per diem 4 feet above the surface. At Dunlop Station, supplies of fresh water have been obtained from wells from 500 to 600 feet deep. At the Government bore at Goonery, 54 miles west of Bourke, water flowing at the rate of from 600 to 270 gallons, at a height of 20 feet above surface, has been found; and at another Government bore, 7 miles further west, a supply of 106 gallons an hour, rising more than 6 feet above the surface, was obtained from a depth of 464 feet. Comparing the depth of the two bores, the Superintendent comes to the conclusion that there is a dip in the cretaceous basin in this locality at the rate of 60 feet per mile.

Presence of salt water near surface not a discouragement.

In almost every case in which fresh water has been discovered, salt water has been struck at higher levels, and often near the surface; and therefore the prevalence of salt water near the surface should not act as a discouragement to deeper exploration. The Government Geologist, however, says that the clay-beds in which water is confined, but through which it does not circulate, do not usually extend far in any direction. Where the well is tubed, it is an easy matter to shut out the salt water; but as the great majority of wells are sunk by pick and shovel, if the inflow of salt water is very strong there is the utmost difficulty in puddling it back, more particularly when clay suitable for the purpose has had to be carted 30 and in some cases 60 miles.

Presence of salt water explained.

The prevalence of salt water in all the alluvial formations is explained by the Government Geologist as being caused by their fresh-water origin. The debris washed from the ranges has been deposited quickly, and the decomposition of mineral constituents arising from the moisture has converted the fresh water into salt. Sulphate of alumina, lime, and magnesia have been formed, and salts have been chemically produced. In the marine formations the soluble parts of the minerals have been washed out by the long-continued action of the sea-water. Wherever the water flows underground it is fresh, and wherever it is stationary, as it may be in clay-beds a few yards away from the current, it will be salt. The saline nature of the soil has given rise to well-marked peculiarities in the herbage, such as in the salt-bush.

Diminution of saltness of water.

It has been found that after wells have been freely worked for some time the water in them becomes much less salt by reason of the exhaustion of the mineral salt contained in the soil through which the water drains into the wells (Q. 2870). Mr. H. A. Gilliat, the Inspector of Tanks and Wells, speaking of the brackish wells between the Lachlan and the Darling, says :—

> There is an ample underground supply, and my belief is that the water gets its saline properties from the strata in which the wells are sunk. The strata are heavily charged with salts. In 1879 I tasted water from the Holybox well; up to that time it was so salt that no animal would drink it. I collected from 20 to 30 lb. of clean crystals of salt which had formed around the service tank and troughing. I recommended that the well be condemned, and forwarded the statements of people who had resided in the locality from the time the well was sunk ; they all agreed that from the very first the water had been undrinkable. At the end of 1883 a tank was being constructed in the locality, and the contractor not having any supply of water for his horses tried that in the well, and found that the animals would drink it; on making further inquiries, I found that there was much more water in the well than there was in 1879 ; this I attributed to surface drainage. The water was baled out of the well, and that which came in afterwards found to be good enough for stock. There are several other wells in which the quality of the water has improved in the same way.

Bore at Goonery Springs.

Considering that there has been an enormous fruitless expenditure upon wells, it cannot be expected that pastoralists will continue to invest their capital in well-sinking—however much a good well is to be preferred to tanks—until the boring rods shall have given better assurance than any which now exists (except in certain localities on Liverpool Plains, the Murrumbidgee, the Lower Lachlan, and the Macquarie) of the probability of striking the underground channels through which the fresh water circulates. The value of the bores west of Bourke is very much lessened from the fact that there was already an abundant supply of water from the Goonery Springs before the bore was put down; and the great cost of the boring operations conducted by the Government is not calculated to lead pastoralists to view the enterprise with much favour.

Drilling plant.

Should Mr. Wilkinson's anticipation, that fresh water in abundant quantity is to be found all over the cretaceous basin, within a maximum depth of 700 feet, be realized, we may hope that engineers, having their own boring plant, and trained men to work it, will find a large field for employment in the north-western districts. With the certainty of finding water there can be little doubt that boring appliances, adapted to the special work required of them, would be forthcoming, and that tube-wells would be sunk with an amount of economy and dispatch which has not hitherto been attained. Reference to the evidence of Mr. Darley (Q. 1674 and sequel) shows that in California, where wages are as high as in New South Wales, and the strata similar, the owners of drilling plants eagerly compete with each other in the business of well-sinking; they accept all risks arising from breakages to plant, and if they do not find water it is a condition of the contract that they are not paid.

Use of metal tubing.

The secret of getting the water to rise to the surface lies in the use of metal tubes, for no matter what the pressure might be from below, it is hardly likely that water would rise higher in the well than to the permeable strata. Without the casing, the water when it rose to a certain height would disperse with the upper drainage. The same conditions no doubt exist in many of the wells of this Colony in which the height of the water cannot be increased by any inflow from the surface, nor its depth reduced more than temporarily by any amount of pumping it has been possible to apply to them.

Influence of atmosphere on flow of springs.

It has been observed that the flow of water from some springs in different localities is very sensitive to the pressure of the atmosphere; and the Government Astronomer offers the following explanation of these interesting phenomena.

> In several places, notably on the Kallara Run, there are wells where the supply of water varies with the state of the atmosphere. That has been noticed in a number of places in the Colony; that is to say, the differing states of the atmosphere affected the quantity of water discharged. There has been a marked instance of this effect on a station to the south of Cooma—Babandarra Run. The water there in a certain creek stops running; and when it commences to run again, the circumstance is regarded as a sign of rain. The explanation of this is to be found in the variation of the barometer; when the barometer falls the pressure is removed, the air inside expands and forces the water out. When a barometric depression has passed over the country, water has been known to commence running in many places. There are wells in the Murrumbidgee in which the quantity of water varies with the state of the atmosphere. There is another instance on the Gundare Run, close to Coolah.

(8.) IRRIGATION.

Erroneous views on irrigation.

The first use to which water saved in the country districts will be put will be for domestic and stock purposes; and after these demands have been satisfied there is no better service in which water can be employed than that of irrigation. An erroneous impression which we have found to prevail among some witnesses is that the advocates of irrigation think it practicable to irrigate the whole of the western plains. It is not a matter for surprise, therefore, that the notion of irrigation should be scouted by those who are painfully familiar with the sparse and irregular character of the rainfall in that part of the Colony. In no part of the world, not excepting countries the most favourably situated for the purpose, can any large proportion of the soil be brought under wet cultivation.

Spain.

It should be borne in mind that, as a general rule, the countries in which the land most requires artificial watering are those in which the rainfall is most limited. For instance, Spain, which is a dry country with an uncertain rainfall, is in a great measure dependent on irrigation for agricultural produce of all kinds; and, although irrigation has been practised there for many hundreds of years, it is estimated that the land treated constitutes only 5 per cent. of the total area of the country. This small proportion includes irrigation of every kind, and is the amount estimated in the Spanish Government returns; but Moncrieff, after inspection of the agriculture in all the provinces, concluded that this estimate is greatly in excess of the actual area. In Lombardy circumstances favour irrigation to a degree scarcely approached elsewhere. Remarkable fertility of the soil, a supply of water far in excess of the requirements of the entire country, regularity in the slope of the land, beneficial legislation, and an industrious peasantry, combine to make Lombardy, as it is, the best irrigated country in the world. Yet even here the irrigated land is only one-sixth of the whole area, or one-fifth of the productive area.

Lombardy.

India.

In the preparation of estimates for canals in India it is generally assumed that of the land actually irrigable from a canal not more than one-third will ever be under irrigation at the same time. The most highly irrigated of the large territorial divisions of that country is the one included under the name of "the North-west Provinces and Oudh." The Upper and Lower Ganges canal system far exceeds in magnitude and importance any other irrigation work in the world, and in addition to these, there are in that part of India similar works of the first rank. Yet here the total irrigation from canals is scarcely 5,000,000 acres, out of a total area of nearly 68,000,000 acres. It must, however, be added that in these provinces wells for irrigation are reckoned by the thousand, though no records of the areas so cultivated are available. Still it is improbable that the total irrigated area exceeds one-tenth of the area of this province. The total area included within the territory now known as the Punjab is about the same as that of the North-west Provinces and Oudh, being slightly over 68,000,000 acres. The area irrigated in 1877–78 was 1,320,000 acres; but as the Great Sirhind Canal, designed to irrigate three-quarters of a million acres, has been in operation for the past three years, the area now irrigated from canals is probably not less than two million acres annually. In this province also well-irrigation is carried on very extensively, but on a much smaller scale than in the North-west Provinces and Oudh. Still it is improbable that the irrigated area amounts to more than 5 per cent of the whole country. In the Bombay Presidency, of a total area of nearly 79½ million of acres, only about three-quarters of a million acres are irrigable from Government works; but here also there is irrigation on an extensive scale from private works, particularly from reservoirs. Altogether the irrigated area cannot exceed 1½ or 2 per cent. of the Presidency, and even this approximate estimate is based on the assumption that the works under construction in 1882 are now in operation. Of a total area of 89½ million acres in the Madras Presidency, only 2,620,000 acres, or less than 3 per cent., was irrigated from public works in 1878; and though irrigation from private tanks and wells is extensively practised, it would in all likelihood be safe to assume that the area irrigated from all sources does not exceed 5 per cent. of the total area of the Presidency.

Proportion of irrigated land in India.

Proportion of irrigated land in America.

According to Mr. Deakin's Report on Irrigation in America, the great arid tract comprised in the south-western portion of the United States is one million square miles in extent, and of this not more than 3 or 4 per cent. can be irrigated at any price. The probable area irrigated during the year is estimated by Mr. Deakin at 2½ million acres, which is less than the two hundred and fiftieth part, or in other words two fifths per cent. of the area in which irrigation is required.

Proportion of irrigated land in different countries.

Summarizing these facts, we find that in countries where irrigation has been practised for centuries, and in which the results of irrigation are considered to be of great national importance, the actual area irrigated in an average season is from 1 to 5 per cent. of the total area, while in the United States it is not nearly the one thousandth part of the whole country, and only about the two hundred and fiftieth part of the area requiring an artificial supply of water for raising crops. Such facts as these should be borne in mind by those who are disposed to underrate the value of irrigation in New South Wales.

Protected areas.

When considered in its relation to possible famines, land in Upper India is generally classed as "irrigated," "protected," or "unprotected." The "protected" areas are those which, though not irrigated, are so near to the irrigated districts as to place the people and the stock beyond the reach of famine. In the North-west Provinces and Oudh the system of irrigation is so complete that the whole country may be classed as irrigated or protected. On the other hand, even the best portion of the Punjab, that is the part lying between the Indus and the Jumna, is irrigated and protected to only one-third of its extent. In New South Wales, although private enterprise has in a few cases initiated arrangements for providing against drought by irrigation, the great national importance of a comprehensive system of protected areas is not sufficiently understood or appreciated.

Irrigation experiments in New South Wales.

The few pastoralists who have irrigated land in this Colony, for the purpose of growing lucerne and other fodder plants, have obtained heavy crops ; but the experience which has been gained in different districts has not been made the subject of close observation and record; and hence there is no means of accurately exhibiting in figures the crops obtained, the quantity of water applied, and other conditions under which the cultivation has been carried on. Mr. George Mair has irrigated on a small scale at Groongal for the last four or five years, throwing the water over the land by means of pumps, which draw their supply from the Murrumbidgee. Without preparing the land for irrigation he has been able to obtain crops of hay, wheat, oats, maize, and English grass, but has made no calculation as to the profitableness or otherwise of irrigation. Without irrigation he could not be sure of getting any crop, unless in a season exceptionally good, but with irrigation he is sure of a crop. This year he has a fairly good crop on 40 acres of irrigated land, while the seed sown at the same time on land which was not irrigated has not produced any crop whatever (Q. 2065).

Irrigation at Hay.

Another instance of irrigation of a different character, in the same district, is given by Mr. John Andrew, of Hay. Mr. Andrew says that nearly every householder in Hay irrigates to a small extent, and now there are beautiful gardens full of flowers where before nothing would grow. The streets have been planted with shade trees, the growth made by some of which has been very rapid, owing to the town water-supply, and now some of the trees are large enough to allow 100 men to stand under the shade of a single tree (Q. 2350). Of still more importance, however, is the information supplied by a gentleman owning extensive property in the neighbourhood of Hay, and who has visited some of the irrigated districts in Spain. This witness (Qs. 9776 and 9810), speaking from his own experience, states that the successful irrigation of fruit-trees, and particularly olive-trees, in the Hay district, has been placed beyond question, and that the yield of one of his olive-trees was four times the average yield of the trees which he saw in Southern Europe.

Irrigation from the Namoi.

Turning to the north-west, we find another instance of irrigation at Gunnible, 5 miles from Gunnedah, where, upon the banks of the Namoi, Mr. T. P. Wills-Allen erected in 1876 a 30-h.p. stationary engine, primarily for the purpose of sheep-washing. After it had served the purpose of sheep-washing the water was allowed to flow over the land, but the soil was not specially levelled for irrigation. Last year Mr. Wills-Allen obtained 80 tons of wheaten hay from 25 acres of land. He also irrigated a crop of lucerne, and between November, 1884, and the date of his examination before us (11 May, 1885) he had obtained five cuttings, each cutting averaging about 1 ton per acre. After the crop of wheat was removed the land was planted with maize, in January this year, and the result has been a crop estimated at fully 40 bushels to the acre, in addition to a luxuriant growth of pumpkins grown among the corn. The land was not selected for the purpose of cultivation, but was used because of its nearness to the wool-washing plant, and in point of fertility is rather below the average of the district. There was not £50 expended in preparing or clearing the land for irrigation. Without irrigation, Mr. Wills-Allen is perfectly sure that in the season through which we have just passed the land would not have returned the seed. He further says : " My success has been assured within the past six months. I have been practically irrigating for only six or eight months, and the result has been so thoroughly satisfactory that I have not the smallest doubt as to the issue." He is of opinion that each separate irrigation of the soil for agriculture is worth from 5s. to 10s. per acre. He is preparing to extend the area under irrigation, and hopes to be able to preserve 2,000 tons of hay, which he believes will place him beyond the danger of drought (*Evidence*, pp. 161–164). The proprietors of Burburgate, a pastoral holding of about 300,000 acres, about 7 miles from Gunnedah, are making preparations for the irrigation of 170 acres upon a systematic plan, and they purpose to include an area of 2,000 acres within the scope of their operation (Qs. 4337–4339).

Importance and value of irrigation.

We attach the greatest possible importance to the results of operations such as these, as indicating the commencement of a new era of pastoral and agricultural prosperity. The fact that in the dry districts of Victoria some capitalists are preparing to irrigate to the extent of from 2,000 to 10,000 acres for pastoral purposes, shows that irrigation has already passed beyond the stage of mere experiment in these Colonies; and we anticipate that the public will soon become sufficiently alive to the importance of the subject to insist upon the conservation of all the water which can be spared for the purpose. The fact that twenty-one farmers near Kerang have, by voluntary association, brought water sufficient for the irrigation of 3,000 acres for a distance of 13 miles also affords an illustration of what might be accomplished in numerous parts of the Colony by small communities of farmers settled on the banks of creeks and rivers capable of affording the requisite amount of water storage. There is ample evidence to show that water for irrigation would be well worth £1 per acre per annum for farming purposes; and that, in such districts as Gunnedah and Narrabri, those who have attempted cultivation, and now lead a nomadic sort of life, as wool-carters and sheep-shearers, must, without irrigation, be starved off the land. Mr. Dewhurst and other witnesses say that all the farms along the Cockburn could be irrigated to some extent, that the value of the land would be threehold (Q. 3828), while Mr. A. Rogers says that some land which is now worth £2 per acre would, if irrigated, be worth £30 to £40 per acre (Q. 3934). In the present state of information and experience we are not disposed to accept statements of the value of water as being arithmetically accurate, but as proof of its great importance they are beyond dispute.

Lucerne.

Lucerne is, no doubt, the most valuable fodder-crop which can be grown in this Colony. Mr. H. B. Wright, writing from Winbar, near Louth, on the Darling, says:—"We have about 7 acres here irrigated —6 under lucerne. I sowed it on the 4th of May, 1884, and have watered it six times, giving it about equal to 6 inches of rain each time, and have cut five good crops of it during the twelve months. I have also tried sorghum, oats, and prairie grass, but the lucerne is by far the most profitable." In this connection it may not be amiss to turn to the experience of America, under conditions of soil and climate similar to, although perhaps less favourable than, those which obtain on many of the rich alluvial river-flats of New South Wales. Mr. Deakin, in his report already referred to, says:—

> A prevailing misconception as to irrigation is, that it is employed only for small areas under high culture. The fact that great stock-growers in California, such as Messrs. Haggin and Carr, or Messrs. Miller and Lux, irrigate thousands of acres for stock purposes appears to be lost sight of. Much Mexican irrigation is carried on upon the same plan. Where the great land-owners have their immense estates, one can see not hundreds but thousands of acres artificially watered; and where similar proprietors enjoy a share of the coveted irrigable area they cultivate so closely to each others' borders that the fenceless area as far as the eye can reach appears one gigantic irrigated field. * * * On the great cattle and sheep ranches of New Mexico the proprietors, some of them Australians, are enlisting the same invaluable ally, in order to protect themselves against the occasional ravages made in their flocks and herds by bad seasons. It pays, as a rule, to irrigate natural grasses, for, by this means, the carrying capacity of land is increased 33 per cent. The Chowchilla Canal, in Fresno County, Cal., 30 miles long, 30 feet wide at its mouth, and 2½ feet deep, is used almost solely for this purpose, and there are 20,000 acres of natural grass land irrigated in one property in Kern County.

Alfalfa.

> But the mainstay of the American stock-farmer, large and small, is lucerne, there styled alfalfa, which, though unsuccessful in England, is highly prized in France. In every western state this is grown to profusion. There are 35,000 acres of it grown by irrigation at Bakersfield. In Yolo County, Cal., almost the whole of the 13,000 acres watered from the Woodland Canal is under lucerne; it is to be found upon almost every colony plot in Southern California, and is the surest source of revenue in Utah and New Mexico. The area planted with this crop is increasing with marvellous rapidity. It is said to carry ten sheep or even twenty sheep to the acre, if it be cut for them. It is not a new growth in Victoria; but without irrigation its marvellous qualities have only partially developed themselves. At Dookie, with only the natural rainfall, it can be cut but once a year, yielding about three quarters of a ton to the acre; while at Bacchus Marsh, with irrigation, or water within reach of its roots, it can be cut five or six times, yields seven or eight tons, and lasts fifteen or twenty years. There are some 300 acres of it in this locality, thriving upon a natural seepage, and, though rather delicate in its earlier stages, owing to the lack of irrigation, when once firmly rooted it raises the value of the land to from £50 to £75 per acre. It is sown broadcast and freely, with a little wheat, oats, or barley mixed in it; it is rarely manured, though better for an occasional scarifying and top-dressing; is never fed down, but cut early and often, and found to possess splendid fattening qualities. It has succeeded just as well, but upon a much larger area, on stations south of Ballarat. It is said that it has been grown on the flats of the Hunter, N.S.W., for

many years without replanting, yielding a regular and heavy crop, and that in parts of Queensland it is employed for fattening store stock with excellent success. This latter practice has been reduced to a system at Watrous, N. Mex., where not only are the cattle sustained upon it during the few times in the year when the ground is covered with snow; but store stock are fattened for market at any season by stall-feeding them with 40 or 45 lb. of lucerne per diem, the average gain in weight per beast being set down at 3 lb. per day. It pays well, therefore, to buy stores at from £4 to £6 a piece and sell them again in three months at £14 or £15. Under irrigation lucerne seems to flourish everywhere, particularly in sandy loam, and in a warm climate free from frost, and though the yields given vary they are all great. Three cuttings are sometimes obtained in the first year, making a total crop of 4 tons to the acre, but the general thing is, as in Utah, to obtain only one crop in this period. After this, 6 tons are expected in the second year, and 8 to 12 tons in the third year. There are poor soils where it is cut only twice or three times, and other soils on which its quality does not keep pace with the quantity; but on those that most resemble our own plains the cutting is rarely less than four times, and the yield generally over 10 tons per acre in the course of a year. It can be sold, at 28s. a ton, at a profit of from £5 to £10 per annum. Much higher profits than this have been made from lucerne in Victoria; but, even under competition, the net returns should be at least as high. The lucerne-field is said to be green a week after it is cut, and knee-deep five weeks later. The crop presses well, and improves by keeping, lasting for three years, though losing a large percentage of its weight when turned into hay. One of its advantages is that it thoroughly cleanses and restores exhausted soils without manure, and thus is of special value as a rotation crop. Some authorities in America consider it difficult of eradication, while others maintain that with a thorough cutting of the roots about three inches below the surface it can be entirely destroyed. In some districts it is considered judicious to plough it in about every seven years. It can absorb a large amount of water, and will send its roots many feet in search of moisture. In Utah it is found best to sow as much as 30 lb. of seed to the acre, but the average is from 8 to 16 lb. elsewhere. At present there is an excellent market for it on every hand, as many farmers consider one acre of it better than two acres of the best blue-grass land of the famed Ohio Valley. It is claimed for irrigated lucerne that it will carry one or even two beasts to the acre on land which, without the water, would not carry a beast to 20 acres, and that with fertilization its capacity is doubled. It stands first in the popular esteem, but is not by any means the only grass irrigated, red-top, timothy, and clover giving excellent results as well, while, in the opinion of some, Arabian millet surpasses all. A natural grass known as alfileria (Spanish alfilerilla) is so very highly prized for its nutritious and drought-resisting qualities that a supply of the seed is being secured for the Experimental Farm, in order to admit of its acclimatization upon our own arid lands, on which artificial waterings cannot be looked for. It should lend an impetus to the great stock interests of Australia to be reminded that their rivals in America are making almost as much use of irrigation as the agriculturists.

Artificial feeding.

It has been ascertained, beyond all doubt, that 1 lb. of hay per diem will keep a sheep in fair condition during the summer months if near water and not compelled to walk any great distance. We think we have good reason to assume that the produce of an acre of land under irrigation would yield five crops in the year, and, making allowance for shrinkage into hay, we put the produce of each cutting of lucerne at 20 cwt., or a total yield from one acre per annum of 11,200 lbs. Putting the worst case possible—that there was no natural herbage of any kind available—it would appear from this calculation that the produce of 321 acres of land under lucerne, properly irrigated, would be sufficient to supply 10,000 sheep with food, at the rate of 1 lb. per diem for a period of six months. We believe, however, that we have under-estimated the produce of the land under the conditions referred to; and that we are justified in concluding that the terrible mortality in stock which now periodically afflicts the country can be averted by a wise and prudent use of the water at our disposal. In the report of the Victorian Royal Commission on Water Supply it is stated that "at Bacchus Marsh, lucerne, with irrigation, or water within reach of its roots, can be cut five or six times, yields seven or eight tons, and lasts fifteen to twenty years."

Ensilage.

The system of preserving fodder in a green state, known as ensilage, is one which promises to confer important advantages on the stock-owners of the Colony; and, although it has no necessary connection with the growth of crops by means of irrigation, it, nevertheless, would be a most valuable supplement to any such attempt to make provision forthe feeding of cattle against the exigencies of an irregular climate. It sometimes happens, following a copious rainfall, more particularly after a year of flood, that the natural grasses grow so luxuriantly as to form extensive meadows, which, if mown and stored in pits from which the air and moisture are excluded, would retain their nutritious properties in a greater degree than if converted into hay, and for a considerable period—there is reason to believe for many years. Almost every description of fodder plant has been successfully preserved in this manner, either whole or, in the case of thick-stemmed plants, cut into chaff before being thrown into the silo. The longest period of which we have any information of ensilage having been preserved is four years; but, in the absence of experiment to test the point, there is no reason whatever to place that as the extreme limit at which green fodder so stored will retain its nutritive properties. All descriptions of graminivorous animals will eat ensilage as readily as hay; and the rapid extension of the system adopted by M. Goffart (who preserved 250 tons of green maize by means of pits in 1874) throughout France and the United States of America, is proof of its value. The simplicity and economy of the means to be adopted should form a strong recommendation of it in a country where labour is often scarce and dear, and presumably the dryness of our climate furnishes a special reason why ensilage pits or silos should be availed of by agriculturists and pastoralists here. Mr. Walter Lamb, of Woodstock, Rooty Hill, who has given considerable attention to the subject, and who has enjoyed the advantage of inspecting the silo constructed by the Viscount Arthur de Chezelles of Chateau Boulleaume, Liancourt, St. Pierre, Oise, France, regards that as the largest and perhaps most perfect of its kind.

Mr. Lamb's experiences.

Mr. Lamb, on his return to the Colony in 1883, proceeded to construct a pit, and the experience which he has gained in so dealing with the harvest of 1884 was so satisfactory that he has been encouraged to extend his operations, and he strongly recommends the adoption of ensilage-pits to the farmers and pastoralists of the Colony. From the want of opportunity we have not yet been able to procure Mr. Lamb's evidence on the subject; but, in response to our inquiry, that gentleman has obligingly placed some notes at our disposal, from which we quote the following:—

> "When commencing to construct the Woodstock silos, a mistake was made in adopting the European system of lining, experience having proved the same to be unnecessary in this dry climate. Even if a slight penetration of moisture occurs, the damage is trifling compared with the heavy expense of lining. My present plan is to select, if possible, the top of a hill, cut right through from one side to the other, so that the road into the silo at either end is slightly lower than the bottom of the silo. As the earth is excavated it is placed on the top of the banks, thus raising the sides about the same height as depth of excavation. In this way it will be found a 5-feet excavation will form a silo 10 feet deep.
>
> "The silo being thus constructed with a fall at either end, internal drainage is provided for. It is, however, necessary to form a drain outside to remove any soakage that would otherwise find its way into the silo. A narrow surface-drain, 6 inches lower than the bottom of the silo, will answer the purpose.
>
> "The excavation work at Woodstock is all done with plough and scoop, worked by a team of ten bullocks, consequently the cost is reduced so low that I can find

hardly any record of silos costing so little per ton of ensilage ; thus, a silo to hold 100 tons can be constructed as under particularized :—

	£	s.	d.
Excavating 50 ft. × 12 ft. × 5 ft., which will make a silo 50 ft. × 12 ft. × 10 ft. = 111 yards, @ 6d. per yard	2	15	6
Double paling fence at each end	2	8	0
50 sheets of galvanized iron, to cover (say) ⅔ of a ton, at £22, or 4s. per ton	14	13	4
	£19	16	10

"If bark be used instead of iron the cost can be reduced to £10, or 2s. per ton.

"The silo being ready, the fodder is cut in the most economical manner, none more so than with the ordinary horse mower. It is thrown into the silo either whole or cut into chaff. With grasses, the former plan is recommended ; but when dealing with maize, sorghum, or other thick-stemmed fodder, chaffing is considered necessary. As thrown into the silo the fodder should be laid evenly, and when the accumulation has reached the thickness of 18 inches or thereabouts, horses or cattle should be driven round and round, or rather up and down the silo, until the hitherto loose mass becomes almost solid, special care being taken that more pressure or treading be given to the sides close in to the wall than to the other parts. Where there exists difficulty in getting animals into the silo, men must be substituted—on no account must the trampling be neglected.

"Excepting for economy's sake, there is no necessity to fill the silo rapidly ; on the contrary, delay is recommended to allow the mass to settle down. Although it is customary in many cases to place first a layer of straw, then planks, afterwards earth, then again weights on the top of all, I have found the method successfully adopted by Viscount de Chezelles quite sufficient for all purposes. I simply throw on top of the fodder 2 feet of dry earth or less, where I have heavy produce or material requiring storage room in the same shed. This simple process of covering, excluding air, and pressing, all with the same material, overcomes difficulties which appear to be causing some trouble in England.

"My method of closing the ends is simply to erect a double paling or slab fence. Two strong posts are let into the ground at bottom of the silo ; slabs the exact width are placed inside horizontally, not necessarily fastened, because the pressure of the fodder keeps them in their place ; outside the posts slabs are nailed. Thus a cavity is formed, which is filled with earth and the air effectually excluded.

"All the covering required to keep out rain-water consists of sheets of iron or bark, simply placed on top of the earth, with stones or logs of wood to prevent their blowing off. Over my Woodstock silos, large sheds, used for hay, &c., answer this purpose, but at Merilong (Liverpool Plains) the former less expensive method will be adopted.

"My experience extends only to maize, sorghum, barley, and oats, but from all accounts, lucerne, clover, vetches, rye, trefoil, and all sorts of grasses, are suitable.

"The best condition for ensilaging all sorts of fodder is during the flowering stage, when they possess the most nourishment. They should come away from the field as quickly as they are cut. In case of rain there need be no apprehension of damage.

"Salt, although sometimes used, is unnecessary for the purpose of preservation, nevertheless a slight sprinkling over coarse inferior grass may prove beneficial."

Vegetable production.

The conditions of climate and soil in this Colony favour the cultivation of all the vegetable productions of temperate and semi-tropical countries, if only water can be had at the right time and in sufficient quantity. Were there room for doubt on this point, we need only point to the luxuriant gardens which the Chinese have established in every part of the Colony. A little reflection upon the great range of our agricultural and horticultural industries will show how vast are the capabilities of the Colony for the production of wine, dried fruits, tobacco, and other high-priced commodities, which are in demand in all parts of the globe, as well as for maize, wheat, and other grains, which being less valuable in proportion to bulk, do not afford so large a margin for profit, owing to the cost of transportation. Our agricultural and fruit-growing industry falls far short of meeting the demand for our own consumption, as may be seen by the excess of imports over exports, and there is ample room for the employment of a very large population to meet the present food requirements of the Colony.

Excess of imports over exports.

The subjoined Statement of the Imports and Exports of Breadstuffs, Feeding Grains, Fruit, &c., for the five years ending 31st December, 1883, shows an excess of imports over exports to the value of £4,939,888 for five years, or a yearly mean of £987,977·6 :—

Article.	Imports.	Exports.	Excess of Imports.
	£	£	£
Arrowroot	19,166	346	
Bran and pollard	116,212	20,799	
Butter	221,005	144,694	
Cheese	38,859	26,440	
Flour and bread	2,214,422	94,246	
Fruits, dried	487,305	nil	
,, bottled	17,545	nil	
,, green	396,798	488,655	
Wheat	515,435	67,709	
Barley	68,090	1,261	
Oats	344,551	5,644	
Maize	54,290	397,695	
Maizena, or corn flour..	17,627	9,719	
Beans	2,347	nil	
Pease (dried and split)	9,040	75	
Sharps	5,195	nil	
Hay and chaff	420,699	20,919	
Jams and jellies	457,546	1,687	
Oatmeal and groats	117,916	345	
Pearl barley	8,894	nil	
Potatoes	678,692	30,504	
Sago	3,315	nil	
Tapioca	35,677	nil	
Total.......... £	6,250,626	1,310,738	4,939,888
Yearly mean £	1,250,125·2	262,147·6	987,977·6

Future agriculture.

When the element of risk is eliminated from farming, as it may be to a great extent by irrigation, and the husbandman is assured of the fruits of his labour with almost as much certainty as an artisan receives the wage for which he hires, we may expect that agriculture will be undertaken upon system and with success. The copious rainfall over the coast districts and the large amount of rich alluvial soil along the courses of the rivers seem to invite co-operation on the part of an agricultural population to bring about as great an improvement as that which is obviously possible.

Profits from irrigation progressive.

Irrigation will probably be resorted to slowly in the first instance, but once its great advantages are made known by experience in any locality, it may be expected that the demand for water will exceed the power of supply. After the construction of an irrigation work, it must be expected that some time will elapse before its capabilities are availed of to their full extent. At first the direct returns from irrigation works will probably be unremunerative, as they have been in almost every other country ; but, as the management of water and its advantages become better understood, the revenue will here as elsewhere increase, and the ultimate profit of properly designed works of this description will be assured. It should however be clearly borne in mind that the direct returns from irrigation works are sometimes of much less importance than the indirect returns. The latter are due to the increase in national wealth caused by the increase of production, and their immediate consequences are apparent in enhanced value of the land, increase in railway traffic, and promotion of settlement. In India, where one of the most important taxes is that on land, this indirect return is more easily estimated than it could be here. Cultivators there readily pay double or treble the ordinary land revenue in addition to the water rate when water for irrigation is supplied. It is, however, perhaps not expedient that we should anticipate difficulties or a condition of things which has not yet arisen, further than to say that, in the apportionment of water for irrigation, consideration must be had for the fact that it will sometimes happen that the rainfall for a period of three or four years in succession may fall below the average. Provision must be made for that contingency, and care must be taken that the abundant water storage of one year shall, to the extent available for irrigation, be spread over a reasonably long period, such as experience would soon indicate.

Irrigation from storage reservoirs.

The perpetual snows of India and of Northern Italy constitute immense storage reservoirs which provide a liberal supply of water during the hottest part of the year. The absence of perpetual snow in New South Wales involves the necessity of conserving water on the largest practicable scale, so as in some measure to equalize the supply and provide for droughts.

Storage reservoirs in various countries.

Southern India, Ceylon, and Spain are countries in which the circumstances in this respect correspond with those of New South Wales, and in each of which storage reservoirs have been resorted to to a large extent. An official return prepared for the Ceylon Government in 1867 showed that in that country there were then 4,900 irrigation tanks and reservoirs. In the Bombay Presidency the capacity of the reservoirs constructed by Government before the year 1882 was 10,269 millions of cubic feet, and the area irrigable from them was 143,000 acres. If the reservoirs then under construction be included, the total capacity was 26,416 millions of cubic feet, and the total irrigable area 782,000 acres. This takes no account of the works constructed and maintained by the landowners. In the Madras Presidency the number of irrigation reservoirs is enormous, and the capacity of some of them is very great. One of these reservoirs, or tanks as they are there called, contains 3,000 millions of cubic feet of water, and has an area of 9½ square miles. In Mysore the number of irrigation tanks is over 20,000.

Considerations of the importance of reservoirs.

The irrigation done from a reservoir may seem small, but the proper and practical view of their results is that every reservoir represents a protected area. In Madras, where the principal crop irrigated is rice, which requires a very high supply of water, it is reckoned that every cubic yard of capacity in a tank represents a square yard of highly cultivated land. The quantity of water required for one crop of rice in Madras would be ample for three crops of lucerne in New South Wales. Private enterprise has already done much in providing water for stock throughout the interior of the Colony; but the storing of water on an extensive scale for equalizing the flow in our rivers, for the combined purposes of stock and irrigation, has still to be initiated. Mining enterprise has shown at Kiandra what can be done by a private company in storing water for mining purposes; and though in many places very complete provision of drinking-water for stock has been made by the owners and lessees of land (as, for instance, by a firm on the Gwydir, who, by pumping water through 30 miles of channels, are able to stock country otherwise waterless) the storage of water for irrigation purposes can scarcely be said to have commenced. The most economical works of this description are in those cases where large bodies of water can be conserved by dams of moderate length, and where large holding capacity is combined with great depth of water. That these conditions are not wanting in this Colony has been shown in regard to the upper portions of the Murray, Murrumbidgee, and Namoi. Favourable sites for great storage reservoirs are said to be found on the Upper Macquarie; and they probably exist on those portions of the other rivers which lie in a hilly country. The creeks and ana-branches of the rivers, while in many cases capable of extensive use for holding supplies of water for stock, are in only a few cases of sufficient depth and capacity to admit of their use for irrigation purposes. Their functions, as a rule, in connection with irrigation will be as inundation canals.

Facility for storing flood water.

We have seen that along the course of the Darling remarkable facilities are afforded for storing flood-water. Ana-branches and creeks capable of holding large supplies abound on both sides of the river, and numerous lakes of great holding capacity are found in the neighbourhood of the river, especially from Louth to the junction with the Murray. Arrangements for filling these lakes and maintaining a supply in them can in many cases be carried out at a very moderate cost. This has in fact, in some cases, been done already by private enterprise and with most beneficial results. As a rule water stored in this way will probably be used more for stock purposes than for irrigation, but by acting on the principle that all the water not required for the former purpose should be utilized for the latter, much can be done to provide for the exigencies of bad seasons. It will seldom happen that irrigation done under such circumstances can be conducted by gravitation alone. Pumping will be required; but the lifts will as a rule be much less than in those cases where irrigation is now being done by pumping on the Murrumbidgee and other rivers, and the quantity of water raised with the same power will be greater in a corresponding degree. As irrigation with the higher lifts is remunerative, the advantage of irrigation under the circumstances described will be apparent.

Quantity of water used in irrigation.

The irrigation now being carried on in the Colony by means of pumping is, as a general rule, conducted in a very primitive manner so far as regards the distribution of the water, and without any preparation or levelling of the soil. The immediate result of this is that the quantity of water used is out of all proportion to actual requirements. In Colorado, where, as in Australia, irrigation is in its infancy, it has been found that as much water is frequently used for one watering as would be equal to a depth of 12 inches over the entire area irrigated. In the few cases in which irrigation has been done by gravitation in this Colony similar waste has occurred. As a general rule, the irrigation practised in New South Wales has consisted in pumping water from the rivers and using it in fruit or vegetable-gardens, or for wheat, and other

Economical distribution of water for irrigation.

cereals, and for lucerne. It is natural to suppose that water made available under such circumstances would be used economically; still, the waste of water in this Colony wherever irrigation is practised is very great, and is due entirely to disregard of the first principles in the management of the distribution. In the proceedings of the Royal Society of New South Wales for 1883 there is a paper by Mr. H. G. McKinney, C.E., on the subject of irrigation in Upper India, in which a concise description is given of the system of distribution adopted there. Briefly stated, this system is to have distributing channels proceeding from the main and branch canals, and to fix the outlets for the smaller water-courses at such places in either side of these distributaries as may be deemed advisable. The small water-courses leading from the distributaries to the field have to be constructed and maintained in an approved manner by the cultivators. To ensure regularity in the times of irrigating various crops, an irrigating period is arranged for different lengths of each distributary or for the whole distributary. The irrigating period on one distributary or a portion of a distributary corresponds with the non-irrigating period of another distributary or portion of a distributary, and in this way is utilized the supply flowing in the canal. The practical results obtained by care in the distribution of the water are shown by the duty in acres obtained from a flow of 1 cubic foot per second. The following are the results obtained in various countries, reckoning in this manner:—

Results.

India—Ganges Canal	240 acres
India—Eastern Jumna Canal	250 ,,
France—Marseilles Canal	70 ,,
Spain	140 ,,
Italy	84 ,,
Colorado...	50 ,,

Duty of water for irrigation.

The conditions as to rainfall, nature of crops irrigated, temperature, and length of irrigating season all influence the area which 1 cubic foot per second will irrigate. It may therefore give a more definite comparison if the quantity required for one watering is stated. While, as already mentioned, as much as 12 inches in depth has been given in Colorado at one watering, 3 inches is considered an ample depth in Spain and Egypt, and from 3 to 5 inches in India, the latter quantity being allowed as a maximum at the first watering of dry ground. These figures agree closely with the quantities of rainfall required to saturate the ground on the plains in the interior of this Colony. It is frequently reckoned that in late spring or summer a fall of less than 3 inches is sufficient to reach the roots of the grass or produce a good crop. The rainfall in the interior of this Colony is meagre and uncertain, even when compared with that of countries where irrigation is most extensively practised.

Rainfall in irrigated countries

Among countries whose climatic conditions bear more or less resemblance to those of New South Wales the most interesting in connection with questions relating to rainfall and irrigation are Spain, Italy, Southern France, India, California, and Colorado. In Valencia the mean rainfall is about 16 inches, and this appears to be about the average for the greater part of Spain. It is owing to the fact that but a small proportion of this rainfall takes place in the seven irrigating months, from March to September, that irrigation in that country is so necessary. Under the most favourable circumstances not more than one crop in two years is obtained from unirrigated land, while from irrigated land two or three crops in one year are repeated. In New South Wales five and six crops of lucerne could be grown in the year. In regard to Italy, although the mean rainfall in Piedmont is 37 inches, the period of fall is so unseasonable that extensive irrigation works have been carried out.

South of France.

In the South of France the rainfall varies from about 12 inches to 27 inches in the irrigated districts. As in Spain and Italy, this amount of rain does not give a correct idea of the necessity for irrigation. In the irrigated districts in France it frequently happens that during the hottest months, namely, June, July, and August, there is not one good shower of rain, and the rains in Spain are even more uncertain and more unseasonable.

India.

In India the great extent of the country, and the different causes which affect the rainfall in different parts of it, naturally produce very considerable differences in the quantity of rainfall and in the seasons in which it takes place. In the North-west Provinces and the Punjab the rainfall for some distance from the Himalayas is so regular and so plentiful that irrigation is unnecessary; but the amount of rain rapidly diminishes in the latter according to distance from the mountains. Thus, at Kangara, on the slopes of the mountains north of the Punjab, the mean annual fall is 115 inches, while at Gurdspur, about 30 miles from the foot of the mountains, it is only about 31 inches, and the diminution is further shown by the respective falls at Amritsar, Lahore, and Multan, which amount to 20 inches, 15 inches, and 6 inches, the respective distances from the foot of the mountains being about 70, 100, and 350 miles. In the irrigated districts of the Punjab the mean annual rainfall varies from 6 to 30 inches, and in the North-west Provinces from about 15 to 40 inches, except in the Dehra Doon Valley, where irrigation is carried on with advantage, although the average annual rainfall is 88 inches.

Colorado.

California.

The mean annual rainfall in the irrigating districts of Colorado is about 14 inches, while in California, according to Mr. Deaken's Report, the amount varies in different parts of the State from 4 to 40 inches; the latter being obtained in the mountainous parts of Northern California, and the former in the arid districts in the southern part of the State.

New South Wales.

Comparing these figures with the rainfall in New South Wales, we find that in this Colony the mean annual rainfall in the basin of the Darling, excluding the hilly portion is only 12·81 inches. In the plain country between the Lachlan and Murrumbidgee the rainfall is 16·33 inches, and in the corresponding district between the Murrumbidgee and the Murray, 14·56 inches. These amounts of rainfall would be sufficient for the production of ordinary crops of cereals if the rain occurred at the times when it is required; unfortunately the rule is that rain comes in such small quantities as to be of little or no benefit to vegetation. Evaporation from earth under ordinary circumstances is double that from water, and it has been found in India that with a hot wind blowing as much as half an inch has been evaporated from a water surface in twenty-four hours. Bearing these points in mind, what effect could be expected from an inch of rain falling on the heated plains of the west?

Rainfall and evaporation in regard to necessity for irrigation.

Methods of irrigation practicable.

Private enterprise has already proved that in New South Wales two methods of irrigation are practicable. The first is by pumping from the rivers, and the second by making cuts from the rivers to flood the land by gravitation when the rivers are high. Works of the latter class are termed inundation canals. On all the important rivers of the Colony there are great facilities for the construction of works of this description. In the alluvial plains the slope of the ground is generally from the rivers, the highest ground being the river bank. The immediate result of this feature is that creeks leading from the rivers are numerous, so that when the floods rise these creeks act as distributary channels in carrying off the flood-waters. Notable instances of this are found on the Murray at and near Tocumwal, on the Murrumbidgee near Narrandera, on the Lachlan in the case of the Willandra Billabong, and on the Darling in the case of the Cato, Tarrion, and many other creeks. In the year 1877–78 the inundation canals of the Punjab irrigated over 537,000 acres. The outlay on these canals was small in proportion to the benefits conferred by them. They are seldom provided with permanent head-works, and there are no dams across the rivers which feed them. The silt deposits are cleared out every year, and the supply depends solely upon the natural rise of the floods at the beginning of summer. The floods in New South Wales are irregular in their occurrence, and it cannot be expected that crops of cereals will be irrigated by means of inundation canals as in the Punjab ; but the practicability of irrigating grass-paddocks by taking advantage of flood-water has been most successfully proved by Mr. James Tyson, junr., on his stations on the Lower Lachlan, and corroborated by others who have followed his example. Mr. J. L. Gwydir, who flooded two large paddocks with water from the Lachlan, found as the result that whereas these paddocks had failed to carry 4,000 sheep in the season before the flooding, in the succeeding season they successfully carried 12,000 sheep, 120 cattle, and over 200 horses.

Permanent canals.

The highest class of irrigation is that practised on a regular system from permanent canals. Unfortunately, the only rivers beyond the Dividing Range from which canals of this description can be constructed are the Murray and the Murrumbidgee. Permanent irrigation canals from some at least of the rivers flowing into the Pacific on the eastern coast are quite practicable; but as the rainfall is greater and more regular than in the interior of the Colony the want has not yet begun to be so much felt. There is no doubt, however, that even on the coast district the question of irrigation will demand attention as population increases.

Canals from the Murray and Murrumbidgee.

The practicability of constructing permanent canals from both the Murray and the Murrumbidgee is beyond question. In a report of the Engineer to the Commission it is pointed out that at a short distance west of Albury the hills cease and only open plains are met with ; that there is a regular fall in these plains towards the west and north-west ; and that the minimum discharge in the river is ample to guarantee a permanent supply for a large irrigation canal. It was also pointed out that if the water of the Murray were made available for irrigation, its letting value might be reckoned at £200 for every cubic foot per second of discharge. With a canal discharging 1,000 cubic feet per second as proposed, the gross income from the water would be £200,000 per annum. The crop generally irrigated would probably be fodder, and considering that it has been stated by a witness before the Lands Inquiry Commission that 100 acres of hay will sustain 5,000 sheep for three months in a bad season, the enormous benefit conferred by such a canal is at once evident. The idea of constructing a canal from the Upper Murray to divert a supply into the Billabong Creek was suggested twenty years ago by Mr. W. C. Bennett, Chief Engineer for Roads. (In this connection, *vide* reports by Mr. F. B. Gipps, C.E., and Mr. H. G. M'Kinney, M.I.C.E., in Appendix.) The question is important, and can be settled only by levels and a survey of the intervening district. The question of utilizing the supply in the Murray by Victoria has been brought to public notice in that Colony.

Comparison between the Murrumbidgee and Murray.

As a source for a permanent irrigation canal the Murrumbidgee is inferior to the Murray, on account of its smaller discharge; but on the other hand, in the case of the Murrumbidgee, there are no intercolonial difficulties involved. From the levels which have been taken by the Railway and Harbours and Rivers Departments, it is evident that the nature of the doab or district between the Billabong Creek and the Murrumbidgee is as favourable for the construction of canals as that between the Billabong and the Murray. There is a regular fall towards the west and south-west, there are no engineering or other difficulties as far as can be judged from the preliminary examination made, the soil is of excellent quality, and there is a good supply of water.

Storing flood-water on the Murray and Murrumbidgee.

The supply in both the Murray and the Murrumbidgee can be made more uniform by storing up water in the mountainous country near their sources, and allowing it to flow into the rivers when the supply in them is low. A preliminary examination of the Upper Murray was made at our request, and it was reported that water could be stored there on an extensive scale; but this requires confirmation by a fuller examination. The facilities for storing water in the Upper Murrumbidgee appear more favourable. The Tantangara Basin, of which a survey was made under our instructions, is capable of containing on a low estimate 15,120 million gallons, a quantity of which would supply 200 cubic feet per second for 140 days continuously to increase the summer discharge of the river. This basin is well worthy of further examination. There is also a proposal, originally due to Mr. P. F. Adams, Surveyor-General, to divert a portion of the water from the Snowy River to increase the supply in the Murrumbidgee. The Snowy River rises in New South Wales, and has in this Colony a catchment area of 3,360 square miles. The water from this area which is all mountainous, is now entirely lost to the Colony, so that it is highly desirable that it should if practicable be utilized in the manner proposed. A survey of the country through which a supply would have to be carried from the Snowy River to the Upper Murrumbidgee was ordered by us, but it has not yet been completed.

Tantangara Basin.

Diversion of Snowy River.

Inundation canals.

Inundation canals are practicable on almost every important river in the interior of this Colony. As in the case of the inundation canals from the Punjab rivers, the flood-water can in many places be drawn from the rivers without the expense of damming them. In a number of instances the natural channels from the rivers can be utilized as inundation canals, and under such circumstances the cost will be trifling compared with the advantages gained. In connection with the damming of rivers for the purpose of diverting the flood-waters, the Darling probably affords better facilities than any of the other rivers. The rocky bars found in it at frequent intervals would afford good foundations for dams, and the creeks and ana-branches would in some cases serve to a greater or less degree as canals. We are of opinion that the rocky bar forming the rapids at Brewarrina may be regarded as a proof that dams can be erected across the Barwon without silting taking place.

(9.) NAVIGATION.

Snagging

The sum of £170,000 has been expended in improving the Murray, Murrumbidgee, and the Darling. The cost of "snagging" the Darling is about £45 per mile, while in the more thickly timbered country it amounts to from £45 to £60; on the former river about 12 miles per month are cleared; on the latter, about 5 miles. Vessels can now go up the rivers with from 3 to 4 feet less water than formerly, and can also travel at night. (Q. 1144.) Mr. Moriarty points out that the first step to improve the rivers is to remove the dead timber which has been accumulating for ages, and this cannot be done if the height of the river be raised. Operations on the Murray have ceased, and snagging is now confined to the Murrumbidgee and Darling.

Use of rivers.

The attention which the Engineer-in-Chief for Harbours and Rivers has been able to devote to the rivers of the Colony appears to have been wholly confined to the removal of obstructions to navigation; but now that railways have been extended, at great cost, to the Murray, Murrumbidgee, and the Darling, and that subsidiary lines have been projected having their termini at points other than Bourke on the Darling, it may be well to consider whether the rivers should not, as the Commissioner for Roads puts it (Q. 1241), "be used in producing something to transport rather than in transporting it."

Locks.

To open the Murrumbidgee between Hay and Wagga Wagga, and the Darling between Wentworth and Walgett, for navigation by vessels establishing communication with Melbourne by way of Echuca, and with Adelaide by way of Blanche Town, it will be necessary to construct locks as well as weirs, and the cost of establishing through communication would be increased by the additional works required. If, however, the rivers are to be primarily considered as sources for water supply, and navigation is to be regarded as an adjunct to the railways, the locking of the rivers would not be needed to the same extent, if needed at all, for a comparatively few weirs would create many miles of water-way which station-holders along the banks of the rivers could take advantage of for the carriage of their wool and return supplies to the nearest railway terminus. For this purpose vessels having a draught of from 2 to 3 feet would be built, as was done in the attempt which was made to keep open navigation to Walgett (Q. 5285).

Traffic on Darling.

The census returns of population appear to include the whole of the population on the Darling in the registry districts of Bourke and Wentworth; and from these it will be seen that the population of the former district (into the heart of which the railway has already been taken) is one person to six square miles, while that of the latter (whose boundaries extend so far south as to include Euston on the Murray) is only one person to ten square miles. From the Report of the Collector of Customs for 1884 we observe that the Darling at Bourke has not been navigable for any but short periods since 1879. In 1880 it was "navigable for a short period"; in 1881, for a "very short time"; in 1882 the river "rose twice during the season"; in 1883 it was "unnavigable nearly the whole season"; and in 1884 it was "navigable twice, but of very short duration." The total value of the imports at Wentworth, upon which all the Darling trade is concentrated, during the five years ending December, 1884, was £1,872,439, and of the exports, £4,534,068, the annual mean value being £374,487 and £906,813 respectively.

