Geodetic Survey of Australia

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A brief history of the development of the geodetic survey of Australia.
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Introduction

We should feel grateful to the early administrators and State Surveyors-General for their foresight during the latter part of last century in establishing part of the geodetic survey of this country.

In these days of modern theodolites, accurate invar tapes, geodimeters and tellurometers, modern transport methods and wireless communication it is not easy to appreciate the difficulties facing the geodetic surveyor operating in Australia prior to World War I.

In presenting this paper on the development of the Australian geodetic survey it has been found convenient to first deal with the period prior to 1915 and then to deal with 15-year periods thereafter.

It should be noted that although the general title of "geodetic survey" has been used no reference is made herein to precision spirit levelling of which, so far, little has been completed in Australia.

Prior to 1915—Period of State Activity

In 1912 a conference to discuss survey and mapping of Australia was convened by the Commonwealth Minister for Home Affairs and was attended by the Director of Commonwealth Lands and Surveys, the Surveyor-General and the Government Astronomer of New Zealand, and Surveyors-General of the States of the Commonwealth.

Appended to the report of this conference[1] were detailed descriptions of the geodetic surveys that had been completed by the various States.

It is of interest to briefly review the status of the geodetic survey as reported to this conference (it was then usually described "trigonometrical" survey). Figure 1 shows the actual coverage of these surveys.

New South Wales[1, 2]

Some very early trigonometrical surveys were carried out in the vicinity of Jervis Bay and also around Sydney Harbour during 1828 by Thomas Florance.

In 1828 and 1829 Mr. Dixon carried out triangulation in the Camden area and near the Murrumbidgee and Molonglo Rivers.

Sir Thomas (then Major) Mitchell took part in and directed a combined trigonometrical and astronomical survey. This was commenced in 1828 and formed the basic framework of his "Map of the Nineteen Counties" which was published in 1835 and covered some 38,000 square miles.

In 1854 a trigonometrical survey of Sydney and environs was effected with a fair degree of accuracy, and in 1855 the Governor, Sir William Denison, initiated action for the erection of an observatory to form the starting point of a State trigonometrical survey.

This observatory was established some years later, but the survey proper did not commence until 1867 and was then continued up to about 1915 in conformity with the best practices of the day.

It covered about one quarter of the State, mostly in the east, and the results of the primary work are of the highest standard.

Base lines were first measured with steel rods and at a later stage with invar wires when these became available.

Theodolites used were heavy and cumbersome but were the best that could then be obtained and they produced the required results.

Stations were all well marked with subsurface metal plugs set either in bed rock or large buried stones and on these were superimposed a wooden pole usually held in posi-

FIG. 1

MAP OF AUSTRALIA
SHOWING PROGRESS OF TRIGNOMETRICAL SURVEYS
AS REPORTED TO CONFERENCE OF SURVEYORS GENERAL
1912

tion by an extremely well-built rock cairn.

Adequate Laplace stations were established and additional astronomical azimuths and latitudes observed at many other stations throughout the survey.

In all, 201 first-order triangles were observed with an average misclose of 0·7 second and an additional 728 secondary triangles were observed with an average misclose of 1·3 seconds.

Comparisons with check bases were good and the station elevations as computed from vertical angles were checked by spirit levelling at about 12 points, the average discrepancy being about 3·5 feet.

Victoria[1]

The first Victorian trigonometrical survey was started in 1839 by Mr. Tyers and extended from an initial point at Batmans Hill westward to the South Australian boundary.

A point near Portland Bay was defined by deep trench in the form of a broad arrow and filled with limestone.

This marked point was later used as a starting point for Mr. Wade's measurements to establish the location of the Victorian-South Australian interstate boundary, the marking of which was afterwards the subject of considerable litigation.

In 1852 Mr. Hodgkinson commenced a local trigonometrical survey of Melbourne and environs.

However, the real geodetic survey of Victoria commenced in 1858 and in the early stages consisted more of definition of meridians and parallels embracing squares of one-tenth of a degree.

In 1858 Mr. Ellery, Government Astronomer, was appointed the Superintendent of Geodetic Survey and the work was carried out under his direction up to the year 1872, when for all practical purposes the early geodetic survey was suspended.

In 1860 the proper scheme of trigonometrical survey was commenced and a base line measured at Werribee using 10-foot long bars.

From this base a triangulation scheme was expanded over the whole of Victoria with the exception of the north-western section.

Of 91 triangles examined by the Lands Department in the last few years it was found that there was an average misclose of 3·20 seconds and with the largest misclose of 8·18 seconds.

This survey linked up with the New South Wales triangulation between Mt. Pilot and Mt. Buckle and was extended to Mt. Gambier and Mt. Schank in South Australia where it was intended to measure a check base but this work was never carried out.

