with horizontal and vertical veins, and, as used in New South Wales, they are 30 and 56 lbs. in weight.

The discharge of streams has been obtained by means of chemicals and also by weirs, the latter method being unusual only from the point of view of impracticability in the case of large rivers; but many low flows in small streams are measured by means of weirs, and in some cases, where structures have been placed in streams, and can be used more or less as measuring weirs, large flows are estimated.

Chemical gauging of rivers has been carried out on occasion in Great Britain, the Continent, and on the Nile, but not to any extent. It is a laborious method, and necessitates a great deal of chemical analysis.

VELOCITY OBSERVATIONS.

With all types of meters, the method of observing the velocity in a cross-section are the same. They are divided into four classes:—(1) multiple point; (2) one point; (3) two point; (4) three point. At intervals across a river the velocity in the vertical is obtained by these methods. The interval, in general, is 10 per cent. of the total width, and at these points the velocity is measured at the surface, the bottom, and at several points between; a curve is drawn through the points when plotted, and the mean velocity obtained by measuring the area enclosed and dividing by the depth. This is the multiple point method. The "one point" method consists of observing the velocity at .6 of the full depth, and adopting this as the mean velocity. The "two point" method is used to find the mean velocity by observing the velocity at .2 and .8 of the depth and taking the arithmetic mean. In the "three point" method, velocities are taken at .2, .6, and .8 of the depth. The reduction of observed surface velocities to mean velocity is not a very reliable method, and is very little better than that obtained by the use of surface floats.

The use of the point methods depends for its accuracy on the vertical velocity curves taking up a parabolic shape. This, in general, is the case; but it rests with the judgment of the observer as to which method is the best to adopt in each case.

The writer investigated 688 velocity curves obtained by the multiple point method at four stations in Queensland, and found that the average depth of the filament of mean velocity was .641 of the depth.

The co-efficients obtained to reduce the mean velocities obtained by the one, two, and three point methods to the "true mean" velocity, were .997, .999, and 1.001 respectively; and using surface velocities only, the mean co-efficient was .885; but in this case the range of values was much wider than in the one, two, and three-point methods.

The advantages of using these methods are that a complete observation can be made in a much shorter time, and when the river is rising or falling rapidly, the inaccuracies involved are not so great as those caused by the changing stage. The discharge can also be readily calculated in the field.

STATION RATING TABLES.

When a station is established, discharge observations are taken at various heights on the gauge. A curve is drawn through the points plotted from the co-ordinates of discharge and gauge height, and in course of time the gauge is thus calibrated for every inch.

From the table so computed and the daily readings of the gauge, the volume of water flowing past the gauge is tabulated each day.

It is not always possible to obtain discharge observations at a sufficient number of points between low water and flood height, and the curve has to be produced to the height necessary or expedient.

Various methods have been employed in producing these curves, notably by plotting the logarithms of gauge height or cross-sectional area and discharge. This gives, at the higher stages, approximately a straight line, which can readily be extended. However, even with the best methods, it is not expedient to produce these discharge curves much beyond the highest discharge measured.

MONTHLY DISCHARGE DETAILS.

From the daily discharges the monthly volumes are tabulated in acre-feet, millions of cubic feet, or millions of gallons as desired, and also the maximum, minimum, and mean daily rates of discharge, the depth in inches run off the catchment, and also the cusecs per square mile run off. The percentage of rainfall on the catchment discharged by the stream is a very unsatisfactory factor when considered monthly, and this percentage is now only computed for twelve-month periods.

FLOODS.