Traffic on the Murrumbidgee.

This may be taken as representing the aggregate value of the trade of all the ports on the Darling with South Australia, the Victorian share of it being inconsiderable. Victoria, on the other hand, appears to enjoy almost a monopoly of the river-borne traffic of the Murrumbidgee, which, for the Customs purposes, centres at Hay. Mr. J. C. Bowden states (Q. 2959) that the depth of water in the shallowest places at ordinary summer level is from 1 foot to 1 foot 6 inches, and he has seen it year after year as low as that in numerous places. The river remains at summer level from January till the end of May at Balranald, and probably two months longer at Hay, so that navigation to Balranald is practicable for five or six months, and to Hay for four or five months. The aggregate value of the imports at Hay for the same period of five years was £71,267, and of the exports, £2,462,506, the mean annual value being £14,253 and £492,501. The railway was opened to Hay on the 4th July, 1882, and it will be seen from the following figures that there has been a steady and marked decline in the river-borne traffic to and from Hay since then :—

Year.	Imports.	Exports.
1882	£32,762	£489,081
1883	13,395	293,689
1884	6,591	160,386

Railway to Bourke.

The effect of the railway to Bourke upon the river-borne traffic of the Darling will, in all probability, be much more rapid and decisive than that upon the steamer traffic with Hay. The natural result of the present condition of things would be to extinguish the trade with South Australia, and transfer it to Sydney by way of Bourke. It will be of as much consequence to pastoralists to get their wool rapidly into the market, as it will be to merchants to reduce the amount of their unproductive capital. Vessels of a smaller draught than those which are anchored in the river, sometimes for nearly a twelvemonth, will probably be brought into requisition, to distribute the river trade to and from Bourke, or any other railway terminus on the river which may hereafter be created ; and, in this way, there is reason to expect that communication, hitherto by an annual or semi-annual voyage to Adelaide, will be cheap, quick, and regular by rail with Sydney.

River traffic intermittent.

Navigation, as it has hitherto been practicable between the points named, has been very risky and intermittent. At intervals of years a steamer from Adelaide will arrive at Walgett, while almost the same may be said of Brewarrina. Under ordinary conditions it has been no uncommon thing for pastoralists to have had two or three seasons' clips of wool upon their hands, awaiting the arrival of the larger barges to carry it to Melbourne or Adelaide. With the railway actually opened to Bourke, and the probability of other lines being constructed to points on the Darling to the south of it, it seems certain that railway traffic will wholly supersede the intercolonial river-borne traffic of the Darling, as the railway to Hay has to a great extent superseded that on the Murrumbidgee, where navigation is practicable for longer and more regular periods.

Railways preferable to water carriage.

In regarding the rivers as sources of water-supply for stock and agricultural purposes, we discover in them the means of bringing fertility to large tracts of rich but now unproductive soil along their course, and of vitalizing all the industrial capacities of the districts through which they flow. Viewing them simply as highways for traffic, we anticipate that after a vast expenditure of public money the country adjacent to them will remain in pretty much the same condition as it is at present, with even its pastoral capabilities only partially developed, and that the sole result of that expenditure will be the transportation of what little wool a mere handful of people are able to produce to colonies which contribute nothing towards the cost of the carrying facilities by which they are benefited. From the consideration which we have been able to give to the question, we are of opinion that railways will give all the facilities for carriage which are requisite, and that public expenditure upon the rivers of the southern and western portions of the Colony should be made with a view to increasing the means of conserving and distributing water over the dry districts through which they flow. The only exceptions which we should make to this rule would be that, if in any case it should be found that navigation can be adopted at a moderate expense, as a means of feeding our railways without interfering with the interests of water-supply, the works carried out on the rivers should be designed to suit both purposes.

(10.) PRINCIPAL RIVER BASINS AND OTHER DRAINAGE AREAS.

General Remarks and Explanations.

In defining the outlines of the different river basins of the Colony, it has been found necessary to depart in several important instances from the ideas generally accepted as to what constitutes their drainage areas. In the first place, the fact has to be recognized that on the lower portions of the western rivers the bank on one side (sometimes on both) frequently constitutes the boundary of the river basin. Another point which has not hitherto been sufficiently recognized is that a large portion of the Colony is without a defined river system. Throughout that part of the Colony lying to the north of the Murrumbidgee and Lower Murray and to the west of the 148th parallel of longitude, not only is the proportion of the rainfall which reaches the river infinitesimally small, but there are important catchment areas entirely independent of the recognized river basins. The general description applicable to this part of the Colony is that it consists chiefly of immense plains more or less timbered, and varied with occasional sand ridges, but partly also of an irregular series of low ranges of hills, the course of what was probably important mountain ranges. In both cases the tendency of the natural features of the country is to prevent drainage into creeks or rivers; and when to this is added the fact that the rainfall generally varies from 8½ to 15 inches, and that the temperature in the shade during seven months in the year probably averages a very high range, it is not surprising to find that there are immense areas which contribute absolutely nothing to the discharge of the rivers. Under these circumstances, the boundaries of drainage areas in the western portion of the Colony can only be fixed approximately. The boundaries of these drainage areas, though necessarily approximate, are sufficiently accurate for all practical purposes, for the instances in which most difficulty is experienced in fixing them are those where the rainfall and the surface drainage are smallest.

Small proportion of rainfall reaching the rivers.

Indefiniteness of western drainage areas

Closely connected with the question of river basins is the physical structure of the Colony. The Blue Mountains or Australian Alps, extending in an irregular line approximately parallel to the coast and with

Blue Mountains.

their highest ridge at a mean distance of about 75 miles from it, constitute a continuous divide between the coast districts and the rest of the Colony, the area of the latter division being about five times that of the former. The strip of low-lying land between the Dividing Range and the coast varies in quality according to the nature of the formations from which the soil has been derived, and the manner in which it has been formed and deposited,—the poor sandstone soil near Sydney reaching one extreme, while the rich basaltic soil near Kiama and the deep alluvial deposits on the banks of the Clarence, Manning, and Hunter Rivers represent the other.

Varieties of soil in the coast districts.

The western plains.

On the western side of the Dividing Range there are extensive tracts of high table-land, with a gradual descent to the great plains, the latter constituting about two-thirds of the area of the Colony. With respect to the origin and formation of the western plains, the theory of Mr. Tenison-Woods and others qualified to express an opinion is, that the red and yellow clays of the western districts were frequently formed by the weathering of the surface of granite, and in particular by the decomposition of the felspar and mica contained in it, while the quartz crystals, set free in the same process, were the origin of the sand ridges so frequently met with. The numerous isolated hills and low ridges of granite are described by him as the outcrops of the basis of the country. It is agreed by that gentleman and the Government Geologist that a mountain range extended across New South Wales from the vicinity of Orange in the direction of Cobar and Wilcannia, thence to South Australia, and that to the north and north-west of this range there existed a sea in which the water-bearing strata of the cretaceous period were deposited. Mr. Tenison-Woods is of opinion that at that period the country south of that range was a desert, the character of which was, in a subsequent geological epoch, altered by the outpouring of volcanic rock.

Their origin and formation.

Old mountain range.

Change in the drainage system.

Beyond doubt the drainage system of the country has materially altered; but, though in wells old river-beds have in some cases been met with, very little information has been obtained regarding the direction of underground currents or of percolation. The stream of all rivers flowing through the alluvial formation of our western plains represents only a portion of the discharge of the river valley, the balance, after allowing for evaporation, filtering through the soil beneath and on both sides of the rivers. The wells sunk in these alluvial tracts are affected more or less quickly by the rise and fall of the rivers according to the greater or less porosity of the subsoil; but in other cases, owing to the intervention of impervious strata, the wells remain unaffected by changes in the water-level in the river. A number of witnesses, and particularly some of those who were examined at Narrandera and Jerilderie, stated that throughout a large extent of the district bordering on the Murrumbidgee, and lying between that river and the Billabong Creek, there is a remarkable uniformity in the nature of the wells. A small supply of water, generally brackish, is struck at depths of from 70 to 80 feet; and at depths varying from 120 to 200 feet, an apparently inexhaustible supply of good fresh water is met with. This fresh water rises rapidly in the wells till its surface is at the level at which the brackish water is met with, and it remains at that level whatever may be the height of the water in the river. The conclusion is that the source of this underground supply is in the higher parts of the Murrumbidgee basin, and that the intervention of impervious deposits near the river maintains for it the character of an independent flow.

True mean of rainfall in the Colony.

In his last annual report on the rainfall, the Government Astronomer, after giving the mean rainfall of the Colony as obtained from all the stations, adds the remark—"It must, however, be clearly understood that the average spoken of is simply the arithmetical mean of the rainfall at all stations, for at present it is impossible to obtain the exact average." As there are now 496 observing stations distributed over the Colony, and every large drainage area is well represented, a fair approximation to the mean rainfall in every basin can be obtained by using the results from only such stations as have observations for at least three years. We have in this manner calculated the mean rainfall for every principal drainage area. *The averages so obtained have placed us in a position to deduce the mean rainfall of the entire Colony, by using each average in proportion to the area it represents. The mean rainfall as obtained in this manner is* 18·66 *inches.* More extended observations and an increased number of stations will probably give a slightly different result, but we do not anticipate that the difference will be of any great importance.

Field for further investigation.

Before proceeding to a detailed account of the principal river basins it may be remarked that, while valuable service has been done for this Colony by geologists in connection with the question of underground supplies of water, there is still a very rich field for investigation and much new ground to be examined.

Catchment areas which are not drainage systems.

In dealing with these extensive tracts of country which do not belong, except in times of high flood, to any of the recognized river basins, it has been found convenient to consider them as catchment areas. It must however, be understood that, owing to the small rainfall, the absence of well-defined natural features, the absorbent nature of the soil, and the high temperature, these areas are not possessed of any well-defined drainage system. Each of them, in fact, comprises a number of catchment areas. The tracts of country which come under this description are seven in number, namely:—

1. THE BASINS OF THE MIROOL, THE BLAND, AND OTHER CREEKS;
2. THE MANARA COUNTY DISTRICT, LYING BETWEEN THE LACHLAN AND THE DARLING;
3. THE YANTARA COUNTY AND BULLOO DISTRICT, IN THE NORTH-WEST AND NORTH OF THE COLONY;
4. THE TARA COUNTY DISTRICT, IN THE WEST AND SOUTH-WEST OF THE COLONY;
5. THE PAROO;
6. THE BIG WARRAMBOOL;
7. THE NARRAN.

Flow of rivers intermittent.

The basins of the Paroo, the Big ·Warrambool, and the Narran are of an intermediate type between the catchment areas mentioned and the permanent rivers. It is, however, an unfortunate circumstance that the flow of every river in the interior of the Colony, with the exception of the Murray and the Murrumbidgee, is intermittent. The great importance, therefore, of conserving water permanently is at once apparent, and an important function for future canals in this Colony is clearly indicated. This function is the filling of dams and storage reservoirs. In all the western basins the supply of water available is so small in proportion to the area requiring it that a thoroughly economical system of distribution is of the first importance.

THE COAST RIVER BASINS.

Area.

The most important river basins of the coast district are those of the Hawkesbury, Hunter, and Clarence, each of which has an area of more than 8,000 square miles. After these come the Macleay, the Shoalhaven, the Richmond, and others, the first of which has a catchment area of over 4,000 square miles, while those of the second and third are respectively about 2,800 square miles and 2,650 square miles. The most plentiful and most regular rainfall in the Colony, the most valuable deposits of coal, and some of the most fertile tracts of alluvial soil, combine with its geographical position to make the coast district more capable of supporting a dense population than any other part of New South Wales. Comparing the coast district to Northern Italy, it is found that while the mean temperature of the latter is 55°, that of the former is about 63°; and while the mean annual rainfall in Northern Italy is about 37 inches, that of our coast district is only 35⅓ inches. It therefore appears that, judging from both temperature and rainfall, the necessity for irrigation in our coast district is greater than in the part of Italy where irrigation is practised on a very extensive scale. There can be no doubt that the adoption of systems of irrigation in the basins of our coast rivers is only a question of time; hence, wherever possible sites for storage reservoirs have not yet been alienated they should be permanently reserved, and in all works undertaken in connection with the eastern rivers future irrigation works should be kept in view, and nothing should be done which would interfere with their success. Nor is the time distant when the question of irrigation in the coast districts will come prominently forward. This part of the Colony was the first settled, and is divided into the smallest holdings, the latter being an important circumstance in favour of the successful adoption of a system of irrigation; also, as already shown, a comparison of the temperature and rainfall with those of other countries points to the conclusion that irrigation can be resorted to with advantage. This is made clearer by a closer consideration of the following points:—

Natural advantages of the coast district.

Irrigation more needed than in Italy.

Variations in the climate.

Along a coast-line extending over 9 degrees of latitude there are naturally important differences in the climate. While on the whole the temperature of the coast district may be compared with that of Italy, the range of temperature throughout the year in the latter country is considerably greater. As a mean of the whole of this part of New South Wales, it may be stated that we have the winter of Southern Italy combined with the summer of Northern France. While the variation of mean temperature in summer from the extreme north to the extreme south of the coast-line is about 8°—from 76° to 68°, the difference of rainfall is much more important. At Antony, situated at the mouth of the Tweed, the mean annual rainfall is about 64 inches, while that at some places in the basins of the Hunter and Hawkesbury is only about 19 inches.

Foreign comparisons.

Mean rainfall: Clarence, Hunter, and Hawkesbury Rivers.

The following table, which shows the mean rainfall in the basins of the Clarence, Hunter, and Hawkesbury during the hottest months of the year, furnishes useful data for estimating the agricultural capabilities of these districts:—

Basin.	October.		November.		December.		January.		February.		March.		Remarks.
	Rain-fall.	Rainy days.	Rain-fall.	Rainy Days.	Rain-fall.	Rainy days.	Rain-fall.	Rainy days.	Rain-fall.	Rainy days.	Rain-fall.	Rainy days.	
Clarence	3·25	8	2·64	7	1·72	6	4·89	7	4·63	11	3·36	10	These figures are averages of five years.
Hunter	2·78	7½	2·39	7	1·22	4	1·68	4½	2·65	6	1·25	4½	
Hawkesbury..	4·01	12	2·20	10	1·21	7	2·30	9½	3·30	10	2·15	10	

The conditions above shown are more favourable than are obtained in the irrigated districts of Spain and Southern France, but less favourable than those of Northern Italy.

Fertilizing nature of silt.

The fertilizing character of the silt carried down by the Hunter and the consequent beneficial effects of floods are well known. Irrigation from the Hunter would therefore have this important point in its favour, that to a certain extent it would supply manure as well as moisture to the soil. The valley of the Hunter is already widely known for its great yield of lucerne, which yield could be greatly increased by irrigation.

THE SNOWY RIVER BASIN.

Area.

The basin of the Snowy River, that is, so much of it as falls within the Colony of New South Wales, may for all practical purposes be considered as including the whole area of the counties of Wallace and Wellesley, on the border of Victoria. The area of this basin is 3,360 square miles, and it has on its boundaries the highest mountains in Australia. On the eastern side of the basin is the Snowy Range, the summit of which, near Mount Kosciusko, widens out so as to form a table-land which extends for a length of over 20 miles, and which maintains an average height of 5,000 feet. Around this strip of table-land, which has an area of about 160 square miles, several peaks attain an elevation of more than 7,000 feet, the most important amongst them being Mount Kosciusko and Mount Townsend, whose heights are 7,171 and 7,256 feet respectively.

Height of peaks.

Rainfall at Kiandra.

The number of observing stations within the Snowy River basin is insufficient for forming an estimate of the mean annual rainfall throughout its area. The annual fall at Kiandra is estimated at 61 inches, while at two stations in the valley it is only 23½ and 18½ inches respectively. It seems highly probable that if there were an observing station on the eastern slope of the range, near Kosciusko, where the vapour-laden clouds from the Pacific strike on the hills, a much higher rate of fall would be registered than even that at Kiandra. The remarkable difference between the rainfall at Kiandra and that in the valleys below is in all probability due to the physical features of the basin. The centre of the basin is a deep valley, which is sheltered from the rain-clouds by the ranges on each side.

Snowfall.

An important feature of this basin, and one which greatly enhances its value as a catchment area, is the fact that snow not only falls in large quantities in winter, but also at all times of the year at an elevation of over 5,500 feet. The snow melts in all exposed places as the summer advances, but occasionally, on the south-eastern slopes of the mountains, where it has been drifted in large quantity by the wind, it lasts throughout the year.

Effect of the snowfall.

Discharge of river into Victoria.

The effect of the accumulation of snow in winter is to reduce the discharge of the river at that season and increase it in summer, thereby maintaining a more uniform flow throughout the year. The mean rainfall at the three observing stations, Kiandra, Bukelong, and Jindabyne West, is 34·41 inches; but bearing in mind that this is probably much below the actual average, and that from such a mountainous country a very high proportion of the rainfall runs off, there is little doubt that it would be safe to assume that 14 inches per annum over the entire catchment area flow off into the river. Under this hypothesis, the mean discharge throughout the year which flows across the frontier into Victoria is 3,700 cubic feet per second.

Comparison of temperature.

Diversion of Snowy River water into the Murrumbidgee.

Necessity for intercolonial agreement.

The mean temperature at Kiandra is only 45° Fahr., which is slightly lower than that of Dunfermline, in Scotland, and 2½° lower than that of Edinburgh; so that with a high rate of rainfall and a cloudy sky the rate of evaporation is necessarily low, and is probably balanced, or nearly so, by the heavy dews which prevail. Under these conditions, drainage, and not water conservation, is required for the development of the capabilities of the land. The diversion of a supply from the Snowy River to the Murrumbidgee would therefore be an actual advantage to the Snowy River basin, as well as an enormous benefit to the country depending on the Murrumbidgee. Having at its source the streams which flow down the eastern slopes of Mount Kosciusko, the Snowy River, though a rapid torrent at the upper part of its course, does not fall to an elevation of 3,000 feet above sea-level till it reaches the junction with the Crackenback Creek. The practicability of diverting a supply of water from this part of the Snowy River into the basin of the Murrumbidgee was first suggested by the Surveyor-General, Mr. Adams; and, though positive proof has not yet been obtained, the balance of evidence available goes to show that such a work is at all events possible. While the total area of this basin, from which the water flows to waste through Victoria to the ocean, is considerably over 3,000 square miles, the portion from which Mr. Adams proposed to divert the surface drainage into the Murrumbidgee basin was only 258 square miles. These figures show at a glance the insufficient grounds for the objections raised in Victoria to the proposed diversion of the waters of the Snowy River. The quantity proposed to be diverted was a mere fraction of that flowing to waste from its gathering ground in this Colony, through comparatively worthless land in Victoria, where it cannot possibly be utilized. To comprehend this question properly, the case of the Snowy River should be compared with that of the Goulburn, Campaspe, and other tributaries of the Murray, to the waters of which New South Wales has as strong a claim as Victoria has to the waters of the upper portions of the Snowy River. The necessity for an intercolonial agreement is strongly shown by the proposal for the appropriation of the water in the Victorian tributaries of the Murray, without reference to the undoubted rights of New South Wales and South Australia.

Geological features.

The main geological features of the Snowy River basin are the presence of immense masses of granite forming the cores and the summits of the hills, while the slopes consist chiefly of stratified rock of the earliest geological period. The soil, as in all granite districts, is less productive than in places where trap and basalt are abundant, and, owing to the severity of the climate and the mountainous character of the whole basin, the land as a whole is unsuited for agriculture. On the other hand, abundant rains, a moist atmosphere, and the presence of perennial streams, combine to make this part of the country valuable for grazing purposes. It is, therefore, not surprising that considerably over one-third of the basin in this land has been alienated.

Metals

Gold, copper, tin, and iron have all been found within the drainage area of the Snowy River. The situation of the principal gold-field near the head and along the course of the Eucumbene affords facilities for hydraulic sluicing such as are probably not to be found in any other part of the Colony. The mountain valleys afford favourable sites for storage reservoirs at a great elevation, while the heavy rainfall provides an exceptionally large supply of water to replenish them.

BASIN OF THE BILLABONG CREEK AND EDWARD RIVER.

The Billabong an independent drainage line.

Tuppal Creek.

Yanko Creek.

Edward River.

Although the Billabong Creek and its continuation, the Edward River, carry a much smaller and more uncertain supply of water than either the Murray or the Murrumbidgee, still the lower portions of their channels exist under more stable conditions than either of the last-mentioned rivers. The course of the Lower Billabong is in the bottom of a basin, along the margins of which flow the Murray and the Murrumbidgee; hence these rivers constitute to a great extent the boundaries of the catchment area of the Billabong. It must, however, be understood that the Billabong is an independent main drainage line only in the upper portion of its course, and that after emerging on the plain country it becomes a subsidiary channel for the discharge of flood-water from the Murrumbidgee and also (according to a witness, Q. 2027) from the Murray. The Tuppal Creek, proceeding from the latter river, and the Yanko Creek, from the former, are examples of the channels which assist in relieving excessive floods in the Murray and Murrumbidgee, by discharging part of the flood-water into the Edward River and Billabong Creek. The latter, as mentioned above, is a true main drainage line throughout the upper part of its course; but the Edward River, into which it flows, is merely one of a series of anabranches of the Murray, which depend almost entirely on the flood-water of that river for their supply, and which, after uniting, flow again into it at about 15 miles from its junction with the Murrumbidgee.

Fall towards the Billabong.

Area of basin.

The direction of flow of the creeks shows that there is a fall in the country towards the Billabong from both the Murray and the Murrumbidgee. Of the total area of this basin, only about 1,300 square miles can be considered as hilly or mountainous, while fully 15,200 square miles consist of immense plains, generally of great fertility, but destitute of any permanent natural supply of water. In the hilly portion of the basin the mean annual rainfall is nearly 25 inches, while in the plains it is only about 14½ inches. In ordinary seasons surface-water flows only from the hilly portion of the basin, and the stream thus produced is diminished by evaporation, percolation, and absorption till it finally disappears altogether. This generally takes place either before the stream leaves the hills, or at no great distance from them. The Billabong flows into the Edward only during or immediately after periods of abnormal rainfall.

Mr. W. C. Bennett's opinion.

Possibility of irrigation.

Levels.

More than twenty years ago, in his evidence before a Railway Commissioner at Deniliquin, Mr. W. C. Bennett, Commissioner for Roads and Bridges, gave the opinion that irrigation could be carried out successfully here on an extensive scale. Since then levels and surveys of the Murray and Murrumbidgee and of the Yanko Creek have been made, under the direction of the Engineer-in-Chief for Harbours and Rivers, several lines of levels have been taken by the Railway Department, and levels and surveys have also been carried out by the Deniliquin and Moama Railway Company. These levels have been collected and summarized by direction of the Commission, and the results are highly encouraging, confirming Mr. Bennett's opinion regarding the practicability of canals. In the Engineer's report on the Murray River it is pointed out that, from the place where the Jindera Hills meet that river, about 10 miles below Albury, to Jerilderie, there is a total fall, in that distance, of 119 feet, being equal to a fall of about 18 inches per mile; while from the same point on the Murray to Deniliquin the fall is at the rate of about 21 inches per mile. Again, he reports that the fall from Murrumbidgee at the gap in the Malebo Range, about 6 miles below Wagga, to the point where the Colombo Creek leaves the Yanko—a distance of 56 miles—averages about 2 feet per mile.

Fall to Jerilderie.

Fall of Colombo Creek.

Creeks and anabranches.

In addition to the facilities afforded for the construction of canals by the regularity and favourable slope of the ground, the creeks and anabranches may in some cases be considered as ready-made inundation canals, which only require to be surveyed and levelled and brought to a fairly uniform slope. The most important instance of this is the Yanko Creek, a project for the improvement of which was inquired into by the Commission.

Lake Urana.

Capacity of lake.

Lake Urana, situated within the drainage area of the Billabong Creek, has already been referred to as an extensive shallow depression. The extreme area of the lake, as shown in the county map prepared by the Survey Department, is about 21¼ square miles. The greatest depth of the lake is stated to be 10 feet (Q. 2035). It is fair to assume from these data that a mean depth of 6 feet might be stored over an area of about 20 square miles. This gives a storage capacity of over 3,345 millions of cubic feet, or nearly 20,909 millions of gallons. If a sufficient supply of water could be added from time to time to balance the loss by evaporation, percolation, and absorption, the quantity of water mentioned above would afford a continuous supply of 53 cubic feet per second for a period of two years. The state of affairs here assumed was in reality closely approached in 1870 and the succeeding years. We have been informed by Mr. S. M'Caughey that the flood of 1870 filled Lake Urana to such an extent that a stream flowed from it to the Billabong for several years afterwards. It must, however, be explained that Lake Urana is fed by the Urana and Coonong Creeks, the former of which draws its supply chiefly from hilly country. So that, on the occasion here mentioned, the water which flowed to the Billabong Creek consisted partly of flood-water which had been stored in the lake, and partly of supplies flowing into the lake from the Urana and Coonong Creeks.

Its flowing into the Billabong.

Excellence of land for grazing.

Wheat.

Throughout the plain country in this basin the land ranks among the best in the Colony for grazing purposes, whether for fattening stock or for the production of a high class of wool. In addition to this, extensive areas are known to be well suited for the cultivation of wheat and other cereals. It is therefore not surprising that in several of the included counties over 75 per cent. of the total area is alienated. The offer made by the owners of land in the vicinity of Yanko Creek, to bear half the cost of the work required to improve that creek, showed that they were fully alive to the importance of an increased water-supply. A similar question has been raised in connection with the Lower Billabong, and a proposal has been made for the construction of a canal from Hay to Deniliquin. Private enterprise has already done much for water conservation and supply in this part of the Colony, by the construction of dams, tanks, and wells; but the field for work on a large scale is so promising, and the results likely to be obtained so important, that we think the survey, design, and construction of the works should be done under a well organized national system.

Canal from Hay to Deniliquin.

National system.

BASIN OF THE MURRAY.

The Murray has its source in the perennial streams of the Snowy Range, and as in the case of the Snowy River, it flows within this Colony throughout only a portion of its length. From its source to the boundary of South Australia the Murray flows within New South Wales territory, but for purposes of navigation the Colony of Victoria has an equal right to the Murray waters.

Source of the Murray.

The basin of the Murray is hilly from the source of the river to about Howlong, beyond which place its course is through plain country. Although large alluvial deposits are met with on one or both sides of the river, even before it emerges from the hills, the great alluvial plains, properly so-called, do not commence till Mulwala is passed. Beyond Mulwala the general fall in the district along the New South Wales side of the river is north-westerly, that is, from the Murray towards the Billabong Creek and the Edward River. Throughout this portion of its course the Murray overflows its banks in high flood, and the water takes the direction mentioned; in other words, the catchment area is here limited to the narrow tract of low-lying land between the bank proper and the river.

Fall of country.

The mountainous or hilly portion of the Murray basin includes an area of about 2,400 square miles. The only meteorological observing station in it is Albury, which has a mean rainfall of 26·17 inches. The country on the Upper Murray is mountainous throughout, the river flows in a deep and generally narrow valley, and the conditions altogether are favourable to the discharge of a high proportion of the rainfall. Under these circumstances, it seems safe to assume that the quantity of surface-water which flows off in the Murray from the hilly portion of its basin is equal to a depth of 15 inches over that area. This would give a mean flow for the year of 2,652 cubic feet per second proceeding from the elevated catchment area within this Colony. The discharge of the river is highest in spring, when the water is most required, and Mr. Gipps, who was deputed to report on the possible storage of flood-water on the Upper Murray, believes that much may be done towards this object by the construction of dams. The Engineer to the Commission, in his report on the river Murray, after mentioning that at a time when the river was most unusually low he had found the discharge at Albury to be 1,200 cubic feet per second, suggested the practicability of constructing a canal with a discharge of 1,000 cubic feet per second from the river at the foot of the Jindera Hills, which would be readily obtain-

Area.

Rainfall.

Mean flow.

Dams on Upper Murray.

Discharge at Albury.

able if the storage capacity above referred to were availed of. The importance of such a work can scarcely be over-rated, and the evidences of its practicability are more than sufficient to warrant the cost of the surveys required.

Utilization of flood-waters of the Murray.

Area of land which might be benefited.

As already mentioned in the description of the basin of the Billabong Creek and Edward River, the facilities for utilizing the flood-waters of the Murray throughout the lower portion of that basin are unusually great. It might be supposed that the utilization of those flood-waters is a point which, owing to their abundance, can give rise to no misunderstanding; but this is a mistake. Before the junction of the Murray with the Murrumbidgee is reached, the extent of land in this Colony which can be benefited by the flood-waters of the Murray through inundation canals is little if at all less than 3,500 square miles. On this area it would be quite possible to utilize the whole available supply in an ordinary flood if the means of distribution were provided. The action of the neighbouring Colony of Victoria, in having already arranged for the appropriation of a portion of the flood-water in the Murray, is one more reason for hastening the conclusion of an equitable agreement between the Colonies.

BASIN OF THE MURRUMBIDGEE.

Physical features.

Area.

Rainfall.

Strata.

Climate.

Foreign comparisons.

Next to the Murray, the Murrumbidgee is the most important of the western rivers in the quantity and regularity of its discharge. At and near its source its basin adjoins that of the Eucumbene, one of the most important tributaries of the Snowy River. Although in the catchment area of the Murrumbidgee, except near the head of the Tumut River, there are no mountains whose heights approach the peaks of the Snowy Range, still the extent of mountainous country is great, snow is frequent in winter, and the rainfall is in many places exceptionally high. The catchment area of the Murrumbidgee, computed from the most recent maps, so far as the junction of that river with the Lachlan, comprises 11,800 square miles of hilly country and 3,600 square miles of plain. The mean annual rainfall taken from fifteen stations throughout the former area is 21½ inches, while that in the latter is 14½ inches taken from eight stations. In the higher parts of the basin the strata met with belong to the oldest geological periods, and are frequently broken and intersected by intrusive masses of granite. The soil varies much in quality, but it is, as a rule, excellent for grazing purposes, while on the table-land and in the valleys it is highly suitable for agriculture. With a height above the sea varying from 1,000, to 6,000 feet, the climate of the basin of the Upper Murrumbidgee leaves little to be desired. The following comparison of the meteorological features at two places in it—Cooma and Queanbeyan—with those of Dublin, London, and New York, indicates the temperate character of the climate of this part of New South Wales :—

Place.	Latitude.	Mean temperature.	Mean summer temperature.	Mean winter temperature.	Highest reading of thermometer.	Lowest reading of thermometer.	Mean rainfall.	Remarks.
	° ′	°	°	°	°	°		
Cooma	36 12 (S)	52·2	64·6	41·6	107·0	15·5	18·4	
Dublin	53 21 (N)	50·0	61·1	40·7	......	25·0	30·0	
London	51 32 (N)	50·8	62·9	39·5	95·0	5·0	24·0	
Paris	48 50 (N)	51·3	64·7	37·8	104·0	—10·3*	22·9	*10° below zero.
New York....	41 6 (N)	53·2	70·9	30·1	97·0	2·0	46·5	
Queanbeyan ..	35 20 (S)	53·6	67·2	41·9	109·0	20·0	23·7	

Mildness of the climate.

These figures are from the valuable returns of Mr. H. C. Russell, Government Astronomer, and, as will be seen, they show at a glance the superiority of the climate of Queanbeyan and Cooma over that of Paris and New York. While the mean temperatures for the year are nearly the same, it will be observed that New York is on an average hotter in summer and much colder in winter than Cooma or Queanbeyan. In its mean summer temperature Paris occupies a position between these places; but its mean winter temperature is lower than that of either of them, and its mean range of temperature for the year is greater. The mildness of the climate of the basin of the Upper Murrumbidgee is very striking when its latitude is compared with that of Dublin or London.

Geological formation.

Metals.

It has been mentioned that granite outbursts are frequently met with, and it may be added that, near or in conjunction with them, dykes or reefs of quartz are often found. Gold is widely distributed in these quartz-reefs, and is found in many places in alluvial deposits, the most important gold-fields in this part of the Colony being those in the neighbourhood of Gundagai, Adelong, and Tumut. Silver and lead have also been found in this basin, and promising deposits of slate have been opened out at Gundagai.

Necessity for water conservation.

Tantangara Basin.

Contents of reservoir.

The necessity for water conservation in this district, both for agricultural and mining purposes, is rapidly becoming more pressing. The practicability of storing flood-water on an extensive scale on the Upper Murrumbidgee and its tributaries has been suggested, and its importance is beyond question; but in only one case, namely, that of the Tantangara Basin, on the Upper Murrumbidgee, has any investigation of even an approximate description been made. In this case, by order of the Commission, a rough survey of the Tantangara Basin was made, and the plan was reported on by the Engineer to the Commission, who pointed out that, according to the information obtained, a dam of 84 feet in height, and of a mean length of 300 feet, would throw back the water to a distance of 6½ miles. This reservoir would contain a sufficient quantity of flood-water to afford a supply of 200 cubic feet per second for 140 days, at a time when the Murrumbidgee is low. We concur in the opinion expressed in that report, that this basin is well worthy of a more complete examination.

The Murrumbidgee as a source of canals.

Necessity for a weir.

The suitability of the Murrumbidgee as a source for canals has already been referred to in the description of the basin of the Billabong Creek and Edward River, and the practicability of a permanent canal, with its head at or near the place where the Murrumbidgee emerges on the open plains, was suggested. A canal of this description would necessitate the construction of a weir across the river. The weir should, in our opinion, be movable, so that when open there would be no contraction of the waterway, and no obstacle to the passage of flood-water. The remarkably high range of floods in our rivers renders it necessary that, in any works which are carried out for their improvement or for the utilization of their waters, the utmost care should be exercised to avoid raising the flood-level. Under these circumstances it may be laid down as a general rule, that where weirs are to be constructed to raise the surface-level in any of our rivers, such weirs should be movable. The importance of works of this description has long been recognized on the Continent of Europe and in India, but till lately it received very little attention in England. In admitting this fact, in a recent address, the President of the Institution of Civil Engineers, Sir F. J. Bramwell, said :—"I think there is good reason to believe that, by the adoption of movable weirs, rivers in ordinary times may be dammed up to retain sufficient water for the mills on their banks, while in time of flood they shall allow channels as efficient for relief as if every weir had been swept away."

Movable weirs.

Discharge of Murrumbidgee.

Regarded as a source of supply for canals, the Murrumbidgee is inferior to the Murray in the quantity and regularity of its supply ; but it has the advantage of being in New South Wales territory throughout its whole length. When the river was unusually low, in March last, its discharge was found to be 630 cubic feet per second. This discharge, as already suggested, may be materially augmented by the adoption of a system of storage reservoirs in the higher reaches of the Murrumbidgee and its tributaries, and possibly also by the diversion of a supply from the Snowy River. A suggestion has also been made by the Surveyor-General that there is a possibility of supplementing the supply in the Murrumbidgee, by the diversion of a portion of the discharge of the Tooma. Even without the prospect of any such increase, the present supply, as well as the favourable nature of the district, warrants the prosecution of a survey for a permanent canal. There is strong evidence that the water flowing in the Murrumbidgee represents only an important portion of the quantity which flows from the higher parts of the catchment area, the remainder passing off by underground percolation. This being so, it is probable that the abstraction of a large proportion of the supply in the river will not affect the discharge lower down to the extent which might be popularly anticipated.

Diversion of portion of the Tooma River.

DRAINAGE AREAS OF THE MIROOL AND OTHER CREEKS.

Between the Murrumbidgee River and the Lachlan is an extensive tract of country consisting chiefly of open plains, but including (chiefly in its upper portion) numerous low ranges of hills. Within this area, which amounts to over 14,000 square miles, are situated the Bullock, the Bland, the Mirool, and several other large creeks, besides many of less importance. These creeks as a rule are dry, except during and immediately after exceptional floods. On such occasions water flows in the creeks to a greater or less distance according to the depth of the rainfall, and in most cases disappears in a swamp or lake. A portion of the water probably passes to feed an underground supply ; but, as in the case of the Narran already referred to, evaporation would account for the great part of the loss. Throughout an area of from 2,000 to 3,000 square miles in the extreme eastern portion of this tract of country the mean annual rainfall is 19½ inches, and the mean number of rainy days sixty-seven. These results are obtained from three observing stations, and the mean number of years is seven. In the great portion remaining the mean annual rainfall is under 16½ inches, and the number of rainy days thirty-five, these results being obtained from thirteen stations for a mean period of four and a half years. As the series of basins which constitute the whole tract extend over a length of about 200 miles, it seldom happens that exceptionally heavy rains occur over the whole area simultaneously. In its usual parched condition the ground will readily absorb 3 inches of rain ; and as a fall of this quantity in one day is a very rare occurrence, it may, under the circumstances of this district, be inferred that it is not natural to expect any

Area.

Dry creeks.

Disappearance of water underground.

flow whatever in the creeks. Examination of the rainfall in each month makes this point more clear. Within the great portion of this series of basins to the west of the 148th parallel of longitude, the two meteorological stations which show the best average rainfall are Combaning and Bynya, the respective amounts being 18·80 and 18·48 inches. During the year 1884, in only one month did the rainfall exceed 3 inches, namely June, and in that case the total fall, which amounted to 4·54 inches, was spread over a period of twelve days. At Bynya, the rainfall during the same month in 1884 was 2·33 inches, and this was the greatest during that year for any one month. In 1883, the rainfall exceeded 3 inches in only one month at each of these places, the month being October, and the respective quantities at Combaning and Bynya 4·17 and 3·24 inches. The fall occurred during seven days at each place.

Benefits of clearing scrub. Trampling of stock.

The clearing of the country from scrub and useless timber, and the consolidation of the ground by the trampling of stock, tend to increase the flow of surface-water. The result of this will be to increase the supply available for storage in dams and tanks. So far as can be judged at present, such increased storage, together with the development of the use of the underground supply, are the only practicable objects to be aimed at in this district in connection with the conservation and supply of water.

BASIN OF THE LACHLAN.

Area.

The basin of the Upper Lachlan lies between the basins of the Murrumbidgee and the Macquarie, and is separated by the Main Dividing Range from that of the Hawkesbury. The total area of the Lachlan basin is about 13,500 square miles, of which 7,200 square miles consists of hilly country and 6,300 square miles of plain. In the former portion, the mean annual rainfall, as reckoned from six observing stations, is 20·33 inches, and the mean number of rainy days sixty-six, the mean number of years being five. In the latter, the corresponding results, reckoned from ten observing stations, were 13·41 inches of rainfall, and forty-one days on which rain was registered. The length of the Lachlan may be taken at 700 miles. It appears from the above figures that the catchment area of the Lachlan is inferior to that of the Murrumbidgee in its extent, and still more inferior in its nature, and that in addition, the rainfall in the basin of the Lachlan is considerably less. As might naturally be inferred, the Lachlan is much smaller in its discharge and more uncertain in its flow than the Murrumbidgee.

Further survey justified.

Although we have not had an opportunity of obtaining information excepting of a general nature in regard to the Lachlan and its tributaries, the Abercrombie and the Fish Rivers, we have ascertained beyond doubt that much can be done to improve the resources of the Lachlan basin by conserving the flood-waters, and that the prospects of work for this purpose are so assured as to justify a much more extended examination than we have up till the present been able to make.

Lake Cargelligo. Storage capacity.

Lake Cargelligo is a great natural reservoir of about 10 square miles in area, and with an average depth of about 11 feet when full. (Q. 3279.) This is equivalent to a storage capacity of 2,300 million cubic feet, or 14,375 million gallons. The lake derives its supply from the Lachlan in high floods, being connected with that river by a creek known as Lake Creek. When the lake has been filled and the river begins to fall, the water tends to flow back to the river. To prevent this, a dam has been constructed by private enterprise in the Lake Creek, but both the nature of the dam and the extent of the storage capacity are capable of much improvement. The plans and sections of Lake Cargelligo, referred to in the answer to Q. 3347, will be found in Appendices to the evidence, T 2 and T 3.

Private dam.

THE MANARA COUNTY DRAINAGE AREAS.

Area.

The tract of country bounded by the basins of the Darling, Bogan, and Lachlan, and possessed of no river system, is about 34,000 square miles in extent. Though hills are met with in isolated conical peaks and low ranges, their dimensions are so insignificant when compared with the area of the district, and their effect on the meteorological conditions are so inappreciable, that the whole of this drainage area may be classed as plain country. Throughout its whole extent the mean annual rainfall, as reckoned from twenty-nine observing stations, is 12·83 inches, and the mean number of days on which rain is registered is forty-one. The rainfall varies in an important degree in different places. It attains a maximum along the watershed line between the Manara drainage area and the basin of the Upper Bogan, and in particular where these two catchments meet that of the Lachlan. In this neighbourhood the mean annual rainfall is about 20 inches, while in the lower parts of this drainage area, near the district in which the basins of the Lachlan, Lower Murray, and Darling meet, the rainfall does not exceed 11 inches.

Insignificance of the hills.

Rainfall.

Nature of the country.

The general description of the land is that it is gently undulating, and abounds in pine and mallee scrub. Frequent patches of low ground are met with where local surface drainage collects, and is lost chiefly by evaporation. Low ridges of schistose rocks or of granite are numerous, and occasionally the granite is found with its surface at the ground-level. Besides the great areas covered with dense and worthless scrub, there are immense plains timbered with yarran, belar, and box.

Trial railway survey, Condobolin to Wilcannia.

The remarkable absence of well-defined natural features in the Manara drainage area is strikingly illustrated in the section along the trial line surveyed for a railway from Condobolin to Wilcannia. The length of this line is 270 miles. The average elevation of the country traversed in the first 70 miles from Condobolin is 570 feet above the sea, in the next 100 miles 370 feet, and from the end of that length to Wilcannia 270 feet. The difference of level between Condobolin and Wilcannia would give a fall of slightly over 2 feet per mile from the former place to the latter; but in the last 70 miles, ending at Wilcannia, there is practically no fall, the ground being very gently undulating, and having the lower parts of the undulations below flood-level.

Levels.

Shallow depressions.

There is no difficulty here in accounting for the disappearance of the rainfall. While the small rainfall and the features of the country are sufficient guarantees that the surface-water will not run except on extraordinary occasions, the great dry shallow depressions which are frequently found with creeks leading to them clearly indicate the ultimate destination of the surface-flow. Before the construction of wells and tanks the Manara drainage area was uninhabitable, even by the aborigines; now, through the construction of numerous wells and tanks, an almost permanent supply of water is assured.

Beneficial effect of wells and tanks.

So far as water conservation and distribution are concerned, the most important feature in this drainage area is its slope towards the Darling. As a natural result of this slope, when high floods are passing down the Lachlan, the flood-water escapes in large quantities in the Booberoy, Willandra, Merrowie, and other creeks, and flows in a westerly direction towards the Darling. It is stated in evidence (Q. 3006) that in a high flood the Willandra Creek carried a supply to within a distance of 30 to 40 miles from Reed's Lake, which is filled by the flood-water from the Darling. It appears, however, that within this intervening space there is a high sand ridge running approximately parallel to the course of the Darling, and that this effectually prevents the flood-water of the one river from mingling with that of the other at this point. No surveys have been made or levels taken of the three creeks mentioned—at least none which would show their capabilities as distributing channels. In the case of the Willandra Creek, however, water flows from the Lachlan to a distance of about 200 miles, and the course of the creek can be traced in a southerly direction beyond even that distance. Considering that the Willandra, though practically in its natural state, has done excellent service as an indundation canal, and that a regular supply so obtained would raise the adjacent land in value to the extent of 400 or 500 per cent., it is sufficiently evident that the improvement of the Willandra and the construction of a weir in the Lachlan, to give it a supply in ordinary floods, are questions of great practical importance.

Slope towards the Darling.

Willandra Creek.

Reed's Lake.

Sand ridge parallel to the Darling.

Flow from the Lachlan.

Improvement of the Willandra.

The Booberoy and Merrowie Creeks are similar in their nature to the Willandra, but are on a smaller scale; still they must be considered as channels which might be made to play an important part in contributing to the supply of the dry country between the Lower Lachlan and the Lower Darling. It is improbable that the supply which could be made available would be sufficient for irrigation purposes except on a very small scale, but it would afford a plentiful supply to tanks and dams; and the importance of that alone is clearly shown by a witness (Q. 3079), who stated that if wells could be constructed in the Manara drainage area at a cost of £1,000 per well they would be very remunerative. On the whole, the evidence of all tends to show that there is an area of at least 10,000 square miles through which the flood-water of the Lachlan can be conducted by gravitation. The part of the country thus situated has a rainfall of only about 11 inches, and the difficulties connected with obtaining supplies from wells are unusually great. In this district we find that there is a pressing demand for water, while there are also unusual facilities for in a great measure meeting it. The evidence of several witnesses has shown how the Willandra Billabong has already been utilized extensively, and suggests the greatly increased value it would have if dealt with systematically as a whole. In regard to the Merrowie Creek, it has been stated that flood-water has been conveyed a distance of 50 or 60 miles along that channel (Q. 2885). That it is not only desirable but practicable to divert the flood-water from the Lachlan along a series of dry creeks into the district here included under the Manara drainage area is confidently asserted (Qs. 2867 and 2868).

Booberoy and Merrowie Creeks.

Value of wells.

Area to be benefited by irrigation.

Practicability of scheme for diversion of the Lachlan.

BASIN OF THE DARLING.

On account of the immense extent of its basin, the fertility of the districts through which it flows, and the great highway it affords for commerce, the river Darling, notwithstanding the comparative insignificance of its average discharge, is in some respects the most important

Importance of the river.

Area.

What becomes of the rainfall ?

The contributing area of the Darling and the non-contributing.

river in New South Wales. The portion of the catchment area of the Darling lying within the Colony of Queensland is 103,650 square miles in extent, but of this only 15,000 square miles belong to that part of the river above Walgett. In New South Wales the area of the basin, as far as the junction with the Namoi at Walgett, is nearly 20,000 square miles. The total drainage area as far as Walgett, and not including that of the Namoi, may therefore be taken as 35,000 square miles. Bearing in mind that below Walgett the river flows a distance of 2,345 miles before it reaches the ocean, its importance can be better appreciated when it is considered that the above-mentioned catchment area at Walgett is nearly seven times the entire basin of the Thames. As the ordinary discharge at Walgett is a mere fraction of even that of the Thames, it is not surprising that the question, "What becomes of the rainfall ?" has given rise to much discussion. This question presents little difficulty when the nature of the catchment area, and the amount of rain, and the time and manner in which it falls, are taken into account. In treating of other basins, it has already been pointed out that in the west of this Colony not only does the plain country contribute almost nothing to the rivers, but that evaporation and the growth of vegetation are sufficient to account for almost the entire rainfall. While rain is actually falling, the basin of the Darling may be considered as consisting of two classes of country—the contributing and the non-contributing area. In dry periods the river depends almost entirely on percolation from the hilly parts of its basin. At such times the basin may be divided into two principal heads, which may be termed respectively the contributing area and the reducing area. As rain seldom falls simultaneously over the entire extent of the Upper Darling basin, and as evaporation is continuous, there is at all times a greater or less extent of reducing area. It may therefore be broadly stated that the basin consists of contributing, non-contributing, and reducing areas, which are all constantly varying in extent. The hilly portion of the basin represents, except in extraordinary floods, the maximum extent of the first-mentioned area.

Catchment area at Walgett.

Temperature.

Causes of rainfall not reaching the river.

It has been mentioned that the catchment area of the Darling or Barwon at Walgett is about 35,000 square miles, of which 15,000 square miles are situated in Queensland. Of the latter area, approximately 8,000 square miles may be classed as plain country, and therefore non-contributing, leaving in Queensland an effective catchment area of 7,000 square miles. The catchment area in this Colony above Walgett may be taken as comprising 10,400 square miles of hilly and 9,300 square miles of plain country. The proportion of the basin from which surface-water can, under favourable circumstances, be expected to reach the Darling is thus reduced to 17,400 square miles. Even of this diminished area a large proportion is intermittent and irregular in the supply it yields. Add to this that the mean temperature in the shade throughout this part of the country is probably not less than 70°, that hot winds are of frequent occurrence, and that the drainage from the contributing area has to flow in a tortuous course and with a very low velocity through the non-contributing area. All these points have an important effect in preventing surface-water from reaching the river, and diminishing the volume of water flowing in the river. There is, in addition, another point of the highest importance in its influence on the discharge of surface drainage, namely, the manner and the season in which the rainfall occurs. Taking Myall Creek as an instance by which to judge the contributing area, we find that in 1882 the rainfall was only 20 inches, and that in not one month did the quantity registered reach 3 inches. The number of rainy days was seventy-four. It is sufficiently evident from these figures that the neighbourhood of Myall Creek cannot during 1884 have contributed more than a merely nominal proportion of the rainfall to the supply of the river. In 1883 the rainfall at the same station amounted to 26·89 inches, of which 14·58 inches fell on thirty-six days during the months of November, December, January, and February. The quantity exceeded 2 inches per month only during five months, and the highest falls were in January and February, the hottest months of the year—the period when the loss by evaporation and absorption would be the greatest. As the streams which feed the Upper Darling are numerous, and many of them flow long distances through plain country before they reach that river, the loss of water from the causes above-mentioned must be exceptionally high. In the case of a river 1,000 miles in length, and with a mean width at the water of 100 feet, a loss of one quarter of an inch per day from evaporation would be equal to a constant discharge of nearly 130 cubic feet per second. The tributaries of the Darling and that river itself as far as Walgett would have a much greater surface than such a river as that supposed. Bearing in mind that a river loses by evaporation not only from the water surface, but also from the surface of the banks, which are more or less saturated by capillary attraction, the loss here mentioned must be considerably within the actual amount. Again, in the case of rivers such as the Darling, flowing in alluvial soil, a loss of half a cubic foot per second per mile by absorption would be by no means remarkable.

Rainfall.

Losses through evaporation.

Rate of absorption.

From the foregoing considerations, it is evident that the quantity of water which passes to underground currents cannot be nearly so great as is sometimes supposed. There can be little doubt that little or no surface-water passes off to feed the underground supplies, excepting from the mountainous portions of the basin. The line along which the greatest loss by underground percolation is likely to occur is at the place where the granite and the silurian strata end and the great alluvial plains begin. The data at present available are not sufficient to enable an accurate estimate to be formed of the proportion of the rainfall thus disposed of. In any case it would be a difficult point to determine. In the hilly portion of a catchment area the surface-water reaches the main stream through many small channels, but, in addition, the crevices in the rock and the interstices in the ground become innumerable passages through which the water percolates by gravitation till it reaches the river at a lower elevation among the hills, or else passes on to feed underground supplies in the plains. The fact that at least 3 inches of rainfall is required as a rule to saturate the plains sufficiently for one irrigation, and that such saturation is a rare occurrence, precludes the idea that any portion of the rainfall in the plains is, under ordinary circumstances, lost by percolation. As an apparent exception to this rule, when the supply in the Darling is low, there is percolation into it throughout a great portion of the length between Walgett and Bourke. On the other hand, when the river is high, there can be no doubt that there is percolation from the river for a short distance from its banks; so that it is not improbable that the subsoil, which becomes saturated from the river in times of flood, yields the water of saturation again when the river is low. Under the circumstances, this explanation, so

Quantity of water reaching underground supplies insignificant.

