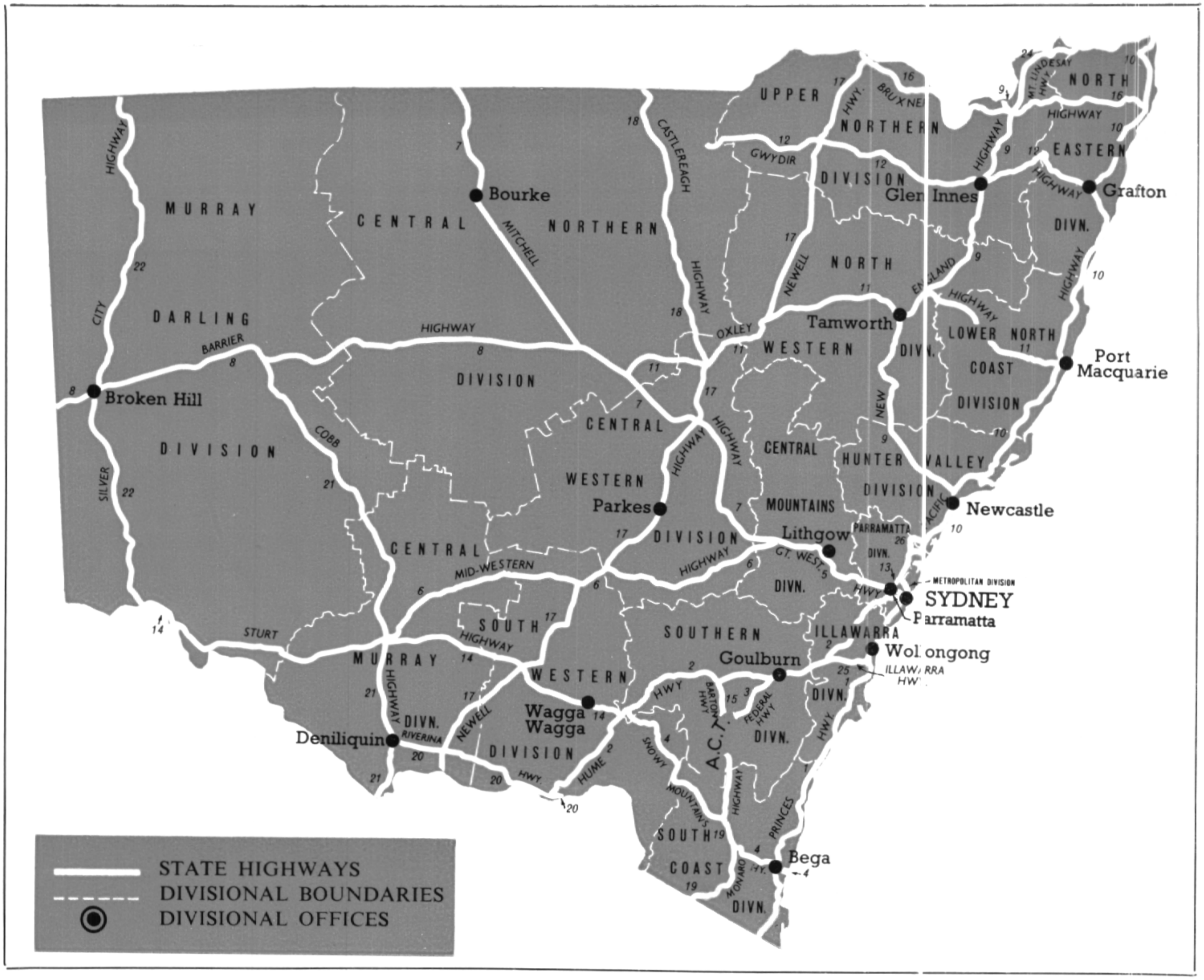
MAIN ROADS

DECEMBER 1971



Area of New South Wales—309,433 square miles

Length of public roads within New South Wales—129,745 miles

Population of New South Wales at 31st March 1971—4,653,000 (estimated)

Number of vehicles registered in New South Wales at 30th June, 1971—2,009,831

ROAD CLASSIFICATIONS AND MILEAGES IN NEW SOUTH WALES

Mileage of Main, Tourist and Developmental Roads, as at 30th June, 1971

Expressways	27
State Highways	6,536
Trunk Roads	4,332
Ordinary Main Roads	11,513
Secondary Roads (County of Cumberland only)	170
Tourist Roads	243
Developmental Roads	2,670
	25,491
Unclassified roads, in western part of State, coming within the provisions of the Main Roads Act	1,569
TOTAL	27,060

MAIN ROADS

JOURNAL OF THE DEPARTMENT OF MAIN ROADS, NEW SOUTH WALES

DECEMBER, 1971

VOLUME 37 NUMBER 2

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Front Cover: *Highway through Garden Suburbs*
Three scenes along Pennant Hills Road (*State Highway No.* 13) *between Carlingford and Normanhurst*

Back Cover: *The Prince's Highway at Benandra State Forest approximately* 5 *miles north of Batemans Bay*

ENCOUNTER

During recent years, there has been a growing acknowledgement that, in the future, Australia's involvement with Asian and African countries will increase and deepen.

Under Australia's external aid programme, we already send, among other things, copper tubing and chemicals to Indonesia, flour to Mauritius, seed potatoes to Ceylon, dairy cattle to India, rice irrigation equipment to Fiji, mining equipment to Pakistan and road construction equipment to Burma.

Our links, however, are more than mere formal financial assistance or gifts of goods and equipment. During 1971, we welcomed the 10,000th Colombo Plan student to arrive for study in Australia. It is not so widely known that numerous training courses for senior officials from Asian, African and South Pacific countries are held throughout Australia in such fields as customs and police administration, photogrammetry, crop protection, public health engineering, management and librarianship. From these courses personal relationships develop between people who are undertaking similar tasks in different countries.

Prior to 1968, individual State Road Authorities initiated schemes for inviting selected African and Asian engineers to visit Australia in order to study road and bridge building techniques and to gain experience and knowledge which would be valuable to them in their own countries. Following a proposal by NAASRA, a scheme was evolved in 1969, under the auspices of the Commonwealth Department of Foreign Affairs, to provide a series of such sponsored courses on a regular basis (see article on page 36).

These courses have not only provided our guests with a beneficial look at Australian methods and developments, but have also, through discussions on difficulties in other developing countries, encouraged us to approach our own problems with fresh enthusiasm. Extensive periods of technical exchange between guests and hosts have thus expanded knowledge, deepened international friendships and, in many ways, made these visits from our neighbours a mutually satisfying experience. Each has been a very pleasant and very worthwhile encounter.

BRUXNER HIGHWAY

NEW DEVIATION WEST OF BONSHAW

The Bruxner Highway (State Highway No. 16) is 272 miles long and extends from the Pacific Highway near Ballina to the Queensland border near Goondiwindi. At its eastern end the Highway passes through farming and grazing country adjacent to the Richmond and Clarence Rivers and then, after leaving Tabulam, crosses over the Great Dividing Range to Tenterfield on the New England Tableland. West of Tenterfield, the Highway traverses rolling to steep terrain to near Mingoola where it is located adjacent to the Dumaresq River. Grazing is practised and tobacco and lucerne are extensively grown along the section of Highway from near Mingoola to near Texas.

The Bruxner Highway previously followed the general course of the Dumaresq River and, being located in relatively low-lying terrain in the river valley, it was liable to flooding in various sections between 5 and 18 miles west of Bonshaw. Construction work was therefore recently undertaken and involved the relocation of this section of the Highway to higher undulating country south and west of the old route.

The relatively sparse tree growth allowed the preliminary road location to be determined from aerial photographs. The final location was undertaken using a contour survey and the detailed design was prepared in the Department's Divisional Office at Glen Innes. This design provides for a 60 m.p.h. standard with a 20 feet wide bituminous surface and a 32 feet wide formation. The minimum radius is 2,300 feet and the maximum gradient is 4·9 per cent.

A seismic survey was carried out to determine the construction problems likely to be encountered in the crests. The strata formed part of a group of rocks known as "The Beacon Mudstones" of the lower carboniferous age. This group take their name from "The Beacon", a high point approximately two miles east of Texas where they occur in prominent outcrops. The Beacon Mudstones consist of variably metamorphosed mudstones and fine sandstones. These rocks are locally interspersed with cherts, rhyolitic sandstones, limestones, intermediate amygdaloidal lavas and aphanitic rhyolites.

The Department's R.S. 4 Seismic Recorder fitted with two channels was used for this survey work. Shot points were set at 220 feet intervals with normal detector spacing. Compression wave velocities of between 10,000 and 12,000 feet per second were recorded in the crests below ten feet from the surface. From this survey, it was then established that a Class 8 tractor-dozer (approximately 380 H.P.) would be required to rip the upper layers in most cuttings, assisted by drilling and blasting in the lower layers.

Subsequently, a Class 8 tractor-dozer with parallelogram rippers was used on the work and drilling and blasting were, in fact, necessary in the lower levels of most of the cuttings encountered. Drilling was carried out by hand-held rock drills. Ammonium nitrate fuel oil mixture was used in blasting. Bulldozers moved the excavated materials on very short leads. Two motorised open-bowl scrapers of 30 cubic yard capacity moved the bulk of the earthworks. Compaction was achieved with vibrating sheepsfoot rollers and vibrating smooth wheeled rollers.

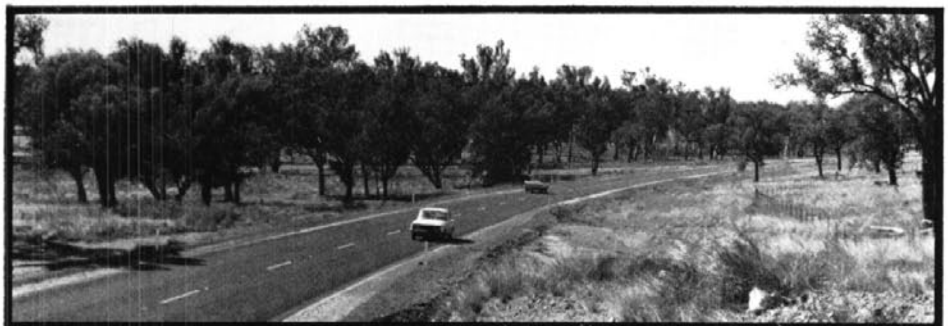
Pipe culvert sizes ranged from 18 inch diameter to 72 inch diameter multi-cell structures. Five bridge-size culverts and four bridges were provided over the larger creek crossings. Spread footings and reinforced concrete piles were determined as appropriate for the bridge foundations after bridge site borings were carried out. Prestressed deck planks were used in the bridges for ease of construction. The bridges and culverts were generally built by contract to the Department as follows:

- Bridge over Lickinghole Creek (east branch)—9·9 miles west of Bonshaw—3 x 30 feet spans. M. R. and E. M. Firth, Tamworth.
- Bridge over Lickinghole Creek (west branch)—10·4 miles west of Bonshaw—2 x 30 feet spans. M. R. and E. M. Firth, Tamworth.
- Bridge over Oaky Creek—12·5 miles west of Bonshaw—3 x 30 feet spans. M. R. and E. M. Firth, Tamworth.
- Bridge over Dinner Corner Creek—15·5 miles west of Bonshaw—2 x 35 feet spans. M. R. and E. M. Firth, Tamworth.
- Reinforced concrete box culvert at 5·4 miles west of Bonshaw—three cells each 8 feet x 5 feet. Department of Main Roads.
- Reinforced concrete box culvert at 6·4 miles west of Bonshaw—six cells each 10 feet x 5 feet. Enpro Constructions Pty Ltd, Tamworth.
- Reinforced concrete box culvert at 6·8 miles west of Bonshaw—four cells each 5 feet x 3 feet. Department of Main Roads.
- Reinforced concrete box culvert at Horse Gully Creek, 13·9 miles west of Bonshaw—three cells each 12 feet x 9 feet. K.A. Constructions Pty Ltd, Scone.
- Reinforced concrete box culvert at Horse Gully Creek, 14·7 miles west of Bonshaw—three cells each 12 feet x 6 feet. K.A. Constructions Pty Ltd, Scone.

The roadworks were undertaken by the Department's Works Organisation located at Bonshaw, where a Works Office (with quarters for male staff) was established to reconstruct the section of Highway from near Mingoola to near Texas. The Works Office was staffed by a Works Engineer, Assistant Engineer, cost clerk, clerical officer, typist and storekeeper. A camp was also established at Bonshaw for the workmen, most of whom had their homes outside the Bonshaw area.

The 13-mile flood-free deviation, together with a two-mile connection from the Bruxner Highway to the Queensland border near Texas, cost over $1 million and was opened to traffic on 20th September, 1971●

The following articles on the Bruxner Highway have appeared in recent issues of "Main Roads":
- *Reconstruction from Tabulam to Drake, December, 1969—Volume 35, No. 2, page 35.*
- *Historical Roads of New South Wales series, March, 1968—Volume 33, No. 3, page 58.*

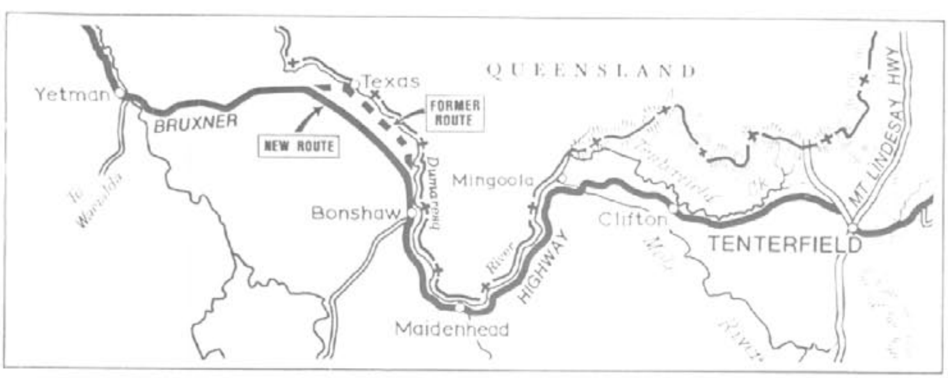


Section of new deviation

Bridge over Dinner Corner Creek, 15.5m. west of Bonshaw

Junction of Bruxner Highway and Main Road No. 138 which leads to the Queensland border near Texas

Bridge over Lickinghole Creek (east branch) 9.9m. west of Bonshaw



Colour photographs of the new deviation appear on pages 48 and 49.

A SPREADING PATTERN OF INVOLVEMENT

NAASRA COURSES FOR AFRICAN AND ASIAN ENGINEERS

This article shows how, in conjunction with the Commonwealth Department of Foreign Affairs and using the technical resources of individual State Road Authorities the National Association of Australian State Road Authorities is helping nations of the African and Asian regions attain greater efficiency in road communications.
A brief review of the foundation and development of NAASRA is also given.

For some years the State Road Authorities have provided training for selected engineers from African and Asian countries but until 1968 training attachments were on an individual basis. In 1968 a proposal was made to the Commonwealth Department of External (now Foreign) Affairs that NAASRA might be able to assist countries in Africa and Asia by providing group study courses for selected engineers to help evolve more efficient design and management methods for low cost road and bridge construction and maintenance. Following approval, a series of sponsored courses of approximately three months for Senior and Intermediate Level Engineers from these countries were planned and invitations extended to those with construction conditions familiar to many parts of Australia.

Under the proposal, all members of NAASRA signified their willingness to take part.

The scheme, which is closely linked to Australia's obligations under the Colombo Plan, became a reality in mid-1969 and has functioned most satisfactorily.

PLANNING THE GROUP COURSES

Between the inception of the Colombo Plan in 1951 and 1966 the Commonwealth Government had contributed over $880 million in External Aid for technical and economic assistance to developing countries in the African and Asian area. It was given with the hope of having a multiple effect on the economic and social development of associated countries.

NAASRA having realised, through long experience, the significance of improved road communications to Australia's development and the need for similar facilities in these countries, readily offered to organise a series of engineering training programmes.

With the principle of sponsored courses satisfactorily established, the Department of Foreign Affairs then proceeded to invite Governments of Asian and African countries to nominate applicants to fill both senior and intermediate level courses.

In view of the highly technical aspects of each course, the Department of Foreign Affairs laid down a firm standard for qualification, and the necessity for each applicant to be proficient in English even though this might mean spending up to three months in Australia prior to being approved for one of the courses.

Each host State having planned its course has the right of final approval based on the applicant's capacity to benefit, and his ability to pass on and turn these experiences to good effect in his own country.

SENIOR LEVEL COURSES

These courses were planned for Senior Engineers with between twelve and twenty years experience in all forms of road and bridge design and construction, with qualifications from recognised universities or technical institutions. The first such course was held in Queensland between August and November, 1969.

In view of experience gained from an earlier Intermediate Course conducted in March, 1969 by the Department of Main Roads, New South Wales, the senior level programme was redesigned to give it a broader range of discussion and experience in many aspects of higher administration. This was done because the Senior Engineers involved were invariably more concerned with engineering management than technical aspects.

Although the course remained similar, much technical content was eliminated and greater scope given to seminar type discussion, and the opportunity to visit private companies and organisations of a sub-contractural nature.

After the induction period the seminar portion was divided into three segments with a two-week attachment to regional divisions for practical observation between each segment. The decrease in the intensity of the course allowed for a more objective appreciation of specialist attachments and the final period of review.

This was highly successful but, in view of the time Senior Engineers are expected to be absent from their Departments, it was decided that future courses for this level should be shorter, more concentrated seminars.

The next Senior Seminar was held in New South Wales in August, 1971 (see details on page 40). After allowing only two days for arrival and induction the Seminar moved into the presentation of papers. Three weeks were allowed for presentation and discussion and three days for specialist attachments. For those who wished to follow up with further attachments, and other technical activities, another week was made available at the end of the Seminar.

No formal lectures were delivered to these Senior Engineers but, instead, selected papers were presented by senior staff of member Authorities as well as speakers from the Commonwealth Bureau of Roads, the University of New South Wales and from some private organisations. These papers dealt with the latest Australian developments in design, construction, maintenance, research and management of road and bridge works. The Senior Engineers were expected to critically discuss the application of techniques outlined in the papers and to present at least one paper on developments or problems in their own countries. The Seminar was conducted on a residential basis with all Fellows and the Course Director living in. Presentation of papers was interposed with site visits and some evenings were occupied in group discussion.

INTERMEDIATE COURSES

These courses have been planned along a similar pattern for the younger engineer with a minimum of five years experience in road and bridge engineering, who may be selected from any country in Africa and Asia.

