"SOME ASPECTS OF HYDROGRAPHY IN EASTERN AUSTRALIA."

By A. Morrison, B.E.

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The development and progress of Hydrography in the Eastern States of the Commonwealth is a subject to which one cannot do justice in a short paper, but it is hoped that this brief account will afford members some idea of the progress of the work in Queensland, New South Wales, and Victoria, and indicate the directions in which development may take place, and the economical and technical value of the results.

It is not proposed to enter into the many details of the methods adopted in making Hydrographic Surveys, but rather to deal with the larger aspects of the question with reference to Australian conditions.

In general the complete study of the Hydrography of a region embraces:—

(1) Meteorology.
(2) Geology, including Physiography.
(3) Topography.
(4) The Gauging of Streams at Selected Stations.

From the results obtained by a study of the above subjects, and an adequate method of compiling and recording, the water resources of the country can be ascertained, and economic conservation and distribution assured.

METEOROLOGY.

The Meteorology of Eastern Australia is particularly interesting in as much as the rainfall is dependent on several climatological conditions. In the north the bulk of the rainfall is due to the monsoons and tropical disturbances, and here we have a "summer type" of rainfall. North of the tropic this type has its maxima in January, and its minima in July or August, the period of maxima being delayed in several areas till February or March, and the minima till August, this lagging being particularly noticeable towards the southern limit of the type, where the intensity of the rainfall is not so great. This "summer type" extends into New South Wales as far south as Bourke, Moree and Grafton.

In the southern portions of the area the bulk of the rainfall is due to the V-shaped Antarctic depressions, which skirt our southern shores during the winter and spring seasons, giving a "winter type" of rain. The northern limit of this type includes Wentworth and the Riverina, but excludes the south-eastern corner of New South Wales.

The "neutral zone" lying between these limits has no distinctive type, being subject to both tropical and Antarctic rains, and also to spasmodic thunderstorms during the summer months.

Anti-cyclonic rains occur at all times of the year, but most markedly from March to September. They benefit the southern areas, and are responsible for many of the highest rainfalls and floods on the coastal districts of New South Wales.

Unfortunately none of these conditions are dependable in their incidence. As the monsoons penetrate into higher latitudes the rainfall lessens, and tropical disturbances approaching the north-east coast in a curved path are particularly capricious, at times threatening the south-eastern division of Queensland with disastrous floods, then veering off to sea in a south-easterly direction, with a very sharp decline in the isohyets of the storm.

The Antarctic rains are the most reliable and consistently regular.

The consideration of rainfall and its distribution is of the utmost importance to the Engineer in its influence on stream flow investigations in connection with all classes of conservation work. The regular publications of the Bureau of Meteorology, and also the special bulletins, deal with this subject exhaustively, and are well worth close study.

GEOLOGY.

The geology of Eastern Australia has an important bearing on Hydrography, not alone from the Physiographical aspect. The run-off from catchments depends a great deal on the actual geological character of the country; the porosity of the rock formations outcropping in the catchment, their extent, location, and the direction and continuity of the strata, are determining factors in the ultimate run-off. For instance, the outcrop of the Blythdale Braystones and the Cretacious Sandstones on the western slopes of the Great Divide, are now generally recognised as the intake beds, and the source of supply and maintenance of the Artesian Basin. These outcrops absorb a large proportion of the surface flow of the natural streams crossing them. This aspect of Hydrography has not yet been thoroughly investigated, nor has the influence of geology, on the yields of catchments; but considering the great economic value of our artesian supplies and surface conservation works, it will undoubtedly receive more consideration in the future.

PHYSIOGRAPHY.

Physiography has been defined as the latest chapter of geology, and in its relation to the formation of watersheds and streams it is of special interest to this subject.

The Great Divide forms the western boundary of the coastal area. The width and extent of the coastal belt in Queensland, as compared with that of New South Wales and Victoria, is very great, and whereas the largest coastal stream in New South Wales (the Hunter River) has a catchment of only 11,000 square miles, the Burdekin River in Queensland has an area of 53,500 square miles, and the Fitzroy River an area of 55,600 square miles.