Percolation into the river.

far as that part of the river is concerned, seems more likely than that the percolation comes from a great distance.

Tributaries of the Darling below Walgett.

Flow from Paroo into Darling.

Area of Paroo basin.

Rainfall.

Below Walgett, the principal tributaries of the Darling are the Castlereagh, the Macquarie, the Narran, the Bokhara, the Culgoa, the Bogan, the Warrego, and the Paroo. These rivers are all intermittent. The only well-authenticated instance in which the Paroo flowed into the Darling occurred in January last, and this was due to a fall of rain which was altogether unprecedented in that neighbourhood. Near Wilcannia, 9 inches to 10 inches of rain fell within three days; and in some parts of the basin of the Paroo the fall in the same time was as much as 12 inches. Within this Colony the area of the basin of the Paroo is over 15,700 square miles, while in Queensland there is a further area of 13,400 square miles. As heavy rain fell throughout the greater part of this immense area, the fact that the flood in the Paroo rose to an unprecedented height is not surprising. When it is considered that the mean annual rainfall throughout the basin of the Paroo is only 10·77 inches and the mean number of rainy days thirty-two, and that the basin consists chiefly of plain country, it is but natural that in ordinary seasons the Paroo is a river only in name.

The Narran.

The Big Warrambool.

Its area.

The Narran has already been referred to under the head of "Evaporation" (p. 15). Between that river and the Darling or Barwon there is a large creek known as "The Big Warrambool," which is in reality a river of the same class as the Narran, although of less importance, and with a catchment area of more than 3,100 square miles in this Colony alone. It is in fact more deserving the name than is the Narran, for the latter, and also the Bokhara, Biree, and Culgoa, are only branches into which the Balonne River divides. All these are of the same types that is to say, water flows in them to the Darling only in times of flood, or in exceptionally rainy seasons.

Drainage area of the Darling.

The drainage area of the Darling as far as Walgett has been considered separately, because the most reliable portion of the contributing area lies above that place. The total drainage area of the Darling at its junction with the Murray, including the basins of its intermittent tributaries, is 231,000 square miles. At Wilcannia the area is 201,600 square miles, and at Bourke, 148,000 square miles.

Mean rainfall.

The mean annual rainfall, as calculated from forty-six stations in the plain or non-contributing portion of the drainage area of the Darling proper, is 12·81 inches, and the mean number of rainy days, thirty-five. The corresponding figures in connection with some of the tributaries show better results. On the Upper Bogan the rainfall is 18¼ inches, and on the Lower Bogan 14½ inches, and the corresponding figures for the Upper and Lower Castlereagh are 19 and 17⅓ inches respectively. The most favourable rainfall returns for any portion of the Darling basin are those for the mountainous country at and near the sources of the M'Intyre, in the mountains of New England. There the average annual rainfall, as reckoned from eleven observing stations, is 28·17 inches, and the average number of days in the year on which rain is registered, 76.

Non-contributing area.

Of the total area af the basin as far as Bourke, at least 100,000 square miles must be classed as non-contributing. The mean distance of Bourke from the contributing area cannot be less than 450 miles; the fall in the intervening country is very slight, and the velocity in the river correspondingly low, and the river banks consist of alluvial deposits, covered with an abundant growth of varieties of eucalyptus trees, which appear to absorb more moisture from the ground than those of almost any other species. Under these circumstances, it is obvious that the loss of water from the river must necessarily bear an exceptionally high ratio to the discharge. Also while the maximum contributing area above Bourke is about 48,000 square miles, it is evident that, judging from the high temperature and the low rate of monthly rainfall, as well as from the unfavourable nature of much of the basin, the actual contributing area is generally only a small proportion of that mentioned. The information obtained by actual gauging is altogether insufficient to lead to a conclusion as to the actual proportion of the rainfall which flows off in the river. In January last, the discharge at Bourke was found by our engineer to be only 376 cubic feet per second; and in May last, when the river was considerably lower, he found the discharge at Walgett to be scarcely 15 cubic feet per second. When the latter gauging was taken, the discharge at Brewarrina and Bourke was higher than at Walgett. This was attributed partly to the percolation into the river, and partly to the interception of the underground flow by the bar at Brewarrina.

Discharge of river at Bourke. Discharge at Walgett.

While no exact conclusion can be arrived at regarding the proportion of the rainfall discharged, there is sufficient information to account for the fact that this proportion is very low. Australia is not by any means the only country in which rivers beyond certain points in their courses gradually diminish in volume till they finally disappear, but it is probable that the instances of this feature which are found in this country are more striking and on a more extensive scale than are found elsewhere.

Proportion of rainfall discharged.

From the foregoing description of the Darling, it is evident that the discharge is too small and too uncertain to provide for permanent irrigation canals under present conditions. On the other hand, the immense volume which passes down in floods might in many places be utilized with advantage and at a moderate cost. This could be best done in the majority of cases by diverting the water into lakes, lagoons, ana-branches, and other great natural depressions, and storing it there for the use of stock or for irrigation. There are, however, cases in which the water could be used for flooding the land, and thereby greatly increasing the yield of grass. That this system can be carried out with excellent results has been practically demonstrated on the Lower Lachlan, and there is no reason why it should not be successful on an extensive scale on the Darling. To facilitate the utilization of the flood-waters, weirs should be erected in suitable places, and for this purpose the rocky bars which cross the bed of the river in many places will afford favourable sites. The erection of weirs, besides aiding in the diversion of a supply from the river, will maintain the water at a high level in times of drought, and will thereby greatly add to the facilities for obtaining supplies by pumping for irrigation and for the use of stock. Great encouragement to the construction of weirs is furnished by the fact that no silting up of the river has occurred on the upstream side of the falls near Brewarrina, but that on the contrary deep water extends to a distance of several miles. Our engineer reports that with a low supply in the river, the difference in level between the water above and that below the falls was 10 feet 9 inches. At that time, the depth of water near the centre of the river to a distance of six miles above this barrier was in all places over 10 feet, and was stated to be as much as 30 feet in some places near Brewarrina.

Permanent canals impracticable.

Utilization of flood-waters.

Weirs.

Value of the rocky bars as weir sites.

Absence of silt at the Brewarrina Falls.

Prospects of irrigation.

The work already done in the Darling basin towards water-conservation clearly shows, first, that the land is eminently suited for irrigation; second, that irrigation is remunerative; and third, that legislation which will define and secure the national right in the water-supply, and will at the same time encourage local and private enterprise, is urgently called for. On the Gwydir and other tributaries of the Darling, as well as on that river itself, pumping machinery, in some instances of a very powerful description, has been erected and brought into use. While enterprise of this character deserves to be commended and encouraged, grave misunderstandings are certain to arise if legislation of the nature referred to above is not soon provided. The pressing importance of this point is made clear by the fact that the pumping machinery on the Gwydir for filling natural channels for stock purposes, here referred to, is capable of raising a supply of water far in excess of the entire discharge which was gauged in the Darling at Walgett, in May last.

Pumping on the Gwydir.

Legislation necessary.

Culgoa River.

So far as the evidence obtained enables us to state, the most favourable places, in addition to the bed of the Darling itself, for intercepting water during high floods and storing it for future use, are to be found in the Culgoa and other tributaries of the Darling, in the Cato and Tarrion Creeks, and in the lakes and other great natural depressions which are found at intervals on both sides of the river from Wilcannia to its junction with the Murray. On the whole, the natural facilities afforded for the storage of flood-water are very extensive, and the future development of the Darling basin will depend on the extent to which these facilities are employed.

Cato Creek.
Tarrion Creek.

BASINS OF THE BOGAN, MACQUARIE, AND CASTLEREAGH.

With its sources on the western slopes and among the high tablelands of the Dividing Range, and having in its catchment area a large proportion of hilly country, the Macquarie would naturally be expected to rank among the most important tributaries of the Darling. The area of the basin of the Macquarie is about 15,440 square miles, of which 9,830 square miles may be classed as hilly, and 5,610 square miles as plain. The mean annual rainfall, calculated from eleven observing stations in the hilly portion of the basin, is 23·17 inches, and the mean number of rainy days sixty-six; in the plain portion of the basin, the mean annual rainfall, as calculated from three observing stations, is 15·67 inches, and the mean number of rainy days forty-six. The length of the Macquarie is estimated at 750 miles. In the upper parts of its basin, gravel ridges, deep deposits of disintegrated granite, and extensive areas of permeable soil are met with; these conditions, together with the comparatively low monthly rainfall, limit the proportion of the surface-water which reaches the river. The fall of the river here is considerable, so that the water which reaches it flows off freely. As the river reaches the plains and passes in a tortuous course towards the Darling, the rate of fall diminishes, and the channel decreases in size till it reaches the Macquarie Marshes, where it divides into a number of creeks; with a low discharge in the upper parts of the river the water disappears before it reaches these marshes. In ordinary floods the diminished section of the channel obstructs the passage of the flood-water and forces a portion of it over the left or lower bank; the remainder of the flood-water passes on to the marshes, where it spreads

Area of the Macquarie basin.

Rainfall.

Nature of country.

Macquarie Marshes.

Flow from the Macquarie to the Darling.

Marra Creek.

out in a thin sheet over immense reed-beds, and is there retained till it disappears by evaporation and absorption. In extraordinary floods only does the Macquarie water reach the Darling; on such occasions the floods escape over the left bank of the Macquarie in many places, the first being at Narromine, and flow in a series of creeks to the Bogan and thence to the Darling. In addition, the Marra Creek carries a portion of the discharge from the Macquarie to the Darling direct.

Geological formation.

From the place where it leaves the hills, the course of the Macquarie lies almost entirely through alluvial deposits. In the hilly country the valley occasionally opens out into rich alluvial flats bounded by rocky ridges, through which the river seems to have cut a passage. Mr. James Samuels, jun., of Dubbo, in an interesting paper communicated to us, suggests that there was at one time a series of lakes along the course of the Macquarie between Wellington and Narromine, and that these became filled up with gravel and shingle. The presence of very deep deposits of this description at intervals throughout the portion of the river here mentioned gives considerable weight to this theory.

Discharge of the Macquarie.

Absorption by trees.

The discharge of the Macquarie was gauged by our Engineer in February last, and again in April. On the first occasion, it was found that, while the discharge at Dubbo was 140½ cubic feet per second, that at Warren was only 52 cubic feet per second; and it was shown that, of the proportion lost, not more than 16½ per cent. could be accounted for by evaporation. On the second occasion, the discharge at Dubbo was only 20 cubic feet per second, while at 18 miles up stream from Warren the flow entirely ceased. Owing to altered conditions, evaporation would in this case account for 38 per cent. of the loss, leaving the remaining 62 per cent. to be accounted for by absorption and percolation. The latter division of the loss in February was equivalent to about two thirds of an inch per day over the wetted surface, or to half a cubic foot per second for every mile of the river. In the case of the smaller discharge, the loss due to percolation and absorption was about equal to a quarter of an inch per day over the wetted surface. These rates of loss by absorption and percolation are by no means remarkable or exceptional. In Mr. Russell's Rainfall Report for 1882 it is mentioned that experiments made in connection with European forests have shown that a moderate-sized tree will absorb from the ground 16 gallons of water per day. The eucalypti absorb an exceptionally large quantity of moisture, so that it would probably be safe to assume that an average tree on the banks of the Macquarie absorbs 18¾ gallons or 3 cubic feet per day. On this hypothesis, and taking the number of trees at 2,000 per mile of river, the quantity of water required for these trees alone on a length of 180 miles would be equal to a constant flow of nearly 12½ cubic feet per second. When the discharge at Dubbo was about 20 cubic feet per second, the loss by evaporation between that place and the point at which the flow ceased was about 7½ cubic feet per second. It appears, therefore, that the requirements of 2,000 trees per mile of river would have accounted for the entire loss by absorption. It is not intended to be conveyed that this is the precise manner in which the entire loss was accounted for. These points are brought forward to show that, as already stated, there is nothing abnormal in the proportion of loss from the Macquarie.

Percolation in the hills.

Mr. Samuels has observed that a flood in the higher reaches of the Macquarie has only a slight effect at Dubbo, and that a high flood at the latter place generally occurs when the upper parts of the basin have been saturated by a preceding flood. This fact, together with the very large supply obtainable from wells at and near Dubbo, shows the extensive scale on which percolation takes place in the hilly part of the basin.

The Castlereagh and the Bogan.

In high floods the waters of the Lower Castlereagh unite with those of the Lower Macquarie; and at the same periods, the floods in the Macquarie are relieved by various outflows to the Bogan, chiefly from places between Narromine and Warren. On this account, to obtain a comprehensive view of the question of water conservation in this part of the country, it is necessary to consider the basins of the Castlereagh and the Bogan in conjunction with that of the Macquarie.

Area of Castlereagh basin.

Rainfall.

The area of the basin of the Castlereagh is about 6,750 square miles, of which 3,890 may be classed as plain, and 2,860 as hilly. The mean annual rainfall in the plain, as reckoned from ten observing stations, is 17·43 inches, and the mean number of rainy days forty-three. In the hilly portion of the basin the mean annual rainfall at two stations is 19·10 inches, and the mean number of days on which rain falls fifty-two. The basin of the Castlereagh does not extend to the Dividing Range. The hills amongst which that river and its tributaries have their sources are of very moderate height, and exercise comparatively little influence on the flow of surface-water; and the course of the river, which has a length of about 300 miles, lies chiefly through arid plain country. These conditions, together with the scanty and irregular rainfall, combine to constitute the Castlereagh an inefficient escape-channel for wide-spreading floods, while its normal condition is that of a dry receptacle for drifting sand.

"The Monkey" sand ridge.

Almost midway between the Lower Macquarie and the Castlereagh, and at the junction of the counties of Clyde and Gregory with the county of Leichhardt, there is a remarkable sand ridge, commonly known as "The Monkey." Good water, but in limited quantities, is found everywhere in this sand ridge, at depths generally varying from 15 to 25 feet from the surface. The source from which the supply in this ridge is obtained, and the possibility of augmenting or conserving it by sub-soil dams or otherwise, are questions well worthy of further consideration.

Area of Bogan basin.

Rainfall.

The catchment area of the Bogan, like that of the Castlereagh, is unsatisfactory so far as its capability of delivering surface-water is concerned. Of a total area of about 13,150 square miles, 9,750 is plain country and only 3,400 square miles hilly. The mean annual rainfall reckoned from eight stations in the former area is 14·51 inches, and the mean of two stations in the latter is 18·23 inches. The corresponding numbers of rainy days are 40 and 50. The length of the Bogan is 450 miles. These conditions show that the description already given of the Castlereagh applies in almost every particular to the Bogan; but the latter, owing to the greater area of the hilly portion of its basin, runs more frequently than the former.

Fall of country.

In the description of the general configuration of the country it has been mentioned that, while the Castlereagh, Macquarie, and Bogan flow in a northerly direction, there is also a fall almost at right angles with these rivers in a westerly direction. The consequence of this is that in floods the Castlereagh overflows into the Merri Merri Creek, and the

Various creeks.

Muddall Dam.

Necessity for a national system;

flood-water unites with that of the Macquarie. The latter river also overflows in many places, and flood-water from it passes to the Bogan in the Beleringa, Duck, Gunningbar, and other creeks. Nature has therefore already demonstrated that the flood-water from the Castlereagh can be distributed through an extensive tract of country lying between that river and the Macquarie, and also that the flood-water of the latter river can not only be distributed throughout a great portion of the district between the Macquarie and the Bogan, but can also be used to supplement the supply in the latter river. Already private enterprise has done valuable work for the conservation of flood-water in this part of the Colony, particularly on the Bogan and on the creeks leading towards it. As an instance, the Muddall dam on the Bogan may be referred to, which holds back a permanent supply of water to a distance of 10 miles. It is, however, evident from the circumstances of the case that the lower portions of these three rivers—the Castlereagh, the Macquarie, and the Bogan—together with the intervening creeks, might be advantageously considered and dealt with conjointly. Works carried out by private enterprise are naturally intended only for the use and convenience of the persons at whose cost they are constructed; but all such works should be in harmony with a comprehensive system, under which the available supply of water should be made to benefit the greatest possible area.

BASIN OF THE NAMOI AND PEEL.

Area of Namoi basin.

Rainfall.

In the length of its course and the extent of its catchment area the Namoi is one of the most important of the tributaries of the Darling. The basin of the Namoi has an area of about 16,250 square miles, of which 11,800 square miles is plain country and 4,450 square miles hilly. The mean annual rainfall in the former portion, as reckoned from eight observing stations, is 19·20 inches, and the number of days on which rain is registered fifty-five. In the hilly part of the drainage area the mean annual rainfall, as obtained from seventeen observing stations, is 22·37 inches, and the mean number of rainy days fifty-eight. The mean temperature of the basin may be taken at 63° or 64°.

Necessity for weirs.

Weirs impossible below Narrabri;

Mr. Gipps' survey.

The contributing portion of the catchment area of the Namoi is small compared with the whole area of the basin, and on this river is irregular in its flow, and frequently ceases to run for months together. The methods which suggest themselves as remedies for these disadvantages are, first, to construct a series of weirs in the river, and second, to store the flood-water in the higher parts of the basin, and allow it to escape by degrees when the river is low. So far as we have been able to ascertain, both these methods of conserving and utilizing the available supply can be adopted. On the subject of weirs, a witness who has given much attention to the question of water-supply in the Namoi basin has informed us (Q. 1756) that in his opinion weirs could not be adopted on the Namoi below Narrabri, on account of the friable nature of the soil; but he also states that above Narrabri there are good sites for weirs in the river, and that there are also places suited for storage reservoirs both in the Namoi and its tributaries. The evidence regarding probable sites for storage reservoirs was so definite and encouraging that in order to obtain further information on the subject we deputed Mr. Gipps to inspect and report on these sites. The result of this examination was to convince him that, at a place on the Namoi, about

Site for dam.
Capacity of reservoir.

7 miles above its junction with the Peel, a dam 75 feet in height would hold the water back to a distance of 13½ miles, and would secure the storage of 10,000 million gallons of water. The foundation and flanks of this dam would be in rock, and its length at the top and base respectively would be only 812 feet and 115 feet. Other favorable sites were found, and on the whole the investigations made were sufficient to warrant a further examination of the Namoi and its tributaries.

Source of underground water.

The information which we have elicited tends to show that, as a rule, the source from which underground supplies of water are derived is in the hilly portions of the river basins. In the case of the basin of the Namoi and Peel the reasons in favour of this conclusion are exceptionally strong. In the higher parts of this catchment area, springs yielding remarkably large supplies of water are found. Some of these springs have already been referred to, under the heading of "Wells" (p. 29), and need not be further described here. Going towards the west, the underground supply becomes smaller and more precarious, and salt water is more frequently met with. The most reasonable explanation of this is that the rain falling on the tertiary and other more or less permeable strata among the hills percolates into them and passes under the plains, spreading over a wider area as it flows westward. Under this hypothesis the strong springs near the hills would be accounted for by the underground flow being confined within narrow spaces, while being at the same time under the direct influence of a considerable "head." In the plains, as the underground water spreads over a wide area, its rate of flow becomes diminished, the quantity available at any one place is more restricted, and with the approach to stagnancy the proportion of salts in solution increases. While this may be taken as a general rule, exceptions and modifications caused by irregularities in the underground strata are frequent. The improbability of the occurrence of percolation, except on a very small scale, in the plain country, has been discussed in connection with other river basins—particularly that of the Darling—and the reasons there given apply with almost equal force to the basin of the Namoi.

Insignificance of percolation.

Fertility of the district.
Water conservation imperative.
Legal protection.

This basin includes extensive tracts of land, which are unsurpassed in fertility in any portion of the Colony west of the Dividing Range. Its remarkable productiveness when irrigated has been practically demonstrated in several instances, while, on the other hand, the liability of the plains of the Namoi to be devastated by droughts, and the uncertainty of obtaining crops of any kind, even in fairly good seasons, show that water conservation is an absolute necessity. To provide this we require, first of all, legislation to direct and foster private and local enterprise, to protect individual and public rights, and to provide means for initiating and carrying out such works as are beyond the capabilities of local effort.

YANTARA DRAINAGE AREAS.

Absence of a river system.
Area of catchment basin.
Rainfall.

The entire portion of the Colony lying to the west of the basin of the Paroo is destitute of any large river system. It comprises a number of separate and independent drainage areas, but these are included here under one designation, and are considered together for the sake of convenience. The united area of these catchment basins is about 22,100 square miles. The mean rainfall, reckoned from twelve observing stations, is 8·56 inches; and this being obtained from an average period of six years, may be relied upon as a close approximation to the average fall over the whole area. The mean number of days during which rain is registered in the course of a year is 26.

As in the Manara drainage area, low ranges of hills are common in the north-western district, but here also the hills are of little effect either on the quantity of the rainfall or in influencing the flow of surface-water. The Kooningberry and the Mount Brown Ranges are two of the most important, and the heights of these above the surrounding plains were found by Mr. H. Y. L. Brown, Geological Surveyor, to be only 700 and 400 feet respectively. Still, there is a fairly defined watershed line extending south from the Queensland frontier, and maintaining generally a distance of 40 to 50 miles from the boundary of South Australia. This watershed line passes into South Australia, near Silverton. Thence in the tract of country north of Silverton and west of the watershed described the course of surface drainage is towards South Australia.

Kooningberry Range. Mount Brown Range.

Watershed line.

There is in Queensland an extensive and important natural drainage line, which is finally lost in the Yantara Drainage Area. This is the Bulloo River, which in times of flood empties itself into a large clay-pan or swamp which has a length of from 40 to 50 miles, a breadth of about 12 miles, and a depth of 12 to 15 feet (Q. 3024). The extreme dimensions here given would be equivalent to an area of 600 square miles; but, assuming that the area is 200 square miles, a river with a discharge of 1,344 cubic feet per second would be required to replenish the loss by evaporation alone, taking the rate of this loss at a quarter of an inch in twenty-four hours. It is under these circumstances, quite natural both that the water should disappear rapidly and also that, with such extensive evaporation, salts should be deposited in the soil constituting the bed of the swamp. Again, taking the area of the swamp, as above, at 200 square miles, and its mean depth throughout that area as 10 feet, the quantity of water required to fill the swamp, and allowing for evaporation, would be equal to a flow of more than 8,000 cubic feet per second for 100 days. The practicability of utilizing the water of the Bulloo by cutting a channel from this swamp to the Yantara Lake has been suggested by a witness who has had an extensive experience in this part of the country (Q. 3024).

Bulloo River.

Area of Swamp.

Channel to Yantara Lake.

The Yantara, Cobham, and Salt Lakes are the receptacles for the surface drainage of an extensive area. The available information regarding these lakes is meagre; but the first has been favourably mentioned as a place in which flood-water can be stored, and from which it can be distributed. In a published report to the Commissioner for Roads by one of his officers, Cobham Lake is described as being at the time of the report "a grand sheet of fresh water;" but details regarding its dimensions are not supplied. The Yantara and Cobham Lakes are fed by several intermittent creeks, but the supply is irregular and precarious; so that if it can be supplemented from the Bulloo, a good permanent store of water in these lakes will be available.

Yantara, Cobham, and Salt Lakes.

The scanty and uncertain rainfall, the value of gold and other mineral deposits, and the general absence of permanent natural supplies of water, render the construction of tanks or reservoirs for water conservation of the utmost importance for the development of this part of the Colony. To make these works permanent, it is necessary to provide in them for a depth of at least from 18 to 20 feet of water. From his experience of such works, the Commissioner for Roads and Bridges has adopted a standard

Necessity for water conservation in this district.

Standard depth of Government tanks.

depth of 18 feet, and a capacity of from 12,000 to 20,000 cubic yards—that is, 2,000,000 to 3,400,000 gallons, exclusive of any conservation above the ground level.

TARA COUNTY DRAINAGE AREA.

Area.

In the south-west corner of New South Wales there is an area of over 6,000 square miles of plain country which contributes practically nothing to either the Darling or the Murray, and which on this account is here classed as the Tara Drainage Area. The range of hills which has been referred to as crossing Wilcannia into South Australia forms the northern boundary of this tract of country. Very few rainfall returns are received from it, but from those published by the Government Astronomer it would appear that the mean annual rainfall is about 9 inches. The information which we have up till the present been able to obtain regarding this part of the Colony is insufficient to enable us to form an opinion regarding it.

Rainfall.

LAKE GEORGE BASIN.

Area.

Rainfall.

Evaporation.

Necessity for further survey.

The basin of Lake George includes an area of nearly 490 square miles. The lake itself is at an elevation of about 2,200 feet above the sea-level, and may be regarded as a shallow depression in the table-land near the summit of the Dividing Range. The mean annual rainfall at Gundaroo, which is in the vicinity of the lake, is 22 inches. The question of evaporation and of the nature of the water has already been referred to at length, in an extract from a communication received from the Government Astronomer. The information available shows that, before Lake George can hold an important place in connection with any large scheme for water conservation and supply, two points require to be established—first, that it is practicable to conduct a supply by gravitation into the lake from one or more streams situated outside its basin; and, secondly, that it is practicable to tap the lake in order to distribute the supply so obtained. To prove that such works can be done, plans and a report were submitted by Mr. Gipps, and from examination of these we concluded that a further survey is desirable to place the matter beyond question.

(11.) RIPARIAN RIGHTS AND PROPOSED LEGISLATION.

Reservations for water-supply.

In the administration of the public estate Governments have had some regard to the future requirements of the Colony by reserving land from sale for the purposes of water-supply. The Surveyor-General has instructed his staff that in the subdivision of land for sale the surveyor should in view of future settlement exercise judgment in selecting, and recommending for reservation for public use permanent waterholes, springs, and parts of rivers desirable for water-supply, which in this arid climate might be beneficial for the occupation of surrounding country; and to the extent to which the survey staff have exercised intelligently the important discretion vested in them, facilities have been provided for the conservation of water. Although many valuable reservations have been made, it is greatly to be feared that the public interests have not always been sufficiently protected. In view of the different degrees of importance which so large a number of officers might be expected to attach to an instruction of this kind, and to the circumstances under which the alienation of the public lands have taken place, it would be strange if some errors were not committed; and perhaps on the whole there is reason for congratulation that even so much prudence and forethought have been exercised. The Surveyor-General, recognizing that certain indefinite riparian rights would be conferred by the alienation of Crown Lands with frontages to lagoons, swamps, and lakes, has embodied in the regulations for the guidance of licensed surveyors, a direction that the contour of such swamps and lakes should not be treated as a boundary, but that the land to be alienated should be defined by right lines, and the instruction is apparently designed to avoid giving a right to their beds as far as possible without direct legislation. Throughout the Colony, more particularly along the navigable streams of the Murray and Murrumbidgee, a large quantity of land has been sold of which the rivers form part of the boundaries, and thus riparian rights, whatever they may be worth, have been alienated. In the administration of the law so far, dams have always been recognized by the Government as improvements, in virtue of which special concessions have been made to the pastoral lessee. This departmental encouragement, however, to private individuals to conserve water has no legal validity as against the rights of other owners whose land has frontage to the watercourse. Many such dams have been cut away in reliance upon the riparian doctrine, which entitles all who have frontage to a stream to the undiminished flow of its waters, subject only to the limitation of reasonable use. The sense of insecurity which prevails in regard to the legality of dams has operated very powerfully to discourage the construction of such works. although in many localities they form the best means available of storing surface-water. The antagonism which has been shown to the erection of dams has doubtless been intensified by the absence of any regulation as to their height and other details of construction, and there has been an impression, in many cases well founded, that the dams which have been constructed have been designed so as to divert the water from its natural channel, thereby causing a waste over the plains.

English law inapplicable to Australia.

We are of opinion that the doctrine of riparian rights which obtains under the common law of England is not applicable to the conditions of Australia, and that it is calculated to be a very serious obstacle to the progress of this Colony, in so far as that progress depends upon the conservation of water. In Victoria no such rights can accrue, because the frontages to all rivers are reserved from sale; but, inasmuch as a different policy has been pursued here, and alienations have taken place which involve the legal right of ownership to the middle of the bed of a stream, it seemed desirable that we should obtain a clear definition of what riparian rights are. In addition to valuable suggestions on the subject of riparian rights, we have been favoured with the following memorandum on the subject from Mr. Alex. Oliver, M.A., Parliamentary Draftsman:—

Memorandum by Mr. Alex. Oliver.

Riparian rights as existing by the Common Law of England, are rights which are annexed to the ownership of land through or past which a river runs; and derivatively to all persons having a right of access to such a river.

Riparian rights do not attach quoad the bed or alveus, but only quoad the bank of a river.

Two kinds of rivers are known to the Common Law: 1. Public navigable river in which the tide ebbs and flows, and of which the ownership of the bed in *primâ* *facie* in the Crown. 2. Private rivers or streams beyond the ebb and flow of the tide, which by use or statute have in many cases become subject to public rights of navigation, fishing, &c.

If such a river runs through the land of a private individual, he is at Common Law *primâ facie* the owner of that river's bed; if it separates the properties of two persons, each is *primâ facie* the owner of the bed of the river to the central line of the stream, or, as it is termed, *ad medium filum aquæ*.

When the Crown assumed sovereign rights over the Australian Colonies, then known collectively as New Holland, the beds of all the rivers, navigable or not, became vested in the Crown in the same way as the *terra firma* itself. And the Crown at this day is the absolute owner of the beds of all rivers (which in England would be considered *primâ facie* the property of the frontage proprietors *ad medium filum*) so long as the ownership of the frontages to those rivers remains in the Crown. But it is probably settled law, since the decision in Lord v. the Commissioner of the City of Sydney, a case which went home afterwards on appeal to the Privy Council, that upon the alienation in fee of frontages to rivers which are not navigable, and in which the tide does not ebb and flow, the ownership of the beds of such rivers passes to the alienee *ad medium filum*.

It is apprehended that derivative riparian rights can be claimed by a lessee of Crown lands or by any person deriving title through alienee of riparian land.

It is also apprehended that no riparian rights in the proper sense of the expression attach to ownership of the frontage to a lake, pond, or other stagnant water.

In England, if a private river is subject to the right of public navigation (a very common case) the owners of the bed may, as against the public, do what they like with the water and the bed of the river, provided they do not obstruct the navigation.

That is a case which I do not think can occur in this Colony.

In this Colony a large number of rivers are navigable only at certain seasons of the year, and some are only navigable after floods or exceptionally wet seasons.

Nevertheless, I think it would be held by our Courts that a river once navigable remains always a navigable river, and that in that case the Crown does not part with its estate in the bed of such a river. What, however, would be considered to constitute navigability in regard to the draught of water of the navigating vessel, it is difficult to say. The point has never arisen, and, indeed, very few cases have come before our Courts in which riparian rights have come up for consideration or determination, or in which the public or private character of our rivers, streams, and watercourses, has been considered and defined.

The following extracts from decisions of high authority comprise nearly all the Common Law doctrine in respect of riparian rights to the use of flowing waters which are likely to be of any practical use to the Commission:—

In *Tyler* v. *Wilkinson* (4 Masons U.S. Reports 327), Mr. Justice Story laid it down that "*primâ facie* (*i.e.*, the law presumes) every proprietor upon each bank of a river is entitled to the land covered with water in front of this bank to the middle thread of the stream, or, as it is commonly expressed, *ad medium filum aquæ*. In virtue of his ownership he has a right to the use of the water flowing over it in its natural current, without diminution or obstruction."

In *Embrey* v. *Owen* (6 Exch. Rep. 369) a judge of the greatest eminence, Baron Parke, stated it as a clear proposition of law that the right to have the stream to flow in its natural state without diminution or alteration is an incident to the property in the land through which it passes; but flowing water is *publici juris*, not in the sense that it is a *bonum vacans* to which the first occupant may acquire an exclusive right, but that it is public and common in the sense only that all may reasonably use it who have a right of access to it; but none can have any property in the water itself, except in the particular portion which he may choose to abstract from the stream and take into his possession, and that during the time of his possession; but each proprietor of the adjacent land has the right to the usufruct of the stream which flows through it.

The logical consequences following from the principle that no riparian proprietor has any *property* in the water, but only the user of it as it passes along, are thus expanded by Mr. Justice Story, in the leading case of *Tyler* v. *Wilkinson*, cited above:—

"The consequence of this principle is, that no proprietor has a right to use the water to the prejudice of another. It is wholly immaterial whether the party be

> a proprietor above or below in the course of the river, the right being common to all the proprietors on the river; no one has a right to diminish the quantity which will, according to the natural current, flow to a proprietor below, or to throw it back upon a proprietor above. This is the necessary result of the perfect equality of right among all the proprietors of that which is common to all. The natural stream, existing by the bounty of Providence for the benefit of the land through which it flows, is an incident annexed, by operation of law, to the land itself. When I speak of this common right, I do not mean to be understood as holding the doctrine that there can be no diminution whatsoever, and no obstruction or impediment whatsoever, by a riparian proprietor in the use of the water as it flows, for that would be to deny any valuable use of it. There may be, and there must be allowed to all, a reasonable use. The true test of the principle and extent of the use is—whether it is to the injury of the other proprietors or not. There may be a diminution in quantity, or a retardation or acceleration in the natural current indispensable for the general and valuable use of the water, perfectly consistent with the common right. The diminution, retardation, or acceleration, not positively and sensibly injurious, by diminishing the value of the common right, is an implied element in the right of using the stream at all. The law here, as in many other cases, acts with a reasonable reference to public convenience and general good, and is not betrayed into a narrow strictness, subversive of common sense, which would destroy public rights. The maxim is applied, *sic utere tuo ut alienum non lædas.*"

As to the extent and nature of a riparian proprietor's right to the flow of water, the following extract from the judgment of the Privy Council in *Miner* v. *Gilmour*, a Canadian case (12 Moore, P.C. 156), may be useful:—

> "By the general law applicable to running streams, every riparian proprietor has a right to what may be called the ordinary use of the water flowing past his land; for instance, for the reasonable use of the water for his domestic purposes and for his cattle, and this without regard to the effect which such use may have in case of a deficiency upon proprietors lower down the stream. But further, he has a right to the use of it for any purpose, or what may be deemed the extraordinary use of it, provided that he does not thereby interfere with the rights of other proprietors either above or below him. Subject to this condition, he may dam up the stream for the purpose of a mill, or divert the water for the purpose of irrigation; but he has no right to interrupt the regular flow of the stream if he thereby interferes with the lawful use of the water by other proprietors, and inflicts upon them a sensible injury."

Difference in English and Australian conditions.

The doctrine of riparian rights as enunciated above appears better adapted to England, where the people are more concerned to drain off the water as quickly as possible than to New South Wales, where the all-important question is how best to retain it. The unwritten law may be appealed to by a riparian proprietor to constrain the action of those who construct the works which have the effect of depriving him of participation in the advantages of a flowing stream, or who makes such a diversion of the water as would inundate his land; but the position with which we have to deal is not so much with flowing water as with dry channels through which water flows only at long and irregular intervals. It is required that these watercourses should be made to hold water—to be in effect converted into inundation canals; but this would not be possible under the present state of the law, by which any litigious person could, if so minded, interpose a bar to the erection of weirs or other works. We believe there is a large amount of uncertainty as to what the application of the Common law of England would be in cases which might be brought before the Courts, inasmuch as those cases would be founded upon circumstances entirely novel, and to which no analogy could probably be discovered in causes tried elsewhere. A few out of many cases which could be supposed have been stated by Mr. Oliver (*Vide University Review*, July, 1882), in support of the view that special legislation is urgently needed "to define rights and prevent wrongs."

Cases like the following occur repeatedly : A constructs a dam, say half a mile long, across a shallow watercourse. This dam prevents any average rainfall from benefitting the lower runs of B, C, and D. Can B, C, and D cut that dam and remove the obstruction ? Or suppose a heavy rainfall, and flood-water escaping at the extremities of the dam converts the runs of B, C, and D into a swamp, without re-entering the line of the watercourse. What redress has B, C, or D ? These are cases likely to occur to many runs in the district under consideration. Again, is a lessee entitled to construct a weir in a permanent or any other watercourse, in order to divert flood-water over his run ? And if so, under what conditions? There is no power, express or implied, given to a lessee to cut a channel through ever so narrow a strip of his neighbour's run, in order to take water from a river to a billabong or watercourse, and so to perhaps a score or more waterless back runs. Can he excercise the power, even if the strip is made part of a reserve ?

Further, suppose that A excavates the site of a large dam or tank, and that before rain comes B and some other employés, having had a quarrel with A, free-select the site. Or suppose the same thing happens in case of a well sunk for artesian water, a few hundred feet, but without tapping water. In either case, it is said, is a dam, tank, or well without water considered an improvement capable of barring selection ? What is A's remedy ? Has he any at all in the first case? And in the second, is it to take up a 40-acre mineral conditional purchase at 40s. per acre, or apply for a special lease at (say) £10 per annum for five years ? Or suppose this same A constructs a large dam, and a series of wells and tanks, sufficient to serve five or six blocks of 25 square miles each ; no rain comes to fill them ; he however applies for an extension of his lease under the 15th section of the Occupation Act already noticed: is he entitled to the extension ?

Retention of rights by Victoria.

The sister Colony of Victoria has not parted with this riparian right, except, perhaps, in the case of a few old grants made before the Colony enacted its own legislation on the subject. We are not aware of the extent to which riparian rights have been alienated in this Colony, but we apprehend that there ought to be no difficulty in superseding the presumption of the English Common Law by a clear enactment of State ownership ; for the common law, as we understand it, only gives a riparian owner power to use so much of the water of a river as he requires for his own consumption and that of his stock, while the object and effect of the principle of State-ownership would be to increase the supply of water which now often wholly fails, and to make it permanent. We do not imagine that the rights of riparian owners, when water is provided for their requirements, can give any claim to compensation. If, however, we had reason to think otherwise, we should still be of opinion that State-ownership to all rivers and watercourses is so essential to any widely beneficial scheme for providing and supplying water as to make it desirable that the Government should resume the title to ownership by giving compensation. Public policy hitherto has jealously asserted the right of the State, or of municipal bodies delegated by the State, to all the main arteries of communication such as roads and streets, and has kept in the hands of the Government the sole right to construct and manage railways (with few immaterial exceptions), and telegraphs ; and when the value of the watercourses of the country come to be properly estimated, it will be seen that the policy which is designed to protect the interests of the community as a whole against the exactions of private monopolies should be applied to water conservation as it has been to roads, railways, and telegraphs, to which it is quite as applicable, if not indeed far more so.

Private enterprise.

By the above provision for State ownership over all rivers and watercourses we do not propose to prohibit private enterprise by capitalized companies or syndicates for the purpose of undertaking works for the irrigation of land, for the water-supply of towns, and for the promotion of the mining and manufacturing industries. On the contrary, we recommend that certain concessions and privileges, with regard to diverting water from any stream or river, and as to the use of such water-supply, should be granted to such companies or syndicates: Provided always that the works necessary for any such enterprise do not interfere with any general system of irrigation, and shall be of public utility, that the purpose of such enterprise shall be first submitted to Parliament in the shape of a Private Bill, and that such privileges shall only be granted for a limited period, according to the cost and character of the enterprise.

LEGISLATION FOR THE CONSERVATION AND UTILIZATION OF WATER IN NEW SOUTH WALES.

In considering the subject of Legislation on Water Conservation we have examined the enactments which have been passed on the subject of water conservation and supply in various countries which seem most likely to furnish examples worth imitation, and have drawn conclusions therefrom which are embraced in the form of a rough draft of a Bill.

Though we suggest the provisions herein mentioned as only the most important points in the outline of required legislation, still, in preparing even a rough draft of an Act, it seemed best to follow the phraseology adopted in legal enactments.

Reasons in favour of the majority of the clauses are given in the notes after the various chapters. In the cases in which no explanations are given it was deemed that none were required.

For convenience and system of arrangement, we have divided the subject under parts or chapters as follows:—

PART I.—*Preliminary.*
PART II.—*Definition of Water Rights.*
PART III.—*National Administration—Board.*
PART IV.—*District Administration—Local Water Trusts.*
PART V.—*Loans—how sanctioned, incurred, and repaid.*
PART VI.—*Drainage Works.*
PART VII.—*Navigation.*
PART VIII.—*Offences and Penalties.*

Insert post

NEW SOUTH WALES.

An Act to provide for the Conservation and Utilization of Water for Irrigation and other purposes.

Preamble.

WHEREAS it is expedient to define the public right in all rivers and streams flowing in natural courses, and in all lakes or other natural collections of still water, and to establish a system for the conservation and distribution of the water flowing or contained in such rivers, streams, and lakes, whether above or beneath the surface of the ground: Be it therefore enacted by the Queen's Most Excellent Majesty, by and with the advice and consent of the Legislative Council and Legislative Assembly of New South Wales, in Parliament assembled, and by the authority of the same, as follows, ~~that is to say~~ :—

Insert ante

PART I.—Preliminary.

Short Title of Act.

1. This Act may be called "The Water Conservation and Utilization Act," and it shall come into force on receiving the sanction of the Governor.

Repeal of portions of Acts at variance with

2. So much of the "Municipalities Act of 1867," and of "The Country Towns Water and Sewerage Act of 1880," as is repugnant to the provisions of this Act in respect of the construction or maintenance of works or the storage, distribution, or supply of water, or in respect of the borrowing of money, the valuation of property, and the fixing and levying of rates, is hereby repealed, but only so far as the said enactment might be construed to control or limit the provisions of this Act.

See N.S.

Repeal of parts of Mining Act of 1874.

3. Section II, paragraph 15, of the "Mining Act of 1874," is hereby repealed absolutely, and all other portions of the same Act which are at variance with this Act are also hereby repealed, but only so far as the said Mining Act might be construed to control or limit the provisions of this Act.

~~Definitions.~~ Interpretation

4. In this Act, unless there be something repugnant in the subject or context, the following terms ~~in inverted commas~~ shall have the respective meanings hereby assigned to them.

Governor

"~~Government~~"—The Governor, with the advice of the Executive Council.

"Minister"—The Colonial Secretary for the time being, or other member of the Government acting on his behalf.

"Board" or "Central Board"—The Central Board for Water Conservation and Utilization as constituted under this Act.

"Trust" or "Water Trust"—Any ~~Local Council~~ persons appointed under the terms of this Act to design, construct, administer, or maintain local works for water conservation and utilization, or for drainage.

"Trust District"—The portion of the Colony included within the jurisdiction of a Trust as constituted by this Act.

"Water rights"—The right, title, and interest to a supply of water from any source, whether above or beneath the ground.

surface of the

"River"—Any stream of water, whether perennial or intermittent, flowing in a natural bed or course, either above or beneath the surface of the ground.

"Lake"—Any lagoon, swamp, lake, or other collection of still water, whether this supply of still water be permanent or temporary, and whether it be found above or beneath the surface of the ground.

NOTES AND EXPLANATIONS.

Notes and Explanations regarding Part I.

Preamble and name.

In the preamble of the Bill we have adopted the same style as in the Country Towns Water and Sewerage Act of New South Wales, but the wording of the important part of it follows closely the preamble of the Northern India Canal and Drainage Act. The name proposed for the Bill is suggested as being both brief and comprehensive.

Repeal of certain clauses in Acts.

2. The Acts mentioned in section 2 would, in some respects, interfere with the administration of this Act. The method of dealing with these Acts is precisely that adopted under similar circumstances in section 2 of the "Country Towns Water and Sewerage Act of 1880."

Miners' rights.

3. This paragraph regarding miners' rights is required to prevent confusion, and to bring the administration of the water-supply under one complete system. It is believed that under the arrangements now proposed, namely, the constitution of Water Trusts, the supply of water for mining purposes and for the domestic use of miners will be placed on a much more satisfactory footing, and in a more favourable position for the development of private enterprise.

— The Minister in charge of Water Conservation & Utilization

"Domestic use"—When employed with reference to water supply, includes use for drinking, culinary operations, baths, and washing; but does not include use for irrigation of gardens, or for watering or washing ~~stock~~. Sheep.

Stock

"Stock"—Cattle, horses, sheep, and all other domestic animals.

"Watercourse"—Any stream of water of smaller dimensions and discharge than would entitle it to the name of "river" as this term is generally understood, whether such stream of water be permanent or intermittent, and whether its flow be above or beneath the ground, or partly above and partly beneath.

Surface of the

prescribed.

PART II.—DEFINITION OF WATER RIGHTS.

5. To the Crown belong—subject to the provisions of section 6 of this Act:—

~~State~~ rights.

Rights to water vested in the Crown

(a) The water flowing or contained in every river, stream, creek, or watercourse, whether the said river, stream, creek, or watercourse be permanent or intermittent, and whether the whole or only portion of the land through, under, or adjacent to which such flow takes place belongs to the Crown.

~~State property~~ in lakes.

Crown rights

(b) The water contained in every lake, swamp, lagoon, or other collection of still water, situated wholly or partially within or under Crown Lands, whether the supply of water in such lake, swamp, lagoon, or other collection of still water be permanent or intermittent.

Crown rights ~~State property~~ in lakes.

(c) The water contained in every lake, swamp, lagoon, or other collection of water supplied wholly or partially by a river, stream, or creek belonging to the Crown, whether such lake, swamp, lagoon, or other collection of water be situated on, within, or under Crown Lands or private lands, or lands belonging partly to the Crown and partly to private individuals.

Crown ~~State~~ right to springs. s

(d) All springs situated within Crown Lands, and all springs whether situated in Crown Lands or in private property which have overflowed into or contributed water to any river, creek, stream, or lake, belonging to the Crown.

Right of Crown to bed of rivers and lakes.

(e) The right to control for the purposes of this Act the land covered either permanently or intermittently by the water of any river, stream, or lake.

6. The owner, lessee, or occupier of any land shall in virtue of such ownership, occupation, or right of possession, have a right to the use of water as follows, that is to say:—

~~General~~ limit to private ownership of water.

(a) The whole of the rain which falls on such land, with the exceptions or additions described in section 7.

Riparian rights limited.

(b) So much of the water of any river, stream, creek, lagoon, or lake adjoining such land as is required by the said owner, lessee, or occupier, for domestic use and for the watering of stock, provided always that no owner, lessee, or occupier of such land shall have a right to a larger supply of water than at the rate of 2,000 gallons per day for every mile of river, or lake frontage.

Rights already acquired.

(c) Any rights, whether permanent or temporary, which have been acquired under the Mining Act of 1874 or under any other Act or regulation in force prior to the passing of this Act.

NOTES AND EXPLANATIONS.

Notes and Explanations regarding PART II.

Definition of State rights.

5. This section and the next are among the most important in the Bill, and must be accepted as the basis of legislation. In California and Colorado the future prospects of remunerative irrigation are seriously imperilled; either by a want of a clear definition of the State rights, or by neglect to maintain those rights, or by pernicious legislation, through which permanent right to rivers has been wholly or partially transferred to private individuals. In Italy, France, Spain, and India, questions regarding water rights and the conservation and distribution of the water-supply have been practically set at rest by successful and beneficial legislation. In Article 420 of the Italian Civil Code, the following rule is stated regarding the rights of the State :—" The rivers and torrents, and generally all those portions of the territory of the State which cannot become private property, are considered as dependencies of the royal domain." Article 33 of the Spanish Law of Waters is as follows :—" There pertain to the public or public property

(i) The waters which spring perennially or intermittently within the public lands.

(ii) Those of the rivers.

(iii) Those, whether perennial or intermittent, of the springs and torrents which flow through their natural channels."

Similar regulations prevail in France. In India the preamble of the Northern India Canal and Drainage Act begins with the words—" Whereas throughout the territories to which this Act extends the Government is entitled to use and control for public purposes the water of all rivers and streams flowing in natural channels and of all lakes and other natural collections of still water," thus assuming the Government right as a starting-point for legislation. The declaration of the rights of the Crown in a river or lake bed is necessary, though we have not found it clearly enunciated in any legal enactment. It is, however, mentioned by Mr. W. H. Hall, in his work on " Problems of Irrigation," that in France " the tendency of decisions and administrative rulings is towards a declaration of ownership by the nation of the beds of streams, so long as they are occupied by the waters."

Individual rights to water.

6. The rights of private individuals are dealt with in this section, and the statement of ownership to water is on the lines of the Spanish Law of Waters, in which Article 30 is as follows :—" There belongs to the owner of an estate the rain water which falls or is collected on it while passing through it ; he may, in consequence, within his own property, construct cisterns, tanks, ponds, or reservoirs to preserve it, always providing it does not injure the public or third parties." The definition of the extent of riparian rights is based partly on Article 166 of the Spanish Law of Waters, which lays down the rule that " while waters run through their natural and public channels all may use them for drinking, washing clothes, vessels, or any other kind of object, far bathing, or watering or washing horses and cattle, subject to the rules and restrictions of municipal police." Regarding the limit to the quantity allowed to a riparian owner or occupier, we have assumed that 2,000 gallons per day is the maximum quantity which a riparian owner or occupier would require for domestic use and for the stock, which could receive a supply direct from the river or lake under the terms of this Act. As already explained in the notes on Part I, this Act is intended to provide for the conservation and distribution of water for all purposes, and the trusts constituted under it may be trusts for irrigation or for pastoral or mining purposes. After the passing of this Act, water rights can be obtained only in accordance with its provisions ; but

Right to springs

(*d*) The exclusive right to the use of any spring of water rising or situated in such land, if neither any other person or persons, nor any corporation, nor the Government has acquired a right to such spring or to a portion of the water from it by uninterrupted use for a period of not less than twenty years.

Right of landowner to underground supply.

(*e*) All the water found under the surface of such land, and the said owner, lessee, or occupier may make any lawful use of such underground supply; but no owner, lessee, or occupier of land has a right to use the underground supply in such manner or to such extent as to affect injuriously the supply in any well or boring previously existing in any adjoining property.

Amend

Acquisition of water rights.

7. Whenever the owner, lessee, or occupier of any land has been for a period of not less than twenty years allowed the use free of charge or hindrance of a supply of water, whether permanent or intermittent, running from or through or situated in any other land, such owner, lessee, or occupier shall have a permanent right to the use of such supply of water; but the water to which a right may in this manner be acquired may be used only for domestic purposes and for watering stock.

Limitation of acquired rights.

