Oral History Program

Road Location and Design

SUMMARY REPORT

Researched and written by OHM Consultants

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About this oral history...

Oral history has been described as *"a picture of the past in people's own words"*. It reveals what you often won't find in the files and the history books - the facts and the real reasons things happened. It is told by the people who were there - those who were involved, who made it happen, who were affected - in the colour, passion and inflection of their own voices.

Oral history accounts can also tell about relationships, perceptions, social and political climates, all of which are part of life and influence our actions and those of others. It often reveals the unsung heroes, the names of those actually responsible for innovations and important changes.

So, oral history provides a counterbalance to the formal written record by providing the personal, intimate, human and social account of events and why they happened.

The RTA Environment Branch established an Oral History Program in 1997, to investigate various topics of historical interest. *Road Location and Design* is the seventh thematic oral history to be undertaken as part of the Program. As with previous projects, this oral history did not seek to present a definitive history of developments in this field, rather it involved a recounting of interesting stories and insights, told by those involved.

The *Road Location and Design* oral history project comprises 24 interviews recorded on digital audio tape with road designers, engineers, surveyors, information technology specialists and others. Compiled excerpts from these interviews may be accessed on the RTA website at www.rta.nsw.gov.au. Click on "Environment", then "Heritage", then "RTA Oral History Program".

This Summary Report traces the significant developments in the field and explores many of the themes raised during the interviews. It offers insights into the culture of surveying, the variety of surveying equipment used, data collection by remote sensing, the use of computers and model making. It also covers the evolution of design philosophy including a consideration of environmental and social influences, urban design principles, safety issues and road design standards.

The opinions expressed in the oral history interviews are those of the individuals concerned and do not necessarily represent in whole or in part the position of the NSW Roads and Traffic Authority.

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1. Introduction

1.1 The Client

The client for the oral history is the Environment Branch of the NSW Roads and Traffic Authority.

1.2 Liaison

The Project Manager is Stuart Hill, Environmental Officer Planning and Assessment, Environment Branch.

1.3 Authorship and acknowledgments

This report has been researched and written by Mary Ann Hamilton and Sue Andersen. We would like to thank the people we interviewed for their valuable contribution to this oral history:

Stewart Amery commenced working for DMR in 1976 as a field hand and is currently an Engineering Surveyor specialising in Global Positioning System.

Russell Ayling joined the DMR in 1981. In 1999 he went to work for Fujitsu and is currently a Senior Support Specialist with the company.

David Bennett was a consultant to the DMR during the 1970s and 1980s. He now is with Melbourne based ARRB Transport Research.

Jeff Chandler joined the DMR in 1986 as a Junior Model Maker. He is currently a GIS Officer with the RTA.

Raeburn Chapman joined the RTA in 1991 in Technical Services, Consulting Services Bureau. He is currently Senior Manager, Urban Design Section.

Peter Cooper joined the DMR in 1951. Now retired, Peter held the position of Locations Officer with the RTA.

Steve Dunlop has worked for the DMR/RTA since 1969. He is currently Policy and Strategy Manager of the Infrastructure Maintenance Branch.

Peter Ellis joined the DMR in 1979 and is currently a Senior Road Designer with the RTA.

Peter French joined the DMR in 1973 as a Road Designer. He is now an IT Desktop Specialist.

Jack Giddy joined the DMR in 1941. He retired in 1984 from his position as Senior Road Design Draftsman in the Rural Investigations Section.

John Gillies joined the DMR in 1966 as an Articled Surveyor. He retired from his position as Survey Manager – Geosystems, with the RTA in 2002.

Dr Peter Gipps was a consultant to the DMR/RTA since the mid 1980s and is now Research and Development Manager of Quantm, based in Melbourne.

John Goossens worked as a DMR Model Maker DMR from 1970 till his retirement in 1990.

Dr Lee Gregory is co-founder and Managing Director of 4D Solutions, an Australian software development company specialising in civil engineering and surveying applications.

Steve Levett joined the DMR in 1973 as a Road Design Draftsman. He is currently Manager, National Blackspot Program.

Mick Mancone, now a Senior Road Designer, joined the DMR in 1965 as a Junior Engineering Draftsman.

Brian Myers has been working as a Photogrammetric Officer for the DMR/RTA since he first joined the organisation in 1972.

Wayne O'Mara worked in both survey and road design areas since commencing with the DMR in 1972. He is now a Project Officer in Road Environment & Light Vehicle Standards Section.

Gerald Park joined the DMR in 1954 as a Junior Draftsman and retired from the RTA in 1995.

Peter Sandwith joined the DMR in 1966 as an Articled Surveyor. He retired from his position as Principal Photogrammetrist with the DMR in 1987.

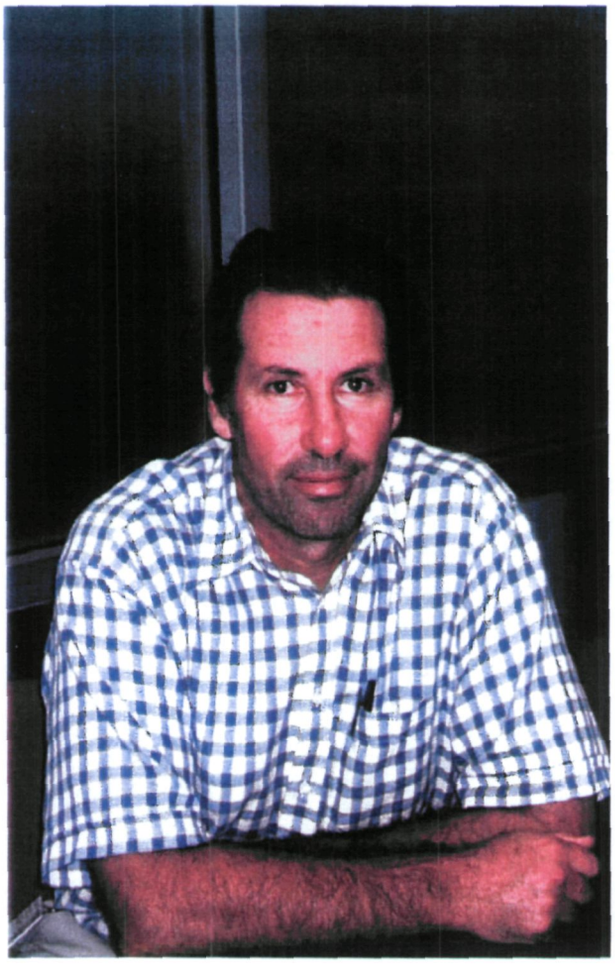
Rob Shipton joined the DMR in 1961 and is now Design Support Manager, Project Management Office.

John Vickery started with the DMR in 1968 in the design office. He is a Senior Road Designer currently in charge of updating and distribution of the RTA's Road Design Guide.

Theo ten Brummelaar commenced with the DMR in 1957 on a Civil Engineering scholarship and worked in road location and design until 1964 when he took up a lecturing position with the School of Highway Engineering, University of New South Wales.

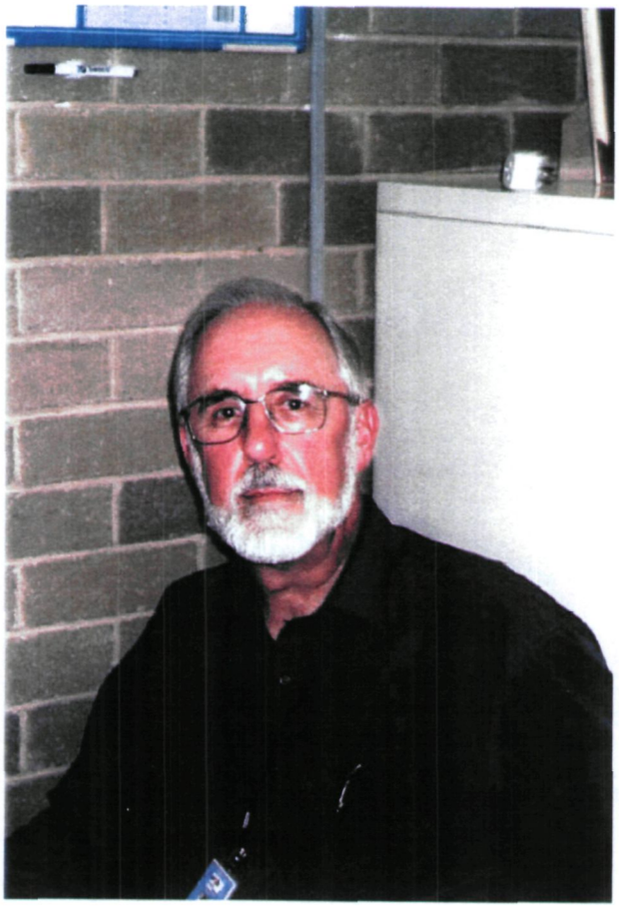
Chris Woodham joined the DMR in 1964 and is currently the Manager, Photogrammetry and Geoinformation in the RTA Operations Directorate.

We would also like to thank **Bill Evans** and **Felicity Barry** for their invaluable assistance in photographing some of the RTA's surveying instrument collection.



