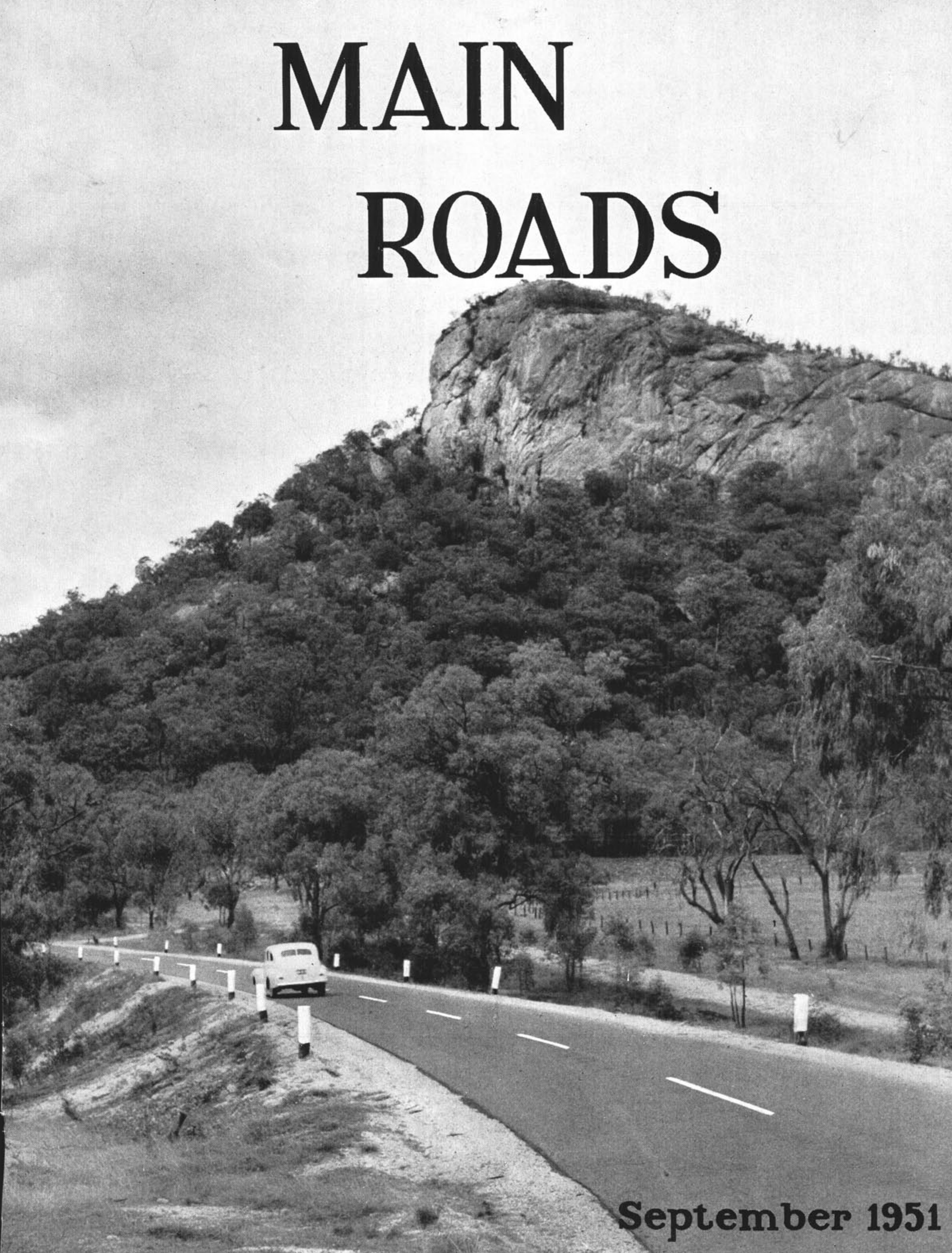
MAIN ROADS



September 1951

MAIN ROADS.

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Cover Page.

View of Bluff Rock on the New England Highway (S.H. 9) approximately 9 miles from Tenterfield.

Next Issue: December, 1951.

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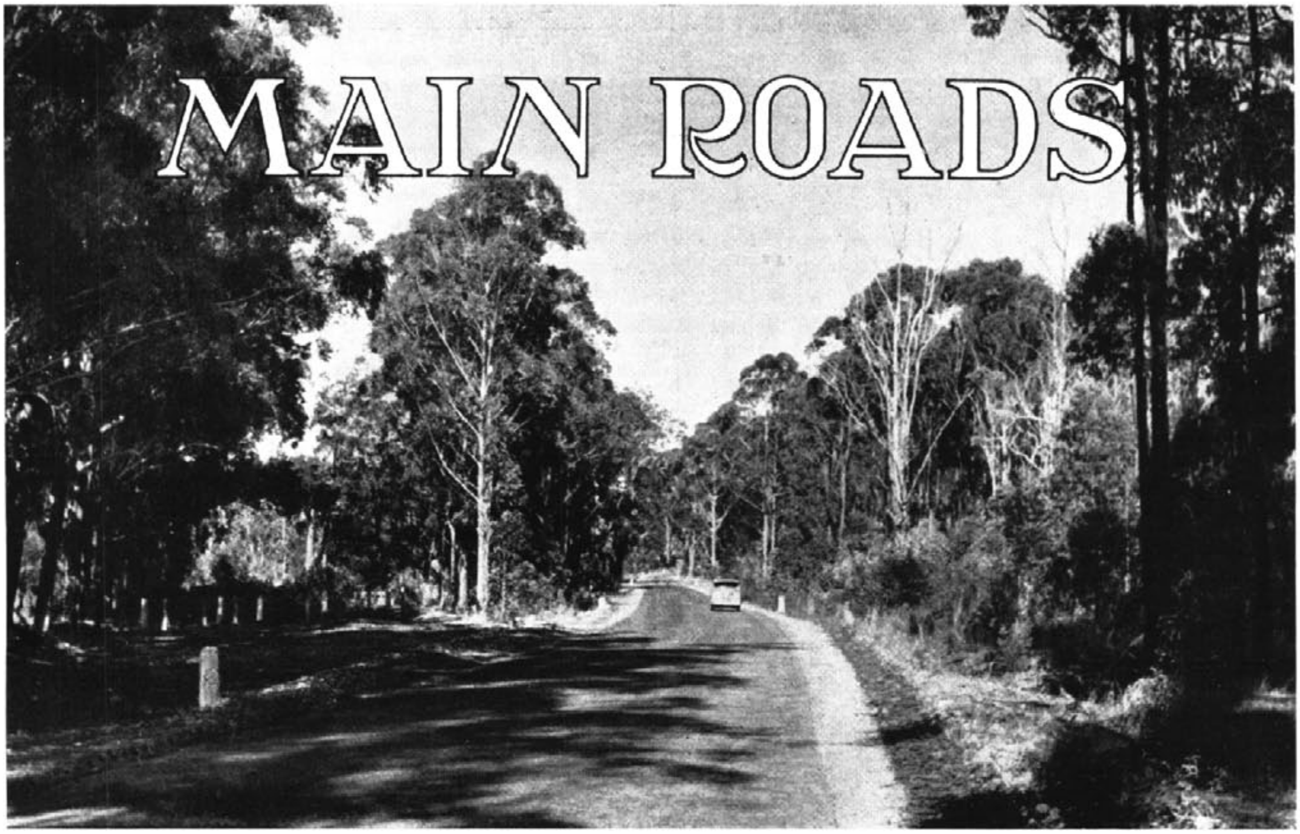

Vol. XVII, No. 1. *September, 1951.* 1

Main Roads Development in the Metropolitan Area

Effect of County of Cumberland Planning Scheme.

The County of Cumberland Planning Scheme embracing the Sydney metropolitan area became a "Prescribed Scheme" under the Local Government (Town and Country Planning Amendment) Act, on the 27th June, 1951.

The Scheme includes a network of arterial or "County" roads which, broadly, represent the future pattern of main road development in the metropolitan area of Sydney.

The Scheme does not include any detailed planning of the central business area of the city, and does not show roads within that area. However, a complementary road layout for the central area has been prepared and adopted by the City of Sydney Planning Conference, thereby providing a continuous network of arterial roads.

The arterial roads for the central area include an "inner ring" of distributor roads around the central business area for distribution of traffic into the city, the principal radial arterial roads feeding on to the ring distributor roads. Details are given in the December, 1946, number of this journal. The suitability of this layout was tested and supported by the results of an origin and destination survey of city traffic in 1947, which was reported and illustrated in the June and December, 1947, numbers of "Main Roads."

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Preparation of the Main Roads development plan.— In 1943, the Department of Main Roads commenced a comprehensive analysis of the future main roads needs of the metropolis and the County of Cumberland. At that time there was no certainty that Town and Country Planning legislation would be introduced in New South Wales, and the Department thus proceeded without the co-operation of a planning authority.

Traffic volume movement depends on several factors, including amount and distribution of population, extent of motor vehicle use, relative positions of homes and places of work, and others. It was decided, therefore, first to relate existing traffic movement to existing land use and population distribution, then to estimate probable future land use and population and from this to estimate the probable future traffic demand. At the same time, allowance had to be made for the probable future increase in motor vehicle use.

A series of studies was thus involved, of which the following were the most important:—

1. Present and future population of Sydney metropolitan area and County of Cumberland;
2. Present and future area covered by city;
3. Present and future land use;
4. Present and future distribution of population;
5. Present and future motor vehicle registrations;
6. Present and future traffic volumes and directions.

A land-use map of the whole of the County of Cumberland was prepared, the drawing up of which was much facilitated by the use of air photographs. The land-use map was subsequently of value to the Cumberland County Council, as well as to other authorities. In addition, it has proved to be of educational interest in schools and at the University of Sydney.

A population distribution map was also prepared, and printed over a softly coloured copy of the land-use map.

With the aid of these two maps and studies of population growth and of acreages of land required for each of the various uses per thousand population, a map of probable future land use was prepared representing the anticipated position in about fifty years' time. From this map, and from estimates of corresponding population distribution and motor vehicle usage, it was possible to deduce probable future directions and volumes of traffic from present directions and volumes as ascertained by traffic surveys.

The foregoing is a simplified description of the work actually carried out. Other factors had to be considered. For example, traffic into the central part of a city is not directly proportional to the size of the total population, and traffic figures for Sydney and overseas cities were studied to get data on this aspect. Then traffic "runoff" from the various sectors of a city, including Sydney, is not proportional to population resident in the area. This also required study and explanation.

The volume of week-day peak-hour traffic linking each part of the county with each other part was estimated, and this traffic was shown as "desire lines," of width proportionate to traffic volume, on a map. These traffic flows were fitted to existing roads and additional roads tentatively selected in general locations based upon general knowledge of the area, upon consideration of all applications made by Councils for roads to be proclaimed as Main Roads, upon stereoscopic examination of air photographs, field inspections, and with particular regard to existing and proposed development. It was soon found that the factors of traffic capacity, safety, economy, keeping of property interference to the practical minimum and reasonable direction of routes, required that a limited number of the new roads be expressways, that is, roads segregated from frontage access, cross traffic and pedestrians. The tentatively selected general routes were drawn on a 40 chains to an inch map and reviewed several times. Thereafter, the planning of the road system proceeded in stages of increasing detail. First each route was stereoscopically examined on air photographs and drawn in greater detail as to location on air photographs of 1,000 feet to an inch, and in some cases on air photographs enlarged to a much greater scale. Then followed a search for, and investigation and comparison of alternative routes. Field inspections and design on contour plans of 2 chains to an inch scale brought the planning to a much greater and in some cases sufficient degree of detail, but on many of the roads there is necessary and still proceeding further detailed investigations on specially prepared strip base plans drawn to a scale of 40 feet to an inch.

The degree of detail in planning already reached on the different roads and sections of roads varies to a considerable extent because it has been necessary to give priority to the detailed planning and fixation of road boundaries in those areas where the Cumberland County Council, local Councils and members of the public have sought information as to the extent to which particular properties are affected or likely to be affected by the planned-road system. Over 6,000 such enquiries have been dealt with by the Department of Main Roads. As a result, much land required for road purposes has been protected against adverse development and the community protected against later uneconomic expenditures.

Detailed planning for the development plan as a whole must continue until the whole of the land required for the county and main road system is defined in detail.

In 1946, the Cumberland County Council was established as the planning authority for the County, including the Sydney metropolitan area. At that stage the Department's investigations and planning were well advanced. The Department was able to make available to the Council its planning data, including the land-use and population density maps previously referred to. The land-use map was subsequently used by the Council as the base for the interim development control plans issued by the Council.

The tentatively planned future main road system was supplied to the Cumberland County Council while the Department of Main Roads investigations continued. When the County Council's proposals for zoning of land use became available, the tentatively planned road system was reviewed in the light of that information. It was not found necessary or desirable to make any major alterations to the planned road system, for it to adequately and efficiently serve the county's development as planned by the County Council. The future population of 2½ millions used by the Department of Main Roads as a basis for the main roads planning was found to be substantially the same as that adopted in the County Council's planning. Thus the work done by the Department of Main Roads in planning the future arterial road system successfully fitted into the broader planning carried out by the Cumberland County Council.

The County Scheme, now statutory, will ensure that land required for the construction of future arterial roads will be not further developed for building purposes.

The development of the future main roads system as planned is a work likely to extend over a very considerable number of years, section by section being built as the traffic need develops, and funds and other resources permit.

Medium and Low-Cost Rural Roads in U.S.A.

Some Examples of Current Work

Extracts from a preliminary report by J. A. L. Shaw, D.S.O., B.E., M.I.E. Aust., Chief Engineer, Department of Main Roads, New South Wales, following attendance during 1950 at a course on "The Theory and Practice of Highway Improvement and Utilization in the United States of America," arranged and conducted by the Bureau of Public Roads, Washington, D.C.

(Further extracts will be printed in a subsequent number of "Main Roads.")

In this section there are described some examples of medium- and low-cost rural road construction which are thought likely to be of practical interest to Australian highway engineers.

The whole range of medium and low-cost work in U.S.A. is not represented by the selected examples. The selection has been made principally to illustrate the improvement of country roads carrying, or likely to carry for a considerable time to come, a relatively low volume of traffic. Some preference has been given to those examples of maximum use of local materials.

The price figures given are merely indications of position in the United States scale of construction costs. Reliable conversion to Australian equivalents could not be made without detailed study of labour, materials and plant hire rates. As a very rough guide, the equivalent New South Wales mid-1950 cost in pounds (Australian) might be taken as one-quarter of the quoted dollar costs for bitumen-surfaced gravel roads. For road work with greater content of bituminous material, perhaps one-third would be more accurate.

NORTH CAROLINA.

Over a long period this State has endeavoured to provide improved roads for farm traffic, and in 1950 it set out on a programme to provide another 3,500 miles of such roads, which will carry a traffic of 125 to 150 vehicles per day with infrequent axle loads up to 18,000 lb. In general, the improved roads will consist of treated soil pavements with more or less normal type sprayed seal coats, or treated soil bases overlaid by a surface course of 1-in. to 1¼ in. of hot plant-mixed sand-asphalt. In 1950 the cost ranged on the average from $7,500 to $10,000 per mile, but most of this amount would be expended on pavement, as the earthworks and shouldering are usually very light. As regards the soil bases, these are either mixtures of sand and clay, or clayey soil and Portland cement. In practically all cases soil mixing is done by the rotary hoe type of mixer. The depth of mixing and compaction is such as to give a finished base of 6-inches thickness and this is achieved in five or seven passes of the mixer on a width of 18 feet.

For the surfacing, or surface course, machine-laid hot sand-asphalt is generally preferred, and it was stated to me that 1 inch of such a mix is very little, if any, more costly than ordinary seal coat work. The principal reason for this satisfactory position is that a suitable sand for the mix can be obtained from pine forest reserves close to the proposed road works. Large capacity portable hot mixers are used and the only importations are the asphalt which, in the case of North Carolina, arrives hot in large road tanker waggons, and Portland cement or fine stone dust for mineral fillers where necessary.

North Carolina. Mixing clay with sand soil to produce a 6 inch base to carry a sand-asphalt running course.

Photo. by courtesy of Bureau of Public Roads, Washington, D.C.

Attached to each sand-asphalt mixing outfit there is a mobile field laboratory which keeps check on the mixes being produced.

NORTH CAROLINA.

A Market-to-Farm Road leading off the State Highway between Winston-Salem and Asheville.

This land service road passes through rolling farm country of which the surface layers are red clayey soil. A broken stone pavement 16 feet wide and 6 inches thick was being constructed. This is one of the few jobs on such roads in North Carolina on which a broken stone pavement was being provided. More commonly soil-cement bases are built in this State, but here local broken stone was available from commercial quarries. At the time of my visit the earthworks had been completed and the broken stone pavement was in various stages of construction.

Prior to laying of the 1½-in. nominal gauge crushed grano-diorite, a thin layer of stone dust was spread on the subgrade.

The crushed stone for the pavement was spread in two layers and to each layer stone chips and stone dust were added and rolled in with ample water in order to secure tightness and high density. The consolidation process was effected by rubber-tyred rollers (and the construction trucks), with ordinary three-wheel heavy rollers operating between traverses of the rubber-tyred rollers. After allowing the ordinary road traffic to use a length of the finished top layer for a few days, or at the most for a week, the surface was lightly broom-dragged, then watered and given a heavy rolling. When the pavement was dry, M.C. Asphaltic binder was sprayed as a priming coat, at the rate of 4/10ths of a gallon (U.S.) per square yard. No chips or stone dust was spread on the priming coat, which was sprayed full width, and ordinary farm traffic was allowed on to the primed surface as soon as it had dried. At the time of my inspection no seal coat had been placed over the primer, but it was intended to spray hot bitumen with a cover of ¾-in. crushed stone, which would be dragged and rolled in the usual way and be followed by another sprayed coat of bitumen with cover of ¼-in. crushed stone.