In 1870 it became necessary to mark the boundary line between Victoria and New South Wales. This was surveyed on the basis of geodetic values of adjoining hills and resulted in an extremely accurate delineation on the ground.

The geodetic survey included 209 primary stations and 267 secondary ones, together with many additional points of a lower order of accuracy.

The types of station marks varied but cairns surrounding wooden poles were erected on some stations, and on others either stone and cement monuments or timber beacons were used.

The usual ground mark was a broad arrow cut in the natural rock or marked on a buried stone.

Tasmania[1]

The old trigonometrical survey of Tasmania was a truly remarkable effort.

Preliminary work was carried out between 1833 and 1837 with a break to 1847 when the work continued to 1858, occupying a total time of 14 years.

The survey was carried out by, and under the direction of, James Sprent, who was Surveyor-General of Tasmania for many years.

The instrument used for the angular observations of the major triangulation had a 12-in. circle and was read directly to 10 seconds, but had a "repeating table" which permitted repetition of angles. A smaller instrument was used on secondary stations.

In 1854, Major Cotton, the Deputy Surveyor-General, reported that in about 300 calculated triangles "the nearness with which the sum of the triangles corresponds with the sum of 180° and the spherical excess gives the greatest proof of the accuracy of the angular observations the error rarely amounting to more than 4 or 5 seconds and generally not exceeding 2 seconds".

Base lines were measured at Ralph's Bay and Norfolk Plains with the aid of wooden rods that had been standardized against steel rods imported from England. Very good comparisons were obtained between the different measurements of each base.

The length of Ralph's Bay base line was used in the computation of a chain of 13 well-shaped triangles which connected to the Norfolk Plains base line.

In these triangles the greatest angular misclose was 3·3 seconds and the computed length of the verification base differed from the measured length by 1 part in 86,000.

The survey covered the whole island. It was unfortunate that stations were not very permanently marked in all cases and most of the records seem to have since been lost or destroyed.

Queensland[1]

The triangulation work carried out in Queensland was commenced in 1879 and was discontinued in 1891. It covered only a small area in the immediate vicinity of Brisbane.

The base line which was situated in an open plain between Mt. Irving and Mt. Maria, on the summits of which are the terminal points, was very nearly seven miles long. The tapes were each 100 feet in length and were supported in wooden troughs and shadowed by a board while tension was applied by means of a spring balance. The angular work of the triangulation was carried out with two 10-inch Everest pattern theodolites. A 12-inch Alta-azimuth instrument was also used for portion of the triangulation.

The average misclose was just under 1 second and the maximum misclose just under 4 seconds.

South Australia[1]

This State in its early developmental period insisted on triangulation surveys in advance of settlement.

This policy resulted in the completion of

a considerable amount of trigonometrical survey which eventually covered most of the eastern half of the State.

The work was commenced by Colonel Light at Adelaide in 1836 and subsequently extended by Major Frome during the period 1839-49 to cover 8,000 square miles.

The further extension of trigonometrical survey was carried out by many surveyors whose names are famous in their own State.

The work ceased in 1892 when the areas then considered most suitable for development had been completely covered. This amounted to about 125,000 square miles.

The standard of survey varied a great deal; good angular closes were obtained in many instances but the reports published on the standard of base line work indicate that this was not very high.

A particularly fine characteristic of these surveys was the excellence of the rock cairns erected over stations; even today, when some of them are 100 years old, they can still be found in a state of almost perfect preservation.

Western Australia[1]

Quite a lot of triangulation of about third-order standard was carried out in Western Australia, the bulk of it being completed during the period 1882-7, but continuing at a limited rate up to 1910.

The instruments used were 6-inch and 8-inch vernier transit theodolites.

Early base lines were measured with steel bands but invar bands were used on most base lines from 1904 onward.

Many of the cairns erected on inland trigonometrical stations have remained undisturbed to the present day.

Northern Territory[1]

Several local trigonometrical surveys were completed in about 1870 and in 1880 a reconnaissance was commenced for a survey over 9,000 square miles in the vicinity of Alice Springs and the MacDonnell Ranges in the course of which many hills were beaconed, but no survey observations are available.

About 1884 Mr. David Lindsay made a small trigonometrical survey in the Mataranka-Roper alley area, and in 1906/8 Mr. L. A. Wells triangulated 20,000 square miles from the neighbourhood of the Victoria River to the West Australian border.

Some good angular closures are reported on these early surveys but due to the quality of base line measurement and the types of theodolite used they should probably be assessed as of third-order standard.