8. Wherever a right has been established to a supply of water from or through any land not owned, occupied, or leased by the person or persons by whom such right has been acquired, the owner, lessee, or occupier of such land may appeal to a Water Trust or to the ~~Board~~ for a limitation of such right, and when making such appeal shall send a copy thereof to the person who has established the said right. After the service of such notice of appeal, the person who has established the said right will have no power or authority to take from the same source any water in excess of the quantity which he has already been in the habit of obtaining, unless and until the ~~Board~~ or the Local Trust having jurisdiction in the district in which such supply is situated shall otherwise order or permit.

Amend

Compensation for interference with water rights.

9. Any person who has under this Act a right to a supply of water from a river, creek, stream, lagoon, or lake, or from any spring or from any underground source, may claim and obtain compensation if such supply be prejud~~icially~~ interfered with by the construction of any canal, channel, cutting, well, or boring, or by the erection and working of any machine, or by any other means whereby such supply of water has been diminished in quantity or rendered less useful than it was previous to the construction, erection, or bringing into operation of any such means of interfering with the supply; but on the person making any such claim for compensation will rest the onus of proof that actual damage has been done to him, and no compensation shall be allowed unless the said claimant shall prove that he is unable to obtain as much water of useful quality as he was in the habit of obtaining prior to the abstraction of the supply on account of which compensation is claimed.

-iced or

dam, weir,

Onus of proof of claims.

Restrictions as to conveying water to a distance from source of supply.

10. Wherever the owner, lessee, or occupier of land adjoining a river or lake has already arranged or wishes to arrange for the abstraction or diversion of a supply of water for domestic use, or for the use of stock, and for the conveyance of such supply, whether in natural or artificial channels, to a distance of more than 1 mile from such river or lake, a license for the abstraction or diversion of such supply must be obtained from the ~~Board~~ or from the Water Trust having jurisdiction in such

it is necessary to recognize existing rights of miners and of others who have acquired water rights in a legal manner, and clause (*c*) of this section is intended to meet such cases. Clauses (*d*) and (*e*) of this section on the subject of rights to springs and underground supplies are in accordance with Article 33 of the Spanish Law of Waters, which has already been quoted, and also in accordance with Article 440 of the Italian Civil Code, which is as follows :—"Whoever has a spring on his estate may use it at his pleasure, saving the right which the owner of a lower estate may have acquired by title or prescription."

Acquisition and limitation of water rights.

7 and 8. These sections, dealing with the acquisition of rights to water and the limitation of those rights, are in accordance with principles of equity, and in harmony with the spirit of this Act.

Onus of proof. Principles on which compensation can be granted.

9. Section 9 throwing the onus of proof on claimants for damages in cases concerning water rights, and defining the principles on which compensation can be obtained, is based to some extent on the Indian Canal Act.

License required for conveying a supply of water more than 1 mile.

10. This regulation, that a license should be obtained for permission to carry water from a river or lake to a distance of more than 1 mile from such river or lake, is suggested chiefly in order that the arrangements for the conveyance of the water should be more directly under the control of the proposed Board. It need scarcely be pointed out that it would be easy to convey water in such a manner as to irrigate a strip of land by means of the water escaping by percolation or otherwise from the channel conveying it. This would be an evasion of the regulation that water used for irrigation must be paid for ; any such evasion would be prevented by a license which could be cancelled if its terms were not strictly attended to.

case. Wherever supplies for domestic use or for stock are now being conveyed or diverted from any river or lake to distances exceeding 1 mile from such river or lake, the owner, lessee, manager, or user of such arrangement or appliance must, within three months after the passing of this Act, obtain a license for the further use of such arrangement or appliance.

Frontage, how measured.

11. Frontage to a river or lake, as referred to in section 6 or elsewhere in this Act, shall be taken to be the length measured along the edge of the water in a river or lake at the time of abstraction or diversion of the supply.

Limitation of water rights.

12. No owner, lessee, or occupier of land adjoining a river or lake has any right, power, or authority to interfere in any way with the flow or the supply of water in such river or lake except to the extent and for the purposes detailed in this Act.

Waste of water prohibited.

13. No owner, lessee, or occupier of land adjoining a river or lake has a right to abstract or divert from such river or lake for domestic use or for stock a larger supply of water than he requires. Any breach of this regulation, or any loss of water through defective channels or other causes, shall render the defaulter in such case liable to the penalties fixed under this Act for waste of water.

Rights of Municipality not to be interfered with.

14. Wherever any arrangements have been made, or are in progress, or have been officially proposed in connection with the drainage or the water-supply of any Municipality or union of Municipalities, such arrangement or proposed arrangement shall not be in any way interfered with by the ~~Board~~ or by any Water Trust except by agreement with such Municipality or union of Municipalities.

Right of riparian owners to use of beds of rivers and lakes.

15. Where water ceases to flow or to be stored over the whole or a portion of the bed of a river, creek, stream, or lake ~~belonging to the Crown,~~ the owners, lessees, or occupiers of the adjoining land have a right to the use of the land thus left clear of water; provided always that the bed of such river, stream, or lake shall not be used in such manner as to alter, diminish, or retard the flow of water in any river or stream, or diminish the holding capability or capacity of any lake.

Present trespass on Crown rights.

16. Wherever in contravention of Crown rights a supply of water has been drawn from any river, creek, stream, lagoon, or lake, whether by pumping or other lifting machinery, or by artificially raising the water-level, or by canals, drains, or pipes, or by any combination or modification of these means, the works so done and the machinery or appliances so used shall, after the passing of this Act, be inspected and reported on by an officer acting for or empowered by the Board; and if the continued operation of such works, machinery or appliances be not detrimental to public interests, a license shall be granted to the owner, lessee, or ~~manager~~ of such works under such conditions as the Board may deem necessary in the interests of the Government, and such license must be renewed at least once in every five years.

Limit of time for application for license.

17. If in any case after such inspection of works, machinery or appliances as described in section ~~15~~, which have been used, or are intended to be used, for the purpose of obtaining a supply of water from a river, creek, stream, or lake, the owner, lessee, or ~~manager~~ of such works, machinery, or appliances, neglect to apply for a license within ten days after the notification of the result of such inspection the said owner, lessee, or ~~manager~~ shall be liable to the penalty fixed by this Act for illegally using water.

NOTES AND EXPLANATIONS.

11 and 12. These sections are necessary corollaries to 6 in regard to the limitation of water rights.

Definition and limitation of riparian rights]

13. The prohibition of waste is a useful point, and one which has been found necessary in all cases where anything like complete legislation on the subject of water conservation has been carried out. The Italian rule on this point is that "irrigators who have legitimate titles to water their lands possess no rights to the surplus waters, which shall be allowed to flow freely to the rivers, for the benefit of proprietors below." "The Northern India Canal and Drainage Act" orders a penalty for waste of waters under any circumstances where proper precautions have not been taken.

Prohibition of waste.

14. This paragraph is intended to exempt from the operation of this Act all towns and municipalities which have already acquired vested interests in any river or stream, or in any catchment area.

Exemption of Municipalities.

15. The right of riparian owners or occupiers to the use of the beds of rivers or lakes appears to be generally understood; but we have not found it clearly enunciated in any recent legislation. There is no question of the necessity for a clear statement of the law on this subject.

Private rights to beds of rivers and creeks.

16. It is well known that in a number of cases water has been and is now being taken from rivers and lakes for irrigation and other purposes. These works are the result of private enterprise, and the owners of them should be dealt with in a liberal spirit. Still, such works must be carried out and maintained only under Government sanction, and as those in existence have been carried out without any legal right or sanction, no time should be lost in putting these matters on a proper footing. That their owners understand that the works of this kind which are in existence have been carried out and maintained under sufferance only was shown by the evidence of at least one important witness examined by the Commission. This gentleman, who has pumping machinery erected on the Murrumbidgee, stated that he was quite prepared for the contingency of being required by the owners of property further down the river to suspend or stop his pumping operations.

Trespass on Crown rights.

17. This section is a necessary sequel to the last.

Limit of period for application for license.

PART III.—National Administration—Board.

Appointment of Board.

18. For the management under this Act of all rivers, streams, creeks, lakes, springs, and underground supplies of water in the Colony of New South Wales, it is hereby ordered that a Board for Water Conservation and Utilization shall be appointed without delay after the passing of this Act.

Constitution of Board.

19. The Board shall consist of a Chairman or President and members. The Chairman of the Board shall be a permanent Government officer specially appointed for the purpose of the administration of this Act, and shall devote the whole of his time to the duties of this office. The members of the Board shall also be appointed by Government, and shall hold office permanently, but their duties shall extend only to attendance at meetings of the Board and the despatch of business brought before such meetings.

Duties of Engineer to the Board.

20. The Government shall appoint an Engineer, whose duty it will be to examine into and report on the propriety, practicability, and probable results of work proposed by Trusts, and to carry out works undertaken by the Government.

~~Establishment,~~ permanent and temporary Staff

18 ~~21.~~ The Govern~~ment~~ shall have power to appoint any ~~further~~ permanent or temporary staff necessary for the administration of this Act.

Powers of the ~~Board.~~ Minister

19 ~~22.~~ Subject to the sanction of the Govern~~ment~~, the Board shall have authority to fix the boundaries of districts to be administered by Local Trusts, and to alter, enlarge, diminish, unite, or separate such Trusts and Trust Districts, and to alter the name of any Trust or Trust District.

Works for water conservation to be inquired into and sanctioned by the ~~Board.~~

y, to be made

20 ~~23.~~ The ~~Board~~ Minister cause shall inquire into and decide on the propriety of sanctioning any work for water conservation and utilization, or for drainage, proposed by any owners, lessees, or occupiers of land, or by a Local Trust. If such works appear to ~~the Board~~ to him to be of proper and useful description, and if no loan be required by the Trust for the carrying out of such works, ~~the Board~~ he may sanction the commencement and prosecution of such works by the said owners, lessees, or occupiers of land, or by the said Trust.

Projects for which loans are applied for by Trusts.

21 ~~24.~~ When the Trust proposes to carry out works for the purposes of the conservation and utilization of water, or for drainage, and applies for a loan guaranteed by Government to enable it to ~~complete~~ such works, the ~~Board~~ Minister shall cause to be examined the plans and estimates of such works, and shall require the aforesaid Trust to supply any further information which may appear necessary. The Board may also, through ~~its~~ his officers, carry out such levels, surveys, measurements, and investigations as may be required to furnish a satisfactory check on the surveys, designs, and estimates for the proposed works. The ~~Board~~ Minister shall then ~~report to Government on the propriety, feasibility, and cost of the proposed works, and on the profit likely to be obtained from the construction of the said works, and shall~~ make such recommendations to the Govern~~ment~~ as ~~it~~ he may deem just and necessary in regard to the propriety of granting the whole or a portion of the loan applied for.

Works carried out by Trusts to be subject to approval of ~~Board.~~

22 ~~25.~~ No work, whether for water conservation and utilization, or for drainage, which affects in any way the rights of the Crown, as described in section 5 of this Act, shall be undertaken without the sanction of the ~~Board;~~ Minister and every such work, whether carried out by a Trust, or by the owner, lessee, or occupier of land, shall, both as to construction and maintenance, be subject to the inspection and approval of the ~~Board~~ or ~~its~~ officers.

NOTES AND EXPLANATIONS.

Notes and Explanations regarding PART III.

It may be remarked here at the outset that the necessity for a Board was in a large measure suggested by the defects in Victorian legislation, as pointed out by the Secretary to the Commission in his Report on the Conservation of Water in Victoria.

Appointment of Board.

18. The appointment of a Board, as proposed in this section, will ensure the administration of water conservation and supply on a complete and uniform system, while the organization of Water Trusts will provide for attention to local wants and the economical treatment of details and maintenance. It appears to us that, by the appointment of the Board here proposed, the weak points in the Victorian legislation, which have been remarked on in the Secretary's Report already referred to, will be provided against. An attempt is now being made in India to place the maintenance and management of irrigation distributaries under the charge of the village communities benefiting by them. The system there aimed at is almost an exact parallel to that now proposed. The board would have powers similar to those possessed by the Irrigation Department, while the village communities would be in the position of local Water Trusts. In the South of France the irrigation works, with the exception of the Marseilles Canal, which is only partially intended for irrigation purposes, are carried out and managed under a system almost identical with that now suggested. There the Public Works Department of France occupies almost the same position as that of the Board, while the Associations of Landholders correspond very closely with the Water Trusts.

Power of Board to define Trust Districts.

22. The Power of the Board to settle the boundaries of Trust Districts, subject to the sanction of Government, is similar to that reserved to the Government of Victoria in Act 778 of 1883.

Duties and powers of Trusts.

23 to 28. These sections are specially intended to provide against the defects pointed out by the Secretary of this Commission in his Report to the President regarding Victorian water conservation.

Tenders to be called for publicly.

23 ~~26~~. Tenders for works for water conservation and utilization, or for drainage, whether such works are to be carried out under the direct management of the ~~Board~~ or under Trusts, must be called for by public advertisement ~~in the same manner as in the case of Government contracts~~. If the tenders ~~have been~~ advertised for by a Trust, and if the proposed works are intended to be constructed wholly or ~~partially~~ by money lent or guaranteed by ~~Government~~, such Trust shall examine the tenders, and shall forward them to the ~~Board~~ with a report stating the opinions of the said Trust regarding the tenders. The ~~Board~~ shall then decide which tender shall be accepted, and shall direct the local Trust accordingly.

~~Acceptance of tenders for works to be carried out by loans.~~

Minister

Minister Minister

Local works to be carried out by contract.

24 ~~27~~. When works are carried out by Trusts, with the aid of funds lent or guaranteed by Govern~~ment~~t, only contract work shall be engaged, and the terms of every such contract, and the nature and amount of security required, must be approved by the ~~Board~~ before tenders are invited.

Minister

Accounts of Trusts to be open to inspection.

25 ~~28~~. The certificates and vouchers for all payments for work done by Trusts, with the aid of loans obtained from or guaranteed by Government, must be countersigned by the ~~Chairman~~ and Engineer of the ~~Board~~, and all accounts in connection with such works shall at all times be accessible for inspection by the ~~Board and~~ ~~its~~ officers.

Minister's Department

Powers to make surveys and carry out works.

26 ~~29~~. Subject to the sanction of the Govern~~ment~~t, the ~~Board~~, through ~~its own~~ officers, aided, if necessary, by a temporary staff, may carry on surveys and prepare designs and estimates for work. ~~It~~ may also, subject to the same provision, call for tenders and carry out ~~the~~ works for water conservation and utilization, or for drainage.

Minister his He

Local works to be managed by local Trusts.

27 ~~30~~. On the completion of works carried out under the immediate directions of the ~~Board~~, the charge of the maintenance and administration of such works ~~shall, as soon as can be arranged~~, be transferred ~~by the Board~~ to one or more Water Trusts.

Minister may

Powers of ~~Board~~.

28 ~~31~~. For the purposes of this Act the ~~Board~~ shall have power, by ~~itself or its~~ officers, or by Water Trusts or their officers, to enter on any land, remove any obstruction, close, open, or alter in any way any channel, stream, creek, or river, take levels, make surveys and measurements, and do any excavation or construct any works, or do anything that may appear necessary or expedient in connection with any works, whether such works be done or are in progress, or proposed to be done. The ~~Board~~ may also resume, purchase, or lease any water privileges which may have been acquired previous to the passing of this Act.

Minister his

Governor

Compensation ~~to be paid~~ for damage ~~done~~ under this Act.

29 ~~32~~. Whenever any person employed in pursuance of this Act shall, while in the execution of his duties, cause injury to land or fences, or other property, or shall cause loss or damage to any owner or occupier of land or other property, the Trust or other authority under which such person is employed shall be liable for all such injury, loss, or damage.

Limitation of time within which claims will be admitted.

30 ~~33~~. Claims for compensation on account of injury, loss, or damage caused to persons or property by any person employed under this Act, must be made within one month after such injury, loss, or damage is sustained; and no claims of such description made after the lapse of more than one month from the date of occurrence of such injury, loss, or damage shall be valid, unless satisfactory reason be shown, for the delay in preferring such claims.

Compensation may be settled by arbitration.

31 ~~34~~. When any person claims compensation from a Trust on account of injury, loss, or damage sustained, and such claim is disputed by the

NOTES AND EXPLANATIONS.

29 and 31. In these sections the general powers of the Board are stated; the powers provided being similar to those secured to Government in India, in New South Wales, and in Victoria, in cases relating to the construction and management of public works. Powers of Board.

30. In this section the management of works for water conservation and supply is ordered to be placed in charge of those directly interested. This is the general practice in France, Italy, and Spain, and it is the practice aimed at in India, New Zealand, and Victoria. Management of water-supply by Local Trusts.

Sections 32 to 34 inclusive, relating to the responsibility incurred through entering on land or interfering with property, declare the right of the owner of such land or property to compensation for actual damage done by such entry. These sections are based on legislation already in force in New South Wales, Victoria, and India. Claims and compensation.

said Trust, the settlement of the amount of compensation (if any) may, with the joint consent of such Trust and such claimant, be submitted to arbitration. In such case one arbitrator shall be appointed by the said Trust and one by the said claimant; and should such arbitrators fail to agree as to compensation they shall appoint an umpire, whose opinion as touching the question or questions in dispute shall be final. If the amount awarded by such arbitrators be not at least two thirds of the amount claimed as compensation, the said claimant shall pay all the costs and expenses of such arbitrators.

Minister

Power to obtain water-rights from Municipalities.

~~35~~ 32. The ~~Board~~ shall, for the purposes of this Act, and with the sanction of Govern~~ment~~or, have the power to obtain from any municipality, or combination of municipalities, by agreement with the said municipality or municipalities, the whole or a portion of the water-rights possessed by the said municipality or municipalities, and referred to in section 14 of this Act.

Power to acquire or sell land.

~~36~~ 33. The ~~Board~~ may also, for the purposes and subject to the provisions of this Act, acquire, purchase, or take on lease any land required for any work, and may sell, exchange, or let on lease any such land whenever it ceases to be necessary.

Minister with the Sanction of the Govnr

Procedure in the acquisition of land.

~~37~~ 34. Before proceeding with the construction of any permanent works the ~~Board~~ shall publish, at least once in each of three consecutive weeks, in some newspaper circulating in the district in which the proposed works are situated, a notice stating the names of the owners or reputed owners of the land required, the situation of the land, the acreage required from each of the various holdings. The notice shall also specify the place and hours at which a plan of the required land can be seen.

Minister cause to be d

Notice of intended resumption of land.

~~38~~ 35. The ~~Board~~ shall serve a notice on every owner or reputed owner, lessee or reputed lessee, and occupier of such land, and shall define in the notice in each case the position and area of the particular land intended to be resumed, and requi~~ring~~ a reply stating the amount which the said owner, lessee, or occupier is willing to accept in settlement of ~~compensation~~ for the said land.

Minister cause to be d

Amount of compensation, how arrived at.

~~39~~ 36. In estimating the amount due as compensation to any owner, lessee, or occupier, the ~~Board~~ shall deduct from the value of the land resumed, and the damage done, the amount by which the remaining land of the said owner, lessee, or ~~manager~~ shall have increased in value through the ~~sanction of the proposed~~ work; provided always that such increase in value does not exceed the cost of the land resumed and the damage done. In no case shall the owner, lessee, or ~~manager~~ have a right to claim for resumed land the increased value due to ~~propose~~d works.

Minister

occupier

occupier

Action in case of absence of owner or occupier of land.

~~40~~ 37. If, through absence of the owner, lessee, or occupier of land proposed to be resumed, or from any other cause, the owner, lessee, or occupier fail to forward a statement of his claims within two months after the last date of publication of the notice by the ~~Board~~, no interest on the amount of compensation shall be allowed, and the increase in value of the remaining property of the said owner, lessee, or occupier up to the date of receipt of the said claims by the ~~Board~~ shall be reckoned, as in section ~~40~~ 36 of this Act, in diminution of the compensation to be awarded.

Minister

Minister

Resumption of water rights.

~~41~~ 38. The ~~regulations ordere~~d in the last two sections shall also, as far as they are applicable, be acted on in the purchase, resumption, or lease of water rights.

Power of the ~~Board~~ to fix rates.

~~42~~ 39. Wherever works have been carried out under the provisions of this Act with the aid of loans, the ~~Board of~~ Trust will have power to fix

Minister or

NOTES AND EXPLANATIONS.

Power of Board to make agreements with Municipalities.

35. This section is intended to provide for cases in which a portion of a supply is required for a town, while the remainder is available for irrigation and other purposes.

Power to acquire or sell land.

36 and 37. The procedure here proposed is similar to that prescribed in the New South Wales Country Towns Water and Sewerage Act.

Compensation for land, &c.

38, 39, 40, and 41. It is assumed that on the sanction of the construction of a canal, reservoir, or other work for water conservation, or of any cutting for water-supply or for drainage, an immediate rise in the value of adjoining land will take place. We have ventured to propose that, in estimating the compensation to be paid, this rise in the value of property should be taken into account to lessen the amount which an owner or occupier should receive. This course is not without precedent, and we think that the justice of it is manifest. The proposal seems reasonable, and in some cases this regulation might have an important bearing on the remunerativeness or otherwise of useful works. Section 39 is specially intended for dealing with cases in which miners' rights to water have been acquired, and with cases in which it would be advantageous to the public to obtain by resumption or otherwise water rights possessed by individual landowners, lessees, or companies.

Power to fix rates for water, and methods and units of measurement.

42. The necessity for the portion of this paragraph bearing on the fixing of rates is at once obvious ; but wherever there is no reason to the contrary, the rates for water should be fixed by the Local Trusts, subject merely to the sanction of the Board. With regard to the power of the Board to prescribe or sanction units and methods of measurement of water, it appears to be a better arrangement to give this general authority than to prescribe any method or unit in the Act. In no country has it been found practicable to follow one system or method of measuring water. Different modules for the measurement of water for irrigation and other purposes have been adopted in Italy, France, and Spain ; and not only so, but several methods of measuring the water are adopted in each of these countries. For the purposes of an irrigation outlet, or for any small supply required from a canal or distributary, the module adopted on the Marseilles Canal appears least open to objection. In India, water supplied for irrigation is paid for according to the nature of the crop and the area irrigated, while that supplied for grain mills

rates and charges for water supplied from any source by means of the said works, and it shall also have power to prescribe or sanction methods and units for the measurement of such water.

40

Right of ~~Board~~ to inspect works.

Minister

~~43.~~ The ~~Board~~ may at any time cause inspection to be made of any works for water conservation and utilization, or for drainage, which are under the management of a Trust; and may also, wherever Crown rights are affected, or believed to be affected, cause similar inspection to be made of such works which are under the management of the owners, lessees, or occupiers of land, and if the maintenance and management of such works be found ~~so~~ unsatisfactory ~~as~~ to cause waste of water, the Board shall require such Trust or such owners, lessees, or occupiers of land to improve the maintenance and management of such works.

41

Power of the ~~Board~~ to cancel constitution of Trusts.

advice

Minister

Minister

~~44.~~ In any case where, as described in section 43, the members of a trust, or the owners, lessees, or occupiers of land, manage or maintain works for water-supply, or for drainage, in an unsatisfactory or discreditable manner, the Governor may, on the ~~report~~ of the ~~Board~~ withdraw all or any of such works from the control of the said Trust, or of the said owners, lessees, or occupiers of land, and may cancel the constitution of the said Trusts, and may place all or any of the rivers, streams, creeks, lakes, and underground supplies of water within the district in which such works are situated under the immediate charge of the ~~Board~~, to be managed and administered under this Act.

PART IV.—DISTRICT ADMINISTRATION—LOCAL WATER TRUSTS.

42

Formation of Water Trusts.

~~45.~~ Whenever the owners, lessees, and occupiers of land desire to combine for the purpose of constructing works for the conservation or utilization of water, or for drainage of land, a petition, signed by at least five of such owners, lessees, or occupiers, and setting forth the nature and extent of the works desired by the said owners, lessees, and occupiers, and the quality and extent of the land likely to be benefited by such works, shall be submitted to the ~~Board by the said owners, lessees, and occupiers.~~

Minister

43

~~Board~~ to inquire ~~into propriety of forming Trusts.~~

Minister

cause to be made

an

ion

y

he

Minister

the

~~46.~~ The ~~Board~~ shall without delay investigate and inquire into the feasibility and propriety of the proposed works; and if after such investigation and inquiry the ~~said Board~~ shall deem it right and expedient that a Trust shall be formed for the survey, construction, maintenance, and administration of works for water conservation and utilization, or for drainage, ~~the said Board~~ shall subject to the sanction of Governor order the appointment of the said Trust, and shall assign a name to the said Trust, and shall describe the boundaries of the district to which the jurisdiction of the said Trust shall extend, and shall define the limits of the water-supply which such Trusts shall be entitled to use and administer.

44

Formation of Water Trusts to be notified publicly.

~~47.~~ The constitution of a Trust shall be publicly notified in the *Government Gazette*, and in at least one newspaper circulating in the district ~~of the said Trust,~~ and such notification shall state briefly the boundaries and name of the said Trust, and the number of representative members, and the names of the persons qualified to vote for members of the said Trust, and the date on which the first election of members of such Trust shall take place.

45

Boundaries of Trust district ~~how decided.~~

Minister

~~48.~~ In deciding the boundaries of Water Trusts the ~~Board~~ shall be guided by watershed lines, and by the position of rivers and other is charged for by the number and size of the millstones used ; but it is not an uncommon practice for Government to build the mills and let them by public competition, on certain fixed terms regarding the quantity and regularity of the water-supply.

Mismanagement by Trusts—how dealt with.

43 and 44. In the south of France, where, as already stated, the system of canal management is similar to that now proposed, it is found that the local associations, through either ignorance or carelessness, frequently allow irrigation works to fall into such disrepair as to cause waste of water and interfere with the efficiency of the works. This and other kindred evils are intended to be here provided against.

Notes and Explanations regarding PART IV.

In the Victorian Water Conservation Act of 1881, Part VII is devoted to powers conferred on private individuals. It appears to us that this part of the question could be better dealt with by making the definition of "Trust" more elastic, and including within the same regulations and the same administrative system all Water Trusts, however extended and however limited. All the regulations for Trusts here proposed are framed so as to suit Trusts whether large or small, and whether the water be conserved for and distributed to irrigation works, or to graziers or to miners.

Procedure in constituting Trusts.

45 to 48. In these sections the procedure followed when constituting a Water Trust is detailed. In framing the proposed regulations the Victorian legislation has been only partially followed, as in some cases it is not applicable, and in others not sufficiently concise. The fixing of boundaries of Trust Districts here dealt with is a matter requiring judgment and care. The principle on which alone the boundaries can satisfactorily be dealt with is to follow the natural boundaries, that is, the ridge and valley lines, and not any artificial boundaries which have been fixed for municipal or other purposes.

Minister —

natural sources for water-supply; and ~~the Board~~ shall, wherever practicable, arrange the boundaries of Trusts in such manner as to include one or more complete catchment areas.

46
Procedure of ~~Board~~ when organizing a Trust.
Minister

~~49~~. When making preliminary investigations and inquiries regarding the formation of any Water Trust, the ~~Board~~ shall ~~prepare, or~~ cause to be prepared, a list of the owners, occupiers, and lessees of land within the boundaries of the proposed Trust District; and this list must show the nature of tenure, the area, and the quality of the land held by each owner, occupier, and lessee in the said proposed Trust District. By means of this list the names of all persons entitled to vote for members of the said Trust, and the number of votes which every such person will have a right to give, will be determined.

47
Members of Trusts.

~~50~~. The conservation and utilization of water, and the drainage of every Trust District, shall be managed and administered by members of the said Trust, who will be elected from time to time by the owners, lessees, and occupiers of land ~~and the owners of miners' rights and leases within the~~ said Trust District, and the number of members thus elected in every Trust shall be not less than three or more than nine.

48
Qualification of Trust ~~representative~~.

~~51~~. In the Western Division of New South Wales, as constituted by the Land Act of 1884, every representative member of a Water Trust must either be owner of not less than 640 acres of land, or lessee or occupier of not less than 10,000 acres. In the Central Division, as constituted under the same Act here mentioned, every representative member of a Water Trust must either be owner of not less than 160 acres of land or lessee or occupier of not less than 2,560 acres. In the Eastern Division, as constituted by the same Act here mentioned, every representative member of a Water Trust must either be the owner of not less than 40 acres of land or the lessee or occupier of not less than 640 acres.

49
Qualification of voters.

~~52~~. For the election of members of Water Trusts the owner, lessee, or occupier of not less than 1 acre or more than 640 acres shall have one vote for every vacancy; the owner, lessee, or occupier of more than 640 acres, and not more than 2,560 acres, shall have two votes for every such vacancy; the owner, lessee, or occupier of more than 2,560 acres, but not more than 10,000 acres, shall have three votes for every such vacancy; the owner, lesssee, or occupier of more than 10,000 acres shall have four votes for every such vacancy.^

^ but no ~~member~~ voter shall have more than four votes for one Trust

50
Formation of Mining Trusts.
Minister
~~See Under Secty~~

~~53. Wherever it is found impracticable for any local Trust to deal with the mining and manufacturing interests within its district the Government may, on the recommendation of the Board, authorize the formation of Special Water Trusts for mining or manufacturing purposes only. The qualification for the representative membership of every such Trust shall be the registered possession of a mineral or special lease, and the qualification of voters in such Trust shall be the registered possession of a miner's right.~~

50
Method of recording votes.
Minister

~~54~~. The Secretary to a Water Trust, or other person authorized by such Trust or by the ~~Board~~, shall, as soon as possible after the notification of the constitution of such Trust, transmit by post or otherwise to every voter residing at a distance of more than ten miles from the nearest polling place a printed or written or partly printed and partly written ballot-paper containing the names of all the candidates qualified for the office ~~of representative members~~; or if such voter have a right to more than one vote, then the number of ballot-papers supplied to the said voter shall be equal to the number of votes to which he is entitled.

NOTES AND EXPLANATIONS.

Qualifications of members and of voters for Trusts.

49 to 54. These paragraphs deal with the qualifications of members and of voters for Water Trusts, and the main principles on which they are founded are those accepted in recent Acts to extend local government. It may be mentioned that the Victorian Water Conservation Act of 1881 orders that the appointment of Water Trust Commissioners shall rest with Municipal Councils. We entirely fail to see the propriety of such a course, and think that Water Trusts and Municipal Councils should be regarded as two entirely separate bodies, each dealing with the other as it would with a private individual or a private company. On the other hand, there is no reason why a municipal councillor should not also be a member of a Water Trust, and no regulation is proposed which would be inimical to such an arrangement. The principle now advocated is, briefly, that members of Water Trusts should be elected by and from those interested in the equitable and economical distribution of the available supply.

Votes ~~should~~ be recorded on the papers ~~according to prescribed regulations~~, and every voter ~~should~~ sign all his voting papers and return them to the Secretary to the Trust in a cover stamped with the words "Voting Papers." Such covers will be transmitted free of charge by post, and shall, in every way, be treated as registered correspondence. Qualified voters residing within ten miles of a polling place shall record their votes by ballot in the manner prescribed for municipal elections. The names of the Trust representatives so elected shall be notified in the Government Gazette, and in at least one newspaper circulating in the said Trust district.

51.

Procedure on election of Trust ~~representatives~~.

Minister

~~55~~. Within one month after the election of ~~members~~ of a Water Trust the said members shall meet at some convenient time and place to be sanctioned by the ~~Board~~, and at that meeting, or at an adjourned meeting, the said members shall elect a Chairman, and shall transact such business as may be brought before them ; and such members shall thereafter meet and adjourn as they think proper from time to time and from place to place. A special meeting of the members of any Water Trust may at any time be called, on the requisition of the ~~Board~~ or of the Chairman of such Trust, or on the requisition in writing of any two members of such Trust, addressed to the Chairman or Secretary of the said Trust.

Minister

52

Power to rest only with quorum of members.

~~56~~. All powers vested in a Water Trust may be exercised by such Trust at any meeting held in pursuance of this Act at which there is a quorum of the members present, but not otherwise.

Number required to form a quorum.

~~57~~. Whenever there is an even number of members in any Trust a quorum shall consist of not less than half the members of such Trust. When there is an odd number of members in any Trust the smallest number constituting a quorum will be half of the number obtained by adding one to the number of members.

53.

Minister

Power of ~~Board~~ to alter number of members or quorum.

~~58~~. The ~~Board~~, subject to the sanction of the Govern~~ment~~or, shall have power to alter the name of any Trust, or the number of members of any Trust, and also to alter in any Trust the number of members required to form a quorum.

54

Power to postpone or adjourn meetings.

~~59~~. If at any meeting of a Water Trust there be not a quorum present within half an hour after the time appointed for such meeting, then it shall be lawful for the members present, or the majority of them, or any one member, if only one be present, to adjourn such meeting until another hour or another day ; and if no member be present, then it shall be lawful for the Secretary to adjourn the proposed meeting till another hour or another day.

55

Members not to be paid.

~~60~~. No ~~Member~~ of any Water Trust shall be the holder of any paid office or situation under the said Trust, nor receive any salary, emoluments, or expenses of any kind from the said Trust unless with the special sanction of Govern~~ment~~or ~~and with~~ the recommendation of the ~~Board~~.

upon Minister

56

~~Members~~ not to be contractors.

~~61~~. No ~~member~~ of any Water Trust shall tender for, obtain, or hold any contract or any part or share in any contract for works or surveys under the charge or authority of such Trust.

57

Penalty for illegally acting as members.

~~62~~. Every person who, being incapacitated or not duly qualified to act, or having become disqualified from acting as member of a Water Trust, is present at a meeting of the members of such Trust, and acts thereat as a member shall, for every meeting on which he is so present and acting, be liable on conviction thereof before any two Justices to a penalty not exceeding £50.

NOTES AND EXPLANATIONS.

55 to 62. The details of the system of procedure of meetings of local Trusts is based on the New South Wales Municipalities Act and the Victorian Act for the Conservation and Distribution of Water, but are arranged to suit the altered circumstances of Water Trusts.

Procedure at meetings of Trusts.

58 58

Trust to be a body corporate.

~~63.~~ Every Water Trust shall be a body corporate, and shall, subject to the sanction of the ~~Board~~, have power to purchase and hold lands, tenements, and hereditaments and other property for the purposes of this Act. It shall also, under the same conditions, have the power to sell, exchange, or let on lease the whole or any portion of such lands or other property for the benefit of such Trust.

Minister 59

Powers delegated by ~~Board~~.

Minister

~~64.~~ Subject to the sanction of Govern~~ment~~or, the ~~Board~~ may delegate to any Water Trust all or any of the right, power, and authority of the said ~~Board~~ to hold, use, and administer the rivers, streams, creeks, lakes, springs, and other sources of water-supply situated within the boundaries of the district included within the jurisdiction of such Trust.

Minister 60

Powers of Trusts.

~~65.~~ Subject to the sanction of the ~~Board~~, every Water Trust shall have and exercise, for the purposes of this Act, all the powers given herein to the ~~Board~~ in sections 29, 31, 35, and 36.

Minister 61

Right of appeal.

~~66.~~ The owners, lessees, or occupiers of land, or other persons affected by any action taken in regard to water conservation and utilization, or to drainage, or by any neglect to take action in regard to such works, shall make application for redress to the Local Trust, or in the absence of a Trust, to the ~~Board~~, and shall have a right to appeal to the ~~Board~~ against any decision of a Trust, ~~and to the Minister against a decision of the Board~~.

Minister

Minister

62

Tenure of office by members.

~~67.~~ In every Water Trust which consists of an even number of ~~members~~, one more than half the number of ~~member~~s elected on the formation of the Trust shall hold office for three years, and the remaining ~~member~~s for two years. In any Water Trust which consists of an odd number of ~~member~~s, half the number obtained by adding one to the authorized number of members shall be the number which will hold office for three years, and the remainder shall hold office for two years. At the first election of members for any Water Trust the elected members shall be placed in order according to the number of votes received by each. The members who have obtained the higher number of votes shall, to the number hereinbefore described, be declared elected for three years, and the remaining members for two years; but as vacancies arise the members elected to fill them shall in all cases be elected for three years, and outgoing members may be re-elected if otherwise eligible. The members shall elect from among their number a Chairman, to preside at the meetings of the said Trust. The said Chairman shall have the same right as other members ~~of the Trust~~ to vote on all questions which are brought before the said Trust, and if in any case the number of votes for and against any matter before the said Trust be equal, the said Chairman shall, in addition to his ordinary vote, have the right to give a casting vote. The tenure of the office of Chairman of every Water Trust shall not be for more than one year, and shall in all cases terminate in the month of December, but the members of any Water Trust may re-elect a Chairman on the expiration of his term of office.

63

Election of temporary Chairman.

~~68.~~ In the absence of the Chairman from any meeting, ~~a majority~~ of the members present may elect one of their number to act as Chairman for that meeting only.

64

Regulations regarding compensation for land.

~~69.~~ The regulations herein directed for the settlement of claims for compensation where any damage is done or loss occasioned to any owner, occupier, or lessee of land or tenements of any kind, through the prosecution of surveys or other investigations by the ~~Board~~, shall apply also to damage done or loss occasioned by any Water Trust in the administration of this Act.

Minister

NOTES AND EXPLANATIONS.

63. In declaring every Water Trust to be a corporation, the precedent of the Victorian Act (No. 716) of 1881 has been followed, but in any case the necessity for this provision is evident.

Water Trusts to corporations.

64 and 65. The arrangement here adopted of making over charge of the rivers, streams, lakes, and other natural sources of water-supply to Water Trusts, to be held by them on behalf of the Government, and under the directions of the Board, is one of primary importance. While it is an accepted rule in almost every country that all such natural sources of water-supply belong to Government, it is also unfortunately a state of affairs common to several countries that the Government rights in natural sources of water-supply have suffered seriously, or been altogether lost, through neglect to define and maintain them. It is a vital principle of the Act now proposed, that not only should the rights of the State be clearly set forth, but that the protection and perpetuation of those rights should be ensured. In Colorado and California the right of the State to the water-supply was at one time admitted, but in both this right appears to be almost entirely lost or alienated.

Making over charge of rivers and other sources of supply to Trusts.

67, 68, and 69. These sections, relating to the details of the constitution and management of Trusts, require no comment.

Constitution and management of Trusts.

65

Power of Trusts to employ engineers and others.

~~70.~~ Whenever the members of any Water Trust have reason to believe that works for the conservation and utilization of water can be carried out with profit in their district, they may, subject to the sanction of the ~~Board~~, employ qualified engineers and surveyors and any others necessary for the preparation of the surveys, designs, and estimates for such works.

minister

66

Sanction of ~~Central Board~~ required for all works.

~~71.~~ No ~~local~~ Trust shall have power to carry out any works for water conservation and utilization without the sanction of the ~~Board.~~

minister

67

Power of Trusts to act in cases of emergency.

~~72.~~ But whenever there is reason to apprehend that damage may be caused by floods before a reply could be obtained from the ~~Board~~, or whenever there is an opportunity to conserve flood-water, which opportunity might be lost before a reply could be received from the ~~Board,~~ any Water Trust may, on its own responsibility and at its own risk, deal with the necessities of ~~each~~ such case as it may deem proper. In every such case the ~~Board should~~ without delay be informed of the case in detail, and ~~the~~ sanction ~~of the said Board should without delay~~ be applied for. forthwith

minister

minister

minister must

his approval

67

Power of Trusts to make by-laws.

~~73.~~ When works for the conservation and utilization of water are administered by any Trust, such Trust shall have the power, subject to the ~~sanction~~ of the ~~Board,~~ to make by-laws for the maintenance and management under this Act of such water-supply ; and if any person or persons neglect or refuse to obey the said by-laws, the supply of water given to such person or persons may, after warning has been given, be stopped till the said by-laws are properly observed.

minister

68

Water-rights not ~~to be~~ transferable, except by sanction of Trusts.

~~74.~~ No person supplied with water by any Trust shall have a right to tranfer such supply or any portion of it without the sanction of the Trust. In all receipts for water-rates paid to Trusts, and in all papers and documents referring to rates, a note shall be entered that the said water-rights are not transferable except with the ~~sanction~~ of the said Trust.

69

Water supplied by Trusts to be used only in manner sanctioned.

~~75.~~ All supplies of water provided by local Trusts shall be delivered subject to this Act and to the by-laws ; and no person shall have a right to convey or use such water in a wasteful manner different to the terms and regulations ordered in this Act, and prescribed by the said Trust with the sanction of the ~~Board.~~

minister

and all such

Governor.

By-laws must be approved by the ~~Board.~~

~~76. The by-laws proposed for the regulation of details under Trusts must in every case receive the sanction of the Board before they can be put in force.~~

6

Right-of-way for water.

70

7~~7~~. Any Water Trust may acquire by purchase or lease a right-of-way for water through any land, whether it belong to private individuals or to corporations or to ~~Government.~~ If a right-of-way for a drain or distributary or channel of any kind be required by any person from any Trust, or from the ~~Board,~~ to enable him to obtain a supply of water, or for the purposes of drainage, the Govern~~ment~~ may, on the recommendation of the ~~Board~~, resume a right-of-way for such water-supply ; and the rules under which compensation is regulated for any land resumed for works carried out by the ~~Board,~~ or by Trusts, shall apply to all waterways and lands for the passage of water so resumed.

the Crown

minister

minister

minister

7 71

7~~8~~. Under no circumstances shall the passage of water through the land of any owner, occupier, or lessee confer on such owner, occupier, or lessee any right or title or vested interest in such water.

72

Trusts not liable for failure of supply.

7~~9~~. If a Trust in charge of the administration of any canal, channel, or water-supply ~~of any kind~~ fail to furnish the established quantity of water, or the quantity required by the user of any watercourse or irrigation channel, the said Trust shall not be liable for any damage so arising,

NOTES AND EXPLANATIONS.

70 and 71. These sections further define and limit the powers which may be delegated by the Board to Trusts.

Powers conferred on Trusts.

72. The principle of this section, regarding the power of Trusts to deal, on their own responsibility and in anticipation of the sanction of the Board, with works of emergency, is borrowed from the Spanish Law of Waters, which has a corresponding clause.

Power of Trusts in cases of emergency.

73. It is here intended that these by-laws should include rules suitable to the Trust District in which they are in force. It is anticipated that entirely different conditions will exist in different Trusts, and the course proposed is to have a comprehensive Act which will include all, while the by-laws framed in accordance with this Act will suit each individual case.

Intention of by-laws.

74 and 75. Unless the Government maintain complete control over the water-supply, vested interests of a troublesome nature are certain to be acquired. It is also necessary not only that the quantity supplied to every person shall be decided by the Trust, but also that the means and method of using the supply shall be approved. On this point the practice in India, and particularly in the North-west Provinces, is very stringent, and it is the immediate result of experience derived from Southern Europe. In the case of the Lower Ganges Canal, one of the most recently constructed in India, the greatest care was taken in fixing the position of irrigation outlets; the nature of the soil, the inclination of the ground, and the general features of the neighbourhood being in every case taken into account. No outlet was allowed where the water would run through soil impregnated with salts, nor where there was likely to be much loss by percolation.

Necessity for Government to maintain complete control over the water-supply.

76. This rule requires no comment.

77 and 78. In connection with the distribution of water for irrigation and other purposes, one of the most important points is to secure the right to obtain a passage for water through any land between the source of supply and the place where the water is to be used; it is necessary to guard against the chance of individual caprice or ill-will being allowed to prevent the execution of useful work. It should be remarked that it is specially provided that the Water Trusts, and not the individuals directly interested, acquire the strip of land or right-of-way required for a channel. It is specially intended by this arrangement that the public interest and property in the water should be secure in every detail.

79. Provision is here made against liability for damages in case of failure of the supply. The Trusts are left responsible for damage done by any neglect of their members.

73 if ~~such~~ failure of the supply was due to causes beyond the control of the said Trust.

Right-of-way for water across roads.

74. ~~80~~. The right-of-way for water, as described in section ~~67~~, applies also to the right to cross public or private roads and public or private watercourses. 76

74

Bridges or culverts to be built at road-crossings.

~~81~~. Wherever it is necessary to construct a canal or channel of any kind, or to divert a supply of water across any road or watercourse, a suitable bridge or culvert or ~~any~~ other means of crossing without hindrance to the traffic on the said road must be constructed.

75

Water to be sold by measure.

~~82~~. In the ~~management~~ of water-~~supply~~ every Trust shall, as far as practicable, sell ~~the water~~ by measurement. The appliance for or means of measurement must be approved by the ~~Board.~~ minister

76

Regulations for economical use of water.

W.S.

~~83~~. Wherever water for irrigation is not sold by measure, the Water Trust shall have power to regulate ~~in its by-laws~~ the manner in which the land ~~proposed~~ to be irrigated shall be prepared for cultivation, and the manner in which water ~~is~~ used for mining and manufacturing purposes. ~~approved of the Minister and the~~ Governor,

77

Power of Trusts to fix rates.

~~84~~. Subject to the sanction of the ~~Board~~, every Trust shall have power to fix rates for water supplied, or ~~on account~~ of land benefited by drainage works. The rates for water shall ordinarily be of three kinds: first, for domestic use and for watering stock and washing ~~stock~~; Sheep second, for irrigation; third, for power. In addition to these rates, Trusts may fix a rate per acre on land benefited by drainage works; and ~~Trusts may~~ also, when measurement of water for irrigation is not practicable, fix rates per acre for different kinds of crop grown. Also, where it is not practicable to measure water used by stock, a Trust may fix rates for every kind of stock to which water is supplied.

Regulations to be observed in fixing rates.

PART V.—LOANS—~~HOW SANCTIONED, INCURRED, AND REPAID.~~

78

Procedure when a loan is required by a Trust.

~~85~~. Whenever ~~the representatives of~~ a Water Trust desire to raise money on loan for the construction of any works for water conservation or drainage, such Trust ~~representatives~~ shall make application ~~to Government, through~~ the ~~Board,~~ Minister setting forth in their application full particulars regarding the nature and extent of the works proposed, and of the land to be benefited.

~~79~~

Inquiry previous to sanction of loan.

Minister

~~5. 86~~. After a full inquiry regarding the statements contained in such application, the ~~Board shall report to the Government~~, and shall make such recommendations respecting the said application as ~~it~~ he may deem just.

79

Power of ~~Government~~ to grant or guarantee loans.

~~6. 87~~. On receipt of such application and recommendation, the Govern~~ment~~or may temporarily advance funds to such Trust, or ~~it~~ may sanction the raising of a loan by the said Trust, and may guarantee the payment of interest on such loan.

80

Trusts prohibited from raising loans without ~~sanction.~~

~~7. 88~~. It shall not be lawful for a Water Trust constituted under this Act to obtain money on loan from any source, or for any purpose, without previously obtaining the sanction of the Govern~~ment~~or.

81

Security on which loans can be raised.

~~8. 89~~. Loans required by Water Trusts shall, when sanctioned, be raised on the security of the rates leviable on the lands benefited, or to be benefited, by the works carried out, or proposed to be carried out, or on the security of the lands and works belonging to such Trusts.

NOTES AND EXPLANATIONS.

80 and 81. The necessity for these clauses is obvious.

82, 83, and 84. The necessity and importance of the first and last of these clauses is evident. In the case of section 83, it may be explained that careless cultivation is one of the most fruitful sources of waste of water in irrigation. It is necessary therefore to provide some check on the manner in which the water is used. In India the land for irrigation has to be divided into rectangular plots, the areas of which are fixed by local regulations.

— Shall be

Notes and Explanations regarding Part V.

Sections 85, 86, and 87, conferring powers to raise loans for carrying out works for water conservation, or for drainage, are intended to ensure that loans will be sanctioned only for works which may be depended on to prove satisfactory.

— Shall lay a report before the Public Works Committee

^ with the approval of ~~the Public Works Committee~~ Parliament

Section 88 is in accordance with the Municipalities Act of this Colony, which directs (clause 190) that "no money shall be borrowed except with the sanction of the Governor." Municipalities Act of 1867.

Section 89 is almost identical with clause 29 of the Victorian Water Conservation Act of 1883." Act 778 of Victoria, 1883.

82 Purposes to which rates are to be devoted.

89. ~~90.~~ Wherever a Trust has carried out works with the aid of a loan, the rates levied by such Trust from the persons benefiting from such works shall be used as follows—that is to say :—

(*a*) For payment of interest of the loan.

(*b*) For the maintenance, repairs, and management of the said work.

(*c*) To contribute to the sinking fund.

(*d*) For the useful extension and development of the works.

83 Limit to the total amount of loans.

Minister

Minister

0 ~~91~~. When ~~the representatives of~~ any Trust make~~s~~ application for a loan, or for permission to raise a loan, and furnish to the ~~Board~~ the information required in this Act regarding the nature and extent of the land to be benefited, the ~~Board~~ shall cause an estimate to be made of the value which such land and other property will possess on the completion of the proposed works. The total amount of the liabilities of a Trust shall not be permitted to exceed two thirds of the enhanced value thus estimated, w~~hich the land and other property benefited will possess on the completion of the works for which the loans are raised.~~

84 Change of names or boundaries of Trusts not to affect agreements.

1 ~~92~~. If, ~~after due consideration,~~ and ~~with the sanction~~ of the Govern~~ment~~ or, the boundaries of any Trust District, or the name of any Trust be altered, no bond, mortgage, or agreement entered into by such Trust previous to such alteration shall be rendered invalid or shall be in any way affected by such alteration.

85 Points to be specified in applications for loans.

2 ~~93~~. In every application to the Govern~~ment~~ or for a loan or for permission to raise a loan Local Trusts shall specify the rates proposed to be levied by them, the rate of interest to be paid, the amount which will annually be credited to a sinking fund, and the number of years for which the loan is required ; and in no case shall the Government have power to grant or authorize a loan unless the proposals on all these points are deemed satisfactory.

86 Borrowing in excess of amount sanctioned—how dealt with.

3 ~~94~~. If, in contravention of this Act, any Trust shall borrow money without the sanction of the Govern~~ment~~ or, or in excess of the amounts sanctioned by the Government, all the members of such Trust who have consented to the borrowing of such money shall be jointly and severally liable to pay the same, together with all interest thereon, to the persons from whom the same was borrowed, and the same may be recovered from such members in any Court of competent jurisdiction ; but in no case shall such moneys be recoverable from the Trust District ; and if any appropriation of moneys belonging to the Trust be made for the purpose of liquidating any claim for money so borrowed, such members of such Trust who have consented to the misappropriation of money for that purpose shall be jointly and severally liable to refund the same and all interest thereon, and the same may be recovered from such members of such Trust, or any of them, and may be sued for by any ratepayer of the Trust District.

87 Separate accounts to be maintained for every loan.

Minister

him

the Minister

he

4 ~~95~~. Every Trust shall keep a separate account for every loan incurred by it, and such accounts shall at all times be accessible to the ~~Board~~ or to any officer deputed by ~~the Government~~ to inspect them ; and copies or abstracts of such accounts shall be submitted to ~~Government in~~ such manner and at such times as ~~Government~~ may direct.