The first Intermediate Course was conducted by the Department of Main Roads, New South Wales, commencing in March, 1969, for 10 engineers. The Country Roads Board of Victoria organised another in March, 1970 for 13 engineers. Commencing in April, 1971, the Queensland Main Roads Department hosted a further group of 20 from Asian countries. A typical three-month course includes a week's induction, followed by lectures and project inspections in near areas, practical attachment to regional divisions, lectures at headquarters, attachment to divisions and specialist sections culminating in a review of the entire course. Before entering the technical and practical aspects of the course, a week's induction is provided at which officers of the Departments of Foreign Affairs, Education and Science and host organisations explain the characteristics of the people and areas among which the participants would be moving during the course.

Almost every aspect of Australian life is outlined, from its economy to types of food, religion, politics, banking, shopping and education. Questions are invited so that maximum assimilation can be effected in this brief time. This is followed by each visitor presenting a biographical

One of the linemarking machines developed by this Department created considerable interest among visiting African and Asian engineers during an International Seminar held recently in Sydney summary of his personal history, country, and the functions for which he is responsible. In each case this early familiarisation increased confidence and has led to keener participation in course discussion than would otherwise have occurred. Towards the end of the first week, the courses are officially opened, the visitors welcomed and the objectives of the courses outlined.

In the early weeks, the engineers are given a comprehsnsive and balanced programme of technical lectures and discussion on aspects of planning and design, organisation and administration, job management and road construction methods (including such specialist activities as pavement design, foundation investigations, computer techniques, traffic surveys and intersection design). In reviewing the courses, members concluded that there is considerable scope for the adaption of the practices and techniques studied in Australia to their countries, taking into consideration differing economic, climatic and social conditions.

On the practical side, they are shown field application of bituminous surfacing, road maintenance, bridge design and construction, plant operation and maintenance, materials investigation and testing, aspects of contract work and job management techniques.

Whilst they are shown many activities of a highly technical nature, it is always borne in mind that the course objective is to give the greatest appreciation of "low cost stage construction methods".

PROMOTING GOODWILL

Whenever possible Australian Road Authorities, like those in other countries, notify the press and other information services of any newsworthy activity of public interest. This is done by host States from the outset of each course. By the time the visitors return from regional tours they all receive excellent group coverage. These press reports are subsequently collated and forwarded to their Governments.

The friendly atmosphere in which the courses are conducted and the hospitality extended by officers of the Department of Foreign Affairs and the State Road Authorities, as well as other organisations and individuals, are building a most cordial relationship between the visitors and their hosts which should benefit each successive course.

CONCLUSION

The Department of Foreign Affairs, NAASRA and the host State Road Authorities are most appreciative of the

NAASRA

AN HISTORICAL REVIEW

Ever since the motor vehicle began to replace horse-drawn conveyances as the major means of travel in the early 1920's, the Governments of Australia have shown concern for the development of a co-ordinated system of national highways. Because each State was operating independently with minimum funds and unrelated policies, the Prime Minister in 1926 called a conference of State Road Authorities to establish a Federal Aid Roads Board to review road development needs on the broadest possible scale.

The Board, consisting of Commonwealth and State Road Ministers supported by a committee of technical members of each State Road Authority met regularly until disbanded in 1931.

By 1933 however, the need for unified direction had become a matter of urgency, and a year later led to the formation of the Conference of State Road Authorities, commonly called COSRA. This organization was joined by a member of the Department of the Interior and in 1949 the Commonwealth Department of Works.

COSRA functioned actively in the development of national highways until 1959. Then, because of emerging defence road needs and improved road construction techniques demanded by the volume of vehicles, their design and speeds, it changed to a more comprehensive organisation called the National Association of Australian State Road Authorities (NAASRA).

Throughout the life of this organisation, firstly as the Federal Aid Roads Board, then as COSRA, and now as NAASRA, the member Authorities have maintained a farsighted objective of pooling technical and administrative experience; of inaugurating and co-ordinating road research; of developing construction and safety standards; and of keeping the public informed of Australia's road needs and associated problems.

To assist in bringing together ever widening aspects of highway needs, NAASRA established a close relationship with the Australian Transport Advisory Council, through the Department of Shipping and Transport, representatives of which, together with the Commonwealth Bureau of Roads, regularly confer with NAASRA on major roading policies. As it became evident that NAASRA could not depend on regular information from overseas and state research facilities on mounting highway problems, the Australian Road Research Board was formed in 1960 to investigate an ever increasing field of technical and practical requirements in road construction, highway safety and operation, and vehicle performance.

The member Authorities of NAASRA are:
☐ New South Wales—Department of Main Roads ☐ Victoria—Country Roads Board ☐ Queensland—Main Roads Department ☐ South Australia—Highways Department ☐ Western Australia—Main Roads Department ☐ Tasmania—Department of Public Works ☐ Commonwealth Territories—Department of Works.

The following Standing Committees meet regularly:

☐ Principal Technical Committee ☐ Secretarial and Accounts Committee
☐ Advance Planning Committee ☐ Bridge Engineering Committee
☐ Computer Committee ☐ Geometric Road Design Committee
☐ Materials Research Committee ☐ Plant and Equipment Committee
☐ Traffic Engineering Committee ☐ Construction and Maintenance Practice Committee.

NAASRA relies on the Principal Technical Committee of Chief Engineers of the member Authorities operating through specialised committees, for implementation of NAASRA's policies.

ready response shown by African and Asian Governments to the project. In any initial scheme of this nature it would have been difficult for these Governments to assess in advance the value of such courses. However, with the return and involvement of these men at many levels of engineering and administration, response to future courses should now be more spontaneous. It may take time to evolve the best system of sharing knowledge and experience likely to give the greatest benefits to these levels of engineers in developing countries, but we believe this will be achieved as we further appreciate the difficulties under which these countries operate and the type of information best suited to their local conditions. Those associated with the conduct of each course are rewarded by the interest and friendship of the participants. It is believed that these mutual exchanges of technical knowledge and experience are valuable and could lead to the use of techniques which, having proved successful in Australia, may also have application to the road systems of African and Asian countries●

This article has been adapted from a 12 page illustrated brochure producea by NAASRA and entitled "Improving Skills for a Better Future". Copies of the brochure may be obtained from this Department or from the Engineer-Secretary, NAASRA, P.O. Box 198, Haymarket, N.S.W. 2000.

Senior overseas engineers were shown modern photogrammetric plotting equipment and methods during their visit to the Rural Investigations Section at the Department's Head Office in August, 1971

INTERNATIONAL SEMINAR

SYDNEY, AUGUST, 1971

During August, 1971 the Department conducted a four-week residential International Training Seminar for Senior Highway Engineers. The course was arranged by NAASRA, on behalf of the Department of Foreign Affairs, which provided a Course Manager to look after personal matters for the visitors (e.g. mail, passports, transport of baggage, and travel arrangements).

Forty-four papers, on the latest developments in highway engineering in Australia, were presented by 36 authors, including 21 from this Department.

The visiting engineers noted in discussions that what they most expected to get out of the Seminar was:

* A first-hand view of recent development and techniques in the planning, construction and maintenance of highways.

* An insight into the structure of Australian Road Authorities.

* An insight into the Australian way of life.

* To establish friendship with their counterparts in Australia.

In a final review of the course, they declared they had achieved all four objects.

The photograph above shows the eighteen visitors from Africa and Asia with their Departmental hosts.

* Back Row: (left to right:)

□ Mr J. Agustin, Supervising Civil Engineer II, Bureau of Public Highways. Philippines.

□ Mr L. T. Trinh, Chief, New Construction Division, Directorate General of Highways. Vietnam.

□ Mr A. Eufemio, Chief—Operations, 51st Engineer Brigade, Philippine Army. Philippines.

□ Mr N. X. Mong, Chief, Central Highland District, Directorate General of Highways. Vietnam.

□ Mr J. C. Webb, Department of Main Roads, N.S.W.

□ Mr A. S. Sheikh, Superintending Engineer, Kashmir Circle. India.

□ Mr P. Verasopon, Section Head, Design of Highway Structures, Department of Highways. Thailand.

□ Mr N. D. Sharma, Executive Engineer, Sunauli Pokhara Road Project. Nepal.

□ Mr B. Mortensen, Department of Foreign Affairs, Canberra (Course Manager).

* Centre Row:

□ Mr J. Stacey, Department of Main Roads, N.S.W.

□ Mr S. Nagaich, Superintending Engineer, Circle State of Jammu and Kashmir. India.

□ Mr H. Soegijanto, Secretary, Directorate of Road and Bridge Maintenance, Directorate General of Highways. Indonesia.

□ Mr R. P. Sikka, Superintending Engineer (Standards), State of Madhya Pradesh. India.

□ Mr J. Neeson, Engineer for Technical Training, Department of Main Roads, N.S.W. (Course Director).

□ Mr M. Mulsid, Sub-Section Chief, Highway Location and Design, Bureau of Public Highways. Philippines.

□ Mr I. Bornu, Controller of Works, North Eastern State, Ministry of Works and Survey. Nigeria.

□ Mr S. Subramaniam, Deputy Director of Works—Central Region, Ministry of Highways, Power and Irrigation. Ceylon.

* Front Row:

□ Mr O. A. Falase, Chief Civil Engineer, Lagos State, Ministry of Works and Survey. Nigeria.

□ Mr A. Jayasekera, Director of Works (Planning)—Highway and Irrigation, Ministry of Highways, Power and Irrigation. Ceylon.

□ Mr M. J. Dennett, Supervising Engineer, Road and Aerodromes, Commonwealth Department of Works, New Guinea.

□ Mr R. J. S. Thomas, Commissioner for Main Roads, New South Wales.

□ Mr A. F. Schmidt, Assistant Commissioner for Main Roads, New South Wales.

□ Mr T G. Park, Senior Engineer, Engineering Division, National Expressway Planning and Research Office. Korea.

□ Mr K V. Abraham, Superintending Engineer (Bridges) Planning, Central Government—New Delhi. India.

PERMEABILITY TESTS USING PIEZOMETERS on route of Southern Expressway

The Department's helicopter provided a fast and reliable means of transport to the swampy test sites

The proposed route of the Southern Expressway, between Darke's Forest and the top of Bulli Pass, extends for about four miles across an area known as Madden's Plains. This area is characterised by swampy high plains set in the midst of undulating country of general elevation between 1,150 and 1,300 feet above sea level, near the headwaters of the Cataract River and Madden's Creek systems.

High water table conditions persist over much of the ground, which is swampy, even in dry weather. The grass tussocks have a natural tendency to grow in rows, giving the ground the appearance of having been contour ploughed, and water lies for a long time in the "furrows". Other parts of the area are sandy or have outcrops of sandstone.

A piezometer being extracted from the ground

Early attempts at taking road plant into the area resulted in the plant quickly becoming bogged. The question then arose as to whether it would be possible to drain the wet areas with, for example, a herringbone layout of trenches. For such an undertaking, knowledge of the permeability of the soil at various locations was needed, and this was measured, at each site, by means of piezometers. These investigations were carried out by officers of the Department's Materials and Research Section.

The Department's piezometers consist of an unglazed porcelain filter, set in a perforated protective brass sheath, and mounted on the end of galvanized steel piping. The filter end is driven into the ground by means of a jack. The permeability of the soil is determined by pumping all water out of the pipe and timing the subsequent rise of water in the pipe.

The jack forms part of an interrelated set of equipment used for soil mechanics field investigations and, in addition to driving piezometers into the ground, it is also used for driving undisturbed soil samplers and vane shear apparatus.

On completion of the tests at Madden's Plains, the piezometers were recovered, using the same jack, and reconditioned for any similar future use. ●

Close-up view of the tip of a piezometer

PHOTOGRAMMETRY for Road Engineering Purposes

This is the second in a series of three articles, edited from a paper prepared by the Department's Senior Photogrammetrist, Mr P. G. Sandwith. The first article entitled "Aerial Photography for Road Location and Design" appeared in the September, 1971 issue of "Main Roads" (Volume 37, No. 1, page 23).

AN INTRODUCTION

Photogrammetry is the science of obtaining measurements from photographs and includes the recording and storage of the measurements and the display of the stored data. To the mathematician, photogrammetry entails the problem of transforming x and y co-ordinates on a perspective projection into X, Y, and Z co-ordinates on an orthogonal projection. To the cartographer, photogrammetry entails the recording of detail that is visible on a photograph onto some other medium, such as a map, at a predetermined scale. To the engineer, photogrammetry entails some of the requirements of the mathematician and the cartographer, but the engineer's requirements are more specialised and varied.

Photogrammetry has had many applications ranging from the mapping of the surface of the moon to the measurement of weathering on the face of ancient monuments. There are applications in dentistry, in recording of evidence by police at traffic accidents, and in measurement of stockpiles and mine dumps. The data obtained from the photograph can be displayed in the form of a map, or an engineering drawing, as a "rectified" photograph at a uniform scale, or in numerical form as a "digital terrain model".

MAPPING FROM AERIAL PHOTOGRAPHS

The difference between an aerial photograph and a map was outlined in the previous article "Aerial Photography for Road Location and Design", which appeared in the September, 1971 issue of "Main Roads". It was pointed out that a photograph most nearly resembles a map drawn to scale when the terrain is flat and the camera axis is vertical. If the terrain is flat but the camera is not vertical, the photograph has a variable scale and accurate measurements cannot be made from it. However, an enlarging-type camera known as a "rectifier" can be used to obtain a fresh photograph which is tilt free and therefore has a constant scale. A series of photographs over flat ground can be rectified and enlarged or reduced so that they are all of the same scale. These photographs can then be joined together to form a rectified mosaic which has all the characteristics of a map, namely that measurements can be taken from any part of the mosaic at a predetermined scale. No contours or heights can be obtained from a single photograph.

If the terrain is not flat but the camera axis is vertical, the scale of the photograph is again variable. The scale of a photograph is directly proportional to the flying height of an aircraft so that if the aircraft is 10,000 metres above one point on a photograph and 11,000 metres above another, there will be a 10 per cent variation in scale over the photograph and measurements can be made to an accuracy of ± 10 per cent only. This is insufficient for most mapping.

If two photographs of the same object are taken from two different camera stations, the images of that object will appear differently on each photograph. If the two photographs are viewed under certain conditions the different angles at which the object is viewed by each eye causes an observer to see a three dimensional picture. This means that the observer can also perceive depth or height, and will see the combined images of the two photographs as a "stereoscopic model". An analogy of the stereoscopic model is the three dimensional cinema picture which uses twin projectors to form an image with depth.

A stereoscopic model of a pair of photographs can only be formed under the following conditions:

(a) The camera axes must be in approximately the same plane.

(b) The scales of the two photographs must not vary from each other by more than 10 per cent to 15 per cent.

(c) The ratio of the distance between the camera stations and the distance from the camera to the object must be within a certain range.

Photogrammetric instruments make use of pairs of photographs to form stereomodels whose scales are the same horizontally and vertically, so that maps may be produced from these instruments showing detail and relief, including spot levels and contours. In the previous article, it was mentioned that if strips of photographs are flown with 60 per cent overlaps, the pairs of photographs, and therefore the stereomodels, will also overlap, and large maps can be produced from strips and blocks of photographs.

In order to fulfil the above conditions, aerial photography of a high standard must be provided.

ENGINEERING PHOTOGRAMMETRY

Engineering photogrammetry may be divided into the categories of investigation, location and design.

Investigation photogrammetry covers the initial stage where the site of the project is undecided. Aerial photography may cover a wide area at a small scale, and plans prepared from these photographs will most nearly resemble a conventional map. The object of the investigation is to cover the widest possible area and to eliminate as many unsuitable alternatives as possible. Accuracy on this type of survey is a secondary consideration as the completed plans are only used to decide which areas require more detailed survey.

An example of an investigation survey would be the planning of a new highway link from the coast to a developing inland centre. Aerial photographs covering several hundred square kilometres could be required, so that alternative routes could be chosen to avoid the obvious barriers such as mountain ranges, swamps, and lakes (all of which can be seen on the photographs).

Mapping of selected routes can then be carried out. The mapping could consist of strip plans at scales of from

1 : 15,000 to 1 : 5,000 with contour intervals of 10 metres or 5 metres. The width of the strip maps could vary from 2 km upwards, with the alternative routes perhaps separated by areas which are unmapped. From this mapping, one route can be selected which, for ease of construction and economy, outweighs the others.

Once a general route has been selected, photography at a lower altitude is flown along that route only to give a coverage of the roadway at, say, a scale of 1 : 2,500–1 : 1,000 with contours at 2 metre intervals. These plans would be used to locate the best crossings of streams, to determine the properties that would be affected along the route, to calculate preliminary earthworks, and to select the best alignment for the road.

When the alignment has been selected within the limits of a strip 100–200 metres wide, low-level photography at an altitude of 1,000 metres or less can be used to produce large scale plans for design at scales varying from 1 : 500 to 1 : 1,000 with $\frac{1}{2}$ or 1 metre contour intervals. These plans can be used to interpolate cross-sections from the plotted contour lines for more detailed calculation of earthworks.

Photogrammetric surveys rarely require the three separate stages of investigation, location and design. In heavily timbered country where the ground is obscured and it is impossible to interpolate contour lines to intervals closer than 10 metres, the survey for investigation can be covered by photogrammetry, after which a detailed survey can only be carried out on the ground.

In many cases mapping at small scales can be dispensed with and the location photogrammetry can become the first stage after inspection of available small scale photography.

On many projects it may be preferable to dispense with design photogrammetry and complete the survey in the field after the location has been determined.

The advantages of photogrammetry over conventional field survey are as follows:

1. A much greater area can be covered in a shorter time, especially in difficult country.
2. Mapping is carried out in the office and, therefore, there are no seasonal restrictions or communication problems for survey parties.
3. There are fewer problems with property-owners likely to be affected since no field survey need be carried out along a selected alignment until all other alternatives have been considered.

The disadvantages of photogrammetry are that:

1. It involves considerable expense in capital equipment, such as aerial cameras and photogrammetric plotting instruments. This can be obviated by the use of consultants and contractors for specific projects.
2. Trees or long grass sometimes obscure the natural ground surface.
3. It is difficult to obtain good aerial photography under certain climatic conditions.

COMPARISONS OF ROAD ENGINEERING AND MAPPING

PHOTOGRAMMETRY

As most photogrammetric literature deals with production of maps it is necessary to compare the requirements of mapping and road engineering plans in order that planning of photogrammetry may be kept in its true perspective.