Recommendation of 1912 Conference

At the 1912 Conference it was recommended that a geodetic survey of Australia should be undertaken by the Commonwealth Government on the grounds (*inter alia*) "That such survey is absolutely necessary for the production of accurate maps, will be of high value in connection with cadastral and geological surveys, and form a basis for topographical work for defence and other purposes.

It will, moreover, provide a standard of accuracy for surveys of every description throughout the Commonwealth. That it will afford an invaluable base to which settlement surveys already effected can be connected, providing data for re-establishing boundaries, which, with increasing density of settlement, becomes a matter of great importance. Further as regards the sparsely occupied areas of Australia, such a survey, if carried out in advance of settlement, will be of the greatest utility and assistance in effecting the settlement surveys, which can, at any future time, be reproduced with a minimum error and at a relatively low cost, preventing litigation consequent upon other methods."

The Defence Forces as early as 1907 took steps to allot survey and mapping responsibility to a nucleus body which was the forerunner of the Royal Australian Survey Corps. At the same time, advice was sought from the British War Office as to the best method of tackling the stupendous task of mapping Australia for defence purposes.

Subsequently, the reply from the War Office, based on a report from Colonel C. F. Close of the Geographical Section, was received and the "outstanding feature of Colonel Close's reply was his condemnation of any system of mapping not based on triangulation".[3]

The Survey Section of the Royal Australian Engineers commenced survey operations proper in the middle of 1914 in the Ballan-Sunbury-Meredith-Melbourne area.

1915-30—Period of Inactivity

No great progress in survey and mapping was achieved during this period due to the intervention of World War I and the inactivity following in the 1920's.

However, in 1928, a committee was formed in Melbourne, known as the Australian Geodetic, Topographical and Geological Survey Committee, comprised of leading surveyors, engineers and geologists.

This committee submitted a report to the Commonwealth Government directing attention "to the direct monetary saving in national expenditure over a number of years which would be rendered possible by the preparation of geodetic and topographical maps and their utilisation for geological, land settlement, forestry, irrigation, water supply, road and railway construction, town planning, aerial survey, defence and other purposes".

1930-45 —Period of Army Survey Corps Activity

At the Interstate Conference of Australian Surveyors' Institutes held in Melbourne in November 1934, the following resolution was carried unanimously:

"That this Conference, fully seized with the urgent necessity for an accurate geodetic, topographical and aerial survey of Australia, urges the Federal Government to take immediate steps to commence the survey, the time having definitely arrived when further delays cannot be countenanced in the interests of the people, and exhorts the Minister to be guided by the reports of the years of patient research of the Australian Survey Committee, which this Conference, representing every State in Australia, wholeheartedly and unanimously endorses."

Actual geodetic survey during this period was largely kept alive by the activities of the Australian Army Survey Corps.[4]

The Survey Corps carried out investigations designed to co-ordinate the geodetic surveys already completed by the State authorities in New South Wales and Victoria.[5]

This involved close study of the New South Wales and Victorian records and also recomputation of the triangulation between Albury and the Werribee base and as a result of these investigations it was decided that the best method of co-ordination was to run a new survey through both schemes.

In 1934 the Corps measured the base lines at Millicent and Tarlee and carried out further triangulation in South Australia.

Between 1935 and 1939 Colonel (then Captain) FitzGerald, in conjunction with Professor Kerr-Grant of the University of Adelaide, developed a new method and special equipment,[6] based on measurement of electrical resistances, for more accurately determining temperature corrections when standardizing base line tapes in the field.

This equipment permitted a marked increase in the accuracy of base line measurement.

On the civilian side, a triangulation survey of about 12,000 square miles was completed in the Alice Springs area in about 1937 by Surveyors J. H. Driver, F. P. Shepherd and A. J. Blakeway of the Northern Territory Administration. The angular work was of about second-order accuracy but the base line measurement was of a much lower order. Most of the stations were marked with permanent ground marks which were covered by rock cairns.