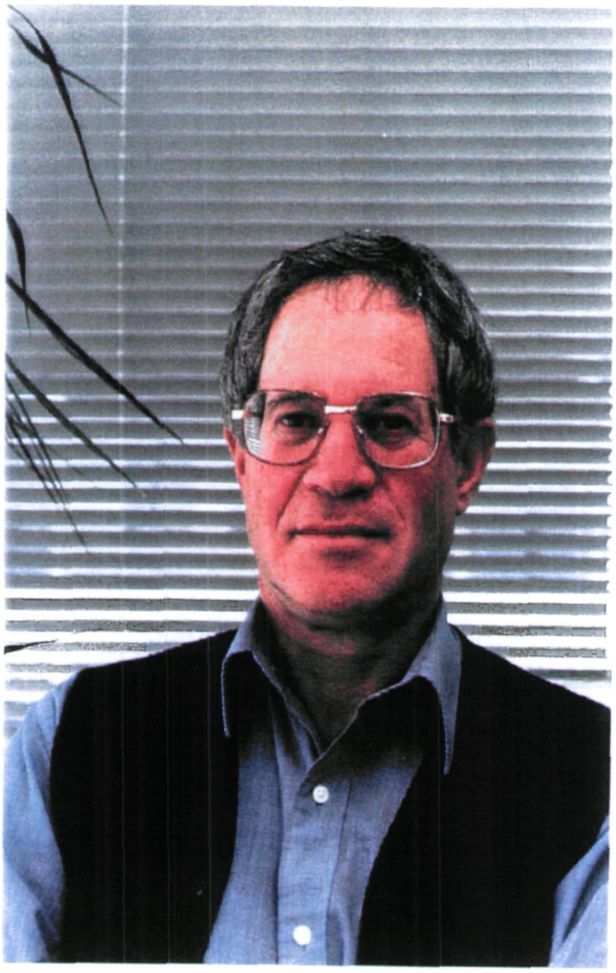
Stewart Amery

Russell Ayling

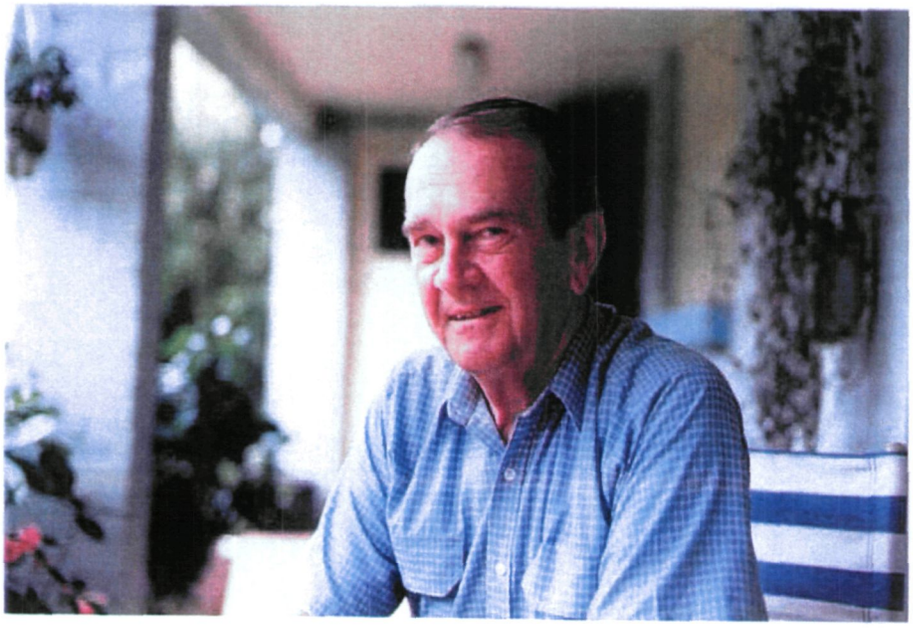


David Bennett

Jeff Chandler



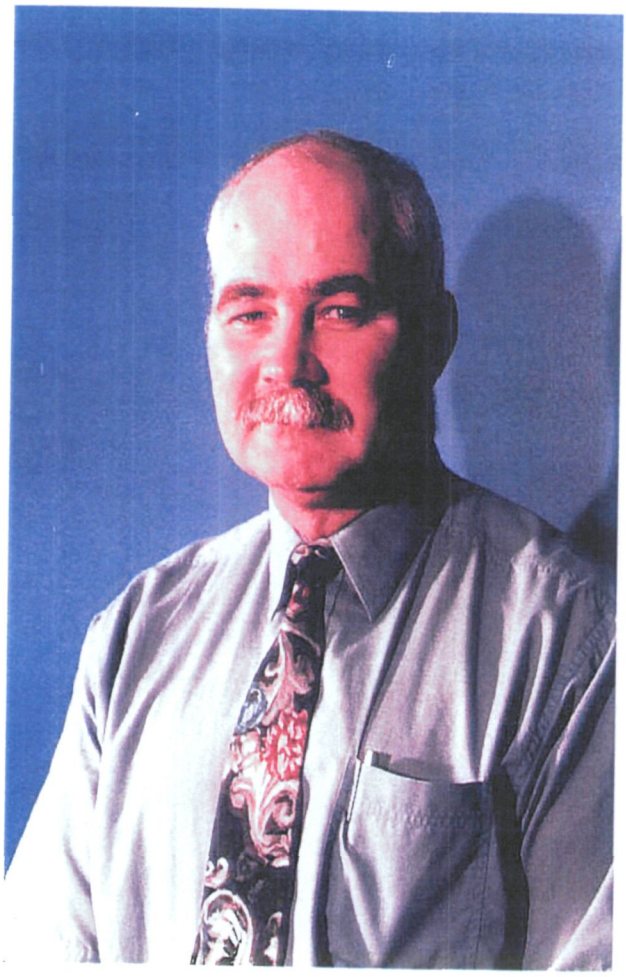
Raeburn Chapman



Peter Cooper

Steve Dunlop

Peter Ellis

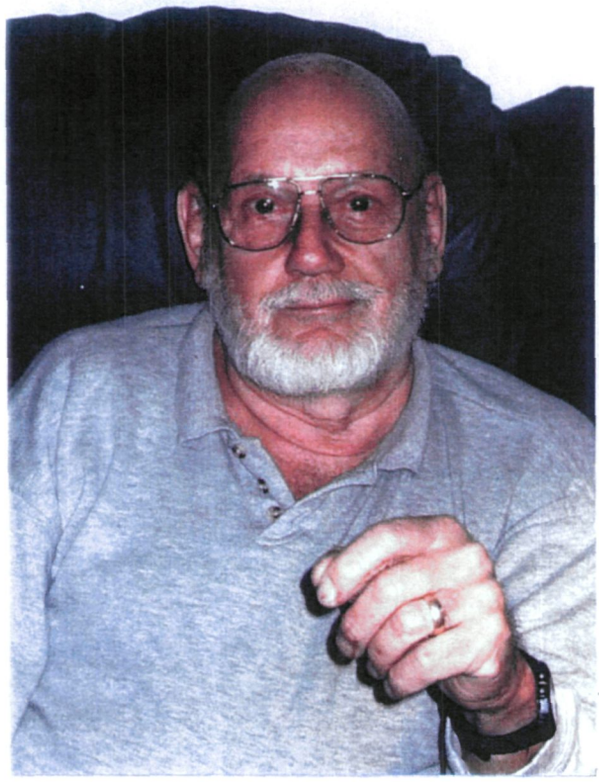


Peter French

Jack Giddy

John Gillies

Dr Peter Gipps

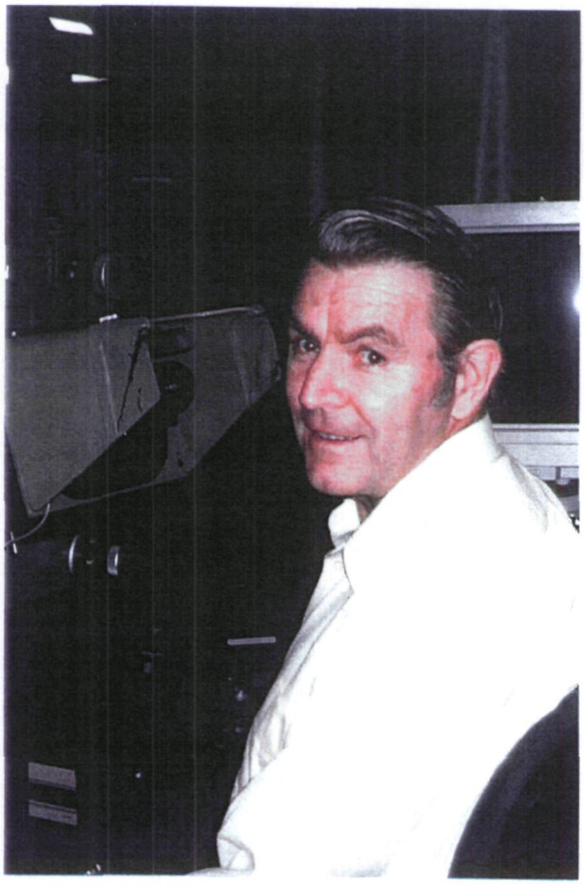


John Goossens

Dr Lee Gregory

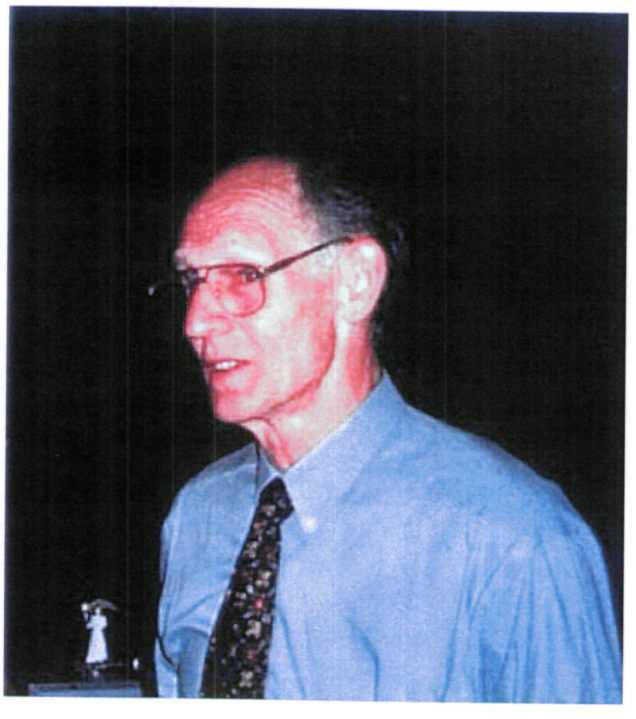
Steve Levett

Mick Mancone

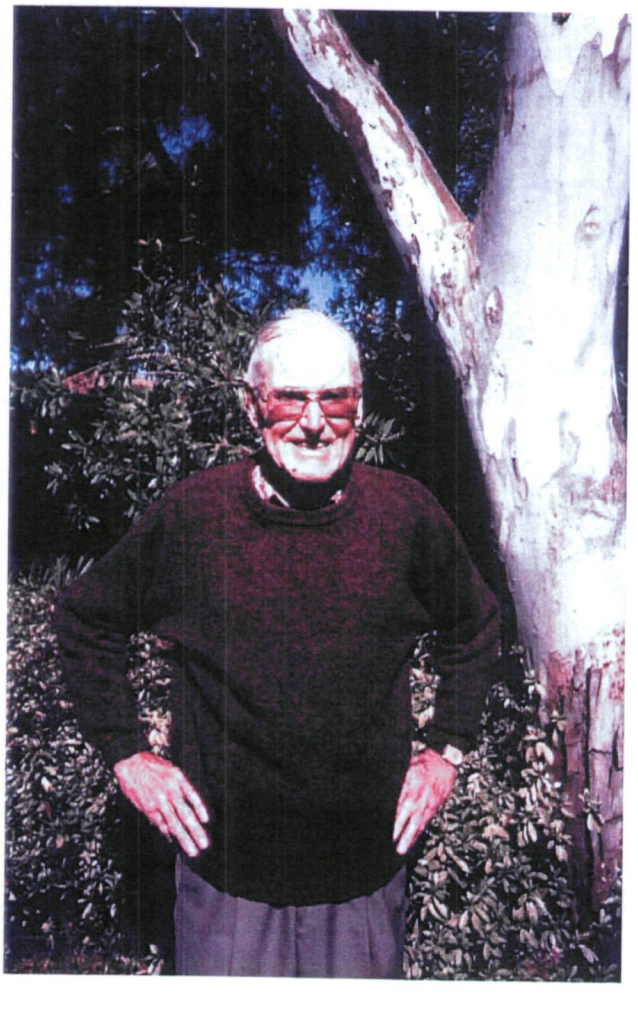


Brian Myers

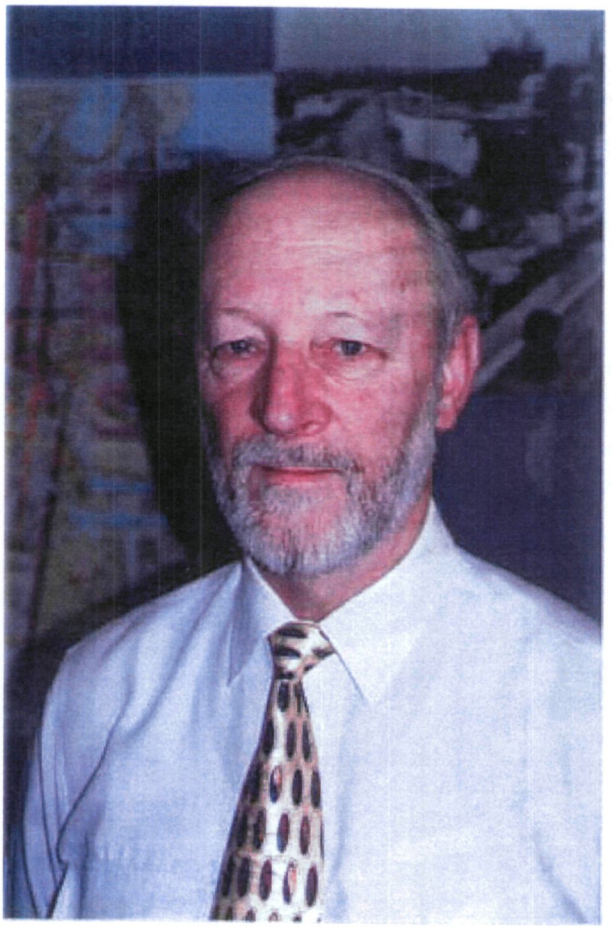
Wayne O'Mara



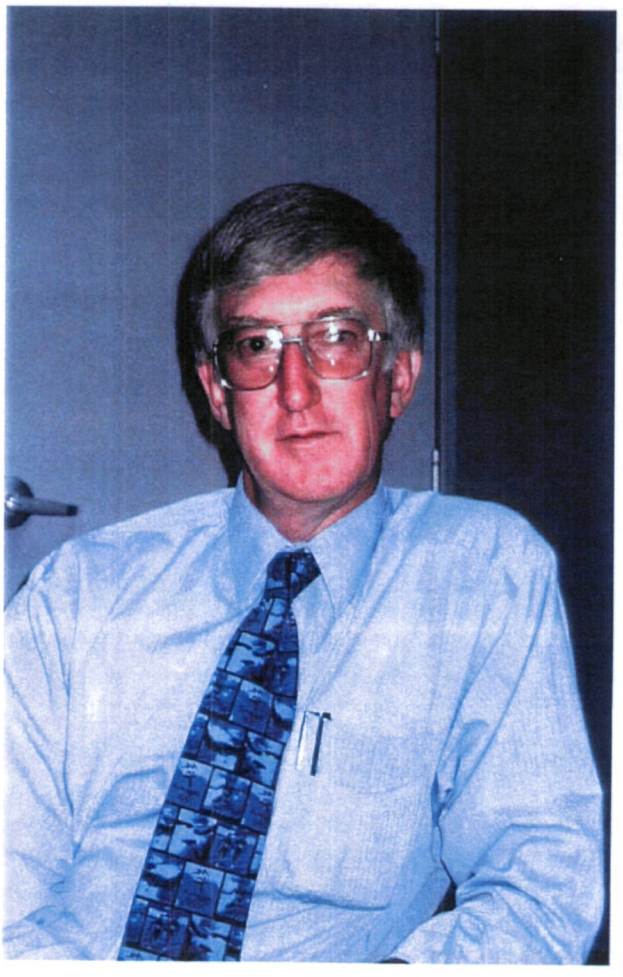
Gerald Park



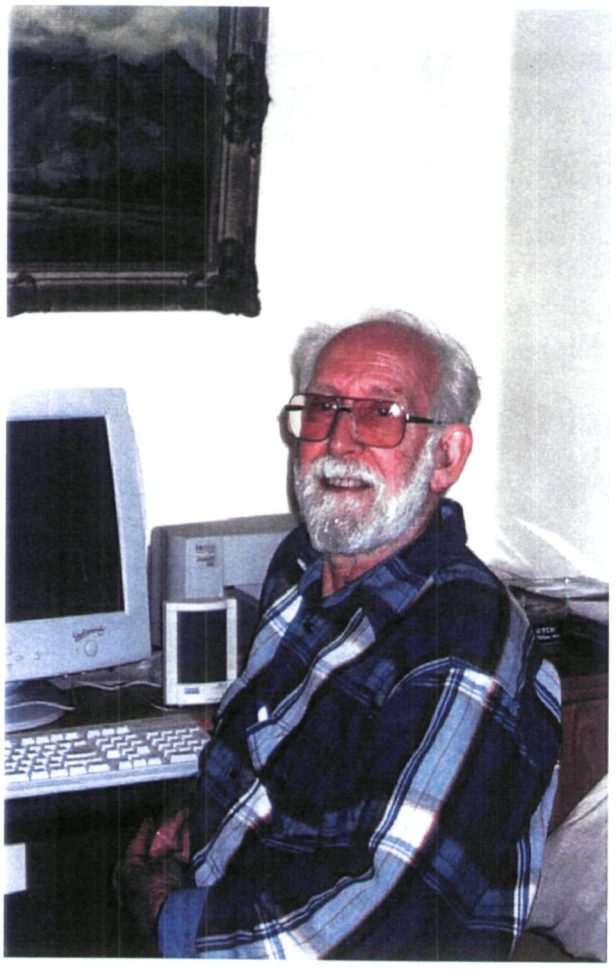
Peter Sandwith



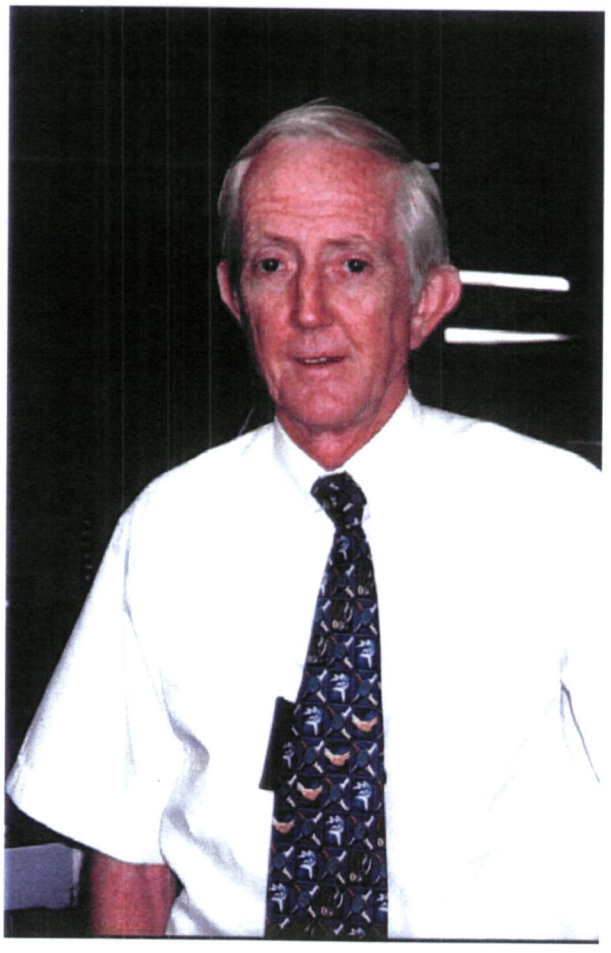
Rob Shipton



John Vickery



Theo ten Brummelaar



Chris Woodham

2. The Project – Road Location and Design

2.1 Aims

The aim of the oral history was to record a series of oral history interviews with people who worked in the area of road location and design in order to extend the historical knowledge of the RTA's road location and design activities over the years. The interviews are intended to contribute to documenting the history of the developments in road location and design, providing a rich social and historical context within which to view those developments.

2.2 Methodology

A period of preliminary research was undertaken which canvassed historical information available through the RTA Library as well as material available through the State Library of New South Wales. Preliminary interviews were undertaken with each interviewee to assist in developing questions for the oral history interviews. Letters and an information package about the oral history were sent to each interviewee.

A series of oral history interviews were conducted with twenty-four people associated with road location and design. Most interviewees were present or past RTA employees involved in road location and design. Other interviewees were consultants working with the DMR/RTA on specific elements of road location and design.

While mindful of the necessity for oral history to be open to the direction of the interviewees, the interviews were structured around a series of themes and included;

- information relating to the very early days of road making and design in New South Wales
- the development of the road system in New South Wales reflecting the historical growth and development of the State
- the changing context for locating roads over the years
- road location - why were roads historically constructed where they were, have the reasons for road location changed over the years?
- surveying – technology and changes – theodolites to GPS
- photogrammetry - description, usage, changes

- road design – changes in methods and technological changes
- impact of broader developments in transportation and the movement of goods and people on the development of road location and design
- State and national historical themes, thus providing a valuable contribution to the broader research community

A series of broadcast quality interviews was undertaken with current and former staff and contractors associated with field survey, photogrammetry and road design.

To retain the personalised focus of the interviews these themes were discussed in terms of the interviewee's personal experience.

The interview tapes were logged and bound in volumes that accompany the interview tapes. A summary of the findings of the oral history has been developed and is contained in the main body of this report.

Material for this report has been gained primarily from the oral history interviews. As well as outlining the story of the development of road location and design in New South Wales, the interviews provide a rich social context in which to understand the history of road location and design. The report also provides a broader historical background to the history and role that roads have played in the development of road transportation networks in New South Wales. This information also has been derived from library and archival sources.

It should also be remembered that the oral history interviews and the report have not dealt with road construction and materials.

3. Overview

Surveyors, Draughtsmen and Engineers have undertaken road location and design since the first days of the colony of New South Wales. In those early days, roads provided essential links for transport and communication between isolated pioneering settlements. Since then, Surveyors and Designers have remained in a firm partnership in the development of the State's roads.

Colonial roads were located by the Surveyors who laid out Crown Lands in the new Colony. Military Engineers, who also oversaw their construction by convict labour, designed the early main roads such as the Great Northern Road. This road provided a vital link between Sydney and a number of growing but isolated settlements in the Hunter Valley to the north.

The Great Western Highway was constructed on the trail taken by Blaxland, Wentworth and Lawson. The explorers found that the ridgeline was the only way to cross the Blue Mountains from Sydney. Similarly, many of the routes heading north were trails that followed the rivers and then wound their way up and over the mountains. Many of these roads were opened up by cedar loggers and later pastoralists.

Other more localised roads were established by the regular travails of bullock carts plying goods and supplies to and from outlying farms and settlements. These tracks often provided the blueprint for more established roads – in fact the development of the Pacific Highway is characterised as a series of "goat tracks" that linked settlements up the north coast.

After the early colonial years, responsibility for construction and location of roads passed to the NSW Department of Public Works. Peter Cooper, who was a Locations Officer with the DMR/RTA for many years, commented that New South Wales roads during these years were typically low speed roads which, when they arrived at a mountain pass or hill, would continue on straight over the rise (Peter Cooper RTA RLD 10 Side B 799).

Such roads were adequate for the passage of bullock and horse drawn vehicles but not for motor vehicles which had become the increasingly common form of transport by the 1920s. In 1925 a new government agency, the Main Roads Board, was set up to exclusively look after the location, design and construction of New South Wales roadways.

Post World War II, the role of the State's roads underwent a significant change in response to the burgeoning population and subsequent growth of towns and industries such as timber logging, sugar growing and dairying. The DMR set about the task of providing access roads to service these growing rural communities.

Over the years since 1925 the Main Road Board and its successor the Department of Main Roads continued to advance the science of road design and construction. The Roads and Traffic Authority has become one of the foremost road construction Authorities in Australia and internationally. Its reputation has developed as a result of its responsiveness to the changing requirements of road location and design and its readiness to apply new technologies to these activities.

4. Road Location – Surveying and Investigation

4.1 Surveying

The DMR/RTA surveying teams continue to play an integral part in the locating of New South Wales roads. Over the years since 1925, surveying teams attached to regional and city based DMR drawing offices have provided the basic geographical data from which road locations can be determined.

A road survey records all the features of the surface of the land lying in a planned road corridor. It details land levels and bearings for the corridor of the roadway and references this data to known survey control points. Survey information also documents other significant features that may impact on the road such as significant stands of trees and streams or the location of public utilities in an urban situation.

As was explained by John Gillies, who joined the DMR as a trainee Surveyor in 1966, there are several types of survey that contribute to the location and design of a road. These include the field or photogrammetric survey, the boundary survey and the engineering survey.

In general terms the process of locating a road begins by looking at topographical, military, council and other maps to ascertain the most effective passage through the terrain. In the old days once this corridor of interest was decided, the Surveyor went out into the field to record data on distance, bearing and level for all the features of the land in the corridor. This information was then developed as a contour map and given to the Designer to plot and start preliminary designs. In later years contour maps were also developed from photogrammetry.

In both urban and rural situations boundary surveys were, and still are, carried out to define the old boundaries of private property and to define the new road corridor. This assists in determining whether privately owned land needs to be acquired.

> *"The process of finding boundaries is part science and part skill and experience. As a boundary surveyor you are always working with those who have surveyed the land before you... You get to know... the style or approach of a particular Surveyor because you work with the plans of the previous Surveyor – you feel like you are on a first name basis with them."*
> (John Gillies RTA RLD 12 Side A Tape No 716)

As John explained, the process of boundary surveying entails locating previously established survey marks and connecting them to the current survey to define the old boundary. Surveyors mark the corners of a property using a variety of different markers. In rural or less built up urban situations, corners may be marked using a

white peg. If the corner falls on concrete it can be marked with a drill hole and wing and if there is a fence post there a nail may be hammered into it. These marks are noted on the survey and given a bearing and distance reference in relation to the boundary (John Gillies RTA RLD 12 Side A 860).

In rural areas, Surveyors rely on finding evidence of original Portion Surveys that were laid out in colonial times. These reference marks were often made on old trees. Stewart Amery, who commenced work as a Surveying Field Hand with the DMR in 1976, noted that he has found many shields cut into trees as survey reference marks. This was done in preference to pegging as pegs often rot away over time. Many of these marks have a certain heritage value as some of them date back to colonial days (Stewart Amery RTA RLD 8 Side A 1686).

As well as these surveys there are engineering surveys, where the centreline of the road is pegged on the ground. After the centreline is pegged the Surveyor marks out cross sections of the road at regular intervals along the centreline, recording all distances and levels to each feature of the cross section – the edge of pavement, edge of shoulder, drain, edge of cutting. This information would be drawn up or tabulated in a field book and given to the Designer to compare to his designed cross sections (John Gillies RTA RLD 12 Side B 1108).

A final survey of 'works as executed' documents the actual placement of all the features of the new road.

4.2 Surveying instruments

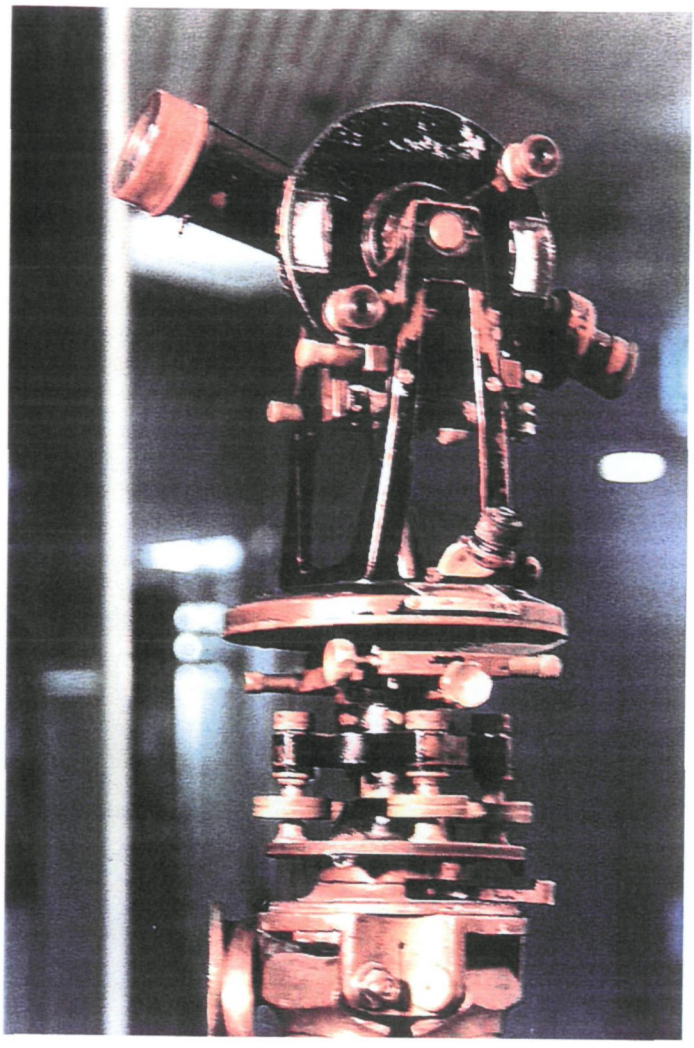
Peter Cooper started work as a Surveyor with the Investigations Section of the NSW Department of Main Roads in 1951 where he was articled to Dave Hill. Later he was transferred to Grafton where he completed his training with another Master Surveyor, Wes Harrison. Peter's first job in Grafton was to assist Wes peg the section of the road between Glen Innes and Grafton that crosses the Gibraltar Range. Pegging the line involved marking the centreline of the proposed roadway with white pegs. The bearing or direction of the road was gained using a theodolite that measured vertical and horizontal angles. The theodolite also gave information on land levels although usually a level and staff were used (Peter Cooper RTA RLD 10 Side A 510).

Distance was measured using a steel band or linked chain. In Australia, measurement using chains and links dates back to colonial times and involved literally using a chain made up of a hundred links. This early form of measurement was still used by Stewart Amery when he first began his career with the DMR in 1976.

