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NEW ZEALAND

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Australia

THE FIRST AUSTRALASIAN CONFERENCE ON ENGINEERING HERITAGE 1994

OLD WAYS IN A NEW LAND

Christchurch, New Zealand
27 - 30 November 1994

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PREPRINT OF PAPERS

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Learning Service Achievement
Our Engineering Heritage

F N STACE
BE (Elect Mech) BE (Mech) FIEE FIPENZ
formerly Technical Publications Ltd, New Zealand

SUMMARY When adopting a motto the New Zealand Institution of Engineers (now the Institution of Professional Engineers New Zealand) drew from the example set by its foundation members and "Learning Service Achievement" became part of the Institution's heritage. This paper considers the professional careers of its founder and eight other long deceased members who all personified learning, service and achievement in order that present day members may emulate their example and so preserve and enhance the Institution's heritage.

1 INTRODUCTION

Lives of great men all remind us
We can make our lives sublime
And, departing, leave behind us
Footprints on the sands of time
- Longfellow

From the early 1940s for about a quarter of a century the author worked closely with most of those remembered below. All of them, now deceased, gave exceptional and distinguished service to the engineering profession in New Zealand. This year (1994) the author studied the life of William Ferguson who died in 1935 and who is regarded as the founder of what is now the Institution of Professional Engineers New Zealand.

The following does only scant justice to nine Institution members whose lifetime contributions bequeathed to the engineering profession its heritage of learning service and achievement.

2 THE CATALYST - WILLIAM FERGUSON

Learning was an early priority for William Ferguson.

After completing his mechanical engineering apprenticeship in Dublin in 1873, for the next 10 years, while engaged diversely in mechanical and hydraulic design, waterworks and railway extension schemes (and working for up to three employers concurrently), Ferguson was at the same time acquiring arts and engineering degrees with distinction at Trinity College! As well, during the final two years, he not only assisted his engineering professor but, with the professor's death, took over all his duties for the last six months before sailing to New Zealand.

From 1884 for the next 40 years outstanding service was to be Ferguson's contribution. First as engineer, secretary and treasurer, and later consultant to the Wellington Harbour Board for 25 years, he made the port of Wellington the best equipped in the southern hemisphere. Next as managing director of the Wellington Gas Company for eight years he had completely new works built. Then from 1916 to 1920 he devoted himself to war work as the government appointed honorary chairman of the National Efficiency Board. In addition during all this time he was made available by his employers for a host of diverse activities. Ferguson advised on land reclamation, sewerage, river silting, proposed canals, ironworks, health problems, tramway systems, railway extension and freezing works, as well as harbours in Australia and New Zealand. Indeed for a period of 20 years until ill health in 1925 forced a curtailment of his activities, William Ferguson was the inevitable choice for any engineering inquiry.

In the context of this paper, however, his greatest achievement was in 1914.

As a member of the Institution of Local Government Engineers, William Ferguson led with wisdom, urbanity and skill the negotiations that resulted in the formation of the NZ Society of Civil Engineers and then the merging of the local government engineers into the new body now the Institution of Professional Engineers New Zealand. His catalystic action entitles William Ferguson to be regarded as that body's founder as well as its first honorary secretary from 1914 to 1918, its president in 1919 and 1920 and a member of its council until 1924.

Yet despite all his achievements William Ferguson died unhonoured in 1935 after 10 years of ill health.

3 THE GRAND OLD MAN - F W MACLEAN

Ill health never bothered the spritely 80 year old who in 1938 came bounding up five floors - he always scorned the lift - to see 'this young graduate who has gone into the literary side of engineering.' That's when I met F W MacLean.

Born in Boston, USA, MacLean had been taken to Scotland at an early age and educated there, gaining first-class honours in engineering from Edinburgh University. Then he was a railway engineer in Northern England before joining the New Zealand Railways in 1884, serving finally as chief engineer from 1916 to 1924.

A foundation member of the NZ Society of Civil Engineers he was its president 1921-22. A foundation member of the Engineers Registration Board in 1925, he served on that board until 1943.

At the time of our meeting MacLean was regarded as the 'grand old man' of the Institution, and he continued to be so regarded until his death in 1951, aged 93.

MacLean took a kindly interest in me, and his eminence and his energy were always an inspiration, so that I was delighted to be asked by the secretary of the Institution for ideas for a suitable award to commemorate MacLean's outstanding contribution to his profession. But the secretary pointed out that a medal or similar award was not favoured by his council because 'the Institution already has enough of these with the Fulton gold and silver medals, the occasional special award for papers, and the newly established Furkert Award.' (These three have now grown to 13!)

As an avid reader of American professional engineering journals I suggested a citation, but then had to explain just what that was. Eventually the MacLean Citation was established for presentation, from time to time, to persons who have rendered 'exceptional and distinguished service to the profession.'

4 THE FIRST MACLEAN CITATIONS

Naturally the first presentation of the MacLean Citation was a most significant occasion. At the 1954 conference the president (N L Vickerman) highlighted MacLean's career after which the incomparable L B Hutton declaimed for eight minutes in heroic couplets on the life and work of Frederick Templeton Mannheim Kissel, who responded by saying that he too could exaggerate and be a bit of a liar!

Nevertheless except perhaps for F W Furkert, who had died some five years earlier, no more appropriate person than Kissel could have been cited. His career with electric power development in New Zealand was unparalleled.

After his graduation from Canterbury College in 1905 that career first encompassed railway and water engineering before the pioneering Lake Coleridge development, and finally the whole of New Zealand's electrical development, as chief electrical engineer of the Electrical Branch of the Public Works Department from 1922 until his retirement in 1948 as the first General Manager of the State Hydro-electric Department.

A foundation member of the NZ Society of Civil Engineers in 1914, the following year Kissel presented one of its first two papers. He was president 1932-33 and later, in 1937, he successfully promoted the change of name to the New Zealand Institution of Engineers.

Like MacLean a foundation member of the Engineers Registration Board, Kissel served on that board for 23 years, and he continued his engineering interests long after his retirement (with a well deserved ISO) as a director of various companies. Indeed he too outlived most of his contemporaries and died in July 1962 at the age of 82.

Outwardly Kissel was rather gruff and certainly he was uncompromising. But I found him kindly, conscientious and informative as censor of the *NZ Electrical Journal* throughout World War II during which he held the positions of Electricity Controller and Lighting Controller - the latter a job he said he detested.

In 1957 William Langston Newnham became the second recipient of the MacLean Citation, not long after he had been elected a Fellow of the Royal Society of Arts, London.

Newnham, who joined the Public Service in 1906 as a cadet, worked mainly in the field until 1921 on survey and construction for such projects as the Otira tunnel, the North Island Main Trunk, the Rimutaka deviation and the Featherston and Trentham military camps. He then joined the Public Works Department design staff, became design engineer in 1929 and was Engineer-in-Chief and Undersecretary of the department from 1941 until his retirement in 1946.

Like MacLean, Newnham was part of the first Engineers Registration Board in 1924, but as its first registrar and for many years its chief examiner. He became a full board member in 1940 and was chairman 1945-65.

After his retirement from the Public Works Newnham served on the Soil Conservation and Rivers Control Council, being chairman 1952-57. He was also chairman of the Standards Council 1953-57. His CBE was well deserved.

A foundation member of the Wellington Branch of the Institution in 1920, Newnham won a special Institution award in 1935 for a paper on the protection of structural steel. For 18 years he served on the Institution education committee, mostly as its chairman.

During his presidential term (1945-46) we met by chance in Auckland's Queen Street and laid the foundation for the Institution's participation in *New Zealand Engineering* to be launched in April 1946.

Perhaps Newnham's most memorable contributions - and certainly the most onerous ones - were his editing (over three years) of *Early New Zealand Engineers* from an incomplete manuscript left by the late F W Furkert, and his compilation of the Institution's golden jubilee publication *Learning, Service, Achievement: Fifty Years of Engineering in New Zealand* begun in 1953 and published in 1971, three years before his death at the age of 85.

He is commemorated by the annual Newnham Lecture and is remembered as 'kindly and courteous, one who was respected with affection.'

But told once that he was 'too soft' in taking on too much, Newnham replied that during his 50 year engineering career he had experienced and survived the aftermath and repercussions of two world wars, numerous flood disasters, the Murchison, Napier and Wairarapa earthquakes, and Bob Semple (Labour's first Minister of Works) and Jack Fletcher (NZ's first construction tsar) not listed in any descending order of magnitude.

And that Newnham was 'kindly and courteous' I personally confirmed when he remained friendly and uncomplaining after I had edited out 40% of his manuscript for *Learning, Service, Achievement!*

A prolific writer who needed minimal editing was Leslie Bertram Hutton, in 1959 the third receipient of the MacLean Citation.

Several years prior to his death in 1972 Hutton even prepared his own obituary which was published substantially as he wrote it. Few engineers could emulate Hutton in his reading, writing and speaking in the English language, and none in Latin, or in Roman or Greek mythology.

Hutton's articles were historical or political, often controversial rather than technical, although in 1935 he won a special award from the Institution for a paper on lightning and electrical distribution systems. For his presidential address in 1948 his title was 'Of ye and me, my learned friends' which continued the theme of a 1936 presidential address to the Electrical Supply Engineers Association entitled 'An Engineer's Leisure.'

Nearly 60 years ago Hutton advocated continuing education and in 1936 exhorted his fellow supply engineers to so regulate their leisure that some of it might be devoted to an organised advancement of their knowledge of electricity, also to make a special and continuous study of some important branch of their work, but as the same time to read write and talk on other than strictly technical subjects - advice always carried out by Hutton to his customary standard of perfection.

Hutton was another of those engineers who pioneered electricity supply, first at Lake Coleridge, then in the Waikato and later in Southland, before coming to Wellington in 1937 for 17 years with the city Tramways and Electricity departments, 10 of those years as general manager of both.

For countless years Hutton worked on key engineering committees, often as chairman, most notably in the fields of education, publications, awards and standards.

During World War I Hutton had served overseas as a company sergeant major (before being commissioned and winning an MC). Yet much later when Hutton chided it was usually more amusing than abusive. 'Some engineers in this room can neither read nor write,' he once remarked at an engineering conference. And the chief culprit cherished the remark, well deserved for much unanswered, as well as unactioned correspondence about an unwritten engineering history.

History, maintained Hutton, must always be recorded before it is too late and he practised to the full what he preached.

The next MacLean Citation, in 1965, was rather unusual because Francis Malcolm Corkill had spent most of his first 10 postgraduate years away from New Zealand and most of the next 40 or so in New Zealand's most remote city.

After completing an outstanding scholastic career - dux at his secondary school, a junior and then a senior university scholar, then winner of the engineering travelling scholarship after completing the degrees of Bachelor of Engineering and Master of Science with first class honours - Corkill joined the NZ Expeditionary Force in the Corps of Engineers. After his demobilisation in 1919 he took an appointment with the Public Works Department of the Federated Malay States where he continued also to take an active interest in military affairs. In fact for over 40 years he maintained active or territorial service.

On his return to New Zealand in 1923 Corkill was engineer to the Opunake Harbour Board for two years, then Egmont county engineer for three years. In 1928 he was appointed city engineer, Invercargill, a position he held until his retirement in 1952. After that he practised in Invercargill as a consulting engineer until his death in 1970.

President of the Institution in 1944, Corkill was a man of the highest integrity, always maintaining and demanding the highest standards of professional conduct. Perhaps he was influenced by his long friendship with F W MacLean who characteristically had taken an interest in Corkill on his return to New Zealand. In his turn Corkill befriended many younger engineers and kept in touch with them even though their meetings might be only at the Institution's annual conferences.

As well as wide professional interests, particularly in municipal, water, and road engineering, Corkill had a diversity of other interests including the University Association of Southland, the Royal Society of New Zealand, the Southland Aero Club and the NZ Alpine Club.

Although situated a long way from the Institution headquarters in Wellington, Corkill was always an active and loyal member of it. He served on its council for 13 years and was twice chairman of the Southland Branch.

For his exceptional and distinguished service he received a well merited CBE in 1966.

For sheer volume of Institution activities few could have emulated Charles Stephen Plank, in 1967 the fifth recipient of the MacLean Citation.

In 1950 Charles Plank was elected honorary treasurer of the Institution; he was a member of the finance, house, public relations and rules committees at the same time. Having served five years as honorary treasurer, he then served a further five as honorary secretary-treasurer and then two more years as an ordinary member of the council. In all Plank served continuously on Institution committees over a period of 20 years.

As honorary secretary-treasurer Plank was an ex-officio member of the administration committee, the council, and the three executive committees and, after his retirement from the position of divisional engineer, Post Office, in 1962, Plank attended inter alia all their meetings and consequently on occasions was more informed on their views than either the Institution secretary or his deputy, who shared between them the meetings of some of the major committees. Plank's continuously up-to-the-minute knowledge of committee views plus his knowledge of meeting procedure and his financial acumen made it hard to challenge his views successfully, impossible to overrule him and incredibly difficult to get approval from him for some expenditure items. At one time he even suggested that to cut costs the Fulton gold medal might be made of some baser metal! As for rules, Plank almost single-handedly during a six month period completely revised the Institution's rules, at the same time as he compiled its examination and professional interview regulations.

He could be both an invaluable ally or an implacable opponent, sometimes both at the same meeting, but during the mid 1960s no one could deride or emulate the enormous amount of work he put into the Institution finances, including its new building Molesworth House, its rules and its examination requirements.

In a different sphere Charles Plank did as much for the Karori Tennis Club, holding at some time every administrative position in that club. He also played a major part in the management of the Lawn Tennis Umpires Association and was deeply involved with the Victoria University Council up to the time of his death in 1970.

The sixth recipient of the MacLean Citation - Cyril John Mulley Choat - always known as 'Bill' Choat, was a modest friendly and true gentleman. Perhaps because he was so unassuming little has been recorded about his work and he was certainly not a great presenter nor discusser of technical papers.

After a 'middle group' education and training in the United Kingdom Choat, aged 25, emigrated to New Zealand in 1926. Following brief periods with British Pavements and the New Zealand Railways he joined the Shell company as a draughtsman in 1927. Twenty five years later, as a professional engineer, he was admitted to corporate membership of both the NZ Institution of Engineers and the Institution of Mechanical Engineers, London. He achieved the position of chief engineer for Shell New Zealand before his retirement in 1962.

Then he was able to be more active in Institution affairs and became chairman of its Wellington Branch in 1964 and a member of the council of the Institution for several years.

The Institution's Dobson Lectures to secondary school students, initiated in 1961, were proposed by Choat and were modelled on the Leonardo da Vinci lectures run by the Institution of Mechanical Engineers.

Probably because he had come up 'the hard way' Choat was always interested in education and training, particularly for middle group engineers. Therefore his appointment in 1962 by the Minister of Works to the newly formed Engineers and Associates Registration Board was appropriate and most successful. Choat chaired the board for its first 12 years and served on it for another four years until his retirement in March 1978. Then in his 77th year he was still outwardly as spry as F W MacLean whose citation he received in 1971.

Always coupled with Choat's concern for education was his feeling for human needs - particularly hospitality and friendship - and an example of this trait was given when, as one of the directors planning the Institution's golden jubilee conference in 1964 he realised that visiting dignitaries from overseas might appreciate guidance in unfamiliar surroundings. Consequently he provided 'ghosts' for each dignitary, hand picked hosts who were always unobtrusively in the background ready to offer hospitality, help or advice.

At his funeral in December 1982 another facet of this unassuming man's ability was revealed. He was a skilled craftsman with wood who in his spare time had specially made for his church some of its most treasured objects.

5 THE INDOMITABLE F W FURKERT

In the year of his death (1949) Frederick William Furkert had been chairman of the Institution's publications committee for five years and, as one of its members during that period, I can confirm that his vigour and ability were still evident. Had Furkert lived another five years and achieved his 78th year, he would surely have been the first recipient of the MacLean Citation. Fortunately he is commemorated with the Furkert Award and by his book *Early New Zealand Engineers.*

Furkert could himself become the subject of a book - or books - with such titles as:

"From PWD cadet to Engineer-in-Chief and Undersecretary" (1884 to 1920)

"Pioneering New Zealand's Transport Systems" (4 Volumes)

- Vol 1: Rail (North Island Main Trunk 1908-1918)
- Vol 2: Road (Chairman, Main Highways Board 1924-32)
- Vol 3: Sea (Chief government adviser on marine engineering)
- Vol 4: Air (Member of New Zealand's first Air Board)

"Trying for Active Service in Two World Wars (2 volumes)

- Vol 1: World War I (Appointed to command NZ Tunnelling Company but held back in NZ and put in charge of military camp construction at Trentham, Maymorn and Featherston)
- Vol 2: World War II (In Fiji as adviser on flying boat bases and government agent for defence construction and purchasing)

For all this only a CMG in 1926 seems a paltry award.

Furkert served the Institution equally fully and well: Foundation member in 1914, president 1923-24, contributor of several papers and, for long after his retirement in 1933, prodigious committee work. For example in 1938-39 he was honorary secretary of the Institution, chairman of the publications committee, member of the house committee, the finance committee, the Centennial Engineering Congress executive committee (and chairman of its programme, publicity and papers sub-committees) a trustee of the Fulton bequest and honorary secretary of the Benevolent Association!

Ten years later Furkert was still a potent force and thinker ahead of most of his contemporaries. For instance, when I was presenting to the 1949 conference a plan for a public relations campaign, there were comments from senior members who 'deprecated making themselves prominent' and as engineers did not want 'anything that savoured of self advertisement' nor 'seeking economic benefits.'

Then Furkert (himself a previous convener of the public relations committee) came in with: "He who whispers down a well about the goods he's got to sell, will never reap the gleaming golden dollars like he who climbs a tree and hollers.' The motion for the adoption of my report was then carried without further dissent.

5 CONCLUSION

Ferguson, MacLean, Kissel, Newnham, Hutton, Corkill, Plank, Choat and Furkert between them spanned 100 years of engineering in New Zealand from Ferguson's arrival in 1883 to Choat's death in 1982. As one who knew all but the first of them and who worked with most of them I realise that this paper barely does justice to their diverse achievements.

Four of these nine men were foundation members of the Institution and seven of them became presidents of it. Three established well deserved reputations as historical writers but only two of them received awards for papers and not one of them the Fulton gold medal! Perhaps that was because they were all fine administrators who encouraged those below them to write and make names for themselves.

All of them fulfilled Hutton's dictum that they must not only continuously update their professional knowledge but must also devote some time to pursuits other than professional engineering. All of them excelled not only in their profession but in at least one other activity. And historical writing, project evaluation, Latin and Greek mythology, sports administration, territorial military service and wood craftsmanship are as diverse as could be imagined!

All of them added to our engineering heritage of learning, service and achievement.

C.Y. O'Connor — Public Works Engineer 1843-1902

R.D. GRANT BE FIPENZ, Retired, former District Commissioner of Works,
Public Works Department, New Zealand.
A. MOULDS MIE Aust, Chairman, National Committee on Engineering Heritage,
The Institution of Engineers, Australia.

SUMMARY The paper deals with C.Y. O'Connor's career, his years of maturing experience in New Zealand, where he rose from an assistant engineer's post in Canterbury Province, in 1865, to become Under Secretary for Public Works, and his period subsequently as Engineer in Chief in Western Australia.

It draws parallels between O'Connor's work in New Zealand and Western Australia, in the construction of harbour works, pioneer railways and hydraulic schemes through difficult terrain.

INTRODUCTION

Charles Yelverton O'Connor was said by his contemporaries to be a man ahead of his time, an engineer of genius. His living monuments in Australia are the inner harbour at Fremantle and the Eastern Goldfields Water Supply Scheme; both are acknowledged as national engineering landmarks. He also presided over the Western Australian Government Railways during a period of unprecedented growth.

This paper traces O'Connor's career, his years of maturing experience in New Zealand, where he rose from an assistant engineer's post in Canterbury Province, in 1865, to become Under Secretary for Public Works, and his period subsequently as Engineer in Chief in Western Australia.

The paper draws parallels between O'Connor's work in New Zealand and Western Australia, in the construction of harbour works, pioneer railways and hydraulic schemes through difficult terrain.

At times the 'old ways', brought from the motherland, were found inappropriate in a frontier setting.

It draws parallels also between the growth in size and professionalism of the Public Works Departments of both countries, in which O'Connor was instrumental; from his selection in 1871, as one of a hand-picked group of young and highly competent engineers which formed the first Department in New Zealand; to the rapid evolution of the Works Department in Western Australia, following his arrival in 1891.

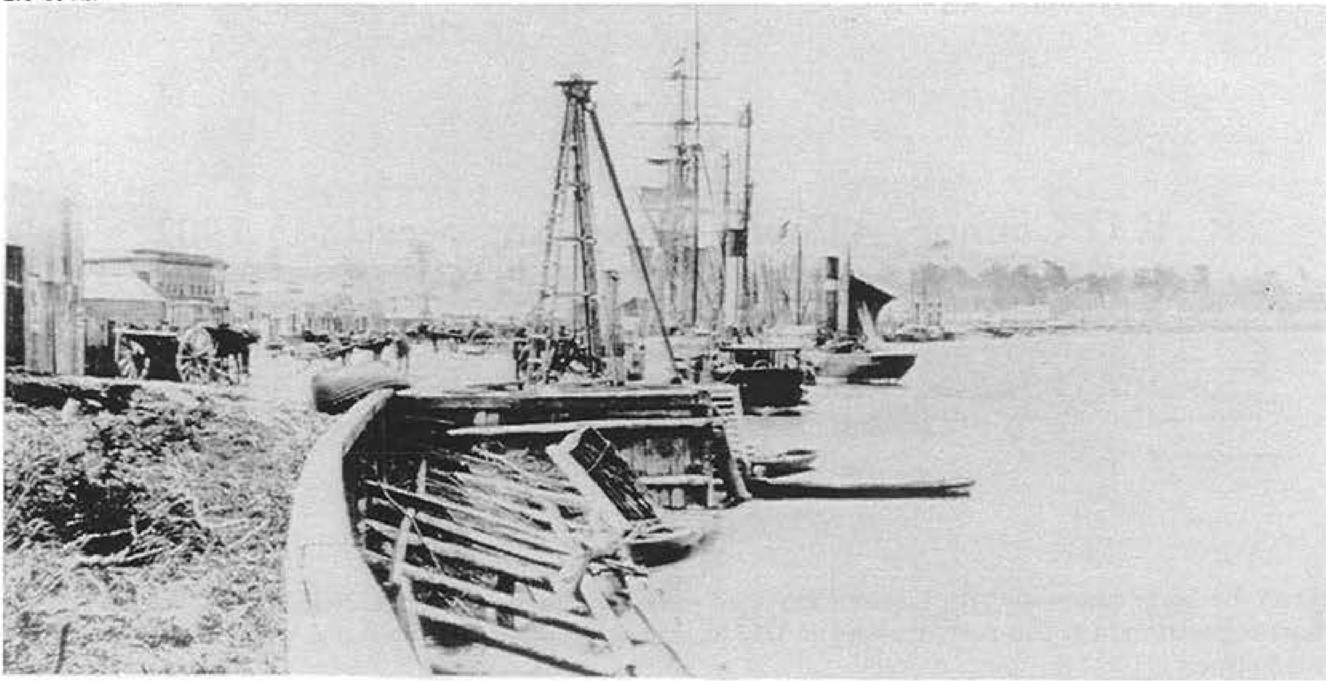
A CAREER IN NEW ZEALAND

A member of the Anglo Irish Gentry, Charles Yelverton O'Connor was articled in 1859 at age 17 to Dublin Railway Engineer, John Chaloner Smith who at that time was Resident Engineer to the Waterford and Kilkenny Railway. Smith later entered into partnership with a Mr Bagnell as railway contractors and O'Connor received an excellent grounding in surveying, draughting, contract estimation, and management and not least, in the management of men.

Economic conditions in Ireland were deteriorating and in 1865 he forsook that country to seek his future in New Zealand. Just why he chose New Zealand is not entirely clear. A relative by marriage, Foster Goring was Secretary to the Executive Council of New Zealand, a position of some importance and may have influenced O'Connor in his choice. Certainly Goring found him some surveying work in the Waikato on his arrival but this could not have occupied him for very long for in September 1865 he commenced employment with the Canterbury Provincial Council as an assistant engineer on the construction of the West Coast Road between Canterbury and the Hokitika goldfields.

The goldfield had been prospected from 1862 onwards but it was not until mid 1864 that good returns from the Greenstone Creek near Hokitika revealed the richness of the ground. The goldfield was proved to extend considerably north and south of the Hokitika River and the new township and port of Hokitika became established. By early 1865 diggers from all over the South Island converged on the field while in April the first miners from Victoria arrived by sea at which time 7000 men had arrived. This was to swell to 20,000 before the end of the year.

The West Coast of Canterbury Province was for practical purposes cut off from Christchurch not only by the mountains of the Southern Alps but also by the untouched subtropical rain forests, swamps and fast flowing rivers on the western slopes. Diggers straggled along rough foot track over Harpers Pass between the Hurunui and Teremakau watersheds but for the most part they came by sea to the risky rivermouth harbours of the Hokitika and Grey Rivers. Supplies also came that way, locally from Nelson and directly from Melbourne. Canterbury interests looked for a share of this trade and the Canterbury Provincial Council determined on the construction of a dray road over the Southern Alps to the diggings.



Gibson's Quay, Hokitika, 2 March 1868. *Photo by D.L. Mundy, courtesy of Canterbury Museum, Christchurch, N.Z. (ref. 1401)*

The route adopted was via Arthurs Pass. Edward Dobson, the Provincial Engineer put the work in hand with extreme rapidity. Some forty miles of road from Christchurch to Springfield already existed. Overall control of the project, though initially in the hands of George Thornton, was by George Dobson, the Provincial Engineer's elder son. Three resident engineers were each responsible for the detailed location and construction of their particular sections; Walter Blake from Springfield over Porters Pass to the Bealey; Blake's brother Edwin over the main divide and down the Otira and Teremakau Rivers and Alexander Aitken over Kawhaka Saddle through the goldfields and on to Hokitika. O'Connor, when he arrived was assigned to assist Edwin Blake. Construction was by contract, notable contractors being William White and E.G. Wright.

O'Connor's initial work was in the detailed location and construction of the Otira Gorge section where work was already in progress when he arrived. The route through the defile was being blasted out of the rock by E.G. Wright. In places space was so cramped that the road had to be cantilevered out from the rock wall on timber beams. The route, while improved, is that which is in use today.

The first coach to travel the full 147 miles from Christchurch to Hokitika did so in March 1866, a mere ten months after the adoption of the route, a tremendous achievement by the standards of any time. While it was a triumph of pioneer engineering organisation it was far from a commercial success. Little other than stock on the hoof and the mails travelled that way. Melbourne merchants supplied most of the goldfields needs and it was to Melbourne that the gold bullion was despatched. Risky harbours or no, the seaborne trade continued undiminished. George Dobson, shortly before this had been appointed District Engineer for Westland but had hardly taken up his appointment when he was murdered by bushrangers. Edwin Blake as Resident Engineer, West Coast Road continued with the bridging and the completion of the work with O'Connor as Assistant Resident Engineer. O'Connor's salary in 1867 being £20 16s 8d per month.

The roadwork being largely complete, O'Connor was then ordered to make a reconnaissance survey for the transalpine railway. This was to leave the projected Great Northern Railway of Canterbury at Horseley Downs, near Hawarden and to go by way of Lake Sumner and the Hurunui River over Harpers Pass, thence down the Teremakau, over Kawaka Saddle to follow the south bank of the Arahura River before reaching Hokitika. It was not an easy route, there being three lengths where grades of 1 in 12 had to be resorted to. These were intended to be worked on J.B. Fells centre rail traction system, Fell's initial line over the Mont Cenis Pass then being under construction. Costs were given by Edward Dobson as £6000 per mile.

In August 1867, following a reorganisation of the Provincial Council staff, O'Connor was appointed as an Assistant Engineer Lands and Works Department at Hokitika. Much of his time was to be spent on the original triangulation surveys between the Grey and Mikonui Rivers to the requirements of the District Surveyor.

A greater contrast of the countryside of Westland and that of Ireland would be hard to imagine. The forest cover was so tangled with vines and undergrowth that it was extremely difficult for a man to travel more than a few hundred yards in an hour equipped as he may have been with a machete to slash out his way. The riverbeds were the routes but the channels were often deep and dangerously quick to rise during rain. The sea beach piled as it was with driftwood and intersected by rivermouths and steep bluffs was the main north-south route.

Before the gold rush, a small number of Maoris, the Poutini Ngai Tahu, survivors of raids by Te Rauparaha, inhabited small sparse settlements at the river mouths. Early explorations had shown that the West Coast was a forbidding forest-covered mountainous country difficult if not dangerous to travel through Apart from the existence of some coal seams it seemed of little use for farming or any other economic activity.

By November 1867 there were almost 30,000 miners in this wilderness. Part was administered by Canterbury Province, while the land north of the Grey River was part of Nelson Province. The towns of Hokitika and Greymouth were shack and tent cities as were the mining settlements themselves.

The Provincial Government having concentrated on the construction of the overland road from Christchurch considered that it had spent enough. The formation of local horsetracks between the settlements was left to the local miners and storekeepers. The province gave the trackmakers the right to levy tolls and guaranteed protection from competition for a period. Along the busier routes, wooden railed horse tramways plied for passengers and freight. They were granted similar protection and also the right to levy tolls on those pedestrians, horses and stock using the tramway as a road. Hokitika harbour had a substantial breastwork wharf in Gibsons Quay but the ever shifting harbour entrances at both Greymouth and Hokitika were often traps for unwary and unfortunate sea captains. The larger Melbourne ships anchored in the roadstead off Hokitika, being tendered to and from shore by paddle tugs.

Initial mining methods were simple enough. The gold had been deposited by alluvial process, the metal itself generally lying below shingle above a pipeclay layer, the washdirt. Individual claims, usually 50 feet by 50 feet were hand excavated by sinking shafts to the washdirt. Gold was recovered by water separation methods, by washing the washdirt through a miners cradle or on a larger scale, through sluice boxes — in both cases the gold was saved by being caught in matting or cloth surfaces as the water sluiced the lighter material by.

To work the deeper fields the cooperation of all claimholders was necessary. Experienced Californian or Otago miners constructed water races not only to supply water to the sluice boxes but also to operate overshot water wheels to wind out excavated material and to dewater the mines by Californian pumps. Where a suitable drainage fall was available the overburden was sluiced away. A high level water race was brought onto the claim by tapping or damming a stream at an elevation above the claim. As the race was brought down to the claim, head was maintained and where necessary trestle flume viaducts some up to 100 feet high crossed the intervening gullies. At the claim, the flume terminated in a vertical iron pipe, the elevator, down which the water flowed to concentrate its force and velocity through a nozzle mounted on an adjustable swivel, the monitor. The monitor operator could direct this high pressure water jet at the excavation face, demolishing it spectacularly. The larger material was disposed of while the finer gold bearing material was turned to the sluice boxes, the gold being caught in the washcloths lining the lower end of the boxes. The water races were some miles in length and engineered to deliver a given quantity of water. More often than not the race was the property of a water company that sold the water to the individual claim holders.

The Province, which administered gold mining through its wardens and a system of mining rights and claims, collected a duty on all gold mined and encouraged gold mining. In July 1868 O'Connor, now on the District Engineer's staff was appointed Mining Engineer. While we have no schedule of his duties it is clear from his reports that he was to assist the warden and among other things to provide what amounted to an engineering consulting service to mining parties where it was deemed to be in the overall interest of the miners of the district.

Numbers of inadequate water races had been allowed to sprawl over the goldfields with little if any overall coordination. Most miners held a water right but few had a regular supply of water. Draining the water away too was a continuing problem such that much of the mining ground could not be adequately worked for lack of drainage. This chaotic situation could only be resolved by the Province taking a coordinating hand in planning races, storages, sludge, channels and drainage outfalls to adequately serve the field. Control and ownership of such works was initially intended to remain in private hands but the overall engineering proposals were to be completely prepared by the mining engineer. It speaks a great deal for O'Connor's powers of persuasion and competence in hydraulic work that the 5¼ mile 35 head Hohonu Water Race was constructed by a private company on this way particularly as existing water rights had to be extinguished by agreement before construction. He put together similar proposals for the Mikonui (18½ miles — 40 heads) and Kaniere (15 miles — 40 heads) water races and comprehensive water supply proposals for the Waimea and Maori Gully Fields.

These works were put in hand by the Westland County Council (later Westland Provincial Council) which in 1868 was separated from Canterbury following general dissatisfaction over the lack of roading and other public works.

In December 1869, James Rochfort, the County Engineer, resigned to become Provincial Surveyor of Hawkes Bay. O'Connor was appointed in his stead. He now had responsibility for all public works — not only roads and water races but also the harbours of Hokitika, Greymouth and Okarito and all public buildings. Following separation from Canterbury, a much more active programme of road construction and harbour improvements followed while in its facing up to coordination of miners interests on the goldfields, the council constructed and administered many of the major mining water races. As is the manner of mining, inevitably comes the long slow decline. While gold mining was to continue to be important for another 50 years or more, revenue was dropping.

From 1852, New Zealand had operated a federal system of government with each province being responsible for its own public works programme. The revenue necessary was collected from customs duty on goods imported. The system initially worked reasonably well giving a local control of works necessary to the then isolated settlements while the need for communications between them remained minimal. Progress, such as it was, related directly to prosperity of each of the nine individual provinces between which there was little cooperation. During the late sixties economic conditions declined for a number of reasons, among them the fall in gold revenues and unrest due to the Maori Wars. New Zealand lacked a reliable export base and had no adequate system of internal transport on which to build a united economy. It was plain to some politicians but by no means all that the General Government must plan and execute a properly coordinated plan of public works to such an end.

Julius Vogel, the Colonial Treasurer on 28 June 1870 put forward such a plan to the Government. It was an ambitious scheme to open up the country with extensive public works, particularly roads and railways all to be under the control of the General Government, rather than the Provinces and also to attract settlers by assisted immigration. It was to be financed by borrowing £10 million over a period of 10 years. The resulting Immigration and Public Works Act became law on 12 September 1870 and little time was lost in setting up the Public Works Department of New Zealand. An undersecretary, G.S. Cooper, was appointed and John Blackett, the very well regarded Provincial Engineer of Nelson was appointed acting Engineer-in-Chief pending the recruitment and arrival of an engineer experienced in railway building. This latter was to be John Carruthers, well experienced in railway construction in Canada, United States, Russia, Mauritius and Egypt as well as in irrigation works in India. He took up his duties in June 1871, Blackett continuing as Assistant Engineer-in-Chief.

Blackett had made a most extensive tour through both islands, both to get an appreciation of provincial works in hand and of the basic requirements to achieve Vogel's plan. He arranged for control of the works on a district basis and commenced appointing District Engineers each being responsible for works in his district technically to the Engineer-in-Chief and administratively to the Undersecretary. O'Connor, aged 28, was appointed as District Engineer, Westland on 15 July 1871 with headquarters at Hokitika. Much of the public works responsibilities of the provinces under the new Act became the responsibilities of the General Government but the scope was to be much wider.

The great Public Works era had commenced. Ten years after the passing of the Act, 1267 miles of railway were open for traffic; arterial roads connected all centres of any importance. Major harbour works were in progress while the basic system of lighthouses round the coasts was in place. Gold and wool were the main sources of export earnings so it is not surprising that gold mining water races were constructed in the Thames, West Coast and Otago goldfields.

The very speed and economy of construction required owed much to standard practices promulgated by means of a very complete series of standard drawings and technical memoranda which covered most situations. Just exactly how these came about is a story yet to be told but the combined experiences of Carruthers, Blackett and others of pioneer engineering towards eventual unified systems would surely guide thinking towards such a solution. No longer the highly individual one-off drawings for each creek to be crossed. True, some particular sites called for special designs as Mr Jones' paper to this conference points out.

Further, the designing and constructing experience had been recruited to this end. Engineering staff were not only engaged locally, particularly from the Provincial Councils, but also from overseas on the recommendations of well regarded English consulting engineers. This added up to a tremendous reservoir of experience. A high professional standard was expected from the outset.

The standard drawings covered a variety of fields, railway equipment from points and crossings, level crossing furniture, coal stages, water vats, windmill pumps, staff cottages and houses, engine sheds, goods sheds, station buildings from the smallest shelter shed and the class 5 station with its tiny one man office to the class 2 station for the larger provincial towns. Standard plans for bridges covered short stringer spans and culverts followed by a range of standard composite timber and wrought iron truss spans ranging from a 20 feet pony truss to the deep 140 feet spans used for the major deep flowing rivers in difficult foundation conditions. They were used singly or in multiple for both rail or road bridges, indeed many early bridges catered for both traffics. They continued to be built well into this century and some are still with us today.

O'Connor was to remain at Hokitika until December 1872 only. Canterbury Province while wanting all the benefits of the Vogel Scheme was reluctant to surrender any sovereignty. There were two schools of engineering thought. The province did have a number of works, notably the Lyttelton Harbour and the local broad gauge railway system, to which it could point with justifiable pride. They were well but expensively built works.

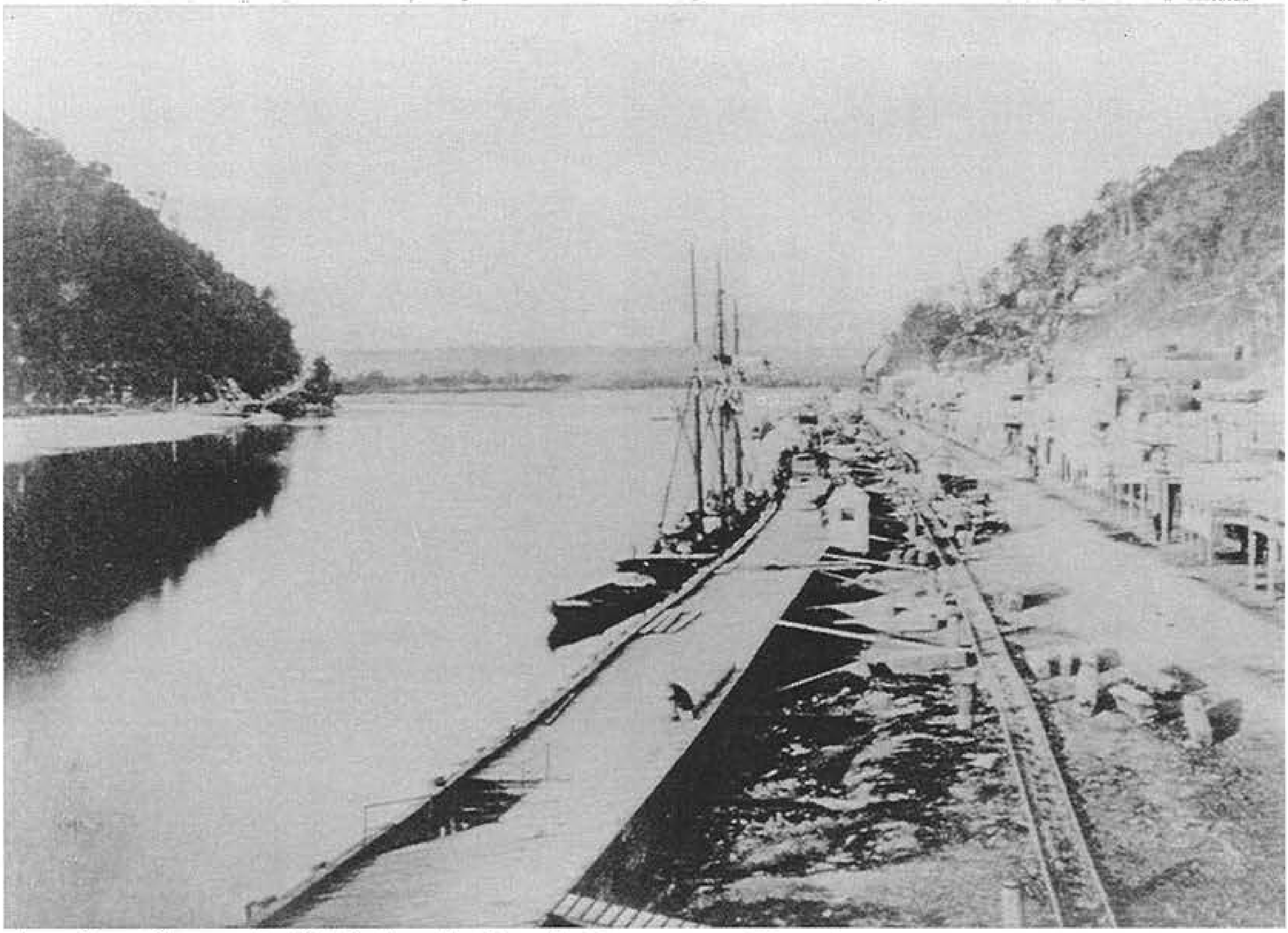
The Vogel proposals were of necessity economical in outlook. The railways were to be built to the narrow 3 feet 6 inches gauge. Initially light inexpensive construction was to be preferred, the object being to construct as many miles as finance allowed. Improvements could follow as the country served developed and traffic increased.

As often occurs in such circumstances some unhappy compromises followed. The broad gauge was allowed to extend even though branch lines feeding it were to be narrow gauge, Thornton, now Canterbury Provincial Engineer was to remain in control of some general government works and it would seem only conferred with the Government Engineer when he wished to do so. Two Government Engineers in succession found the situation intolerable; Bray and then Tancred, resigned in turn. O'Connor transferred to Christchurch to fill the gap.

Broad gauge railway extensions were in progress both north and south of Christchurch. The contractor for the mile long Rakaia River Bridge, White, appears to have made the most of the situation by playing off one engineer against another while he went his own sweet way and left out much of the bracing and used substandard timber. The bridge and the railway was opened in mid 1873 but had to be closed in late 1874 for rebuilding. Whether it settled the question of the Canterbury Railway gauge or not is open to doubt but the bridge reopened to the narrow gauge and the conversion of all the broad gauge to narrow followed rapidly.

O'Connor, having married in the meantime, returned to Westland as District Engineer in December 1874. F.H. Geisow had kept matters moving there in the meantime and the district was extended to include Westport and the Buller district. The General Government Programme of Public Works on the West Coast was now well underway.

The potential of the Grey and Buller coalfields had been early recognised. Railways from Greymouth to Brunnerton and Westport to Mount Rochfort along with coal wharves and staiths at both ports were in progress. The Greymouth Harbour had been studied by E.O. Moriarty, New South Wales Engineer-in-Chief for Harbours, who had been engaged to design the works. His proposal was to stabilise and deepen the main channel by a stone training wall projecting out into the ocean from the south bank. Major improvements were also proposed to the Buller River channels at Westport. The PWD was to construct



Mawhera Quay, Greymouth, 1875-6. Photo by Alexander Tait, courtesy of Canterbury Museum, Christchurch, N.Z. (ref. 16326)

these works. Improvements to Hokitika harbour too, while not part of the Government scheme was a consulting responsibility of O'Connor to the Westland County. Roads north to Reefton and south to Ross and beyond were put in hand while mining water races with their intake dams, tunnels and flumes continued to be a major PWD item. One of these the Nelson Creek water race, 18 miles long from the intake dam at Lake Hochstetter included some miles of tunnelling and 1½ miles of fluming including five flume trestle bridges each straddling the gullies they crossed by over 100 feet in height. The Waimea race a 16 mile, 40 cusec race served the country round Stafford while a later extension of 30 cusec capacity continued for a further 5 miles. It has been estimated that by 1885 that there were some 1200 miles of water races on the West Coast goldfields, though most of these were small privately owned races.

The original works programme was based on the forward thinking of the Provincial Councils as reviewed in the light of the usefulness to New Zealand as a whole. The District Engineer would arrange for detailed surveys, engineering drawings and estimates. Where major works were involved either Carruthers or Blackett would visit the site and discuss the project fully with the District Engineer before approving the plans. Once plans were approved (by the District Engineer on the water race and roading works) and provision had been made in the Parliamentary estimates it was up to the District Engineer to get the job done, usually by contract or a series of contracts. For the larger works there was a Resident Engineer in local charge who took his orders from and reported to the District Engineer who personally kept in touch with works on the sites. Where railways yet remained to be built, that meant much of one's life was spent on horseback, by coach or coastal steamer.

O'Connor's letter books for a period covering 1877-79 are now held in the National Archives, Christchurch. They give an excellent idea of how a PWD District Office worked then — in fact very little different from the workings and 'command and staff' principles that successfully guided the Department's staff until the rise of the specialist divisions from the nineteen sixties onwards.

O'Connor's salary at that time was £700 p.a. plus forage and travelling expenses of £100. (All engineers were expected to be competent horsemen.)

F.W. Martin, who was to succeed O'Connor as District Engineer, Hokitika and to continue his association with him in Western Australia, was O'Connor's deputy and chief assistant with particular responsibility for South Westland. Eugene Mainwaring with the rank of Resident Engineer (and a salary of £325 plus £75 forage allowance) was what we would call today the office engineer, keeping control of the expenditure, the draughting room, surveys and the general running of the office.

The Nelson Creek water race construction was under the control of Assistant Engineer H.A. Gordon (£275 + £75). Gordon

Headworks, Nelson Creek water race, Lake Hochstetter. *Photo by W.H. Perkins, courtesy of Canterbury Museum, Christchurch, N.Z. (ref. 2023)*

was later to become Inspecting Engineer of Mines, a post he fulfilled with distinction. John Gow, Inspector of Works, at 5 guineas a week plus 30 shillings, was in charge of the Waimea race construction. There were two engineering cadets at salaries of £120 while three overseers of works on the Christchurch Road, the Bowen to Okarito road and the Greymouth area had charge of those road construction works. The construction of Government buildings at Greymouth, Reefton, Kumara and Hokitika were under the control of two Inspectors of Works (Colonial Architects Branch).

The Greymouth harbour works and its associated Brunner Railway was the charge of Engineer R.J. Johnston. At this time the railway was largely complete and operating, Thos Ronayne, a locomotive engineer by profession and later to become a most able and notable General Manager of Railways being the local manager. The wharves, coal staithes and coal handling gear was practically complete while a start had been made with the river training works towards the mouth, the quarries being in the process of being opened up. The training walls and moles were based on the designs of Mr Moriarty in 1874 and considerably added to and amended by Carruthers and O'Connor. The railway, being on the south bank of the Grey River, with the Brunner coal mine being on the north bank, was approached by a suspension bridge over which horses were to haul the railway coal hoppers. During erection in 1876 this 300 feet suspension bridge collapsed before the cables had been grouted and the whole lot tumbled into the gorge. The cause was faulty cast iron anchors which broke under load — one of the very few construction accidents of the public works era.

At Westport was Resident Engineer Arthur Dobson (later Sir Arthur) (£500 + £100), G.C. Hill, Assistant Engineer (£250 + £75) while A.R.W. Fulton (£150 + £50) later to be Engineer and Traffic Manager of the Wellington and Manawatu Railway Co was engineering cadet. The wharves, coal staithes and the railway to Waimangaroa were practically complete — T.A. Peterkin, another locomotive man being Railway Manager. Coal traffic was light, the Wellington mine being the only one operating. The Westport Coal Coy's Denniston incline to the high level mines on the Mount Rochfort coal plateau was not built until 1878-79 after which the Westport area became New Zealand's major source of coal for many decades thereafter.

The telegraph was used as we used the telephone in our day. All outward telegrams were copied into the letter book. Questions and answers would exchange between District Office, Head Office or the outlying engineers and inspectors and before the end of the day the final decision would be telegraphed.

Brunnerton Bridge, circa 1886. *Photo by James Ring, courtesy of Canterbury Museum, Christchurch, N.Z. (ref. 2179)*

O'Connor would by the same means keep in close touch with Hokitika as he travelled to Greymouth or Westport. One soon realised why there was a messenger on the payroll!

Several items from the letter book are worth mentioning. There is a glorious two page 'rocket' in O'Connor's own handwriting to the overseer Christchurch road. The coach from Christchurch got trapped between slips about the Arthurs Pass Zig Zag in a heavy downpour one afternoon. The driver and passengers trudged on to Otira, got no sense out of the road gang, went back with shovels and gear and finally got the coach and four into the Otira Hotel at 2.00 am, the road gang meanwhile sleeping on! O'Connor left them in no doubt as to their responsibilities.

A real curiosity is a very full 'Report on Roads for the Imperial Government'. Every road and horse track on the West Coast is fully described, its width, how many soldiers could march abreast, fords, bridges (very few), wire foot bridges are all described as are suitable camp sites, natural strong points and how these could be defended. Were all District Engineers throughout the empire reporting thus to Her Majesty's Government in Whitehall? Was some harrumphing colonel in the War Office collating all this?

Sir John Coode visited Westland in April 1878. Coode was the most notable British harbour engineer of his day, having first gained prominence in the construction of Portland Harbour. He was consulted worldwide on harbour works and in 1877 he was invited to New Zealand to advise on a number of our harbours where developmental problems were apparent. Coode accompanied by Carruthers and Blackett met O'Connor and his staff at Hokitika, Greymouth and Westport. For some days current proposals, sea, tidal and riverine characteristics were discussed and observed, Coode leaving detailed instructions with O'Connor as to the surveys and detailed information he would require before reporting fully. At this stage wharves had been in use for some years but the real questions over effective channel improvement works to enable larger ships to enter in safety had still to be solved. The works to his instructions subsequently carried out at Westport and Greymouth served the coal mining industry well right through the days of King Coal. Hokitika, by then declining as a port, could afford to put only part of the works in hand thereby ensuring their eventual failure as such.

Up to 1877-78 there had been little political interference with the workings of the Public Works Department. The energy and speed with which works were commissioned alarmed an Opposition concerned that loan repayments might be unaffordable. That South Island agriculture and commerce had greatly expanded and prospered with the construction of the railways, made little difference to its concerns. Gold field returns were diminishing while country districts were still the domain of large sheep stations, runholders being well represented in the General Assembly. In their opinion too much was being spent on public works. Some of the railways were not paying as well as was expected though, indeed, some that the department had not recommended on economical grounds had been added to the programme by political pressure. Certainly much of the proposed infrastructure was by then by this time in place or

C.Y. O'Connor

C.Y. O'Connor

arranged for. A slow down was inevitable. A new Government took office in October 1877.

James Macandrew, the new Minister of Works, became responsible for a number of reforms; one desirable one being to pass the operation of completed railways from the Public Works Department to a newly formed Railways Department. What in retrospect was undesirable was the decision to decentralise the Public Works Administration by dispensing with most of the head office staff and creating separate organisations for the North and South Islands.

W.N. Blair, District Engineer, Dunedin was to take charge of the South Island, while Blackett was to occupy the North Island position. The post of Engineer-in-Chief was to be abolished, Carruthers being offered a post at a reduced salary. He resigned and returned to England in 1879 to commence practice as a Consulting Engineer while Blair took up his duties as Engineer in Charge, Middle Island (as the South Island was known) from about June 1878. Carruthers had been unceremoniously pushed aside!

While Blair was a most able and energetic engineer, one cannot help thinking that his appointment may have owed something to the fact that both he and Macandrew were from Dunedin and well known to each other. His headquarters remained in Dunedin. The Undersecretaryship was still situated in Wellington. John Knowles, who had occupied the position from April 1871 remained in place in what was now the key position. With the engineering staff thus divided, he was the only person in the department concerned with all its activities and being based in Wellington he had easiest access to the Minister.

O'Connor continued as District Engineer at Hokitika but almost immediately the confident professional inter-relationship previously experienced with Carruthers and Blackett changed with Blair's appointment. Blair, while a well regarded Engineer in the Otago District, seemed to have little confidence in the competence of O'Connor. Whether this also applied to Blair's other District Engineers I do not know.

All plans and proposals now had to be submitted to Dunedin for approval. Often alterations were made and it would seem not always for the better. Decisions that both Blair and O'Connor had discussed and concluded during O'Connor's visits to Dunedin were sometimes countermanded by Blair sometime after, possibly for political reasons.

A diversion of the Buller River above Westport had been discussed and agreed during Carruther's and Coode's visit. The intention was to promote a larger tidal flush and hence greater depths through the harbour area. O'Connor's scheme involved the excavation of a pilot cut which the frequent river floods would develop to the full depth and width required. Thus the grade of the bottom of the cut was a series of steps intended to create turbulence such that the fine material would be scoured away. Some £20,000 worth of excavation would be induced naturally for an outlay of £5,000. The method had been used successfully on the Waimakariri River in Canterbury.

The plans came back from Dunedin, with the pilot cut realigned and the steps omitted, a straight (and flatter) grade being substituted. Excavation costs would now be only £3,500. O'Connor's opinion was that the chances of the channel developing successfully were severely prejudiced by the amendments; in fact, if the subsequent floods turned out to be minor freshers only, the probability was that the pilot channel would silt up. His letter of 9 December 1878 to 'My dear Blair' and marked 'private' pointed this out and concluded 'I hope you will see your way clear to approving the old line'.

O'Connor had little sympathy for political posturing. Doubtless this brought about his political downfall both in New Zealand and Western Australia.

Richard John Seddon, storekeeper and miners advocate, was Mayor of the gold rush town of Kumara. He clashed with O'Connor several times over such matters as the siting of the Dilmanstown Bridge over the Teremakau River. The shorter site at Dilmanstown had been preferred by the PWD to the much longer site at Kumara. Another bone of contention was the proposed route of the Greymouth-Hokitika Railway. It followed the direct water level route along the sea coast in preference to a much longer route via Kumara.

The mining water race through Kumara was an open channel and Seddon raised the matter with the Colonial Government in Wellington demanding that it be covered.

On 13 December 1878, O'Connor wrote to Blair on the subject. 'I consider the allegations of the Town Clerk and Mr

Seddon to be overstrained and scarcely borne out by the facts of the case. I do not, therefore, see any reason to alter my previous recommendation on this subject and think that it is very probable that the Government will not hear much more about the covering in question, Mr Seddon's term of office having expired and a new Mayor, who is a common sense sort of a man, has been elected in his stead.

Had Mr Seddon continued in office however, it would probably have been as well to give in at once however ridiculous it might be to do so, as he is proverbially one of those men who would stick to their point even if it is for years until they wear the other side into compliance'.

The Government was to hear a great deal more of this and many other matters from

Mr Seddon for he was elected to Parliament as member for Hokitika on 5 September 1879 and very quickly became a most influential member whether in Government or in Opposition. He had an elephantine memory and never forgave an enemy. He became Minister of Public Works in the Ballance Ministry on 24 January 1891 and Premier in 1893, reigning as the pragmatic and flamboyant 'King Dick' until his death in June 1906.

In the series of letters, O'Connor comes through as a very strong-minded and forthright character, not given to suffering fools gladly. He expected a very high standard of committal from his staff but was generous in his attempts to better the position of those who met his exacting standards. He was ruthless in the correction of those who did not.

In 1880, O'Connor was appointed Inspecting Engineer, Middle Island, that is Blair's roving assistant with headquarters in Dunedin. The times were not exciting for engineers. Few new works were started and many of the PWD staff were dispensed with. New Zealand was in the grip of a depression.

Undersecretary, Knowles, retired in March 1883 and was not replaced immediately. Benzoni, Knowles' Assistant, was appointed as Acting Undersecretary only, with no-one in real charge of the department. This was a most uneasy interregnum until in November, Blair's Assistant, O'Connor was appointed, the first time an Engineer had been considered for this up to now entirely administrative position. The new Undersecretary fully understood the power of the position. What Blair thought of this is not hard to imagine. A power struggle developed between the two. To make things worse, it was a time of Government instability, there being four successive Minister of Works appointments over the next twelve months. Then in 1884, the Atkinson Government reconstituted a single central Public Works Department with the appointment of Blackett as Engineer-in-Chief with Blair as his deputy.

At this stage the two men were confronted with O'Connor, both administratively and technically competent and yet professionally their junior. There is no evidence that Blackett found this difficult. Cordial relations between Blackett and O'Connor dated back to their respective neighbouring Provincial Engineer days. Blair was a different matter.

In March 1889 Blackett resigned from the position to become Consulting Engineer to the New Zealand Government in London. For a time no-one was appointed to the position partly because the department was about to be abolished and partly because of the apparent struggle between Blair and O'Connor. Which of the two was to be preferred was finally resolved by Thomas Fergus, Minister of Works on 10 March 1890. It had been decided that Blair should take up the joint position of Engineer-in-Chief and Undersecretary. O'Connor was to be released from his duty as Undersecretary and, if he wished, could take up an offer to be Marine Engineer to the colony. Up to then (and since) this latter position was regarded as a part-time responsibility of the Assistant Engineer-in-Chief. O'Connor had no alternative but to take it or look elsewhere.

Blair was to live only a short time. It has been suggested that his death in May 1891 was hastened by the struggle. Because he had been ailing some months, W.H. Hales, District Engineer, Wellington had been appointed in January to be Acting Engineer-in-Chief and Acting Undersecretary. Seddon, no friend of O'Connor, had in the meantime become Minister of Works. Under his stewardship was clear that Hales would succeed Blair as Engineer-in-Chief and Undersecretary.

O'Connor, his ambitions thwarted, resigned his position in April 1891 to leave New Zealand for Western Australia. A great deal of ill feeling between officers of the department had been created by the struggle. It was to linger for many years thereafter.

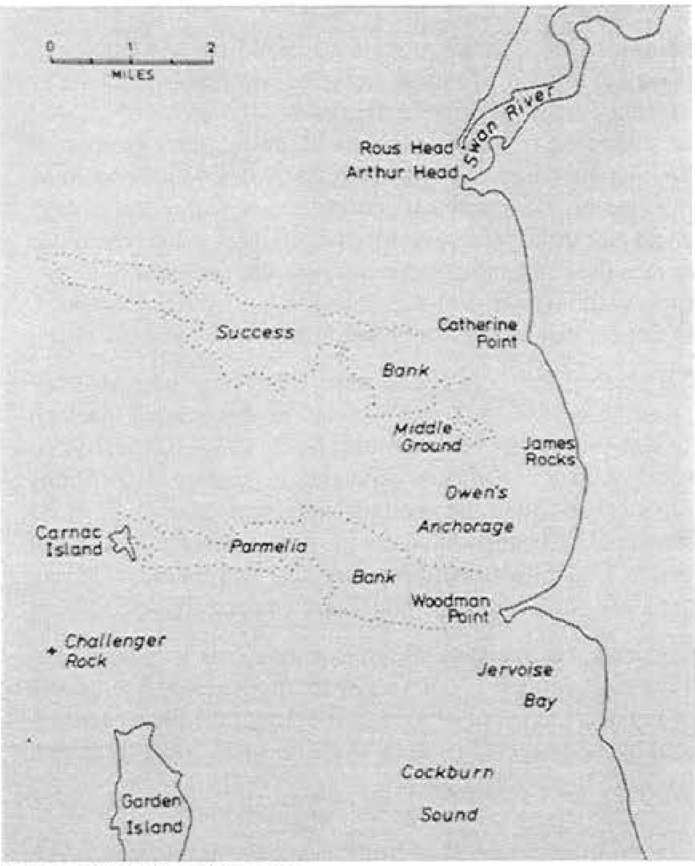
When O'Connor arrived in Western Australia in June 1891 to take up his post as Engineer in Chief he was immediately faced with Premier John Forrest's programme for development, a programme full of public works, including the pressing problem of providing a port for the Capital, Perth.

This was not his only problem, for he found there was only a tiny Works Department with virtually no professional staff and, omitted in the previous correspondence from John Forrest. While he was in New Zealand he had been given an additional responsibility — management of the Government Railways. There were also acute shortages of skilled labour and funds for public works.

A PORT FOR THE CAPITAL

The problem of an all weather port was a vexing one. From the very first days of the Colony shipping had suffered the strong onshore winds and winter gales which sweep in from the Indian Ocean and batter the exposed western coastline. However, the mouth of the River Swan leading up to Perth was blocked to all but the shallowest draught of boats by a solid outcrop of limestone known as the rock bar. Thus in the early years of the Colony ocean jetties were constructed adjacent to the mouth of the river to provide berthing facilities for shipping. The jetties provided little protection from the weather, the boats alongside frequently suffering damage. As a result most ships anchored offshore, and the cargo handling was carried out by lighters, with ensuing delays and high cost.

Fremantle gained an unenviable reputation in maritime circles and many ships including the mail steamers avoided calling there, preferring the protected King George Sound at Albany as the port of call, much to the resentment and inconvenience of the residents of the Capital some 250 miles to the north.



Fremantle Outer Harbour

The Colony engaged the world renowned consulting marine engineer, Sir John Coode to solve the problem. Coode made two reports, the first in 1877, based on data sent to him from Western Australia (which was subsequently found to be misleading) and the second ten years later, after visiting the Colony to inspect the site himself.

In preparing his 1877 report Coode was given to understand that there was evidence of significant sand travel. These were the days before the introduction of the suction sand dredger, and the risk of incurring large recurring expenditure for dredging was to be avoided. His proposals therefore allowed for the unimpeded movement of sand along the foreshore and were similar to those he submitted at that time for Timaru in New Zealand, where the shingle travel was the largest he had met with up to that date.

Coode proposed two alternative schemes, both calling for construction of open timber viaducts out to sea and terminating in solid breakwaters. However it was beyond the capacity of the Colony to finance either scheme and the proposals were shelved.

At the request of the Colonial government Coode visited Western Australia for five weeks during the winter of 1885. His subsequent report, received in 1887 was, in part, based on the results of borings he had requested be taken in the submarine Success and Parmelia Banks. From these logs, showing the banks consisted totally of marine sands, Coode concluded they were fed by the southerly movement of sand along the coast.

Coode's report discounted the viability of works in Cockburn Sound, echoing the vested interests in Perth and Fremantle which feared that the Sound was too far south for the harbour, and also because of the alleged sand travel. An inner harbour in the river with an outer harbour formed by solid works connected with the shore was also deemed undesirable partly on account of the sand travel and also because of river sediment silting up the inner harbour. For Coode there remained only one alternative, and he confirmed his earlier design concept of an outer harbour of solid concrete breakwaters connected to the shore by an open viaduct. He estimated however that in order to construct such a harbour to accommodate the mail steamers in all weather conditions would require expenditure of almost one million pounds in total. This was enough to shelve the scheme again.

Despite this setback, the newly elected Premier Forrest was still most anxious to establish a port close to the Capital which would attract the mail steamers of the P & O and Orient Lines, and to this end he now believed that this might best be achieved at Owen's Anchorage, south of Fremantle.

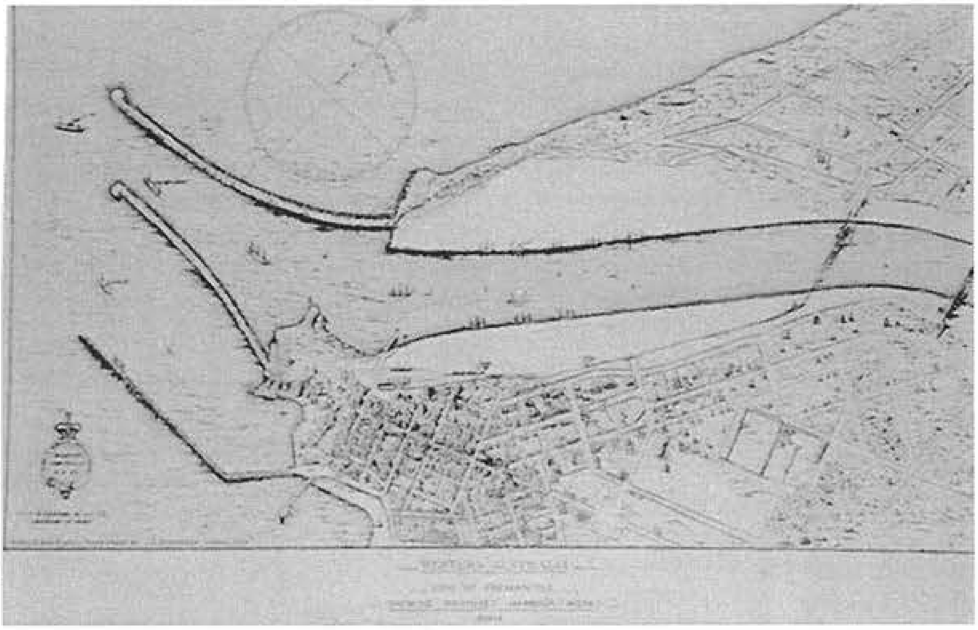
Before O'Connor arrived, Forrest had asked Coode to look at the practibility and cost of opening and maintaining a passage through Success Bank and into Owen's Anchorage with the objective of berthing the mail steamers there. Coode responded in August 1891 with estimates of cost for dredging a channel through Success Bank and a suggested channel through Parmelia Bank also, as a precaution to give a more sheltered approach to the anchorage during northerly gales. He estimated the cost of dredging the channels at £214,500 plus a further £77,000 for dredging plant. Dredging the channels would take up to five years.

On his arrival O'Connor was instructed to prepare a draft plan and estimates for the Premier of what would be needed to connect the Owen's Anchorage berthing facilities to Fremantle. Forrest set a cap on the expenditure at £150,000 — 'all that the Colony could afford'.

While doing this O'Connor began studying the earlier proposals for development of Fremantle Harbour, in particular he carefully studied Coode's proposals, and the pre-occupation with the problem of sand travel. O'Connor was familiar with Coode's work and had met the marine engineer in 1878 when Coode had visited the harbour works at Hokitika, Greymouth and Westport. He now made his own inquiries and gradually came to the conclusion that there was little real evidence of significant sand travel and that the fears of Coode and others about sand travel were misfounded.

O'Connor's estimates showed up what meagre facilities an outlay of £150,000 would provide at Owen's Anchorage, which included the need for three miles of railway to connect with the Fremantle rail terminus. He concluded that to ensure a first class harbour at Owen's Anchorage a sum of £400,000 to £500,000 would be needed.

Meanwhile he was increasingly forming the opinion that an inner harbour had great advantages and could be developed in the river mouth. Forrest was not convinced, but O'Connor was undeterred. He continued with his proposals and in December 1891 presented a report to the Minister for Public Works, Harry Venn, recommending strongly for a harbour at the mouth of the Swan River. He advised that he was convinced there was a negligible problem with sand travel and dismissed the possibility of a newly dredged harbour in the river mouth silting up.



Fremantle Harbour. Pictorial view of proposed works, June 1894.

O'Connor's estimate of cost for the full scheme was £800,000. A first stage to meet the foreseen requirements for several years could be carried out for £560,000 and the full scheme was capable of further development in the future.

The proposed works included construction of breakwaters up to 3000 feet long at the river outlet, blasting out the shallow rock bar at the river mouth, dredging an outer channel and inner harbour to a depth of 30 feet with a turning basin capable of taking the largest mail steamers in use, and the provision of extensive timber wharves on the north and south sides. The first stage would take five years to complete, the full scheme would require a further three.

Minister for Works Venn was quick to realise the implications, and upon receipt of O'Connor's estimates for Forrest's outer harbour scheme at Owen's Anchorage he told Forrest that for such a sum, '. . . an almost perfect landlocked harbour could be made at the mouth and in the river itself for all vessels drawing certainly not less than 30 feet'. Clearly, O'Connor had already convinced his political boss that he could successfully achieve what other engineers had considered a risky plan.

For the breakwaters, O'Connor's experience in New Zealand and his own assessment of local shore conditions convinced him that random tipped stone, the 'pierres perdue' method, would provide adequate strength. This choice had the advantages of economy and flexibility to accommodate design changes, and it utilised the adjacent resources of limestone.

Forrest was impatient, and concerned at what he saw as a difference of opinion between Coode and O'Connor on the inner harbour, and particularly on the vexed question of sand travel. He went to Parliament in December 1891 with his outer harbour scheme but the motion was defeated. A Parliamentary Select Committee was set up in January 1892 to examine once again the question of harbour works at Fremantle.

The Select Committee was composed entirely of laymen and was generally antagonistic to the new Engineer in Chief. However O'Connor had faced this type of situation before and fielded the committee's questions with skill, confidence and patience, despite concerted attacks on his professional competence. In the event, the Committee came down firmly in favour of the inner harbour scheme, and the scheme was endorsed by Parliament in March 1892. Construction on the North Mole commenced officially with stone tipping starting on 16 November 1892.

For O'Connor it was a triumph. In view of the multiplicity of alternative plans in evidence when he arrived in the Colony barely eighteen months previously, the extent of opposition to the 'newcomer's' scheme and the shortage of funding, the works were commenced in an impressively short time.

Construction of the scheme was to take eight years, as O'Connor had predicted. By mid 1894 the North Mole provided sufficient protection to permit the South Mole and dredging to start. The South Mole was completed to the planned length by August 1897. On 4 May 1897 the first coastal steamer arrived and finally in August 1900, the RMS *Ormuz* entered the new harbour.

O'Connor's evaluation of the sand travel was shown to be completely vindicated. No substantial problems resulted nor did siltation require any dredging over the years. Financially the harbour has paid its way from the beginning.

GROWTH OF THE DEPARTMENT

O'Connor found on his arrival that the colony effectively had no public works department, there was no professional staff of surveyors and engineers, no support staff, no system of recruitment and training — it had no public works tradition.

Professional men would have to be recruited from outside the Colony.

In order to act quickly he sought out engineers whose quality and expertise he knew. James Thompson, an engineering graduate of Dublin with experience in Britain and Victoria came to join O'Connor. By 1893 three experienced engineers from New Zealand, where employment conditions had continued to deteriorate, had also joined him: Francis W Martin, with a full range of experience of harbours and railways on the west coast and who had taken over from O'Connor as District Engineer at Hokitika; William W Dartnall, versed in railway construction; and Arthur W Dillon Bell, with wide experience in both Britain and New Zealand. Between them they formed a small staff, closely knit by mutual trust and loyalty. 'Between us,' said Thompson, 'we had to do everything.'

In 1891 the Works staff numbered 9 and the Railways, 33. By 1896 the public works policy of the Forrest government was in full swing and the number of staff in the Works Department alone had grown to over 400; by the end of 1897 it had peaked at almost 900.

The volume of work was increasing rapidly with about £650,000 expended from loan in 1895/96, the greatest proportion of which went to railways and harbour works, and £639,000 expended from consolidated revenue, principally on public buildings, water conservation works in the goldfields areas and the railways. The total expenditure for 1895/96 was up 70% on that of the previous year. Expenditure in the following year was up 76% more.

Fremantle Harbour was part finished with some wharves in use, and design work had commenced on the Coolgardie Water Scheme. The Eastern Railway reached Coolgardie in March 1896 and was immediately continued on to Kalgoorlie; the railway from Fremantle to Perth and Midland was under duplication.

At O'Connor's request the Government decided to split the works organisation into two departments, 'Public Works' and 'Working Railways and Tramways'. The engineering department was organised into separate branches, partly to relieve the pressure on the Engineer in Chief. On 1 July 1896 the branches and their heads were as shown below:

(Under Secretary for Public Works)	M.E. Jull
ENGINEERING DIVISION	
• Engineer in Chief	C.Y. O'Connor
• Engineer in Charge of Roads and Bridges, Harbours and Rivers, Sewerage and Water Supply for Towns	T.C. Hodgson
• Architectural Division, Assistant Engineer in Chief	G.T. Poole
• Engineer in Charge of Railway Construction	J. Thompson
• Engineer in Charge, Goldfields Water Supply	M. Hector
• Engineer in Charge, Fremantle Harbour Works	J.A. McDonald
• Inspector of Surveys, Engineering Surveys Branch	J. Muir
• Stores Accountant, Stores Manager's Branch	J.H. Rogers
• Consulting Engineer, London	J. Carruthers

O'Connor and his staff were responsible for many innovations in those early years and are credited with establishing practices and traditions which survived in the Western Australian Public Works Department for over ninety years until the department's demise in 1985.

A system of training engineers by admitting suitable candidates as cadets was introduced into the department about 1894 and was formalised by regulations signed by O'Connor as Engineer in Chief in January 1897. A cadetship was of four years duration, three and a half of which were spent in the field on surveys and works under the engineers of the Department.

Registering of plans of 1891 origin, along with the daily plan output of the drawing office, commenced with plan PWD WA 1100 on 22 June 1891. Maurice Morley, in a meticulous essay on the origin of the PWD Plan Journal, considered that responsibility for the introduction of the journal probably rested with George Temple Poole, O'Connor's predecessor, who may have seen the need for an orderly plan system with the impending arrival of the new Engineer in Chief.

Following O'Connor's arrival, a new format for contract drawings for construction of government railways was introduced and continued in the same style until the PWD Railway Construction Branch was disbanded in 1930. This set the pattern for all subsequent Public Works drawings.

Imperial sized lithographed prints were bound into books. The title of the particular contract plus identification as the Book of Drawings, a contents list of drawing number, title and sheet number of the prints in the book and the PWD WA Plan Number for the contract drawings, were printed on the face of the front cover.

The PWD plan number allotted to the contract drawings was generally used for the component plans for that railway — the locality plan, plan and section, cross sections of the formation, block plans of stations, etc. Each classification was given a Drawing Number consecutively from No. 1 and, for multiple sheet content for a particular classification, Sheet Numbers were also allocated sequentially within relevant Drawing Numbers.

Standard Drawings were introduced at this time also. For railways these included cutting and embankment profiles, permanent way rails and fastenings, points and crossings, level crossings, fencing, structures, buildings, etc. When bound into the books of drawings they retained their original PWD plan number and, as before, were given Drawing numbers and, where applicable, Sheet numbers.

The contract drawing book of plan and section was sometimes amended for design change during construction or to accommodate topographical or site peculiarity. After completion of the project, the cover of one set of Book of Drawings was endorsed 'AS CONSTRUCTED'.

RAILWAYS

O'Connor took up the appointment as acting General Manager Railways on his arrival in 1891. His own Works Department was responsible for the construction of new lines and upgrade of existing lines, while a separate Railways Department was responsible for maintenance of the operating lines. As General Manager he was responsible for the overall management of the government railways, duties which he carried out until the reorganisation of the Works Department in 1896 and the formation of a separate railways construction branch.

O'Connor brought with him from New Zealand ample experience of building railways for a small population in widely scattered settlements in wild country, as well as decided views on railway policy suitable for a developing colony. He insisted that public works had to be economically justifiable, with returns which would cover not only their construction, operating and maintenance costs, but the interest incurred on the capital loans and sinking fund as well. Public works must be able to pay their way.

By 1891 the government railway system had not developed far and principally connected the main agricultural centres of the inland Avon valley, including Beverley, to Perth and Fremantle. A privately built line, opened two years previously, ran from Beverley some 250 miles south to Albany. Another privately built line to connect Perth with Geraldton, a coastal town and port some 265 miles to the north, was just starting up and was to take a number of years to complete.

The government lines, all narrow gauge, had been built on a shoestring, with consequent low design standards; maintenance costs were high and destined to increase. Of particular concern were the steep grades and tight curves on the Eastern Line, between Midland and Mount Helena, on the Darling Scarp, which with underpowered locomotives and poorly built rolling stock were a recipe for continuing trouble; incidents and derailings were frequent.

Shortly after his arrival O'Connor inspected the existing lines and assessed the working of these lines and the inadequate provision for maintenance and repairs, and finally examined the railway accounts. O'Connor made it clear in his subsequent report that to provide better service with greater safety and economy, three major changes were urgently necessary. In order to carry traffic with safety and efficiency the poorly surveyed Eastern Line, the key line in the colony, should be rerouted and upgraded with heavier duty rails. The government railways should have better designed locomotives and rolling stock suited to Western Australian conditions, and finally; the existing locomotive and repair shops in Fremantle should be upgraded and eventually replaced by new workshops on a more suitable site.

O'Connor set John Muir, newly arrived from Victoria, the task of finding a more suitable route for the railway up the Darling Scarp, a granitic escarpment up to 900 feet high in places, lying to the east of Perth. Muir was an experienced railway engineer and licensed surveyor with a fine eye for grade and contour. He finally investigated three routes in detail, recommending a deviation through the valley cut by Deep and Mahogany Creeks. The Mahogany Creek deviation included Western Australia's first and only railway tunnel, 16.5 chains long, with some significant cuttings, embankments and trestle bridgeworks.

Despite O'Connor submitting the proposal early in 1892 it was almost another year before Parliament sanctioned the funding for the deviation and for relaying the Eastern Railway with heavier rails. The rail relaying was accomplished by late 1893 and heavier locomotives were purchased, but the deviation and tunnelling contract ran into trouble and was not completed until 1896.

Muir was subsequently to complete a number of significant surveys for O'Connor, including work on the Goldfields pipeline route, and in 1908 as Inspector of Surveys was to head the team which would survey the Western Australian section of the transcontinental railway.

The first railway workshops had been built near Fremantle at the time of the Eastern Railway in 1881, some years before the decision to develop a harbour in the river mouth. O'Connor realised in 1891 that before very long the Fremantle workshops would get in the way of the new harbour work and proposed to build new workshops on a much larger site elsewhere. This proposal was resisted strongly by the residents and traders of Fremantle because the workshops employed a considerable number of tradesmen who lived in the Fremantle area.

Despite this the Government acquired land for new workshops further up the line at Midland Junction and appointed Allison D. Smith, Locomotive Superintendent of the Victorian Railways to review O'Connor's proposal. Smith had recently supervised construction of locomotive workshops in Victoria and had long experience of railways in New Zealand and Victoria. He quickly came to the conclusion that the Midland Junction site was well suited to construction of the new workshops.

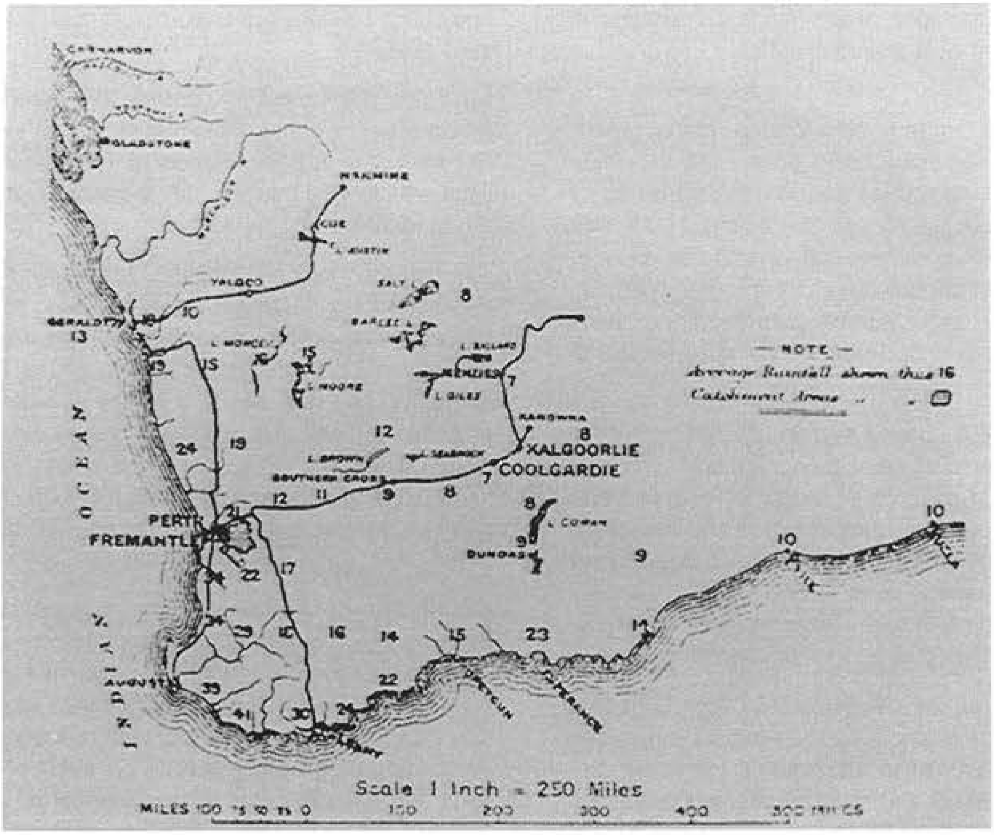
However, Parliament was undecided and in 1893 a Commission was appointed to examine the question. The Commission called many witnesses including O'Connor, J.A. Wright (the previous General Manager of Railways), C.T. Mason, F.W. Martin and others, but returned a split decision. The matter of the new workshops was to drag on until 1905.

O'Connor was so deeply involved with the major projects of his public works activities that he found it necessary to resign from the position of acting General Manager Railways in mid 1895; but his resignation was not accepted until January 1897.