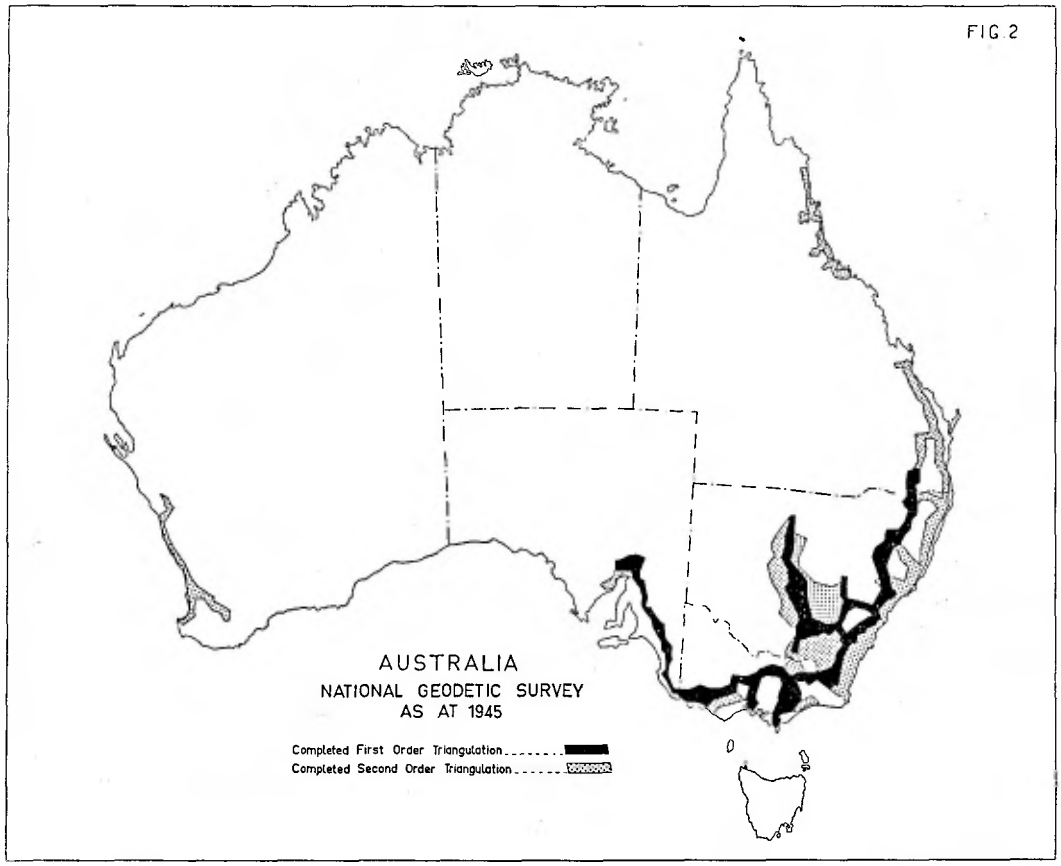
World War II now intervened and the Australian Army Survey Corps in addition to extensive surveys and mapping in the islands to the north of Australia, mapped, at varying scales, a large part of the Australian continent. Included in this war effort was the extension of the geodetic survey along the north-eastern coast of Australia.

The status of the Australian geodetic survey at the end of the war is shown in Figure 2.

As part of the war-time mapping effort the State Lands Departments and Commonwealth Civil Departments undertook, on behalf of the Army, quite an amount of topographic and some geodetic survey.

All this war-time activity resulted in an increased civilian interest in, and appreciation of, the part that air photography and topographic mapping could play in Australia's post-war development.

It is significant that in its third report towards the end of the war, the Rural Reconstruction Commission made a number of recommendations relating to maps and dealing with such matters as forestry development, soil erosion, land settlement, irrigation projects, public works, geological surveys and regional planning.



1945-60—Period of National Activity[7]

This period has brought in a great increase both in the number of authorities undertaking geodetic survey and in the actual achievement of results.

In January 1945 the (then) Commonwealth Surveyor-General (Mr. F. M. Johnson) arranged a conference between the Commonwealth Survey Committee and the State Surveyors-General with the objective of reaching agreement on a co-ordinated post-war plan for a national geodetic and topographic survey.[8]