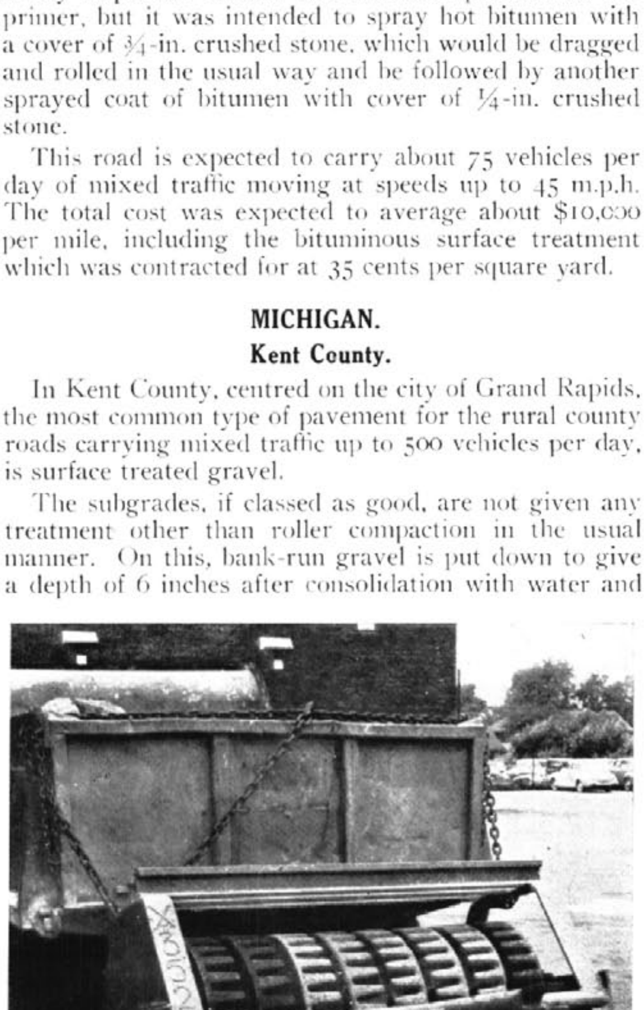
This road is expected to carry about 75 vehicles per day of mixed traffic moving at speeds up to 45 m.p.h. The total cost was expected to average about $10,000 per mile, including the bituminous surface treatment which was contracted for at 35 cents per square yard.

MICHIGAN.

Kent County.

In Kent County, centred on the city of Grand Rapids, the most common type of pavement for the rural county roads carrying mixed traffic up to 500 vehicles per day, is surface treated gravel.

The subgrades, if classed as good, are not given any treatment other than roller compaction in the usual manner. On this, bank-run gravel is put down to give a depth of 6 inches after consolidation with water and rollers, including a special toothed-wheel roller devised by the county engineer. The gravel, which has the appearance of Australian river gravels, is either non-plastic or has a P.I. less than 4. I was informed that if the non-plastic gravel is too harsh for working, then selected fine top-soil is added and grader mixed so that it is evenly distributed throughout the full depth. Great care is taken to see that the P.I. of the resulting mix does not exceed 4.



Kent County, Michigan. Toothed-wheel roller devised by county engineer to assist consolidation of gravels.

If the subgrade is classed as inferior, then before the bank-run gravel is spread, a layer of river sand 12 inches thick is placed on the subgrade to form an "insulation" course.

After the gravel has been fully consolidated with water and the rollers, it is primed with 3/10th (U.S.) gallon per square yard of priming tar which is allowed to soak in. Sand is added to blot up the wet spots and the road is then opened to traffic for a few weeks. At the end of this period the primed gravel is examined for riding quality and if the pavement is judged sufficiently smooth, then ordinary sealing is carried out, but generally using a road tar. The application of hot tar is 3/10th gallon (U.S.) per square yard and the cover screenings are applied at the rate of 30 lb. per square yard and well rolled in. If, however, it is found that the riding quality is not satisfactory, due to settlement and differential consolidation under traffic after priming, restoration is made by applying road-mix and, again, a suitable road tar is generally used. The general method for road-mixing is that 1/10th gallon (U.S.) per square yard is sprayed on the swept, primed road, then 25 lb. per square yard of ⅜-in. screened pea gravel from local washing and screening plants is spread and sprayed with 2/10th gallon (U.S.) per square yard of road tar or M.C. 3 asphalt. Mixing is carried out by a blade fixed under the body of a 4-wheel drive truck. After mixing and spreading smooth, the pavement is rolled with an 8-ton tandem roller and opened to traffic. Before the next winter, and always in warm sunny weather, the final seal of 0.15 of a gallon (U.S.) per square yard of hot bitumen is applied and, perhaps, a light coating of sand. It was stated to me that this seal is essential to keep water out of the road-mix, and it was also stated to me that the county would prefer to seal all its newly-constructed gravel roads with road-mix, as a stronger and better riding pavement results and, further, no screenings are lost from the surface. As, however, the cost is somewhat more than that of ordinary sealing, and as more skilled labour is required, the county has still to carry out a considerable volume of ordinary sealing.

MICHIGAN.

Oceana County.

In this county some experimental lengths of road-mixed gravel and bitumen on sand formation were being carried out on secondary roads adjacent to Lake Michigan. In general, the method was to mix 3 inches (loose) of gravel and 3 inches of the underlying sand formation with M.C. 2 bituminous material, using a rotary type mixing machine and blade graders. After spreading the gravel, which was of quality suitable for ordinary flush bituminous surfacing, the binder was

Oceana County, Michigan. Experimental length of gravel mixed with sand-formation using asphaltic binder. View after second application, mixing and spreading.

applied from an ordinary truck-mounted sprayer at ½ gallon (U.S.) per square yard for each of three or four applications. After each application the whole of the loose gravel and the subgrade to a depth of 3 inches were churned up by the rotary mixer and then windrowed and spread by blade graders. When a uniform mixture was finally secured (and additional time and windrowing given to aeration) compaction was carried out by multiple-wheeled pneumatic-tyred rollers. The final finish was secured by blade grader and a 6/8 ton tandem roller.

The results of the work so far done seemed satisfactory. The special equipment used is not very costly, this being a mixer of the engine-operated semi-trailer type drawn by rubber-tyred tractor. It needs to be pointed out, however, when considering whether such types of work could be adopted in New South Wales, that the bituminous binder content was approximately 2 gallons (U.S.) per square yard, or 15 gallons (U.S.) per cubic yard of mixed materials.

NEW YORK STATE.

Onandaga County.

A considerable proportion of the mileage of roads in this county, other than State Highways, is constructed of bituminous surface treated gravel. I was informed that these roads stand up to traffic under winter conditions and during the thaw, owing to the care taken in selecting and blending the road gravels.

In general, the pavements are 18 feet wide and the gravel is spread at the rate of 2,000 cubic yards per mile on a flat sub-grade. That is, the cross-fall is provided in the gravel itself, the centre depth being 9 inches. The bank-run gravel is very carefully selected and mixed with either sandy or clayey material to give a P.I. of less than 6 and preferably 4. These gravel roads may be trafficked for a considerable period before they are surface treated, and during such periods maintenance is carried out by grading with a medium-weight motor grader. It was stated that by giving several applications of calcium chloride at the total rate of ¾ lb. per square yard per annum it was possible to reduce the need for patrol gradings to three or four per year.

> The bituminous surface treatment is carried out as follows:—Sweep the road and apply ¼ gallon (U.S.) per square yard of light priming tar and apply 160/180 tons per mile of No. 2 cover stone followed by an application of 3/10th gallon (U.S.) per square yard of heavy retread tar covered with 110/115 tons per mile of No. 1 stone. The final seal is 3/10th gallon (U.S.) per square yard covered by No. 1A stone at the rate of 110/115 tons per mile.

This treatment gives a mat 1 to 1¼ inches thick, which is lightly sprayed the following year and receives no further treatment for at least four years.

On occasions in Onandaga County it is decided to apply a road-mix mat to a gravel pavement rather than give it an ordinary surface treatment. In such cases the pavement is scarified and any required new gravel is added and consolidated. Road-mixing is carried out in the normal manner laid down in the New York State specifications and produces a mat 2 inches thick, which is given a seal coat of 2/10th gallon (U.S.) per square yard of hot asphalt. It was stated to me that the secret of success in the road-mix process is the great care taken to ensure thorough mixing.

When either road-mix or surface-treated county roads need strengthening or smoothing, open-textured plant mixed bituminous macadam is laid by one or other of the various spreading and consolidating machines. A mat thickness of at least 2 inches is aimed at. The hot premixed material is purchased locally from one of a number of commercial plants which have been set up by contractors to meet the local demand for premix.

OHIO.

Near Granville, Ohio, on a road in the Federal Aid Secondary system, I saw work on a length of three miles over which a 6-in. (consolidated) cement-treated, rolled, gravel base was being laid. The subgrades on this three-mile length were A4 and A7, according to the Bureau of Public Roads soil classification and, as stabilization of these subgrades would have required from 14 to 16 per cent. of Portland cement, it was found more economical to treat the bank-run gravel with cement rather than the subgrades.

The non-plastic bank-run gravel obtained locally was mixed in a pug mill with Portland cement at the rate of three bags per cubic yard. The damp mixture was spread directly on the compacted and smoothed, but otherwise untreated, subgrade by a truck-towed spreader and consolidation was effected by an ordinary 10-ton smooth-wheel roller. The base was then left for a curing period under a membrane of bituminous emulsion. Following expiry of the curing period, hot bituminous concrete was to be spread to give a depth of 1½ inches after tamping and rolling.

The actual crushing strength, at twenty-eight days, of a number of test specimens of the gravel-cement base was 2,500 lb. per square inch, and it was considered locally that the road will give satisfactory service for a long period under the expected traffic of 500 vehicles per day with axle loads up to 19,000 lb.

The estimated total cost of the road pavement was given to me as $1.55 per square yard, which may be compared with an estimated cost for a normal cement concrete pavement of $4 per square yard.

No specialized equipment was required and experience showed that there was no need for side forms to confine the gravel-cement mixture during spreading and consolidation.

CALIFORNIA.

State Highway No. 41—Yosemite to Fresno.

The Fresno end of this State Highway passes through almost flat or undulating wheat-lands and, whilst the alignment is good to excellent, the grading has not been improved—in fact, the road very closely follows the natural surface of the country. As traffic is not very heavy in volume and as the soil has an appreciable stone content, a dustless running surface has been provided at a low cost and quite simply by grading-in the natural surface from the sides, mixing it in windrows with S.C., M.C.2 or S.C.3 bituminous binders (according to the weather and other conditions), smoothing out, aerating as necessary by repeated windrowing and spreading, followed by rolling to give a width of 18 to 20 feet.

There are no drainage ditches or culverts for the reasons that rainfall does not exceed 11 inches per year and the road has to carry traffic for only a few years until standard construction is carried out.

California. S.H. 41 near Fresno. Vertical close-up of natural surface prior to "oiling" and mixing.

California. S.H. 41 near Fresno. Low cost "oiled" surface.

CALIFORNIA.

Tuolumne County.

To see an example of the low cost class of rural road construction carried out by the State Highway Commission, I visited a job approximately 12 miles long in undulating to hilly country near Sonora.

The work was nearly complete and, although the road was stated to be a secondary route of the more important market-to-farm type, it had for me the appearance of a country State Highway such as we have in New South Wales. The contract cost worked out at $15,850 per mile.

No bridge structures or large culverts were included in the contract and all the paving material, which is

California, Tuolumne County. Newly completed secondary road with sealed shale pavement.

Southern California. Road in forest park at 5,000 ft. elevation near Idyllwild. Travelling continuous mixer for production of cold mix from local decomposed granite gravel and 6.6% of S.C. 3 asphaltic binder. Output is 1,250 tons in 8 hours.

shaley, was obtained by selection from the spoil from cuttings. This shaley material was spread 26 feet wide to a depth of 6 inches in cuttings and 10 inches on fills respectively, and was then worked over by a grader in order to get the over-size material to the sides of cuttings or down the batters of fills. The 26-ft. width was then repeatedly watered and rolled and, when dry, was primed with ¼ to ½ gallon (U.S.) per square yard S.C.1 or S.C.2 asphalt. The seal consisted of ¼ gallon (U.S.) per square yard of normal 85/100 asphalt, and the cover material was ⅝-in. crushed metal applied, dragged and rolled in the usual way.

Southern California. Park road near Idyllwild. Spreading (and aerating) cold mix by power grader. After rolling, thickness of finished cold-mix course is 3 inches

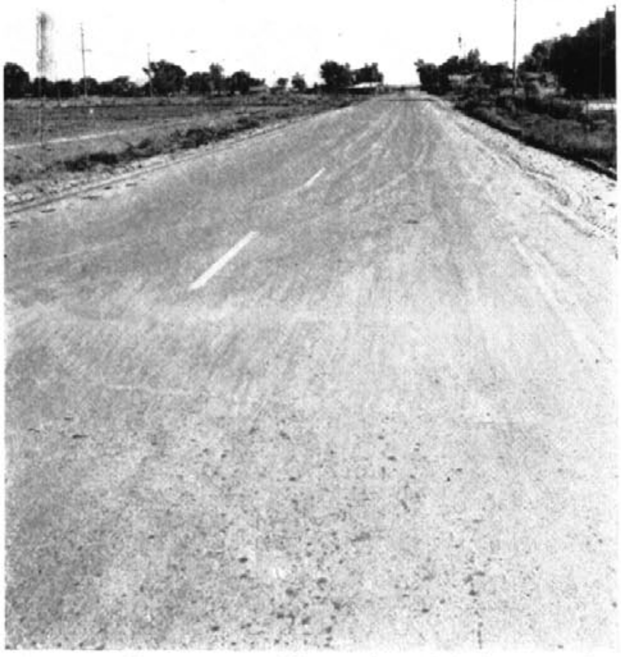
It is of interest to note that the selection of shale from the cuttings for use in the pavement was decided by the Hveem Stabilometer method. Also, the cross-section in box cuttings provided a width of 30 feet, the outer 2 feet on each side being for drainage purposes with invert 1 foot lower than the edge of the surfaced 26-ft. carriageway. On fillings the top width was 26 feet, the whole of which was surface treated.

ARIZONA.

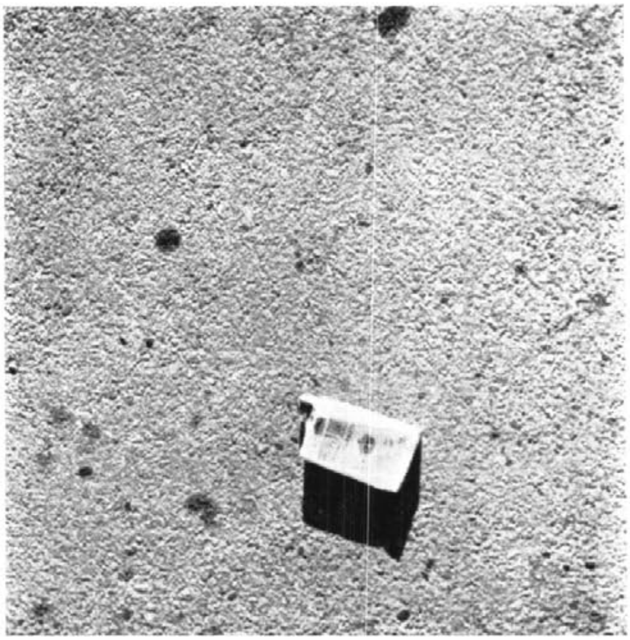
Southern Sandy Area near Yuma.

In the above area where rainfall rarely exceeds three inches per annum and gravel deposits are very scarce, the State Highway Commission has been resurfacing old black-top sections of State Highways and constructing new pavements, using dune sand plant-mixed with asphalt. The first work was done in 1946 and the pavements so treated or constructed have stood up successfully under mixed traffic arising from irrigated farming areas and, of course, under some through traffic, including heavy buses and semi-trailers.

Full technical details of the method and specifications were kindly supplied to me but, in principle, the method is to obtain local dune sand with 8 to 15 per cent. of —200 content and use this for the formation and sub-base, consolidating (or rather setting) it with water and rubber-tyred rollers. On this is placed a machine-mix of dune sand (with 6 to 10 per cent. under 200 mesh) and 3½ to 4½ per cent. by weight of R.C.3 asphalt. The finished depth of the dune sand asphalt mix is 2 inches to 3½ inches depending upon the degree of "set up" in the sub-base sand and also upon the expected traffic. After careful rolling (to avoid pushing) of the mix it is sealed with S.C.6 binder or, preferably, hot fluxed 85/100 bitumen with "pea" gravel cover aggregate.



Arizona, Yuma area. View of sealed dune sand-asphalt pavement on sand formation.



Arizona, Yuma area. Close-up of sealed dune sand-asphalt pavement.

The chief advantage of this type of work is that only local materials are required, *i.e.*, there is no addition of either limestone dust or Portland cement. If fine material is required in order to bring the grading of the sand, either for sub-base or sand-asphalt, within the limits set out above, a non-plastic river silt available in the vicinity is used.

Another advantage is that the thickness of sand-asphalt can be adjusted to the value of the underlying dune sand as a supporting base. For success, close engineer supervision and skilled workmen are required in addition, of course, to a suitable travelling type mixer and a range of rollers.

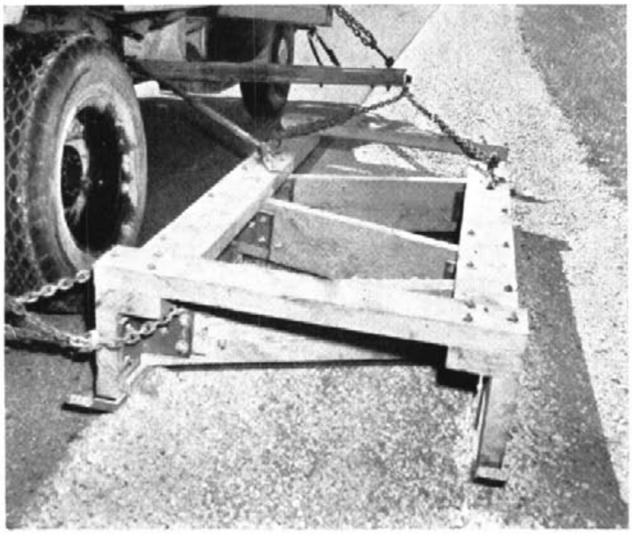
It is of interest to note that none of the sand-asphalt mixes so far used in the Yuma area was acceptable according to the standard stability and strength tests. But, nevertheless, the appearance and service history of the older lengths (laid down in 1946) suggests that the pavement is stable under present conditions.

I was informed locally that any dune sand free of clay balls which will carry a car when the sand is well watered, can be satisfactorily mixed with asphalt to form a pavement surface course. It was added, however, that in the absence of quantitative tests in the laboratory, considerable trouble and perhaps some failures must be expected before reliable mixes are arrived at. In the case of the Yuma sands and sand/silt mixtures, just sufficient binder (within the range given above) is used to give a mixture which has a chocolate-brown colour in bright sunlight, but all mixes of this colour are given the A.S.T.M. swell test. Those samples which show more than 0.065 inches on a 3-inch cylinder are rejected.

MAINTENANCE.

The need for low-cost construction and long mileages of such construction implies need for low-cost maintenance. In this field U.S. Highway Engineers have been very active and have devised methods and improvised or adapted equipment which keep down maintenance costs and so make "the low-cost road" a sound investment.

In the first place, maintenance requirements and methods are given consideration in the survey and design stages and then there is insistence upon specifying good quality materials, whether local or "imported," with equal insistence upon testing and skilled supervision.



Ohio. Shoulder drag on outrigger from maintenance truck, working on a State Highway.