O'Connor took the opportunity to study developments in the design of railway workshops while in England in 1897. He sought the advice of J.A. Aspinall who was then Chief Engineer of the Lancashire and Yorkshire Railways. Aspinall produced a design for the workshops in Midland Junction and his plan was submitted to the Working Railways, but no action resulted.

A new Chief Mechanical Engineer, T.F. Rotherham then prepared another plan for the workshops, the seventh received by the Government. A Select Committee was appointed in 1901 but it was January 1905 before the transfer of operations to the new Midland Workshops was completed, fourteen years after O'Connor's first recommendation.

Another pressing problem to be tackled was the extension of the Eastern Railway inland to Southern Cross and the Yilgarn Goldfields. The decision as to which of the three competing towns in the Avon Valley should be the starting point for the further extension eastwards was a politically loaded question. There was the need also to secure permanent supplies of water



Average rainfall and catchment areas, 1908

for the railway as it progressed into increasingly more arid country.

O'Connor initiated the first systematic examination of the surrounding country for permanent water when the survey of the route of the Yilgarn line was undertaken in 1892. However the problems of providing sufficient water to keep the railway operating and to avert the recurrent menace of water famine to the people on the eastern goldfields would be solved only when O'Connor's plan to provide a permanent supply of fresh water was finally implemented some eleven years later.

Construction of the eastward extension from Northam started in 1892. Under intense demand for access to the goldfields, the line was taken over for traffic in July 1894, although the works were not entirely completed. By the time the line was completed to Southern Cross a decision had been made to extend the line to Coolgardie, 115 miles further east, which was reached twenty months later in March, 1896. The terminus did not remain long at Coolgardie and was already being extended the extra 24 miles to Kalgoorlie and points beyond to serve the eastern goldfields. However, it was to be another 16 years before a start would be made under the authority of the new Commonwealth Government on extending the railway further east as part of the transcontinental railway.

O'Connor's tenure as General Manager coincided with a period of tremendous growth in railway traffic and, with growth rates at times in excess of 25% a year, the following decade saw the construction of something like 1000 miles of railways.

GOLDFIELDS WATER SUPPLY

The discovery of gold in the 1880s and 1890s was a turning point in the affairs of Western Australia, bringing people, development and jobs.

By 1890 gold was being mined in small but rich quantities in the Kimberley, Pilbara, Murchison, Ashburton and Yilgarn districts. Expectations were raised much higher by the discovery of a bonanza at Bayley's find at Coolgardie in 1892. Hopeful prospectors ranged far and wide from Coolgardie and in the following year the Kalgoorlie 'field' was found.

Men flocked to the eastern goldfields. Spurred on by the glint of gold and almost regardless of hardship the prospectors went deep into waterless country, with every additional man further taxing the meagre water supplies that came to hand.

By January 1893 Minewarden Finnerty, reporting on the new find at Coolgardie and the ensuing rush stated, 'Much difficulty was experienced by those persons in obtaining a sufficiency of water even for drinking and for washing none was obtainable . . . The price of water at Coolgardie, where in a short time about 700 men had collected, averaged one shilling a gallon.'

However the wells, soaks, rock catchments and carted water could only supply a small population in such an area of low and uncertain rainfall.

By mid 1895 the idea of a pumping scheme from a higher rainfall area near the coast was becoming widely accepted. By

Coolgardie Water Supply: Pipe caulking machine specially invented for the scheme.

that October O'Connor's staff were well advanced in preparing estimates for such schemes. In all 31 alternative schemes were examined and three were short-listed for placing before the Government. All three schemes involved pumping from a reservoir in the Darling Ranges just to the east of Perth with water pumped in successive lifts to Mount Burges, north of Coolgardie. Two Victorian Engineers, T.C. Hodgson and W.C. Reynoldson joined the Department. Reynoldson worked with Muir in examining the potential reservoir sites.

The dry winter of 1895 caused a water crisis in Perth and an even more desperate situation inland. Premier Forrest visited the goldfields in November and December 1895 to see conditions first hand. By this time the alluvial gold was waning and milling at the mines had stopped for want of water. There were desperate pleas for government assistance with water supplies.

Fortuitously, Forrest had a plan prepared by his Engineer in Chief. This scheme proposed the construction of a large dam on the Helena River and a succession of nine (later reduced to eight) steam-powered pumping stations with water delivered to the goldfields 320 miles inland through a steel pipe of 30 inches diameter. The work was estimated to cost £2,500,000 and, if used to its capacity, water would cost five shillings per 1000 gallons.

In the circumstances of the colony — its paucity of development, small population and mounting public debt, and given the ephemeral nature of mines — O'Connor and his advisers were fully aware of the boldness of the engineering solution they offered.

O'Connor realised also the political value to be had from an independent assessment of the proposals. In March 1896 he wrote to his friend from New Zealand days John Carruthers, by then the consulting engineer used by the Agent General's Office in London, for his opinion of the scheme. At O'Connor's suggestion, Carruthers set up a committee of eminent engineers in London to advise on the practicability of design aspects of the scheme.

After a protracted and sometimes stormy passage Forrest's Loan Bill to raise £2,500,000 for a Goldfields water supply scheme was passed in that same year.

O'Connor left for England in January 1897, primarily to meet the committee of engineers in London. He returned in September, bringing with him an interim report of the committee which supported the scheme proposals as being entirely feasible.

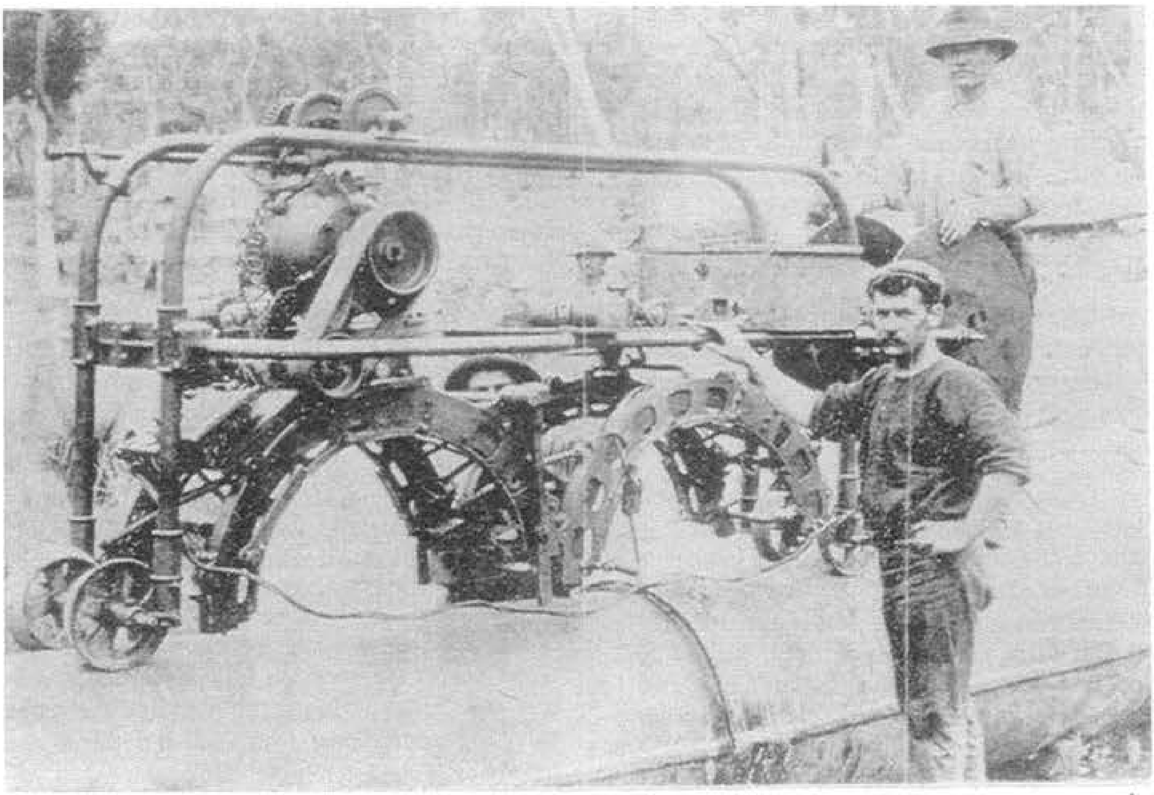
However, the initial effort to raise the first stage of the loan had been unsuccessful despite the committee's interim report, and O'Connor found that little progress on the project had been made while he was away.

It was to be another year before the Coolgardie Goldfields Water Supply Construction Bill was passed, but in the meantime the shortage of loan funds caused the retrenchment of many experienced men, which added to the pressure on those remaining.

Constructed between 1898 and 1903 the work is recognised as an engineering achievement of international significance.

The completion of construction by January 1903, in less than five years and within estimate, speaks for the success of those in charge — and the efforts of a large workforce. Yet characteristically, O'Connor and his team were not averse to adopting the latest technology and encouraging innovation.

Coolgardie Water Supply: Pipe caulking machine.



Coolgardie Water Supply: On the pipe track, 1902. *Photo courtesy of Battye Library.*

All cement, steel and machinery was imported from Europe or America, over six weeks by steamer or 90 to 100 days sailing time distant; pipes were manufactured locally using American and German steel plate, adopting the revolutionary locking bar patent of the Victorian, Mephan Ferguson. The dam was the largest in the southern hemisphere and the length and rise of the pipeline unprecedented. The pump duty obtained was a record for pumping engines of the duplex class.

There were also numerous setbacks to the scheme and in addition O'Connor had to endure almost constant criticism in sections of the Press and resist continual political pressure and interference.

In early 1902 a Select Committee was appointed, followed by a Royal Commission, to investigate aspects of a major contract for work on the scheme and allegations of corruption against some of O'Connor's staff. A campaign of personal vilification against O'Connor conducted over a number of years by Perth newspaper, the 'Sunday Times', was also at its height and attacks by many Members in Parliament were particularly worrying. O'Connor had met criticism of his professional opinions in the past and was not unduly worried by it. However, this was an assault of a new dimension which overtly attacked not only his professional skill but also his personal integrity.

Despite his years of overwork and bearing the stress of his office, researchers have been unable to establish what finally made him succumb to the pressure; but O'Connor committed suicide on 10 March 1902.

To quote John Pollard, in his brief biographical sketch —

> 'New Zealand politicians had ill-used an outstanding engineer, Australian politicians destroyed him.'

In his book, from which I have borrowed freely, John Le Page gives a thoughtful and very fitting reprise (p 304):

> Although O'Connor is remembered first and foremost for the Coolgardie Water Supply Scheme it may be that his other great triumph at the Fremantle Harbour was the greater professional accomplishment. At that time he was new to the Colony and had an extremely tiny departmental staff. His proposal was quite contrary to the advice of a world famous harbour engineer in Sir John Coode. It may be said to have been O'Connor's scheme almost in entirety. Every departmental project of comparable magnitude since that time has been achieved by team effort although certain individuals have almost always carried out leading roles.
>
> Such was the case with the Coolgardie Water Scheme. Although C.Y. O'Connor's guiding hand was always on the tiller there were a number of competent engineers associated with the task from the beginning such as Hodgson, Reynoldson, Muir, Robertson, Pidgeon, Leslie and others, not forgetting the committee of engineers in London. This is not to deprecate O'Connor's role in the Water Scheme but rather to elevate his role with Fremantle Harbour to its rightful place.

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Issues in Heritage Management of a 19th Century Provincial New Zealand Town - Oamaru: A Case Study

HELEN STEAD
Guest Lecturer, Heritage Management, Department of Management Systems, Massey University, New Zealand
Former Board Member, New Zealand Historic Places Trust. Former Councillor, Oamaru Borough Council.

SUMMARY: Hall & McArthur (1993) believe that 'heritage can only be preserved for future generations if appropriate management policies and processes are developed and implemented'. This paper will examine Oamaru's establishment as a town in the 1850s in relation to heritage management issues and the retention in the 1990s of much of the town's distinctive 19th century limestone heritage.

Recent global enthusiasm for 'green' issues has been matched with national and local initiatives developing and promoting New Zealand's eco-heritage resources for commercial and tourist purposes. The call is made for a more holistic approach to heritage management. Using the Oamaru Case Study as an example strategies are recommended which will ensure the integrity and sustainability of that heritage.

1. INTRODUCTION

The heritage of Oamaru and the surrounding Waitaki district rests heavily on two aspects of its geophysical character; plentiful supplies of quality limestone for use as a building material; and quality soils for food and agricultural production.

Cumulating twin benefits of location came with the discovery of gold in Otago in 1861 and the New Zealand Government's expansionist immigration and public works policies of the 1870s. Similarly Oamaru's location almost equal distance between New Zealand's two most economically and politically powerful provincial towns of that time - Dunedin and Christchurch - was a vital contributing factor.

As a local decision-maker who later had some responsibility for national heritage protection, and who for more than a decade has been developing and running eco-heritage education programmes and tours for schools, polytechnics, universities and special interest groups, the author of this paper seeks to stimulate discussion about heritage management as a process.

For Oamaru the management strategies of the 19th & 20th century can be roughly divided into two broad types; local and distant decision-makers. Local decision-makers from Oamaru (and Otago) drove Oamaru's establishment for the first two to three decades from the late 1850s. In the 20th century the decision-makers for Oamaru became increasingly distant from Oamaru and Otago. From being a town with a future it increasingly became a town with a past.

The difference between local and distant decision-maker became much more marked in the late 1970s/early 1980s. Local decision-makers respected the Oamaru stone 19th century character of their town, simply by continuing to use and re-use buildings. On the other hand, the distant decision-maker not only ignored the town's character, they often did so against the prevailing attitudes of the local decision-makers. This trend escalated with the restructuring of the public and private sector and the formation of State Owned Enterprises in the late 1980s.

The trend away from local to distant decision-making has become more pervasive with national concern to relieve unemployment. Local heritage and conservation projects have proliferated throughout New Zealand, mostly relying upon subsidies and lottery board money. The concept and intention of these programmes is endorsed, however there are fundamental flaws from the heritage management point of view. Theories of heritage protection are stated yet questions remain about outcomes, methodology, commitment, accountability and most important of all, sustainability of the heritage resource as a result of running such programmes.

The 1991 Resource Management Act promotes sustainable management yet no guidelines or standards exist for the operation of government community employment programmes. Little to no formal consultation takes place between government and the wider community. Finally there is considerable concern that 'heritage' has been relegated from 'Matters of national importance' to (e) 'Other matters' under the Resource Management Act.

The Oamaru Case Study notes the shift away from 'local fire fighting' on single issues to commercially driven broadbased interventionist eco-heritage tourism development and government employment programmes. Recommendations are made for heritage management policies and processes which can be integrated and implemented locally and nationally.

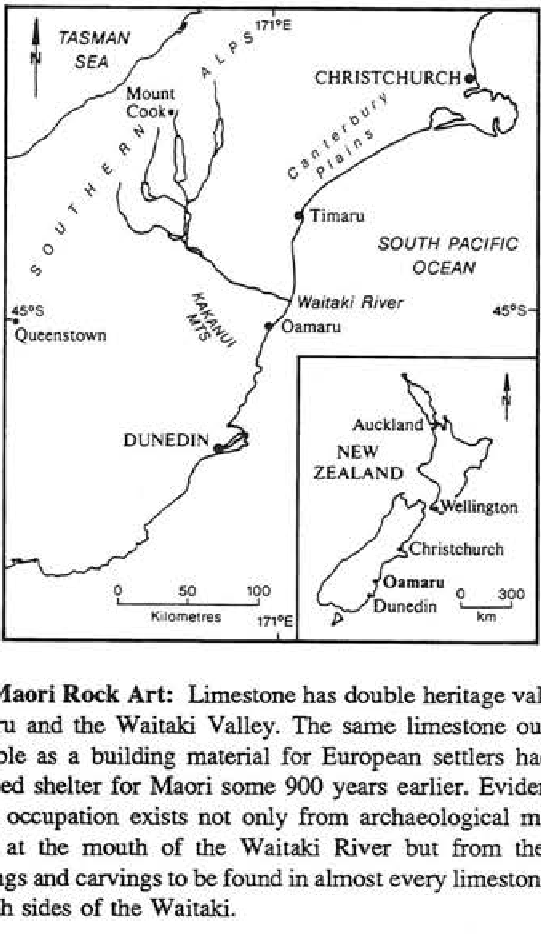
2. BACKGROUND

2.1 Location: Oamaru is located beside the Pacific Ocean some ten kilometres below the 45th parallel on the east coast of the South Island of New Zealand. The catchment area serviced by

Oamaru stretches in an elongated triangle to the Waitaki River in the north, the Kakanui Mountains to the west, then south to the Pacific coast near Palmerston, Otago.

The climate varies from inland with cold dry winters and hot dry summers; to the coast which has a more equable climate. 'Nor westers' blow down annually from the Southern Alps exacerbating drought conditions which in turn affect demand for water for hydro energy, irrigation, for stock & Oamaru's town supply. The type and quality of soils when combined with water produces a fertile area which was early recognized as being most conducive for animal and grain farming. Bereft of its pre-historic forest cover the dominant characteristic of the rolling hill country surrounding Oamaru is limestone.

Figure 1: Map showing Oamaru's location



2.2 Maori Rock Art: Limestone has double heritage value for Oamaru and the Waitaki Valley. The same limestone outcrops available as a building material for European settlers had also provided shelter for Maori some 900 years earlier. Evidence of Maori occupation exists not only from archaeological material found at the mouth of the Waitaki River but from the rock drawings and carvings to be found in almost every limestone cave on both sides of the Waitaki.

While mention is briefly made here, the issue of how the cultural heritage of the Maori in the Waitaki district is managed is outside the scope of this paper.

3. EUROPEAN SETTLEMENT & USE OF LIMESTONE

For the newly arrived European settler the ready availability, ease of working, consistency of colour and quality meant that Oamaru limestone was soon used for building throughout the district. Local demand was met by individual property owners who simply quarried the stone from the hillside for sale, as well as for home, fence or farm buildings.

The first stone structure in Oamaru was built in 1860 indicating early commercial demand. Accompanying the growth of Oamaru was growth both in the number of quarries and amount of material extracted. Accuracy in stating the number of quarries or the origin of stone is difficult since supply was usually through architects, contractors or carriers.

Demand during the 1870s and 1880s was particularly high. There was some concern about quality at this time from outside markets, but it was not until after WWI that the industry undertook self-regulation. One quarry 'Parkside' produces the total amount of stone today, supplying local and overseas markets.

4. OAMARU'S GROWTH PATTERNS - 1850s TO 1990s

Generally speaking Oamaru has only had two main growth patterns. Rapid growth to the mid 1880s, then slowing and sometimes declining growth rates to the present day.

As an indicator, Oamaru in 1878 had a population of 4,927 and was the ninth largest town in New Zealand, ranked behind Dunedin, Christchurch, Wellington, Auckland, Nelson, Invercargill, Thames and Napier. Just over a century later the 1986 census showed Oamaru's population as 14,247 and listed it as the ninth largest of secondary urban areas, i.e. populations of less than 25,000.

The socio-economic changes of the 19th Century were primarily associated with rapid and sometimes erratic growth, particularly when associated with the demand and price for agricultural products. Oamaru continued in its role as a distinctive rural servicing town and retains this character to the present day.

Table 1. Socio-economic factors affecting Oamaru's growth in the 19th century

1. The Otago Goldrushes of the 1860s
2. Vogel's expansionist Public Works and Immigration programmes in the 1870s
3. Development of the frozen meat industry in the 1880s
4. Liberalising land legislation breaking up the large estates in the 1890s

Two other positive factors outside Oamaru affected its growth. Firstly was the absence of land wars in the South Island which had both a restrictive and a debilitating effect on growth in the North Island. Secondly the changes taking place on the other side of the world, particularly in Britain and associated with agricultural 'reform' and the Industrial Revolution helped drive New Zealand's and Oamaru's early colonization.

Oamaru, with its above average agricultural producing capacity attracted numbers of farm labourers and, like Dunedin it also attracted artisans and craftspeople displaced by industrial change in Britain. In Oamaru there was soon plenty of work building 'buildings of stone of the utmost brilliance' (McDonald 1962).

Socio-economic changes of the 20th century, such as rural depopulation; the drift north and to the larger cities; associated urbanisation and suburbanisation; growth of the servicing and manufacturing sectors combined with external national and international factors all resulted in further decline and slow growth for Oamaru.

Table 2. External factors affecting Oamaru's growth patterns in 20th century

1. Changing markets for agricultural products post EEC
2. Global oil crisis of the 1970s and resulting 'Think Big' policies in New Zealand
3. Industrial unrest, inflation, devaluation of the New Zealand dollar
4. Restructuring and de-regulation of public and private sectors in 1980s and 1990s
5. Continuing and contiguous technological and industrial change especially in agriculture

Oamaru and North Otago's reputation for agricultural innovation started with development in 1874 of a new breed of sheep, named Corriedale after a local property. Population growth and economic stability came with two more ideas in the 20th century. North Otago pioneered a system of low cost, low technology, community based rural water schemes which allowed dry land farming the opportunity to diversify as markets at home and abroad changed or contracted. Retail turnover in the town has always been affected adversely under drought conditions.

The second change came with development of the Lower Waitaki Irrigation Scheme in the mid 1970s. This ability to control water on the soil increased production as well as allowed further diversification particularly into dairying. Another development based on the Waitaki River impacted upon Oamaru three times during the 20th century - hydro electric energy development. The Waitaki Dam was built in the 1920s, Benmore and Aviemore in the 1960s, Upper Waitaki in the 1970s.

Surprisingly no socio-economic assessment has been done in the Waitaki Region on the impact of large-scale national energy development. When it is recalled that New Zealand's original Social Security system started on the Waitaki Hydro Scheme the lack of attention to this issue is a sad irony.

Issues of bio-diversity, land quality and sustainability are further areas for research insofar as how land use patterns interact with national and local development. Innovative dry land management practices currently being developed in the Hakataramea Valley (a tributary of the Waitaki) are likely to be of considerable significance when viewed historically.

Two final factors impacted upon the population level and economy of Oamaru. These are education and tourism. Three secondary schools with attached boarding establishments bring over 2000 teenagers into the town each year. Tourist activity has in the past mostly been confined to stopovers between Christchurch and Dunedin. Overseas visitors invariably include the geologically and culturally interesting Moeraki Boulders twenty minutes south of Oamaru on their itinerary. Domestic visitors are more likely to bring a fishing rod or a boat to the Waitaki Lakes, Waitaki River or one of its tributaries.

Oamaru's location within the quadrangle of Queenstown, Dunedin, Mount Cook and Christchurch sees potential tourist traffic mostly fly, bus or drive past the town or the district. More recent promotion and publicity about Oamaru's colony of little blue penguins and its 19th century limestone built heritage is attracting locals, domestic and overseas visitors.

5. 'BUILDINGS RISING IN STONE OF THE UTMOST BRILLIANCE'

5.1 The 1850s: Oamaru Town Survey by J T Thompson: May 21 1858 is known as the date of Oamaru's birth as a town. On this date John Turnbull Thompson (1821-1884), Chief Surveyor for the Otago Provincial Government, made 'notes and sketches preliminary to the layout of a town reserve' (McDonald 1962).

Suitability of the site for a new town was contested by Moeraki which had grown as a whaling station after 1836. Moeraki's extensive Maori connection reaching back some 900 years reinforced its location, especially as a sheltered port, however drinking water supplies were found to be brackish. Local availability of fresh water swung the pendulum in favour of the Oamaru site. Oamaru's suitability as a harbour was to be long a bone of contention.

Pastoral settlement of the Oamaru district came with Otago's early settlers from 1848 onwards. Johnny Jones, whaler turned farmer, of Waikouaiti had however, been farming at Waikouaiti since 1840 and his northern boundary came to Palmerston. The population of North Otago in 1854 was 107 with only 48 shown as living in the Waitaki district. Few people lived in the town at that time. Most of the land surrounding Oamaru was taken up by 1860 but few buildings had been built. Speculation in land was high, deals often taking place in Dunedin or back 'home' in Britain.

Consideration of Maori land issues such as how fair the purchase of 20 million acres (most of Canterbury and Otago) in 1848 for two thousand pounds, was a management matter left to simmer for a few more generations.

5.2 The 1860s - Wool, Grain and Gold: The first stone structure in Oamaru was a bridge with a 24 foot span and 18 foot roadway over the Oamaru Creek on Thames Street opening in December, 1861. Designed by John Roy (1823-1864) the Provincial Engineer for Otago, it not only allowed extension of the town to the north it also improved access to the harbour from the rural hinterland which was a vital factor for shipping wool and grain.

In 1861 the Oamaru Town Board was established, the Tyne Street sewer was built and a survey of streets was done by J.S.Brooking. That same year, gold was first discovered in the Lindis Pass and then in Central Otago. Miners poured through Oamaru by the hundreds, on their way to the goldfields.

Table 3. Limestone structures built 1860 to 1870.
An * indicates structure stands in 1994.

1860 - *Thames Street Bridge
1861 - *Casa Nova House, Alt Street
- *Stables for Star & Garter Hotel
1863 - *Shrimski & Moss build Oamaru House
- First Courthouse built
1864 - *Dalgety, Rattray & Co store (now Scottish Hall)
- Cargill & Co (later Cargill & McLean)
- *'The Homestead', Awamoa
*Oamaru Post Office (W.H.Clayton (1823-1877)
1865 - First St Paul's Presbyterian Church built (William

- *Anglican Church (W B Armson (1834-1883) supervising architect) completed 1913.
- Bank of New Zealand - *single gate-post remains.

1866 - *Maheno Valley Roller Flour Mills built

1867 - *First Presbyterian Manse in Perth St (R A Lawson)
- *Star & Garter Hotel (R A Lawson)
- *Bank of Otago in Tyne Street
- James Hassell erects eight storey windmill Severn St

1868 - *Totara Estate Farm buildings & Homestead built (4,000 sq.ft for NZ & Aust. Land Co - cost £2,000)
- *Windsor Park Farm buildings & Homestead built

1869 - *Cave Valley School (Weston) built (July 9)
- Oamaru Gaol Demolished 1921. *Stables remain today.
- *Finch & Co Wine Merchants - also served as Colonial Bank of New Zealand 1875-1878 built in Tyne St
- *Meek's flour mill (Severn St) built
- Customs wing added to 1864 (Clayton) Post Office

Between 1864 and 1867 the population doubled. By 1867 the Oamaru electoral district statistics showed there were 3,691 persons living in 779 houses of which 160 were of stone, the highest proportion of any town in New Zealand at that time (McDonald 1962). Agricultural statistics (McDonald 1962) reinforced the farming nature of the local economy. 7,256 acres of ground sown in oats, 4,668 in wheat, 612 in barley and 5,654 in sown grass. There were 303,701 sheep, 7,800 cattle and 1,872 horses.

There was the odd bad year when the price of wool slumped. Runholders could either sell some land to new settlers or move into grain and milling. For the townspeople the revenue from wool and grain through the stores or on board ships provided work and a steady income.

5.3 The 1870s. Wool, Grain and Vogelism: The New Zealand Government's acceptance of Premier and Colonial Treasurer Sir Julius Vogel's financial plan to borrow ten million pounds over ten years for Public Works and Immigration was to have a profound and compounding effect upon Oamaru.

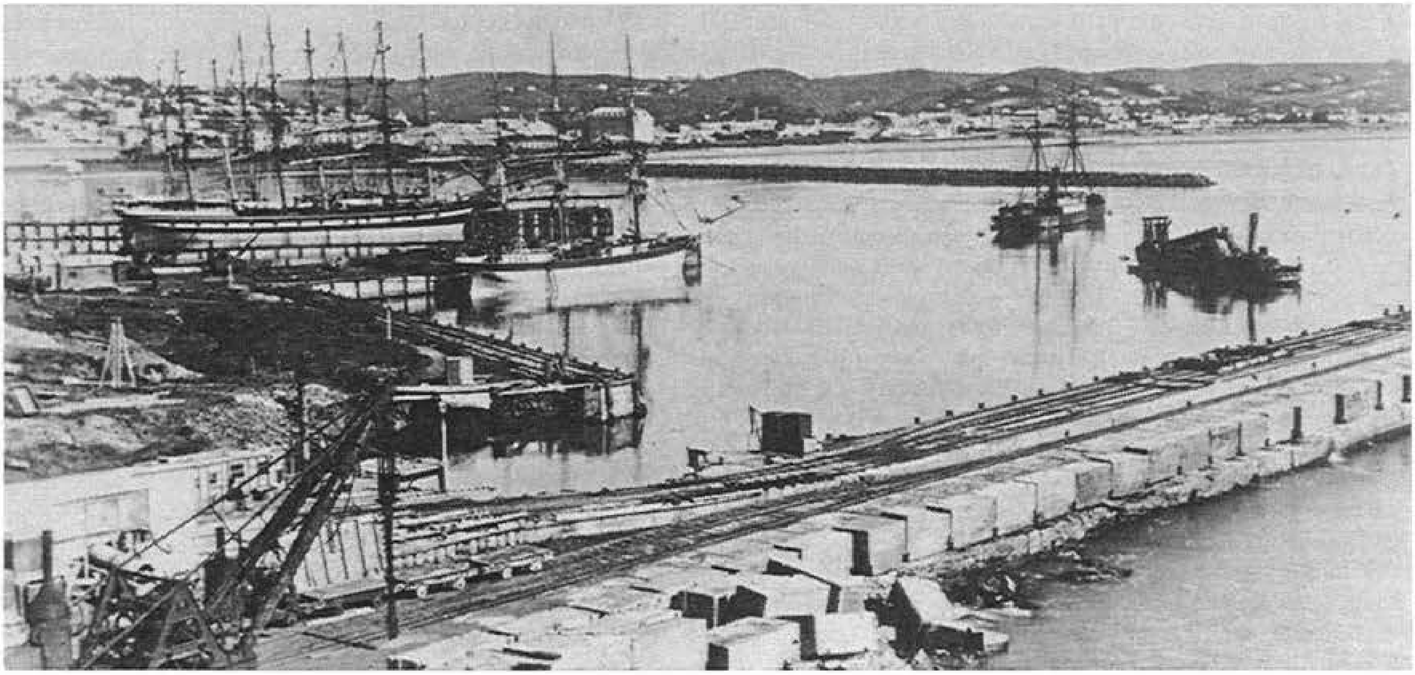
With a Provincial system of Government in New Zealand until 1876 it is not surprising that central government politicians were under considerable pressure from economically and politically strong Otago and Canterbury.

With land wars soon to finish in the North Island, pressure was now on from both the North and South Island for further development. Ports and railways were considered the greatest need. Oamaru was no exception with a growing list of wrecks, reaching thirty by 1872, giving the town a bad name (Furkert 1953). Oamaru quickly took advantage of Vogel's scheme and borrowed heavily overseas specifically to develop a safe harbour for its constantly growing exports and imports. Immigrants arriving in Oamaru in the 1870s were likely to find work first on port development, then railways and at the turn of the decade, building the town's water race.

The Oamaru Breakwater, started in 1871 was, along with four new wharves, finished by 1884, all at a crippling cost of nearly £300,000. The port was soon affected by rail traffic with the first train from Christchurch arriving in 1877. The next year (1878) saw the first through train from Christchurch to Dunedin with ten trains daily using the Oamaru Railway Station, built in 1873.

1878 was to be the pinnacle for the Port of Oamaru. Over £100,000 worth of exports went out that year; £61,000 worth of imports came in. There were thirty vessels from overseas, mostly from Australia with coal and hardwood, or to Britain with wool and grain although passenger traffic of migrants in and out, is well reported in local newspapers. A total of 451 ships came into Oamaru in 1878. Such a number was never to be seen again with the port officially closing to all but fishing and recreational boats in 1978. (McDonald 1962).

The population of Oamaru in 1878 was young with more than half under the age of twenty-one. Of nearly 5,000 Oamaru residents, only 67 were aged over sixty years. Of persons aged over twenty-one, the next largest age groupings were in their late twenties (467), and late thirties (455) (McDonald unpub MS).



Photograph 1: Oamaru Harbour with Breathwater c1884. Dredge 'Progress' (R) and Kinnaird steam crane in (L) foreground

The first building site in the Harbour Board Block, on the west side of Tyne Street was sold in 1874. Within three years every site was built on. All were substantial limestone business premises of single and double storeys. Business boomed. A few went bust. As an indication there were 42 bankruptcies registered in Oamaru in 1877 and 31 in 1878 (McDonald 1962).

The speed of growth is best exemplified by the expansion of the Thames Street bridge in 1876 to 40.24 metres in width with a span of 7.32 metres. Status as the widest main street bridge in the Southern Hemisphere was claimed by the bridge until 1932 when the Sydney Harbour Bridge was opened. A rough count of structures built from 1871 to 1880 excluding the breakwater, wharves, railways, homesteads and private residences produces thirty-four church, state, civic and business buildings of stone.

Visiting Oamaru officially in 1878 Sir George Grey, Premier of New Zealand, coined the phrase that is most fondly recalled by Oamaruvians. Wondering aloud about what name might be given to Oamaru he said

> 'From her youth I will call her a maiden, she has youth and beauty. Then as I looked at your buildings rising in stone of the utmost brilliance, of a kind I have never seen before thought, Oamaru is a fair maiden who sits beside the sea. When I thought of the harbour you have created here. I said that this fair maiden holds a horn of plenty in her hand....' (McDonald 1962)

5.4 The 1880 & 1890s - Agricultural Innovation: Buildings 'in stone of the utmost brilliance' continued to be built in the early 1880s, partly because of the cheapness of labour but mostly continuing the momentum of the previous decade. Grain growing gained in importance with contemporary reports stating that 'Oamaru flour was quoted at £1 per ton higher than that of Dunedin, and in like manner Dunedin flour is estimated to have a higher value than that of Christchurch by about the same amount' (McDonald 1962).

An early Oamaru historian WHS Roberts (undated) reported that in January 1882 'no fewer than 31 buildings were in the course of construction'. Two of Oamaru's largest grain stores were under construction at that time. They were the three storey NZ Loan & Mercantile's building (capacity 100,000 sacks) and J & T Meek's five storey Elevator building which used the very latest 'American style' handling technology, a system of worm gears and elevators carrying grain to 36 storage bins..... each 54 feet deep. (McCarthy 1975)

The Architect for Meek's Grain Elevator building was Thomas Forrester. His output over nearly twenty years was prodigious, both as architect and as Engineer overseeing the development of the Breakwater and wharves. His buildings built in the 1880s nearly all have a NZ Historic Places Trust Category 1 grading.

Table 5: Limestone buildings built by Forrester & Lemon after 1880. An * denotes building still stands in 1994.

1881 - *John Bulleid's Drapery store, Thames St
- *Sumpter's Grain store, Harbour St
- *Connell & Clowe's Grain store, Tyne St
- *Queens Hotel, Cnr Thames & Wear St

1882 - *Athenaeum, Cnr Thames & Steward St
- Emmanual Congregational Church, Wansbeck St
- *Neil Brothers' store, Harbour St

1883 - *Oamaru Courthouse, Thames St
- Public Hall, Cnr Thames & Coquet St
- *Columba Presbyterian Church, Wansbeck St
- *Waitaki Boys' High School, Main bldg & Rectory
- *Meek's Elevator building, Tyne St

1884 - *Oamaru Mail Office & Hodge & Jones Saddler
- *Customs House, Tyne St
- *Oamaru Chief Post Office, Thames St

1886 - *NZ Refrigeration Co's Freezing works

The completion of the Oamaru borough water race in 1883 was the last big civic project to be undertaken. The engineering feats involved with bringing the water in an open race twenty-five miles from the Waitaki River, across valleys and through hills was indeed considerable. Insurance against fire for the town's buildings was now readily available.

The 1880s were important also for the start of New Zealand's frozen meat industry. Technology for freezing meat was already in use in other parts of the world. New Zealand had to follow or lose its position as a commodity exporter, particularly to Britain. The New Zealand and Australian Land Company owned over a million acres in New Zealand and Australia. On their Totara Estate eight miles south of Oamaru they successfully killed stock for what was in February 1882, the first shipment of frozen meat to leave from New Zealand.

Dramatic changes occurred over the next eight years. By 1890 there were twenty-three freezing works scattered throughout New Zealand. Rail and shipping transport systems grew in tandem. With the establishment of New Zealand's frozen meat industry came a demand for smaller holdings, particularly from migrants attracted to New Zealand by Vogel's schemes.

A staunch advocate of the small farmer, politician Sir John McKenzie of Palmerston backed Oamaru's efforts to break up some of the district's large land holdings. The level of interest in farms divided from the Ardgowan Estate which lay on the outskirts of Oamaru was high. In May 1896, it took two days to call seven thousand names in the ballot for sixty-four farms.

From frozen meat and the breaking up of the large estates there was a consequent rise in demand for fencing wire and farm machinery. However, the days of high wool, grain and meat prices were now limited. There were now recessions; gluts at home or abroad. Other problems were more insidious such as overcropping, drought and rabbits. Early settlers' enthusiasm for recreating the British lifestyle rebounded on them when they consciously brought or inadvertently allowed four-legged 'immigrant killers' into New Zealand. A fact that continues to be a major problem to the present day. (King 1984)

The new century arrived. The town and district settled into a pattern of less dramatic activity as events moved overseas with two world wars, to larger urban areas and north, especially to the north of the North Island.

6. MANAGEMENT OF OAMARU's 19th CENTURY HERITAGE IN THE 20th CENTURY

Management of Oamaru's 19th century heritage in the 20th century has two characteristics. One relates to the laissez-faire manner in which local and district decision-makers operated. The second factor is interwoven with the first in that philosophical and ethical debate about how best to preserve Oamaru's character was split and stifled by political or economic considerations. Alternatives were difficult to support without conservation guidelines or standards.

Oamaru's 19th century heritage mostly remained intact until after WWII when earthquake and planning legislation brought two changes.

Oamaru's limestone buildings were targeted as earthquake risks in the late 1940s/early 1950s. Balustrades and other unreinforced structural or architectural features on buildings were removed by Ministry of Works personnel for public safety reasons. Heritage aspects were not considered although local opposition to the possible demolition of the clock tower on top of Oamaru's Chief Post Office was sufficiently strong to reverse the decision.

Nor were heritage aspects considered when Council by-laws were changed in the 1950s for car parking requirements. All verandahs were to be free-standing and tied back by bracing to the front of each building. Not only was the requirement haphazardly observed, not all buildings lent themselves easily to the tying process. Streetscapes lost their harmony and assumed a jumbled appearance with some verandahs and posts removed and not replaced, and some replaced with a different design and angles.

Opportunity existed to remedy this situation when the town's first District Scheme was drawn up in 1968. Unfortunately the effort was a mechanical exercise with chunks of the Town and Country Planning Act taken out and 'peppered' with names of Oamaru streets and places (Stead 1978).

However it was government earthquake regulations that had the greatest impact upon the town's heritage. New buildings were built in other than Oamaru stone and existing educational and departmental buildings were increasingly under siege. The demolition of Waitaki Girls' High School Senior Block and the threatened demolition of Waitaki Boys' High School Main Building in the early 1980s became catalysts for action.

Table 6. Impact of earthquake regulations upon Oamaru's 19th century limestone heritage.

1. Unreinforced architectural features removed
2. Older unreinforced buildings not maintained, left empty or demolished
3. New buildings built in other than Oamaru stone (usually concrete, but also wood & aluminium)
4. Pre-fabricated and re-locatable buildings used

Local opinion surveyed in 1978 (Stead) produced strong evidence of local people's appreciation of their 19th century heritage. Fifty-four heritage buildings were named, many in the 19th century CBD (Harbour/Tyne Street) as well as in Thames Street, today's commercial centre.

Over the next decade a number of local buildings were successfully upgraded to meet earthquake standards yet no effort has been made to research and use these examples as a base for national heritage management guidelines.

Table 7. Local examples of existing heritage buildings upgraded to meet earthquake standards

1. National Bank - upgraded own buildings
2. Forrester Gallery - prev Bank of New South Wales
3. Waitaki Electric Power Board - upgraded own building
4. Waitaki County Council - prev. Farmers Mutual building
5. Waitaki Boys' HS Main Building - upgraded own buildings
6. Waitaki District Council - prev Oamaru Chief Post Office

In the mid 1980s the Oamaru Borough Council promoted a Scheme Change requiring developers and owners of buildings in the historic part of town to 'respect the Oamaru stone built character of the town'. Opposition was strongest from Wellington and included the Minister of Works, banking (not the National Bank) and the insurance industry. Faced with this opposition the Council withdrew the Change.

Two final examples are given of how the local community was divided down political and economic lines and how local and distant decision-makers became polarized when debating heritage preservation.

They were a proposed new cement works as part of central government's 'Think Big' policies in the 1970s; and the sale of Oamaru's Chief Post Office and the setting up of State Owned Enterprises in the late 1980s.

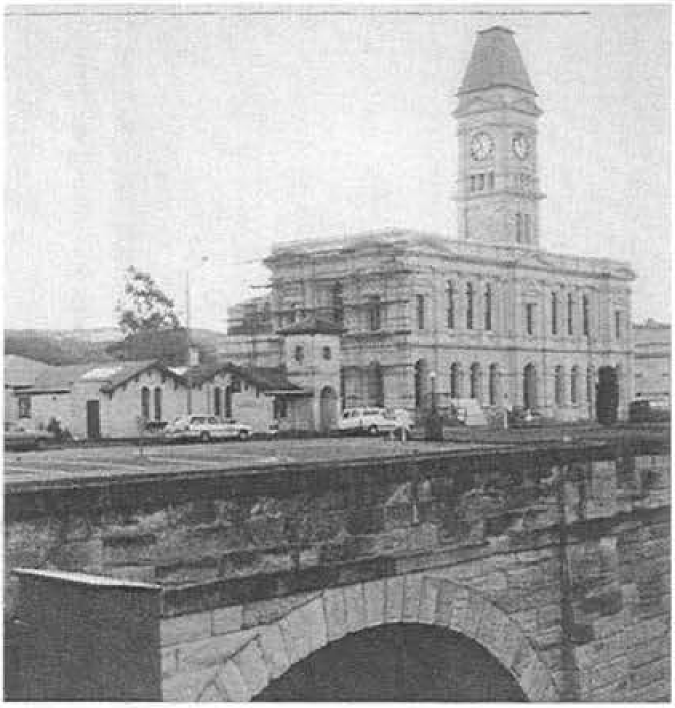
A $100m cement works was proposed at Weston, on the outskirts of Oamaru which would utilize the district's substantial lime reserves. The project included the possible reopening of the Oamaru harbour at a cost of c$10m to service cement barges. Combined the project was expected to bring eighty new jobs to the district once operating. Discussion on the short-term impact of the construction workforce clouded the issue of what the long-term impacts were. Without proper research on which to base decisions local discussion became polarized and divided along party political lines.

At the built heritage level the possibility of cement trucks travelling to the port through Oamaru streets at the rate of one truck every six minutes for ten hours a day, six days a week was reluctantly accepted by a number of local decision-makers as a fair cost to pay for more jobs. Implicit too, in the design for re-opening the port was installation of nine storey high cement silos sited in the harbour basin. The project has not gone ahead.

The second controversy involving Oamaru's Chief Post Office in the mid 1980s was initially the predictable pattern of the building being either an earthquake risk, unsuitable or too big for one or other of the recently established State Owned Enterprises, Telecom, Postbank and NZ Post. Without consulting either the Council or the community the SOEs relocated or built new buildings in four different parts of town. Local opinion was united in its opposition to the building being sold. Public meetings, a 5500 signature petition, requests under the 1982 Official Information Act, and finally to the Ombudsman were all to no avail. The building was eventually sold to an out of town consortium for less than $100,000, a figure believed to be less than ten percent the government valuation of the building.

National and local concern about NZ Post's lack of accountability remains. Ombudsman John Robertson cited the Oamaru case in his '10th compendium of case notes published last year' noting 'NZ Post's refusal to supply details to a local action committee, "frankly ... none of their (Oamaru's) business" he quoted NZ Post saying. When ordered by the Ombudsman to release the information, NZ Post complied - 'after it had stalled long enough for the sale to be completed' he said (Listener 1994).

Photograph 2: Oamaru's 1864 (L) and 1884 (R) Post Offices



As a footnote the Waitaki District Council purchased the building in 1993 and are currently strengthening and upgrading it for Council Offices. Oamaru ratepayers were not pleased to have to pay twice the alleged price paid to NZ Post for a building the town considered belonged to them as taxpayers.

Table 7: Heritage development and management initiatives taken by Oamaru since the 1980s

1. District Scheme Review following Oamaru Towntalk 78 incorporates heritage aspects
2. Frozen meat centennial and setting up of Totara Estate Centennial Park by the NZ Historic Places Trust - 1982.
3. Conversion of Bank of New South Wales into Forrester Gallery at cost of $250,000 - opened 1983
4. Local branch of the NZ Historic Places Trust established 1984
5. Establishment of North Otago Heritage Fund early 1980s. First in NZ with funds lent at low rate of interest to maintain, & upgrade heritage buildings.
6. Expansion of North Otago Museum and building of Archive - $180,000 - opened 1986
7. Harbour/Tyne Street feasibility study completed. Area to be conserved & developed for tourist & commercial use
8. Oamaru Whitestone Civic Trust set up in 1989

The debilitating and frustrating experience of backing or opposing these 'one off' national development schemes is considerable. Oamaru initiatives developing and managing its own heritage is likewise considerable. Existing resources like Oamaru's limestone 19th century heritage have been dramatically affected by change yet no research or impact assessment has been done. The Oamaru Whitestone Civic Trust's conservation programme for Habour/Tyne Street relies heavily upon Lottery Board funding and NZ Employment Service subsidised work schemes. This raises all the issues of sustainability detailed earlier. Oamaru is but one programme among thousands throughout New Zealand.

This paper raises philosophical, ethical and practical differences between local and distant decision-making affecting Oamaru. Debate on the sustainability and integrity of New Zealand heritage resource management systems is evolving. The heritage management processes recommended below seek to encourage universal effort ensuring New Zealand's and Oamaru's 'heritage is preserved for future generations' (Hall and McArthur 1993).

7. RECOMMENDATIONS

Table 9: Heritage management policies, processes and strategies for eco-heritage protection.

1. All government and community programmes to
   1. Meet sustainability requirements of the Resource Management Act.
   2. Adopt professional standards for skills and research.
   3. Provide participants with recognisable qualifications and marketable skills.
   4. Provide opportunities for skill and knowledge exchange across cultures and generations.
   5. Be accountable nationally and locally, within and between public and private sectors.
2. Eco-heritage management information, guidelines and advice be developed for all types of property ownership.
3. Eco-heritage tourism industry visitor interpretation information and tour guiding standards be developed.

Acknowledgements: Photographs; North Otago Museum (copyright): The Oamaru Mail & Anthony McKee. Comments on Draft by Joanne Cheyne Buchanan appreciated.

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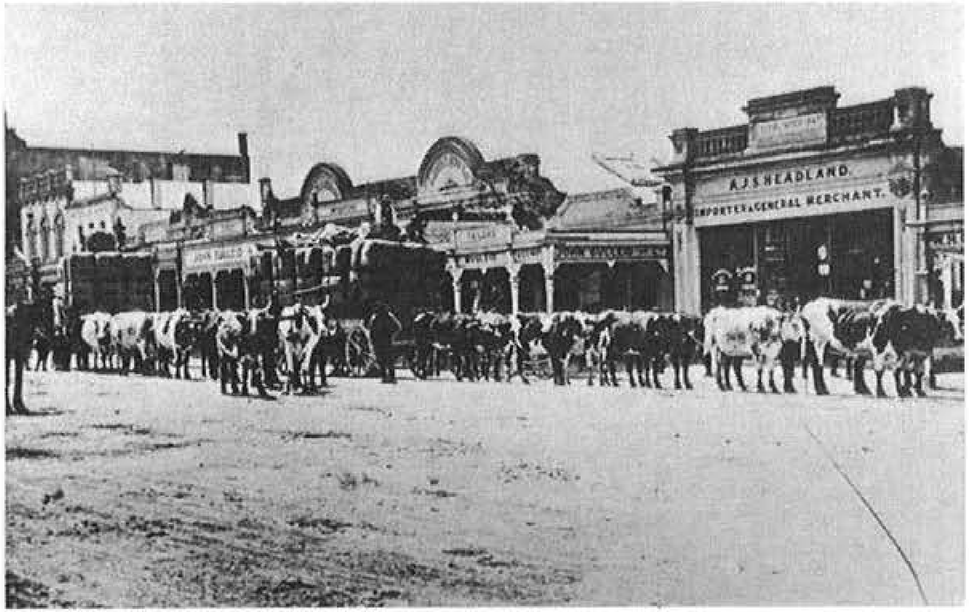
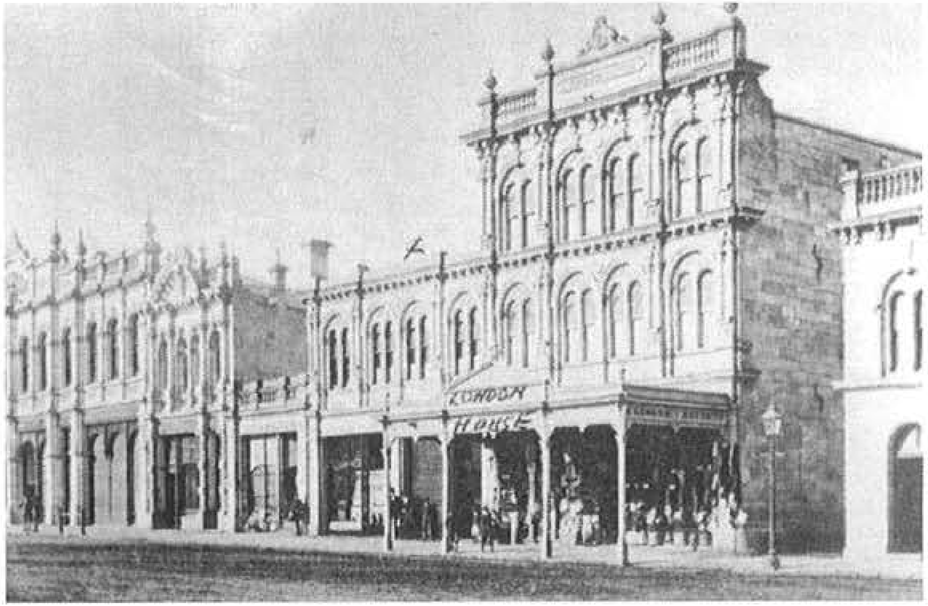
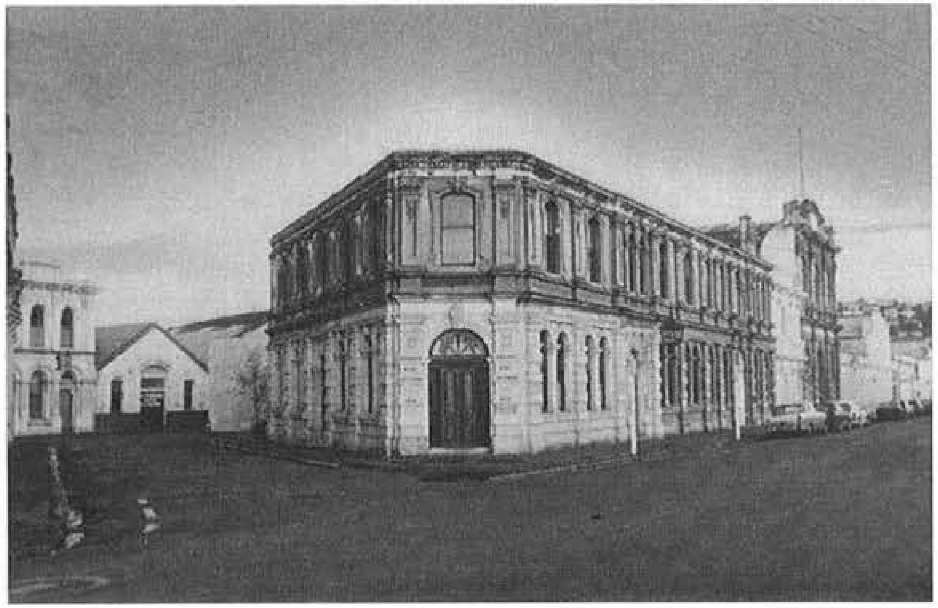


Photograph 3: Thames Street in the 1870s.



Photograph 4: Thames Street in the 1880s.

Photograph 5: Harbour/Tyne Streets in the late 1870s with Criterion Hotel in centre



Photograph 6: Harbour/Tyne Streets in 1994.

Engineering Heritage of the Rocks - Sydney

Austin Chapman BE MIE (Aust)
Austin Chapman and Associates Pty Ltd

SUMMARY

The Rocks area of Sydney is now well known as a major tourist attraction but for those who have not visited, a background is appropriate.

When the First Fleet landed in Sydney cove in 1788 the convicts went to the "rocky" ground on the western side of the Cove. The Governor, his staff, soldiers and freemen went t the Eastern side.

Over the years the Rocks developed as a "tough" area centred on the maritime trade of the port. In 1900 it was the seat of the bubonic plague in the Colony. From 1930 a series of committees, commissions, enquiries were held to determine its future. One scheme almost came tofruition in the late 1950's - fortunately the "almost" applied. In 1970 following recommendations by Sir John Overall the Sydney Cove Authority was established.

The author was appointed as Professional Services Manager and held the position until leaving the Authority in 1986. The experiences from the basis of this paper.

INTRODUCTION

As is my want I found from the dictionary that "Heritage" is what we inherit. Not being of great use I found to "inherit" was to "receive by legal descent or succession". So I have highlighted those "things" which we found, were able to find traces of which I feel engineers would find of significance as an inheritance from our forebears. These things range from Cadmans Cottage, through Circular Quay, the Argyle Centre, the old overform sewers through the Harbour Bridge, Campells Storehouse, the Overseas Passenger Terminal to the cobbled streets, tramtracks, roads and the modern buildings of the present era. All are part of what we have "inherited" and what we leave for our successors.

Unfortunately we cannot lay physical claim to the Opera House but we had a marvellous view of it particularly as the sun set in the west and the shadow of the bridge with its traffic movements was imprinted on the white sails.

This is not a technical paper. As a soldier and management engineer, I have rejoiced in my profession, which has taken me on many a wonderful journey. This journey is through the Rocks.

Water Supply

Aqua vitae - I believe the Scots have a better product but nevertheless the Colony needed water. The early supply came from the tank stream which ran into Sydney Cove from the south rather on the present line of Pitt Steet. It is now confined in a tunnel from which on odd occasions it seeks its freedom. This source quickly became polluted and a series of wells were dug. We found one.

An area south of the Cahill Expressway was the chosen site for the first major Hotel - The Regent. From our historical maps we knew it was also the site of the first jail. The goalkeeper stated that he could "hang seven at a time - five comfortably". The drawing you will see on the screen was what we had. The Department of Planning and Environment said when any excavation started we would have to stop when we found the well. We decided to excavate first. We did and found the well. It had been filled in with a brown gravelly soil for some depth. The excavation was being observed by the DPE staff. The Minister was coming down on a Monday. They asked if they could continue working over the week-end and "guess what they found - some convict shackles and leg irons". I must admit to some suspicion that "the mine had been salted". We continued excavating "brown gravelly soil" for another week until we reached the bottom.

Power

In 1902 a new DC Power Station was built in the Rocks. It was never used as such because AC took over. The building including a brick chimney 220 ft high still stands today as is an exhibition centre for Mining and Geology. I must say that for an engineer somewhat disingenious when it comes to heights that my quinquennial inspection with the aid of steeplejacks was inclined to be traumatic - but the view was fabulous.

When we arrived in the Rocks we still had three lifts operated by hydraulics. The pumping station was some distance away towards Darling Harbour. The system leaked like a sieve and the service was discontinued around 1975. About that time the last of the DC lifts also went out of service.

On the harbour side of Campbells Storehouse you will see some of the basic hydraulic systems.

Also there is a single cylinder gas engine. We found that in a basement in 1976 restored it and placed it in a public area in Campbells Store. The name plate is fascinating and here it is on screen.

Wharfage

The two heritage items would be Circular Quay and the Overseas Terminal.

Circular Quay was originally called Semi-Circular Quay and you will see its form from the reproduction. Built by Colonel George Barney RE we (the Authority) caused a memorial to be erected to him. The funds for this were provided by the Royal Engineers and the Royal Australian Engineers. Barney was the first, and only, Governor of Northern Australia (now Queensland) and anything else "to the North".

The Overseas Passenger Terminal enables ships from four masted to the QEII to tie up in the heart of Sydney. These few slides show some of these ships. The terminal was completed around 1951 and was built along the lines used to construct the Mulberry Harbour for the D Day landing at Normandie. Large concrete caissons were constructed on the Parramatta River, floated into position, sunk in place and filled with rubble. The illustrations show how this was achieved.

Roads

The original roads were little more than bullock tracks. When roads were laid down in the early 1800s they were named after the Dukes of England - Argyle, Gloucester, Clarence, George, York, Cumberland. The high ridge between the eastern and western sides of the Rocks and hence the wharves necessitated a long journey around Millers Point. It was decided to cut through the ridge at the line of Argyle Street. It was started with convicts but because of the lack of progress was completed by free labour. Naturally little of the original road remains. However the Argyle Courtyard with its cobbles is a tourist attraction.

When we carried out the work on the Rocks Square in 1979/80 we found the cobbled road to the west of the Coachhouse and "brought it to the surface". We also found a section of cobbled road leading to an area where Francis Greenway was reputed to have lived. Such works bring "modern problems" as cobbles are very slippery when wet, can cause injuries and hence have legal implications.

When excavating in Playfair Street we found evidence of the old convict road. Unfortunately much of the photographic evidence which we carefully accumulated has not been retained in a readily acessible form.

The old tram tracks are still in place under parts of George Street.

Building Heritage

We were fortunate to have examples of building construction from the early 1800s. Cadman's Cottage was built around 1806. George Cadman was the Governor's boatswain and lived in the cottage with his wife and two step-daughters. In 1972 we undertook its restoration. The work was directed by Phillip Cox - now deservedly one of Australia's best known architects - then making his mark in the restoration field. The cottage was completely stripped out. One original window remained and some of the timbers were still sound. At ground level the removal of plaster exposed the sandstone block with GR III cut in it - a memorable day.

The method of making lime by crushing seashells and burning was quite obvious in the mortar used with little pieces of shell grit still visible.

Other building practices were not so welcome. View Terrace was to be retained as a facade for a two storey office building. The terrace turned out to be a piece of "1880s" spec building. It cost $110,000 in 1981 to keep the facade - we used steel hairpins, braces and ended up making modern "testudos" to work under. I'm sure it would have been cheaper to rebuild but alas not authentic.

We were fortunate to have examples of construction through the 1800s up to 1950. The Archives building which we put up in 1976/77 was the first building since the 1950s. In fact the 1950 building was for the Maritime Services Board now the Museum of Contemporary Art. The building was designed in 1936 and built after the war. To me it was always very "Germanic" and seemed out of place on the harbour foreshore.

The Rocks was typified by its lanes and stairs leading up to the heights of Cumberland Street. Such name as

Bakehouse Place	Greenway Lane
Surgeons Court	Kendall Lane
Nurses Walk	Foundation Park
Suez Cananl	Custom Officers Stairs

All evoke pages from history. Some are old, some are new but all carry a story. The slides tell the tale.

Dawes Point

Dawes Point was the site of one of the gun batteries to defend the colony. Very little remains today with the park overshowed by the Harbour Bridge.

The Harbour Bridge

I do not propose to elaborate on this "national" icon except to say that the punt location on Hickson Road can still be seen as of course the southern "pin" of this two pin arch.

The construction of the bridge with its associated approaches effectively cut the area into the Rocks and Millers Point.

In 1950 the establishment of the Cahill Expressway effectively cut off another piece of the Rocks and isolated what was left from the city.

It is interesting to see how history moves. There is now talk of pulling down the Cahill Expressway and one wonders whether there will be an outcry from "heritage". One cannot help wonder how anyone could perceive this monumental blockage of a city foreshore as anything but an ugly, monstrous desecration of a magnificent view. One has to wonder what Captain Phillip would say afterall "Gentlemen and ladies to the left" and "convicts to the right". The latter went up onto the rocky ground on the western side of Sydney Cove.

Campbells Storehouse

This building was originally called the Old Metcalfe Bond Store and had its origins with Robert Campbell, the Colony's first merchant trader.

The building is a series of two storey stores with pitched slate roofs. The construction whereby the dividing walls went up through the roof space thus isolating each section was the building method devised after the great Fire of London where the fire "raced" through the ceiling spaces.

We had a visit from Customs Officers who told us we were breaking the law by using the words "Bond Store". Not wishing to visit Long Bay, we obliged by changing the name.

The building was heavily attacked by rising damp and salt. Continuous rendering had only drawn the salt higher. The task was to insert a damp course. The first attempt was to use a technique developed in the work on the Temple of Dawn in Thailand using a sawing technique but this was too severe on the structure. I recalled my time with Worthington and high pressure pumps used for cleaning tube stacks in refineries. So we tried high pressure water at 3500 psi (I am still in the old school of psi) and cut our way through the joint. We found their was two "walls" of stone with a rubble core. We then inserted aluminium pieces with a claw on one side and a bulb on the other so they locked together along the line of the saw cut - a shot of waterproof grout and we had it a workable damp course.

Getting the salt out of the stone above the dampcourse was another story - we tried everything, sacrificial render, you name it. In the end just plain water worked ok.

We had to reslate the roof - some kind people around 1929 - 1932 had done the reslating using galvanised nails, God bless them - my successors and assigns will find the copper nails of 1976/77 still in place.

We would have liked to drop the level of the road in front of the Storehouse on the harbourside. However the Electricity Commission wanted a "few million" to lower their cables so we desisted.

Opera House

Across the bay was the great wonder and tribute to engineering. I delighted during autumn to look out my office window at the Opera House with the sun dropping behind the big coathanger and seeing the shadows of the buses, trains and cars pass across the white sails of the new Sydney Icon.

People of the Rocks

What a wonderful group they were. From people who had seen the plague in Sydney to a very special coterie of so called "derelicts' who delightfully each had a story to tell and a "place to live". As we renovated each building we inevitably turned up a "pied-a-terre" of one of our friends.

Then there were people like Dolly Bonette - born in No 1 Atherden Place, grew up in No 3, married in No 5 and retired to No 2. Sadly I last saw her in 1993 and when I called recently she had passed away. She told me some fascinating stories of the Rocks which are better in the telling than the writing.

After all history is people and without them their is no history.

Well this paper has been short on technicalities and long on an historic journey. It was a great privilege to serve history - I trust you enjoyed the journey.

Thank you for your time .

Claremont: A Case Study of Engineering in Building Conservation

J.W. Jordan, FIEAust
Bill Jordan & Associates, Consulting Engineers, Newcastle NSW.

SUMMARY
Claremont is a two storey Georgian residence in Newcastle, NSW dating from c.1840. Its conservation and adaptation for re-use involved many engineering challenges in order to provide necessary strengthening while causing least disturbance to the existing fabric. Requirements included underpinning and strengthening of the whole building to resist earthquake loadings. The paper describes the work carried out, including technical aspects of the engineering design and relates the work to the principles of the Burra Charter of ICOMOS, used as a basis for the IEAust Engineering and Heritage Guidelines.

1 INTRODUCTION

1.1 History

The site of Newcastle, New South Wales, was first discovered in 1797 and settled permanently in 1804 with the establishment of a permanent convict camp and military garrison with the object of mining coal. Commercial mining was commenced by the Australian Agricultural Company in 1830, when the population was about 300, and this promoted the town's growth.

The origins of the building known as "Claremont" or "Claremont House" are uncertain, but it is known that the land was first sold to a Richard Read in 1835 and that a building did exist by 1838. It is possible that this building forms the basis of the present Claremont. It is definitely known that the building then known as Claremont was occupied by Alexander Brown and his family in 1846 and that he is recorded as having "built Claremont". Alexander Brown went on to be a prominent figure in Newcastle's mining history.

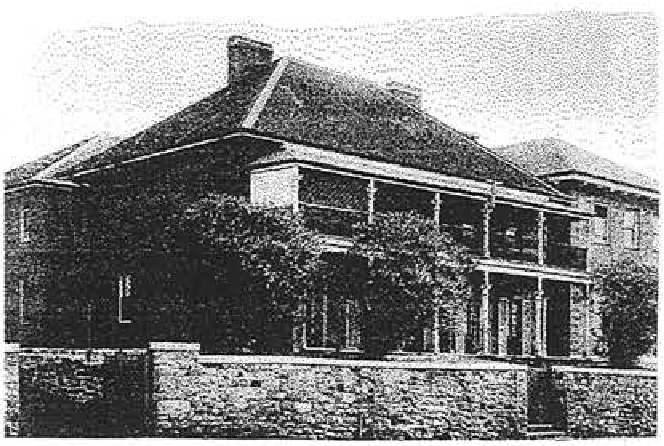


Figure 1: Claremont in 1924.

1.2 Description Of Building

As it presently exists, Claremont consists of a two-storey brick building 13.8m wide by 9.9m deep. It has sandstone block footings founded on sand and has a hip roof. The symmetrical floor plan consists of four rooms of equal size on each floor with a central hallway. A two-storey verandah is built along the front and early plans show that it had a wing for the kitchen and other services at the rear.

Original fabric was retained throughout the building thanks to its not having been altered in any significant way since acquisition by its present owners after World War I. Examples of some of the important retained fabric include:

- timber shingle roof intact under the corrugated steel sheeting,
- adzed paper-bark (*Melaleuca* sp.) log floor joists on the ground floor,
- pit-sawn hardwood first floor joists,
- original lime plaster internal finishes on walls and ceilings,
- original hardwood timber flooring in most rooms,
- original cedar (*Toona Australis*) joinery and window shutters,
- Georgian/early Victorian cast iron fire grates.

It has been suggested that the survival of so much early fabric makes the building one of the most important early colonial buildings in Australia.

In 1879 the building was "Victorianized" by the addition of a two-storey front verandah with cast-iron lace balustrades. Services were installed progressively throughout the building's life, not always sympathetically to the fabric. Found during conservation were lead waste piping, remains of an early electric door bell and the wires and pulleys of an internal servant signalling system.

The building was connected to the adjacent new building as the new owners took control in the 1920's and was then used as part of the owner's premises.

1.3 Structural Niceties

Many aspects of the buildings structure are of interest and indicate a level of building skill which is rare for the period. In particular, the hipped roof structure in hardwood timber is notable for having a system of ceiling joists, running parallel to the rafters above, which are tenoned and pegged to tie the structure together in both directions. The building also has an articulation joint in the side and central walls which coincides with the probable position of the cut/fill line on the site. Even some present day builders seem to be unaware of the need to counteract roof spreading forces at hip ends and are very loath to articulate brickwork.

2 CONDITION OF THE BUILDING

2.1 Before the Earthquake

After acquisition by the present owners, the building continued in residential use without change for many years. Some restoration was carried out in the early 1960's which included replacing the external render with a more waterproof cement-based render and re-sheeting the roof. After that time the building was mainly used for storage and staff amenities until deterioration became too great.

Termite infestation was the dominant problem in the period up to the Newcastle earthquake of December 1989. This mainly affected the first floor where many joists were completely destroyed and the floor only stayed intact by being held together by the flooring. During conservation work the nest was found located within the first floor structure.

No termite damage was found in the roof structure and only a small amount in the ground floor structure. Very little of the cedar joinery was affected.

2.2 Earthquake Damage

Earthquake damage to the building was extensive, but relatively minor, consisting mainly of minor (less than 5mm) masonry cracks and loss of plaster. The southern wall had bowed outwards in the middle. Survival of the building is considered to be due to:

- the strong roof structure holding the building together at the top and
- the ability of the soft masonry to absorb energy without major deformation.

The need for conservation training of engineers is illustrated by the divergent opinions given by those who inspected it soon after the earthquake: recommendations ranged from minor repairs to early demolition.

The owners were placed in an almost impossible position. The potential insurance cover to repair the earthquake damage did not appear sufficient to put the building back into use, yet they were prevented from demolishing it by heritage requirements. Moisture ingress from cracking in the walls was leading to accelerated deterioration of the brickwork and delay could have led to structural instability.

To add to the problems, the Newcastle earthquake led to a re-evaluation of building requirements in Newcastle which included the need to provide strengthening for earthquake resistance as part of any repair or restoration. In the end the impasse was resolved by a grant under the Australian Government's Heritage Properties Restoration Programme which, together with the insurance settlement and the owner's own funds was sufficient to conserve the building properly and return it to use.

3 THE AUTHOR'S INVOLVEMENT

The author was first asked to give an opinion on the building in early 1992 when it became apparent that conservation in some form was the only option available to the owners. Up to that time opinions had been obtained from three different firms of consulting engineers, two architects and a reputable builder with the majority seeming to be of the opinion that demolition was the only viable option. In the first instance the engagement involved providing information used in making and assessing the insurance claim. Following notification of the Government grant the author's then firm, Hughes Trueman Ludlow Engineers, was engaged to project manage and provide engineering services for the conservation and adaptive re-use of the building.

4 GEOTECHNICAL INVESTIGATION

It was readily apparent that foundation movements had contributed to the earthquake damage and that the building had also either moved or been expected to move early in its life as provided for by the articulation joints. The first stage of the project was therefore to undertake a geotechnical investigation of the foundation soils to determine:

- whether the foundations could carry the loads likely during its proposed use, and
- whether further movements were likely during future earthquakes.

The investigation consisted of a series of augur holes, penetrometer tests and geological mapping of the site, followed by laboratory testing of recovered materials. The site was found to consist of loose to very loose sands up to 3.2m deep overlying dense indurated sand. Nobody would contemplate putting a lightweight framed building on such a site today, yet a solid masonry building had stood there for 150 years with very little foundation movement.

The geotechnical report concluded that "The 1989 Newcastle Earthquake may have caused some densification and settlement of the soils beneath the foundations which would cause or contribute to the observed structural distress. Further earthquakes and other sources of ground vibration could cause similar effects if the foundations remain in their condition."(1)

It was clear that the foundation conditions would have to be improved in order to meet the new earthquake resistance requirements.

It is interesting to note that, in general, insurance companies did not consider that foundation conditions were insurable and that any underpinning of a building was an expense that should be borne by the owner. In this case, however, it was accepted that the statutory requirement to strengthen the building for future earthquake loading extended to the foundations.

5 CONSERVATION PLAN

5.1 Basis

Under the terms of the relevant legislation and planning requirements, preparation of a conservation plan was the next step in the process to commence work on the building. It was prepared by a firm of Architects(2) on behalf of the author's firm and in accordance with the recognized procedure in Australia set out in J.S. Kerr's "The Conservation Plan"(3).

It is useful to quote from Kerr's book as it explains the procedure which followed:

"...a conservation plan is a document setting out what is significant in a place and, therefore, what policies are appropriate to enable that significance to be retained in its future use and development."(4).

Note the implication, more fully explained in Kerr's book, that conservation is not a process which excludes modern development but one which assists that development when it encompasses historic works. Conservation certainly does not imply, as many believe, that heritage works are only suitable for preservation and to be a continung drain on scarce resources.

In turn, the procedure set out in Kerr is based on the "Burra Charter" of Australia ICOMOS. This document has more recently been set out in full in "Engineering Heritage & Conservation Guidelines" of the Institution of Engineers, Australia(5).

5.2 Procedure

In the first phase of preparing the conservation plan, a professional historian was engaged to prepare a history of the building which was essential in establishing its cultural significance. This involved obtaining information from primary sources such as colonial land transaction records and newspapers of the time. It was instructive to note the differences between the properly researched history and the otherwise "known" history of the building: the original owners, Read and Brown, had not been previously recorded and the age of the building was up to ten years greater than previously thought. The significance of the building was also increased by this knowledge.

The building's owners wished to use the conserved building for meeting rooms and accommodation and so the next phase of the conservation plan involved the architects in preparing designs for adaptive re-use which allowed the new use within the original fabric and as sympathetically as possible. Luckily, the proposed use was very similar to the building's original use which appeared to have comprised bedrooms, sitting rooms and dining room, the kitchen and bathroom having been in the long demolished annex at the rear.

The accommodation requirements included the provision of attached bathrooms. This was accomplished by the architect by the provision of a new link building between the rear of Claremont and the remainder of the owner's premises and the placement of the bathrooms in the link building. Not only did this make it unnecessary to include a use not previously located in the building, but it did not require the major modifications and inevitable compromises associated with providing plumbing in an old building. The link building also provided the necessary fire safety egress from the upper floor and allowed the original staircase to be retained without modification. Preliminary design for these facilities comprised a necessary part of the conservation plan.

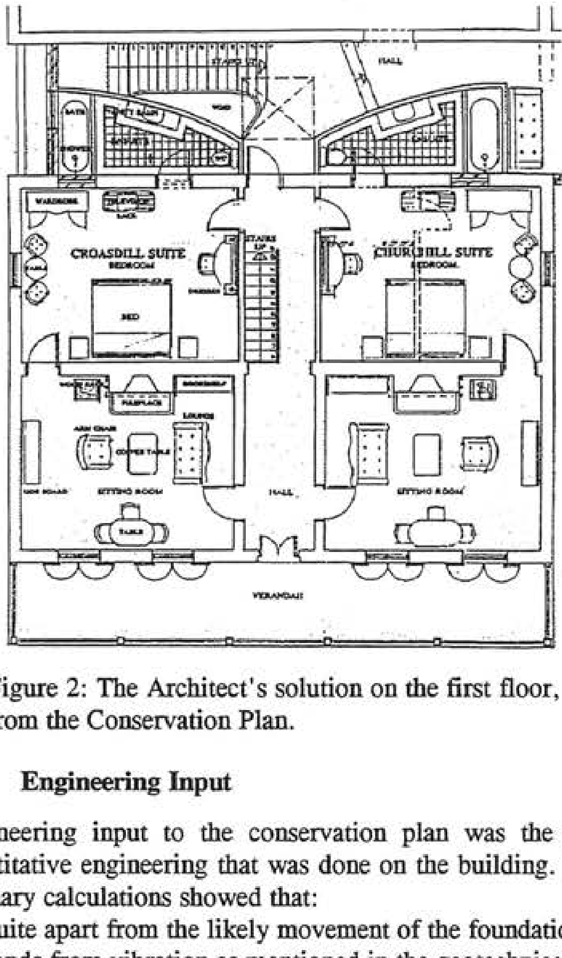


Figure 2: The Architect's solution on the first floor, from the Conservation Plan.

5.3 Engineering Input

Engineering input to the conservation plan was the first quantitative engineering that was done on the building. Preliminary calculations showed that:

- quite apart from the likely movement of the foundation sands from vibration as mentioned in the geotechnical report, the footings were not of sufficient size to spread the required dead and live loads from the proposed new use;
- the roof was adequate for current design code loadings but needed more positive tie-down to the walls;
- the walls required support and strengthening to satisfy wind and earthquake loading requirements;
- even discounting the termite damage, the first floor joists were below currently accepted sizes.

6 ENGINEERING SOLUTIONS

6.1 Commencement of Work

Conditions of the government grant included a requirement that the work was to be effectively finished in nine months. This was at a time when documentation had been scarcely commenced and neither development approval nor building approval applications had been made to the City Council. The owners therefore accepted the recommendation that the work be carried out by project management using a number of smaller preparatory contracts in the lead up to the main building works contract. This allowed time for documentation to be completed and the necessary delays between various phases of the work could be used by the approvals processes.

Separate contracts were awarded to:

- remove all joinery and floor boards with careful position recording and their placing in safe storage,
- restoration if joinery with the contractor being nominated as a sub-contractor for re-installation in the subsequent building contract,
- foundation stabilization,
- provision of a damp-proof course and, finally
- a major building contract to complete the conservation including adjacent new works.

Removal of the floor boards at this early stage had a number of advantages:

- the archaeological investigation could be carried out more easily and the underfloor areas proved rich in small items;
- injection of the foundation stabilization material could be carried out inside as well as outside the building;
- a thorough structural inspection of the floor could be carried out prior to preparing building contract documentation.

6.2 Foundation Stabilization

The standard method used for underpinning a building is to dig under the footings and extend them in concrete or masonry to satisfactory underlying bearing material. Alternatively, the work is sometimes carried out by placing piers or piles beside the walls, either straight or skewed, and then to transfer the building load to the piers by transfer beams or "needles". Neither of these common methods was considered suitable as:

- the existing footings were made from small unbonded sandstone blocks and did not have sufficient stiffness to carry the walls over a temporary excavation of any size;
- the soft crumbling wall masonry may have been damaged badly by the work necessary to construct beams through it to transfer loading to new piers;
- the mechanical process used to install the piers may have caused wall damage.

The geotechnical investigation had shown that the sands beneath the building were relatively porous and so it was considered that some form of in-situ strengthening of the sands by liquid injection was possible. This method was also the one least likely to disturb the building during installation.

Specialist firms were contacted and, after confirming the feasibility, tenders for the strengthening were invited from three experienced firms. The tender documents were drawn up on a quality assurance basis and with the requirement that the contractor provide a certificate of adequacy at the end of the work. This was considered necessary as proprietary products were to be used and the consultant team had little direct experience in the process.

The contractor used a system which injected catalysed sodium silicate. The work commenced with the conduct of trials near the building to determine the viscosity requirements of the injected material: too high and it could not be pumped into place, too low and it would spread instead of building up under the footings. The mixture also had to be adjusted slightly for the different sands on the site.

The test areas were cored and tested by the geotechnical consultant and, after some minor adjustment to the installation procedure all foundations of both internal and external walls were stabilized, creating in effect, a large platform with the bearing capacity of soft sandstone (300kPa or more compared with as low as 30kPa unstabilized).

6.3 Damp-proof Course

The building fabric, particularly the walls, was being damaged by rising damp as well as moisture penetrating the walls. The foundation stabilization was expected to worsen this problem as the building site would not drain as easily once the sand foundations had been made less porous.

Considerations in choosing a damp-proof course for a heritage building have been discussed elsewhere by the author(6). In this case it was decided that an injected material was most appropriate and a licensed contractor for a proprietary process using a siloxane compound was engaged. In addition, a subsoil drain was installed during the later building works to carry away any groundwater trapped by the "dam" formed by the foundation stabilization.

6.4 Wall Strengthening

The walls presented the most challenging aspect of the engineering required to conserve the building. They were built using soft sandstock bricks with lime mortar: the bricks did not appear to have been fired at very high temperature and the lime mortar contained much unaltered shell indicating poor preparation of the lime.

An attempt was made to carry out a bond wrench test(7) to determine if the brickwork had any flexural strength: all bricks could be removed by hand with very little effort. It was therefore reluctantly concluded that the walls had no flexural strength except to the extent that any tensile bending stresses were less than the compressive stresses induced from loads above. This meant that, providing the brickwork was adequately secured to the first floor and that the floor was strong enough to transfer the loads, the ground floor external walls could resist the design wind and earthquake loads but the first floor walls needed strengthening.

Two methods of strengthening the first floor walls were considered, the insertion of reinforcing bars into the masonry and the provision of a reinforced skin on the face of the masonry.