88 Misappropriation of loans.

5 ~~96~~. Under no circumstances, except by the sanction of the Govern~~ment~~ or previously obtained, shall any Trust apply any portion of a loan to a purpose other than that for which the said loan was raised ; and if, in contravention of this Act, any Trust mi~~r~~appropriates a loan or any portion of it, the members of such Trust who consent to such misappropriation of funds shall be jointly and severally responsible for the repayment of such funds, together with interest, as described in section 9~~1~~3.

NOTES AND EXPLANATIONS.

Section 90 is similar to clause 60 of the Victorian Act last quoted.

Section 91 contains an important principle regarding the manner in which the maximum amount which a Trust may be allowed to borrow should be estimated. There are cases in which works for water conservation would raise the value of land tenfold, and it would clearly be short-sighted in such cases to estimate the borrowing powers of a Trust on the basis of present value. The justice of the principle of fixing the maximum borrowing powers of local bodies according to the enhanced value anticipated as a result of proposed works has already been recognized by the Crown Law Officers of this Colony.

Section 92 is based on provisions made in the most recent amendment of the Victorian Water Conservation Act for the effect of changes of names of Trusts.

Act 829 of 1884—Victoria.

Section 93 is intended to indicate the points connected with the financial prospects of any project which a Trust will be required to prove satisfactory before a loan can be sanctioned.

Section 94 is almost identical with clause 57 of the Victorian Water Conservation Act of 1883, and its importance is obvious.

Act 778 of 1883—Victoria.

Sections 95 and 96 are based on clause 54 of the Act last quoted.

— [illegible]

PART VI.—DRAINAGE WORKS.

Powers granted regarding water conservation to extend to drainage.

89 6 ~~97~~. The powers herein conferred on the ~~Government~~ minister and on Local Trusts to enter on, survey, and resume lands, and to undertake, construct, and maintain works for the conservation and distribution of water, shall also extend to projects and works for the drainage of land.

Procedure regarding drainage works.

90 7 ~~98~~. Whenever it shall appear to the ~~Board~~ minister or to a Water Trust that works for the drainage of any land are required in the interests of the public, the ~~said Board~~ minister or the members of the Water Trust within whose district such land is situated may, with the sanction of the Governor ~~Government~~, proceed to make investigations and to prepare surveys, designs, and estimates for such works, in the manner herein described in connection with works for water conservation. The ~~Board~~ minister or the said Water Trust may also construct such works, and for this purpose may levy rates and raise loans.

Project to be submitted to the ~~Central Board~~. minister

~~99~~ 8 ~~99~~. Before a Trust can be permitted to carry out any drainage work, a statement must be furnished to the ~~Board~~ minister showing the nature and extent of the land which will be benefited by the proposed works, and setting forth clearly the value of such land and the extent to which it will be benefited. This statement of the anticipated results of the proposed works, together with the plans and estimates, must be approved by the ~~Board~~ Minister before such works can be sanctioned.

Assessment of rates.

~~99~~ 91 99 ~~100~~. In assessing rates on lands benefited by drainage works ~~the members of Water~~ Trusts shall be guided by the ~~proportionate extent of~~ the increase in value due to such works.

Combined drainage and water conservation works.

92 ~~100~~ ~~101~~. Wherever drainage works are constructed by the ~~Board,~~ Minister or by a Water Trust, the drainage water thus made available shall, as far as practicable, be conserved and utilized; and no ~~designs~~ for drainage works shall be sanctioned unless the conservation of the drainage water is considered fully, and as far as practicable provided for.

Assessment on combined works.

93 101 ~~102~~. When drainage and water conservation are provided for in the same project, the rates for such works shall be assessed both on the lands drained and on the lands benefited by the water-supply so provided.

Works aided by loans to be subject to Government sanction.

94 02 ~~103~~. Drainage works proposed to be carried out with the aid of loans must be first sanctioned by the Minister ~~Government~~, and must be subject to Government inspection and approval.

Projects for water conservation to be considered in relation to their effect on drainage.

95 03 ~~104~~. When any project for irrigation works, or for works for water conservation, is submitted to the ~~Board~~ minister by a Local Trust, the ~~Board~~ he shall consider such project in relation to its bearing on drainage; and if it shall appear to ~~the Board~~ him that such project should, either on sanitary grounds or to prevent injurious effects to the land, include provisions for a system of drainage, ~~the Board~~ he shall require that such provision shall be made in the design and estimate for the proposed works.

Tail-water from mines and manufactories.

96 04 ~~105~~. When ~~the use of~~ a supply of water for mining or manufacturing purposes is granted by any Trust, such ~~use~~ supply shall in all cases be subject to the provisions of this Act in regard to waste or ~~to~~ use in a negligent manner; and every person using ~~a supply of~~ water for mining or manufacturing purposes shall be required to make such arrangements as will render such supply of water available for ~~further uses~~ other purposes as far as it is practicable to do so.

NOTES AND EXPLANATIONS.

Notes and Explanations on PART VI.

Sections 97 and 98 are intended to confer the same powers in regard to drainage works as those already conferred in regard to works for water conservation.

, as hereinbefore set out in the manner for works of Water Conservation & utilization

Sections 99 and 100 involve precisely the same principles as have already been provided for in the case of water conservation.

, as hereinbefore described in Sec 85 & 86.

Sections 101, 102, and 104 are intended to meet a well-known objection to irrigation. Most opponents of irrigation, and even some of its advocates, lay down the rule that no irrigation works should be undertaken without provision being at the same time made for drainage. If this system were strictly carried out, there would be few irrigation works attempted. While it may safely be stated that, as a general rule in this Colony, irrigation works will not involve a necessity for systems of drainage, still it is necessary to provide against the possible evil effects of injudicious irrigation. Another important point for which these sections are intended to provide is that the drainage of some of the great swamps, which form evaporation pans in which valuable supplies of water are lost, should be carried out in such a manner as to render these supplies available for use. It is hoped and expected that works of this nature will, so far as drainage is concerned, be the most important which Local Trusts will undertake.

Section 103 applies to drainage works a rule already laid down in connection with works for water conservation.

Section 105 is one of great importance, and is intended to provide against evils such as have arisen in California through the unregulated use of water for hydraulic sluicing. Under this section Local Trusts will also have the power to regulate the disposal of impure water escaping from manufactories.

PART VII.—NAVIGATION.

Trusts to regulate navigation within their own districts.

106. When the whole or any portion of a navigable river is situated within the bounds of a Trust District, the Government may, on the recommendation of the Board, delegate to such Trust the authority to regulate the navigation within such district.

Authority of Trusts to carry out projects or works for navigation.

107. In pursuance of this authority, any such Trust may make surveys, designs, and estimates for works connected with the improvement of navigation, and may for such purposes exercise the same power and authority as herein authorized for projects or works for water conservation.

Navigation to be provided for as far as advantageous.

108. In all cases where works for water conservation and supply interfere, or are likely to interfere, with the level or flow of water in any river, the requirements of navigation may be provided for, so far as this can be done, without detriment to the interests of water-supply and irrigation.

Regulations for preparing navigation projects to be similar to those for water conservation.

109. The regulations hereinbefore ordered for the preparation of projects and for the carrying out of works connected with water conservation and supply shall, so far as they are applicable, extend to projects and works connected with navigation.

Power of Trusts to levy navigation rates.

110. Subject to the sanction of Government, and for the maintenance or improvement of any river or other navigable channel, any local Trust constituted under this Act may levy rates from any person using such river or channel for the purpose of navigation.

Power to detain a vessel till rates are paid.

111. Any Trust possessing jurisdiction over any navigable river or channel shall have power to detain any vessel, boat, raft, or other floating body, till the authorized navigation rate on such vessel, boat, raft, or other floating body, together with the expense of such detention, has been paid.

Sanction required before levying rates.

112. Before rates for navigation can be levied or altered by any Trust the sanction of Government must be obtained.

Trusts not responsible for failure of supply.

113. No Trust shall be held responsible for any damage which may be caused through failure of the supply of water in any river or navigable channel.

Power to raise loans for navigation.

114. Loans for the improvement of navigation may be raised under the same restrictions and subject to the same conditions as are hereinbefore described for works for drainage and water conservation.

Conference of Trusts on matters of common interest.

115. When the whole length of a navigable river or channel is not within the jurisdiction of one Trust, the members of every Trust through whose district such river or channel passes shall have the power to appoint one or more of their number as a deputation to confer with a similar deputation from every other such Trust. At such conference a combined system of management of such river or channel may be arranged, and other matters of common interest to such Trusts may be settled; but all such arrangements and settlements must be ratified at a meeting of every such Trust, and must receive the sanction of the Board before such arrangements or settlements can be acted upon.

NOTES AND EXPLANATIONS.

Notes and Explanations on PART VII.

India—Act VIII of 1873.

Absence of guiding enactments.

For reference, in the preparation of this portion of the Bill, almost the only available information of a useful description was that contained under the heading of "Canal Navigation" in the "Northern India Canal and Drainage Act." Even this authority could be adopted to only a very limited extent, the circumstances of the country being entirely different to those of India, and the proposed administrative machinery being still more widely different. Hence, in framing this portion of the proposed Bill, it was necessary, in the absence of guiding enactments, to consider the various questions most likely to arise in the management and development of navigation, and to meet the requirements of every case by suitable regulations. While the attainment of this object has been held in view, it follows, from the circumstances of the case, that authorities cannot be quoted in support of the enactments proposed.

97 –
Insert clauses for
~~promotion~~ encouragement of private
enterprise –

PART VIII.—OFFENCES AND PENALTIES.

101

105 ~~116.~~ Whoever without proper authority and voluntarily does any of the following acts, that is to say :—

Obstructing Government or Trust Officers.

(*a*) Obstructs, in any way, any person ~~in the employment of a local Trust, or of Government, or of the Board,~~ when such person is acting under the authority of ~~the said~~ Trust, or of ~~the Government~~, or ~~of the Board~~ :

a local

the Minister

Interfering with marks.

(*b*) Removes, injures, or in any way interferes with any pegs, bench-marks, or other marks, or objects for reference, placed in the execution of his duty by any person employed in pursuance of this Act, in making surveys, levels, or other investigations in connection with any work or project for water conservation or for drainage :

Depositing material on land belonging to Government or to a Trust.

(*c*) Deposits material or refuse of any kind within the bounds of any land resumed or otherwise required for any work of water conservation or drainage :

Polluting water.

(*d*) Pollutes or renders less useful the water standing or flowing in any river or drainage work or work for water conservation :

or maintained

or by the Crown

(*e*) Interferes with the supply or flow of water in any river, creek, stream, or lake managed by a Trust, or causes injury to fences, works, land, or any other property held or managed by a Trust : or by the Crown

or maintained

Penalty.

shall for every such offence be liable, on conviction before a magistrate, to a penalty not exceeding twenty pounds, or to imprisonment for a term not exceeding three months; and every such offender shall be liable to a further penalty of ten pounds for every day during which such offence is continued after such person has received notice, in writing, to discontinue the same.

162

Wilful injury to works.

106 ~~117.~~ Any person who wilfully damages or obstructs any work for water conservation or for drainage, and any person who, without proper authority, interferes with the supply or flow of water in or from any work constructed or maintained under the provisions of this Act, shall for every such offence be liable, on conviction, to imprisonment for a period not exceeding ~~three years~~, or to a fine not exceeding ~~five hundred~~ pounds, or to fine and imprisonment combined within the limits here ordained.

blank

blank

163

Waste of water.

107 ~~118.~~ Any person who being responsible for the proper use and management of a supply of water, subject to the provisions of this Act, neglects to take proper precautions for the prevention of waste of the water thereof, or interferes with the authorized distribution therefrom, or uses such water in an unauthorized manner, shall for every such offence be liable to a penalty not exceeding ten pounds or to imprisonment for a term not exceeding one month.

164

the

108 ~~119.~~ The penalties directed under last section for the wilful or negligent waste of water shall apply to ~~the~~ water-rights acquired under the "Mining Act of 1874" or under any other Act or regulation in force previous to the passing of this Act.

NOTES AND EXPLANATIONS.

Notes and Explanations on PART VIII.

Section 116 is framed on the model of Part X of the Northern India Canal and Drainage Act, but departs from it in some important particulars. In the Victorian Water Conservation Act of 1881 the penalty for letting foul water into any stream or reservoir belonging to a Waterworks Trust is limited to five pounds and a further penalty of twenty shillings for every day on which the offence is continued. In the New Zealand Counties Act Amendment Act of 1883 the corresponding penalties for the same offence are one hundred pounds and ten pounds per day. The penalty now proposed lies between these, and appears adequate to meet such offences.

India—Act VIII of 1873.
Victoria—Act 716 of 1881.

New Zealand—Act 36 of 1883.

Section 117 deals with a much more serious offence than the foregoing, namely, that of wilful damage to works. In the Victorian Act, above mentioned, this offence is classed as "a felony," and the maximum punishment is imprisonment for ten years. In the New Zealand Act, quoted above, this offence is termed "a misdemeanor," and the offender is declared liable to imprisonment for three years or to a fine of five hundred pounds, in addition to paying the cost of repairing the damage done.

Victoria—Act 716 of 1881.

New Zealand—Act 36 of 1883.

Section 118 is based on the Spanish Law of Waters and the Northern India Canal and Drainage Act. The principle has already been dealt with under Part II.

Spanish Law of Waters.
India—Act VIII of 1873.

Section 119 is based on the principle enunciated in Part II, that no one has a right to waste water obtained by him from any public river, lake, or other source, whether natural or artificial. This principle is acted on in India, and also in Italy and Spain; and certainly none of those countries calls so much for stringent regulations regarding the waste of water as this Colony does.

105

Compensation to injured parties.

09. ~~120.~~ Whenever any person is fined under this Act the magistrate may direct that ~~the whole or any part~~ of such fine may be paid by way of compensation to the person injured by such offence.

one half

106

Offenders liable to pay compensation as well as penalty.

10. ~~121.~~ Any person offending against this Act may be sued for compensation on account of the damage incurred or sustained through his offence ; and this liability for the loss and damage caused will not in any way mitigate or affect the concurrent liability to punishment for the said offence under the terms of this Act.

107

Offenders liable to punishment under other Acts.

11. 122. Nothing herein contained shall prevent any person from being prosecuted under any other law for any offence punishable under this Act : Provided that no person shall be punished twice for the same offence.

108

Careless navigation.

12. 123. Whoever causes any vessel, boat, raft, or other floating body to enter or navigate any river or other channel contrary to the rules and regulations for the time being which have been sanctioned by the Government, and whoever while using a river or other channel for the purposes of navigation neglects to take proper precautions for the safety of such river or channel, or of his vessels, boats, rafts, or other floating bodies, shall for every such offence be liable to a penalty of twenty pounds or to imprisonment for one month, and shall in addition be liable for the value of the damage caused by every such offence.

113. Regulations to have the power etc

NOTES AND EXPLANATIONS.

Section 120 is adopted from the Indian Canal Act. India—Act VIII of 1873.

Section 121 is in accordance with the general practice of legislation on such points, and is identical in principle with section 93 of the Victorian Water Conservation Act of 1881. Victoria—Act 716 of 1881.

Section 122 is adopted from the Indian Canal Act. India—Act VIII of 1873.

Section 123 is also based on the Indian Canal Act. India—Act VIII of 1873.

(12.) CONCLUSIONS AND RECOMMENDATIONS.

LEGISLATION AND RIPARIAN RIGHTS.

While the Draft Bill already given embodies in detail the principles which, in our opinion, legislation should include, and on which it should be based, the following may be taken as a brief summary of our opinions on this most important branch of the question.

State ownership.

We are of opinion that the most simple, and at the same time perfectly equitable plan, to get rid of the mysterious complications of the common law so far as riparian rights are concerned, is for the Legislature to establish the ownership of the State over all rivers and watercourses, giving to the owner of the land the right to conserve the rain which falls upon it, but not the right to intercept the water of streams or springs which naturally flow through it except by legal sanction. The 30th Article of the Spanish Law of Waters enacts that there belongs to the owner of an estate the rainwater which falls or is collected on it while passing through it. He may in consequence construct within his own property cisterns, tanks, ponds, or reservoirs to preserve it, always providing he does not injure the public or third parties.

Works to be carried out by Local Boards.

Although we attach the greatest importance to ownership by the State of all rivers, watercourses, and lakes, we do not think that, as a general rule, it would be wise that the Government should itself undertake the works which would be necessary to supply the country with water. Having obtained full and indubitable power to carry out al. works which may be necessary, and to dispose of the water as may be deemed expedient, we think that the State ought to delegate its powers (with certain limitations) both as to construction and management of works to those whose interests are immediately concerned.

The right to construct overshot dams.

The question of the right to construct overshot dams in creeks and rivers is one which has given rise to litigation, and which is still in a very unsatisfactory state. Owners or occupiers of land adjoining creeks and rivers have, as the law now stands, no right to obstruct the flow of running water, or to erect a dam of any kind. The natural consequence of this state of affairs is that both pastoral and farming interests have been seriously interfered with. The opinion at which we have arrived is, that the privilege of erecting dams, as well as the limits of their heights, and the general nature of their design, can be best decided by local Trusts, composed of persons interested in the creeks or rivers in which such dams are proposed to be constructed. In the draft of the proposed Bill we have, therefore, given ample powers to Trusts to deal with all such questions. In the absence of a local Trust the regulation of the heights of dams, as well as the decision of all other questions relating to water conservation and supply, will rest with the Board which we propose.

Schemes to be controlled by elective bodies.

Inasmuch as the expenditure upon water-supply within any particular district must be mainly borne by the landowners within that district, we are of opinion that the initiation and control of schemes necessary to accomplish the end in view should as far as practicable be vested in bodies to be elected by those who would have to pay the rates and who would reap the benefits. These representative bodies might be the members of local governing Boards, or they might be distinct and separate Water Trusts, such as exist in Victoria, and as described in our Secretary's Report, appended. It is obvious that the residents of a district are better able to judge of their own requirements than any governmental or official authority at a distance; and, so long as care is taken that they shall pay a large proportion of the cost of what they require, they will themselves apply the most effective checks upon neglect, extravagance, and incompetence.

Appointment of permanent Board.

For the general management of the water-supply of the Colony, and the supervision of its administration by Local Trusts, we believe that a permanent Board should be appointed, and that this Board should have power to deal with the construction or management of necessary works in cases which are beyond the capabilities of Local Trusts.

Department under a Minister for Water Supply.

In order that the interests of water conservation and supply may receive in Parliament the attention which they deserve, we are of opinion that a separate Department, under a responsible Minister for Water Supply, should be established.

Professional Staff.

While we do not think that it would, except in the case of head or other extensive works, be expedient for the Government to undertake the construction of works for water-supply to rural districts, still we are of opinion that it would be absolutely necessary that Government should maintain a small staff of highly skilled engineers, who would be competent to advise them upon the merits of any scheme proposed by the residents of a locality in connection with their application for a loan; and, in the event of the scheme being approved, to periodically inspect and report upon all important works while being carried out under the supervision of the engineer employed by the Local Board or Water Trust, as the case might be. It is important that the Government should have such advice, for several reasons, but principally because without it they would not have the information which would enable them to decide equitably upon conflicting applications, or to ensure that the water available for the supply of a certain area of country was not monopolized by the residents in a particular portion of it; they would not be able to deal satisfactorily with the claims and interests of conterminous Trusts drawing their supply from the same source; they would not have an assurance that, as acting for the whole country in authorizing the allotment of portion of a loan and Parliamentary grant, the works proposed were sufficiently stable and valuable to the general community to justify the expenditure; nor would the particular district more immediately interested have so good a guarantee of the soundness of the scheme propounded by their own engineer as they would have after that scheme had been checked and indorsed by independent and perhaps more highly skilled engineers.

Finance.

We advise that legislation authorizing the making of loans by the Government to Trusts should provide—

(1.) For the taking of a mortgage over the works and revenues of the Trust to whom the loan was granted.

(2.) For the levying by the Trust of a rate sufficient to pay, as a first charge, *(a)* the interest stipulated in the mortgage; *(b)* sinking fund, say at the rate of 1½ per cent. per annum, for the liquidation of the principal sum; and *(c)* for the maintenance of the works in a good state of repair.

(3.) For the Government being required to levy and collect such rate in the event of failure, from any cause, of the Trust to do so.

(4.) For an annual audit of the accounts of the Trusts, so long as they remained in the position of debtors to the State.

Loan for Water Trusts.

The Government of Victoria initiated their system in 1881 by raising a loan of £400,000, which amount has been lent at 4½ per cent. to different Water Trusts upon the security of their works and revenues, in sums proportionate to the character of the works to be constructed, and Parliament appropriated a further sum of £100,000 as a free grant to the Trusts. The allotment of this subsidy is dependent upon the magnitude of the works undertaken by the Trusts, and is intended to act as an incentive to localities to enter upon water schemes. The area of New South Wales being larger, its population sparser, and the extent of unalienated land being greater than it is in Victoria, afford reasons why the amount of the Parliamentary grant should be larger than that of the sister Colony. The loan would be for the construction of specific works, to confer a direct pecuniary benefit upon those who undertake them, and not of the continuing, fluctuating, and general character of municipal expenditure ; hence a grant in aid seems to be better adapted to meet the requirements of the case than would an annual endowment.

Publicity.

Provision should be made for the utmost publicity being given to all applications for the formation of Water Trusts and for loans to carry out works, and they should be dealt with by the Government only after opportunity had been given to all persons or communities whose interests might be affected to state their objections, in the same way as has always been customary at the inception of new municipalities. In fact, presuming the Water Trust to be a body distinct from the local governing body, all the machinery under which they would act might be almost identical with that established under a Local Government Bill, *e.g.*, the municipal valuation might be used for assessing rates on property.

Head-works.

It may be found that two or more districts would derive their supply from the same source, and that the head-works necessary to provide it would be beyond the means of any, and perhaps of all, to accomplish.

Union of Trusts.

In view of this by no means improbable contingency, we suggest that power should be given for the union of one or more Trusts; and it might perhaps even be expedient that the Government should construct the head-works required, where these are of exceptional magnitude and difficulty, and to apportion the rate of contribution by each Trust using the water according to the extent to which it would be benefited.

Urban and Irrigation Trusts.

It would be desirable and necessary that provision should be made for the subdivision of any Trust area, so as to allow an urban population devising and carrying out a scheme of water-supply as a separate Trust, or of a community of farmers forming themselves into an irrigation Trust. The requirements of such classes as these are distinct from those of a rural population, and it is obviously just that those who need a special service should pay for the benefits which they exclusively receive, or are capable of receiving. With regard to town supplies, the Engineer-in-Chief for Harbours and Rivers, says (Q. 1117) :—" I think it would be a very good thing if the Government were relieved of a great deal of the work now thrown upon them. I think, for instance, that the water supply to country towns ought to be carried out by the local municipalities, and that the Government should be relieved of the duty of carrying them out."

IRRIGATION.

While the evidence which we have obtained on the subject of irrigation is contradictory, as might be expected from the very limited experience in this Colony of the expense and effects of irrigation, still we have carried our investigations so far as to enable us to arrive at the following important conclusions:—

(1.) That on the alluvial plains extending along the courses of the rivers west of the Dividing Range irrigation of crops can be profitably carried out by pumping.

(2.) That flood-water can under favourable circumstances be profitably used for the irrigation of the natural grasses.

(3.) That the soil throughout the Western Plains is, as a rule, eminently suited for raising crops by irrigation.

(4.) That as evidence has been given of large purchases of hay by pastoralists during past years, it is evident that irrigation would increase settlement on the land by making farming on a moderate scale remunerative.

(5.) That by the irrigation of comparatively insignificant areas of lucerne or other crops for hay or ensilage the preservation of stock throughout periods of drought can be ensured.

(6.) That under average circumstances the irrigation of 100 acres of lucerne for every 20,000 acres of pastoral land would afford complete protection against drought.

(7.) That owing to the small available supply, the general dryness of the climate, the absorbent nature of the soil, and the long distances which water will in many cases require to be conveyed, great attention should be given to the economical distribution of the water; and for this purpose we trust that it will be found practicable to make extensive use of pipes, whether of iron or of earthenware, or of some such composition as asbestine.

AGRICULTURE.

Destruction of forests to be under control.

Irrespective of their commercial value, forests render important service in reducing the temperature in their neighbourhood, in moderating hot winds, in increasing the humidity of the atmosphere, in protecting the soil from erosion, and in diminishing the rate of evaporation from the surface of the land or water near them, and we therefore think that the destruction of forests should be under strict and judicious control.

Agricultural irrigation farms.

Agricultural farms established by Government in a locality having command of water for irrigation would probably be very valuable, not only as a means of educating youth in practical and scientific husbandry, but also as affording an example to the agricultural community of the advantages which wet cultivation possesses over every other description of farming. The experience which would soon be accumulated with respect to the returns from various kinds of crops under irrigation as compared with ordinary dry tillage would be of very great value.

DRAINAGE AREAS.

Coast River Basins.—Although we have taken no evidence regarding the coast districts, the papers placed at our disposal convince us that the question of irrigation in some at least of the coast river basins has up till the present remained in abeyance, simply because the farmers and fruit-growers did not fully understand the benefits which irrigation would confer, and which are so well illustrated in results obtained in the coast districts of Southern California. The best methods for the improvement of the productive capabilities of the coast districts should in our opinion be fully inquired into, and means should be taken, either by lectures in connection with the Board of Technical Education or otherwise, to make known as widely as possible the importance of irrigation as an aid to production.

Basins of the Snowy River.—The evidence we have obtained tends to show that, in the volume and regularity of its discharge, the Snowy River is one of the most important rivers in the Colony. We are of opinion that it would be a great advantage to this Colony if a portion of the waters of the Snowy River were diverted into the Murrumbidgee, and we have initiated the investigation of the practicability of such a project, but are not yet in a position to come to a decision regarding it. This Colony occupies the same relative position in regard to the upper portion of the Snowy River as the Colony of Victoria holds in regard to the Mitta Mitta, Goulburn, and other tributaries of the Murray.

Basins of the Billabong Creek and Murray and Murrumbidgee.—The Compilations of levels made by our instructions have shown clearly that, in the plains between the Murray and Murrumbidgee, the country slopes from the Murray towards the north-west, and from the Murrumbidgee towards the south-west. This conformation of the country is so favourable for the diversion of supplies from these rivers that the question should in our opinion be dealt with in detail as soon as possible. The discharges of the Murray and the Murrumbidgee should be measured twice every year—once while the snow-water is flowing, and once while the rivers are low. We are of opinion that the creeks and ana-branches should be utilized as far as possible as distributaries, and in our opinion the practicability of such work is so assured as to warrant the commencement of surveys without delay. Being convinced that in addition to the intermittent canals suggested above, permanent canals can be constructed and supplied from the Murray and the Murrumbidgee, we recommend that the surveys required to determine the financial practicability of such canals should be undertaken. The storing of water near the heads of the basins of the Murray and Murrumbidgee, and the diversion of a supply from the Upper Murray, are questions which have come under our attention. We have not yet been able to complete our inquiries regarding them.

Drainage Areas of the Mirool and other Creeks, Basin of the Lachlan and Manara County Drainage Areas.—We recommend that, with a view to conserving and utilizing the flood-water of the Lachlan, that river should be carefully surveyed and levelled. All rocky bars should be noted, and the general character of the bed and banks of the river should be recorded. Surveys should be made and levels taken along the courses of the Booberoy, Willandra, and Merrowie Creeks, on the north side of the Lachlan, and of the Island and other Creeks on the south side. The survey should, in the first instance, include the Lachlan from Cowra to the junction with the Murrumbidgee.

Basin of the Darling and its Tributaries, the Bogan, Macquarie, Castlereagh, Namoi, and Peel.—Water conservation is a work of vital importance for the development of the whole Darling Basin, so that the practical question to decide is in regard to the places where such works are most urgently required. We are of opinion that the Gwydir is the first affluent of the Darling which calls for Government interference. That river should be surveyed, and levels should be taken along its course and thence by the Darling to Walgett. The Great Ana-branch should be included in this survey, the object of which would be to determine the best method of utilizing the flood-waters, and of satisfying the requirements of the riparian proprietors. Next after the Gwydir, the Namoi and the Macquarie require to be similarly surveyed and examined.

Yantara County and Tara County Drainage Areas.—In the west and north-west of the Colony, the work being done by the Roads and Bridges Department, in providing supplies of water for travelling stock, is a most important and necessary step towards a system of water conservation. More than is being thus done we think the circumstances of the country would not at present warrant. The necessity for water conservation for the development both of the mineral and pastoral capabilities of the western districts is undisputed. The information at our disposal is, however, insufficient to enable us to form a decided opinion, but we believe that the further development of the underground water-supply is the first step necessary.

SUMMARY OF LEVELS AND SURVEYS NOW CALLING FOR ATTENTION.

Examination of drainage basins.

The Government, by advising the appointment of this Commission of Inquiry, has recognized that the welfare of the community and the further progress of the Colony depend in large measure upon the establishment of a right system for the conservation of water; and by virtue of the State ownership of the land still unalienated, it has a direct pecuniary interest in the settlement of the people upon the public estate. Both these considerations lead us to recommend that an examination of the country should be made with as little delay as possible, by engineers competent to advise the Government as to what schemes are practicable (having regard to the population, resources, and requirements of the district), and most advisable for supplying water within the area of each drainage system. They should be instructed to discover if there exist any natural depressions which are capable of being converted into large reservoirs for the storage of water; and, in defining the course of distributing channels throughout any given area, they should, as far as possible, follow the higher levels of the country, so as to give the greatest facilities for irrigation. It should be quite possible for a small staff of engineers, acting in concert with the district surveyors, to indicate within twelve months the most important works necessary to be carried out in the Colony. It is important that the Government should have accurate information as to the nature and extent of the water-supply which could be made available; and until this is obtained no useful scheme can be entered upon. The publication of schemes devised by these engineers would show the residents in the particular districts concerned the means by which they could supply themselves with water; and it may be expected that the projects devised by them will form the basis of schemes which the people will themselves seek to carry out.

From the examination of the levels of the Colony and the gauging of the rivers the following recommendations are warranted:—

(1.) That as the entire country or doab between the Murray and the Murrumbidgee possesses remarkable facilities for irrigation, both from permanent and from inundation canals, a complete series of cross-sections should be made from river to river, and an estimate prepared for distributing the whole available supply of water on a comprehensive system.

(2.) That the practicability of storing water on the Upper Murrumbidgee, and of conducting a supply from the Snowy River to the Murrumbidee, should be determined by surveys and levels.

(3.) That the practicability of diverting water from the Tooma River or the Upper Murray into the Billabong, and also of storing supplies in the Upper Murray, should also be determined.

(4.) That the adaptability of Lake George and the principal lakes of the Colony as storage reservoirs for flood-water should be investigated.

(5.) That such cross-sections of the country or doab between the Macquarie and the Bogan should be made as will show the lines along which flood-waters from the Macquarie can be most usefully diverted, and that traverse surveys and longitudinal sections of the Macquarie and Gwydir Rivers should be made.

(6.) That where the Harbours and Rivers Department has not already done so, longitudinal sections of the Murray, Murrumbidgee, Lachlan, and Darling, beginning from Tintaldra, Gundagai, Cowra, and Walgett, respectively, should be made, and that when taking such sections, particulars as to heads of creeks and ana-branches should be noted.

The existence and direction of subterranean supplies and currents can only be determined scientifically, and to full advantage for the benefit of the country, by a compilation of special hydrological and geological maps, which we recommend should be commenced without delay.

Expression of thanks.

We desire to express our grateful sense of the promptitude and courtesy with which our applications for information have been replied to by the Secretary of State for the Colonies, the Governments of various European States, the Government of India, the Governors of the States of California and Colorado, the Royal Commission on Water Supply for Victoria, the Departments of Water Supply of Melbourne and Adelaide, the Campbelltown Water Trust, Tasmania, the Government of Queensland, and the Heads of Public Departments in Sydney.

Appendices.

We attach hereto Appendices, as follows :—

Report on canals and irrigation in India, by Mr. F. A. Franklin, C.E.

Report on river-gauges, showing list of present and proposed sites, by Mr. H. G. M'Kinney, M.E., M.I.C.E., the Engineer to the Commission.

Report on railway and other levels in the interior of the Colony, by the Engineer to the Commission.

Further report on levels, by the Engineer to the Commission.

Report on the Tantangara Basin, Upper Murrumbidgee, by Mr. Cornelius Haylock, L.S.

Report on Mr. C. Haylock's survey of the Tantangara Basin, by the Engineer to the Commission.

Report on the River Murrumbidgee as a source of canals, by the Engineer to the Commission.

Report on the River Murray as a source of supply for canals, by the Engineer to the Commission.

Report on the Namoi River, *with plan*, by Mr. F. B. Gipps, C.E.

Report on conservation of water in Victoria, by the Secretary.
Report on the Barwon River, and Tarrion and Cato Creeks, by the Engineer to the Commission.
Report on the Macquarie River and the district between the Macquarie and Bogan Rivers, by the Engineer to the Commission.
Report on the Upper Murray Valley, by Mr. F. B. Gipps, C.E.

Minutes of Evidence taken.
Sketch map of the north-eastern portion of the Western Division of New South Wales.
Colony map of New South Wales, showing drainage areas and levels.
Diagrams illustrating the rainfall, temperature, and evaporation in the Colony.

The maps, plans, and diagrams, will be found in the accompanying portfolio.*

We have the honor to be,
Your Excellency's most obedient servants,

(Signed) WILLIAM JOHN LYNE, *President.*
RUSS. BARTON,
JOHN B. DONKIN,
F. A. FRANKLIN, C.E.,
R. L. MURRAY,
D. McMORDIE, B.E., M. Inst. C.E.,
GEO. W. TOWNSEND,
WALTER S. TARGETT.
I concur in the above Report generally, but dissent from recommendations with regard to Administration and Drainage Areas. (Signed) FRED. B. GIPPS.
Members.

CHAS. ROBINSON, Secretary.
Sydney, December 15, 1885.

---

* The portfolio of maps accompanies the original edition of the Report.

APPENDIX.

REPORT ON CANALS AND IRRIGATION IN INDIA.

To the Colonial Secretary,—

Sir, Sydney, 30 July, 1884.

I have the honor to furnish you with a report on the Ganges, Jumna, and Sone system of canals and irrigation in India.

In accordance with your instructions, conveyed to me by telegram on the 8th February last, to examine into the system of water conservation of Bengal and Upper India, I took the earliest opportunity, on the completion of my work in connection with the Calcutta Exhibition, to proceed first to Arrah, the central district of the Sone circle of canals. At that place arrangements had been made by Colonel J. M. Heywood, R.E., Superintending Engineer, to proceed with me to Dehree, the head works of the system. The whole of the works were minutely described, and the practical working of shutters, sluices, and regulators illustrated by G. Shawe, Esq., C.E., Executive Engineer for the district. Upon completion of the inspection of the highly interesting system of the district, the next work visited was the terminal point of the Ganges Canal at Cawnpore. From thence I proceeded to Agra, and examined the escape of the Delhi Canal at that place. I afterwards went on to Delhi to make myself acquainted with the head works on the river Jumna, at Okla, 10 miles below that city.

On completing my inquiries at Delhi I went on to Roorkee, and thence to Hurdwar, the headworks of the Ganges Canal, 20 miles above the town of Roorkee. Being provided at this place with an elephant, and accompanied by the resident engineer, I was enabled to inspect the mode of training the Ganges towards the off-take of the canal. When returning to Calcutta, I branched off by the Oudh and Rohilcund Railway to Rajghat, and visited the headworks of the Lower Ganges system.

The Upper Ganges Canal.

This project was first conceived by Colonel Colvin, R.E., in 1836, but nothing of a practical nature was done until the great famine of 1837–38 forced the question on the serious attention of the Government. Colonel Cautley having succeeded Colonel Colvin, who was very sanguine of the success of the scheme, strongly urged his successor to continue the examination. In 1848 the work was commenced with great vigour.

The head works of this great canal are situated at the sacred town of Hurdwar, within sight of the snow-capped peaks of the Himalayas. The source of the great river is at Gungotri. A little above Hurdwar the Ganges throws off a branch about 250 feet broad, which is used as the supply-channel for the canal. The quantity of water taken off is regulated by sluices, and the remainder is allowed to rejoin the main river lower down. The bed of this branch has been deepened to an uniform slope of 8½ feet per mile, and the erosion of the banks is prevented by spurs or bunds placed transversely with the axis of the stream. The general bed of the Ganges above this point is but ill defined, and the current liable to constant change. Therefore, in order to obtain a regular supply, the head of one of the main channels is closed by a temporary dam, composed of timber cribs filled with boulders, and built up to flood level, which can be removed when threatened by more than ordinary flood. The other channels are closed by temporary bunds of moderate height, so that the supply-channel to the canal is under complete control. Just above the entrance to the canal a permanent bar has been constructed as an escape (communicating with the main river), and to regulate the cold-weather level.

The entrance to the canal is at Myapoor, and then commences a complete series of works of a most extensive character. They consist of a masonry dam some 600 feet in length (in course of reconstruction at the time of my visit) across the Pyree branch. This dam is provided with sluices, and across the entrance to the canal is a masonry bridge of ten arches, each 20 feet wide, fitted with shutters or gates for regulating the admission of the water as may be required for navigation or cultivation.

Between the Myapoor headworks and the high land on which Roorkee is situated, the canal traverses a line which bisects several mountain streams. On this portion of country the most formidable obstacles to the project were met with. The tract of country referred to is triangular in shape, the northern side being formed by the Sewalik hills, the eastern by the river Ganges, and the western by the high land which constitutes the boundary of the valley of the Ganges. Along the direction of a rapid slope the line of canal is carried, and the drainage of three mountain streams which cross the canal at right angles is provided for by works which will be hereafter described.

The canal is 140 feet wide at the bottom, has a slope of 1½ to 1, and the water is 10 feet deep. It is constructed with a fall of 15 inches in every mile, but this is much less than the natural fall of the country ; the excess of slope is therefore provided for by artificial works. To this end masonry falls are formed between Hurdwar and Roorkee. To regulate the slope of the channel from Hurdwar to Roorkee there are four such falls of 9 feet each. The navigable canals which form loops round these falls are furnished with locks, compensating the fall in the main canal. The total fall of 36 feet delivers the water at Mahewar, 27½ feet above the level of the Solani River valley, within a mile of Roorkee. The first mountain-stream or rao is the Puttree, conveyed over the canal by superpassage, which merely acts as a watercourse during floods, and at other times may be used for the purposes of cross-communication. The work is of a very massive character, with strong parapet walls. The catchment area of this torrent is about 80 square miles, having a width of 5 miles, and an average length of 16 miles, commencing at the Sewalik range of hills and terminating at the superpassage. The superpassage consists of eight arches, of 25 feet span each, which discharge the canal supply. The fall of 9 feet takes place above each arch, and the ninth arch provides for navigation, the lock-gate being attached to the bridge. The waterway over the superpassage is 300 feet in the clear, the parapets being 14 feet high. The Ranipore superpassage is in most respects similar to the above, except that its waterway is only 200 feet wide in the clear.

The next work of magnitude is at Dhunowree, at the intersection of the Rutmoo Rao or River, which it meets and crosses on the level of the canal-bed. The works designed for the passage of this river across the canal consist of a masonry apron on the right and a regular escape dam on the left bank, provided with forty-seven sluice-gates 10 feet wide, with sills flush with canal, and connected by revetment walls, with a traffic-bridge on the up-stream side of the canal, and a regulating bridge on the down side. In addition to the sluices just referred to, there are on each flank five other sluices, with sills raised 6 feet, and on the extreme flanks are platforms or weirs at the permanent or maximum level of the canal, so that in extreme floods an escape across the canal is provided for a width of 800 feet. The whole of the escape sluices can be opened very quickly by a very simple contrivance, the chains holding the gates being released by a slight tap with a hammer.

The regulating bridge is composed of ten arched spans of 20 feet each in the clear, with necessary apparatus for raising and lowering. By these means an immoderate storm discharge is completely under control. On the occurrence of a flood the dam sluices are opened and the regulating gates of the canal bridge closed, so that the excess water is conveyed away harmlessly to the natural bed of the river, the middle sluice-gates allowing the escape of silts to the level of canal-bed. On the termination of a flood the canal regulator is again opened, and the dam sluices are closed, thus allowing the canal supply to run at its ordinary level. This is a most important work, and upon its accurate supervision depends the safety of the works lower down.

The next work is the deservedly famous Solani aqueduct. This great work is situated at the 19th mile from the head, at the point where the canal leaves the high land of the Ganges. The Rutmoo and Solani rivers are separated by a high ridge of land, about 2 miles in breadth, through which the canal passes in a deep excavation. This runs out at the Solani Valley, which is 11,680 feet wide, or nearly 2¼ miles. The canal is now carried above the surface of the valley by an aqueduct 15,700 feet long. The masonry aqueduct itself, which crosses the river bed, is 920 feet long, and consists of fifteen arches each of 50 feet span (giving a clear waterway of 750 feet), with 9 feet piers. The width of foundations in piers is 252 feet, and the extreme width of waterway on top is 172 feet, by a maximum depth of 10 feet. It is divided in the centre by a wall throughout its length, and grooved to receive planks, in order that one half of the aqueduct may be closed if necessary. The canal level at this point is 24 feet above the Solani river-bed, and the whole work is of stupendous dimensions. The banks of the canal on the up-stream side of the aqueduct are revetted by masonry steps for a distance of 10,713 feet, and for 2,723 feet on the down-stream or Roorkee side; that is, a total of 13,436 feet. The embankment supporting this channel has a base of 350 feet, and a top width of 290 feet, which provides for a road on either side. At the time of my visit the velocity of water was 3½ miles per hour, and the depth on gauge 8 feet, or 2 feet below the maximum. The total height of the aqueduct above the river is 38 feet. The deficiency of elevation robs it of much of its grandeur when viewed from below; but above, when its extreme width and length of masonry channel are viewed, the effect is most striking.

The foregoing is a brief sketch of the works on the first section, from the training works to Roorkee. It would be impossible to give anything like an estimate of the amount of labour expended on them.

The canal, after passing the high land of Roorkee, flows east of Mozuffurnuggur and west of Meerut, following the high land to near Bolundshuhur, where a short branch occurs, and continues to a short distance below Allyghur, where it terminates or, rather, diverges into the Cawnpore and Etawah branches.

The former flows on the high land between the rivers Esun and Rind, and discharges into the Ganges at Cawnpore, a distance of 170 miles, and navigable throughout. The latter continues through the high land, and after a course of 170 miles flows into the Jumna, near Humeerpore.

Throughout the length of the main canal and branches the longitudinal section is laid out in a series of steps, the length of tread and height of rise being determined by the profile of the country. These weirs or overfalls were originally designed in the form of an ogee, but it is now agreed that the vertical shape is the best. There are fourteen of these falls in a distance of 165 miles from the head, aggregating 110 feet. The falls consist of bridges, as already described, with varying numbers of arches, according to the waterway required. At 68 miles the canal is diminished in width to 150 feet, and at 149 miles to 100 feet to compensate for the quantity of water taken off for irrigating purposes.

The navigation in the canal is of minor importance, but in order to maintain it small channels 20 feet wide are constructed three-quarters of a mile above each fall, and re-entering the canal at about the same distance below.

On these channels locks are provided at the point corresponding with the weir or fall in the main channel. At most of these locks corn or sugar mills have been erected, worked by water-power.

In consequence of local irrigation, and frequently of an irregular abstraction of water from the main channel, the equilibrium between the supply and the capacity of the channel is liable to be disturbed. At its source the climate is moist, but on entering the plain country the climate is entirely changed, and demands are made on the supply which varies with regard to climate and soil, and is greatly influenced by local rainfalls. These conditions are met by providing escape outlets at intervals along the line of the canal, so that when overcharged the surplus water may be passed off into side channels. These escapes on the Ganges Canal are situated about 40 miles apart. They consist of a number of sluices about 6 feet in width, are built in the side road, and are arched over so that a free passage is open to both traffic and water.

At the end of the main canals, where it divides into the Cawnpore and Etawah branches, are two regulating bridges, one over each branch, connected by a masonry wall. These bridges have each five openings of 20 feet, fitted with gates and apparatus to admit of proper subdivision of supply; and in cases of necessity one or other of the branches can be laid dry.

On both banks, along the whole line, plantations of useful shade trees have been formed. The distances are marked by substantial mile-posts, and at nearly every bridge are provided bathing ghats for the natives.

The Cawnpore terminal line passes the station near the Cantonment. At this point it has wide and handsome esplanades, with trees, ghats, and bridges, which are quite an ornament to the locality.

The junction with the Ganges is effected by a series of locks for the passage of boats to or from the Ganges or Cana.

The total length of main and branch navigable canals in this system is 890 miles, and 3,700 miles of distributing lines, along which are established 17 dams or escapes, 202 bridges for the purpose of traffic or regulation of supply, with waterways varying from 200 feet to 20 feet, 297 inlets for local drainage, 16 falls, and 31 locks and side navigable channels, and 282 outlet heads for irrigation.

The preceding details will suffice to give an impression of the extent and dimensions of the Ganges Canal. Up to the end of 1877–78 the expenditure on the canal had been three millions and fifty-five thousand pounds (£3,055,000). The area irrigable is 1,205,000 acres.

THE LOWER GANGES CANAL.

This is comparatively new work designed to compensate for the admitted fault of placing the head of the upper system so high up the river at Hurdwar. The work was recommended by Sir Arthur Cotton in 1863, and after some alteration in the design first proposed the work was commenced by the construction of the masonry weir across the Ganges, at Narora, in 1871. This weir is situated about 3 miles below the crossing of the Oudh and Rohilcund Railway at Rajghat, 30 miles from Allyghur, on the East Indian Railway. From this point the main canal traverses the Allyghur, Etah, and Mynpoorie districts, crossing the Cawnpore branch of the Upper Ganges Canal, 76 miles from the terminus, thence running westward of the town of Cawnpore to the district of Futtehpoor. The length of canal channel is 531 miles, of escapes 56 miles, of navigable channels 428 miles, distributaries for irrigation 1,834 miles.

The works at Narora consist of a masonry weir across the Ganges, having sluice openings only on the flank where the canal takes off. At the time of my visit I was unable to obtain the assistance of the resident engineer; the measurements given with the following description are therefore only approximate.

The weir sluices are divided in bays of 14 feet and 8 feet waterways; the shutters are of iron, with very improved apparatus for lifting. The weir is connected with the canal take-off by a wing wall 130 feet in length, and the bank on the lower side is protected in a similar manner for the same distance. At the end of weir openings a ramped-wing wall, 7 feet wide, extends down stream 130 feet as a protection to slope of dam. The main dam or weir is constructed on a loose sand-bed, and the long down-stream slope is packed with large pieces of kunker in the absence of stone. The crest of the weir is 10 feet above the river-bed, but this height can be further increased by the use of iron shutters hinged to crest of weir. On the up-stream side of the weir the low nature of the country necessitates the maintenance of a bund for a distance of 5 miles, to prevent the spread of flood-water.

The water is taken off to the canal by thirty sluice-gates, the width of inlet being 300 feet. The shutters or doors are fitted to the full depth of the river at entrance, and any silt that may collect at the entrance is removed by the scour from the sluices in the weir already described above. At a distance of 750 feet above the weir is the lock-entrance, with gates of the ordinary kind, the river bank for the whole length from weir to lock-entrance being protected by a masonry revetment, which also extends beyond and protects the upper wing of the lock.

The design and construction of this work embrace every improvement that long experience and modern science could suggest, and may be looked upon as a reliable type to follow in any works of a similar character projected in this Colony.

It is to be regretted that time and an unfavourable season did not permit of a thorough examination of this system, as the head works offer sufficient promise that all the details throughout would prove of a highly interesting and instructive character.

THE AGRA CANAL.

The canal was completed in March, 1874, and the distribution of water commenced in the following cold weather. It commands an area of 375,800 acres. The headworks of the canal are situated at Okla, 10 miles below Delhi, on the River Jumna. The weir is 2,400 feet in length, and the crest is 7 feet above summer level of the river. The maximum height of flood at the weir is 11 feet, with a velocity of 5¼ miles per hour. The rear slope is composed of large size, hand-packed rubble, laid to an incline of 20 to 1. The through walls of the weir are laid directly on the river-bed, without block or well foundation. This was the first attempt at construction of this nature on a bed of the finest sand, and the work appears to stand well. At the end of the weir, where the canal takes off, there are sixteen sluice openings of 6 feet 6 inches each, flanked at the land side with a revetment extending down stream for protection of the bank, and up stream 60 feet, where commence the under sluice-openings for canal supply. The width of canal is 100 feet, and the water entrance is arched over to form a traffic road. The masonry wall continues for 150 feet, and it is then curved to entrance of lock communicating with canal. The whole of the work is executed in rubble, with brick strings and copings, and is of a very substantial character. The sluice-shutters are dropped in a cast-iron channel plate, and are lifted by a traveller provided with winch and gear, running on a line of rails attached to the piers. The depth of water at entrance is 8 feet, and the canal entrance is formed in excavation 90 feet in depth.

The main weir on the up-stream side is well protected with rubble stone, and, excepting at the entrance to sluice openings, is silted to level of dam-crest.

Shutters are now being fixed to the weir, which will raise the level of the water impounded 3 feet 6 inches.

An embankment along the river margin for about 8 miles protects the low lands from inundation, and the chance of turning the flank wall.

From Okla the canal follows the high land, nearly parallel with the Jumna, at a distance of from 3 to 12 miles from the bank of the river, and finally discharges into the Utongou River, 20 miles below Agra. Branches connect the canal with Muttra and Agra. Both of these are navigable, and when a full supply of water is obtainable boats can pass into the Jumna again at Agra. At the time of my visit the outlet was temporarily closed.

The discharge of the Jumna at Delhi in the dry seasons of the year is about 700 cubic feet per second, although the Upper System draws off the entire discharge of the Jumna, as it passes out of the Sewaliks.

The length of the main canal for navigation and irrigation is 140 miles, and the short junction to Agra and Muttra and length of distributaries 288 miles. The entire work cost £932,907, and the returns realized 10 per cent. on outlay.

New extension works are now in progress to make a navigable junction with the Western Jumna System at Delhi; and at its junction with the main canal near the head the excavations are heavy for some distance.

The foregoing is a brief sketch of the canals in the north-west provinces and Oudh, which I was enabled to examine during my visit; and for the assistance rendered in my inquiries by the officers in charge of the several works I am indebted to the courtesy of Lieut.-Col. J. G. Forbes, R.E., Engineer-in-Chief of the district.

The following is an extract from a report on the highly prosperous condition of the irrigation works of the North-west Provinces, dated 22nd February in the present year:—"The gross assessments for 1882-3 amounted to £645,000, and the working expenses to £215,000. The net revenue is therefore set down at £430,000, which is equal to 6·36 per cent. on the capital invested. The length of main canals is now 1,384 miles, of the distributaries 5,596 miles, and of the drainage cuts 1,403 miles. The total irrigated area is no less than 1,974,175 acres, or 3,085 square miles."