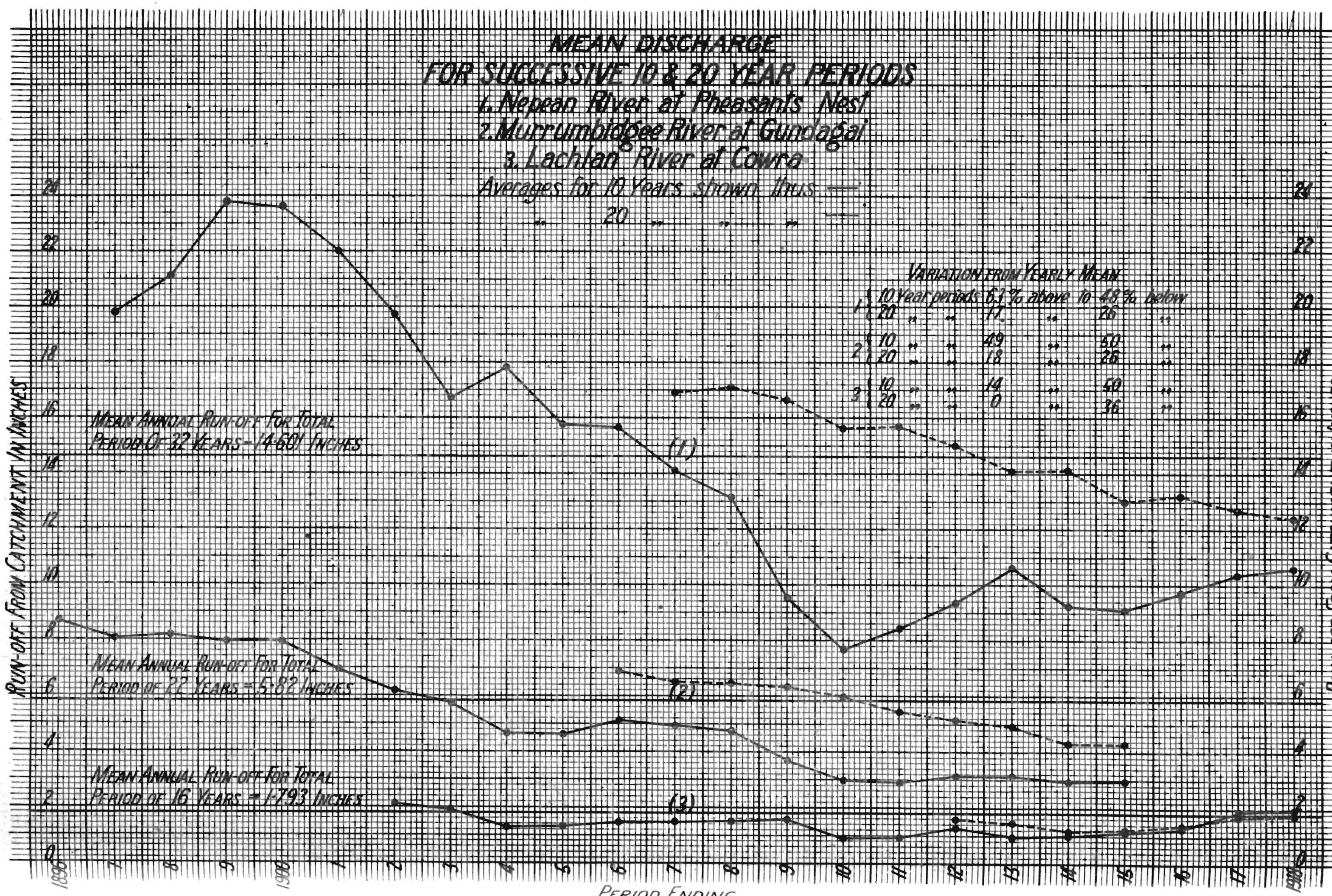
A great deal might be written on the big floods that have occurred in Eastern Australia. Mr. H. H. Dare read a paper before this Society in 1913, describing the flood in the Hunter

River in May of that year, and the methods adopted in measuring the discharge. The discharge of this flood, as measured at West Maitland, was 169,910 cusecs. Since then a big flood was measured on the Warragamba River in 1916 giving a discharge of 115,700 cusecs. And another big measurement was made at Corowa in 1917 which gave a discharge of 125,000 cusecs.

The floods in south-eastern Queensland in February, 1893, will be remembered for the great damage that was done in the City of Brisbane, and the whole valley of the Brisbane River. Colonel Pennycuick, in his report on a flood mitigation scheme for this river, estimated the discharge of this flood at Indooroopilly Bridge, near Brisbane, as 100,000 cusecs. However, at Lowood, which has only about three-fifths of the total catchment of the Brisbane River above it, the river rose to 84 feet. A measurement was made at this station in 1911 by the writer when the river rose to 27 feet 2 inches, and the discharge was 50,000 cusecs, so that the estimate of 100,000 cusecs for the 1893 flood was very low indeed. This again shows how far out an estimate may be when there are no actual observations of discharge to base it on. Probably the greatest flood discharge of any river in Australia would be that of the Fitzroy in 1917, but unfortunately no discharge measurement was made.

When gauging stations have been established and rating tables have been formed, it is still necessary to check the discharges periodically. Unfortunately, unless there is a permanent bar (weir or dam) across the stream below the gauge, the relation between gauge, height, and discharge is constantly changing, especially at the lower stages. It is thus necessary to have station rating tables for the various periods between the changes. From a limited observation, extending for eight years in Queensland, the writer has noticed that these changes do not appear to be cumulative in their effect; that is to say, the changes at carefully selected stations are not progressive, but rather oscillate about an average condition, so that for long periods there would not be a large error in the total volume. This must not, however, be used as an excuse for not checking discharges from time to time, as when the data are used for particular investigations it is imperative that the volumes available during low periods of comparatively short duration should be known exactly.