Reinforcing bars in the walls were rejected because of the likelihood of causing serious damage to the brickwork

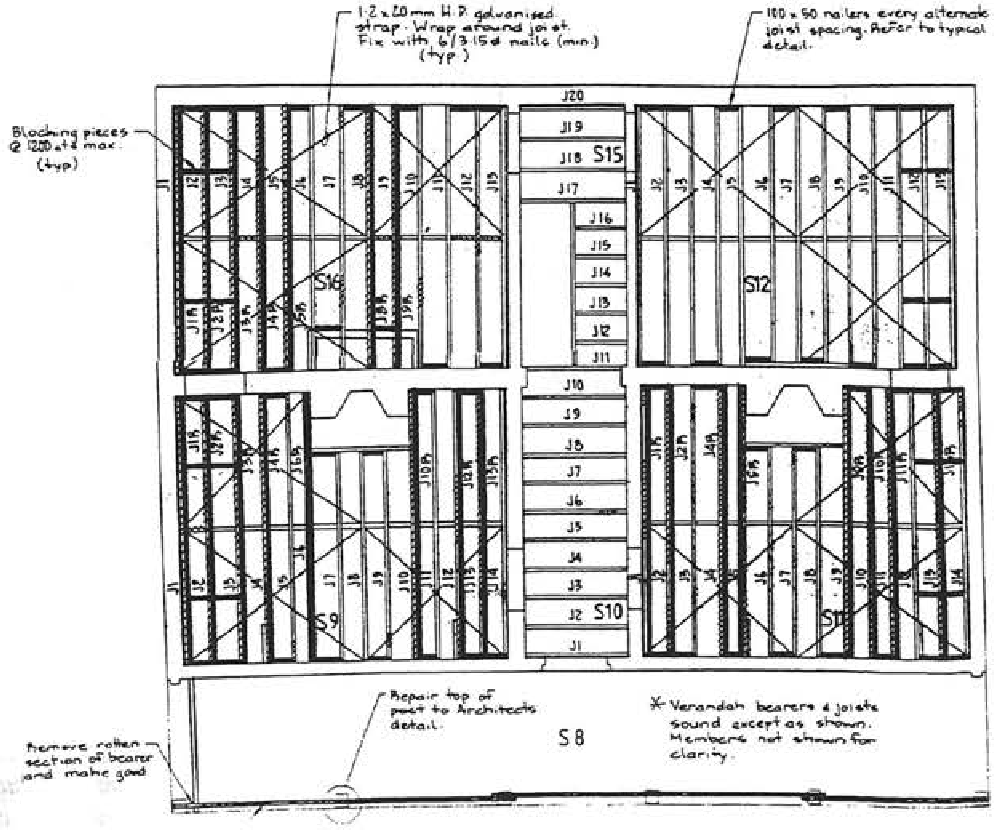


Figure 3:

Extract from structural drawings showing bracing and strengthening. Note how each individual existing member was assessed and shown on the drawings with a separate schedule for details of the repair requirements.

during drilling and the problems of anchoring the reinforcement at the top and transferring the load to it.

The design of a reinforced skin was complicated by the need to retain the original internal plaster finishes, allowing only the external face to be reinforced.

At this stage a careful re-assessment of the dead loads was made to ensure that the calculations took full account of any compression in the brickwork: the presence of the original shingles in the roof and the thick lath and plaster ceilings were of considerable assistance in this. The resistance of the building to lateral loading was also assisted by the attachment of the full length and height of the rear wall to a new structure. Calculations then indicated that adequate lateral resistance could be given to the rest of the building by reinforcing the base coat of the external render (The external walls were finally finished with coats of lime render to match that of the period as closely as possible.). Calculations in a case such as this can not be precise and a good deal of engineering judgement was required in the final assessment.

The building is located less than 500m from the coast so reinforcement corrosion was of concern. After investigation of the alternatives, it was found that a polypropylene reinforcement would give satisfactory results.

6.5 Floor Structure

6.5.1 Requirements

Problems that had to be solved in conserving the first floor structure were:

- the extensive termite damage,
- its large span to depth ratio compared with current standards and
- the need to have it act as a diaphragm to stabilize the masonry.

The floors in each of the rooms of the first floor were the same and independent of each other. The short span floor in the hallway was of no structural concern.

6.5.2 Termite damage

Despite the termite damage, the ceiling in the ground floor rooms was relatively intact and had to be retained if at all possible; the joists and joist fragments which were intact were also of historical significance. It was decided to leave all existing materials in place and place additional joists alongside them.

6.5.3 Floor strength

If the work had been carried out strictly in accordance with current building codes it would have been necessary to either increase the depth of the floor or use a stiffer material than hardwood timber for the joists. Increasing the depth of the floor would not have been easily possible as it would have affected so many other parts of the fabric. Galvanized cold-rolled steel joists were considered but rejected as being prone to corrosion where bearing in the external walls.

A consideration of the design requirements for the floor joists was made from first principles. Hardwood joists would have the strength to carry the loads required by current loading codes, but their deflection would not be in accordance with current expectations. The likely service loading was considerably less than those laid down in the SAA Loading Code.

It was firstly determined that the conserved ceiling would be able to cope with the deflections and then the whole situation was explained to the owner who was willing to have a slightly "bouncy" floor. In the finished building the movement in the floor helps give the building character and does not seem to be objectionable to occupants.

Second-hand hardwood timbers were obtained of the same section and laid alongside damaged joists.

6.5.4 Diaphragm action

It was necessary to strengthen the floors to act as a diaphragm and connect the walls on all sides. This was done using chemical masonry anchors in a manner developed for strengthening buildings following the Newcastle earthquake and described in an earlier paper(8).

The butt-jointed floor boards were not able to resist racking loads that would be imposed in transferring loads through the floor. The floor structure was therefore braced with a system of braces made from galvanized steel strapping nailed to the top of the joists before the flooring was re-laid.

6.5.5 Ceiling

The ground floor ceiling was secured to the upper floor joists using an acrylic resin in a procedure now common in similar conservation projects.

7 THE BURRA CHARTER

7.1 Application

Work on a place such as Claremont involves application of most aspects of the Burra Charter. Many of the engineering decisions were controlled by Charter principles and a description of some of the considerations will provide a fitting conclusion to this paper.

Of particular note is the hierachy of measures implicit in the Charter. This can be briefly set out as:

- *preservation* is the first choice,
- *restoration* is only appropriate if it reveals cultural significance and bearing in mind that the contribution of all periods should be respected;
- *reconstruction* should be limited to what is necessary for survival of the place;
- *adaptation* is acceptable where conservation cannot otherwise be achieved;

Readers are referred elsewhere for the Burra Charter in full (3)(5). In particular, the definitions of the terms used should be considered carefully as they are more precise than for the same words in common use.

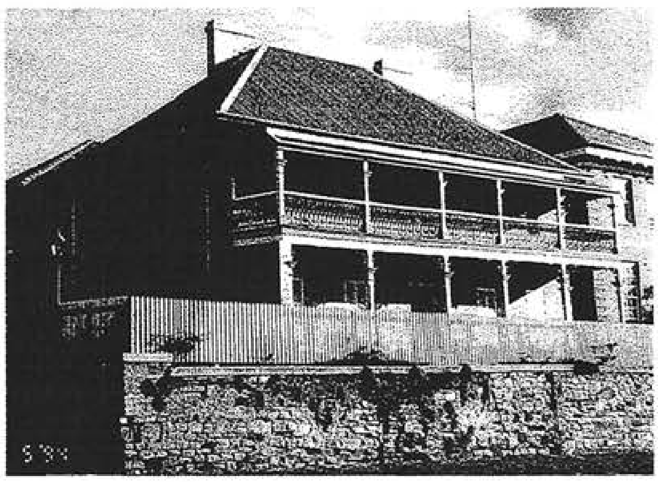


Figure 4: Claremont following conservation.

7.2 Examples

7.2.1 In the examples which follow, "Article 2" etc. refers to articles (sections) of the Burra Charter.

7.2.2 Article 2

The whole project, including negotiations to ensure adequate finance, was aimed at providing for "its security, its *maintenance* and its future."

7.2.3 Article 3

As examples of measures to "involve the least possible physical intervention" to the existing fabric:

- existing floor joists were left in place, however damaged, and supplemented by new ones;
- the first floor was not strengthened to meet current deflection requirements;
- the internal plaster finish was retained rather than replacing it to make wall strengthening easier.

7.2.4 Article 4

"Techniques employed should be traditional but in some circumstances they may be modern ones.....". Examples include:

- the use of fibre reinforcement in the base coat of the external render;
- the use of chemically bonded masonry anchors;
- the use of acrylic resin to reinstate the ceiling adhesion.

7.2.5 Article 11

Preservation of much of the fabric of Claremont was considered appropriate because of its significance. It was also fortuitous that the preserved fabric was adequate to continue its function.

7.2.6 Article 12

Stabilization of the existing fabric by strengthening the masonry with the reinforced render and securing it to the floors was a part of preservation and did not distort the cultural significance.

7.2.7 Articles 13 to 15

Little restoration was necessary (or possible) at Claremont. However the procedure used to remove floor boards, for example, allowed their restoration in accordannce with Article 15: all were carefully marked and restored to the same locations.

7.2.8 Article 16

The decision to leave the building in the Victorian style rather than attempt to return it to the original was an example of respecting all periods in the history of the place.

7.2.9 Articles 17 to 19

The inclusion of scribing in the new external render to represent stonework was an example of reconstruction. It was based on evidence and helped reveal the cultural significance of the whole.

7.2.10 Article 20

Adaptation of a building is always necessary for an owner to obtain worthwhile use of it. At Claremont this was made easier by the proposed uses of the rooms being very similar to original uses. Attention to design detail by the architect ensured that the adaptation had minimal affect on the fabric, especially:

- the location of all facilities requiring plumbing outside the building;
- the disguising of air conditioning units as items of furniture;
- the use of string-pull light switches;
- the concealment of electric power outlets behind hinged sections of skirting.

8 CONCLUSIONS AND RECOMMENDATIONS

Use of the Burra Charter for the conservation of buildings is not a hindrance to the engineering solution but leads the engineer along a path of discovery and innovation. The final result can give professional pride and satisfaction which is often missing from engineering practice when dealing with small scale works.

9 ACKNOWLEDGEMENTS

The author wishes to thank his former colleagues of Hughes Trueman Ludlow Engineers for access to their records and architect Barney Collins of EJE Architecture, Newcastle for his inspirational architectural solutions which made the project what it became.

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An Historic Bridge Lives On.

J. A. INCE, City Engineer (retired) Christchurch, New Zealand.

Christchurch was established in 1850 when the first English settlers arrived in Lyttleton. By that time the Canterbury Company, which was responsible for founding the city, had decided the location of Christchurch and had surveyed the layout of the new city. The site on the eastern edge of the Canterbury Plains was close to Lyttleton but was beset with swamps and two small rivers. One of these, the Avon, ran through the centre of the city and its presence was to become a challenge to the citizens as they attempted to go about their daily business. Bridging the river was vital to providing access both within the boundaries and also to the hinterland from which Christchurch was to derive its wealth. The Victoria Bridge which is the subject of this paper was the first permanent bridge to be built by the pioneers and provided a vital link across the Avon River to the north west settlement of Papanui and farmland beyond..

1. INTRODUCTION.

The bridge which is the subject of this paper is located in Victoria Square, two blocks north of Cathedral Square and identified by a circle in Fig. 1. Along with several other bridges in central Christchurch it is classified by the Historic Places Trust and listed in the City Council District Scheme as a structure of historic importance. Significantly this bridge is the oldest of those listed and has been selected for special treatment.

In the young city, Victoria Street and the bridge over the Avon River were part of a vital link to the north-west to Papanui. Victoria Square was called Market Square at that time and the activities in the square seem to have created a lot of traffic on the bridge. A survey undertaken one day in 1862 records that

> *10 bullock drays with 58 bullocks, 51 horse drays with 60 horses, 36 carts with 51 horses, 199 saddle horses, 20 cattle, 204 sheep, one solitary donkey & cart and 1000 foot passengers (used the bridge) (4)*

This was a busy place.

Since the 1960's the streets surrounding Victoria Square have experienced great change. The first evidence of this change was the construction of the Christchurch Town Hall in 1974 on the north side of the Avon River and adjoining the bridge. Next came the Park Royal Hotel. For that to proceed Victoria Street was stopped between the bridge and Durham Street and the route to Papanui which had served for 120 years was gone.

As a final stage of rebuilding the block bounded by Durham Street, Kilmore Street, Colombo Street and Armagh Street, the City Council stopped nearly all of the remaining streets within the block and undertook a complete reconstruction of Victoria Square. Although no longer needed for traffic, the bridge was retained as a focal point of this new design. A number of ideas had been advanced for incorporating the bridge in the landscape design for the square but what was selected was an opening of the bridge deck to show the structural components and the river below. The designers elected to surround the opening with a replica of the fine cast iron balustrade which was erected when the bridge was widened in 1885. The replica is cast in aluminium and although the style is the same as the original, the section is thinner. Sufficient of the below deck structure remains to show the uninformed public and the informed engineer something of the art of the 19th century engineers.

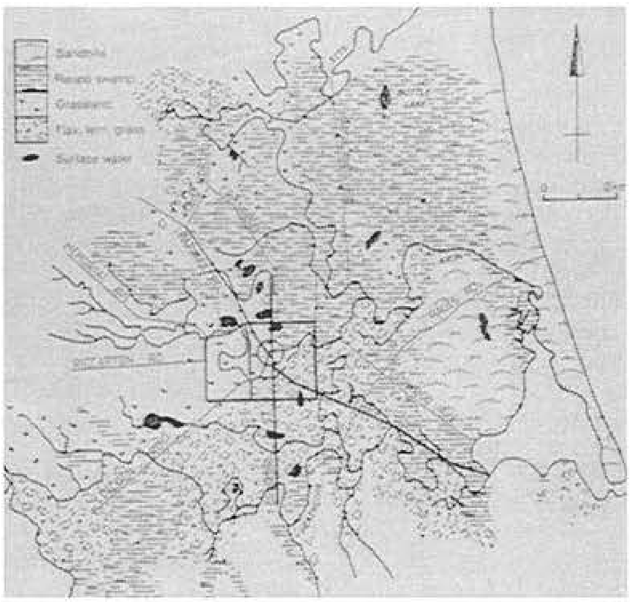


Figure 1 Christchurch: Swamps & Vegetation 1856 (from Drainage Board Black Maps)

2. THE BEGINNINGS.

A glance at the old black map (Fig. 1) of Christchurch as it was in the 1850's shows that much of the land chosen for the settlement was swamp. Certainly the city was to be located on a tussock covered gravel island with Cathedral Square somewhere near its centre. But even this bit of high ground was crossed by a river which we now know as the Avon. Other watercourses crossed the present city centre so that movement must have been quite a problem. The city as founded was entirely within the four belts which are now known as Bealey Avenue and Moorhouse Avenue, forming the north and south limits, and Fitzgerald Avenue and Rolleston Avenue forming the east and west limits. The city could not survive on its own internal economy so there was obviously an immediate need for access to the hinterland.

In particular the early settlers needed to have an all weather route to the north west to gain access to Papanui which in 1850 was a source of timber (from the Papanui Bush) and to the plains farmland beyond. The road to Papanui had as its first obstacle to cross the Avon River. The first bridge was known as Papanui Bridge and to those early settlers it was on Whateley Road. The bridge was built in 1852 and was a three span wooden bridge of one cart width.

No doubt the wooden bridge was built of local materials of unproved quality for by September 1863 the Provincial Council declared that it was unsafe.

3. THE PERMANENT BRIDGE.

Because of the regional significance of the route, and probably also because the newly formed City Council and its residents were strapped for cash, the provision of funds for the new bridge was the responsibility of the Canterbury Provincial Government. Even presuming that the Provincial Government had the cash the building of a permanent structure was no simple matter. No doubt memories of their homeland influenced the settlers to look for a style which would remind them of where they had come from. This must explain why they elected to build in stone and cast iron with the latter being imported from England. Not the easiest of materials to choose but one which has provided a lasting memorial to the pioneers.

How they selected the manufacturer is not recorded but the difficulties were formidable. No telephones, no fax, just sea mail by sailing ship. That means between ten and twelve months for a reply! Early in 1863 an order was despatched to Messrs Fox & Henderson, iron founders, in England for an iron bridge. Again there is no record of how the size of the girders was arrived at. Probably the manufacturers were left to decide what to do to suit the span that must have been fixed in Christchurch. Perhaps the letter just said

> *"Please supply an iron arch bridge suitable for a span of fifty feet and dispatch by ship to Lyttleton, New Zealand at your earliest convenience. The bridge will be used by cart traffic and should have a width of 30 feet."*

The following report of events was part of an article by R.E.Green (2). He was present at the opening of the new bridge in September 1864.

> *These girders were each cast in three pieces with stout flanges to be bolted together to form one span. They were very massive and strong. When they were ready to be shipped the agent condemned a lot of the parts of the castings which were found to be faulty. This caused much delay. However in the meantime the Council decided to call tenders to build the bridge so as to get on with the stonework. The tenders were called for on September 23 and were to be in by October 20. They were not considered satisfactory, and it was then decided to hand over the building of the bridge to the City Council on the understanding that the total cost did not exceed £3000. This sum was to include the ironwork which was to cost £605 landed on the spot. On November 5th 1863 the Provincial Secretary wrote to the City Council to that effect and added that the City Council could have free of charge all the stone required from the Provincial Council yard, opposite Government Buildings in Durham Street.*

> *The plans were handed over to Mr F. W. Moore, the City Surveyor, who altered them. They were afterwards approved by the Provincial Council, which on December 3rd, called fresh tenders to be in by December 14. Four tenders were received. The highest was that of W. H. Barnes, £4875 --- Barnes had a foundry in Durham Street just south of the Devonshire Arms now the Gladstone Hotel. The lowest tender was that of E. G. Wright --- £2375. This was accepted and on January 11th 1864, the City Surveyor reported that the erection of the iron and stone bridge was in the contractor's hands. On that date the Papanui Bridge passed out for ever.*

While the new bridge was being constructed, businessmen and citizens alike had to make other arrangements for a period of eight months. This meant using one of the quite inadequate bridges nearby. An early photograph shows the stonework under construction (Fig 2).

Figure 2. Building the Bridge Foundations 1864
- Dr A.C.Barker (courtesy Canterbury Museum)

The ironwork was eventually dispatched to New Zealand on the *Amoor* which duly arrived in July 1864 after a quick passage. Unfortunately the ship rolled badly for most of the voyage causing the cargo to shift and roll from side to side making matters very uncomfortable for the passengers. That the ship did roll was evident by the state of the cargo and when the ship did arrive it transpired that three of the girders were badly cracked. Another extract from Green's article tells the story.

> *However the ironwork arrived in the first week of August and then mountains of trouble were manifest. It was landed on the ground in dire disorder and it cost £150 before each part was cleaned and assigned to its place. This was only the beginning of the greater trouble. It was found that three of the girders were cracked and otherwise damaged. They were absolutely useless as they were. However, Mr John Anderson took the repairs in hand, and by riveting wrought iron plates on each side of the cracks and otherwise strengthening the girders, they were made as strong as ever. This entailed an expenditure of over £300.*

The John Anderson mentioned was, of course, one of the founders of the well known Christchurch company of Anderson Bros. which contributed to the industrial strength of Christchurch for over a century. Evidence of the quality of John Anderson's work comes from the uneventful working life of the bridge. The photographs in Fig. 3 & 4 show the rough but effective way in which this work was carried out. It seems that as well as the substantial plates bent over some of the web stiffeners at the end of the cast sections and smaller web plates covering cracks, John Anderson added extra iron on both top and bottom flanges of the girders. Some of this work may, however, have been done in 1882.

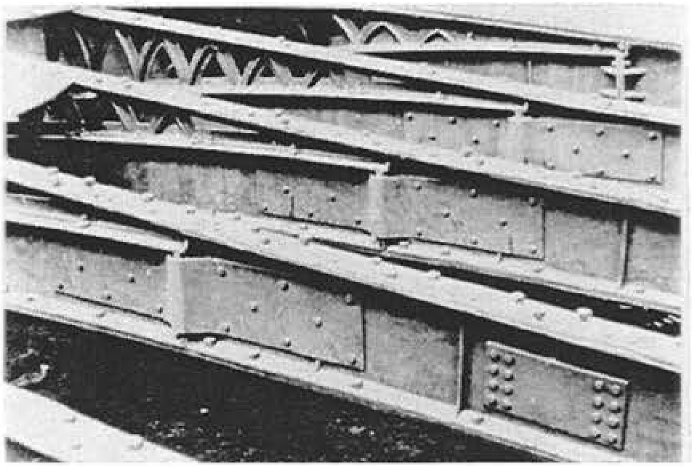


Figure 3. 19th Century Repairs.

Green continues:

> *The contractor was well ahead with the stone work, and when the iron work came to hand, he pushed on with all speed, and by the second week in September he had practically finished his contract. The whole of the bridge surface was covered with asphalt, something uncommon for that period, and a footpath was formed on each side. On Monday September 26 1864 the City Surveyor reported to the council that the iron and stone bridge was a last ready to be opened for traffic. The cost was already said to be £3410, but other charges had to be added to this, which brought the cost up to quite £4000.*

The new bridge would have been a permanent structure if it had not been for the subsequent need to increase the width. Given that the population at that time was between 2000 and 3000 it was a creditable effort.

For those who are interested, several pictures of this first stone bridge are shown in *Old Christchurch* in Plates 100, 101 and 131 (3).

4. THE NINETEENTH CENTURY CHANGES.

Two widening jobs were done before the final width was reached. The first of these jobs commenced on February 16th 1875.

> *The work of widening Victoria Bridge was commenced this morning*

the council was informed at its weekly meeting. Evidently progress was rapid so that by May 31 1875 the council heard that

> *If we are favoured with three or fours days fine weather, the Victoria Bridge footpath and roadway will be finished this week.*

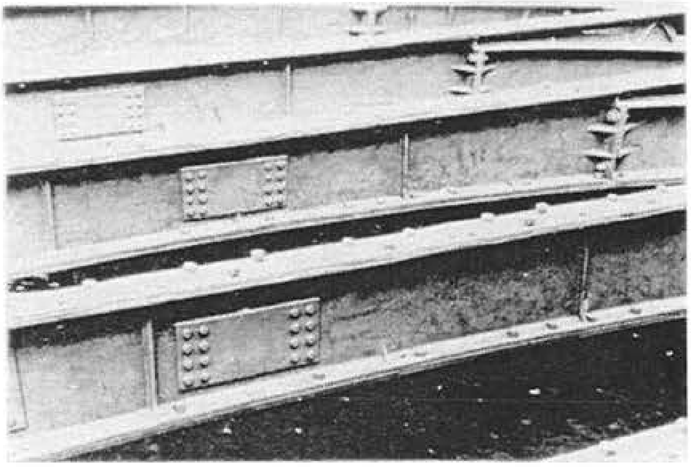


Figure 4. 19th Century Repairs.

By June 28th the Press reported that it was now finished except for the painting.

The cast-iron arch members evidently continued to give problems as on April 17th 1882 the City Surveyor reported

> *I find that two of the iron girders in the Victoria Street bridge are fractured and will require some measures being taken to prevent the damage extending. I do not*

imagine it will be a very expensive affair and I hope to be able to repair it without taking down the bridge.

The second of the 19th century changes to the bridge occurred in 1885 when a loan of £1400 was raised to widen the bridge to 66ft overall. The work was undertaken by W.B.Scott who was also building the Worcester Street bridge at that time. Fig. 5 shows one of the plans for the work signed by W.B.Scott on April 24th 1885. He experienced problems with the supply of stone but completed the job in September 1885. The source of the extra cast iron girders is not recorded but could well have been Anderson's foundry.

5 VICTORIA BRIDGE TODAY.

The plaque on the south east abutment tells the story.

> A wooden bridge "Papanui Bridge" was erected on this site in 1851. That bridge was reconstructed in 1855 - 56 to a width of 16 feet.
>
> The cast iron and stone "Victoria Bridge" was built in 1863-64. It had a width of 27ft. 6in. and was reputedly the first such bridge in New Zealand.
>
> In 1875 the bridge was widened by the adding of wing piers and wooden outrigger footpath. A further widening in 1885 brought the bridge width to 66ft. and saw the bridge in its present form.

he present form did not in fact survive for long after the plaque was erected in 1985 as changes to Victoria Square and the closing of Victoria Street resulted in yet more changes to this much altered bridge.

> "Victoria Bridge" was closed to traffic in April 1988 prior to the commencement of Stage I Redevelopment of Victoria Square.
>
> The deck was opened up in June 1989 as part of the Stage II Redevelopment of the Square.

As part of this opening up a new balustrade was cast in aluminium to protect the central void. This is the same pattern as the original cast iron balustrade but has a reduced thickness. Inside the void can be seen four of the cast iron segmental arches which supported the deck. These show quite severe cracking which as the above history tells were a consequence of the rough sea trip in 1864. Close examination discloses a variety of strengthening plates applied to both webs and flanges of the cast iron members. This must be a fine early example of Kiwi ingenuity!

When the bridge was widened additional arch segments were added. Two of these may be seen under the concrete deck to the north and south of the opening. These arch members are of slightly different design and do not show signs of damage or repair.

The bridge had a hard fill and asphalt deck supported by iron plates two of which have been left in place at the east end of the opening. Lateral bracing was also provided but was removed when the bridge was altered in 1989.

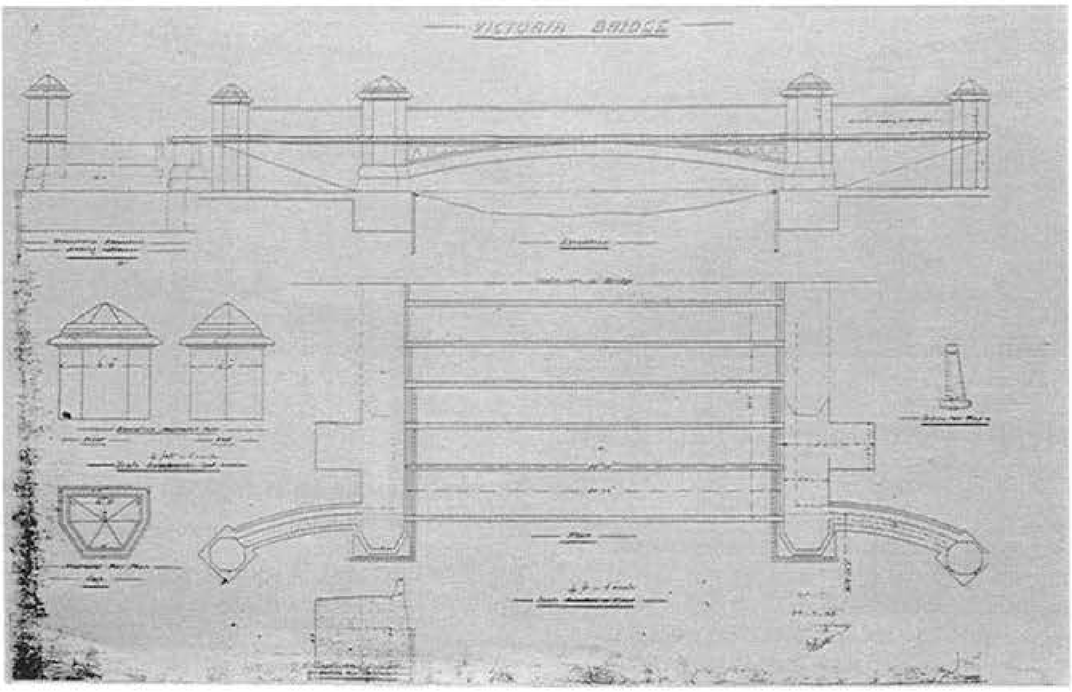


Figure 5. The 1885 Plan for Widening.

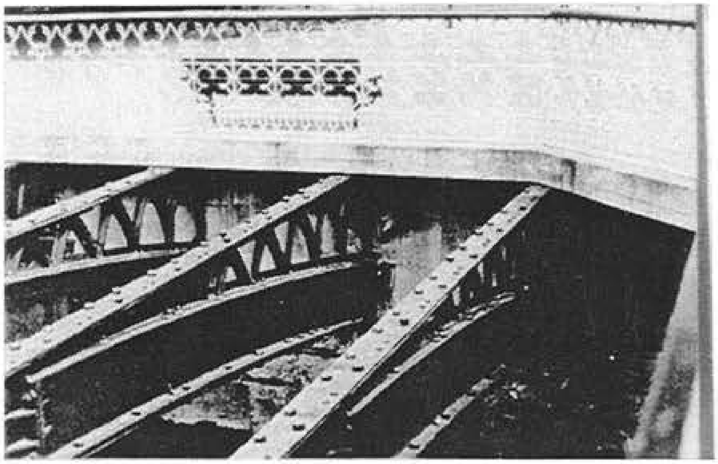


Figure 6. The New Balustrade.

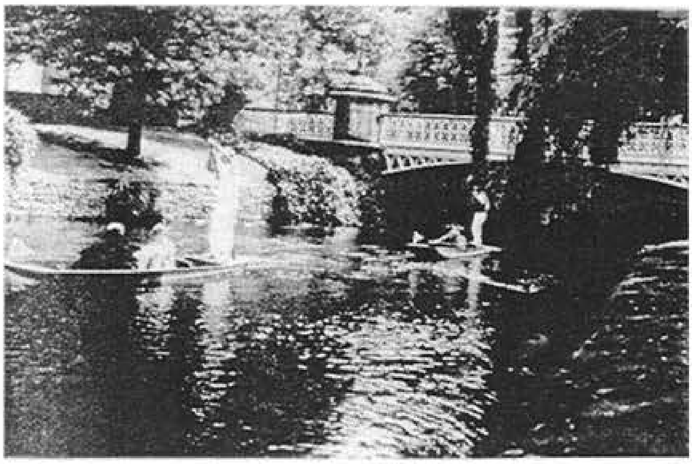


Figure 7. The River and Bridge.

To commemorate the occasion of completing Victoria Square and converting the bridge to its present form the City Council gave it a new name.

> **The Hamish Hay Bridge**
>
> This historic bridge was renamed by the Christchurch City Council on December 18th 1989 to honour the distinguished service to Christchurch by
>
> Sir Hamish Grenfell Hay.
> Mayor of Christchurch 1974 - 89
> City Councillor 1959 - 74
> Chairman Christchurch Town Hall Board 1962 - 89

Just below the name plaque is another plaque explaining the reason for some tram rails let into the deck at this point. When the Author first inspected this bridge in 1960 and noticed the extent of repair to the cast iron girders the obvious conclusion was that this had been brought about by the heavy tram traffic. It is clear from comments in section 2 that this is not the case. The early designers built a strong bridge which carried loads that they could not have envisaged.

> **Trams across the Bridge.**
>
> The rails below commemorate 74 years of public tram service in Christchurch and mark the Papanui and Fendalton routes. First operated by steam locomotive then horses. Electric services began in 1905. Trams crossed this bridge from June 1880 until Sept. 1954.

6. CHANGING ROUTES.

To citizens of 1860 the importance of routes like Victoria Street / Papanui Road and High Street / Ferry Road must have been quite obvious. The roads ran south east - north west across a city which was laid out with predominantly north south and east west streets. But the diagonal routes went where people wanted to go so it was not surprising that these were the sites of the two most remembered of the early bridges, Victoria Bridge and Ferrymead Bridge. The preference for these roads was made very obvious with their use as tram routes for the Papanui and Sumner trams respectively. After the demise of the tramway system in the mid 50's the bus service continued to use the same routes. Not surprisingly the motorists coming and going from the city also preferred the traditional routes. The need to bring some order to motor traffic in the 70's and 80's has seen dramatic changes to popular routes with both Papanui Road and Ferry Road falling out of favour with the growing pressure of traffic. Today High Street has become a pedestrian mall over some of its length and Victoria Street has vanished between the Armagh/Colombo intersection and the Durham/Kilmore intersection. What would the pioneers say if they found an international hotel in the middle of their favourite street?

7. CONCLUSIONS

The Papanui Bridge, the Victoria Bridge, the Victoria Street Bridge or the Hamish Hay Bridge all refer to the same historic structure which is a lasting feature of Christchurch's heritage. As an engineering work it has stood the test of time and the burden of modern traffic. Subtly changed as part of the Victoria Square development the bridge now provides visitors with a glimpse of 19th century engineering as well as forming an attractive backdrop to other river activities (Figs. 6 &7).

The Author acknowledges the assistance of the Christchurch City Council in the preparation of this paper.

8. REFERENCES

(1) J.P.Morison *Evolution of a City* (p44)
(2) *The Sun* newspaper Nov. 12th, 1932 (p20).
(3) Johannes Andersen *Old Christchurch* (Plate 99).
(4) Selwyn Bruce *The Early Days of Christchurch* (p43)

RAKAIA GORGE BRIDGE - THE TRUSS THAT ISN'T

G M JONES

B.E. (Hons,) MICE, MNZIPE Retired

SUMMARY

New Zealand's historic Rakaia Gorge Bridge has long been known and described in the literature and on local signs as a Bollman Truss, the second surviving one in the world, and the only one still in everyday use.

Investigations by the Author have shown that although geometrically of Bollman shape it does not follow the Bollman Patent and should not therefore be described as a Bollman Truss. It is, however, a most interesting and historic bridge, in good state of repair, and should be preserved as an important part of New Zealand's Engineering Heritage.

INTRODUCTION

Engineering legend in New Zealand has long held that the Rakaia Gorge Bridge is one of only two surviving Bollman Truss bridges in the world. The other, designated a National Historical Civil Engineering Landmark is at Savage, Maryland near Washington, DC USA.

The Civil Department of the School of Engineering in Christchurch used to have a great collection of bridge models, not least of them a 2.4 metre (8 ft) Bollman deck truss in varnished wood. Students, the author included, grew up in the knowledge that our local bridge, completed in 1882 was an example of this somewhat unusual US invention. In later years, when a walkway was opened beside the Rakaia river, engineering advisers ensured that the information boards erected by the Department of Conservation drew attention to the novelty and rarity of the bridge design.

In 1988 the author suggested that the bridge warranted some form of IPENZ plaque. The IPENZ 1990 plaque programme was no more than an idea at that time but the Bollman association would make it one of the first choices. There was only one problem. The IPENZ Engineering Heritage Committee had suggested to J H Stephens, Editor of the Guinness Book of Structures, that the book's statement that there was only one surviving Bollman truss in the world was not correct. There was a second in daily use across a New Zealand river. The letter had been backed with photographs to confirm the bridge's existence. Stephens wrote back with an opinion that he could not classify it as a Bollman Truss bridge, it was a girder bridge.(1) An initial follow up indicated that the bridge's design history was indeed complex; its claim to heritage fame extended well beyond a Bollman association, true or false as that might be. It was agreed to defer putting a case for an IPENZ Heritage plaque until the whole history had been researched. This paper and the plaque to be awarded at the Heritage Conference are the outcome of that decision.

THE NATURE OF THE BRIDGE SITE

The South Island of New Zealand, approximately 800 km long and of average width of perhaps 200 km has a major mountain chain running for almost its entire length rising to a height of some 3,700 metres and lying in a N-E direction. This mountain chain intercepts the prevailing moisture laden westerlies with resultant strong winds and heavy precipitation in the Alps. Most South Island rivers commence in these Alps and run laterally to the sea. From an engineering standpoint they bring very big floods and ferocious Foehn winds can roar down their valleys.

In Canterbury the largest of these rivers is the Rakaia. It rises on the Main Divide and flows in braided channels along the high-sided valley left by the last glacial retreat. Just before it reaches the Canterbury Plains there is a narrow barrier of foothills. Here the river has cut a gorge which itself divides just before bursting out from the rock bluffs to ramble across the alluvial gravel plain. The southern minor gorge has become no more than a flood channel and normally the whole river flow goes through the equally narrow northern route. Between the two is a rock remnant, Goat Island. Above and below the gorge the river bed is very wide with the water flowing in unstable braids. The gorge area is therefore the logical crossing place for travellers but one subject to floods of up to 6000 cumecs. The rock walls and Goat Island offer firm foundations for bridges but the height above the water is some 17 metres and designers must also contend with wind velocities in excess of 160 km/hr. Figure 1 shows the location of the Rakaia Gorge in relation to Christchurch, the Southern Alps, Arthurs Pass and the South Island Main Trunk Railway Line.

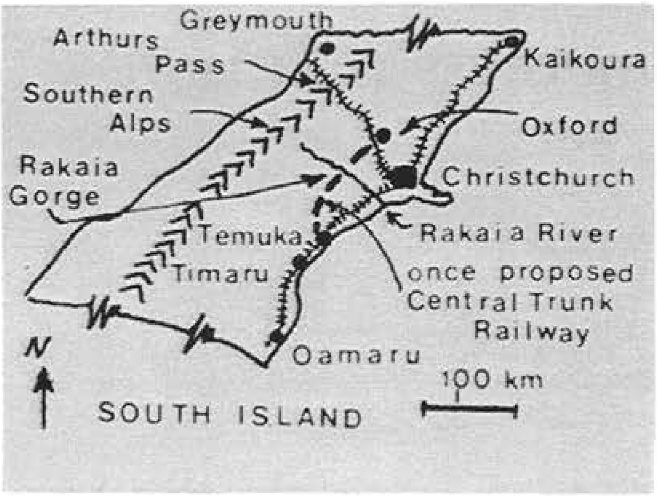


Figure 1

The importance of the Rakaia Gorge crossing was recognised in the early 1850's when it formed part of the route to inland Canterbury taken by drovers and early settlers. At the time the way up the river from the gorge and thence over the Browning Pass was considered one of the best prospects for a direct cattle and dray route to the West Coast. It did not eventuate; the road went over Arthurs Pass.

The Phillips family built an accommodation house at the mouth of the gorge in 1851 and a ferry was established soon after. John Bryan was an early ferryman; he and his wife built a second and much superior accommodation house nearby which lasted until it burnt down in 1874. The first mention of a railway crossing the river was in 1863 when the route of the main south railway line from Christchurch southwards was being considered. It was suggested the railway should deviate inland and cross the Rakaia River at the gorge, mainly because of fears of problems nearer the mouth due to shifting shingle in the unstable river bed and the length of the bridge needed. However, a Commission in 1864 recommended that the gorge route be abandoned and the direct route be chosen even if it meant building the longest bridge in the Southern Hemisphere. In fact the railway did cross the Rakaia on the direct route in 1873 and still does. (The adjoining multispan highway bridge has a length of about 1.7 km - the longest in New Zealand.)

PROPOSALS FOR THE RAKAIA GORGE CROSSING

Following continuing agitation from local landowners on the need for a bridge or bridges near the gorge, the Provincial Engineer examined in particular two sites, one at Goat Island (the present crossing) and one further upstream. There was much correspondence between the Canterbury Provincial Engineer, Central Government officials in Wellington, the politicians and local landowners as to where the bridge should be, and what it should be capable of carrying. Should it be pedestrians and sheep only or carry stock, drays and even light locomotive traffic; whether it should be a suspension bridge or an iron bridge or bridges. As ever the problem, confirmed by pencil notes on the back of the internal reports and correspondence, was cost. Doubtless, too, the whole issue was complicated by the very existence at that time of two tiers of Government, Provincial and Central.

Provincial Engineer Thornton in 1875 responded to an instruction from the Secretary of Public Works in Wellington and forwarded a design, estimated to cost £15,000. This comprised two iron bridges and a cutting over the island. The northern bridge over the main channel was to be 61 metres (200 ft) span and the southern flood channel span 47 metres (154 ft) with both capable of carrying light locomotive traffic.(2). No plans or details of the proposal have been found. However, in fact, a sum of only £5,000 was placed on the estimates for a footbridge for pedestrians and sheep.

One of Thornton's assistants, W G Bull, examining the feasibility of a suspension bridge set on the site upstream from Goat Island, reported that it would be "blown clean away from the towers before six months were over" and that "taking all circumstances into consideration we may dismiss from our mind the practicality of bridging the river at this point"(3).

In Wellington the Public Works Department's Engineer-in-Chief, John Carruthers, reported to his Minister on 27.7.1876 that he agreed the island was the best site but felt that a suspension bridge (so effective in other parts of New Zealand) was not in his opinion a good design for the site. The span was too short "for the advantages of that style of construction to become available"(4). Instead he suggested a pier in mid river in the main channel and an embankment to close off the flood channel to eliminate one bridge. Obviously he had not seen the site nor appreciated the true problems of the river crossing. Figure 2 shows the gorge mouth with Goat Island and the flood channel and the proposed embankment.

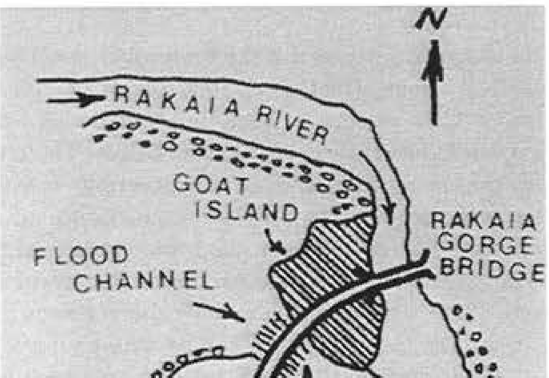


Figure 2 Goat Island and Rakaia Gorge

Further to Carruther's suggestion, Thornton on 24.10.1876 wrote to the Secretary of Public Works stating that Carruthers's proposal to put in an embankment in the flood channel and a pier in mid river would result in flooding of the flat where the accommodation house was sited. He also felt the cost of the bridge would be increased by having a centre pier which would be liable to be damaged and probably destroyed. Thornton ends his report "I can only add that had he (Carruthers) seen the site I feel sure he would not have recommended either the pier or the closing up of the flood channel" (5).

Nearly 70 years later there was an amusing sequel to the proposals to close the flood channel. Around 1942 when the Japanese military forces were moving south in the Pacific there was concern about military attack. It was known that the existing wooden bridge over the flood channel would not carry a Matilda Army Tank (it was estimated a 5 ton axle load was its limit) and urgency was given by the War Cabinet to the design and construction of a new reinforced concrete bridge over the flood channel to replace the old wooden truss. As a temporary expedient, big concrete culverts were laid in the channel with a causeway to Goat Island. No sooner done than the lot disappeared in a flood. The crossing was restored only again to suffer the same fate. No photographs of these culverts have been located and the author has "reason to believe" that the Army checked the locals to ensure none survived.

The wooden flood channel bridge was built in 1884 by a contractor Daulby and had a main span of 36 metres (120 ft) and three smaller side spans. It was replaced by the present reinforced concrete arch bridge in 1945. There is a story relating to the width of this bridge. After letting the contract the War Cabinet instructed that the carriageway be doubled to 7 metres (24 ft). Credit for this decision has been attributed to a duck shooting crony of the then Minister of Public Works, fiery Australian-bred Bob Semple. His friend had convinced him a one way bridge would be like a full choke shotgun so there was a ministerial instruction that the width be doubled.

SOUTH ISLAND CENTRAL TRUNK RAILWAY

It has been said that 1870 was the year that set New Zealand on its path to nationhood for it saw the start of Julius Vogel's great railway and public works programme. To carry it out a Public Works Department was created with John Carruthers as Engineer-in-Chief. The stage was set for the astonishing development of the 1870's which saw New Zealand's 7.2 km of railways (nearly all in Canterbury) grow to 1900 km within the decade (6). As a part of the programme the Canterbury Provincial Council lost to the Central Government the right to construct its own railways but fortunately liability for the provision of the Rakaia Gorge crossing was accepted by the Central Government when the Canterbury Provincial Council was abolished in 1876.

A late fantasy of the Vogel era was a Main South Island Central Trunk railway. This was to run along the foothills of the Southern Alps from Oxford to Temuka. (See Figure 1) The Oxford-Sheffield section including the Waimakariri Gorge Bridge (1877) was indeed eventually constructed (1884).

It is this railway to which Carruthers refers in a report to his Minister in 1877 on the progress of the Rakaia Gorge Bridge. He reports "this (bridge), like the Waimakariri Gorge Bridge, is intended to eventually carry a railway. No work has yet been done but plans for an iron bridge are now in the draughtsman's hands and will be completed by the end of July" (7).

This proposed railway may also have been in George Thornton's mind when he prepared his iron bridge proposal in May 1875.

The depression of the 1880's killed the concept of what would have been a very extravagant railway. Fortunately the crossing was completed by that time and the load carrying capacity of the iron bridge is one of the few relics of Vogel's grandiose scheme.

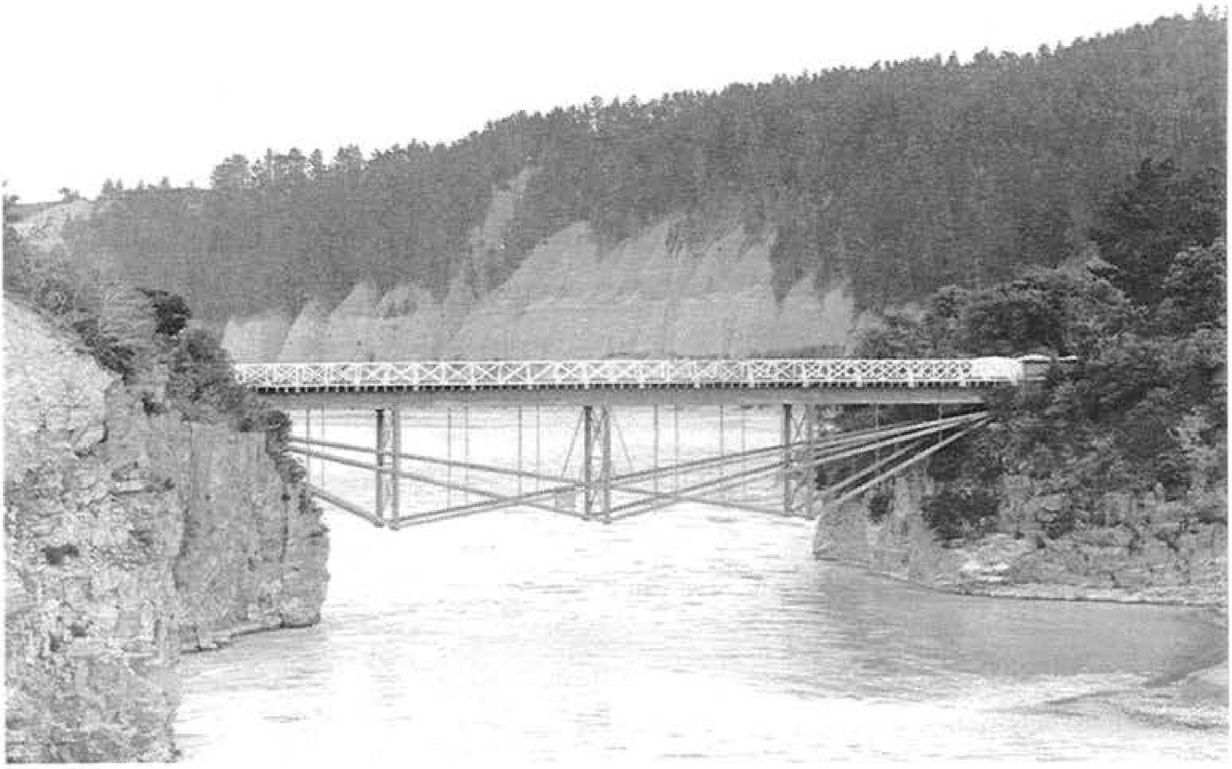
DESIGN OF THE RAKAIA GORGE BRIDGE

It is not known definitely who conceived the design of this structure nor how it came to have a strong affinity with Bollman's American patent.

Various articles on the bridge have stated that the design was prepared in the USA but there is absolutely no evidence of this and the author considers it most unlikely. Another story is that the bridge was built for India but eventually came here. This is obviously incorrect. Such stories have also been heard in relation to other bridges but commonsense engineering economics renders them all most improbable.

This much is certain; the design was prepared under the direction of John Carruthers and Carruthers was surely familiar with the work of Bollman.

Although born and educated in Scotland, Carruthers began his professional engineering career with the Great Western Railway of Canada. He subsequently worked on the survey and construction of railways in Michigan, Illinois and Minnesota and later in Russia and Mauritius. He could therefore be expected to be familiar with American railway bridging practice especially as, having been born in 1836, his sojourn in the USA was probably around the 1860's before he went to India in 1866 and to New Zealand in 1871. The period 1850-1860 may be regarded as a watershed in the history of American bridgebuilding, for the designing then came into the hands of trained engineers and rational design really began; the time when the bridges designed by Fink and Bollman first came into use.



The Rakaia Gorge Bridge

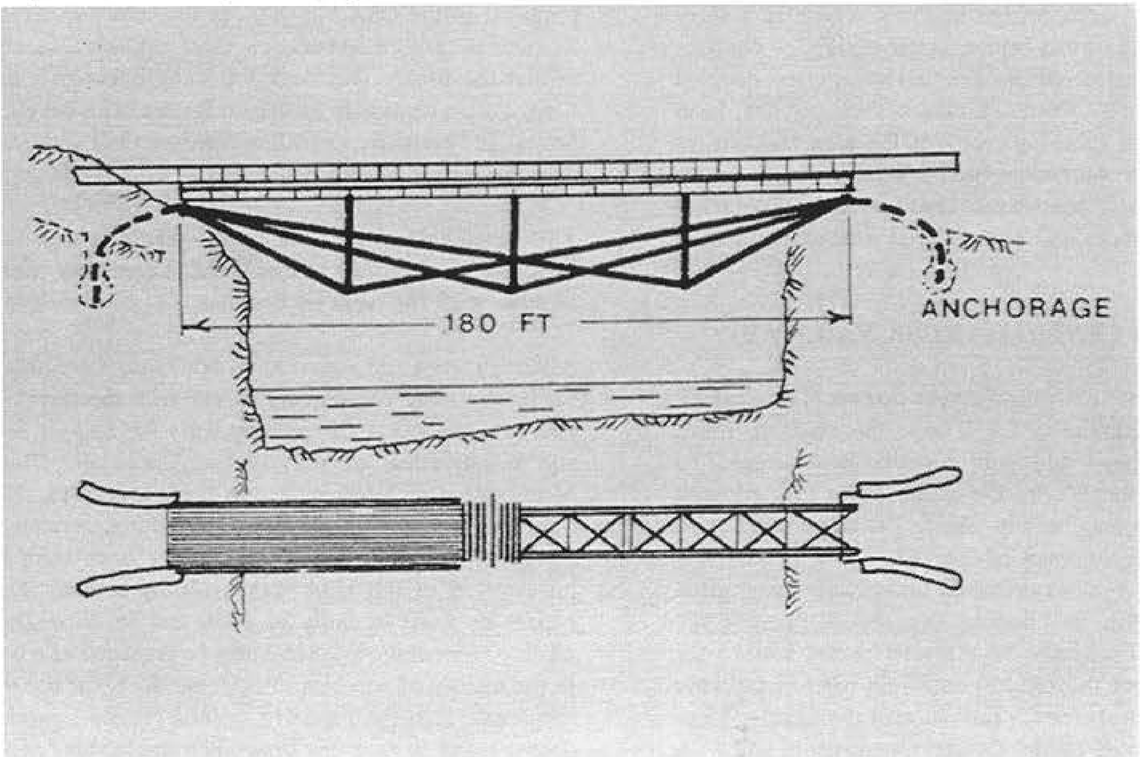


Figure 3 Outline Plan and Elevation Rakaia Gorge Bridge

WENDEL BOLLMAN AND ALBERT FINK

Born 1814, son of German parents, Wendel Bollman was a self taught Baltimore civil engineer and the first to "evolve a system of bridging in iron to be consistently used on an American Railroad becoming one of the pioneers who ushered in the modern period of structural engineering"(8). The story of Wendel Bollman is inextricably interwoven with that of the Baltimore and Ohio Railway for he was employed by them for some 29 years and later contracted to them.

The "B and O" was in every respect a truly pioneer enterprise. It was the first practical railroad in America, the first to use an American designed locomotive and the first to cross the Alleghenies.

Bollman joined the B and O as a carpenter about 1829 and participated in the laying of its first track, this was about two years after its establishment. He was later made foreman of bridges. By intense self study he eventually came to assist the Chief Engineer, Benjamin H Latrobe (one of the sons of the great architect/engineer) in bridge design. The other bridge designer trained by Latrobe was one Albert Fink, German born and trained and who started as a draughtsman in Latrobe's office. Bollman's bridges were chiefly used on the older eastern portion of the original main line while Fink's were constructed on the western extension in the region of the Ohio Valley.

The first impulse given to the general adoption of iron for railroad bridges in America had been given by Latrobe and when the extension from Cumberland to Wheeling was begun he decided to use this material in all the new bridges. In 1851 a span of 38 metres (124 ft) upon the Bollman plan was completed at Harpers Ferry and about the same time three 62 metres (205 ft) spans over the Monogahela River upon the Fink plan were built. Both these styles of bridges were different developments of the trussed beam.

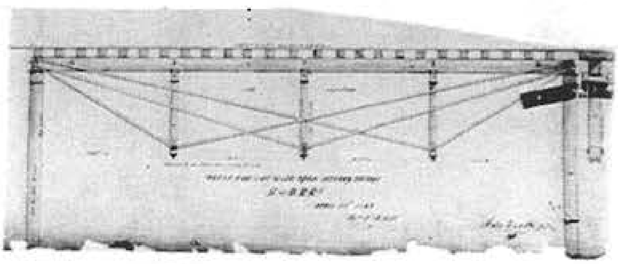


Figure 4

This figure shows a simple beam of 50 foot (15 metres) span with three independent trussing systems. Bollman's use of this method of support led to the development of his bridge truss. This drawing is of a temporary span used after the timber bridge at Harpers Ferry was destroyed during the Civil War (B and O collection, Smithsonian Institution Washington D.C.)

It has to be recorded that other designers had been building iron bridges in America since the first iron truss of a kind by Earl Trumbull in 1840. In 1840 Squire Whipple, a US civil engineer built his first iron bridge - a bow string truss. He took out a letters patent for this in 1841 and a large number of bridges on this plan were built. He also published in 1847 a "Work on Bridge-building" which marked the beginning of rational bridge design in the US.

Robert Vogel, formerly of the Smithsonian Institution feels that Bollman's career with the B and O is of particular interest because he was the most successful and probably the last of the self taught engineers. He may be said to be a true representative of the transitional period between intuitive and exact engineering (8).

BOLLMAN'S PATENT

The Bollman truss was the subject of a patent in 1852. This claimed it to be "a mode of bracing bridges and constructing trusses by which I carry the whole load upon the bridge at any given point in the centre or either side thereof directly back to the abutments and at the same time retain all the forces of thrust and tension within the truss frame, resting the weight merely upon abutments or piers without any anchors or other similar devices..."(9).

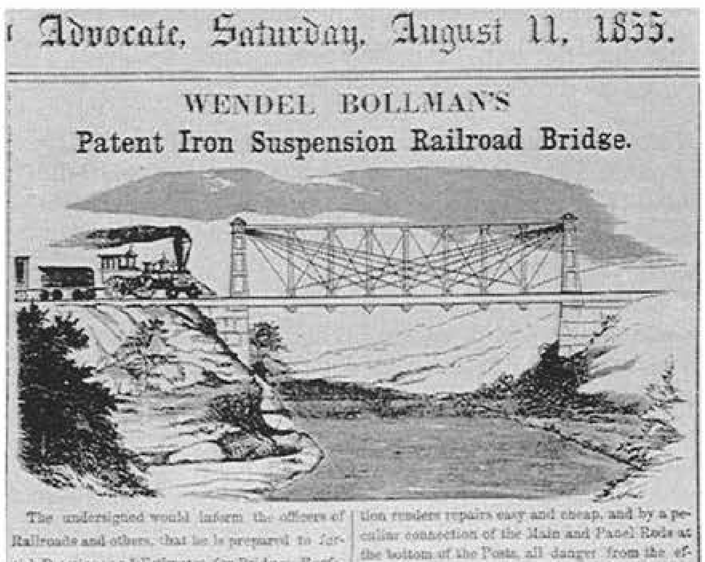
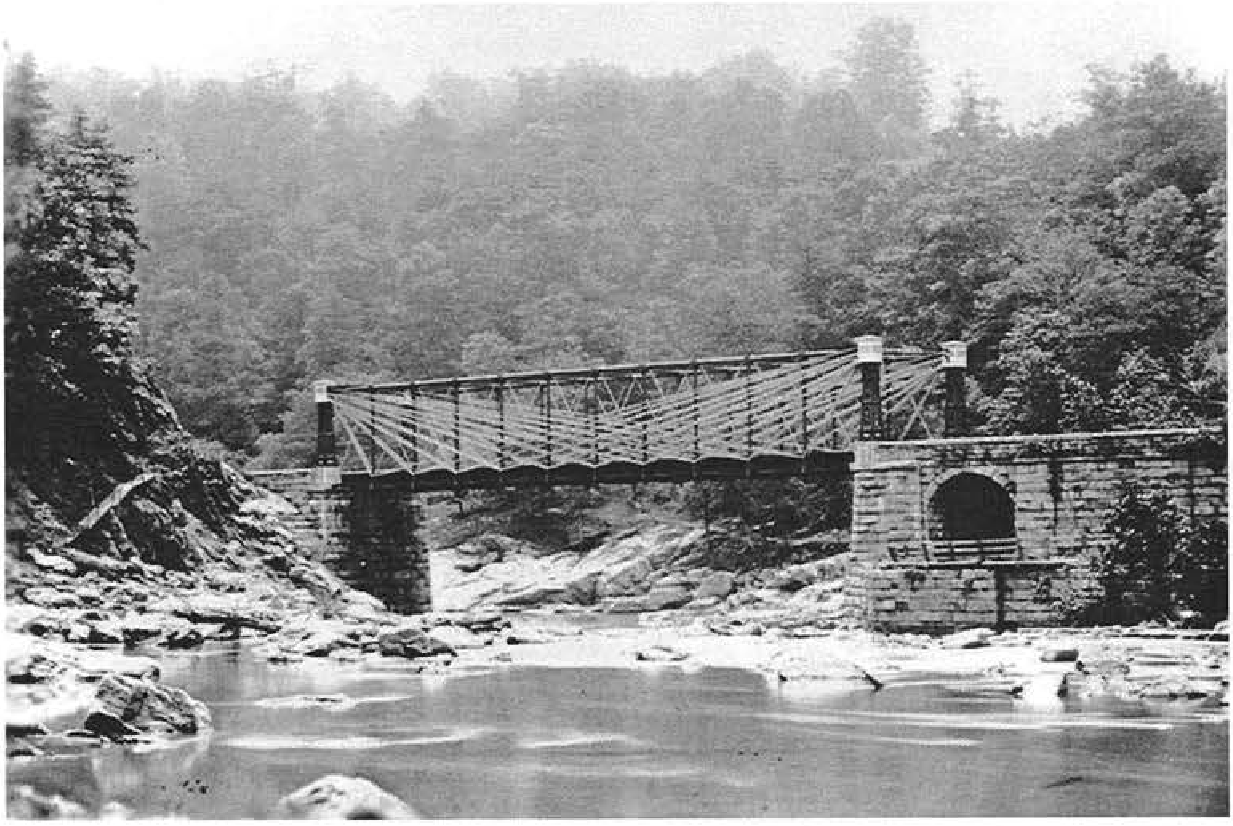


Figure 5 Advertisement in the Railroad Advocate, Aug 1855



Patapsco River Crossing of B and O, Maryland, Bollman through truss c, 1869 (photograph B and O collection Museum of History and Technology Snithsonian Institution, Washington D.C.).

EVALUATION OF THE PATENT

Although the Bollman truss components were simple to fabricate it was inefficient in the use of materials and had other problems with unequal deflections.

The American Railroad Journal of January 1855 published a letter from Whipple which reads:

"Bollmans Patent Iron Bridge

A kind of structure thus designated having attracted a degree of public attention, the question of its value and originality becomes a legitimate subject of investigation, for any who take sufficient interest therein.

It appears that Wendel Bollman of Baltimore, has obtained a patent for a sort of mongrel bridge, something between a Suspension and a Truss bridge and partaking in a measure of the character and qualities of both. Its general characteristics are shown in Figure 1; and; as there represented, it is more properly termed a Truss bridge. But remove the top thrust piece (ak), and the five posts that support its intermediate positions; and substitute guys, or back stays, running back from a and k, and anchored into the earth, to secure those points from being drawn inward by the suspension rods (ac, ad, etc) it becomes strictly a Suspension bridge; differing from Suspension bridges as commonly constructed but in principle precisely like the plan shown in plate 5 of my Treatise on Bridge Building printed in 1847, some years it is believed, previous to the date of Bollman's patent."

After a detailed discourse on the greater amount of material required for a Bollman design the letter continues ... "It appears then that this famous 'Bollman Truss' the invention of which Mr Vose considers 'the great step of the age', in the advancement of the science and practice of bridging, is the mere fossil of one of Whipple's discarded principles, dug up, and probably considered original and valuable by Wendel Bollman, and here attempted to be thrust into the first rank in the order of merit among iron truss bridges applicable to openings of 200 feet." The letter is signed S Whipple 7th January 1855.(10)

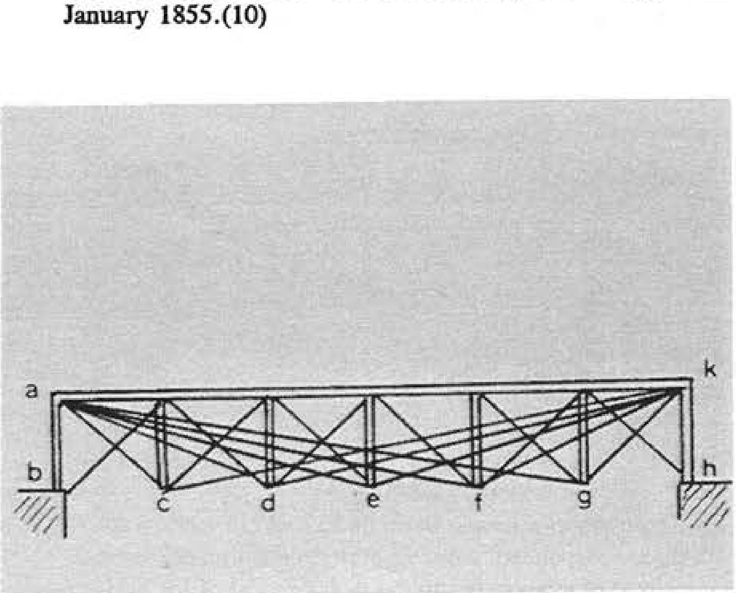


Figure 6, Whipple Letter, Figure 1

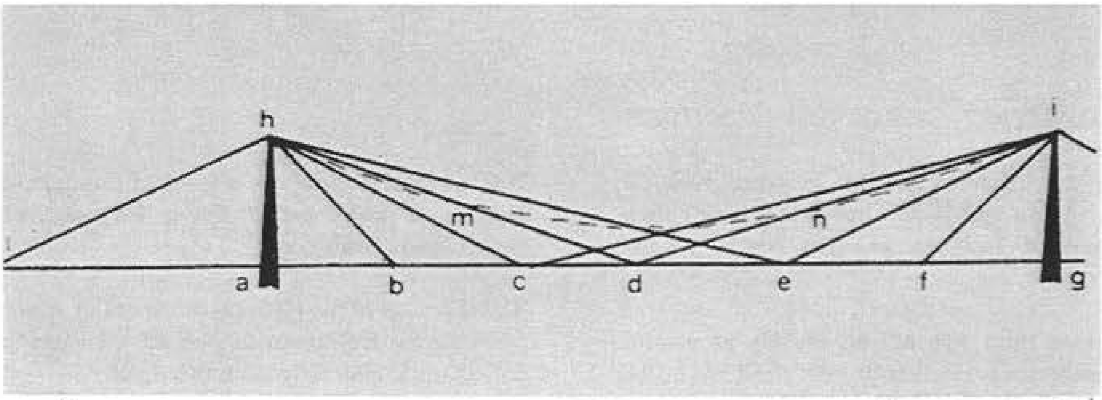


Figure 7, Part of Whipple's Plate V

However it appears that Bollman was still profitably erecting his bridges as late as the competitive early 1870's, perhaps indicating that the harsh criticism of Whipple was not entirely justified.

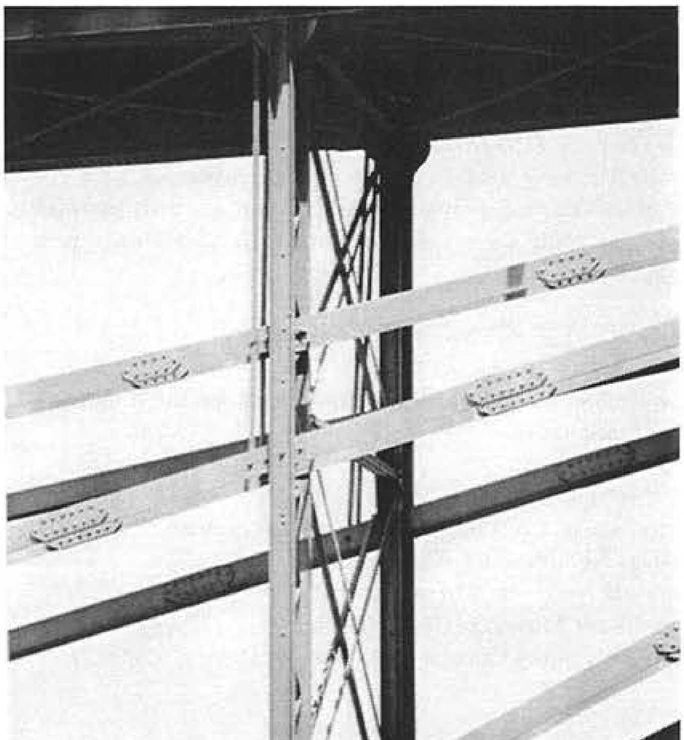
Ironwork Rakaia Gorge Bridge

DESCRIPTION OF THE RAKAIA GORGE BRIDGE

The bridge is a deck truss and has the geometrical shape of a Bollman Truss, as shown in the photographs and figures. It is of wrought iron with a span of 55 metres (180 ft), is 17 metres (55 ft) above the river level and with a 4 metre (13 ft 6 in) wide deck. The main girders are of rivetted construction using plates and angle irons and are approximately 1 metre (3 ft 6 in) deep. They were shipped out in 7 metre (22 ft 6 ins) lengths. The ties are anchored at each abutment by massive concrete anchors tunnelled into the rock walls of the gorge. Iron pins connect the anchors, ties and columns. The two main girders supporting the roadway are propped at mid span and quarter points by the columns and at one end sit on rollers while the other end is restrained. The timber deck has been replaced at intervals. Around the year 1890 the bridge was damaged in a very severe gale and additional wind bracing installed. The drawings for this work are signed by P S Hay, one of New Zealand's most notable bridge design engineers.

CONSTRUCTION OF THE BRIDGE

Tenders were called for the ironwork of the bridge in Britain in January 1878. It is not known who was the successful tenderer but by September 1879 the ironwork had arrived at the railhead at Coalgate. Tenders for foundation and erection were called three times in all. The first time the successful tenderer declined the job, the second time no tenders were received. The third time of calling was more fruitful and a contract was let to W H Barnes on 5 November 1880 for completion in 18 months for a price of £3,619 (ironwork supplied). Due to delays with consequent penalties Barnes ended up with receiving only £3,313. The bridge was completed November 1882 but has never been used for rail traffic.



Ties and pins - Rakaia Gorge Bridge
(Photograph - J.S. Pollard)

WHAT IS THE HERITAGE OF THE GORGE BRIDGE

The influence of the better technically qualified Fink on Bollman's ideas is an unknown question. Fink often apparently referred to Bollman as "the wheel barrow man"(10).

Even if the Bollman truss was not an entirely successful form it did give profound impetus to the development of the metal bridge. According to Vogel (8) its influence was even greater than that of two more original and daring forms represented by Robert Stevenson's tubular iron bridge and Roebling's Niagara suspension bridge. Whereas the B and O adopted the Bollman truss and began replacing its timber spans, the suspension form was never again used by the railroads and Stevenson's only once more.

In all over 50 Bollman trusses appear to have been constructed; a figure which includes replacement spans on the same site, for some which were blown up by the Confederate forces in the Civil War - a hazard of the times!

It is obvious that the Rakaia Gorge Bridge does not "retain all the forces of thrust and tension within the truss frame ..." and therefore cannot properly be described structurally as a Bollman truss even if it has the visual geometry of one. At best, in the words of Robert Vogel of the Smithsonian Institution, "It clearly is Bollmanesque..."(8).

Perhaps Carruthers owed a debt to all three, Bollman, Fink and Whipple. (10) And if so he did what generations of New Zealanders have done since; take an overseas idea, pick out the essentials and adapt it to their country's own peculiar needs. In doing do he selected a very effective design for a difficult site.

ACKNOWLEDGEMENTS

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University of Canterbury School of Engineering
and to the many people whom he has consulted in the preparation of this paper.

The approval of the National Museum of American History, Smithsonian Institution to publish photographs from their collection is gratefully acknowledged.

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APPENDIX A

Notes on the New Zealand engineers associated with the Rakaia Crossing. (Abridged from "Early New Zealand Engineers", 1953, F.W. Furkert, A.H. and A.W. Reed, Wellington and the Institution of Civil Engineers, Proc., Vol 198, 1913-1914.) (Carruthers).

A.D. Austin	1839-1903, Educated in England and came to New Zealand in 1855. Appointed District Engineer, Christchurch 1878 in charge of all development work. Retired 1887 due to ill health.
W.G. Bull	An engineer with the Canterbury Provincial Council.
John Carruthers	1836-1914, Scottish born with world wide railway experience. Came to New Zealand in 1871 as Engineer-in-Chief of the newly formed Public Works Department. During his eight years in this position he organised and trained a staff from among the youth of the Colony to carry out the great public works policy of Sir Julius Vogel. It included some 1600 km of railways with feeder roads, land drainage, water races, harbours and public buildings. In 1893 he was Consulting Engineer to the Government of West Australia and in this capacity advised on the design and construction of the Coolgardie water supply.
P.S.Hay	1852-1907, Scottish born Hay arrived in New Zealand with his parents in 1860. Graduating as the first B.A. from Otago University to be followed by M.A. with first class honours in mathematics. Joined the Public Works Department as an engineering cadet and became a talented designer of engineering structures. He designed the major viaducts on the North Island Main Trunk Railway. His signature is on the drawings for the stiffening required on the Rakaia Gorge bridge after wind damage about 1890.
George Thornton	1829-1914, Thornton was appointed Assistant Provincial Engineer for Canterbury 1863 and became Provincial Engineer in 1874. He was involved in many public works projects in Canterbury including water schemes, bridges and railways, etc. He was later in private practice with Bull in Christchurch.
G.P. Williams	1847-1909, Williams was educated Cambridge, England where he took his B.A. He arrived in New Zealand in 1869. Resident Engineer for the Christchurch-Rakaia railway and later carried out much civil engineering work in Canterbury. He was involved in the Rakaia Gorge flood channel surveys.

Great Lake, Tasmania and Waddamana Hydro-electric Power Development, First (1916) and Second (1923) Stages an Engineering Heritage Perspective

H.H. McFie, MC, FIEAust, Retired Civil Engineer

Hydro-Electric Commission (1946-83)
Past Chairman National and Tasmania Committees for Engineering Heritage

SUMMARY: Situated on the Central Highlands at about 3,340 feet above mean sea level (SL) with a surface area of about 40 square miles, the development of the large, shallow, Great Lake for its potential hydro-electric (h-e) energy was inevitable and after controversial promotion and Government approval (1909) work commenced in Aug. 1911. With 49 MW installed capacity (1923) under 1123 feet static head Waddamana was the fifth and largest h-e development in Tasmania, being preceded by "Duck Reach - The First Significant Hydro-Electric Power Development in Australasia. (1895)" (1); Mt Bischoff (1907); Moorina (1909) and Lake Margaret (1914). Their total installed capacities was 63,000 KW, compared with Victoria's thermal 94,000 KW. (1924/5), the populations being 219,000 and 1,625,000 respectively" (1) It became the foundation of the Government's Hydro-Electric Department (HED - 1916), Commission (HEC) from 1930, which has investigated, designed, constructed and operated 30 h-e power stations, 10 major pumping stations the, 240 MW Bell Bay thermal station and several small diesel stations. The System now has 2,519 MW installed and 1,157 average output. Its high load factor, c. 70% is unique as was c. 85% in the 1920's, with electrolytic loads still dominant.

The paper describes some aspects of the investigation, promotion, design and construction of the development of Great Lake and the headwaters of the Ouse River to Waddamana power station in the deep Ouse River valley. Dimensions are given their historical values, mainly Imperial Units.

1. INVESTIGATIONS

The first recorded visit to Great Lake was by John Beamont (1817) who on 6 Dec ..."came to the border of a large Lake ... from this Lake the Shannon R. has its source" (p588) and in answer to Commissioner Bigge (p344) "Q. Did you make the circuit of the Lake yourself. A. I did not, but a man who was with me .. Jones, said he had been 5 days going round it."(2) Beamont was Private Secretary to Lt Gov., Colonel Davey (1813), Naval Officer in charge - Van Diemens Land (Tasmania) (1818) and Provost Marshall (1819). He was buried (1872) at St Johns Park cemetery, Hobart but his elaborate lead-lined casket was subsequently re-buried at Miena dam (1963) and relocated on a nearby knoll (1970) with an inscribed monument after the raising of the storage by No3 dam. His coffin was kept in the Poatina power station store for several years whilst the legal aspects were resolved . Thomas Scott's map of Tasmania (1824) shows the Shannon River and an outline of about the Southern third of the Lake. The first detailed survey with soundings was made by Kingsmill & Legge, ; Drg No H7, (17Nov 1911) "Soundings taken by Messrs. H. Kingsmill, MA; & Col. W.V. Legge, RA - March 1903". "Width 8, length 17 & perimeter 98mi max depth 22ft (3)

The Lake was successfully stocked with introduced brown trout, **Salmo trutta** Linn (1870) and became a mecca for hardy anglers and fly fisherman, "A.D. Wall (1898) in one day caught 18 fish .. a total of 148.5lbs" One of the biggest fish to come out of Great Lake caught (1897) by Mathew Seale was a 25.5lb. brown trout. (4) The Lake's fame continued when 53 brown trout taken by three rods (11-12 April 1912), averaged 9lbs. with the largest 17.5lbs; that is from the natural lake.(3)

There were a number of reports of possible h-e power developments of Great Lake and other sites from the late 1800's. The Engineering Inspector of the Central Board of Health, A. Mault, advised the Minister for Lands & Works, Parliamentary Papers (PP) No. 59 - 22nd Oct. 1897, inter alia. "that in connection with the Great Lake alone (ie. excluding Ouse River) Tasmania possesses capabilities that if utilised would put her into the front rank of industrial communities employing the most economical of all sources of motive power - water (5).

In 1901 K.L. Rahbek, a Danish civil engineer advised the Government of water power sources, including St. Clair, Echo & Great Lakes, indicating potential power outputs of 46,000, 4,000 & 27,000 horse power (hp) respectively as basic run-of-river values without storage works.

Other projections of 100,000 hp from Great Lake were theoretical, ignoring the physical requirements and site location. (PP No. 29 of 1901). G.E. Brettingham Moore, MICE, (arrived Tasmania (1899) after service in Indian railways, MHA (1903-9)) who later fixed the power station site, recognised that schemes and dreams are relatively cheap, but that their realities required bold men, materials and money as his evidence to the Parliamentary Select Committee (1909) indicated. "Ten years ago ... there was not the slightest chance of doing anything by way of applying the power commercially ... the engineering side ... looks very favourable. The fall however was ... far removed from any centre like Hobart ... what are we going to do with the power when it is generated ... as soon as I fixed that in my mind, I entered into communications with various experts, metallurgists and others". The answer was provided by Gillies (qv) and the engineering knowledge & management by Butters (qv) who brought the project to its successful completion (1923).

2. PROMOTION

James Hyndes Gillies of Sydney, then of Melbourne (1906) and his Gillies Sulphide Concentrating Company had been experimenting with the Flotation process and the electrolytic deposition of metallic zinc. His success with the latter was assessed by an independent mining and metallurgical engineer, James Taylor, "The zinc is solid and compact in character and has been produced regularly during the numerous trial runs made in the course of my investigation ... the full quantity of zinc practically attainable having been deposited ... The ores being treated contained zinc, lead, copper, gold, sulphur, iron and a small quantity of silver" (5) The commercial application of the process required a large block of cheap power which was only available from h-e sources. "Indicated costs of Mainland steam power were 50-75 pounds per hp-year, the major contracts with the HED in the 1920's were 2 pounds and 2 pounds 10 shillings" (1)

Gillies visited Tasmania (1908) and after examining various proposals, including the Pieman River and Great Lake had discussions with the Premier, J.W. Evans, Government Officers and others. In 1909 more detailed site work and surveys confirmed the levels required to divert the Ouse River and to bring waters from Great Lake to Waddamana. Gillies obtained a statutory franchise for his Complex Ores Co. of 1908 and the Complex Ores Act 1909 passed through both Houses of Parliament on 10th Dec 1909. This authorised his company to develop the potential energy of Great Lake, but with restrictions which subsequently proved crippling.

These financial and management difficulties which eventually denied Gillies the fruits of his inventiveness and enterprise are too lengthy to be included here. They are well described and documented by his son in A.J. Gillies (1984) "Tasmania's Struggle for Power" (5)

3. FIRST STAGE (1911 - 1916)

The Great Lake concession was assigned to Gillies' subsidiary, the Hydro-Electric Power and Metallurgical Co. Ltd. and work commenced with Butters as chief engineer (Aug 1911) W. McK. Jeffrey, civil engineer with experience in South Africa with the Victoria Falls Power Co., and Leslie Butler, surveyor. There was plain summer accommodat2ion at Miena, the damsite, with a poor access road and track which was impassable in winter. From the rail terminus at Apsley, a coach service was provided by A. Batt to Bothwell (8mi) and one vehicle per week ran to The Steppes (20mi). Subsequently, Dunkley Bros., contractors kept the road open to handle the many motor lorry loads for the works.

Since there was no access road to the power station site at Waddamana all stores and machinery were transported by horse-drawn bogies on wooden rails and timber tressle bridges for the last 17mi from Red Gate, North of Bothwell.. It was completed (1912) and teams of up to 15 draught horses averaging seven ton loads, completed the return trip each two days. Surveys including the then and future perimeters of the Lake, setting out the works, timber clearing, the tramway plus work at the Miena dam, canal, penstocks and power station occupied the first two years. A road (6mi) was built from Waddamana to "Kanna Leena" the Company's field headquarters near the canal intake. The station's capacity was increased, 6,000 to 8,100 kVA, but the inability of the Company to raise additional funds in London and the exceptionally severe winters caused a shut down (1912) forcing it to seek financial support from the Government. When this was not given the Company offered the works-in-progress to the Government, which engaged E. Parry, BSc, MIEE, AMICE., of New Zealand to report on the works and their value.

He commended them as well designed and built and they were acquired, Hydro-Electric Purchase Act 1914-1915, George V.-No.4; which provided "immediate arrangements for the establishment of the HED and .... recommencement of operations ".

Butters was retained as Engineer-in-Chief and General Manager and in his first report (1914 - 1915) to the Minister for Lands & Works, he stated, inter alia, that "Messrs A. Dickenson & Co. English Consulting Engineers ... inspecting the machinery before leaving the manufacturer's works - on 17 Dec 1914, advised that practically the whole ... was completed and awaiting shipment ... from England during Jan 1915 or thereabouts, except certain small, but important items which were interned in Germany."(3) Despite these delays the completion of the First Stage resulted in the Governor General, Sir Ronald Crauford Munro-Ferguson (later Viscount Novar) switching on the output, firstly at Waddamana (6 May 1916) and at Hobart, (pop, 27,000-1916) at a public meeting of about 3,000 people on 8 May. Commercial operations began on 15 Aug 1916 to some 2,000 consumers in Hobart plus its tramways. The national importance of the project is indicated by those present on the 5th May during the inspection of the works by the official party. The sluice gates at Great Lake were opened by Hon. John Earle, MHA, former Premier ; Hon. W.H. Lee, (later Sir Walter) MHA, the Premier diverted this outflow from the Shannon River into the canal and subsequently the Governor of Tasmania Sir William Ellison-MacCartney opened a valve at the Penstock Lagoon to the penstock.(a pressure pipe which supplies water to a water turbine). Horses were a major means of travel and a photograph of the inspecting party shows 18 horsemen abreast. (3)

The layout consisted of a small diabase (dolerite) masonry dam (No 1) 12ft 6in high and 11ft to spillway crest. The outlet sill of the 10 sluice gates was RL 3334.1, now SL 3343.56 which is also that of the outlet of No 2 dam (1923). The 300ft long dam was built across the natural outflow from Great Lake at its southern end, that is the Shannon River a tributary of the Ouse River in the deep valley of which the Waddamana power station was built, with some 1,150ft net head (RL 3,005 at forebay and RL 1,852 at turbine nozzles.) The discharge from the Lake continued in the Shannon River for 5 miles to a rockfill and puddled clay weir and intake to the 3.4mi (270ch) 280 cubic feet per second (cfs) canal. A series of drop structures or masonry weirs (ripples) to control the canal velocities and consequential scouring were built since the hydraulic gradient would otherwise be excessive. A natural lagoon of half a square mile in area was enlarged by three earth dams to provide Penstock Lagoon and the forebay at the pipehead and its volume provided for several hours of peak output. The concrete entrance chamber included extensive trash screens and walkways to permit cleaning and the removal of ice which occurred frequently in the winter.