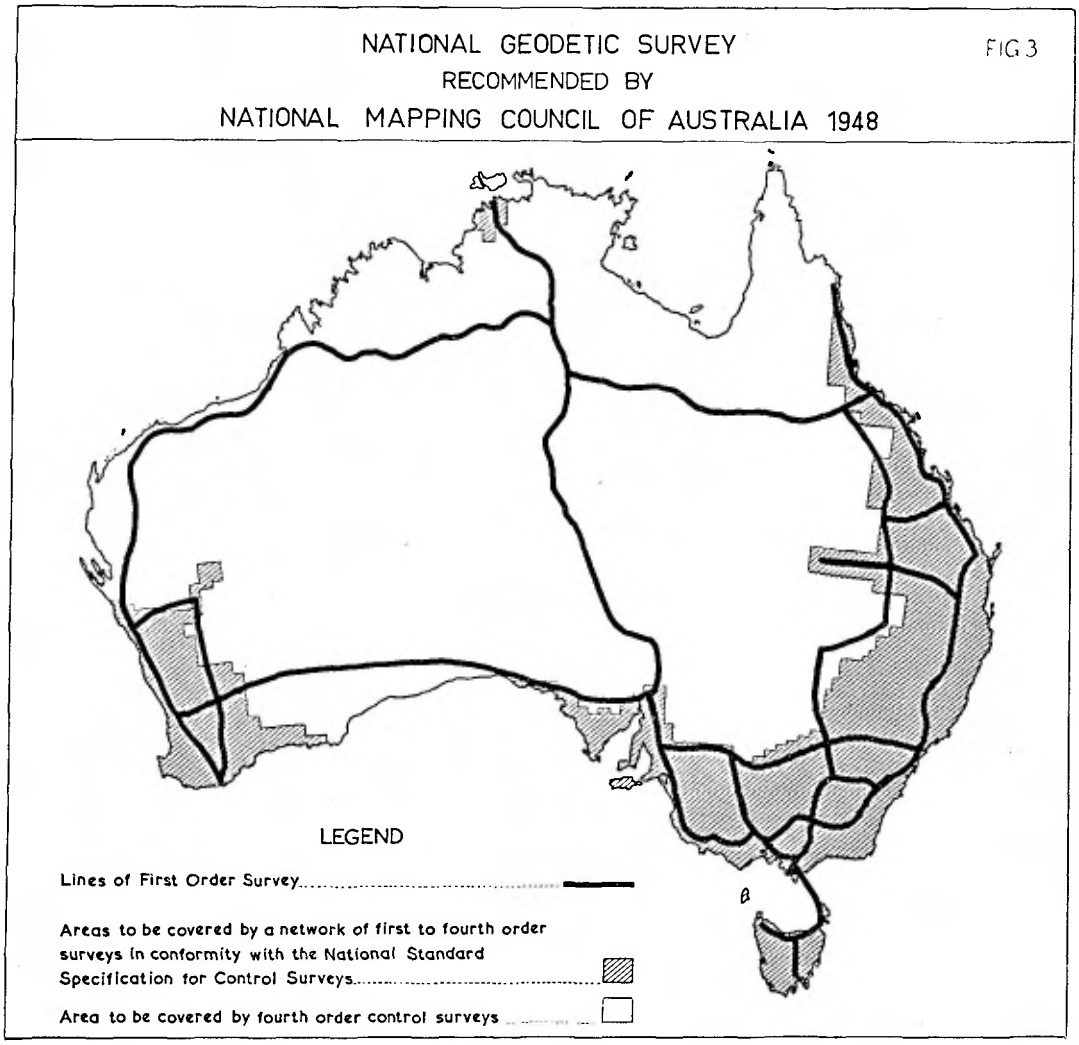
This was a significant step forward and resulted in an agreement between the Commonwealth and State Governments in 1945 to set up a National Mapping Council for the purpose of co-ordinating mapping on a national basis.

The Council now consists of the Commonwealth Director of National Mapping who acts as Chairman with the Commonwealth Surveyor-General, the Director of Army Survey and each State Surveyor-General as members.

Since its formation the National Mapping Council has met at least once each year and has, as necessary, made many recommendations in respect of specific geodetic and topographic survey and mapping activities in Australia.

The Council first gave consideration to the practicability of using airborne radar for the geodetic survey but, after reading the reports of a very thorough investigation by the Radiophysics Division of C.S.I.R.O.,[9] and in the light of the developments then just beginning in respect of ground instruments for electronic measurement of distances, the Council did not recommend proceeding with an airborne radar survey.

In 1948 the Council resolved that a basic scheme of geodetic survey be proceeded with —this scheme is shown in Figure 3.



In 1950 the Council adopted a national specification for horizontal and vertical control surveys.[10]

The progress made with geodetic surveys since 1945 is perhaps best conveyed by the following brief summaries prepared on the basis of the annual reports presented to the National Mapping Council.

New South Wales

During this period the State Department of Lands measured a new base line at Condobolin and computed a first-order chain connecting Lake George, Condobolin and Bourke base lines. In addition it observed and computed a net of second-order triangulation in the southern part of the northern tablelands.

A connection of 200 miles in length of first-order triangulation was also made by the State Lands Department between the Somerton base area and the Condobolin base area. In addition, second-order triangulation adjacent to this chain and in the Tamworth-Coonamble area was established. Further second-order work has been completed in the Boggabri, Blackville, Jenolan and Collyblue areas by the State Lands Department.

A number of Laplace stations have also been established by the State Lands Department.

Lengths of sides of first-order base line

figures at Bourke, Somerton and Richmond bases were measured by tellurometer by the Department of Lands for analysis of measurements with a view to the application of this instrument to first-order work.

A first-order triangulation connection was established by the Division of National Mapping between Broken Hill area and the Cobar area. This joined to the first-order New South Wales triangulation and completed the south-eastern loop in New South Wales, Victoria and South Australia.

One Laplace station was established by the Division of National Mapping at Mt. Stromlo and the Division also measured a few geodimeter lines in this State.