Mapping

☐ Mapping is carried out systematically at selected scales for a particular map series. A map series at 1 : 100,000 may cover a whole country: the 1 : 1,000,000 International map series covers the whole world.

☐ Map sheets are mostly bounded by lines of latitude and longitude or by grid lines on a particular map projection. Heights are given above sea level.

☐ It may be necessary to apply a scale factor to distances between points derived from map co-ordinates.

Certain standards of accuracy are prescribed for plotting of detail and contour on maps.

Road Engineering Plans

☐ Road engineering plans are prepared for a specific project. Scales used will depend on the detail required to be shown on the separate plans for investigation, location and design.

☐ Road engineering plan sizes are variable. For some projects, it may be convenient to include the whole area on one sheet but for road plans, sheets may be several metres long. In general, sheet edges will run parallel to the direction of the road and the grid may be skew to the sheet edge.

☐ The co-ordinate system used for the survey and plotting may have a local origin. The direction of North may be magnetic or approximate only. Levels can be given on an assumed datum. It is inconvenient for engineers to have to apply scale factors to measured distances from co-ordinates.

☐ The standards of accuracy required will vary according to the engineer's requirements and should not be related to the scale of the plan only. Discrepancies of several millimetres in position or of several times the plotted contour interval could be tolerated on road engineering plans.

GROUND CONTROL

Some field survey information is always required in order to relate the scale of the photography to the plotting scale. The photogrammetric plotting instrument will perform the task of relating the positions of certain points visible on the photographs to the positions of those points plotted on a plan at a nominated scale. The simplest way to fix the points initially is to obtain the co-ordinates of the points relative to a grid which can also be plotted on the plan. If the positions of the points are not known relative to each other on the ground, some field survey is required to connect them.

Field survey for mapping will require a national network of geodetic survey stations of first order for small scale mapping and second, third, and fourth order stations for successively larger scales. Field survey for road engineering purposes may be connected to the national network if required, but this is not essential and can add greatly to the costs.

The field survey for a photogrammetric project often comprises the major part of the total costs and therefore should be carefully planned. Points co-ordinated from cadastral or other existing surveys can often be related to points of detail on photographs and further field survey of these points may not be necessary.

A minimum of two points fixed in position relative to each other is required to scale a single pair of photographs for plotting. A minimum of three points whose terrain heights are known is required to control the tilts of the photographs. These points must not be colinear as the stereomodel of a pair of photographs can be tilted in more than one direction.

If every pair of aerial photographs in a strip were to have two scale and three level control points, the field survey costs to fix all these points would be very high. However, if strips of overlapping stereomodels are available, it is possible to connect the overlaps graphically, mechanically or by computation using a photogrammetric instrument, so that the whole strip can be scaled and levelled as a unit using ground control at the beginning, middle and end of the strip only. This process is known as aerial triangulation.

Field survey for photogrammetry can be carried out before or after photography is flown. If the field survey is carried out first, artificial markers can be placed over selected survey stations. These markers, known as "targets" must be of a distinctive size and shape in order to be readily identified on the photographs when they are flown. Targets should not be placed too long before the photography otherwise there is the danger of damage or loss.

If field survey is commenced after photography, suitable artificial or natural detail points visible on the photographs can be selected as ground control points. The field surveyor must be able to locate and fix the positions of these points. Many errors in photogrammetry are caused by misidentification of ground control points on photographs and in the field and the use of targets placed before photography is to be preferred.

PHOTOGRAMMETRIC INSTRUMENTS

The simplest and best known instrument is the stereoscope. A lens or **pocket stereoscope** consists of a pair of convex lenses set in a frame supported on a stand about 10 cm high. A pair of photographs may be set under the stand and moved until the overlap is seen through the lenses as a three dimensional picture. A **mirror stereoscope** has a wider stand and allows large photographs to be laid flat for viewing. Binoculars may be fitted to the mirror stereoscope for viewing portions of the stereomodel at a larger scale (Fig. 1).

An instrument called a **parallax bar** can be used in conjunction with the stereoscope for measuring differences in height between points in a stereomodel.

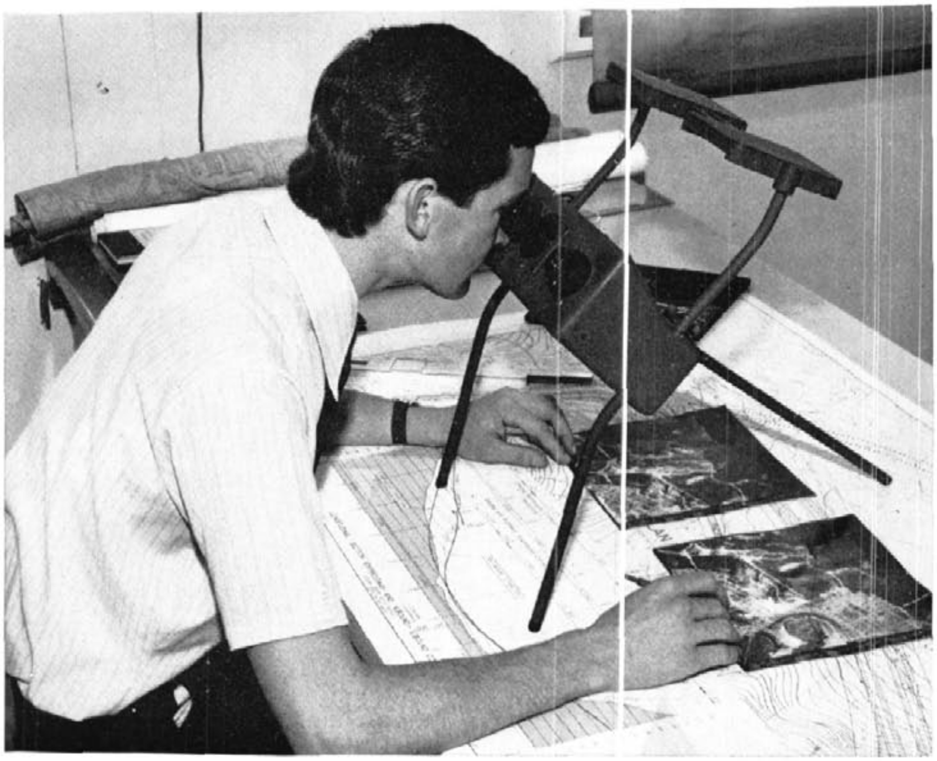
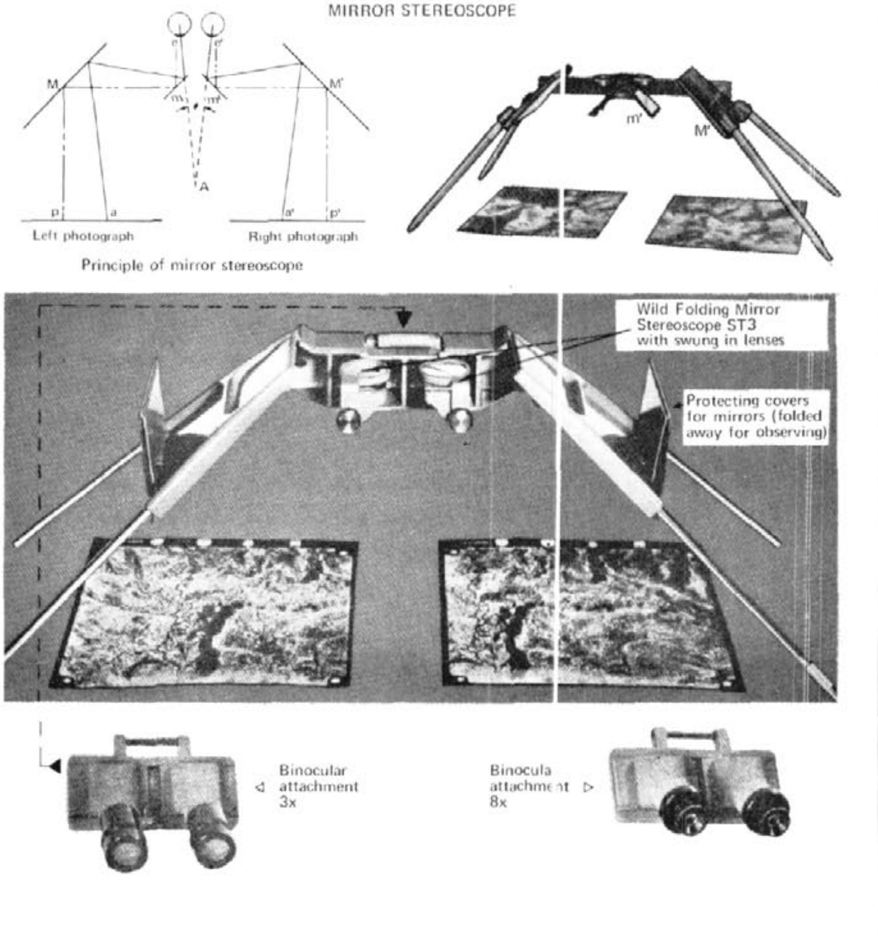


FIGURE 1.

MIRROR STEREOSCOPE



Readings are recorded in millimetres on a micrometer scale (Fig. 2).

More complicated instruments employ combinations of the stereoscope fitted with binoculars, parallax bars and devices for scanning pairs of photographs. The scanning device is connected to a pencil by a pantograph, enabling lines to be traced by the movements of the scanning device. In some cases heights can be read directly from a dial. Plotting can be carried out at scales up to 2½ times the photograph scale.

Various types of **stereoplotting machines** exist that reconstruct the relative positions of two camera stations in air space. These machines use projectors instead of aerial cameras and transparent diapositives printed from the negatives of two successive photographs with a common overlap.

Each projector can be rotated about the three conventional X, Y, and Z axes, X being the direction of flight, Y across the line of flight, and Z the vertical axis. The distance between the projectors can be varied, and in some cases the projectors can be moved laterally or vertically relative to one another.

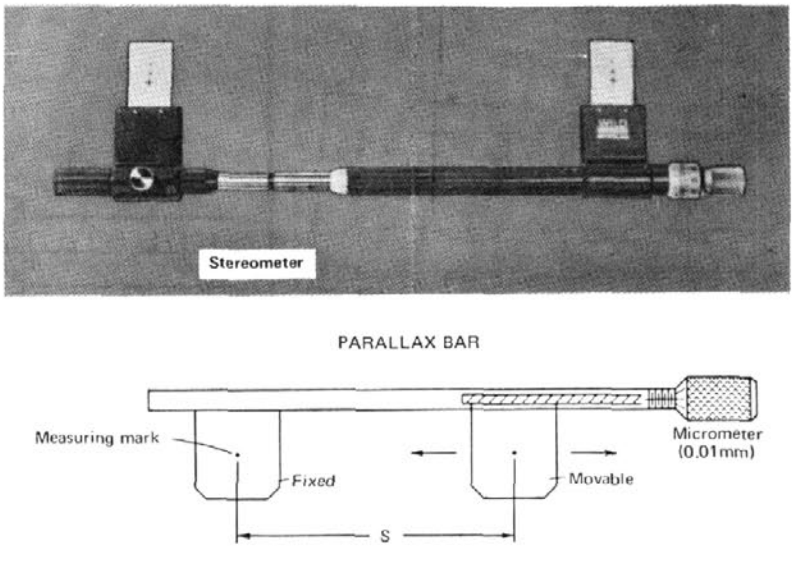
Light sources project the three dimensional image from the overlap of the two photographs and binoculars are fitted to many instruments to enable the operator to view the stereomodel at an enlarged scale.

A measuring mark can be attached to a scanning device on each projector so that the mark can be set over the same image in each photograph. There are usually hand guidances for driving the scanning devices in X and Y direction and a foot disc for driving in Z direction. The X and Y guidances are connected to dials registering scanning distances in millimetres from point to point and the Z disc is connected to a scale for reading heights directly in metres or feet at the scale of the machine. The scale of the stereomodel is usually about twice that of the photography.

A plotting table stands alongside the instrument. The table has a co-ordinatorgraph mounted on it with primary and secondary axes of movement which are driven by the operator's movement of the X and Y guidances. A pencil-holder is mounted on the secondary axis to trace the path of the operators scanning movements. Gears are available to vary the plotting scale from the machine scale.

It is possible to attach a co-ordinate recording device and card punch to a photogrammetric plotter. Machine co-ordinates in three dimensions can be recorded at a number of points observed in the stereomodel whose terrain co-ordinates are known. A mathematical transformation on an electronic computer will convert observed machine co-ordinates into terrain co-ordinates.

FIGURE 2.



STEREOPLOTTING OF ROAD ENGINEERING PLANS

Plotting can be divided into two categories—detail and relief. In mapping, detail is the most important category whilst the road engineer is often more concerned with the shape of the terrain. Detail that should be shown on road engineering plans includes:

- Buildings. Some of these may have to be moved before construction.
- Existing lines of communication including transmission and telephone lines.
- Existing fences that may be related to cadastral boundaries. It is important to know whose land may have to be purchased.
- Drainage and swamps.
- Vegetation. Thick vegetation may obscure detail that can only be seen on the ground, and field survey may be required.
- Physical features that may impede road construction, such as rock outcrops, cliffs, sand dunes, etc.

Relief is usually portrayed by contours and spot levels. The contour interval to be adopted is normally chosen by the engineer in charge of the project and usually relates to the contour interval adopted for stadia surveys. The accuracy that can be obtained from a stadia survey may be well known to engineers but the accuracy attainable from a photogrammetric survey is less well known. In general, contours to mapping standards of accuracy can be obtained if the ratio of the contour interval to the flying height of the aircraft is 1 : 1,000. For example, 5 metre contours can be plotted from photography flown at 5,000 metres.

If accurate levels are required for a specific project, the 1 : 1,000 ratio should be adhered to. However, on preliminary investigation surveys, the ratio can be increased to 1 : 1,500 or 1 : 2,000 especially where the engineer is only concerned in obtaining the difference in height. Five metre contours plotted from 10,000 metre photography will indicate general slopes only. To avoid confusion, such approximate contours are plotted as broken lines on plans and are called "form lines".

Spot levels are more accurate than contours and should be shown on plans at critical points such as the highest point on a hill, on watersheds, on existing roads and bridges, and along the beds of streams.

It is useful to have a grid on the plans. The original plotting should be carried out on stable material such as "Cronaflex", but copies on unstable material such as sensitized paper may be produced for use in the field. The positions of points relative to each other may be measured by co-ordinates read off the plans from the nearest grid lines. The distances between the points can then be calculated from the co-ordinates.

The title of the plans should include the following information:

- ☐ The locality of the project.
- ☐ The plotting scale.
- ☐ A plan index showing the numbering of the various plans and the relationship of the road or bridge project to other nearby communications and towns.
- ☐ Details of field survey.
- ☐ Details of the photography used.
- ☐ The organisation which carried out the photogrammetric work.
- ☐ The name of the organisation for whom the plans are prepared.
- ☐ The estimated accuracy of plotting detail and contours.
- ☐ The date of completion of the plans.

The maximum accuracy that can be obtained from photogrammetric plotting is ±·2 mm in position on the plan or ±2 metres on the ground at a plotting scale of 1 : 10,000. The maximum spot height accuracy that can generally be obtained is ±0·15 metres per 1,000 metres flying height of the photography. Accuracy depends on the quality and height of the photography and the density of the ground controls points, but unnecessary costs can be expended on obtaining too high a standard of accuracy.

The following specifications have been used for road investigation, location and design in New South Wales:

	Photograph Scale	Flying Height	Plotting Scale	Contour Interval	Plan Accuracy	Height Accuracy
Investigation	1 : 50,000	20,000 feet or 6,000 metres	1 : 6,000	20 feet or 6 metres	± 10 feet or 3 metres	± 5 feet or 1·5 metres
Location	1 : 12,000	6,000 feet or 1,800 metres	1 : 2,400	5 feet or 1·5 metres	± 2 feet or 0·6 metre	± 1·5 feet or 0·5 metre
Design	1 : 5,000	2,500 feet or 750 metres	1 : 1,200	2 feet or 0·6 metre	± 1 foot or 0·3 metre	± 0·7 foot or 0·2 metre

AUTOMATION IN PHOTOGRAMMETRY

The use of computers in photogrammetry is increasing. Initially, hand-operated calculating machines and graphs were used to obtain ground co-ordinates from photogrammetric stereomodel co-ordinates. More sophisticated adjustments have now been devised for the instantaneous adjustment of co-ordinates read on large numbers of stereomodels covering a block of aerial photographs. These adjustments are now performed on an electronic computer.

Automatic plotting machines exist which displace much of the routine scanning by an operator. A single rectified photograph of the stereomodel, known as an "orthophotograph", can be produced by automatic scanning in *X* or *Y* direction of narrow strips of a stereomodel. A by-product of the orthophotograph is a display of contours from a storage unit attached to the plotting machine.

Automatic recording of co-ordinates during scanning of a stereomodel can be performed at a predetermined number of observations per second of time or per millimetre of scan distance covered. Many thousands of co-ordinated points are required to define the surface of the ground covered by a single model. The network of observations is known as a "digital model". An electronic computer can be used to transform an observed digital model into a "digital terrain model" with *X*, *Y*, and height values in metres.

The digital terrain model can be plotted automatically on a data plotter which receives its plotting information from the computer. Contours can be interpolated between plotted spot levels using a complicated computer programme. Alternatively a selected centre line and standard cross-section can be "fitted" to the digital terrain model mathematically in the computer to provide earthworks information.

The use of automation in photogrammetry as applied to road engineering surveys in Australia is still in the experimental stage and the costs of equipment run into hundreds of thousands of dollars●

NEW EXPRESSWAY BRIDGE

On 11th October, 1971, a ceremony was held at the new bridge over the Nepean River at Regentville to mark not only the official opening of this bridge and its immediate approaches but also the opening to traffic of the first section of the Western Expressway, which will eventually link Sydney with the Blue Mountains.

Constructed of prestressed concrete, the five spans of the new bridge measure 1,045 feet overall. The two end spans each measure 170 feet and the three centre spans 235 feet. Initially, this bridge has been constructed with a single carriageway, providing two lanes of traffic and two footways. Provision has been made for the bridge to be widened later when traffic conditions warrant an extension. It will then have dual three-lane carriageways, separated by a median, and flanked by two footways. For this purpose, extra foundations were constructed concurrently with those for the present structure.