The low head upper half of the two mile penstocks consisted of the Australian Wood Pipe Co's 48 inch ID oregon pipe branching at 150ft head into 2 x 38 inch ID welded steel pipes supplied by J.O. Boving London and manufactured by Ferrum of Kattowitz, with average internal diameters decreasing from 950 to 850 to 750mm in three sections each 1300ft long. At about 3,000ft the penstock was c.50ft below the static hydraulic gradient and for governing and safety reasons butterfly valves, stand pipes, pressure relief valves, air inlets and large concrete anchors on the steep lower sections, transitions etc, were installed. The steel framed and galvanised iron clad power station was built on sound rock and concrete foundations and two horizontal Boving pelton wheel turbines were installed rated at 4,900 bhp, jet velocities 260ft-sec and 375rpm; coupled to 4,050kVA, three phase 50 cycles, 6,600V alternators manufactured by British Westinghouse of Manchester and installed under the direction of their representatives. Output was 7,000kW and static head 1,123ft. The concrete tunnel under the turbines discharged the spent tailwaters via the concrete lined tailrace to the Ouse River. (No1) transmission line was carried 65 miles to Hobart on 589 galvanised steel lattice towers about 68ft tall, providing the initial requirement of 8,100kW (but designed for expansion to 40,000hp). It crossed the Derwent River at Bridgewater with one tower 160ft tall, span 1,180ft and 100ft clearance over the navigation channel and terminated at the New Town sub-station, later at Risdon, pressure was 88kV and distributed at 6.6kV(3)(5)(6).

During the First Stage the labour force varied considerably due to the extremely cold winters, long delays with overseas equipment and the financial problems. It reached 450 men, but when Gillies returned from London (June 1912) as managing director and pipes were being erected to the power station and the adzed bedlogs for the woodstave penstock were complete only some 230 men were employed, whilst in Nov-Dec 1912 the works were closed down for several months. Butters stated (Annual Report to the Minister 1914/15) "I desire to bring to your special notice ... staff, who have been untiring and loyal ... C.C. Halkyard..."(MCE; MIEAust; AMIntCE; Asst. Engineer; Engineer-Hydraulics Designs; Hydraulic Engineer; Asst. Deputy Chief Engineer (1912-1925)..."who as Resident Engineer has had local charge of the whole of the works from the power station to the dam; A. Grigg, Supt. of Transmission Lines and E.A. Bennison, ... of Transport". "He also included a number of foremen. In June 1920, Halkyard presented the first paper to the Tasmanian Division IEAust. Notes on Large Water Power Pipe Lines. Transactions Vol 1pp 248

In addition to the contracts to supply the Hobart City Corporation; including trams and the Hobart Gas Co., a contract was being negotiated with Gillies Co. for 3,500hp with a further option up to 10,000hp (later 20,000hp) for their carbide works and the first stage of electrolytic refining of zinc from complex ores and concentrates. Additional loads were sought by advertising, contacts with Australian and Overseas industries to foster such industries in Tasmania and emphasising its very low power prices. An electrical exhibition was held at Hobart.

4. SECOND STAGE

However Amalgamated Zinc (De Bavay) Ltd. had been encouraged by the Commonwealth Government and particularly by the Prime Minister Hon, W.M. Hughes to assist the War effort by producing spelter with strong financial support from the British Government. The newly elected Tasmanian Government also offered very favourable conditions which resulted in a contract between the Government and Amalgamated Zinc including the lease of the 50 acre site at Risdon which Gillies had selected, but was refused because of objections by the Corporations Health Officer; forcing his Company to locate 17 miles South of Hobart and pay for the additional transmission line. Amalgamated Zinc established the Electrolytic Zinc Co. of A/sia Ltd which contracted. to receive 4,000hp from May 1919 with rights to an additional 26,000hp for 20 years and a third block of 20,000 i.e. a total of 50,000hp at 2 pounds hp/yr. At a dinner in Melbourne in honour of Hughes, W.L. Baillieu concluded, "Mr. Hughes' utterances were flying round the world like an electric torch, and finding an echo in all our breasts" (5) Reactions to these proposals in the Tasmanian Parliament were similarly mixed, but Gillies' company was forced to abandon its electrolytic proposals.

The Electrolytic Zinc Co. set up an experimental pilot plant at Risdon to produce 10 ton/day of zinc; increased to 100t/d (1920); now 220,000 tonnes per annum, with H.W. Gepp (1877-1954) later Sir Herbert, manager (1917). He had joined the Zinc Corporation (1905) and worked on its development of the flotation treatment of complex ores and their sulphide problems, in which Australia was World leader and is said to have made one of the greatest economic contributions to international metallurgy by resolving the treatment processes. He was manager of De Bavay's Treatment Co. Ltd. (1907).

Due to the increasing electrical load and the Zinc Co.

exercising its option (1919), the HED obtained Government approval (1918) to increase Waddamana's capacity to 52,000hp continuous and 63,000 half hourly demand (peak).

With W.H.R. Nimmo (later Sir William) engineer-in-charge of the Ouse River "Conservation Works" the headwaters were diverted into Great Lake by the 450cfs (later 650) Liawenee canal, consisting of a concrete diversion weir; reinforced concrete tied flume, unlined canal and rock cuttings. In total about 5.5 miles long plus about 2mi from the tail-weir to the Lake via a natural creek-bed. The upstream 180ft of flume was built initially in trapezoidal section in timber to allow for the design of an automatic intake control based on subsequent hydrological data and hydraulic measurements. Subsequently Edward Rowntree, DFC; BSc; BMechE; FIEAust; designed an adjustable orifice control and skimmer plate which automatically regulated the inflows to the flume by converting velocity head to static-a fine example of low cost hydraulic engineering for a remote, unmanned area (3). "Canal Creek" to the Lake became a major spawning run and has provided an Inland Fisheries Commission site for stripping, measuring and monitoring the trout population and more recently a laboratory. The Ouse R. Conservation Works were completed in 1923.

The Lake storage was considerably increased by the construction of No2 dam 100ft downstream of the Miena masonry dam. Some five years earlier American work had shown that multiple-arch and buttress dams had cost and other advantages for sites with difficult and uneven foundations and or with high costs of materials, including concrete and labour. The Miena Multiple Arch dam (1920-22) designed by Halkyard (qv) was the first to be built outside USA and the longest in the World. It was 40ft high (35ft storage) 27 arches each 40ft wide plus small gravity abutments and total length 1,180ft and was of international interest. After initial delays with supplies immediately after the Great War and a tight programme to meet the EZ Co's supply contract, work was continued under difficult conditions. "The Winter of 1921 (with excavations in full swing) was exceptionally severe. The Lake was a sheet of ice .. men played football on it and storms were frequent and furious. Working just below the old dam .. depths up 50ft below Lake level .. necessitated heavy pumping. Fortunately the gangers were experienced miners from the West Coast .. only one accident is a testimony to their vigilance and skills". The risks of tapping major inflows from the Lake with its then c.500 square mile-feet volume resulted in no blasting in excavations close to and below its level, massive support timbers and much bar and hand work (8).

The foundations averaged 6ft deep to good rock, but the W. Rift was - 32ft and E. Rift - 52ft where the arches and buttresses were carried down to solid rock. (When the third raising of Great Lake was being investigated the depth of these rifts and related uncertainty led to the decision to build a separate (No3) rockfill-clay blanket dam (1967) downstream of No2).

The arches and buttresses were heavily reinforced and stiffened with edge beams including crest beams and the works were well designed and managed, eg. both aggregate and water was heated in cold weather, fresh concrete covered with tarpaulins and warmed with fire-pots with no concreting at -34 degrees F. Sieve analysis and testing of concrete, mortar and cement cubes were regularly carried out with 6" x 6"cubes cast each 2nd day of pouring and sent to the University after curing for testing (8). The result has been leak-free dense concrete with only minor weathering such as ice and frost effect on flat surfaces and the loss of surface fines due to water action over some 70 years. Due to the long Northerly wave fetch and the extrados slope of 60 degrees to horizontal, considerable run up with up to 1,000cfs crest spill has occasionally occurred when the Lake was near full supply level, but with minor damage only and gunwhale type fillets were fitted to the arch junctions c.1925. When construction reached 25ft height storage behind the new No2 dam commenced. Since the Lake inflow is 100% regulated no spillway was provided. The batching and mixing was done in an 80ft high x 120 ton (loaded) mobile tower which contained 2 x 30 cu-yd aggregate and 1 x 175 cu-ft cement bins, the batch being delivered from its 1/2 cu-yd mixer via articulated and crane supported chutes. The outflow was controlled by 4 CI bell-mouthed outlet tunnels and hand-operated sliding gates (Qmax 2,000 cfs) protected by upstream fish and debris screens. They .."were made in a Hobart foundry .. and a very credible piece of work." (8) Construction power was supplied from Waddamana at 6,600V, 3 phase AC at 415/240V and night lights were used.(8)

The intake to Waddamana canal 5 miles down the Shannon River was extensively altered to consist of a 4ft high rock and puddled clay weir armoured with dolerite spalls and controlled by 6 sluiceways. A needle dissipator or fall and extensive concreting and rock protection was installed to eliminate scouring. The canal capacity was increased to 600cfs by widening and providing extra freeboard. This work was done with the older canal in operation and loop diversions were added at two rock cuttings to avoid blockage of the existing canal during blasting. Concrete and rock weirs (drops or ripples) with reduction in canal width and reinforced concrete and rock protection to sides and inverts were provided to reduce hydraulic slopes to 3 and 4ft/mi.

Additional concrete chambers were built at the forebay and the screens, cleaning walkways and freeboard increased with twin reinforced concrete chambers each serving two pipelines.

Three additional 60" dia woodstave pipelines were installed, parallel to No1 48" dia oregon (1916); two karri and a second of oregon; A rivetted steel surge tower, 69'H x 15'dia was built about 3,000ft from Penstock Lagoon.

Due to War-time restrictions on the supply of boiler quality steel plate, one of the 49" dia. woodstave pipelines was continued about 2,300ft to 390ft head, requiring special one inch flat bands and special shoes by Aust Wood Pipe Co., the contractors. It was considered to be the highest head in the World applied to a woodstave pipeline of its diameter.(7) Below the major anchor block at the end of the low head hilltop pipelines, the 5 penstocks were No1 line welded steel 2x38"O.D., Nos3&4 rivetted steel 2x54"; plus the woodstave (No2) continued as No3. At the high head transitions No1 line continued as three welded steel pipelines, 24"+2x785mm. No2 (the woodstave) joined a steel welded line 51" decreasing to 48" O.D. Of special note was the use of Mephan Ferguson's Patented Lockbar pipes (M. Ferguson was a Director of Gillies' Complex Ore Co.) with No4 penstock continuing in 51" O.D. (Lockbar) and then bifurcating to 36" Lockbars. The construction of the penstocks and appertenant works for the First Stage was done with steel tram and steam driven winch to approx 830ft above the power station level, and wooden tram and horses serviced the low pressure hilltop. Drilling was by hammer and tap with hand mixed concrete. For the Second Stage two steel tramways and electric drive was used plus a steel tram and electric winches at the low pressure sections. The buspipes were parallel and adjacent to the station with valves to isolate any section. C.I. tees and crosses at 750mm for the new 7x8,000hp turbines and 600mm for the 2x4,900hp (1916) machines fed the jets.

The First Stage power station was extended on solid rock foundations and included three concrete lined tunnels, the tailrace plus one each for cooling air and hot exhaust air from the alternators, the latter two regulating temperatures for the m/c's and the station and eliminating m/c noise. The superstructure was extended with steel frames and galvanised wrought iron cladding. Seven additional turbines were installed of the same type, make and speed, but with twin jets and 7,050kVA alternators from Australian General Electric Co. The m/c sets plus the auxiliary units were all of high quality design, fabrication and performance and their efficiency remained high throughout their 40-50 years service. The turbine wheels and buckets were cast steel and their casings cast iron. Boving patent deflected-jet governors and Johnston-Boving patent inlet valves were installed. The installed capacity was 66,000hp. The transformer yard 6,600/88,000V and switchyard adjoined the station which remains complete, with blackwood timber panelling to the office areas and the whole well maintained as the HEC Power Museum, available to the public.

The station was taken out of service (June 1965) after 50 years of operation when the Poatina Power Development was completed, the Great Lake having been further augmented from adjacent catchments and diverted via a single tunnel and a banded steel penstock to Poatina Power Station 600ft underground at the foot of the Northern escarpment with 300MW installed. With 2,720ft static head at minimum operating level it was the 6th highest in the world.

The transmission lines were increased; (88kV, distributed at 6.6kV) Nos 1 and 2 supplying Hobart and the 1916 No 1 terminus changed to a switching station for the Electrona line which was built with wooden towers c.40ft tall. No 2 line carrying two conductors and No 3 one conductor to Launceston, were commenced in 1921 and completed in late 1922. No 2 continued on the East bank of the Derwent River to the EZ Co Risdon Works where it crossed on towers 136'-6" and 171' - 6" tall, providing 155 ft shipping clearance. Major sub-stations were built at Hobart (Risdon), Launceston, Electrona and Bridgewater (3)(6).

The level of interest in the development is indicated by the extensive coverage in newspapers and technical journals. Also, separate small ceremonies were held at which each m/c set was started up by Tasmanian notabilities, Nos 3 to 7 came into service on Nov. 1919, Dec. 1922, Feb. May and Nov. 1922 respectively and No. 8 April 1923. They included Sir Francis Newdigate-Newdegate (Governor), Hon. J.B. Hayes 2(Premier), Sir Walter Lee (Premier) and Sir Elliott Lewis (Past Premier). Hon. W.M. Hughes (Commonwealth Prime Minister) also officiated. However the Official Opening was held on the completion of No. 9 m/c on 19 January 1923. after H. E. the Governor-General, Lord Forster and Lady Forster had previously travelled from Deloraine to Breona at the Northern shore of the Lake, then in very rough weather by launch; "Governor Newdegate" to Miena at the Southern end where the sluice gate was opened. The party rode on horseback to the station inspecting the canal and pipelines en route. The Hobart "Mercury" printed several (broadsheet) pages on these events complete with photographs and considerable detail.

However a reporter wrote ".......the accommodation provided by man for his horses is frequently more pretentious than .. for himself..... the same cannot be said of the stabling for the electrical hp of the State. The structure housing.the magnificent aggregations of machinery is ....outwardly indistinguishable ... from .. a .. cow barn".

5. BIOGRAPHICAL NOTES

Only a few of the many engineers, technicians and workmen who contributed to these projects can be referred to here. Photographed "Staff" (6-p65) are Butters (q.v), Halkyard (q.v) and H.A. Curtis, AMIE Aust; A Am IEE, Power Station Supt; Chief Operator; Engineer for Electrical Construction, Acting Chief Engineer (1916-24)(ie. to date - published 1925) and first Commissioner, HEC (1930-d.1933). Six others are briefly described as follows, F.M. Nicholl, M.I.E.Aust; Electrical Engineer, Asst. General Manager, (1919-21); Major R.V. Morse, D.S.O., AMIE Aust; MI.Mech.E; Engineer for Electrical Designs (1920-22); (Morse - War Mining Notes on the Western Front, was the second paper read to Tasmania Division IEAust. (1920). He died Jan. 1925) A.H. Bastow; MA; MCE; M. InstCE; AMIE Aust., MIME, Engineer for Hydraulic Construction (1919-22); N.V.S. Wilton, MIEAust, Engineer for Sub-Station Construction, ditto Electrical Designs (1915-22); W H Nimmo, qv; BCE, AMIE Aust; A M Inst. CE; Resident Engineer (RE) Ouse Diversion; F.A. McCormick, RE Waddamana Civil Construction; W.E. MacLean, A Soc. CE, RE Great Lake Dam construction;(HEC Commissioner 1933-1946) A.P. Binns, B.Sc; AMIEAust, AMIEE; Hobart District Enginee6r (1918); H.A. Child, BE, AMIE Aust; Country Districts Engineer (1923) G.H. Lofts, AMIEAust; Manager Hobart District (1917).

However, Gillies & Butters were outstanding in their contributions, but were very differently rewarded. James Hyndes (ADB incorrectly "Hynds") Gillies (1861-1942) was born in NSW, studied at the Sydney School of Mines and worked to develop processes to recover minerals from complex ores. He held patents in USA, Germany, Belgium, Mexico and Australiasia (1907) for the electrolytic treatment of refractory zinc ores and subsequently initiated the h-e power development of the Tasmanian central highlands and directed it until c1914 as already described. He was strongly and unfairly attacked particularly by E. Mulcahy and other Tasmanian Parliamentarians who hobbled his company with conditions which eventually destroyed it. He died a poor man although on two occasions the Lower House of the Tasmanian Parliament voted him a small pension, (Resolved, nemine contradicente) the Upper House rejected both proposals without debate or explanation.

He was granted an annuity of 350 pounds in 1935. Butter wrote on 6th November 1957 (5) "You are quite correct in crediting J H Gillies with the enterprise of trying to get the treatment of zinc ores introduced into Tasmania. I always thought he should have been officially recognised, either by a honorary degree at the University or a decoration and went so far as to suggest it to some of the powers that be, but could not stimulate any interest".

John Henry Butters (1885-1969) studied at Hartley University College, South Hampton for 3 years and received a University of London B Sc (Engineering) and a 1st Class Electrical Engineering Certificate (Hartley). After training with Thornycroft & Co he joined Siemens Bros Dynamo Works Ltd at Stafford, then assistant engineer at their London Head Office (1908). He was transferred to Australia (1909) as their chief engineer and advised Waihi Gold Mining Co. NZ; on its h-e station at Hora Hora - Waikato R.; the Adelaide Tramway Trust and was consultant to Gillies Complex Ores Co Ltd. In August 1911 he was appointed engineer and manager of its Tasmanian subsidiary and visited England and USA (1911) to order the machinery and equipment for the First Stage. His role in it and the HED has already been briefly described herein, he was made MBE (1920) and CMG (1923). He sought overseas service having joined the Australian Royal Engineers (1909) but was refused and served as Staff Officer, Engineers at Hobart (Major 1919), and at Army H.Q. (Hon. Lt. Colonel (1927)

Butter was President, Tasmanian Institution of Engineers (1918) and Chairman Tasmanian Division and Commonwealth Councillor (1920) I.E Aust. In January 1925 he commenced a five year appointment as Chief Commissioner and full time executive of the Federal Capital Commission on 3000 pounds pa (HED - 1500) to complete Canberra, Parliament House and all related services, schools (13 by 1925) buildings etc. before the planned opening (1927). He was chosen from more than 100 applicants and fully justified his selection by achieving the Governments targets under very difficult and highly criticised conditions. The workforce peaked at 3000 men. He was created knight by the Duke of York (later King George VI) during the opening of the new Parliament on 9th May 1927, but refused an extension of his appointment and left Canberra for Sydney (Oct-1929) having been inaugural chairman, Canberra Division I.E.A. and Commonwealth President (1927/28) As an engineering consultant until c1954, Butters continued his very active professional career, but also devoted much energy to honorary roles and served on the boards of numerous industries and organisations (9).

His view (1925) was farsighted; "The fact however remains that water power schemes whether economic at present or not, must some day be developed on account of the rapid and ever increasing depletion of the Worlds' supply of coal and oil."6 He had earlier convinced the Tasmanian Government(s) that with a small population and no large power industries it was necessary to attract to the State those who required large blocks of very cheap power and that "Tasmania's industrial future necessitated something really big being done ... to turn an unimportant electricity supply system into an undertaking of national importance". (Notes on the Development of the Power Resources of Tasmania; J.H. Butters, Paper No1, Vol VII, 1926; IEAust.)

6. CONCLUSIONS:

The development was described as the "first major works of this type in Australia" (1) and steps are now being undertaken to designate it a National Engineering Landmark, but more importantly it provided a very large increase with a continuing multiplyer in Tasmania's economy, the affects of which have continued to the present. It also provided work experience for a large number of engineers, technicians and workmen and the development of their capabilities which were subequently applied throughout Australia. For example, Sir John Butters in Canberra and elsewhere, Sir William Nimmo in Queensland, Sir Herbert Gepp in major industries and Federal Government service, E.J. Rowntree's technical investigations for Proposals to Divert the Snowy (1950) and his subsequent appointment to Snowy Mountains H-E Authority and C.C. Halkyard as chief engineer for Humes Ltd. The 75th anniversary of IEAust. (21st Oct 1994) is a reminder that c.40% of the foundation members of Tasmania Division were employed by HED, as were the majority of those employed by EZ Co.

The reinforced concrete tied flume for Liawence Canal and its remote intake control; Miena Multiple Arch dam; penstock designs and construction, particularly the woodstave pipelines under 390ft head and the Lockbar pipelines; power station construction and fit-out are items of historic engineering heritage. They are now memorials to the bold initiatives and professionalism of the Workforce and their perserverence against harsh working conditions, financial and delivery problems, particularly during the First Stage. Also after the initial public and parliamentary opposition to Gillies proposals, to successive Governments' acceptance and support for the proposal put before them. It is of interest to note that some of the strongest parliamentary critics were subsequently HED supporters.

Great Lake, initially developed South to Waddamana, but now North to Poatina with a beneficial factor of 2.5 times, has been and still is the "Goldmine that never runs out of Gold". It and the Waddamana Power Development provided a low cost solid base to the subsequent growth of the Tasmanian hydro-electric power system.

"Wherefore praise we famous men
From whose bays we borrow
They that put aside To-day -
All the joys of their To-day -
And with the toil of their To-day -
Bought for us To-morrow"

Kipling "A School Song" (1899)

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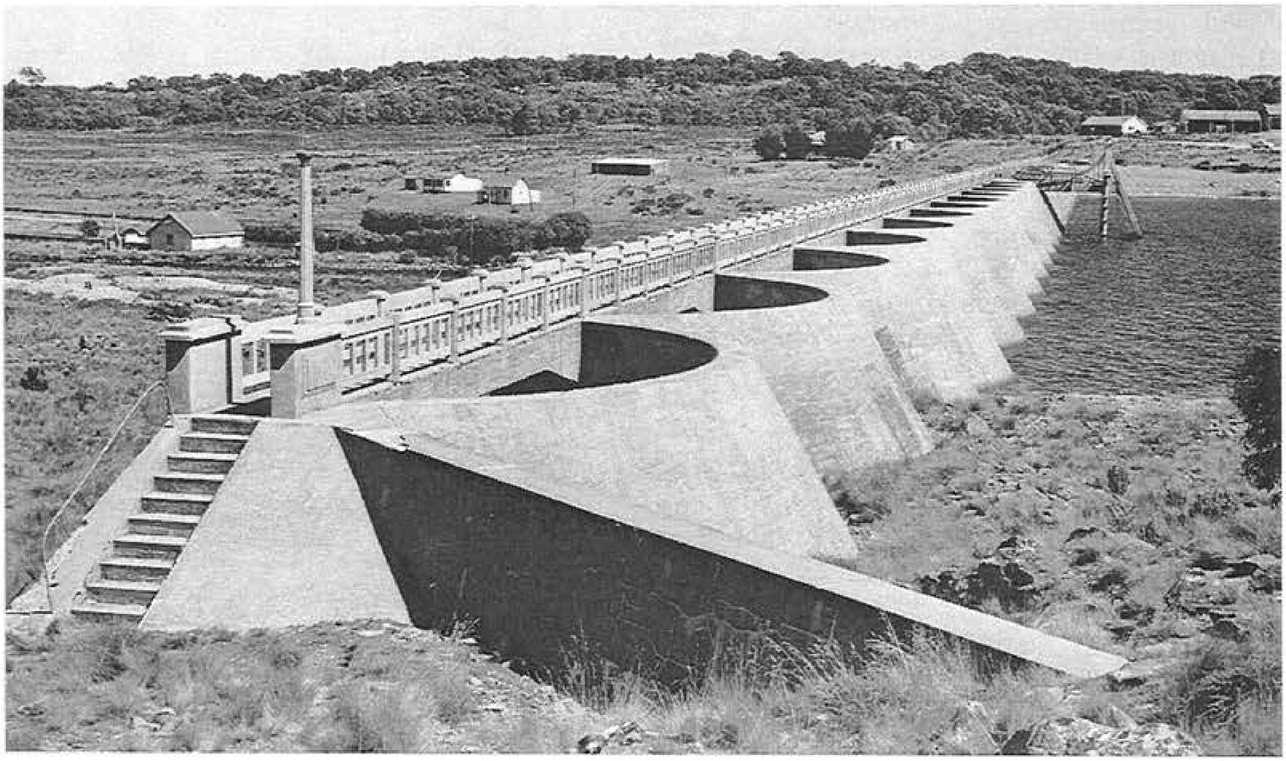

FIG. 1 Multiple Arch Dam - Great Lake (Tas). Completed 1922. Photo c. 1950

FIG. 2 High Pressure Steel Penstocks, Waddamana Power Station, Tailrace, Village & Ouse R. (c. 1923 - looking South).

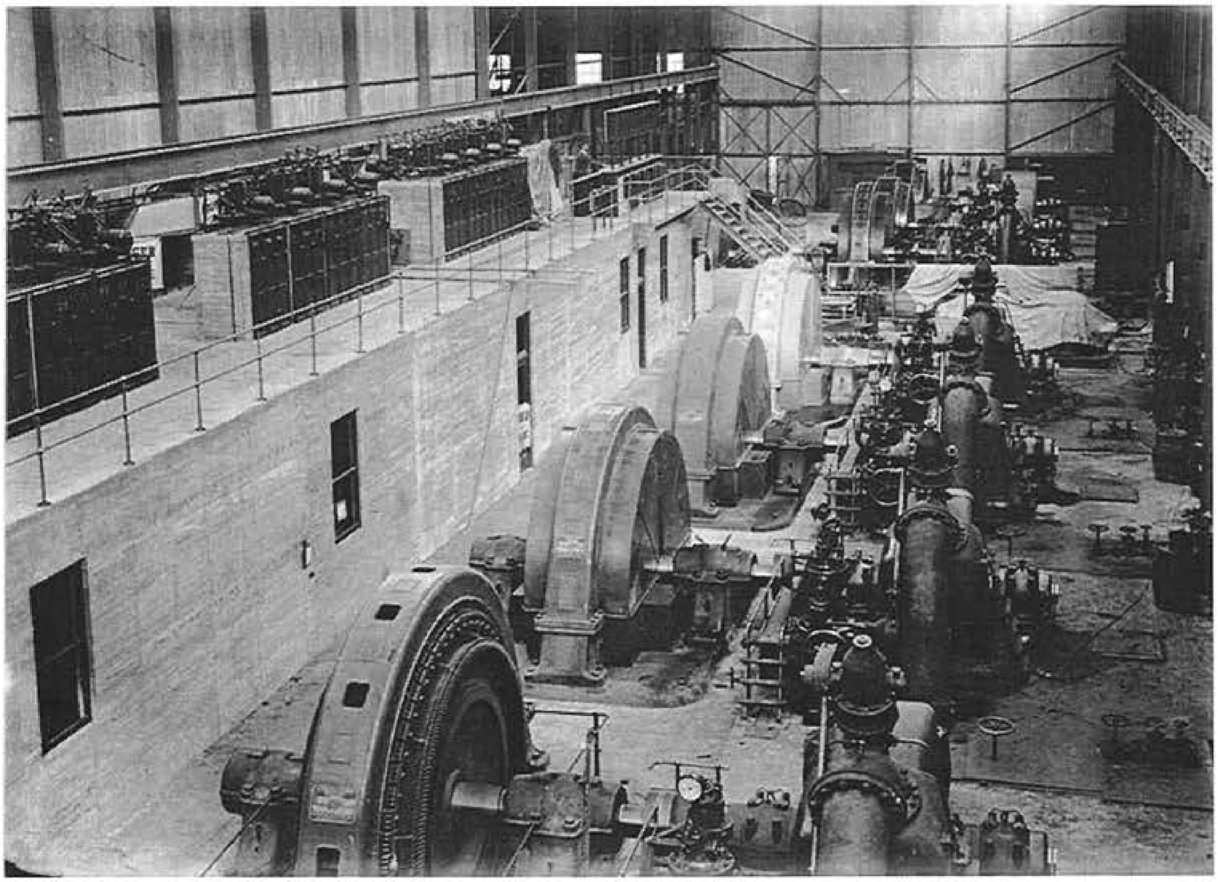

FIG. 3 Waddamana Power Station, work-in-progress. (1923 - looking South).

Water for Ipswich

Em. Prof. Ray Whitmore, Hon. F.I.E.,Aus., B.Sc., Ph.D., D.Sc.

SUMMARY Settlement began in earnest in Queensland after its official proclamation as a British colony in 1859. A basic need of all its townships was a reliable supply of clean drinking water, and the Imperial government was able to provide considerable assistance in developing suitable schemes. Unfortunately the tried and true technologies of the motherland did not always work out in the alien Queensland climate, resulting in systems that often required extensive on-the-spot modifications. Ipswich was the first Queensland township to adopt a pumped river-water supply and the paper describes the scheme, the difficulties that it met with, and the methods that were adopted to keep it in operation for some 45 years. The physical remains of the scheme are described and illustrated.

1. INTRODUCTION

It is widely accepted that a primary requirement for the well-being of a healthy community is a reliable supply of clean, reticulated water. Without it the inhabitants live under the constant threat of disease and sustained growth becomes impossible. In 1859 at the time that the colony of Queensland was established by its separation from New South Wales, even the major town - Brisbane - had no piped water, the residents relying for their supplies on shallow wells and run-off. There, the construction commenced almost immediately after Separation of a dam at Enoggera some 10 kms away, from which water could be piped to a reservoir in the town and then reticulated beneath the main streets but other communities had to wait much longer[1].

The townships of Ipswich, Rockhampton, Toowoomba and Maryborough were officially proclaimed as municipalities in 1860 and there was an immediate undercurrent of concern from their newly-elected councillors about the quality of the water. Indeed, the first resolution passed by Rockhampton's town council was that it should apply to the colonial government for a grant for a water supply facility at the nearby Yeppen Yeppen lagoon[2]. The Ipswich council directed that a preliminary survey be made of the practicability and cost of bringing water from the Brisbane River[3]. In 1865 there was a petition from Maryborough for a grant towards the cost of developing a water supply, while Bowen - and even tiny Clermont - applied to the government for help[4].

The government realised that it had a problem and in July 1865 it made the Engineer of Harbors and Rivers, Joseph Brady, responsible for provincial water supplies[5]. Brady, who was 36 years of age at the time, was an experienced, British-trained, civil engineer who had been involved in water engineering in Victoria for at least six years and had previously been Engineer to the Brisbane Board of Waterworks[6]. At the government's request he prepared full-scale plans for water supply systems for Ipswich, Rockhampton, Maryborough and Bowen and preliminary plans for Gladstone, Mackay, Toowoomba and Dalby. To assist him in this work he acquired the services of a young engineering assistant, William Highfield[7].

In July 1866 Queensland was suddenly faced with an economic and political crisis. A bank through which the government had been negotiating a loan of ú1m collapsed and the Governor refused to accept the remedial measures proposed by the Legislative Assembly. The Premier protested that the Governor had exceeded his powers and resigned, and there was a fortnight of confusion and political turmoil[8]. When calm finally returned the promises about water for provincial towns were forgotten, Brady and Highfield were dismissed and the waterworks section was disbanded[9].

Three years later, in 1869, the government introduced a water supply bill into the Legislative Assembly in which it proposed establishing a colonial water board, operating along similar lines to the Brisbane Water Board but the reaction was lukewarm and the bill was dropped[10]. Water became a relatively low-priority item, and three years later the colonial secretary was able to claim that the government had not introduced a new water supply bill in that session because of the amount of other business on the agenda[11].

2. IPSWICH

The city of Ipswich stands on the Bremer River (Figure 1) and by the late 1860s its population had grown to about 5,000[12]. Its importance lay in the fact that it was at the limit of inland river navigation for transport between the mouth of the Brisbane River and the Darling Downs: Queensland's first railway opened in 1865 and it reinforced the importance of Ipswich by running from Ipswich to the Darling Downs. The town's drinking water which was drawn from the Bremer River or from springs or wells was of indifferent quality, and in 1871 the Ipswich Town Council appointed a water supply committee to reinvestigate the scheme that Brady had proposed in 1866[13]. His plan had involved drawing water from the Upper Brisbane River to the north of Ipswich, pumping it to a service reservoir on a nearby hill and then piping it to the town under gravity.

Queensland rivers are notorious for the fickleness of their flow and Brady had proposed to control the height of the water at the intake by building a low masonry dam across the river. The water was to be led down a tunnel driven in the south bank of the river to the foot of a well where a couple of steam-driven combined lift-and-force pumps would raise the water 70 metres (230 feet) to the service reservoir. The condensing engines, each nominally of 30 horsepower, were large enough to permit the pumps to handle 91,000 litres (20,000 gallons) of water per hour, and either engine was sufficiently powerful to supply the town with water (if run for 10 hours per day) until the town population exceeded 10,000[14]. Brady had costed the proposal at £32,464 but the water supply committee, fearful of the expense, pared it back to £21,119 by eliminating the dam and one of the engines[15]. The council then applied to the government for a loan of £22,000 but it was rejected, the government suggesting that a scheme relying on drawing water from the Bremer River could be built for half the price[16]. The council refused to accept the suggestion and allowed the matter to drop.

Figure 1 Modern map of Ipswich, showing Highfield's plan for the location of the waterworks and the reticulation system.

Rockhampton was still persevering with its scheme, where Brady had planned to draw water from lagoons and filter it because of its high vegetable-matter content. Even after eliminating the filters and minimising the size of the engines Brady had been unable to reduce the cost below £25,000 and it was clear that the government was not interested in lending the council anywhere near that amount of money[17]. Finally the council's surveyor, Thomas Burstall, pared the scheme down to £10,000 and in 1873 the government granted a loan of £10,500 to carry out the project[18]. The local gas engineer, William Smith, was made responsible for the detailed design, and site work site commenced in February 1874.

Ipswich had been closely watching Rockhampton's progress and by 1873 the council had resigned itself to abandoning the Brisbane River scheme and drawing the town's reticulated water supply from the Bremer River because it would cheaper[19]. The government offered the council a loan of £12,000, and the Under-Secretary to the Public Works Department (who doubled as the Commissioner for Railways) instructed his engineer, John Thornloe Smith, to carry out a survey[20]. In December 1874, at the suggestion of the Toowoomba and Ipswich councils, the government appointed Highfield to the position of Engineer-in-Charge of Waterworks, making him responsible for the construction of all provincial waterworks in Queensland[21].

Highfield, born in Italy of British parents, was later referred to by the Premier of the day, John Douglas, as "a gentleman of professional ability" although the only evidence of it was the self-styled C.E. (civil engineer) which he placed after his name[22]. His experience in hydraulic engineering before emigrating to Queensland in 1864 appears to have been restricted to acting as resident engineer for works connected with the supply of water in Cheshire[23]. An energetic, stockily-built man with light brown hair and hazel eyes, he was 35 years of age when he accepted the government appointment[24].

Smith published his survey at the end of 1874, putting the cost of his Bremer River scheme at £17,759, but when Highfield turned his attention to the matter he told the town council that his estimate of the cost of the Brisbane River scheme when he had been employed as Brady's assistant had been only £15,500, although it might be higher now because of an increase in the price of iron[25]. When he re-estimated the cost at £21,500 the council thankfully grasped the opportunity of reinstating their favoured scheme[26]. The government finally agreed, made a loan of £23,000 available, and in June 1876 the Public Works Department began calling construction tenders[27].

3. THE PLAN

Brady had chosen a place for the pumping station on the Brisbane River where there seemed to be a constant stream of water flowing over a bed of gravel; it was there that he had proposed to build a masonry dam[28]. "Owing to the great height to which floods rise at this place" he wrote," special precautions are necessary to guard against damage to the works; and instead of pumping direct from the river, it is proposed to erect machinery at about one hundred and thirty yards (120 metres) from the south bank, and one hundred and eight feet (33 metres) above the bed of the river; a well shaft to be sunk in this position and connected with the river by a short tunnel". Highfield, however, eliminated the dam and placed the pumping station nearer to the river; this reduced the cost of the scheme by reducing both the length of the tunnel and the depth of the well[29]. To guard against innundation in times of flood the pumps were erected in a second well, sunk close to the first and connected to it by a pipe which could be closed off if necessary.

For the engine, boilers and pumps, Highfield drew up short specifications defining in general terms the nature of the duty required and including a cross-section of the territory to be traversed by the rising main. It was then sent to Queensland's Agent General in London who called for tenders. The tenderers submitted their own designs and the government consulting engineer in England selected the successful contractor[30]. The contract was won by Appleby Bros. of Emerson Street, Southwark, London SE and a cross-section of the equipment is shown in Figure 2. It differed from Brady's proposal in replacing the two reciprocating lift-and-force pumps by four small single-acting, lift pumps. The vertical pump rods were connected to cranks keyed to two horizontal shafts running across the top of the shaft and driven through clutches and bevel gears from the main engine crankshaft which carried a flywheel 4.25 metres (14 feet) in diameter. The crankshaft was powered by two horizontal, high-pressure, single-cylinder engines although only one was initially installed[31]. The four pumps, situated 7.5 metres (25 feet) above the bottom of the well, could be operated simultaneously or in pairs.

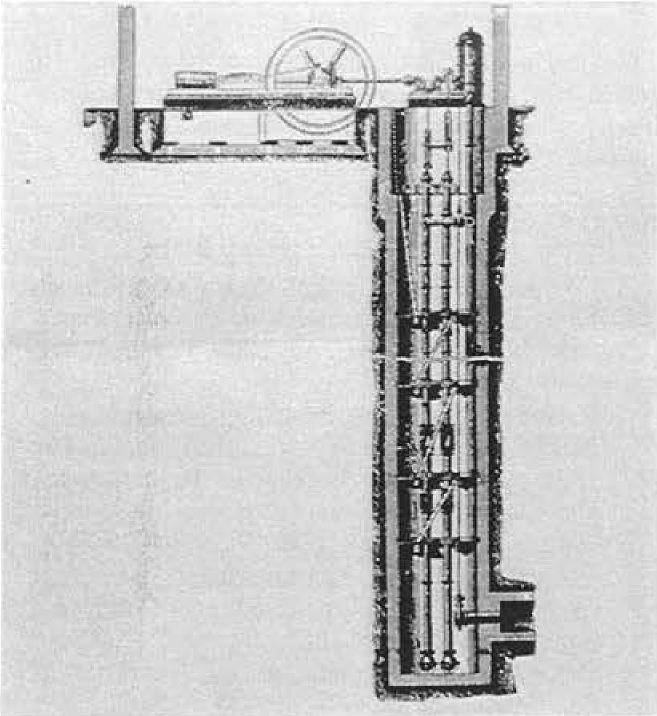

Figure 2 Cross-section of the well, pumps and pumping engine, taken from Appleby's 1880 catalogue

Brady's proposal to install three Cornish boilers was discarded in favour of two water-tube boilers and the size of the air vessel on the water-delivery line was reduced. The pumping station, built in two bays and made of corrugated galvanized sheeting attached to a hardwood frame measuring 18 metres by 14 metres (60 feet by 46 feet), was lit by glass windows on one side and louvres on the other. The diameter of the rising main running from the pumping station to the service reservoir was reduced from 250 mm (10 inches) to 225 mm (9 inches) and the capacity of the reservoir increased from 1.36 to 1.82 megalitres (300,000 to 400,000 gallons). The reservoir was excavated out of the native rock, lined with brick, and the space between the lining and the rock filled with concrete[32].

The whole scheme was completed in June 1878 and Highfield officially handed it over to the Ipswich town council two months later[33]. It cost the Ipswich Town Council £31,000 in government loans, or £9,500 more than Highfield's estimate but the council seemed satisfied and commended him on the "choice of the source of the water supply, the manner in which the works had been designed, and with the faithfulness with which their construction has been carried out"[34]. It proudly named the engine Millie Francis after the mayor's daughter[35]. Figure 3 shows the completed station.

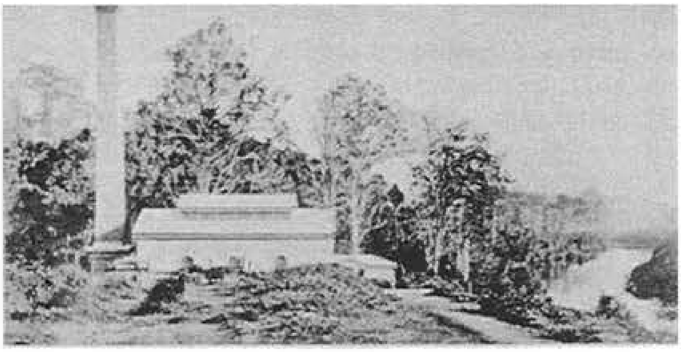

Figure 3 The completed pumping station

The government's wisdom in undertaking the design and construction of the Ipswich waterworks seemed to be confirmed by the experience of Rockhampton where the locally-designed system was completed in June 1875 but was a failure. Highfield, who already had the responsibility for the waterworks at Toowoomba and Warwick, was put in charge of Maryborough's scheme but in 1879 the government had second thoughts as to the wisdom of taking responsibility for building waterworks. Legislation was enacted that allowed the local councils to plan and implement their own water supply schemes and the responsibility for advising town councils on water supply matters was transferred from the Department of Public Works to the Colonial Treasurer's office where John Henderson was made Engineer-in-Charge of Waterworks and Highfield was told that his services would not be required after the end of the year[36]. Shortly before that time he was accused of misappropriating public funds, found guilty, and imprisoned in Brisbane gaol for 12 months with hard labour. Subsequently he was banned from participating in any work connected with government contracts although the ban was not rigorously applied.

4. THE AFTERMATH

Within a year of Highfield's removal his section had been disbanded and the staff dismissed. The Warwick and Toowoomba councils reacted predictably to Highfield's departure, complaining bitterly that they had been overcharged for their waterworks. and asking the government to scale down their loans but official enquiries rejected their claims and exonerated Highfield of any gross financial misdeeds or engineering incompetence[37]. However, all the schemes encountered difficulties; Ipswich was probably the best of them, or at least Highfield thought it was. "Without egotism", he wrote to the Under Secretary for Public Works "I think I may point to Ipswich as a test of my ability"[38].

Problems soon began to appear. South-East Queensland can experience long periods of near-drought conditions interspersed by violent heavy thunderstorms which cause large variations in the flow rate (and thus in the height) of the Brisbane River[39]. In near-drought conditions it became little more than a series of pools and the waterworks engineer was reduced to digging channels through the sand banks and erecting a temporary dam to hold back sufficient water to supply the inlet tunnel[40]. After heavy rain the load of sand, silt and debris carried by the water blocked the pump inlets, the grit played havoc with the pump buckets, and the leather washers required constant replacement[41]. Ultimately a new intake had to be constructed, taking water from a deep pool higher up the river.

Ten years after its opening the publicity bulletins were still claiming that "These are considered to be the finest waterworks in the Colony"[42]. But the pump rods fractured, pump buckets and bodies wore out, and the variations in river height constantly interfered with operations: Alderman Springall (who ran a local engineering firm) said the pumps had been a waste of money and should be thrown away[43]. Flood waters reached the operating floor on two occasions, and after the station was completely submerged in the 1893 floods the council decided that it had had enough (Figure 4). A new site on higher ground was selected for the pumping station, new pumps were purchased and in 1894 the old station was finally abandoned. A photograph of the site in 1993 is shown in Figure 5.

Figure 4 The pumping station after the 1893 floods (courtest Helen Hughes)

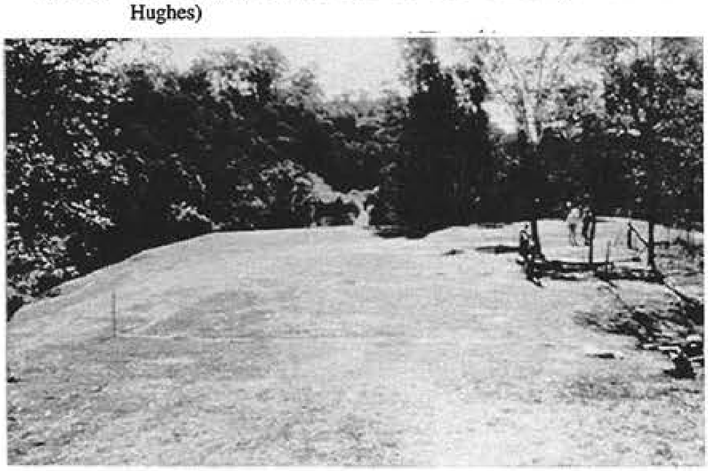

Figure 5 The Pumping Station in 1993 (Courtesy Helene Hughes)

5. CONCLUSION

So what went wrong? Why did a project that started so well finish so ignominiously? The reasons can be traced, first, to inexperience on the part of the designer, second, lack of information on river conditions at the site and, third, a paucity of funds that forced Highfield to accept suboptimal solutions. Experience as a resident engineer for a provincial water supply development in Britain was not a sufficient qualification for designing a waterworks in Queensland. Brady's plan had answered the problem of big variations in the flow rate of the Brisbane River by putting a low dam in the river and siting the pumping station well above any possible flood level. Highfield took risks in eliminating the dam and putting the pumping station nearer the river. By so doing he reduced the initial cost of the works but he lost heavily on both the other counts.

Highfield did not let his tribulations overwhelm him. He continued living and working in Queensland, raising a family of twelve, and dying in1923 at the ripe old age of eighty-four.

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Development of Water Power in Southern New South Wales and the Australian Capital Territory

K M Baker, Engineering and Heritage Management Consultant, Canberra.

SUMMARY The author has recently undertaken a heritage study in the Shire of Tumbarumba, emphasising the history of the use of water power for timber milling, mining, electricity generation and farm applications in an alpine area of New South Wales. He is also a member of the Australian Capital Territory Engineering Heritage Panel, which has restored a water powered pump at the Cotter Pumping Station in the ACT as a recent project. The panel is encouraging further research into the associated machinery and its setting on the Cotter River. The aim of this paper is to review the history and physical evidence of the past use of water power in the region, drawing out the earlier influences from overseas and elsewhere in Australia, recognising the ingenuity displayed in harnessing the available energy by improving on past designs, citing the natural disasters and human intervention which cannot always be foreseen, and noting the problems this can leave for conservation of equipment and interpretation of water powered sites.

1 INTRODUCTION

Water power has been very important to the development of the remote alpine areas of southern New South Wales from the 1870s through the following century,where it found a wide range of applications in mining, saw milling, agriculture, food processing and electrical generation. Until the development of the Snowy Mountains Hydro-electric scheme, the use of water power in southern NSW was characterised by local people with limited resources making use of the materials and technology available to them, and persistently extending the boundaries of their use.

By contrast, the early development of Canberra was arranged remotely, with the resources available to the newly formed Federal Government based in Melbourne, and infrastructure was designed for the future more than the present. Water power was not a big issue,as the Kingston steam power station, built in 1915, was one of the earliest post-federation Canberra landmarks[1]. Other industrial sites such as the Yarralumla brickworks which preceded the powerhouse used their own portable steam engines until electric power became available a year later. Water supply was the issue rather than water power, but the remoteness of Canberra from Melbourne and the over-design of the water supply system for initial requirements lead to an interesting experiment in the use of water power.

How such applications related to earlier technology is the theme of this conference,and I will try to trace their origins, their Australian advances, and some of the problems encountered in their use and more recent conservation, or lack of it. I will set these developments in a wider historical context, before concentrating on Tumbarumba where I have recently undertaken a heritage study, and Canberra where I live.

2 BRIEF HISTORY OF WATER POWER DEVELOPMENT

Before the industrial revolution, water, wind and animals were the main choices of power for mills and pumping applications. Water power has been used from ancient times, with the Chinese and Roman empires providing surviving evidence of open water wheels. Water power was well established in Europe in the middle ages. The Doomsday Book recorded more than 5000 water driven mills in England alone in the 11th Century[2].

Early wheels were undershot, relying on the speed of stream flow for their power, while later more efficient development made use of available head. Cossons describes 8 different configurations found in England[3]. The overshot wheel had most application in the dryer Australian context, where external stream flow was not required. The full diameter of the wheel could be taken advantage of to extract maximum power from the water through gravity rather than by impulse.

The water turbine was developed in the early to mid 1800s to convert the energy of water into a high speed source of power in an enclosed or semi-enclosed system. In 1889 Lester Pelton developed the Pelton Wheel, which was to become popular in Australia, employing one or more jets of water impinging on a series of curved buckets spaced around the rotor of the turbine. Advertisements for mining machinery in 1890 listed several available impulse and reaction turbines, with the pelton wheel included [4]. For operation of any of these turbines there was a requirement for a dam at a higher elevation with an enclosed headrace or penstock which delivered the water under pressure to the turbine below. The flow and hence the speed and power output of the device could be controlled by smoothly sliding a mechanically controlled spear inside the nozzle of the turbine.

3 EARLY USE OF WATER POWER IN AUSTRALIA

There are examples of use of water power early in the history of most states in Australia. The Australian Heritage Commission's Register of the National Estate contains about 20 examples in the south-eastern states. Tasmania has the earliest examples, with registered sites dating from 1822 when the first Thorpe Mill was built at Bothwell. Victoria's earliest water powered mill was built in 1839 at Dight's Falls in Melbourne.

Until turbines were introduced, requirements for greater power lead to the construction of bigger wheels. Other things being equal, a larger diameter wheel would produce more power,but the torque transmitted through the central shaft was very high, often leading to shaft failures. Transmission of power from a gear on the periphery of the wheel became more common with large iron wheels, allowing a lighter central construction of shaft and spokes. Such a wheel of about 10m diameter can be seen on the mill at Bridgewater in South Australia. It was fabricated in Glasgow and erected on site in 1860. Probably the largest water wheel in Australia was at the Garfield mine at Forest Creek near Castlemaine in Victoria. It resembled a huge bicycle wheel 22 m (72ft) diameter and operated for 17 years from 1887.

Probably the earliest turbine which is still in its original location is at the Waverley Woollen Mills at Launceston, Tasmania. It produced electricity for the mill in 1889, 6 years before the hydro station at Duck Reach supplied the town of Launceston.

From the point of view of my study area in Southern New South Wales, the most influential place appears to have been Beechworth in Northern Victoria. From there a number of key families moved further north to settle or work the alpine areas in New South Wales, after Beechworth's goldrush of the 1850s had abated and gold was discovered during the following decade at Adelong, Tumbarumba and Kiandra. It is reasonable to assume that technology was transferred from Beechworth to Southern New South Wales as people familiar with mining and milling operations moved north to live and work. Beechworth had a very prominent flour mill driven by a water wheel at Newtown Falls[5] dating from 1855, and there were a number of water powered timber mills in the Beechworth and Bright districts.

In 1890 Beechworth was also the first Australian location of pump dredging[6], a revolutionary form of mining which was soon transferred to Adelong and Tumbarumba.

4 EARLY USE OF WATER POWER IN SOUTHERN NSW

Water power was central to the Adelong Falls gold processing battery which operated from 1870 to 1910, and is now listed in the Register of the National Estate. Hide's saw mill near Batlow was water powered as early as 1876, and photographs held by the NSW Forestry Commission show water power was also important to the 19th Century timber milling industry at Bombala on the eastern side of the Dividing Range[7]. But the most extensive, diverse and prolonged use of water power that I am aware of in New South Wales and possibly in mainland Australia is in the Tumbarumba area.

5 DIVERSITY OF USE AT TUMBARUMBA

I will give a little of the social history of Tumbarumba including mention of 3 or 4 leading families, as this will give some context for the use of water power, and its technical inspiration.

Tumbarumba was settled for pastoral purposes in the 1830s, and the population increased substantially in the mid 1850s after gold was discovered. But it was not a short sharp rush like some other places, as gold mining continued steadily for about 70 years, coupled with a timber industry, high country grazing, horticulture and varied agriculture.

The best known early use of water power in the district was Hussell's Mill, built by the Hussell and Gaylard families when they moved from Beechworth to West Burra Creek in about 1880. It was important for being the source of most of the sawn timber in the town's early permanent buildings such as the court house, and is remembered by some old timers and is known to more recent residents through the marvellous photos of the Hussell and Gaylard families in front of the 9.1 m (30 ft) diameter wooden wheel[8]. The mill continued in operation until the 1920s and was later destroyed by a bush fire.

A second generation of timber mill to become known as Hardys Mill was developed by Walter Gaylard and others at Back Creek after the turn of the century. From a simple mill the water powered operation expanded to include not just the saw benches but also high lead cableways for hauling sawlogs several kilometres to a point above the mill, and a tram way to bring them down from the high plateau into the mill. The cableways were converted to steam power, and later replaced with motorised trucks, but the saw benches remained water powered through the use of two pelton wheels until an electric mill was constructed in 1972. A high technology computerised operation now maximises the production of sawn timber from the various sized logs, but nearly 100 years of water powered sawmilling operation in the district is an impressive record and a heritage valued by the local people.

Gold mining in Tumbarumba, as in most places, was dependant on water for the extraction process of washing the gold to separate it from the dirt and gravel or sand. When the scale grew from a hand operated process using pans,cradles or long toms, it required long tail races containing riffle boxes over which the material could flow gently under gravity. Such tail races were blasted in the rock at Burra Creek and by Nathan Gitchell, an American mining engineer and saw mill owner who operated between Beechworth and Tumbarumba. Gitchell pioneered the use of dynamite in mining at Tumbarumba[9], and was also an early user of the sluicing technique of open cut mining, where the excavation was performed with a high pressure water jet.

While sluicing dramatically improved the scale and efficiency of mining, if not the environmental impact, it was limited by the need for the tail race to be lower than the area being sluiced, so that the wash could gravitate over the separating boxes. This was changed by the introduction of pump dredging in 1890, whereby the wash was elevated by a centrifugal gravel pump, allowing deeper deposits to be extracted and treated. The form of motive power for the pump was not critical to the process, but in Tumbarumba it was water power, using the same source of high pressure water for both the sluicing nozzle and a pelton wheel. This process was further refined at Tumbarumba by George Heinecke,a member of a German family to become very influential in the area after they moved from Beechworth in the 1870s. GT Heinecke in 1905 patented the hydraulic jet elevator[10], making use of a primary jet of high pressure water to lift the wash with it from a sump, without the need for a mechanical turbine or pump.

Other very early mining applications of water power in the area included driving de-watering pumps and fans in mine shafts and the use of stamper batteries by Storey at Quartzville, and the use of Chilean mills for crushing quartz and a buddle for separating the ore at Adelong.

The availability of water races, storage dams and high pressure pipelines for sluicing and turbines resulted in other spin-offs for water power. This was in no small part due to the work of Charles Heinecke, brother of George, who set up most of the infrastructure, using home made surveying equipment, hand made rivetted pipes and wooden flumes, and excavation of a 35 km water race around the contours of some very rough country to bring water from Paddys River to Tumbarumba and beyond. This infrastructure made possible the electrification of the Tumbarumba Hotel for Fred Heinecke using a small hydro system in 1913, the electrification of the whole town in 1928 by a privately owned 75 kW hydro scheme, it provided water to power a saw mill, a freezing works, a major shearing shed, as well as water for ongoing mining works. The Burra woolshed, which still stands after nearly a century, is one of three which were water powered in the district. It retains evidence of overhead shafting for 12 shearing stands which were powered from a turbine by a belt drive, and also the remains of a wool scour under the main floor, where the water from the turbine was re-used before being discharged to the creek.

6 USE OF WATER POWER IN THE ACT

Following Australian federation in 1901, Canberra was selected as the site for the national capital in 1910, taking into account the abundance of fresh water in the Cotter, Murrumbidgee, Molonglo and Queanbeyan Rivers in the vicinity. Water supply for the capital was provided for by construction of the Cotter Dam in 1915, and water was pumped through a 12 km pipeline to storage tanks at Mount Stromlo some 200 m elevation above the pumping station, for gravitation to users in the town. The two original pumps were powered by 485 kW electric motors,and had a capacity of 260 l/s[11]. When the system was installed, the population of Canberra was only about 1000 people and the capacity of the pumps was far in excess of requirements. Consequently, they only needed to run two or three days per month. But because of the relatively modern nature of the installation, the operation of the pumps was considered specialist, and operators had to come to Canberra from Melbourne on each occasion to run the pumps.

Since capacity of the dam was not a problem at this stage, it was decided it would be economic to make use of the excess water to power a continuously operating simple, low flow, high pressure hydraulic pump. This was constructed in 1923, consisting of a turbine connected to the inlet side of the electric pumps, receiving water at a head of up to 30m, and mechanically coupled to a reciprocating pump by a belt drive and a gear box, to produce a smaller flow at a necessary head of more than 200m. The hydro pump was successful in supplying water to Canberra, but was inefficient in terms of the amount of water needed to drive it, and was unreliable mechanically, with faults including a torsional failure of the crankshaft. It was used for only four years until 1927, when the blockhouse in which it was installed on the bank of the river was submerged in a flood. The population of Canberra had increased by that time with the opening of Parliament House (designed by the same architect, J S Murdoch, as the Cotter Pumping Station and the Kingston Powerhouse buildings), so the hydro pump was abandoned, with water supply reverting to the use of the electrically driven pumps. Although supplemented several times, the electric pumps continued in service for 65 years until 1980, and remain as part of a display of several generations of pumping equipment, in an operational ACT Electricity and Water installation. The Hydro pump remained partly submerged in sand and vegetation in its blockhouse until 1986 when it was removed for restoration by its then owners, the Commonwealth Department of Housing and Construction. This was on the urging of the Institution of Engineers (Canberra Division), whose Engineering Heritage Panel has undertaken the restoration work jointly with the present owners, ACTEW.

7 INFLUENCES ON THE CHOICE AND DEVELOPMENT OF TECHNOLOGY

At Tumbarumba, the influences on the community were British, German and American. Local influence in sawmilling and mining clearly came from Beechworth, while Hussell and the Heineckes were German, Gaylard and other influential miners such as Storey were British, and Gitchell was from the USA. Most of the technology practised was similar to that in California and available from the UK, but much of it was clearly home grown. For example, Hussell's Mill would have been built from local timber with the iron work probably obtained through links with Beechworth. Insufficient archaeological work has been done to establish if there are any remains which can have their source identified. Relics remain at Hardys Back Creek mill and in the Tumbarumba museum which could verify the belief that some pelton wheels were made locally by bolting cast iron cups to flywheels. This would be consistent with the degree of local manufacture evident in Charles Heinecke's water supply system.

Pump dredging was first used in Australia at Beechworth in 1890, and there is evidence of it being proposed for use at Tumbarumba in a mining prospectus in 1891, and photos exist of its use at George Heinecke's Union Jack mine at Tumbarumba around the turn of the century. The idea behind his patented hydraulic jet elevator was not new in 1905, as a similar principal was illustrated in the Town and Country Journal in 1872[12]. The principle of the jet pump had been used in mining at that time and it was in use with fire hydrants and other applications in the UK last century. However Heinecke obtained an Australian patent, presumably on the arrangement and specific application rather than the principle, had the equipment cast in a range of sizes, and sold it to customers in Australia and overseas. An American mining bulletin in the 1946 illustrated a similar elevator without acknowledgement to Heinecke, so it may have been independently developed as with some other technological achievements[13].

The technology used in the Canberra hydro pump was clearly not new, having a common idea with the pump dredging used at the turn of the century at Tumbarumba and elsewhere. In essence this is that one flow of water at a given pressure can be used to pump another flow of water at a different pressure, in much the way that an electrical transformer is used to change the voltage with inversely related current flows.

What was different from the pump dredging scheme (apart from clean water) was the step up in pressure, and the means of achieving this. use of a reciprocating pump with a turbine drive, and the need for a speed reduction rather than the option of a direct drive to a centrifugal pump. If a pressure increase of 7:1 were feasible with such an arrangement, it surely would have been simpler and more reliable than the reciprocating pump proved to be. Both turbine and pump were supplied by Weymouth Ltd, Victoria, but whether they were designed for the application or simply put together because they were available is not clear.

8 PROBLEMS ENCOUNTERED IN USE

The problems encountered in use with water power in Tumbarumba which would not have been quite those which could be anticipated in Europe were drought and bushfire. As in other places technological change with consequent redundancy had its effect, but not to the extent felt in other places.

Although alpine areas have a higher rainfall than the plains, there were many times in the 19th Century when mining around Tumbarumba was reported to have ceased because of insufficient water. The extension of the race system to the Paddys River dam by Charles Heinecke seems to have overcome that problem, as the town hydro electricity supply operated successfully from that source for over forty years before Tumbarumba was connected to the NSW grid. Hussell's mill was destroyed by bushfire, although it was superseded by Hardys Mill before that time. Hardies Mill also suffered from several bushfires, most recently in 1972 when this also affected the new electrified section which was to take over from the water powered mill.

The electrification of the town area in 1928 made a number of the applications of water power redundant or made a less compelling case for maintaining the associated water races. When the Tumbarumba district was connected to the state electricity grid in 1972 the small hydro generating set which had powered the town was relocated to Yarangobilly Caves where it remains in service. Hydro power from the area continued on a much bigger scale when from 1955 the state electricity grid was progressively connected to the 3000 MW Snowy Mountains Hydro-electric scheme, a major part of which is located within the Tumbarumba Shire. At the other end of the scale of size, a private hydro plant of about 300 KW was connected to the electricity grid in 1986, as part of a development which made use of the hydraulic mining works blasted by Gitchell more than a hundred years earlier.
The history of water power in the Tumbarumba area is fascinating in the way it reflects people responding to needs and overcoming their isolation by using available resources. In short, there were few problems which were recorded which were beyond the ingenuity of the people who were living with them.

Canberra's hydro pump had operational problems of two kinds; mechanical failure and flooding. The first is recorded because the government kept records, and the second is symptomatic of insufficient earlier records to be able to have anticipated the height of floods.

The hydro pump's purpose had been served, and it remained submerged in sand and weeds in its concrete blockhouse for nearly 60 years, with some corrosion and minor souveniring of parts over that time.

9 PROBLEMS ENCOUNTERED IN CONSERVATION

In spite of its rich heritage of water power, Tumbarumba has little left to conserve. What wasn't destroyed by bushfire was removed for reuse elsewhere or for its scrap value. There are some movable objects in collections, but little of the machinery is left on site. When the Shire Council wanted to install a water wheel in their bi-centenary park, they had to obtain one from the adjoining shire. It has been well restored as an item, but its placement in a park without a load and with a small diameter pipe providing just enough water to turn it, must give it more ornamental than educational value.

Canberra's hydro pump has had some physical problems in conservation, but plenty of enthusiasm and good will. The first problem was having to remove it from its original location to conserve it, but this was essential if it was to survive beyond the next flood. The second problem was its relocation into a transformer room. This was a compromise, as the location was still at the Cotter Pumping Station where it could be viewed in the context of the dam, the river, the pipeline and the electric pumps, but this meant the pipes could not be reconnected and it became a static display. It is part of an ongoing program with ACTEW, IE Aust. and the University of Canberra and the National Trust to study, conserve and interpret the whole precinct, which hopefully will be made more accessible to the public. Research has been undertaken by Cultural Heritage Management students on the records and physical evidence, with further documentation required to relate he various aspects of the place.

10 CONCLUSIONS

The cases studied illustrate the ongoing adaptation of technology to suit changing conditions, and the harsh impact of natural events. Connections can sometimes be seen between sources of technology or technological inspiration and the physical remains, while in other cases they are more tentative. Further archaeological study and historical research would be useful in connection with the water powered sawmills which existed at Tumbarumba, and relating to the development of the hydraulic jet elevator. Additional study has been initiated for the Cotter precinct in the ACT.

The contrast between conservation of places illustrating water power at Tumbarumba and Canberra shows that conservation of engineering heritage is opportunistic, both in terms of the materials remaining and the resources available to undertake conservation. This highlights the need for identification of significant places before they come under threat, and the value of continued use by sympathetic owners of industrial sites.

It is not too late to do some conservation and interpretation of places related to water power at Tumbarumba, but the results would have been more impressive if the process had started much earlier.

The comparisons also tend to indicate that intelligent committed people on the spot with limited training can sometimes adapt available technology and develop better solutions to problems than professionals who are more remote. For engineers,this may be worth considering in relation to development aid and recognition of appropriate technology for third world countries.

If heritage conservation is to have practical benefits, it should not only be in encouraging people to value the past, but also in avoiding future mistakes. Compared with our forebears, we can then be more mindful of the problems as well as the opportunities of transplanting old ways in new lands.

11 ACKNOWLEDGEMENTS

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Old Ways in a New Land - The Case of Light Railways

J.K. LONGWORTH, B.Sc., Grad Dip Leisure Studies, M.A.I.H., Agronomist, NSW State Rail Authority.

SUMMARY & ABSTRACT

Light railway technology was imported into Australasia during the first half of the last century. Light rail was widely adopted and used in primary and secondary industries, until about the middle of this century. Australasian engineers adapted, modified and totally rethought the basic technology in response to local physical, social and economic conditions. Many uniquely innovative designs were developed. Some were successful some were not. A universal situation.

1. INTRODUCTION

Engineers build, operate and maintain complex machines and structures. The physical artefacts are overt manifestations of their work, skill and knowledge. Physical works display facets of engineering heritage. Characteristics of the constructed works vary through time, showing many discernible trends in their design philosophy. Methods used to construct, operate and maintain the works, also vary through time.

Structures such as the Egyptian pyramids, statues on Easter Island, or Stone Henge of England, prompt the often asked question *"How could people of such ancient times build such structures?"*. The same is true of many early Australasian engineering works. Authors such as Radcliffe [1] suggest that, how the works were built, or how the structure was operated, are as much part of our engineering heritage, as are the physical artefacts that were actually created.

Light railway technology was developed in Europe during the sixteenth century, for transport in mines. Loads were found to be more easily moved in a horizontal plane, in a four wheeled vehicle running on fabricated track or a "way". The way consisted of two parallel strips of wood ("rails"), set and maintained at a determined distance apart. The way followed the natural ground surface as far as practical.

Light railways have been used in Australasian primary, extractive, manufacturing, service and construction industries, since about 1831. In primary industries they have hauled; sugar cane; logs; milled timber; sawdust; mushroom compost; animal foods; milk churns; wool bales; hashmagandy; fish and animal carcasses. In extractive industries they have hauled; overburden; sand; gravel; clay; shale; kerosene shale; coal; limestone; hard rock and precious ores. In manufacturing industries they have hauled; molten metal; component parts and finished products. In service industries they have hauled; coal; sewage screenings and passengers. On most major civil engineering construction sites they have hauled; spoil; aggregate; sand; concrete; tools; and component parts.

Persons with engineering skills migrated to Australasia, bringing their artisan skills. However, physical isolation in Australasia, meant that knowledge about developing technologies was slow to spread. Major exhibitions were held at which manufacturers could display their wares. Some enterprising local managers took extended trips to England and/or America. They brought back ideas on the latest developments there.

This paper describes a range of industrial situations where the basic light railway technology was imported into Australasia. Sometimes the technology was used directly as imported. Other situations required extensive adaption, others invention. Technology that was regarded by overseas manager's as outmoded, still found application in Australasia, due to the poverty of our industry's economic base, and lack of alternatives.

2. EQUIPMENT SUPPLIERS

Towards the end of the nineteenth century, advantages of using a temporary or semi-permanent light railway, were becoming evident to many industrialists. Demand had expanded such, that specialist suppliers emerged to cater to the market for equipment.

Some suppliers such as Arthur Koppel of Germany, John Fowler of Leeds, Robert Hudson Ltd of Leeds, Paul Decauville of Petit-Borg France, and Krauss of Munich, could supply complete light railway systems. All the needs of a prospective operator could be obtained from these "one stop shop" suppliers. Complete systems comprising trackwork, locomotives, wagons, carriages, and spare parts, could be bought by telegram or cable from profusely illustrated catalogues. Track could be purchased as plain rail and other metal fixings, or as completely prefabricated panels of track and points. Wagons could be purchased as complete ready-to-run units, or as kits containing all the necessary items of metal work. The buyer would then provide the wooden components and assemble the kit, so saving on freight costs.

Off the shelf equipment was expensive to import and delivery could be protracted. At least two ships were lost at sea, complete with their cargo of locomotives, etc. Maintenance facilities in the field were rudimentary, bearing closer resemblance to the blacksmith's art than to a precision engineering workshop. Designs were typically minimalist, cheap, experimental, one offs, job specific, and used materials that were available locally.

A flourishing second hand market existed. Several locomotives were imported already second hand from the England. Light railway equipment changed hands regularly through the pages of the nation's daily newspapers. Machinery dealers such as Cameron and Sutherland, produced thick catalogues describing equipment in their yard or believed to be available. Auctions of plant and equipment frequently itemised and described locomotives, giving their principle dimensions to indicate the capacity of the unit.

Some agents or dealers removed the manufacturer's plates, or obliterated the name or details, to discourage the owner from dealing directly with the manufacturer for spare parts or additional equipment. This ruse also disguised the real age of a locomotive, especially its boiler.

3. LOCOMOTION

3.1 Port Arthur Convict Railway

The first known use of a "railed way" in Australia, was installed about 1830. The Australian Agricultural Company's railway, was on an inclined plane which lowered coal from their mine to a wharf on the Hunter River near Newcastle.

However, the first general carrier railway built in Australia, also showed most clearly the potential to adapt, modify and totally rethink the then extant technology of light railways.

Operated from 1836 to about 1853, the track stretched for five miles across the Tasman Peninsular southeast of Hobart. Connecting the settlement of Port Arthur with the sheltered waters of Norfolk Bay, the line obviated the long and dangerous sea route around the coast.

A plentiful supply of cheap convict labour, was used to both construct and power the line. Having a cheap and expendable power source, meant that the line did not have to follow an economic grade. Minimising earthworks, the line followed the natural form of the ground.

Four men holding onto handles, propelled each rough wooden wagon, supported on four small spoked wheels. Sweating convicts would push a single wagon up the hills, then climb up onto the wagon as it sped downhill on the other side. Braking was by placing a shoe on the wheel or by drag. Half way along the line was a rest station, where crews were changed for the remainder of the journey.

3.2 Traction Engine Conversions

Without access to a supply of suitable secondhand steam locomotives (as overseas), many timber tramway managers opted to convert steam driven road traction engines, to run on rails. Traction engines were readily available in rural areas, and were cheap to buy.

The simplest conversion entailed no great engineering problems. This conversion simply removed the flat-treaded road wheels and installed flanged ones, to create a 2-2-0 locomotive, eg, Buckingham's at Collie in WA. A minimum gauge was set by the distance between the outside faces of the main bearings. This was generally restricted to a minimum of 3'6". The front axle could be held parallel to the rear one, by fixing it rigidly in position, or by adding a stiffening bar between the two axles. Wheel sets could be purchased from certain engine manufacturers, or supplied by a local foundary. New locomotives based on road traction engine designs, were available from suppliers such as John Fowler of Leeds [2], or Aveling & Porter of Rochester.

A couple of enterprising engineers converted steam lorries into four wheeled locomotives running on rails, eg the two at the construction of Bunnerong Power Station NSW. These utilised Foden steam lorry boilers and driving mechanisms, mounted onto a purpose built frame. The Forster Over Type steam wagon at Beaudesert Qld [3], was more complicated with its bogie leading truck, giving a 4-2-0.

More complex conversions mounted the boiler and driving cylinder/s on a frame, supported by a pair of four wheeled bogies. Thus a simple and cheap articulated locomotive could be built from materials already to hand. Conversions are recorded in Tasmania, at Circular Head and the "Harlot".

3.3 Articulated Units

Attempts at home made steam locomotives in Australia, were usually based around imported designs. Rigid frame rod locomotives were built locally, together with rough copies of the more advanced American articulated units. Many new Heisler, Shay and Climax locomotives were imported from America, into both Australia and New Zealand. No Heislers were imported into Australia, and no Shays into New Zealand.

Geared locomotives were commonly used on steeply graded timber and mining lines. Gearing allowed increased torque to be applied to the wheels. Powering small four wheeled swivelling bogies (articulated), rather than wheels suspended in rigid frames, allowed locomotives to traverse tight curves and rough undulating track as found on light tramways.

3.3.1 "The Final Flutter"

Built from scrap and second hand components in 1923, "The Final Flutter" was modelled on the American Climax geared locomotive. A second hand NSW Railways "F" Class locomotive boiler, was connected to a second hand ex-Sydney Harbour tugboat, two cylinder, vertical, marine engine.

On its maiden run the locomotive's great weight crushed the wooden rails. Steep grades on the line, caused water in the boiler to incline away from the firebox crown, so excessive heat melted the lead safety plugs. On the return descent, the brakes locked and tore away, because of the swinging movement of the bogies [4]. The locomotive never made a second run, but was promptly dismantled. Re-usable parts were salvaged for more productive use.

3.3.2 A. and G. Price Ltd and J. Johnston and Son 16 Wheelers

Price and Johnston built locomotives which were carried on four, four wheeled bogies, with all wheels powered. Power was provided by a two-cylinder vertical marine type engine, mounted in the rear of the cab. Drive was transferred to all 16 wheels by gearboxes, drive shafts, universal joints and bevel gears. One home-made hybrid ran on three, four wheeled bogies, giving 12 driven wheels.

These designs were modified later. A number of Price locomotives have combined features of the Climax and Heisler designs. At least one has survived and operates on the railway at "Shanty Town", near Greymouth on the South Island.

3.3.3 Harman

In 1927, the Forests Commission of Victoria advertised for a locomotive to operate their Tyers Valley timber tramway. The engineering firm of Alfred Harman, tendered with an unusual design, but one that could be built locally at their North Port Melbourne works. As no other tenders were received, his was accepted. The locomotive frame was supported on two four wheeled power bogies. The two pairs of 6" by 6" cylinders were connected to steel spur gears, then by chain and sprocket to the axle, giving a final ratio of four to one.

Delivered in November 1927, the locomotive failed to meet expectations. Multiple minor design faults made it too rigid, and lacking in power. The worst problem was that with a total weight of 26.5 tons, the loco was at least 10 tons overweight [5]. This gave a poor power:weight ratio.

3.3.4 Day's 0-4-0 0-4-0T

In 1928 the South Melbourne engineering firm of W. Day & Sons, constructed an articulated steam locomotive, for Messrs. Ezard to run on their timber tramway at Erica, Victoria. True to tradition, it was a compromise of salvaged parts incorporated into new construction. The boiler was salvaged from an 0-6-0T (orthodox) locomotive, built by Krauss & Co. in 1912. The cylinders and cab, were from an Orenstein & Koppel locomotive also of 2' gauge. Both locomotives had formerly been used on the Goodwood Timber Co.'s line. Drive employed the cardan shaft principle (similar to a "B" class Climax). This uses two external cylinders to drive a cross shaft, through a gearbox with a jointed shaft from it, connecting to each bogie.

This locomotive was more successful than the Harman (3.3.3). Another unit was made with six wheeled power bogies, for a timber line at Gembrook. But this other unit, used new materials throughout, and had a slightly different drive mechanism.

3.4 Tractor Conversions

During the early 1920's, many engineering manufacturers began to produce chassis units, into which Fordson tractor engines and transmissions were mounted. The result was a small locomotive weighing about four tons [6]. Some built locally, eg at Emu Bay, were nothing more than standard tractors, minus their mudguards. Flanged railway wheels were fitted, replacing the original agricultural ones, giving a 2-2-0. One axle drive, severely restricted the locomotive's adhesion.

More advanced versions replaced the belt drive pulley with a sleeve and gear wheel fitted to a chain driven 4WD frame. Some used connecting rods to drive all four wheels. Australian manufacturers included the Tractor Appliance Co. Ltd (TACL), W. Day, Malcolm Moore, and Armstrong Holland. At least one adaption of a "Cletrack" power plant is known.

Tractors were used widely in the construction, quarrying and timber industries.

In Europe, purpose built small diesel and petrol locomotives, surplus from the War Department were used. The locomotives had been used on light railways in the 1914-1918 war, to supply forward positions. None are known to have been imported into Australia. Manufacture of purpose built locomotives has continued in Europe until recent times. Magnitude of the American timber industry required larger locomotives. Large orthodox and geared locomotives, continued to be used into the 1940's. In the construction industry development of huge dump trucks and scrapers replaced light rail, except in tunnelling.

3.4.1 Day's Tractors

W. Day and Sons Engineering of South Melbourne started producing internal combustion locomotives in the mid 1920's. Their early models used plate frames to support imported Fordson power plants. By the late 1940's the firm was using International power plants, centre pivoted sprung drawgear, cast frames and cast iron footplates [7]. Quite a sophisticated unit.

3.4.2 Malcolm Moore

During the early 1920's Malcolm Moore & Co. (a Melbourne based manufacturer of contractor's equipment) started marketing their own Fordson based small locomotive. The loco was advertised as having the benefit of being able to lift out the power plant for use as a normal agricultural tractor. By the late 1930's Malcolm Moore was using Ford V8 truck engines. Refinements included, fitting an additional reverse gearbox to allow four speeds in both directions and an extra low gear, plus sprung buffer couplings to lessen buffer shock [8].

3.4.3 Natrass Tractors

In November 1924 Howard Nattrass of Wellington NZ, took out a NZ patent for improved self propelled hauling units. The object of the design was to, simply, increase the hauling capacity of the units [9]. Increasing the tractive effort, was achieved by connecting a drive shaft to the tractor's differential. This drive shaft, then drove a second powered chassis, giving eight powered wheels. Chain drive connected both pairs of wheels on each chassis or bogie. The second bogie then carried part of the dead weight of the first log or bundle of sawn timber that was being towed [10]. Apparently the tractors broke down frequently and often broke castings.

3.5 Diesel Re-engineing

With limited access to steam boiler suppliers and marginal economics, many firms re-engined old steam locomotives. Once the boiler was beyond repair, the locomotive was useless. So instead of replacing the boiler with a new steam boiler, it was removed and replaced with a diesel engine, mounted onto the locomotive frames. Power was transferred to an axle by transmission or chain drive. Piston rods were removed, leaving the old cylinders in place, but unused. The original coupling rods continued to transfer power to the driven wheels.

3.6 Car/Truck Conversions

One step on from re-engining steam locomotives, and a more recent equivalent of converting traction engines, was to mount car or truck bodies on rail wheels.

By the beginning of the 1920's, Colonel Stephens was using rail-buses on lightly trafficked rural branch lines in England. They were notoriously uncomfortable. America also had a great variety of designs. Sometimes flanged wheels were slung under automobile touring cars, sometimes a passenger cabin was married to a truck chassis. Passengers preferred automobiles and busses.

In Australia, line managers mounted a series of commercially available cars and trucks onto rail wheels, eg J&A Brown's Cadillac. Used mainly for inspection work by railway workers, their greatest development occurred in Queensland. There many formed the basis of a rail ambulance network [11]. The NZ Public Works Department used Ford Model T parts, to build 2' gauge locomotives for hauling rakes of skips on construction works [12].

3.7 Caldwell Vale Engineers V Friction Wheels

During May 1912, Felix Caldwell of Auburn NSW, applied for a patent to increase the tractive effort of locomotives. Increasing the tractive effort, was to be achieved by increasing the adhesive factor through reduced slippage of the driving wheels. Friction wheels were to be lowered onto the track when required. Chain driven for synchronous rotation, the friction wheels were suspended from the locomotive's rigid frame, between outer pairs of normal driving wheels.

The friction wheels consisted of two vertical half wheels, held together by bolts, and kept apart by variable thickness distance washers. The wheel's peripheral groove, approximated a "U" in section, which was to effect a wedge grip on the head of the rail [13].

The idea was a total failure. Lowering the friction wheels, just transferred weight off the other driven wheels. The "legs" of the inverted "U" were lower than the running surface of the rail, which meant that points and crossings could not be negotiated with the device in the working position. Out of gauge rail could not be accommodated, which was unfortunate, as light railways have notoriously rough trackwork. Requiring the whole line to be constructed from rail of uniform width head, was a utopian dream for industrial lines.

4. PERMANENT WAY

4.1 Timber Railed Trackwork

The first iron rails to be made in Australia, were rolled at the Fitzroy Iron Works at Mittagong NSW c.1860. Otherwise, all iron rails had to be imported. They were expensive, beyond the finances of most firms constructing light railways. However hardwood was readily available in long lengths, from the virgin forests blanketing the landscape.