The Sone Circle System—Bengal.

The country benefited by this system of canals lies southward of the river Ganges, near the junction of that river with the Sone. It comprises portions of the district of Shahabad, with Gija, and Patna on the east. The first idea was to irrigate the Shahabad district from storage reservoirs in the hills; but subsequently the supply of water in the Sone River was found sufficient to irrigate an area of 800,000 acres. It was therefore finally determined to construct the works now existing, of which the following is a description, at a cost of £3,775,000, and to command an area, when complete, of 2,611,000 acres.

The estimate provided for irrigating 1,305,000 acres of rice land, and the allowance of water for this crop was fixed at 1 cubic foot per second for 133 acres; hence the eastern main canal was designed to carry 4,511 cubic feet per second, but, as will be shown further on, the expectation was not realized.

The excellent works on this system were commenced in 1869. The weir across the Sone, which is the headwork of this system, is situated at Dehree, about 27 miles below where the river leaves the Kymore range of hills. It is the longest weir in one length which has ever been built. It is 2⅓ miles in length, and 8 feet high to surface of crest. The sill level is 326·00, and highest flood level 342·00. The flood therefore rises 8 feet over the crest of the weir, and discharges about 1,026,000 cubic feet per second. Its average minimum supply in the cold season is 3,000 feet per second, but at times in exceptionally dry seasons it has been known to fall below this quantity. The catchment area of the Sone is 23,000 square miles. The river runs for 225 miles through the hilly parts of Central India, until it reaches the plains of Rhotas. From that place it has a course of about 100 miles through an almost deltaic country, which is the area commanded by the Sone canals. For some 40 miles below the weir the floods do not overflow the banks, but below that point large areas are inundated. Up to the point where flooding occurs the canals on each side follow the line of river closely, and then follow the high ridge of the country down to the Ganges.

The following are the lengths of navigable canals:—

Main Western	21½ miles
Arrah branch	65 ,,
Buxar branch	45 ,,
Main Eastern	7 ,,
Patna branch	79 ,,
The length of branch canals is 107 miles.	217½ miles.

In addition to the above there are 1,130 miles of distributaries connected with the mains. The full summer supply carried by the canals is ascertained to be 5,171 cubic feet per second, and the minimum at the end of dry season 3,500 cubic feet; but it has been known to fall 500 cubic feet in a very dry year, about May and June. The total irrigable area is 1,100,000 acres, and the total area commanded by the canals is estimated to be 2,934 square miles, making the area irrigable about 70 per cent. of that commanded.

The headworks are situated 58 miles from Arrah, and the journey is performed by steamer. On this branch there are thirteen locks, two of which are double. Some two hours are occupied in passing the locks, which have an average rise of 12 feet each. The total fall from the bed of the Sone at Dehree to low water in the Ganges is 180½ feet, of which 161 feet are overcome by means of the locks, the difference being accounted for by the slope of the canal. The steamer used was a side-wheel, with breadth over sponsons of 19 feet, for the clearance of locks, which are 20 feet wide in the clear. The passenger and goods traffic is considerable, and is said to pay.

At intervals of 2 miles, pontoon bridges or stages are moored to either bank for the convenience of ryots who may wish to cross over themselves or convey produce from bank to bank. And in addition there are frequent over-bridges for general traffic.

At the side of this lock, in a loop branch of the main canal, is a masonry weir, with a fall corresponding with that in the locks. The openings for discharge are regulated by boards fitted into slots worked in the masonry. At a short distance from and on the upper side of the locks are sluice openings for supplying the side channels, which in this system run on either side of and parallel to the main canal, and from which the distributaries are supplied, instead of from the main channel. The connections with the distributaries are made by village channels, formed by the natives in any direction required under the supervision of local officers.

The Anicut, or main weir, is 12,351 feet long between the abutments. It is constructed of rubble masonry, having foundations of rectangular wells sunk in the river bed, supporting longitudinal walls, 5 feet and 4 feet respectively, placed 35 feet apart, the intervening space being filled with large ordinary packed rubble. The front or up-stream slope is formed at 3 to 1, and the rear or down-stream slope at 1 to 12, formed also of large size, hand-packed rubble. The packing on the crest is closely cemented.

There are three sets of under sluices in the weir, one at each flank and in the centre, each with twenty-two vents or openings of 20½ feet each. The piers between the openings are 4 feet thick, and 32 feet in length. These sluice piers are set in ashlar masonry to a height of 10 feet over river-bed. The shutters or gates used for closing the sluices are extremely novel in construction, being in a great measure self-acting. The shutters are arranged in two lines each at the end of the piers, fixed by hinges to sill of opening. The back of the up-stream shutter is supported by six tension rods, 2¾ inches in diameter in wrought-iron tubes, the rods being packed with leather to act as pistons. When the shutters are up, the packing fits close to the inner surface of the tube. If it is desired to lift the shutters during a rise in the river they are raised by means of appliances 8 inches, when the pressure of the water does the rest, the shock of the sudden pressure being modified and injury prevented by the tube and piston arrangement. The front shutters being up, the back ones are easily raised. The space between them is then filled with water through a valve in the front shutter. When the water is *in equilibrio* the front shutter is again lowered to its bed, and one only is left to retain the water. The remaining shutter is attached to the floor by strong iron rods hinged to gate and floor, and fixed below the centre of oscillation, so that when the water rises beyond the height required to serve the canal, the shutters fall, and the river discharges itself throughout the whole length from bank to bank.

It was proved in my presence that by this admirable arrangement these shutters can be safely and expeditiously lifted against 10-feet head of water without shock to the structure. It is an interesting and instructive sight to watch a stream of water 20 feet broad and 9 feet deep flowing with a velocity of about 18 feet per second through the sluices suddenly obstructed by a single gate. When the shutter reaches the vertical, the water leaps in a wave 2 feet above the top and flows over for a few seconds, and then sinks to the mean level of the upper pool.

The set of gates in the centre being over a mile from the shore, it was on one occasion found impossible to reach it in time to disengage the chains, and to drop the shutters on the approach of a sudden flood. A great deal of damage was done in consequence to that portion of the work. Since then automatic means have been devised to meet the difficulty in future.

As in the case of all other headworks described, the revetment walls are continued some distance up and down river at right angles with the weir, the take-off for the canals being on each bank near the up-stream side of the weir. The western and eastern head sluices discharge 4,342 cubic feet per second. They consist of twenty-four vents of 6 feet each, fitted with gates in two panels, one or both in each opening being removed at will. Above them again on each side of the river is situated the navigable lock entrance.

The dimensions of the western main are, at the head, 180 feet in breadth of base, with slope 2 to 1, giving a surface waterway of 220 feet with a maximum depth of 9 feet, the fall being 6 inches per mile. Five miles from the head the canal branches to Arrah and Buxar. On the latter branch, at its junction, a regulator was being built at the time of my visit, to compensate for increased slope and consequent excessive discharge. From this point the width of each canal is reduced to 124 feet, the Buxar branch taking off 2,835 cubic feet of water, and the Arrah 1,447 cubic feet per second. At the 12-mile the Chousa branch occurs, 1,226 cubic feet being taken off, leaving 1,669 cubic feet to be carried on. From this point the canal narrows to 100 feet, and the fall to 2½ inches per mile. At the 19th and 21st mile respectively the Khurgur and Chowbay branches take off, depriving the main canal of 620 cubic feet of water, leaving 1,049 cubic feet to be carried on to the end of the canal at the 22nd mile.

The Arrah branch has already been described, as seen on the trip up from Arrah ; and the same description will apply to the branch on the eastern side of the river, the details in all cases being similar. All drainage streams are crossed by masonry aqueducts ; the distributaries are supplied by side sluices arched over to carry roads ; the banks are closely planted with trees, and light iron bridges with timber floors span the canals at frequent intervals. At some of the locks sugar and flour mills are worked by water-power applied by turbine, and are productive works. The same power, placed at the disposal of the enterprising settlers in this Colony, would be availed of to its fullest capacity. In India the Government provide the whole of the working appliances.

In concluding this brief description I must express great indebtedness to H. C. Levinge, Esq., C.E., late chief engineer of the works, for much valuable information, and to Lieut.-Col. J. M. Heywood, R.E., the present chief engineer, who provided means of transit, and placed at my disposal the valuable plans of his Department, and accompanied me for several days on a tour of inspection over the works. It is through the instrumentality of this gentleman that the Government of New South Wales has been furnished with complete sets of drawings and books of reference of the whole of the irrigation works of Bengal.

The distance travelled by rail, canal, and road, for the purpose of inspecting the foregoing works, was 2,740 miles, and the character of the climate of the country passed through was as various as the systems adopted by the natives in economising and distributing water for irrigation. It may, therefore, be interesting to describe the various methods of raising water in vogue among the natives of India.

Well Irrigation.—The two methods which are to be frequently met with between Calcutta and the north-west provinces are the pecotah, in Bengal, and the môt, in the north-west provinces.

The pecotah is a lever fixed in an upright forked post, with a bucket attached to the short end by a rope, and a counterpoise at the other end. It is worked by two men, and it is stated that in six hours they can raise and distribute 1,500 cubic feet of water from a depth of 20 feet. When the depth is not more than 16 feet, one man works the pecotah with the following results :—With a bucket containing 3 gallons and discharging 3 per minute, or 540 gallons per hour, or, deducting spillage, 4,000 gallons per day, which is sufficient to water two-thirds of an acre.

The môt consists of a leathern bag, having a leather pipe-like extension at the bottom. When the bag is filled, it is raised by means of a rope, running over a pulley, worked by two bullocks walking down an inclined plane, either excavated or made over the surface to the level of the raised masonry of the well. At the side of the well is a trough into which the water is discharged. Three men and two bullocks work this appliance from morning till evening, with a mid-day rest of an hour. The bag contains 4·5 cubic feet, and can be raised thirty times in the hour, which gives a result of 6,720 gallons per day of eight hours.

Both of the above systems, notwithstanding the cheapness of labour, are considered very expensive compared with surface irrigation, and they are therefore of only restricted application.

The wells generally are not very deep, reaching from 18 to 20 feet, but the supply in most parts is very scanty, and a very small depth of water remains while the môt is in use. The ordinary field well is simply a round hole, lined for a few feet of its height from the bottom with a plaited brushwood casing.

The country in India, through which the great systems of canals are carried, resembles very much in appearance our western and north-western country. The main channels in every case are formed on the ridges to be found on each side of the main rivers. These ridges, which exist in varying widths, right and left of the river channels, have been formed by the gradual deposit of alluvial matter when the rivers have been in a state of flood, and they occur at points where the velocity of the stream is checked. The effect is to leave on each bank a stratum of silt, in the sectional form of a long wedge, with the thick end towards the river. The width of this slope on the plains of India varies from 300 yards to a distance of many miles. Beyond these deposits, which occur also on all tributaries of such rivers, the country is low, and although not perceptible to the eye, yet instrumental excavation shows in which direction the drainage tends to flow. The irrigation of India is therefore based on a very simple principle.

At all the sites selected as the headworks of several systems which I visited, the river appears to have ceased to overflow the banks at time of floods. By raising the level of the water at these points by means of a fixed weir, and excavating a channel through the wedge deposit, the lower country is reached, and as the line of canal is carried in a straight direction, while the course of the river is tortuous, the fall is more rapid ; for every mile of its course it then gains considerably on the surface level of the river. As an example, if the fall of the Darling or Murrumbidgee is 1 foot per mile, with a tortuous course of one-half more than a direct line, there will be a gain of 6 inches fall in each mile in an artificial channel. So that if the excavation of the canal were 5 feet below the top of the river-bank at the head it would gain that amount on the river in 10 miles. If the cut were made in ground on the same level as the margin of the river-bank, the water it carried would then come to the surface, and be available for distribution.

But as the wedge-shaped alluvial deposit carries a fall at right angles to the axis of the stream as well as in its course, the required level would be obtained at a shorter distance, and as the fall in the cut need only be 6 inches in the mile the water would come to the surface in 5 miles. The foregoing is practically the system adopted in India. The excavations are made so as to be little more than sufficient to provide material for the embankments, which are made to retain the water at as high a level as possible consistent with their stability. And then occur the lock and weir as described in the Ganges and Sone systems.

In many parts of India large tanks or reservoirs are established in the upper watershed, to collect and distribute by means of sluice regulators the water which would otherwise inundate the lower land. These tanks are provided with escapes or waste weirs, which convey the surplus supply to the natural bed of the drainage. The plan adopted is to select a natural hollow in good holding ground on the moderate slopes of the catchment area, by closing up all depressions on its sides where water can make its exit, and excavating in the solid, throwing the material into a dam or bund at the lower end. The supply for these tanks sometimes depends entirely on local rain, or on streams swollen by rain on the higher ground above ; or, as is more generally the case, the tanks are filled by tanks connecting several of these streams, or by channels widening round more remote hills.

When practicable, the head of supply is cut off when the tank is filled, and the surplus water discharged into the natural channels ; otherwise one or other of the following methods is adopted. When the banks at the site of the dam are high, as in the bed of a mountain stream, and of a great width, the dam is constructed entirely of solid masonry throughout, so that the waste water may pass over the whole length of the dam. If so large an escape is not desired, and the embankment be of earthwork, then a portion of the dam is built in masonry, with the top 2 or 3 feet lower than the earthwork ; but where the position is favourable, several waste weirs excavated in the solid ground are much more reliable. In Mysore, there are upwards of 20,000 tanks, the dams of which are of lengths from ¼ of a mile to 1½ mile. They are principally formed of earthwork, 12 feet broad at top, 60 feet on bottom, and 18 feet high. They are faced with a rough stone revetment, having a batter of 2 to 1, the facing averaging 3 feet to 4 feet 6 inches in thickness, packed on loose rubble backing.

The largest tank in India is the great Chembrambaukum, 9 square miles in area ; it is situated 14 miles from Madras ; its capacity is 102·91 millions of cubic yards, and the water spread is 5,729 acres, or 8·95 square miles. The Government is now considering the question of forming large storing tanks at the head of the watersheds under the mountains. In the Bombay Presidency five examples of tanks are found. The Ekruk tank is one of the largest of its class ; it comprises a reservoir or tank formed by an earthen dam, and three canals for irrigation. The dam is 7,000 feet in length, and 76 feet in maximum height ; it is thrown across the Adhila River, a tributary of the Lind. The drainage area above the tank is 160 square miles. The tank is 60 feet deep when full, and contains 3,350,000,000 cubic feet. The area of the water surface is 4,640 acres, or 7¼ square miles.

The Bhatode tank is situated on the Mekhri River, which rises 10 miles north-east of Ahmednagar. The masonry dam is 2,400 feet long, and 50 feet in maximum height, with a waste weir, 450 feet long, 7½ feet below the top of dam. A canal for irrigation is 4½ miles long, and is capable of discharging 140 cubic feet per second at the head, and commanding altogether 14,000 acres of land. The drainage area of the tank is 50 square miles, its capacity 149,000,000 cubic feet, and its area, when full, 310 acres. It is estimated to fill with a rainfall of 5·40 inches.

The Naini tank is situated on a small tributary of the Yula River. The work comprises a storage reservoir, capable of containing 190,000,000 cubic feet, and having an area, when full, of 380 acres. It is formed by an earthen dam 2,870 feet long, and 57 feet in greatest height. The catchment area of the river above the dam is 54 square miles. The canal leading from the tank has a discharge capacity at the head of 33 cubic feet per second.

There are in the Presidency seven smaller works of the same description, some of them undertaken entirely by the Government, and others being old native works restored.

In the Western Punjab, where rain is very scarce, and the ground near the hills at so high a level that it is impossible to irrigate it either from canals or wells, the natives obstruct the dry bed of the stream with dams formed of earth and brushwood at every favourable point, thus raising the level of the water, and directing it into secondary channels, natural or artificial, whose mouths are just above the dam. Each of these in its turn is bunded as may be required to throw the water into the smaller irrigating channels for distribution over the land. So skilful is this arrangement that although these floods last but a few hours, the water is distributed in the above manner by hundreds of weirs and minor channels over a large extent of cultivation, with very few disputes.

The great defect in this system is that, if only a small quantity of water comes down, the dams lower down the stream go without; and if a large quantity comes down, the violence of the torrent is too great, whereby the temporary dams are carried away in succession too rapidly, and a large quantity of water is wasted. If masonry dams were established in these places, the water would be stored up for future use in the bed of the river. For example, in a creek 15 feet deep with a fall of 20 feet per mile, if dams were constructed every ¾ of a mile, the surplus water passing over the tops in succession, a series of still-water canals would be formed, whence the water could be drawn by smaller channels. By a proper application of this method there is little doubt that a great extent of country in this Colony now lying barren could be brought under irrigation.

I regret that my duties in connection with the Calcutta Exhibition did not admit of my visiting the irrigation works of India before the season was too far advanced for extended inspection, and that from the same cause I was unable to go over the Madras and Bombay systems. But, in the interest of future operations in the conservation of water in this Colony, it would be of great service if a detailed report on works applicable here could be obtained from those provinces.

I have, &c.,
F. A. FRANKLIN.

REPORT ON RIVER-GAUGES, SHOWING LIST OF PRESENT AND PROPOSED SITES.

To the Secretary of the Commission,—

Sir,
Sydney, 6 January, 1885.

I have the honor to report that, in accordance with verbal instructions received from the President, I have made inquiries regarding the most suitable sites for river-gauges, and as the result of these inquiries I beg to submit a list showing the places at which gauges will be most useful on the various rivers of the interior.

2. While preparing the list I consulted Mr. Russell, the Government Astronomer, and Mr. Moriarty, Engineer-in-Chief for Harbours and Rivers, and obtained valuable information from them. The gauges on the Macquarie, Peel, Namoi, and Talbragar, are entered in the list, on the suggestion of Mr. Russell. Mr. Moriarty very kindly supplied me with a copy of a river-gauge book which was prepared by him in 1864. The positions of suitable road bridges were obtained from Mr. Bennett's Department.

3. In order to obtain a connected record, the positions of the gauges relatively to Sydney highwater-mark should be determined. A table of discharges, corresponding to various readings of the gauges, should also be prepared.

4. With a few exceptions the discharges hitherto calculated have been only rough approximations. As the determination of the discharges of the rivers, and particularly the minimum discharges, is a matter of great importance, I beg to recommend that this question of gauges and discharges should receive early consideration, and that the necessity for sanctioning the expenditure required for fixing the gauges without delay should be brought to the notice of Government.

5. In addition to the list of gauge sites and the gauge book supplied by Mr. Moriarty, I append a gauge register-sheet for daily observations, which I recommend for adoption. It is very similar to the rain-gauge register-sheets supplied to observers by Mr. Russell. Owing to the increase of population and the spread of settlement, daily readings can more easily be obtained now than weekly readings at the time Mr. Moriarty's book was prepared.

I have, &c.,
H. G. M'KINNEY, M.E.,
Engineer to the Commission.

River-Gauges—List of present and proposed Sites.

No. of Gauge for each River in order.	River.	Proposed Sites of Gauges.	Bridges available for fixing Gauges.	General Remarks and Explanations.
1	Snowy River ..	....		The available information regarding the Snowy River is not sufficient to enable me to suggest a site for a gauge. The places marked "(R)" are those from which Mr. Russell, Government Astronomer, has obtained observations for some years past. The places marked "(H)" are situated on the portions of the rivers which were levelled under the directions of the Engineer-in-Chief for Harbours and Rivers. If the bench marks then fixed are still to be found, the gauges can easily be connected with them by lines of levels. At the places marked "(L)" the gauges will easily be connected with the railway levels. It may not be practicable to level to the remaining sites at the time of fixing the gauges; but the gauges should eventually be levelled in every case, as, until this is done, the observations though useful will lack completeness and continuity. While the list includes the sites at which gauges are most necessary, other gauges would be useful, and records kept by private observers would be worthy of note.
1	Murray River..	Dora Dora		
2	Do ..	(L) Albury (R) ..	Railway Bridge and Road Bridge.	
3	Do ..	(H) Howlong....	Timber Road Bridge.	
4	Do ..	(H) Wahgunyah or Corowa.	do do	
5	Do ..	(H) Mulwala (R)		
6	Do ..	(H) Tocumwal ..		
7	Do .	(L) Moama (R) ..	Railway Bridge on iron cylinders.	
1	Edward	(L) Deniliquin ..	Timber Road Bridge.	
1	Murrumbidgee	(L) Gundagai....	Road Bridge on iron cylinders.	
2	Do ..	(L) Wagga (R) ..	Railway Bridge and Road Bridge.	
3	Do ..	(L) Narrandera..	Railway Bridge on iron cylinders.	
4	Do ..	(L) Hay (R)	Road Bridge on iron cylinders.	
1	Lachlan	(L) Cowra	Timber Road Bridge.	
2	Do	(L) Forbes	do do	
3	Do	(L) Condobolin ..	do do	
4	Do	Hillston		
5	Do	Oxley	Road Bridge on 5″ screw piles.	
1	Murray—Murrumbidgee—Lachlan.	(H) Euston (R) ..		
1	Murrumbidgee—Lachlan.	(H) Balranald (R)	Road Bridge on iron cylinders.	
1	Talbragar	Brocklehurst....	Timber Road Bridge.	
1	Macquarie	(L) Dubbo	Railway Bridge.	
2	Do	Warren	Timber Road Bridge.	
1	Peel—Namoi ..	(L) Tamworth ..	Bridge.	
2	Do ..	(L) Gunnedah ..	do	
3	Do ..	(L) Narrabri	Timber Bridge.	
4	Do ..	(L) Walgett	Timber Bridge over the Namoi.	
1	Macintyre—Barwon—Darling.	Goondiwindi	Timber Road Bridge.	
2	Do	Mungundi	do do	
3	Do	(L) Walgett	Timber Bridge over the Barwon.	
4	Do	(L) Bourke (R) ..	Road Bridge on iron cylinders.	
5	Do	(L) Wilcannia (R)		
6	Do	(H) Menindie (R)		
7	Do	(H) Pooncarie (R)		
8	Do	(H) Wentworth (R)		
1	Murray—Darling.	Moorna		

H. G. M'KINNEY, M.E.,
Engineer to the Commission.

NEW SOUTH WALES.

ROYAL COMMISSION—CONSERVATION OF WATER.

River ____________________

REGISTER of Gauge at __________ for the Month of __________ at __________.

Day.	Reading.	Remarks.
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

____________________Observer.

In the column of remarks, any trustworthy information regarding the changes of level during the interval between the gauge readings should be briefly noted; also particulars of any considerable accumulation of silt in the locality. Such information should, if possible, include the time of the beginning or end of any rapid rise or fall of the river. Any heavy fall of rain should also be noted.

(*By Authority*) H. G. M'KINNEY, M.E.,
Engineer to the Commission.

REPORT ON RAILWAY AND OTHER LEVELS IN THE INTERIOR OF THE COLONY.

To the Secretary of the Commission,—

Sir, Sydney, 15 January, 1885.

In accordance with verbal instructions received at the last meeting of the Commission, I have the honor to submit the accompanying report, which is based almost entirely on levels received from the Railway Department and from the Department of Harbours and Rivers.

2. Next to the fixing of gauges and the determining of the supply in the rivers, I consider that the two sets of levels recommended in the report are the most necessary field work in connection with water conservation on a large scale in the interior of the Colony.

I have, &c.,

H. G. M'KINNEY, M.E.,
Engineer to the Commission.

(A.) The levels taken by the Railway Department and by the Department of Harbours and Rivers afford only a general idea of some parts of the Colony, and conclusions arrived at from them can only be considered as approximate. Bearing this in mind, the available information permits of the following deductions :—

1. That the fall from the place where the Billabong Creek is crossed by the Great Southern Railway to Jerilderie is over 300 feet, or at a mean rate of more than 4 feet per mile; also, that from Jerilderie to the junction of the Murray and Murrumbidgee the fall is about 170 feet, which is at the rate of about 13½ inches per mile.
2. That the country between the Murray and the Murrumbidgee must be regarded as two main doabs and not one, the Billabong Creek representing the intermediate river.
3. That so far as levels are concerned, the Billabong Creek could be supplied from the Murray as well as from the Murrumbidgee.
4. That the levels of the country are not sufficiently known to enable any one to state positively that high-level canals commanding large areas could be constructed, but that all the evidence available goes to show that such canals could be carried out from both the Murray and the Murrumbidgee.
5. That the flood-water of both rivers can be utilized to some extent ; that of the Murray in the Edward River and the creeks flowing into it, and that of the Murrumbidgee in the Yanko, Columbo, and Billabong Creeks.
6. That the practicability of useful work in this part of the country is so assured that cross sections from the Murray to the Murrumbidgee should be taken at every 5 miles, with a view to determine the nature of these works.

(B.) In the district between the Murrumbidgee and the Lachlan very few levels have been taken, and the information available from all sources is very meagre. The only conclusions justifiable regarding water conservation in this district are—

1. That it is improbable that flood-water from either the Murrumbidgee or the Lachlan can be conveyed to any great distance in the interior of the district.
2. That the flood-water from both rivers can be utilized to some extent by diverting it into creeks and natural depressions in the low land near them.

(C.) Taking into consideration the great extent of country between the Lachlan and Darling, but little information of a definite nature is available regarding it. There is, however, sufficient to lead to the following conclusions :—

1. That the Willandra Billabong is a great natural inundation canal, which should be surveyed and levelled with a view to its improvement.
2. That there are unusual natural facilities for utilizing the flood-water of the Darling in creeks, ana-branches, and lakes, particularly in the portion of the river south of Wilcannia ; and that on this account a line of levels should be taken along the Darling, and branch lines from it to the lakes and large natural depressions.
3. That it is improbable that any supply of water can be taken from the Bogan in the direction of Cobar.
4. That the Macquarie could probably be diverted into the Bogan.
5. That the fall from Narrabri to Walgett is about 260 feet. The direct distance being about 100 miles, the fall in the country in the direction of the river is slightly over 2½ feet per mile.

(D.) No connected levels have been taken in the country beyond the Darling.

H. G. M'KINNEY, M.E.,
Engineer to the Commission.

FURTHER REPORT ON LEVELS.

To the Secretary of the Commission,— Sydney, 22 January, 1885.

Sir,

In continuation of my report of 15th instant, and in accordance with verbal instructions received on that date, I have the honor to furnish, for the information of the Commission, plans showing a number of levels obtained from the Railway Department and from the Department of Harbours and Rivers.

2. The scale of plans does not permit of the entry of levels at less intervals than 2 miles, but those which have been entered will give a fair general idea of the slope of the country on the various lines on which they are marked.

3.* The Railway Department cannot give any information about the trial line to Wilcannia, as the books and sections have not yet arrived in Sydney. This information will be available in about a month.

4.* The Deniliquin and Moama Railway Company has been asked for information regarding the levels of the country along that line, but a reply has not yet been received.

5. Under these circumstances, I can add to my report of 15th instant only the following items of information :—

(A.) That the town of Cobar is 200 feet above the flood-level of the Bogan at Nyngan.

(B.) That at 58 miles from Nyngan and 22 from Cobar the railway line crosses a ridge at an elevation of nearly 500 feet above the flood-level at Nyngan.

6. The levels now supplied include all those of the western plains which are at present available. I have &c.,

H. G. M'KINNEY, M.E.,
Engineer to the Commission.

REPORT ON THE TANTANGARA BASIN, UPPER MURRUMBIDGEE.

To the Secretary of the Commission,—

Sir,
Cooma, 15 March, 1885.

In pursuance of instructions received, I have the honor to transmit herewith a plan showing traverse and section, also cross sections and contour line on west side of part of the Murrumbidgee River, in the parish of Tantangara, county of Wallace.

I have to observe that, on arriving at the locality, I found that the area of water to be impounded, unless by a dam of exceptional height, was much less than my impressions (of sixteen years since) led me to suppose ; but I have executed such survey as I considered desirable, in order to place before the Commission such an amount of information as would guide them in forming an opinion of the value of the site for storage purposes. I did not consider myself justified, under the circumstances, in entailing further outlay.

From the plan † it will be seen that, with a height of 83·09 feet above water-level at C, there will be a height of 44·66 feet at J, the junction of Currangorambla Creek and the Murrumbidgee River; the direct distance between these points is about (by scale) 272 chains, and the average fall per mile is 11·3 feet ; with this proportion the contour line, if produced, would extend up the Murrumbidgee above its junction with Currangorambla Creek about 3¼ miles.

With a view to the possibility of the water being retained by a series of low dams, I have shown a section of the river at T, where I observed there would be a natural by-wash. I may point out that from this point of the river upwards there are, I believe, many suitable points for the erection of dams, so that the whole bed of the river may be made a reservoir.

On my arrival at Tantangara, there had been but little rain for some time ; the river was then running at the rate of (I estimate) 2 miles per hour, with an average depth of 6 inches at or about the point C. While there, very heavy rains fell, but the river did not rise more than 2 or 3 inches, and the water was but slightly discoloured ; there are no evidences of scour, nor is there any drift or timber brought down by flood-waters from the head of the river to the Gulf. I am informed by old residents that in high floods (for the locality) the river is crossable on horseback at and above the point D, shown on plan ; that during the past and in all seasons the river maintains an even flow during the summer of about the delivery estimated in the former part of my letter. The whole country towards the head of the river is of a spongy nature (in flat lands) ; and two very constant streams, Nungar and Tantangara Creeks (also flowing from swampy country) flow into the river. There are, I believe, many minor streams of same character running into the river above the junction of Tantangara Creek and Murrumbidgee River.

---

* The levels to Wilcannia have since been received from the Railway Department, and the Secretary to the Deniliquin and Moama Railway Company has courteously supplied a list of levels of the country along that line of railway. In both cases the information so obtained has been summarized and shown on the map of the Colony appended to the Report.—H.G.M'K.

† The plan is retained in the office of the Commission.

While in the locality, I inspected Currangorambla Creek for some distance up its course, at the south-west corner of portion 2, parish of Currangora, county of Cowley. I observed there was a site for a dam, with a natural by-wash to the east; above this point the bed of Currangorambla Creek (which flows slowly) opens out, and I am of opinion that a large amount of water could be impounded.

I will draw the attention of the Commission to the question as to whether a series of low dams from the Gulf upwards to the head of the Murrumbidgee River and tributaries would answer the purpose of conserving the water to a valuable extent.

I made inquiries as to whether stone for building purposes could be obtained; and I find that large quantities of basalt, in long lengths, can be obtained about the junction of Tantangara Creek with river; limestone can be obtained within a few miles; there is also an abundance of clayey loam in the immediate vicinity of the Gulf.

I have, &c.,
CORNELIUS HAYLOCK,
Licensed Surveyor.

REPORT ON MR. HAYLOCK'S SURVEY OF THE TANTANGARA BASIN, UPPER MURRUMBIDGEE.

8 April, 1885.

ALTHOUGH, in his report, Mr. Haylock expresses disappointment with the Tantangara Basin, I do not think that his report and plan are by any means discouraging. Mr. Haylock's plan and sections show that with a dam having a mean length of about 300 feet, an extreme height of about 84 feet, and a mean height of 60 feet, the water of the Murrumbidgee would be thrown back to a distance of about 6½ miles. So far as I can judge from the plan, it seems probable that the reservoir so formed would average 40 feet in depth throughout the width of a third of a mile. The quantity of water thus impounded would be 2,416,000,000 cubic feet. If the gap at the lower end of the Tantangara Basin would afford a good foundation for a dam of masonry or concrete, such a dam could be built at a cost of about £40,000. The rate which the water impounded would cost would thus be 3,020 feet for one shilling. This rate is too high to admit of the use of the water for ordinary irrigation purposes; but it is very probable that the capacity of the reservoir is here understated, as several creeks flow into the Tantangara Basin, the valleys of which would afford considerable storage.

It would appear from Mr. Haylock's report that the discharge of the Murrumbidgee at Tantangara was about 183 cubic feet per second at the time of his survey.

Considering that the Tantangara Basin would, on a low estimate, contain sufficient water to give a supply of 200 feet per second for 140 days, I think that, although the cost of storage (judging from the information available) seems high, the basin is well worthy of a more complete examination.

H. G. M'KINNEY, M.E., M.I.C.E.,
Engineer to the Commission.

REPORT ON THE RIVER MURRUMBIDGEE AS A SOURCE FOR CANALS

8 April, 1885.

ALONG the course of the Murrumbidgee the country may be considered mountainous as far as Wagga. Regarded as a source of supply for canals, this river is very similar to the Murray, and similar difficulties would attend the construction of canals above the point where it reaches the open plains. The time at my disposal did not permit me to follow the course of the river throughout the length between Gundagai and Wagga, but I examined the plans in the office of the District Surveyor, and obtained much valuable information from that gentleman in reply to questions which I put to him. In consquence of information so obtained, I saw the advisabilty of visiting the Malibo Range, and the District Surveyor very kindly undertook to drive me to it. The Malebo Range is about 6 miles by road from Wagga, and is the last range which crosses the river before it emerges into the open country. The width of the gap through which the river flows appears to be under half a mile. The Malebo Range occupies the same position on the Murrumbidgee as the Jindera Range on the Murray. Both places are favourable sites for weirs; but that on the Murrumbidgee is at the narrower gap, and a weir there should be less expensive than on the Murray.

From the "summer level" at Wagga to the ground level at the junction of the Yanko and Colombo Creeks there is a fall of 138 feet. The rate of fall in the Murrumbidgee, near Wagga, is under 1 foot per mile; it would, therefore, be practically correct to assume that the summer level at the Malebo Range is about 128 feet above the ground level at the head of the Colombo Creek. As the distance is about 56 miles, the fall is at the rate of over 2 feet per mile.

With regard to the available supply, my instructions in regard to taking discharges did not include Wagga, so that I cannot state the discharge there; but at Gundagai I found that it was 630 cubic feet per second. It is evident, under these circumstances, that the prospect of a remunerative permanent canal from the Murrumbidgee, as well as from the Murray, is most promising. Before entering more fully into the subject, it will be necessary to make a further examination of the river and take the discharge at Wagga.

On the subject of inundation canals from the Murrumbidgee, some time ago, in my report to the Commission regarding the Yanko Creek, I pointed out that that creek must be considered as an inundation canal. My instructions then did not include a complete examination of the Yanko Creek, but merely related to improvements near its head. I hope that the improvements of the entire creek will yet be taken up, as I think that in every case such a work should be dealt with as a whole.

In addition to the Yanko, I have reason to anticipate that at least two other useful canals of the same description can be made to carry a supply of flood-water from the Murrumbidgee at a moderate cost. I think it is better, however, to postpone entering into detail till I am in possession of more complete information.

In conclusion, I have only to add that, while I confidently anticipate that canals will be found to be practicable in the district between the Murrumbidgee on the north and the Billabong and Edward on the south, still I think that a further examination of the Murrumbidgee is necessary in the first place, in order to determine the lines which the survey for such canals should take.

H. G. M'KINNEY, M.E., M.I.C.E.,
Engineer to the Commission.

REPORT ON THE RIVER MURRAY AS A SOURCE OF SUPPLY FOR CANALS.

8 April, 1885.

In considering the question of tapping the Upper Murray, there are two arrangements which suggest themselves. The first is to carry the supply along the Murray Valley, at an increasing elevation above the river, till a place is reached at which the canal could leave the valley and take a north-westerly direction to the open plains. The second arrangement is to draw the supply from some point at such an elevation that the water could be carried through or over the dividing range between the watershed of the Murray and that of the Upper Billabong.

The investigations which I have already made, together with the past records regarding the supply in the Murray, afford ample evidence that the available discharge is sufficient to warrant the construction of a canal, if such a work were proved to be practicable.

The supply then being available, the next point to consider is the nature of the river valley. From examination of the plans in the office of the District Surveyor in Albury, from inquiries which I made of that gentlman, as well as of Mr. Basil Gray and others who know the district thoroughly, and, lastly, from my own observation of the river up to 12 miles from Maraket, I came to the conclusion that there was no chance of constructing a canal beyond the Seven-mile Creek, so that it was unnecessary for me to go beyond that point in my inspection.

From the Seven-mile Creek down to some distance below Wagra the river valley varies generally from half a mile to three-quarters of a mile in width. The hills are steep, and in most cases of granite. The slopes are rugged, with out-cropping rocks, and the soil consists chiefly of loose and porous granite detritus. The soil at the foot of the hills is of the same composition, while that in the river valley proper is a light, sandy, alluvial deposit. The porosity of the soil is at once apparent; but, in addition, substantial evidence of this is afforded by the numerous surface springs, and by the manner in which the water flowing in some of the small watercourses appears and disappears. The river follows a tortuous course along its valley—sometimes washing the base of the hills on the New South Wales side, and sometimes passing close to those on the Victorian side. The rate of fall in the Murray near Albury, and on the up-stream side of the Union Bridge, is under 2 feet per mile, while at Dora Dora, which is 40 miles by road above

Albury, the rate of fall is scarcely 3 feet per mile. From inquiries which I made, and from my own observations, I have no doubt that, for the purpose of a preliminary investigation such as this, it would be safe to assume that the mean rate of fall from Dora Dora to Albury is not more than 2½ feet per mile.

The various points enumerated show that the valley of the Upper Murray is very ill-adapted for canal construction. The hills are steep and rugged, and come in some cases close to the water's edge; the roads are of the hardest description; the soil, as a rule, is of an unsatisfactory character, and the fall in the river is so slight that any gain in head which could be obtained would be acquired at a cost absolutely prohibitive. The idea of tapping the Upper Murray and bringing a supply down the river valley may therefore be dismissed as impracticable.

With regard to the second arrangement for obtaining a supply from the Upper Murray, namely, by carrying it through or over the watershed dividing the Murray from the sources of supply of the Upper Billabong, examination of the plans in the office of the District Surveyor of Albury was sufficient to show that, if it were possible to carry out this project, the canal head would require to be between the Dora Dora Station and the Seven-mile Creek. Beyond the latter place the distance of the Murray from the watershed of the Billabong increases, while there is no increase in the rate of fall in the river. For this reason I selected Dora Dora as the place for ascertaining the discharge and the rate of fall of the Upper Murray. As already stated, the rate of fall in the Murray from Dora Dora to Albury may safely be taken at 2½ feet per mile. The distance by road is about 40 miles, and by river about 80 miles. The reduced level of the surface of the Murray at Albury was 490, so that when I measured the discharge at Dora Dora the reduced level there could not be much over 690. The flood-level of the Billabong at Culcairn is 694, and the bed-level of the creek at the same place is 672. The distance of the Murray opposite Basin Flat from Culcairn is over 30 miles in a direct line, and the intervening country is mountainous throughout. Although the estimated reduced level of the river at Dora Dora must only be regarded as approximate, it is abundantly evident that the Woomargama Creek, which is a mountain stream flowing into the Billabong from within a few miles of Dora Dora, must be at a much higher level than the Murray, and therefore could not be utilized in carrying a supply to the Billabong. Yet this Woomargama Creek is in a more favourable situation than any of the other sources of the Billabong for the purpose of carrying a supply from the Murray. It is also clear that if it were possible to divert a supply from the Upper Murray to the Billabong—which is extremely doubtful—tunnelling would be required on such a scale as to make the undertaking altogether impracticable.

The points which have been advanced to show the impracticability of canals from the Upper Murray as far as the Seven-mile Creek would hold in much greater force in regard to the portion of the river beyond that place. Still, as the main objection to the idea of diverting the Upper Murray into the Billabong arises from the want of sufficient fall from the Murray, and as the levels of the Upper Murray have only been deduced approximately, I think it would be advisable to place the matter beyond dispute by levelling the Dora Dora from the railway station at Bowna.

Although there would be an advantage in diverting the whole available supply from the Upper Murray, still the main purposes of drawing a permanent supply from that river can be gained without the expense of carrying a canal through difficult and hilly country. I believe it will be found that the first, and probably the only place on the Murray at which a permanent canal can be taken off at a remunerative cost, is situated on the Bungowannah, or Bungowannah Run, at the end of the Jindera range of hills, and near the boundary of the counties of Goulburn and Hume. At the place where the river meets these hills it flows in a north-westerly direction and close to the foot of the range, which is here steep and rocky, with rough masses of granite cropping out over the hill face, and granite boulders forming the river bank. As it emerges from the range the river turns off almost due west, having an alluvial flat of increasing width on its northern side. At this place, where the river changes its course, there is a bar of pebbles forming a rapid, the difference of level above and below the bar being about 6 inches. This bar is at the place at which I think a weir can be constructed with advantage to throw a supply along a canal, which for a short distance near the head would follow the line in which the high ground meets the alluvial flat. The length of the weir proper would be only about 250 feet; but protective works might be required at some places on the low land, extending to the foot of the hills on the Victorian side of the river. The banks of the river were from 12 to 13 feet above the surface of the river at the time of my inspection. By using a movable weir, which would remain raised only while the supply of the river was low, and which would lie flat in the river-bed during floods, I believe it would be quite practicable to obtain a permanent supply without interfering with the flood-levels.

The points in favour of the proposed site are as follows:—1st. It is at the last range of hills, with only open plain country beyond, so that there would be no rock excavation and no difficult country to pass through. 2nd. The river valley is at this place moderate in width and bounded by hills. 3rd. The depth of cutting, so far as can be judged without a survey, would be comparatively slight from the outset.

The distance of the Jindera hills from Albury by river cannot be more than about 10 miles, and the fall in that length is at the rate of about 1 foot per mile. The reduced level of the water surface, as I found it, must therefore have been 480, or very nearly so. The reduced level of the country round Jerilderie may be taken as 361, and that at Deniliquin at 289. The former place is 78 miles, and the latter 111 miles, from the proposed canal head. From the Murray at Jindera hills to Jerilderie there is therefore an average fall of more than 18 inches per mile, and between the same place and Deniliquin a fall of nearly 1 foot 9 inches per mile. As the fall of the country is regular and in a westerly and north-westerly direction, the conditions are remarkably favourable for the construction of a permanent canal for irrigation and water-supply in the upper portion of the district between the Murray and the Billabong Creek.

In considering the discharging capacity which should be adopted for such a canal, the question whether the navigation of the river can be interfered with at once suggests itself. Navigation as far as Albury is considered practicable when the height on the old guage there is at least 4 feet, that is when the surface of the river there is about 494 feet above sea-level. The discharge at Albury at the time of my visit was nearly 1,200 cubic feet per second, and the river was only 490·21 feet above sea-level. If a canal carrying 1,000 cubic feet per second were constructed, the navigation-level would probably be raised to 7½ feet on the gauge. The question as to the effect on the navigation at Echuca and other places could not be determined without further investigation into the sections and discharges at those places. I have not at present any means of estimating the value of the navigation which would be lost through the abstraction of such a supply; but, in regard to the advantages which would be acquired, I may mention that 1,000 cubic feet per second should irrigate about 200,000 acres of land, and as £1 per acre per annum would not be an excessive rate, the gross revenue arising from the distribution of that quantity of water would be £200,000 per annum. A canal having a bed width of 62 feet, slopes of 1 to 1, a depth of 6½ feet of water, and a fall of 1 in 5,000—that is slightly over 1 foot per mile—would discharge the quantity assumed.

In connection with the available supply there is still another question, namely, whether the quantity of water flowing into the Murray, in the Mitta Mitta and Little Rivers, can be depended on. This also is a matter requiring further investigation.

On the whole there is a strong probability that a remunerative permanent canal can be constructed from the Murray at the place mentioned. For the design of such a canal, accurate surveys and levels, carried out on a comprehensive scale and in a systematic manner are indispensable.

The canal which has already been discussed would carry a permanent supply, and utilize the whole available portion of the minimum discharge of the Murray near Albury. In addition to this, I have ascertained that much can be done in saving flood-waters by means of what in previous reports I have termed "inundation canals." The first place at which there appears to be any prospect of such a work being practicable is at Howlong. The hills on the New South Wales side of the river gradually become lower and more distant till Howlong is reached, and there they almost entirely disappear. Near Howlong, and extending in a direction approximately parallel to the river, there is a valley, or rather depression, between the river and the hills. This valley is separated from the river by a ridge along which a ridge passes from Albury to Corowa. At Howlong there is a low and narrow place in this ridge, where it is said that in extraordinary floods the water passes over into the valley beyond. It is also alleged that in high flood a channel called the Twelve-mile Creek receives a supply from the Murray through a lagoon at Howlong, and that in exceptional cases the flood-water passes along this creek to the Billabong at about 10 miles from Jerilderie. Some of the farmers at Howlong believe that if the ridge were cut through, a supply could be obtained from the river in ordinary floods at very little expense. This is doubtful, but the question is worth further investigation.

From Howlong to beyond Corowa the high land bordering on the alluvial flats, through which the Murray flows, appears to range from 30 to 40 feet above the ordinary low supply in the river. It seems very improbable that any supply of flood-water can be drawn from the Murray throughout this distance.

Between Corowa and Tocumwal the level of the country becomes lower relatively to the river, and the colour of the soil becomes darker. In the neighbourhood of Tocumwal the ordinary surface of the river is only about 10 or 12 feet below the surrounding country, and the township is situated on the only piece of land which is not liable to be covered in high floods. Here the practicability of inundation canals on an extensive scale is beyond question. The river banks, as already stated, are low, the surface of the surrounding district is remarkably uniform, and the ground has a steady fall from the river in a north-westerly direction. Beginning at Mr. M'Farlane's Baruga Station, and about 8 miles up-stream from Tocumwal, there is a series of creeks into which the flood-water of the Murray occasionally flows. It is not unlikely that the levels and surveys will show that several of these creeks can be utilized with advantage; but, so far as I could ascertain in the limited time at my disposal, the Tuppal Creek will be the most easily dealt with in proportion to the benefits it will confer. Commencing as an ill-defined depression in the ground at the bank of the Murray, about 2½ miles down-stream from Tocumwal, the Tuppal Creek becomes deeper and better defined, till at 12 miles from Tocumwal its depth is about 12 feet, and its top width about 35 feet. This creek is here very similar in appearance to the Yanko, to which it is in other respects a counterpart, as its relation to the Murray corresponds exactly to the relation which the Yanko Creek bears to the Murrumbidgee. There is, however, a difference in regard to the manner in which the Tuppal receives the flood-water. When the surface of the Murray at Albury is 9 or 10 feet above what is then termed "summer level," no supply is received into the Tuppal Creek at its head; but the flood-water passes into it through several small creeks near Wopperana. The most important of these small creeks are the Narangi, Tuppal, and the Native Dog Creeks. Before the flood-water will pass into the Tuppal Creek at the head, the height on the gauge at Albury must be 12 feet or more, that is, the reduced level of the surface of the river at Albury must be about 502. Mr. Brown, the owner of the Tuppal Run, was so confident of being able to obtain a good supply from the head of the Tuppal Creek in ordinary floods, that he endeavoured to secure the co-operation of his neighbours and carry out the necessary work as a private enterprise. I think it is better that this arrangement was not followed out, as it is improbable that anything more would have been aimed at than providing a partial supply in the first 20 or 30 miles of the creek. That the question is one which merits treatment on a comprehensive scale is at once evident, when it is considered that the fall from the flood-level at Tocumwal to the ground level at Deniliquin is 77 feet, and from the latter place to the junction of the Murray and Murrumbidgee 100 feet, and that the fall, as far as can be judged, is regular.

After examining the levels, which I compiled for the Commission from the plans and records in the Government Departments, I ventured to give the opinion that there was then sufficient information to warrant the expense of a complete set of cross-sections of the country between the Murray and the Murrumbidgee. In this report I have dealt only with that portion of the country between the Murray on the south, and the Billabong Creek and Edward River on the north. The paramount importance of canals in this district is indisputable, and I think I have shown clearly that the practicability of constructing them is beyond question. Under these circumstances, and considering the extent to which this part of the country is sometimes devastated by droughts, I think the necessary surveys and levels should be commenced without delay. It is almost unnecessary for me to add that the more complete and comprehensive the surveys are made, the less will be the first cost and the subsequent maintenance of any works which may be undertaken.

H. G. M'KINNEY, M.E., M.I.C.E.,
Engineer to the Commission.

REPORT ON THE NAMOI RIVER.

To the President and Members of the Commission,—

Gentlemen, Sydney, 15 April, 1885.

In accordance with your decision, at a meeting of the 19th March, I have inspected the Namoi River in the neighbourhood of Gunnedah and Narrabri, with special reference to certain sites for the conservation of water, suggested by Mr. T. K. Abbott, S.M., in his evidence before the Commission in October last, and I have the honour to forward you my report thereon.

Reservoir site, No. 1.

The first site examined is situated at a point on the Namoi River about 2 miles from Carroll, where a spur from a conspicuous conical hill strikes the right bank of the river. This spur would form the western extremity of the proposed dam, whilst the eastern end would abut on a long spur about 2 miles from the opposite bank of the river. The banks are steep, and vary in depth from 20 ft. to 30 ft., and the channel is about 50 ft. wide. The country between the above spurs and on the site of dam is almost level, and is composed of post-tertiary alluvial drifts which have not been bottomed. Wells have been sunk on this plain to a depth of 30 ft., when a constant and ample supply of water for stock and household purposes was tapped. A brief inspection of this position satisfied me that it was unsuitable for a dam, because of the great distance of deep permeable country between the bounding spurs.

Reservoir site, No. 2.

The next site I inspected is situated in a gap in one of the numerous ridges crossing the country in this vicinity, and in proximity to the western boundary of the parish of Yarrari. This gap is about a mile wide, and is intersected by the Tulcumbah Creek. A hard conglomerate spur immediately approaches the left bank of the creek, and dips under it apparently on the line of strike at an angle of 10 degrees. The country rises very gradually till it meets the opposite spur, which consists of porphyritic rock. The country between the spurs is composed of alluvial drifts, which have been proved, by two wells sunk at some distance apart and on each side of the gap, to be over 140 feet deep. There is therefore the same insuperable objection to dam constructions in this position as before in the first site.

Reservoir site, No. 3.

The third position I examined is situated on the Namoi River, about 1½ mile north-west of Mr. Winter's head station, and in the parish of Namoi, about 7 miles by river course above the junction of the Peel River. At this point the Namoi has cut through a bold ridge of hard conglomerate, which forms steep banks on either side. (*Vide plan in accompanying portfolio.*) At about 100 yards higher up the river it is flanked by a basaltic dyke, which separates it from a hard blue encrinital limestone belt traceable for miles, at times forming conspicuous and detached ridges or spurs, and at times, as in this instance, sinking so as only to be just visible above the surface of the ground. This narrow gorge offers many advantages for the construction of a dam. Its base and extremities would be embedded in the solid rock of the above ridge, which appears to terminate the divide between the Namoi and Peel Rivers. A dam 75 feet high would only measure 115 feet across at base, and 812 feet across at top. There is abundance of material in the vicinity for its construction. It would require to be an overshot dam, to provide for the contingency of an extensiue flood discharge; consequently it would have to be constructed of solid masonry in cement, or on the same principle as the mining storage reservoirs in California. Such dams have proved very successful there to a height of 70 feet, at a cost of only 12s. per yard. They consist of dry masonry, lined in front with 3-inch planking to prevent leakage. The faces are built up by hand, and the interior filled with stone, thrown in promiscuously. The outlet could be formed by a tunnel piercing the spur on the right bank of the river, and the by-wash by a cutting of about 20 feet in a depression of the ridge, about a mile from the left end of the dam.