Photo. by courtesy of Bureau of Public Roads, Washington, D.C.

Ohio, Knox County. Improvised mobile unit for production of semi-hot mix for maintenance purposes. View is of concrete mixer drawn behind maintenance truck carrying aggregate.

Photo. by courtesy of Bureau of Public Roads, Washington, D.C.

From these bases, and notably aided in many cases by adequate policing of weight of load regulations, the maintenance engineer proceeds to ensure that the road is not diminished in service or asset value. Drainage is given the full necessary attention, using graders, simple ditchers and loaders. Resheeting and resealing are carried out before pavements show signs of distress and by using good-quality materials only in the most suitable weather conditions, the intervals between general resheetings are increased. Shoulders are kept to width, level and cross-fall and free of water and traffic erosion by means of power mower, drag and patrol grader or 4-wheel drive truck with under-body grading blade. This latter item of plant is a most useful unit by itself or with a simple drag attached for rear or side operation. Added to the still pre-eminent medium-weight motor patrol scarifier grader, the truck with under-body blade forms a sound nucleus for low-cost maintenance of a length of road. Specialised labour-saving equipment might be hired or purchased for a sufficiently large pavement maintenance or strengthening job, but even in the production of appreciable quantities of cold-mix for patching or resheeting, the possibilities of the ordinary one-bag concrete mixer and the patrol grader have been seen and exploited. Examples of the use of these machines for maintenance patching and correction of riding quality and strengthening were seen in Ohio and Arizona. In the latter

Arizona. Roadside production of maintenance cold-mix. Outer circular windrow is of finally mixed materials.

State, use of the motor grader and the ordinary bitumen pressure sprayer for the production of cold-mix in "circuses" on flat ground adjoining the highways was a very striking demonstration of the reduction of maintenance cost through maximum use of normally available equipment.

Bridge Building in New South Wales

Part II. Early Timber and Iron Bridges

In Part I of this article, which appeared in the December, 1950, issue of *Main Roads*, was given a brief description of the building of stone bridges in early New South Wales, with particular reference to those constructed between 1832 and 1840 by David Lennox. The purpose of this part of the article is to describe the story of the building of timber and iron bridges in New South Wales, from the days of the first settlement in 1788 to the close of the nineteenth century—a period of just over 100 years.

EARLY TIMBER BRIDGES.

Reference has been made in Part I of this article to the first bridge in Australia, that built over the Tank Stream in 1788 near the present site of Bridge-street, Sydney.

Major Grose is credited with the erection of one of the earliest timber bridges in New South Wales. The bridge was built by convict labour over the Parramatta River at Parramatta in 1794, but was swept away by floods in 1802.

Improvements to the road from Sydney to Parramatta were being effected in 1797 and it was at this time that the first bridge over Duck River was built. By 1805 the road was again in bad condition and a public subscription was made towards its improvement. In the *Sydney Gazette* of 8th September, 1805, the following notice appeared:—

> "Wanted immediately to be erected, Ten Bridges upon the road leading from Sydney to Parramatta, viz.:—
>
> 1. Between Grose Farm and Major Johnston's.
> 2. Opposite Major Johnston's paling.
> 3. Corner of White's Farm.
> 4. At the foot of Prentice's Hill.
> 5. Corner of Captain Rowley's Railing.
> 6. Next to Hacking's Creek.
> 7. Hacking's Creek.
> 8. Blanket's Bridge.
> 9. Captain McArthur's Creek.
> 10. Beckett's Bridge.
>
> The above bridges are to be 16 feet wide with Four Sleepers of at least a foot and a half in diameter, either of ironbark, or blue gum, bedded on timber of the like dimensions, to be covered with three inch plank, 16 feet long and properly secured by truncals of 1½ inch diameter.
>
> The timber and plank to be prepared by the Contractor as near to the respective spots as possible; after which it will be conveyed there at the expense of the Road Committee.
>
> Any persons willing to undertake the above work or a part thereof are requested to give in sealed tenders to me on or before the 30th instant, stating how much per square they are willing to complete it for; And to find proper Security for its due performance, for which they will be paid in cash or approved bills.
>
> By Order of the Committee.
>
> G. Blaxcell, Treasurer."

In 1810 the Tank Stream was bridged at a second place with a timber trestle structure. There is no record of the designer of the bridge but it was probably built under the direction of Captain Augustus Alt, the first colonial engineer, who assisted Governor Phillip in the laying out of the settlement.

William Cox in his epic building of the road over the Blue Mountains in 1814, constructed two bridges over the Lett and Cox's Rivers. On the 6th December, 1814, Cox "examined the river and rivulet up and down, and fixed on a site over each as being less trouble and more economical than making one bridge over the river." The first bridge which spanned the Lett River was 22 feet long and 13 feet wide and was completed within two days. "The carpenters, etc., made a good strong job of it."

On the following day the men were at work procuring timber for the second bridge, and were obliged to bring most of it down the river. Six men who were in the water nearly all day were recompensed by a gill of spirits each. This bridge which was 45 feet long and 14 feet wide, was also completed in two days. It was a strong structure, with a causeway on each side filled with stone and covered with earth.

The pontoon bridge built over South Creek at Windsor in 1802 by Andrew Thompson, referred to in Part I, was replaced by a timber structure in 1813 by the trustees of Thompson's estate. This bridge, 214 feet long, supported by four rows of piles, stood 24 feet above flood level and was the largest bridge in New South Wales at the time. It took seven months to build and was named after its builder "Howe's Bridge." In 1830 the bridge was rebuilt, and in 1848 was replaced by the Fitzroy Bridge, named after, and opened by, Governor Fitzroy. This bridge, in the form of a timber arch, was replaced in 1880 by an iron structure which is still in use.

In 1826 a timber bridge was constructed over the Nepean River at Bird's Eye Crossing near Menangle. It was designed and built by a convict named Wainwright. A bridge to carry the railway was built on this site in 1861.

The Nepean River Bridge, Penrith.—At Penrith the earliest means of crossing the Nepean was by ferry. Settlement around Emu Plains and Penrith before long rendered the ferry inadequate and in January, 1856, the first bridge was opened by Governor Fitzroy.

Wrought Iron Box Girder Bridge Built in 1897 over Nepean River, Penrith, Great Western Highway. Originally carried Railway but converted to road use in 1907.

The *Sydney Morning Herald* of 2nd January, 1856, records, "The opening of the Victoria Bridge, built across the Nepean River at Penrith, was celebrated yesterday (New Year's Day) in a manner worthy of a great national work by private enterprise (The Nepean Bridge Co.). The bridge spans the river in one of the noblest reaches, the breadth being 700 feet and the total width thirty feet. The structure of the bridge is very plain. It is indeed without ornament at all. It is composed almost entirely of the ironbark of the colony and will cost, finally completed, about £10,500. . . . Mr. John Perry proclaimed the bridge to be henceforth open to the public on paying the respective tolls."

Despite its propitious opening the Victoria Bridge did not enjoy a long life; it was washed away by floods in the following year. The bridge was re-erected but was swept away again in 1860. Crossing by ferry was resumed until 1867, when the most severe flood in the history of the district up to that time caused the water to rise to the centre of the present site of Penrith, this time carrying away even the ferry.

The position was ameliorated in 1867 when a bridge was opened to carry the extension of the railway from Penrith to Weatherboard (Wentworth Falls). The bridge was sufficiently wide to carry a single line of road traffic as well as the railway. An electric bell gave audible notice that the road was occupied to anyone at the farther end. It was commented that "the bridge is said to be unique, but the bell is proven erratic and is a gurgling tremulo as terrifying to the unitiated horse as the sound of the train itself." The bridge was given wholly to road traffic in 1907, when a new railway bridge was opened, and is still in use.

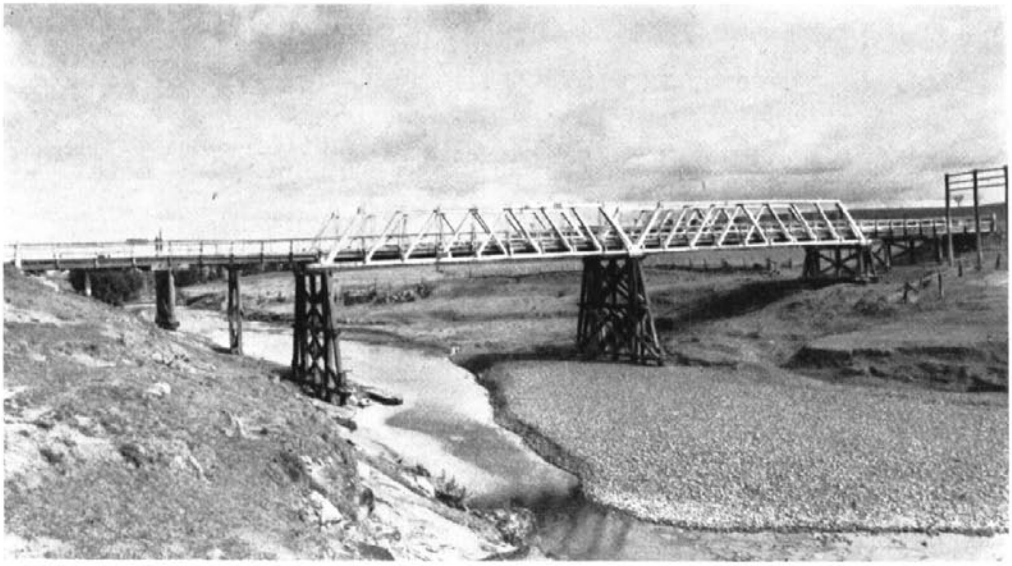
Although the bridging of streams had proceeded steadily during the first half of the nineteenth century as settlement extended throughout the State, it was the second half of the century which saw numerous bridges constructed mainly by the Public Works Department which had been established in 1858.

Captain Martindale's Report.—Captain Martindale in his report in 1859 on Internal Communication of New South Wales reported that on the Main Southern Road alone thiry-seven bridges had been completed that year or were under construction. "The Berrima bridge and the Mulwaree Ponds bridge have been completed and opened; and the necessary drawings and specifications will be put in hand for those over the Wollondilly and at Bungonia." Apparently staff problems were even acute in those days, since the report states "as soon as any officer can be spared to prepare them." The report goes on, "the Government having decided, after considering my report upon the bridge to be constructed over the River Murray at Albury, that the structure should be of wood, and erected at the Wodonga Street site, the approaches can now be proceeded with, and the necessary plans and specifications for this service are in hand. Revised plans for the bridge are also in hand. . . ."

The timber trestle bridge over Mulwaree Ponds at Goulburn was built in 1855. The reference to the completed work at Berrima bridge is to extensive repairs carried out following serious damage in a heavy flood in 1858. The construction of this bridge is described in Part I of this article. The first bridge over the Murray River at Albury was built in 1861.

At Richmond a low-level timber bridge was erected in 1860 over the Hawkesbury River to connect Richmond and Kurrajong. It was constructed by a company formed for the purpose, called the Richmond Bridge Company. The bridge was a low-level structure of 19 spans and was 537 feet long. Tolls were collected on this bridge until it was taken over by the Government in 1876. In 1890 it was repaired at considerable expense and in 1906 was replaced by a reinforced concrete structure, still in use.

Standard Timber Designs.—The creation of a Public Works Department in 1858, ushered in a period of widespread activity in bridge building in New South Wales, which was notable for the extensive use of New South Wales timbers in truss spans, many of which still exist.



Timber Truss Bridge over Glennie's Creek north of Singleton, New England Highway. Built in 1895 by Public Works Department. Length of spans, 90 feet.

A standard design for timber bridges of one piece principals and top chords with single suspension bolts passing through the chords with spans of 60 to 100 feet was introduced and followed up to 1886. A bridge of this type was built over the Mann River on the Grafton-Glen Innes road in 1877. The bridge which still stands consists of four 90 feet truss spans with one plain beam approach span. It is 383 feet long with a deck width of 14 feet.

Another bridge of this type was built over Cockfighter Creek at Warkworth on the Singleton-Jerry's Plains road in 1871. In 1930 it was flooded to a depth of three feet above the top chord of the truss. The bridge withstood the ravages of time until June, 1949, when it was washed away by heavy floods.

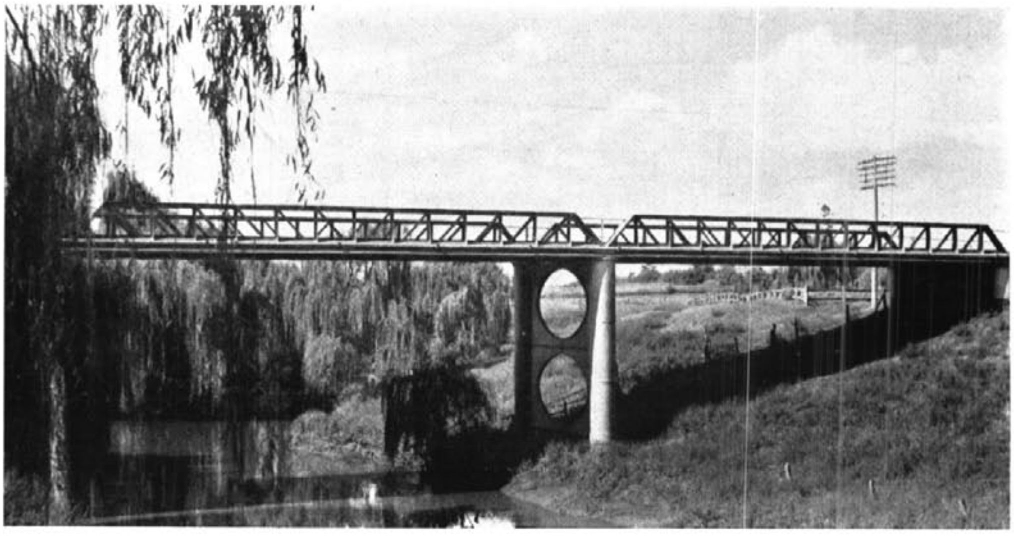
In view of the increase in settlement and the greater risk of structures being subjected to heavier loads, a new type of truss for 90 feet, 75 feet and 65 feet spans was introduced. The new design featured a double principal truss, with double suspension bolts and haunches and wedges at the feet of the braces. Bridges of this type were erected at Denman in 1884 and at Kynnumboon over the Tweed River. The latter has since been replaced. The bridge at Denman is now due for replacement.

Further improvements to standard timber bridge design were effected in 1893 with the production of a new design for a truss, having open top and bottom chords, double principals, no wedges at the feet of the braces and cross girders only at the suspension bolts. Spans for this design were 70 feet and 90 feet. Another feature of the design was the introduction of cast iron shoes top and bottom for the diagonal bases to butt on.

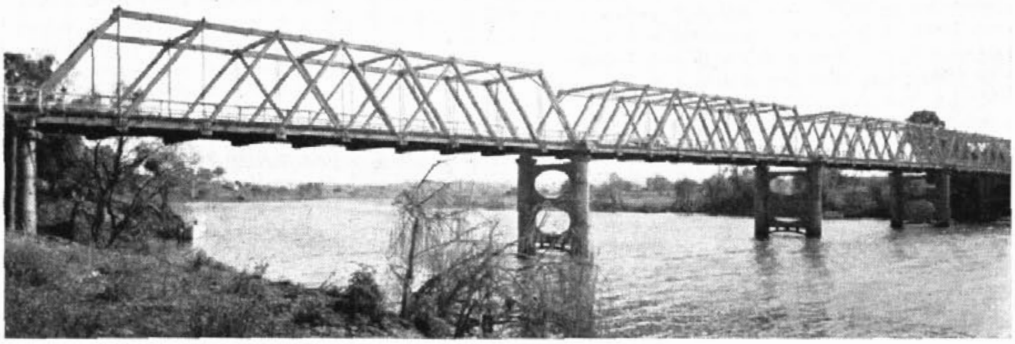
The new design was used for the erection of many bridges throughout the State including the existing bridge over the Wingecarribee River at Berrima. A modification of the design was used for a number of other bridges including that of the existing bridge over the Murrumbidgee River at Wagga.

The bridge over the Murrumbidgee River at Wagga had an interesting history. A bridge had been constructed by Victoria over the Murray River at Echuca

Wrought Iron Truss Bridge over South Creek, Windsor (M.R. 184). Built in 1879 by Public Works Department.



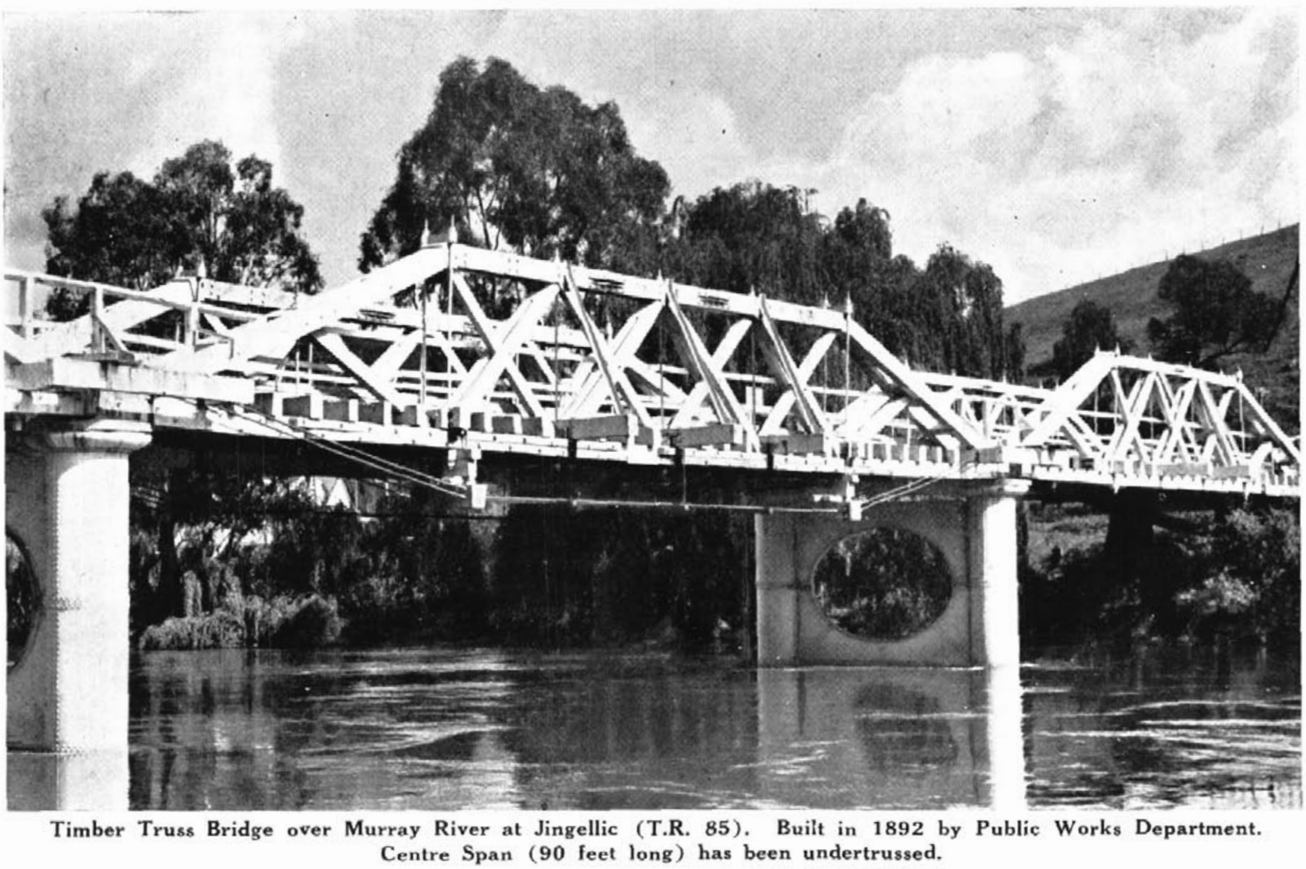
Timber Truss Bridge over Macleay River at Kempsey. Built in 1900 by Public Works Department. Trusses are the longest ever erected in New South Wales, being 154 feet long. Trusses will shortly be replaced by Steel Trusses on the same piers.



in 1861. As a result of this Melbourne merchants began to take over trade with the settlers on the New South Wales side of the river, to the concern of Sydney merchants, who joined forces with a local agitation at Wagga and other settlements in the Riverina and founded a joint stock company with the object of erecting a bridge over the Murrumbidgee River at Wagga. The bridge which was built in 1864 was of timber supported on three piers and 636 feet long. The bridge was replaced by a new structure consisting of six timber trusses on iron piers in 1895. This is still in use.