In the timber industry, Australian hardwoods could be cut to a section of about 4" by 4" for use as rails on logging lines. The timber rail was sometimes topped by metal strapping. However, this was usually reserved for curves where wear was worst. Often only the outside rail was strapped, or a metal rail used in lieu.

Logs 6" to 8" in diameter left "in the round", were used in America for rails on their "pole roads". Only a couple of lines in Tasmania, adopted even a form of it. This technology was abandoned well before the demise of timber rails here.

4.2 Short Log Bridges

Typical of the minimalist approach to construction, were the tree trunk bridges. Where a narrow but deep creek had to be crossed, two substantial tree trunks were sometimes used as a bridge. Short heavy lengths of log, were placed along the creek banks at either end, to act as bearers. Two tree trunks were then placed across the gully to the required gauge. Rails were then simply spiked directly to the top of the logs.

4.3 Crib Log Bridges and Makeup Track

NSW and Victorian timber tramways sit midway between the small scale European examples, and the massively constructed American examples. NSW and Victorian lines were built in the vernacular using a minimum of technology. In particular, the use of timber in bridge building, shows uniquely Australian characteristics. In Victoria the more valuable stands of Mountain Ash grow in rugged sub-alpine mountain environments. Wood was plentiful in the high mountain valleys, so a form of bridge building known as crib log was common. Crib log is like continuous pig sty construction.

Crib log bridges use massive amounts of timber to nearly fill the gully void with wood. Unlike timber trestles, they are easy to build, requiring neither accurate survey, complex calculations, nor intricate techniques to construct. Once constructed they are robust, but will not withstand torrential flows of water through them. Unfortunately crib log construction, does not utilise the inherent structural values of Australian hardwoods.

Makeup track uses a form of low crib log construction, to maintain a railway grade over low ground. Instead of heaping earth up into a low embankment, logs are laid one on top of another to construct a long low continuous crib. Bearers and rails were then laid on top, to the desired grade. The assumption was made that, use of the line would be finished before the logs rot out, so would not need replacing.

4.4 Suspension Bridges

Bridges to carry railways are traditionally designed as rigid structures. Flexible structures would presumably distort badly under the high moving point loads of a locomotive and heavy train. Rails would bend downward, so pushing the limits of allowable undercarriage movement and stressing couplings. Lateral variations in sag which would tend to tip the train sideways, would be hard to estimate and counter.

At least two Australasian examples of railway suspension bridges are known. In 1912 a high suspension bridge was designed by the NSW Department of Public Works, for crossing the Nepean River on the then proposed Cordeaux Dam construction tramway. The line was to be of 2 foot gauge and worked by two 0-4-0 saddle tank locomotives. With a span of 240 feet and towers 57 feet high, the bridge was to have had a parabolic curve 30 feet deep. It was estimated as going to cost 6,373 Pounds. An alternative tall wooden trestle was estimated at 1,514 Pounds. Ultimately the proposed bridge was never built, but was replaced with an aerial ropeway spanning the entire river gorge [14].

One suspension bridge for a light railway known to have actually existed, was on the G.A. Gamman & Co. timber tramway in the Dannevirke district of NZ [15].

5. DEMISE OF LIGHT RAILWAYS

Until the late 1940's light railways could be found operating in most sugar estates, many forests, mines and quarries, manufacturing plants, and on most major civil engineering construction sites. With improvement in the pneumatic tyre, sealed roads, and motor trucks, light railways came to be seen as inflexible. The fixed route of steel rails, was too rigid to compete with the infinitely flexible routes offered by independently operable, motorised road vehicles. Rising wages for labour, made the financial cost of transhipping goods between the light railway network and other forms of transport uneconomic. Technology in industry changed rapidly from 1945 onwards.

The sugar industry had previously used three rail systems to harvest cane. Temporary tracks were laid across the field, at the edge of the cane to be cut. As the cane was cut, the sticks were loaded crossways onto the trucks, which were drawn alongside. As the trucks were loaded, horses hauled them to the feeder line, which was in a semi-permanent position along an internal roadway. From there they were drawn by tractor to the permanent mainline, and marshalled into trains. Locomotives finally hauled the rakes of trucks to the mills. As cutting progressed across the field, the temporary track was moved by hand to follow the cutting face. This track was in panels which could be lifted by two men, as if a stretcher. In the 1940's a cane cutting machine was developed in Queensland. Not only did it cut the stalks, but chopped them up into short pieces, which were loaded directly into trucks moving along with the machine. Holding the cane truck on a trailer drawn by a tractor, eliminated the need for temporary track in the fields. Development of the concept eliminated the feeder line, depositing the loaded trucks directly onto a siding on the main line.

Caterpillar tractors began to haul logs extended distances across rough terrain, to fewer centralised log dumps. Construction of roads funded from state government revenue, displaced light rail from the forests. Logging companies no longer had to cover the cost of building, operating, and maintaining light railways through the forests from their own revenue.

Track mounted and/or rubber tyred excavators, high capacity dump trucks, long distance conveyor belts, and slurry pumping, displaced light rail in quarries and mines. Fork lifts, motorised trolleys, roller conveyors and continuous chain production lines, displaced light rail from moving components around within manufacturing plants. Front-end loaders, 4WD dumpy trucks, concrete pumps, and tower cranes, displaced light railways on construction sites.

6. CONCLUSION

When looking back at the history of engineering, often the greatest contrast to to-day's activities, is not seen in what was done, but is seen in the way in which work was carried out. With improved communications, ready transport, and bigger manufacturing units, standardisation has overtaken the individual character of transport solutions. Engineers to-day still grapple with and solve transportation problems in their daily work. But they mostly solve the problems, rather much in the same way.

Light railways provide one of many high points in Australasian engineering ingenuity. With off the shelf complete items often not available (as they were in many overseas countries), local operators adapted, modified, and sometimes totally rethought the overseas technology. Rarely qualified, these operators produced light railways at minimum cost, constructed locomotives from available parts (often of diverse parentage), and permanent way from the bush being traversed. They displayed a degree of enterprise, willingness to experiment and freedom to innovate, rarely seen today.

7. ACKNOWLEDGMENT

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Bush Enginuity

PAUL.J.MAHONEY, Department of Conservation, Head Office, Wellington.

SUMMARY Bush tramways were the light railways that served the New Zealand timber industry from the 1850's to the 1950's. From both mechanical and civil engineering aspects, they were an extreme application of railway technology. In this paper key distinctive features are identified and compared in the context of both conventional railways and overseas forestry railways. Notable preserved items of bush tram heritage are identified.

1. INTRODUCTION

"Darcy Collier looked up the bush tram in the direction of a very alarming noise. It was the sound of the rail tractor, out of control, careering down the gradient towards the mill. The driver had already abandoned hope and jumped off. Luckily for all concerned, there was a curve in the track near the mill. Hitting this, the whole train left the track, flew through the air, and landed in a small swampy lake, a mass of scrap iron[1]."

This is a bushman's recollection of the dramatic final day of operation of the Waitatapia tram at Otaki Forks about 1931. This accident spelled the end for "Denny's Sawmill, already tetering on the brink of insolvency. Bush trams were a very colourful and distinctive part of the New Zealand timber industry, even if at times life threatening! For almost a century they played a major role transporting logs and sawn timber, but their remote locations consigned them to relative obscurity. This paper presents some engineering aspects of bush trams that were distinctive to New Zealand and identifies key heritage that survives today.

The timber industry has its own language, which in New Zealand begins with *bush* for "forest" and *bushmen* for "men who work in the forest". *Bush trams* are the light railways used by the timber industry, and *lokeys* are the locomotives that worked them. The word *lokeys* is used elsewhere in the world, but *bush trams* seems to be unique to New Zealand. All specialist terms are clarified in the glossary.

Because bush trams were part of the cost of production, sawmillers always sought to minimise the capital investment and operating costs, consistent with maintaining a reliable transport service. Tracks and bridges were built as lightweight as possible and earthworks kept to a minimum. Trams into difficult country resorted to the steepest gradients and tightest curves of any railway, and required specialised lokeys to operate in such severe conditions. Bush trams were therefore at the extreme limit of railway technology and this contributes to their special interest.

Another attribute of bush trams was their small scale compared to the logging railroads of North America. The biggest tram had a 81 km mainline and 28 km of logging lines. It was operated 1904-44 by the Taupo Totara Timber Co. (TTTCo) and required a fleet of six lokeys. Another 27 "large" trams existed with fleets of two or more lokeys in daily use and carrying a daily log traffic of over 30 cubic meters[2]. However most trams were much smaller scale undertakings.

Most of NZ's forest was government owned. Policies favouring "the small man", and which ranked farmers ahead of sawmillers, made it difficult for millers to secure rights to large bush areas[3]. This reduced the size of plant that a miller was prepared to invest in. The few large bush trams mostly served bush areas not owned by the government. Had government policies been different, many more large bush trams would have been constructed.

2. EARLY BUSH TRAMS

The opening of the first bush tram has not been identified but records show they were in use in the 1850's. Railway technology was relatively new then, and England had been its birthplace. Primitive industrial railways with wooden rails dated back to the 18th century. However there was no direct English "bush tramway" experience to call upon, and so all the adaptation to bush conditions occurred in the new land. And it happened quickly; an overseas forester reported in 1877: "The universal use of the tramway forms a marked feature in the treatment of New Zealand forests. I have seen them of all descriptions and no sawmiller ever dreams of working a forest without one."[4] In the new land, railway technology would be pushed to the extreme limits of its application.

Typical early trams were laid with wooden rails and worked by teams of up to eight horses. The industry progressed greatly in the 1870's; the capacity of sawmills grew and trams lengthened. More pulling power was required and it is not surprising that some progressive millers adopted steam haulage. In 1871 William Brownlee of Havelock was the first to introduce both steel rails and a steam lokey on a tram[5]. Even in a world context, Brownlee's move seems to have been innovative. From then up to 1899, 34 other lokeys entered tram service. Statistics for 1901 record 334 sawmills in operation, so horses were still used on most trams.

The typical bush lokey of this early period was the four-wheel *direct* drive type imported from England weighing 5-10 tonnes[6]. However some diversity existed, including early examples of *geared* lokeys. These were similar to direct drive but with a 2:1 gear ratio included to give more power. The early lokeys working on bush trams were typical of those in railway or industrial service, rather than designed especially for bush conditions. Most bush trams were on fairly easy country and these small lokeys were powerful enough.

3. BOGIE LOKEYS

In the new century, sawmill capacity continued to increase and trams lengthened further creating a demand for more powerful lokeys. Trams were constructed into more difficult country, requiring steep grades and sharp curves, conditions not suited to the direct drive lokeys.

In response a new type of lokey appeared that was distinctive to trams; the *bogie* lokey. This type was first developed in the United States timber industry. A boiler and engine were mounted on a chassis riding on two or more bogies. All bogie wheels were driven by driveshafts and gears. These lokeys were powerful because all wheels were driven and they could negotiate uneven track.

Again it was Brownlee at Havelock who in 1903 imported the first bogie lokey, a "Heisler", manufactured in Erie, Pennsylvania. Over the next 20 years seven Heisler and seven "Climax" lokeys were imported from the USA and all worked long and successful service lives of 43 years.

Of particular interest was the quick and innovative response of four New Zealand engineering companies to this new market. In the period 1907-1912 production commenced of distinctive designs of lokey by Dispatch, Davidson, Johnston and Price. Together they cornered the major portion of the domestic geared lokey market against American competition. Bush lokey production to 1930 totalled at least 103 with a final four built up to 1943.

Dispatch Foundry of Greymouth offered two designs of bogie lokey, including models with three bogies. One design used a standard log winch unit mounted at one end to drive the wheels through shafts, whereas the other model used a horizontal engine mounted between the frames in the middle of the lokey.

G. & D. Davidson of Hokitika offered bogie lokeys distinguished by their chain drive system. Second-hand boilers were used to keep costs down. The heavy chain included a patented collars feature that lessened the pull on the pins and thus reduced wear. These lokeys pulled tenders (holding fuel supplies) to which the chain drive could be extended.

Johnston & Sons of Invercargill offered a geared type from 1896 and bogie types from 1910. Their classic product was the legendary "16 wheeler" driven by a vertical engine mounted centrally in the cab. This rode on four bogies to give a low one ton axle weight, which allegedly allowed it to be introduced on horse trams without special upgrading. Many Dispatch, Davidson, and Johnston lokeys operated on wooden rail trams, but they were more successful on steel rails.

TABLE: Summary estimate of geared lokeys introduced on bush trams from 1896-1968:

Manufacturer	Location	Dates introduced	number in service	last in service	average service life (years)
American	Pennsylvania	1903 - 24	14	1968	43
Dispatch	Greymouth	1907 - 24	18	1930	11
Davidson	Hokitika	1908 - 18	21	1948	13
Johnston	Invercargill	1896 - 30	22	1958	18
Price	Thames	1912 - 43	21	1964	24
Other	various	1904 - 33	14	1948	18
		1903 - 43	107	1968	

A & G Price of Thames offered three main designs of bogie lokey, all of which were copies of competitor's designs. Two 1912 designs, a 16-wheeler and the "C" series, used a vertical engine mounted centrally in the cab. Their larger "E" type plagiarised successful patented American concepts; the Climax drive system and Heisler bogies. These designs had been perfected by many hundreds in of examples in North American service before Price copied them.

The most distinctive and original New Zealand designs were the Johnston 16-wheeler - for sheer complexity - the Davidson chain drive, and the Dispatch winch lokeys. Although they are all fascinating to consider in retrospect, none were masterpieces of mechanical design and the Dispatch and Davidson lokeys had short average service lives of around 12 years. The best designed and most successful lokey was the Price "E" type. The Price lokeys had the longest average service lives of 24 years. The imported American lokeys had the longest average service lives of all, at 43 years. However the indigenous bush lokeys with their lower capital cost did severely limit the sales volume of imported lokeys.

4. OTHER LOKEYS

This century, direct drive lokeys continued to be popular and another 67 entered service. Some were imported, and others came second-hand from the main railway system (NZR), but there was no competitive local manufacture. Their power range generally remained limited to that possible with four coupled wheels, supplemented only by the addition of a pony truck leading or trailing. Only four major trams, at Mamaku, Matahina, Ruatapu, and Ross, developed alignment standards adequate for heavier lokeys with six coupled wheels. The lokeys used were all ex-NZR class "F" or "Fa", the latter weighing 29.8 tonnes.

Several types of articulated direct drive lokeys, readily available from overseas, were potentially suited to bush tram conditions. This type, in broad concept, employed two groups of direct driven wheels articulated separately under a boiler and chassis. They utilised flexible steam lines in contrast to the flexible driveshafts on bogie lokeys. Potentially they combined the simplicity of a direct drive with the flexibility of bogies.

The four examples that operated on bush trams, while interesting and successful, remained isolated examples: a Fairlie, Mallet, Meyer, and a duplex[7]. The reason for their lack of wider acceptance was probably related to the uneven alignment of the rails on bush trams. It proved much simpler to maintain the flexible driveshafts on bogie lokeys than to maintain the flexible steam pipes and control linkages on articulated lokeys.

5. RAIL TRACTORS

While the widespread introduction of bogie lokeys from 1903 was revolutionary, it did not benefit the smaller miller. Their trams, characterised by wooden rails, tight curves, steep grades, and lightweight bridges, were too primitive for any lokey. Horse teams remained in service on these trams for another twenty years until the advent of the Fordson, the world's first cheap farm tractor.

Although some millers had previously experimented with internal combustion power, the Fordson formed the basis of the *rail tractor* revolution. The leader in this process of change was the Traill's tractor, developed in Southland in 1924 and the first to be commercially available[8]. Competitors quickly appeared on the scene, and from 1924-29 an estimated 94 rail tractors entered service, bringing the horse tram era to a swift end. On the cost of fuel alone, there were claims in the technical press of rail tractors being eight or ten times cheaper!

Eventually seven key rail tractor manufacturers emerged, offering three main types. The rudimentary type was a *four-wheel* unit; more common and successful was the *extended* version with driveshafts powering the wheels on log bogies front and rear. The third type was the *bogie tractor*, similar to the bogie steam lokey but with the engine above one bogie and a log bolster above the other. A great innovation with rail tractors was being able to use some of the weight of the log loads to increase adhesion on the rails.

In the period from 1924-56, an estimated 204 rail tractors were built[9]. Arguably the most successful of these were those built by Oliver Smith at Mamaku; bogie tractors which combined power and speed. They were fitted with the latest off-the-shelf heavy transmission components and had relatively sophisticated braking systems. The Wilson, Melhop, and Dispatch tractors could all be judged as well engineered for their day.

Rail tractors did not supplant many of better designed steam lokeys, but they certainly ended any further steam lokey construction. They were easier on the track and faster, giving better utilisation. In the late 1920's two manufacturers attempted to export rail tractors to Australia. Although success was limited, this may well constitute a significant early export initiative of a locally designed and manufactured product. The success of the designs certainly precluded any overseas manufacturer ever supplying the New Zealand rail tractor market.

6. TRAM SPECIFICATIONS

Bush trams varied greatly in length and life expectancy. The longest log haul was 31 km on the Matahina tramway. The most enduring was More's Pourakino tramway which operated for 58 years from 1902-60. Many trams evolved into a system with a main line and a series of branches for logging, such as at Port Craig. The densest concentration of trams was found at Mamaku, where ten tram systems radiated from one town, with a combined extent of hundreds of kilometers. The total length of bush tramways built in New Zealand is probably comparable to the NZR system, but not all were operating at the one time.

Few bush tram specifications are available for historians to study. Some better quality trams were laid out by formal survey and specification, but most were located by field surveys which created few paper records. Research of civil engineering aspects of trams relies heavily on photographic evidence, oral sources, and field measurement.

Most bush trams in New Zealand were laid to a gauge of 3'0" (914mm) or to the 3'6" (1067mm) used by the NZR system. Wooden rails were mostly in the range of 100-150mm square section, while steel rail sizes ranged from about 20-30 lb/yd (10-15 kg/m). A Forest Service guide highlighted a key advantage of the more expensive steel rails: "one horse on steel can do as much as three on wood". However, it was not until this century that steel rails became widely used. Even then, wooden rails continued to be used by some smaller operators; the last did not close until 1966.

Some sections of tram were laid on logs to avoid filling or cutting, and little evidence of them remains today. Earthworks were minimised elsewhere by adopting steep grades and sharp curves. But some trams had extensive sections of earthworks; striking examples were at Waitawheta and Charming Creek. The use of switchbacks or tunnels to maintain grade was unusual. However the Ongarue tram include a complete spiral with a tunnel and a bridge. Two celebrated features of bush trams were the steep cable-worked inclines and wooden viaducts used in heavy country, and these are described later.

The manufacturers specifications for Heisler and Climax lokeys show that they could climb 1 in 10 grades and negotiate 30 m radius curves, 21 m radius in extreme conditions. In contrast the minimum curve on the main railways is 100 m radius. Oral research has confirmed a steepest grade of 1 in 10 for steam lokeys, compared to a steepest grade of 1 in 35 on the NZR near Mamaku. The trams built for operation by horse or rail tractor included more extreme conditions. Media reports of rail tractor trials during 1924-25 claim success on grades up to 1 in 6. At least one steep grade was verified by a Forest Service survey[10]. Recent field measurements at Otaki Forks, on two trams worked by rail tractors, supported these extreme figures[11]. A 100 meter long grade of 1 in 6 was measured on the Sheridan Creek tram, and a curve of 5 m radius on the Waitatapia tram is the sharpest recorded bush tram curve. These figures represent the extreme limits of railway technology.

Early rolling stock was four wheel trollies. This required crosscutting the logs into short lengths in the bush. The use of log bogies later became almost universal. These had four wheels on a wooden chassis with a short wheelbase. They were not sprung and so deep flanged wheels were fitted to avoid derailments on uneven track. A swivelling bolster was mounted centrally on each bogie. The bogies were used in pairs and were spaced apart to suit the length of the logs which could then be brought out full length.

A critical aspect of bush tramway operation was braking. A typical loaded set of log bogies weighed 8 tonnes. Runaways were all too frequent, at times resulting in the destruction of equipment and even death. Four brake systems were in common use; sprags (bars jammed in the spokes of wheels), wooden shoe brakes applied to the tread of the wheels, wooden board brakes applied to the face of the wheels, and centre rail brakes.

7. INCLINES AND VIADUCTS

The maxim that the shortest distance between two points is a straight line inspired the building of inclines worked by cable and winch in steep terrain. Improvements in flexible wire cables made this possible; an early English incline opened at Brendon Hill, Somerset, in 1858. The first known New Zealand logging incline was built by Roe at Waimauku about 1881[12]; at least 45 inclines were built up to 1938.

Arguably the most spectacular incline was the Billy Goat incline, built in 1921 for the Kauri Timber Company (KTC). This rose vertically 290m with a steepest grade of 1 in 2.7 over 1160 meters[13]. The most extensive incline system was built by the KTC on Great Barrier Island and operated up to 1940. It comprised 10 distinct inclines with a total operating length approximately 9km and aggregate vertical rises and falls of 1160m.[14].

Streams are such a typical feature of the New Zealand bush that bridges were frequently necessary on bush trams. The simplest approach used whole logs to form a beam bridge spanning smaller streams. Wider crossings utilised a series of beams spanning between sets of piles. Truss bridges were rare, the most notable was a 72 m long wooden trussed arch suspension bridge at Ongaroto on the TTTCo tram designed by J E Fulton[15]. Most spectacular of all were the viaducts.

Wooden railway viaduct technology dates back at least to the 1850's; I K Brunel built a series of 64 wooden viaducts 1849-64 in the West of England. Large wooden viaducts were concurrently appearing on the East Coast of the USA. The type matured on North American trans-continental line construction from the 1870's to the 1890's, and progressed to its zenith in American logging railroads in the 1930's. In New Zealand, 12 large viaducts were built on the NZR, and at least 20 on bush trams. The

Mangatukutuku viaduct built in 1925 was one of two on the Ongarue tram. It was 104 m long and 28m high and notable for being built on a curve[16]. The largest bush tram viaduct was the Percy Burn at Port Craig, built in 1923 of Australian hardwood. Still standing, it is 125m long and 36m high, and comprises 13 braced beam spans of 10m[17].

8. HERITAGE TODAY

In spite of the obscure locations of bush trams, and the passing of more than 40 years since most closed, some heritage has survived. The rare TTTCo Mallet lokey is operational on the Glenbrook Vintage Railway. It was possibly the first logging Mallet ever built, and is likely the oldest american Mallet surviving in the world. At the Pukemiro Line are examples of the Price E, Price Cb, Climax, Heisler lokeys. At the township of Mamaku, Olly Smith's finest rail tractor is on display, having worked on the last tram until closure in 1977.

The sole surviving Davidson chain drive lokey is displayed on the roadside near Ngahere. Ferrymead museum has an operational Price Cb lokey. Shantytown museum has examples of Dispatch and Nattrass rail tractors, Climax and Heisler lokeys, and an authentic working steam sawmill. The Traills rail tractor at Tautuku, and Johnston geared lokey at Pourakino are both displayed on sites where they worked. Unfortunately no examples of Dispatch or Johnston 16 wheeler lokeys survive.

The Department of Conservation maintains some fine tram exploration experiences including the Great Barrier inclines and the Billy Goat incline. Other scenic walks on notable tramway systems are at Waitawheta (15km), Charming Creek (8 km) and Port Craig (12km). This last walk features the only four surviving wooden viaducts, including the Percy Burn which is likely the largest wooden viaduct extant in the world.

At Otaki Forks a bush scramble provides a challenging visit to the steepest recorded grade at Sheridan Creek, and a fine steam log hauler preserved on site. Nearby is the sharpest recorded curve at Waitatapia. On that same tram, you can still stand on the hill above the mill site, as Darcy Collier did back in 1931, and look at the pond where the runaway disappeared from sight and consider his claim that it still lies there beneath the water. All these tram exploring options are achievable by an average fit person, and they are experiences that will not be forgotten!

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10. SOURCES

Marine Department boiler records 1888-1966 provided reliable information on steam lokey manufacturers and their service lives. The NZ National review 1922-53 included a dedicated timber industry section. Newspaper reports from 1871 have provided valuable contemporary accounts. NZ Forest Service files from 1923 include some very useful technical descriptions and statistics. Over three hundred oral history interviews with old bushmen since 1964 have helped clear the obscurity and retouch the colour. Colleagues have been a great help, especially L R Young, R D Grant, and A C Bellamy.

11. GLOSSARY

articulated direct drive: two groups of direct driven wheels moving independently under a frame
bogie geared: a steam locomotive riding on bogies which are driven by gears and shafts or chains.
bolster: A cross-beam which can swivel horizontally on a centre pin mounted centrally on a log bogie. The log is loaded on and fastened to the bolster only.
direct drive: a steam locomotive with the main wheels in a rigid frame and directly driven from the pistons by rods.
direct drive geared: a direct drive steam locomotive with a geared reduction incorporated in the drive.
log bogie: (also trolly) four wheel rail vehicle with a single bolster; used in pairs on tram lines - one at each end of the log to be hauled.
lokey: locomotive used on a bush tram (NZ)
pony truck: an extra set of non-driven wheels under a lokey which are free to pivot sideways on curves.
rail tractor: a bush tram locomotive powered by an internal combustion engine
tram: bush tram; railway used in the timber industry (NZ)

Christchurch Trams Roll Again!

M. L. GADD C.Eng, M.I.C.E., F.I.P.E.N.Z., Registered Engineer
Consultant Transportation and Civil Engineer

SUMMARY After an absence of almost exactly 40 years, trams will once again be seen on Christchurch city streets. The tracks are currently being laid and it is hoped that the first tram will operate on 21 September 1994 - 40 years to the day of the last one ceasing operation.

This paper describes the background and history of the project, including some of the difficulties which have to be overcome before the trams could once again be accepted on the public highway. Reference is made to the support from the Tramway Historic Society, owners of the vehicles which it is intended to use.

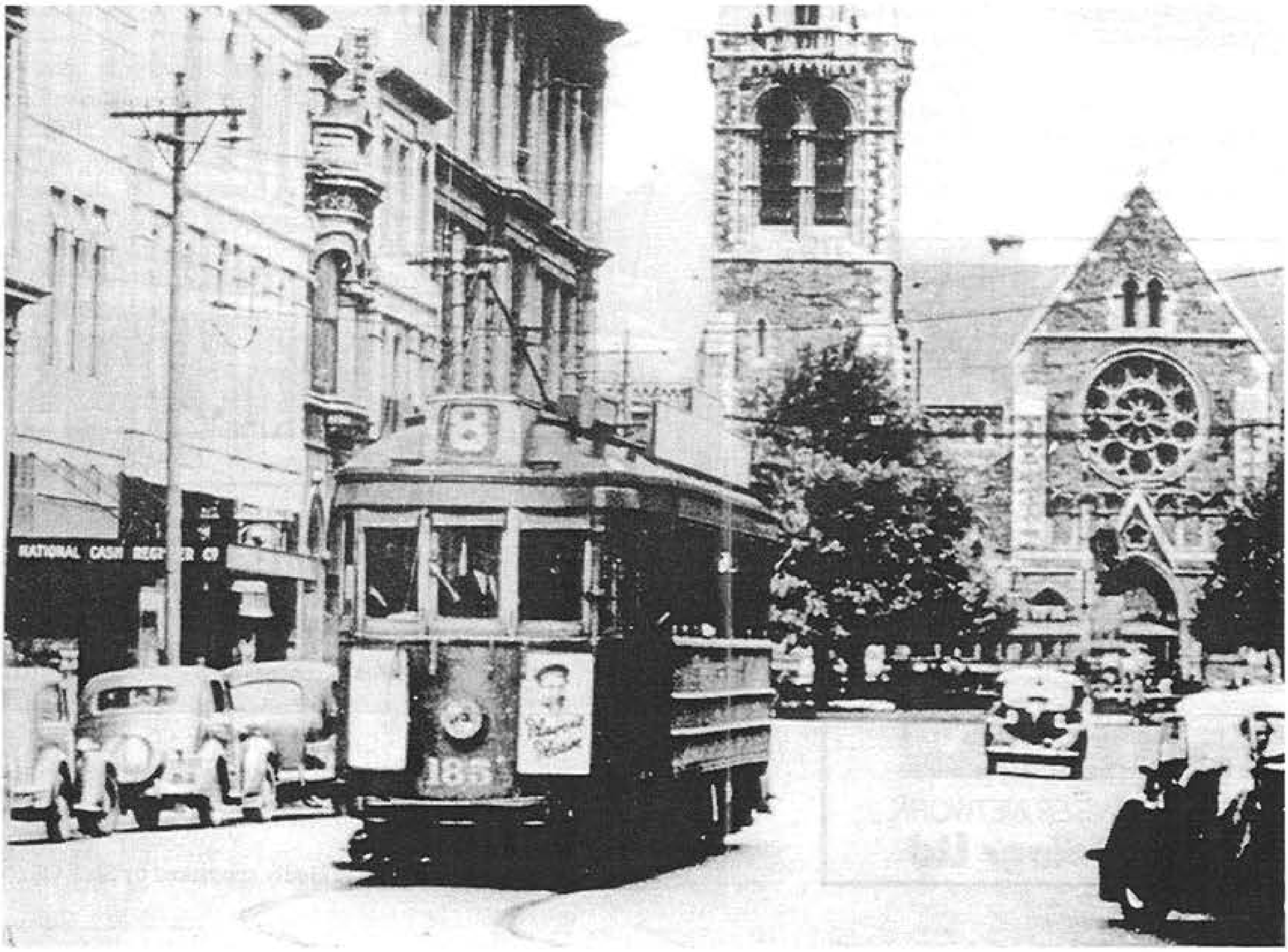


Figure 1 An historic view - to be seen again!

1 INTRODUCTION

Trams were a popular - possibly essential - mode of travel 50 years or so ago, in most significant cities of the western world. Christchurch was no exception. Cathedral Square was the hub of the transport system with the spokes radiating out to the coast, the hills and to the west. Worcester Street (above) echoed to the clanging and grinding of almost innumerable trams, most of which ended up as garden sheds, chicken coops or worse.

One may ask why bring such noisy and antiquated vehicles back on to our busy streets. The answer probably has several facets. We have a longing for things of the past to remind us of the slower tempo of those days. Trams are a fun ride. And perhaps we are revolting against the ever mounting pressure of traffic by reintroducing a system which could act as a deterrent. Also, tourists enjoy a ride on a tram. tend to go for historic or antique experiences - and have dollars to spend. They may well stay another night or two if the city has enough genuine attractions. It all adds up.

In those days, local styles of trams based on American originals known as the "Boon", "Brill", "Yank", and "Hills" were to be seen clanging and rumbling around the city, carrying people to and from the suburbs as the city grew. Indeed, the tram routes helped determine the form the expanding city took, allowing suburbs to be created like extended fingers on either side of the routes Shopping centres and other civic features tended to locate along these routes.

Private vehicle ownership was very low and the trams were an essential part of the city transport. Eventually, the growth of private mobility and the ease and flexibility operating rubber tyred buses led to the demise of the trams, as in most other cities in the world - with notable exceptions in Eastern Europe and closer at hand, the very fine systems operated in Melbourne (and elsewhere in Victoria), Australia.

One example of each of the types of tram then used is preserved at Ferrymead Historic Park, being owned and operated by the Tramway Historic Society. Five cars will be fully restored by November 1994. So there is, in fact, a tram experience already obtainable. . Why introduce another rival system?

2 HOW DID THE IDEA OF REINTRODUCING TRAMS ARISE ?

The Christchurch City Council has for many years, been active in modernising the city centre, while at the same time, protecting areas and features of historic interest. There has been a strong move to limit access by general traffic to many areas of the city, including Cathedral Square, Victoria Square, the City Mall and more recently, the magnificent Worcester Boulevard,. Figure 2 illustrates the original choice of routes to be taken by the tram).and Figure 3 shows the Tourist focus including the Malls and river precinct, and many top class hotels.

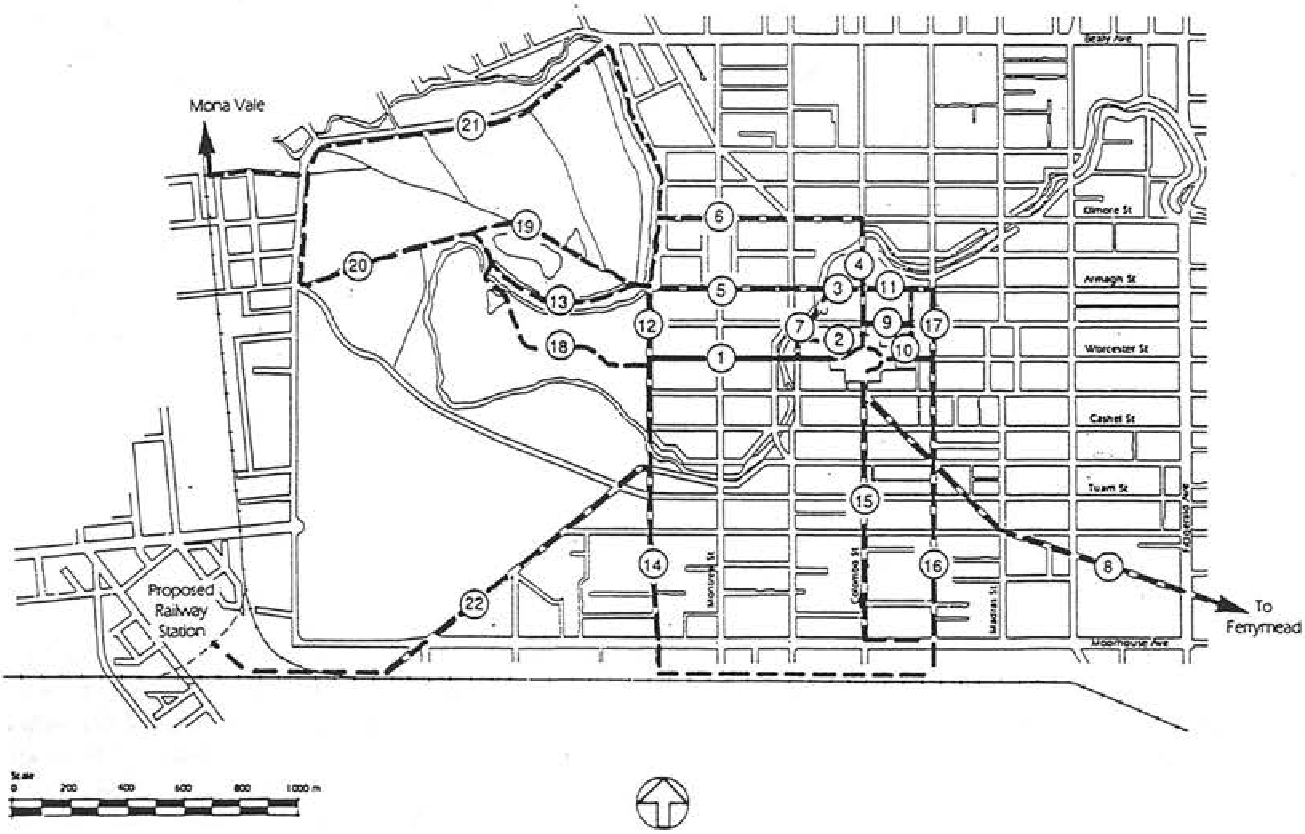
Just who had the idea of once again operating a tram - described by its detractors as noisy, dangerous and antiquated - is not certain, but the idea seemed to arise spontaneously as an exciting addition to the Worcester Boulevard. There was some opposition to the idea amongst both the staff and elected members of the Christchurch City Council, but a small dedicated band of enthusiasts managed to keep the idea alive through all the difficulties of getting the approval of the Council and preparing and presenting a tangible and buildable project. Perhaps the most significant element of support in those days came from the Tourist Transport Committee of the Christchurch City Council chaired by Councilor Alex Clark. The Tramway Historic Society was enthusiastic about getting a real system going, even if it detracted from Ferrymead.

An opportunity arose to push "big concept" the idea. A group of members of the staff, including the author had been asked to find a way of connecting all the significant tourist venues located in and near to Christchurch. The Tourist Transport Committee had successfully launched the idea of an inner city bus and hired a London type double decker bus (one of the several rugged vehicles that seemed to make their way across Asia and India to Australasia!).. However, this service known as "The English Connection" simply served attractions in or close to the central business district, though excursions outside were possible. A scheme was therefor prepared to link the other major tourist attractions, including the proposed Gondola in Heathcote Valley, the Port of Lyttelton, Ferrymead, the Wigram Air Force Museum and Mona Vale.

The concept is illustrated in figure 4. The plan was to install a tram track between Cathedral Square and Mona Vale, which lies close to Riccarton on the western fringes of Hagley Park. At Mona Vale, there is a fine old (for New Zealand) house and public garden. The main railway line (with trains daily north, south and west) passed hard by the garden wall, and also the site of a now demolished railway station. Tourists (and locals of course) could then be transported on the railway right of way to the more distant attractions. It sounded brilliant.

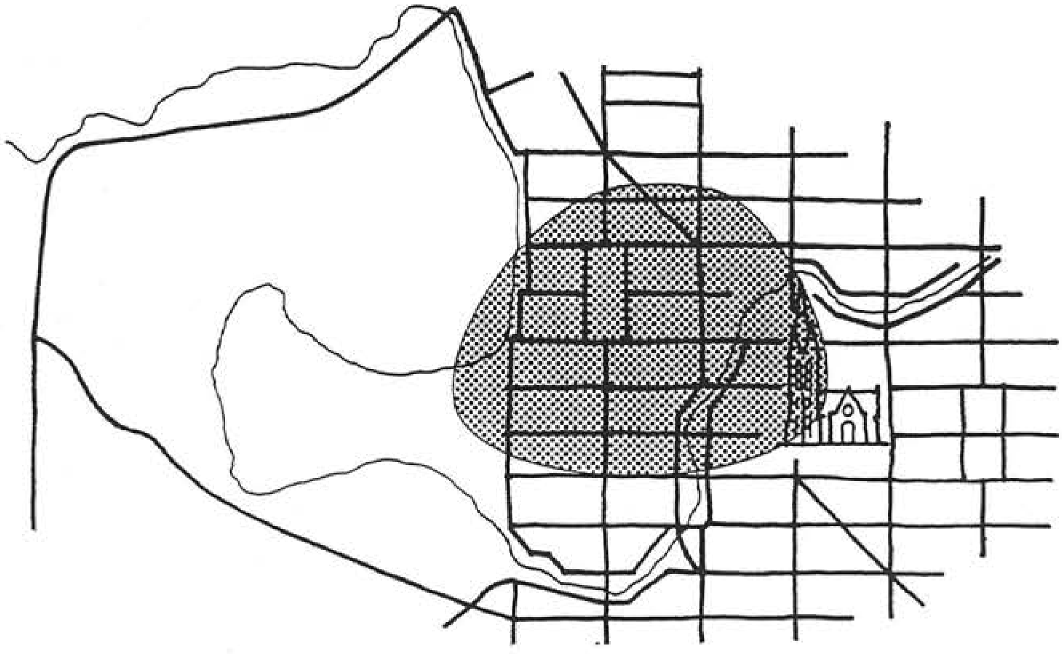
We had high hopes of running three foot six gauge trams both on the new on-street track and on the railway tracks. Only later did the author learn that tram flanges were incompatible and there was only one three foot six gauge tram in existence in a somewhat decayed state.

With a considerable amount of cheek and perhaps over confidence, I described the route to the Tourist Transport Committee and eventually to a session attended by representatives of all the adjoining local authorities - who are now in fact part of greater Christchurch city. There was surprising support and enthusiasm, and at the time very few people had cold feet about the idea of running a tram track across Hagley Park.



Christchurch Tourist Tramway Extension : Options Investigated

Figure 2



Central City Tourist Focus

Figure 3

Later, sanity prevailed and I think we all realised that the difficulties of overturning the protective Act of Parliament in getting it through the public arena would be impossible at least in the short term.

The three foot six gauge idea was scrapped and standard 4" 8 1/2" tracks proposed so as to take advantage of the restored or about-to-be restored trams already operating at Ferrymead. The Tramway Historic Society was keen to assist despite the fact that a city centre tram could detract from Ferrymead. It proves that tram supporters are enthusiastic when the chance of a real life scheme appears.

At about this time, New Zealand Rail were looking for a new location for the Christchurch Railway Station. For operational reasons, the old one had to go, and the new station had to lie somewhere along the main north south rail track, which meant that the Railway Station had to lie somewhere to the west of the city centre. New Zealand Rail Properties considered that Mona Vale was a suitable location. No doubt the local property manager had been inspired by the enthusiastic report describing the possibility of linking Mona Vale to the city centre by tram, and had visions of passengers - including overseas visitors - hopping off the train and onto a tram to complete the city bound journey. It was an attractive idea.

Unfortunately, the locals did not take to the idea of a Railway Station outside their back door, even if it was to be a re-located historic built station building from Kaiapoi. The idea died and the Railway Station site moved into what is at present a rather open site in Addington. (The area is to be re-developed and the open character should disappear in time.)

This left the Tourist Transport Committee and other working groups in the city with a challenge to prepare a tram proposal which would make use of the Worcester Boulevard, provide a decent ride, visit interesting parts of the city centre, and be buildable. It would clearly have to fit in with traffic requirements and if possible, be economically self-supporting. But not go to Mona Vale or across the Park or Botanic Gardens Yet for a time the most enthusiastic members still toted with the idea of a track along the northern edge of the Botanic Gardens.

A real incentive arrived when it was announced that the western part of Worcester Street was to be reconstructed with the old dished channels replaced by flat channels, standard section kerbs and a 14 Metre roadway. .A plan had to be produced and quickly if this was to be avoided. Supporting architects, planners and engineers (and fortunately key councilors) were united (well the tram enthusiasts anyway) in an unprecedented manner.

Plans and diagrams were produced, estimates thrashed out and after a publicity campaign public opinion was sounded. Apart from some of the locals who didn't like the prospect of the noise, most citizens and the media were enthusiastic. Editorials were favourable and letters to the editor in favour outnumbered the opposing views 4 to 1 (without any orchestration to my knowledge!)

Submissions were called for, and the Tramway Historic Society put in a very positive response. However, not all were supportive. One real rival system proposed a rubber tyred pseudo tram which appealed to some but filled the supporters with horror. We wanted the authentic thing!

The latest concept was approved in principle in May 1988, submissions were sought in 1990 and the Armagh Loop was approved in 1992.

3 THE EVOLUTION OF THE PLAN

Several alternatives were tried, and some members of the working group were enthusiastic about still taking the tram into Hagley Park, possibly to the footbridge which gives access to the Tea Kiosk in the Botanic Gardens. The staff at the Botanic Gardens were also quite enthusiastic about this idea as it would provide a wonderful form of transport for visitors to the Botanic Gardens, some of whom could then transfer to the electric toast rack vehicle which takes visitors around the Botanic Gardens in silent comfort while they admire the wide range of species in this world class garden.

Once again, their enthusiasm was not shared by all Councilors, - particularly for one version which actually ran the tram track through the Botanic Gardens - and eventually the idea was dropped.

4 THE ROUTE SELECTED

The route finally selected consisted of a loop illustrated in Figure 5 over. This would pass through Cathedral Square, up Colombo Street, along Armagh Street, down Rolleston Avenue and back down the Worcester Boulevard.

This route both served the need to link the Botanic Gardens (and Hagley Park), Museum, Arts Centre (old university), and City centre (Cathedral Square and the banks of the Avon River).

5 ECONOMIC VIABILITY

A study was carried out by the Canterbury Development Corporation which proved to their satisfaction that the

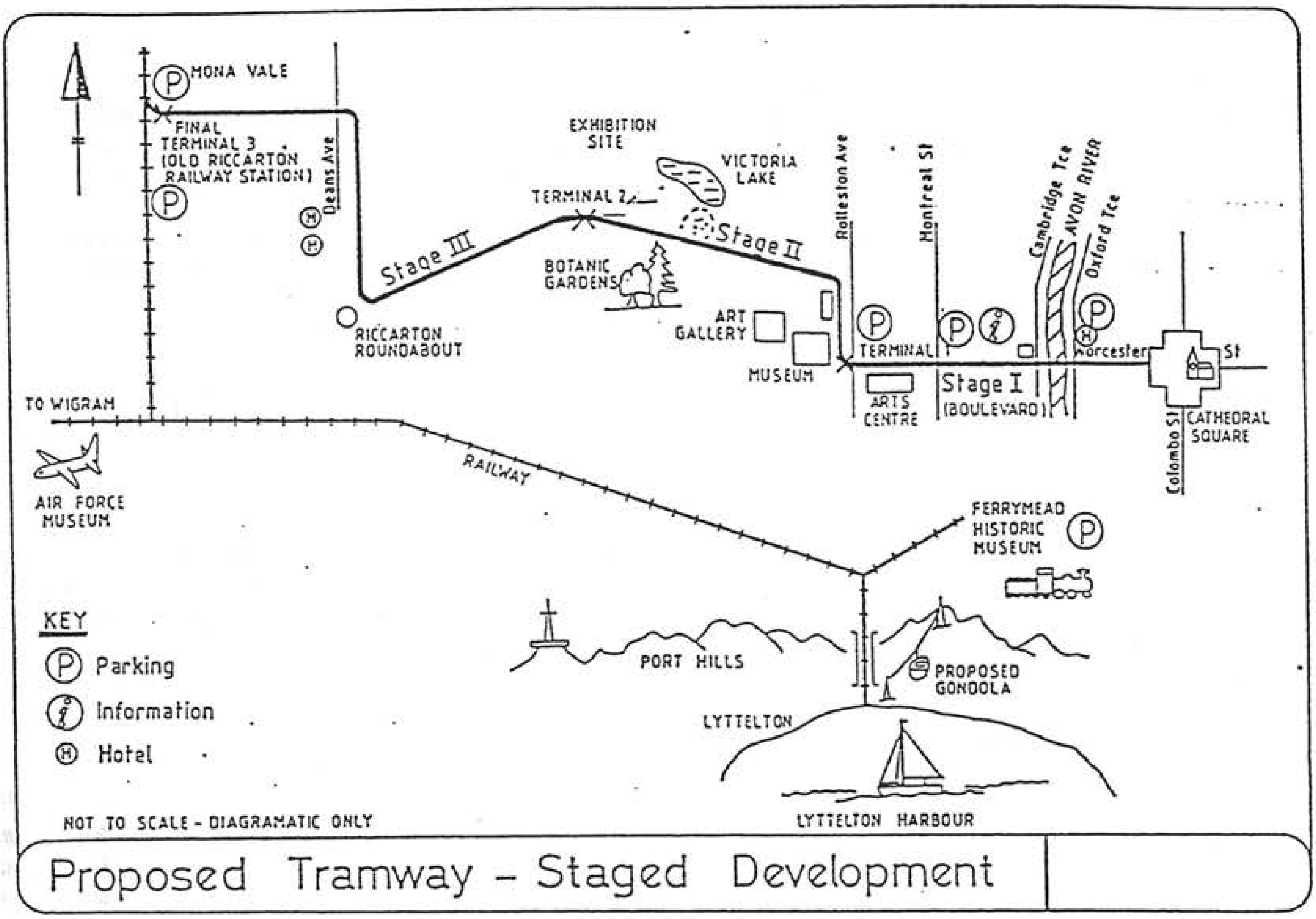


Figure 4 The Original Tourist Transport Concept

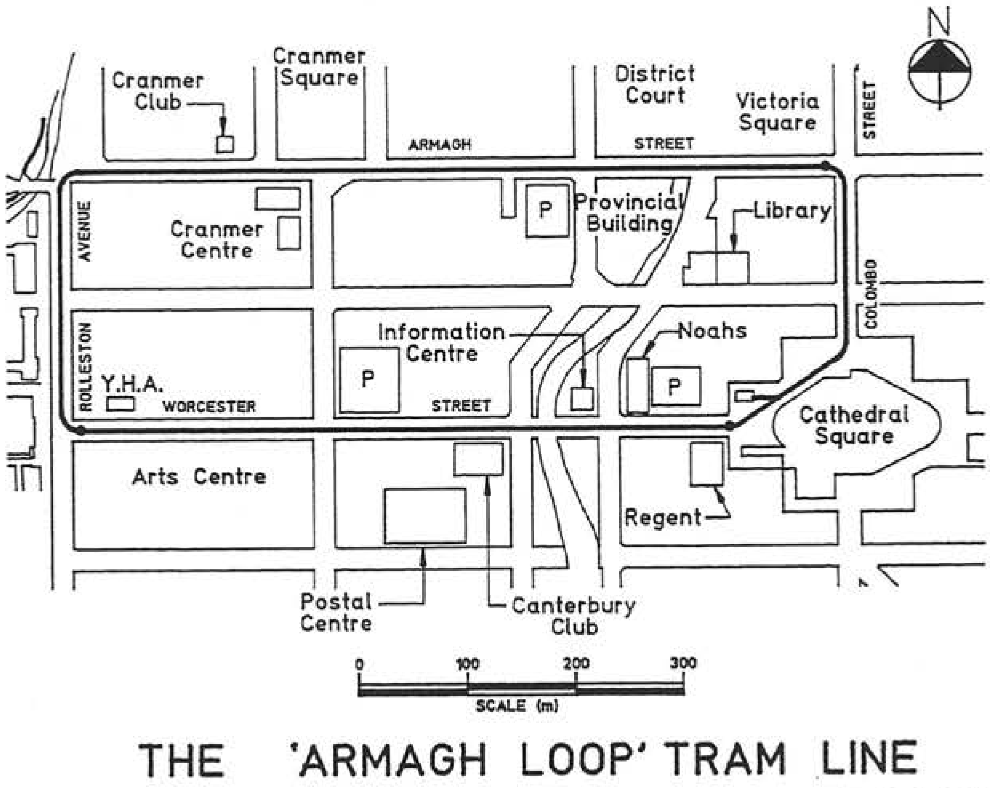


Figure 5 The Armagh St. Loop

likely ridership of the proposed fare would yield a positive balance. Just how the tram was to be operated and who would operate it was not determined, but it was

generally accepted that the City Council would own the infrastructure, including the overhead electric conductors and DC power supply. The trams would be hired from the Tramway Historic Society and the operator would presumably pay a fee for the privilege of using both the infrastructure and the trams. A survey of public opinion carried out by the Town Planning Department showed considerable public enthusiasm for the idea of a tram. Indeed, the residents of Christchurch often show considerable enthusiasm for any improvements to the city centre and this climate of public support has been most helpful in overcoming any potential political opposition.

One recalls that one elected member felt that trams were "noisy, clanking dangerous things" and another member, having witnessed a fatal accident, could never be persuaded to accept trams on the city streets!

6 TECHNICAL INPUT

I won't concern this gathering with excessive technical detail, except to comment that a report commissioned from the Melbourne Tram Consultancy (ex-staff members of the Met.) gave considerable support to the Design Services Unit in deciding on the physical details of the rails and their foundation (concrete pad) and help on questions of noise..

Traffic engineering design was carried out by the Traffic Unit of the Christchurch City Council. Many problems were to do with conflict with street traffic were overcome

The design services Unit designed the trackwork and foundations using standard railway track sections. Particular care was taken to lay a smooth track. All contractors have taken great care with this aspect. We have promised the locals that clanking (other than the warning) will not accompany this modern system!

7 THE TRAM TO-DAY

The lines are being laid, and by the time this conference is held, should be the complete loop described above. Any access to Hagley Park or to the Botanic Gardens remains a dream for the future, thought there will always be stalwart opponents of this intrusion.

However, the tramway did attract considerable public support when the rails appeared and ideas were proposed which could modify the route. One such modification - namely to take the tram through New Regent Street and round a small loop to the north east of the city centre - has found favour and has been approved by the Christchurch City Council. This small addition adds considerable interest and facility to the tram route.

I have been unable to get details of the economics, fare structure and frequency of service as this information is commercially sensitive. I believe the service will be fairly frequent (say 15 minutes) and cost low dollars.

One of the difficulties to overcome was the question of safety and the legality of operating trams on the public highway. It was so many years since this was a regular feature, that legislation had lapsed. Indeed, proposed legislation designed to cover interaction with railway tracks and railway vehicle operations omitted reference to trams and there had to be some hurried submissions made directly to the Minister and Department concerned to ensure that trams did have a home in this legislation. Fortunately, the gap was closed in time!

8 HISTORIC ACCURACY

One of the most important features of the proposed tram is an attempt to retain authenticity and be true to the style of trams and infrastructure which used to exist in Christchurch. Not only are the trams themselves genuine originals, lovingly restored by the Tramway Historic Society, but the other supporting equipment, including poles, outreach arms and - tram stop features, are all designed and installed so as to closely resemble equipment which existed on the streets 40 years ago.

9 THE NEED FOR A TRAM SHED

To satisfactorily operate a tram service in the city centre, it is necessary to house vehicles over night. The original idea was to locate these close to Cambridge Terrace and provide public viewing, cafeteria facilities, etc. This idea - like many others - fell through for a variety of reasons, and the current idea is to build a special housing east of the city centre in Hereford Place. Not only is a shed necessary for security and weather protection, but it will be necessary to carry out minor repairs and maintenance on the trams over night. Provision will be made to load them on a low loader and take them back to Ferrymead for major overhauls.

The Tramway Historic Society has shown a good deal of enthusiasm for the project, although it might be argued that this track would reduce the attraction of the Ferrymead Tramway which runs for just under a kilometre in the Historic Park at the mouth of the Heathcote River.

By the way, this site is well worth a visit as it gives not only a good chance to see the trams in operation, but also the very fine historic village and other features which are unique in New Zealand.

10 MARKET ASSESSMENT

Following consultation with the Canterbury Development Corporation, John D. Rodwell Limited carried out an economic and marketing assessment. This was reviewed by two independent outside sources, including a well known firm of Chartered Accountants. The January 1993 study included surveys of the views of Christchurch citizens and businesses and - supplementing the smaller but similar survey undertaken in 1990. There was very strong support for the proposal.

An A3 size pamphlet was prepared for public distribution which summarises both the plan and the most important features which people need to know.

In particular, the Art Centre is very supportive of both the tram and the proposed extension. They will of course require a tram stop adjacent to the Art Centre's Market Square.

11 CATHEDRAL SQUARE

Cathedral Square is being remodeled and the tram tracks have to be taken into account, in addition to the need to retain the bus service focus in Cathedral Square. This has provided quite a challenge, but the layouts for the Square proposed do indeed give the tram pride of place, although the tram shed which was once to be sited in the north west quadrant, is now located elsewhere. At the time of writing this paper, public debate is hotting up, - and historically Christchurch citizens are liable to engage in quite fierce debate about changes to the city. It is, however, a fact that many difficult decisions have been made over the years and the reputation as a quiet, sleepy English style city seems to have faded. The tram project illustrates this go-ahead but still conservation conscious spirit.

12 SUMMARY AND CONCLUSION

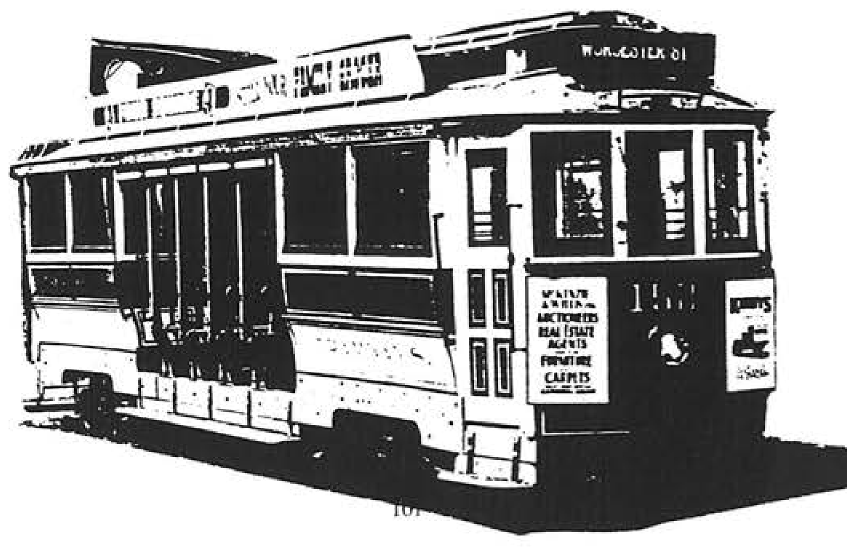
So there we have it. Despite all difficulties, a tramway will once again operate in Christchurch. Or with any luck is operating by the time this conference opens. Delegates will no doubt be able to enjoy a ride on one of the fine vehicles during the conference.

Those of us who have been intimately involved in the project are, of course, delighted. We feel that Christchurch is both a go-ahead city in that the City Fathers are prepared to invest and show confidence in the city centre and in improving the amenities there. However, there is a leap of faith to reintroduce a form of transport that is apparently as antiquated as a tram and we feel we are very grateful that this bold step has been taken - and taken with such confidence. Of course there are still opponents. Many people feel that the tram will lose money. However, if the Council is prepared to invest in the track work and infrastructure in the same way it has invested in paving and other features, and consider this as a sunk investment, then there seems little doubt that the tram will operate satisfactorily.

Not only will a service be provided at regular intervals and at modest cost throughout the day, but there is the possibility of night time operation and even restaurant or buffet cars and a historic experience known as the "Bickerton Experience" in which the tram is used as an educative tool. The possibilities seem almost endless.

This paper is really a commentary on what happened. Technical details are available. My only recommendation, as a person involved but now retired from direct employment by the Christchurch City Council, is that we heartily congratulate the Council and staff on a bold and far sighted venture and wish them every success.

And if some of the additional track described in my original paper is eventually laid by popular demand, I will personally be very pleased!



Australia's Overland Telegraph Line 1870 - 1872

N. LEYBOURNE-WARD B. Arch (Sydney), B. App. Sc (Biology), (CCAE)
Dipl. Conservation Studies (York)

SUMMARY The Overland Telegraph Line (OT Line) from Port Augusta to Port Darwin was Australia's first national development project and the greatest engineering achievement of the last Century.

It is significant for its political, military and economic importance. The route was over country which had just been traversed by John McDouall Stuart and was considered by the Government of the Colony of South Australia to be vital to the opening up of the centre of Australia to pastoral and mining ventures.

Telegraphy was at its infancy and undergoing rapid improvements; communication technology was under trial. Further, the organisation and administration was of vast proportions and a credit to the will and determination of the men involved especially the SA Postmaster-General, Charles Todd.

The relics (including the building complexes) that remain deserve to be conserved as a testament to an important period of engineering heritage.

1. INTRODUCTION

The crude notice on the angle pole near Oodnadatta where the line veered north puts it succinctly:

> "The OT Line was the greatest engineering achievement of the last century. It spanned the continent from Adelaide to Darwin before Australia was traversed from west to east. From as early as 1875 it allowed two way conversation from Adelaide to London via a continuous land line."

The Overland Telegraph Line (OT Line) owed its existence to the need for fast news from Europe especially with regard to the volatile political situation there and the demands that the rapidly expanding young Colony of South Australia had for speedier responses to trade initiatives.

Communication by mail was the usual 110 days by ship or, at the very best, 50 days by fast steamer. At the time of the Crimean War (1854 - 1856) it became a matter of urgency to shorten the time for Australia feared an invasion by the Russian naval might[1]. The opening of the Suez Canal in 1869 shortened the shipping time but the initiative had switched to telegraph cable. The earliest cable was laid in 1850 from Dover to France[2] and development advanced to an ambitious scheme to lay cable and overland line from England to Moreton Bay (Queensland)[3, 4]. This proposal spurred the SA government to commence direct negotiations with Britain; the thought of the Eastern Colonies having the advantage was anathema.

South Australia was, at that time, a British Colony; by 1863 the British government, in its wisdom, decided to hand over the Northern Territory to the South Australian government[5] (which retained it until ceded to the Commonwealth of Australian in 1911[6]). The colonial government thus had jurisdiction over the entire north-south extent of the land.

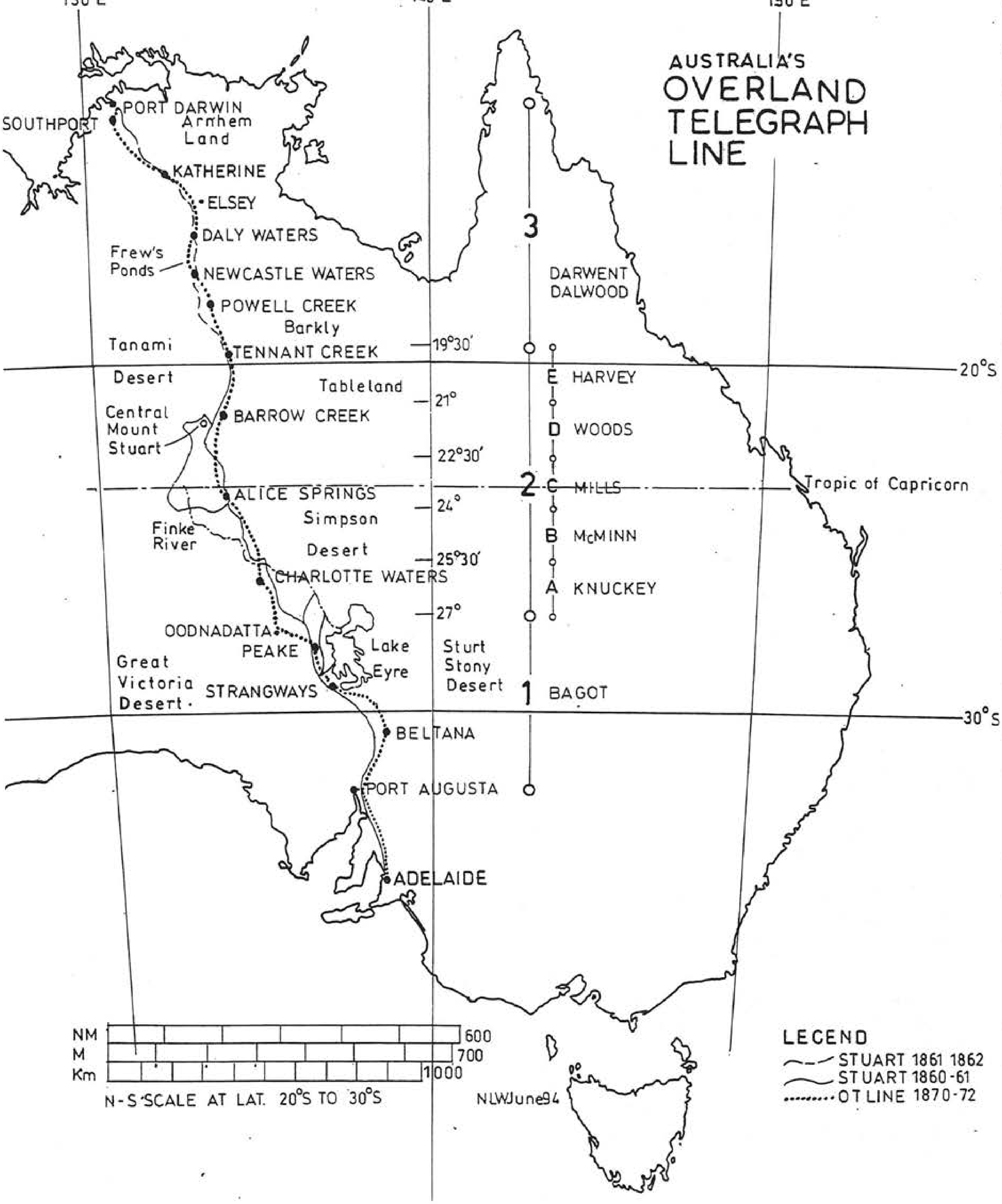
The SA government had earlier decided to establish telegraphic communication between Adelaide, Port Adelaide and Semaphore (the signal station south of the Port) and it requested the Secretary of State for the Colonies to appoint a Superintendent of Telegraphs[7] to take charge of all telegraphs including the ultimate project - connection with England.

2. THE NEW TELEGRAPH ADMINISTRATION

Enter Charles Todd. The Government position was for a Superintendent of Telegraphs and Observer and Todd fitted all requirements. He had been recommended by the Astronomer Royal and appointed by Lord John Russell[8]. Todd brought with him the necessary telegraph plant in November 1855 and by December had commenced the Adelaide - Port Adelaide Line[9]. This was followed by an extensive telegraph network in the southern part of the Colony including a line to Port Augusta through Horrocks Pass and Stirling.

By 1858 governments were considering various schemes for connection between England and the Australian continent. One in particular was by F Gisbourne; it was the Red Sea and Indian Telegraph Company's proposal to connect Singapore and Moreton Bay (Queensland) by cable; this was the Rangoon - Singapore and Singapore - Batavia connection which was to touch Timor and the top end of Australia at Port Essington[10].

When Charles Todd reported in 1859 to Governor MacDonnell on the various proposals he preferred Gisborne's scheme[11] but then changed his mind and favoured and overland line to open up the country for settlement[12]. It really was Governor MacDonnell's initiative[13] for it was he who was impressed by the success of Warburton and Babbage's expedition. Todd took


130°E
140°E
150°E
AUSTRALIA'S
OVERLAND
TELEGRAPH
LINE
PORT DARWIN
SOUTHPORT
Arnhem
Land
KATHERINE
ELSEY
DALY WATERS
Frew's
Ponds
NEWCASTLE WATERS
POWELL CREEK
Barkly
Tanami
TENNANT CREEK
19°30'
Desert
Tableland
21°
Central
Mount
Stuart
BARROW CREEK
22°30'
ALICE SPRINGS
24°
Simpson
Desert
Finke
River
25°30'
CHARLOTTE WATERS
27°
OODNADATTA
PEAKE
Lake
Eyre
Sturt
Stony
Desert
Great
Victoria
Desert
STRANGWAYS
BELTANA
PORT AUGUSTA
ADELAIDE
3
2
1
DARWENT
DALWOOD
E HARVEY
D WOODS
C MILLS
B McMINN
A KNUCKEY
BAGOT
20°S
30°S
Tropic of Capricorn
NM
M
Km
600
700
1000
N-S SCALE AT LAT. 20°S TO 30°S
NLWJune94
LEGEND
STUART 1861 1862
STUART 1860-61
OT LINE 1870-72

to the idea, no doubt to please MacDonnell, and set about planning the route to follow that explored by John McDouall Stuart.

Stuart had made six journeys of exploration, the first in 1858 a 1500 mile round trip into completely new territory, the second in 1859 to survey land claims and this took him ninety miles further north, the third in 1859 - 1860 to survey land claims and to do some gold prospecting, the fourth in 1860 reaching the centre of Australia where he named a hill after Captain Sturt (later changed by the Governor of South Australia to Central Mount Stuart). The fifth expedition was a short one further north but forced to return after eleven attempts to cross scrubland; the sixth and successful expedition in 1862 reached the Indian Ocean, a journey of about 2,000 miles for ten men and 71 horses[14].

Thus Todd had a good knowledge of the land and its resources and the difficulties which would be encountered. The first 500 miles of terrain was familiar territory.

3. PLANNING THE ROUTE

By 1870 the war of the cable routes had intensified; there were many proposals. However, the SA Government was seriously considering one by the Telegraph Construction and maintenance Company and its prospectus for the British - Australian Telegraph Company. The terminus for its cable was to be Normanton, North Queensland, with a land line over the Northern Territory. The project thus had to be considered by the SA Government which, through Todd's intervention, provided a loan for the construction of an overland telegraph line from Port Augusta to Port Darwin and it persuaded the British - Australian Telegraph Company to terminate at Darwin[15].

Charles Todd was a meticulous planner. With the knowledge gained from Stuart's expeditions he set about organising the route dividing it into sections and calling for tenders for the construction of the line.

The project was divided into three sections:

1. Port Augusta to latitude 27°S
2. Latitude 27°S to 19°30'
3. Latitude 19°30'S to Port Darwin

It was originally proposed that all three were to be by contract but negotiations for the centre section (No. 2) failed when Rounservell's tender fell through the cracks[16].

Section 1 was relatively easy compared with the remainder of the Line. The contract was awarded to E M Bagot at the rate of £41 per mile[17], a price which reflected the then knowledge of the terrain and the short lines of communication with Port Augusta and Adelaide.

Section 3 was a far different matter; the only route known was Stuart's fifth and sixth explorations and these were through difficult country in an exasperating climate. The Contract was let to Darwent and Dalwood at rates per mile varying from £39 to £92 over 639 miles (see Table 1)[18]. It was destined to be a disaster.

Section 2 was undertaken by the SA Government. It was divided by Todd into 5 sub-sections; A. 27° to 25°30'; B. 25°30' to 24°; C. 24° to 22°30'; D. 22°30' to 21° and E. 21° to 19°30' each under the command of an overseer. Those men were, respectively, R R Knuckey, G R McMinn, J Beekwith (replaced by W W Mills), A T Woods (Chief Officer) and Harvey[19].

For the contracts the SA Government provided all wire and insulators and, to Bagot, in addition, about 1500 iron poles[20].

The Parliament voted a loan of £120,000 for the whole project and set a completion date of 1 January 1872[21]. As often with such large undertakings, neither target was kept.

Work started on Section 1 (Bagot's contract) in September 1870[22] the first pole being planted at Stirling (where the OT Line connected with the existing telegraph service to Port Augusta) on 1 October of that year[23, 24].

At the top end (Section 3) Darwent and Dalwood commenced working south with the first pole planted on 15 September 1870 by the Government Resident's daughter Harriet Douglas[25, 26]. Government work on the centre section followed a route surveyed by John Ross who was appointed by the SA Government on 7 July 1870 to lead an expedition for this purpose[27] and to meet the advance construction parties at the end of September or middle of October 1870.

Thus, Todd's plan was to work north from Port Augusta, North from latitude 27°S and south from Port Darwin. His instructions to Ross were not to go east of the 136th meridian and in his survey to pay special attention to timber suitable for poles (20 or more being required per mile) to permanent waters and to such important matters as favourable places for crossing water courses and sites for stations and depots[28].

The above outline is necessarily brief as the main purpose of this paper is not a detailed history or day by day account of the difficulties but to discuss some of the technicalities.

4. CONSTRUCTING THE LINE

The poles and their spacing were of greater significance. Todd, as mentioned before, was extremely meticulous; there is excellent evidence of this in his 71 clause *Instructions to Overseers in Charge of Works* (with addendum on directions for loading Colt's or Whitney's revolving pistols). Regarding poles, clause 56 states, in part[29]:

> "The poles may be straight rough gum, pine, or stringy-bark saplings, or other timber not liable to be attacked by white ants, perfectly sound, stripped of the bark, eighteen to twenty feet long, nine to ten inches in diameter at the butt and five or six at the

top; or square poles, perfectly sound, of the same length, eight inches square at the base and five inches at the top. The butt of each pole to be charred for five feet up...."

Each pole had a hole drilled vertically in the top for the insulator pin and this driven in five inches and tightened with a wedge or leather collar. Poles were set to a depth of four feet in a square cut hole, vertical and to only 'just admit the pole'. The spacing was four chains apart or 20 to the mile but Todd allowed seventeen to eighteen feet poles on condition that they were spaced at twenty five to the mile. Angle poles were strutted with an extra pole sixteen or seventeen feet long. Every second pole had a lightening wire stapled to the pole projecting three inches above the insulator and ten or twelve yards coiled horizontally in the ground at the foot of the pole. Poles at the 'top end' or northern section were *Callitris Columellaris or C Intratropica*[30].

Insulators were specified as the "most approved form"[31]. The author has two types in his collection, a glass insulator which had been screwed to a wooden pin (from Barrow Creek) and a white ceramic insulator with a steel pin which had been fitted to a cross-arm possibly when the second wire was installed (from Grove Hill near Pine Creek NT).

The wire originally used was a simple 8 gauge galvanised iron wire 400 lbs/mile in use for 27 years until 1899 when a 200 lb/mile hard drawn copper wire was added as a second line[32]. The iron wire was manufactured by Johnson and Nephew[33]. Todd specified that the deflection was to be three feet in every four chain span and wire tied to insulators with No. 15 tie wire, the joints to be Britannia joints well soldered with 2:1 tin:lead washed afterward to remove acid[34]. Wiring started in Section 1 in May 1871[35] and finished when the final joint was made at Frew's Ponds (between Daly Waters and Newcastle Waters) on 22 August 1872[36] nearly eight months over the scheduled completion date.

To get an overview of the progress made and the difficulties encountered the significant dates for each of the three sections are noted:

Section 1: The southern section officially began on 5 October 1870 and finished in December 1871 a period of fourteen months at a mean rate of 36 miles / month.

Section 2: Subsection A (Knuckey) began in January 1871 and finished in September 1871 a period of eight months to cover 1½° of latitude; Subsection B (Gilbert McMinn) began in February 1871 and finished on 15 November 1871 a period of nine months to cover 1½° of latitude; Subsection C (Mills) began in March 1871 and finished in December 1871 a period of nine months to cover 1½° of latitude; Subsection D (Woods) began in April 1871 and finished in December 1871 a period of eight months to cover 1½° of latitude; and Subsection E (Harvey) began on 1 June 1871 and finished on 1 November 1871 a period of only five months for 1½° of latitude. Thus, the whole of the government work took about 12 months at a mean rate of 52 miles / month: this was a tribute to Todd's organising ability for a section that was considered to be the most difficult. Todd, of course, had good resources including government money; the other two sections were contracted for tendered prices.

Section 3: The northern section began with the planting of the 1st pole on lot 533 Town of Darwin on 15 September 1870. The contractors, Darwent and Dalwood, entered into a contract with the SA Government about 15 July 1870 the same time as Bagot contracted for Section 1. By 9 December 1870 the northern party had reached Adelaide River (which is now only 111km by road from Darwin) with all poles erected[37] and then the top end "wet" set in and this slowed up progress. However, the northern party had erected poles as far as Pine Creek by Christmas 1871[38] and on 23 January 1871 they reached Katherine River. This obstacle was overcome on 24 February 1871 when the party crossed the river on rafts. The progress as far as Katherine was approximately 200 miles in 5 months or about 40 miles/month.

But disaster struck after approximately 225 miles of poles and 156 miles of wire had been erected; it was then that the contract broke down[39]. On 14 March 1871, William McMinn, the Departmental Overseer for the northern section[40] complained that progress in the north was unsatisfactory and by 3 May 1871 progress was so bad that McMinn cancelled Darwent and Dalwood's contract and then left for Adelaide. News of this contractual break-down reached Todd in July 1871[41] when he was supervising operations from Strangways Springs.

Events then moved rapidly for a new Government northern party was assembled under the charge of Robert Charles Patterson[42, 43] and the party left Adelaide by sea on 27 July 1871 reaching Darwin on 24 August. The party then set out for King River reaching that camp by October; six months had been lost. Then, in November, the northern "wet" set in again. The whole project had, at that stage, reached a position of extreme urgency because the SA Government had agreed with the Telegraph Construction and Maintenance Company in association with the British - Australian Telegraph Company to have the overland line ready on or before 31 December 1871[44] on condition that the Company would undertake to lay the marine cable connecting Singapore and Darwin[45]. By 7 November 1871 the cable was brought ashore from the *Hibernian*[46] at Darwin near the corner of Bennett Street and Mitchell Street. The *Hibernian* then proceeded to lay cable from Darwin to Banjoewanji at the east end of Java[47].

Todd sent Knuckey, Mills and Bagot to explore north from Subsection E; they set out on 19 December 1871[48]. The party was authorised to pole at twice the standard distance or 10 poles to the mile[49] (one wonders just what deflection was allowable). The net effect of that action was that 82 miles of the southern end of Section 3 were constructed by Harvey's party (Harvey had completed Subsection E by 1 November 1871).

By 4 January 1872 Todd set sail from Adelaide for the north getting to his new depot on the Roper River which runs from near Elsey Station ("We of the Never Never"[50]) to the Gulf of Carpentaria. The Elsey was near the present day Mataranka 108 km south of Katherine. The new northern party worked from the Roper having supplies sent up the river by the steamers *Omeo* and *Young Australian* in company with *Bengal*[51] - a separate story in itself and not within the compass of this overview. Suffice it to say that by 1 January 1872 when the telegraph line should have been completed there was a gap of 394 miles[52]. At this stage R R Knuckey was instructed to organise a pony express or estafette service to close the gap; the line had to be put into operation. The gap was from Elsey station to Tennant's Creek. The first experimental message by this means was sent by Charles Todd from Port Darwin on 22 May 1872 and it arrived at Adelaide on 20 June 1872 - four weeks. The gap gradually closed with the assistance of a private contractor by the name of John Lewis who later became a foundation member of Broken Hill Proprietary[53]. The estafette service officially began on 15 June 1872 and ceased when Stapleton made the final connection near Frew's Ponds 28 miles north of Newcastle Waters on 22 August 1872. On 24 June 1872 the BAT cable broke so that communication with Europe was delayed until it was restored on 21 October 1872 - two months after the OT Line was put into operation. There was a right royal banquet in Adelaide on 15 November 1872.

5. OPERATING THE LINE

By the time that Todd arrived at Adelaide (1855) the Henley Magnetic Double Needle Telegraph was in use; the first type of sending receiving equipment with a speed of 9 to 10 words per minute[54]. It operated by a current generated at the sending station by a magnet near a copper wire coil the impulses being read as deflections on a needle at the receiving station. To read the Henley the telegraphist had to observe the sequences of left and right deflections and the chart on the Henley gave the corresponding letter or numeral. The operator had to send the same message on to the next repeater station and so on - a very time consuming operation. The Henley did not have batteries being entirely an electro-magnetic function.

Improvements to transmission were made when the Morse Code was introduced and sending was by the 'simplex' method[55, 56]. With this a single current key was used by the sender and under normal conditions with a short line the signals were received by a sounder or inker. This was known as 'direct working' but in the case of long distances the signals were first received on a relay and thence, by means of a local circuit, on a sounder or inker and was therefore known as 'local working'. The current applied in either case was 15 to 20 milliamps[57]. Todd (1884) reports that the Morse system superseded the Henley system as the telegraph was extended to other Colonies[58]. It is reasonable to assume that the Morse system was in use by April 1857 when the telegraph to Melbourne commenced[59] and so the spacing of the repeater stations on the OT Line was based on that technology. In practice the repeater stations were at from 150 to 200 miles apart.

The change over from the Henley system to the Morse system is reflected in the change in name of the authority from the Magnetic Telegraph Department to the Observatory and Telegraph Department[60]. At that time a Parliamentary Paper (SAPP 67/1865) referred to the Electric Telegraph Regulations[61].

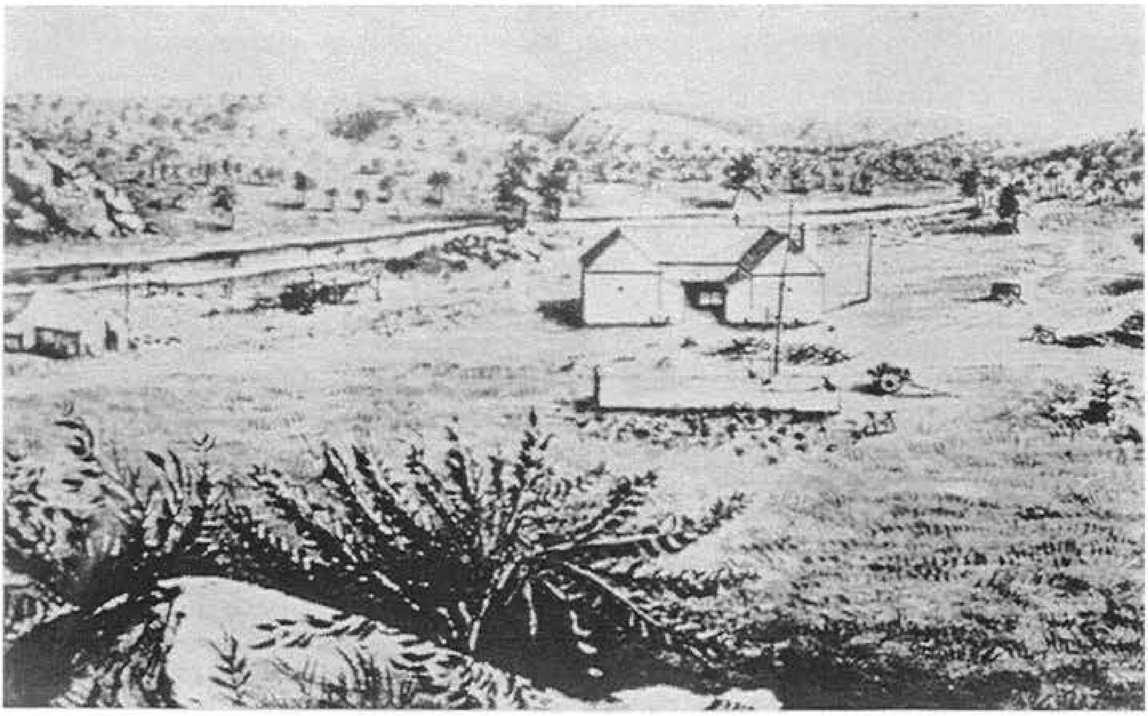
By 1876 the system in South Australia was changed to the 'duplex', the first installation being on the Adelaide - Port Adelaide line[62]. The duplex was a single current system but it involved simultaneous transmissions in opposite directions of two messages on a single wire. It can be worked in either the 'differential system' or the 'bridge system'[63]; in the differential system a local current is made to oppose the line current and the signals are recorded as the balance is upset by each station sending. It is the one most largely used in telegraphy. The bridge system is so named because the apparatus is arranged on the Wheatstone Bridge principle and used chiefly in conjunction with cable working.