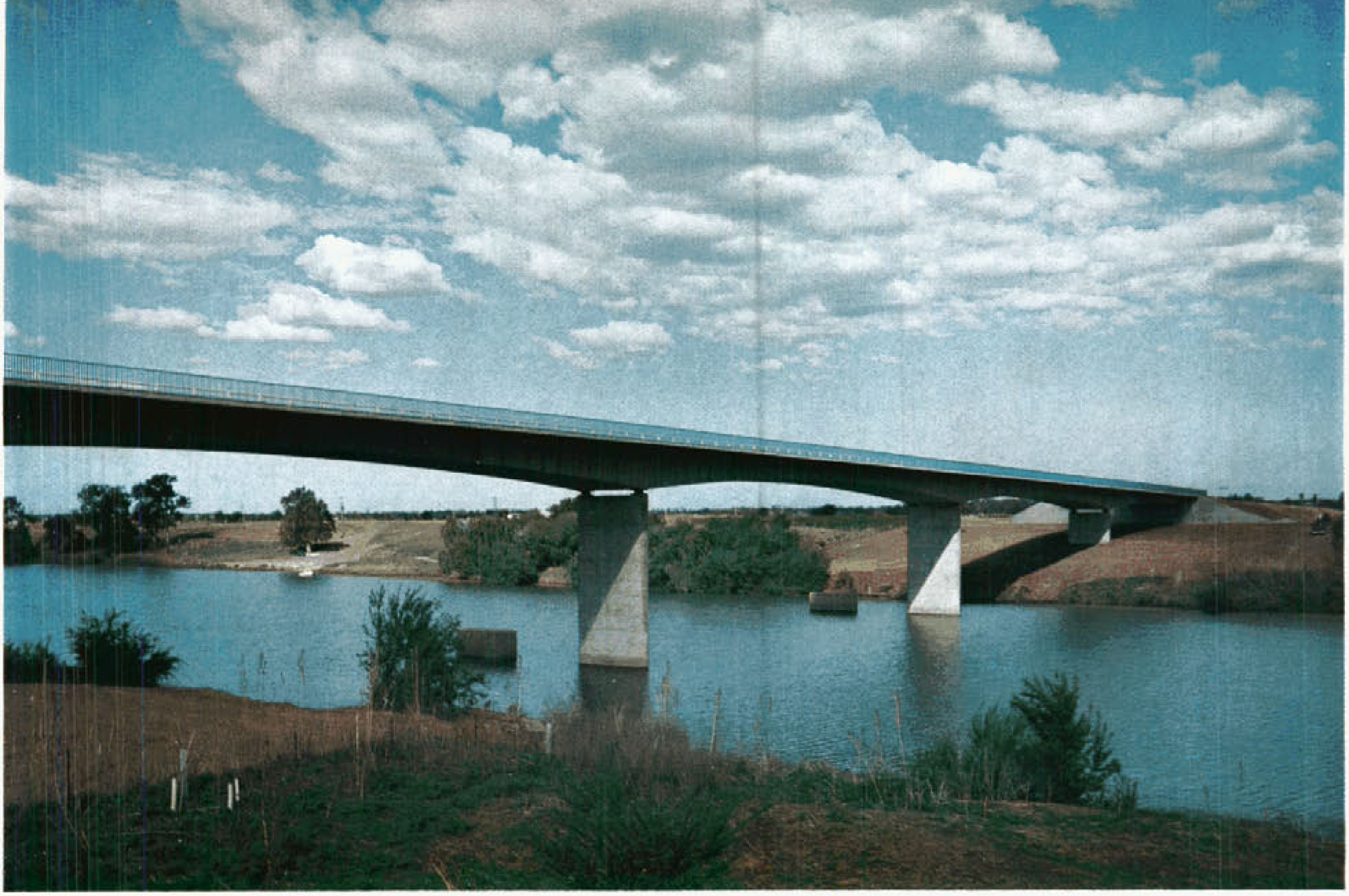
The bridge was designed for the Department by G. Maunsell and Partners, Consulting Engineers, with architectural assistance from Mr D. Maclurcan, of Messrs Fowell, Mansfield, Jarvis and Maclurcan. In designing the bridge, consideration was given to the need to observe Olympic standard rowing conditions on the Nepean River, and space has been provided for four 50-metre rowing lanes under the centre span with a 15-metre clearance to the piers.

The bridge was built by The Hornibrook Group, under contract to the Department and the total cost of the bridge and its western approaches was in the order of $2·12 million.

At this stage, only a short 3-mile section of the Western Expressway has been opened for use, that is, from the new bridge easterly to Bringelly Road. This deviation will avoid the busy Penrith Shopping Centre, and forms part of a 12-mile section of the Expressway which is currently under construction to Wallgrove Road at Eastern Creek.

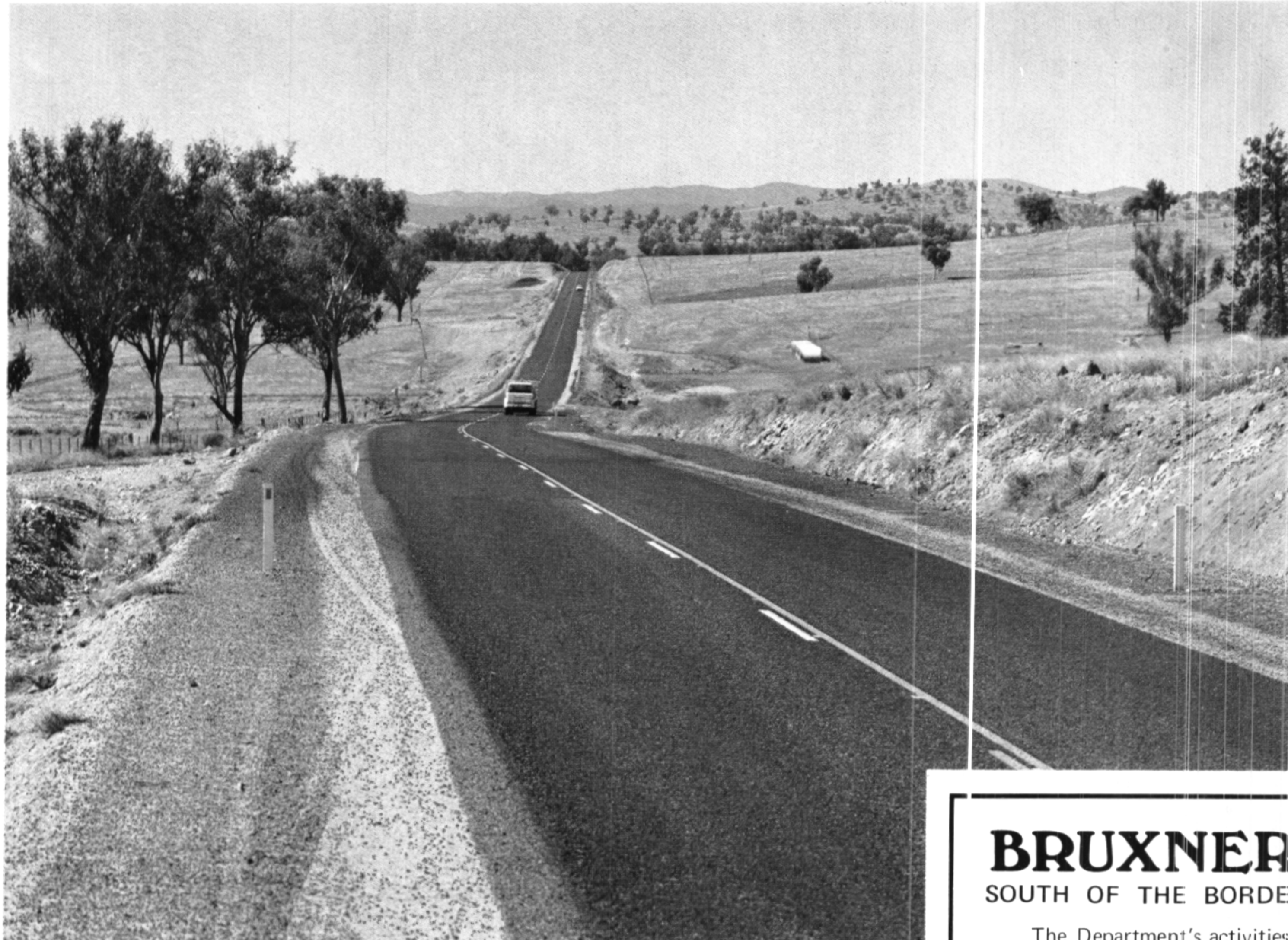
On the western side of the river, connection is made with the Great Western Highway via Russell Street, Emu Plains which has been improved to provide additional lanes.

The section of Expressway to Bringelly Road, including overpasses at Bringelly Road and Mulgoa Road, and the eastern approaches to the bridge, cost approximately $3·95 million.



NEW EXPRESSWAY BRIDGE

This attractive bridge spans the Nepean River at Regentville (to the south of Penrith) and is part of the first section of the Western Expressway. The blue-painted handrails are an appropriate colour, because this bridge will increasingly become the motorist's "gateway" to the Blue Mountains.



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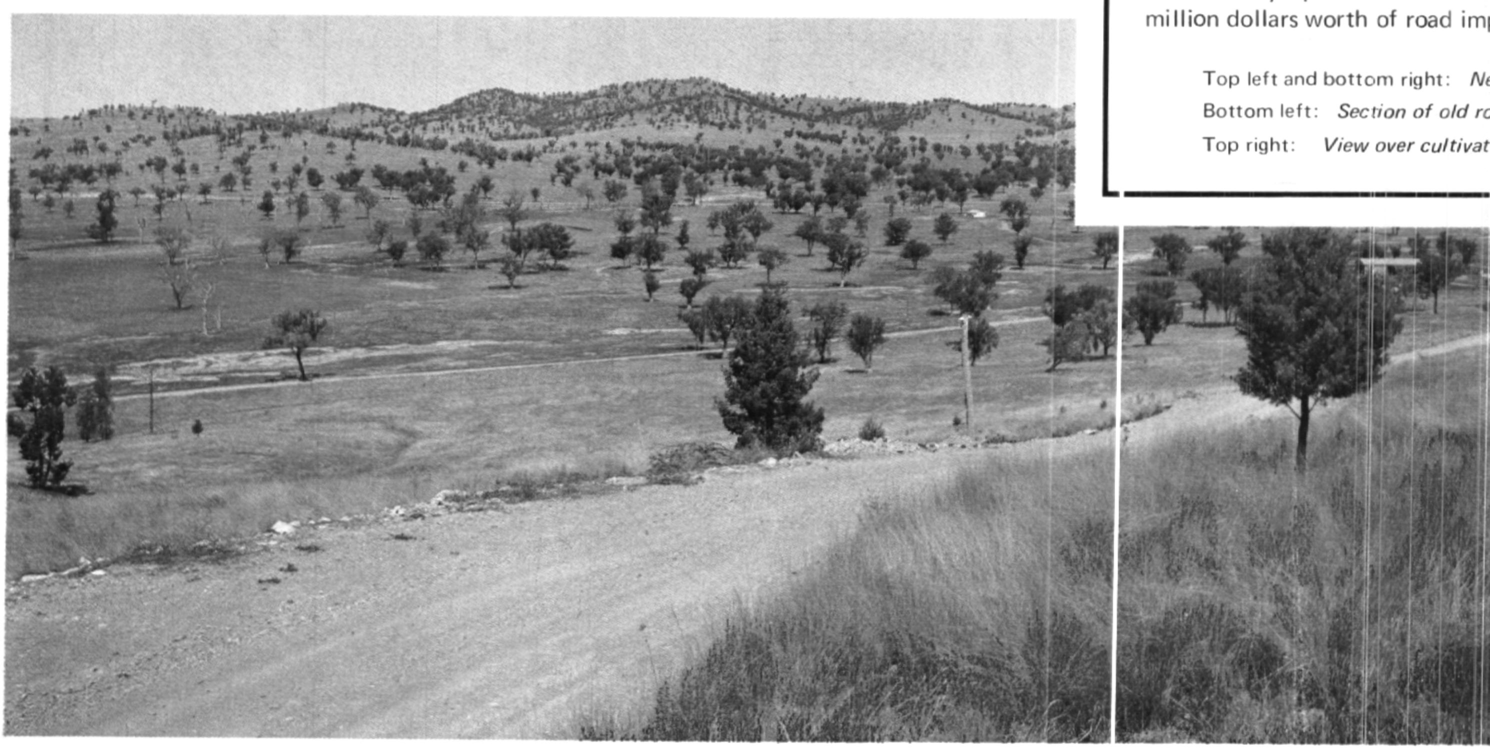
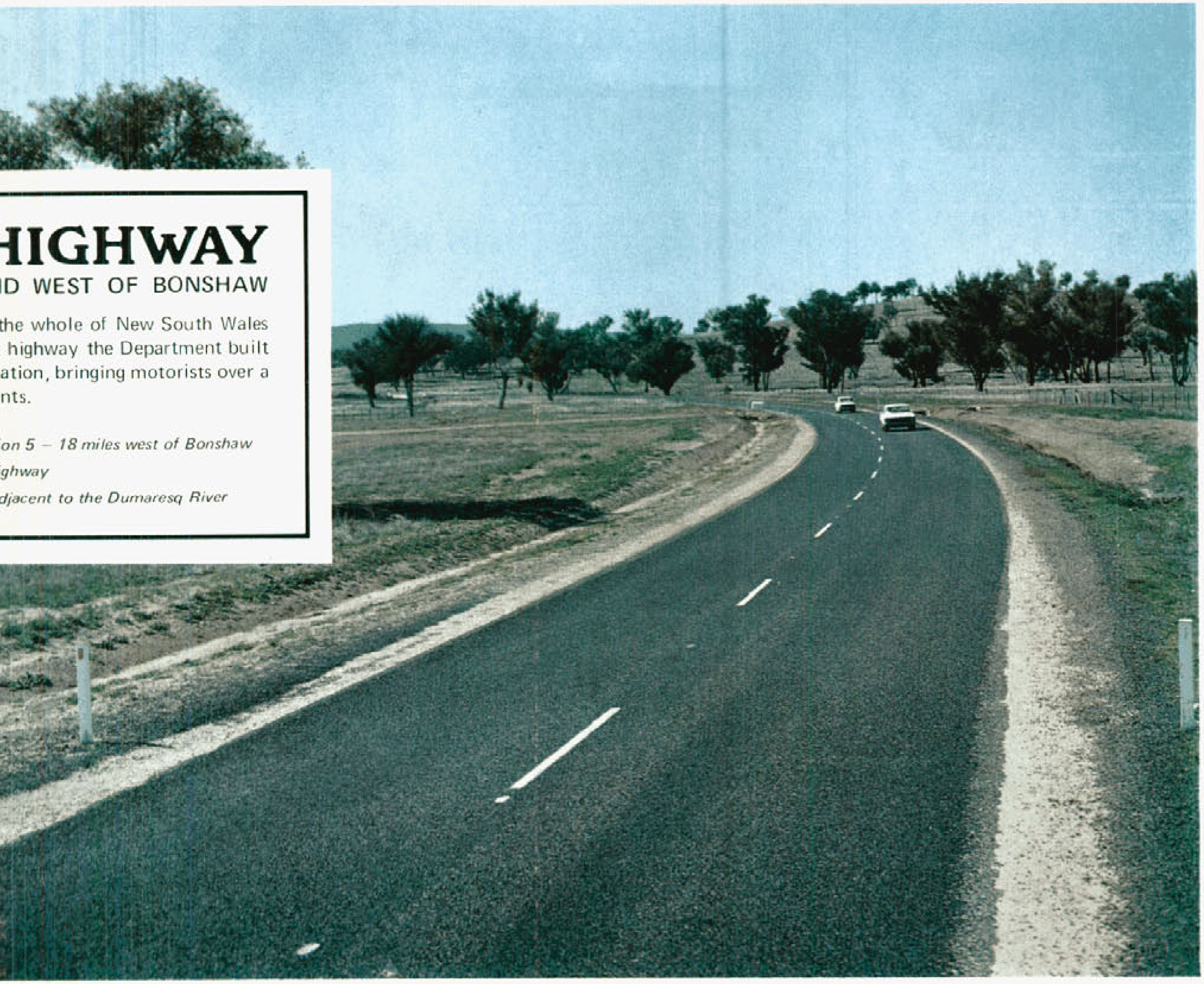
Bottom left: *Section of old rout*
Top right: *View over cultivated*





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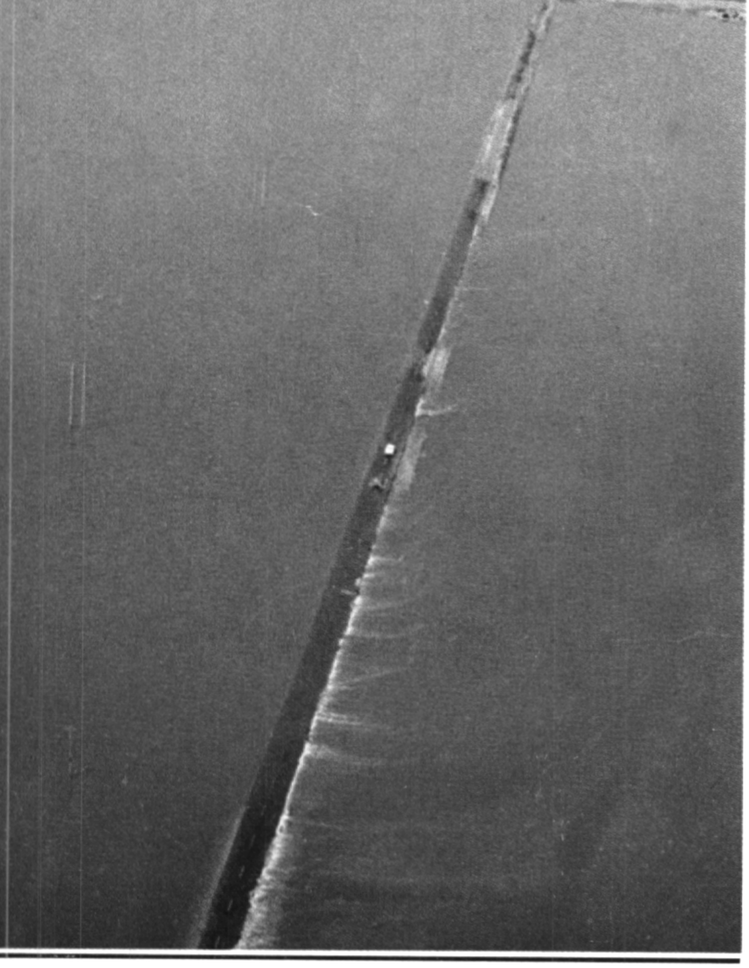
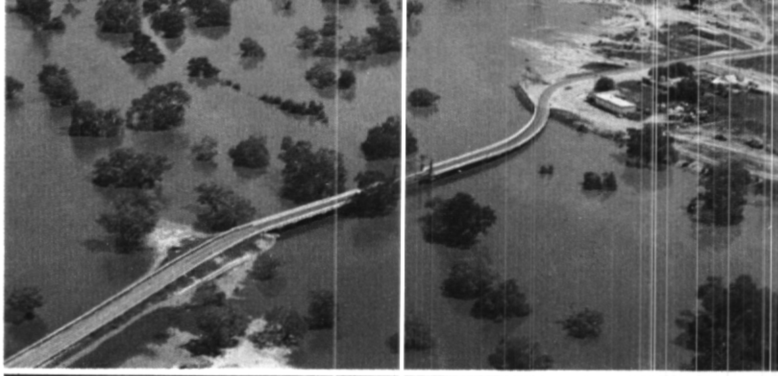
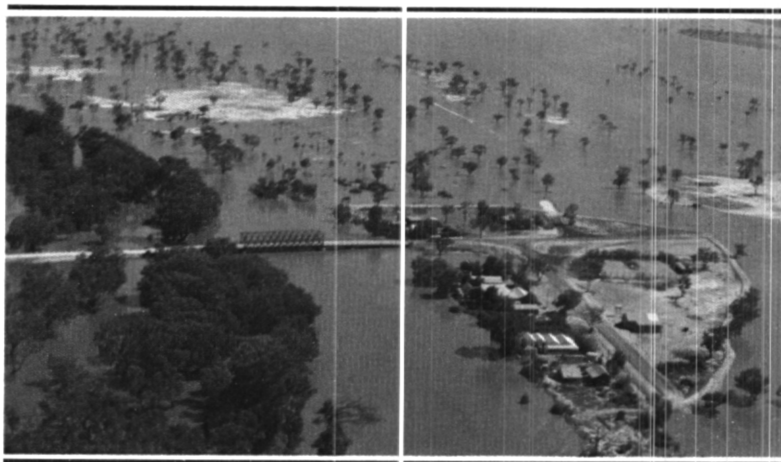






Flooding:

"I love a sunburnt country,
A land of sweeping plains,
Of ragged mountain ranges,
Of droughts and flooding rains."