Objection.

Such a dam would throw the river back about 13½ miles, and would enclose a large basin, which, judging from Mr. Higinbotham's partial survey, would impound over 10,000 million gallons of water. Thus all the conditions for the construction of an extensive reservoir at this position appear highly favourable, especially as regards the position of the dam and the facilities for its construction at a moderate cost, as also regards the natural advantages for a capacious by-wash and outlet tunnel, and the firm impermeable bed generally of the basin it would enclose.

Advantages.

There is, however, one grave objection to such a project, in the deposition of silt during floods and freshes. From reliable authority I am led to conclude that this deposit is enormous. Some are of opinion that it could easily be prevented from accumulating by a large sluice in the dam or outlet tunnel. But any such attempt to provide for the discharge of flood-waters would be hazardous, very costly, and would in every probability prove a failure. Further, any fresh as it met the rim of the reservoir would at once begin to lose its velocity and to deposit silt. Such a dam, therefore, in the course of a few years would completely alter the present *régime* of the river, gradually raising its bed and necessitating expensive works for its restoration to primal conditions.

Objection modified.

This difficulty might be considerably modified by constructing a series of similar impounding reservoirs at different intervals higher up the river, or where opportunity offered in the surrounding watershed, for which, according to report, the country offers unusual advantages.

Reservoir site, No. 4.

About 6½ miles higher up the river I examined another basin, formed by two low spurs running from the dividing ridge of the Peel and Namoi River, which converged as they approached the latter river. A dam 30 feet high at this spot would enclose a fine flat, with steep bounding sides, fully 3 miles long and half a mile wide. The converging spurs on which it would abut apparently consist of a brownish, close-grained Devonian sandstone, tilted at an angle of 30 degrees. As the rock was exposed in the water course representing the outlet to the river, a sound foundation for a dam would probably be found right across. As no survey has been made of this valley I am unable to furnish further particulars as to its value for conserving water. Mr. Higinbotham's levels of the previous reservoir show, however, that a large portion of this basin would be included within its area, whilst, if the dam were increased in height to 85 feet, the whole of it would be covered with deep water.

Particulars of Namoi River and valley.

The average width of the bed of the Namoi River in this district is about 40 feet at bottom and 180 feet at top. It has steep banks, which vary from 15 feet to 25 feet in height. Its declivity averages 5 feet per mile. Its present discharge is estimated at 45,360,000 gallons per diem. Its highest flood-mark is about 40 feet from bed. Its bed is chiefly filled with gravel and sand, whilst its banks are composed of clay, gravel, and sand, in varying proportions according to depth. In its course to Gunnedah it intersects numerous rocky spurs, where it exposes the strata on either side. The whole country appears to have been subjected to violent igneous eruptions, as shown by the frequent dikes of porphyry and basalt, which account for its broken character and for the numerous cross spurs and ridges. In places the sandstones and schists appear tilted at a very high angle and completely metamorphosed, whilst in other places they are soft and more evenly bedded, but rarely dip at a less angle than 20 degrees.

Turrawan waterhole.

After staying in this neighbourhood for two days I proceeded to Narrabri, to examine a large waterhole on the Namoi River in the neighbourhood of the township of Turrawan. This waterhole, or rather pine reach in the river, is very deep, is about 3¼ miles long, and has an average width of about 300 feet. The banks are steep, and are about 20 feet deep. At the upper end on the right bank there is an outcrop of hard tertiary sandstone with ferruginous bands, which has a very slight northerly dip. There is no indication of rock on the opposite bank, but about half a mile higher up a rocky sandstone spur abuts right on the left bank. At the lower end the right bank appears to be alluvial mixed largely with gravel, whilst the left bank is formed by a shelvy beach of almost pure gravel, offering an imposing obstacle to the construction of a weir or dam; besides which, the country being higher on both banks, there is no facility for an off-take.

Spring Creek basin.

Having heard of a probable site for a large reservoir at the mouth of Spring Creek, about 20 miles north of Narrabri valley, as its watercourse debouches from the mountain ridges, I spent another day in examining this locality. I found the country covered with dense scrub on both the ridges which flanked the valley, and also in the valley itself, consequently it was impossible to judge as to the capacity of the basin, or the length of dam required to impound it. Spring Creek heads in the Nandewar Range, which forms the main divide between the Namoi and Gwydir Rivers. This range takes a zig zag south-easterly course, and finally abuts on the main Cordillera, a few miles south of Uralla. After leaving the mountains, the creek flows through a rich plain, which has a gradual fall towards the Namoi of about 20 feet per mile. Nearer its source it is enclosed by high rugged ridges, which rise over 1,500 feet above the plains. Two long spurs from either ridge converge at the mouth of the valley, and offer certain advantages for a dam. The valley behind opens out to a flat of some extent, but without survey it is impossible to estimate the area of the basin which would be enclosed, or the quantity of water it would conserve. I was informed that there was another fine site for a reservoir at Maule's Creek, about 30 miles from Narrabri, and which I recommend should be examined at some future opportunity.

Maule's Creek.

Nandewar Range.

The whole aspect of the country on the southern flank of the Nandewar Range is distinctly volcanic, and, owing to the junction of strata of such widely different lithological character and age, will probably be liable to constant disturbances by earthquakes more or less severe, which will take the same course as those which upheaved the long parallel north and south ridges. In the same vicinity that tertiary rocks occur Devonian rocks crop out, greatly disturbed and crushed with faults and dislocations, caused by dikes of eruptive rocks, which constantly obtrude through them. The Nandewar Range terminates about 30 miles north-west from Narrabri, when it throws out numerous spurs in every direction. The above evidence of disturbance, together with the numerous conical shaped hills which stud the country, indicate the whole country to have been liable for ages to volcanic action and earthquakes. I have, &c.,

FREDK. B. GIPPS, C.E.

REPORT OF THE SECRETARY ON THE "CONSERVATION OF WATER IN VICTORIA."

To the President of the Commission,—

Sir, Sydney, 5 May, 1885.

I have the honour to report that, pursuant to your direction and to the invitation of the President of the Royal Commission on Water Supply for the Colony of Victoria, I accompanied the members of that body on their recent visit to the northern districts of that colony. They expressed much regret that you were unable to be with them, and they were pleased to extend to me a very cordial welcome. I had an opportunity of seeing several important works which Water Trusts in Victoria have constructed; and, as I was privileged to attend the meetings of the Commission held in the different townships for the taking of evidence, I had a favourable opportunity of learning the views of the principal residents in the several localities visited. I am indebted to the Secretary of the Victorian Royal Commission (Mr. Stuart Murray, C.E.), and to the Acting Secretary of the Department of Water Supply (Mr. C. H. Langtree), for their prompt and obliging compliance with applications I had occasion to make to them for official information.

The average annual rainfall of Victoria for the last twenty years has not exceeded 25½ inches; but in Victoria, as in New South Wales, the rainfall is very unequal in its distribution,—in some districts exceeding 50 inches, in others being less than 10. The lightest rainfall occurs in the northern districts, and over an area of nearly one-half of the Colony the rainfall of late years has been less than 15 inches, and over a considerable portion of it less than 10. The physical conditions of this area in other respects also very much resemble those of the level country in New South Wales, which falls from the western slopes of the Main Dividing Range to the Murray and the Darling.

The Victorian Land Act of 1869, which provided for an extension of the area which could be taken up by free selection, and which gave other facilities for the acquisition of land from the Crown which had not before existed, coupled with the heavy rainfall of 1870 and 1875, appear to be the principal causes which led to the occupation of the northern and north-eastern districts by an agricultural population. The floods of 1870 and 1875 produced a luxuriant growth of herbage and abundant crops in the succeeding seasons; but the continuance of dry seasons from 1878 to the present time has changed the prosperous conditions of settlement in those districts, and the people have had to wage a severe struggle for bare existence. Some have had to succumb under the pressure of successive droughts, and nearly all have been reduced to the direst straits to obtain water for their stock and for ordinary domestic purposes. In some of the localities which I visited, the farmers have had to drive their stock 15 and 20 miles to water, and it was no uncommon thing for the few muddy sources of supply to be besieged as late as 3 o'clock in the morning by farmers who had come long distances and had to wait their turn for many hours. In other places the inhabitants were almost wholly dependent on the water trains which the Government despatched from Sandhurst for the relief of their most pressing necessities.

Severe privations such as these quickened the perceptions of the people as to the need of permanent water-supply. While the country was under pastoral occupation a large amount of capital was expended in making provision for the storage of water, and as population thickened the Shire Councils devoted a very large part of their revenues to a similar purpose. Anything which could be done in this way, however, was felt to be desultory and inadequate to the requirements of the case. Schemes of general application were felt to be indispensable, and Messrs. Gordon and Black were called upon by the Government to report as to what could be done at a reasonable expense to obtain a supply of water to the northern plains—in the first place for domestic purposes and for the use of stock, and in the next for irrigation. They pushed forward their inquiries with all practicable speed, and in the years 1880 and 1881, they were in a position to advise the Government as to what was best to be done. They arrived at the conclusion that the yearly discharge of the rivers flowing northwards into the Murray, combined with the local rainfall, would be far more than was sufficient to meet the requirements of the settlers for stock and domestic purposes, if the winter rains were stored by a system of local works and made available for distribution during the dry period of the year; and at the same time such works could be made to form an integral part of any system of irrigation which might be found practicable, having regard to the capacity of storage and the cost of distribution. The general results of their proposals were thus summarized by them in their last report to the Minister:—

"Having now completed our report on the first part of the inquiry with which we were charged, we have arranged in a tabular form the information contained in the reports and the results of the approximate estimates.

"It will be seen that the total area proposed to be supplied with water for stock and domestic use under the different schemes (excluding Huntly, No. X, which is a minor work) is about 8,560 square miles, or nearly 5½ million acres, and that the population settled on this area, as nearly as we have been able to ascertain it, with the kind assistance of the Government Statist, is 54,493. This population varies in density from 2·75 to 8·1 per square mile, the average being 6·8. The estimated cost of the proposed works, exclusive of the purchase of land, varies from £18 2s. to £55 4s. 9d. in the different schemes, the average being £29 16s. 10d. per square mile of country, and the annual cost of interest and management from ½d. to 1½d., the average being under ¾d. per acre. Assuming the average numbers of a household to be four and a half, the annual cost per household will vary from 18s. 3d. (in the Wimmera) to £2 17s. 4d. (in the Gunbower scheme), the average being £1 6s. 2d. Assuming that an acre of land will yield 12 bushels of wheat, or support one sheep, and that the annual net profit per acre is respectively 12s. and 10s., or an average of 11s., as statistics seem to show, then this average annual cost will be equal to nearly the annual value of 2½ acres ; and as each household has on an average 434 acres, the annual cost would, on these data, amount to the yield of about half an acre in every hundred acres."

Most of the schemes propounded have been taken in hand by local bodies, and some of them are far advanced to completion. I purpose briefly referring in detail to the more important schemes, because, as it appears to me, they contain features of great value to New South Wales. Before I do so, however, it is desirable that I should invite your attention to some of the principal provisions of the law of Victoria on the conservation and supply of water, which have given scope and protection to the great works upon which energetic and self-reliant communities in Victoria were not slow to enter when with quick intelligence they perceived, from Messrs. Gordon and Black's reports, the lines upon which they could safely proceed. In the present condition of our laws, or rather the want of law applicable to our circumstances, and the total absence of local governing bodies, it is not conceivable how any schemes for the conservation and distribution of water over large areas of country can be initiated or carried out, or, if undertaken, how they can be protected and maintained ; and, if I am correct in this view, it seems to me that the provisions of the Victorian Statutes applicable to country which is almost identical in formation and level with the larger part of New South Wales must have deep interest to us. The Victorian Statutes bearing upon the subject are named in the margin. Copies have been obtained.

44 Vic. No. 688.
45 Vic. No. 716.
47 Vic. No. 778.
48 Vic. No. 829.

The Act under which the present Water Trusts were called into existence was brought forward in the Parliament of Victoria by the Hon. Charles Young, then Minister for Water Supply, and he still takes a very lively and intelligent interest in the question. Victoria has for many years enjoyed the advantages of local self-government; and, of its total area (87,884 square miles), 83,211 square miles are under the control of local municipal bodies, designated in one class of cases as cities, towns, and boroughs, and in the other as shires. The system has many advantages as compared with that under which roads, bridges, and other public improvements are devised and executed by central authorities and paid for directly from the general revenue. It is obvious that ratepayers, knowing that they must provide a large part of the cost of any work for the improvement of their district, if not indeed, in many cases, the whole of it, are careful to enter upon such works only as are of public utility; and, having an immediate interest in the efficient and economical construction of the works—the ratepayers may be regarded in the light of a body of unpaid inspectors, whose constant vigilance is calculated to exercise a check upon extravagance and to create a healthy public opinion inimical to jobbery, while at the same time it tends to ensure an equitable distribution of the funds for shire improvements. In all probability there are cases in which the action of Shire Councils gives rise to complaints of partiality, pretty much as in municipalities of more restricted character in New South Wales. An alderman is sometimes popularly supposed to provide for improvements against his own door ; but it by no means follows that such complaints are well founded ; and even if they were, they are an evil small in comparison with the dilatoriness and expensiveness of what is known as centralization. The annual endowment by Government to the local governing bodies in Victoria is £310,000, but their total revenues amounted in the year 1883-4 to £1,086,502.

Mr. Young, in framing his bill (45 Vic. 716) "for the Conservation and Distribution of Water throughout Victoria," took advantage of the organization which he found in healthy operation under the Local Government Act, and he sought to induce the Shires of different districts to co-operate in undertaking the duty of providing for their united requirements. The Water Trusts which were thereby brought into existence were constituted on the principle of Shire Councils, with only such modifications as seemed necessary to meet the new and larger functions they were called upon to exercise. The principle of local taxation for local benefits by works carried out under local supervision runs through all the statutes bearing on water conservation. The fact, however, that the Water Trusts would have entrusted to them the expenditure of Government loans, in some cases amounting to nearly £100,000, was probably the reason why it was determined that one Commisioner on each Trust should be appointed and removable by the Government, while the others were elected from among their own number by the members of the Shire Councils brought into co-operation. Section 2 empowers the Council of one or more municipal districts, singly or acting together, to prepare plans and descriptions of such waterworks as they desire for their districts; and if these are favourably reported on by professional men employed by the Minister, the Governor in Council may approve of or modify them in such a manner as, upon further investigation, and after the interests supposed to be in conflict with the scheme of the promoters have been expressed, may be judged expedient. The approval of the works and the constitution of the Trust is legally effected by an Order in Council, which must state—

(*a*) The amount of money which the Governor in Council will grant as a loan for the purpose of carrying out the same and paying the cost and expense of the plans and application for the same, and also the rate of interest which will be charged for such loan, such rate being at least one-half per centum more than the rate payable by the Government on the public loan out of which such loan may be granted;

(*b*) Shall proclaim the limits of the lands—whether within or without the municipal districts of the Council or Councils applying for the proposed waterworks—within which such Trust shall have authority to be called a Waterworks District;

(*c*) Shall state what are the principal works proposed to be constructed; and

(*d*) Shall contain such provisions (not inconsistent with this Act) as, according to the nature of the application and the facts and circumstances of each case, the Governor in Council shall think fit.

As a matter of fact, the plans which the Water Trusts have been formed to carry out are in the main those which were prepared at the instance of the Government by Messrs. Gordon and Black. The Government, while no doubt they rendered a very substantial service to the districts interested by securing the plans, are in no way responsible for them; they treat them as the plans of the parties applying for the Trust. The examination to which they subject them is to satisfy themselves as to the stability of the projects upon which they are asked to lend money, and they cannot be supposed to accept anything in the nature of a partnership liability. If the plans and estimates upon which a loan was procured were subsequently found wholly fallacious, and if it should happen that a Trust had squandered the loan upon works which turned out to be worthless, the Trust would not be able to evade their responsibility for the repayment of the loan, on the ground that the Government had approved of the plans. The Local Government Act of Victoria makes provision for the examination of municipal surveyors and engineers and the issue of certificates of competency. I am informed that the examining Board are very stringent in their requirements; and it is very probable, therefore, that the Shire Councils of Victoria have at their command an amount of highly skilled professional assistance which but for this circumstance would not be available. The relation of the Government to the Trusts is that of mortgagee and mortgagor. There are several sections in the Acts which provide for the supervision of the principal works—one which forbids the acceptance of a tender for the principal works until the terms of contract have been approved by the Governor in Council; another which enables the Government to require the Trust to dismiss their engineer; another which provides that, if the Minister so requires, the municipal works shall be carried out under the supervision of an officer appointed by the Government, the certificate of which officer may be made necessary before any portion of the cost of the works becomes chargeable against the loan. Another section provides for the annual audit of the accounts of the Trust by a Government auditor, all this being in addition to the direct representation which the Government have upon the Trust. The constitution of a Trust is provided for in section 18 (No. 716) as follows:—

"Each Waterworks Trust shall consist of Commissioners to be elected from time to time by the Council of each of the municipal districts which will, in the opinion of the Governor in Council, be directly benefited by the proposed waterworks, and which shall be specified in the Order in Council approving the construction of such waterworks or in any subsequent order, and of one other Commissioner who shall be appointed by the Governor in Council; and the number of Commissioners to be elected by each Council, not exceeding two, shall be determined by the Governor in Council.

"Every such Commissioner so elected or appointed the Governor in Council may remove from office, but no elected Commissioner shall be removed from office except on the application of the Council by which he was elected."

The scrutiny of the plans, &c., by an independent authority at the instance of Government, and the provisions made for Governmental interference at subsequent stages, were no doubt primarily intended for the protection of the interests of the Colony which provides the loan; and, if the scrutiny be sound and thorough, it must incidentally be of even greater benefit to the district more immediately concerned. From statements which I have heard in different quarters, I am led to think that there is very great danger lest these provisions—however excellent they may be theoretically—should be allowed to fall into disuse, or that the supervision for which they provide should become perfunctory and valueless. I am not aware that any defect so serious has been disclosed in the working of the Acts; but it should be remembered that they have been in existence for only a very short time; and the limited experience gained is by no means conclusive against the inference which I draw from the fact that the Government have not in their service any officer whom they can hold responsible for the advice upon which they act in the approval of plans and the constitution of Water Trusts. The Government are in a position analagous to that in which our own Government would be placed if, in the various cases they have to litigate, they had no Crown Solicitor or Attorney-General to advise them, but had to depend upon the casual services of the legal profession. It is possible—at least so I have been informed, on what I take to be trustworthy authority—for an engineer to devise a plan of waterworks upon which a district proposes to obtain a Government loan, to be called in by the Government to advise them, and he may also be afterwards engaged by the Shire to carry out the works; that is to say, at different periods of the negotiation he can act for the Trust and the Government—for the mortgagor and the mortgagee. The principle of self-government is one of such inestimable value, and the sacrifice which Shire councillors make of their time and personal comfort to enable them to render voluntary service to the general public is so great, that Governments may be expected to deal with such bodies as Water Trusts in a generous, confiding spirit; but inasmuch as the future of a "dry" district will depend upon the stability and success of the waterworks constructed, to say nothing of the ability of the ratepayers to repay the loan to the general public, it does seem of first importance that the examination of the schemes submitted for Government approval shall be of the most searching character, and be undertaken by the best engineers in the Government service. While the works are under construction, also, there should be a periodical inspection by competent officers, whose responsibilities should be solely to the Government. A very small staff would suffice for examining and inspecting purposes. The business would be likely to be better done, and on principles uniform in their application, as compared with the diversity which might be expected from the employment of a large number of non-official experts, paid by fees. A small staff would probably enable the Government to dispense with the provision for special representation in the membership of the Trust. While it might be taken to imply a doubt as to the capacity of the representative constituents of the Trust, the nominee element would not, in most country places, give any better security to Government than that which they would obtain by means of their engineers and auditors. It may be feared that appointments of this character might be sought after by persons who covet distinction in particular localities, and that the Government would find insuperable difficulty in discovering those best qualified to act.

As to the general power of the Trusts, they are so varied and important that I prefer to quote the definition contained in the Act itself (section 38 of 45 Vic. No. 716), rather than to attempt any generalization of my own. It reads thus :—

"For the purposes of this Act any Waterworks Trust by its officers or servants may subject to the provisions and restrictions herein contained and in accordance with plans approved by the Governor in Council as aforesaid exercise any of the following powers (that is to say) :—

It may enter upon any lands described in the plans and take the levels of the same and set out such parts thereof as it thinks necessary and dig and break up the soil of such lands or trench the same and remove or use all earth stones trees or other things dug or gotten out of the same.

It may enter upon take possession of and appropriate such land as shall be necessary for the construction or improvement of the works or for securing or improving the water to be supplied or the quality or purity thereof.

It may purchase or lease any existing waterworks and erect or construct all necessary waterwheels hydraulic engines and pumping or any other machinery.

It may from time to time sink wells or shafts and make maintain alter or discontinue reservoirs waterworks cisterns tanks aqueducts drains cuts sluices pipes culverts engines and other works and erect buildings upon the lands and streams authorized to be taken by or vested in it.

It may from time to time divert water from any lake lagoon swamp marsh river creek or watercourse to the extent specified in the authorized plan and descriptions of the waterworks.

It may from time to time divert or alter as well temporarily as permanently any part of the course of any rivers creeks or watercourses roads streets or ways in order the more conveniently to carry out any of the powers conferred on the Trusts.

It may construct weirs and dams in any river creek or watercourse.

It may cut drains and deliver water into or take water from and embank widen or deepen any river creek watercourse lake lagoon swamp or marsh.

It may at any time enter upon any lands roads or streets for the purpose of repairing or altering any watercourses and other works under the control of the Trust or in any way connected with such works."

The Water Trusts and local municipal bodies have powers similar to those reserved to the Government of this Colony under which they may enter upon lands to obtain timber and materials for roadmaking, but they wisely abstain from the exercise of them unless necessity arises in very exceptional cases. As a general rule all work is done by contract, and the contractor is left to his own resources in providing materials, quite as much so as a builder in providing bricks. Water Trusts, however, are compelled to enter upon and make watercourses through private property, and the law provides for compensation to the owner in the form of "easement" privileges over lands required for channels and other works, "such lands not being the site or curtilage of any house or garden, yard, court, plantation, planted walk, avenue, or nursery for trees." The compensation to be paid for the easement may be either as a gross sum or a yearly rent, as agreed upon by the parties or as may be determined under the Lands Compensation Statute. The question of compensation is one which ought to be well considered in any legislation on the subject, so as to protect individuals from oppression on the one hand and the general public from extortion on the other. The bulk of the channels will be for subsidiary distribution, not more than two yards wide. None that I saw were fenced in; but provision was made by substantial bridges for stock to cross from one part of the paddock to another; and suitable slopes were also made at which the stock can drink. The right of "easement" includes the channel and the "spoil," which is thrown a yard or two away on the lower side, and soon forms a neat grassy ledge along the line of the drains. Provision is also made on the lower side at regular intervals, to the extent of 300 feet per mile, for the escape of storm-waters in the event of the conduits being filled. These channels already number many hundred miles in length; and owners who are disposed to put a fancy valuation upon their property will try to drive hard bargains. The "easement" right over the bulk of the property which I saw had been settled at £3 an acre, but there were those who were holding out for £10. It is extremely questionable whether in nine cases out of ten any compensation ought to be given for carrying a running stream of water through what would otherwise be waterless country—the increased value given to the land being greater than any loss of pasturage. In ordinary cases compensation may form an important item in the cost of works; and I am disposed to suggest that no compensation ought to be given to any man who cannot show that he has, by the expenditure of his own money in water-supply, taken all necessary precautions to keep his stock alive. The works of the Trusts are exempted from municipal taxation.

The financial aspect of the question is one to which, doubtless, you will attach importance. The tanks and wells constructed by the Government of New South Wales have been chiefly meant to facilitate the travelling stock, and in a few instances they have also been available for the supply of small townships. The expenditure (£210,000) as a whole, however, may be regarded very much in the light of a subsidy to the pastoral interest, and as being purely eleemosynary; for while the revenue derived as rent for the leasing of the watering-places amounts to £400 per annum, the yearly cost of supervision, as distinct from maintenance, amounts to nearly £5,000. Victoria being well supplied with railways, all the stock from long distances for Melbourne are trucked. It will have been inferred, from what I have already written, that the principle upon which Parliament has proceeded in Victoria is, that each district shall pay for its own improvement—water conservation being no exception to the rule. It is true that, in addition to the £400,000 loan raised for the purpose of being lent to the Water Trusts, the Legislature has appropriated £100,000 as a free grant. Of this sum £91,000 has been allotted; but the rule which governs its distribution is based upon the readiness of the inhabitants to tax themselves, as shown by the magnitude of the works they undertake. The particulars of the disbursement of the loan and of the grant will be found in the return (*Appendix* A) which the Acting Secretary of the Water Supply Department has been good enough to prepare for me. The £100,000 was granted as an encouragement to the inhabitants of particular districts to assume the heavy responsibilities which it was seen that any large scheme of water supply must involve; but, unlike the endowment to the municipal bodies, it is a final and not an annual subsidy.

The law empowers any Trust to which the Government have granted a loan for the construction of waterworks to levy upon all lands and tenements situate within the district supplied "for all or any of the purposes of—

(*a*) Paying interest on such loan;
(*b*) Maintaining such waterworks in an efficient state; or
(*c*) Extending the waterworks as the Governor in Council may authorize." (Sec. 53, No. 716.)

The late Act (47 Vic. 778, sec. 97) provides that the rate shall not be levied until notice has been given in the Government Gazette that the district, or part of the district, as the case may be, is supplied with water under the provisions of the Act. The municipal valuation is to be taken as the basis of assessment (sec. 57, No. 716), and no rate shall exceed 10 per cent. per annum on the annual valuation of the property (sec. 54, No. 716). The rates may be recovered summarily before any two justices; and, in the case of any property in a water-supply district being unoccupied, and the rates accruing thereon being unpaid for a period of five years, the Trust may take possession of it and hold it as against any person interested, and may from time to time grant leases of the property (sec. 61, No. 716).

The interest which the Government charge the Water Trust is one-half per cent. higher than that at which they negotiate the loan, which—making allowance for the cost of floating the loan, exchange, and the time before interest becomes payable by the Trusts—is practically the price which the Government themselves pay for the use of the money. The last loan was raised at 4 per cent.—a much lower rate than the Trusts could expect to obtain if they borrowed the money direct. The Act 47 Vic. No. 778 provides that the aggregate amount which can be borrowed by a Trust shall not at any time exceed 70 per cent. of the value of the land within the area of the Trust (sec. 30); and if a Trust borrows money on the credit of the area which the Trust is not legally bound to pay, then all the Commissioners of the Trust who have consented to the borrowing are made jointly and severally liable to pay the amount (sec. 57, No. 778). The proviso to section 91 of the same Act sets an important limit to the borrowing powers of the Trust, with a view to protect the ratepayers from exhorbitant taxation. It is in these words:—

"Provided that the amount of any such additional loan granted under the provisions of this Act to any waterworks Trust shall be such that the sum of the yearly interest payable thereon and of the yearly interest payable on any other loan granted by the Governor in Council to such Waterworks Trust shall not exceed the amount which can be raised in any year by a rate of one shilling and sixpence in the pound upon the ratable property within the waterworks district of such Waterworks Trust."

The quotation which I have made from the principal Act (No. 716, sec. 53) indicates that the payment of interest is to be one of the objects to which the rates shall be applied; but there is nothing in the section to make it a first charge, or to prevent a Trust from applying £99 out of the £100 to the maintenance and extension of the works, leaving the payment of interest postponed indefinitely. Under the 51st section, it would be competent for the Board of Land and Works, when accepting the mortgage which the Trusts execute for the repayment of their loans, to make such a contract in regard to the disposal of the rates as the Board may deem advisable. The Amending Act of 1883 (47 Vic. No. 778) contains explicit provisions as to the payment of interest and principal. Thus, for example, section 46 enacts that every Trust shall from time to time make and levy such rates as are sufficient to pay the interest due upon any loan obtained by the Trust under the Act, and to provide for the necessary annual payments for the sinking fund of such loan, and also for all current expenses incurred by the Trust in the control and management of the area over which their powers extend. The sinking fund mentioned in this section is a very important supplement to the legislation of 1881. The extent and operation of it are set forth in the three following sections (115, 116, 117 of No. 778) :—

"115. When any Waterworks or Irrigation Trust has obtained a loan under the provisions of this or the Principal Act a sinking fund shall be formed to liquidate the same in the manner following :—

Such Waterworks or Irrigation Trust shall after the levying of its first rate cause a sum being such percentage of the principal sum of such loan as may be agreed upon between such Trust and the Governor in Council not being at any time less than one pound ten shillings per centum of such principal sum to be in every year after the date of the granting of such loan and until the complete liquidation thereof or until the Commissioners of Audit or any two of them by writing under their hands certify that the amount of the sinking fund formed hereunder is sufficient to secure the liquidation of such loan invested in the purchase of Victorian Government stock which stock shall be placed in the stock ledgers in the names of the Treasurer of Victoria and of such Waterworks Trust as aforesaid to an account entitled as of such loan. Provided that in all cases in which Trusts cannot secure Government stock at par the Trust shall pay into the account of the Treasurer of Victoria and such Trust the money percentage hereinbefore directed to be invested in Government stock and all such moneys shall carry interest not being at any time more than four pounds per centum per annum and such interest shall be placed to the credit of the sinking fund in the same way as provided for interest accruing on Government stock.

"116. All interest accruing due on any stock or moneys for the time being standing to the credit of any account forming any sinking fund shall be invested in the purchase of Victorian Government stock or moneys which shall be placed to the credit of the same account.

"117. As soon as conveniently may be after the amount of any sinking fund shall have increased to such sum as shall be sufficient to secure the liquidation of the loan in respect of which such sinking fund was formed the Victorian Government stock placed to the credit of the account entitled as of that loan shall be sold out and the proceeds thereof shall be applied in the first place to the redemption of such loan and thereafter to such purposes as the Waterworks or Irrigation Trust which invested the same directs."

There is one other provision in the law of Victoria bearing upon this part of the subject to which I must draw your attention. I refer to the 4th section of the Act of 1884 (48 Vic. No. 829), which provides that the Governor in Council may, if in his opinion there be sufficient reason therefor, notwithstanding the provisions of the Acts of 1881 and 1883, or of anything contained in any mortgage made under the authority of these Acts, "direct that interest on any moneys secured by any such mortgage shall be charged from a day not more than two years subsequent to the day in that behalf specified in such mortgage." I am not aware of the reason which led to this amendment of the law ; but considering the magnitude of the works to be constructed—that experience in the construction of such works in Australia is as yet very limited—that there are often great fluctuations in the supply of labour, and occasionally great vicissitudes in the amount of the rainfall—it will probably be acknowledged that there must have been strong grounds to recommend such a modification of the original contracts. Whether it is advisable to give to the executive authority power to postpone the day of payment in one district and to refuse the like concession to another appears to be a question of expediency ; and the assumption that a Government will exhibit partiality in the exercise of the discretion vested in them may not be more creditable to those who make it than to those assailed by it. In the absence of some flexible provision as this, the alternative of a rigid insistance upon punctual payment might entail great hardship.

In the contingency of ratepayers or Councils failing to elect Commissioners to the Trust, the Governor in Council has power to constitute the body by appointing them (sec. 21, No. 716) ; and should a Trust fail to meet their financial obligations to the Government, the law empowers the Board of Land and Works (which acts for the Government in its relations to the Trusts) to take possession of the works and to levy the rates. The sections bearing upon this point are 52 of No. 716, and 46 of No. 778.

The question naturally arises as to the disposition of the people to pay interest on the loans. It should be borne in mind that the Trusts are of recent formation, and that in only two or three of them have the works been completed sufficiently long to admit of a rate being struck. I am informed that the Wimmera Trust, whose expenditure has exceeded £95,000, has struck a rate, and that other two Trusts whose works are on the point of completion are about to do so. It would probably be somewhat remarkable if the people did not regard the Government as a lenient creditor; and in different localities through which I have passed I have heard views expressed which appeared to me to savour of repudiation; but when the idea has been nakedly put to a witness in so many words, repudiation itself has been disclaimed. In one case, where a witness was avowing views such as I have expressed, and condemning the levying of a rate, the audience in the Court-house instantly, and with much warmth, expressed their strong dissent. It must be extremely difficult for a visitor passing through a community to know precisely what weight attaches to the opinions of persons whom he meets in the briefest possible way; and if I had had longer opportunities for gaining information, I should greatly distrust my ability to form a correct judgment. If the question was one which merely concerned the honesty of our neighbours, I should feel myself chargeable with presumption in referring to it; but, because I think it not improbable that the Government of New South Wales may be led to act on lines similar to those on which Victoria has proceeded, I feel bound to suggest your consideration of the subject purely as an abstract question. Just now, when the residents of the northern areas of Victoria are still painfully sensible of the sufferings and loss entailed upon them by five or six years' drought, they readily acknowledge the immense benefits which a permanent supply of water will confer upon them; but after the lapse of a cycle of wet years, during which their crops might be destroyed by superabundant moisture and some of their waterworks swept away by floods, they might be less disinclined to listen to those who make large bids for popularity by counselling repudiation than they are at present. Dropping the question of honesty, I will not asperse the intelligence of the majority of the ratepayers by supposing that they would not be quick to perceive that a policy of repudiation would be more disastrous in retarding permanent settlement than the effects of the most desolating drought; but it does not occur to me that the provision made by the law of 1883 for the repayment every year of a portion of the debt is one wholly in the interests of good government and sound morality. If, unfortunately, it should ever happen that one Trust should be led to try and shuffle out of its obligations, all the other Trusts who had steadily paid their interest and contributions to the sinking fund would form a strong make-weight with the rest of the community in strengthening the hands of any Minister whose duty it would be to insist upon payments due to the State by debtors whose suffrages he might have to seek.

Works of the magnitude of some of those which I have seen are calculated to evoke the liveliest admiration of the communities who have had the courage to undertake them and the energy and skill to push them on to such rapid completion, more particularly when it is obvious that the pressure of taxation must be great. It requires but little foresight, however, to perceive that present self-denial in the intelligent pursuit of their own immediate welfare must be followed by the most beneficent and splendid results to the Colony as a whole. The arid plains of northern Victoria are without doubt destined to become well watered, and much of them as fruitful as a garden. As the railways of Belgium have paid for themselves and become a source of great wealth to its people, vivifying production and giving value to the smallest articles before not worth the cost of carriage, so it may be expected that the Water and Irrigation Trusts of Victoria, having extinguished their debts by the annual payment of one and a half per cent., will become most valuable properties to the districts which have had the enterprise to construct them, and coming generations will enter upon a goodly heritage.

A feature of Victorian legislation upon this subject which strikes me as very admirable is the adaptability of its provisions to any area, say a combination of municipal districts, a single shire, a riding (which is a division of a shire), or a town, so that none are excluded from the benefits of Government help to united effort to obtain water-supply, and none are included in the area of taxation whom that supply does not in one form or other benefit. (Sections 67, 79, 80, 94 of 47 Vic. No. 778.) The constitution of the several kinds of Trusts are the same in principle, and there are provisions under which individuals other than ratepayers may combine to acquire the right to conserve and distribute water, but their powers are more restricted than those conferred upon representative bodies. Waterworks districts may also be provided, and differential rates levied according to the extent of the advantage conferred. The law appears to be designed to confer substantial equity upon all—however varied the physical condition of the country embraced in the Trust—however abundant or scarce the natural supply of water in the different localities may be. I say substantial equity, because I suppose absolute equality is a thing unattainable in dealing with so many interests as are involved in any large tract of country. The man fortunate enough to own land whose configuration readily admits of the storage of water, and provident enough to construct the dams or tanks necessary to supply his wants, may object to pay taxes for works designed to benefit the majority who are less fortunate or less thrifty, pretty much in the same way as many residents in the western suburbs of Sydney, having provided themselves with abundant storage for water, might object to pay rates for the Nepean supply when it shall be brought through their boroughs on its course to Sydney. Such cases may have the appearance of hardship if the certain tendency of water supply to increase the general value of property be ignored.

The Trusts can, if they choose, arrange with the municipal bodies to collect their rates for them, but the presumption is that in most cases this dual form of local government will entail the employment of two staffs—an engineer and secretary for water purposes, a surveyor and clerk for road purposes. If there be any value in the suggestion which I have made in a previous paragraph, that special representation of the Government on the Trust might be dispensed with, by a thorough examination of plans in the first instance and periodical inspection during the construction of the principal works, it might be found desirable by the Government of this Colony, in any proposed legislation on the subject of local government, to relegate the business of conserving water to them, and thus obviate duplicating the machinery of government by the creation of special Trusts. In that view of the case, it would probably be found expedient and quite practicable in the level country to determine the boundaries of municipal districts by the lines of their natural drainage areas. I assume that on the western plains the conservation and distribution of water is of paramount importance. The country being destitute of road-making material must depend upon railways, which are not regarded as local works, and as the traffic chiefly occurs in the dry time of the year the surface of the soil is sufficiently hard to bear traction.

The necessity for schemes of water conservation is no doubt common to all the Colonies of Australia ; but, as it appears to me, there are special reasons which make the need more urgent in New South Wales than in Victoria. In the latter Colony frontages to creeks and rivers, a mile wide on either side, are reserved by the Government, so that whatever water may be found in the natural channels is accessible to the general public quite as much as to the lessee. In New South Wales these frontages and the natural waterholes have to a very great extent been alienated to private individuals, with the consequence that the lands adjacent thereto must almost of necessity pass by lease or otherwise into the hands of the pastoralist who has acquired a monopoly of the water. I presume it cannot be expected that the Government will advance money to private individuals, or permit them to intercept the flow of water in creeks and rivers ; and that therefore any schemes for the conservation of water will have to be carried out by municipal bodies. Inasmuch, however, as the Crown is still the owner of immense areas of land, care should be taken, in the examination of any scheme submitted for their approval, to see that it was so designed to benefit the largest possible area, and that the whole of an available supply of water should not be monopolized by a comparatively few persons. It cannot be expected that municipal bodies would take water through unoccupied Crown lands from which they could expect to derive no revenue ; but their schemes ought to be so devised that they should be capable of commanding such areas if the natural features of the country permitted of that being done. The effect of such schemes must be to break up any existing monopolies of water, by the multiplication to the extent of many hundreds (I will even hope thousands) of miles of water frontage, and that the value of the public estate will be correspondingly increased thereby. In this view of the matter, Government will be fully compensated for such moderate grants as it may be in their power to make by way of supplement to their loans to local bodies ; but I suggest that it would not be expedient to allow district municipal bodies to levy a water-rate upon *unoccupied* Crown lands, for it is conceivable that cases might occur in which such bodies might so use their powers as to throw the burden of taxation from their own shoulders on to those of the general public. In all probability, where water is caused to flow through unoccupied land, occupation will almost immediately follow, and the taxable area will be thereby increased. The rating powers of Water Trusts in Victoria are, as I have stated, based on the municipal assessment ; and if Crown lands in private occupation are rated by any municipality, a Water Works Trust has also the power to levy rates.

It seems to be a characteristic of all the rivers flowing through the level districts to form banks higher than most of the country which they drain; and as in Victoria, so also in New South Wales, there are numerous effluent creeks which draw off the flood-waters from the main streams. Inspection of the works carried out in Victoria will demonstrate the soundness of the views which, if I mistake not, you have long since formed that, by the construction of weirs at suitable points across the main streams, much of the flood-water which is now lost in the soil or which flows on to the sea might be thrown back into these effluent creeks, such as the Yanko, Colombo, and the Billabong, so that for a comparatively small outlay for headworks in improving and defining the channels, hundreds of miles of natural storage might in flood-years be utilized.

"Riparian rights" are, I believe, held to be an insuperable obstacle to water conservation in many districts, in the present state of the law. May I suggest for your consideration that the vesting of the control of watercourses in the hands of Trusts or District Municipal Councillors, elected by the owners of property whose interests are concerned, would be a fairly satisfactory solution of the difficulty in New South Wales, as it appears to me to have been in Victoria? I assume that here as there the Government would exercise the right of defining boundaries after the fullest publicity had been given to all proceedings and a careful scrutiny of the projects submitted for their approval. If it were proposed to vest the power of determining boundaries and granting charters in the larger authority of Parliament, I should fear that, in the absence of any machinery by which conflicting interests could be reconciled, the expense, delay, and difficulty of obtaining special Acts of Parliament would be so great as to amount to a prohibition to the adoption of large schemes for water conservation. It is by no means improbable, although I only heard one complaint, which was afterwards shown to be grounded on wrong information, that the residents of one locality included in the area of a Water Trust do not receive the same amount of benefits as do others; but it is necessary that I should point out that the works of the Trusts were constructed with a view to equalize the benefits of water conservation as widely as possible. Weirs which impounded water at the heads of the streams are provided with compensation sluices through which a certain regulated quantity of water is allowed to flow to the people living lower down the stream. These, in the present development of water conservation, cannot have the same abundant supply as those living above the weir; yet if it were not for the weir they would have no supply at all—they would be left to the full enjoyment of their "riparian rights," that is to say, the privilege of contemplating an empty creek, the dryness of whose beds would absorb a large proportion of even a very copious rainfall. It seems to be only a question of time when, by the multiplication of weirs, everybody will be almost equally fortunate.

Another point in the construction of weirs in Victoria ought not to escape attention; and that is the great length of their wings. The soil of the plains is of so fine a texture that it may be said to almost disolve under the action of water; and a very slight obstruction has often turned the course of what in flood-time is a large river. A weir which would merely extend from bank to bank would be swept away, or it would divert the flow of the river into some new channel. This danger appears to be fully recognized and successfully combated by making the crest of the weir of such a width and elevation as will permit of the even flow upon the aprons below of any flood discharges which cannot be impounded, and by carrying out the wings of the structure to whatever distance may be necessary to annihilate the scour. The designs for the weir which it is proposed to construct across the Goulburn shows a total length of 1,663 feet. Everything depends upon the stability of these structures, and no care which can be exercised appears to have been omitted in the construction of those which the Commissioners examined. The cost of them, however, does not appear to be larger than the resources of the district can meet—a result chiefly attributable to local control.

The distributing channels often intersect the public roads, and form watering-places for stock on each side of the bridge which carries the roadway over the middle of them. The channels at these points are pitched with blue-stone cubes. As there is no stone in the soil, the excavation of these channels is very cheaply made by means of horse-ploughs and scoops. The work is mostly done by farmers living in the district. The price paid for the excavation of the smaller drains and depositing the soil a yard or two away from the edge was 7d. and 7½d. per cubic yard. At the Waranga basin, where one side of the lake is being enclosed by a bank, on the top of which a water conduit is to be made, the cost of doing the following work was only 1s. per cubic yard of stuff in the bank:—Ploughing the surface upon which the bank was to be built, excavating soil for bank and carting it a distance of 2 chains, rolling the clay every 4 inches, so as to consolidate and practically make it into a puddled wall. The length of this bank, which is far advanced in construction, is two miles and a half, width across the top 25 feet, side slopes 2 to 1, and average height 12 feet. The price of 1s. a cube yard also includes the excavation of the conduit which will be formed in the top of the bank, and the proper disposal of the spoil. Here also horse-scoops and ploughs were the only excavating machinery employed.*

I see from Mr. Hayter's Victorian Year Book that there are forty-three towns and three Shires supplied with water, inclusive of Melbourne and its suburbs, whose population, numbering about 300,000 souls, have an abundant supply at high pressure. There are several other towns which have completed their works since that return was compiled (1883-4), and it is not brought down to a date sufficiently late to include all the Trust Works to which this memorandum has almost exclusive reference. It may not be out of place, however, to mention that the storage capacity of the reservoirs included in Mr. Hayter's return is stated as being 13,292,483,932 gallons, and the cost of the works, actual or estimated, as being £3,877,485. As it may not be deemed to be within the scope of your inquiries to institute any comparison between what has been done in this direction in Victoria with what has been projected here, I purpose to abstain from writing out much of the information placed at my disposal, although I may be permitted a passing allusion to what is known as the Coliban scheme, which, though financially among the least remunerative, has nevertheless been productive of immense advantages in other respects. The water impounded in the reservoir at Malmsbury flows for a distance of 100 miles to Sandhurst, supplying several small towns on the way; and by its agency Sandhurst, which was a place perfectly hideous in its desolation, probably without a parallel in its bad pre-eminence, has become one of the most attractive and healthful towns in Victoria. It has a fine sheet of water for boating, its streets are adorned by avenues of lofty trees, whose leafy beauty is the pride of its citizens, if not indeed of the people of Victoria. This city of 30,000 souls is indebted to its water supply for an incalculable amount of comfort and prosperity, and in large measure for its continued existence. The most instructive feature in regard to town supplies seems to me to belong to those towns which have provided for their own requirements by means of loans advanced to them under the "urban" sections of the Water Conservation Acts. I may mention Echuca (population, 4,800) and Kerang (population, 400) as specimens of several others which offer a fine example to a large number of towns in New South Wales, which, having rivers flowing at their feet, could easily erect the pumping machinery and water-towers necessary to supply the inhabitants by a system of reticulation; and as an example of what may be done by towns farther removed from flowing water, I may mention Kyneton (population (3,300), which, at a cost of £25,000, including the reticulation, brings its supply through pipes from storage reservoirs at a distance of 9 miles, and which, by a 1s. rate, pays both interest and sinking funds. Here, as I believe is the case generally, the water rate covers the domestic supply; but all supplies to manufactories, brewers, livery stables, and gardens, are paid for by meter.

The desire to obtain water sufficient for irrigation is very strong in the northern districts of Victoria; indeed I think I should be justified in saying that the people are becoming clamorous on the subject, so satisfied are they that wet cultivation can be carried on with results far more profitable than dry. The subject was pressed upon the attention of the Commissioners in every township and by several witnesses. This is a point upon which I have taken rather full notes, but on further reflection it seems inexpedient that I should trouble you with many details. The advantages of irrigation have been demonstrated in many countries; and it may suffice to say that the experience which is being gained in Victoria is no exception to the general rule. As showing the extent to which it is being practised where water sufficient can be obtained, I may mention that one gentleman near Echuca has pumping appliances for the irrigation of 2,000 acres, another at Gunbower for an area of 10,000 acres, and a farmer at Kerang, who said that he irrigated successfully for thirteen years, described a voluntary association of twenty-one farmers who, by combining their labour, managed to bring water for a distance of 13 miles, and to irrigate 3,000 acres of land. In every case the witnesses expressed themselves as highly satisfied with the

---

* Since the remarks in the text were written Mr. Donkin has returned from America, and by the courtesy of the Honorable Charles Young I am able to lay before you descriptions and sketches of the buck scraper and ditching plough. The former implement may be used for excavating channels with slopes of not more than 4 to 1, and is especially suited for sand and loamy soils, in which situations it is superior to the scoop, removing such soil with a lead of 50 feet for 3d. per cubic yard.

results when water sufficient was obtainable; and many witnesses expressed the pleasure they would feel in paying a rate of 10s. per acre for water with which to irrigate their crops. While I was at Kerang, meetings of the "Irrigation Leagues of Victoria" were being held at the Shire Hall. The Rev. E. C. DeGaris, the President of the Central League, has been good enough to supply me with the following information respecting the Associations:—

"About two years ago the agitation for water-supply began to take the form of Irrigation Leagues. One was formed at Kerang, another at Durham Ox, another at Echuca, others at Rochester, Kyabram, Pyramid, Mocoena, Mysia (Korong Shire). Eventually these local Leagues were united in an organization called the Central Irrigation League. This body has no particular place of meeting, and has held sessions in Sandhurst, Melbourne, Echuca, Rochester, and Kerang.

At the meeting at which you were present the other night nearly all the delegates travelled long distances; one came 300 miles, several 150, and the average distance travelled was about 70 to 90 miles each delegate, excluding of course the few who were local residents. The country embraced by the Leagues is very wide, including chiefly plains bounded by the Murray, the Dividing Range, and the Avoca River. In Wimmera the agitation is only now beginning, and the delegate from that territory, present the other night, was the first sent to our League meetings. Besides the country indicated, Bacchus Marsh, and portions of Gippsland, are also discussing various schemes.

"There is no doubt about the earnestness of the people of the plains on the subject now, and every month furnishes new evidence of the growth of public opinion."

Much of our level country resembles that of the northern plains of Victoria, with the exception that it contains larger areas of very rich soil; but the land is owned in large blocks, and the circumstances of the population are not similar. There is no room to doubt whether the rural population of Victoria for many years to come will be dense enough to utilize all the water known to be available for irrigation; but in New South Wales the population is more sparse, and those who cultivate the soil are not grouped together in communities as in Victoria. The industry of the country is almost wholly pastoral, though probably the time has come when pastoralists are prepared to irrigate largely for fodder crops as a sort of insurance against drought, The examples of irrigation, carried on with such remarkable profits in California, with which the Press has lately made the country familiar, relate almost wholly to fruit-growing near railways, giving quick access to a protected market of about 60,000,000 souls, and are such as we can scarcely hope to emulate here; but it is very gratifying to find that, as far as experience obtained in Australia itself has gone, it is almost uniformly satisfactory.