Line operation was subject to interference such as atmospherics which changed the line capacity. Early in the line construction this was noticed, a specific instance being Patterson's attempt on 7 November 1871 to get a message through to Darwin from Depot 1 (Darwent and Dalwood)[64]. The solution lay in what is known as the 'artificial line'. For example the Post Office pattern made by Siemens in 1922 consisted of one adjustable condenser (7¼ microfarads), one rheostat, one condenser coil and one retardation coil. The artificial line was to act as a compensation circuit for differential work on duplex or quadruplex system - to compensate for the conditions on the line[65]. The repeater station operator's job was to carry out such balance at the beginning of the day's operations.

As the traffic increased there was a need for improved technology. The next system was the 'quadruplex' and the design of this system was based on the fact that currents may be made to differ from each other both in strength and direction and providing a means for transmitting simultaneously two messages in each direction over a single wire[66].

The next improvement was the high speed automatic Morse transmitter invented by Charles Wheatstone. This permitted the telegraphist to punch out a series of holes on a paper tape by operating a keyboard or 'perforator'. The punched tape produced electric impulses in the 'transmitter' and at the receiving end a high speed receiver printed the Morse code onto a moving paper tape. Operators decoded the symbols and wrote the message on a 'telegram' form. This system was first used in South Australia in 1905[67].

Transcribing Morse signals to standard telegraph forms was a time consuming process. The English Company 'Creed' introduced the 'perforator and printer' to operate on wheatstone equipment. At the receiving end the Creed printer printed the message in letters and numerals on a moving tape which was then cut and manually gummed to the telegram form.



Alice Springs Telegraph Station 1872

Much later (December 1927) messages were speeded up by the introduction of the carrier system based on thermionic valve amplifiers and the addition of the 'Murray Multiplex' designed by Robert Murray[68] of New Zealand. This introduced two concepts; time division multiplexing and page printing. The multiplexing was a process of allowing the transmission of more than one message over one channel interleaved in time[69]. The Murray Multiplex used in October 1921 in New Zealand (the invention of Donald Murray[70]) was capable of sending eight messages, four each direction, at a rate of 40 words per minute over a single wire[71].

The supply of electricity was by batteries at each station. Early batteries were Leclanche sal-ammoniac / carbon / zinc cells in glass jars each delivering 1.5v; each repeater station had batteries of about 130v[72]. Meidinger cells were also used but it is not clear when. Meidinger cells were copper sulphate / lead / zinc and each battery consisted of 120 to 150 cells[73].

6. THE REPEATER STATIONS

The most substantial stations and complexes were constructed of stone. These were, when the line was put into operation, at Strangways Springs SA, the Peake SA, Charlotte Waters NT, Alice Springs NT, and Barrow Creek NT. The others were temporary huts at Tennant's Creek NT, Powell Creek NT, Yam Creek NT and Beltana SA, with substantial log huts at Daly Waters NT and Katherine NT. The first telegraph station on lot 533 Town of Darwin was also a log hut. Later, Tennant's Creek, Powell Creek, Darwin and Beltana were replaced by substantial stone buildings[74].

The buildings that remain at present, the condition of the extant fabric some historical evidence and depot locations are discussed below:

Port Augusta Telegraph Station

The first telegraph station was opened in 1866[75] and the second post office was situated on the western side of the old customs house built in 1861[76] then, in the 1870's the main post office was erected on the eastern corner of Mackay Street and Commercial Road the site of the 'modern' post office[77]. Unfortunately none of the early structures remain today.

Stirling

As the telegraph line from Adelaide to Port Augusta ran through Horrocks Pass and Stirling to Port Augusta the position of the first pole of the OT Line was selected so that connection could be made into the exiting service. That was 1 October 1870 and the pole location was on the north side of the Port Augusta - Quorn Road west of the present Oval Road opposite the Council Reserve. There is no extant pole.

Beltana Telegraph Station

This station was opened on 23 August 1872 and closed in 1914[78]. At first there was a small iron hut as temporary accommodation and later (1874) tenders were called for the erection of the post office and telegraph station which was built on Lot 9. The facilities included an office and four rooms, pantry and bathroom with outbuildings consisting of the kitchen, bedroom and storeroom and stone and cement tank of 6,000 gallons[79]. The stone buildings are now part of the Beltana Historic Preservation area; they are currently privately owned and being restored.

Strangways Springs Telegraph Station

This large complex of buildings and stockyards was officially opened on 22 August 1872 and closed on 21 September 1896[80] with A Bowley appointed as stationmaster.

The Peake, August 1993

Todd reported in 1884[81] that the building (the first?) was stóne with six rooms, large detached store, detached stone building containing kitchen, cook's room, mens' living room, large stone underground tank (10,000 gallons), smithy and paddock of about one mile square. The site was purchased from Messrs Warren and Hogarth[82]. The present state of the buildings is fair as most of the stone walling is extant but roofing has disappeared except for a little of that on the tank building left flapping in the wind[83]. The site has been marked for preservation as an historic ruin under the South Australian Aboriginal and Historic Relics Preservation Act[84].

The Peake Telegraph Station

Another extensive complex officially opened on 23 August 1872 and closed on 1 November 1891[85]. There are many stone buildings including a seven room house, blacksmith's shop, cartshed, harness room and stockyard. This was Todd's headquarters for organising the centre section parties and where Ross reported back after his explorations. It is, to the author, as well as to other commentators, the most picturesque of all the repeater statoins. The isolation, the still loneliness, the stark inland beauty is very captivating. As with Strangways, the site is declared under the South Australian Aboriginal and Historic Relics Preservation Act.

When the station was closed in 1891 the original telegraph line route was kept in operation until 1895[86]. The OT Line through Beltana, Strangways and the Peake was disused and mostly dismantled when the line ran parallel with the completion of the railway to Oodnadatta in 1891.

Charlotte Waters Telegraph Station

The main station building was of stone with eight rooms and a stone tank (about 10,000 gallons). There was also a blacksmith's shop, a cart shed and harness room as well as a stockyard with a large capacity tank. The station was opened on 31 August 1872.

Charlotte Waters was a busy station with a peak period of importance at the beginning of the 20th Century right up until December 1930. With the extension of the railway (the "Ghan") from Oodnadatta to Alice Springs, and the removal of the telegraph circuits to new wires on a new pole line beside the railway, the importance of the station declined[87].

The building was transferred to the Police Department and operated as a police station until 1938. Later it was sold to Bob Smith of Crown Point Station and it was dismantled, the stone being used for construction of the cattle station.[88].

Alice Springs Telegraph Station

Alice Springs was named by Mills, Todd's overseer for subsection C, in honour of Todd's wife Alice. It was Mills who found the site, a waterhole on the river now called the Todd.

Construction commenced in 1871 under G R Minns' supervision and reported by Todd to be complete in 1873[89]. "The Alice" was opened for traffic on 22 August 1871 and closed on 26 January 1932. Todd's report of 1884 describes the station as eight rooms, office, station master's quarters, men's hut, blacksmiths shop, cartshed all of stone and stockyard and well[90].

The famous drawing of 1872[91] show the 'Barracks'[92] U-Shaped on plan and the cartshed under construction. On this a 2 wire line is seen entering from the north-west. Winnecke's survey of 1881 shows two small buildings south of the 'barracks' with the line entering the western most one. The present interpretation of the history of the station uses the easternmost building as the telegraph office. This is historically incorrect. The 1872 drawing does not show the stationmaster's residence nor does the Winnecke 1881 plan. It appears that the line entered the 'barracks' initially and then into the westernmost of the two small buildings. The rest of the complex including the residence and Stationmaster's office was obviously built later than 1881.

The buildings on site are now owned by the NT Conservation Land Corporation and managed by the Conservation Commission of the Northern Territory (CCNT). Restoration work carried out in the early 1980's is overdone and not truly representative of the original construction.

Tennant Creek Telegraph Station

The temporary telegraph station, a stone hut with a thatch and iron roof, was built by (Tom) Bee under the direction of Gilbert McMinn; this was July 1872 a month after the estafette was established to relay messages to and from Elsey station on the Roper River. In December 1872 Harvey advised Todd that Tennant Creek was a better location than Attack Creek for a permanent station on account of the availability of stock feed and suitable stone for the buildings. By July 1873 Todd realised that "he would have to send a mason up the line to build the Tenant Creek Station". Building during that period consisted of two timber structures to serve as a temporary telegraph office and men's quarters; these were demolished in 1891.

Construction of the permanent stone telegraph office began in early 1875 and by July the stone walls were completed. Between 1877 and 1881 Charles Winnecke conducted a series of surveys throughout Central Australia using Tennant Creek Telegraph Station as his base. He prepared the first known plan of the station.

The present fabric is not all original: the kitchen building (there are two buildings) was re-roofed some time between 1906 and 1933. However, the roof to the telegraph office building appears to date to the early 20th century. The cartshed and harness room were built sometime between 1876 and 1881.

Between 1881 and 1891 an open skillion verandah was constructed on the southern side of the telegraph office and about 1900 a verandah was added to the kitchen building. In 1935 the station ceased to carry international traffic following the laying of the Indian Ocean Cable (1902), the Pacific Ocean Cable (1926) and the radio service out of Sydney (1930). It was then proposed that the buildings become a hospital but they continued as a linesman's depot.

During the period 1951- 1986 the station and its reserve were put into use as a pastoral property. It was leased by the PMG's Department to Con Perry who made some alterations. Then, in 1977, the station was purchased by the Tennant Creek Pastoral Company Limited and in 1985 the pastoral lease and buildings were purchased by R Mortimer. While under private ownership, in 1984, two architectural reports on the condition of the buildings were prepared and through 1987 to 1989 further surveys were made and some conservation work was carried out. Then, in 1990 - 1991 the CCNT had further work performed.

That piecemeal approach was not satisfactory. Fortunately, under Commonwealth funding, a comprehensive Conservation Management Plan has been prepared by Domenico Pecorari and Associates, architects of Alice Springs and this is being put into effect[93].

Barrow Creek Telegraph Station

In September 1871 Barrow Creek was chosen as the site for the telegraph repeater station following Ross's survey. Poling and wiring of the line was being carried out and building material supplies were being organised in Adelaide. Then, in January 1872 a little stone hut was constructed for temporary accommodation and the front wall of the main telegraph office was commenced. Work was completed by 16 August 1872 in time for the official opening of the line on 22 August 1872.

By 1876 the station had taken on its present form of a U-shaped structure with a courtyard and rear wall with gate. It was recorded by Winnecke on a survey in 1881 and Todd, in his 1884 report, describes the station as eight rooms, blacksmith's shop, harness room, cartshed and store all of stone, stockyard tank and well. At the turn of the century verandahs were added to the north and south walls.

As with Tennant Creek, Barrow Creek ceased to carry international traffic in 1935. In 1941 a gale destroyed the original roof and it was replaced by a lower pitched corrugated galvanised roof with steel framing. This detracts from the historic integrity of the structure. In 1942 the telephone carrier repeater station was constructed. Later, 1946, the PMG's Department used the original building as a linesman's depot.

Today the buildings are owned by the NT Conservation Land Corporation and conservation work is being carried out under the Commonwealth funded Conservation Management Plan prepared by Domenico Pecorari and Associates[94].

Powell Creek Telegraph Station

This is a complex of three main buildings in stone one being the stationmaster's residence a quite commodious building with verandahs all around. When it was reported on in 1972 by the Australian Post Office journalist[95] it was used as a stockman's cottage and a store for Newcastle Waters Station. It is now abandoned and deteriorating rapidly.

Newcastle Waters Depot

As a depot Newcastle Waters has some significance. It is associated with Thomas Jones the son of John and Anne Jones who operated the store on Lot 16 from 1849. Thomas was a teamster for the OT Line and it is recorded that he crossed the continent twice in that capacity[96].

Daly Waters Telegraph Station

The foundation concrete slabs are all that remain on a site near "Stuart's Tree" which is the butt of the tree on which he carved the initial S on 23 May 1962 during his last and successful journey from Adelaide to Darwin. The foundations are for three buildings, a dwelling, an office and men's quarters.

Katherine Telegraph Station

The building is extant but is now a private residence therefore there is little local involvement in interpretation and conservation.

Yam Creek Depot

There is no sign of any remnant[97].

Pine Creek Depot

It is recorded that there are some original cypress pine poles still standing[98].

Darwin Telegraph Station

There is absolutely nothing left. On the site of the first OT pole (Lot 533) there is an interpretation sign prepared by the National Trust of Australia (NT) recording the date of the pole as 15 September 1870 and the completion of the line as 22 August 1872, and that there was a log hut on the site. The unveiling was on Thursday 9 November 1989. The site of the permanent telegraph buildings between the Esplanade and Mitchell Street near the Government Residence is now occupied by the grotesque $110m NT Parliament building. The cable and telegraph office and post office were severely damaged in the Japanese air raid of 19 February 1942.

A NOTE ON COST

Apart from overrunning time there was a cost blow-out. Todd's original estimate was £120,000[99] but the cost of the works, the line and the building complexes is recorded as £338,600[100] or £479,174 / 18 / 3[101].

AFTERWORD AND RECOMMENDATION

The remains of the OT Line have exceptional heritage significance and as much as possible should be conserved. There has been much neglect because, principally, most of it is in remote areas and not before public scrutiny, on the other hand this has perhaps been their salvation. Unfortunately, the telegraph stations are variously owned and there have been different attitudes with regard to maintenance and preservation varying from professional approaches to neglect and abandonment.

The author considers that there is a case for a conservation management plan for the whole of what remains. This would involve liaison between and with the three governments, Commonwealth, South Australia and Northern Territory and with the private owners - no mean task. Perhaps such a project could be initiated at National level by an organisation such as The Institution of Engineers, Australia.

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Abbreviations

SAPP	South Australian Parliamentary Papers
TMA	Telecom Museum Adelaide
CCNT	Conservation Commission of the Northern Territory

TABLE 1
THE CONTRACTS

Section 1	Contractor Edward M Bagot	500 miles	£20,500 Contract Sum
Section 2	South Australian Government	626 miles	£53,779 assumed
Section 3	Contractors Joseph Darwent William Dallwood	639 miles 1765 miles	£45,721 Contract Sum £120,000

Bagots contract rate was £41 per mile.
Darwent and Dallwood's contract rates were first 39 miles @ £39; second 250 miles @ £60; third 250 miles @ £80 and last 100 miles @ £92.

Charles Todd's Estimate for the whole works was £120,000. the final cost is reported as £338,600 or as £479,174.18.3 (see text).

Based on the original estimate Section 2 would be assumed to be £53,779. The main component of the cost blow-out would be in Section 3.

The whole project took from 15 September 1870 to 22 August 1872 a period of 23 months therefore the cost per month (as a mean only) was £20,834 and the cost per mile (as a mean only) was £271.5 based on the highest reported cost[101].

TABLE 2
CONSTRUCTION TIMES

Section 1		E M Bagot	500 miles 14 months; 36 miles/month
Section 2		Government	626 miles 12 months; 52 miles/month (over all sub-sections)
Subsections	A	Knuckey	125 miles 8 months; 16 miles/month
	B	McMinn	125 miles 9 months; 14 miles/month
	C	Mills	125 miles 9 months; 14 miles/month
	D	Woods	125 miles 8 months; 16 miles/month
	E	Harvey	125 miles 5 months; 25 miles/month
Section 3		Darwent & Dalwood et al	639 miles 23 months; 28 miles/month

The actual construction rate per sub-section was slow <u>but</u> by carrying out five sub-sections almost concurrently, Todd managed an impressive rate of 52 miles/month for Section 2 - considered to be the most difficult and not attractive to tenderers. The actual mileage per sub-section can be obtained from Nick Wilson's Survey[78]

The CA-15 Fighter - An Item of Aeronautical Engineering Heritage

R. L. MARTIN, Dip. E.E., Grad. Dip. E.E., M.Sc., M.I.E.Aust., M.Aus.I.M.M., Senior Lecturer, School of Engineering, University of Ballarat, Australia.

SUMMARY: During the Second World War, the Commonwealth Aircraft Corporation of Australia, designed and built a prototype high performance fighter aircraft, which for the times, was the epitome of fighter aircraft design. The aircraft was designated the CA-15 and only one was ever built. The performance of the CA-15 far exceeded that of any other piston driven aircraft during and just after the war, but unfortunately the introduction of gas turbine powered aircraft spelt the demise of piston engined fighters, and so too further development of the CA-15.

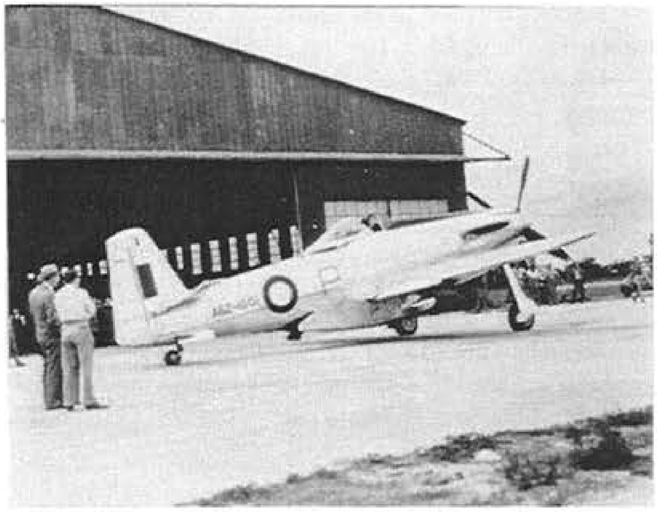

Fig 1.

The CA-15

1. INTRODUCTION

1.1 Initial Concepts

In mid 1942, engineers of the Commonwealth Aircraft Corporation (CAC), now Hawker De Havilland Victoria, an aircraft production facility jointly owned and financed by BHP, ICI, and GMH , under the general manager (Sir) Lawrence Wackett, proposed the design of a high performance fighter as a further development of the Australian designed Boomerang fighter. The CA-15, it was never given a name as such, started its designed life as an advanced Boomerang.

In November 1942, Wackett reported to the board of CAC that *"We have been investigating the design of a new fighter to follow the Boomerang, and are now able to put forward a complete scheme"*.[1] The fighter was to use the Pratt and Whitney R2800 Twin Row Wasp engine.

By February 1943, a a wooden mock up of the fighter was begun, now with an official contract No: CA-15. This culminated in late May with a conference with the RAAF concerning the future of the fighter. Figure 2 shows the mock up with the R2800 engine.

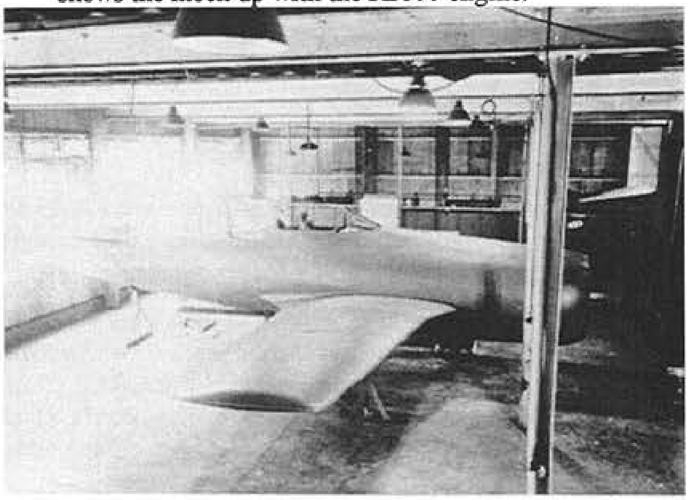

Fig 2.

Wooden Mock-Up, Radial Engine.

1.2 Development

In June 1943 the design was approved by the RAAF, which issued specification 2/43 issue 1 for the aircraft. The prototype with the radial engine was begun almost immediately with the formation of an experimental production engineering department by Wackett specifically for the purpose.

An interesting report to the Board of CAC by Wackett in August 1943 reflects his attitude to research and development. To quote Wackett: *"After considering all aspects of the matter, and having regard to the commitments in hand and others ahead in the form of establishment of CA-17 (Mustang) production, it is considered advisable to regard the CA-15 as an exercise to keep alive the spirit of design, rather than a war weapon for urgent development. Accordingly, it is proposed to employ some of the most promising younger* *design engineers on this job and to give it a low order of priority for the next six months, and avoid the job becoming an embarrassment to an already overloaded production department".* [2]

Problems with the supply of the R2800 from the USA in August 1944 lead to a change of design to utilise some other suitable engine. Coupled with this was the decision of the War Cabinet in October 1944 to suspend the project. Wackett kept the project running slowly pending representation to Cabinet, and in February 1945 the project was fully revived, this time utilising the Rolls-Royce V12 Griffon 125 engine. This revival occurred after the British Air Ministry showed great interest in the design.

The Griffon 125 engines were unavailable so the British Air Ministry loaned two Griffon 61 engines to CAC for the project, and in October 1945, the Department of Aircraft Production order No. CS1502, was issued to CAC for the delivery of one CA-15 fighter, at a budget of £150,000. Due to the pre planning and development by CAC it was expected that the CA-15 would fly within 3 months. To hasten the project Wackett assigned additional personnel to it.

1.3 Flights

On the 4th of March 1946 at 6.10 pm, the CA-15 flew for the first time with the CAC test pilot James Schofield at the controls. The flight lasted 15 minutes. [3][4][5]

Between then and mid June 1946, Schofield carried out 24 more test flights where the performance and handling characteristics of the aircraft were investigated. During this time, various modifications to the controls, control surfaces, brakes, and engine were carried out to optimise the performance of the aeroplane.

1.4 RAAF

The CA-15, RAAF number A62-1001, was officially handed over on the 2nd of July 1946 and flown to Laverton RAAF base south-west of Melbourne for further trials. These trials continued until December, when a wheels up landing occurred, damaging the aircraft somewhat. Complete repairs and some modifications were not completed by CAC until March 1948, when the CA-15 was returned to the RAAF.

Little of the history of the CA-15 within the RAAF is known from this time on. The introduction of jet powered aircraft superseded all piston driven aircraft, with only a few Spitfires and Mustangs remaining on active service, there was no need to continue with the CA-15 as a service aircraft.

In 1953 it was proposed to enter the CA-15 in the New Zealand Air Race [6], but this was opposed by the RAAF high command. It would appear that around this time also, the CA-15 was partially disassembled, with parts known to be stored at that time at the RAAF base Laverton.

1.5 Finale

From that time on, only apocryphal stories exist of the fate of the CA-15. A "Mustang" was supposed to exist somewhere in the Melbourne suburb of Frankston, but this was never confirmed [6].

In 1986 an aircraft enthusiast from America [6][7] proposed to build a replica of the CA-15. CAC were willing to give him the plans of the aeroplane, and had them collected and boxed up for delivery, but here fate takes a hand. A rubbish removal contractor mistakenly took the boxed plans to the Footscray tip. CAC staff proceeded with great urgency to the tip to retrieve the plans, but by the time they arrived the plans had been burnt. The only plans remaining currently at Hawker DeHavilland are a few minor components and general layout drawings.

2. ENGINEERING

From the current concepts of aircraft design, there is nothing particularly spectacular concerning the structure of the CA-15, but at the time (1942), compared with Australian aircraft design then, some quite new design concepts went into the CA-15. These concerned the wing section, the fuselage stressing, and engine cooling protection (from bullets).

2.1 The Designer

There were many engineers, technicians, and general workers associated with the design of the CA-15, many still alive and active in the aircraft world today, and who all deserve much credit for the design and construction of the CA-15. But the major theoretician behind the design was Freidrich David. David had an interesting background which holds some irony in its association with the Second World War.

David was a Jewish refugee from Austria, trained in aeronautical engineering prior to the 2nd world war [5]. He worked in Germany for the Heinkel company where it is thought that he was involved with design of war planes. He was later seconded to the Tokyo Denki company in Japan where he was employed in the design of the Aichi HED3A torpedo bomber, the bomber which attacked Pearl Harbour. [6]

Persecution of the Jews in German and Austria forced David to seek refuge in Australia where he obtained a position with CAC on war plane design, this time for the allies. As an Austrian during the war in Australia he was an enemy alien, but was given total freedom because of his contribution to the allied war effort, except for having to report to the police in Melbourne weekly. [6]

2.2 Overall Dimensions

The overall dimensions of the CA-15 are as follows:-

Wing span: 36 ft (10.97m)
Length: 36 ft 2.5 in (11.03m)
Height: 14 ft 2.75 in (4.34m)
Wing root chord: 10 ft 3 in (3.12m)
Aspect ratio: 5.12
Dihedral angle: 5^{o}
Wing area: 253 sq ft (23.5 sq m)
Tailplane span: 13 ft 10 in (4.22 m)
Tailplane dihedral angle: 10^{o}
Weight: (loaded): 10,764 lb (4,882 Kg) [5]

Figure 3 shows an overall line drawing of the fighter.

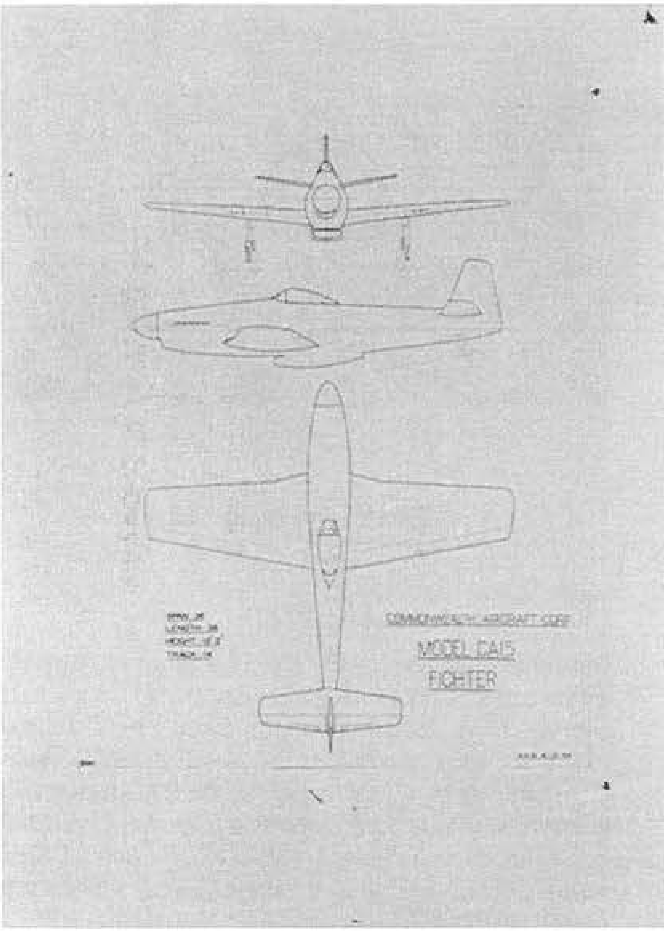

Fig 3.

CA-15 Line Drawing

2.3 Wing Section

The CA-15 was the first aircraft in Australia to utilise laminar flow aerofoil sections. Previous aircraft had used the older British or American NACA, 4 figure sections, which suffered from transitional flow over the upper wing surface. David decide to use the new NACA 6000 series laminar flow aerofoils which considerably reduced the drag of the wing and hence improved performance. [5][8]

The actual section chosen was the NACA 66,2-116 section shown in Figure 4.

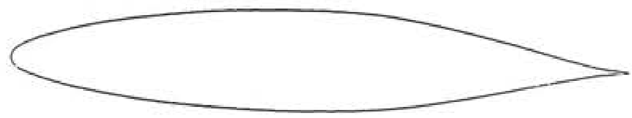

Fig 4.

Wing Section- NACA 66,2-116

2.4 Fuselage

The fuselage was a semi-monocoque construction with stressed skin, with the empennage separate from the fuselage. Lateral duralumin frames supported fabricated longerons and stringers to which was flush riveted the aluminium skin. Figure 5 is a general view of the starboard fuselage framing under construction in its jig.

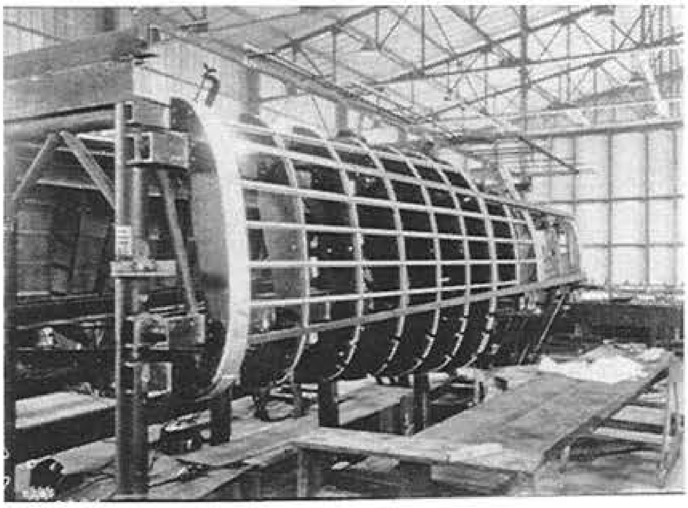

Fig 5.

Starboard Fuselage Framing

2.5 Wing Structure

The wing structure consisted of a composite duralumin box spar with front and rear longitudinal spar flanges stiffened by the wing ribs and stressed skin upper and lower surfaces. Various cut-outs within the spar were for housing the landing gear and armaments. Figure 6 shows the partially assembled wing.

The completed wing was assembled in one piece before mating with the fuselage. The cockpit was over the rear section of the wing and had a bubble perspex canopy and armour glass windscreen. The pilots seat was armoured underneath and in the rear.

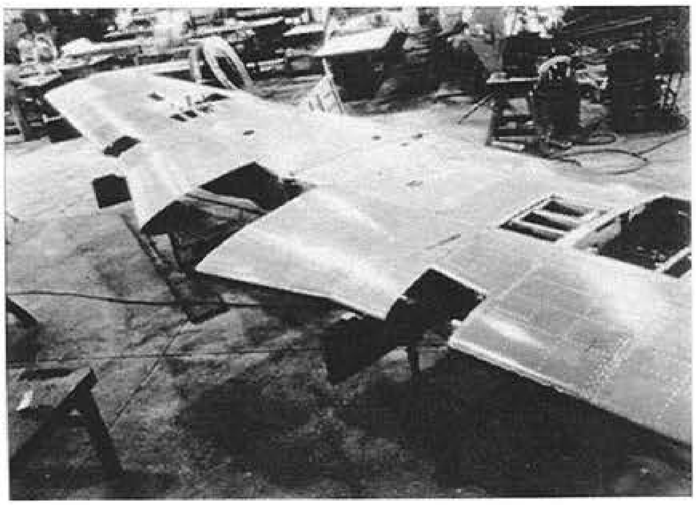

Fig 6.

Wing Assembly

2.6 Engines

Although it is acknowledged that two types of engine were seriously considered for use in the CA-15, there was at least four proposals. At the initial concept stage in 1942 when the CA-15 was to be an improved Boomerang, the Pratt & Whitney R2600 engine was proposed [5], but when the design became a unique fighter, the R2800, 18 cylinder Double Wasp, 2200 HP engine was chosen. [9]

When the R2800 no longer became available, it was proposed in CAC Engineering report AA.32, that a Bristol Centaurus CE-12SM engine replace the R2800, but one month later in September 1944, the Rolls-Royce Griffon 125 was chosen. [10]

The Griffon is often thought of as an advanced Merlin engine, but this is not true, although similar in appearance, it was a separately designed, more advanced, and much more powerful engine than the Merlin.

The use of the Griffon in the CA-15 gave the aeroplane a much smoother and streamlined shape as can be seen in figure 1.

Later, near the end of production of the prototype, another minor engine change occurred when the Griffon 125 was replaced by the Griffon 61 engine, maximum war rating of 2035 HP. Figure 7 shows the mounting of the Griffon 61.

2.7 Armament

The CA-15 itself was never actually armed as it was the development aircraft. However, various armament options were considered and the wing structure built to include these options.

These options were: Six 0.5 inch Browning machine guns, or four 20 mm cannon, or two Browning machine guns and two cannon. The ammunition load, irrespective of configuration, was 250 rounds for each machine gun and 120 rounds for each cannon.

Provision was also made on the underside of each wing for the carriage of one bomb of any type up to 500 pounds. [5]

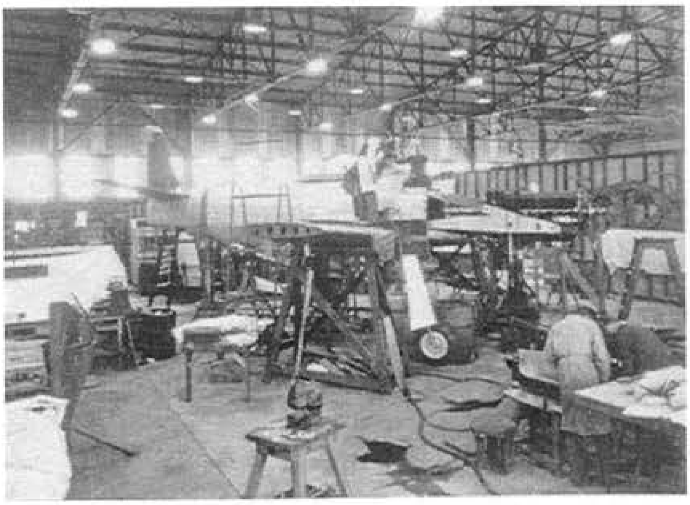

Fig 7.

Griffon Engine Being Mounted.

2.8 Development and Testing

During development of the CA-15 a range of structural, aerodynamic, and other tests were carried out on the aircraft; these included wing torsional tests, fuselage torsional and bending tests, and fuselage stress distribution tests, all carried out at the CAC factory. The aerodynamic tests were carried out at the Council for Scientific and Industrial Research , now CSIRO, Aeronautical Research Laboratories, using a 1/6th scale model. [11][12][13]

3. PERFORMANCE

3.1 Flight Performance

The predicted performance of the fully loaded CA-15 is shown in Table 1. This performance is based on the Griffon 125 engine of 2200 HP. Actual performance was never fully tested as the aircraft became redundant, although a terminal speed of 502 mph was measured in a dive. [14]

Altitude Feet	Engine Power Horsepower	Max Speed mph	Climb Ft/min
Sea level	2450	417	5570
2000	2480	430	5400
12,000	2370	448	4860
20,000	2210	476	4400
28,000	1680	495	3800

Table 1.

3.2 Aerodynamic Characteristics

The aerodynamic characteristics of the aircraft in terms of total lift and drag for various angles of incidence is shown in Table 2. [13]

Incidence Degrees	Coefficient of Lift	Coefficient of Drag	L/D Ratio
0	0.054	0.0182	2.97
2.1	0.204	0.0206	9.90
4.3	0.365	0.0275	13.27
6.4	0.46	0.0358	12.85
8.5	0.59	0.0465	12.69
10.5	0.712	0.0625	11.39

Table 2.

The L/D ratios are quite respectable, giving the CA-15 a glide angle of 4.3^{o} at (coincidently) 4.3^{o} angle of incidence. A modern fighter has a typical L/D ratio of around 3.7 and glide angle of 15^{o}.

4. CONCLUSION

4.1 Comparative Performance

To appreciate the level of development and the sophistication of the CA-15 design, it is necessary to compare its performance with contemporary fighter aircraft of the time. Table 3 compares the CA-15 performance in speed and rate of climb for specified conditions (altitude) against the Spitfire XIV (UK), Mustang (USA), Thunderbolt (USA), and Hawker Tempest (UK). [5]

From these comparisons it is quite evident that Australia was leading the world in the development of piston engined fighter aircraft design. Unfortunately though, it was too late, the development of the gas turbine engine was to completely revolutionise warplane design from 1945 on, and the English then Americans were to take the lead in this development.

Aircraft	Max Speed mph at 28000 ft	Climb Ft/min
CA-15	495	5570
Spitfire XIV	443	5000
Mustang	434	3475
Thunderbolt	402	na
Tempest	402	4700

Table 3.

At the time of the CA-15 going to the RAAF, Wackett at CAC had seen the possibilities for jet aircraft, although he initially took some convincing of this [15], and began contracting the development of gas turbine engines, and later the production of the Vampire and Sabre fighters for the RAAF, and later still, the Mirage and the F 111.

4.2 A Heritage Item

Although the CA-15 no longer exists, its development, engineering, and short flying life is well documented [5]. It is a great pity that the American enthusiast was unable to proceed with a replica of the aeroplane.

As an item of aeronautical engineering heritage, the CA-15 should be remembered world wide as the epitome of piston engined fighter design, and it was an Australian company and expertise that developed the aircraft.

Lawrence Wackett is often credited with the actual design of a range of aircraft, but this is not true, he was the driving force behind aircraft development, and it was under his guidance that aircraft designers within Australia were able to exercise their engineering art.

5. ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Mr. Dennis Baker, Manager, Historic Projects Division, Hawker De Havilland Victoria for his assistance, and also the cooperation of Hawker De Havilland in general in allowing the author unrestricted access to its records and use of their facilities during research for this paper. Thanks should also go to Keith Meggs, former employee of CAC who gave invaluable background information on the CA-15 and those associated with its development.

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Mr Frankham Builds a Fort

DAVID VEART, MA (Hons), LLB, Archaeologist
Department of Conservation, Auckland, New Zealand

SUMMARY This paper describes the use of archival material relating to the building of a 19th Century coastal fort in Auckland, New Zealand during an archaeological investigation into allegations of a sealed tunnel network containing unexploded ammunition and old aircraft. The paper describes how this material was used to explain perceived problems, including the presence of volatile hydrocarbons in the tunnels, anomalies in the design and structures excavated during the investigation. The paper also tries to demonstrate the importance of archival research in archaeological investigation of historic sites and in dealing with popular mythology.

Mr Walter Frankham of Devonport, Auckland was Inspector of Defence Works and between January 5th 1889 and February 11th 1893, carefully prepared for submission to his superiors, weekly and monthly reports on the progress of the building of Auckland's coastal defences, especially the fort at North Head (1).

One hundred years later I was asked by my employers, the Department of Conservation to investigate the vast number of stories and rumours that the old fort at North Head, Auckland contained a labyrinth of hidden tunnels containing it was said, unexploded ammunition, maps, files and possibly the first two aircraft built by the Boeing Aircraft Company.

Over the past three years I have become very appreciative of Mr Frankham and his very Victorian penchant for recording every detail of the building of the fort at North Head.

This then is a story with two main themes, a major Victorian engineering project, the building of the fort, and the investigation of a late 20th Century myth which had created it seems an imaginary fortress occupying the same space as Mr Frankham's real fort.

New Zealand's 19th Century coastal defences were built mostly between the period 1885 and 1893.

They were constructed to defend the colony against a perceived threat of attack by the expanding Russian Empire.

Once, while showing a visitor from Poland around the fort at North Head, I told him that the fort had been built because of fear of Russian attack. He commented that in Poland they had this problem too, it was only that the Russians tended to arrive there with more regularity.

Whatever the validity of this 19th Century concern the fear was definitely real.

From the 1840's, Auckland's main defences consisted of Albert Barracks and Fort Britomart. After the departure of the last imperial troops in 1870, both the Albert Barracks and Fort Britomart were demolished. The whole point on which Fort Britomart stood being cut down to provide fill for harbour reclamation (2).

Assisted I suspect by that peculiar feeling of isolation New Zealanders often experience, the colonists felt exposed and vulnerable. War scares at regular intervals led to public pressure for some coastal defence system (3).

Numerous schemes were suggested but was not until the first Russian War scare of 1877 that anything was done. At this time, the colonial government ordered a number of 7 inch and 64 pounder rifled muzzle loader guns from England which were then promptly put into store (4).

The arrival of Sir William Jervois as Governor in 1884 seemed to stir the colonial government into action. Jervois, a noted coastal defence enthusiast who had already prepared a report for the Premier Julius Vogel on New Zealand's defences (5) strongly urged the government to fortify New Zealand's main ports (6).

Jervois recommended and had accepted harbour defences based on the guns already in store together with new 6 inch and 8 inch breech loading guns on hydro-pneumatic "disappearing" mountings (7).

Major Cautley R.E., after whom the fort at North Head is named, drew up plans for elaborate brick and masonry fortifications (8).

Before any of this could be started, the Russians occupied Penjeh in Afghanistan starting yet another war scare and emergency earthworks were built by the Armed Constabulary supervised by Cautley to emplace the muzzle loader guns.

By April 1885, one 7 inch RML was emplaced at North Head and by the time Cautley departed for England in June 1885, almost all the guns were emplaced, mostly in temporary wood and earthen forts (9).

As the Russian scare subsided, work tailed off. Cautley was replaced by Major E.M.T. Boddam, Staff Officer for the Artillery and Engineering Departments. His unenviable job was to make something more permanent out of the temporary muddle he had inherited. He had two main problems. Firstly, Cautley's elegant brick and masonry forts were seen by the colonial government as too expensive, and secondly, the muzzle loaders were all emplaced in the best sites, leaving no room for the newer breech loaders.

The first problem he solved by redesigning the forts using concrete and surplus railway line as reinforcing. The solution to the second problem was to replace existing guns and to rework Cautley's plans to accommodate the new guns (10).

In 1888, Boddam was replaced by a civilian, Mr A.D. Bell (11), under whom Frankham worked and to whom his reports were made.

Accounts from official sources seem to indicate that by the time Frankham arrived at North Head in 1889 to supervise construction of the fort, a large amount of the work had been completed (12). His weekly reports, however, tell another story (13). Frankham's major work at North Head was to supervise the building of two 8 inch breech loading "disappearing" gun emplacements at North and South Batteries, the reconstruction of a third and the building of magazine complexes for all three. He was faced with three partially constructed gunpits, open wooden lined trenches and rudimentary magazines. His work force consisted of between 30 and 50 prisoners housed in the Armed Constabulary barracks on the summit of North Head with occasional assistance from civilian tradesmen (14). By the time his reports cease in 1893, most of the major work was completed, transforming what Bell had described as an "untenable shell trap" into a useable fort.

Frankham's reports are useful in that they give so much more detail than official documents for use higher up the chain of the government bureaucracy.

Reports to the government deal only with the big picture; what gun emplacements have been completed, are the guns installed yet, how much work is left to complete. Frankham records the minutiae of the job; how many workers he has, what their health is like, are there any carpenters or blacksmiths, how much material needs ordering, what is the weather like. As such these reports allow a fascinating insight into a large 19th Century construction site.

The first page of the reports dated January 5th 1889, gives a good general picture of how life will be for the next four years.

"Four wardens with guard of eight men of the Permanent Militia and forty-one prisoners have been employed on works, five days of the past week, getting out excavation for North and South batteries and mixing fifty experimental concrete blocks composed as per specifications sent by Mr Bell. Three carpenters (civilians) getting up racer and timber platform and framing of 7 inch ML R gun at North Battery, one carpenter driving steam pump two days, one driver (civilian) carting as required and repairing wheelbarrows when not so engaged" (15).

For the next four years, Mr Frankham and his prisoners dig, lay bricks, pour concrete, repoint picks, repair wheelbarrows and move the huge guns and their mountings up a steam hauled tramway. He gives depths of excavations, heights of walls and amounts of bricks used. It is as I have stated, this level of detail that has made these reports so useful in the work I have been doing.

What I would like to do now is to explain what this work was and to demonstrate the use I have made of the record left by Mr Frankham, a use I am sure he never imagined in his wildest dreams.

The fort at North Head was not really "finished" in any sense in the 19th Century. While all the major installations date from this period there has been continually modification up until the disbanding of the coastal artillery in the late 1950s (16).

After Frankham's time, the guns he installed were declared obsolete. Newer guns were installed, more searchlights built, generators upgraded and permanent barracks built (17). The magazine complexes and underground structures have, however, remained much as the Frankham built them. The fort was handed over by the Army in the late 1960s to first, the Devonport Borough Council and later to the Hauraki Gulf Maritime Park Board from whom it was inherited by The Department of Conservation.

From at least the 1950s, there have been an ever growing number of stories that a mystery exists at the fort. This has mainly centred on the claim that what can be seen today is in fact, only a fraction of what really exists. It is claimed that a huge network of tunnels and underground installations is concealed beneath the hill. These, it is said, contain large amounts of dangerous ammunition sealed off by the Army prior to the handing over of the fort for public use. To support this it is claimed an elaborate conspiracy has been formed involving the Army and subsequent administrators to suppress information and to hide tunnel entrances. Included in this claims is the suggestion that the first two Boeing aircraft, Bluebill and Mallard, also lie concealed in their crates somewhere in the hill.

The claims of hidden and dangerous ammunition finally lead to local residents approaching the Government for some reassurance. The Government then asked the Department of Conservation to investigate these stories as it appeared official defence sources could not provide an answer that satisfied a sceptical public.

There were, however, no doubts from the old soldiers who had closed down the fort. They were adamant that they had not left any ammunition behind or that there were any hidden tunnels.

What we were faced with, therefore, were two totally conflicting pictures of North Head. On one hand were the old soldiers who maintained that what you could see today was all there ever was. On the other were a growing number of people who claimed to have entered tunnels that could no longer be seen.

The investigation was divided into a number of stages. Firstly, an extensive search of archives was undertaken. There had been claims that the archives had been systematically purged to remove all traces of the existence of the hidden tunnel network. For this reason, all possible avenues were explored and an attempt was made to find any gaps that might appear in the archival record (18).

The other information source at this time was the group of people who claimed to have entered the hidden tunnels. These people were interviewed and an attempt was made to place these stories onto the map of North Head.

One area where this information clustered was on an old gunpit on the summit of North Head. This gunpit had been converted into a water tank by the Navy who still occupy the summit area. It was claimed that the water tank walls concealed an entrance leading to a large underground network of tunnels.

The summit area once housed a battery of two 7 inch rifled muzzle loader guns, one 8 inch disappearing gun and two Nordenfelt quick firing guns. There is also an extensive underground magazine complex, built by Mr Frankham. He had, however, had no part in building the 8 inch gunpit. This was already in existence when he arrived, built by the Armed Constabulary and a group of "the unemployed" (19). This then, was one of the gaps in the record. There was no detail of the construction of this gunpit. No Frankham, no record.

In the area of the summit battery there was another problem. Throughout this tunnel complex, there was a strong smell of naphtha, a smell not unlike mothballs. It was claimed that this was the smell of decaying ammunition coming from sealed tunnels beneath the main complex. Before we could start work, this smell had to be analysed. To do this a series of small holes were drilled in the walls and floor of the complex and the air tested by a gas chromatograph. When drilling the holes, a black tar like substance was found coating the inside of the brick walls. This smelled strongly of naphtha.

In a fortuitous coincidence a few days later, I received another volume of Frankham's reports from National Archives in Wellington. Tucked amongst the pages was a list of materials ordered for the month of March 1891 (20). Together with a list of two gross of brass screws, one box of candles and one ton of coal was an order for 54 gallons of tar from the Auckland Gas Company. This in turn lead to the discovery of Frankham's Monthly Summaries. In these were orders for almost 2,000 gallons of coal tar from the Auckland Gas Company. This material was used to waterproof the tunnel walls and roofs. These were built by a cut and cover method meaning that the waterproofing could be carried out prior to the backfilling of the underground structure.

Both my father and grandfather had been employed by the Auckland Gas Company and by using family connections, I managed to track down the last chemist employed by the Gas Company in the days of coal gas production. He confirmed that the volatile hydrocarbons we were identifying were more likely to come from the coal tar than from ammunition. Reassured by this we proceeded to drain the watertank and core drill the walls in the place where this hidden entrance was supposed to be.

What we found was a rather shoddy 19th Century concrete gunpit wall. Under the plaster the concrete consisted of loosely bonded aggregate and rubble. We stripped the walls and floor out of the watertank to expose a relatively intact 1880s gunpit, complete with the painted drum recordings used by the gunners to aim the gun. No tunnels, no entrances.

Also on the summit we excavated a 7 inch muzzle loader gunpit that had been backfilled sometime in the 1960s. There was no good record of this emplacement either, Frankham had merely modified it. After the soil and rubble had been removed we found another reasonably intact gunpit with no added tunnels or entrances. It did, however, have some of the features described by the witnesses as being in the other 8 inch gunpit.

As well as the archival and witness evidence we started to collect every photograph of North Head we could find. These were later used in the creation of a series of computer generated maps based on the 1940 and 1950 aerial stereo pairs. These were used to plot every visible change in the surface features of North Head (21).

One of the features noted was a cut in the north eastern side of the hill. In some photos this looked a little like a tunnel entrance. We located this and it was excavated. What we found was a large idler pulley mounted in concrete in the bottom of the cut, the remains of the tramway described by Frankham. This structure features frequently in the reports as it is repaired, altered and used to haul both material and the guns themselves up the steep hillside. For example, in September 1891 Frankham describes the repair of the "heavy trolley" and excavations for the "heavy winch" and the positioning of holdfasts in preparation for dragging the 8 inch guns up the hill (22).

This particular part of the tramway appears to have been re-used in the early 1900s to drag the "new" 6 inch MKVII guns up to their emplacement. This later date is suggested partially by the discovery of a celluloid 1914 calender wedged under the pulley wheel.

A number of other sites were investigated at this time located by either witness evidence, photographs or the use of a magnetometer, used to try and locate the railway iron reinforcing in the roofs of the tunnels. None of this work, however, related directly to Frankham or his records.

The final service he rendered was to explain some rather anomalous structures in the tunnel system. There were a number of features for which people could find no explanation and in turn suggested that they were the product of tunnel concealment.

Both these features were located in South Battery, the only one of the three main batteries for which no full drawings had survived.

The first anomaly was the existence of small rectangular space and room in the tunnel leading to the 64 pounder gunpit. This is unlike any other area in the complex. Close reading of Frankham's records, however, provides an explanation. In the first week of January 1892, he records "excavating passage from 64 pounder gunpit leading through or under old gunpit to junction of passage leading to 8 inch pit. I had reserved this part until now, as the floor of the old pit was the best place to mix concrete" (23).

He continues in February 1892 to describe the building of a "shelter" and "recesses" in the same area (24).

The realisation that another older gunpit once existed at this point helps explain the rather odd shape of the tunnel. Frankham had moved the 64 pounder emplacement closer to the nearby cliff leaving a larger space than is usual in the tunnels from which these oddly shaped spaces were made.

The other problem was the apparent existence of two entrances on the north eastern side of the South Battery complex, one of which was sealed off. Careful reading of Frankham's descriptions, however, may explain this. It seems he discovered a seam of what he calls "grey ash". This is the volcanic tuff found in this part of the volcano. Frankham was using this material to mix the concrete for his magazines on the summit. It seems that once he had completed the entrance as designed he kept his men tunnelling to get more of the ash for concrete work, creating in the process another entrance (25).

The work at North Head is now complete. In total 20 sites were investigated using demolition crews, excavation machinery, drilling rigs and spade and trowel. We have dug every site that could be identified by research, photography and eyewitness accounts. No extra tunnels were found although the public can now see two gunpits that were originally hidden from view and part of the old tramway. We have collected a large number of historic photographs and large amounts of documentary evidence. We have also, I feel, convincingly explained away the Boeing mystery. These aircraft, it seems, were never taken to North Head, although one of the engines has been traced to a racing powerboat that was destroyed by fire in 1927 (26) and another of the engines is now in the possession of Mr J. Earnshaw, a film-maker with a long interest in the tunnel mysteries.

This work has been fascinating and at times frustrating, but it would have been much more difficult if it had not been for Mr Walter Frankham and his dedicated recording of the process of building the fort at North Head.

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Some Challenges Faced By Early New Zealand Power Developers

Peter Campbell,
Electricity Corporation of New Zealand Limited, Wellington

1. SUMMARY

Early this century the New Zealand Government charged its Public Works Department to develop hydro electric power resources to meet the anticipated demand. This paper describes the challenges faced in the commissioning of the Arapuni, Waikaremoana and Waitaki schemes. It also acknowledges the role of P G Hornell a review engineer who influenced the design of all three schemes.

1. INTRODUCTION

Electricity was first generated for public use in New Zealand in 1887. As early as 1896 Parliament passed the Electric Motive Power Act to authorise the government to investigate suitable sites for generating hydro-electric power. Interest grew considerably after 1900 leading to the preparation in 1904 by P S Hay, the Superintending Engineer of the Public Works Department of a survey of water resources suitable for the generation of power.

Money to finance the first major project was approved in 1910 and work began in the following year on the first hydro-electric project, Lake Coleridge in Canterbury. It was successfully constructed and the 1915 Public Works annual report stated that Lake Coleridge was both an engineering and financial success. The First World War then intervened and little was done due to a lack of government money for new projects.

At this time it became obvious that to meet a perceived dormant demand for power the government must become involved in the development of large scale power development. By 1916 surveys had been done on a number of new sites down the Waikato River and Evan Parry the Chief Electrical Engineer was preparing plans to meet an expected increase in power demand especially in the North Island. His final report in 1918 provided the basis for more than two decades of development. The Hydro-Electric Branch was so confident of these plans that in 1919 it issued a Christmas card emblazoning the proposed schemes of Arapuni, Waikaremoana and Mangahao and a private scheme in Northland, (Fig. 1).

This paper discusses the challenges faced by the Hydro-Electric Branch of the Public Work Department as they sought to develop two of these schemes; Arapuni and Waikaremoana plus one more, Waitaki. For the first time in New Zealand use was made of a review engineer, Professor P G Hornell who influenced the design of all three schemes which were under construction at the time of his visit in 1930.

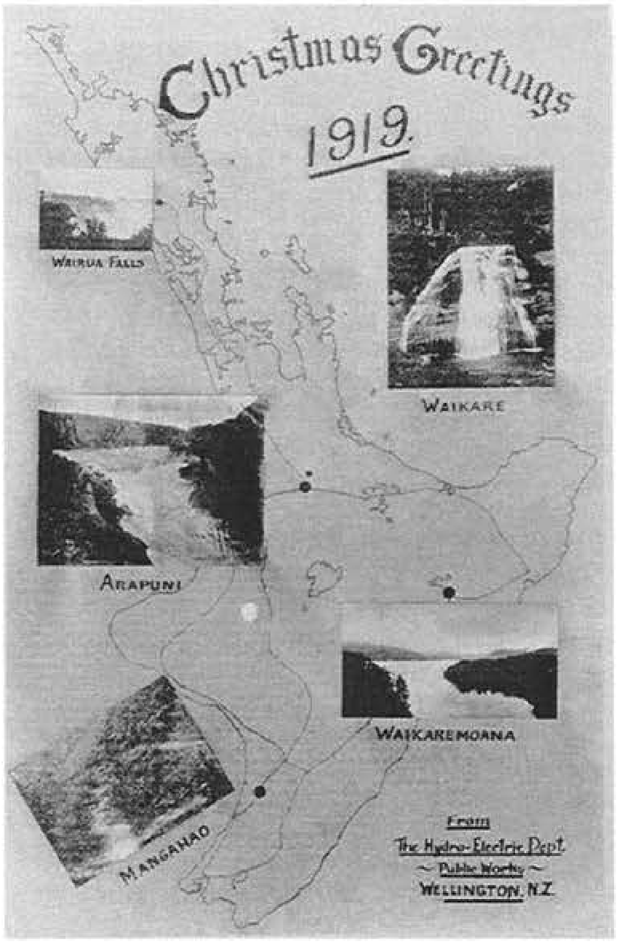

Fig. 1 Christmas Greetings from the Public Works Department

2. ARAPUNI

The site for Arapuni was a deep and narrow rocky gorge on the Waikato River 56 km upstream of Hamilton. An old river channel, parallel to the current river and some 45 m above it, provided a natural headrace. With a dam to provide a reservoir, water could be diverted into the old channel leading to a forebay. The water would then fall through penstocks excavated in the side of the gorge to a powerhouse beside the river. Surplus water could be spilled along the old channel to eventually join the river further downstream of the powerhouse. (Fig. 2).

In early 1919 shafts were sunk and tunnels driven into the abutments and under the river to assess the likely stability of the dam foundations. Samples taken during this investigation and the Wellington tests represented some of the earliest rock mechanics testing carried out in New Zealand. They concluded the foundation was suitable for a dam.

However, there was technical debate over the type of dam to be built. F T M Kissel, the Assistant Chief Electrical Engineer at the time, wanted a concrete gravity-arch dam, with load sharing between the bottom and the walls of the gorge. Others argued that the abutment rock was insufficiently strong to support arch action and that a full gravity section should be constructed. This difference of opinion became public, and was referred to a committee of engineers. In April 1921 it recommended the design allow for complete gravity action, even though the structure be arch-shaped.

Because of a belief by the New Zealand Government that the project would be too large and difficult for the Public Works Department to cope with, a contract was let in June 1924 for the construction of a 60 MW power station comprising, diversion works, dam, forebay, powerhouse and generating plant to the English firm of Sir W G Armstrong, Whitworth and Company. The completion date was set for July 1927. The New Zealand component concentrated on the roading, bridges and village for the work force.

River diversion around the dam site was by a tunnel in the right abutment. Delays to this work was caused by a workers' strike and floods in 1925 and 1926. After diversion the construction of the dam progressed well. However construction on the powerhouse met with problems from the outset. The contractor could not construct an effective coffer dam to enable the site to be de-watered during excavation. He declared the site unmanageable, and claimed that the Department had chosen an impossible site. Work ceased on the power house and nothing was done on the powerhouse site during 1927 while the contractor attempted to persuade the Government to relocate the structure. His efforts were unsuccessful and late in 1927 Armstrong was relieved of further construction responsibilities for the powerhouse. This work was taken over by the Public Works Department.

The dam was sufficiently close to completion for the gate in the diversion tunnel gate to be closed in December 1927, allowing a new lake to form in the Waikato river. By January 1928 the lake was filled. The river was redirected along its ancient course and because of the delays in the construction of the powerhouse, over a spillway at the end of the headrace.

Flow over the spillway and further down the old water course was planned as a contingency against times when the power station could not accept the river flow, such as during floods or station maintenance. However no special measures had been take to prepare this water way for long periods of continuous river flows, and this shortcoming was soon exposed.

A short distance downstream of the spillway was 'The Falls', a 30 m drop over a terrace edge to the Waitete Flat underlain by an alluvial sand deposit some 13 m deep. The flows resulted in erosion of the Falls and a deep channel was formed in the Waitete flats exposing a preserved prehistoric forest of standing tree trunks. In less than a week about 5 million cubic metres of sand and silt was transported to the Waikato river forming a bar. That compounded water level problems at the powerhouse site and abraded the turbines at the Horahora Power Station, downstream. In March, 1929, the Falls eroded 30 m back towards the spillway before remaining temporarily stable.

Meanwhile the Department had taken over the powerhouse construction with a revised design and larger de-watering pumps. In April excavation had recommenced and with a concerted effort construction was completed quickly; the first machine operating in June. In August a further 60 m of the Falls collapsed. This did not prevent the commissioning of the second machine in September and another in December.

The foregoing challenges were mild in comparison with the repercussions which were to result from an event on the 7 June 1930. Early on that date a 20 mm wide crack appeared at the intakes, sub-parallel to the river and the line of the headrace. The crack extended 300 m upstream from the powerhouse, and downstream towards the Falls. A whole block of country some 600 m long, 50 m thick and 100 to

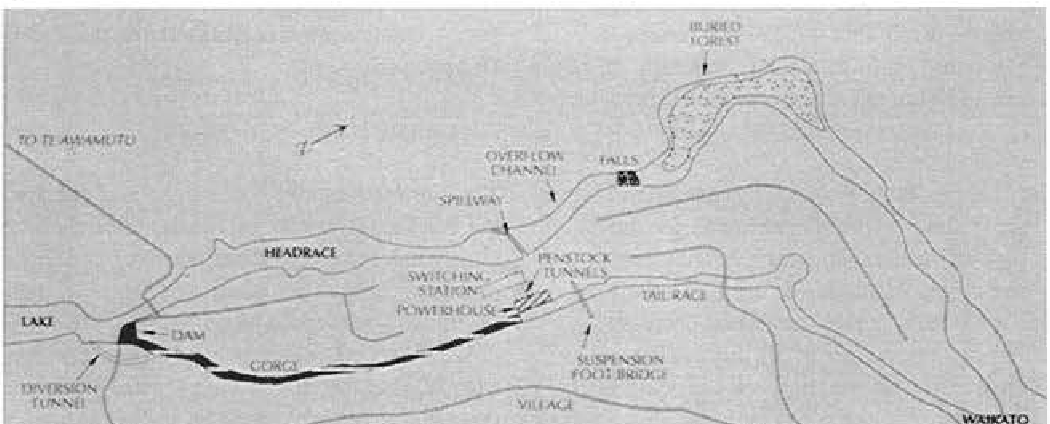

Fig. 2 Arapuni Scheme Layout

300 m wide rotated slightly towards the river gorge. The penstocks broke away from the concrete encasement at their top, the powerhouse tilted and leaks appeared from the natural country behind the powerhouse. The suspension bridge providing pedestrian access for the work force across the gorge, and for tourists today, shortened visibly, increasing its sag. "On measuring, the span was found to have been reduced by an inch or two" in sympathy with the tilting.

It was obvious that water was finding its way into the ground beneath the headrace and applying a driving force towards the gorge. The station was closed down immediately, and the lake drained by re-opening the gate in the diversion tunnel. This was the first time in New Zealand that a large hydro lake was lowered for safety reasons. (The second would not be until some 57 years later when the Edgecumbe earthquake lead to the preventative lowering of the Matahina Dam reservoir). Lake lowering at Arapuni effectively de-watered the headrace and prevented further ingress of water into the ridge between it and the gorge. The result was unexpected. "Tilts in the powerhouse and the bridge tower decreased as the forebay was emptied." (Public Works). The ridge returned through three quarters of its displaced position and the leaks behind the powerhouse dried up.

This serious situation was fertile ground for criticism that the Department was to blame for locating a power project in an impossible site, and had not taken appropriate geological advice. Aucklanders were understandably angry as they were forced to re-open their recently de-commissioned Kings Wharf steam plant, and order a new plant, after gaining special financial concessions from government. Extra pressure was placed on existing North Island generation plant to ensure sufficient power to meet the current power demand with the doubt on Arapuni's future.

Meanwhile engineers and Ministers asserted the dam was safe and the Falls erosion would be limited when the headrace problem had been solved and the power station was generating. Instead of passing over the spillway and continuing on to the Falls all the flow would then be diverted through the penstocks and exit back into the gorge at the tailrace of the powerhouse. Parliamentary opposition members went on to the attack, with Bob Semple referring to Arapuni as the "greatest engineering blunder and political crime of its time in modern history."

Overseas specialist advice was sought. From a number of eminent engineers a Swedish consultant, Professor P G Hornell was appointed to report on the problem. He was a director of a firm with a wide experience in the construction of dams on difficult foundations in Sweden, Finland and Russia. While in New Zealand he was also engaged to assess other current power projects, namely, Mangahao, Waikaremoana, Lake Coleridge and Waitaki.

After his arrival in New Zealand on 25 August 1930, Professor Hornell made a hurried visit to Mangahao on his way to Arapuni. Seeing nothing contentious he thought a report on Mangahao unnecessary. When he later saw Lake Coleridge he held a similar view.

Hornell attributed the problem at Arapuni to a water loss from the headrace into the underlying rocks. Capillary action had promoted further penetration into the rock causing it to swell and fracture. The hydraulic pressures which developed caused the ridge to move. Professor Hornell had no doubts of the suitability of the site for the economical generation of power. Therefore to prevent a recurrence of the tilting of the gorge ridge it was judged important to prevent water from the headrace entering the foundation. The dam was in the correct position and its stability under full head "complies with the main rules now universally conceded as governing the design and construction of a solid gravity dam."

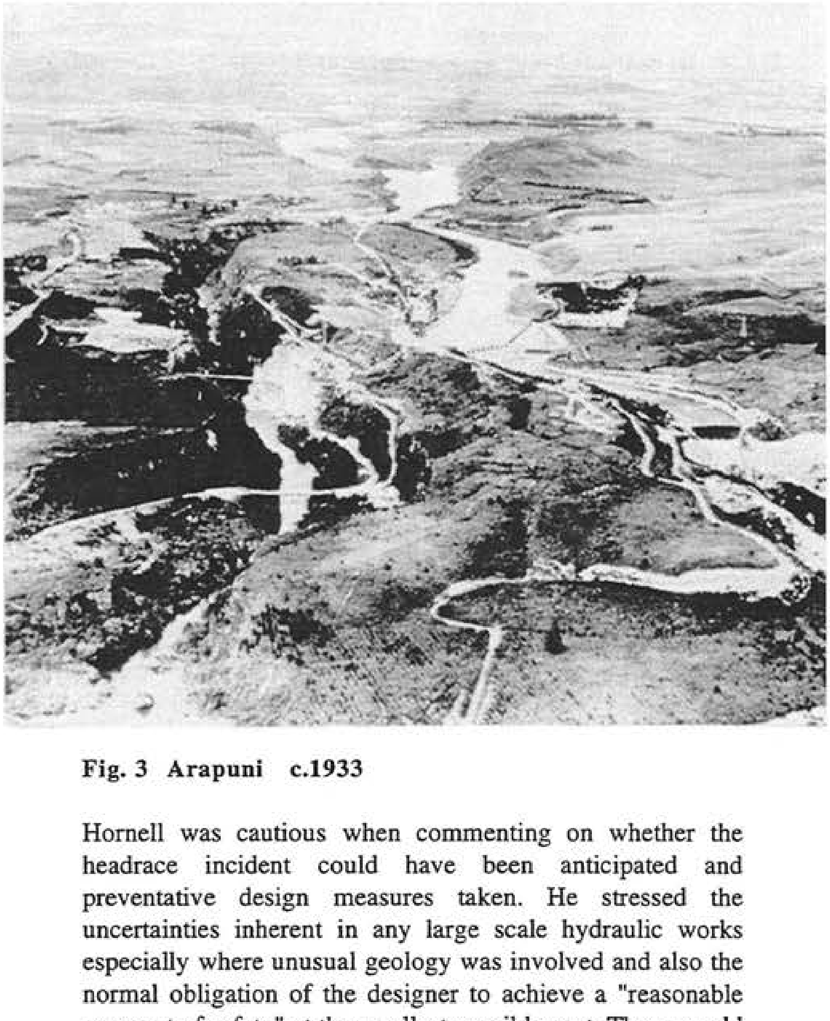

Fig. 3 Arapuni c.1933

Hornell was cautious when commenting on whether the headrace incident could have been anticipated and preventative design measures taken. He stressed the uncertainties inherent in any large scale hydraulic works especially where unusual geology was involved and also the normal obligation of the designer to achieve a "reasonable prospect of safety" at the smallest possible cost. There would not have been a rupture if the bottom and sides of the forebay had been lined and watertight. The decision of the designers not do this was, "in the light of information known prior to the failure", a justifiable risk.

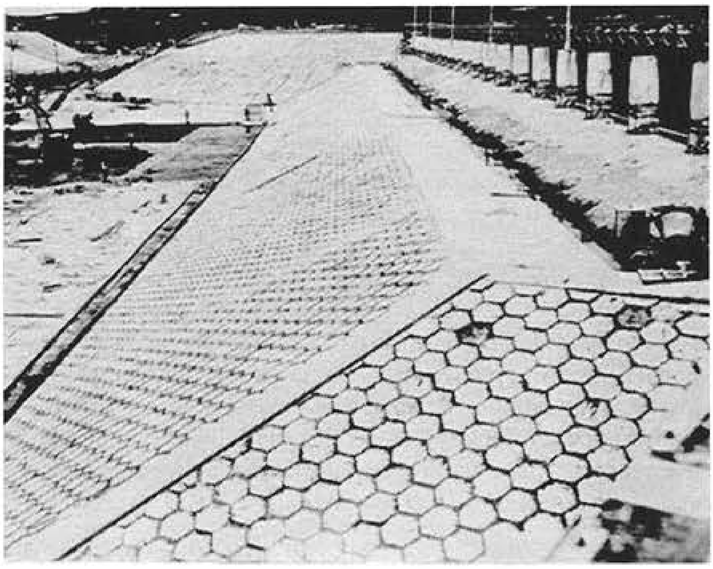

Fig. 4 Hexagonal Slabs of The Forebay Lining

Repair work began in January 1931. This involved the lining of the forebay and about 450m of headrace, strengthening the headrace crack with grouted bars and the excavation of dräinage drives in the ridge behind the powerhouse. The fall were concreted to prevent uncontrolled erosion under future flows. F W Furkert, Engineer in Chief of the Public Works Department had recommended a conventional concrete lined headrace. However Hornell suggested an innovative flexible lining comprising overlapping metal sheets sprayed with pitch and covered with precast hexagonal concrete slabs.

(Fig 4). Any future movement of the ridge, for any reason, could be accommodated by the sliding of the metal sheets. A more rigid concrete channel would be likely to crack and again expose the underlying foundation to the previous hydraulic pressures.

In March 1932 the lake was refilled, and two months later the fourth generator was commissioned. In 1933 approval was given for the addition of two more units. This required a major addition to the powerhouse, Fig 3. Two were commissioned in February 1938 and a further two during the Second World War bringing the capacity to 158 MW.

Hornell's headrace proved a successful design, only requiring replacement in 1989 after 57 years of service. Recent advances in foundation design, particularly in the area of filter protection to control expected seepage, and inconstruction technology, would have ensured that the original water barrier lasted even longer.

4. WAIKAREMOANA

Having provided his advice at Arapuni Professor Hornell travelled to Waikaremoana some 40 km inland from Wairoa in Hakes Bay. Here 207 m of the 454 m available head had been developed with the commissioning of the 52 MW Tuai Power Station in 1929. Tuai was meeting the current power demand but investigations were proceeding for further development. Figure 5 shows the developed scheme. At the time of Hornell's visit the landslide dam origin of the naturally formed Lake Waikaremoana had been recently recognised, though still hotly debated in detail by geologists and engineers.

Modern understanding is that the lake had formed 2,200 years ago following a massive two phase natural landslide blocking the former Waikaretaheke River. The triggering mechanism for the landslide is thought to have been a large nearby earthquake. (Read et al 1992). Collapse of the left bank of the Waikaretaheke River deposited landslide debris for 7 km along the river valley. The debris material was a chaotic mix of broken sandstone and siltstone blocks of all shapes. In the second phase a 1 km block of rock moved about 2 km, running into and deforming the debris of the first phase. It is considered by Read et al that both phases occurred as a single landslide event with perhaps only minutes separating them.

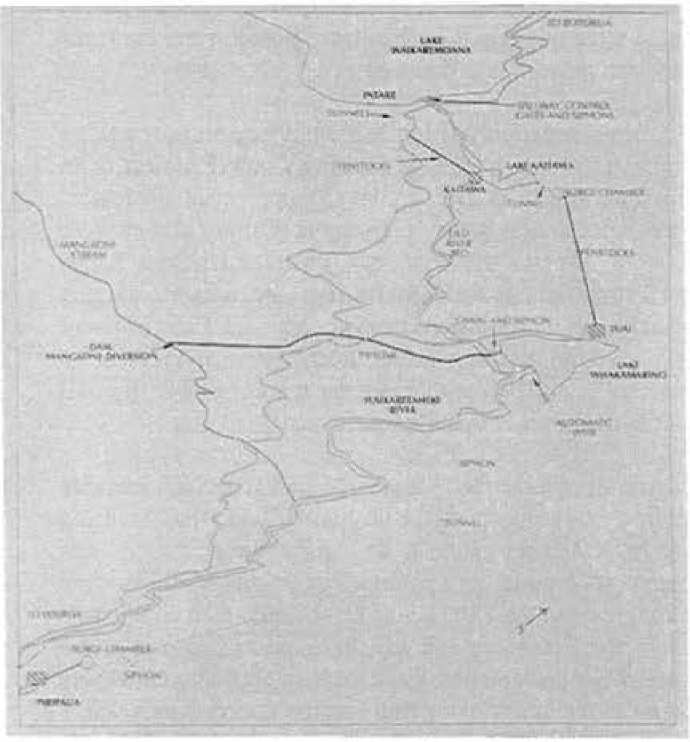

Fig. 5 The Developed Waikaremoana Scheme

The Lake took about 10 years to fill, and overflowed at the lowest point in the crest of the barrage only after periods of prolonged rainfall. The balance of the water leaked through the barrage appearing as springs on the downstream face of the landslide

Serious investigations into the potential of developing the approximate 600 m. fall from Lake Waikaremoana to the sea at Wairoa for hydro-electric generation had begun as early as 1916. In 1926, with pick and shovel and horse drawn scoops, construction started on the Tuai Power Station. A small earth dam had been constructed, and the Waikaretaheke River which carries the water from most of the leak fed springs, was diverted to form the Lake Kaitawa. This lake lay in a hollow on the edge of the landslide, some 120 m below Lake Waikaremoana. The Tuai Power Station utilises the 200 m head between Lake Kaitawa and the Whakamarino Flats. There was a surge chamber near Lake Kaitawa and the two penstocks, sited off the landslide leading to the power station on the edge of the flats.

When Hornell arrived, investigations had begun to collect data on the sources of seepages from Lake Waikaremoana. Leakage through the barrier was recognised as a major problem to be solved; not only because it represented loss of flow which could otherwise be developed, but also because of its contribution to potential instability of the landslide. One plan was to tunnel into the lake below the level of the leaks. Lowering the lake would provide access for the sealing of the leaks and allow a wide operating range for increased storage. Furkert had written to the Minister about the environmental issues raised by this action and, while advocating its practicality, drew attention to the potential for serious public criticism should this plan be implemented.

Hornell agreed that the seepage of water through the embankment was pivotal to the stability of the landslide. He believed that sealing of the upstream face of the landslide at the lake outlet to reduce seepages to "a practically negligible quantity" would ensure the embankment "would not threaten public safety." However, Hornell was concerned that the cavities through which the seepage travelled were both large and deeply located. This was based on his conclusions on the failure mechanism of the landslide which resulted in blocks of intact sandstone with their interstices surrounded by papa. He maintained that this material was susceptible to erosion from seepage from the lake and had resulted in the formation of the cavities. He gained support for his theory from known cavities above the current lake level which had formed by the passage of seepage water when the lake had existed at a higher level. Sealing of the entrances to low level cavities was therefore necessary for the integrity of the landslide.

Hornell recommended the driving of a tunnel 30 m below the current level of the lake and excavating a vertical shaft to intercept the lake bed. The lake bed at the shaft the lake could then be lowered up to 30 m to expose the lake shore for sealing operations. It was important that the cavities be exposed for effective sealing to be accomplished. He concluded that the current works at Tuai were not safe without such remedial action to seal the lake and improve the stability of the embankment as a whole.

The New Zealand geologists and engineers disagreed with the professor's model in which the lake had been at higher levels, and that the leaks originated in large cavities deep within the landslide. Subsequent to his visit they were able to confirm their judgement with evidence gained from mapping and saline tests which confirmed a link between known leaks and springs on the downstream slope of the landslide. These tests and further investigations involving a team of divers exploring caves at the lake outlet convinced the developers that most of the leaks were within 10 to 16 m of the normal water level.

They also believed that the pre-historic safe performance of the embankment was an indicator of future safety, and that while the barrier would undoubtedly change over the span of geological time it was, on a human time scale, permanent and stable. Confidence in this view was strengthened when the natural barrier showed no sign of being affected by the Napier earthquake of February 1931. Hornell stoutly maintained that past safe performance was not necessarily an indicator of future safety, and he reported that if his advice were not accepted he refused to accept any responsibility for any disaster that might occur in the future. His report was considered alarmist and received limited distribution.

Work on the Kaitawa scheme to utilise the 130 m head between lakes Waikaremoana and Kaitawa re-commenced in 1934-35, with a test shaft to 16 m below the Waikaremoana Lake level and preliminary drives towards a proposed intake at the lake. A shallower shaft than that recommended by Hornell was decided upon because the designers were confident that most of the barrier leakage paths originated at higher levels.

However all tunnelling work was stopped on the notice of Bob Semple the new Minister of Public Works. As a past miner and tunneller he declared the work too hazardous for the workers. Instead a start was made in 1939 on the lower, 40 MW scheme, Piripaua. This involved an earth dam to form Lake Whakamarino, a canal, 3 km tunnel, surge chamber, penstocks and powerhouse with the water discharging into the Waikaretaheke River. The second world war slowed progress on Piripaua but the first machine was commissioned in 1942 and the second in 1943.

Work re-commenced on the 32 kW Kaitawa scheme in 1943 with Semple now more confident in the safety of improved tunnelling methods. It took almost four years for the tunnel to break through the difficult conditions to the shaft which was to link it with the intake structure on the shore-line of Lake Waikaremoana, (Fig 6).

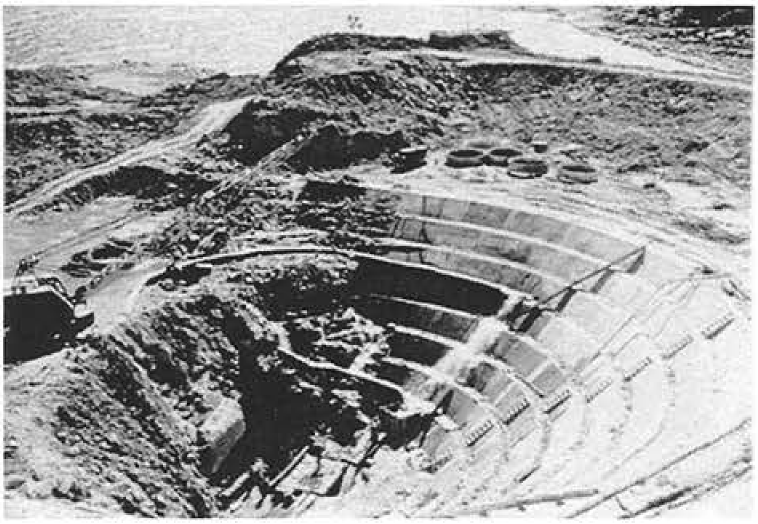

Fig. 6 The Kaitawa Intake Structure Under Construction

The task of removing the last of the insitu coffer dam between the intake structure and the lake was carried out under the direction of Resident Engineer N R Carter. He detonated a single blast of almost 2 and a half tons of dynamite to completely remove the coffer dam, and causing some damage to the finished concrete structure. This earned "One Shot" Carter an official reprimand from his head office.

The lake water level was lowered by 5 metres below the lowest outlet level and in 1948 the first generating unit was commissioned. Work on sealing leaks at the outlet from Waikaremoana was to continue until 1955 by which time leakage through the landslide had substantially reduced.

A recently completed study on the barrier stability has concluded that the landslide has an adequate factor of safety against failure. Development of the hydro-electric resource has in fact improved the potential longevity of the landslide by reducing the possibility of the barrier being overtopped and lowering ground water levels.