—from "My Country" by Dorothea Mackellar.

* * *

In the latter half of 1970 and well into 1971, ***flooding rains*** proved to be a threat not only to communications but to the very livelihood of many rural communities throughout New South Wales. Now, late in 1971, the seasonal wheel has turned full circle and some areas, especially on the South Coast, have since suffered from severe droughts. Such are the erratic fluctuations in weather which bring extreme hardship to those living in affected areas.

Words do not adequately describe the general devastation or the personal losses which occurred as fencing, livestock, crops, roads and bridges were swept away or damaged by the "violent maelstrom of unrelenting floodwaters". After a brief description of the extent of some of the floods earlier in the year, this article summarises the general effect of floods on the State's Main Roads System for the twelve months to 30th June, 1971. The formal and concise style, obviously, cannot reveal the full story behind many of the descriptions, and the difficulties experienced by those who have been faced with the responsibility of trying to keep road communications open must be read between the lines.

* * *

Top left: The Mitchell Highway, 2 miles east of Bourke (March, 1971)
Top right: Looking west towards the bridge over the Darling River at Bourke on the Mitchell Highway (March, 1971)
Centre right: View showing the bridge over the Darling River at Louth (southwest of Bourke on Trunk Road No. 68—March, 1971)
Bottom: Flooding across the Barrier Highway, 10 miles east of Cobar February, 1971)

During the latter part of January and throughout February and March, 1971, major flooding was experienced along the Macintyre, Darling, Barwon, Gwydir, Culgoa, Bokhara, Birrie, Narran, Namoi, Peel, Talbragar, Macquarie, Castlereagh, Hunter and most South Coastal Rivers.

The emergency was the worst since the destructive floods of 1955. Along the Namoi, Barwon and lower Gwydir Rivers, flooding was more severe than in 1955. This was due to record volumes of water and the lengthy period of inundation resulting from successive flood peaks. It has been estimated that about three million acre feet of water inundated the watercourse area of the Gwydir, whilst about 1½ million acre feet passed through Gunnedah on the Namoi River. To this figure must be added record discharges from the Cox's Creek and other tributaries which feed the Namoi.

The flood emergencies on the various river systems resulted from very heavy rain which fell over much of North and Central-Western New South Wales during late January, 1971. Heavy falls persisted until the end of the first week of February, 1971. The rainfall eventually extended into the Hunter system causing major flooding at the centres of Denman, Muswellbrook, Singleton, Maitland, Morpeth and Raymond Terrace.

Early in February a low pressure system, centred off the South Coast, deposited very heavy rain from the Shoalhaven River south to Victoria. The heavy falls resulted in rapid rises and major flooding along the Bega, Moruya and Bombala Rivers as well as other South Coast streams.

Some districts received falls of 20 inches to 30 inches within three to four days, whilst in others, falls of up to 20 inches in 48 hours were not uncommon. Property owners along the South Coast described the flooding as the most severe in living memory.

In the township of Bega, families were evacuated, telegraph lines were either destroyed or broken and public utilities damaged. The village of Tathra was isolated for a week and the water supply was affected. The estimated damage along the South Coast was assessed as between eight to ten million dollars.

the wet threat

In the north-west, the most seriously affected centres included Moree, Gunnedah, Narrabri, Wee Waa, Quirindi, Tamworth, and Carrol.

In Wee Waa, most of the town was inundated and heavy crop and stock losses were sustained in the Wee Waa and Narrabri areas. Damage to cotton and other crops was particularly severe. Four hundred and fifty people were evacuated from Moree, on the Gwydir River.

In the lower parts of the Namoi and Gwydir Rivers, where the ground is relatively flat, floodwaters covered millions of acres. Numerous grazing properties were inundated. Large numbers of stock were lost and over two hundred thousand sheep and cattle became trapped.

The towns of Walgett, Rowena, Burren Junction and Pilliga were isolated. R.A.A.F. and Army aircraft dropped over 3,000 tons of fodder to starving stock, over some 7,000 square miles of the lower Gwydir, Boomi, Macintyre and Namoi River basins.

At one stage water from the Namoi had linked up with the Mehi-Gwydir and made the entire area back to Narrabri and Moree-Boggabilla a virtual ocean of floodwater.

Fodder drops were also made in the lower Macquarie and Bogan River basins. Widespread flooding occurred when the two rivers broke their banks. Warren and Nyngan were isolated but levee banks protected the towns.

Dozens of people, trapped by floodwaters, were rescued by R.A.A.F. and Army helicopters. Food was dropped to numerous homesteads surrounded by water. Persons in isolated areas who required urgent medical treatment were lifted by helicopter and transported to hospitals in flood free districts●

—Reproduced from "Civil Defence Bulletin", April, 1971

Detailed flood information is also recorded in the January and July, 1971 issues of the "Civil Defence Bulletin", which is published by the N.S.W. Civil Defence Organisation.

FLOODWATERS—THE WET THREAT TO COMMUNICATIONS

Expenditure by the Department on the repair of flood damage on full cost roads to 30th June, 1971 totalled $1,006,852. The expenditure actually incurred by Councils to 30th June, 1971, amounted to $917,692. This amount was made up as follows:

	$
State Highways	91,348
Trunk and Main Roads ..	826,344
	$917,692

The anticipated expenditure on works on Trunk and Main Roads after 30th June, 1971, is estimated at about $800,000.

CENTRAL MOUNTAINS DIVISION*

Flood damage as a result of the January and February floods was not extensive. One bridge abutment was partly washed out. The most expensive single pavement and formation deterioration was on Trunk Road No. 55 in Coolah Shire and, apart from the loss of the bridge approaches to Developmental Work No. 3211 in Cudgegong Shire, all other problems were of a comparatively minor nature and mostly within Cudgegong and Coolah Shires.

ILLAWARRA DIVISION

Flood rains in February, 1971 caused several wash-outs of roads, particularly at bridges and minor drainage structures on the coastal area south of Wollongong. The rains caused considerable damage to construction work in progress on Macquarie Range (State Highway No. 25) and restoration was not complete at 30th June, 1971. Wash-outs at other locations caused delays to traffic but restoration work quickly re-opened these roads.

NORTH EASTERN DIVISION

Record rainfalls were recorded between December, 1970 and March, 1971, but there was only minor flooding in the major rivers. Flood damage was negligible but the following sections of road deteriorated rapidly and required special maintenance attention:

Trunk Road No. 83—Wiangaree to Mt Lindsay Highway.

Trunk Road No. 76—Dorrigo to 30 miles west of Dorrigo.

UPPER NORTHERN DIVISION

Damage to Main Roads in Severn and Ashford Shires resulted from heavy rain in September, 1970.

During December, 1970, January and February, 1971 extensive rain was experienced over most of the Division and major flooding occurred in all local river systems.

Lengths of State Highways Nos 12, 16 and 17, Trunk Roads Nos 63 and 73 and Main Road Nos 133, 134, 137, 187, 232, 367 and 507 were extensively damaged and several roads were closed to traffic for varying periods as follows:

Gwydir Highway — Moree-Warialda, closed for 7 days from 2nd to 9th February, 1971.

Gwydir Highway-Moree-Collarenebri, closed for 39 days from 5th February, 1971 to 16th March, 1971.

Bruxner Highway—Tenterfield-Tabulam, closed for 4 days from 15th to 19th February, 1971.

Bruxner Highway—Bonshaw-Goondiwindi, closed for 13 days from 2nd to 15th February, 1971.

Newell Highway — Moree-Boggabilla, closed for 7 days from 3rd to 10th February, 1971.

Trunk Road No. 63—Yetman-Bingara, closed for 7 days from 8th to 15th February, 1971.

Main Road No. 133—West of Bingara, closed for 14 days from 8th to 22nd February, 1971.

Main Road No. 137—Ashford-Bonshaw, closed for 4 days from 11th to 15th February, 1971.

Main Road No. 232—Moree-Boonangar, closed intermittently north of Boomi from December, 1970 until February, 1971, and closed south of Boomi for 5 days from 4th to 9th February, 1971.

Main Road No. 367—Garah-Mungindi, closed for 27 days from 5th February to 4th March, 1971.

NORTH WESTERN DIVISION

Near record flooding was experienced in February, 1971. Although, in general, flooding did not reach the record levels of 1955, severe damage was caused to roads throughout the Division. Although approaches to a number of bridges were washed away, all bridges remained intact. However, some bridges were damaged to the extent that it was necessary to impose a temporary load limit until repairs were completed.

The areas most severely affected were Namoi and Merriwa Shires and Narrabri Municipality.

CENTRAL WESTERN DIVISION

In the first half of 1971 floods caused extensive damage to the Mitchell Highway between Molong and Dubbo and between Narromine and Parkes, the Newell Highway between Parkes and Dubbo and the Castlereagh Highway north of Gilgandra. Repairs were carried out promptly and the roads were returned to good condition.

CENTRAL NORTHERN DIVISION

This Division was affected by widespread flooding from January to April, 1971 which caused extensive damage to Main Roads within the area particularly in the Shires of Brewarrina, Cobar and Walgett. A considerable amount of restoration work was still required at 30th June, 1971.

MURRAY DARLING DIVISION

In the early months of 1971 heavy rains and flooding closed, for varying periods, most of the unsealed main roads in the Division, particularly along the Darling River and in the areas north of Broken Hill and Wilcannia. The Barrier Highway was closed for several weeks at about 6 miles east of Wilcannia due to flooding by the Darling River and Talyawalka Creek.

Due to the nature of the materials and the open causeways at many creek crossings, the heavy rains and flooding caused severe damage and scouring. Restoration works were still being carried

* *See Divisional Map inside front cover.*

out at 30th June, 1971 and some roads, in particular, parts of Main Road No. 429 and Trunk Road No. 68 and Main Road No. 433 were not trafficable.

SOUTH WESTERN DIVISION

Heavy rainfall and major flooding in the Murrumbidgee and Murray River systems occurred during the period August to November, 1970 and caused damage to Main Roads in the area. Roads mainly affected were the Hume, Sturt and Newell Highways and Trunk Road No. 85. Other Trunk and Main Roads were affected by flooding but to a lesser extent.

SOUTH COAST DIVISION

Heavy rain and flooding occurred in December, 1970 followed in February, 1971 by a major flood in the Bega Valley and in the river systems of the south eastern Monaro, causing great damage to the Prince's, Snowy Mountains and Monaro Highways and other Main Roads. Roads were closed for periods of several days to several weeks because of flood waters, debris or damage to the road pavement and formation. The worst affected areas on the Snowy Mountains Highway were on the Brown Mountain and from the Nunnock River to Tathra; while on the Prince's Highway they were the Tuross River Flat and between Quaama and Bega. Major slips and washaways occurred at Walls Flat, about 10 miles west of Bega and also about 6 miles west of Bega. The mountain roads over Mount Darragh (Trunk Road No. 91) and the Tantawanglo Road (Main Road No. 275) were also damaged but to a lesser extent than on the Snowy Mountains Highway. Two timber bridges were washed away, one at Narira Creek on Main Road No. 320 (one mile east of Cobargo), the other on Main Road No. 275 over Candelo Creek at Candelo. In addition, a large number of smaller structures were damaged or completely destroyed.

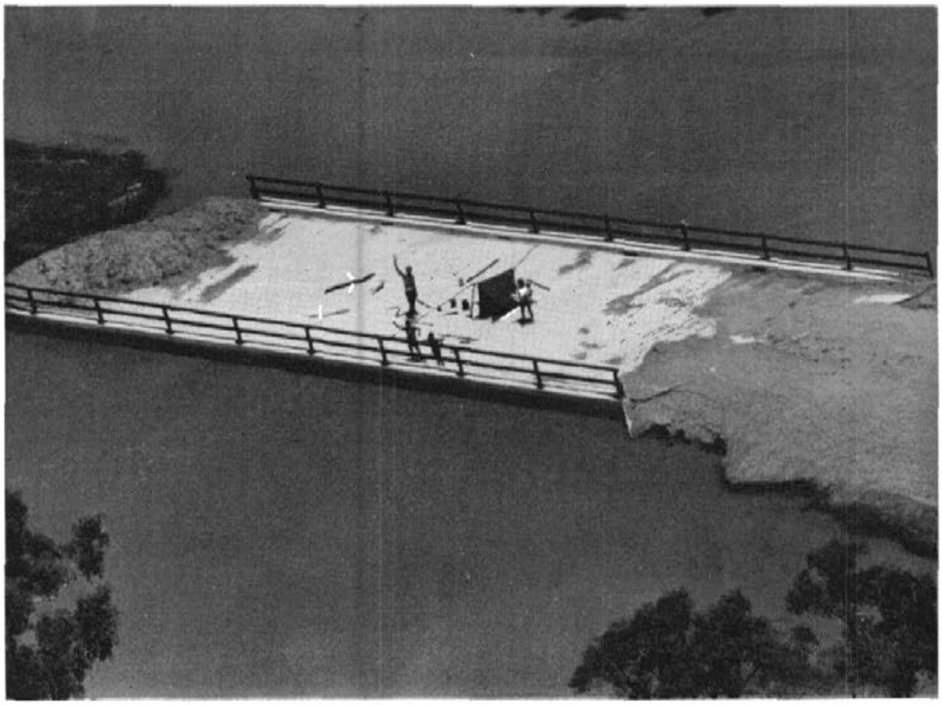
Following the very heavy rains and flooding, maintenance activity on the Highway system increased, to repair flood damage and to control the large number of springs which developed, damaging sections of road. These springs had not been evident prior to the rain. The areas mostly affected by springs were those sections of the Snowy Mountains Highway and the Monaro Highway recently completed in the crossing of the Brown Mountain●

BRIDGE OVER TROUBLED WATERS

In February, 1971, a newly constructed reinforced concrete box culvert over Browns Creek, approximately 32·5 miles west of Moree on the Gwydir Highway, proved to be an island of safety for a family of five who were marooned on it for two days by floodwaters.

A news team flying over the area sighted the family camped on the 99 ft long x 28 ft wide deck and photographs taken by them (above and below) show a makeshift tent strung between the handrails and distress signals made from pieces of wood and rolled clothing. The family, whose car and caravan had stopped about a quarter of a mile away with floodwaters almost over the wheels, were rescued by an R.A.A.F. helicopter.

Although the culvert had not been opened to traffic at that time, its premature use as a "refuge in a sea of floods" was symbolic of the contribution which flood-free crossings can make in times of emergency and danger●



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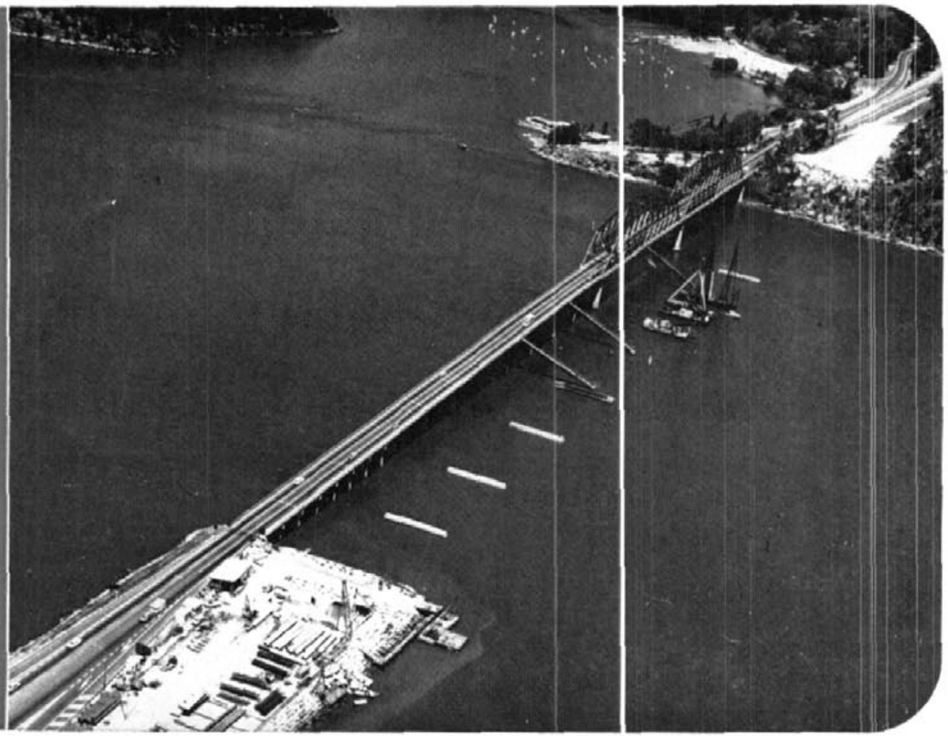
CONSTRUCTION OF EXPRESSWAY BRIDGE OVER HAWKESBURY RIVER



Aerial view—looking south—October, 1970

A new six-lane bridge, 2,020 feet long and 84 feet wide, is being constructed by the Department to carry the Sydney-Newcastle Expressway over the Hawkesbury River, approximately 30 miles north of Sydney. The Expressway already extends from Berowra to near the southern bank of the River and from the northern bank to Calga. At present, expressway traffic must merge with Pacific Highway traffic in order to cross the River via the existing bridge. The construction of an additional bridge will enable expressway and highway traffic to have separate crossings. This will dispense with the necessity for toll barriers at Mooney Mooney and will enable the Department to arrange one toll collection only from expressway traffic at Berowra.