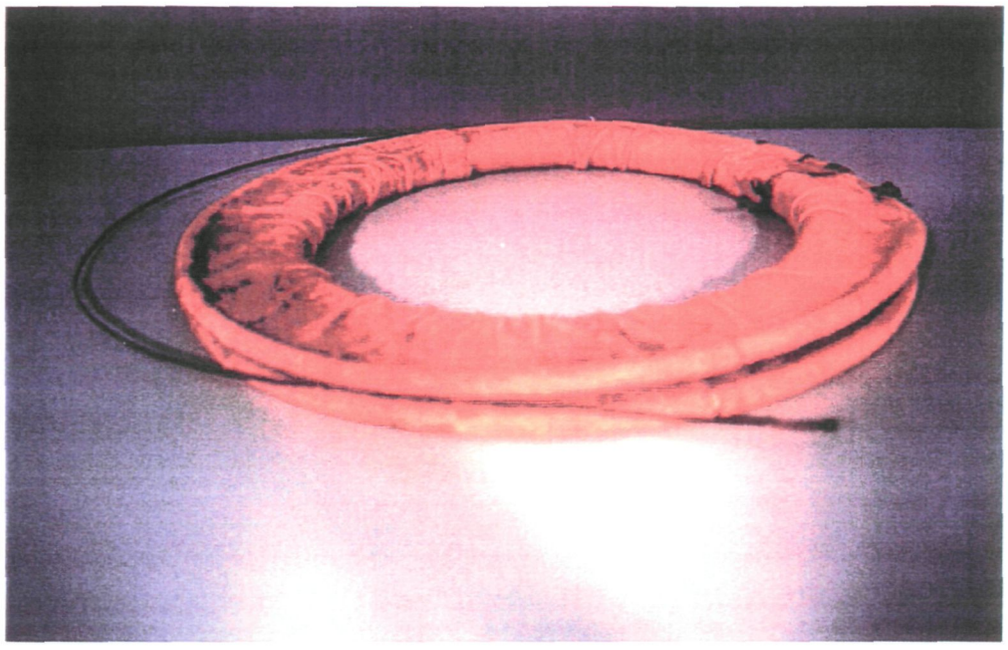
John Gillies recalled using a steel band to measure distance. This was a precision instrument. It was 300 feet long and was hand wound and contained in a canvas bag. The steel band was standardised and the effects of different temperatures on the length of the band could be accurately calculated. A spring balance was also used to

Compass and case

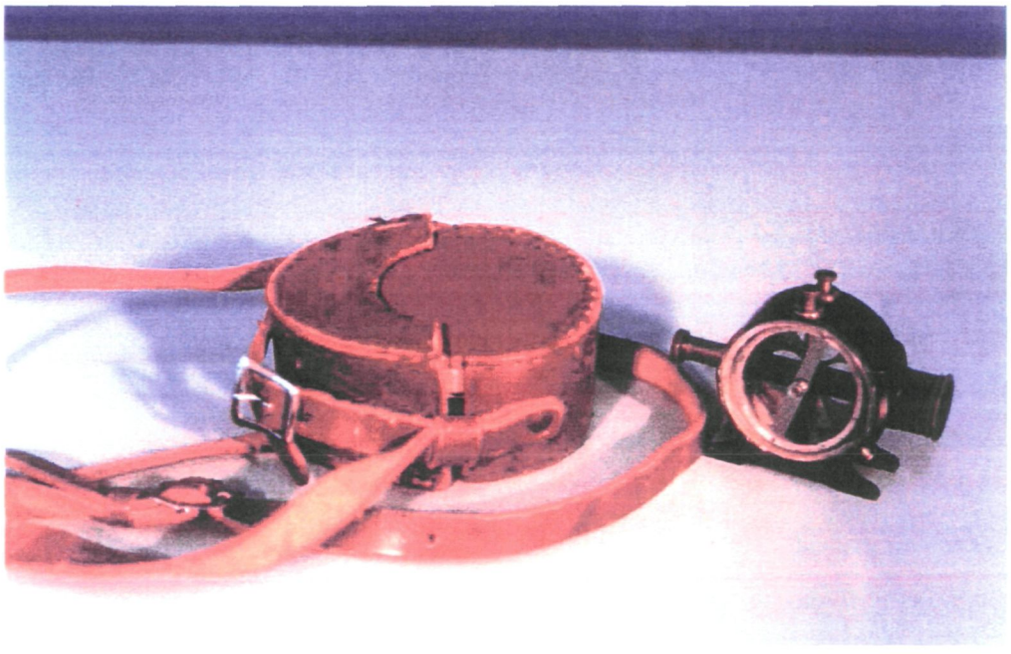
Modern theodolite



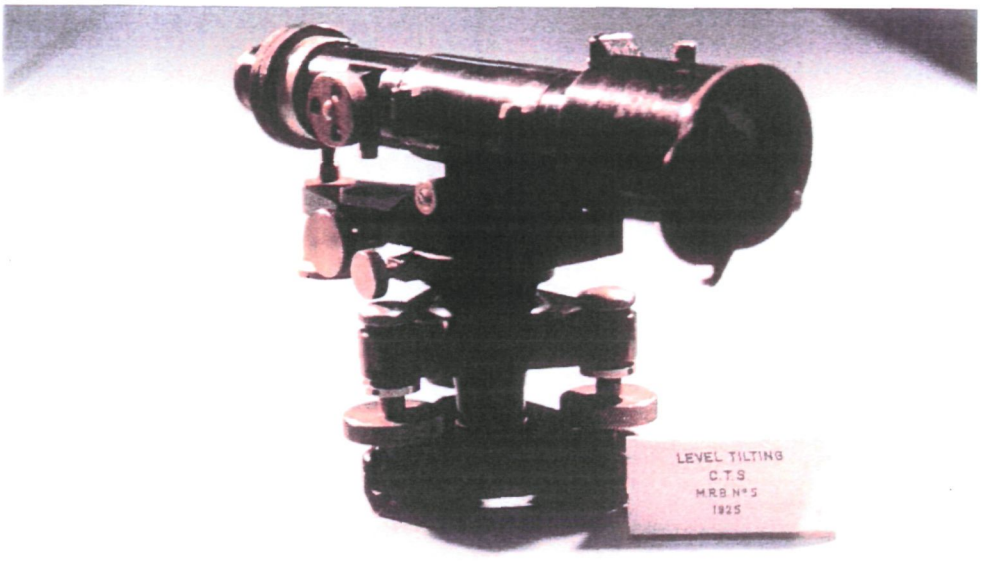
Theodolite



Steel band and leather bag

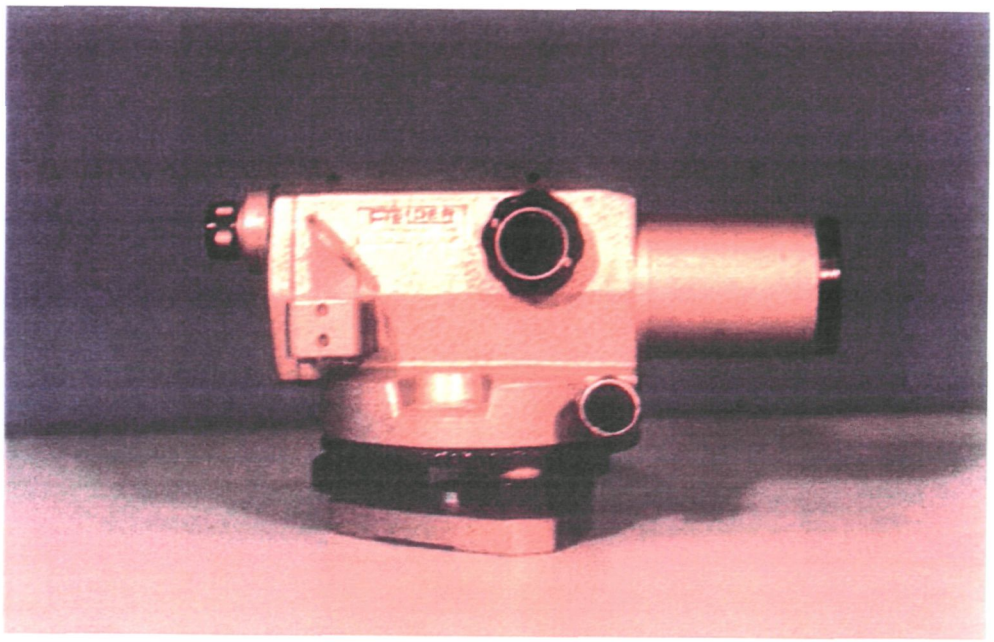


Clinometer and case



Level Tilting 1925

Level with wooden case and leather carry case



Level circa 1964

Level circa 1980-1985

apply an exact tension to the band to counteract sag and further ensure the accuracy of measurement.

A revolution in surveying technology occurred in the 1970s when the measurement of level and distance was done using Electronic Distance. Measuring or EDM. John Gillies explained that this device emits a beam of light that is reflected back from a designated reflector. The device then calculates relevant measurements from this electronic information.

In more recent years surveying information is derived through the use of Global Positioning System. The GPS receiver sits on the Surveyor's tripod over a position on the ground. The GPS data recorder reads all the positioning information, latitude, longitude, height and time, as the GPS satellites beam it down. Distance can also be calculated using GPS data.

According to Chris Woodham, who joined the DMR as a trainee Surveyor in 1964, Surveyors were the first professionals in the civilian community to make use of GPS. This technology has made huge improvements in the productivity of surveying teams. John Gillies and Stewart Amery both stressed that these technologies have dramatically reduced the size of survey teams and the length of time required to do the survey.

The recording of the survey data developed in parallel to instrumentation. Up until the early 1970s survey measurements were recorded in a field book. Wayne O'Mara, who joined the DMR in 1972 as a Survey Field Hand recalled that between 1975 and 1977 the DMR surveying team started using an electronic tachometer called a Regalto. This instrument measured distance and bearing and transferred all this information onto tape on site. This field information was then transferred onto one punch tape and fed into the DMR's new mainframe computer.

These days information collected using the GPS is downloaded directly to GEO LAB, a program designed especially to work with GPS information.

4.3 Culture of surveying

Surveying in the years up to the end of the 1950s was often through unpopulated, rough country such as the Gibraltar Range between Glen Innes and Grafton. In such country a Surveyor often had to travel on horseback or foot, equipped with only a map, swag, a clinometer and compass. These field trips could take from several days to weeks according to Chris Woodham (Chris Woodham RTA RLD 26 Side B, No. 1574).

Peter Cooper recalled that he and his boss camped in a tin shed in the tropical bush land at the foot of McKeys Spur while completing the Glen Innes to Grafton survey in the 1950s. When they camped out in the field they each received a camping allowance of four and tuppence per week for supplies which they carried

in to the campsite. They supplemented their rations with wild duck, turkey and pigeon that they shot and cooked in a camp oven.

Peter's experience out in the field in the 1950s was part of a long tradition of surveying culture. Peter related a number of tales about surveying parties early in the 20th Century. One surveying party working in the 1920s was headed by a Surveyor named Jansen, and surveyed a route from Tumut to Canberra. Peter had found numerous letters from Jansen to Head Office requesting that they be able to purchase corn bags from the general store in Tumut. These were to be stuffed with grass and used as mattresses for the team members. This request was denied. Facing the lack of home comforts in the snow country, the team sought solace in the rum bottle as evidenced by later correspondence reporting that Jansen had to take a field hand to Tumut hospital, suffering from alcoholic poisoning!

By the 1960s and 1970s when Surveyors such as John Gillies and Stewart Amery joined the DMR, rural New South Wales had become far more developed and had a reasonable infrastructure of roads. In these circumstances motel facilities replaced the necessity to camp out and live too roughly. As well, rather than travelling on horseback, these younger Surveyors made good use of four-wheel drive vehicles in less accessible country.

In the mid 1960s the DMR purchased a helicopter that was used for a number of purposes, including general route location identification, land use surveying, traffic management, flood photography and surveying. It was particularly useful in providing Surveyors with access to remote and rough locations.

> *"Occasionally we had to fly into locations, the pilot was good, but it was sometimes hairy, particularly when we were flying in fog...it became too expensive and because the State's road network is so good we don't need to fly in so much"*
> (Stewart Amery RTA RLD 8 Side A 1614)

4.4 Road investigations from 1960s

Along with other changes in surveying and road design there was also a significant shift in approach to locating roads during 1960s. Peter Cooper noted that right up until the mid 1950s the DMR had been preoccupied with simply upgrading existing low speed roads in both urban and rural situations. From the early 1960s there was a realisation that modern vehicles needed new, modern roads to travel on. There was a lot of work conducted around this time on defining new road corridors.

The process of locating a road begins with determining a route between two geographical points. Peter Cooper described the process of determining the best location for a road.

> *"...downhill and in a straight line is probably the best location for a road!.. but it's not always possible to do... And generally the route that is the shortest possible distance is the best location "*
> (Peter Cooper RTA RLD 10 Side B 1340)

By the early 1970s computerisation was beginning to be used in the process of locating the best possible route for a road. David Bennett, who worked as a consultant for the DMR at this time, had developed a computer program called Optloc used to optimise locations for new or relocated roads. Working with Bruce Smith, who was initially with the Surveying Section and later in Photogrammetry, David first applied his location program to finding the optimal route for the upgraded Hume Highway in the rugged country between Goulburn and Yass.

> *"The [existing] road followed the alignment of the railway ... it was problematic because there were a lot of steep cuts and fills and the road had to cross the railway line several times ... we used a digital terrain model and got the curvatures and grade constraints from there ..."*
> (David Bennett RTA RLD 32 Side A 362)

While the shortest route between two points on a map can be easily determined, the reality of locating a road is detailed by the investigations of a Surveyor whose information reveals the constraints of geography and other factors. For many years it was construction cost alone that determined the route. These days many other constraints are considered when deciding on the location of a road. User costs associated with the route, environmental factors, tourism, property boundaries, safety and land use are all considered.

Wayne O'Mara recalled an early environmental survey associated with the location and construction of a section of the F3 Freeway at the back of Hornsby in the mid 1980s.

> *"The planned road went through a National Park...the DMR chose the preferred line of the road and the personnel from the National Parks and an archaeologist walked the proposed route and found endangered species and wildlife and Aboriginal sites. The plans had to be adjusted...It's now standard practice to do archaeological and flora and fauna surveys..."*
> (Wayne O'Mara RTA RLD 17 Side A 1405)

Rob Shipton, who has worked in road design since he commenced with the DMR in 1961, noted that the investigation of the natural environment in a planned road reserve could require the services of numerous specialist personnel. Such personnel may include botanists who study the site and set safe traps to comprehensively survey and identify fauna and vegetation (Rob Shipton RTA RLD 1 Side B 566).

In many cases, road construction projects include landscaping using local species of vegetation. Landscaping is started well prior to the commencement of construction. This precaution reduces the degradation of the land around the road during construction and also maintains the integrity and diversity of the local flora.

Flooding and drainage patterns impact on the location of a road, on the design process and the on the long term maintenance of a road. Therefore a flood study is an extremely important component in the location and design of roads.

Information on flooding is gathered from statistical sources but personnel also spend a lot of time gathering anecdotal information on flooding. Peter Ellis, who began work with the DMR in 1979 as a Junior Draughtsman, recalled one flood investigation of a freeway near Wyong. In this case a calculation was made as to the level of the floodwaters in a particular area. This estimated level was then backed up with anecdotal evidence from locals.

> *"Ian Lovelock did all the calculations for the highest flood level on the F3 at Wyong. When he had done this, we both went out and started talking to a local resident about a flood that had occurred and told him of our calculations... he showed us a mark on the wall of his house that was where that flood had come to – we were about two feet out – it was two feet higher than our calculations. So we did all the calculations again and came up with the same numbers. We went back to the gentleman to check his levels and he said 'yes I'm sure that's the level there is the date --- -oh but I have put the house on piers since that flood to keep it out of the water'... the piers were about two feet high!"*
> (Peter Ellis RTA RLD 23 Side A 151)

5. Data collection by remote sensing

5.1 Aerial photography and photogrammetry

Aerial photography has been used by the DMR for the purposes of investigation, location and design of the State's road system since the late 1930s. Military maps and aerial photographs were available at the time but their accuracy and clarity were not considered detailed enough for road location and design.

According to Peter Cooper, the DMR was the first organisation in New South Wales to use aerial photographs specifically for road location investigations. This was in about 1937, when the DMR was investigating a location for a road over the Gibraltar Range (Peter Cooper Tape 10 Side B 451). Chris Woodham noted that a reconnaissance camera was used for aerial photography in the early days (Chris Woodham RTA RLD 26 Side A 1180).

When they were first employed aerial photographs were used to note major geographical features such as rivers, mountains, ridges and valleys. Field Surveyors then further investigated the route and documented the terrain using traditional surveying techniques and measurements.

During the War years there was a general improvement in the process of mapping. The Lands Department's Central Mapping Authority was set up in 1949 (Department of Main Roads, 1957, *Main Roads*. Vol XXIII No2 p 58) and this Department worked hand in hand with the DMR on improving techniques of taking aerial photographs. Methods of making accurate measurements of distance and land contour from aerial photographs were developed. This was done through photogrammetry.

Peter Sandwith who worked for the DMR as a Photogrammetric Officer from 1968 to 1987, recalled that the DMR's Photogrammetry Section, as a distinct Departmental Section was established by Bruce Smith not long before Peter joined the Section. As Peter recalled the Section was initially located in the DMR building on Castlereagh St.

> "*In the old building, the accommodation was terrible. We were in one room, with only one or two windows and they were high up...there was no real place to store our photo library. I was pleased when we moved to the building opposite Central Railway Station ...we were high up with good windows and light and it had a good floor – the thing is you must have a good stable floor for photogrammetry ...*"
> (Peter Sandwith RTA RLD 49 Side B 1189)

In 1968 the Photogrammetry staff numbered three; Peter, Bruce Smith and Peter Swart. All three had trained at the Institution for Aerial Survey and Earth Sciences in Delft, Netherlands. The Photogrammetry Section grew rapidly in the late 1960s and through the 1970s and the staff swelled with both Netherlands and Australian trained graduates such as Brian Myers, Bob Payne and Chris Woodham. Demand for photogrammetry became so strong by the late 1970s and 1980s that the Section regularly employed outside consultants to both fly photography and produce contour maps for projects (Peter Sandwith RTA RLD 48 Side A 720, 48 Side B 303, 49 Side B 1167).

Photogrammetry comes from the words 'photogram' and 'measure' and in simple terms is a technique of rendering a plan of terrain from aerial photographs. The photogram is taken by a special survey camera mounted to a plane that flies over the terrain and takes a series of photographs that overlap by 60% to 80%. These overlapping images are viewed through a stereoscope that produces a view of the terrain in three dimensions (Chris Woodham RTA RLD 26 Side A 1180).

> *"The stereoscope was basically a four legged raised binocular with two eyepieces and having two reflective mirrors on each side. The two photographs were put underneath. The photographs had a 60% duplication factor and this was the part you would view. You looked through the eyepieces moving the photographs until they come together as one image – then the mountains jumped up and the valleys receded."*
> (Rob Shipton RTA RLD 1 Side A 1433)

It is crucial to plan the photography flight according to the proposed uses for the photogrammetry. Aerial photography for initial road location purposes requires photographs that cover a wide area of terrain. These photographs are taken from a high ground height level and use wide or super wide angle photography. From these photographs the actual location of the road was refined. Project photography, that details the narrower corridor of the road route, is flown at a lower fixed ground height level using a less wide angle lens.

> *"The plane was set to fly at a certain constant altitude and maintained a stable and slow pace through the course of the flight.*
> *The camera was set up in the fuselage and took shots every ten seconds or so depending on the height of the flight "*
> (Rob Shipton RTA RLD 1 Side A 1374)

Brian Myers, the last of the DMR/RTA Photogrammetric Officers, joined the DMR in 1972 and has worked in photogrammetry for most of his career, which started in the Lands Department in 1960. As a Photogrammetric Officer, Brian is responsible for planning photography and checking its integrity. He reflected on the aerial photography of twenty years ago, saying that the process was all done manually.

> *"...the aircraft would be lined up manually, as was the adjustment on the intervalometer and the camera was operated manually...they didn't often get it wrong...now it's all automated, flying levels are fixed and the camera operates automatically...this doesn't allow for changes in the terrain and the photographs can get distorted"*
> (Brian Myers RTA RLD 41 Side B 1246)

Brian indicated that these days the camera's functions are set automatically before the run is flown. This can lead to some mistakes in photography as was illustrated during recent work on defining the road reserve on the Alpine Way, in Kosciuszko National Park. The responsibility for the road reserve will be transferred from the National Parks and Wildlife Service to the RTA and boundaries need to be defined. This has been difficult due to the dense bush and the lack of any control markers. Accordingly this project has proven to be challenging for Brian, the Surveyors, and it seems, the pilot doing the aerial photography.