5. WAITAKI

Meanwhile back in 1930 Hornell left Waikaremoana to continue his journey of the then current New Zealand power projects. In October he arrived at the Waitaki Power Station, 6 km upstream of Kurow on the Waitaki River. Construction was in full swing on a 36 m high concrete gravity dam, arched in plan, with a free overflow spillway. (Fig. 7). As the cost of diverting the river through a tunnel had been considered too costly, the decision had been made to construct a dam across a major river without a separate diversion. The dam across the river channel was to be constructed in two sections on either side of a central pier, (Fig. 8). On the left of the pier, the Canterbury side, eleven sluices were constructed in four of the dam blocks, through which the river would be diverted for the construction of the dam on the right of the pier, the Otago side. The powerhouse and intake structure were to be constructed in the dry on the terrace above the river level on the Otago side of the river. A few months before Hornell was due to arrive on site, while the sluices were being constructed, the biggest flood in 52 years was experienced.

Professor Hornell was not very impressed with the dam he saw under construction, considering the design inadequate. In his preliminary October 1930 report, he recommended a widening of the base of the dam to improve stability, and he returned to Sweden to carry out detailed calculations before completing his report. In a cable which notified that the report was in the mail he stated the "intake safe: dam essentially weaker than conceded by universally applied rules for similar constructions especially on dubious ground." His main concern was that the designers had not taken sufficient account of the destabilising uplift load case. The significance of uplift was a new concept and not used by the New Zealand designer at that time.

Professor Hornell's final report confirmed the need for an increase in the width of the dam and also recommended that a cut-off wall be excavated below the foundation of the upstream face of the dam. The top of the wall was to be returned to the dam face to form the roof of a gallery along the dam. The primary purpose of the cut-off was to aid the existing and some new drains at the base of the dam in controlling water pressures in the foundation. He concluded in his final report by stating "I do not consider the stability of the Waitaki Dam satisfactory even after the unconditional improvements already suggested by me".

The designers contended that Professor Hornell's conclusions had been faultily based on an unrealistically high flood level and a low density concrete. In addition his concerns about an additional load from silt accumulating in front of the dam were considered to be of "no considerable moment". Reference was also made that many countries did not recognise the existence of the uplift pressures Hornell warned as contributing to the instability. However the professor's recommendations of increased dam base, cutoff, gallery and drains were followed and the river was diverted through the eleven sluices in 1933. The remaining width of the river was de-watered and the rest of the dam was completed in 1934.

Fig. 7 Waitaki Powerhouse and Central Dam Pier

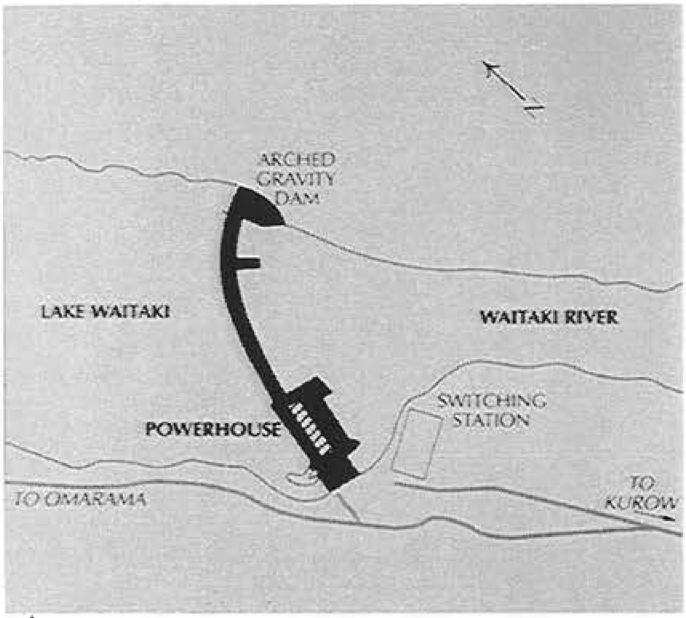

Fig. 8 Waitaki Station Layout

Instrumentation installed in the dam foundations has confirmed the levels of uplift in the foundation predicted by Professor Hornell. High pressures were also measured within the dam itself, some of which related to the difficulties experienced when the sluices were permanently blocked prior to lake filling. In the 1950s the dam was strengthened by vertical stressed cables from its crest to the foundation. These were drilled from the dam crest to anchor in the foundation resulting in an improvement in the stability of the dam. Refurbishment and extension of drainage measures currently being implemented are bringing the stability of the dam up to modern standards.

6. CONCLUSIONS

Of all civil engineering projects, major hydro-power structures have potentially the greatest impact on the local ground conditions. Yet in most cases, design must rely on a investigation programme that has provided a limited sample of available data. Only after final excavation, when the foundation is exposed, can the best assessment be made of the implications of construction at that site. Throughout this process the geological model is being continuously refined to take into account each piece of additional knowledge.

At Waikaremoana the importance of deducing an appropriate geological model was demonstrated. Such models can only be deduced form a careful analysis based on adequate investigations. Professor Hornell acting in limited time and with insufficient data found it prudent to offer conservative advice.

However, even with an appropriate geological model, design must take into account the most up to date knowledge. Only by taking advantage of advances of current modern theory can informed decision making take place. Following Professor Hornell's visit the Waitaki dam experienced modifications initiated by advances in design methods. The first followed the introduction of the concept of uplift to dam design in New Zealand. Later continuing improvements in analysis and design techniques provided the basis for the undertakings in the 1950s and the current refurbishment to enhance the dams predicted performance.

With sound investigations, an appropriate geological model and the application of modern theory, innovative design can follow. These elements were successfully integrated at Arapuni where the analysis of an appropriate geological model met the challenge of a unique engineering problem and provided the basis for Professor Hornell's innovative design of the headrace lining.

Engineers who successfully met the challenges imposed at Arapuni, Waikaremoana, Waitaki, as well as at all the early hydro generation projects such as Mangahao and Lake Coleridge, ensured New Zealand had the electrical energy needed for a developing country. The effort of all involved in the investigation, design and construction of these early projects is part of New Zealand's engineering heritage.

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Cobb River Hydro - electric Power Scheme

A K BLAIR, Nelson, New Zealand
BA, Dip Ed, Dip Ed Admin, Adv Dip Tchg

SUMMARY

In the mountains of North West Nelson is a powerstation unique in the history of New Zealand hydro-electric schemes. Cobb Station has the highest hydraulic head (almost 600m), was the scene of New Zealand's first seismic and magnetic survey for dam foundations, has the country's first high earth dam (over 30m), first piezometer system for testing pore water pressure, first exceptionally long transmission line span (1.3 km), and was the first with radiographic testing of penstock welds.

It was also the first New Zealand power scheme on which bulldozers were used and the last that employed horses and much use of hand tools - pick, shovel, crowbar and timber-jack.

Licensed in 1935 for private development to provide electricity for public use at state rates within two years, the scheme was taken over by the Government in 1940 after the Company failed. It was four more years before power was generated and fifteen before dam completion and the station's 32 MW capacity - vital to Nelson and Marlborough at the time - was reached.

With the great fall, which had attracted planners, were problems not fully appreciated at the outset: remoteness, difficult access, steep rugged working slopes and high intensities of cold and rain. The engineering firm (long gone) planned to use conventional methods and provisions which while successful in easier country and climates were at the Cobb but "old ways in a new land". Here new thinking was required.

A young Australian's experience of seeing honey extracted from the comb by being spun in a hand-turned machine led to the building of the Cobb River powerstation, unique among hydro-electric power schemes in New Zealand.

Out to work at age 12 to help support his widowed mother Walter Hume's remarkably inventive mind was to produce a world-wide winner, the Hume spun concrete pipe, made by application of centrifugal force. It was the discovery of the value of asbestos as a "preventive of corrosion and deterioration from the effects of electricity on concrete pipes in city streets" - electrolytic action - that took Hume on foot through the bush into the Cobb area to a sizeable deposit of this sought after and relatively scarce fibrous mineral.

The Golden Bay district already had a flourishing cement works and Hume saw that with a power source and asbestos mine in the area, both to be reached by one road into the mountains, there was very favourable opportunity for a large local asbestos-cement products industry.

A monumental 1904 government report on water power resources in New Zealand had identified the Buller River at Lake Rotoiti as a prospect for an electricity scheme for Nelson and Marlborough. But although the Government had from 1914 built schemes to supply cheap hydro-electric power to almost all populous areas of New Zealand, the relatively isolated and underpopulated north of the South Island had been left to fend for itself with inadequate local plants. By 1934 it was in dire need of an inexpensive assured electricity supply. In the midst of a worst-ever economic depression the Government was however not willing to provide a state scheme, on the Buller or anywhere else.

It therefore urged acceptance of the Hume Pipe Co. (Australia) proposal to build a scheme at the Cobb and within two years provide power for the public at state rates from an expected substantial surplus. Although the Cobb River scheme had not been considered in the 1904 report a government geologist had drawn attention in 1924 to the remarkable natural fall from the high, glaciated Cobb Valley. A firm of engineers, Vickerman and Lancaster, reported to Hume on the scheme in 1934 and it was this favourable survey which in 1935 resulted in the Government granting the company a licence to use Cobb River water for power.

Vickerman (civil) and Lancaster (electrical) had successfully built a number of small hydro schemes. One semi-automatic one in relatively low tussock-covered country an easy 25 km from Blenheim, had been built within two years by labour-intensive conventional methods of the day. The Cobb scheme was planned along similar lines with the same completion time except that being a high pressure station the Cobb would have pelton wheels - 4 three thousand kilowatt, English Electric machines.

Before building began at the Cobb a change of government brought New Zealand's first Labour administration to power and raised the ideological difficulty of a private company - Australian to boot - providing an important public amenity. It was not resolved until August 1936 when a New Zealand company was floated - the Hume (Cobb River) Electric Power Company - and took over the licence.

This company began the 16 km road to the powerhouse site up the Takaka River gorge by pick and shovel methods but within three months the very difficult terrain forced it to replace the contractor with Downer and Co. who brought their first earth moving tractor (D8 "No 1") to the job. It was the first to be used on a power scheme, and one of the first in New Zealand. Whereas 15 or 16 barrow loads were needed to shift one loose cubic yard of spoil, the "bull-nosed tractor" could shift more than three with each scoop of its blade and people flocked to see it. Even so, with sheer bluffs having to be drilled for blasting by men lowered on ropes, it was over a year before the bulldozer and road reached the powerhouse site.

A winch tramway built by hand from there rose over 2,600 ft in five stages to the top of the range. Diesel motors hauled the 12 ft wagons at each stage except the fourth where the line leading to the eastern tunnel portal was at an easy gradient and haulage was by horse. Other sections were as steep as 1 in 1.5 and caused many a hair-raising ride.

At the top, a mile and a half of road built by hand ran along the ridge to opposite the site for the dam and western tunnel portal. From here a gravity winch jig-line tramway dropped down the steep slope to the flat floor of Cobb Valley.

To complete the link a motor truck was dismantled, hauled to the top, reassembled and run along the road connecting the two railways.

The tramway was the only practicable means for placing the 2 km of steel penstock pipe with sections weighing up to 4 tonnes, but to save the time and expense of building a road up the mountainside and over to Cobb Valley all transportation to there was by tramway. The three on and off - loadings from the powerhouse site however added cost to every tonne transported to Cobb Valley. A cubic yard of river shingle costing 16 shillings at the powerhouse, had cost 25 and sixpence by the time it reached No. 3 winch, "not including overheads". Further, when it snowed heavily on the road at the top, as frequently happened, men had to shovel the one and a half miles by hand, or if too deep, man-haul a sledge with supplies for those in the valley. Nevertheless the engineers and power company proposed to drive the tunnel and build a 90 ft concrete dam in Cobb Valley with only the tramway system for transportation.

An austere powerhouse with asbestos-cement board cladding was built and in Cobb Valley six exploratory shafts for dam foundations were sunk apparently to bedrock. The Government wanted the foundations proved by drilling but heavy flow of water and problems of obtaining a suitable drill induced the company to use modern science - a geological magnetic and seismic survey, the first for any New Zealand dam site. With an ingenious locally made seismograph (the design of which had been surreptitiously copied from one brought to New Zealand for search for oil), and a Schmidt magnetometer, the survey was made. As well as indicating extraordinarily complex geology it showed that in three of the shafts the "bedrock" found was in each case a huge morainic boulder.

But with this work and only half the tunnel complete the company had to give up. The completion date had been extended four times but the company had had financial trouble from the start and was deep in debt. Not enough people had confidence to invest in a power scheme and months before war began in 1939, secret negotiation arranged for the Government to buy the works and pay the company and its debts with government securities. This happened in May 1940.

War provided a heavy brake on the scheme's progress and never again was there ample manpower. Three weeks before Japan's shock attack at Pearl Harbour the USA secretly asked for military aerodromes to be built in Fiji and almost all Cobb workers were taken within 24 hours to join the 1,200 which New Zealand sent. Despite such difficulties a 13 km road was built from powerhouse to dam site, the tunnel completed and steel penstock constructed. After lying crated on the powerhouse floor since before the war the pelton wheels and generators were installed and power first produced in May 1944. But it was by run-of-river as there was no dam, only a low weir. A notable engineering feat at the time was a 1.3 km transmission line span required by the difficult terrain.

Post-war priorities were to build the dam and a second larger penstock to increase generating capacity to 32 MW. This however took until 1955 during which time, to meet burgeoning power demand, a temporary low earth dam was built and four glacial lakes were also dammed. The largest of these was even pumped down to thick mud before the water crises ended on completion of the permanent dam.

Excavation for a concrete structure in 1947 had revealed an unsatisfactory rock base leaving no alternative but to build an earth dam - New Zealand's first high (over 30 m) earth structure. Even so a very extensive grouting programme was carried out until late 1956 to seal and strengthen the foundation rock.

The climate was one of the most testing possible for building with earth and first New Zealand use was made of a piezometer system, laid in the dam, to monitor pore water pressure during construction and thereafter. The experience and expertise gained from the Cobb dam was very valuable for design and construction of a series of high earth dams in New Zealand which soon followed, including mighty Benmore. Cobb engineers had major roles for these; it was a case of new methods with the oldest of dam materials.

Design and construction of the second penstock also involved new thinking, which reflected in particular greater awareness of the earthquake problem in this new land. The first penstock built in wartime - a mixture of riveted and welded sections - had taught early lessons on electric welding, such as the need to work unceasing on circumferential welds, in factory or on mountainside, or cracking would occur. Testing was by destruction methods - water pressure and heavy hammer - but in 1954, radiography was introduced. Pinhead size isotopes flown out from the U.K. enabled each whole circumferential joint to be photographed at one exposure. Pre-heating of thick steel (toward the powerhouse end of the penstock) was also introduced, at first by cumbersome gas-heated collars, but electric induction heating - like an electric blanket pioneered on the mountain site was much better.

The outcome of these changes was greatly improved welding, and with a new ring - girder system for penstock support, ability to withstand movement stresses was increased.

Although completion of the Cobb scheme to full power took more than 20 years from the 1935 licence (with its 2 year stipulation), the final result was an efficient and well balanced scheme vital to then under-developed Nelson and Marlborough and now very cost effective. At time of completion, however, it had cost more per kilowatt of capacity than any previous New Zealand scheme.

CONCLUSION

Undoubtedly the greatest cause of cost and time over-runs on the Cobb scheme was its location and what the early planners had overlooked or underestimated with regard to it. The high altitude, which provided the great fall and water speed of 320 k.p.h. at the turbines, also ensured great intensities of cold which virtually halted construction for even weeks at a time. Nor was there adequate allowance for Cobb rain which apart from being frequent is subject to great orographical intensification - 17 inches in 24 hours in March 1954.

Added to that were remoteness and isolation, not so much by distance as time, for access was by a narrow, testing one-way road, then the most elevated in use by public in New Zealand - access which during the week forced separation of men from their families domiciled in UpperTakaka. As well there was inadequate appreciation of the rugged terrain with 30 degree working slopes in places, and the planners took too much for granted regarding the area's geology. Cobb Valley had looked easy to dam but that was far from the reality.

New strategies and methods had to be developed, and through Cobb being starved of manpower and resources from war-time onward, keys to its progress were improvisation, adaptation and perseverance. Cobb heralded the new mechanical age of bulldozer, carryall, mobile crane and giant dump truck, but it was also the last scheme on which much work still had to be done by hand.

With many vulnerabilities, and for some years the sole source of power for its region, Cobb powerstation was fully manned with three shifts a day. Now, under the Electricity Corporation of New Zealand, it has modern safeguards and fail-safe shutdown involving a computer link 800 km to Benmore. The station has thus been automated - as envisaged by the early planners but only now able to be achieved.

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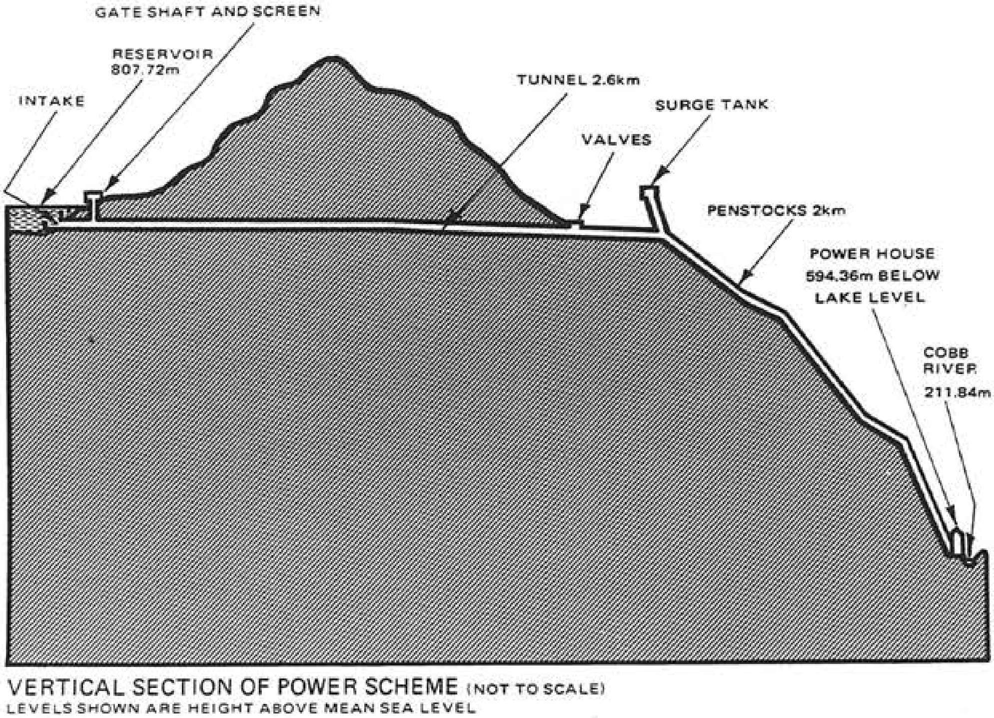

Fig 1. Vertical Section of Power Scheme

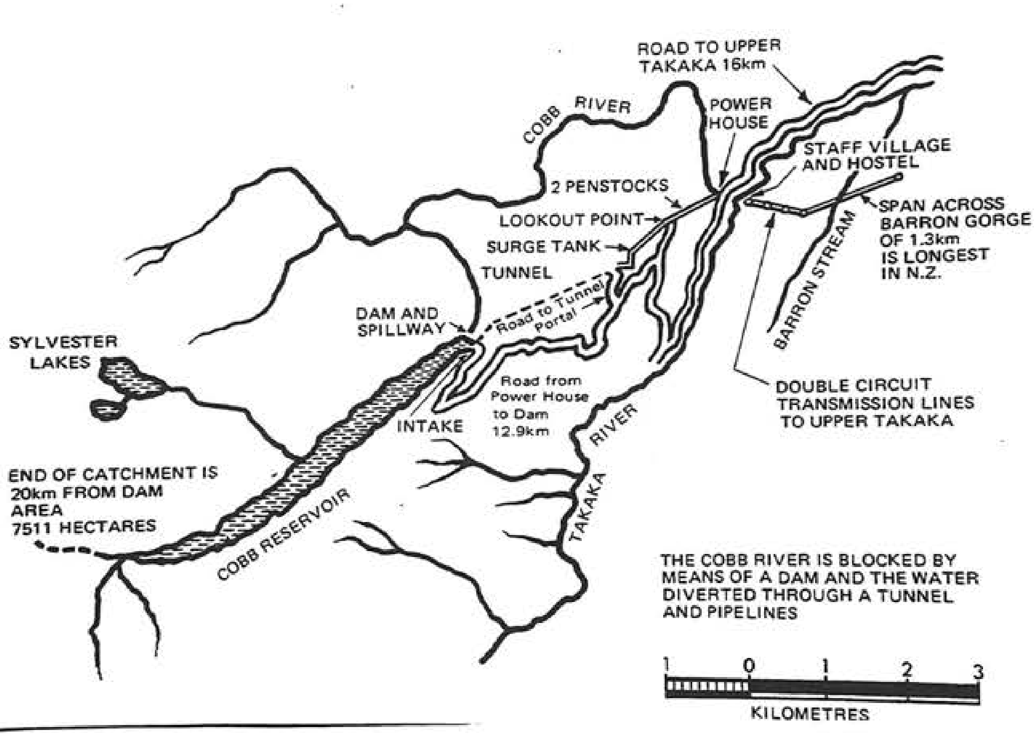

Fig. 2 Cobb Valley 1939
All transportation for the Hume (Cobb River) Electric Power Company's work in Cobb Valley was by this steep gravity-winch jig line
Acknowledgment to the Making New Zealand Collection, Alexander Turnbull Library.

Fig. 3 A small section of the tramway.
The power house is at the bottom on the left (1940) (E. Heine)

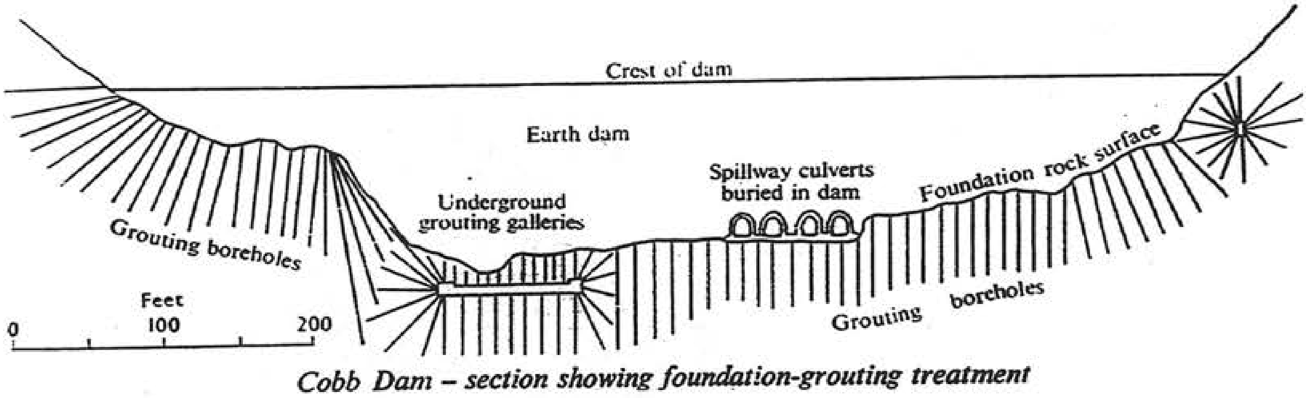

Fig. 8 Cobb Dam - section showing foundation-grouting treatment
Encyclopedia of NZ Govt Printer

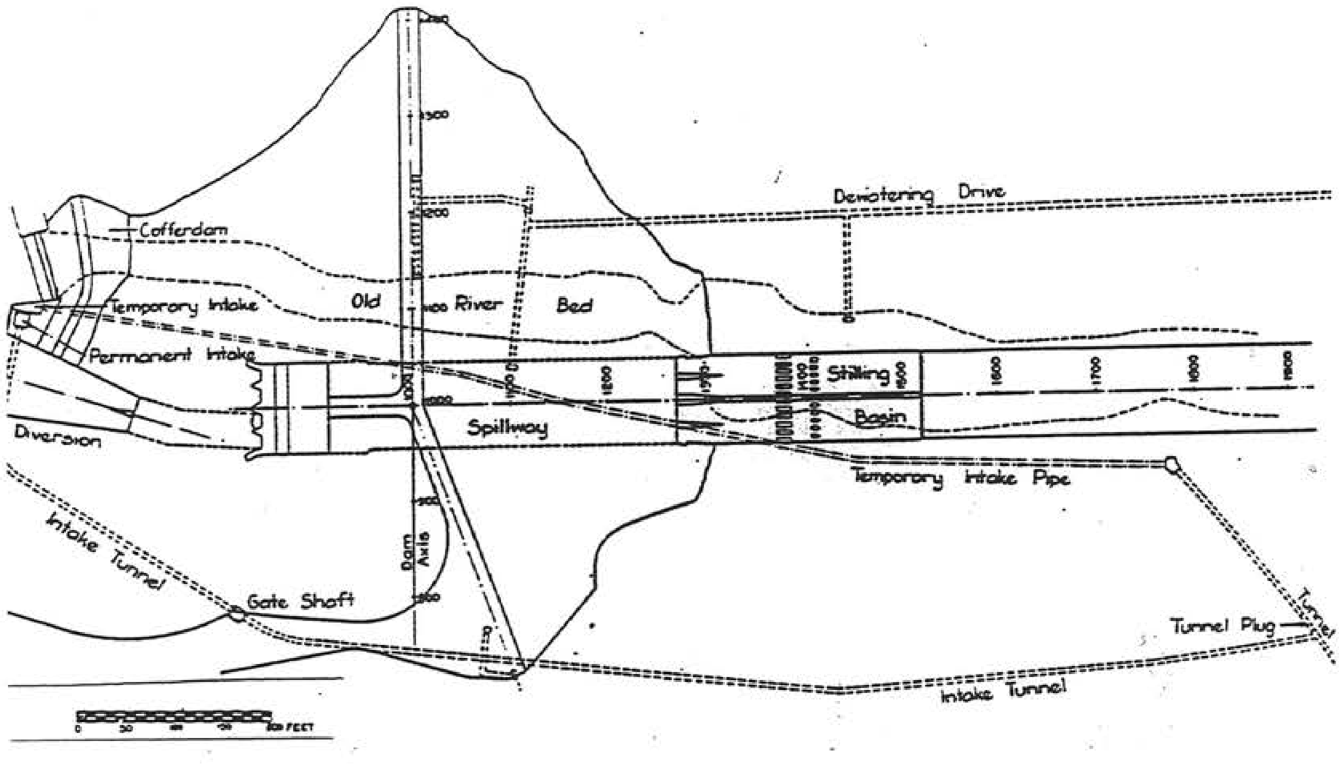

Fig. 9 Plan of Cobb earth dam, completed 1955
(O T Jones)

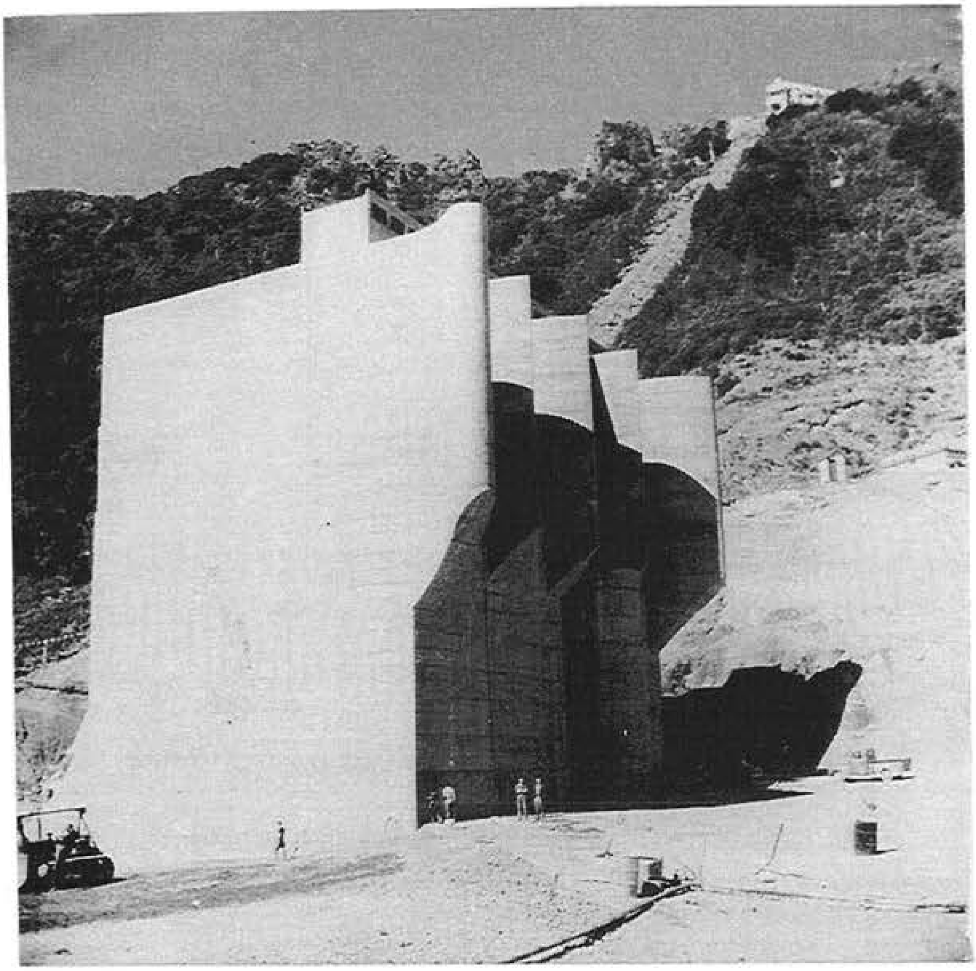

Fig 4. The spillway block has been completed and the earth dam is being built.

Fig. 5 Dam and Reservoir, 1957 (ECNZ)

Fig. 6 1955, Station at full 32 MW power with second penstock and new powerhouse. Road to dam left, Takaka right, and village in foreground. (ECNZ)

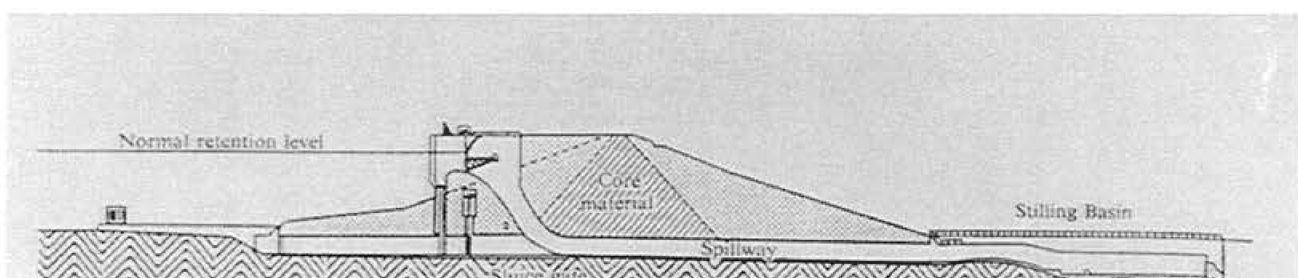

Fig. 7 Cobb Dam - section through spillway system, showing sluice gate.

Nineteenth Century Engineering for the Ballarat Water Supply

R.J. FORD, B.Sc; B.Eng (Hons); Grad Dip Bus (Admin); MIE Aust; MASCE;
Engineer-in-Chief, Central Highlands Region Water Authority.

SUMMARY

During the 1870's large volumes of water were required by gold mining companies in Ballarat for mineral processing. To meet this demand a major augmentation project was proposed. Flow control devices, reservoir outlet equipment and high pressure valves were designed and manufactured locally.

To protect the water supply catchments long term research into forestry commenced. This was completed forty years later with a decision that future reafforestation of the Water Commissioners' lands would be with Radiata Pine.

INTRODUCTION

The need for a reticulated water supply appeared to begin to exercise the minds of the local community in 1856, about five years after the discovery of gold. The recently created Municipality of Ballarat West decided to obtain water from Yuilles Swamp, (now Lake Wendouree an urban recreational lake). Tenders were called for cast iron pipes in June, 1857 and, following their arrival from England in July, 1858, the first reticulated water became available in December, 1858.

Meanwhile, in February, 1858 the Town Surveyor had prepared a detailed report examining the likely yield of the swamp. This report took into account estimates of runoff, evaporation, usage and future growth. It concluded that the swamp would be inadequate as the long term source of water for the area. The surveyor's report recommended that the Yarrowee Creek be considered as a future supply source and suggested that a reservoir be erected on the Creek at a point about five miles east of the town. This storage would be 54 feet high and could impound 85,000,000 cubic feet of water.

The estimate accompanying the report suggested a return on the investment of twenty percent per annum could be achieved. Levels taken by the Surveyor showed an adequate pressure would be available in the town.

The swamp soon proved to be inadequate and in December 1860 a submission was made to the Colonial Government to construct a new supply from Yarrowee Creek. This submission claimed that each year 1,100 million gallons of water would be required for mining purposes and for a population of 35,000 persons 82 million gallons would be needed for domestic and sanitary purposes. Water could be sold for twopence per 1000 gallons for mining and one shilling per thousand gallons for domestic purposes. (The then current price was quoted as being forty shillings per 1000 gallons). The new supply was to be met from dams constructed on the Yarrowee Creek. The yield of the catchment was estimated at 3,500 million gallons per year. The top water level was quoted as being 170 feet above the door-step of the Bank of Australasia. In June 1862 the State government purchased 'Kirks Dam' on a tributary of the Yarrowee. At the same time the water supply was taken out of the hands of the councils and a separate Water Commission established.

Kirk's storage was originally built by speculators for supplying water to gold sluicing parties. During 1863 a start was made on a 18 inch diameter cast iron main from this reservoir to the town. The specification required all pipes to be tested to a head of 400 feet and while under pressure to be struck frequently with a hammer of 4 pounds weight! However, a major delay was caused by the failure of the supply contractor to provide sufficient pipes and thirty extra pipes had to be specially cast in Melbourne before the Yarrowee supply became operational in November, 1864.

The growth of demand was such that a new reservoir at Harry Beales Swamp, in the adjacent catchment of the Moorabool River about 6 miles east of Kirks Dam was designed and constructed. This was connected to Kirks Dam by a gravity channel. These works were constructed by day labour under the supervision of the Engineer.

A drought in 1865 resulted in both new reservoirs being dry.

The measurement of water to consumers must have been difficult at this time. Water was sold initially using a complicated scale of charges. This included a weekly rate of 3 shillings per stamp head for water used in quartz crushing and one pound per week per horse pudding machine. By

1866 water meters appear to have become readily available as the scale of charges for that year required all mining companies to pay by meter at a rate of 9 pence per 1000 gallons.

THE COGHILL'S CREEK DAM

In 1862 the Government also granted a sum of £2000 towards a water supply for Clunes, a town about 20 miles north of Ballarat.

The future Engineer of the Ballarat & Ballarat East Water Commissioners Mr. C.H. Ohlfsen Bagge, was the Government Inspector. It was decided to erect a dam across Coghill's Creek which was to have a capacity of 186,000,000 gallons. The work commenced and the first payment was made, and the Council applied for a further grant. In May, 1863, Mr. Bagge condemned the work and would not authorise further payments. By this time considerable water had banked up, and as the 16 inch outlet pipe had not been laid in concrete, leakages had occurred, and water began undermining the dam. The wall had been built within 17 feet of its total height, and frantic efforts were made to seal the leak and complete the dam. However heavy rains set in and the dam continued to leak. On Saturday, 6th June, 1863, after very heavy rains the dam failed. No further attempt was made to supply Clunes until 1870 when a separate Water Commission for Clunes was formed. Mr. Bagge's experiences on this project are likely to have influenced his stringent attention to detail on later projects.

STRATEGIC PLANNING

Following the 1865 drought the Ballarat and Ballarat East Water Commissioners commenced a major long term plan for the town supply.

The Engineer arranged a detailed survey of the catchment of the Moorabool River and his report recommended that about 250 hectares of land at a sufficient elevation to gravitate to Kirks Reservoir be reserved for future water supply purposes. (Much of this land was not needed until about 1908).

Detailed survey work and shaft sinking commenced for the proposed large reservoir on the Yarrowee Creek at Gong Gong downstream of Kirks together with land acquisitions.

Much public speculation occurred about an 'underground lake' east of the town. At the request of the Commissioners the Engineer reported in 1868 on the possibility of underground water being obtained in the vicinity of Mount Warrenheip together with capital and annual costs for pumping plant. As a result of this study which included a detailed geological survey the Engineer reported that he was unable to recommend underground water as a possible source.

By September, 1868 it was reported that detailed survey plans were finalised for the Gong Gong reservoir including pegging of the top water level, preparation of cross sections of the storage basin to complete capacity calculations and plans for a road deviation.

Trial shafts were sunk in early 1869 to determine foundation conditions and a complete geological plan and sections of the site were available for design to commence.

At this stage the Water Supply Committee decided to review the plan and closely examined two options:-

a) The proposed Gong Gong Reservoir, and
b) A reservoir on the Moorabool River 16 miles east of Kirks together with a line of pipes to transport water by gravity out of the Moorabool catchment to the Beales-Kirks channel.

A report prepared by the Commissioners' Engineer-in-Chief, Mr. Bagge, considered the yield of the two catchments, Cost estimates of the various alternatives including a comparison of the cost per million gallons for existing and proposed works. In his conclusion, the Engineer-in-Chief recommended that the time taken to build these schemes would be so long that, in order to ensure a plentiful supply of water for the constantly increasing demand, both works should commence next Spring.

Because of the urgent need for extra water a small additional reservoir was built on the upper reaches of the Yarrowee Creek upstream of Kirks at Pincotts in 1869. The Commissioners finally made their decision in February, 1870 to proceed with the Gong Gong Reservoir only.

THE GONG GONG RESERVOIR CONTROVERSY

The plans for this reservoir show it was to be 106 feet high, 15 chains long and impounding 1,076,703,805 gallons. The spillway was to pass a flood of 1,682,100 gallons per minute. The catchment was to be supplemented by a gravity diversion from the West Moorabool River.

These works were estimated to cost £220,000. The Water Commissioners were having difficulty in raising such a sum of money and applied for Government support. Before considering this request the Government of the day commissioned a report from the Chief Engineer of the Victorian Office of Water Supply, Mr. G. Gordon.

This report was received in February, 1873 and made the following comments on the proposal.

1. The volume to be stored appeared excessive and a volume of 800,000,000 gallons would be ample.

2. The spillway capacity appeared incredibly high for the kind of watershed.

3. The pressure to be supplied, even after providing for friction loss, was more than adequate and could be reduced by 20 feet.
4. The dam appears to have been designed more for getting the necessary pressure than storing water.
5. Every foot that could be taken off the height would lessen the risk of accident.
6. No part of the formation of the puddle wall or banks should be done by contract.
7. The cast iron valve tower appeared a very expensive piece of work and water could be better drawn off by a deep sluice.
8. The supply from Moorabool should be left out, however, the catchment should be carefully conserved and the reserves planted out as this water will not be needed for many years.

Two weeks later an anonymous letter appeared in the "Ballarat Star" suggesting that a site for a dam capable of holding three times the present supply at one quarter the cost of the proposed new Gong Gong and with greater pressure existed upstream of the proposed site. The newspaper produced an Editorial in support of the new site on the grounds of safety of a lower embankment and lesser cost.

The Water Commissioners' Engineer submitted a report on both sites on 5th April, 1873 stating that: "The Gong Gong Reservoir is the best site for a storage basin for a comprehensive water supply for the Town and will be safe and sound however if a site for a smaller reservoir were required I would have proposed a site close to the one now surveyed".

The Water Commissioners also engaged Mr. Langtree, the Engineer of Clunes Water Supply to report on the two options. Mr. Langtree's report supported the Commissioners' Engineer and included the summary set out in Table 1

.In April, Mr. Gordon who had also been asked to comment on the various schemes stated that "he considered the proposed Gong Gong dam to be too high and the element of danger always present in large dams would be needlessly increased."

The opposition newspaper opposed the alternate site and accused the Water Commissioners of procrastination.

In view of the high estimated cost and under pressure from the community that the reservoir located above the town would be a risk to the public the Water Commissioners resolved, in May, 1873, to abandon the original Gong Gong site after four years of work and instructed their Engineer to commence work on the smaller Upper Gong Gong Reservoir.

A stringent design specification for a reservoir impounding 400,000 gallons was prepared by Mr. Bagge and tenders let in April, 1874. The successful tender being well below all other offers. The works were completed in 1878 but a lengthy and expensive legal dispute between the contractors and the Water Commissioners followed. The Contractors claimed the Engineer refused to accept many sections of the work. The major claim however involved additional payment for work on the puddling trench, which bottomed at 94 feet. This was much deeper than expected. The costs of the dispute almost bankrupted the Commissioners.

TABLE 1

Reservoir	Capacity (Gallons)	Total Cost	Cost per 1 million gallons
Gong Gong (present design)	1,076,703,805	£113,641	£105/11/3
(Mr. Gordon's design)	792,310,096	£ 88,997	£112/6/6
New Reservoir (as proposed by letter in the "Star")	420,000,000	£ 77,252	£183/18/8
Kirks raised by 30 feet	215,514,500	£ 66,797	£309/19/3
Moorabool (including connecting pipeline)	58,515,500	£ 30,000	£512/16/5

It is interesting to note however that a 1905 report by the Department of Water Supply stated that:

> *"There is little doubt that a much better supply could have been obtained at a less capital cost had the original scheme of Mr. Bagge's be carried out in its entirety. The exceptionally dry season of 1902-1903 made this but too evident".*

EXAMPLES OF LOCAL DESIGNS DEVELOPED FOR THE WATER SUPPLY

When the Ballarat West Council ordered pipes for the first pipeline in 1857, thirteen months were to elapse before they were delivered. Over the next twenty years manufacturing industries were established in Ballarat with the capability of providing materials for the water supply system.

The combination of need for special items and suitable local manufacturers resulted in the design of many special items by the Water Commissioners' staff. These range from special junction pipes designed to the exact angle of the individual street intersections to large valves.

Figure 1 is a detail of the operating mechanism of a 24 inch diameter gate valve designed and manufactured for the Gong Gong pipeline. Some of these valves are still in use.

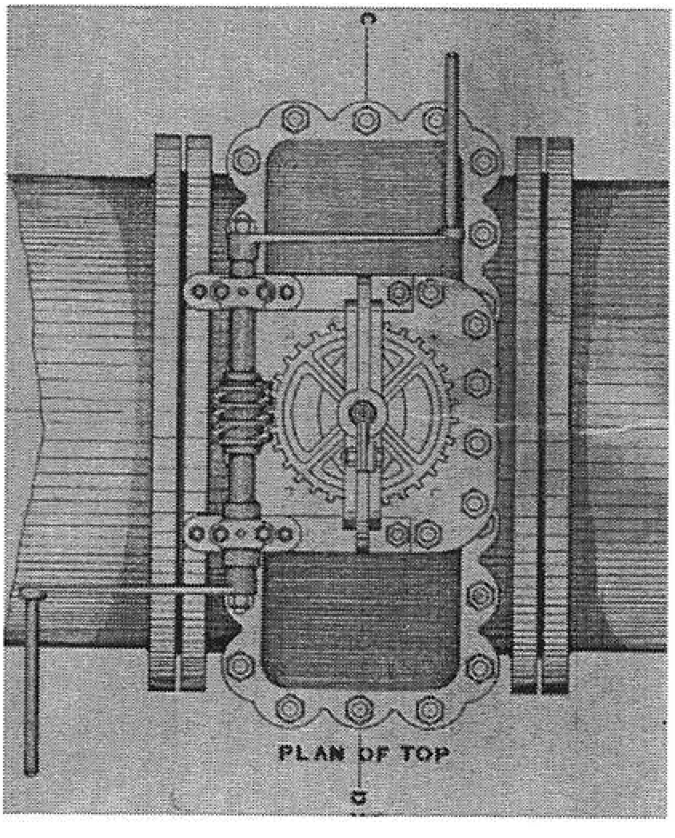

Figure 1 - Details of 24" gate Valve

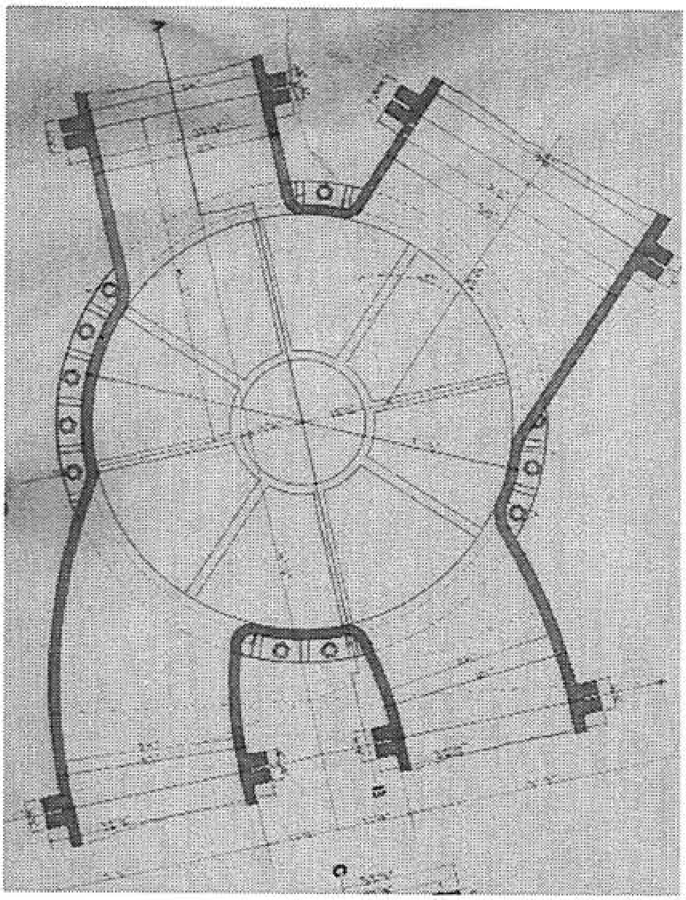

Figure 2 - Plan of Junction

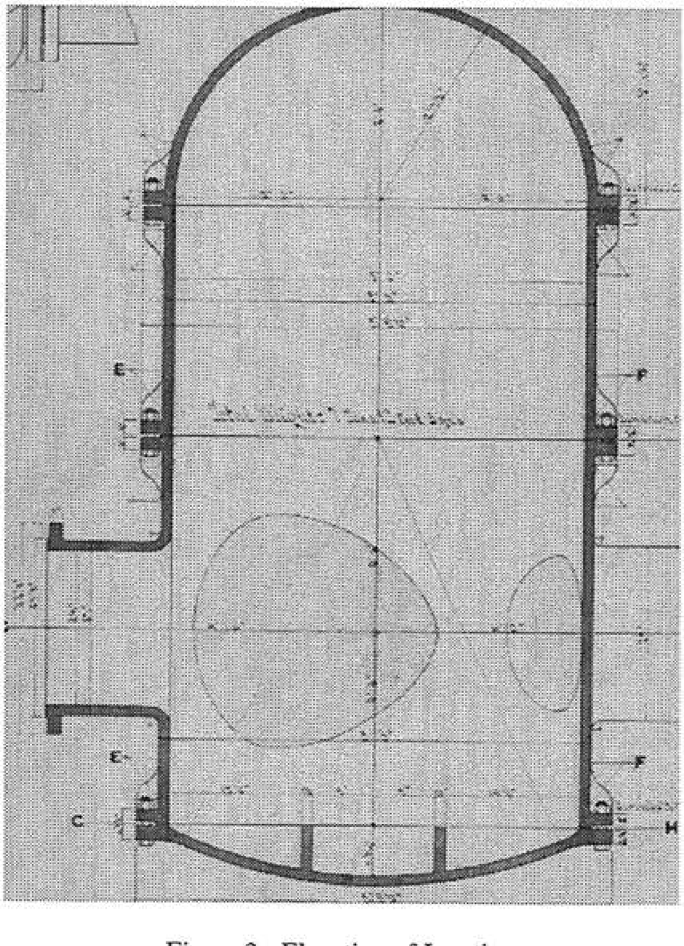

Figure 3 - Elevation of Junction

Figure 2 and Figure 3 is a cast iron junction located downstream of the Gong Gong Reservoir. The casting which is 8 feet high provides a connection between two 18 inch outlet pipes from the reservoir the 18 inch trunk main to town and a 24 inch scour outlet. The large chamber appears to be for retaining entrapped air to ensure the trunk main remained fully charged as no design for automatic air release valves can be found for this period in the Commissioners' records. It appears any air trapped in this casting was released manually by the Reservoir Keeper. Cast iron sluice gates were designed and manufactured locally to control flow in the gravity channel system used to bring water to the reservoirs. These gates still remain in use.

By 1868 it is clear the Commissioners' staff had a good understanding of the geology of the catchment areas and a number of reports exist which contain quite detailed geological plans. Surveying was also well established and many miles of gravity channel were built to convey water across catchment boundaries to the storage reservoirs.

By early 1870 the need for accurate rainfall and flow records became obvious. Rainfall gauges established at Beales and Kirks Reservoirs in 1868 have provided the Water Commissioners with a continuous record of daily rainfall totals.

FORESTRY

The growth of deep mining in the Ballarat area created a need for firewood to drive the steam pumps and winding machinery. By 1865 much of the catchment area from which the water supply was derived had been cut out. This created a concern for the Water Commissioners and the general public.

In 1867 the Water Commissioners engaged Dr. Mueller, the Curator of the Melbourne Botanical Gardens, as a consultant. Dr. Mueller provided 6,000 trees and several packets of seeds for trials.

With these, the Water Commissioners established a nursery and commenced a program of planting and evaluation to determine the most suitable species of trees for reafforestation. The Annual Report for 1879 records that 6,000 young trees from the Water Commissioners' nursery were distributed to local schools.

A report in 1874 by Mr. Ferguson, the Inspector of State Forests, recommended the planting of the following tree species:

> Oak, Elm, Ash and Blue Gum;
> Willows and Osiers in swampy areas;
> Pinus Insignis (which he considered "The most important and valuable coniferae for the purpose of planting the Water Reserves, seeing how rapidly it grows into timber");
> Pinus Austriaca ("Perhaps the next in value to Insignis of rapid and robust growth").

Pinus Insignis is now referred to as Radiata Pine.

Planting continued each year and in excess of 100,000 trees being propagated each year and planted out.

During period 1880 to 1890 many fires, some deliberately lit, occurred in the Water Commissioners' forests. However, in 1903 a major report on the results of the last 40 years of forestry operations was presented by the Engineer.

This recorded that the 40 year old Oaks and Ash trees averaged 20 feet high and a circumference of 33 inches. The Pinus Insignis, also 40 years old, were 80 to 100 feet high and averaged 9 feet 9 inches in circumference. Pinus Laricio were 35 feet high and averaged 5 feet 6 inches in circumference.

Blue Gum raised from seed was considered too susceptible to frost damage by the Engineer for him to recommend its general use.

The Engineer, in his report, indicated that although the tree planting would normally be considered from a commercial point of view, in this instance the conservation of water, is considered of greater importance. He also reports a reduction in wave action on embankments for reservoirs surrounded by shelter trees.

He went on to argue that although there appears to be no evidence from the Water Commissioners' rainfall records that trees attract rain, they are a valuable means of conserving water and reducing evaporation by providing shelter from the wind and hot sun. He based this statement on the cool moist nature of the atmosphere within the Commissioners' forests.

CONCLUSION

The works constructed by the Water Supply Committee of the Councils and later the Water Commissioners resulted in the establishment of water catchments and works that provide a domestic and industrial supply to Ballarat. The long term strategic plans developed by these Authorities were ultimately implemented and provided an adequate supply until 1974 when a major reservoir at Lal Lal, on the Moorabool River, about 25 miles below the original works, was constructed to supplement the earlier supply system.

I would like to thank the Central Highlands Region Water Authority for their permission to access their archives and to publish this paper.

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The Brunner Industrial Site: A Colonial Coalbrookdale

James R. McKinlay M.A.
Formerly Senior Archaeologist
New Zealand Historic Places Trust

SUMMARY:

Coalbrookdale in Shropshire, England is generally acknowledged as the birthplace of the Industrial Revolution. The remarkable iron bridge across the River Severn is its enduring icon. The industrial technologies developed there were transported elsewhere in the world. The similarities between Coalbrookdale and the Brunner Industrial site in New Zealand are remarkable. Coal, clay and human enterprise came together at Brunner to build a site of national, perhaps international, industrial heritage significance.

INTRODUCTION

The Industrial Revolution in 17-18th century Britain initially depended for its fuel on charcoal from the apparently inexhaustible lowland forests. But increasingly it was coal, and the coke that could be made from it, which fired the hearths of industry. The associated limestone, iron ores and clays were the raw materials of the iron, brick and ceramic industries. While industrial centres generally developed where the materials were clustered, water transport was utilised to bring them together at other centres and to transport the often bulky and heavy finished products.

During the last period of Pleistocene glaciation, the principal river draining northwards from the Welsh highlands was confronted by the impenetrable barrier of the northern ice-sheet. Turning eastwards and then southwards, it cut a permanent course through the low hills between modern Shrewsbury and Kidderminster to its present-day route as the River Severn to the Bristol Channel. As it did so it eroded a significant gorge in which it exposed the strata of coal, ores and clays which in the 18th century were to nourish the birthplace of the English Industrial Revolution. In this gorge there developed a unique industrial complex which in the 20th century has become a major tourist and museum complex known from the remarkable cast-iron bridge which spans its shoulders as the Ironbridge Gorge.

The key physical elements of this development were the coal, limestone, iron ores and the river, but the most significant element was the genius of Abraham Darby, a Quaker ironmaster, who at Coalbrookdale in 1709 first succeeded in making iron of reasonable quality using coke rather than charcoal. By the 1750's his iron was competitive in every respect with that made using charcoal, and the Shropshire industrial complex was established. A variety of subsidiary industries - potteries, tobacco-pipe factories, lead smelters, brickworks and saltworks - developed to flesh out the basic iron-based industries. The gorge became the focus of a number of small industrial townships, but they were denied a true physical coherence until the building in 1779 of the Iron Bridge [1].

At Brunner, on the West Coast of the South Island of New Zealand, there is an industrial site which in a number of ways recalls its English predecessor at Coalbrookdale - a river cutting a narrow gorge to expose seams of coal and clay, and providing water for a convenient transport system until a railway was in place, with the two sides of the river linked by a substantial bridge. Although limestone was locally present, in the absence of iron ores Brunner did not become a major industrial complex, being restricted to the production of coal, coke and industrial ceramics.

THE BRUNNER SITE

The coal seam in the Grey River gorge was first recorded by the explorer Thomas Brunner in his diary for January 26, 1848, but it was not until 1864 that coal was first mined commercially at the site, the coal produced being shipped to Nelson. The contract with the Nelson Provincial Government provided for the building of a railway to Greymouth, but this did not eventuate until 1876. In the meantime, the coal was taken downriver by barge to Greymouth, the empty barges being pulled back upriver to the site by horses. In 1876 a suspension bridge was built over the river at Brunner to enable the coal to be loaded into wagons on the new railway, and to join the developing settlements on both sides of the river. It collapsed on the night before its formal opening. However, it was replaced immediately by the structure seen at the site today. Later in its life this bridge, too, became insecure, and was strengthened by Bailey sections underneath the decking. From 1874 other mines were opened, including several on the southern side of the river. The names of these pits are reminders of the old world, and even Australian, origins of the miners - Coal-Pit-Heath, Pig and Whistle, Tyneside, Wallsend, Coolgardie, St. Kilda, and even Coalbrookdale. During this period, the first Brunner mine adit at the river side was abandoned, and a new mine driven from the terrace above [2,3].

On 23 March, 1896 a shattering explosion in the Brunner mine resulted in the deaths of 65 underground workers. This event, New Zealand's worst mining disaster, left an indelible imprint which endures to the present day on the memories of residents of the West Coast. The victims were interred in a mass grave at nearby Stillwater.

Peak production was achieved in 1901, but it then fell away quite rapidly, and the main mine was closed in 1906. Limited activity continued at the adjacent smaller mines until the last recorded production of coal from the Brunner area in 1942.

THE BRUNNER COMPLEX

In addition to the production of coal the two principal industries which developed at the Brunner site were the production of fire bricks and coke. These developed in conjunction with the production of coal, and when this ceased, so did the ceramics and coke.

With the rundown of coal production from 1906 until its extinction in 1942, the structures associated with the industry also deteriorated, falling into disrepair and ruin. The site was invaded by the vigorous West Coast vegetation, and by the 1970's the only structures readily visible to the passer-by were the bridge, and the brick ventilation chimney at the Tyneside mine on the south side of the river. The brick structures hidden in the trees were not, however, entirely forgotten, as local residents retrieved them for building walls and paths. In the 1960-70's the development of a craft pottery industry on the West Coast created a demand for quality kiln bricks, and at this time considerable damage was done to the coke kilns by the enthusiastic potters.

In the late 1970's the West Coast Regional Committee of the New Zealand Places Trust brought to the attention of its parent body the sorry state of this uniquely important industrial heritage site. The Buildings Classification Committee of the Trust, on one of its infrequent forays to the Coast, braving rain and water-logged underfoot conditions forced its way through trees and blackberry to rediscover the site. Driven by the enthusiasm of Mr B. Wood, Chairman of the local committee, and of Mr G. G. Thornton, member of the Classification Committee and later Deputy Chairman of the Trust Board, the Trust resolved to undertake a major program to recover the site, to conserve the structures which remained, to undertake the historical and archaeological research on which these programs could be based, and to present the site locally and nationally as a symbol of New Zealand's heritage of industrial history. A development committee which involved the Trust (locally and nationally), local government, the (then) Department of Lands and Survey, the Ministry of Works and Development, and the Harbour Board was formed. Research was commenced, a site manager was appointed, and clearance and rehabilitation of the site was begun. With the reorganisation of government structures in the 1980's the Trust agreed to devolve the general management of the site to the newly-formed Department of Conservation, in whose hands the management of the site remains at the present time.

THE INDUSTRIAL EVIDENCE

At the Brunner site, structures relating to each phase and element of a major industrial undertaking still survive. The principal areas consist of:

i) *The 1866-74 mining venture:* the adit and the associated 'twin' coke ovens at the river edge.
ii) *The Brunner Mine 1874-1906:* the most visible remains are the return air adit, winding gear, the foundations of the coal screen and bins, and major engine foundations.
iii) *The brickworks:* the grinding shed and pug-mill, the brick drying rooms with hypocaust floor, and the kiln remains.
iv) *The coke-making complex*: the double line battery of bee-hive ovens, and the loading platforms.
v) *The Grey River bridge:* a wooden deck suspension bridge with later Bailey section reinforcement.
vi) *The Tyneside mine*: brick air return chimney.
vii) *Incidental mining structures:* site railways and tramways, building foundations, the barge mooring irons.

THE PRODUCTION OF COKE

The manufacture of coke from coal in 18th century Britain developed from the manufacture of charcoal from wood. In the simplest method heaps of coal were formed on an area of flat ground called a coke hearth, and ignited. Burning was regulated by a layer of fine coal slack or by watering. [4] About 1763 the brick bee-hive oven was developed. This was a circular oven of 10-12 cubic foot capacity with a domed top which served to reflect the heat on to the charge of small coal. Ovens were charged from overhead through a central hole in the roof. With a bank of ovens an overhead rail system provided for the transport of the coal in small wagons to the charging ports. These ports also allowed the escape of the noxious volatile gases driven off in the coking process. Later, exhaust flues were incorporated by which the gases collected from a bank of ovens could be led away in a controlled manner, and perhaps used for heating elsewhere in the plant. Single, vertical side doors, often sealed by clay, controlled the entry of air into the oven and determined the degree of combustion. These doors were also used for the removal of coke from the oven at the completion of the process.

An oven would be filled to about 2/3 capacity with coal which would be levelled off with a hand rake. If the bricks remained sufficiently heated from the previous firing the charge could ignite spontaneously. Otherwise it would be separately ignited. Combustion was controlled through the single door, it being necessary to maintain a flow of air over the surface of the coal, but not to allow complete combustion. It required about 48 hours to complete the coking process for a single charge of coal. The sealed-off oven would then be left to cool, or water would be poured on the coal to prevent further burning. Alternatively, the cooled coke would be raked from the oven and sprayed with water on the loading platform. The coke would then be bagged and removed from the platform.

The product required from the bee-hive oven was coke, and the volatile gases were an unwanted by-product, which was freely exhausted in an uncontrolled manner. It is not difficult to imagine the environmental consequences of the wasteful industrial process. Contemporary photographs of the Brunner site show a complete devegetation of the slopes above the site, no doubt largely a result of the noxious fumes expelled from the ovens.

Oven complexes were made to fit the available site. Where they were inset into rising ground, only a single line of ovens might be built, but where flat land was available, as at Brunner, a double line of back-to-back ovens could be accommodated. Very large numbers of ovens were used at larger sites. In 1900 there were 7,300 bee-hive ovens in the state of West Virginia alone [5]. Bracegirdle [6] notes that the last bee-hive ovens to operate in Britain remained in use until 1958.

Illustrations in works already cited [5, 6, 7] when compared with the evidence at Brunner, provide a graphic statement of the survival of successful, even if wasteful, industrial processes and their associated structures over time. They were readily transported from one country to another, even to the other side of the world.

THE BRUNNER COKE OVENS

The set of bee-hive coke ovens at Brunner was built over a period of 23 years. The first three ovens were located on the site of the original Brunner settlement. Within a year a further three ovens had been constructed. These ovens must have been front loading as no overhead structure shows on contemporary photographs. By 1884 there were twelve ovens producing 60 tons of coke per week. By 1899 a second bank of twelve ovens was built back-to-back with the first set. These ovens were all overhead charged, and stone-faced loading platforms appear in the photographs. The tall brick chimneys of the time appear to be associated with the collection of the exhausted gases, probably for heating, rather than for the extraction of tars and chemicals. In 1906 the main Brunner mine closed. Coal from adjacent mines kept the ovens in production at a reduced scale until the mid-1930's. Unused ovens were progressively demolished to provide bricks, or were vandalised. By the 1980's only three of the original 24 ovens remained substantially intact [8].

Much of the coke produced at Brunner was used locally, but considerable quantities were exported to Melbourne and New Caledonia for use in metal smelting. The doubling of the number of ovens in 1899 seems to have been prompted by the promise of a considerable market in Melbourne but this failed to eventuate.

CONCULSION

The Brunner site has survived, at least in part, because the land was not required for a subsequent industrial use. The buildings and structures were left to struggle for their survival against the barely resistible forces of nature, and the not so easily resisted human recyclers and vandals. Elsewhere, large complexes of ovens have disappeared as iron works have increased in size, and as the coal gas industry with its new technologies became more important. Yet even at Brunner the site and its structures are continually at risk. The plea made by Raistrick [4] for the preservation of oven complexes applies equally to all industrial heritage monuments - "It is to be hoped that while looking to the preservation of colliery remains, the coke ovens of all ages will not be overlooked. A bank of bee-hive ovens sometimes found near smaller collieries would be a valuable monument. Every year sees more of the few remaining examples swept away in the non-selective clearance of derelict sites". [4]

ACKNOWLEDGMENTS

Without the efforts of Brian Wood and Geoffrey Thornton within the New Zealand Historic Places Trust, the Brunner industrial site would probably not have survived. I would also fully acknowledge the researches and work of Brian Wood (history), Robyn Oliver, Janet Leatherby and Peter Morgan (archaeology), Lance Beckford (site development and management), and the members of the Brunner Site Committee of the New Zealand Historic Places Trust particularly Geoffrey Thornton. Nor should we forget the workers and their families whose hard labours and difficult lives built the Brunner Industrial Complex.

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Cocks Eldorado Dredge

R.G.SUPPLE,

B. Surv., Grad. Dip. U. & R. P., Post Graduate Student University of Melbourne,
Planning Officer, Historic Places Section, Department of Conservation and Natural Resources, Victoria.

SUMMARY
A brief history of gold dredging in Victoria is outlined to provide context for consideration of the Cocks Eldorado Dredge, which is the last surviving bucket dredge in Victoria and probably Australia. It was constructed in 1936 during a new phase of dredging in Victoria. The dredges built in Victoria about this time had increased capacity and incorporated design features from the large dredges developed in Malaya and elsewhere. The dredge mined gold and tin until 1954. Control of the dredge eventually reverted to the Victorian Government and options for its conservation are considered.

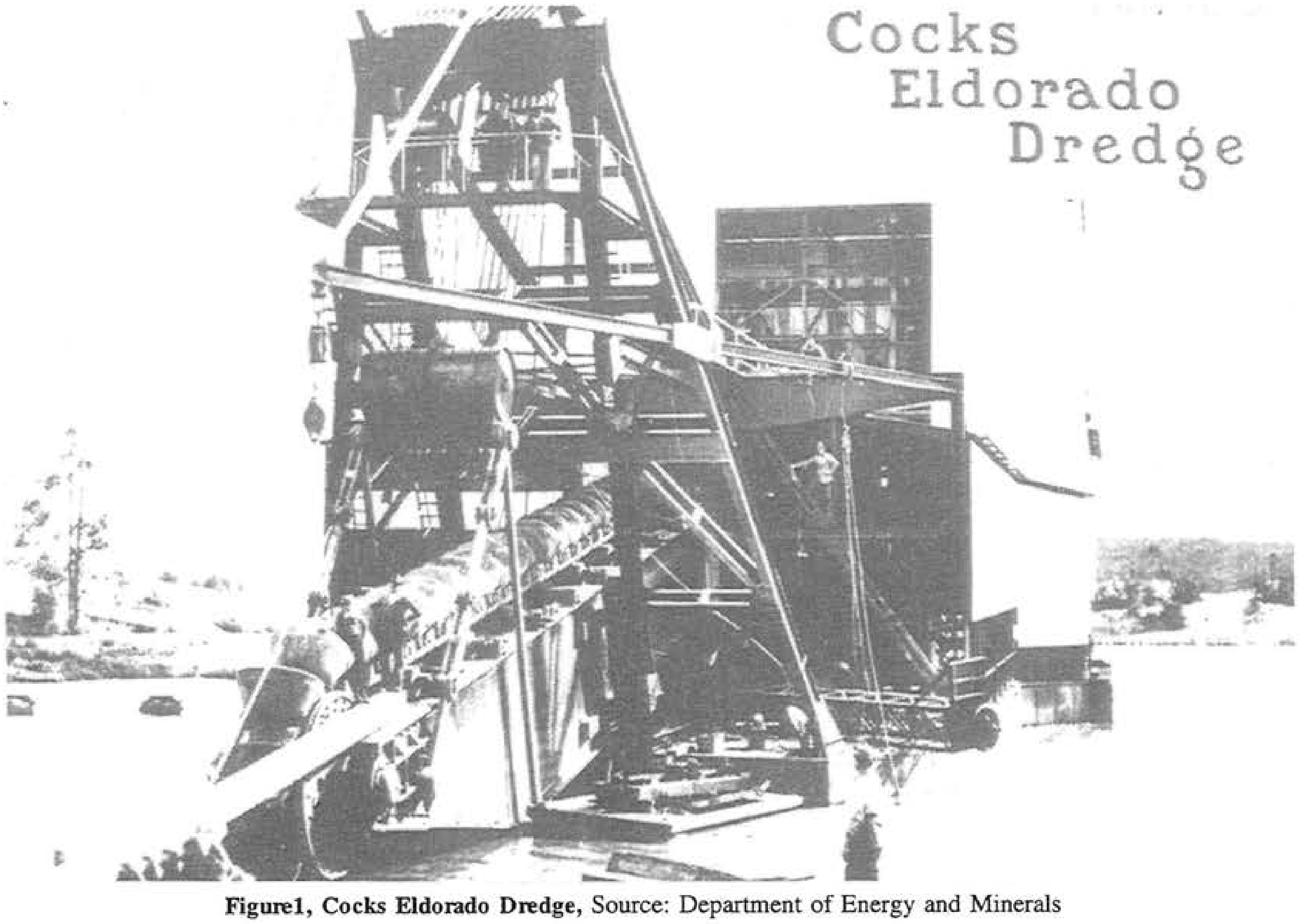

Figure1, Cocks Eldorado Dredge, Source: Department of Energy and Minerals

1.0 INTRODUCTION

Dredging of alluvial deposits was an important industry in Victoria from 1900 to 1914 and again in the mid 1930s. It was particularly suited to mining of the deep leads, buried alluvial deposits of gold and tin, at Eldorado in north east Victoria. Shafts were sunk to access the deep leads at Eldorado from 1860 to the late 1870s, and again in the 1890s. Dredging began at Eldorado in 1899 and culminated in the commissioning, in 1936, of the Cocks Eldorado Bucket Dredge, shown above.

2.0 MINING AT ELDORADO

Eldorado is situated on Reedy Creek 15 km north-east of Wangaratta and a similar distance from Beechworth. Surface alluvial gold at Eldorado was distributed across the Reedy Creek valley which widens out below Woolshed Gorge. Eventually Kneebone & Co. and McEvoy & Co. in 1860, and Wellington & Co. in 1866 succeeded in sinking shafts and locating the leads in the very wet and shifting ground. These companies were the only consistent gold producers on this field. Attempts by other companies ended in failure.

Yields were diminishing by 1870 and mining had stopped by the end of the decade. By which time the miners had proved that the ground was 180 feet deep with three false bottoms, each with a layer of washdirt, at depths of 30, 60 and 90 feet. Mining recommenced when the McEvoy shaft was reopened in 1890 and operated until 1901. In 1895 six miners were killed when water and sand swamped the lower workings of this mine.

In 1899 with the advent of gravel pumps Eldorado saw a resurgence of mining when the Cocks Pioneer Electric Gold and Tin Sluicing Co. began pump hydraulic sluicing. This company's plant consisted of a 340 kilowatt steam-powered generator which drove a 500 hp plant mounted on a barge. At the time it was one of only three electrically powered sluicing operations in Victoria. By 1912 the ground had become too deep for the company to work and operations ceased.

Then in 1914 the Cocks Pioneer Gold and Tin Mines N.L. Co. was formed to mine the area on a larger scale. It operated until 1929. Its plant consisted of two sets of high speed triple expansion engines driving three phase alternators. The alternators provided 1000 hp to barge mounted 14 inch gravel pumps and a nozzle pump via a three mile transmission line. Between 1899 and 1929 this mine treated 12,600,000 cu. yds. for a yield of nearly 100,000 ozs of gold and tin worth £175,000. In 1934 the Cocks Pioneer Gold and Tin Mines (1934) N.L. was formed. It took over from the previous company and by the following year was the second highest dividend paying mine in Victoria.[1] It paid the State Electricity Commission of Victoria to supply power to the mine which operated until 1942. During this period nearly 5,000,000 cu. yds of material was treated for a yield of 18640 ozs of gold and 260 tons of tin.[2] When this mine and the dredge were both operating, Eldorado was the third largest consumer of electricity in Victoria outside Melbourne.[3] The general arrangement of the Cock's Pioneer Gold and Tin Mines N.L. Co. mine in 1934 remained essentially unchanged from the previous mine. Operations involved the breaking down of the ground by hydraulic monitor up to a maximum distance of 700 feet from the barge, flow of pulp in channels along the floor of the open cut to the barge, elevation by gravel pump to the sluice boxes, further elevation of the tailings to a dam behind the barge from which water was returned to the nozzle pump supplying the monitors.[4]

The Cocks Eldorado Dredge N.L. Co. was formed in late 1934 to acquire and work some of the leases held by the Cocks Pioneer Gold and Tin Mines (1934) N.L. Co.

3.0 DREDGING IN VICTORIA

Dredging in the form of pump hydraulic sluicing commenced in Victoria in the 1887.[5] It was described in 1889 as a "novel principle of working alluvial flats and river beds" which involved pumping a mixture of water and gravel from a river bed and passing this mixture through sluices.[6] Difficulties were experienced in designing a gravel pump that could stand the wear and tear of the wash dirt. These difficulties were finally overcome and commercial operations commenced in 1892. Dredging in Victoria was more precisely defined in 1900 as the processing of large quantities of alluvium by pontoon mounted bucket dredge, pump hydraulic sluice, or jet elevator hydraulic sluice. Jet elevator sluicing plants were used when the head of water was great enough to produce a suction sufficient both to lift the wash from the sump to the sluice boxes, as well as to break down the face. Hydraulic sluicing plants used gravel pumps to lift the wash to the sluice boxes. These plants also used nozzle pumps if the head of water was insufficient to break down the wash.[7]

Bucket dredges were first introduced into Victoria in 1897 but did not operate successfully until 1900.[8] As early as 1901 there were concerns raised about disturbance to soil profiles and dredged areas being left in a state that was useless for agriculture or pastoral purposes.[9] Despite these concerns, some of which were well founded, by 1902 dredging had become an important industry.[10] Experience was showing that in order to achieve success the machinery had to be powerful and efficient enough to treat large quantities of wash dirt.

Modifications to bucket dredges were improving their ability to resoil dredged areas. This was a major challenge, because achieving this would open up more agricultural and pastoral land to dredging. Specialisation of design saw variations in treatment methods for dealing with different types of wash. Greater control of dredging was being exercised through legislation. Amendments to the Mines Act introduced requirements for settling dams which would keep sludge out of streams and placed restrictions on dredging of high value agricultural land.[11] In 1909 the Briseis Co. was the first company to satisfactorily use a conveyor to strip top soil and overburden material in advance and then deposit it on top of the course tailings at the rear of the dredge.[12]

Figure 2, Quantity of material dredged and gold won from 1900 to 1957. Note the quantity treated was not recorded for 1920 to 1930. Source: Mines Dept. Annual Report.

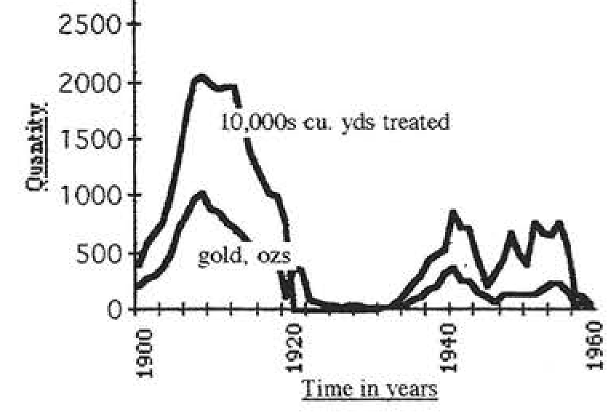

Figure 2 plots the quantity of material treated by dredges in Victoria and the amount of gold they produced. 1907 was pump hydraulic sluicing plants and 6 jet elevator sluicing plants. By 1912 the number of bucket dredges increased to 56, of these 47 were in north east Victoria. While the number of pump hydraulic sluicing plants, most of which were in central Victoria, declined after 1907.[13]

If the ground was suitable then bucket dredging was considered to be more economical than hydraulic sluicing. It was a cheaper way of moving ground. Conditions were more suitable for hydraulic sluicing where surface and bottom contours were irregular, or where the bottom was hard. Hydraulic sluicing was better suited for thoroughly cleaning up the bottom and was preferred where gold values were very high. Hydraulic sluices also had a 10% better recovery rate than bucket dredges which tended to spill a percentage of the wash.[14]

The number of dredges in Victoria declined during World War I. Following the war in 1925 the price of gold was brought back to the pre-war price of £4/4/11 per ounce and the mining industry was in a depressed state. However following the abandoning of the gold standard in 1932, and the fixing of the value of the £A there was a turn around. Costs were low and labour plentiful, these circumstances stimulated the gold mining industry.[15]

Australian Gold Development N.L. Co. was part of this new phase of mining in Victoria . It re-established the Cock's Pioneer Gold and Tin Mines (1934) N.L. Co. and also set up the Cocks Eldorado Dredge N.L. Co.

4.0 EVOLUTION OF THE MODERN BUCKET DREDGE

Dredging was introduced to the USA and South East Asia from New Zealand, and over the years dredges used in these countries were enlarged and constructed of steel. In Asia dredges were used for tin mining. They were increased in size to allow working at greater depth, and jigs were developed for use in the treatment plants. In the USA stackers with endless rubber belts replaced tray elevators, close connected buckets replaced the open link-connected type, and hexagonal upper tumblers and circular lower tumblers were introduced. In addition to these changes in design, electricity supplied by trailing cable became the normal power source, and the winch controls were elevated to a pilot house that gave greater visibility and better control.[16] The construction of the Eldorado Dredge brought the latest dredging technology into Australia.

5.0 COCKS ELDORADO DREDGE

The Cocks Eldorado Gold Dredging N.L. Co. was set up to mine ground which had become attractive for working by a modern electric dredge with the increase in the value of gold and tin. The ground was considered to be ideal for dredging because fine wash was located on soft false bottoms, the largest pebbles were 0.1 metres in diameter, the ground was friable and the timber had been removed.[17] The prospectus issued by the company estimated that the total value per cubic yard had risen from between 5d and 7d to between 9d and 12.6d. Profits were estimated to be between £258,750 and £335,271 over a period of between 11 and 13 years. The leases were acquired from the Cocks Pioneer Gold and Tin Mines (1934) N.L. Co. It was proposed in the first instance to try and acquire a second-hand dredge or if necessary build a new one. The dredge was to be capable of treating 1,000,000 cubic yards per year to at least a depth of 75 feet and to be fitted with jigs, the best means of saving both gold and tin.[18]

The dredge was designed by Mr. D. P. Fletcher, a consulting engineer with experience in dredge construction in the Federated Malay States. The design of the dredge was altered at his suggestion to allow digging to a depth of 90 feet, to increase the size of the buckets to 12 cubic feet, and to increase the capacity to 2,000,000 cubic yards per annum. The contract for construction of the dredge was let to Thompson's Engineering and Pipe Co. of Castlemaine and Williamstown in January 1935. Assembly of the pontoon commenced in June 1935 and was completed by November. The dredge was completed, tested and operating by 26 May 1936. It was handed over by the contractor to the company on 1 June 1936.[19]

The rise in gold values had prompted the re-erection of the old Adelong dredge in 1933 and another old dredge at Campbells Creek in 1935. These dredges were capable of digging to depths of 20 to 25 feet. The Cocks Eldorado Dredge was the first large modern dredge built in Australia. It is 210 feet long by 65 feet wide at the stern and 50 feet wide at the bow. The pontoon is 11 feet 3 inches deep at the centre and 10 feet 6 inches at the sides. It has 118 close connected 12 cubic foot buckets. The roof over the superstructure is 60 feet above the deck and the total weight of the dredge was 2080 tons. Initially 900 hp was required to operate the dredge. It was distributed between the 200 hp motor that drove the bucket band, and another 13 motors that ranged from 3 to 165 hp.[20]

It was almost completely constructed from Australian materials. When built it was the largest ever constructed in Australia. It included design features that were new to Australia. A water tight compartment at the lower end of the bucket ladder reduced its weight by 60 tons when it was working at a depth of 90 feet An air compressor maintained a pressure in the compartment equivalent to a 90 foot head of water. A Frenier pump, which did not need anyone to control it, was used instead of a gravel pump to elevate to the screens any material that spilt from the buckets. Jigs were employed as the sole means of saving the minerals because of their compactness, continuity of operation, minimal labour requirements, and their proven ability to recover both gold and tin. Provision was included for sand tailings to by-pass the sand chutes and be elevated by gravel pumps capable of stacking tailings 40 feet high and 75 feet behind the dredge. This last feature allowed greater manoeuvrability and digging to greater depths.[21]

the year in which the greatest number of dredges were working in the Victoria. There were 49 bucket dredges, 89 pump hydraulic sluicing plants and 6 jet elevator sluicing plants. By 1912 the number of bucket dredges increased to 56, of these 47 were in north east Victoria. While the number of pump hydraulic sluicing plants, most of which were in central Victoria, declined after 1907.[13]

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Year	Treated, yds³.	Gold, ozs	Tin, tons	Value of gold, £s	Value of tin, £s	Dividend, £s
1936	239600	144	5	1156	1400	0
1937	427800	395	8.5	3145	1618	41250
1938	1728425	8542	149	73874	25140	55000
1939	1786794	5491	134	57770	25924	13750
1940	2139235	6630	109.25	69914	22467	41250
1941	2400640	3476	71	36788	15690	6875
1942	2286900	4859	82.6	50513	18954	20625
1943	2262700	3431	60.1	35597	14162	6875
1944	193600	3254	55	33930	12835	6875
1945	1761760	2042	42	21618	9869	0
1946	1750000	2786	64	29543	14917	0
1947	1936000	3047	87	32406	25397	10312
1948	1880340	2933	54	31194	20695	0
1949	1560120	2512	49	26716	20109	6875
1950	1810160	1760	40	27121	21327	0
1951	1773700	2357	50	36321	35252	0
1952	1897400	3091	52	47631	42218	0
1953	1973400	2389	31	36814	22756	10312
1954	1686400	2124	36	32966	24114	0

Table 1. Production figures Cocks Eldorado Dredge, Source:Department of Mines Annual Reports
Note: The total gold production listed by the Mines Department does not tally with the sum for the individual years.