The methods of making and computing discharge observations and tabulating the results are much the same throughout Australia, and they are, in general, based on the methods adopted in U.S.A.



MEAN DISCHARGE
FOR SUCCESSIVE 10 & 20 YEAR PERIODS
1. Nepean River at Pheasants Nest
2. Murrumbidgee River at Gundagai
3. Lachlan River at Cowra
Averages for 10 Years shown thus
" 20 " " "
VARIATION FROM YEARLY MEAN
1 { 10 Year periods 63% above to 48% below
1 { 20 " " 17 " 26 "
2 { 10 " " 49 " 50 "
2 { 20 " " 18 " 26 "
3 { 10 " " 14 " 40 "
3 { 20 " " 0 " 36 "
MEAN ANNUAL RUN-OFF FOR TOTAL PERIOD OF 32 YEARS = 14·601 INCHES
MEAN ANNUAL RUN-OFF FOR TOTAL PERIOD OF 22 YEARS = 5·82 INCHES
MEAN ANNUAL RUN-OFF FOR TOTAL PERIOD OF 16 YEARS = 1·793 INCHES
(1)
(2)
(3)
RUN-OFF FROM CATCHMENT IN INCHES
0 2 4 6 8 10 12 14 16 18 20 22 24
1896 7 8 9 1900 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 1918
PERIOD ENDING

The accuracy of the results of stream gauging depends not only on the care with which the observations of discharge and office computations are carried out, but also on the careful and conscientious way in which the gauge readers carry out their duties, and further the manner in which the meters are rated.

Too often has it been found that gauge readers have neglected to read the gauge daily, or have failed to report damage to the gauge and shifting of its position, and so vitiating the results.

Automatic gauges have been used in New South Wales on the Murrumbidgee main canal, but their general use would cost a great deal; and further, there is no type of auto-gauge that could be economically used for all stations.

There is no equipment in Australia for the rating of meters such as is used in America. Each State carries out this work in a different manner. Instead of having a specially designed channel with an electrically driven car, or some other device to give uniform speeds, at the side of the channel, the meters are rated in large reservoirs at Potts Hill, in New South Wales; Enoggera Reservoir, in Queensland; and the Bendigo Reservoir, in Victoria.

LENGTH OF TIME NECESSARY FOR GAUGINGS.

The value of river gauging depends on the length of time during which observations have been made. It is necessary that this period should include good and bad seasons, and as there has been no definite law of periodicity discovered in Australia for good and bad seasons, it is a matter of difficulty to fix upon a period for river gauging that we can safely say is sufficient. In Plate 1 may be seen graphs showing the discharge of several streams in New South Wales for successive 10 and 20 year periods. These graphs indicate the variations that are obtained. Any particular period may, of course, show a maximum variation. They also emphasise the fact that mean values may very often be misleading, as they may contain in the total period an abnormally high or low period.

Long range records of gaugings are most necessary for comparing the volumes discharged during different periods of drought.

In the semi-arid regions of America it is considered that from 25 to 30 years is necessary for complete knowledge of a stream; ten-year periods are the minimum that are advised to approximately estimate the mean, minimum, and maximum flows. These periods are likely to give results which are 10 per cent. in error.

It will thus be seen that it is necessary to adopt pioneering methods in Hydrography in a country like Australia, which is in a state of rapid development. The work of the "river gauger" must precede that of the surveyor and constructing engineer by a good many years, and it behoves the Hydrographer, in the selection of stations, not only to meet the demands of the present, but also to foresee probable and possible development, and arrange his campaign accordingly. In this regard, it may be mentioned that he, as a rule, receives very little encouragement and help; more often he is called upon for results which have to be based on very flimsy data. The number of men who have ever taken discharge observations in the eastern States is less than 25, and very few of these have devoted their whole time to the work. The present personnel engaged can be counted on two hands.

THE NUMBER AND DISTRIBUTION OF GAUGING STATIONS.

New South Wales has by far the largest number of gauging stations in Australia. There are 149 stations of all classes. Of these 11 are merely telegraphic stations, i.e., the river heights are read daily and telegraphed, with the weather report, to Sydney and Melbourne. There are 72 stations at which sufficient information has been obtained to compile monthly discharges.

In Queensland, independently of flood warning stations, there are 51 gauging stations. The gaugings at 20 of these are advanced so far to enable monthly discharges to be computed. In some cases, during high floods, the total volumes cannot be given, as the station equipment is not good enough to measure high-flood discharges.

In Victoria there were, in 1914, 51 stations, and monthly discharges were available for 46 stations in 1915.