> *"We were restricted as to when we could fly because the dense vegetation casts shadows on the road, so we flew as close to December 21st as we could – during spring solstice less shadows are created....but the contractor made a mistake...the lens was knocked and 15 runs were flown with a tilt on the camera...they were unusable so we had to fly the area again..."*
> (Brian Myers RTA RLD 41 Side B 906)

This sort of oversight would rarely have occurred in the days of manually operated aerial photography.

Prior to 1989 the DMR had an extensive aerial photography program that aided investigation for new road locations and provided information relating to upgrading and maintenance requirement of existing roads. Chris Woodham noted that the Hume Highway was photographed every ten years as part of its upgrading process (Chris Woodham RTA RLD 26 Side B 0012).

Currently the RTA only flies aerial photography for specific jobs. It is still the case that depending on what the photographs will be used for – investigation, concept planning or preliminary design - they all need varying requirements of accuracy. If a road or area is straight, a long run of photographs can be taken in one direction. If the geometry of the area to be photographed has deep curves and bends, the photographic run may not fit on the width of photograph so shorter runs need to be taken. In the years before 1990, if the photographs were being used for triangulation purposes then the photographic frames were normally restricted to less than twenty five. This was governed by the method of adjustment of the triangulation. After 1990 more modern adjustment methods permitted longer runs (Brian Myers comments in discussion).

Brian added that most of the RTA's photography is flown with a wide angle lens at a scale of 1:8000 which is suitable for one metre contours. As well, the RTA avoids

applying photogrammetry for merging pavements and bridge design as these need sub centimetre accuracy (Brian Myers RTA RLD 40 Side B 0012).

5.2 Ground Control surveying

Although photogrammetry was devised for mapping, and aerial photographs have the characteristics of a map, Chris Woodham noted that the photographs are never accurate in-scale representations of the terrain. There are scale changes between the photographs taken on a photography run. These are caused by even small changes in the height at which the plane flies, or the plane being buffeted by wind, speed changes and by banking movements of the aircraft during the flight. Because of these inconsistencies, angles or distances cannot be measured from aerial photographs correctly without adjustment (Chris Woodham Tape 26 Side A 674).

Rectification of photographs is made possible using known locations referenced from trigometric stations that lie in the State Coordinate Grid.

By 1957 photograph mosaics were developed where a series of aerial photos were enlarged and cut into 1/8 inch wide strips. These were joined together again with areas of the map shrunk or stretched to account for scale deviations. This "in scale" mosaic was then rephotographed. It was then possible to plot the contours of the terrain accurately (Rob Shipton RTA RLD 1 Side A 1550).

Carefully surveyed ground control points visible in the photographs are also crucial to deriving accurate information from photogrammetry. These control points are used to help the pilot constrain the run of photographs from twisting. The ground control points also assist in aligning the photographs for photogrammetry and provide an accurate reference for height, distance and bearing in the photographed terrain. Surveyed ground control points are thus crucial to being able to use the photographs for producing three dimension plans of the terrain (Brian Myers RTA RLD 41 Side B 0120).

One of John Gillies' tasks with the Rural Investigations Section in the early 1970s was to survey ground control points prior to flying aerial photography. Both John and Chris Woodham noted that ground control points could also be picked from the photographs after they were taken. Details such as a fence corners, gate posts or power poles were chosen and then surveyed on the ground for specific information about their location. In other cases such as the F3 widening at Mt White the ground control was required to be of a particular size for ease of identification. These points were found, measured and positioned before the photography was taken.

Setting up ground control points prior to photography was especially important in terrain considered to be featureless, as John Gillies noted:

> *"We did one fairly famous job near Broken Hill at Dolo Creek where it's all salt bush and not much else. We went out there*

> *prior to photography being flown and laid cloth targets, large 6 foot square sections of white cloth in the positions that the photogrammetrists wanted them. It was always good fun because when the photography came in there was always a bit of competition between the photogrammetrists and the surveyors to see who could pick the targets first. The surveyors usually won because we'd been in the field and had a feeling for the terrain!'*
> (John Gillies RTA RLD 13 Side A 1097)

Stewart Amery has also spent much time providing ground control surveys in rural areas, a task from which he took particular joy at times.

> *"I have had a couple of trips to Mt. Kosciuszko...what better way to spend your day than on top of the mountain for a whole day taking co-ordinates".*
> (Stewart Amery RTA RLD 8 Side A 1264)

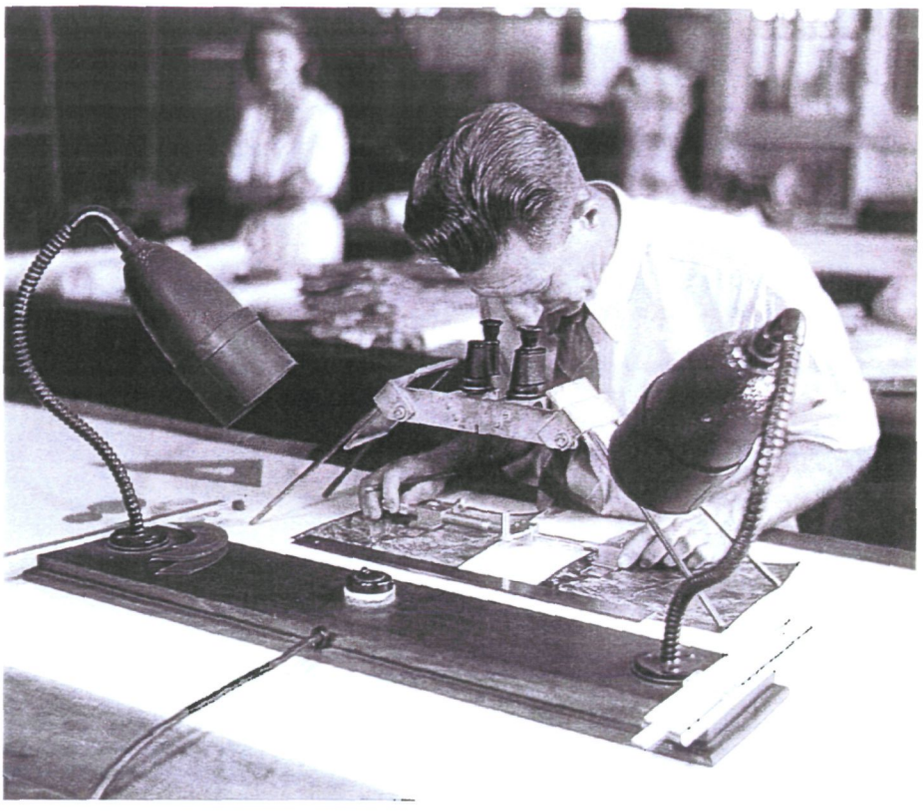
5.3 From aerial photographs to contour plans

For the last 30 years with the DMR/RTA, Brian Myers has used aerial photographs to produce contour maps of road routes. The stereo plotter remains the primary instrument that interprets the photographs as data, which is then rendered as a contour plan by computer. Since Brian joined the DMR in 1972 he has stuck with 'his' analogue stereo plotter, the Wild A10. This instrument was purchased by the DMR in 1968 from Switzerland and was at the cutting edge of this technology at the time. It remains a well used precision instrument.

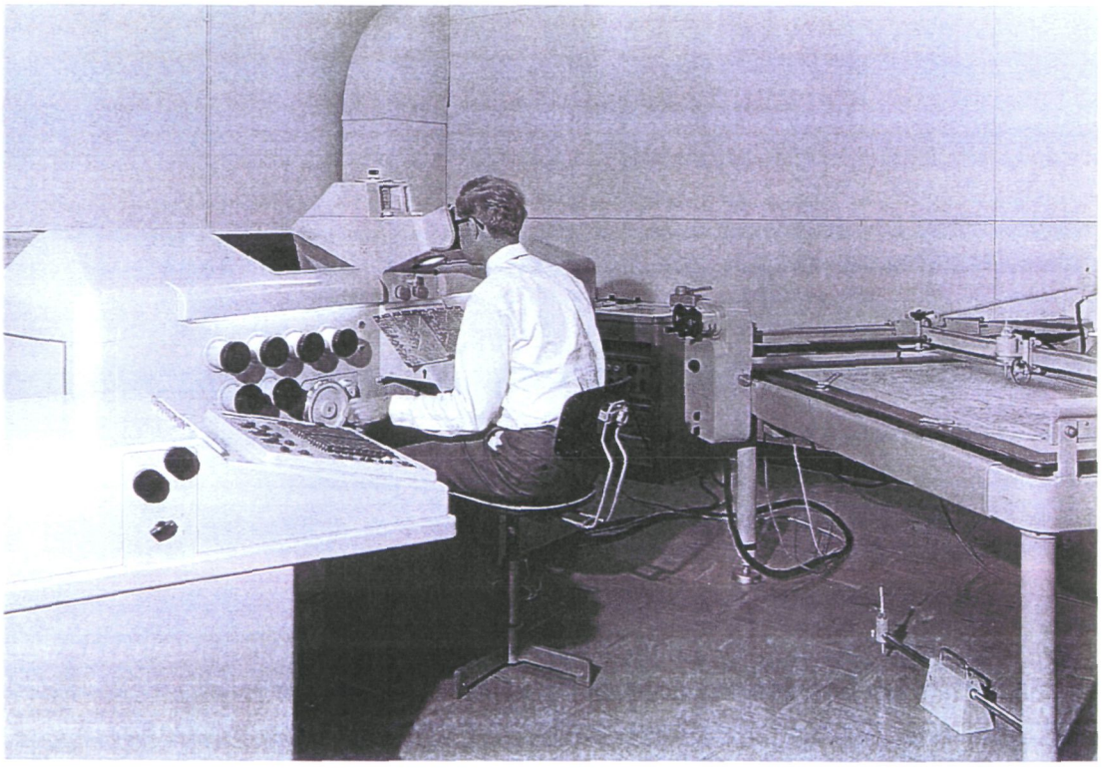
Before computers were introduced, the process of producing line maps from the aerial photographs was achieved using a mechanical procedure. A large flat plotting table with moveable guides was connected to the Wild A10 stereo plotter by a system of gears and rods. The overlapping aerial photographs were placed in position in the stereo plotter and viewed in three dimensions.

> *"The stereo plotter was hooked up mechanically by a train of gears to the plotting table. As the hand wheels in the stereo plotter were driven in the 'x and y' directions, gears to a plotting table translated both the movements. So if you were following a fence line or road or another detailed feature, the movements would be translated by the gears to the plotting table. The plotting table had colour-coded pencils attached which reproduce that movement onto a medium such as paper or stable plastic. That produced a line map"*
> (Brian Myers comments noted in discussion)

In 1971, when Chris Woodham joined the DMR's Photogrammetry Section, he used an instrument called Zeiss Stereometrograph to plot from the aerial



Examining aerial photographs using a stereoscope and stereometer bar, 1949



Zeiss Stereometrograph in use, 1968

photographs. This particular plotter predated the Wild A10. He also worked with the first computer in the DMR, the IBM 1130.

> *"It was purchased for the Advance Planning Section and Surveying were invited to use it...photogrammetry really took off when computers were able to handle large calculations...but you still need survey control marks on the ground"*
> (Chris Woodham RTA RLD 26 Side A 1180)

Chris gave a further insight into early instruments that were used in the photogrammetrical area.

> *"DMR purchased a device that was attached to the stereo plotter called a co-ordometer...so instead of having to write figures down, it registered co-ordinates and punched figures onto cards via a key punch machine situated next to the instrument...this was then loaded into the IBM 1130 and the program read the figures and gave ground co-ordinates for points picked from photography".*
> (Chris Woodham RTA RLD 26 Side A 1350)

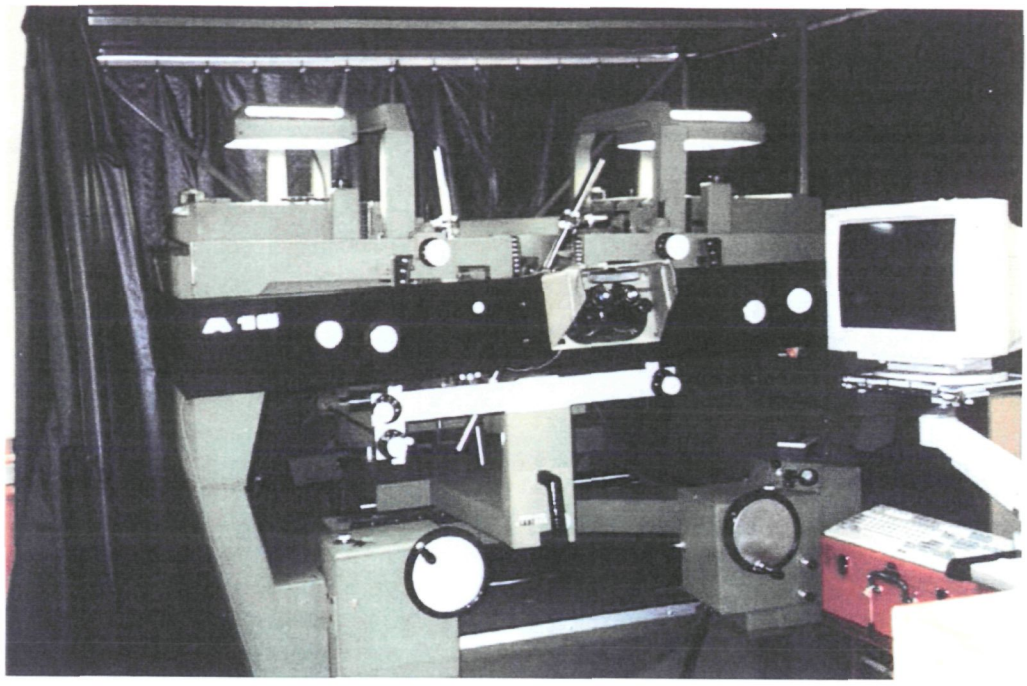
After the IBM 1130, the PDP 1134 computer was introduced. It enabled Surveyors to record streams of co-ordinates into the computer from both the Stereometrograph and the Wild A10. From this information they could produce contour plans on a computer aided plotter (Chris Woodham RTA RLD 26 Side A 1447).

Today, a computer is connected to the analogue Wild A10 Stereo Plotter. A sophisticated software program 3DDD, introduced in the 1990s, digitally represents the terrain and features such as contours, trees or fences, on a monitor. The software calculates all the values of control points and the connecting points. Once values have been calculated it is possible to view overlapping models and re-establish an absolute position using the control points values. The digital terrain models are stored in the computer as digital data. Once the hard copy of the digital terrain model has been checked for missing detail, the data is compiled into one large model. It is then edited and converted to the latest software design program called MX, ready for the Designers to use (Brian Myers RTA RLD 40 Side A 1174).

5.4 Satellite imagery

In the 1970s satellite imagery began to be used to identify geological conditions for potential road sites. Peter Cooper recalled that satellite imagery was used widely in Western New South Wales where it very graphically indicated black and red soil areas. He noted that black soil is an unstable soil base for road building.

> *"In the western areas of the state satellite imagery is great for seeing where there are black soil areas and where red soil is. It is so clear cut you can see everything you want to see ... The*



Wild A10 Autograph stereoplotter

Preliminary road location work on the Sydney-Newcastle Freeway in the mid-1960s: surveyors at work in rugged terrain being aided by the DMR's first helicopter

> *satellite scans the terrain under it in a number of different wavelengths of the spectrum, one being infrared. Infrared radiation is absorbed by water so if you see black or very dark areas on the images then that is water, and if it's dark grey it's wet soil".*
> (Peter Cooper RTA RLD 11 Side B 95)

Black soils absorb lots of water and therefore appear as grey in these images. He also noted that satellite imagery was also used on the North Coast to identify areas of peat, which is also a problematic base on which to build roads. These areas show up as a ghostly blue on the images. Satellite imagery can also denote drainage and vegetation patterns.

Brian Myers used satellite imagery to assist in a road location project in the Moree area in 1980. The DMR wanted to source gravel in the local area for road building as hauling in gravel was an expensive exercise. Initial investigations involved a technique called Thermal Inertia, which scanned thermal wavelengths of different materials. This technique proved unsuccessful, so Brian decided to look at remote satellite imagery to locate gravel in the prior stream beds in the area. After analysing the imagery, Brian identified thirty-five target areas and gravel was found in twenty-two of these spots. Soon after this time the DMR decided to abandon such research works.

5.5 Photographic interpretation

The interpretation of photographs is another technique still used by the RTA to identify the constraints of a road location. Being a qualified geologist, Brian Myers has a particular interest in geological air photograph interpretation. The technology is also used to determine geological hazards to road building, such as landslides and other suspect features or structures. He was also keen to develop interpretive techniques for locating heritage items and apply this within his work in the RTA.

> *"It's quite intuitive, you are looking for clues and have to know how certain structures manifest. With a landslide for instance, you will find it will form a tongue with vegetation on it with a corresponding depressed area...you look for scaring and features of instability, possible poorly drained sand, patterns of streams and certain rock types..."*
> (Brian Myers RTA RLD 40 Side B 1001)

In 1999 the RTA was locating a new line of road down Mt. Victoria and was aware that located somewhere in the area were the remains of a convict stockade. Brian used his interpretive skills to identify the stockade from aerial photographs. Looking at photographs ranging from the 1960s to the present time, it became possible to see the foundation trench line for the stockade. These showed up as lines of dense vegetation that built up in the trench in the shape of the stockade that was almost 50m square (Brian Myers RTA RLD 40 Side B 1001).

6. Road design – concepts and practice

6.1 Evolution of road design philosophy

Roads are designed to specific standards that take into account factors of safety, road cost, user cost, sight line, gradients, and curves. Standards for designing and constructing roads have been in place since the 1930s. They have evolved from a consideration of simply travelling from "a" to "b", to incorporate a focus on driver behaviour, environmental and safety factors.

In the first years of the 20th Century the roads in New South Wales were little more than upgraded tracks, often located on high ground. They followed ridges in the terrain or rivers especially in undulating country.

By the 1920s, the motor car had become a common feature on the State's roads. Since 1908, when the first cars appeared in New South Wales, the speed and power of motor vehicles had increased, as had the number of road fatalities. Road design and construction generally followed the principles adopted by Local Government and Public Works.

In 1926, the Commonwealth Government hosted a conference of all State authorities and set out resolutions of standards for road construction that were adopted by the New South Wales Roads Board.

During the political storms and changing administrations of the Depression years, there was little improvement in road design standards until 1932 when the NSW Department of Main Roads was formed. By 1937 the DMR had instituted a set of standards for the design of State roads that set out the speed limits and the style of road alignment that was suitable for various conditions.

Jack Giddy, a retired Designer with the DMR, noted that the 1937 Road Design Standards were developed by Engineers who had come from designing railroads and the Standards reflected this experience. The main concern of the Standards was the direction and speed of the vehicle. The physics were similar to that of the railroad utilising the same grades, radius of curves and superelevation (Jack Giddy RTA RLD 4 Side A258).

Typically these roads were low speed roads, conceptualised like a railroad; go straight for as long as you can given the direction and grade of the route and then use curves to change direction or start to climb hills and mountains.

The challenge taken on by the 1937 Standards was to "establish a relationship between the speed of the vehicle on the one hand and the road surface, alignment, grade and visibility on the other" (The Roadmakers, The History of Roads in New South Wales, DMR, Sydney, page 138). As the potential vehicle speeds increased, roads required wider radius of curves and more visibility for the driver. The

increased power of the car also changed the maximum grades of road and other design elements (The Roadmakers, The History of Roads in New South Wales, DMR, Sydney, page 138).

The concept of imposing speed limits on different styles of roadway became an important feature of road design. The standard for two lane country roads was based on an average speed of 50 mph. On straight and flat stretches of road the limit was increased to 60 mph and on undulating terrain was reduced to 30 or 40 mph (The Roadmakers, The History of Roads in New South Wales, DMR, Sydney, page 138).

A lot of the work done on the NSW roads in the 1940, such as upgrading, minor improvements and deviations, were designed and constructed to make the State's roads conform to the 1937 Standards. Jack recalled that when he joined the Grafton Office of the DMR as a Junior Draughtsman in 1941 aged 16 years, he was set to work on plans for the widening and straightening of sections of the Pacific Highway and other developmental roads. These were roads deemed to be necessary for the economic development of particular rural areas.