It may be noted here that the Fitzroy River proper is comparatively a short stream, being formed by its two great tributaries, the Mackenzie flowing from the north and the Dawson flowing from the south. These two rivers join together in a due north and south line, and at their junction form the Fitzroy River, which flows due east. It frequently happens that when the Mackenzie comes down in flood before the Dawson, its waters flow up the Dawson River for a distance of 30 to 40 miles; and, of course, the reverse happens if the Dawson should come down before the Mackenzie.

Dr. Griffith-Taylor, in his Bulletin No. 8, published by the Bureau of Meteorology, deals with "The Physiography of Eastern Australia," and he shows how the later uplift of many portions of the eastern territories have brought about "river captures," i.e., the eastern rivers have cut off the head waters of the western rivers. Striking examples occur in the Burdekin and Fitzroy systems. Undoubtedly at some earlier geological period the head waters of these rivers flowed into the Maranoa and Condamine Rivers, and the main tributaries of the Upper Dawson and Auburn Rivers still flow for a great part of their length in a south-westerly direction.

The prominent features of the coastal belt are the high tablelands. That to the west of Cairns, in North Queensland, though well within the tropics, enjoys a temperate climate for the greater part of the year. It has a steep slope to the coast, and the Barron River Gorge, with its falls nearly 1,000 feet high, is the most noticeable feature. The Belinder Ker Range has the highest peak in Queensland. This is Mt. Bartle Frère, and it is 5,438 feet above sea level.

The only other high peaks of the Divide in Queensland are at Toowoomba and Mt. Lindsay, on the Macpherson Range, the spur which forms the Queensland-N.S.W. boundary.

In New South Wales we have the New England Tableland, which is the most massive in Australia, though not the highest. The general height of this plateau is 3,000 feet, and for a considerable distance it falls rapidly to the coast and loses most of its 3,000 feet elevation in about three miles. Dr. Griffith-Taylor describes the Macleay gorges as unique in Australia, and states that it seems probable that they are due to the uplift of the New England massif, possibly to a height of 3,000 feet above sea level. The Nymboida River also flows down a gorge in a general northerly direction. In the Macleay River system we have the famous Apsley and Tia Falls, and in the Hastings River system there are the Ellensborough Falls.

Further south, after passing the Blue Mountain Range, we come to the Monaro Tableland, surmounted by the highest peak in Australia, Mt. Kosciusko, 7,328 feet above sea level. It is on this high plateau that we get our heaviest falls of snow, the drifts forming huge natural reservoirs, which, during the spring and summer, as the snow melts, feed the Murray and Murrumbidgee Rivers and maintain their flow.

In Victoria the Great Divide consists of many high peaks, and the most extensive tableland is in the eastern portion of the State, the western end of it being greatly dissected by the Upper Goulburn, Macallister and Yarra Rivers.

Further west there is the Macedon Range, with Mt. Macedon 3,324 feet high, and it is this range that feeds the Avoca, Loddon and Campaspe Rivers, and partly also the Goulburn River.

The Physiography of the great inland plains does not afford any variable features that are of particular interest to the Hydrography of the region. In general, it may be said that, from the Gulf of Carpentaria to the Murray River, there is a great sameness. The rivers flow generally in a westerly to south-westerly direction. They all have their source of supply in the eastern highlands, and the greater portion of their catchments, except during exceptionally heavy rainfall, are non-contributing. In the north particularly, their channels are not well defined, and during high floods they form extensive "flood plains." The Gulf of Carpentaria is practically a large inland sea, and its effect on the climate is quite unlike that of the east coast. The rivers of the Gulf, situated as they are in the tropics, and fed by the heavy summer rainfall running off the high Atherton plateau, rise very quickly, and carry immense volumes of water to the Gulf; but during the "dry season" they are very much like the other inland rivers.

TOPOGRAPHY.

Topography can scarcely be separated from the Physiography of a region, but it is so treated for the reason that local influence of the topographical features of particular catchments has a very important bearing on the relative yield or run-off influencing stream flow.

The shape of a catchment, the length and meandering of a river and its slope, and also the lengths and slopes of its tributaries, and their general direction of flow with respect to the general direction of the main stream, all tend to vary the intensity of floods and the accumulation of the flood waters at particular points. The extent of the low-lying portions of the catchment, the height of the watershed, and the presence of swamps, lagoons, and billabongs, have all to be considered in their effect on the yield and in comparison with other catchments.