In 1899 a new standard design was produced for a composite truss with timber vertical struts and timber upper chords, steel lower chord and wrought iron diagonal tie rods. An outstanding example of this type is the bridge over the Macquarie River at Dubbo which was constructed in 1904, and is still in use. It replaced a timber truss bridge which had been built in 1863.

The bridge built with the longest timber spans in Australia is that over the Macleay River at Kempsey, opened to traffic in April, 1900. This structure with its truss spans resting on cylindrical iron piers is 920 feet



Timber Truss Bridge over Murray River at Jingellic (T.R. 85). Built in 1892 by Public Works Department. Centre Span (90 feet long) has been undertrussed.

long. On completion of the bridge a test load of 108 tons of road metal was spread over one span, the recorded deflection being seven-eighths of an inch, and upon the removal of the road metal, the span recovered its original position. The timber trusses are about to be replaced by steel trusses.

The 1899 standard was used until the introduction, in 1904, of a design of composite trusses, with timber upper chord and diagonal struts, steel lower chord and wrought iron vertical tie rods.

IRON BRIDGES.

Although iron bridges had been introduced into England in 1776 when the cast iron bridge over the Severn River at Coalbrookdale was built, iron was not used in bridge construction in New South Wales until many years after the colony was founded and even then its use was not extensive.

This was due to the wealth of strong durable Australian hardwood timbers, which were admirably suited for use in bridge construction, the distance of Australia from the overseas markets, and the delay and expense involved in the importation of materials.

Iron had been introduced into bridge designs in New South Wales in the second half of the nineteenth century and was being used entirely in some structures and for piers in others. It was put to its greatest use in bridging navigable waters such as the coastal rivers used by masted vessels and the western river system, embracing the Darling, Murray and Murrumbidgee Rivers used by river steamers and barges.

It is not proposed in this article to describe all bridges built, but rather to select examples of the different types with some historical significance.

As early as 1835 the use of iron for a bridge was suggested when Governor Bourke proposed that the wooden bridge over the Parramatta River at Parramatta be replaced by an iron bridge, the material for which was to be sent out in convict ships. The suggestion, however, was not acted upon. David Lennox being commissioned to build the stone structure which was completed in 1839.

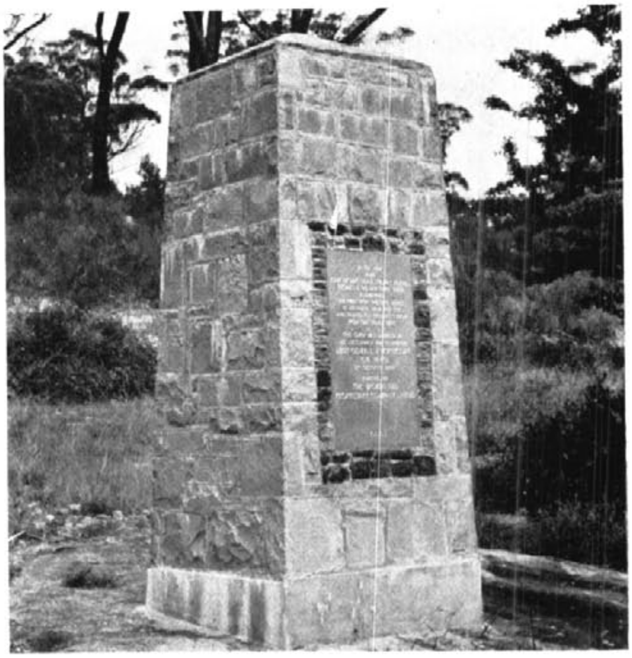
Fitzroy Iron Works.—1833 was a significant year in the industrial history of the colony for it was then that Surveyor Jacques discovered a deposit of iron in the Mittagong district. This was to be the pioneer of iron industry in this country and the first place in Australia where iron was smelted.

The discovery was not exploited until 1848. The settlements of Nattai, New Sheffield, Fitzroy and later Mittagong itself grew up around the Fitzroy Iron Works, named after Governor Sir Charles Augustus Fitzroy. The fortunes of the venture fluctuated under different companies until operations ceased in 1857.

The ore at Mittagong was rich in comparison with British ore, and in 1859 a further attempt at its exploitation was made with the launching of the Fitzroy Iron Works Co. However, little was done until the opening of the Great Southern Railway reawakened interest in the company which received orders for the rails.

In December, 1863, bar iron, the first product of the new company, arrived in Sydney. In August, 1864, it was announced that a contract had been secured by the company for the casting of cylinders and other iron works for a bridge to be built at Gundagai: "They are at present casting some girders and amongst other things have contracted for and cast some tubular piers . . . for one of the public bridges." (Henry Burton Bradley—"Journal of Legislative Council," Vol. 12). The casting of the first of the Gundagai Bridge cylinders was marked by a ceremony, and on 23rd February, 1865, a large party of prominent people, including the Governor, Sir John Young and Lady Young, attended the works to witness the process. "Much importance is attached to the work now commenced, this being the largest casting of iron yet made, and also the first application of our iron to cylinders for bridge piers." (Feb. 25, 1865, *Sydney Morning Herald*). The cylinder was six feet long, six feet in diameter and 1⅛ inches in thickness, it was cast in one piece and weighed two and a half tons.

Success, however, seemed not to smile upon the Fitzroy mine. Imported pig iron at this time was selling for £5 or less per ton and the Fitzroy Iron Works could not stand the competition. On 22nd April, 1866, the works closed down and were never reopened.



Monument adjacent to Hume Highway near Mittagong on site of Australia's first Iron Foundry.

An obelisk erected by the Royal Australian Historical Society on the outskirts of Mittagong, and unveiled by Lieut.-General Sir John Northcott, Governor of New South Wales, in October, 1948, marks the site of this, Australia's first iron foundry.

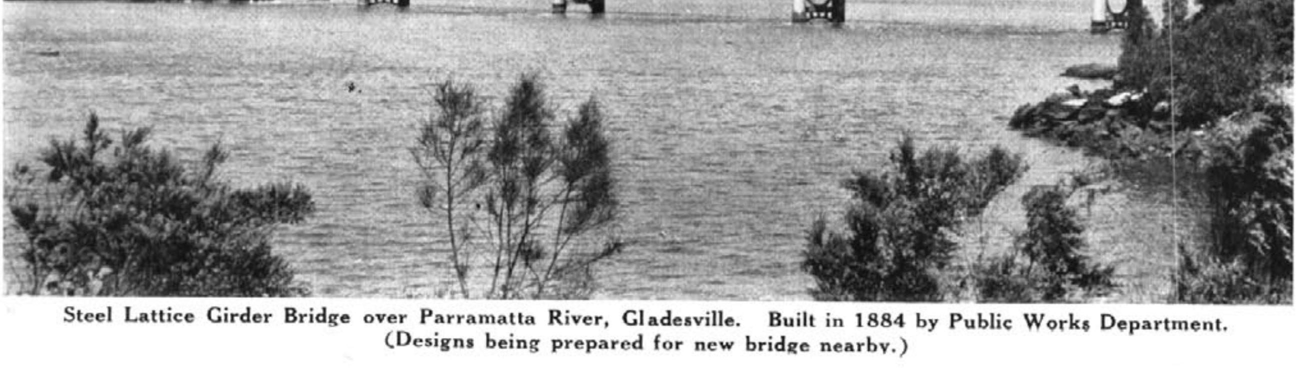
Murrumbidgee River Bridge, Gundagai.—The bridge at Gundagai, referred to, was the bridge constructed over the Murrumbidgee River at Gundagai in 1865. Settlement at Gundagai commenced about 1836. In 1844 the locality was flooded, and in the great flood of 1852, eighty lives were lost and all the flat on the northern side of the river was inundated to a depth of up to 15

Wrought Iron Continuous Truss Bridge over Murrumbidgee River, Gundagai (Hume Highway). Built in 1866 by Public Works Department. Photo taken in 1896 when old timber approach spans were rebuilt.

feet. After the flood, the first land sale was held in November, 1853, and a new town grew on the higher ground overlooking each bank. In September, 1858, Captain Francis Cadell ascended the Murrumbidgee to Gundagai in a steamboat.

The need for a river crossing for the townspeople and travellers following the route of Hume and Hovell to the Riverina and Victoria now became pressing, and the bridge designed in 1865 was of a substantial nature. The bridge consisted of three wrought-iron girder spans of 103 feet each over the main channel of the river. On the south there were two timber beam spans, each of 30 feet, and on the northern side there were twenty-three timber beam spans, each of 30 feet. However, the timber approach spans on the northern side were submerged whenever flood waters covered the flats on the northern bank of the river. The principal spans are still the same in form as when erected in 1865.

In 1896 the approach spans were reconstructed. On the northern approach the original timber spans were abandoned and were replaced by a high-level approach consisting of seventy-five timber beam spans of from 35 feet and one of 28 feet. The total length of the bridge after construction was 3,025 feet.



Steel Lattice Girder Bridge over Parramatta River, Gladesville. Built in 1884 by Public Works Department. (Designs being prepared for new bridge nearby.)

One of the earliest iron bridges erected in New South Wales was that built in 1851 over Wallis Creek connecting East and West Maitland. It comprised three spans of iron girders and was 100 feet long.

The Macquarie River at Bathurst was re-bridged with an iron structure in 1870 when the existing bridge was opened to traffic. This was built, apart from the heaviest of the plates, from materials produced in New South Wales at the Pyrmont Rolling Mills from iron obtained from the Fitzroy Iron Works. The bridge replaced a timber structure which had been destroyed by floods in 1867.

Iron Cove, an arm of Sydney Harbour, was bridged in 1884 with a wrought-iron lattice girder bridge. When a second tram track was placed on the structure in 1935, the existing cross girders were strengthened and rolled steel joists were inserted between the original timber stringers. This bridge is now being replaced by a steel and concrete structure.

In 1888 an iron bridge, 465 feet long, was built over the Murrumbidgee River at Taemas. When the Burrinjuck Dam was constructed it was found necessary to raise the level of the bridge and to extend it and this work was completed in 1924. It was then 855 feet long, consisting of twelve timber approach spans and the three original iron truss spans. It was destroyed in 1925 when a record flood overtopped Burrinjuck Dam. A new bridge consisting of four 150 feet steel truss spans and two 45 feet rolled steel joist spans was erected in 1931.

Suspension Bridges.—It was not until the 1890's that New South Wales saw its first suspension bridge. Two important structures of this type which were built at that time were the bridge over the arm of Sydney Harbour known as Long Bay, at Northbridge, and the bridge over the Kangaroo River in Kangaroo Valley.

The bridge at Northbridge, built in 1892, was designed for light vehicular and pedestrian traffic, but for many years was little used. In 1937, on account of deterioration of the suspension span, it was replaced by a reinforced concrete arch. The sandstone towers of the original structure were retained. The original bridge consisted of a suspension span 500 feet centre to centre of towers, and anchor spans of 125 feet at the northern end and 150 feet at the southern end.

The first bridge over the Kangaroo River in Kangaroo Valley was a timber structure, built in 1879. The suspension bridge which was completed in 1898 and still exists, is one clear span of 252 feet. Local sandstone was used in the massive towers of masonry on each bank. The new bridge was named the Hampden Bridge and was opened by the Honourable J. H. Young, Minister for Public Works, on the 24th May, 1898. "Old stumps had been cleared and all lumber and debris removed, and as far as time would allow, nothing unsightly was allowed to remain in the vicinity to mar or obstruct the beauty of the magnificent structure, and there was little evidence to denote the fact that for two years it had been the site of a large number of workmen." (*Kangaroo Valley Times*, 24th May, 1898.)

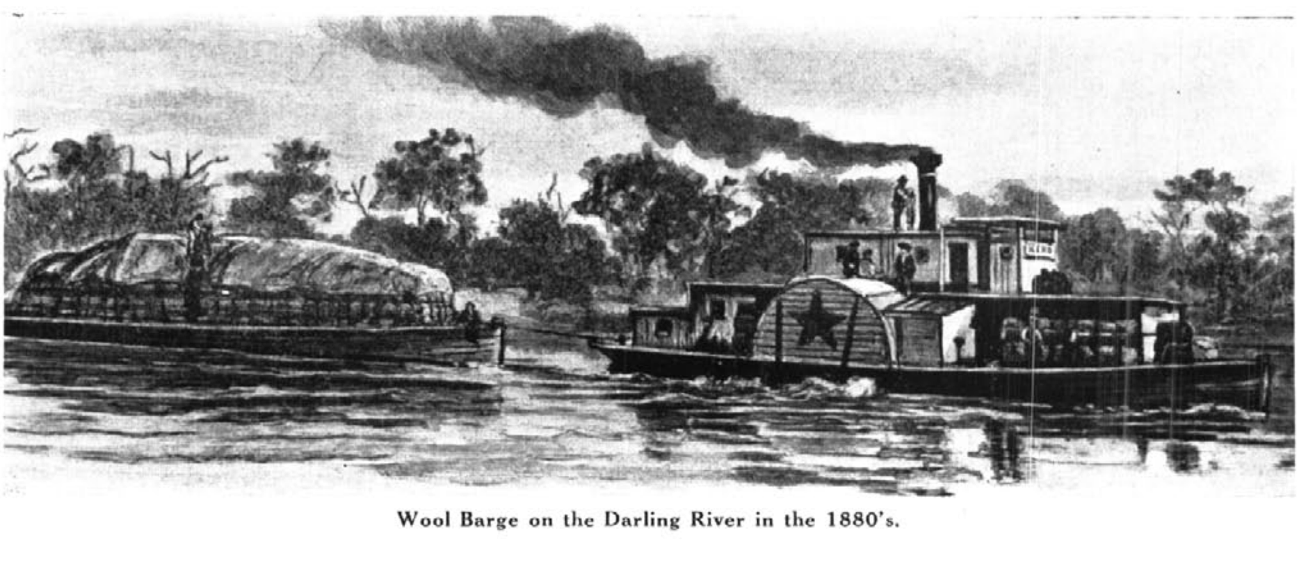
The old bridge, which was to be removed as soon as the new one was completed, was washed away by floods six days after the new bridge was available for traffic.

MOVABLE BRIDGES.

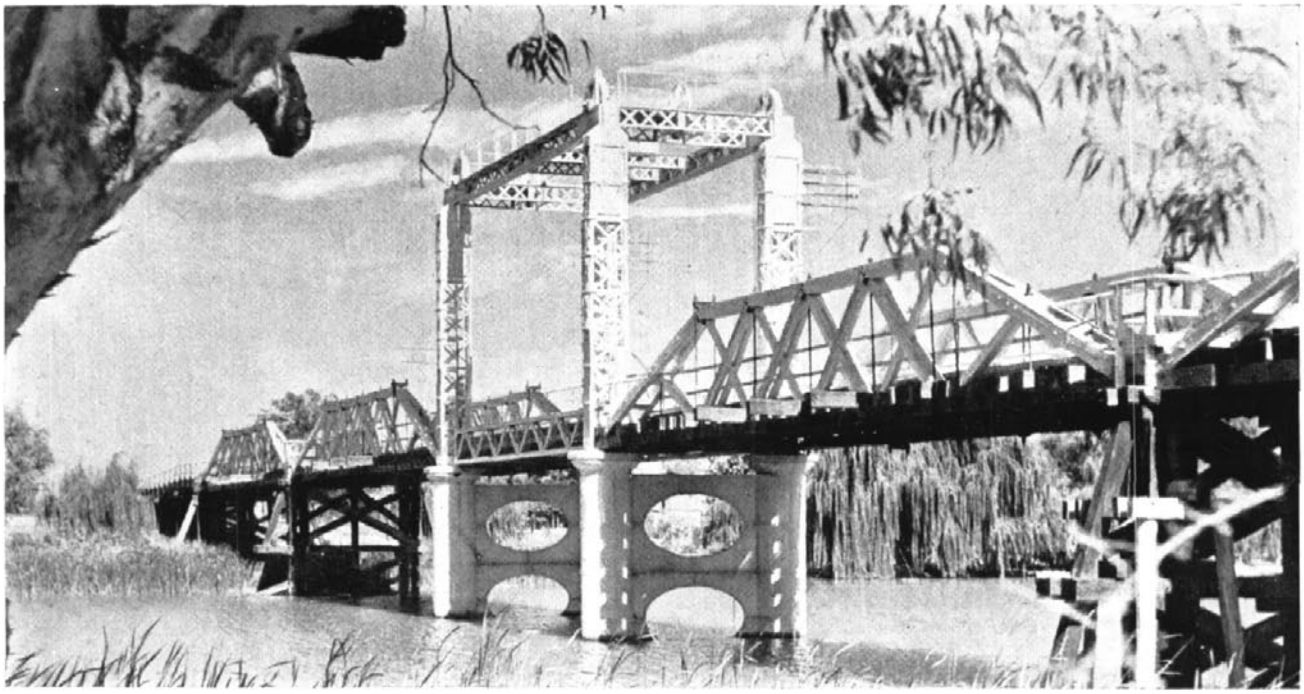
The Inland Rivers.—At most of the sites where bridges have been erected over the navigable inland rivers the banks are low, so that a fixed bridge with sufficient headway, even with graded approach spans, would have been of such length as to be too costly for the service provided. River traffic consisted of barges of small draught but large dimensions, in tow of steamers with low funnels requiring from 19 feet headroom on the Barwon or Upper Darling to 26 feet on the Murray at the time of maximum flood.