The DMR at this time was a relatively decentralised organization with a number of Divisional Offices around the State. These offices managed their own planning, design and construction of roads within the Division. The Divisional Office at Grafton that had an Engineering Section, a Drawing Office and an Administration Section. Jack described the process of interpreting the Surveyors' information on the position, location and features of a new road or upgraded section of road.

> *"There were about ten Designers in the office in 1941. The work would come in from the Surveyors. You'd be given a one mile section the road to plot up on graph paper on a scale of one to two hundred. The work was checked and done to a standard of two decimal points. After the design was approved it was given to a tracer who traced it onto linen from where it could be printed. At that stage the whole road came together."*
> (Jack Giddy RTA RLD 4 Side A 1398)

From the initial plotting of a route, longitudinal sections and cross sections were drawn. A longitudinal section is a plan of a "vertical section through the centreline of a road or a structure ... It shows the existing surface levels along the road control line or other specified line and the level to which the road is to be constructed or reconstructed" (RTA Road Design Guide, December 1989, Glossary of Terms page 27).

A cross section is a measured view of the road in its horizontal plane, depicting significant features from the centreline of the road such as the edge of pavement, kerb, shoulder and where relevant, footpath.

Jack noted that in those early days the main consideration was economy of design and construction. Most importantly, this included achieving balanced earthworks,

"in which the quantity of material taken from cuttings along the road, mathematically equals the fill required to construct the embankments" (RTA Road Design Guide December 1989, Glossary of Terms page 3).

Each Designer would generally design the road in one mile sections, linking the design to the level and grades of adjoining mile sections. Little consideration was given to the continuous flow of alignment or to the aesthetics of the road and the surrounding terrain.

Although the road conformed to the geometric standards, often the final result could be best summed up in a quote from Paddy Hopkirk, the racing and rally car driver, who said something along the lines, "In road construction, there seems to have been a breakdown in communication between the Engineers' design and the driver's eye, and we have a road that is something less than perfect."

In this period the maximum speed for rural roads was 50 mph. This was another consideration in determining the design of a road. The radius of curves is determined by the speed and the gradient of the road. This combination of elements then influences the amount of banking or superelevation necessary on the curve.

6.2 Expressways

During the early period of the 1950s the DMR allocated large amounts of funding to plan and construct new expressways in the State. Both Jack Giddy and Rob Shipton commented on works on the Sydney to Newcastle Freeway that was under construction from the 1950s to the 1970s. They noted the change in the approach to road design and construction during that time.

> *"I was transferred to Sydney in 1961 and after a very short time I started to do the work that I really liked, that was locating and designing major roads. I found I could express myself in the type of road [the Department] should have been aiming for ... The building of the Newcastle Freeway was a good example of the change in attitude...we will build the road first and see about the money later...the job that the engineers did on that project was fantastic, it was done quickly and done well... the results are there to see."*
> (Jack Giddy RTA RLD 4 Side A 1539)

This combination of ample funding, materials and new road building technology enabled the mountainous terrain to be excavated and had an impact on the design and construction of the Freeway. Designers could now design a high speed, curvilinear road with generous curves of between 1800 and a desirable 3000 feet radius in terrain that previously would have required a low speed treatment; tight curves of a radius of 800 feet (Jack Giddy RTA RLD 4 Side B 12).

With the development of photogrammetry and more thorough investigation, the Designers were now able to print out contour information on rolls of plans up to 15 metres in length. A spline (flexible steel band) was used to coordinate curvilinear alignment and grades over long lengths of construction. This resulted in more aesthetically pleasing and safer roads for the driver.

Such long lengths of plans could not be accommodated on the tables and so most of the work was spread out on the drawing office floor.

Rob Shipton pointed out that although the principles of road design have not changed dramatically since the early days, by late 1950s the philosophical approach to road design and construction was beginning to change.

> *"During this project [construction of the Sydney to Newcastle Freeway] the DMR embarked on the biggest cutting works ever done within the organization...the philosophy was if it was possible to excavate you did".*
> (Rob Shipton RTA RLD 2 Side A 1314)

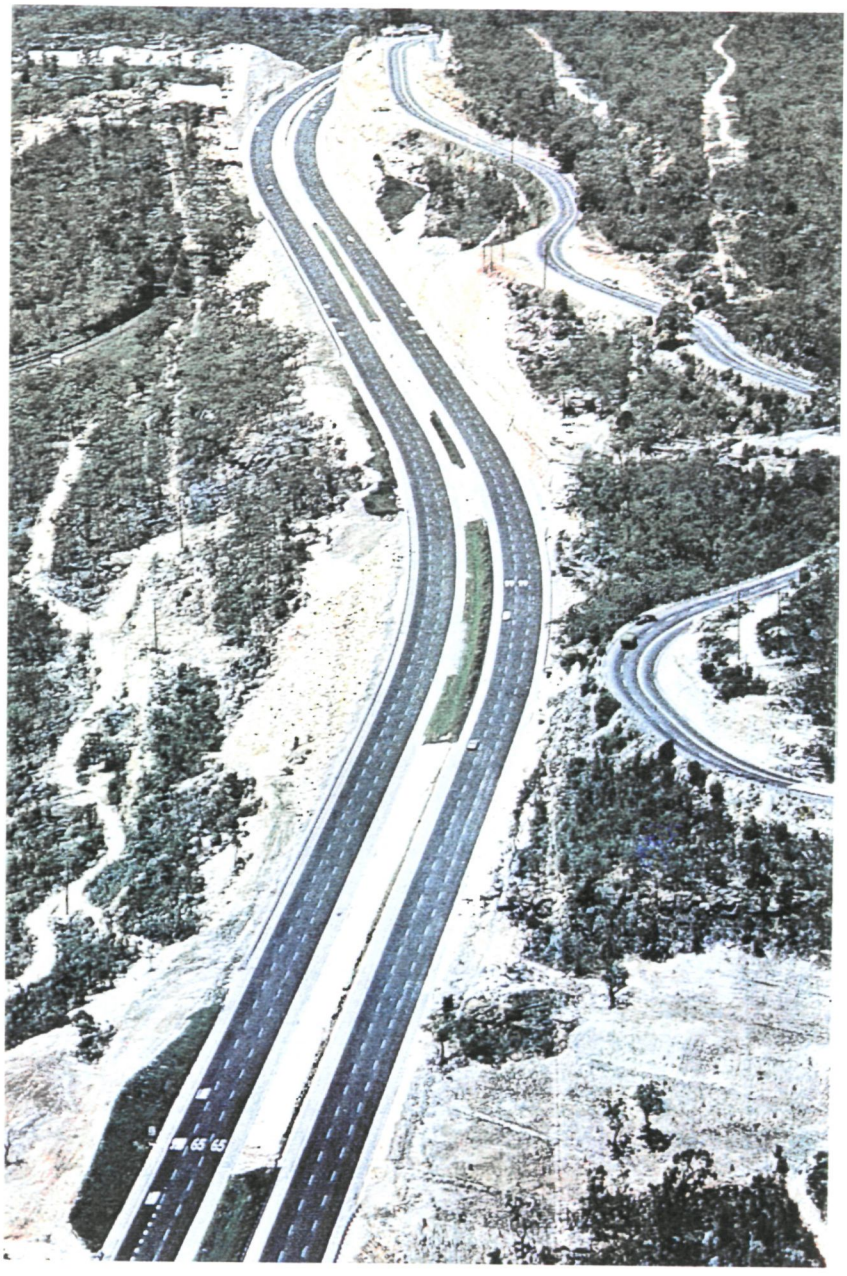
Although the extensive excavation works allowed this road to be built with gentle grades and generous curvilinear alignment, it had its own set of problems such as rock falls from the cuttings. Rob explained that if the road had been built higher and steeper this would have been avoided. However a steeper road would affect user cost, as it increases petrol costs and travel time. The Sydney to Newcastle Freeway is a world class example of good design, has won numerous awards and has an acknowledged preservation value (Rob Shipton RTA RLD 2 Side A 1314 and comments noted in discussion).

At this time there was also a change in thinking about road design. Instead of design formulas derived from railroad engineering, there was a gradual understanding that road design needed to take into consideration not only the parameters of vehicle performance, but importantly, should take into account the 'nut behind the wheel', human behaviour.

> *"In the very early 1960s the Department hierarchy was able to come to terms with the factors that influence drivers, they came to realise that there were human limitations to the driver's ability to handle cars at high speeds."*
> (Jack Giddy RTA RLD 4 Side B 1068)

Road designers should be fully aware that on slow speed or small radius curves of less than 800 feet, drivers drive the car with vision concentrating on the centre line or pavement edges.

The high speed road, where the curves are greater than 1800 feet, the driver is more inclined to aim the car with his visual concentration moving forward, adjusting to the vehicle's speed. The intermediate range of curve alignments of between 800 feet and 1800 feet represents the more dangerous road, with curves



Curvilinear alignment of Sydney-Newcastle Freeway, with winding Pacific Highway on right

of 1200 feet the most undesirable. An example of this sort of road lies on the Newcastle Expressway where on some sections of the road speed limits have been reduced to 90 kilometres per hour. These sections of road have an alignment of 1200 feet radius curves.

Jack Giddy explained that as one travels faster, one's zone of perception is narrowed and the point of concentration recedes. Such considerations resulted in a more flowing curvilinear road alignment.

The key element in designing safe roads is to make a gradual transition from one type of alignment to another. The average motorist does not expect sudden changes in the road.

> *"One section of the Woolgoolga Range on the North Coast, where the road goes up the Range it is very winding and has very steep grades – all the factors that would surely bring about accidents. You get to the top of the Range and the road straightens out and is almost level. It's in that section – the straight section that they get the most terrible accidents. One of the reasons is that drivers drive carefully up the road and get to the top, they see the beautiful stretch of road there before them and they speed up. As they speed up they move the car closer to the centreline of the road and that accounts for a lot of the side swipes and prangs."*
> (Jack Giddy RTA RLD 4 Side B 1200)

These new concepts were partly the result of influences from European and American road design theory in the 1960s. They were expressed in a number of ways; from a concern with the aesthetics, where the road was designed to fit into the terrain, to road standards and safety factors.

Steve Levett, who joined the DMR as a Designer in the 1960s, recalled that it was at this time that Jack Giddy insisted that all the Designers take note of a certain volume "Man Made America – Chaos or Control ?", by Christopher Tunnard and Boris Pushkarev, circa 1964. This book was affectionately referred to as 'The Bible' in the Rural Investigations Section of the DMR and espoused a whole different attitude to road design (Steve Levett RTA RLD 34 Side A 1518).

Amongst the considerations it set out were those of aesthetics. For example, a steep cutting against the skyline was avoided where possible and the road was made a feature of the landscape. Landscaping was another important element that served to define the route and the direction of the road. This is important in a situation where a curve in the road disappears over the horizon (Jack Giddy RTA RLD 5 Side A 645).

These new concepts and considerations in road design continued to influence road design theory through the 1960s and 1970s. Theo ten Brummelaar worked for the DMR as an Engineer in the 1960s and went on to teach at the University of NSW in

the School of Highway Engineering where he taught many of DMR Engineering cadets during the 1960s and 1970s.

> *" I was on sabbatical leave and visited France, Germany and Holland. I came back from overseas in 1975. I had found that in overseas design they used the clothiod (ellipse) element. It was a big change in thinking ...we started to look more at perception theory, optical illusion and the design of the road from the driver's point of view ... we were looking at long radii curves, they give far more information than straight roads. The advantage is that vehicles are not directly behind each other – they are slightly off centre ... also the driving a curve keeps the attention on what the driver is doing, the driver sees change and is less likely to fall asleep"*
> (Theo ten Brummelaar RTA RLD 47 Side A 477 & 47 Side B 180)

6.3 Country and arterial roads – from the 1950s

As well as funding for new expressways, the DMR undertook major reconstruction of the State's arterial roads from the late 1950s to the 1970s. All this work was undertaken by the DMR Divisions through Works Offices that set about straightening and widening roads, sealing roads and improving drainage.

Steve Dunlop joined the DMR as an Engineering Draughtsman in 1969. His work involved him in road design and construction projects all over New South Wales. His first job was to supervise the construction of a road between Bourke and Walgett. The Bourke Design Office provided designs and survey expertise. His work crew of thirty men built their own camp and commenced work completing the construction of five kilometres of bitumen road per year. This was considered a reasonable outcome because of the difficulties of the terrain.

> *"We had some problems. We had to dig some hills out and they were opal bearing... so that slowed us down. The crew got a bit enthusiastic... they thought that they were going to make a fortune, it was fun running around spying on them at night".*
> (Steve Dunlop RTA RLD 28 A 625)

Around the same time, in 1968, John Vickery, joined the Wagga Wagga Office of the DMR as a junior draughtsman. Similarly to Steve, his early work was in rural road design. He recalled that all design work was done manually; from the initial plotting of the alignment, to drawing cross sections and calculating earth works. This was the case on one of his early projects, designing the Snowy Mountains Highway around Kiandra. The existing route was a dirt road and very little ground survey work had been done. Contour plans of the road corridor were developed from aerial photographs. John was then set to work on the design, measuring all the grades and radii appropriate to the design speed of the day using only a set of dividers and slide rule (John Vickery RTA RLD 38 Side A 1024).

Another challenge of this project was to design the road around the many limestone caves in the area. This required a lot of work to precisely calculate the balance of cut and fill for the road, a crucial element in the economies of road building at the time. The aim of design in this respect was to as far as possible use the material from a cutting to raise the level of the road in a low lying area. If there was not enough fill, it either had to be hauled in from elsewhere, an expensive option, or fill was provided from a local quarry site. The latter has always been the preferred option.

The years between the end of WWII and the late 1970s saw huge growth and diversification in rural industry. Up until the mid to late 1960s, rail was the primary way that rural produce and industrial freight was transported. After the mid to late 1960s, road transport overtook rail as the primary mode of transport for freight and people. At this time existing access roads to many rural communities were characteristically unsealed, narrow, winding routes unsafe for large, heavy vehicle traffic. In response, in the late 1960s and during the 1970s, the DMR embarked on a program of upgrading and constructing access roads to rural communities that were able to handle both local and heavy vehicle traffic.

> *"What we built a generation ago now may not be suitable. The role of that road [access roads] may have changed considerably, whole industries have sprung up, particularly when you look at logging roads, these roads were never designed for large trucks, the sight distance were unsafe and the [steep] inclines often made it difficult for the trucks".*
> (Steve Dunlop RTA RLD 28 Side A 952)

6.4 Urban roads – from the 1950s

In Greater Sydney during the immediate post war years there was a pressing need to strategically plan the Metropolitan and State road network and to upgrade the existing infrastructure (Gerald Park RTA RLD 20 Side B 12).

During the 1950s and 1960s the DMR reserved a large number of corridors of land for the future development of the road network. This required the resumption of private property and consequently there was a lot of work done in property investigation. Gerald Park joined the Department in 1954 as a Junior Draughtsman. After a period of initiation to the Office where he spent many days fetching morning tea and lunch for more senior staff and practising his printing, he assisted in the production of Certified Plans for these road corridors.

The plans contained all the details of utilities, terrain and property boundaries which were identified from original land titles and other documents held at the Registrar General's Department, the Water Board or the Land Titles Office. The plans were later traced onto the Master Plans back at the DMR offices (Gerald Park RTA RLD 20 Side B 665).

A few years later Gerald was transferred to the Property Inquiries Section where he continued to deal with road corridor boundaries. He also dealt with many road widening schemes, not only answering householder inquiries, but also providing information to commercial developers in growing urban areas on future road plans. These corridors and widening schemes included roads such as the Wakehurst Parkway and the New and Old South Head Roads. Here he investigated potential property resumption or purchase issues and gave advice on where to set back new buildings in accordance with future road plans.

These land corridors, reserved in the 1950s and 1960s, are in many cases the locations for the major freeways and motorways that have been built in recent years such as the South-West Motorway (the M5). Other corridors such as the Cooks River and the Castlecrag reserves have been sold as the need for large roads in these locations has been reduced.

Reserving swaths of land in the Metropolitan area for future road needs has proven to be problematic in some areas. The Western Sydney Orbital is a case in point as Wayne O'Mara indicated.

> *"There was massive development in the area and houses were built on the boundaries of the corridor. If you needed to change the design or alignment of the road in any way you have to purchase or resume private land...now retaining walls need to be built. An example is the freeway at the back of Beverly Hills, the corridor was set up in the 1950s...people built up to the boundary of the corridor. This limits what you can do with alignments and curves. Also we have to now construct sound walls."*
> (Wayne O'Mara RTA RLD 18 Side A 1493)

Another outcome of the DMR's Urban Design and Planning Section's strategic planning in the 1950s and 1960s was the widening, straightening and otherwise improvement of metropolitan roads. Gerald Park was transferred to the Metropolitan Section in 1955, where he became involved in this massive upgrading program. He noted that widening programs and other improvements like those on Canterbury Road, required the acquisition of parts of private property. Consequently, retaining walls and driveways needed to be redesigned for the length of improved sections of the road (Gerald Park RTA RLD 21 Side A 166).

Up to one third of Sydney's roads were built during the Depression years. These were concrete roads that predated the 1937 Road Design Standards and catered for vehicles of the time. When Jack Giddy started with the DMR in 1941, many road pavements were just gravel. Later as money became available roads were reshaped and sealed. Steve Dunlop pointed out that the majority of urban roads built after the war were chip sealed. The seal was not strong and deteriorated rapidly and required a lot of maintenance (Jack Giddy RTA RLD 5 Side A 320).

With the extensive road building and upgrading that occurred after the 1960s, the DMR built its own asphalt plants at Granville and in Northern Wollongong. Today, pavements are generally the most expensive part of road construction.

By the end of the 1950s car design had changed dramatically and the lower built modern cars were severely mismatched to the old fashioned standards of the roads. The old high kerbed gutters were replaced with six inch kerbs. This in turn necessitated a re-look at the drainage requirements of the road for the lower gutter could not hold as much runoff. Designs came to incorporate more gully pits per length of roadway to overcome this problem (Gerald Park RTA RLD 21 Side A 295).

As well as upgrading works, the Metropolitan Section took on designing and constructing roads for the then outlying areas such as Lakemba and areas past the Spit that rapidly developed in the late 1950s and early 1960s.

6.5 Road design from the 1970s

Many interviewees commented that during the 1970s the location, design and construction of roads became increasingly political. One example given was the construction of the M4 in Western Sydney. John Vickery recalled that by the late 1970s, designs had been completed by a private consultant and many of the bridges and much drainage infrastructure for the Motorway were in place. M4 construction work ceased at that time as funds were withdrawn and allocated elsewhere by the government of the day. During thee term of the Wran government, there was a general increase in road construction work including completion of work on the M4.

Around this time, Steve Levett was seconded to the M4 Construction Office at Homebush. He was the resident Designer doing on the spot design plans for the construction of the Freeway that was not always straightforward.

> *"I was flying by the seat of my pants. One particular bridge was built out of line and too low ... the private consultant had used a false centre line to make the design easier, but had then transposed all those calculations on to the true centre line without appropriate adjustments ... we didn't find this out until the DMR survey team started to survey the bridge. Meanwhile there were truck loads of gravel and sub base ready to be laid on the approaches and then we found out we were working to the wrong level... We had to do a very quick recalculation"*
> (Steve Levett RTA RLD 34 Side A 976)

Gerald Park recalled a Ministerial brief circulating in the early 1980s that initiated an investigation into the replacement of the Tom Uglys Bridge. Apparently the future of the bridge had for many years been a recurring State election theme. The DMR had done some preliminary planning that involved starting the approaches to a

grand new bridge back as far as Blakehurst. This scheme would have involved the expensive business of resuming large amounts of land and was not well received by the locals. Gerald also thought that the type of road use did not warrant such a first class treatment and was reluctant to produce a design that was so expensive that it had no chance of being built.

Convinced that a scheme could be developed and built on a realistic budget, Gerald set about producing a concept design for the bridge and approaches that was practical, affordable and safe. The design needed to accommodate local traffic as well as the major movements of through traffic on the Princes Highway.