Victoria

The State Lands Department commenced second-order triangulation in 1952 based on existing Army first-order triangulation. Since then an approximate area of 12,000 square miles of second-order triangulation has been carried out by that Department.

The Lands Department has also completed 2,000 square miles of first-order triangulation in the Melbourne area.

A number of geodimeter and tellurometer lines have been established both by the Division of National Mapping and the State Lands Department.

The Royal Australian Survey Corps completed a geodimeter-tellurometer loop traverse between Bendigo and Ouyen.

Laplace observations were completed by the Division of National Mapping at Cape Liptrap, Alexander and Major triangulation stations.

Tasmania

The State Lands Department remeasured the Cambridge and Longford base lines and has completed triangulation connections between them as well as extensive areas of triangulation in the central and north-western areas of the State. Recently, with the aid of the tellurometer, a number of figures have been completed in the rugged mountainous area in the south-west of the State. A helicopter was used in this particular operation.

The Division of National Mapping carried out a triangulation connection between Victoria and Tasmania. In addition, the Division observed Laplace stations at both the Cambridge and Longford base lines.

Five geodimeter lines were measured by the Division.

Queensland

A second-order triangulation chain was established by the Royal Australian Survey Corps between Rockhampton and Emerald, and some triangulation was completed in the Charters Towers area.

The Survey Corps also commenced a connecting triangulation chain between Ayr and Rockhampton but this was discontinued before completion.

Geodimeter remeasurements of the Jondaryan base were carried out by the Division of National Mapping and the Royal Australian Survey Corps.

A first-order tellurometer traverse has been run by the Royal Australian Survey Corps from Jondaryan northerly along the east coast to Charters Towers, thence westerly right across the State to Camooweal, and thence across to the Stuart Highway in the Northern Territory.

The Survey Corps is at present active on a similar traverse from Townsville to Cooktown and from the Gulf of Carpentaria near the Northern Territory border to Camooweal.

South Australia

The State Lands Department has completed second-order triangulation in the Adelaide area, the Clare district, the Leigh Creek area, Yorke Peninsula, from Adelaide to Coonalpyn, and in the Whyalla district.

The Royal Australian Survey Corps measured a geodetic base line at Koolymilka and completed first-order triangulation between Carrieton and Koolymilka and second-order triangulation between Carrieton and Cowell.

In 1951 the Division of National Mapping extended from existing Army second-order triangulation at Cowell down Eyre Peninsula to link to Navy triangulation across Spencer Gulf. The Lands Department has since assisted by making the connection between the Navy triangulation and the chains on Yorke Peninsula and in the Adelaide area. A first-order triangulation extension was also made by the Division of National Mapping in a westerly direction from Port Augusta for about 100 miles and then southerly down Eyre Peninsula.

The Division has also completed a first-order extension of triangulation from the Port Augusta area to Cockburn area on the New South Wales border and has extended the triangulation from Port Augusta through

Marree and Oodnadatta to the northern border, and thence due west along this border to enter Western Australia.

The Division has completed a tellurometer traverse from the Eyre Peninsula area due west to the West Australian border and made a "spur" connection to Maralinga.

The Department of the Interior has carried out triangulation in the Woomera area and also between Mt. Sabine and Binda Boudna. In addition this Department has extended control by a combination of triangulation and traverse from Kingoonya to Maralinga.

Tellurometer traverses have been completed by the Lands Department in the south-eastern corner of the State and the Department has other tellurometer traverses in progress from Murray Bridge to Port Lincoln (across Investigator Strait), between Tarlee and Millicent bases and from Angaston to Mildura, Victoria.

A number of Laplace stations and several geodimeter base lines have been established in the State by the Division of National Mapping.