The bridges erected over the inland rivers each included an iron opening span of the vertical lift type, counterbalanced at each corner and giving a clear opening of about 52 feet horizontally, and 40 feet above summer water level vertically when the span is raised to its full height.

In 1872 a pontoon bridge had been built by a private company over the Barwon River at Brewarrina. Tolls



Wool Barge on the Darling River in the 1880's.



Timber Truss Bridge with vertical lift opening span over Darling River at Wentworth. Built by Public Works Department in 1893.

were charged—one shilling per bale of wool, other goods ten shillings per ton, and sheep thirty shillings per 1,000 up to 10,000 when the rate was £1 per 1,000. A bridge with a lifting span of iron was built in 1888. The lift span weighs 20 tons and the iron hollow towers at the four corners of the lift span are connected at the top by transverse and longitudinal girders, thus preventing the towers moving inwards and jamming the lift span when raised. The bridge is still in use.

Iron lifting-span bridges were erected as early as 1883 at Bourke on the Darling River and at Balranald on the Murrumbidgee River. Similar structures were erected over the Murray River at Mulwala in 1893, and at Tocumwal in 1895; over the Darling River at Wentworth in 1893, and at Wilcannia in 1896. These bridges, other than that at Mulwala, still exist.

Sydney and Its Environs.—In the first half of the nineteenth century a timber bridge with a swing span had been built over a creek known as Blackwattle Creek which flowed into Blackwattle Bay. The bridge was located about the present site of Wentworth Park. The bridge provided access to and from the city and the swing span was to allow barges to gain access to a low lying swampy area, which was being filled in. Pedestrians using this bridge were charged a toll of ½d. each. This was the first movable bridge built in the colony of New South Wales.

The need for a bridge to cross Rozelle Bay from Pyrmont to that portion of Balmain previously known as Glebe Island was becoming a pressing necessity in the 1850's and to meet this need a timber bridge with a swing span, constructed mainly of Tasmanian blackbutt, and known as Blackbutt Bridge, was built in 1857. The steady increase in traffic over the years led to agitation for a better structure and a new bridge, which exists at present, was built in 1901. It consists of two fixed steel truss spans and an electrically operated central swing span. The total length of the structure is 354 feet, and at each end filled approaches extend for a length of several hundred feet to the shores.

The first bridge linking Pyrmont and the City across Darling Harbour was constructed in 1859 by a company formed for the purpose. The bridge was a timber structure, with a swing span, similar to that erected to Glebe Island. It was a toll bridge, pedestrians paying 1d., horses 3d. and 4d., and heavier traffic on an ascending scale. The bridge was taken over by the Government in 1884 (£40,000 being paid to the company) and after a short period the tolls were removed.

In 1891 the need for a new bridge across Darling Harbour was apparent. Construction was commenced in 1899 and the bridge was opened to traffic on the 28th June, 1902. It comprises twelve 82 feet long timber truss deck spans, each consisting of six ironbark timber trusses spaced at 9 feet centres, an electrically operated steel opening swing span 222 feet long and three 30 feet spans of steel girder and buckle plate construction in approach on the city side. The overall length of the structure, excluding built-up approaches between retaining walls, is 1,208 feet. This bridge is still in use, the deck having been removed and replaced by reinforced concrete construction in 1948.

Iron bridges with swing spans were constructed also over the Parramatta River between Gladesville and Drummoyne in 1883 and over the Lane Cove River at Fig Tree in 1885. Both bridges are still in use.

In the 1890's several bascule or end lift opening bridges were erected in New South Wales. The lift and towers were of timber. An example of this type of bridge was that over Shea's Creek (Alexandra

Canal), known as Ricketty-street Bridge, built in 1895. This structure consisted of a timber draw span of 43 feet and timber beam approach spans on driven pile piers. The bridge was replaced by a fixed concrete structure in 1937.

CONCLUSION.

Although this article has been confined in general to the eighteenth and nineteenth centuries, it is perhaps appropriate to conclude with brief reference to the Sydney Harbour Bridge, since schemes for bridging the Harbour had been considered almost from the inception of the colony. In 1815 Francis Howard Greenway, the first architect to practise in Australia, in a report to Governor Macquarie, proposed the building of a bridge from Dawes Point at the city's edge to the northern shore. The earliest recorded drawing of a bridge was made in 1857 by a Sydney Engineer, Peter Henderson. Positive action towards building a bridge was taken in 1900 when designs were prepared and tenders called. However, before any decision was reached the proposal lapsed.

In 1922, legislation was passed authorising the construction of a bridge from Dawes Point to the northern shore at Milson's Point. The work was commenced in 1923 and the bridge opened to traffic on the 19th March, 1932. The structure comprises principally a steel arch span of 1,650 feet across Sydney Harbour and five deck truss approach spans leading to the arch on each side. The total length of the arch span and steel approach spans is 3,770 feet.

ACKNOWLEDGMENTS.

Material for this article has been obtained from—

The Public Library, New South Wales.
The Mitchell Library, New South Wales.
The Royal Australian Historical Society.
Australasian Engineer, November, 1939.
Open Road, November-December, 1932.
Industrial Australian and Mining Standard, August-September, 1924.
Proceedings of Institution of Civil Engineers, 1903-4.

PAYMENTS FROM THE ROAD FUNDS FOR PERIOD 1st JULY, 1950, to 30th JUNE, 1951.

	Amount Paid.
COUNTY OF CUMBERLAND MAIN ROADS FUND:	£
Construction and reconstruction of Roads and Bridges	771,983
Acquisition of Land and Buildings for Road Widening	59,392
Maintenance and minor improvements of Roads and Bridges	756,427
Interest, Exchange and Repayment of Loans	69,278
Other Expenditure	185,461
Total	£1,842,541
COUNTRY MAIN ROADS FUND:	
Construction and reconstruction of Roads and Bridges	1,376,333
Acquisition of Land and Buildings for Road Widening	19,200
Maintenance and minor improvements of Roads and Bridges	3,029,350
Interest, Exchange and Repayment of Loans	146,484
Purchase and repair of Plant and Motor Vehicles	590,117
Other Expenditure	315,418
Total	£5,476,902
DEVELOPMENTAL ROADS FUND:	
Construction and reconstruction of Roads and Bridges	46,076
Other Expenditure	311
Total	£46,387
SUMMARY ALL FUNDS:	
Construction and reconstruction of Roads and Bridges	2,194,392
Acquisition of Land and Buildings for Road Widening	78,592
Maintenance and minor improvements of Roads and Bridges	3,785,777
Interest, Exchange and Repayment of Loans	215,762
Purchase and Repair of Plant and Motor Vehicles	590,117
Other Expenditure	501,190
Total	£7,365,830

Note.—The figures in the above statement are subject to slight adjustment upon completion of accounts for the year.

Reconstruction Over Bolivia Range

New England Highway Improvements North of Deepwater

A twenty-four mile length of the New England Highway has been under reconstruction by the Department of Main Roads by day labour. The work extends from five miles north of Deepwater, which is 434 miles from Sydney, crosses the rugged Bolivia Range, and extends to Bluff Rock, situated 8 miles south of Tenterfield.

The section across the Bolivia Range is through steep granite country, with rock frequently outcropping; the road falls 700 feet in 2½ miles. The remainder of the work was mainly through undulating granite country.

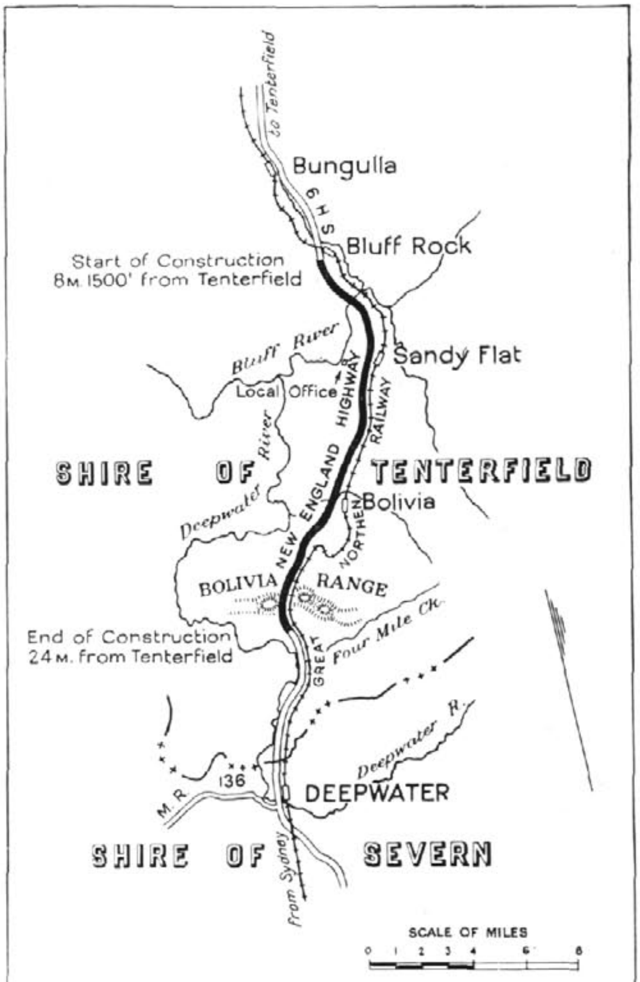
Location and Design.—The crossing of the Bolivia Range has always presented a problem in road location, and in the past hundred years three distinct routes have been used. The pioneer settlers in the area used a route known as the "Centre Ridge," which is the route now taken by the main telephone line from Sydney to Brisbane. This ridge is a narrow spur just west of the new construction, and the scours from the old wheel tracks can still be seen from the present road. The line was almost straight for the whole descent, but the grades are prohibitive even for use by horse traffic, the average grade being about 9 per cent., and the maximum grade 30 per cent. No improvement work was ever done on this line. The next route to be developed is generally known as the "Bullock Track," and is on the next spur to the west of the Centre Ridge. It was probably in use for about forty years, in which time considerable improvement was carried out, including one small box cutting, and a considerable length of dry rubble retaining walls. The route generally had fair alignment and grades, the latter being almost a uniform 10 per cent., with exception of the first 500 feet of the ascent where the grade was 20 per cent. This grade made the route difficult even for horse traffic, and on the introduction of regular services a better route was sought, and attention was focussed on the existing route, which was eventually constructed by the Public Works Department, and opened to traffic in 1901. Side cuttings and retaining walls were constructed for the full length of the main ascent, a two-span timber bridge being used to cross a steep gully. The two engineers principally concerned with the construction were Mr. R. Vowell, who subsequently became Chief Engineer of the Public Works Department, and the late Mr. H. H. Newell, later the first Commissioner for Main Roads, New South Wales. After comprehensive investigation of possible routes, it was decided that the route taken by the Public Works Department in 1901 should be adhered to.

North of the Bolivia Range, the route adheres generally to the old road, with minor deviations as required to secure the required standards of design.

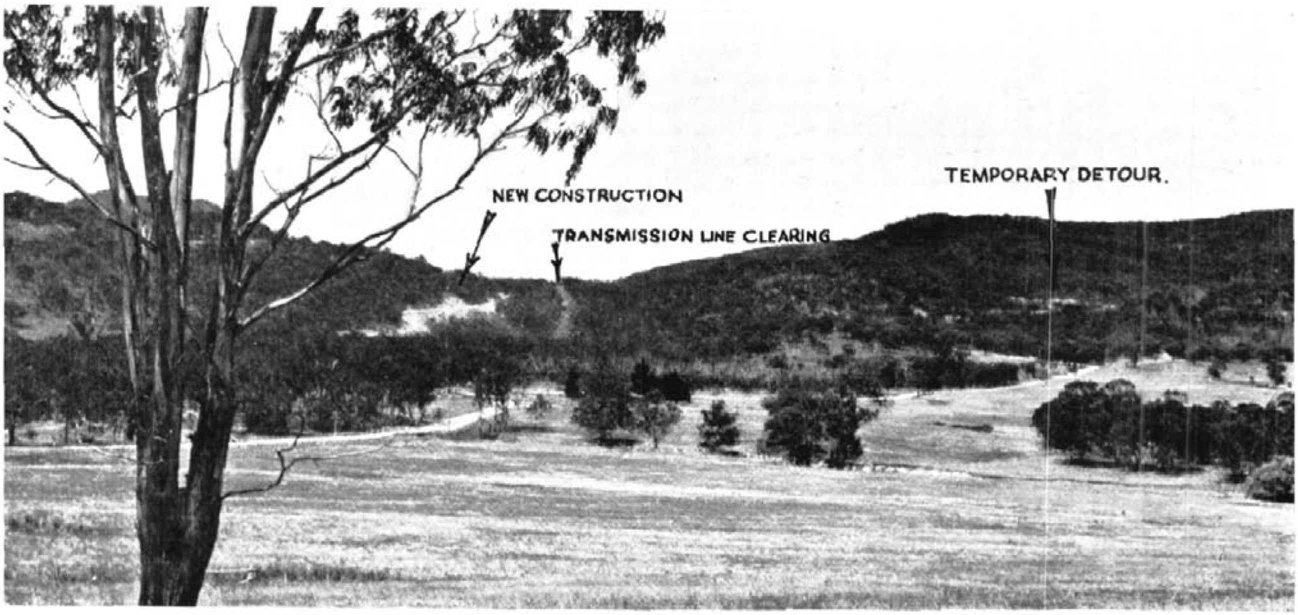
Design Standards.—The road generally has been designed to the Department's 50 m.p.h. standard, the minimum radius curve being 800 feet and 650 feet minimum sight distance. The formation width is 28 feet, and it is intended to construct a 20 feet sealed pavement.

For approximately 1 mile over the Bolivia Range a 40 m.p.h. standard has been adopted, the minimum radius of curve being 500 feet, and the minimum sight distance 450 feet. Heavy cuttings have been put in to eliminate bad bends, and the old timber bridge has been replaced by a fill of 85 feet depth on a 500-feet radius curve, the waterway being provided by a set of twin 36-inch pipes laid diagonally across the fill.

Organisation.—A sheltered site at the village of Sandy Flat, 5 miles south of the northern end of the work, and adjacent to post office and rail siding, was selected for a depot, including office, store and workshops.



Locality Map.



General view showing new construction, transmission line clearing and temporary detour.

Most of the construction equipment for the job was transferred from work which had just been completed by the Department near Coonabarabran. The transfer was made by road, the heavy equipment being moved on the Department's floats, and the lighter stores and materials on hired semi-trailer or 3-ton trucks. The transfer from Coonabarabran to Sandy Flat took place over a period of three months, so as to allow time for the completion of the work at Coonabarabran, and the erection of depot and camps at Sandy Flat. Earthworks were commenced in December, 1948 but were not in full swing till January, 1949.

Construction.—For the purpose of construction the work was divided into two sections, the first being from 8 m. 1,500 feet south of Tenterfield to 19 m. 1,500 feet south of Tenterfield; the second section then extending to 32 m. south of Tenterfield. As the conditions encountered in the two sections of the work differ considerably, they will be described separately.

The first section was in undulating country on the foothills of the New England Range, where the earthworks comprised mainly decomposed granite gravels and sands, 80 per cent. being suitable for moving by tractor and scoop after ripping with heavy-duty ripper and tractor. Construction on this section proceeded smoothly as the material was not greatly affected by wet weather, and for 90 per cent. of the length the material excavated proved satisfactory as a running course for traffic pending gravelling. Little difficulty was experienced in providing safe side tracks for traffic as in most of the heavier excavation the new line was away from the old road.

The second section included the crossing of the Bolivia Range. Work done to date on this section has mainly been concentrated on the crossing of the Bolivia Range.

One of the principal difficulties encountered in the construction over the Range was provision of an uninterrupted safe passing for traffic. It was originally intended to keep traffic on the old road whilst the new road was constructed by constructing half of the new road at a time. This method was tried for about three months, but considerable delays were caused due to blasting and, following the lifting of petrol rationing, traffic increased to such an extent that the construction of a by-track became essential. For this purpose in April, 1950, a start was made on reconditioning of the old road known as the "Bullock Track." The work required the provision of pipe culverts, filling in of washouts, and resheeting with gravel, the latter mainly being obtained from cuttings. A detour approximately a quarter of a mile long was constructed to avoid the 20 per cent. grade at the foot of the climb. This detour had a maximum grade of 10 per cent., and three bends of 80 feet radius. The by-track was opened to traffic on the 21st June, 1950.

After the by-track was complete, work was carried on on the Range without interruption until it was opened for traffic on the 29th March, 1951.

The work over the Bolivia Range involved a deviation at the south end at a grade known as "Little Bolivia." The completion of this deviation will eliminate a short section of 11 per cent. grade on very poor alignment, which has proved to be a hazard to trucks both ascending and descending the Range. The maximum grade on the new route will be 8 per cent. and the alignment almost straight. Borrowed fill has been used extensively on this deviation to eliminate rock cuttings, and to lift the grade line above swampy sections to provide adequate drainage of the pavement.

Drilling and Blasting.—Drilling for blasting operations on the Bolivia Range has been carried out using tungsten carbide bits. The drilling would have been very difficult without their use, as in the solid granite ordinary steel bits would not bore more than four inches without re-sharpening, and the boring rate while actually working was only about one inch per minute. As a comparison, the following figures are given regarding the life of tungsten carbide bits:—

- 1½ inch chisel bits: 54 bits tested to destruction—average life 241 feet.
- 1½ inch cross type bits: 127 bits tested to destruction—average life 218 feet.

The greater life of the chisel bits as compared with cross bits is probably due to their being used to a greater extent in softer rock.

Care had to be taken in the blasting to avoid undue damage to the main Sydney to Brisbane telephone line, which ran approximately parallel to and within 600 feet from the face of the main cutting. The Postmaster-General's Department arranged for the training of some of the Department of Main Roads employees in the jointing of the wires after accidental damage, and provided the necessary ladders and jointing equipment.

Trials were carried out on the works of milli-second delay action detonators. No tests could be made to determine the reduction in vibration due to the blast, but better fragmentation was obtained in pattern blasting, and the direction of flight of the blasted material could be controlled to a considerable extent by placing the shortest delay in the direction in which it was desired to throw the material. Use was also made of instantaneous detonating fuse for the firing of large numbers of holes either simultaneously or with delay action detonators.