It may be said that a close study of the foregoing subjects, in connection with the accumulation of statistics of the water resources of such a large region, are purely of academic interest; but when one gets down to particular cases, that is, when it has been decided to develop the resources of any catchment, such considerations become of immediate economic and technical importance, and the interpretation of the results of the study of these factors may decide the success or failure of a scheme involving a large expenditure of money.

It may be truthfully said that Hydrography in the greater part of Australia is in its infancy, and has been too long neglected, particularly as regards the statistics of stream flow; and we are coming to a stage in our existence when we are turning our thoughts to the greater development of our potential wealth by the increase of agriculture, the establishment of new industries, and the encouragement of immigration. The common need, and the greatest, for all these enterprises is water. We must supplement the low and irregular rainfall by conservation schemes to develop intense agriculture. To make our industries pay in competition with imported articles we must have cheap power, and hydro-electric schemes properly developed afford cheap power; and with the development of these, we also have to supply the increasing population of cities and towns with adequate domestic water supply. So, while we may for the present generally defer the widespread investigation of the Meteorology, Geology and Topography of the territory, with the exception of an adequate record of rainfall data, we cannot afford to neglect a detailed investigation of the natural surface water supplies, which are continually altering and show very great variation.

This brings us to the fourth branch of the subject, viz., "The Gauging of Streams at Selected Stations."

THE GAUGING OF STREAMS AT SELECTED STATIONS.

HISTORY.

In 1879, Mr. H. C. Russell, then Government Astronomer for New South Wales, commenced to keep a record of some of the inland rivers, and established gauges at five stations on the Darling River, three on the Murray River, and three on the Murrumbidgee River, and published diagrams showing the heights "above summer level." It was not till 1885 that measurements of the discharges of rivers was undertaken by Mr. H. G. McKinney.

During the "nineties," Mr. W. Poole carried out gaugings in this State, and in 1900 the work was continued by Mr. H. S. I. Smail, the two latter gentlemen being members of this Society. In July, 1899, Mr. Poole contributed a paper to the Society on "River Discharge Observations," to which reference will be made later. In 1904, Mr. H. Shute was placed in charge of river gauging operations, and the work has progressed, to a great extent, under his administration.

It was stated to the Interstate Royal Commission on the River Murray, as late as 1902, that the gauging records of this State were not complete enough for publication; that is to say, the actual measurements of discharge were not sufficient, either in number or range, to compile station rating curves.

In 1914, however, in the report of the Commissioner for Water Conservation and Irrigation, a complete statement of monthly discharges was published for 43 different stations, some of the records of which were extended back to 1885. This tends to show the great advancement in river gauging during the ten years preceding 1914.

Considering now the history of river gauging in Victoria, except for Mildura and Echuca gauges, the records of which extend back to 1865, and Albury, with records as far back as 1877, the date of the establishment of gauges is not very much before that of New South Wales.

In the case of Mildura, records of river heights from 1st January, 1865, to 30th April, 1872, were obtained from old Mildura station. There is then a gap of four months, and from September, 1872, to September, 1887, the heights were inferred from the readings at Euston, the records at Mildura having been lost; the readings at Euston from 1872 to 1879 were taken from official records in New South Wales.

It was not till 1889 that official readings were kept by the Victorian Department.

In the case of Echuca, the records were obtained from the files of the Melbourne "Argus" up to 1886, after that from official records. For Albury the records were also obtained from the "Argus" to the end of 1888, then for eight months from New South Wales records, and after that from Victorian official records.

The earliest record of velocity measurements are those taken by Messrs. Hargreaves and Dunlop in 1886, but the number of stations established in the "eighties" and "nineties" was greater than in New South Wales, and the work carried out by the Department in Victoria, in the gauging of streams, appears to have been far in advance of New South Wales till about 1904, both in the gauging of natural streams and artificial channels, the latter gaugings affording very useful checks on the efficacy of discharge formulae.

Mr. E. Checchi, who has been in charge of this work for a great number of years, has carried out many useful experiments and brought the methods of gauging up to date.