The construction work for the new expressway bridge was divided into two contracts—one for the foundations and the other for the superstructure.

The initial contract was awarded to the firm of John Holland (Constructions) Pty Ltd and comprised:

☐ the driving to rock of 72 composite piles made up of $\frac{3}{4}$ in and $\frac{7}{8}$ in thick steel tubes 30 in O.D. (i.e. outer diameter) welded to 5 in thick x 48 in O.D. prestressed tubular concrete piles;

☐ the sinking to bedrock of 8 cast-in-situ piles 3 ft 6 in in diameter at pier 2 and of 3 only 2 ft 6 in diameter piles at the northern abutment; and

☐ the construction of 10 complete pile caps.

Work on this contract commenced on 8th December, 1969 and was completed on 18th March, 1971.

The second contract has been awarded to the Hornibrook Group ($2,966,848) and entails the construction of the foundation to pier 1 and the complete superstructure of the bridge from the pile caps upward. Work on this contract commenced on 19th February, 1971 and is now in progress.

The approach work is being carried out by the Department using its own forces.

FOUNDATIONS

Manufacture of Piles

The composite piles were made up from three components:

☐ a steel tubular pile 2 ft 6 in O.D. with wall thickness of $\frac{3}{4}$ in.

☐ a steel tubular pile 2 ft 6 in O.D. with wall thickness of $\frac{7}{8}$ in., and

☐ a prestressed tubular concrete pile 48 in O.D. with wall thickness of 5 in (see Fig. 1).

The concrete section was reserved for that portion of the pile in the water zone and for approximately 40 feet below mud line. The contract drawings tabulated the reduced levels at which the various sections were to terminate. The actual component lengths were made up from this schedule. Considerable scope still remained to the contractor in the selection of the pile lengths for manufacture, handling and driving. The contractor naturally planned to reduce to a minimum the splices required during driving but at the same time was restricted by the lifting capacity of cranes both on shore and floating. The final arrangement was to limit the concrete pile lengths to a maximum of 60 ft, and the steel pile to 120 ft, for handling purposes.

Steel Pile Sections

The steel pile sections were manufactured at factories at Rydalmere, 29 miles south of the bridge, and at Regents Park, 36 miles to the south. Flat steel plates 10 ft long were bevelled at the edges, rolled in stages to curve the plate to the exact diameter than clamped to enable tack welds to be done to secure the edges together. A root weld was then done manually followed by a full automatic submerged arc weld. The ends of the 10 ft sections were then trimmed and bevelled. These units were then matched end to end and butt welded into 40 ft lengths. Seam welds were staggered 90 degrees. The pile sections were delivered to the job, four to a truck.

Concrete Pile Sections

All of the concrete sections for this contract (ranging in length from 10 ft to 60 ft) were cast in the one horizontal steel mould at the factory at Blacktown, 36 miles from the bridge site. The top half of the mould was hinged. Concrete was placed through a slot in the top of the mould. The core consisted of a cardboard tube wrapped in polythene and stiffened internally by a collapsible steel spider. Short lengths of $\frac{7}{8}$ in steel piles were cast into one thickened end of the pile. Steel driving bands were built into the other end. For sections which were to be lengthened during driving, 9 in by $\frac{1}{2}$ in steel bands protruding $3\frac{1}{4}$ in were cast into the one end to enable a welded joint to be made between the concrete sections. Castellations, formed into the last driven pile section, were designed to interlock with a poured in-situ concrete plug at a later stage of the work. Before despatch to the site all cardboard formers were removed, pile ends were ground flush with the steel driving bands, exterior surfaces were cement bagged and all minor imperfections made good with epoxy mortar. In all 5,700 feet of piling was cast in the period 10th February, 1970 to 6th October, 1970. No units were rejected. The concrete strength specified at release of pretensioning strands was 4,000 p.s.i. (pounds per square inch). This was attained by overnight steam curing. For driving, a minimum strength of 6,000 p.s.i. was stipulated. Pile sections were transported to the site by road using flat tray trucks for the short sections and a prime mover with a set of jinker wheels for the longer lengths.

Field Splicing of Steel Piles
—On Shore

The 2 ft 6 in O.D. $\frac{3}{4}$ in and $\frac{7}{8}$ in wall thickness pile sections were butt welded into lengths up to 120 ft on a specially prepared bed on the northern side of the river. The welds were of the single Vee type without backing strips. The majority of the welds were done manually with two welders working simultaneously on the one joint. The weld comprised one root and three hot pass runs, using 35 L.S. $\frac{5}{32}$ electrodes (150A, 70V), followed by three capping runs of $\frac{5}{32}$ in and $\frac{3}{16}$ in Fleet weld 57 or Jetweld 2 electrodes (180–240 A, 80–90V). At a latter stage in the work, the Inner Shield semi-automatic welding process was introduced to speed up the capping runs using NS3M $\frac{3}{32}$ in wire (250–375D amps, 26–33V). Piles were rotated mechanically for this process. During the work, selected welds were examined radiographically and close visual inspection was maintained throughout. Records of every weld were kept. A typical splice would take two welders approximately two hours to complete.

—Over Water

Manual welding only was used for lengthening piles during driving. Bruising of the driven section was minimal. The end of the next section to be pitched was bevelled 40 degrees; the driven end being left square. Screw dogs were used to align the sections quickly. The weld sequence was 1 root 3 hot pass and up to 18 filler and capping runs. The splice took up to $3\frac{1}{2}$ hours to complete by two welders.

Concrete to Concrete Splices over Water

The cross section of this joint is shown in Figure 2. After driving of the first concrete section, the driven end was scabbled. The upper pile section was then lowered, all matching faces were checked and if necessary the $\frac{1}{2}$ in steel jointing band was trimmed by gas cutting. The pile section was then raised, a layer of epoxy mortar applied to the inner landing and the pile lowered to seat onto the mortar and onto the root spacing shims separating the steel bands. As a final precaution the pile was lifted once more to make certain of full and even seating on the inner epoxy mortar. If necessary more mortar was applied. The pile was finally lowered and welded. Cement grout was then pumped into the inner annulus. The remaining outer recess was hand-packed with epoxy mortar supported by an outer sheet-steel enclosing band. Tests had shown that with an 8 to 1 epoxy mortar the compressive strength of 4,000 p.s.i. required at driving is reached in 19 hours at 72 degrees F. or 5 hours at 120 degrees F. Curing of the mortar was therefore accelerated by heating the enclosing band by electrical resistance coils.

Handling Equipment

A stiff-legged Titan crane with a 90 ft boom was erected to off-load the concrete pile sections from the delivery trucks. The crane had a capacity of 25 tons at 60 ft radius. Using eight falls of rope, the hoist speed was between 46 and 75 feet per minute. It was positioned to handle both steel and concrete piles and to place these on barges moored at a small wharf adjacent to the crane.

The floating crane selected for the river work was a Favco stiff-legged derrick of new design. The crane was mounted on 13 ft long columns for additional height and set up on a 72 ft x 60 ft x 5 ft barge. The capacity of the crane was 15 tons at 90 ft radius, and three falls of rope were used. Hydraulic motors were selected for all transmissions. The crane gave good control under all lifts and was quiet in operation.

Pile pitching was speeded up by fitting a cradle to all pile sections before they left the shore. The cradle was grooved to fit snugly into the pile frame runners. Once pitched and centred, a simple bolted keeper locked the cradle and pile into the frame. Pile sections were transported across water on a 60 ft x 16 ft barge, towed by a 60 h.p. workboat. To simplify the hoisting of the heavy concrete sections (up to 22 tons) into the vertical, a hinged saddle was fitted to one end of the barge. The pile was secured in this saddle by a wire strop. On arrival at the work-platform, the workboat positioned the pile barge between the crane and the platform. A wire strop or choker for lifting was then tied around the end of the pile. As the pile was hoisted by the crane the barge was made free to move forward with the lower end of the pile pivoting in the hinged saddle. With the pile vertical and held by the crane, the lower holding wire was removed and the barge pulled clear of the work. The pile was then hoisted, the crane barge winched closer to the platform and, by luffing and careful swing control, the pile section was centred in the leaders.

Spudded Platform

The contractor chose to drive all piles over the water from two identical spudded platforms. These were fabricated in steel trusswork and set up with a timber deck. They measured 86 ft x 16 ft x 5 ft. Sleeves were welded to the platform, four to each side. Steel piles $\frac{1}{4}$ in x 22 in O.D. and up to 120 ft long were stood up in the sleeves and locked into place. The piles were prepared, pointed and filled with concrete for 6 ft at the lower end. A 3 in central jetting pipe was fitted inside each pile. The platforms were floated into position on four small pontoons equipped with hand winches. After careful positioning of the platform with the winches and using two theodolite (one on the bank and one on the existing bridge) to fix line from two directions, the spud piles were released and dropped rapidly. Each pile was then filled with water to increase weight and jetted down by water pumps approximately 30 feet into the mud and silt. Preliminary load tests had proved the piles capable of a safe load of 20 tons without undue settlement. In deeper water the platforms were stabilised by guy ropes run to anchors. As soon as piles were jetted and a falling tide had lowered the platform to the +6·00 level, the spud piles were welded to the sleeves and the pontoons removed.

By using two platforms the work proceeded smoothly across the river. One distinct advantage of this method is that it enables accurate driving and raking of the piles while working from a relatively stable platform as opposed to the less stable deck of a floating barge. A rake to the spud piles would have further improved stability of the platform. All piles were positioned by reference to marks clear of the platform.

Driving Equipment

Two self-standing 95 ft pile frames raked at 1 in 10 were constructed for this contract. They were manoeuvered readily on the piling platform by the floating crane. Perfect alignment of hammer and pile was essential in order to maintain a high standard of driving accuracy. The frames were solidly braced with runners accurately aligned. They made use of hollow steel sections for lightness and stiffness and were of all welded construction. The diesel hammer selected for the work was a Kobe K42 with a rated energy output of 79,600 ft lb and full stroking at 43 blows per minute. Refusal rate for this hammer was accepted at 36 blows per inch. At a later stage in the work, it was supplemented by a smaller K32 for driving the first and easier lengths of piling. Helmets were made up to suit the various types being driven and for steel piles were of standard construction. For the 48 in cylindrical concrete pile, pine board packing 7 in thick was used, topped by a 4 in steel plate. A cast steel helmet of 4 in thick wall and skirt section was used over the pile head and had a free fitting shock absorbing head. Due to the at times "punishing" driving, some damage to helmets occurred. The final solution was to replace the 4 in plate with a 7 in thick steel plate between the pine packing and the helmet. Normal practice was to replace the timber packing at least once during the driving of a full pile. Water was circulated through the hammer during normal servicing "breaks", especially when prolonged hard driving was encountered, in order to reduce any over-heating. To maintain the hammer at full efficiency, hammer piston rings were renewed twice during the contract.

Driving Methods and Problems

All piles were driven open ended. The toe end was enlarged and bevelled inward. Conditions varied across the river and

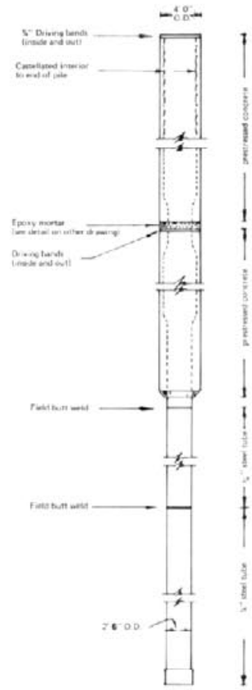


Figure 1: Composite pile

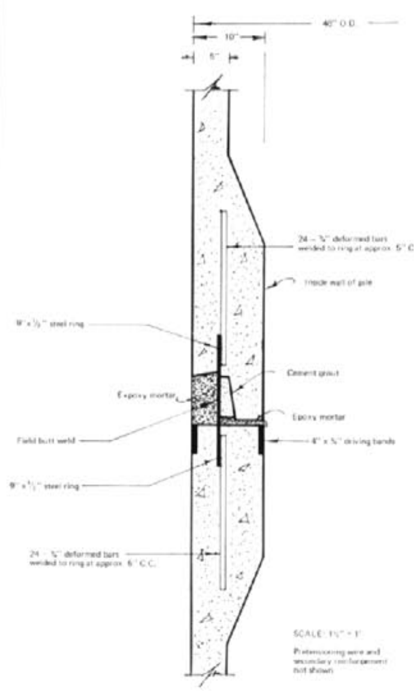


Figure 2: Prestressed concrete pile splice

at pier 11 they proved the most difficult. After the driving of the steel sections of the first pile to RL-170, the concrete pile section was welded on and driving recommenced. The pile refused to drive. It first appeared that the hammer was undersized for the job in hand (from the relatively small appearance of the diesel hammer perched on top of the 60 ft x 48 ft concrete pile). However, overseas experience had demonstrated that piles of equal all up weight had been driven by smaller hammers. The assessment therefore was that the pile was refusing solely because of toe end resistance. A decision was made to drive all steel pile sections first and in the interim period to mobilise drilling equipment.

Reverse circulation type equipment was selected. The drill was driven at the head by an hydraulic motor and used 6 in diameter bolted flange drive-pipes. All of the eight piles were drilled with this equipment down to the toe of the piles and approximately 20 ft below. The deepest drilled was to R.L.-199 ft. Of the variety of materials excavated, the most significant was a tough ironstone of the type observed in the joints of Hawkesbury sandstone. A tricone bit was essential to penetrate this layer. As drilling proceeded from pile to pile, concrete sections were welded on and driving resumed. All of the piles subsequently drove close to predicted rock levels.

Driving was easier at pier 10 but the bedrock was most uneven. Piers 9 and 8 presented no unusual problems. At pier 7, however, although the first steel section drove readily, resistance soon built up. Attempts made to hard drive the pile to rock were unsuccessful. Excavation of all mud, silt and sand from inside the pile to R.L.—188 ft was essential to satisfactory driving. Hard sand conditions at piers 6 and 5 also required air lifting of material and at up to three stages during driving. By contrast, driving conditions at piers 4 and 3 were easy.

In general the bore hole information provided a reliable guide to conditions below. The exploratory boring by the Department's drilling team had taken fourteen months to complete. Steel tubing of 4 in and 5 in diameter had been sunk to rock and 2 in rock cores recovered by diamond drills. Reasonably close agreement was reached between predicted rock levels based on a bore grid of up to 180 ft x 80 ft and the pile toe levels as actually driven.

Bored Piles

Abutment B

The three 2 ft 6 in I.D. (inside diameter) piles at abutment B on the northern side were sunk vertically to approximately R.L.-220 ft using a cable tool rig. The piles were then dewatered and inspected in near dry condition. Mass concrete to R.L.-71 ft was placed by discharging 4½ in slump concrete from agitator trucks directly into the pile. After the removal of 18 in of laitance from the top of the first pour, a reinforcing cage was inserted and the remaining concrete placed by standard tremie methods.

Pier 2

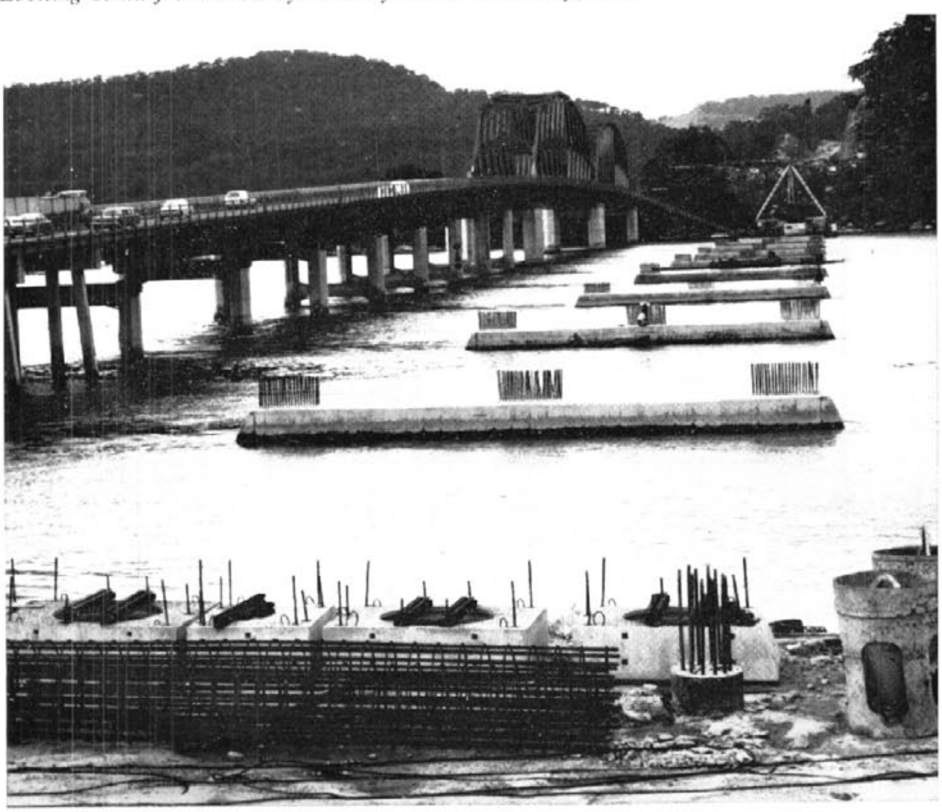
At this pier, eight 3 ft 6 in diameter piles ⅜ in thick were driven to a ¼ in set by the Kobe K32 hammer. Excavation and socketting was then completed by the cable tool rig. The method is positive but slow. The specification required the piles to be socketted 4 ft into sound rock. Over water, and on raking piles, this is a difficult process and to achieve the required standard, reaming was continued through various grades of rock and clay mixtures for a total combined length of 110 ft instead of the anticipated 32 ft.