When detonating fuse was used in conjunction with delay action detonators, the usual practice was to connect the charges in each line of drill holes with the detonating fuse and use a delay detonator at each end of each line. The use of a detonator at each end of the line was to minimise the risk of misfire due to blow out or cutting of the detonating fuse. Where lines exceeded 100 feet in length, a detonator was also used in the centre of the line. Delays were arranged in succession so that the line with the least burden would be fired first. The lines were spaced a minimum of four feet apart to avoid the risk of the detonating fuse in one line being cut by the preceding shot.

The maximum number of shots fired at one time using detonating fuse and delay action detonators was 130.

The largest solid granite cutting was 50 feet deep on the high side, and contained 8,500 cubic yards of rock.

Figures taken over three months, from the 13th September, 1950, to the 15th December, 1950, are as under:—

- Rock excavated: cubic yards—12,830.
- Explosive used: lbs. (Approximately equal quantities gelignite AN.60, AN.50 and monobel)—6,700.
- Detonators used—3,945.
- Detonating fuse used: feet—12,500.
- Footage drilled—33,228.
- Average lbs. explosives, all types, per cubic yard—0.52 lbs.
- Average feet drilled per cubic yard—2.61 feet.
- Average explosives per foot of hole—0.22 lbs.

The monobel and AN.50 gelignite were used in cuttings of partly decomposed granite.

Detonating fuse has also been found to be useful in the cutting of reinforced concrete pipes, two turns around a pipe causing intense shattering immediately under the turns, so that the pipe can be neatly cut either diagonally or on the square with a mattock.

Pavement.—As the country passed through is granite a decomposed granite gravel is being used in the pavement. On the northern end of the work there are ample supplies of granite gravel readily available, which is

Typical view of mountainous nature of Country.

80 H.P. Tractor with 8 cub. yd. Scoop at work.

suitable by test for bitumen surfacing, but on the southern end the quality of the gravel is poorer and prior to bitumen surfacing a surface course of selected good quality gravel from a distance will have to be laid. A temporary running course has already been constructed and this course will be increased in thickness with approved material to bring it up to the depths required for the subgrade as determined by tests.

Equipment.—The following construction equipment has been used:—

- 2 tractors, 100-150 h.p.; 1 tractor, 85-90 h.p.; 2 tractors, 45-50 h.p.—equipped with power control units.
- 3 bulldozer or angle dozer blades for use with heavier tractors.
- 1 12-cubic yard scoop.
- 1 8-cubic yard scoop.
- 1 6-cubic yard scoop.
- 2 4-cubic yard scoops.
- 1 3-tyne heavy-duty power-ripper.
- 1 heavy-duty motor grader, 12 ft. blade.
- 1 ¾-cubic yard power shovel.
- 4 air compressors, 167-cubic feet free air per minute.
- 1 pneumatic-tyred roller.

Most of the work on the northern end was done by tractor and scoop, one of the heavy tractors being engaged on ripping with the power-ripper, or when not ripping, on clearing with the dozer blade, while the other machines worked on scoops. The 4-cubic yard scoops were, as far as possible, used on short leads, and in removing the light stripping from the tops of the cuts, leaving the harder material for the heavier machines.

100 H.P. Tractor-Dozer in operation.

On the Bolivia Range, where the work was largely in rock, the heavy tractors were used almost exclusively with dozer blades. The wear on the tractor tracks while working in granite was found to be very high; in one case the medium duty tractor wore out a set of track blades in three months.

The power shovel was used for loading rock, which was hauled by hired lorries.

Bridges.—A new bridge is being built over Sandy Creek, situated about ten miles south of the northern end of the work. This structure will comprise a single 20 feet 6 inches span of rolled steel joists with concrete deck, on grouted rubble abutments. The rubble abutments are being adopted as it is thought that they could be more readily constructed with unskilled labour than concrete abutments, also that a saving in cement and steel will be made.

A bridge across the main northern railway is proposed at a level crossing near the northern end of the work, but it is not practicable to undertake this at present in view of the shortage of materials and skilled labour for bridge building.

Statistical Data.—The following are the principal quantities and unit costs for the main items of the work. Costs exclude Workers' Compensation Insurance, Pay Roll Tax, Holidays, Camp, Depot, Engineering Supervision and Clerical Costs.

Clearing and grubbing—		
Section I	47.9 acres	£24 2s. 7d. per acre.
,, II	33.29 ,,	£17 3s. 4d. ,,
Earthworks (solid measurement)—		
Section I	99,290 c. yd. (19% rock)	3/10.6 per c. yd.
II	84,130 c. yd (39% rock)	9/8.7 ,,
Trimming and consolidation—		
Section I	32,330 l. ft.	£6 6s. per 100 l. ft.
,, II	59,747 ,,	Work in progress costs incomplete. (Schedule quantity for full length).
Reinforced concrete pipe culverts—		
Size (18 in.—48 in.)— Section I	3,126 l. ft.	£1 10s. 6d. per l. ft.
Size (18 in.—42 in.)— Section II	2,612 ,,	£1 15s. 8d. ,,

Concrete Pipes being lifted into position.

Concrete in box culverts—		
Section I	147 c. yd.	£11 6s. per c. yd.
,, II	309 ,,	Schedule quantity for full length—work in initial stage.
Subsoil drains—		
Section I	10,994 l. ft.	£20 1s. 3d. per 100 l. ft.
,, II	25,927 ,,	Schedule quantity for full length—work in initial stage.
Rubble headwalls (cement grouted) for pipe culverts—		
Section II	144 c. yd.	£4 11s. 8d. per c. yd.
Gravel pavement 6 in. consolidated thickness (work only in initial stage)—		
Section I	126,055 s. yd.	Schedule quantity.
,, II	135,560 ,,	Schedule quantity for full length.

Deferment of Completion of Work.—It has been necessary to defer the completion of the full length of the work undertaken on account of the need to divert the organisation temporarily to the repair of damaged pavements on the New England Highway, resulting from the flood rains of 1950 and the effects of the large volume of heavy haulage using the road.

Supervision.—The work has been carried out under the supervision of the Department's Divisional Office at Glen Innes.

The general supervision of the construction to the end of 1949 was by Mr. L. W. Hawley, Divisional Engineer, and from January, 1950, to date by Mr. H. C. Macready, Divisional Engineer.

The Engineer directly in charge of the work for the full period was Mr. R. Fitzhardinge.

Survey and Design Manual

The Department has issued recently for the use of its officers and the officers of the Municipal and Shire Councils, a manual entitled "Survey and Design for Main Road Works." This manual supersedes bulletins on this subject which had been issued some years ago. A copy of the manual has been supplied to each Municipal and Shire Council. Further copies may be obtained at a cost of three shillings per copy, post free, on application to the Department's Head Office, 309 Castlereagh-street, Sydney.

Remedial Treatment of Slippery Bituminous Surfaces

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Causes of Slipperiness.—Bituminous pavements, when first constructed or immediately after re-treatment have, in general, satisfactory non-skid surfaces, but under the action of traffic, they sometimes tend to become "slick" and slippery. Other factors may contribute, but the principal cause of slipperiness is the presence of excess bituminous binder at the surface of the road pavement.

If the volume of the binder in a surface course exceeds the volume of the voids in the aggregate, the packing of the aggregate under traffic must result in binder being forced to the surface. If the volume of the voids exceeds that of the binder, this action cannot occur, and a satisfactory non-skid surface is generally maintained. If the excess of voids over binder is small, a good tough surface of long life is obtained, but if the voids are much in excess, though the surface is still non-skid, it will have low life. Excessive voids in the surface course reduce its cohesion and allow free access of air and water to the interior of the course, so that the binder weathers much more rapidly than in a surface course with the voids fully or almost fully filled with binder.

The properties and behaviour of the various types of bituminous surface course have an important bearing on the formation of slick surfaces. Assuming in each case that the surface course is laid on a solid well-drained base free from excess binder, the important features are:—

(*a*) *Dense Graded Courses.*—Sheet asphalt and asphaltic concrete are the usual names for members of this group. The aggregate in this case follows approximately maximum density grading, so that the voids in the coarser sizes are filled with fines and the total voids in the aggregate low.

This group of surface courses has a very narrow margin between excess binder, causing slickness, and deficiency of binder, causing lack of cohesion and short life. It should only be made by batch mixers because road and/or continuous mixing give insufficient control, and by the hot process because voids are insufficient for the flux required for cold processes. If properly made with sound aggregate, it will not of itself cause slippery surfaces. The aggregate is cushioned in the mortar like matrix and not prone to fracture, while wear is low and consists of the gradual attrition of the surface as a whole.

(*b*) *Semi-dense (or semi-open) Courses.*—This type is intermediate in composition and in properties between Type (*a*), Sheet Asphalt and Asphaltic Concrete, and Type (*c*), Bituminous Macadam. It consists of a graded aggregate with the voids of the coarse sizes partly filled by fines, and the whole bound with bitumen. As compared with (*a*), the cost of this type is sligntly less and its life considerably less. The voids in the aggregate increase the margin between excess and deficiency of binder, and for this reason this type can be made by road or continuous mixing as well as by batch mixers, while cold processes can be used as the increased voids provide space for the flux.

If the coarse aggregate is hard the mortar partially filling the interstices should supply sufficient support to prevent fracture and, if properly proportioned and mixed, there should be no trouble from excess binder. Lack of exactness in proportioning when road or continuous mixing is carried out, requires that the average binder content should exceed the minimum for cohesion. This reduces the margin against over-filling of voids and slight errors and variations in the work may result in portions of the mix receiving so much binder that "slick" patches and areas develop in the pavement.

(*c*) *Open Graded Courses.*—Surface courses of this type are usually called bituminous macadam, and consist of coarse aggregate, sometimes with sand added but no filler, bound with bitumen. In addition to plant mix and road mix, such courses can also be constructed by the penetration method.

In this type the voids are large in volume leaving a considerable margin between excess and deficiency of binder so long as the original grading is maintained. If, however, these types are used as surface courses their life is less than the preceding types, owing to weathering of the binder and the liability of the aggregate to fracture. The stones have only point contacts and are easily broken if directly exposed to traffic, with consequent degradation of grading and/or loss of stone particles. More binder than that required for the initial grading is necessary to provide for the coating of the new surfaces, and both the changes in aggregate grading and the loss of stone particles reduce the available voids. Such surface courses may, therefore, become slick under heavy traffic, even after they have maintained a non-skid surface for years.

(*d*) *Surface Treatments.*—Another type of bituminuous surface used for light traffic or for rejuvenation of old heavy surfaces is bituminous surface dressing. This usually consists of a single layer of stones embedded rather more than half their depth in a layer of bitumen sprayed on the road surface.

This is a cheap and effective type of treatment in the proper circumstances, but its improper use may tend to create or aggravate slickness. From its very nature it is apparent that this type of treatment will give only a very brief improvement if applied to a slick surface because further embedment and wear of stone under traffic will soon result in the bitumen being exposed at the surface again. Again, a number of successive re-treatments on an originally dry surface without other intervening courses is likely to create a slick surface. There can be no unfilled voids in any of the lower treatments and further packing of the stone under the kneading action of traffic reduces the voids and forces surplus binder to the surface.

Remedial Treatment.—In considering the form of remedial treatment for slipperiness, a factor of importance is that the surplus bitumen creating the slippery surface is liable also to make the course or courses involved unstable so that they "shove" or distort under traffic. The seriousness of this effect depends on the amount of surplus bitumen, its hardness, the thickness of the layers affected and the nature and grading of the aggregate therein.

Where there is only a small surplus of bitumen, and instability of the existing pavement is not feared, the cheapest form of remedial treatment is to provide an open graded pre-mix course with ample voids to accommodate the binder coming from below. For the reasons explained in (*c*) above, a denser graded surfacing, preferably sheet asphalt or fine asphaltic concrete, should be applied over this open graded course if traffic is very heavy.

Where the surplus is large or the existing surface course has become unstable from the excess of binder, the offending course or courses have generally to be removed and new courses constructed in their place. This may also be required even when the surplus is small if the road level cannot be raised above that existing. For this removal, application of heat may expedite and/or cheapen the work of removal.

In some special cases, when a large surplus of bitumen has been found with stable material below, the compromise of removing as much as possible of the surplus binder, by heating and scraping, then proceeding by the first method, has proved successful.

Slipperiness from excess binder cannot be permanently cured by surface dressing. Many attempts have been made to embed stone in the surplus binder, softened by heat or fluxing, but they have in general failed or have not proved of lasting benefit.

Examples of Treatment.

Municipality of Manly: Main Road No. 159: Pittwater Road.—A section of this road between Carlton Street and Collingwood Street given a bituminous resurfacing in June, 1946, developed a slippery surface within twelve months. The following treatment was then carried out:—

> A tack coat of bitumen emulsion was applied at .04 gallon per square yard followed by a mat of ½-inch open hot mix at the rate of 1 ton per 34 square yards giving a finished thickness of about ⅜ inch after drag-spreading and rolling. Trinidad Asphalt 60-70 penetration (plus power kerosene for flux) was used as binder in the hot mix, and the normal quantity for a ½-inch hot mix (approximately 11 gallons per ton) was reduced to 8 gallons per ton. The surface was finally given a light coat of grit and rolled.

This treatment proved successful in providing a non-skid surface. In November, 1947, further sections of Pittwater Road between Denison Street and Eurobin Avenue at each end of the length treated the previous year between Carlton Street and Collingwood Street were approaching a similar condition, and the same non-skid treatment was applied successfully.

Municipality of Canterbury: Main Road No. 167: Canterbury Road.—Sections of Canterbury Road in July, 1947, had developed a smooth slippery surface immediately after bituminous resurfacing. The road carries heavy traffic. A light treatment was carried out from Berna Street to Beamish Street and Victory Street to Holden Street similar to that described on Main Road No. 159 in Manly, except that the tack coat of emulsion was 1 gallon per 11½ square yards and the ½-inch hot mix was applied at 1 ton per 30.6 square yards. This satisfactorily corrected the slippery surface.

Municipality of Manly: Secondary Road No. 2025: Lauderdale Avenue.—A bitumen resurfacing with ¾-inch and ⅜-inch aggregate was carried out in April, 1946, but a section of 760 feet near Bolingbroke Parade with steep grades up to 14 per cent. became slippery after about one year. The surface condition of the pavement appeared to be partly due to braking of heavy buses and lorries, also oil droppings. A new surface was provided with a treatment similar to that on Main Road No. 159 and Main Road No. 167, except that the tack coat of emulsion was 1 gallon per 8 square yards and ½-inch hot mix 1 ton per 28 square yards, and proved to be successful.

Shire of Shoalhaven: State Highway No. 1: Princes Highway.—A section of 0.20 mile between Main Road No. 293 and Nowra Bridge carries heavy traffic between the South Coast and Nowra Station. It was resurfaced in 1944-45 with a light application of tar covered with fine aggregate to reduce slipperiness, but this proved unsuccessful.

It was again resurfaced in 1945-46 with bitumen and covered with ¾-inch-½-inch aggregate, but in little over a year the surface again became very slick and slippery.

A test was then carried out with application of diluted bitumen emulsion covered with ½-inch screenings, but was a failure as within three days the screenings left the surface under heavy traffic, leaving the road as slippery as previously.

A second test was also carried out on a small length by spraying power kerosene and covering with ½-inch aggregate. Some of the aggregate adhered, but most of it was swept off under traffic very soon afterwards. wards.

Finally a drag-course treatment was carried out in January, 1948, with hot mix using a mixture of 60/70 and 80/100 penetration bitumen as binder and ¾-inch-⅜-inch stone as aggregate.

A tack coat of bitumen emulsion was applied at the rate of .02 gallon per square yard, and the hot mix was spread at the rate of 1 ton per 32.5 square yards. The surface was then covered with 3/16-inch grit at the rate of 1 ton per 238 square yards. This treatment has proved to be successful.

Shire of Lake Macquarie: State Highway No. 10: Pacific Highway.—A length of pavement between Swansea and Belmont from Blacksmith's at 91¼ M. to John Darling turnoff at 95⅜ M. was strengthened with 2½ inches of pre-mix bituminous macadam in March, 1937. Traffic, which includes a frequent bus service, is very heavy on this section and slippery conditions developed. The length was bitumen resurfaced in November, 1943, with bitumen at 0.27 gallon per square yard and covered with ¾-inch and 5/16-inch slag at 1 cubic yard per 64 square yards.

By 1946 the pavement was as bad as in 1943. Tests were carried out to determine whether the surplus binder could be softened sufficiently with flame throwers to permit new screenings to be rolled into the surface. A start was made with this treatment on the worst sections in Belmont in December, 1947, with two "Rega" hand-pumping flame-thrower units, supplemented some months later with six additional flame throwers of this type, and work on the full length 91¼ M. to 95⅜ M. on State Highway No. 10 was completed by July, 1948.

The fuel used in the flame throwers was ordinary diesel fuel oil, diluted with kerosene in unfavourable weather to maintain combustion on the road. Most of the fuel reached the pavement in an unburnt condition and then burning continued on the pavement. The burner was moved over the area to be treated until the bitumen was sufficiently soft to permit surplus binder to be scraped off. The final cost of the work was approximately 6d. per square yard.

On completion of the work it was found that a good non-skid surface had been re-established, but the period over which the treated surface will retain this property remains to be determined.

Retirement of Bridge Engineer

Mr. S. Dennis, Bridge Engineer, retired from the service of the Department of Main Roads on the 29th June, 1951.

Mr. Dennis was educated at Fort Street School and Sydney University, from where he graduated in Mechanical and Electrical Engineering in 1909.

He entered the service of the New South Wales Public Works Department in August, 1909. He resigned in September, 1910, to take up a position with the Queensland Water Supply Department, returning to the service of the New South Wales Public Works Department in 1913 as a Designing Engineer on the Sydney Harbour Bridge project. In 1916 he was appointed Designing Engineer of the National and Local Government Works Branch, then Supervising Engineer for Bridge Construction and later Inspecting Engineer.

Mr. Dennis was transferred as Bridge Engineer to the Main Roads Board in September, 1928, when this Board took over the control of bridges and ferries previously administered by the Public Works Department.

During his service with the Public Works Department and the Department of Main Roads, Mr. Dennis was associated with the design and construction of over 1,000 bridges of all types, including many large projects such as the bridge over the George's River at Tom Ugly's Point, the Peat's Ferry Bridge over the Hawkesbury River and the new bridge over Long Bay, Middle Harbour, North Sydney. Large bridges at present under construction with which Mr. Dennis was associated, are the bridges over the Hunter River at Hexham, and the Clyde River at Bateman's Bay and the new bridge over Iron Cove, Sydney.

Mr. Dennis is also a Member of the Institution of Civil Engineers (London) and an Associate Member of the Institution of Engineers, Australia.

Mr. F. W. Laws, B.E., A.M.I.C.E., A.M.I.E. (Aust.) has succeeded Mr. Dennis as Bridge Engineer.