Publications giving the results of observations were issued in 1894, 1900, 1905, and 1912, the first two publications being evidence of the progress of the work as against that of New South Wales.

The first publication in 1894 received much laudatory comment from European journals, and that of "La Technologie Sanitaire" being worth quoting:—

"In Australia, where there exists a Department of Water Supply and Irrigation, observations relating to water-courses, springs, artesian wells, etc., are systematically undertaken, and afterwards embodied in very complete reports, which are distributed with a liberality unknown in our country. The reports which we have received give the discharges of 30 rivers and streams of the province of Victoria, gauged at 50 observing stations. These discharges are given in cubic feet per minute, maximum, minimum, and mean, for each month of the four years 1891, 1892, 1893, 1894. . . . The conclusions to be drawn from an examination of these documents is that the hydrography of the watercourses of Australia is generally better known than that of the watercourses of Europe."

The history of stream gauging in Queensland commences in very recent times. It was not till after the phenomenal floods of 1893 that gauges were established on the principal rivers, and these were put in mainly for flood-warning purposes. This system was inaugurated by the then hydraulic engineer, Mr. J. B. Henderson, and proved very efficient. These readings, however, were not continuous, and were chiefly made by police officers during times of flood. As the river approached danger levels, the readings were telegraphed to Brisbane and stations lower down the particular river, at periods from 24 hours to one hour, and by this means warnings reached the towns contiguous to the rivers, and were the means of saving human life, stock, and other property.

Mr. Henderson recommended his Government to commence systematic river gaugings as early as 1884; and Mr. Stuart-Murray, in his report on river gauging in Victoria in 1900, curiously enough, quotes portion of the Queensland hydraulic engineer's report to his Minister in 1893, urging the economic advantages of river gauging; but it was not until March, 1909, that the writer was appointed to commence the systematic gauging of streams in Queensland.

METHODS ADOPTED FOR THE MEASUREMENT OF DISCHARGE.

The usual methods that have been in use for the measurement of the discharge of streams are as follows:—

1. Floats:—
   - (a) Surface Floats.
   - (b) Submerged Floats.
   - (c) Rod Floats.
2. Current Meters:—
   - (a) Révy.
   - (b) Amsler-Laffon.
   - (c) Large Price.
   - (d) Small Price Acoustic.

Surface, submerged, and rod floats were used exclusively in Australia for the earlier observations of velocity, and the methods of using them have been described in Mr. Poole's paper, and also by Mr. Smail in his paper read before the engineering section of the Royal Society of New South Wales and various other authorities.

The concensus of opinion is that surface and submerged floats have many disadvantages. The ratio of mean to surface velocity has not a fixed value, and the attempt to obtain subsurface velocities by means of submerged floats is very unsatisfactory.

Rod floats are by far the best of the float methods, and in the measurement of the Darling River, Mr. Poole used very long rods. The disadvantages of this method are obvious when we consider the many special conditions that are required for a good observation; the river must have a fairly uniform cross-section for a considerable distance, it must be free from snags, and the bed must be even, and at the time of the measurement there must not be too much wind. It must be well known to members that Australian rivers fulfil very few of these conditions. Further, the rod in its passage is carried forward by one "impulse," and does not give the true mean velocity caused by several "impulses" of the moving body of water. Float methods, except under special circumstances, have now been abandoned in favour of current-meters.

CURRENT METERS.

The first pattern of meter used to any extent was the Révy type. This meter was used first in Victoria, and its shortcomings were appreciated by Victorian officers.

Mr. McKinney, of New South Wales, informed the Royal Commission in 1902 that he had found this meter so unreliable that in his earlier observations he abandoned its use in favour of rod floats.

The types of meter that have given most satisfaction are the Amsler-Laffon, Price, and Small Price Acoustic. These are the meters that are used in U.S.A. and Canada, and it is the methods that have been adopted in the U.S.A. that have formed the basis of our hydrographic work in Australia. The Small Price is generally used by wading into the river, and it is capable of measuring velocities as low as 0.2 feet per sec.

The Large Price and Amsler meters are suspended from a boat or bridge, or from a traveller running on a wire across the stream and controlled from the bank. Lenticular-shaped lead weights are attached to the meter. These weights are fitted