The concreting was done in two stages. Immediately a final clean out to the base of the pile had been done by "air-lift", the first length of reinforcing cage was placed. Concrete of 6½ in slump was then tremied to the bottom to infill the lower 27 ft of the pile. Forty-eight hours later the pile was dewatered and the laitance removed. The amount varied from 6 ft to 11 ft. Cages were then placed and the remaining concrete pumped to the bottom of the pile. The concrete was discharged to within 5 ft of the old surface and compacted by vibration. The men worked in near dry conditions 100 ft below water level. The whole operation was completed without any major difficulties. As experience was gained, some of the laitance in stage 1 was removed by air-lift soon after placing of the concrete.

Pile Load Test

The 500-ton test load to the vertical pile No. 21 at pier 4 was applied by a hydraulic jack and held at full load for 24 hours. A 6 ft deep steel plate girder was positioned across four of the driven piles. The reaction from the jack was balanced by ½ in diameter high tensile strand joined by connectors to the protruding pretensioning wire in the concrete piles. The strand was anchored to heavy flat plates on top of the girder. Careful checks of levels on each pile were kept over a period of 48 hours, the maximum recorded settlement under load being 0·9 in and the permanent settlement after release of load 0·1 in.

Looking south from Mooney Mooney Point—February, 1971



Pile Cap Construction

Pile heads were not cut off until a 7 ft inner solid concrete plug had been poured up to R.L.-1·0. After removal of the pile top by pneumatic drill and jack picks, precast concrete pier-base sections were placed by crane over the piles and suspended by steel channels bolted to the precast units. The cavity between the precast units and the piles was then concreted. A pre-tied reinforcing cage was then placed in position and side shutters bolted to the precast units. Concrete (72 cubic yards) was then pumped into the form to complete the work.

The pile cap work was within the 6 ft tidal range of the Hawkesbury River at this site. Work periods were therefore limited and, in order to keep pace with the programme of construction, much of the work was executed at night under lights. Concrete was delivered by agitator trucks to the existing bridge and pumped via a walkway supported at the one end on the existing bridge and at the other by a steel pontoon.

SUPERSTRUCTURE

At the time of preparation of this report, the superstructure was still in the early stages of construction, the first steel girders having been positioned.

Pier and Abutment Work

Abutment A

This abutment is cut into solid sandstone and is anchored into the rock by two sets of McAlloy bars raking 35 ft. The work is readily accessible to all equipment since the main southern approach to the bridge is already well advanced.

Piers

Two sets of smooth plywood-faced forms have been prepared for this work. Lifts up to 12 ft were concreted using tremie pipes. Internal and external vibrators were used. Concrete was placed by floating crane and skips and by pumping from the existing bridge. Twin rows of McAlloy bars were anchored in the final lifts to stress the composite girder to the piers.

Steel Girders

Fabrication of the steel girders is being done at Newcastle, 77 miles to the north of the bridge. The girders are fabricated in three sections and temporarily braced internally for transport and erection. The sections, up to 60 ft in length and weighing 27 tons, are transported by road to the site and off-loaded by a gantry crane onto level steel stools. These stools are set high enough to allow for an overhead manual weld on the underside of the bottom flange. The welding sequence is:

(1) Web plate splices ($\frac{3}{8}$ in plate).

(2) Bottom flange plate splices (up to $1\frac{1}{4}$ in).

(3) Top flange plate splices (up to 2 in).

(4) Completion of remaining splices.

The submerged arc process is used on the top side of the bottom flange plate. The remaining welds are done manually. All principal butt welds are examined radiographically. After splicing to full length and camber, the girders are removed onto rail tracks and bogies to a new position for the final surface treatment. The girders are then moved via rail tracks on to a temporary timber jetty for launching. A barge, 100 ft x 40 ft fitted with twin 70 ft towers lifts the girders clear of the jetty. With the girder in a low-slung position the barge is winched between the piers. The girder is then hoisted and the barge winched forward to position the girder over the pier for final placement. When three girders in each of three adjacent spans have been positioned, placement of deck concrete will commence and follow a rigid sequence. Falsework for the deck concrete will be hung from the steel girders. When the infill concrete between the ends of the girders has been placed and sufficiently aged it will be stressed vertically to the piers by McAlloy bars. The stressing of the deck concrete in the longitudinal direction over the piers (also by McAlloy bars) will follow, after which the infill girder will be stressed transversely by the P.S.C. system. The last concrete in the spans to be placed will be the transverse stiffening girders and the central deck areas followed by the deck joint closers. The kerbs are integral with the deck.

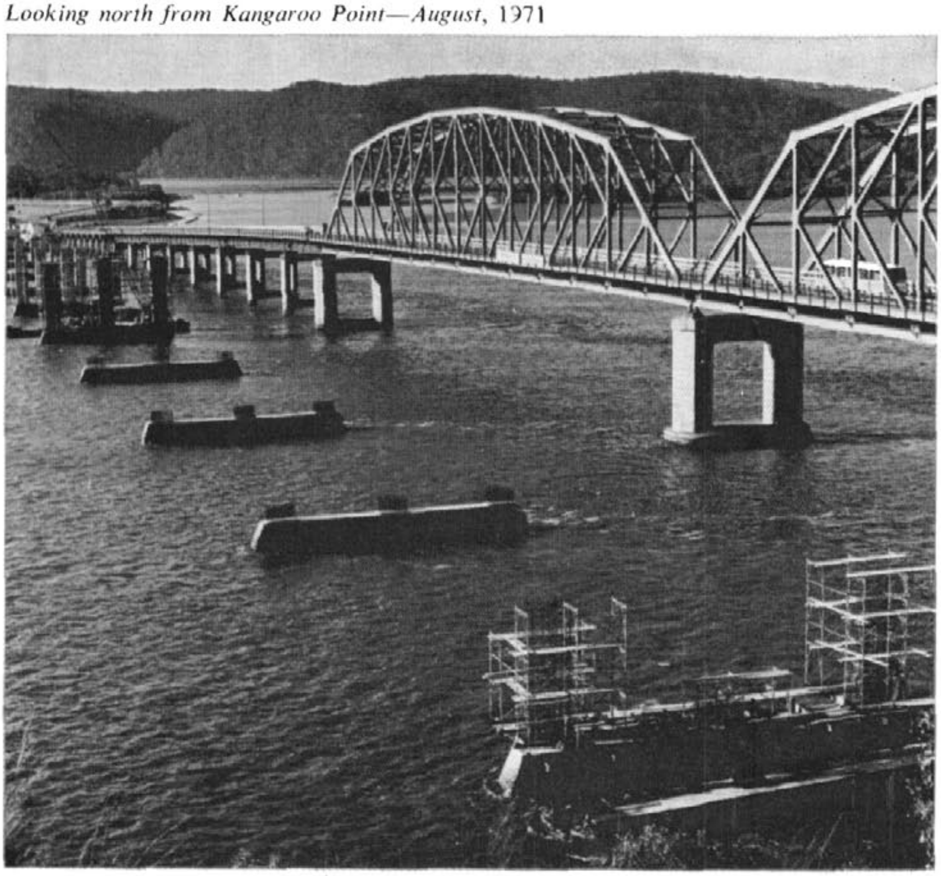
Span No. 1

The placement of the steel girders in span No. 1 required special planning as this section of the work is above the steep southern bank. The contractor plans to launch a set of aluminium trusses from the southern bank onto temporary supports at pier 1. The steel girders will be run out from the southern bank, underslung on the trusses and positioned over the piers.

Surface Treatment

Internal and external steel surfaces of the box girders will be grit blasted and then zinc sprayed. Two coats of primer will be applied before despatch of the girders to the site. After all welding has been completed any untreated areas will be treated with zinc epoxy. Final painting will be done after erection of the girders●

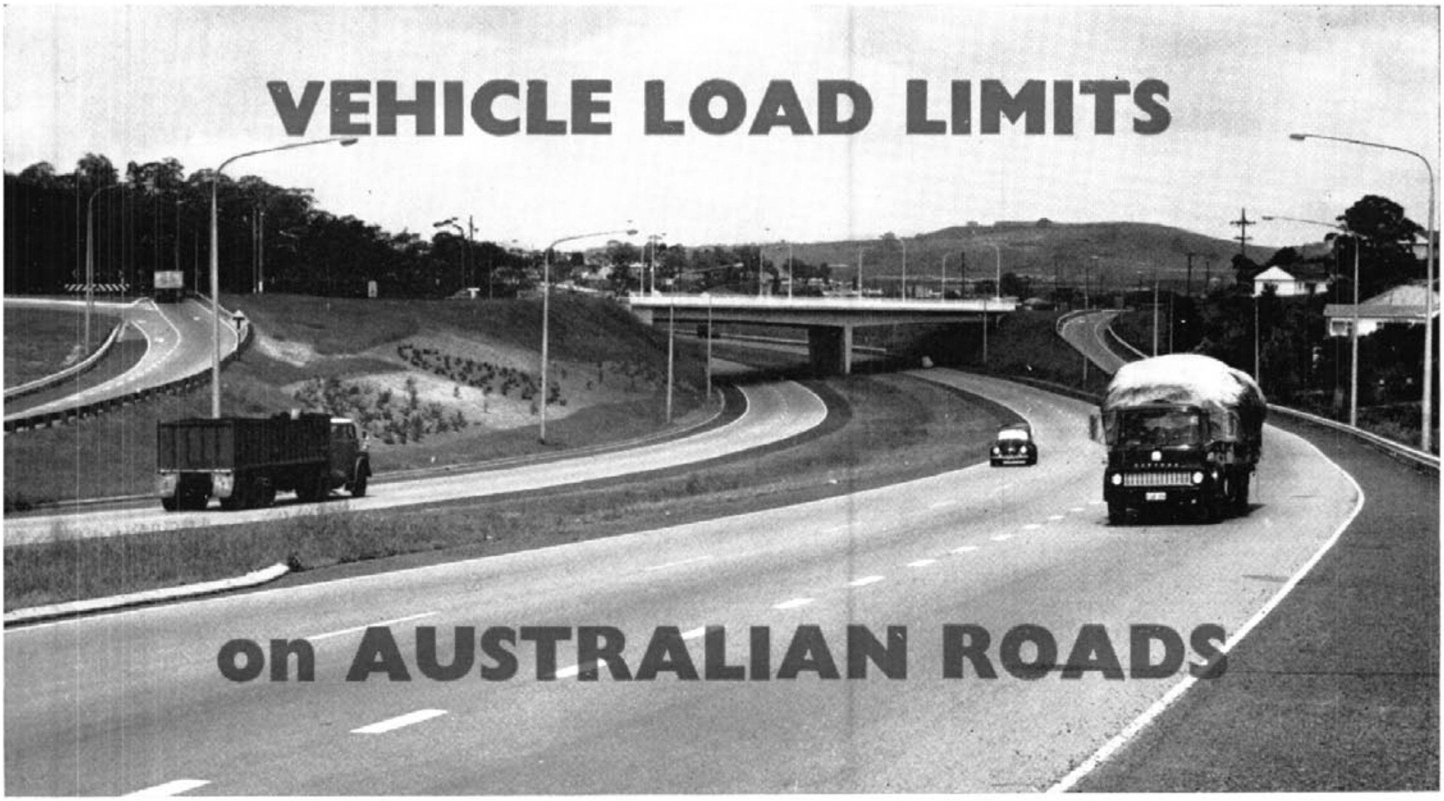
Looking north from Kangaroo Point—August, 1971



This article has been adapted from a paper prepared by Mr L. Doyle, the Department's Resident Engineer, who is supervising construction of the bridge.

An article entitled "Foundations for New Bridge over the Hawkesbury River" appeared in the March, 1970 issue of "Main Roads" (Vol. 35, No. 3, page 66).

VEHICLE LOAD LIMITS on AUSTRALIAN ROADS



If a bridge is sufficiently overloaded it will fail and the load will break through it. Similarly if a road pavement is sufficiently overloaded, the wheels of the vehicle supporting the load will break through into the soil beneath. Even lighter loads, if passed over a road surface sufficiently often, will seriously damage a pavement. In practice, such damage is by no means uncommon, and is one of the reasons why so many miles of pre-war bituminous surfaced rural highways in Australia have had to be rebuilt during recent years to enable them to carry the larger numbers of heavy vehicles now using the roads.

If road costs are to be kept within the reasonable financial capacity of the Australian people who are required to pay for them, it is necessary that vehicle loads be restricted, just as they are restricted in other countries where road transport has been highly developed. Both for reasons of safety and overall economy, it is in the common interest of all members of the community that, in addition to limits on gross vehicle weights, there are limits on axle loads and on the width, height and length of vehicles and their loads.

In the period before the development of the modern motor vehicle, long distance transport was handled mainly by rail or water, roads serving principally to provide local access. Traffic using the roads was slow-moving and the size and weight of vehicles was limited by the continued use of animal-drawn vehicles and the initial introduction of only relatively low-powered engines.

With the growth of motor transport, the significance of many roads altered. Improvements to the roads were needed to suit the faster and higher-powered vehicles. It became necessary to review the existing methods of road finance and control. Central authorities were established to administer control of roads carrying longer distance traffic, and the financial responsibilities of the State for roadworks were re-defined.

Hauliers were quick to take advantage of technical advances in the automotive industry which made it possible to move bigger and heavier loads by road. The roads constructed with the limited funds available were unable to carry unlimited loadings and it was found necessary to place restrictions upon the size and weight of motor vehicles.

WEIGHT LIMITATIONS

Weight limitations draw a distinction between the loadings transmitted through axles fitted with single-tyred wheels, axles fitted with dual-tyred wheels, and groups of axles.

The permissible gross weight of the vehicle as a whole is also dependent on the wheel-base of the vehicle, and may be affected by the spacing of axles.

As a tyre load is transmitted through the surfacing and lower layers of the pavement, it is spread over a large area of the foundation soil and provided there is sufficient depth of pavement the soil is able to support the load. The load transmitted by a single tyre is generally limited by statute to about 5,000 lb, or 10,000 lb, for two single tyres on an axle. If greater axle loads are desired, extra tyres must be fitted to the axle. Where two dual-tyred wheels are used (e.g., four tyres per axle) the load on the road surface from that axle is generally limited to about 18,000 lb, and not 20,000 lb. This is because there is a partial overlap of the areas at the road foundations affected by the load on each tyre of the dual-tyred wheel and this produces a greater intensity of pressure on the foundation soil than that from a single tyre. A maximum tyre pressure is also prescribed because very high tyre pressures increase the wear or disturbance of the top layer of road pavement material.

For short bridges and culverts and for certain parts of long bridges, axle loadings are the critical factors. Limitations on gross vehicle loadings and on the spacing of axles are intended primarily to safeguard long bridges.

VEHICLE LIMITS AND ROAD SAFETY

While weight limitations are intended primarily to limit the damage caused by vehicles to the road itself, they also reduce the tendency for vehicles to be loaded beyond the capacity of braking equipment and tyres, giving drivers more chance of controlling their vehicles in emergencies. In addition, the dangers associated with sudden failure of vehicle components are less likely to arise.

THE ECONOMICS OF VEHICLE LIMITS

Preservation of National Road Assets

In Australia, there are approximately 550,000 miles of public roads in various stages of development. Allowing a conservative asset value of $8,000 per mile, the total Australian investment in roads is an amount of $4,400 million. Vehicle limitations are directed towards the preservation of this asset.

The current availability of finance for roads is such that Australian roads can be expected to provide a reasonable and improving level of service for vehicles and loads which comply with the statutory limits. The imposition of heavier loading would result in serious damage and would amount to misuse of the roads.

The effects of excessive loadings on roads are not always evident immediately. Road pavements and road foundations suffer progressive deterioration under repeated heavy loading and, over a period, failures develop which result in increased maintenance costs for both the road and the vehicle using it. A pavement which could successfully carry 18,000 lb axle loads for many years may fail in a much shorter period under 20,000 lb axle loads (that is, an increase in dual-tyred wheel loading of less than 1,000 lb above the present legal limit in New South Wales).

Bridges and culverts also suffer from progressive deterioration if strained beyond certain limits. Where a structure has been over-strained, ultimate failure is usually sudden and can occur under relatively moderate loading. Bridgeworks, besides being costly, take a long time to complete, especially if located in steep terrain or at a wide river crossing. Consequently, one damaged bridge can cause a long length of road to be out of service for a considerable period, bringing inconvenience to all motorists and often adversely affecting the livelihood of local residents who are dependent on it for access.

ECONOMY IN ROAD DESIGN

Due to past deficiencies in funds available for road construction, much of the Australian road network is not adequate to carry any substantial increases of traffic within the legal limits at present in operation. The statutory vehicle limitations have been accepted as establishing a reasonable basis for determining a target road standard towards which roads are being progressively improved.

Subsidiary roads are used on occasions by vehicles of all classes, including quite heavy loadings such as are required for the transport of stock or primary produce. In practice the light pavements on these subsidiary roads may render satisfactory service for such occasional traffic if they are suitably maintained to restore any damage. However, stronger pavements are necessary on main and intercity roads, which carry large numbers of heavy vehicles daily and are subjected to constant repetitions of extreme loading.

The selection of the road standards appropriate to a particular route or section of road is a question of economics. The greater the traffic volume and the larger the proportion of heavy vehicles, the more necessary it is that the road be constructed to standards corresponding to full statutory load limits.

If roads are to function adequately, the authorities responsible for their construction must have precise knowledge of the types and numbers of vehicles for which they are catering, as the life of a road pavement or of a bridge could be disastrously shortened if subjected to a loading in excess of that for which it was designed.

ECONOMY IN TRANSPORTATION

While the cost of vehicle operation per ton-mile generally decreases with increasing axle loading or more spacious road layout, it is evident that from a point of view of overall economy, this saving is offset by the higher cost of the road. Estimates have been made by Australian road engineers to compare these opposing costs and enable statutory vehicle limitations to be examined on an overall economic basis. These have indicated that present limitations provide a suitable balance between the cost of operating road transport and the cost of providing a reasonable standard of road maintenance and construction.

A major part of the Australian road system has yet to be brought to a standard appropriate to the traffic carried. Much greater road expenditure is required to secure this objective and to secure the higher standard which will be necessary on the more important roads in order to meet the greatly increased volume of heavy traffic expected in the years ahead.

To improve the whole road system to a standard such that it could carry vehicles and loads substantially heavier or larger than those at present allowed would be an enormous and costly task which could only be accomplished over a lengthy period. The only practical approach is to endeavour to obtain a suitable balance between the standards of road or bridge construction and the allowable maximum sizes and weights of vehicles, taking special measures to deal with the occasional vehicle which is required to be of unusual weight or size.