Reconstruction of Liverpool Road, Ashfield

During 1950 construction was completed by the Department of Main Roads by day labour of 4,000 linear feet of cement concrete pavement, 42 feet wide, on the Liverpool-road passing through the Ashfield, Sydney, shopping centre. The work extends from Queen-street to Lion-street. The Liverpool-road forms part of the Hume Highway (State Highway No. 2), and the road thus carries a large volume of long distance traffic, as well as considerable local traffic, including buses. Abandoned tram tracks existed over much of the length, and their removal was carried out in conjunction with the reconstruction of the roadway.

Design.—The old bituminous pavement had a high camber. As a result, moving vehicles tended to use only the central portion of the road, and parked vehicles tended to keep away from kerbs, thereby reducing the effective width of the carriageway.

In designing the new pavement, the crossfall of which is 1 in 48, it was possible in many places to maintain the old kerb levels and avoid the reconstruction of concrete footways and property entrances.

The concrete pavement is of 1:2:3 nominal mix, steel reinforced, seven inches thick, with thickened edges adjacent to the kerbs. No change was made in the alignment except at a point between Miller-street and Lapish-avenue where the curve radius was increased from 200 feet to 300 feet.

Construction.—A depot was established at the corner of Parramatta-road and Dobroyd-parade, Haberfield, two miles from this work and within reasonable distance of other works being carried out concurrently.

At the depot were local office, store, blacksmiths shop and subsidiary buildings. It also contained a hutted camp complete with mess room, kitchen and washroom to accommodate twenty-two New Australian employees. To supplement the labour required, additional barracks were provided at the Department's Central Maintenance Depot, Granville, to accommodate eighteen men.

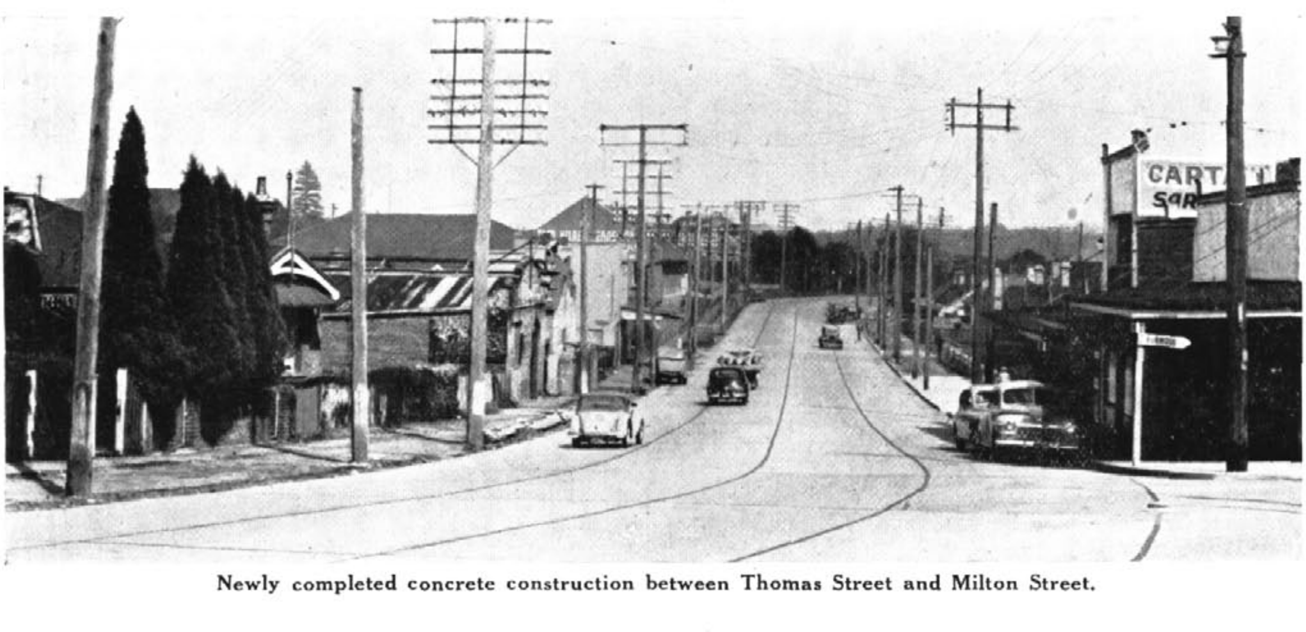
Road work commenced in March, 1949. The major problem involved was in providing for traffic during reconstruction of the road. The fact that the available width between kerbs was only 42 feet added to this problem. It was, therefore, necessary to carry out the work in small sections, and a large amount of temporary work was required to enable traffic to travel from the old pavement on to new sections which were generally several inches below the level of the original pavement. The provision of barriers and lighting was on a large scale.

Kerbside strips eleven feet wide were constructed first, followed by the centre strips each 10 feet wide, which were laid as the tram tracks were removed.

Ahead of construction, it was necessary to arrange with the utility authorities for the lifting from the carriageway and relaying under the footpaths of gas and water mains other than large trunk mains. Telephone cables under the road were adjusted as the work proceeded.

Excavation totalling 5,968 cubic yards of clay, shale and old pavement was loosened and loaded into motor lorries with a skimmer shovel, except where congested traffic conditions did not permit of the use of mechanical equipment when hand loading had to be resorted to.

Following the excavation, a system of subsoil drainage using 4-inch and 6-inch diameter earthenware pipes was constructed to provide for both longitudinal and cross drainage. The total length installed was approximately 12,000 linear feet.



Newly completed concrete construction between Thomas Street and Milton Street.

Reconstructed length in Ashfield shopping centre, following removal of tram tracks.

The excavation was trimmed and consolidated at a depth of 9 inches below the finished surface level except where increased depth was necessary for thickened edges. During this operation, any unsatisfactory materials were removed and replaced by sound material, this generally being salvaged ballast from the original pavement. After trimming and consolidation, timber forms were set up and a sand sub-base of 2 inches compacted depth provided.

The location of the work was such that the use of a mechanical paver on the job would have caused excessive interference with traffic. Concrete was therefore mixed at another location and transported to the work. The supply of concrete was by contract, and it was delivered in special truck-mounted agitator drums from a central mixing plant at some distance from the site of the work.

The concrete was deposited in the forms by chute from the agitator drums and then spread by hand. Packing and levelling was carried out by two or three passes of a mechanically-vibrated screed board. The finish consisted of transverse screeding with a long-handled float and then dragging longitudinally with wet hessian. Special care was taken to ensure satisfactory compaction against transverse expansion joints which were placed approximately 50 feet apart.

The components of the concrete were proportioned by dry weight to give a nominal volumetric mix of 1 part of cement to 2 parts of fine aggregate and 3 parts of coarse aggregate. On those sections where it was essential to open the new pavement to traffic as early as possible both to minimise the interference to business premises and traffic flow and to avoid disorganisation of the work, extra cement at the rate of 12½% of the standard quantity was added to assist in obtaining concrete of a high early strength. These sections were opened to traffic seven days after the concrete was poured but those containing the standard mix were closed to traffic for at least 21 days after pouring.

The concrete was cured by covering with sand or other suitable material to a depth of 2 inches. This covering was kept moist for ten days and was left on the concrete for at least fourteen days, except where earlier removal was necessary to permit those sections containing extra cement to be opened to traffic at seven days.

The work was completed by July, 1950. Despite the difficulties encountered during construction, which was carried out during the wettest period in the history of Sydney, traffic was not unduly delayed and access to business premises was not seriously interrupted.

Quantities of Work.—Earthworks—Clay, shale and old bituminous macadam pavement—total 5,968 cub. yds. (solid measurement).

Trimming and consolidating subgrade—23,170 sq. yds.

Excavation in all classes of materials for stormwater drains—100 cub. yds.

Concrete pipe culverts, sizes 12 in. to 18 in. diam.—345 lin. ft.

Sub-base sand 2 in. thick—19,290 sq. yds.

Cement concrete slab 7 in. to 9 in. thick—19,290 sq. yds.

Steel reinforcement—Dowels 11 tons, Barmat 54.8 tons, total 65.8 tons.

Joints—Transverse 3,990 lin. ft., longitudinal 12,048 lin. ft.

Unit Costs of Main Items of Work.—(Direct costs only exclusive of Workers' Compensation, insurance, pay roll tax, holidays, camp, depot, engineering supervision and clerical costs.)

Earthworks—21s. 9d. per cub. yd. (solid measurement).

Trimming and consolidating of sub-grade—1s. 6d. per sq. yd.

Excavation in all classes of materials for stormwater drains—19s. 11d. (solid measurement).

Concrete pipe culverts—average for all sizes—7s. per lin. ft.

Sub-base sand—1s. 6d. per sq. yd.

Cement concrete slab 7 in. to 9 in. thick (1⅛:2:3 mix, 80%)—£1 1s. per sq. yd.

Steel reinforcement in place—Dowels £25 per ton, Barmat £38 13s. 5d. per ton.

Joints—Transverse 1s. 9d. per lin. ft., longitudinal 11d. per foot.

Supervision.—Construction was under the general direction of the Department's Metropolitan Engineer. The engineer in immediate charge was Mr. R. J. Milner.

Advanced Trees Transplanted

The construction of kerb and gutter on State Highway No. 13 in the Shire of Baulkham Hills fronting the Burnside Homes, necessitated the transplanting of a number of Brush Box (Tristania conferta) trees. The fourteen trees transplanted were part of an avenue of Brush Box trees, planted in 1940, and which by 1949 had reached a height of approximately 12 feet.

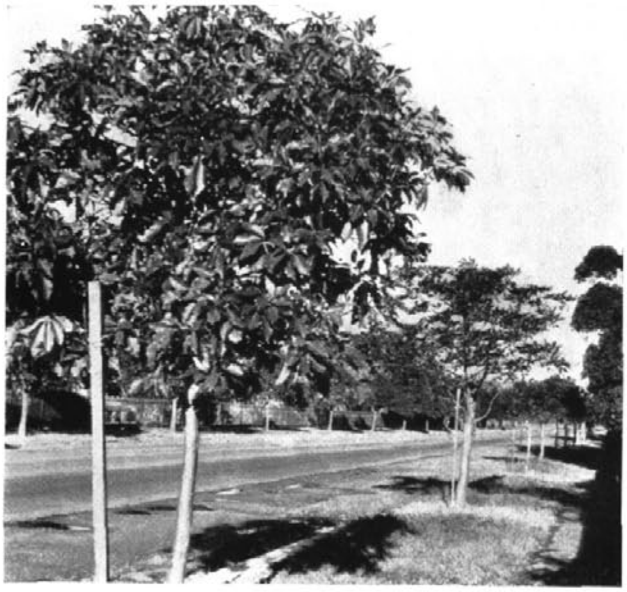
The work was carried out in the winter of 1949 by the Baulkham Hills Shire Council under the supervision of the Sydney City Council's Director of Parks and Gardens.

Sliding Tree into new position.

The trees were first "skeleton" pruned to reduce the weight and height as much as possible. A trench approximately 18 inches deep was dug around each tree, at a distance of 3 feet from the bole. From the bottom of the trench the tree was carefully undermined, care being taken to injure the roots as little as possible, and preferably without removing the soil surrounding the roots. Where damage to any roots was unavoidable, these were cut off cleanly and tar applied to prevent bleeding.

When the tree had been completely undermined, hessian was forced under the tree and brought up around the bole to hold firmly the ball of soil containing the roots. While this was going on, a trench 6 feet wide and to the same depth as the undermining was dug from the old to the new position for the tree. Wooden planks were then pushed under the hessian containing the ball of roots, and the tree skidded to its new position.

Fresh soil was packed in around the tree, water being sprinkled into the hole at the same time. Finally, the



Trees after removal.

tree was securely staked so that support would be provided until the soil again held the roots firmly.

The trees were watered regularly for several weeks after being moved.

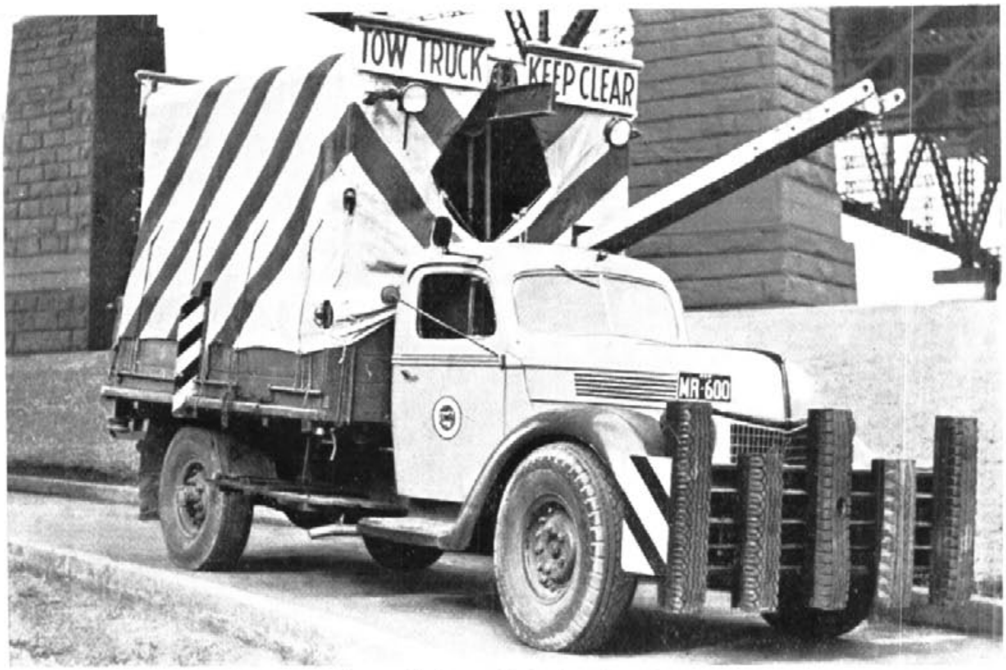
Of the fourteen trees moved, eleven are now flourishing. The failure of the other three trees was not due to damage during removal but to interference to the root systems after the trees had been re-established.

Towing Truck in Use on Sydney Harbour Bridge

A specially equipped lifting and towing truck, owned and controlled by the Department of Main Roads, was placed in service at the Sydney Harbour Bridge on the 31st May, 1951.

The truck is used, under Police authority and supervision, during the week-day morning and evening peak periods to clear disabled or stalled light lorries, utilities and cars from the bridge and approaches.

With its special equipment, the truck is able to cope with all types of breakdowns. Apart from the familiar straight tow by means of a tow rope, vehicles can be removed by the use of clamps attached to the rear of the towing truck, which are fitted on to the front bumper-bar of the disabled vehicle. In the case of a broken front axle or disabled steering a sling is placed around the front bumper-bar and the vehicle is lifted



General view of Towing Truck.

"Skate" on which wheel rests when towing cars with flat tyres.

Method used for bumper-bar Tow.

by a hoist attached to the rear of the towing truck. In the case of punctured tyres the front or rear wheels of the vehicle, as the case may be, are lifted on to specially designed trollies or "skates" and then towed away. The front of the towing truck is fitted with a rubber-faced buffer plate so that a vehicle may be pushed, if necessary, out of a traffic lane before receiving further attention.

Drivers of disabled vehicles are not required to leave them or to request passing drivers to notify the truck crew, this being done by the Police traffic officer patrolling the bridge.

On removal from the bridge and approaches, the disabled vehicle is placed in the nearest suitable side street or lane, and it is then a matter for the driver to make his own arrangements for any further assistance which may be required.

No charge is made for the towing service.

During the three months ended 31st August, 79 disabled vehicles have been attended to.

Tenders Accepted.

The following Tenders (exceeding £1,000) were accepted by the respective Councils during the months of April, May and June, 1951:—

Council.	Road No.	Work.	Tenderer.	Amount. £ s. d.
Abercrombie S. ...	54	Re-seal bituminous pavement 2 m. to 6.1 m.	B.H.P. By-Products Pty. Ltd.	1,183 9 0
Berrigan S. ...	...	Supply and delivery aggregate to Berrigan and Tocumwal. 404 tons to Tocumwal and 526 tons to Berrigan.	Blue Metal & Gravel Co.	2,883 9 8
Bland S.	57	Scarifying pavement. Supply, deliver, spread and roll 4,352 cub. yds. gravel. Average lead 5 miles.	I. N. Miller	1,441 12 0
Blaxland S. ...	55	Construction reinforced concrete culvert at Blackman's Flat.	Bulldozers Pty. Ltd. ...	2,714 0 0
Bogan S. ...	7	Supply, delivery and spreading 2,208 cub. yds. gravel between 247.3 m. and 361.1 m.	D. E. Gibson	1,821 12 0
Colo S.	1194	Construction between 2 m. 1,800 ft. and 3 m. 1,800 ft. ...	J. & A. Lighezzolo ...	2,714 0 0
Conargo S. ...	552	Supply, delivery and rough spreading 10,000 cub. yds. of loam. Average length of haul 5½ m.	D. D. McCallum ...	2,772 10 0
Coolamon S. ...	243	Supply, delivery and spreading 4,523 cub. yds. gravel. Average lead 6¼ m.	C. G. Staines & F. L. Grundy.	1,658 8 8
Gilgandra S. ...	11, 18	Supply and delivery of 4,140 cub. yds. gravel—various locations.	E. W. Hall	1,469 0 0
Gloucester S. ...	1150	Restoration of flood damage and groyne construction, Gloucester River Bridge.	E. W. Milligan... ...	3,539 11 0
Goobang S. ...	...	Supply, delivery and spreading 24,157 cub. yds. gravel at various locations on Main Roads in the Shire.	R. Scarce	7,518 17 3
Gulgong S. ...	...	Winning and loading 16,940 cub. yds. gravel	H. F. Ewin	1,270 10 0
Hastings S. ...	10	Supply and delivery of screenings for bituminous works ...	J. Bowen and W. T. Hayes.	5,792 15 0
Holbrook S. ...	331	Supply and delivery 5,000 cub. yds. gravel. Average lead 5 m.	F. A. Carstens & Sons...	1,125 0 0
Do ...	282	Supply and delivery 8,000 cub. yds. gravel (including spreading). Average lead 4 m.	" " ...	1,966 13 4
Hume S.	125	Supply and delivery 7,600 cub. yds. gravel. Average lead 7 m.	C. G. Quast	1,995 0 0
Illabo S.	3060	Completion construction of 3 concrete crossings with culverts over Wantiool Creek.	A. McKelvie and H. Lawrence.	1,471 0 0
Jemalong S. ...	17	Supply of 500 cub. yds ½-in. surfacing aggregate	Blue Metal & Gravel Pty. Ltd.	1,108 6 8
Do ...	377	Supply, delivery and spreading 9,632 cub. yds. gravel between Forbes and Condobolin.	J. R. Dean	5,973 0 0
Jerilderie S. ...	...	Supply and delivery approx. 23,350 cub. yds. loam and gravel for various main roads.	Tatnell Bros.	6,871 0 0
Jindalee S. ...	78	Supply and delivery of aggregate	Blue Metal & Gravel Pty. Ltd.	1,223 16 11
Lachlan S. ...	230	Supply, delivery and spreading 5,400 cub. yds, gravel ...	Atkinson and Giltrap...	2,767 10 0
Do ...	57	Supply, delivery and spreading 4,200 cub. yds. gravel 31 m. 4,224 ft. and 34 m. 4,224 ft.	L. G. Fuller	1,312 10 0
Leeton S. ...	80	Supply and delivery 11,000 cub. yds. gravel. Average lead 5 m.	P. H. Miechel	3,503 8 0
Liverpool M. ...	535	Earthworks and pavement construction ·58 m. to 2.5 m. west of M.R. 515.	Constructors (Engineering & Industrial) Ltd.	29,069 11 9
Do ...	154	Reconstruction 11.4 m. to 12.75 m. from Narellan... ...	" " ...	11,723 11 8
Lockhart S. ...	370	Supply and delivery 570 tons aggregate	Blue Metal & Gravel Pty. Ltd.	1,263 10 0