The first step was to re-look at the Brief requiring a replacement bridge. It was found that replacement was not necessary in the short term to solve the congestion problem in the area. After investigating the structural integrity of the existing bridge, Gerald developed a scheme that involved keeping the existing bridge to accommodate northbound traffic and constructing a smaller, two lane duplicate bridge, to handle south flowing traffic. He argued that if ever the existing bridge needed to be replaced it could largely be built between the new bridge and the old bridge without any disruption to traffic.

The concept plan alignment for the bridge and approaches developed by Gerald and his team minimised property acquisition and in fact on the northern approaches he proposed that some of the existing pockets of the road reserve corridor could be sold to offset the cost of the project. Other pockets of reserve were retained in the scheme as on/off access ramps to the road for local traffic or as parking bays (Gerald Park RTA RLD 21a Side A 39).

6.6 Environmental and social influences

By the mid to late 1970s, environmental issues were beginning to become a consideration in road design. By this time John Vickery had transferred from Wagga Wagga and was working with the Metropolitan Area Office at Milsons Point. Here he worked on the design of the Wakehurst Parkway, the route of which had been set out in the late 1950s.

> *"By the time I worked on this job all the property issues were dealt with and the corridor was set out. There were Aboriginal carvings in the area that we had to keep clear of. This was the first time that environmental and aboriginal issues were considered by the DMR."*
> (John Vickery RTA RLD 38 Side A 1579)

While this project is an early example of heritage and environmental sensibility, these issues became central considerations in road location and design in the mid 1980s and 1990s. Each road design scheme is now subject to a full environmental impact study and the each design must include various environmental controls to lessen the impact of construction on the surrounding area.

Peter Ellis, who started work with the DMR in 1979 as a Junior Draughtsman, noted that a major environmental consideration in both urban and rural settings is silt filled water runoff from road construction sites. To prevent this water flowing into the urban sewage system or into natural waterways, sedimentation basins are set up to catch the runoff. Here chemical means are used to make the sediment drop to the bottom of the basin and the water then flows out. Siltation fences are used in built up areas. In new urban developments, road construction is often planned for non-rain seasons to minimise siltation problems.

Peter Ellis commented on the noticeable change in attitude to environmental issues.

> *"At first, there was a lot of jumping up and down and screaming by contractors – 'why do we have to do this'. That moved on to doing it because they were told to by the RTA ... now the construction people have got into it and it's second nature. This change in attitude has taken a long time - about 15 years to get to this stage."*
> (Peter Ellis RTA RLD 23 Side A 309)

Another way in which the RTA has come to deal with sedimentation in water runoff and general operating pollutants such as oil, petrol and litter is the

construction of wetlands such as those adjacent to Placey Road in Lane Cove. The wetlands dams are planted with macrophytes that filter the water forcing heavy metals to settle on the bottom of the dam as the water flows through.

These wetlands also facilitate the controlled flow of water runoff into the natural drainage system. Excess water can be stored in the dams and released gradually (Peter Ellis RTA RLD 23 Side B 1085).

Rob Shipton further emphasised the precautions taken to avoid contamination of waterways. Previously many of the elements of the road such as box culverts, were cast on site often causing contamination. Now most elements are precast, transported to the site and installed without chemical runoff (Rob Shipton RTA RLD 1 Side B 761).

Stringent environmental principles and innovative design work was also applied to the design and construction on the F3 Freeway around the Mooney Mooney to Kariong section during the early 1980s. Here there was a significant problem posed by runoff from the road going into the sensitive National Parks area. Steve Levett used a series of filtration traps and dissipaters to slow the water runoff.

> *"Water speeds off sandstone are very fast...you have to slow the water down to stop sedimentation in filtration pools...the energy dissipaters are like a series of baffles laid in the passage way of the water, the water hits the baffles, gushes back on itself and slows down and then this filtered water flows out into the environment".*
> (Steve Levett RTA RLD 34 Side A 1305)

As well as sedimentation, flooding is also an important consideration with environmental and maintenance implications. In the early 1990s, flooding was identified as a serious issue in the Fairfield area, which had become increasingly developed. The RTA was building a lot of hard surface roads and saw that they were contributing to the flooding in the area. So not only did they have to deal with concerns of the quality of water runoff but also the quantity (Peter Ellis RTA RLD 23 Side A 1228).

Prior to the 1990s design considerations to deal with flood drainage was simply to provide a gully trap in the side of the road with a pipe leading to the nearest creek or dam. These days one alternative strategy to deal with flooding has been to install large tanks under the roadway that contains the excess water and allows it to flow away slowly after the storm (Peter Ellis RTA RLD 23 Side A 1228).

Wayne O'Mara pointed out that producing a drainage diagram can take up to a couple of weeks. Information such as average rainfall and average overflow for the area needs to be worked out, as does the catchment area and its size, pit sizes and traffic flow.

According to Steve Dunlop water is the most damaging element to the longevity of roads and pavements fail mainly because of water damage.

> *"Once water gets in to a road it starts to break down the materials. The shale starts to decompose and as vehicles drive over it the particles start to move and a hole develops...small holes can get very dangerous within an hour in certain conditions".*
> (Steve Dunlop RTA RLD 29 Side A 1067)

Protection of flora and fauna has become an extremely important element in the design process. In this context Mick Mancone, a Senior Designer who joined the DMR in 1965, referred to the work done to conserve the habitat of the Green and Gold Bell frog along the M5 Motorway. He also mentioned that during the work on this motorway it was found that one wetland area, used as a feeding ground for a group of migratory birds, was incorporated in the road corridor. As compensation, the RTA designed and developed a wetland at Kurnell.

> *" One design that was a bit different from our usual line of work designing a weir out at the Kurnell Wetland for migratory birds ... These birds used to go to some wetlands at Eve St near*

> *Mascot. When they built the M5 East that wetlands was reduced and as compensation there was another wetland at Kurnell – a disused sand pit. The deal was to fill some of the wetland in to create some mud flats for the Eve St migratory birds to feed. We had advice from a fauna expert that we had to provide a situation where for part of the day the mud flats were out of the water and part of the day they were covered so that it would renourish what ever it was the birds fed on. It was well outside road design methods but we designed something that worked well..."*
> (Mick Mancone RTA RLD 16 Side A 1460)

Some wildlife conservation design solutions have presented their own challenges for the native habitat in some areas.

> *"... on the southern side of the Hawkesbury River, on the Sydney-Newcastle Freeway we had to put culverts under the road to let the wildlife through. One of the funny things was that they put culverts in to give these frogs passage across the road – but all that I could see was it gave the foxes a place to sit and wait for the frogs... "*
> (Jack Giddy RTA RLD 5 Side A 1137)

In recent years much more attention is paid to the impact of noise from large thoroughfares in residential and semi rural areas. According to Wayne O'Mara, the F3 posed a particular problem in this respect as it was the first freeway to be built through an urban area. Guidelines were in place to determine acceptable levels of ambient noise, so before construction started, study teams were set up to record and analyse the existing level of noise in the area over a twenty four hour period. The difference in decibels between the existing noise level and the acceptable noise levels provided the design team with the parameters from which to base their design. With this information, Designers decided to use open graded asphalt to seal the road. As well, sound walls and specialised landscaping were incorporated in the design (Wayne O'Mara RTA RLD 18 Side A 330).

Jeff Chandler, who started his career with the DMR in 1986 as a Model Maker, further commented that materials used for sound walls have become an issue over the years. They are often made of concrete and such solid walls can interfere with residential area views. To overcome this, the RTA occasionally uses Perspex sections in these walls to preserve vistas (Jeff Chandler RTA RLD 46 Side B 1433).

Identifying and conserving Aboriginal heritage has become an increasingly important environmental consideration in the location and design of the State's roads since the early 1980s. One of the most striking examples of a design solution that conserves Aboriginal artefacts is on the Sydney-Newcastle Freeway, not far from the Bobbin Head Bridge. Aboriginal carvings have been left in situ and incorporated in the large rock outcrop located in the median strip in the centre of the road.

There are many other examples in Sydney and state wide where the identification and conservation of Aboriginal sites has occurred. Steve Dunlop pointed out that some Aboriginal remains have been conserved in the M2 road corridor. Aboriginal remains were also identified within the M4 corridor and Designers redirected the road design alignment to avoid these. The RTA now works closely with Aboriginal people to identify sites and ensure that the sites and items are handled appropriately.

Environmental and community issues rarely prevent a road construction project from going forward but such issues can significantly modify a road's location and design. The Eastern Distributor is an example of this. Initial plans located the roadway going through Busbys Bore, a subterranean, convict built, sandstone water channel. The Bore, built in colonial times, was intended to divert fresh water from the Centennial Park Wetlands to the City after the Tank Stream became polluted. It is a significant item of heritage value (Peter Ellis RTA RLD 22 Side B 1048).

> *"No matter where we were going to put the Eastern Distributor we would run into it ... in terms of concept design we put the Distributor where it is now, but there were different configurations of the tunnel underground. That was interesting too because we had not done any tunnels in Australia at that stage..."*
> (Peter Ellis RTA RLD 22 Side B 1200)

There was however, at least one example of a road design being re-routed for heritage reasons. Steve Dunlop related this tongue in cheek story about a road design and construction project around Lightning Ridge.

> *"We were doing a road project around Lightning Ridge and just north of the town there was a popular watering hole and a bottle heap. The road was planned to go through the pub and the old bottles, so we diverted the road to miss them"*
> (Steve Dunlop RTA RLD 28 Side B 1432)

On a more serious note, Steve and John Vickery discussed the strong awareness that the RTA has of the value of preserving items of heritage significance.

> *"The old Glebe Island Bridge was built in 1903 and it is technically and socially significant... we are now looking at how best to preserve this valuable item"*
> (Steve Dunlop RTA RLD 28 Side B 1432)

> *"There was a flour mill up in Allan Street, [Anzac Bridge Project, Pyrmont], the viaduct came in that close to the flour mill we had to cut a notch in the concrete of the viaduct to get it in... everything was very tight there... we had to work hard to save a lot of old buildings".*
> (John Vickery RTA RLD 39 Side A 1442)

6.7 The introduction of urban design principles

Since the 1990s there has been a growing awareness of the importance of designing roads that fit into the social and environmental landscape.

Raeburn Chapman, who joined the RTA in 1991, headed the North Coast Road Strategy team in the early 1990s. The team investigated existing and future transportation needs along the 600kms of New South Wales North Coast in a holistic way. The Strategy looked at providing a major inter capital transportation route between Sydney and Brisbane. Central to this was the question of whether to plan a complete dual carriageway for the whole length or managing travel demands using other options. These other options investigated the promotion of rail travel or the use of the private sector to built particular elements of the route. Another issue was how to open the region up to economic growth without negatively impacting on aesthetic, environmental and community values of the region.

While the impetus for this study was the large number of accidents that occurred on the Pacific Highway, it looked at broad issues such as settlement patterns, population and economic growth and future planning developments. Due to the growth in freight, tourism and the increase of traffic on the highway over the summer period it was found that even doubling the capacity for rail travel would not impact on the amount of road travel.

It was agreed by Government agencies and transport Authorities that the Pacific Highway was the transport spine of the North Coast and had to be planned as such. It was finally decided that the route should be a dual grade separated carriageway and would be funded in a two billion dollar, ten year program by both State and Federal Governments.

During the location and design of this road program, there has been a huge consultation process with communities, Government agencies and the private sector. In addition much attention has been paid to landscape and environmental issues, where the ecological systems in the area have been mapped to draw out the environmental constraints on road location and construction.

A more recent illustration of the holistic approach applied to road location and design incorporating wide ranging urban design considerations was the work on the Eastern Distributor. As Raeburn Chapman pointed out roads are not just for transportation, they are major pieces of infrastructure that structure cities, communities and rural area.

> *"We started looking at the Eastern Distributor as a giant gateway to the city from the port and airport, through the CBD and making a connection with the other major routes up north ....it was designed as a sequence of experiences with gateways and views to the city, taking you into the city... It was a major through route that would take the traffic out of the local areas. ... It was also designed something partly in tunnel and also in*

> *open cut, down South Dowling Street ... by putting it in cut for example, the retaining walls of the cut down South Dowling St served as noise walls. By retaining it in cut you preserved views of the from the Victorian built heritage across Moore Park – you kept the natural landscape and built landscape..."*
> (Raeburn Chapman RTA RLD 44 Side B 828)

Similarly, the treatment of the Eastern Distributor at the Domain where it disappears under a land deck, has improved the space of the park and reduced the noise impact of the road. Raeburn considers it an innovative design; it reinstates the contours of the original landscape that were disrupted by the Cahill Expressway (Raeburn Chapman RTA RLD 44 Side B 900).

Projects such as these have demonstrated the importance of applying urban design guidelines to the design process. The RTA has formalised these strategies in the Urban Design Guidelines - Beyond the Pavement, developed by a team managed by Raeburn Chapman. The aim of the guide is to assist Engineers and Designers to think about the whole area through which a road passes and how the road contributes to the area.

Implicit in this approach is the need to consult widely with communities directly affected by road design plans.

Since the early 1970s, the DMR has presented three dimensional models of proposed road schemes for viewing to the public. At that time, the exhibitions were public relations exercises intended to assist Councils and the public to visualise the relationship of the proposed road to their neighbourhood. These models were usually on display at site offices, Libraries, Council Chambers, shopping centres or RSL Clubs prior to and often during the construction of the scheme (Jeff Chandler RTA RLD 46 Side A 528 1066 1550).

Wayne O'Mara pointed out that it has only been in the last decade that communities have become more directly consulted in the process of road design and construction and have had an influence on the outcome of the design.

During the mid to late 1980s, Wayne O'Mara worked intensively on the Albury – Wodonga bypass. Two corridor options were proposed, one through the town itself and the other around town. Within these options there twenty alternative routes were proposed.

> *"These options went on public display...it was the first time DMR personnel were exposed to talking to the public...we were going into people's homes and talking to them about the impact of the proposed plans...had never done this before".*
> (Wayne O'Mara RTA RLD 18 Side A 467)

Presentation plans used for community consultation have come a long way since the early 1990s. Dr. Peter Gipps, Research and Development Manager with

Quantm, noted the upgrading of computer programs which are capable of producing sophisticated plans for this purpose.

> *"We are talking to software providers to further extend presentation programs used in community consultations where we will be able to take a terrain model, aerial photographs and model of the road to create a database used by a flight simulator. Then we can do fly throughs of the route and we will be able to see what a proposed road looks like from the window of a particular house...these changes are valuable for community consultations, people can see how the road will impact on them."*
> (Dr. Peter Gipps RTA RLD 36 Side B 806*)*

6.8 Safety issues

Road safety has always been an integral consideration in the design process. It has become increasingly important focus of the RTA's design activities in recent years.

Peter Ellis is involved in monitoring the safety of NSW roads. He noted that the RTA introduced a regime of conducting safety audits in the mid 1990s.

There are five types of audit that are carried out at different times during the design and construction of a road. These are the feasibility audit, a concept audit, a detailed design audit, a pre opening audit and a stage five audit on the existing road. At each stage of a project different aspects of safety are evaluated and reported on. For example a feasibility audit ensures that there are enough intersections to handle traffic. Later audits look at widths of shoulder, special road user needs, livestock issues etc.

> *"We did a pre-opening audit on the Woronora Bridge. There was a walkway/cycleway slung under the bridge, but the approaches were at road level with a concrete barrier separating them from the road. We looked at whether these were high enough to protect the cyclist and looked at lighting and signage."*
> (Peter Ellis RTA RLD 23a Side A 1129)

Wayne O'Mara joined the Road Safety Area of the RTA in 1999.

> *"I really like working in this area, it is a challenge to find ways to reduce the road toll and make the road safer. At the moment we are looking into rest areas and finding ways of making people rest during long drives."*
> (Wayne O'Mara RTA RLD 18 Side B 1307)

As well as looking at these important road user safety issues, the RTA has become increasing conscious of the safety of its personnel. Previously Surveyors and

construction workers often worked on roads under traffic with few safety measures in place. Rob Shipton noted that these practices had a terrible toll.

> *"There were two deaths during the construction of the viaduct at Granville and there were several deaths while the Sydney Harbour Bridge was being constructed. Today there would not be any deaths because there are safety guidelines in place. There were no deaths for example on the Anzac Bridge construction."* (Rob Shipton RTA RLD 2 Side B 1449)

6.9 Road design standards

The changes in approach to road design through the 20th Century have been reflected in the evolution of road design standards from the 1937 Standards through to the current Road Design Guidelines. Road design standards have developed and changed over the years as the performance and design of motor vehicles has changed and considerations of driver response and safety factors have come to the fore. For many years the Standards were incorporated in a handbook called the National Association of Australian State Road Authorities (NAASRA) Handbook. These were National road design standards (Mick Mancone RTA RLD 16 Side A 550).

In the early 1980s the Road Design Guide was compiled by the DMR. This is a New South Wales based guide to road standards for both DMR/RTA personnel and outside consultants. The Guide covers a myriad of road design elements, processes and constraints.

Mick Mancone provided an explanation of some of the design details contained in the Guide. He noted that the guidelines are a reference document that details things such as the radius of curves at certain speeds. Mick explained that when Designers sets out a horizontal alignment, they start with a given speed, say 80 kilometres per hour. The Road Design Guide sets out the minimum radius of a curve and a minimum super elevation for that speed (Mick Mancone RTA RLD 16 Side A 700).

This information is contained in tables and gives minimum allowances. There are tables outlining radius for vertical curves (the required curve for a change of grade at a specified vertical acceleration) and sight distance (the distance at which the driver, sitting at a specified height above the pavement surface, can see an object of a specified height). The Guide also specifies parameters such as stopping distance, which is the sight distance required by a driver travelling at a given speed to react and stop (Mick Mancone RTA RLD 16 Side A 700; RTA Road Design Guide, Dec 1989, Glossary of Terms, page 38, 46).

Peter Ellis noted some recent modifications.

> *"... a lot of design calculations are based on the eye height of the driver ... the higher you sit in the car the farther you can*

> *see... the standard eye height used to be 1.15 metres from the road ... now it is going to be changed to 1.05 because cars are getting lower so you can't see as far as you used to ... all our calculations for stopping sight distance have to change accordingly..."*
> (Peter Ellis RTA RLD 23 Side B 631)

Treatment of batters, drainage systems, pipe sizes and safety guide rails are also considered in the Road Design Guide.

> *"The Standards are scientifically based ... they are the physics of the situation and the guidelines convert it into practical sense and produce standards like braking distance, sight distances, superelevation ... they change with things like tyre technology pavement textures, statutory speed limits etc."*
> (Mick Mancone RTA RLD 16 Side A 1033).

In 1990 the Road Design, Policy and Standards Branch of the RTA was established which began to develop a detailed upgrade of the Road Design Guide. This was in response to the RTA's growing practice of commissioning outside contractors to design and construct roads. Now staff from the Branch travel all over NSW training RTA staff and Local Council workers in the application of the Road Design Guidelines.

The process of upgrading the design guidelines is an ongoing task as John Vickery noted.

> *"A lot of the guidelines are not in the Guide, the Designers hold the knowledge and now we need to get all that information written down and put into the Guide. It is imperative for us to keep up with the latest trends in design. Previously we didn't consider what happened in the maintenance area and now these issues are looked at."*
> (John Vickery RTA RLD 39 Side A 278)

7. Tools of the trade in road design

7.1 The Design Office

Interviewees for this project started work over the years from the early 1940s through to the 1990s. Discussions with these people revealed the dramatic changes that have taken place over this period, from the office ambience, to the tools of a Designer's trade.

Gerald Park, who started in 1954, was first introduced around the office by a senior Designer, Granger Head and was then given a departmental desk knife and data book.

> *"Two people sat at these desks ... the drawing desks were 14 feet long by 3 feet wide ... There was a chest of draws either end of the desk and divider in the middle ... [and] all the desks were loaded up with rolled plans ... Everyone wore aprons made from pink made from government issued dish cloths ... [and] some people wore grey dust coats ... The aprons stopped ink from the plans marking our clothes."*
> (Gerald Park RTA RLD 20 Side A 102)

Juniors were expected to purchase their own instrument sets, which included a slide rule made of bamboo. Gerald Park recalled that joining the Union was another task that juniors were faced with on their first day on the job. One of the advantages of membership in those days was that the Union advanced money for a yearly train ticket.