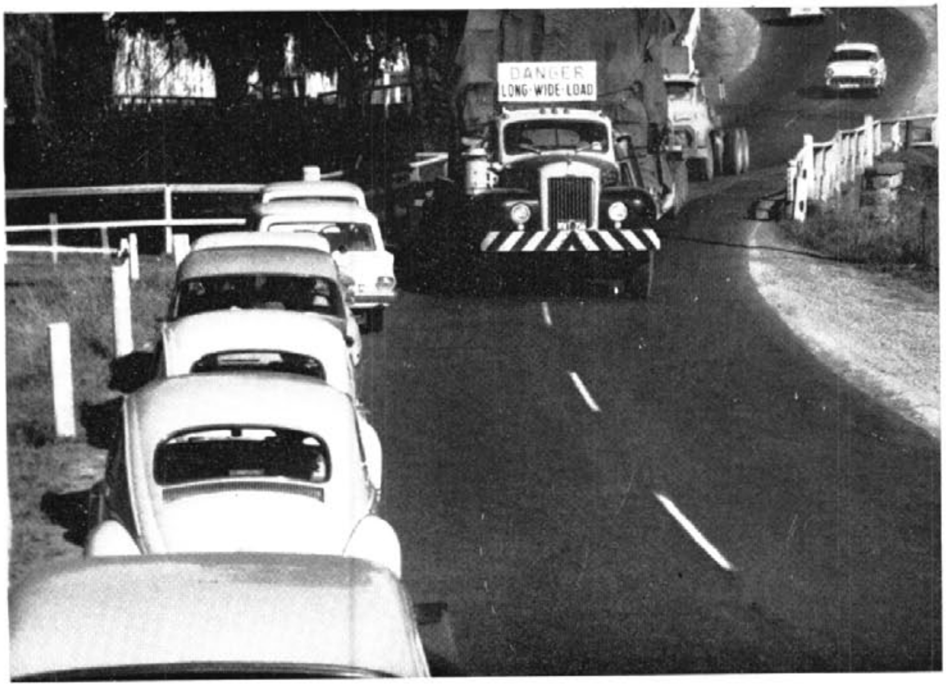
A simple illustration of this principle is the average driveway to a home, which is usually made strong enough to support light vehicles only. The need to have a driveway of more substantial construction arises too infrequently to justify the extra cost. The home owner, moreover, is usually able to keep heavy vehicles out of his property or to control their entry.

By way of further illustration, the operation of railways may be contrasted with the operation of road traffic. Railway authorities construct their tracks for defined loadings, and can order and control the types and weights of rolling stock to correspond with the loading permitted on the tracks. Train drivers are under constant and strict discipline in regard to these restrictions.

This is far from the case with roads where, to prevent or minimize misuse of the roads, authorities have to rely primarily on the understanding and co-operation of a wide variety of individual road users, and on deterrent measures.

Vehicles complying with legal limitations have the right to use public roads subject to such local restrictions as may be applied from time to time on particular sections of light pavement construction or at weak bridges. To provide for those special occasions when the transport of an exceptionally large or heavy load (usually machinery) is necessary, a permit may be issued by the appropriate authority covering the particular trip and specifying the route to be followed. The permit may restrict travel on certain days and may include conditions such as limiting travel to certain hours of the day or night, requiring a police escort, and making the haulier responsible for any damage to road pavements or bridges. In some cases, special precautions (such as providing temporary supports under bridges or removing and replacing roadside structures) may be necessary in order to transport loads which are much in excess of legal limitations for weight or size.

The issue of these permits is not automatic. Permits to allow excess weight or dimensions are not generally issued for the transport of divisible loads nor for the transport of a non-divisible load on an unsuitable vehicle. The permit system, in effect, enables the transport by road (under special circumstances and conditions) of large items of equipment which in many cases could not otherwise reach their destination.



REVIEW OF AXLE LOAD LIMITS

For some years the National Association of Australian State Road Authorities and the Australian Road Research Board have been engaged in detailed investigation of the current statutory axle load limits.

Stated in general terms, the objective is to arrive at a logical and scientific solution to the problem which would arise if axle load limits were to be changed. More specifically, and assuming that axle load limits were relaxed in any way, the need is to determine a reasonable compromise between savings in road transport costs and the increased road costs which would be incurred.

The complexities of the problem have not enabled any firm and final conclusions to be reached as yet, but investigation is proceeding in respect of four broad areas as set out below:

1. *Road Costs*

Any increase in permissible axle loads would obviously result in increased road costs for:

- the construction of new roads, culverts and bridges and the upgrading of existing roads, culverts and bridges in order to cope with the increased loading; and
- the increased maintenance required.

The only estimate made so far of increased road costs is approximately $9 million in relation to upgrading bridges on the Hume and Western Highways (Sydney-Melbourne-Adelaide). Due allowance should be made for the fact that bridges on these State Highways are already of a relatively high construction standard.

2. *Vehicle Operating Costs*

It has been recognised that there is an urgent need to have information on the present axle load distribution on the Australian road system and the National Association of Australian State Road Authorities has put in hand a sample survey to obtain such information in all States and Territories.

The Australian Road Research Board has already obtained substantial data on vehicle operating costs for a wide variety both of types of haulage and types of vehicles. However, such data is not yet

sufficient to enable the Board to assess the savings to the road haulage industry as a whole which would result from, say, an increase in permissible twin bogie axle loadings.

3. *Present axle combinations in use*

It has been found that, because of variations in the statutory axle load limits from State to State, many semi-trailer operators have abandoned standard 4 ft 6 in spaced twin bogies and have modified their axle spacings to the minimum allowable single axle spacing of 8 feet. As a result, the two spread axles can legally support 36,000 lb between them compared with the 30,000 lb allowed on a bogie.

This practice increases the permissible pay load but it also increases the overall cost of operating the vehicle. The cost of axle modifications and generally higher vehicle maintenance costs make the change less desirable from the operator's point of view.

4. *Destructive effect on the roads*

Extensive studies have been made of the destructive effects of heavy wheel loads. These have shown that relatively small increases in loading result in substantially greater destruction of the road pavement. For example, a 20 per cent increase in wheel loading results in a 100 per cent increase in destructive effect and this can reduce pavement life by up to 50 per cent.

Financing the costs of upgrading the roads

An upgraded road system would clearly be of benefit to road transport operators but, unless the benefits exceed the cost of the required roadworks, there is no justification for expending scarce public resources in that direction.

If a full assessment does show that some variation in load limits is justified it would be reasonable to ensure that the operators' savings are passed on to the public, either in the form of lower freight charges or by way of contribution to the cost of the additional roadworks.

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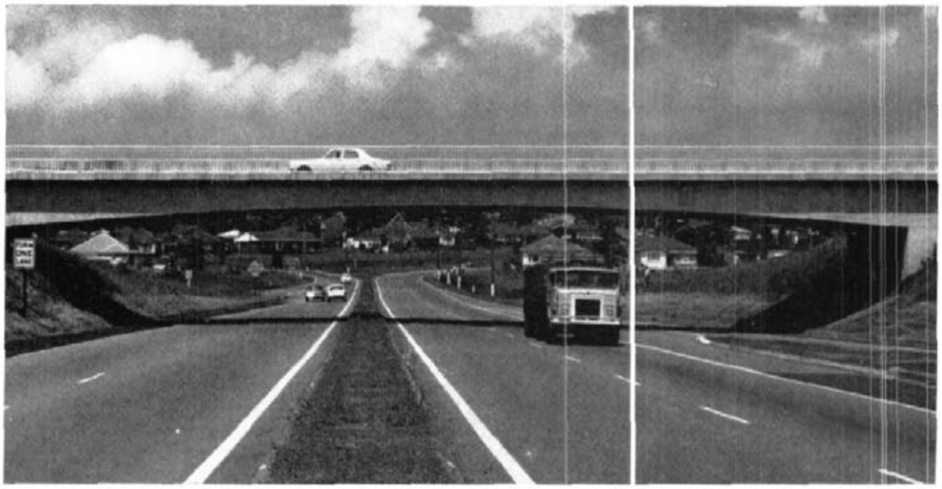
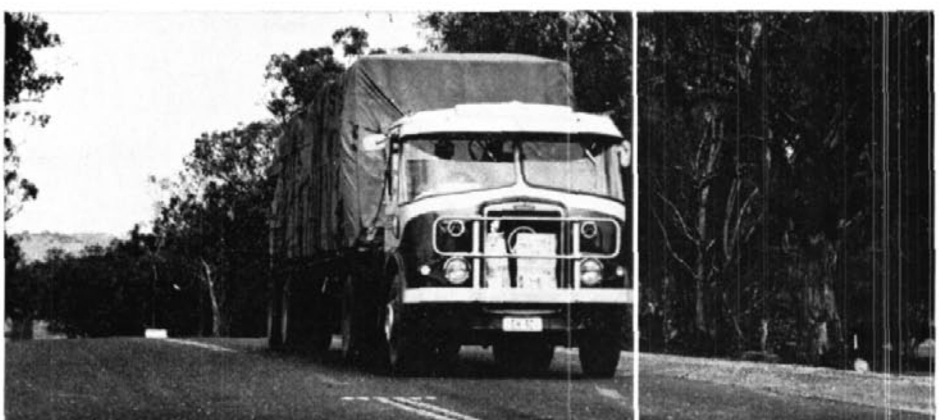
Considerable investigation and analysis has yet to be carried out before conclusive results can be obtained and a complete solution presented●





An article entitled "Weight of Loads on Vehicles" appeared in the March, 1967 issue of "Main Roads" (Volume 32, No. 3, page 90).

NEW BRIDGE NEAR DAPTO

The Department is to construct two new bridges over Mullet Creek on a new deviation of the Prince's Highway, near Dapto. Both bridges, which will be flood-free, were designed by the Department to replace two old timber bridges and an old narrow concrete bridge on poor alignment, all of which were subject to flooding.

The successful tenderer for both new bridges, which will be built concurrently, is Dostal and Co. Civil Engineering Pty Ltd, and the total value of the tenders is $289,410.10. Contract time for completion of the bridges is 78 weeks from 25th August, 1971.

Tender price for the major bridge, an eight-span prestressed and reinforced concrete structure, 600 feet long, is $226,746.80. It will measure 28 feet between kerbs and carry two lanes of traffic and one footway, five feet wide.

The smaller bridge will measure 120 feet over four spans and will form part of the approaches to the main bridge.

Concurrently with these bridgeworks, the Department will undertake, with its own forces, the construction of a deviation of the Prince's Highway. This deviation will be approximately 1·6 miles long and will be located west of the existing bridges.

The old concrete bridge will be retained for access to local properties and will come under the control of the Council of the City of Wollongong●

TENDERS ACCEPTED BY THE DEPARTMENT OF MAIN ROADS

The following tenders (in excess of $10,000) for road and bridge works were accepted by the Department during the three months ended 30th September, 1971.

Road No.	Work or Service	Name of Successful Tenderer	Amount
			$
Southern Expressway	City of Wollongong. Construction of two 3-span continuous steel and reinforced concrete bridges, each 217 feet long, over the Southern Expressway at Berkeley Road and Flagstaff Road at Unanderra.	Transbridge Pty Ltd	295,170.00
South Western Expressway	City of Liverpool. Construction of a 3-span, 260 feet long, prestressed concrete box girder bridge to carry the Hume Highway over the Expressway at 24 miles from Sydney.	Central Constructions Pty Ltd	273,129.00
State Highway No. 1	Prince's Highway. Municipality of Shellharbour. Supply and delivery of up to 70,000 cubic yards of filling to approaches of new bridge over Macquarie Rivulet.	Illawarra Blue Metal Pty Ltd	45,500.00
State Highway No. 1	Prince's Highway. City of Wollongong. Construction of an 8-span reinforced and prestressed concrete bridge, 600 feet long, over Mullet Creek near Dapto.	Dostal and Co. Civil Engineering Pty Ltd	226,746.80
State Highway No. 1	Prince's Highway. City of Wollongong. Construction of a 4-span reinforced and prestressed concrete bridge, 120 feet long, on southbound carriageway of approaches to Mullet Creek bridge near Dapto.	Dostal and Co. Civil Engineering Pty Ltd	62,663.30
State Highway No. 2	Hume Highway. Shire of Mulwaree. Delivery of steelwork to construction site of new bridge over Main Southern Railway, 4 miles south of Goulburn.	D. Normoyle & Co. Ltd	31,689.30
State Highway No. 5	Great Western Highway. Shire of Blaxland. Manufacture, supply and delivery of prestressed concrete bridge planks for new bridge over railway line at Marrangaroo, 4·4 miles west of Lithgow.	Dyson-Holland Concrete Pty Ltd	67,955.50
State Highway No. 8	Barrier Highway. Shire of Central Darling. Construction of a 5-span 150 feet long, reinforced and prestressed concrete bridge 26 miles east of Wilcannia.	Herbert Construction Pty Ltd	58,667.00
State Highway No. 10	Pacific Highway. Shire of Lake Macquarie. Supply and delivery of up to 15,000 cubic yards of gravel to various locations between 40 miles and 26 miles south of Newcastle.	R. L. Scadden	16,000.00
State Highway No. 21	Cobb Highway. Shire of Hay. Construction of a 5-span, 90 feet long, reinforced concrete bridge over Mirrool Creek, 36 miles north of Hay.	Siebels Concrete Constructions Pty Ltd	28,014.00
Main Road No. 108	City of Newcastle. Supply and delivery of up to 1,500 tons of ⅜ in gauge asphaltic concrete to eastern approaches of Stockton Bridge.	Bituminous Pavements Pty Ltd	19,650.00
Main Road No. 556	Shire of Macleay. Construction of a 10-span prestressed and reinforced concrete bridge, 1,125 feet long, over Macleay River at Smithtown 10 miles north of Kempsey.	John Holland (Constructions) Pty Ltd	973,993.00
—	Shire of Gosford. Construction of a prestressed concrete cantilever type bridge, 1,082 feet long, over "The Rip" at the entrance to Brisbane Water.	John Holland (Constructions) Pty Ltd	2,173,640.00

TENDERS ACCEPTED BY COUNCILS

The following tenders (in excess of $10,000) for road and bridge works were accepted by the respective Councils during the three months ended 30th September, 1971.

Council	Road No.	Work or Service	Name of Successful Tenderer	Amount
				$
Abercrombie	Various Trunk Roads and Main Roads	Bituminous sealing and resealing at various locations.	Emoleum (Australia) Ltd	10,725.53
Ashford	S.H. 16 & M.R. 137	Bituminous surfacing on Bruxner Highway on approaches to Middle Creek Bridge between 31 miles and 32 miles west of Bonshaw and on Main Road No. 137 between 7·07 miles and 9·05 miles north of Ashford.	Emoleum (Australia) Ltd	20,246.79
Ashford	M.R. 137	Construction of reinforced concrete box culverts north of Ashford at: 7·8 miles—4 cell 7 ft x 3 ft; 8·5 miles—3 cell 8 ft x 3 ft 6 in; 9·0 miles—2 cell 10 ft x 7 ft; 9·6 miles—3 cell 9 ft x 5 ft.	Enpro Constructions Pty Ltd	23,646.45
Ashford	M.R. 137	Construction of a 6 cell 8 ft x 8 ft reinforced concrete box culvert at 7·15 miles north of Ashford.	Enpro Constructions Pty Ltd	12,650.00
Ashford	Developmental Work 3099	Construction of a reinforced concrete box culvert over Reedy Creek at 0·85 miles north of Main Road No. 137.	N. Del Gatto	25,540.62
Blaxland	M.R. 531	Construction of a 4 cell 10 ft x 10 ft reinforced concrete box culvert and a 2 cell 10 ft x 6 ft reinforced concrete box culvert at 2·9 miles and 3·1 miles north of Great Western Highway.	Enpro Constructions Pty Ltd	36,145.30
Burrangong	M.R. 239	Supply, fabrication, protective treatment and delivery of steelwork for new bridge over Burrangong Creek 12 miles north of Young.	D. Normoyle & Co. Ltd	16,146.00
Colo	M.R. 182	Construction of a 2-span reinforced concrete bridge over Addey's Creek at Sackville.	Dayal Singh (Tamworth) Constructions Pty Ltd	33,020.86
Colo	Developmental Work 3154	Construction of a 3-span 203 feet long steel and reinforced concrete bridge over Webb's Creek, between Greens Road and Webb's Creek Road.	Ermani Constructions Pty Ltd	74,729.80
Hornsby	M.R. 373	Supply and lay 1,000 tons of asphaltic concrete, for reconstruction between Midson Road and Ray Road, Epping.	Pioneer Asphalts (N.S.W.) Pty Ltd	13,880.00
Kyogle	T.R. 83	Construction of a 4-span, 120 feet long, reinforced concrete bridge at Black Gully 14·1 miles north of Casino.	M. O. and P. J. Kautto	36,683.20
Lachlan	M.R. 231 T.R. 57	Bituminous surfacing between 27 miles 4,900 ft and 33 miles 4,340 ft east of Lake Cargelligo. Reconstruction and bituminous surfacing between 22·25 miles and 25·25 miles south of Condobolin.	Allen Bros Pty Ltd	22,896.03
Liverpool	Unclassified	Construction of a 120 feet long prestressed concrete bridge over South Creek at Rossmore 1·25 miles east of Bringelly.	Transbridge Pty Ltd	57,872.00
Merriwa	M.R. 214, T.R. 62, & D.R. 1304	Supply of fencing material for various lengths.	Dalgetty (Aust.) Ltd	15,676.78
North Sydney	Various	Replacement of deteriorated or deformed asphaltic concrete on various roads.	Bituminous Pavements Pty Ltd	10,779.25
Peel	S.H. 11	Oxley Highway. Reconstruction and bituminous surfacing between 16·8 miles and 18·5 miles west of Tamworth.	Dayal Singh (Tamworth) Constructions Pty Ltd	11,375.00
Peel	D.R. 1275	Construction of two 4 cell 15 ft x 12 ft reinforced concrete box culverts at Duff's Gully 2 miles from Main Road No. 130.	Concast Pty Ltd	28,268.00
Port Stephens	Various	Supply, heat and spray bitumen at various locations	Boral Road Services Pty Ltd	17,103.00
Talbragar	Unclassified	Dubbo-Mendooran Road. Construction of a 3-span, 90 feet long, reinforced concrete bridge over Denmire Creek 33·9 miles from Dubbo.	A. Cipolla & Co. Pty Ltd	29,470.70