Tenders Accepted—*continued.*

Council.	Road No.	Work.	Tenderer.	Amount.
Macintyre S. ...	...	Scarify, reshape, supply, deliver and spread 25,120 cub. yds gravel on various main roads in the Shire.	L. W. Keft	9,283 19 0
Mandowa S. ...	63	Supply and delivery of 1,045 tons of crushed river gravel for bituminous seals. Average length of haul 23 m.	R. C. Barber	1,822 17 4
Mitchell S. ...	57, 59	Supply 1,691 cub. yds. aggregate	Murrumbidgee Sand and Gravel Co.	2,113 15 0
Molong S. ...	233, 234, 359	Supply and delivery 18,030 cub. yds. gravel at various locations.	A. C. Stephen & Sons ...	4,475 15 0
Murrumbidgee S.	321, 244	Supply and delivery 10,912 cub. yds. loam average lead 3 m.	F. A. Delaney	2,383 12 0
Port Stephens S....	10	Supply and delivery of crushed slag to stockpiles on Pacific Highway.	B.H.P. By-Products Pty. Ltd.	2,682 5 0
Rylstone S. ...	215	Reconstruction from 12 m. to 14 m. 230 ft.	A. C. Stephen and Sons	25,679 14 2
Severn S.... ...	12	Construction of approaches to Wellingrove Creek Bridge...	Frost and Spriggs ...	3,484 0 0
Timbrebongie S.	354	Supply and delivery of 3,255 cub. yds. gravel. Length of haul 4½ m.	J. M. Wooden ...	1,262 6 3
Tumut S.... ...	85, 278	Supply 713 tons ¾-in. and 181 tons ⅜-in. aggregate	Blue Metal & Gravel Pty. Ltd.	1,948 18 6
Do	4	Supply and delivery 5,500 cub. yds. gravel. Average lead 4½ m.	J. Henrick	2,155 10 0
Do	85	Supply and delivery 7,320 cub. yds. gravel. Average lead 5 m.	A. Sheather	2,414 10 0
Urana S.	...	Ploughing and loading 23,426 cub. yds. gravel for various main roads in the Shire.	Tatnell Bros.	1,484 2 6
Wakool S. ...	...	Supply and delivery to stockpiles 6 m. north of Barham—660 cub. yds. aggregate.	S. G. Weekley	1,062 0 0
Waugoola S. ...	6	Supply, delivery and spreading 2,425 tons of aggregate f.o.r. Woodstock and Cowra.	R. Scarce	7,518 17 3
Wingadee S. ...	...	Supply, delivery and spreading of sandy loam at various locations on main roads in the Shire.	G. Gillham	9,475 9 0
Woodburn S. ...	...	Supply and application of priming tar and binder on Main Roads 145, 148, 149 and 153.	B.H.P. By-Products Pty. Ltd.	2,249 4 9

SYDNEY HARBOUR BRIDGE ACCOUNT.

Income and Expenditure for Period 1st July, 1950, to 30th June, 1951.

Income.	£
Road Tolls	526,309
Contributions—	
Railway Passengers	129,678
Tramway Passengers	13,684
Omnibus Passengers	13,589
Rent from Properties	13,509
Miscellaneous	253
	£697,022

Expenditure.	£	£
Cost of collecting Road Tolls		43,562
Provision for traffic facilities		1,315
Maintenance and minor improvements		60,086
Alterations to archways		351
Widening Bradfield Highway to accommodate new Toll Barrier		2,650
Construction of new Toll Barrier and Office		4,260
Administrative Expenses		2,065
Loan Charges—		
Interest	232,085	
Exchange	24,964	
Sinking Fund	67,372	
Management Expenses	1,562	
		325,983
Miscellaneous		471
		£440,743

Note.—The figures in this statement are subject to adjustment upon completion of accounts for the year.

CORRECTION.

The reference opposite the photograph at the foot of page 108 of the June, 1951 issue of "Main Roads" to the Toll Gate at A'Beckett's Creek on the Parramatta-road, should have been to the Toll Gate near the present site of the Deaf, Dumb and Blind Institution, Princes Highway, Newtown.

MAIN ROADS STANDARDS.

NOTE: Numbers prefixed by "A" are drawings, the remainder are specifications unless otherwise noted

Form No.

EARTHWORKS AND FORMATION.

70 Formation. (Revised, June, 1949.
A 1532 Standard Typical Cross-sections.
A 1149 Flat Country Cross-section, Type A. (Revised, 1930.
A 1150 Flat Country Cross-section, Type B. (Revised, 1936.)
A 1151 Flat Country Cross-section, Type D1. (Revised. 1936.
A 1152 Flat Country Cross-section Type D2. (Revised, 1930.)
A 1476 Flat Country Cross-section, Type E1. (Revised, 1937.)
A 1101 Typical Cross-section One-way Feeder Road. (1936.)
A 1102 Typical Cross-section Two-way Feeder Road. (1931.)
A 114 Rubble Retaining Wall. (1941.)

PAVEMENTS.

71 Gravel Pavement. (Revised, June, 1949.)
228 Reconstruction with Gravel of Existing Pavements. (Revised, January, 1939.)
254 Supply and Delivery of Gravel. (Revised, August, 1939.)
72 Broken Stone Base Course. (Reprinted with amendments. August, 1947.)
68 Reconstruction with Broken Stone of Existing Pavement to form a Base Course. (Revised, October, 1933.)
296 Tar. (Revised, May, 1949.)
337 Bitumen. (Revised, February, 1939.)
305 Bitumen Emulsion. (Revised, September, 1942.)
351 Supply and Delivery of Aggregate. (Revised, July, 1941.)
65 Waterbound Macadam Surface Course. (July, 1939.)
301 Supply and Application of Tar and/or Bitumen. (Revised, June, 1950.)
122 Surfacing with Tar. (Revised, January, 1949.)
145 Surfacing with Bitumen. (Revised, January, 1949.)
93 Re-surfacing with Tar. (Revised, January, 1949.)
94 Re-surfacing with Bitumen. (Revised, January, 1949.)
230 Tar or Bitumen Penetration Macadam, Surface Course, 2 inches thick. (Revised, December, 1936.)
66 Tar or Bitumen Penetration Macadam, Surface Course, inches thick. (Revised, September, 1936.)
125 Cement Concrete Pavement (April, 1939) and Plan and Cross-section A 1147 (March, 1932).
466 Bituminous Flush Seals and Reseals—Fluxing of Binders. (January, 1949.)

GENERAL.

342 Cover Sheet for Specifications, Council Contract. (Revised, January, 1948.)
24B General Conditions of Contract, Council Contract. (Revised, September 1950.)
64 Schedule of Quantities.
39 Bulk Sum Tender Form, Council Contract. (Revised, August, 1946.)
38 Bulk Sum Contract Form, Council Contract.
121 Provision for Traffic (Revised, June, 1947) with general arrangement, A 1323 and details A 1325 of temporary signs. (Revised January, 1947.)
A 1342 Warning Signs, Details of Construction.
A 1346 Iron Trestles for Road Barriers.
A 1341 Timber Trestle and Barrier.
A 1824 Light Broom Drag. (1941.)
A 1924 Pipe Frame Drag.
A 178 Mould for Concrete Test Cylinder.
A 1381–3, A 1452–5 } Tree Guards, Types A, B, C, D, E, F, and G.
197 Hire of Council's Plant. (Revised, April, 1937.)
A 478 Specimen Drawings, Rural Road Design, with drawings A478A and A 478B.
A 478C Specimen Drawing, Flat Country Road Design.
A 1113 Rural Road Plan and Longitudinal Section Form tracing cloth).
A 1114 Rural Road Cross-section Form (tracing cloth).
A 1115 Urban Road Plan Forms (tracing cloth).
193 Duties of Superintending Officer (instructions). (Revised, July, 1938.)
314 Standard Regulations for Running of Ferries. (Revised, December, 1948.)
A 1645 Stadia Reduction Diagram. (1939.)
355 Instructions for Design of Two-lane Rural Highways (1937).
A 1487 Horizontal Curve Transitions (diagrams).
A 1488, A 1488A, A 1488B, and A 1488C.—Horizontal Curve Transitions (tables for speeds of 30, 40, 50, and 60 miles per hour).
A 1614 Widening of Shoulders on Crests.
369 Instructions for Design of Urban Roads (1939).
288 Instructions for Design of Intersections (Revised, January, 1948.)
402 Instructions for Design of Rural Intersections (acceleration and deceleration lanes). (March, 1951.)

Form No

KERBS, GUTTERS, AND GULLY PITS.

243 Integral Concrete Kerb and Gutter and Vehicle and Dish Crossing, (Revised, July, 1939) and Drawing. (A134A.)
245 Gully Pit (Revised, May, 1939) and Drawings (*a*) with grating (A 1042); (*b*) Kerb inlet only (A 1043); (*c*) with grating and extended kerb inlet (A 1352); (*d*) extended kerb inlet (A 1353).
A 190 Gully Grating. (1933.)
A 1418 Concrete Converter. (1936.)

FENCING.

142 Split Post and Rail Fencing and Drawing (A 43).
141 Post and Wire Fencing (Revised, December, 1947) and Drawings (*a*) Plain (A 494); (*b*) Rabbit-proof (A 498); (*c*) Flood gate (A 316).
143 Ordnance Fencing (Revised, February 1934) and Drawing A 7. (Revised, November, 1939.)
144 Chain Wire Protection Fencing and Drawing (A 149).
246 Location of Protection Fencing (instruction). (Revised, May, 1940.)
A 1301 Motor Traffic By-pass 9 feet wide. (1936.)
A 1875 Motor Traffic By-pass 20 feet wide. (1942.)

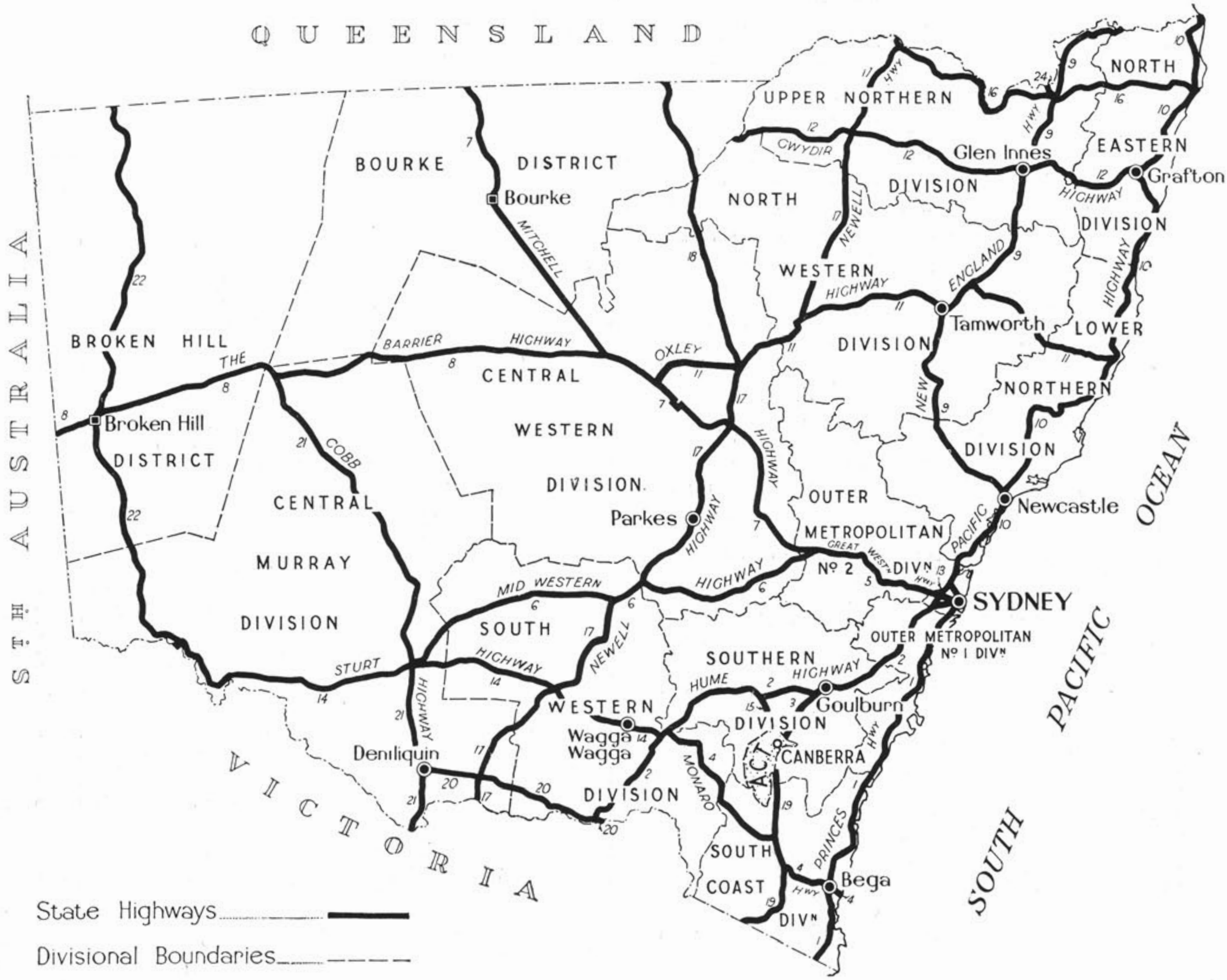
BRIDGES AND CULVERTS.

A 4 Standard Bridge Loading (general instruction). (1948.)
18 Data for Bridge Design. (Revised, November, 1948.)
84 Data accompanying Bridge or Culvert Designs.
A 26 Waterway Diagram. (Revised, 1943.)
371 Waterway Calculations. (1939.)
A 421 Boring Gear. 2 inches. (1930.)
A 44 Boring Gear, 3½ inches. (1949.)
A 2995 Rod Sounding Apparatus, with tripod (1947).
25 Pipe Culverts and Headwalls (Revised, December, 1939) and drawings, Single Rows of Pipes, 15 in. to 21 in. dia. (A 143), 2–3 ft. dia. (A 139), 3 ft. 6 in. dia. (A 172), 4 ft. dia. (A 173), 4 ft. 6 in. dia. (A 174), 5 ft. dia. (A 175) 6 ft. dia. (A 177); Double Rows of Pipes, 15 in. to 21 in. dia. (A 211) 2–3 ft. dia. (A 203), 3 ft. 6 in. dia. (A 215), 4 ft. dia. (A 208), 4 ft. 6 in. dia. (A 207), 5 ft. dia. (A 206), 6 ft. dia. (A 213); Treble Rows of Pipes, 15 in. to 21 in. dia. (A 210), 2–3 ft. dia. (A 216) and Straight Headwalls for Pipe Culverts, 15–24 in. dia. (A 1153).
A 1 Joint for Concrete Pipes. (Revised, August, 1933.)
A 142 Inlet Sump Pipe Culverts for 3 ft. dia. or less. (Revised, December, 1947.
138 Pre-Cast Concrete Box Culvert (Revised, February, 1948) and drawings, 9 in. high (A 485), 12 in. (A 446), 1 ft. 6 in. (A 447), 2 ft. (A 448), 2 ft. 6 in. (A 449).
206 Reinforced Concrete Culvert (Revised, February, 1948) and instruction sheets (A 305, A 359, A 306, A 304).
A 1832 Cast-in-Place Concrete Pipe Culverts. (1942.)
A 309 Concrete Culvert Posts. (Revised, June, 1937.)
300 Pile Drivers, specification for 25 ft., and drawings for 50 ft. (A 209) 40 ft. (A 253), and 25 ft. portable (A 1148).
A 1886 Arrangement of Bolting Planks for various widths of deck. (Revised, September, 1948.)
A 45 Timber Bridge, Standard Details. (Revised, May, 1949.)
A 1791 Timber Beam Skew Bridge Details. (Revised, May, 1949.)
164 Timber Beam Bridge (Revised, April, 1947) and instruction sheets, 12 ft. (A 3469), 20 ft. (A 70) revised, May, 1949, and 22 ft. (A 1761). (Revised, May, 1949.)
A 3470 and A 3471.—Low Level Timber Bridges—Instruction sheets for 12 feet and 20ft. between kerbs. (Revised, May, 1949.)
A 1223 (Revised, May, 1949) and A 3472 (Revised, May, 1949) Single Span Timber Culverts instruction sheets for 20 ft. and 22 ft. between kerbs.
139 Timber Culvert (Revised, January, 1950) and drawings, 1 ft. 6 in. high (A 427), 2 ft (A 428), 3 ft. (A 429), 4 ft. (A 430), 5 ft. to 8 ft. high, (A 431). (1928.)
326 Extermination of Termites in Timber Bridges. (Revised, October, 1940).
A 222 Pipe Handrailing Details. (Revised, July, 1947.)
350 Reinforced Concrete Bridge. (Revised, April, 1949.
495 Design of Forms and Falsework for Concrete Bridge Construction. (September, 1947.)

All Standards may be purchased from the Head Office of the Department of Main Roads, 309 Castlereagh Street, Sydney, single copies being free to Councils.

Sydney: A. H. Pettifer, Government Printer—1951.

State Highway System
of the
State of New South Wales



SCALE OF MILES

40 20 0 40 80 120 160 200

Area of New South Wales, 309,433 square miles.
Length of public roads within New South Wales, 126,272 miles.

MILEAGE OF ROADS CLASSIFIED UNDER THE MAIN ROADS ACT, AS AT 1st JULY, 1950.

State Highways	6,513
Trunk Roads	4,031
Main Roads	12,628
Secondary Roads (County of Cumberland only)	68
Developmental Roads	2,783
	26,023
UNCLASSIFIED ROADS, in Western part of State, coming within the provisions of the Main Roads Act	2,617
TOTAL	28,640