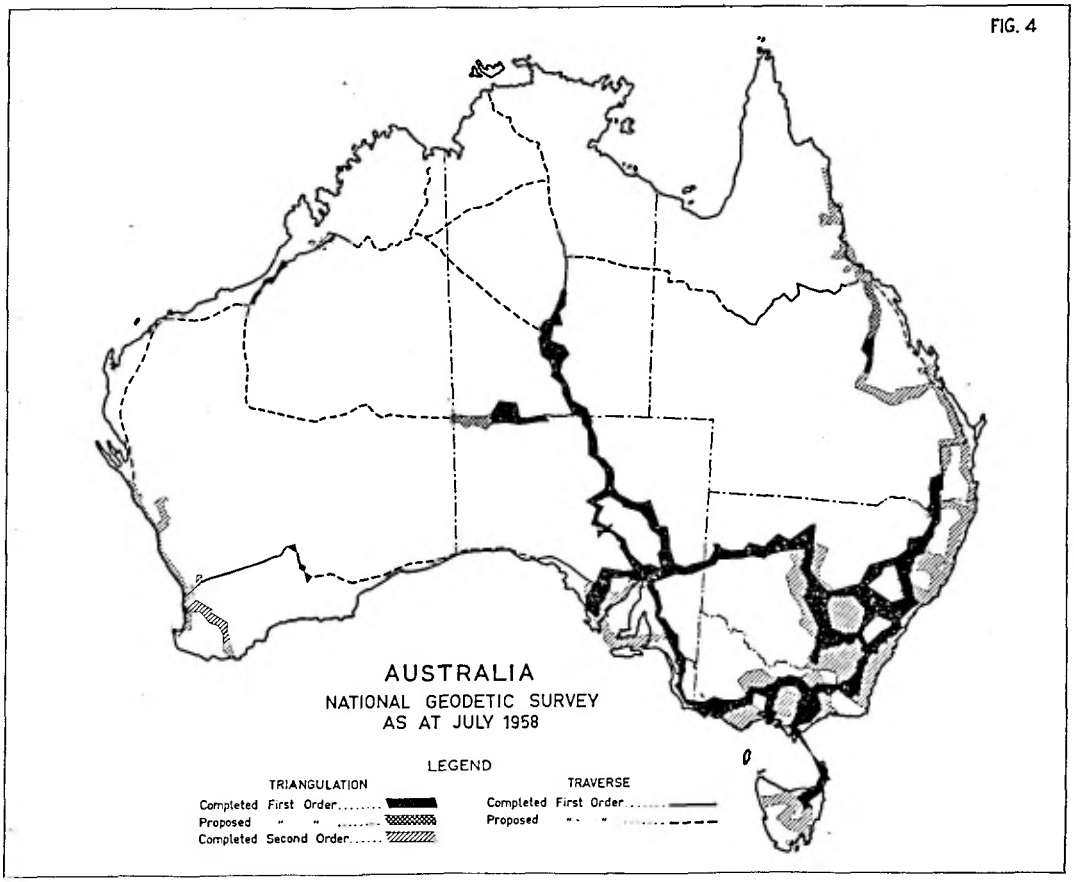
Western Australia

The war-time second-order triangulation in the south-west area has been strengthened by the observation of Laplace azimuths and the inclusion of geodimeter bases and extended from Katanning to the southern coast at Albany, a distance of about 100 miles, by the State Lands Department.

The Department has also made a first-order connection between Roy Hill and Mt. Anderson. This connection combines tellurometer traverse with first-order triangulation based on geodimeter base lines.

The Department has carried out another first-order traverse from the Perth area to Kalgoorlie, thence south-easterly to Norseman and across the Great Australian Bight to link up near Eyre with a National Mapping tellurometer traverse from the east.

FIG. 4



A geodimeter-tellurometer traverse was completed by the Department along 250 miles of coastline in the south-western corner of the State between Cape Naturaliste and Albany.

The Division of National Mapping has observed a number of Laplace stations and carried out first-order surveys from the Warburton Ranges to the Carnarvon Ranges. In addition, the Division has carried a first-order traverse from Eucla to Eyre and now has in hand a survey from Mt. Anderson to Hall's Creek.

The Royal Australian Survey Corps has completed a loop tellurometer traverse in the Hall's Creek-Wyndham area and a survey between Fitzroy Crossing and Kalumburu.

Northern Territory

The first-order traverse along the Stuart Highway between Alice Springs and vicinity of Helen Springs was completed by the Department of the Interior and the Division of National Mapping using invar bands.

The main chain of triangulation has been carried by the Division of National Mapping from the South Australian border as far north as Wauchope and is at present being connected to Darwin by tellurometer traverse. The Northern Territory Lands and Survey Branch is assisting the Division on part of this traverse near Darwin.

A branch of triangulation and traverse from this main north-south chain of triangulation was made about 100 miles north of Alice Springs and this branch passes in a north-westerly direction to Tanami and Hall's Creek.

A number of Laplace stations have been established in the Northern Territory by the Division of National Mapping.

The Royal Australian Survey Corps has made a first-order tellurometer traverse from Cloncurry to Tennant Creek and is currently engaged on similar traverses in the northern and north-eastern areas of the Territory from Mt. Hensman (W.A.) to Katherine to Roper River Mission to the Queensland-Northern Territory border.

General Activity During the Period

It should be noted that with the introduction of electronic distance-measuring equipment into Australia in the form of the geodimeter (in 1954) and the tellurometer (in 1957) the output of geodetic survey began to increase steeply.

The status of geodetic survey as at July 1958 is illustrated by Figure 4.