The amendment of the Victorian Water Conservation Act, made in 1883 (47 Vic. No. 778), enlarged the scope of the Water Trusts so as to include irrigation. The schemes of Messrs. Gordon and Black, while primarily designed for stock and domestic purposes, also embraced provision for irrigation to the extent to which the water was available and the physical formation of the country suitable. Now that the works of the Echuca and Waranga Shires Trust are nearly completed, there is reason to expect that irrigation will soon become part of the farming of the district. The pumps which will lift the water from the Goulburn are of a capacity to supply water enough (beyond what will be needed for stock and domestic use) for the irrigation of 6,000 acres, so that there is here a good opportunity of testing the profitableness of irrigation on a small scale before the Shires commit themselves to the great undertaking of constructing a weir across the Goulburn, which would supply water by gravitation. The site of the proposed weir is at Murchison. The drainage area of the Goulburn above that point is about 4,000 square miles, much of the country having an exceptionally heavy rainfall, and the river being also fed by the melting of the snow on the Great Dividing Range. The readings of the gauge placed on the Goulburn at Murchison for the last three years shows, according to Messrs. Gordon and Black, that the minimum supply available for winter irrigation is 134,000 cube feet per minute, and they estimate that the irrigable area commanded by the scheme is 610,000 acres, one-third of which could be under wet cultivation at any one time. The lowest discharge of the river in summer has been ascertained to be 28,000 cube feet per minute, which it is computed would be sufficient to irrigate 30,000 acres; and when to this is added the flood-water which it is proposed to store in the Waranga Basin (3,600,000,000 cube feet, after making allowance for loss from evaporation), the total area which may be irrigated in summer would be 62,000 acres. In their report upon irrigation, Messrs. Gordon and Black point out population "must be considered as the gradually obtained result of irrigation, and also the indispensable condition of its continuance." They are of opinion that at least eighty-five persons to the square mile, or one to 7½ acres, would be required to carry on a mixed system of farming on the northern plains of Victoria, where one-third the area would be irrigated and two-thirds under dry crops. On this basis the Goulburn scheme would require a population of about 80,000, or about ten times the present population of the locality, to utilize the water available. The following paragraphs embody their reasoning on this part of the subject :—

"17. We find from a return appended to this Report, for which we are indebted to the Government Statist, that, in the agricultural districts comprised in our water supply schemes previously reported on, the population averages 8·3 per square mile. The area *occupied* is 523 acres per square mile, and 58·67 acres per head of population ; and the area *cultivated*, 86 acres per square mile, or nearly 10 acres per head of population. According to the proportion ruling in North Italy, the area of fully irrigated land that could be cultivated per head of the population would be 3⅓ acres, but the difference between irrigated and dry crops would probably be less where agricultural machinery is more largely employed, and for the present we assume that 5 acres of fully irrigated land could be cultivated per head of the population. A simple calculation will show that, with the present population of these districts, supposing one-third of the present cultivated area to be irrigated for root crops, beans, lucerne, &c., only 75 per cent. of the land would be cultivated, *i.e.* :—

50 acres of dry cultivation, at 10 acres per head... ...	5	persons.
25 acres of irrigated land, at 5 acres per head	5	,,
75 acres cultivated by	10	,,

That is to say, 85 per cent. of the land now cultivated would go out of cultivation.

"Conversely, in order that only the present proportion of cultivation to occupied land—about one-sixth—may be irrigated to the extent of one-third, the population required will be 13·3, or an increase of 33·3 per cent.

33·3 acres of irrigation, at 5 acres per head	6·66
66·6 ,, dry cultivation, at 10 acres per head... ...	6·66
	13·32

"18. In the same way it can be shown that, to completely irrigate the ordinary proportion—one-third—of these plains, and at the same time to dry-crop the remainder, a population of at least 85 to the square mile would be required, or, if dry crops were entirely given up, and two-thirds of the land used for grazing, about half that number, *i.e.*, an increase of about 500 per cent. on the present population. From these figures it is evident that, even with an abundant supply of water, the extent of irrigation proper that could be carried on by the present population of the Northern Plains would be very limited.

"19. For the second kind of irrigation, viz., occasional watering or flooding, after the first labour of preparing the land and forming the distributing channels, the labour required would not be so great, probably an additional 25 per cent. would suffice. Assuming this to be a fair estimate, and that it were desired and possible to obtain a sufficient supply of water to give an occasional watering to the whole of the area now cultivated (about one-eighth of the total area, by the official statistics), an addition of 25 per cent. to the present population would be required, or the amount of cultivation would have to be decreased by 20 per cent."

Water for the irrigation of a limited area will be obtainable from the northern lakes, fed by the Gunbower scheme, and elsewhere ; but a great deal of information respecting river discharges, and the extent to which water can be stored in elevated positions at the heads of creeks, will have to be collected before the extent to which irrigation is practicable can be ascertained. The only river which has been gauged for a sufficient time to give useful data is the Goulburn. I append a list of localities where gauges have been or are being placed. (*Appendix* B.)

Witnesses examined at Echuca and in other localities volunteered opinions in favour of weirs across the Murray, so as to divert its waters into depressions on elevated land, whence it could be drawn off by gravitation for irrigation. The time may come when the Colonies interested in the waters of the Murray will be rich enough to weir (and it may be lock) as well as bridge that stream ; but speculation on the subject at present is premature and of little importance. Some concern appears to have been expressed in the Legislature of Victoria lest New South Wales should divert snow-waters from their present flow into the Murrumbidgee ; but this must have been in forgetfulness of the fact that one of the principal schemes sanctioned by the Government of Victoria depends in a large measure upon the waters of the Murray being drawn off by a cutting into Gunbower Creek, and that others are almost wholly dependent upon the impounding of the water of rivers which flow into the Murray.

The first of the schemes visited by the Commissioners is that known as the Gunbower. It embraces an area of 690 square miles, and has been undertaken by the Swan Hill Trust, who have obtained a loan from the Government of £31,000 and a Parliamentary grant of £9,111. Their works may be said to begin at a point on the Murray, 16 miles below Echuca, where the outflow of the flood-water into the Gunbower Creek has been facilitated by a channel 10 feet wide at the bottom, with slopes of 1½ to 1. The water from the Gunbower Creek is admitted by a similar cutting into Taylor's Creek, flowing thence into the Kow Swamp, which covers an area of 16,000 acres, and which it is proposed to fill to an average depth of from 12 to 14 feet. By a weir at the outlet the storage could be still further increased. From this lake the water is to flow along the Box Creek, from which it will be taken by the Macorna Channel into Tragoowell Swamp and the Loddon River. The total length of this line of conduits is 40 miles. Bagot's Creek, 3½ miles, and the Pyramid Creek branch of 30 miles bring up the total length to 73½ miles. The channels along Deep Creek, Gunbower Creek, and Barr Creek extend for a distance of 55 miles ; from the weir across the Loddon at Kerang the channels, to feed a series of lakes lying to the north-west, extend for 12 miles ; and from the Leaghur dam on the Loddon to Lake Leaghur, and northwards by Wandella Creek to Lake Meering, Little Lake, Lake Don, Wandella Lake, Pelican Lake, and Lake Elizabeth, the course is 28 miles. In all, this scheme provides for the conveyance of water for a distance of 168 miles, and the conversion of a large number of lakes and swamps into important reservoirs, from several of which water may be available for irrigation. The surface inclination north-westerly from Mitramo to Kerang, 37 miles is 1 foot to the mile ; and from Kerang to Swan Hill, 33 miles, it is 0·734 per mile. One of the principal works in this scheme is the weir across the Loddon, below the junction of Pyramid Creek, near Kerang, which has been completed at a cost of £5,211. It will have the effect of diverting a large body of flood-water along the Sheepwash Creek to Reedy Lake, Lake Charm, and other natural basins to the west of the river. I am indebted to Mr. H. C. Kempson, C.E., the Engineer to the Trust, for the following particulars showing its construction :—

	ft.	in.
Total length of weir, including wings	512	0
Length of east wing	136	0
,, west wing	176	0
,, crest, including notch	200	0
,, notch	32	0
Breadth of weir	12	0
,, cushions (aprons)	12	0
,, cushions, front of sluices	20	0
Height of weir at notch	9	6
Depth of piles in ground	12 to 18	0
,, sheet piles	8 to 15	0
Slopes of face	Vertical.	
,, aprons	Horizontal.	

Sluices (four in number) each 4 feet by 3 feet in clear construction.

Two rows main piles 12 feet apart, with distance pieces and braces internally ; also tie-rods at 16 feet intervals ; double wailings and sheet piles, both up and down stream ; six cross-walls of shields of sheet-piling ; wings ; single rows of main piles with double wailings and sheet-piles, the interspace filled with gravel and clay, puddle-rammed.

Sluices—Top, bottom, and sides of 3-inch planks, dowelled, and lined with roofing felt, and 1-inch planking fixed diagonally ; doors, two thicknesses of red-pine with roofing; felt between, covered with 4-lb. lead outside worked by 2-inch square-threaded lifting-screws and box-keys extending well above highest flood-level, from special platform.

The next series of works visited by the Commissioners were those of the united Shires of Echuca and Waranga. The most concise description which I can give of these works will be in the language of Mr. Walter Scott Murray, C.E., Engineer to the Trust, whose evidence before the Royal Commission I had an opportunity of taking down in shorthand. He said :—

The principal works authorized and completed, or in process of construction, consist of the main channel, the length of which, from the pumping site on the Goulburn, a mile and a half above the township of Murchison, to the Cornella Creek, is about 85½ miles. The works at the pumping site are in course of construction, and consist of a pumping shaft, depth 46 feet, lined with brick, from which to the river there is a tunnel 6 feet by 4, lined with timber and puddlle with clay. The entrance from the river is closed by a sluice-gate protected by timber wings. The top of the brick shaft is finished with concrete and levelled for the engine-beds. The discharge-pipe from the pumps delivers the water into a brick receiving bay, where it passes into the receiving channel by regulating brick weirs. The engines are of 270 horse-power, and the pumps (Robertson's patent) will discharge 38 cubic feet of water per second, or 20,000,000 gallons in twenty-four hours. The machinery cost about £5,000, and the tunnel and shaft £1,500. Pumping operations will be commenced on the 1st June, 1885. From the discharging bay at the pumping site for a distance of 3 miles the fall of the channel is 6 inches to the mile, the bed width 8 feet 3 inches, and the depth of water 2 feet 9 inches. For the next 5½ miles the fall is 9 inches to the mile, and the bed width 6 feet 6 inches. At this point the north-eastern channel takes off, and follows approximately a course parallel with the Goulburn. The capacity of the main channel up to the point of offtake is 20,000,000 gallons a day; and from the offtake to the Cornella Creek it is 15,000,000; thence to Lake Cooper it is 12,000,000 gallons; thence to Cornelia Creek it is 10,000,000 gallons. The fall of the channel from the offtake of the north-eastern channel to the Waranga Basin Crossing is 9 inches per mile, bed width 4 feet 6 inches, and depth of water 2 feet 9 inches. From the Waranga Basin Channel there is a regular fall of 6 inches per mile, bed width 4 feet 9 inches, and depth of water 3 feet. From the Cornella Creek to the Cornelia Creek the bed width is 4 feet 6 inches, and depth of water 3 feet. Throughout the whole of the main channel the side slopes are 1 to 1, except from the Cornella Creek to Lake Cooper, where the slopes are flattened to 1½ to 1. At the crossing of the Waranga Basin the channel is embanked. The other principal works are timber weirs across the Wanalta Creek, and two across Cornelia Creek. The north-eastern channel is 48 miles in length from the offtake at the main channel to the point where it joins the drainage channel. The branch No. 1 shown upon the plan is about 4 miles in length, and also joins the drainage depression; branch No. 2 is about 18 miles in length, and it also joins the drainage depression. The channel is partly excavated, partly embanked. There are regulating sluices every 3 or 4 miles, and bridges across public roads and private property. In a length of 70 miles of channel only 24 miles pass through private property—the rest are taken along the roads. The capacity of the channel at the offtake is 15,000,000 gallons, diminishing to 5,000,000 gallons in the parish of Koyuga. The capacity of the branches is four and five million gallons each. The fall of the channels averages 12 inches per mile; in some places it is not more than 8 inches, in others it is as steep as 2 feet. The Koyuga drainage channel is 33 miles long. The other channels either cross the lie of the country or follow the highest ridge, while the drainage channel carries the flood-waters into the natural depressions. We supply water when it is wanted, and drain the country when there is too much. Two other channels shown on the plan, one for drainage and the other for supply, the latter having a capacity of from five to two million gallons. Three tanks are in process of construction, and three or four months hence we propose to construct ten or twelve more to give supplies at particular points, so that people and stock can obtain water without damaging the channels. The capacity of the tanks is 200,000 gallons; they are capable of being filled from the channels, and they will be fenced round, to prevent injury and pollution by stock. Floods' patent lifts will be used to raise the water from the tanks to the iron troughs to be placed alongside. The designs for the Goulburn weir have been sent in to the Water Supply Department, but not yet dealt with. The object of this weir is to supply the whole of the channels by gravitation instead of pumping. It would take several years to construct the weir. There are several small channels to make, and the Waranga basin has to be filled. Water will, in June next, be brought within 2 or 3 miles of every property in the district. The channels of the high-level drains command the whole of the country, and they are designed to be enlarged at small cost, so as to serve for irrigation. The present pumping supply will be sufficient to irrigate 6,000 acres at one spot or in different localities as desired. The total area of the district is 880 square miles, and the area of the Waranga basin, which it is proposed to fill with flood-water is 11½ square miles. The drinking-approaches to the channels, where they run through private property, are made with slopes of 4 to 1, and occur at a quarter of a mile intervals. It is estimated that the cost of the Goulburn weir, including compensation for land, will be about £60,000."

The operation of the Wimmera United Waterworks Trust affords another remarkable instance of the way in which a perfectly arid country has become well watered, by the judicious construction of weirs across its watercourses, which were practically dry creeks, for "in summer they retain water only at a few places." These weirs, owing to the level nature of the country, have impounded immense sheets of water which otherwise would have run to waste, and by cutting off channels, the district, embracing an area of some 2,000 square miles, has been reticulated with water to its remotest parts. Water so diverted has also been stored in tanks and natural depressions, and a supply ample for all requirements short of irrigation has been obtained. The schemes of water conservation in this district were also outlined by Messrs. Gordon and Black, and they have been carried to a most successful issue by the Trust. The Trust has expended upwards of £95,000. The works represented by it are so numerous that I shall not attempt to particularize them, but, fortunately, by the courtesy of Mr. A. B. Clemes, the Secretary to the Trust, I am in a position to hand you a full description of the works, with a map showing the outlines of the scheme. You will, do doubt, observe that although the Wimmera was essentially a dry district, having no water in its creeks in summer, so great has been the storage that, in one case, water discharging at the rate of 90 cube feet per second is being carried to the Coorong Swamp—a distance of 80 miles from the point of diversion. A special feature in the scheme is, that a plateau of 200 square miles, 50 feet above the bed of the river storage, is being supplied with water by means of steam-engine and pumps, which raise the water at the rate of 600 gallons per minute, and it is conveyed thence through 6,500 feet of 9-in. cast-iron piping to the reservoir.

I append a return of the various Water Trusts formed under the Water Conservation Acts (*Appendix* C) which will no doubt be of interest.

Reviewing what has been done under the Water Conservation Acts of Victoria, I may be permitted, in conclusion, to suggest for your consideration the propriety of inviting the Government to follow a similiar policy here, with such modifications as your knowledge of the different circumstances of the Colony may lead you to deem expedient. This policy I may briefly recapitulate as follows :—

1. That a survey of the principal drainage areas be obtained with all practicable speed from engineers competent to advise the Government as to the best means of storing and distributing water within boundaries to be proclaimed by the Government.
2. That legislation be proposed, making provision for—
    - (*a*) The incorporation of municipal districts, and conferring on bodies elected by the ratepayers of power to enable them to devise and execute works for the conservation and distribution of water in the districts they represent.
    - (*b*) Empowering Government to raise loans for the construction of works for water-supply, and to lend the money to municipal bodies upon the security of their rates, mortgage being taken for the payment of interest and repayment of loan within a specified period ; the plans and estimates of the works being in the first place subject to the approval of the Government, and the construction of the same being subject to periodical inspection by their officers.

I have, &c.,
CHARLES ROBINSON,
Secretary.

APPENDIX.

A.

WATERWORKS TRUSTS.

Loan raised, 1881, £400,000. Parliamentary Grants, £100,000.

Existing Waterworks Trusts, their Loans and Parliamentary Grants for Head Works.

Trust.	Loan authorized.	Amount paid.	Parliamentary Grant allotted.	Amount paid.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Loddon United	30,000 0 0	30,000 0 0	8,649 16 10	8,649 16 10
St. Arnaud	20,000 0 0	19,490 0 0	5,766 11 3	....
Swan Hill.....................	31,600 0 0	31,551 0 0	9,111 3 4	7,553 1 10
Stawell (North-east Riding) ..	1,370 0 0	1,370 0 0	395 0 0	316 16 3
Wimmera United	94,398 0 0	92,433 0 0	27,217 12 7	10,341 4 7
Bet Bet.......................	6,000 0 0	4,028 0 0	1,353 19 6	....
Avoca United	15,630 0 0	15,630 0 0	4,506 11 5	1,913 18 11
Shepparton	16,000 0 0	15,470 0 0	3,690 12 0	....
Echuca and Waranga	116,000 0 0	45,552 0 0	26,756 17 0	....
Lowan	15,829 0 0	13,246 0 0	3,681 3 2	....
Benalla (Town)	8,900 0 0	7,834 0 0	....	....
Echuca ,, ...	7,000 0 0	6,920 0 0	....	....
Maryborough (Town)	43,000 0 0	43,000 0 0	....	....
Kyneton ,, ...	26,000 0 0	24,560 0 0	....	....
Romsey ,, ...	4,000 0 0	3,934 0 0	....	....
Hornsham ,, ...	14,300 0 0	13,055 0 0	... .	....
	4500,27 0 0		91,129 7 1	
		Unallotted..	8,870 12 11	
			100,000 0 0	

B.

List of Gauges established on Rivers.

Name of River.	Locality where situated.
Murray	Swan Hill.
,,	Wentworth and Albury, New South Wales.
,,	Echuca and Euston, New South Wales.
Goulburn	Seymour and Murchison.
Richardson and Avon..	Banyena.
Wimmera	Horsham.
Campaspe	Barnedown, Rochester.
Loddon	Bridgewater and Kenykavial.
Mitta	Tallangatta.
Kiewa	Kiewa.
Broken	Benalla. Not yet fixed ; in course of erection.
Ovens	Wangaratta. ,, ,,
Avoca	East Charlton. Recently fixed.
Hopkins	Allansford. Not yet fixed ; ,,
Little	Railway Station. ,, ,,
Werribee	,, ,, ,,
Tambo	Brutteen. ,, ,,

C.

General Description of Waterworks Districts, character of Works, &c.

Name of Trust.	Area of Waterworks in square miles.	Population.	Source of Water Supply.	Description of Work.
Loddon United..	1,037	3,888	Loddon River and its anabranches.	Weirs, distributing channels, tanks, and improvement of creeks.
S. Arnaud Shire.	1,940	6,984	Partly from the Avon River, partly from local catchment area.	Storage weirs, tanks, dams, and wells.
Swan Hill Shire.	10,000	6,479	Murray River with its anabranches and the Loddon River.	Off-take weirs, distributing channels, storage weirs, dams, and tanks.
Stawell (N.E. Riding).	128	512	Local catchment areas	Tanks and dams.
Wimmera United	2,100	1,134	Wimmera River and its ana branches and the Richardson River.	Weirs, channels, storage weirs, and dams, and tanks.
Bet Bet Shire ..	360	4,725	Avoca River and local catchment areas.	Weirs, channels, tanks, and dams.
Avoca United ..	450	1,800	Avoca River and anabranch	Weirs, tanks, and dams, and Charlton water supply.
SheppartonShire	715	6,574	Broken River and anabranch	Weir, distributing channels, tanks, dams, and wells.
Echuca and Waranga.	860	6,235	Goulburn River	Pumping machinery, distributing channels, and tanks.
Lowan Shire....	2,680	3,000	Local catchment areas	Tanks, reservoirs, and wells.
Benalla	Township	1,654	Broken River	Steam-pump, iron tank, and reticulation pipes.
Echuca	,,	4,789	Murray River	Steam-pump, tower, tank, and reticulation pipes.
Maryborough ..	,,	3,297	M'Callum's Creek	Reservoirs, and main and reticulation pipes.
Kyneton	,,	3,062	Little Coliban	Reservoirs, and main and reticulation pipes.
Romsey	,,	400	Bolinda Creek	Weir, channel, main and reticulation pipes.
Horsham Borough.	,,	1,644	Wimmera River	Steam-pump, main and reticulation pipes (existing Horsham Waterworks).
Yarrawonga	388 nearly	....	Broken River	Weirs, distributing channels, dams, tanks, and Yarrawonga town supply.

REPORT ON THE BARWON RIVER, AND THE TARRION AND CATO CREEKS.

To the Secretary of the Commission,—

Sir, Brewarrina, 19 May, 1865.

I have the honor to report that, in accordance with your instructions of the 9th ultimo, I have made inquiry regarding the evidence which can be obtained at Brewarrina on the subject of water conservation. I have every reason to anticipate that the witnesses who will give evidence here will furnish much information of a valuable character.

By actual levelling I have found that from still water above to still water below the rapids at Brewarrina there is a fall of 10ft. 8in. At the time when these levels were taken, viz., the 5th inst, the reduced levels above and below the rapids were 353·65 and 342·98 respectively. As the volume of the water in the river increases, the influence of the rapids extends to a greater distance, and in consequence the apparent fall diminishes, till in times of high floods the river surface assumes a uniform slope, and the only indication of the existence of the rocky bar is that furnished by the increased velocity in its vicinity.

Assuming that an effective fall of 9 feet is available, the power which can be derived from it is about 1-horse power for every cubic foot per second of discharge. There is unfortunately no place near Brewarrina which is suitable for gauging the discharge. On the upstream side of the rapids a very deep pool of almost still water extends for many miles. The depth of this pool just above the rapids is said to be no less than 30 feet. I went up the river to a distance of about 6 miles, and failed to find a bed at 10 feet depth throughout that distance. With the experience I have obtained regarding the discharge of the river near Walgett, and after again inspecting the flow at Brewarrina, I have come to the conclusion that, although there is no apparent flow at present into the river between Brewarrina and Walgett, the discharge of the river between these places is increased by percolation. The discharge at Brewarrina is certainly greater than at Walgett. This I attribute partly to the increase by percolation, and partly to the fact that the rocky bar at the former place acts as a dam, in stopping not only the water within the river channel but that flowing beneath it. The discharge at Walgett is only about 15 cubic feet per second, while that at Brewarrina, so far as I can judge, is not less than 25 to 30 feet per second. Assuming that the latter discharge is correct, there is a loss of 30-horse power, and this, too, close to the township of Brewarrina, and in a place where water is generally wanted. Supposing that so much as 30-horse power would be obtainable for the purpose of pumping water from the river, and allowing for a loss of 25 per cent. in the working of the necessary machinery, the quantity which could be raised to the average level of the land near Brewarrina would be about three and a half million gallons per day. This quantity of water would irrigate from 1,300 to 1,400 acres of land under the ordinary system ; or, if used under the asbestine system for the irrigation of fruit trees, it would be sufficient for nearly 30,000 acres.

In connection with the question of putting weirs in the Barwon, I may point out that the rocky bar at Brewarrina gives great encouragement to such a project. The fact that a splendid sheet of deep water can exist permanently in the Barwon is a most important point to have established, as, without such an instance to the contrary, it would naturally be assumed that the immediate effects of a permanent dam of any kind in the river would be to cause the deposit of a large quantity of silt.

At a distance of about 4 miles from Brewarrina the Cato Creek flows in a course approximately parallel to that of the Barwon. The creek is in reality a branch of the Barwon, but instead of flowing into that river direct it joins the Bokhara. The length of the Cato Creek is estimated at 60 miles. At the head its cross section, as measured roughly by me, is 1,500 square feet, and opposite Brewarrina about 2,000 square feet ; while towards the Bokhara its capacity increases considerably. Assuming the dimensions opposite Brewarrina as an average of the whole, the total capacity 633,600,000 cubic feet. As it would probably not be practicable to utilize more than one-third of this, it may fairly be stated that in the Cato Creek there is available storage for 210 millions of cubic feet of water, or (say) 1,300 million gallons. Near the punt at Brewarrina, and on the banks of the Barwon, there is a large boulder which, it is said, must be under water before the flood-water will pass down the Cato. The reduced level of the top of the boulder is 354·59 feet, and it is about 11 feet 7 inches above the present water-level on the down-stream side of the rapids. At the inlet of the Cato Creek, the height of its bed above the present water level is nearly 15 feet, but the effect of a rise at any particular point cannot be estimated without more levels, and in both cases the figures regarding the floods required to fill the Cato should only be taken as approximate. It is, however, quite clear that a large supply could be stored in the Cato, and that flood-water which in ordinary seasons runs to waste could be utilized for this purpose. For the proper investigation of this question a longitudinal section of the Barwon from Brewarrina to the head of Cato Creek should be made, and special cross-sections should be taken at the places where rocky bars are met with. Tarrion Creek, which is distant about 7 miles from Brewarrina, occupies a position on the south of the Barwon, corresponding to that of the Cato on the north. These creeks or ana-branches leave the river on opposite sides near the same place. From the nature of the country the Tarrion Creek appears to derive much more benefit from the surface-water than the Cato does; but on the other hand, the flood in the Barwon requires to rise about 5 feet higher to cause a flow into the Tarrion than is required for flowing into the Cato. Near the place where the Brewarrina and Byrock Road crosses the Tarrion Creek is a splendid sheet of water, which, I was informed, extended for 6 miles without a break, and with a surface width of about 200 feet. At this place the Tarrion Creek is much larger than the Cato. If the dimensions of the Tarrion for 6 miles of its length can be taken as the same as at the Byrock Road crossing, the total storage capacity for that length would be at least 100,000,000 cubic feet, or (say) equal to an available capacity of 45,000,000 cubic feet. The portions of the Tarrion Creek which are adapted for water storage, though said to be much less in the aggregate than the length of the Cato, afford nevertheless a better and more permanent storage than any part of the Cato of which I have heard. On the whole I should recommend that, as a first step towards utilizing flood-water from the Barwon in the neighbourhood of Brewarrina, cross sections of the Cato and Tarrion Creeks should be taken at such intervals as would give a good approximation to their capacity, and that a longitudinal section of the Barwon should be made from Brewarrina to above the inlets of these creeks. I may mention that in the case of the Tarrion Creek there is a perceptible fall in the surface of the ground from the bank of the creek in a southerly and westerly direction, so that the conditions are favourable for the distribution of any water which could be spared for irrigation.

I have, &c.,
H. G. M'KINNEY, M.E., M.I.C.E.,
Engineer to the Commission.

REPORT ON THE MACQUARIE RIVER AND THE DISTRICT BETWEEN THE MACQUARIE AND THE BOGAN RIVERS.

To the Secretary of the Commission,— Sydney, 29 May, 1885.

THE Macquarie being a fair type of that numerous class of Australian rivers which, beyond certain points in their course, gradually diminish in volume, definite information regarding the cause of this diminution is interesting and important. The importance of the question was shown by my investigation of February, in the course of which I ascertained that of 114·5 cubic feet per second which then flowed passed Dubbo only 52 cubic feet per second went beyond Warren. In my inspection of the Macquarie during the past month I found that only about 20 cubic feet per second was flowing past Dubbo, and that the flow entirely ceased at about 18 miles up stream from Warren. In my report on the former experiment I showed that not more than about 9 per cent. of the discharge at Dubbo, or 16½ per cent. of the total loss, could be due to evaporation, so that at least 83½ per cent. of it was due to percolation and absorption. As the discharge of the river decreases, the velocity decreases in a corresponding degree, while but little change takes place in regard to the surface exposed to evaporation. The proportionate loss by evaporation therefore increases with a diminishing discharge. Taking the rate of evaporation as one-eighth of an inch in 24 hours, I estimate that while the discharge at Dubbo was 20 cubic feet per second, 7½ cubic feet per second was lost by evaporation between Dubbo and the place at which the flow ceased. The loss by evaporation was therefore about 38 per cent. of the discharge, leaving 62 per cent. to be accounted for by percolation and absorption. In the first series of experiments the loss of water between Dubbo and Warren, exclusive of loss by evaporation, was about 52 cubic feet per second. This is considerably less than half a cubic foot per second for every mile of the river, or about two-thirds of an inch per day over the wetted surface of the river-bed. The rate of percolation, worked out in the same manner in the second case for the smaller discharges, amounts to only a quarter of an inch per day over the wetted surface. These figures must only be regarded as approximate, as it would not be possible to ascertain the exact wetted area; but the result agrees with the opinion I had formed after inspection of the banks and bed of the river, that the loss arises more from lateral than from downward percolation. Such a loss as this would not be unexpected in the case of a canal following the ridge line of an alluvial tract of country ; but in regard to rivers flowing in stable channels—that is, in channels following the natural drainage lines—it is natural that there should be a gain from and not a loss by percolation. In my report on the Darling, dated the 19th instant, I have pointed out that on the portion of that river between Walgett and Brewarrina there is a gain by percolation, and that in the present low state of the river this gain is of considerable importance. I have ascertained beyond doubt that there is a further gain in the same manner between Brewarrina and Bourke. Percolation into the river at Bourke is at present evident, as the water in the river is about 4 feet below the level of the top of a saturated stratum. That the percolation in the case of the Macquarie is from the river arises chiefly, if not entirely, from the fact that the course of the river north of Narramine is not now a true main drainage line. While the country slopes northward with the river, it also slopes in a westerly direction towards the Bogan ; and I believe it will be found that the line of greatest slope is towards the Bogan in the direction of Cannonbar, and not toward Mount Harris and the Macquarie Marshes. While the river has been depositing silt in its bed in the form of a wedge, the thick end of which is near Dubbo, another wedge having its thick end on the west bank of the river has been formed by the deposits of silt left by successive floods. This characteristic of the Macquarie affords remarkably favourable conditions for the diversion and storage of flood-water. In the district lying between the Macquarie and the Bogan there is a complete network of creeks, all or nearly all of which are well suited for the conveyance and storage of flood-supplies. The first place of this description to the north of Dubbo is about 3 miles from Narramine, in a south-easterly direction. At this place is an immense lagoon about half a mile in width, and probably 30 feet deep in the centre, but which becomes shallow towards the river, from which it derives a supply in very high floods. This lagoon is at the head of the Boggy Cowal, the flood-water in which passes on to the Beleringa and Gunningbar Creeks. I had not an opportunity of following the course of the Boggy Cowal, but ascertained that there are already three dams across it.

At Buggaboo Point, about 10 miles down stream from Narramine, the river takes an abrupt turn in an easterly direction, and although the left bank at the bend is nearly 40 feet high, there is an overflow there in high flood. The flood-water passes from this place in a broad shallow depression to Buddah Lake, which is said to hold a good permanent supply. The left bank at Buggaboo Point consists of an alluvial deposit throughout, and, so far as I could ascertain, there is no favourable site for a weir in the Macquarie near that place.

At about 16 miles by road from Narramine there is a rocky rapid in the Macquarie, which bears some resemblance to the rapid in the Barwon at Brewarrina. The bed of the Macquarie at Rocky Point, as the neighbourhood of the rapid is termed, consists partly of hard conglomerate and partly of soft sandstone, intersected by bands of ironstone. This rock has a mean length of about 250 feet in the direction of the river, and the surface is rough and waterworn, but nearly level from bank to bank. The width of the bed is about 200 feet, and the height of the left bank is about 40 feet. At the time of my inspection the water in the river had a clear fall of about 2½ feet, while there was a further fall of about 1½ feet in the 60 feet on the up-stream side of the vertical drop, making a total fall of 4 feet from still water above to still water below the rapid. Notwithstanding the presence of rocks across the river-bed, Rocky Point does not on the whole afford a satisfactory site for a weir. The river here is unusually wide. The banks consist chiefly of alluvial soil, and the rock is not of uniform soundness ; still, the site is probably the best obtainable on that part of the river.

There are two other possible sites for weirs—one about 200 yards down stream from the Rocky Point cataract, and the other about 250 yards further down. At the former place the bed of the river is only about 100 feet wide, about 30 feet of which consists of rock, the rock also appearing in the right bank to a height of 5 feet above the bed. At the second site, below the cataract, the width of the river-bed is about 129 feet ; and the height of the banks, from 50 to 60 feet, rock appearing in the bed at both sides of the river; and the left bank is of sound material throughout its entire height. From a distance of 200 feet above to nearly half a mile below, the site of the river is almost straight. This is a point of considerable importance, and one which adds materially to the value of this site.

At a distance of about 6 miles south of Warren there are two outlets from the Macquarie. At the river bank these outlets are well defined, and bridges have been built over them at a distance of about 120 feet from the bank. The more southerly and smaller of these outlet channels is provided for by a bridge having one span of 30 feet, while the larger outlet, which is about 600 feet further down stream, has two spans of 27 feet each. The beds of these channels are, in each case, about 23 feet above the river-bed, which here consists chiefly of a yellowish clay. After leaving the river the flood-water spreads over several square miles of low lands. The head of the Bird's Nest Creek at the edge of the lowlands is in a direction almost at right angles to the direction of the river, and at a distance of about a mile and a half. This creek crosses the Nevertire and Warren Road at a distance of about 4½ miles from Warren, and flows into the Beleringa Creek. At the down-stream end of the great lagoon mentioned, that is, at a distance of 5 miles from Warren and 2 from the point where the flood-water leaves the river, another creek, stated by some to be the Gunningbar Creek, takes its rise, and flows past Warren, at a distance less than half a mile from the river. By levelling from the river at Warren to this creek I found that the bed of the creek is only about 5½ feet higher than the bed of the river.

It is necessary to explain that much confusion exists regarding the names of the creeks which run from the Macquarie towards the Bogan, the same creek being known by different names at different parts of its course.

From my inspection of the Macquarie I was in a position to arrive at the following conclusions :—

(*a*) That the damming of the river at or near Warren could be done at a moderate cost, and that the result would be to throw a supply down the Gunningbar and other creeks.

(*b*) That the damming of the Macquarie at or near Rocky Point would be quite practicable, and that with a dam of 20 or 25 feet in height, a supply of water could be drawn from the river in ordinary floods ; but that the cost of damming this part of the river would be heavy.

(*c*) That in the Boggy Cowal, about 3 miles from Narramine, there is storage capacity for a large supply of flood-water.

Considering that the conditions for diverting and storing flood-water in the district between the Macquarie and the Bogan are exceptionally favourable, I think that, as a first step towards carrying out works with this object, the following levels should be taken :—

(*a*) A longitudinal section of the Macquarie, from Dubbo to Mount Harris, with cross sections at every 5 miles, and additional cross sections at places where the flood-water leaves the river.

(*b*) A connecting line of levels between the railway bench-marks and the river at Narramine.

(*c*) A section from the river to the great lagoon at the head of the Boggy Cowal, near Narramine.

(*d*) A connecting line of levels from the river at Warren to the railway bench-mark at Nevertire.

(*e*) A connecting line of levels from the river at Mount Harris to the railway bench-marks at Nyngan.

The lines of level here mentioned are indispensable for carrying out of works for the conservation and supply of flood-water from the Macquarie. That such works are practicable is beyond doubt, and the levels are required in the first instance to show the position, extent, and approximate cost of the works which would be most useful.

H. G. M'KINNEY, M.E., M.I.C.E.,
Engineer to the Commission.

REPORT ON THE UPPER MURRAY VALLEY.

To the President and Members of the Commission,—

Gentlemen, Sydney, 18 June, 1885.

Object of examination.

The object of my examination of the Upper Murray basin was twofold: (first) to determine if it was possible to divert a portion of the river into the valley of the Billabong Creek, and thus establish a permanent stream between the Murray and Murrumbidgee Rivers; (second) to discover if it were possible to impound any large quantity of water on the large flats near the sources of the river to account for the supply of such stream.

Geological features.

In order to give some impression of the principal characteristics of the valley from Albury upwards, I shall commence my report by a brief description of its geological and physical features. The geological formation of the valley on the right bank of the river for about 50 miles above Albury is granite. This is followed by sandstone schists and clay-slates tilted at a high angle, and metamorphosed by the intrusion of traps and gneiss dykes, which strata extend about 25 miles to Ournie. From this point to Bringanbrong Station, just below the junction of the Indi and Hume branches, granite again predominates, intersected in places by belts of schistose and trap rocks. Above Bringanbrong the metamorphic strata again prevail, and as a consequence the mountain ridges assume a wilder and more precipitous aspect. About 12 miles higher up, both branches of the river enter defiles through the above strata, which are almost inaccessible. The Hume heads in the granite spurs of Mount Kosciusko, whilst the Indi heads in limestone springs, from marble or mountain limestone, in which fine specimens of fossil fish have been found.

Physical features.

The physical features of the valley alter perceptibly with its geological features. Where granite predominates, the mountain ranges and cross ridges have a gradual slope, and often near their summit recede into table-lands, whilst the valley itself opens out into large, rich flats, and the river flows over low falls, followed by long stretches of deep and almost level reaches. Where metamorphic schists and eruptive rocks prevail, the valleys of the river and its tributaries close in to narrow gorges and rocky defiles, which rise with rugged precipitous flanks into high ridges or lofty peaks, distinguishable by their sharp outline. Shortly after leaving Bowna the road up the valley crosses low spurs and ridges which enclose the valley on either side of the river. On the Victorian side the ridges rise higher, and are more rocky and precipitous. The principal timber is composed of gum, box, apple-tree, peppermint, and wattle, and patches of fir in some of the gullies. After passing Wagra, about 30 miles above Albury, the aspect of the country all round is wild and mountainous. Everywhere appear high ridges, surmounted by peaks of varied form, which as they descend into valley, throw out numerous long spurs. The junction of every creek or tributary is marked by flats, which increase in area higher up the river at the junction of three main feeders, the Tooma, Hume, and Indi Rivers. On the New South Wales bank of the river the Gingellic, Ournie, Greg Greg, Wellaregang, Bringanbrong, Khancoban, Indi, and Tom Grogan Flats are the most notable.

Declivity of the river.

The height of the Murray at Albury is 490 feet above sea-level. Its fall, for 30 miles below Albury, averages 1·18 feet per mile. From Albury to Jingellic, about 100 miles up by river, it increases to 2 feet per mile ; thence to Tintaldra, about 35 miles higher up, it increases to nearly 3 feet per mile, which declivity it retains to the junction of the Indi and Hume streams. It flows with a most tortuous course through the flats, especially between Tintaldra and the above junction. From this point, following the Hume, the declivity increases but slightly for 10 or 12 miles, averaging about 5 feet per mile to the top of Khancoban Flats, when it enters an almost inaccessible gorge for 15 or 16 miles, then crosses the Geehi Flats ; after which the declivity rises rapidly by frequent rapid falls to its sources in the spurs of Kosciusko. At Geehi Flats the barometer read just 1,400 feet above sea-level, giving a total fall of 910 feet between that point and Albury. Following the Indi from its junction with the Murray, the declivity averages about 5 feet per mile for 15 miles, and then rises rapidly in an inaccessible rocky defile for from 20 to 30 miles, when Tom Grogan's Flat is reached. Here the bed of the river changes again to falls of from 3 to 5 feet, followed by long, almost flat reaches, for a distance of about 5 miles, when it is again enclosed by the huge rocky ridges of the main range, and the declivity increases rapidly by rocky falls to its source in a gully of the Pilot Mountain, which is 5,000 feet above sea-level. At Tom Grogan's Flat the barometer read 1,730 feet above sea-level, or 1,240 feet above Albury.

Discharge of the river.

From a rough section of the river at Tintaldra I estimate its discharge there at over 1,000 cubic feet per second. A few miles above the junction of the Tooma, and about 4 miles below Mr. Findlay's house, the discharge was about 675 cubic feet per second. The volume of the Hume River, just above Khancoban Creek, by rough measurement was about 400 cubic feet per second, and at Geehi flats about 285 cubic feet per second. The discharge of the Indi at Tom Grogan's was about 300 cubic feet per second.

General description of river.

From Albury to the junction of the Hume and Indi, for 15 miles above that point, the Murray stream runs over a succession of low falls, followed by long deep reaches, apparently almost level, the current being so sluggish as to be hardly perceptible. Above the Khancoban and Indi Falls the divided streams run as torrents, the rocky falls being sometimes over 10 feet high, as far as Geehi and Tom Grogan Flats, when they again resume their former condition of low falls and long reaches. Above these flats they again run as torrents. The bars or falls in the river below the junction of the Indi and Hume are chiefly formed of gravel of medium size, mixed with sand; above the junction the gravel is mixed with large boulders, whilst above Geehi and Tom Grogan the river has chiefly a rocky bottom. The average width of the bed from Wagra to Tintaldra is about 160 feet, and it has an average depth at summer level of about 4 feet for such width. Its banks have an average height of 10 feet on the flats above summer level, which increases to 30 or 40 feet when the valley closes in. They generally have a deep stratum of fine river-silt on top, followed by 3 feet of gravel and sand mixed. The water is clear and soft to the junction of the Tumberumba Creek, when the tailings from the gold-fields discolour it.

The stream is generally at its lowest level in June, July, and August, when the hard frosts contract the streams in the higher regions, and the mountains and high table-lands are covered with snow. The thaw sets in about the end of August, and during the next three months, in fact, up generally to the end of December, the river is in flood from the melting of the snow. After that it gradually lowers until March, when the heavy autumn rains again increase its volume for the next month or two until winter sets in.

Canal from the Tooma River to the Billabung Valley.

In investigating the feasibility of diverting the Upper Murray into the Billabung Valley, three objects were especially necessary of attainment: (first) to discover a pass in the dividing range through which the river might be diverted at the lowest possible point in its valley; (second) to discover the point at which a sufficient volume of water could be diverted to cross such pass; (third) to find out if the character of the intermediate country would permit of the construction of a canal at a reasonable cost. Guided by the advice of some of the oldest residents in the district, I examined the head of the Jingellic valley, where I found a low pass by which the main road between Jingellic and Germanton crossed the Divide, about 17 miles distant from each place. By barometric measurement the height of this pass was 1,670 feet. Following the ridges east for about 1½ mile I crossed another pass nearly as low as the first, and possessing the superior advantage of very steep slopes on either side, so that a tunnel about 3,000 feet long would reduce the height by nearly 160 feet. Having determined on the lowest point in the Divide, I proceeded to examine the Tooma River, which is the largest branch of the Upper Murray, to discover if it was possible to divert its stream over the pass. This stream joins the Murray River about 20 miles below the junction of the Indi and Hume branches, and is far larger in volume than either of them. It rises on the northern slopes of Mount Kosciusko, and receives all the drainage of the extensive table-lands and mountain ranges between its source and Mount Manjar, flowing fully 45 miles in a north-westerly direction to that point. On its approach to Mount Manjar it changes its course abruptly to westerly, and rushes through a narrow rocky defile with precipitous sides, and over a series of high falls, till it reaches the base of the mountain, having fallen over 2,000 feet in about 8 miles. Near this point it is joined by Pound Creek from the north, which traverses a fine flat, over 3 miles long, above the junction. The valley now begins to open out into flats bounded by high ridges on either bank, till it is joined 20 miles lower down by the main Tumberumba River, formed by the junction of the Miracle, Paddy's, Tumberumba, and Manus Creeks, when it expands into rich, extensive flats on both banks of the river, which continue until it reaches the Murray, about 12 miles below. By a rough measurement of the river at the junction of Pound Creek, I estimated its discharge there at 450 cubic feet per second,—the height of that point, read by barometric measurement, 1,650 feet above sea-level. The discharge and height were therefore sufficient for the purpose of a canal through Gingellic Pass into the Bullandry. It was impossible without a detailed survey to fix on the actual position of the off-take for a canal, but as the river rises very fast I presume that the required elevation would be obtained 1 or 2 miles higher up than the above point. This is supposing that the canal would be 90 miles long and would have a fall of 2 feet per mile. The distance between the point of off-take and the Gingellic Pass would be about 34 miles in a direct line; but, by a brief examination of the intermediate country and a rough measurement on the map, I estimate the probable distance of a contour canal at 90 miles. Out of the 450 cubic feet now available at the lowest season of the year, I would suggest that 200 cubic feet per second should be diverted by a contour canal, and conducted into the Billabung Valley by the Gingellic Pass.

Size and fall of canal.

The sectional area of such a canal would be 75 square feet, its depth 5 feet, its fall 2 feet per mile, and its duty or discharge 200 cubic feet per second, or 108,000,000 gallons per diem. My reasons for not recommending a larger canal are (first) because of the difficult character of the intermediate country it would have to traverse; (second) because a large supply would not be immediately required and might lead to waste; (third) on account of economy of construction.

Character of country on line of canal.

The character of the country the proposed canal would traverse is, as may be surmised in such a mountainous region, very rough and rugged, whilst the long bounding ridges of the different divides with their numerous spurs would probably increase its length nearly threefold. The dividing ridges generally rise almost precipitously from the beds of creeks to a height of 200 or 300 feet, and then slope away more gradually. Near their base they are but scantily covered with soil; in fact, at intervals they expose a wall of solid rock; but as the slope decreases, the depth of the soil increases. Where granite is crossed the soil is loose and somewhat porous, but the soft granite rock below affords excellent holding-ground when slightly puddled; where the slates are crossed the soil is chiefly a good stiff, impermeable clay. At first sight, and especially to an inexperienced eye, the feasibility of taking a canal across such a rough country would seem very doubtful; but having seen much greater difficulties surmounted in California than this line suggests, and having laid out and constructed different large mining ditches in Kiandra on the same mountain ranges, such a scheme appears to me practicable and at a reasonable cost. Starting from the right bank of the Tooma River, the line of canal would cross the drainage lines of Miracle, Paddy's, Tumberumba, and Manus Creeks, and also of the Ournie and Jingellic Creeks, and would then pass by tunnel into Billabung Valley, whence it might pass on through Germanton and terminate in Urana Lake, affording provision for the irrigation of the intervening rich flats. Most of the above creeks could be crossed by wrought-iron fluming on high trestles, whilst a portion of the larger streams might at intervals be diverted into the canal to account for soakage and evaporation. The cost of such a canal to Jingellic Pass, supposing the distance to be 90 miles, and including tunnel and headworks, might be roughly estimated at £200,000, and, as it would traverse Government land nearly the whole distance, there would be no costly rights to resume.

Duty of canal.

I estimate that a stream of 200 cubic feet per second should be capable of irrigating 80,000 acres, or that each cubic foot should supply 400 acres. On reference to other countries it appears that a flow of 1 cubic foot per second irrigates—

717 acres in India, supplying several waterings;
630 ,, ,, Spain, ,, ,, ,,
786 ,, ,, California, ,, ,, ,,
1,168 ,, ,, Tasmania, for hay only;—

so that my estimate cannot be considered excessive, whilst if subsoil irrigation was generally introduced, it might be safely assumed that 1 cubic foot per second would irrigate over 1,000 acres, as no surface-water is exposed to evaporation.

Return of canal.

Estimating the whole cost of canal at £500,000, and that it would irrigate 80,000 acres, then at a charge of only 10s. per acre per annum it would return 6 per cent. on capital, after providing 2 per cent. for repairs and supervision.

Motive power.

In consideration that the value of every 100 feet of fall of the above stream would represent over 2,000-horse power, in a commercial aspect such a scheme must be highly profitable. It is safe to assume that, owing to the elevation of the proposed canal, it would encourage the establishment of more than one large manufacturing centre, whilst such application would in nowise prevent the water-supply afterwards being equally available for irrigation.

Reservoir sites.

The small declivity of the river between Albury and the junction of the Hume and Indi branches prohibits the impounding of its main stream for diversion into the Billabung Valley; but the large flats at the entrance of and extending some 10 or 12 miles up both these valleys suggest the possibility of completely controlling the river under all conditions, by impounding its whole volume and the equalizing the flow of the stream at all times, or distributing it as the different seasons may require.

Murray reservoir site.

The area of the Murray watershed above the junction is about 1,100 square miles, over which there is an average rainfall of fully 48 inches annually. Supposing one-third of the rainfall to enter the river-bed, then its whole stream would be equal to a discharge of 40,888,320,000 cubic feet, or 254,734,233,600 gallons annually. This supply impounded would permit of increasing the volume of the Murray after the junction of the Tooma River to a constant flow of about 2,000 cubic feet per second. For the purpose of such a reservoir a fine position for a dam offers in the immediate neighbourhood of Mr. Findlay's house, about 1½ mile below the junction of the above affluents. Here two long rocky spurs, somewhat above 100 feet high, approach within about 3,000 feet. An embankment across the river, 95 feet high, connecting them would enclose about 17,000 acres, including nearly the whole of the Bringanbrong, Khancoban and Indi flats. At an average depth of 60 feet this area would impound 44,431,200,000 cubic feet. Large tunnels with regulating valves through the spurs on either bank of the river would provide outlets from the lake, whilst a long bend in the spur on the Victorian side would offer facilities for a by-wash. Only three Italian lakes, viz., Lago Maggiore, Como, and Di Gardi would exceed such a reservoir in area. There is abundance of excellent material for the construction of the embankment in the neighbourhood. As a large portion of the reservoir would be in Victorian territory, it would either have to be purchased from that Government, or its construction might be undertaken by the joint Colonies, which, in consideration of an equitable adjustment of water-rights, would be most advisable.

Khancoban reservoir site.

In case of the Murray reservoir being considered impracticable, there are two or three other sites worthy of notice. At the entrance of the Hume Valley a dam 80 feet high would throw the river back fully 12 miles, and would flood about 7,000 acres, including the Bringanbrong and Khancoban flats. The length of the dam would be about 6,000 feet ; its extremities would abut on steep spurs of metamorphic schists. This basin, with an average depth of 30 feet, would impound 57,422,500,000 gallons of water.

Geehi reservoir site.

A dam 80 feet high across the narrow rocky defile of the river, at its outlet from the Geehi Flats, would cover at least 800 acres with water, and would impound about 8,712,000,000 gallons. The flats are enclosed by the steep walls of long lofty ridges thrown out by Mount Kosciusko. The dam would be overshot, and constructed of rock ; its length at bottom would be about 150 feet, and at top 500 feet. Its extremities would abut on the hard metamorphic rocks forming the walls of the defile.

Tom Grogan's reservoir site.

The outlet from Tom Grogan's Flats offers another somewhat similar position for an overshot dam. Such a construction 80 feet high would flood 2,000 acres to an average depth of 25 feet, and would impound 13,612,500,000 gallons. The dam would abut on walls of hard, metamorphic schists on either side ; it would measure about 100 feet at bottom and 500 feet at top.

Recommendations.

As the result of my examination of the Upper Murray valley I beg to make the following recommendations :—(First) that a longitudinal section of the river be extended from Albury to the junction of the Hume and Indi ; (second) that a line of levels be run across from the mouth of the Gingellic valley to the pass at its head, and from Wallaregang up the Tooma River to the point of offtake of the proposed canal ; (third) that the line of such conduit between these points be levelled and traversed ; (fourth) that the head of the Billabung Valley be examined for a site for an impounding reservoir to receive the canal supply ; (fifth) that failing the discovery of any such receiving basin, Urana Lake should be examined for the same purpose ; (sixth) that the continuation of the canal down the Billabung be surveyed ; (seventh) that a guage be fixed in the river at Tintaldra, and advantage be taken of Mr. Bowden's kind offer to record its readings ; (eighth) that all unalienated lands on the Bringanbrong, Indi, Khancoban, Geehi, and Tom Grogan Flats should at once be reserved from sale ; (ninth) that the sites of the above suggested reservoirs should be surveyed ; (tenth) that a Conference between certain members of this Commission and certain members of the Victorian Royal Commission on Water Supply and Conservation be invited, for the purpose of suggesting certain definite lines of legislation to the Parliaments of each Colony as to the treatment of rivers and watercourses which border or intersect the boundaries of the two Colonies.

FRED. B. GIPPS, C.E.

Sydney : Thomas Richards, Government Printer.—1886.