The office structure was rather hierarchical in those early days. It was noted by several interviewees, that a junior's role was to do odd jobs such as buying the lunches, sharpening pencils, taking rolls of plans to the print room and after a little time on the job, plotting alignments onto graph paper. Rob Shipton, who joined the DMR in 1961, reflected on his first day on the job.

> *"I was eager to do something, but the boss told me that my first task was to learn to do nothing. He said I had to learn patience, then after a while he gave me some plotting to do for the Designers. I had to learn how to plot without using a rubber, because it was the Designers' privilege to use a rubber"*
> (Rob Shipton RTA RLD 1 Side A 271)

Senior Draughtsman supervised the office and checked juniors' work and according to Gerald Park, had first choice of office equipment and positions.

> *"All the seating arrangements were tall stools to go with the drawing desks ... As your seniority went up you might get a*

> *padded top on the stool and then the Senior Draughtsman at the time, Cec Buttonshaw, had a back on his stool ... John Lymbery, a Senior Designer, even had a desk of his own and he had made shelves for all of his equipment..."*
> (Gerald Park RTA RLD 20 Side A 220 & 102)

Not a lot had changed by the time Mick Mancone started in 1965. Juniors started out doing odd jobs and when they gradually progressed to design work, it was all done using drawing pencils which were then 'inked in' using an ink bottle, a tiny dropper and ruling pens.

> *"We had to do all the printing on the plan and there was quite a bit of it on each plan...it was considered an advantage if you had good penmanship. As juniors we had a session every day of practice – copybook type practice. It took me a while to achieve some good printing, I eventually did ... It was awful if you made a mistake in those days ...we had to scratch it out using a razor blade. That [method] was replaced some time later by these electronic rubbers a bit like an electric drill with a little rubber in the end the only trouble was that they left quite a bit of roughness on the plan."*
> (Mick Mancone RTA RLD 15 Side B 223)

Pencils and ruling pens were superseded by drawing pens, which were like a fountain pen with a fine point. Designers used these up until the wide spread computerisation of design.

Wayne O'Mara went from fieldwork into the design office in the early seventies. At this time Designers were still doing all the drawing work by hand.

> *"Four people sat at a long table on stools...the plans would be rolled out and you had scales, stencils, pencils and a rubber and drew on plastic paper...we used calculators called 'coffee grinders'".*
> (Wayne O'Mara RTA RLD 17 Side A 681)

John Vickery also remembered the labour intensive work of his early years as a Draughtsman with the DMR. Even the reproducing of plans involved manually rolling originals through an ammonia product. Rob Shipton recalled that plan printing was done by primitive printing machines (wet copies or sun frames). He noted that it was a major development when in the early to mid 1970s that a basic photocopying machine was used to copy plans.

In the early days the design office plans were drawn on linen. All the old County of Cumberland and Northumberland plans developed in the 1950s were drawn on this medium.

> *"We used to work off the linen plans ...County of Cumberland and County of Northumberland plans –reams and reams of linen plans. The worst thing for a junior was to be sent up to the Lands Title Office on a wet day. All the ink on the linen plans would run on the way home. A lot of the property Plans were still on linen quite often we would have to check our new works off against the old linen plans to see where the properties were."*
> (Peter Ellis RTA RLD 22 Side A 667)

By the time Peter Ellis joined the DMR in 1979, new plans were drawn on a plastic film called *cronaflex* (Peter Ellis RTA RLD 22 Side A 667).

The mechanical calculator that Wayne O'Mara referred to earlier as the 'coffee grinder', was a much welcomed technological advancement in the design office. The Brunsweiger calculator was used for basic calculations such as adding, subtracting, multiplying and dividing (Wayne O'Mara RTA RLD 17 Side A 681).

Peter French joined the DMR in 1973 and used the Brunsweiger calculator to work out design calculations.

> *"When I started we were using the Brunsweiger – a mechanical calculator – you moved some levers and twiddled the dial and away it would go and calculate your numbers. We had one of the first calculators in Road Design [Section] ... it was a valve driven calculator that could add and subtract, multiply and divide that had one memory. It was the size of a modern day PC and it had to be turned on about five minutes before it was needed so it could warm up."*
> (Peter French RTA RLD 24 Side A 505)

Rob Shipton noted that after the Brunsweiger, came an electrical calculator that had a print out function. Later, programmable hand calculators were used which were regarded as a considerable advancement (Rob Shipton RTA RLD 3 Side A 40).

7.2 The arrival of computers

Although calculators were widely used and relieved the tedium of repetitive calculations, it was not until the late 1970s that computers were used to plot road alignments and other design functions. The DMR's large mainframe Cyber computer was housed in an air conditioned room at the rear of the old Commonwealth Bank Office adjacent to the head office in Castlereagh Street. This computer catered for all of the DMR computing needs.

Designers accessed this mainframe computer either directly or later, in the early 1980s, via a remote IBM computer terminal in Metropolitan Design Offices.

> *"The IBM PC was first introduced into the DMR in 1981. Really it was only a calculator, as it didn't have the memory required to run design programs. The mainframe was the only system with enough power to do this and for its day, it was quite powerful".*
> (Russell Ayling RTA RLD 6 Side A 717)

At this time the DMR was running programs developed in-house on the mainframe, which had a capacity of one megabyte of memory. The capacity of this mainframe was upgraded over the years to handle subsequent improving software packages.

During the early 1980s Wayne O'Mara was using the mainframe computer and a system of punch cards to produce design plans.

> *"Co-ordinate data was put onto punch cards and fed into the mainframe computer using a program called COGO. A printout [from the mainframe computer] was available hours later or the next day to check that the measurements were correct. If this was fine, you would have to go back to the mainframe to get a print out and then the plan would be ready to have offsets, distances and cross sections stencilled in".*
> (Wayne O'Mara RTA RLD 17 Side A 681)

Peter French, who joined the DMR in 1973 recalled his first job using COGO to realign the road over the Pennant Hills railway line. The boundaries within which they had to work were very tight, but they had the co-ordinates of the boundaries and these were fed into the computer. Finally an alignment was fitted using the COGO software. Peter reflected that such a job would have been extremely difficult prior to the introduction of computer assisted design.

Another program used by Designers in the early 1980s was a program called DERTH. This program also used the punch card system and was able to calculate co-ordinates and earthworks.

A software design package called MOSS introduced in 1985 heralded a major development in computer assisted design. Unlike previous software packages that were developed in-house, MOSS was an English software package made available by the Ceanet computer bureau. The DMR tried out the software through the bureau before purchasing it (Dr Lee Gregory RTA RLD 30 Side A 278).

Like earlier software programs it ran on the centralised mainframe computer. Rather than providing a two dimensional plan produced by older programs, it drafted a three dimensional database of the ground or a terrain model. It was used to develop the cross sections and long sections of a road design as well as calculating earthworks.

> *"It was an interesting time really when MOSS was introduced. There was a complete change in how you did design and survey*

> *work. The older computer programs used very different and restricted methods of collecting information. MOSS takes a complete model of the surface and can apply 'what if' scenarios to the projects"*
> (Russell Ayling RTA RLD 6 Side A 1188)

Peter French recalled the arrival of the MOSS software and associated equipment at his Design Office in Parramatta in the mid 1980s.

> *"I was at Blacktown at the time and I remember, one day two terminals and a plotter turned up at the office. Nobody seemed to know what to do with it and I was eventually elected to find out how it all worked. Basically the terminals were connected [by landline] to the mainframe in Sydney and we would do some design which was character based and we would eventually get a plot sent back from Sydney."*
> (Peter French RTA RLD 24 Side B 372)

The introduction of MOSS changed ways of thinking about design and it also drove hardware needs. Along with the software package, the DMR also bought twenty Tektronix graphic terminals and plotters for the Design Offices. During 1987, an assessment of desktop requirements was conducted and soon after the Department purchased around thirty Apollo workstations that were networked. Files could be worked on at a workstation in a drawing office.

According to Russell Ayling, the arrival of the Apollo workstations was a very exciting time. The Designers were stimulated by the prospect of such an innovative and useful tool and Russell was kept busy running intensive back-to-back training courses over many weeks. By mid 1989 the DMR had purchased two hundred Apollo workstations and were using them in offices across the State (Russel Ayling RTA RLD 7 Side A 1372).

During 1986, SMIGS (Surface Modelling Interactive Graphics System), another software program, was introduced. It was also developed by Ceanet. Dr. Gregory Lee mentioned this new program was capable of making changes or corrections to the contour plan on the screen (Dr Lee Gregory RTA RLD 30 Side A 1031).

Around the same time as the introduction of SMIGS, came another software package called DOGS (Drawing Office Graphic System). This drafting package worked in conjunction with MOSS to produce more detailed design work.

MOSS, SMIGS, and DOGS were the three main programs used in road location and design. Russell Ayling pointed out that SMIGS dealt with raw data from the Surveyors. This information fed into MOSS, a design and modelling program that produced all the reports that Designers needed and DOGS then produced an electronic plan of the information (Russel Ayling RTA RLD 6 Side B 889).

In 1991, another software package developed by Dr. Lee Gregory was introduced to the RTA. The package, 4D Model was particularly useful for concept planning and design.

> *"4D Model was designed specifically for the Apollo workstations ... It was aimed at the Civil Engineering market, for people doing concept planning work. So Main Roads was using MOSS was used for detailed design but there was this area where you wanted to be able to look at something very rapidly not too much detail, large sections of road before it got to final design – and this concept planning could be a three or four year process of working out where the route was going to be, deciding on the best route, looking at broad brush information ... So we wrote the program for that purpose and one of our early customers was the RTA ..."*
> (Dr Lee Gregory RTA RLD 30 Side A 1428)

Steve Levett recalled using this package for the concept design and public presentation of the Albury / Wodonga Bypass.

> *"Using the package you were able to look at big broad areas of land at different levels of detail. We could then go to property owners and show them details such as what the road would look like at their front door...it also allowed you to view different alignments in a very short time. I recall one farmer was intending to build a big dam in the path of the road that would have to be bridged. Using 4D Model, I was able to design a dam of the same capacity in a smaller area, thus reducing the size of the bridge needed".*
> (Steve Levett RTA RLD 35 Side A 635)

Packages such as MOSS and 4D Model are still being used by RTA's Designers in an upgraded form, MX and 12D Model. DOGS was replaced by Microstation in the early 1990s. According to Wayne O'Mara this software package is a much more flexible and user friendly program. Its ability to produce visual simulations of roads and to drive the road, makes it a particularly useful tool not only in design but also in consultation.

These programs are now used on the new PC platform, integrated throughout the RTA's road location and design offices. Over the past ten years, technology and software upgrades have meant that each Designer has their own PC and all the appropriate software packages on their desktop.

Finding the optimum location or design for roads has never been an easy task. Over time, the number of constraints to be considered in deciding on the best possible route and design has increased enormously. Since the early 1990s Align 3D, an optimisation program, has assisted in this process considerably. The package was

originally designed by the CSIRO and was recently taken over by the Melbourne based company Quantm.

> *"We work mainly with the planners at RTA...we ask questions such as do we need the road, where should it go and how much should it cost and how much will it actually cost...the system operates on a model of the terrain and the constraints are looked at like rivers, streams, zones that have to be avoided, National Parks and areas of flooding...from this information we run the optimisation on the project and give the client twenty to fifty different alignments and costings on them"*
> (Dr Peter Gipps RTA RLD 36 Side B 481)

Recently the package was used to assess a variety of routes and related costings for a proposed Coffs Harbour Bypass. In the traditional design process, this alignment would have been set and then cut and fill calculations and design implications worked out afterwards.

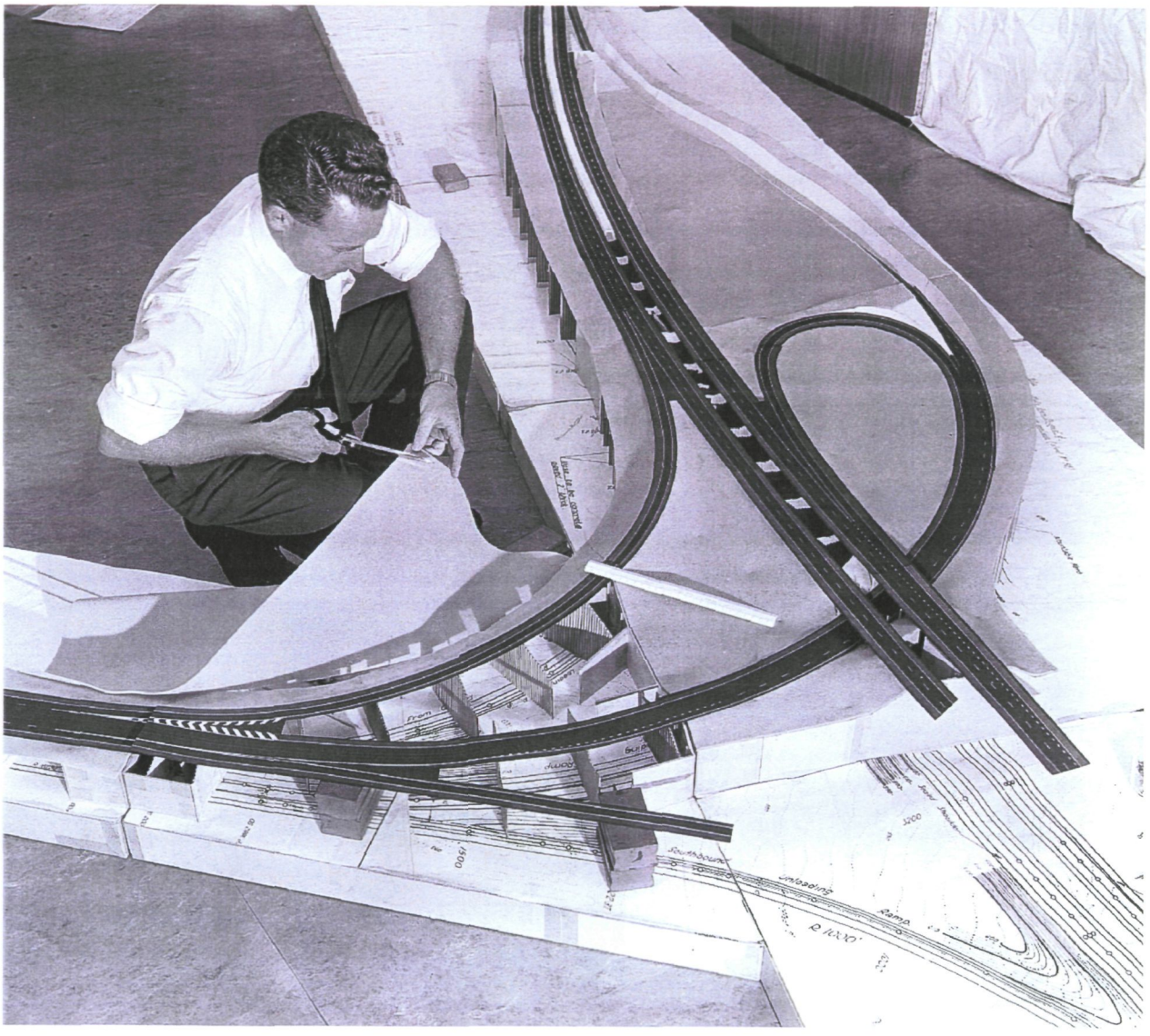
Eighteen months ago Dr. Peter Gipps, began the 3D Align analysis and was able to run over a hundred different sets of conditions for this bypass, providing the RTA with earthworks required and costings for all of these options (Dr Peter Gipps RTA RLD 36 Side A 1455).

7.3 Model making

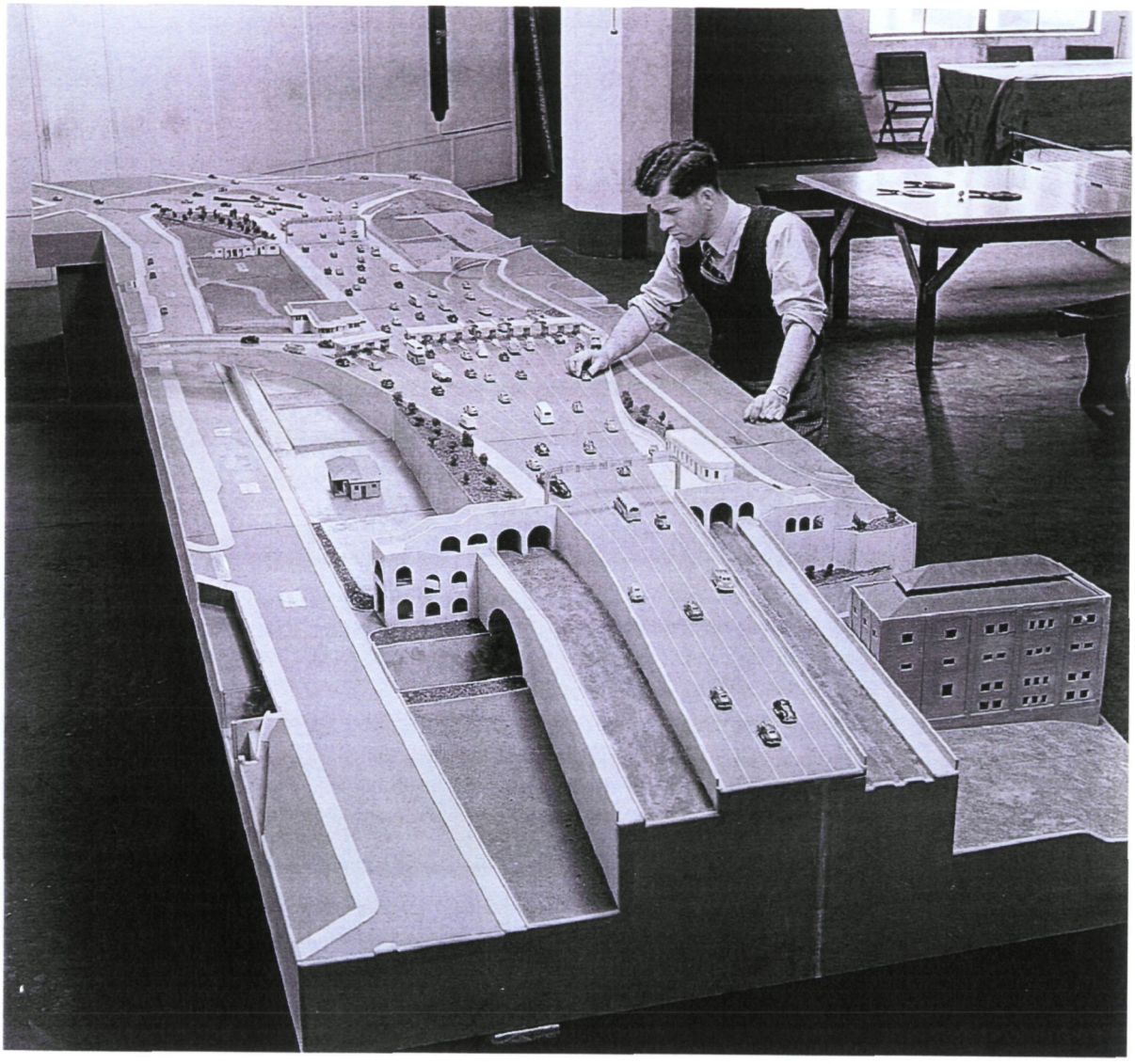
The mid 1960s and 1970s was a period of great road planning and activity within the DMR. The DMR employed its own artist – draughtsman, Wally Willott, to prepare many artists' impressions of urban and rural road and bridge proposals. In tandem with this, was the introduction of three dimension models made to assist with road design and presentation.

An earlier attempt to achieve three dimensional representation of road design was made using an apparatus called "The Abbott". This device was placed over a road plan laid out on one of the 12 foot drawing tables. The devise was aligned to the plan (centre line or edges) using adjustable "T" pieces. Height and tilt could be adjusted on these crucifix elements, which had a tensile wire that could be partially bent. These wires were set to the level of the road and produced the third dimension.