In 1958, the National Mapping Council, on the basis of local experience and in the light of a recommendation from the International Union of Geodesy and Geophysics, adopted 299,792·5 km/sec. as the value for the velocity of light *in vacuuo* to be used in Australian surveys.

Subsequently the Council recommended adoption of the international value of the yard which equals 0·9144 metres.

This now means that all Australian geodetic measurements will be expressed in standard international terms.

In 1957-8, primarily at the request of the National Mapping Council, the Mt. Stromlo and Perth Observatories installed Markowitz Moon Cameras for photographic lunar observations to enable establishment of absolute position to within ±40 metres.[11]

In March 1959, the Council adopted the new scheme of basic national geodetic survey shown in Figure 5, and much of this work is currently under way.

1960-75—Possible Activities

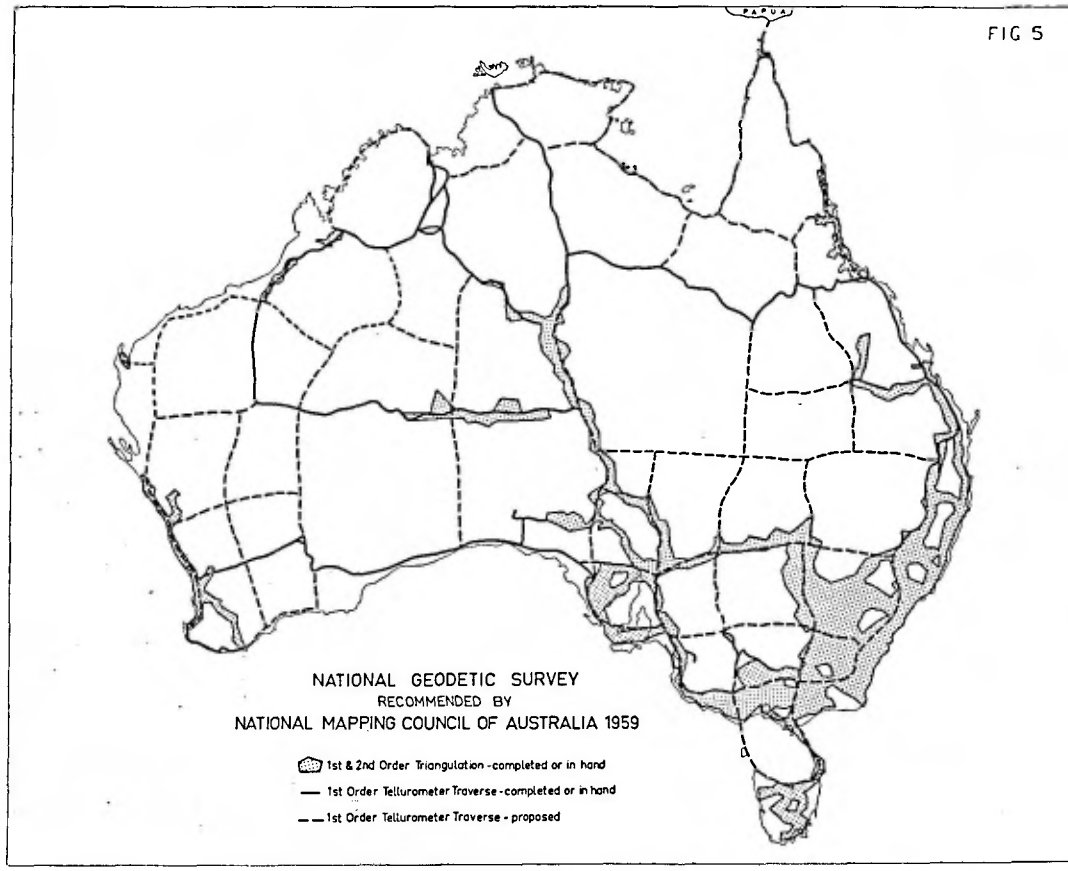
It is, of course, impossible to accurately predict future trends in the geodetic survey, but it can reasonably be assumed that the basic scheme recently approved by the Council should be finished in a period of five years from now and by that time will probably extend into New Guinea.

Recently developed computing techniques should permit a larger overall technique of adjustment which should help to retain accuracy and expedite the production of station co-ordinates.

From the mapping point of view the rapid geodetic surveys possible with modern equipment may mean that the basic survey will consist of more closely spaced chains (or traverses) than hitherto.

Moreover, now that photogrammetric stereo triangulation is moving towards "block adjustments",[12, 13, 14] and the use of super wide-angle camera lenses it may at last become a sound and economical mapping procedure to use stereo triangulation to fill in control between widely dispersed ground surveys.

The next few years should see an interesting "matching" of these two trends.



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