As regards distribution in Queensland, the stations are for the most part on coastal rivers, extending from the Barron River in the north to the New South border. There are six stations on inland streams within the Murray basin, and four on streams draining into the Gulf of Carpentaria, near the border of the Northern Territory.

Owing to the great area to be dealt with in Queensland, and the small staff that are engaged on the work, stations were classified as follows:—

Class 1.—Stations on rivers which are at present, or are likely to become in the near future, the main source of supply for irrigation and water supply to towns and cities within their basins or contiguous thereto.

Class 2.—Stations on rivers, the waters of which are likely at some future time, not very far distant, to be used for similar purposes. And

Class 3.—Stations on rivers, the waters of which are not likely to be utilised for irrigation, water supply, or power projects, until some time more remote.

In New South Wales most of the stations are situated west of the Great Divide, within the Murray basin. There are only 25 stations on the coast.

There is no deliberate classification as in Queensland, but the same disabilities obtain as to large area and small staff, so that in effect the work is carried out in the same way as indicated in the Queensland classes. In this State, river gauging is carried out by the Water Conservation and Irrigation Commission, and they take the initiative in establishing stations in connection with irrigation schemes. When gauging stations are required for the purpose of domestic water supply or hydro-electric power schemes, such stations are established and maintained at the request and expense of the departments interested.

In Queensland stream gauging is carried out by the Water Supply Department, and it devolves on that staff to establish stations and anticipate requirements for all purposes.

UTILISATION OF RESULTS.

In any investigation for proposed irrigation schemes, domestic water supply, or power projects, reliable information as to the amount of water available at all seasons of the year, and the duration of periods of low flow, is absolutely essential for the economic development of the catchment and the design of the necessary structures. For the design of spillways for large dams, a gauging at or near the maximum flood discharge is invaluable, as it settles at once the capacity of the maximum rate of discharge that the spillways will have to carry, and saves money in the design of the structure on a low factor of safety; whereas, lacking such data and using more or less unsatisfactory formulae, the safety of the structure is imperilled.

The results of gauging have been used extensively in regard to the development of the Murrumbidgee Irrigation, and various other smaller projects in New South Wales; also in connection with the equitable distribution of water rights on various streams in the State. In Victoria also gauging data has been utilised in the irrigation projects. In several instances in that State it has been found, by means of improved methods, that large errors were made in the first estimates of maximum flood discharge. In the case of the Laancoorie Weir, on the Loddon, the maximum flood discharge was inferred from gaugings made at relatively low stages of the river, and checked by formulae applied to the drainage area, and the co-efficients from the flood discharge of the basin of the Goulburn River. This gave a maximum discharge of 20,830 cusecs; but later gaugings tend to show that it may be as much as 37,500 cusecs.

River gauging will also play an important part in the development of the Murray River under the recently formed "River Murray Commission." Under the Act which they will administer, the distribution of the available water amongst the three contracting Governments will form a very large portion of their duties.

Investigation of hydro-electric schemes is now engaging the attention of the Governments of the States and a large part of the preliminary work comes within the province of the Hydrographer.

CONCLUSION.

It is not possible in this paper to go into details of various methods employed in making and adequately recording gaugings. It is hoped, however, that the history and progress of the work has, in some measure, been brought before the members, and that some indication of the need for the future extension of Hydrography in Eastern Australia. One may be permitted, perhaps, to hope that the Hydrography of Australia may some day be controlled by one authority; that there may be instituted a Commonwealth Bureau of Hydrography, which will adopt uniform methods throughout Australia, and serve the interests of all, in addition to carrying out research work in hydraulics.

It is inevitable, while the work is carried out by separate States, that variations in methods of observing and recording must occur. One has only to read the evidence given before the many Royal Commissions on the disposal of the Murray waters to find out how discrepancies have occurred, and how many different opinions are held by engineers with regard to hydraulic phenomena.

Hydrography can only advance in this country in proportion to the appreciation of its economic value, and it is being brought home to engineers that the old "hit-or-miss" methods must be abandoned, and exact information as to available water resources substituted, before any conservation scheme is investigated and carried out.

It has been mentioned above that gaugings for 20 or 30 years are necessary for most of our streams, so we must begin now the collection of statistics wherever development is likely to take place 30 years hence.

The writer is indebted to the Water Conservation and Irrigation Commission for permission to read this paper, and to exhibit these diagrams; and also to the Water Supply Department, Queensland, for information supplied. Statistics with regard to Victoria have been extracted from the publications of the State Rivers and Water Supply Commission, and much useful information has been extracted from the publications of the Commonwealth Bureau of Meteorology.