> *"By assuming a similar position to the driver's eye, you could look along the wires and, using a lot of imagination you could get a primitive appreciation of what the road geometry would look like. The devise definitely required quite a bit of user skill and a fair share of 'interpretation'!"*
> (Rob Shipton noted comments)



Draftsman preparing preliminary model of freeway interchange, 1966



Sydney Harbour Bridge - Scale model of proposed new toll barriers and road layout, 1949

The model making section comprised a Junior and Senior Model Maker. They construct small, medium and large scale models of whole road designs schemes or details from these.

John Goossens started with the DMR in November 1970, as an assistant Model Maker to George Kurwaltzki. Together they worked on making a model of the Greater Sydney Metropolitan area, which was exhibited on the 2nd Level of the DMR in Castlereagh Street.

> *"It was all built to scale...we built the landscape out of sheets of cork and then cut out along contour lines to get the hills. We then cut the black and white aerial photographs into small strips and laid over ridges and valleys".*
> (John Goossens RTA RLD 42 Side A 519)

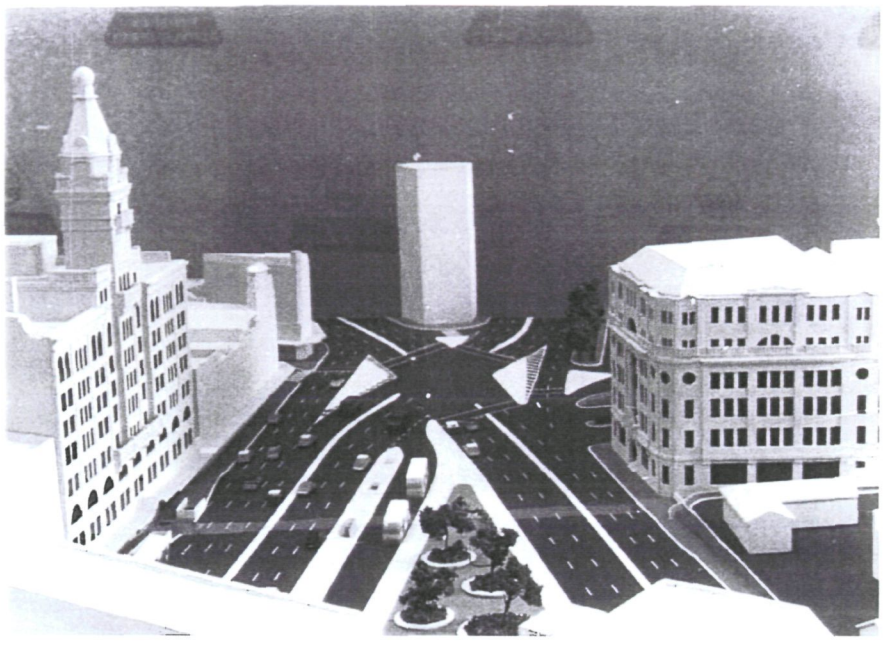
This section was still operating in 1986 when Jeff Chandler joined the DMR as a Junior working with John Goossens. The models were used for exhibition and public relations in that they assisted the public to visualise the road scheme. They represented the height and shadow lines and other realistic features of the design. Jeff Chandler recalled that the Architects, Engineers and Designers would frequently visit the workshop and view the models as they were being made. They occasionally changed aspects of the design after this viewing.

The Anzac Bridge was one memorable model constructed by John and Jeff during the 1980s. It was John's last job with the DMR and Jeff's first job. The model was timber based and constructed in two sections totalling about five metres long. The model was re-made three times to accommodate architectural, engineering and design modifications. The public was able to view this model over the construction period of the bridge.

Jeff Chandler also worked on the City West Link Model, which was rendered in great detail.

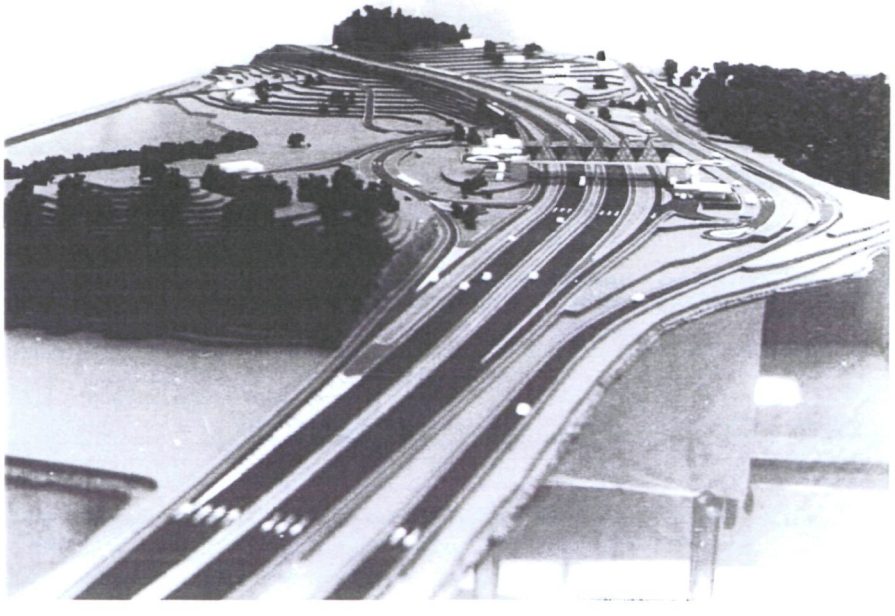
> *"The details were provided by an aerial photograph and stuck onto the timber base ... Both this model and the Glebe Island Bridge model [Anzac Bridge] were big broad brush models showing people how they could get through the new road network to their own houses and located places where they could cross the motorway. These models answered a lot more questions than a plan"*
> (Jeff Chandler RTA RLD 46 Side A 849)

As well as making models of road schemes and detailed sections of roads and intersections, the model making team were occasionally commissioned to make models for other Government Departments and the private sector. Over the years they made models of Darling Harbour, a holiday resort in Byron Bay and of particular interest to John Goossens, a model of Mt. Panorama for the Police Department.



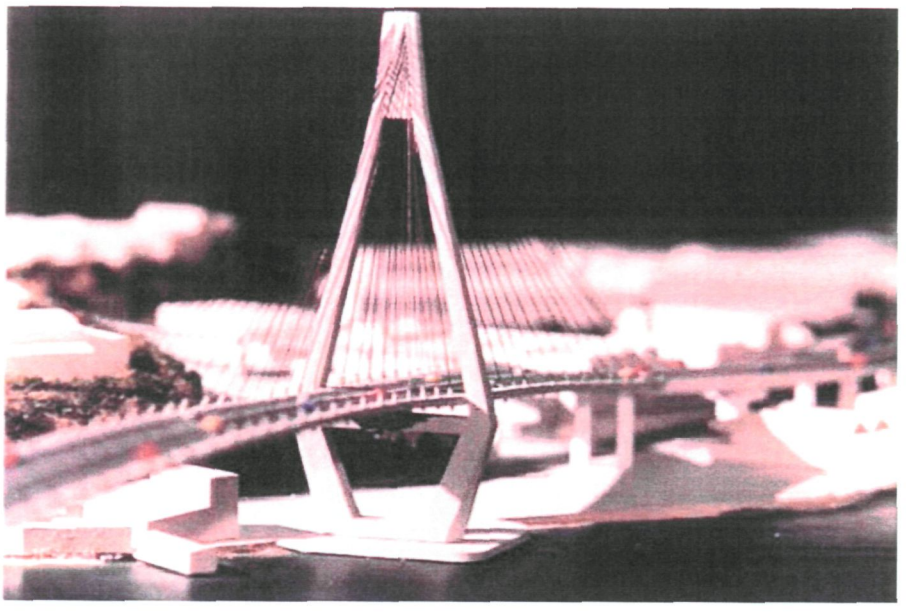
George St and Broadway model circa 1970

(Image supplied by John Goossens)



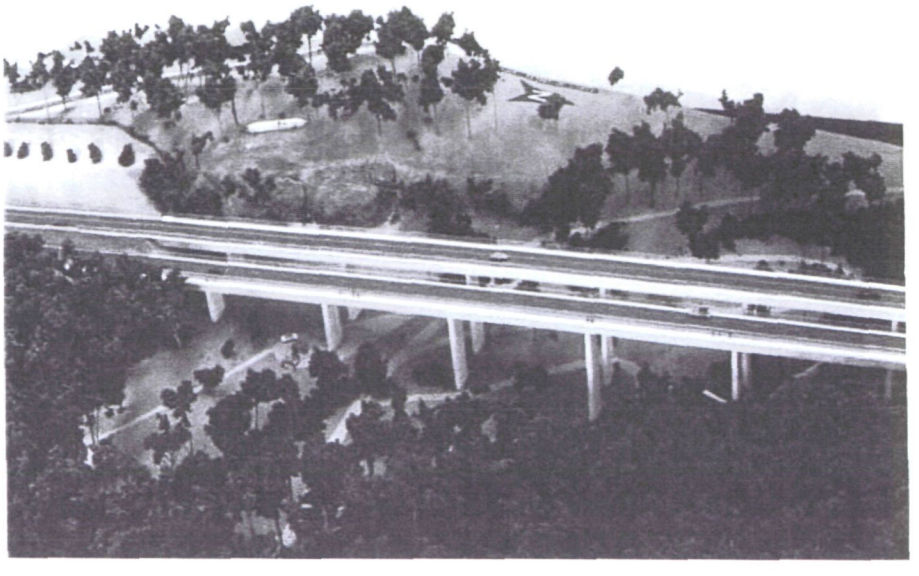
F3 Restaurant model circa 1971

(Image supplied by John Goossens)



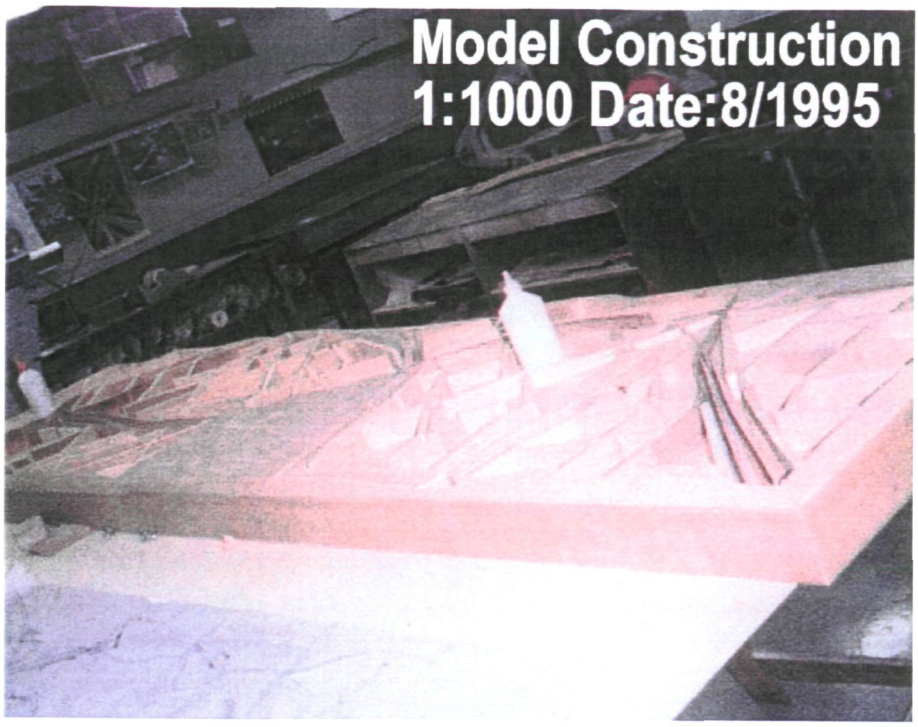
Glebe Island (Anzac) Bridge model circa 1980

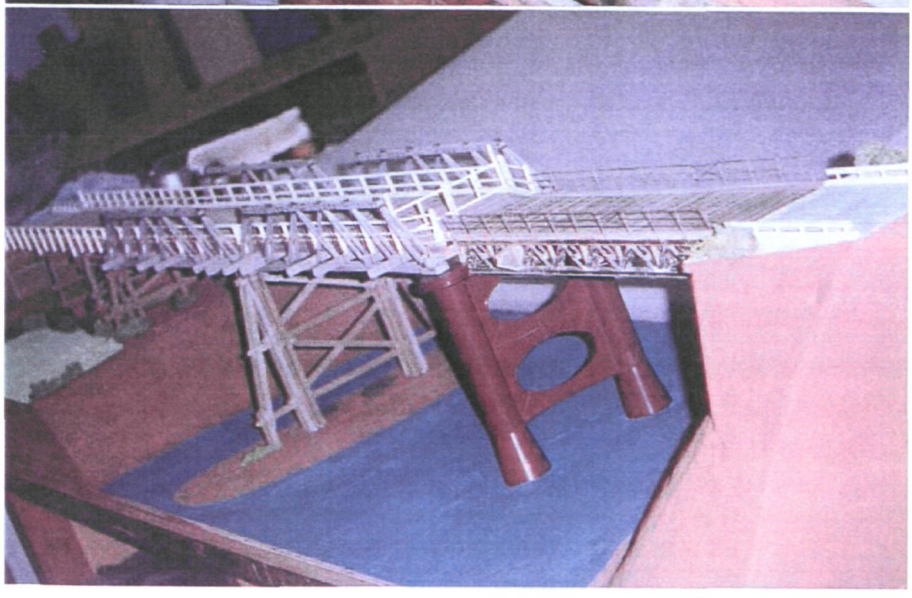
(Image supplied by John Goossens)



Model of bridge at Newcastle

(Image supplied by John Goossens)

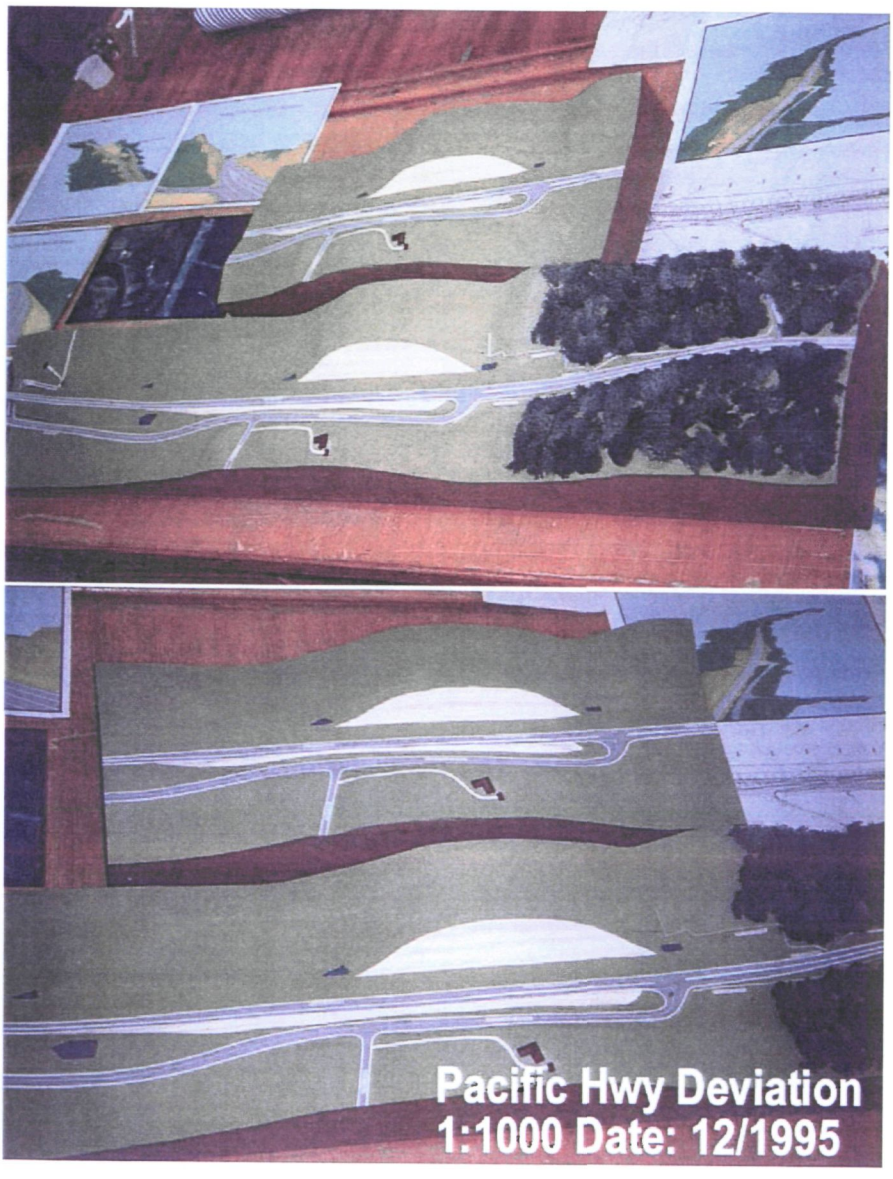




(Images supplied by Jeffery Chandler)

John Goossens

(Image supplied by John Goossens)



(Image supplied by Jeffery Chandler)

> *"There was a big court case after the Mt. Panorama riot and the Police wanted me to make a model of the site. They supplied me with photographs and working from these and military maps I made the model. I had to go to court..."*
> (John Goossens RTA RLD 2 Side B 1132)

Similarly, John made a model of the Granville Railway Bridge after the bridge collapse on 18 January 1977. This model was commissioned by the Coroners Court for the subsequent investigation into the disaster.

John Goossens recalled that the model making team had their workshop in an old power station near the Family Court in Goulburn Street. In 1990 they moved to Brisbane Street near Hyde Park and three years later they moved to Rosebery where they had a large ground floor workshop.

During its heyday the model making section was kept busy churning out a large scale model every couple of months. Jeff Chandler, the last RTA Model Maker, commented that the Department wound down slowly over the years. Since 1998, with the impact of computer modelling, the model making section has been disbanded.

8. Conclusion

There have been dramatic changes in approach to road location and design throughout the 20th Century. This report has traced the development of the New South Wales road network from its beginnings as a series of tracks linking isolated settlements, to a complex and efficient network of motorways, highways regional and local roads. This network of modern roads efficiently and conveniently link communities within the State and beyond its boundaries

Since the advent of motorised road transport, roads have reflected the specific standards of each era. Road design has evolved from employing a series of long straight sections of roadway and tight curved sections, similar to the design of railroads, to long curvilinear roads that enhance driver perception. Road Design Standards have also developed in response to the changing standards of performance and design of motor vehicles.

Most recently the Road Design Standards used by the RTA Designers and Engineers have evolved to incorporate careful and sophisticated consideration of environmental, urban design and safety factors. This trend has been a response to both the need for community amenity and the vital work of protecting our environment. At the same time it has optimised safety and convenience of movement for community and industry in the State and beyond.

Since the Second World War, New South Wales roads have gone through a number of major upgrades in order to ensure that they conform to the evolving Road Design Standards. From the early 1950s to the 1970s, the DMR undertook the planning and construction of new expressways and the major reconstruction of the State's arterial roads; straightening, widening and sealing roads as well as improving drainage.

Parallel to the changes in road location and design philosophy and practice, has been a gradual revolution in the "tools of the trade". Designers who began their careers undertaking all calculations by hand were introduced to computers and specialised design software in the late 1970s. Since then there has been an ongoing improvement in software and hardware designed to assist in locating, surveying, plotting road alignments and completing detailed design of roads. The DMR's large mainframe computer was used up until the mid 1970s. The functions of this computer were gradually upgraded and reassigned to a modern network of personal computers. Today all Surveyors and Designers have their own PCs at their desktop.

The Roads and Traffic Authority and its predecessor organisations have responded to the changing requirements of road location and design and applied new technologies to provide all Australians safe, well designed and well constructed expressways and roads over many years.

Many of the interviewees for this oral history project commented that the next great challenge for the Roads and Traffic Authority is to accommodate the increased traffic on New South Wales roads particularly in Sydney area. In Sydney, the challenge is compounded by the lack of new road corridors within the city area. A number of possible solutions to this issue were discussed. Among these is the development of a holistic approach to commercial and private transportation such as transit ways which privilege public transport, cycle tracks and pedestrian uses of roads as well as using pioneering technology to construct large networks of motor vehicle tunnels.

Finally we would like to acknowledge that all the people we interviewed for this oral history program expressed a sense of great pride in their achievements within the organization. Those who continue to work for the RTA voiced their commitment to developing a responsive and safe road network that is considerate of its natural and urban environment.