The movement of the dredge was controlled by a head line from the fore gantry and by side lines from each of the four corners of the pontoon.

Material from the buckets dropped into an inclined revolving screen which separated the oversized material for discharging into the pond. The finer material passed through the screen and was conveyed into jigs for rough concentration. The concentrates were taken to shore where the gold was extracted through amalgamation with mercury, and the tin was concentrated using jigs, wilfley table and magnetic separator.[22]

Throughout its working life the dredge had to cope with slum from previous mining, and during its initial 10 years the buckets were changed three times. Lack of water in the summer months delayed operations until sufficient water storage was acquired in 1941. Shortages of supplies and labour during World War II caused some delays but also forced the company to become more self sufficient. Additional settling dams had to be built from time to time. These had to be kept isolated from the creek, as did the paddock in which the dredge operated. Other repairs and modifications included replacement of the top and bottom tumblers on at least one occasion, periodic strengthening of the bucket ladder, repair and/or replacement of some motors, a new 320 hp motor for the bucket band was installed in 1939as was a new switch board and the continual reconditioning of the buckets by electric welding or by fitting and welding lips from discarded buckets.[23] A report in 1973 on the condition of the dredge by Griffin, McSweeney & Co. commented that the design was generally a practical one. However it did identify evidence of some of the repairs that were reported in the Superintendents Annual Reports and attributed some to the construction which it described as rough and strangely light.[24]

Despite the repairs, the dredge was the second most productive bucket dredge in Victoria. Table 1 details the amount of material treated by the dredge and the yields it obtained. It is the second largest ever built in Australia. It produced more than 70,000 ozs of gold valued at £750,000 and 1180 tons of tin valued at £375,000, a total £1.1 million from which dividends totalling £220,000 were distributed.[25]

Following the suspension of operations, the dredge was held on a care and maintenance basis. The company intended selling the dredge or finding another suitable dredging opportunity. Neither of these eventuated and the dredge has not moved from the pond in which it was moored.

6.0 CONSERVATION

The dredge was listed on both the State Register of Historic Buildings and the National Estate Register in 1975 which prevented it from being altered or removed. Control of the dredge reverted to the Department of Energy and Minerals in 1984 who in turn transferred it to the Department of Conservation Forests and Lands in 1988.

The dredge has gradually deteriorated since it ceased operating. The electrical switching in the control room has been vandalised and some of the corrugated iron has been removed from the roof. The deterioration of the pontoon is the greatest concern. The superstructure is still above water and in good condition. However the pontoon is continuing to deteriorate. The dredge, partially filled with water, was eventually swamped during a flood.

Investigation of the condition of the pontoon revealed that it is stuck on the bottom of the pond. It is heavily corroded and has some large holes in the rear compartments.

Despite its condition, a report by a naval architect indicated that there was no technical reason why the dredge could not be refloated. A Draft Conservation Study, being prepared for the Department of Conservation and Natural Resources, has developed management options ranging from doing nothing to using cathodic protection to stop the pontoon deteriorating, to raising the dredge and sitting it on a bed of gravel so that the deck is fully above water. These options range in price up to $0.5 million.[26] A decision on how the dredge will be managed needs to be made soon. If the pontoon is allowed to deteriorate it could collapse within 10 years.

Our challenge in managing the dredge is to demonstrate that it is very significant and extremely important for educational and tourism purposes. Important enough to warrant the commitment of resources which will ensure its long term conservation.

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GONE WITH THE WIND

The Development of Windmills and their Use in New Zealand

Ian Jonson, Member, The International Molinological Society
Board Secretary, New Zealand Historic Places Trust

Introduction

The purpose of this paper is to introduce molinology to participants, to briefly describe the development of wind powered mills and to outline the use of windmills in New Zealand.

Part 1. What is Molinology?

Molinology can be the description and the study of mills or other mechanical devices, using the kinetic energy of moving water or wind as a motive power for driving grinding, pumping, sawing, pressing and fulling machines. More particularly molinology aims at the knowledge of those traditional engines which have been condemned to obsolescence by modern technical and economic trends, thus being a chapter in the history of technology and part of the history of civilisation. The word is a hybrid of MOLINUM; a low-latin word extensively adopted in Romanised Europe for mills in general, and the known Greek suffix LOGOS - discourse - in the usual form LOGIA - knowledge of. Molinology as a mental discipline and a field of research should survey and collect all data referring to windmills and watermills as a whole - terminology, technology, ecology, ethnology, economy, history, jurisdiction, protection, preservation and restoration as well as their aesthetic values - in order to determine their origin and evolution, their economic and social role, their human technology and, thus, their ethnological importance. The comparative study of windmills and watermills will bring a new light to the knowledge of the intercourse of civilisations.[1]

Part 2. Types and development of windmills

Development

There is a lot of debate about the emergence and development of windmills but here is a broad outline. The earliest recorded windmills were in Seistan, a border district between Persia and Afghanistan. These windmills could with certainty be ascribed to the tenth century, but tradition from that time suggests that they already existed in the seventh century. The windmills found in Seistan differ from the types common in Europe in that their sails are set horizontally in a circular formation.[2] As the technology spread through Europe localised models developed to suit the local conditions. The earliest references to post mills are to those in Normandy (1180) and England (Yorkshire 1185 and Suffolk 1191).[3] The fantail was invented by Edmund Lee in 1746, the patent sail with automatic control by Cubitt in 1807. The earliest known reference to a tower mill in England comes from a Pipe Roll of 1294 - 95, and refers to a "stone windmill" newly-built in Dover Castle, Kent.[4]

Types

Windmills can be recorded as different types by the way they are turned into the wind:

Fixed Mill: These windmills have no method by which they can be turned into the wind.
Post Mill: Windmills built on a large wooden post, on which the whole body of the mill rotates.
Smock Mill: A tapered wooden tower that has 4, 6, 8 or 12 sides, topped by a cap that turns into the wind. The shape is named after the old English shepherd's smock.
Tower Mill: Conical in shape, built of brick or stone with a cap that turns into the wind.

Sails

The sails are of three types:

- common sails with canvas spread over a wooden frame requiring manual adjusting,
- patent sails similar to venetian blinds with self adjusting mechanism,
- annular sail (like those used on farm wind pumps) features on only three windmills other than pumps.

Winding

The winding mechanism (which turns the mill into the wind) can be described as either:

- tailpole, where the mill or cap is moved into the wind by man or animal using a long pole from the cap, or
- fantail, where the mill structure does not usually rotate, but a fantail is attached to and turns the cap into the wind.

Part 3: Use of windmills in New Zealand

There are three broad categories of windmills in New Zealand:

- Wind powered flour and other mills: The 31 mills in this category are the topic of this paper.

- Farm wind pumps: These pumped water for farm and other use. Kiwis call them "windmills". Research to date shows about 20 local and 10 overseas manufacturers and 40 models. It is likely that more than 15000 were built, only a few hundred, mostly derelict, remain today.

- Railway wind pumps: These pumped water for locomotive and other use; 116 sites are recorded so far.

The pumps are not part of this paper as they were invented in the USA after the initial settling of New Zealand and are therefore not old ways in a new land.

Windmills were built in New Zealand to mainly grind wheat into flour.. Early pakeha settlers consumed flour as one of the key portions of their diet, just as we do today. Because of the undeveloped transport system, travel was arduous and uncertain making flour an expensive commodity. Wheat grew readily, so to solve the high cost of transport problem, people built flour mills all over New Zealand. At least 28 wind and 270 water powered flour mills were built as well as at least 77 steam ones. If water was available a water mill was built as energy can be stored in the mill pond; whereas a windmill can only operate on windy days. It was the lack of reliability of windmills that lead to their demise.

Commercial windmills were built where an area was dry and had no suitable water power site, or where the settler arrived with windmill machinery. Self sufficiency mills were where the settler had the difficulty of readily procuring flour and built a windmill to grind their own. Nearly all the builders of windmills came from Britain.

All of the windmills built were technically outmoded as a steam powered flour mill had been built in Wellington in 1841, before the first windmill.

The first windmill to be built in New Zealand was the Te Aro Windmill of Messrs Simons and Hoggard, Wellington, where construction was under way by March 1843, with the mill being opened in April 1844. The last traditional-sailed windmill to be built was that of Parr Bros of Timaru in 1871; a very up to date windmill with five sails to give smoother power.

By the end of the 1880s only Partington's in Auckland remained operational. This brick tower mill was the only windmill in New Zealand to be increased in height, although it still did not reach the height of the Oamaru windmill. Partington's was the longest operating - 90 years - from 1851 to 1941. In fact, for 53 years from 1888 it was the only operating commercial wind powered flour mill in New Zealand. The only in situ remains are at Oamaru.

Some commercial operations, like the big tower mills of Partington's, and at Oamaru and Timaru were successful operations, but there were failures too. Mr Eliot spent £3,000 in the early 1850s to build a steam and wind mill at Richmond. This mill was incorrectly assembled and failed because the stones were driven backwards.

A mill built with settler ingenuity is well illustrated with the two Gisborne windmills being clad with flattened four gallon tins.

Hayes Engineering at Oturehua Central Otago also showed this settler ingenuity by powering the workshop with a large annular sailed windmill from 1910 to 1927. An oil engine was used on standby. In 1912 they started producing wind pumps - windmills making windmills. This is the only known example in the world of a wind powered workshop.

Conclusion

Windmills played an important part in the development of New Zealand by providing flour until transportation developed allowing flour to be produced by the cheaper and more reliable steam mills. No windmills remain in their entirety. Only a portion of the first course of the Oamaru windmill survives.

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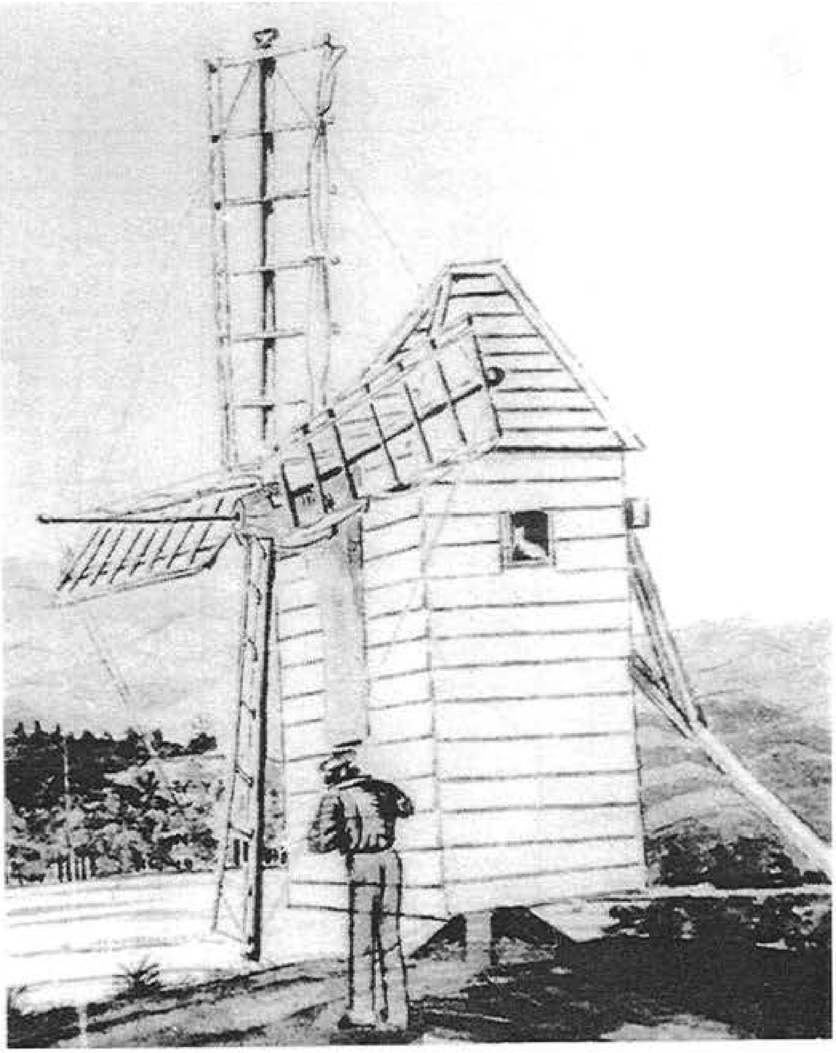
1 Transactions of the First International Symposium on Molinology, 1965, p41.
2 Ibid, p 87.
3 Transactions of the 3rd Symposium of Molinology, 1973 p33.
4 Ibid p 34.

Table of New Zealand Windmills

Location	Purpose (a)	Sails (b)	Product	Type	Built	Last Worked	Demise
Auckland-Eden	C	?	flour, bone	tower	1844	1863	1952
Auckland-Partington's	C	4P	flour	tower	1851	1941	1950
Brightwater	SS	?	flour	?	1845	1850s	?
Chatham Islands	SS	?	flour	?	1847	c1867	?
Christchurch	C	4C	flour	smock	1856	1861	1862
Edenham	SS	4C	flour	post	1854	c1860s	?
Gisborne 'A'	SS	4C	flour and poultry grit	fixed	c1910	?	?
Gisborne 'B'	SS	4C	firewood	fixed	1918	?	c1940
Heathcote	C	?	flour	?	1853	1850s	?
Kelso	C	A	flour	tower	1881	1887	1887
Koromatua	SS	4C	firewood, tool sharpening & corn grinding	post	1940s	?	?
Leithfield	C	4C	flour	smock	1863	1880	?
Little AkaloaSS	?	flour	?	1852	?	?	
Lower Hutt	C	4C	flour	smock	1845	1849	?
Mangungu	SS	4	flour	fixed?	c1850	?	?
Nelson	C	4	flour	smock	1852	1863	1867
New Plymouth	C	A	bone	annular	1880	?	?
Not known - C B Hill	SS	6C	flour, chaff	post	c1891	?	?
OamaruC	4P	flour	tower	1866	1886	1909	
Okains Bay	SS	?	flour	?	?	?	?
Oturehua	C	A	engineering	workshop	1910	1927	1927
Porirua	SS	?	flour	?	?	?	?
Richmond-Eliot	C	?	flour	?	c1853	1855	?
Richmond-Hulke	C	?	flour	?	?	?	?
Russell	C	4	flour	?	1858	1870s	?
Te Ahu	SS	?	flour	?	c1848	?	?
Timaru	C	5P	flour	tower	1871	1888	?
Waimate North	SS	?	flour	?	?	?	?
Wellington	C	4C	flour	smock	1844	c1849	c1849
Whangarei	SS	4C	flour and poultry grit	fixed	?	?	?
Whangarei Heads	SS	4	flour	post	c1864	?	?
Wharehine	SS	4C	flour, maize	smock	1860s	c1930	?

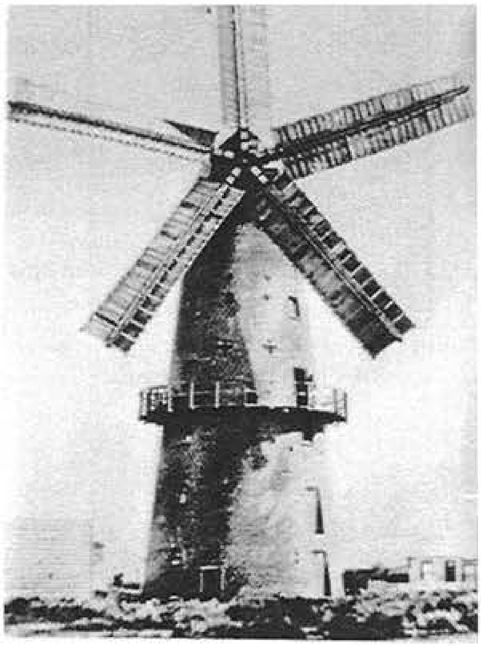
Notes: (a) C = Commercial Operation SS = Self Sufficiency
(b) Sails: P = Patent C = Common A = Annular

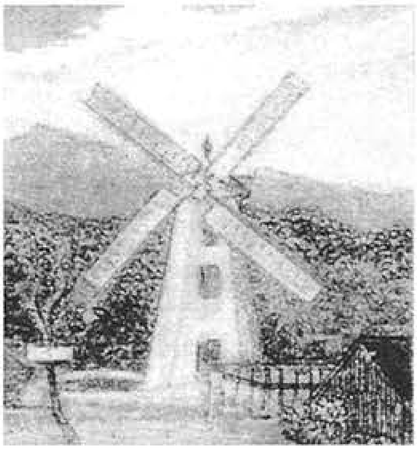
The Three Windmill Types



1. Edenham Windmill, Hawkes Bay. This self-sufficiency **post mill** shows the quarter bars, visible underneath the body of the mill, which support the post on which the whole body of the mill turns. On the right is the tailpole, used to manually turn the mill into the wind. The canvas on the four common sails is furled while the mill is not working. Chapman diary, collection of Hawke's Bay Cultural Trust, Hawkes Bay Museum, Napier.

2. Parr Bros Windmill, Timaru. A brick **tower mill** showing the five patent sails and the staging Noel Crawford, Cave.



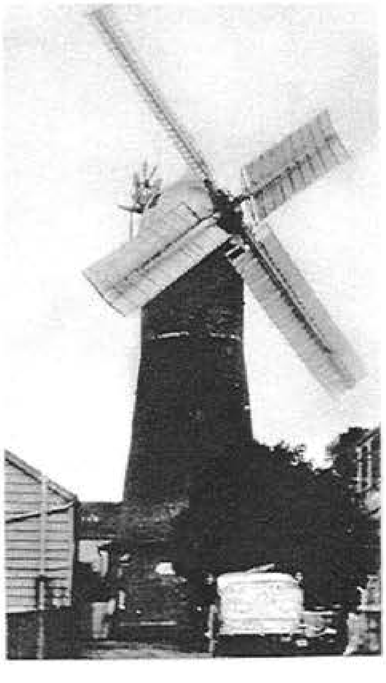


3. Lower Hutt or Newry windmill The typical tapered shape of the wooden smock mill.S C Brees, c1847, (detail - Mr Molesworth's Farm at the Hutt. Alexander Turnbull Library

New Zealand - Specific Windmills

4. Gisborne windmill "A".
A self sufficiency windmill with sides clad in flattened four gallon tins, sails furled and no visible winding mechanism. A good example of settler vernacular construction. Gisborne Museum.

5. Hayes Engineering, Oturehua. The largest annular sail in New Zealand at 22' diam. Centre left is a Hayes "New Idea" wind pump, above the left door is a large unidentified windmill. The workshop survives and is a New Zealand Historic Places Trust property open to the public. NZHPT.



6. Partington's windmill, Auckland.
Notice how the tower tapers to it's original height then rises vertically where it was extended. The fantail turned the four patent sails into the wind. The battle to try and save this windmill in 1950, along with the destruction of other heritage structures, lead to the formation of the New Zealand Historic Places Trust.

A NEW WAY IN AN OLD LAND

AUSTRALIA'S FIRST RAILWAY

D C KEMP BTech, FIEAust, CPEng.

SUMMARY

The paper briefly overviews early means of transportation in Australia and looks at the introduction of railway. Reasons our outlined for the construction in South Australia of the railway from Goolwa on the River Murray to the seaport at Port Elliot and its subsequent extensions to Victor Harbor and the town of Strathalbyn. The railway is briefly described and positioned in perspective with others. The significance of the Goolwa-Port Elliot railway is established with the concluding statement classifying it as Australia's first full scale railway.

INTRODUCTION

The word "way" has its route in the concept of "moving" or "travel" and with many meanings related to a manner, method or means. There are numerous extensions of the meaning in connection with other aspects of human endeavour. This paper briefly overviews land transport in Australia and establishes the significance of the railway in South Australia between Goolwa on the River Murray and the seaport at Port Elliot. The location of the railway is shown in figure 1.

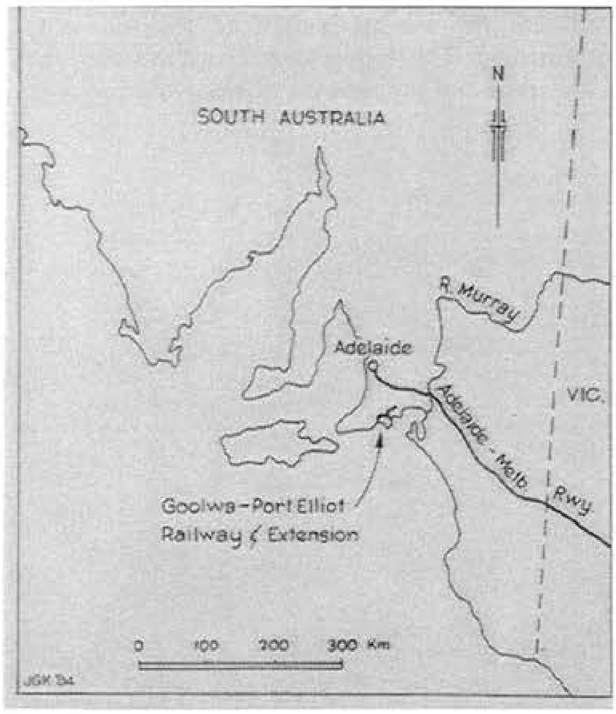


FIGURE 1 SOUTH AUSTRALIA

THE FIRST WAYS

It is likely the first pathways were formed by animals moving through vegetation for food, water and migratory needs. In the fullness of time these ways were adopted, improved and co-ordinated by human travellers as civilisations developed. Religion, war, administration dominance and trade provided the impetus for new and better transport routes.

Transport was initially by foot on footways or footpaths, subsequently animals were used for carrying freight leading to pack transport or summage. This was followed by the use of the sliding sled and after the invention of the wheel in Mesopotamia around 5000 BC, the development of wheeled carts and cartage on wider cartways.

Transport speed by bullock or oxcart at 4 km/hour increased to 30 km/hour for horse drawn vehicles and even with the remarkable Roman road network constructed some 2000 years ago transport speeds were not bettered until the development of the railway and the steam engine during the nineteenth century.

In Australia prior to arrival of Europeans there was a network of Aboriginal footways. In some instances these footways remained viable with their routes followed today while new ways were also formed to new destinations and to suit modes of travel. Transport over land in Australia in the nineteenth century was predominantly by horse drawn vehicle for passenger travel and bullock wagon for freight. When considered against the nature and length of roads the introduction of railway provided a cost effective and efficient transport system.

Additionally, railway by comparison with the unsealed and unmade roads gave a 10 fold or more reduction in vehicle rolling resistance.

THE NEED FOR A RAILWAY

Australia's Murray, Darling and Murrumbidgee Rivers and their tributories traversed a significant portion of the settled inland regions of the south eastern part of the country. While the river system makes a meandering course steamers and barges could overcome the problems associated with the slow, uncertain and expensive transport of freight by road and also carry bigger loads.

South Australia's Governor Henry Young in office for the period 1848 to 1854 was keen to capture for South Australia the whole of the river trade from the interior of eastern Australia. The River Murray and its tributaries which rose as far afield as Queensland, discharged into the sea at Goolwa on the southern coast of Australia. The topography along the eastern coast of Australia and the absence of easily trafficked routes from inland regions to the sea made the River Murray an attractive transport route and to secure the river trade for South Australia it was necessary to overcome the problem that the Murray mouth at Goolwa was not navigable to either river boats or Ocean going vessels.

The engineering solution was the construction of a railway from a river port at Goolwa to a harbour at Port Elliot, thus making the vital link between river and the ocean. It was also essential to do so before the river trade was tapped by the neighbouring colony, Victoria!

DESCRIPTION OF THE RAILWAY

The Goolwa - Port Elliot railway was the first part of an engineered railway system with two subsequent main extensions to Victor Harbor and Strathalbyn. Interestingly the first plans to appear in South Australia's Parliamentary Papers are those associated with the first stage of this railway and were included in Governor Young's Dispatch No. 56 of 6 April, 1850. The plan for this railway is shown in figure 2.

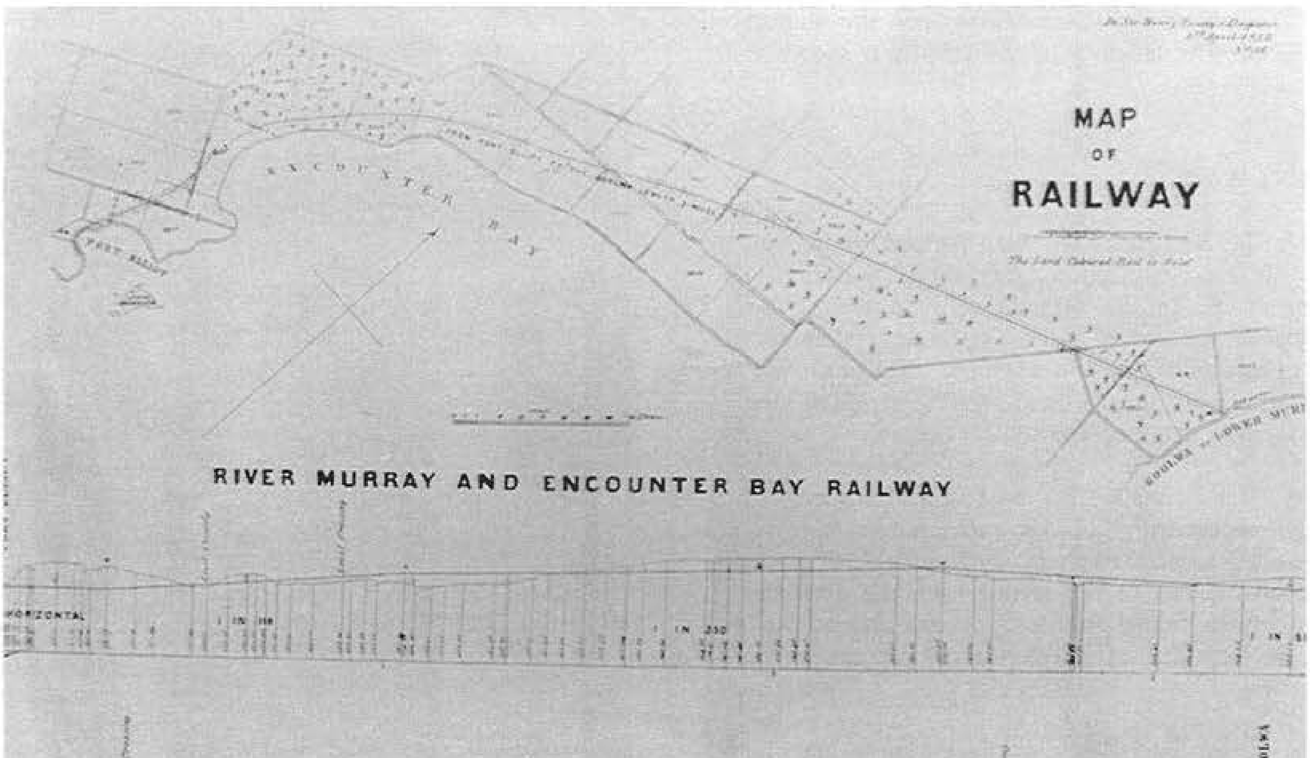


FIGURE 2 MAP OF RAILWAY. SIR HENRY YOUNG'S DISPATCH NO. 56, 6 APRIL 1850

Goolwa - Port Elliot Section

Construction for this railway commenced in 1851. The initial works comprised jetties at Goolwa and Port Elliot, a stone breakwater to provide a "safe" anchorage for shipping at Port Elliot, cuttings at Port Elliot and Goolwa and seven miles (11 km) of interconnecting railway track. The line led from the jetty at Goolwa by the most direct route in a south westerly direction and onto the jetty at Port Elliot. The line was originally conceived for working by steam locomotion with "curves and gradients as well as gradients adopted in the section, are entirely with reference to working of the line by locomotive power". The line was opened, however, using animal power on the grounds of economy. For the same reason the gradients in cuttings at each end of the line were steepened from the 1:100 grade limit originally designed.

The initial rails were 40 lb/yard T section laid at 5'3" gauge on cross sleepers at 2 ft centres. Importantly this rail gauge was established in line with the recommendations of the British Gauge Commission with the agreement of the colonies of New South Wales and Victoria to facilitate the subsequent interconnection of the then proposed separate railway systems. New South Wales, after a change of engineer, subsequently adopted 4ft 8½ inches while South Australia and Victoria honoured their original agreement. That the government of the day took the question of rail gauge seriously is shown by the Legislative Council proceedings in 1853. They proposed to "memorialise the Home Government to disallow that portion of the Sydney Railway Bill which rules that the gauge of the Sydney railroad to be 4 ft 8½".... it seems desirable that one uniform gauge should prevail throughout all Australia".

The first paddle steamers onto the Murray had gone up river in August 1853 with the Governor being anxious that upon their return to Goolwa cargo be immediately transhipped by rail to Port Elliot. In December 1853 with six miles of track completed and work still in progress on the Port Elliot cutting, the line was placed into service. Bullock drays were used to bridge the gap to Port Elliot. The line was completed by 18 May, 1854 although it was never officially opened.

Rolling stock comprising one passenger car and 11 goods trucks were used in the beginning increasing to a maximum 13 passenger cars and 104 goods trucks (1879) before the line was converted to steam operation (1884).

The railway was constructed and operated as a Government undertaking. The British Commissioners of Railways in a report at the time construction commenced stated "according to the system adopted in this country (England), and as far as the Commissioners are aware, in the Colonies likewise, the construction of railways has been left to private enterprise". On the basis of this statement it is reasonable to assert that the Goolwa-Port Elliot railway is the first Government railway in the British colonies.

Port Elliot - Victor Harbor Extension

The difficulties with using Port Elliot as a harbour soon became apparent with 7 ships at anchor being wrecked there by 1864. A safer harbour was needed with Victor Harbor being chosen.

In 1862 work commenced on the construction of a jetty and pier at Victor Harbor. The railway line was diverted from the northern side of Port Elliot (before the cutting) and was extended to the new port at Victor Harbor and was opened for traffic in April 1864.

The line extension, as shown in figure 3, of 4 miles 30 chains (7 km) passed through Port Elliot (where a new station was built) and was constructed using lighter 35 lb per yard rail. It also incorporated two bridges.

Watson's gap bridge built in 1906 to replace the 1863 timber structure is a 32 ft (10 m) span arched reinforced concrete structure.

The Hindmarsh River bridge erected in 1907 to replace the 1863 combined road and rail bridge is also of reinforced concrete with five spans built on the beam and slab principal.

Strathalbyn Extension

As a result of pressure from the people of Strathalbyn and adjacent country areas for connection to a sea port, work commenced in 1866 on a railway line from Strathalbyn to interconnect with the existing line at Middleton between Goolwa and Port Elliot. By December 1868 the first 10 ½ miles (17 km) from Middleton was opened for traffic with the whole line of some 21 miles (34 km) being officially opened by Governor Fergusson on 23 February, 1869 with the first shipment of wheat being carried in the same month.

The structures and earth works in this line extension are most significant with bridges at the Finniss River, Black Swamp and Currency Creek along with culverts at other locations. The Currency Creek viaduct of seven spans and 76 feet (23 m) above the creek bed is the highest railbridge in South Australia. The newspaper of the day reported that "the railway was admirably constructed with rails, sleepers and ballasting quite sufficient to carry locomotives" in line with the design philosophy for the original section of railway line.

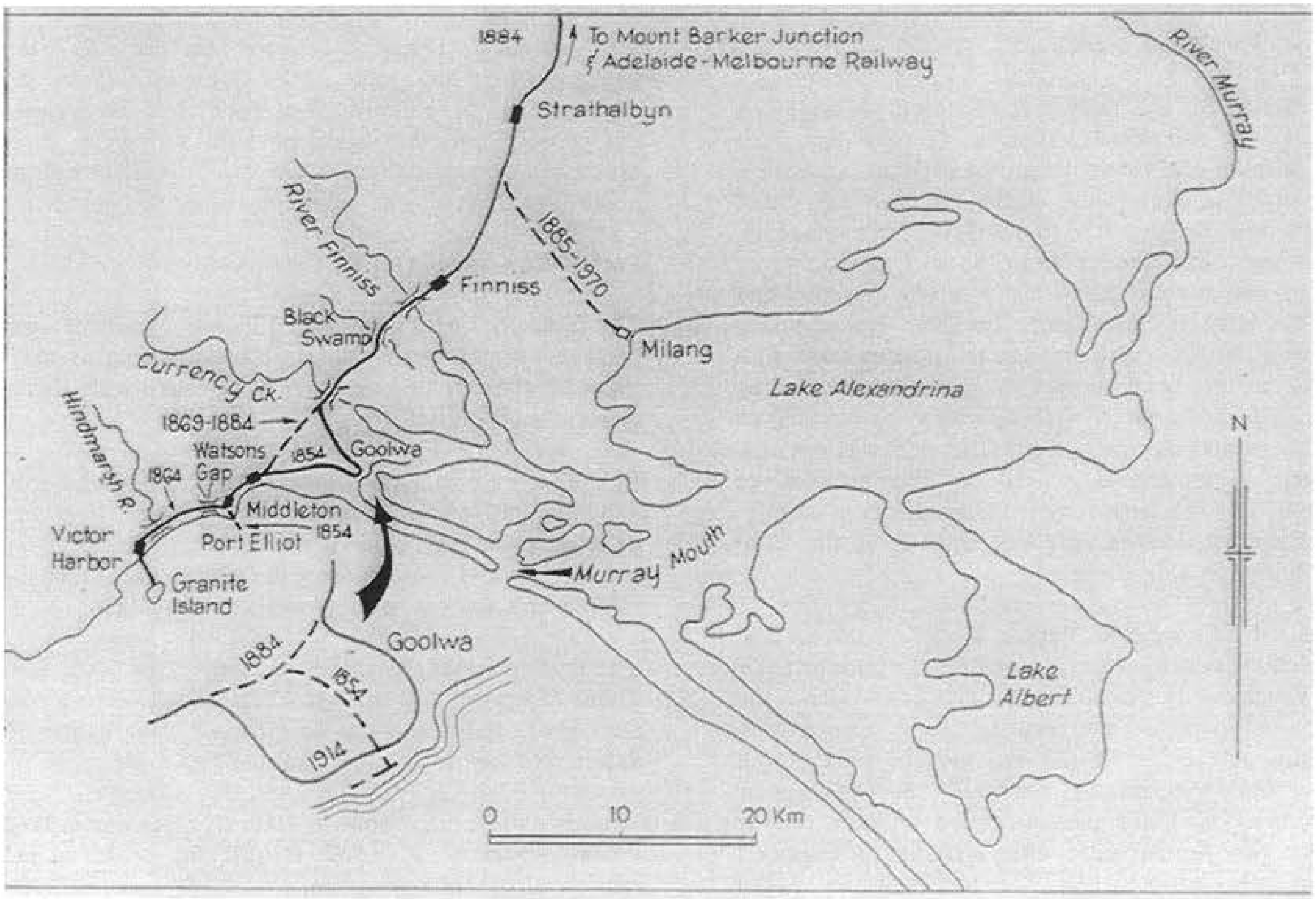


FIGURE 3 GOOLWA-PORT ELLIOT RAILWAY AND EXTENSIONS

DEVELOPMENT OF THE RAILWAY

In the animal powered era using horse traction, stables for the line were constructed at Strathalbyn, Finniss, Goolwa, Middleton, Port Elliot and Victor Harbor. Goods sheds were erected at Strathalbyn, Goolwa, Port Elliot and Victor Harbor with running sheds also at Strathalbyn and Middleton. Passenger shelters were also provided with the last of those associated with the animal powered era being demolished at Finniss in April 1980.

In the pioneering era for the railway from 1853 to 1884 the line handled 253156 tons of freight and carried some 639140 passengers.

By November 1883 the inter colonial railway from Adelaide to Melbourne, then under construction, had reached Nairne. Building of a line from Mt Barker to Strathalbyn then proceeded, being opening in September 1884.

With the introduction of steam locomotives in 1884 the present railway complex at Strathalbyn was constructed and became the largest railway centre on the line. Along with upgrading of facilities at the other stations steam locomotion was introduced as far as Goolwa in December 1884 and to Victor Harbor in April 1885. Concurrent with the use of steam a branch line to Milang on the shore of Lake Alexandrina was opened. The original structures remained without alteration until the replacement of the bridges on the Port Elliot-Victor Harbor section at Watson's Gap and Hindmarsh River. These new bridges are believed to be the first reinforced concrete bridges in South Australia.

Rail for the line has been progressively upgraded from the original 35 and 40 lb/yd to 41 lb, then 60 lb and 80 lb in 1926 to suit increasing train weight while in 1958 94 lb line was laid at Victor Harbor.

With the introduction of larger and heavier steam locomotives during the reign of Railway Commissioner Webb in the 1920's in a major rejuvenation of the railway system, the various bridges on the line between Strathalbyn and Goolwa were upgraded by either replacing the bridge spans while retaining the original masonry abutments and piers or by constructing new bridges adjacent the existing.

After the advent of steam the method of working the line used the permissive block system which was followed by the electric staff system introduced in 1914. As part of the development of the line, the current main line switch stands with their indicators were installed in 1926 when train order working was introduced. This was another innovation first introduced in South Australia on this line.

The Strathalbyn line in 1884 was diverted from Middleton to connect with the Goolwa-Victor Harbor section at a new junction, the Goolwa junction, to the north of the township. To avoid the necessity to "back" trains into the Goolwa station the Goolwa loop was constructed in 1914 to provide a "through" line from Strathalbyn.

The route of the permanent way today is substantially the original route. Apart from changes at the original termini of Goolwa and Port Elliot the route has proven satisfactory.

Commercial operation of the railway ceased in April 1984 on the eve of the centenary of the line's conversion to steam operation. Since then it has run as a tourist railway.

RAILWAYS IN PERSPECTIVE

Railways might be defined as having the five characteristics of utilising a specialised track, acceptance of public traffic, carriage of passengers, a measure of public control, and mechanical traction. To this definition can be added the scope for development and expansion of the system.

The first railway in the world meeting the majority of these criteria was the Surrey Iron Railway opened in England in 1802 to provide access to a quarry as well as to carry goods and passengers over a route unsuitable for a canal. By 1825 the English Stockton & Darlington railway was opened using steam locomotives for freight haulage and animal power for passengers. This railway was followed by the Liverpool & Manchester railway in 1830. By the mid 1840's railway mania was at its height with some 6800 miles of railway having been opened in the United Kingdom by 1851.

In the United States of America the English developments were soon copied with the animal powered Maunch Chunk railway in Pennsylvania being open in 1827. Steam power was first used on the Baltimore - Ohio railway in 1830 while iron rails were first used (and at 4 ft 8 ½" gauge) on the Western Railway in Massechussetts in 1837.

During 1827 to 1831 the transporting of coal by railway the short distance from the coal pits to Newcastle Harbor was Australia's first transport system using specialised track. While iron rails were used at Newcastle the Norfolk Bay to Port Arthur line in Tasmania was opened in 1836, used wooden rails and was hauled by convict labour.

The Melbourne and Hobsons Bay railway from Flinders Street Melbourne to Sandridge of some 2½ miles used steam locomotives from inception and was opened in September 1854. New South Wales followed just a year later with the railway from Sydney to Paramatta, while South Australia opened its second railway from Adelaide to Port Adelaide in April 1856.

The first Queensland railway from Ipswich to Grand Chester was opened in May 1865. Tasmania's first full scale railway from Launceston to Deloraine was opened in February 1871. By July 1879 the Geraldton to North Hampton line was opened in Western Australia while lines into forests (for logging) had been opened some 8 years earlier. The first line in the Northern Territory from Palmerston to Pine Creek was opened in October 1889.

In paralled with Australian activities, railways in New Zealand were being constructed. The 5'3" gauge line between Christchurch and Terrymead was opened in December 1863 using locomotives imported from Victoria while the Dun Mountain tramway was in operation nearly two years earlier.

The Goolwa to Port Elliot railway completed in May 1854 is thus the first full scale railway in Australia with the isolated railway ultimately being connected into a national railway network.

STATEMENT OF SIGNIFICANCE

The railway from Strathalbyn to Victor Harbor is of immense cultural significance because of its identification with some of the earliest and most important features of the history of South Australia. Moreover it is of national significance because it was the first full scale public railway to be built in Australia and the first Government railway in the British Colonies.

It was identified with the foundation and development of the river trade, and the associated inter-colonial rivalry with Victoria for the control of this trade. The railway was built so that the river traders could have access to a deep-sea port, and thereby reflects features of the early history of this trade. The construction of the line from Strathalbyn to Middleton, which was also built as a horse-powered railway was the result of lobbying by the inhabitants of the hinterland to have access to a seaport, and illustrates something of the nature of the issues with which early governments had to contend.

The Goolwa-Port Elliot section is significant also in that it marks the first use of 5 ft 3 inches gauge then planned as the uniform gauge of Australia. With the extent of 5 ft 3 inches broad gauge line in service currently being reduced due to conversion to standard gauge or being abandoned, this line, being used as a tourist railway will increase in significance.

The original railway has undergone several changes.

However, these very changes mark significant stages in the history of the railway, and indeed, sufficient remains of the original alignment to permit the interpretation of this history.

The railway is significant because it illustrates the major features of South Australia's railway history, and the technological changes which took place from time to time. What had been an independent system was linked to Adelaide in 1884 and subsequently the line to Melbourne thus being connected to a national rail system. Then, during the nineteen-twenties much of the system was upgraded in the programme undertaken by Railway Commissioner Webb. the railway retains features which were identified with each of these changes, from the horse-powered railway period to the advent of steam, the Webb revolution and the change to diesel. Indeed the line must be seen as a transport route evolving as an engineered system illustrating changes in use of materials, methods of construction, methods of locomotion and methods of working.

This significance is embodied in many tangible items. Some of these are large and relatively permanent like the railway alignment and the station buildings, others are small and moveable like gates, switching and signalling gear. In addition, there are also other items such as ballast pits which were opened at the time the line was constructed. All are important precisely because they are identified with this significant railway, and are an aid in its interpretation.

That the line after 31 years using horse power was converted to steam locomotive operation without alteration to the route and utilising the original structures is testimony to the soundness of the design of the line and demonstrates that is was capable of development and expansion as originally conceived. Thus it is asserted that unlike the earlier lines at Newcastle and in Tasmania, the Goolwa - Port Elliot line meets the criteria to be classified as Australia's first full scale public railway.

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THE CONSTRUCTION OF THE NAPIER-GISBORNE RAILWAY

G.G.THORNTON M.B.E., F.N.Z.I.A., F.R.S.A., R.I.B.A.
Former Deputy Chairman, New Zealand Historic Places Trust

SUMMARY: This railway was built intermittently from 1911-42 over 191 kilometres of hilly country. There are rivers in gorges requiring five steel viaducts more than 60m high, a reinforced concrete arch viaduct, and several tunnels. After construction had started from the north there was a major change of route to avoid country proving much more difficult than anticipated. Several natural disasters hindered progress. The catastrophic Hawkes Bay earthquake in 1931 and two calamitous floods in 1938 caused much damage to the line. The Depression of the early 30s produced a cessation of work and World War II seriously reduced the availability of staff, workmen and materials. This paper describes the engineering achievements including the spectacular 95m high Mohaka Viaduct.

1. INTRODUCTION

The period of provincial council government in New Zealand from 1853-76 saw a concentration on the development of communications. In particular road and railway construction was undertaken with Canterbury in the lead in having the first public railway in 1863. It ran only 7.2km from Christchurch to Ferrymead.

Much of New Zealand is mountainous and hilly with many fast flowing rivers in deep gorges to wide meanders posing many problems in bridges, tunnelling and gradients. Moreover there was an acute shortage of experienced engineers and skilled workers, to say nothing of sufficient money.

Before long the provincial councils, in their enthusiasm, became overcommitted in expenditure and were in financial straits. Central Government decided to take over all public railways using a standard gauge of 1.66m instead of the several already in operation.

As a means of improving the stagnant economy of the times, Julius Vogel, the Colonial Treasurer, proposed in 1870 a bold policy of public works and immigration. To finance this he requested a massive loan of £10 million over the next ten years. The population of the colony was only 254,928 in the February 1871 census.

Early railway bridges were usually built of timber, as simple beams or trusses having timber piled bents, or sometimes concrete piers and abutments. The superstructures were usually replaced by iron and then steel plate girders, and also trusses of steel. Tall viaducts generally had steel lattice piers. Concrete arches were rare.

At first overseas contractors were used but too often proved to be unsatisfactory in their performance. Central Government therefore took over the works and entrusted them to the Public Works Department. This necessitated building up of staff, including engineers, engineer's assistants, overseers, storekeepers and clerks. Because of the poor standards of many contractors the cooperative contract system was introduced enabling the department to carry out all manner of work with better control of quality and completion dates. This entailed gangs of ten or twelve workers electing their own headman who dealt with the engineer on rates and suchlike.

All construction materials were supplied by the department. but initially this did not apply to picks, shovels and wheelbarrows.

For the first three decades of this system workers' living conditions were primitive and harsh. They had 2.4m x 1.8m tents in which to cook, eat, sleep and live with no communal facilities. The 1920 comprehensive agreement reached between the P.W.D. and the newly established New Zealand Workers Union produced a remarkable improvement in working conditions and accommodation. More spacious timber huts were provided wherever possible including a fireplace and a bunk. Married men had considerably larger space dependant on the number of children. Bath houses and recreation halls were provided, all helping for a better relationship with the department.

2. THE NAPIER-GISBORNE LINE SURVEY

The very nature of the terrain made railway surveys and the route location a challenging task. This 191km long railway was one of the last to be built as part of the national system envisaged in the nineteenth century. However, it was not until 1911 that approval was given by government for the start of a survey.

By 1912 some work had been done on surveys and a portion of formation from both ends. Gisborne was then a small town 216km by road north of Napier, but separated by hilly country rising to almost 1,000m above sea level on the northern portion.

The initial survey was further inland favouring a route through the Hangaroa valley and Tiniroto to Wairoa. There had been wavering between a railway to the north to Rotorua and south to Napier and in 1900 work started on a line to Motuhora which was reached in 1917. In 1911 work began on the line from Makaraka a few kilometres from Gisborne to Ngatapa reached in 1914, although the Waipoua River wasn't bridged until the following year. The P.W.D. then operated a twice weekly passenger service between Gisborne and Ngatapa for a period.

One of the pioneer surveyors of the Napier-Gisborne Railway was Matthew George Easton, M.M., A.M.I.C.E., who was sent to do this work immediately after returning to New Zealand from service in World War 1. After the full survey was completed he was in charge of the construction of the line from Nuhaka to Waikokopu. He was a remarkable engineer of wide experience, including far-sighted proposals for hydro-electric electric development in the National Park-Turangi district, subsequently adopted.

At this stage in the early 1920s most of the formation was carried out using pick, shovel and wheelbarrow. For very large cuttings a steam shovel was used and a small locomotive to haul spoil trucks.

In 1918 work was suspended through labour shortage and in the following year there were more trial surveys in the northern portion. By 1921-22 it was realised that because of the difficulties of line formation, the several viaducts needed, and also the economic conditions it would be a long time before construction could be completed. It was therefore decided to concentrate on road improvement.

In 1923 F.W. Furkert, Engineer-in-Chief of the Public Works Department, sent a strong recommendation to the Minister of Public Works that the line through Ngatapa and south be abandoned because of the nature of the country and the tendency for slips. A trial investigation survey had been made of the Nuhaka-Wharerata route nearer the coast and this would be reasonable as being cheaper in cost and in maintenance. He went on to recommend that `a good road be built to Wharekopae and Hangaroa to pacify the settlers'.

In 1924 full survey work was proceeding and the more easterly route was approved between Nuhaka and Gisborne.

3. MAJOR CONSTRUCTION COMMENCES

The southernmost bridge is the Westshore Bridge on the northern outskirts of Napier completed in early 1918. However, it was designed as a road bridge with a footpath and 4.26m space for the railway track to be laid later. It was a reinforced concrete structure of 21 spans of 15.2m, five of 6m and one 17.4m bowstring arch.

The next rail bridge travelling north is that over the Esk River completed in early 1925. It has nine steel plate girder spans of 12.19m supported on r.c. piers. Meanwhile work proceeded on formation, tunnels and small bridges. All work between Napier and Waikokopu was under the control of Alexander Dinnie, District Engineer; a man of considerable experience and sound judgment.

By 1927 the Waikoau Viaduct, 43km north of Napier, was under construction. It has four shaped plate girders of 18.3m and a 76.2m truss with a height of 71.9m from rail to stream bed. This large structure was completed in the following year.

Meanwhile the next viaduct, the Matahourua, was being built 7.5km further on. It consists of two 12.2m and two 18.3m plate girders with a 76.2m truss. This majestic viaduct spans the Matahourua Gorge at a height of 65.5m with the low level S.H.2 winding through it to offer a dramatic view for the motorist. This viaduct was completed in 1929 having the usual windscreen for exposed sites.

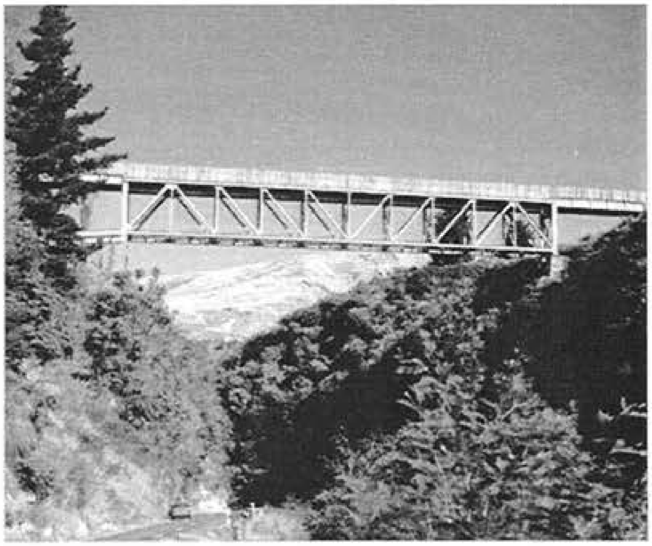

Fig. 1 Matahourua Viaduct

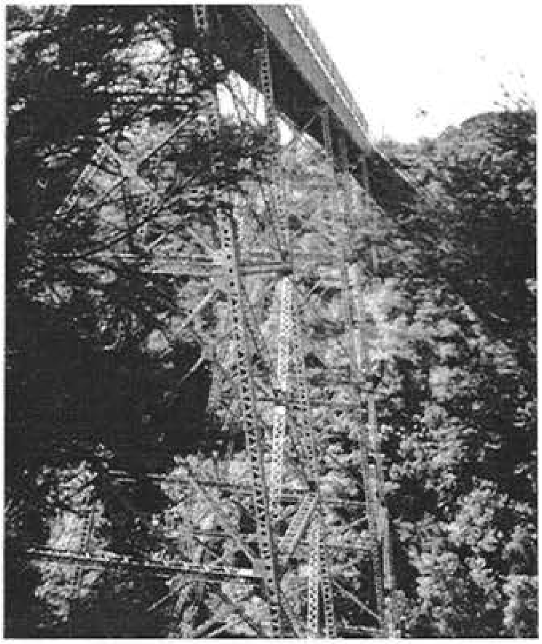

Fig. 2 Waikare Viaduct

A start was made on the Waikare Viaduct another 8km further north. It has five plate girders of 15.2m, one of 18.3m and three 30.5m trusses on steel trestle piers with a height of 79.2 metres.

By 1930 the bridge over the Wairoa River was completed having four through steel trusses of 32m and two 4.57m r.s.j. spans.

4. DISASTERS

As the Great Depression gripped the country some retrenchment of public servants, cuts in salaries and closing of public works bit deeply into everyday life. By 1933 there was no work being done on the Waikokopu to Gisborne portion and soon after all work ceased on the Napier-Wairoa section.

The first disaster was the Hawkes Bay earthquake on 3 February 1931. This destroyed Napier's business and commercial area and also much of Hastings with considerable damage in other Hawkes Bay towns. The railway line to Gisborne was affected. Some minor damage occurred on the Waikoau Viaduct requiring strengthening of the south abutment by concreting and the grouting of cracks. At the south end three steel spans had been pushed over 63.5mm by the abutment requiring straightening and repairs.

There was considerable damage to bridges and culverts on the Napier-Putorino section but this was left for later attention. The earthquake damaged the Westshore rail bridge and the Esk River bridge also suffered severely.

The Waikoau Viaduct fortunately received little damage. On the other hand the Matahourua Viaduct suffered much more, especially on the north bank. Tunnels were driven into the north gorge side, shafts were sunk and drives made to ascertain the nature of the extensive cracks in the country. These were filled with reinforced concrete to tie the country together and the cracks cement grouted under pressure.

Other damage was severe in the several concrete block houses used by the P.W.D. Some were rebuilt in timber.

The next major disaster occurred on 19 February 1938 when a construction camp in the Kopuawhara Valley was swept away with the loss of 22 lives. As if this wasn't enough, in April of the same year disastrous floods caused havoc from Napier to Gisborne with the line being closed for five months.

5. THE BIGGEST VIADUCT OF THEM ALL

In 1932 the foundations for the mighty Mohaka Viaduct spanning the river of that name were completed. The river piers were sunk from 18.3m to 21.3m below the river bed using caissons.

When the Napier earthquake struck there were two men working in one and the lock man in the chamber above them. The caisson rocked alarmingly and there was panic to get out. For a time the water level rose to shoulder height when some compressed air escaped. The lock man was able to lower the winch wire with a stirrup to bring up one man at a time. The first up after some fighting made a grab for the pressure valve but this would have been fatal for all three. The lock man thereupon picked up a short steel bar and laid him out before fetching up the other worker and quietly letting the pressure down over a half hour period, thus saving three lives.

During the period 1932-35 all construction work on the line had ceased but in 1936 a re-start was ordered by the new Labour Government. At first there was considerable work necessary in repairs to huts and in clearing the tracks. It wasn't until 1937 that the delayed earthquake repairs were undertaken involving reforming out-of-shape banks, relifting of the line, and to the damaged bridges and culverts.

It was in 1937 that the Mohaka Viaduct was completed. It had been designed by J.E.L. Cull and W.L. Newnham. John Lelliott Cull joined the P.W.D. in 1914 and became its first Designing Engineer. He took up the Chair of Civil Engineering at Canterbury University College in 1929. William Langston Newnham joined the department in 1906 spending most of his career in design work but rising to become Engineer-in-Chief.

With its length of 276.8m and height of 95m it was at the time the fourth highest viaduct in the world. There are 12 plate girder through spans supported on six trestle piers giving it every appearance of a meccano construction. It consists of four spans of 15.2m, one of 19.8m, three of 24.7m and four of 30.5 metres. All steelwork was fabricated in the P.W.D. workshops in Tauranga to a very high standard and was shipped to Waikokopu in 1932 for eventual delivery to the site. This amounted to 1825 tonnes and there were 450,000 rivets used. A large cableway across the gorge facilitated erection which was achieved in a record time of seven months. The field supervision of all five viaducts was directed by the Inspector of Works, Victor de Malmanche, a man of wide experience in all manner of bridge building. The engineer in charge was D.O Haskell and great credit was also due to him.

With long road approaches it affords dramatic views for the motorist. Before this viaduct came into use for trains it became a temporary crossing for road transport after the low level highway bridge was destroyed in the catastrophic flood of April 1938.

The last steel viaduct on this line, located a short distance north, is the Mangaturanga Viaduct completed in 1932. It had all the steelwork fabricated in Tauranga and this includes five plate girder spans of 30.5m and six 15.2m with a height of 65.4 metres. It can be seen at a distance by motorists.

Fig. 3 Mohaka Viaduct

The next bridge after the Mangaturanga Viaduct is that over the Waihua River near the coast. Completed in 1931 it has spans of 30.5m, three of 15.2m and two of 12.2m on concrete piers.

6. THE NORTHERN SECTION

This was the portion of railway between Waikokopu and Gisborne under the control of Onslow Garth Thornton, District Engineer in Gisborne. He joined the P.W.D. as an engineering cadet in 1908 and his career included considerable railway construction experience. Work had begun in March 1929 but in January 1931 the government had ordered all construction to cease. After resumption good progress was made from 1937. In this year there were 1,300 men working on the whole line from Napier to Gisborne.

Sea walls were built on the Waikokopu Bluffs section. Exposures had shown stratified rock with alternating layers of papa (mudstone) and sandstone. Since the 1860s tunnels had a horseshoe profile but here a semi-circular roof with vertical sides was used for the three longer tunnels. This was the first adoption of the "American" or arched system of timbering which had not been used for single track tunnels in New Zealand. This enabled the whole face of the tunnel to be attacked at once and ensured maximum operating room for the workmen. Mechanical loaders or scrapers were necessary. Lining was done with the concrete pumped into position behind steel formwork by means of electrically driven concrete pumps.

The Waikoura tunnel, 1448m in length, had for access at its south end a 183m jig line with a 28 degree average slope. It was served by a 22.7 c.m. electric air compressor and a 0.76m ventilating fan.

Fig. 4 Waikoura Tunnel Jig Line

Between it and the 925m Coast Tunnel there are 15 small tunnels totalling 302 metres and a sidling 137m above the sea. The Waikoura Valley has a gradient of 1 in 50.

Fig. 5 30m Filling at Wharekakaho

The longest tunnel is the Tikiwhata of 2988m. There were delays in 1940 due to a shortage of tunnellers in wartime, and also the variable ground conditions which had soft seams and was heavily faulted. In the next two years the war shortages continued to hinder progress.

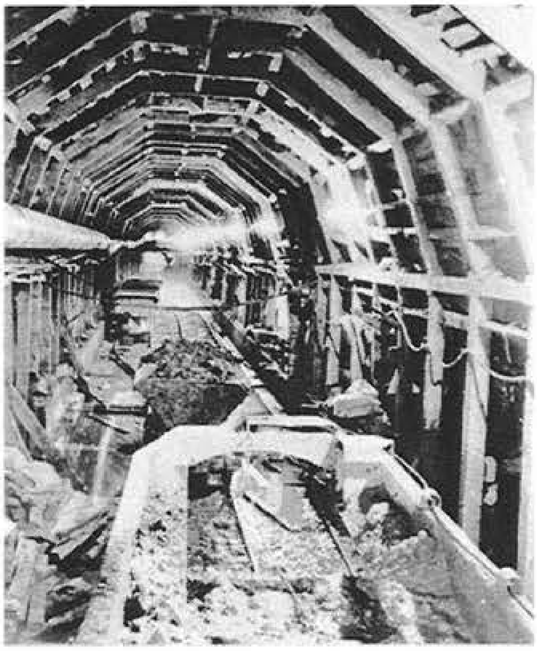

Fig. 6 Tikiwhata Tunnel showing scrapers

South of the Tikiwhata tunnel is the majestic Waiau Stream Viaduct. Unlike all the other viaducts this is a concrete structure 162m long with an open spandrel parabolic arch of 54.9m span and a height of 30.5 metres. Completed in 1942 it has five r.c. girder spans of 12.2m and one of 9.1m on the south side and three 12.2m girder spans on the north all supported on r.c. trestle piers. This viaduct was hailed as a splendid design with its continuous spans, and completely monolithic construction. The abutments have Mesnager hinges. Longitudinal forces are taken by compression in the arch ribs and lateral forces by bending of the bridge deck and transmission to the main bents.

The construction camp washed away in the February 1938 flood was downstream of this viaduct.

On the Gisborne-Waikokopu section there are 16 bridges, the longest being the Waipoua River Bridge eight kilometres south of Gisborne. It has six 9.14m and nine 18.3m plate girder spans on concrete piers and abutments. Tetrahedral concrete blocks were used on the river banks as protection against erosion.

On 7 September 1942 the first train steamed out of Gisborne station for Napier. From 1 February 1943 all construction except cleaning up work had been completed and the entire line was under the control of the New Zealand Railways Department

7. CONCLUSION

Early railways in New Zealand were built by contractors. In the 1870s the Central Government instructed the Public Works Department (established in 1870) to carry out such works using their own forces. It had to build up essential skills from engineers, field staff and to workmen of all kinds.

The 191km Napier-Gisborne railway took 30 years to complete after the initial survey. There were problems aplenty. A major relocation of the line south of Gisborne to avoid increasingly difficult unstable country, the effect of the Great Depression and closure of all work for several years, the extensive damage caused by the Hawkes Bay earthquake of 3 February 1931, the disruption from two disastrous floods in early 1938 including a camp washed away with the loss of 22 lives, and the effects of World War II in loss of manpower and shortages of materials.

The positive achievements included the construction of five major viaducts all over 60m in height, a 54.9m span concrete arch viaduct 30m high, and many other bridges. There are five large tunnels involving some difficult country and many cuttings, sidlings, fillings, culverts and a seawall. All the design work was done in-house and all steel fabrication carried out in the department's workshops in Tauranga to very high standards. This latter, and the erection of two viaducts was done in record time. The Mohaka and Waiau Viaducts were the two most significant bridge engineering structures of their time.

Ironically when the line was handed over in February 1943 the days of new railway construction were virtually over - air travel and greatly improved highways were changing the role and popularity of the train.

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Learning From Our Past Mistakes

D. BEAUCHAMP, BE, MIE Aust, MNZIE, MICE
Director, Beauchamp Consulting Engineers Pty Ltd

SUMMARY Old buildings have many lessons they can teach. This paper looks at six buildings and one bridge and discusses some of the structural problems that have occurred and what lessons in serviceability and durability can be learned from these examples.

1 INTRODUCTION

There are many reasons for preserving old buildings, they may have been associated with an historic event, famous or infamous people may have lived in them, they represent part of our past, they were built by a renown architect, they are the last or best example of a certain style of building. This paper presents the case for preserving buildings that have structural problems so that we can learn from these mistakes. A number of structures will be looked at and the lessons they can teach discussed.

2 DOVER BUILDING

This concrete building when it was originally built in 1909 as a cigarette factory for Snider and Abrahams was a five storeys high. In 1938-39 a further two storeys were added.The floors for the additions were designed by the original engineer and utilized the same flat slab system as was used in the 1909 design. The floor construction is a patented flat slab construction and according to Dr Miles Lewis is possibly the oldest surviving example in the world of this form of construction (1). The building is on the Victorian Historic Buildings Register.

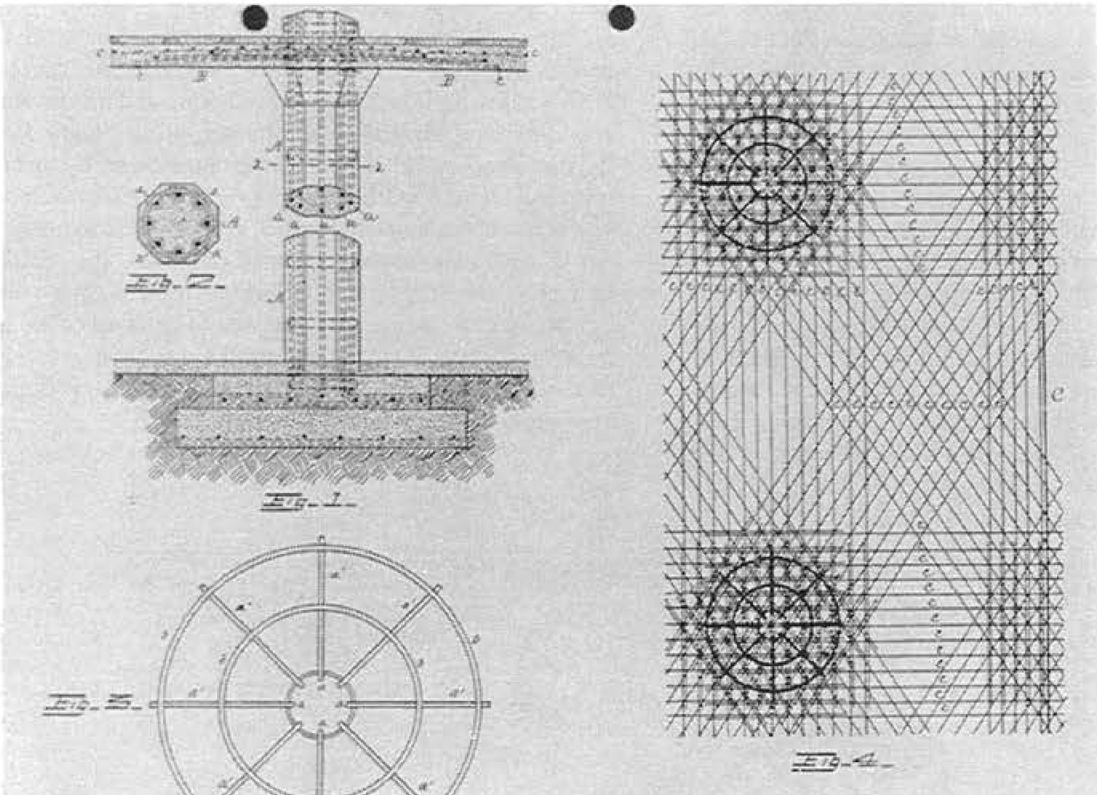

Figure 1 Reinforcement layout from the C.A.P. Turner patent application.

The building was designed by H.R. Crawford, an Australian engineer who had the Australian rights to the C.A.P. Turner Flat Slab System a 1906 American patented system for designing flat slabs. The system consists of a four-way arrangement of reinforcing with bars spanning directly between columns as well as diagonally across the slab, Figure 1. This arrangement causes congestion of steel at the columns where there are four layers of steel as top reinforcement. When the building was erected one of the floors was load tested to prove to the authorities that it had adequate strength. The floor was loaded over an area of 4.88 m by 4.88 m with 35 tonnes and deflected 5 mm. The test load was 14.4 kPa, three times the design load.

In 1985 an assessment was made of the load capacity of the floors to see if they had sufficient capacity to enable the the building to be used to store geological specimens for the Museum of Victoria. Apart from the 6th floor, which was the original roof, all the floors had been designed for a live load of 4.79 kPa (100lb/sq ft). When tested the concrete in the floors was found to be of variable strength, with core strengths varying between 8 MPa and 27 MPa. The floors had deflections of up to 70 mm midspan between columns.

The calculated strength of the slabs was 6 kPa for the 7th floor, 1.5 kPa for the 6th floor, 2.5 kPa for the 1st, 2nd, 4th, and 5th floors and only 1.71 kPa for the 3rd floor. The low capacity of the floors was due to the low concrete strength and to the fact that the top reinforcement over the columns was 20-35 mm lower than it should have been. In most cases it was the shear capacity at the columns that was the limiting factor. It should be noted that the original test load was applied to only one bay and the shear at the columns was equivalent to the shear from a U.D.L. of 2.7 kPa.

The original design was concerned with strength and obviously did not consider long-term creep. deflection. If the lesson from the Dover Building had been known in the 1960's and 70's when there was a spate of building offices in Australia utilizing flat slab floor systems, the costly defects caused by deflection of these floors, such as cracking of brick partitions, jamming of doors, cracking of glazing and the need to pack under compactus units may have been avoided. Problems with deflection of flat slab floors were still being reported to the C.I.R.S.O. Division Of Building Research in the 1980's (2).

3 FREDERICK BLIGHT WAREHOUSE

This bluestone and timber warehouse was built in the late 1800's as a wool store, it later became a warehouse for Frederick Blight & Co., wine and spirit merchants. In 1974 the building was renovated and became Lazars Restaurant.

The timber floors consist of 280 mm x 75 mm oregon joists at 450 mm centres spanning 3.3 m supported by 340 mm x 250 oregon beams which are in turn supported by timber columns at 3.05 m centres. The floors are capable of carrying loads of at least 12 kPa. Because the floors had, for a considerable period of their life, had wool bales stacked on them, i.e. they had been subject to a long term live load, the timber had deflected and there were permanent deflections of up to 115 mm in the floors.

To enable the floors to be utilized for a restaurant and also to help the sound proofing between one floor and another, a light weight concrete screed was poured over the timber floors to level them.

The lesson from the Frederick Blight Warehouse is that when long term life loads are applied to timber beams creep deflection and the possibility of a permanent set in the timber occurring have to be considered in the design.

4 MALVERN HOUSE (VALENTINES)

This grand mansion was built in 1891 at the end the land boom period of Melbourne's history. The 40 room mansion originally stood on 34 hectares of land at the corner of Burke and Wattletree Roads, Malvern. The design of the building is on a grand scale and it is lavishly appointed and decorated. Craftsmen were bought from Italy to install the elaborate plaster mouldings, the ornate staircase and the wood carvings. The first floor balcony was constructed by placing steel R.S.J.s at 2.2 m centres, corrugated iron arches spanned between the bottom flanges of the R.S.J.s and filling over the arches was a lightweight or breeze concrete made with coke as the main aggregate. On top of the breeze concrete slab tesallated tiles were laid. Figure 2 shows a typical example of this system.

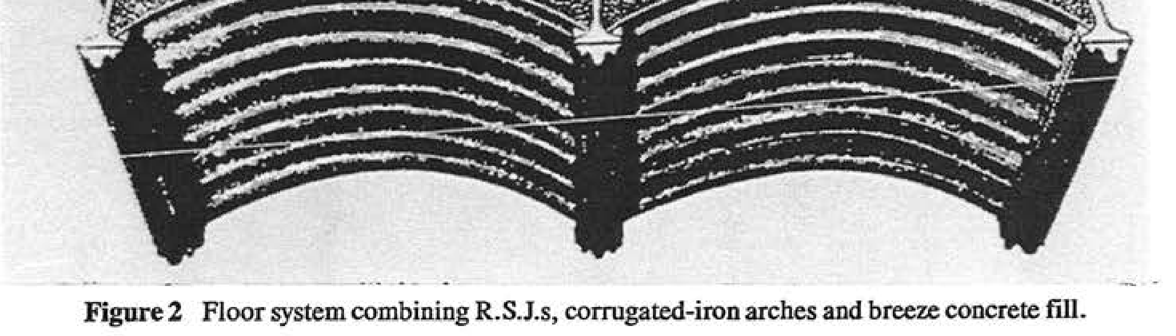

Figure 2 Floor system combining R.S.J.s, corrugated-iron arches and breeze concrete fill.

The system was structurally adequate, deflections were small, weight was kept to a minimum and a solid surface was provided for laying the tiles. The one fault with the system was that water could and did get through the tiles, especially at the spoon drains at the edge of the balconies. The breeze concrete, being porous, allowed the water to get through to the arches and to the bottom flanges of the R.S.J.s, which over time started to rust out. To repair the balcony at Malvern House it was necessary to provide a new concrete slab and beam system. The existing beams and arches were left in place as formwork for the new concrete.

The structural system for the balcony was a good system but it was used in the wrong place. Inside the building where water could not affect the steel or if the surface had been waterproof it would have been a perfectly adequate structural system. Long term durability was obviously not considered when the balcony was built.

5 GEELONG SEWERAGE AQUEDUCT

This remarkable concrete structure was designed by E.G. Stone and was built between 1913 and 1915 to carry the outfall sewer line from Geelong over the Barwon River. The form of the design is similar to the Firth of Forth rail bridge(3,4) The design of the concrete members of the trusses is based on the Considere system. This reinforcing system was developed in France by A-G Considere who found by experimentation that a heavy spiral winding around the main reinforcing substantially increased the strength of compressive members.

The spans of the bridge from centre of tower to centre of tower are 35.4m, nine at 53.7m, 41.5m, three at 53.7m and 35.7 m, making a total of 756 m. There are cantilever arms of 20.7 m which support simply supported girders spanning 12.3 m. The pipe line is ovoid in section measuring 1.3 m by 0.99 m.

This bridge is now deteriorating with concrete spalling and reinforcing rusting The cost of repairs is put at between $3,000,000 and $8,000,000.

The use of small members with close spacing of reinforcement has resulted in a high surface area for each member which means that carbonation and chloride penetration of the concrete readily occurred, followed by rusting of the reinforcement. If,like the Firth of Forth Bridge, this bridge had had a continuous programme of maintenance with, instead of paint, some other form of coating being regularly applied, then the bridge would probably still be in a good condition.

As well as illustrating the problems caused by carbonation and chloride attack on concrete this structure represents a good example of how the shape of the concrete members plays an important part in the durability of reinforced concrete structures.

6 ST FRANCIS CHURCH

St Francis Church is the oldest Roman Catholic church in Victoria, the most important example of architect Samuel Jackson's work and the oldest church in Melbourne still on its original site, it was built between 1842-45 (5).

By 1984 serious cracking had occurred to the Lady Chapel. Cracking had occurred over most of the windows and plaster was falling from the ceiling. The cracking was caused by the roots from the relatively recently planted street trees drying out the silurian clay under the foundations of the chapel causing it to shrink, this in turn allowed the bluestone foundations to settle and the walls to crack. After a three year tussle with the Melbourne City Council, a concrete root barrier was installed in 1987 and the chapel repaired. To date no further cracking problems have occurred.

In 1990 one of the priest at St Francis's discovered that rot had occurred to the ends of some of the roof trusses and as a result an investigation was undertaken to see how serious the problem was and to devise how the trusses could be repaired.

The trusses are made from New Zealand kauri pine; they span 12 m across the nave of the church and at the crossing a pair of trusses span diagonally 15 m. The top chords of the trusses cantilever past the bottom chords to create a coffered ceiling in the church. In the 1950's the slate roof was replaced with terracotta shingles which weigh approximately double the weight of the slates they replaced.

When the extent of the damage to the trusses was investigated, it was discovered that a number of the bolted connections between the top and bottom chords had failed and that these failures were relatively recent. On checking the capacity of the connections it was found that they were overstressed by 97%.

Rot had occurred to the top chords of the trusses because the ends of the trusses had been built into the brickwork, directly above were box gutters which had leaked allowing water to get to the timber. Because the water was trapped by the brickwork the timber remained damp, an ideal breeding ground for fungus to attack the timber. Dry rot, despite its name, only attacks timber with a moisture content greater than 25%. The failure of the bolted connections between the top and bottom chords was caused, in part, by the increased load from the terracotta shingles.

The church is used seven days a week and so it was necessary to devise a method of repair that caused as little disruption to the operation of the church as possible. A system was devised that enabled all the work to be done in the roof space. Access was provided by creating a hole in the roof and erecting a walkway to this hole. The worst affected trusses, which included the diagonal trusses at the crossing, were repaired by installing additional steel members connected to the sides of the trusses and making these members load bearing by jacking between the top of the brick walls and the ends of the steel members. All the steel members had to be small enough and light enough to be man-handled into place. Trusses that had no rot at the ends of the top chord had the connection between the top and bottom chord strengthened with additional steel plates and bolts. To avoid slippage in new bolted connections special bolts were fabricated that could be injected with epoxy resin to fill any gaps between the bolts and the holes drilled in the trusses.

The lessons that can be learnt from St Francis Church are, 1) changing the moisture content of clay soils can cause problems to buildings with shallow foundations, 2) root barriers 1500 mm deep have, so far, been adequate to stop the roots of the street trees causing further cracking, 3) timber needs to be kept dry if decay is to be avoided and 4) the ends of timber beams and trusses should not be built into walls where water may be trapped.

7 THE UNITING CHURCH, OXLEY STREET, HAWTHORN

This church, designed by a brilliant young architect Alfred Dunn and built in 1888-89, has been described as a veritable cathedral of Victorian Wesleyanism (5). The complex timbers of the spire are supported by two timber beams spanning diagonally across the base of the spire. The ends of these beams are built into the brickwork. The ends of the beams have rotted out because, like St Francis Church, the water from leaking gutters has been trapped at the ends of the beams.

While inspecting this problem it was noticed how little corrosion had occurred to the cast-iron columns that support the brickwork at the top of the steeple and the brickwork over the windows and doors of the church. The columns had been painted but no special paints such as zinc rich undercoats were evident.

8 NUMBER TWO GOODS SHED & OFFICES, SPENCER STREET GOODS DEPOT.

This large goods shed was designed by the Railway Department in 1889 and built shortly afterwards. The shed is 34.5 m wide and 370 m long. The building is three bays wide, the central bay where the train tracks ran is 15.85 m wide and the two side bays are 9.30 m. Riveted trusses at 4.57 m centres span onto riveted U-shaped box girders which are supported by cast-iron columns at 9.14 m centres. The riveted girders act as box gutters for the roof drainage and the cast-iron columns as down pipes. The box girders are cambered to ensure that the water drains to the columns. Figure 3 shows a cross section of the box girder.

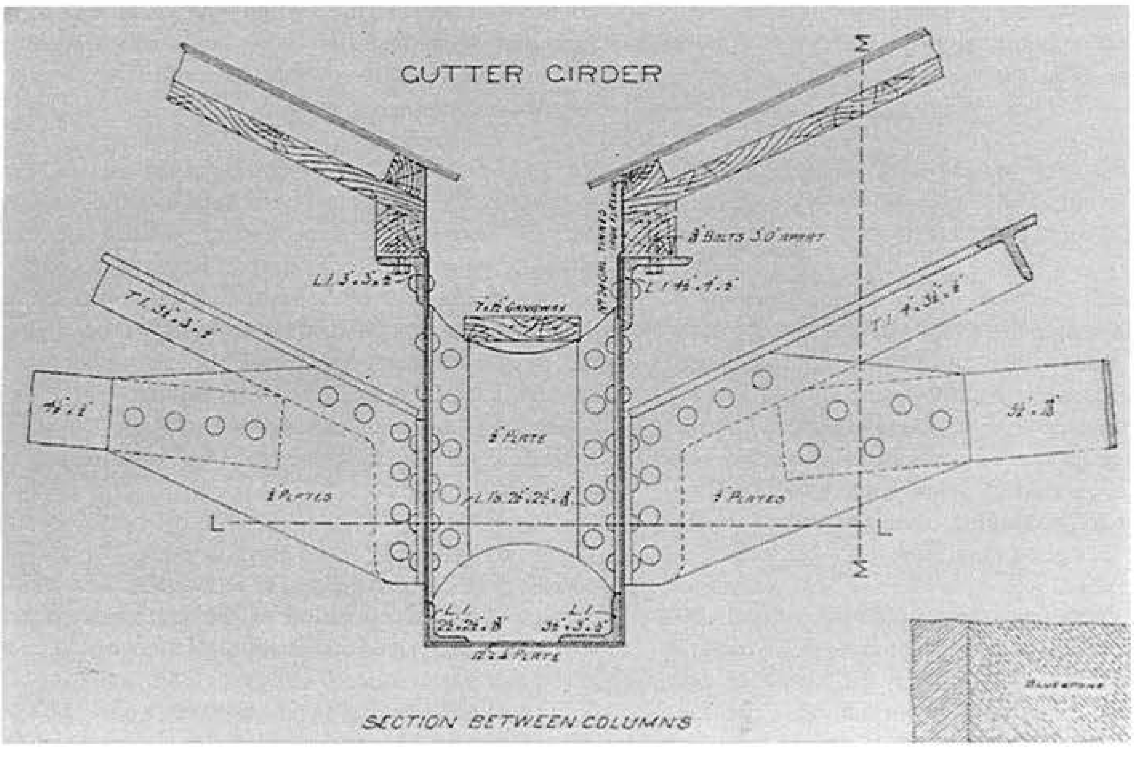

Figure 3 Section through riveted gutter girder.

The riveted girders are most probably fabricated from wrought iron rather than from steel plate. Despite the bottom plate of the girders being only 6.4 mm thick they have not corroded through. Similarly there is no evidence that the cast-iron columns have been damaged by corrosion.

Both good quality cast-iron and wrought iron are more corrosion resistant than mild steel and the evidence from both the Uniting Church and and Number Two Goods Shed suggests that the while the change away from cast and wrought iron to mild steel has given a material with greater ductility and strength, there has been a loss of durability, an important consideration when designing buildings that are to last.

There has been a suggestion that wrought iron used in early reinforced concrete was less prone to corrosion than steel and this was one of the reasons why despite reinforced portland cement concrete being made from the 1820's, no mention of damage due to corrosion of metals in concrete in was found in a survey of the U.S. literature before 1900 (6).

9 CONCLUSIONS

Historic buildings can teach valuable lessons about the durability and serviceability of materials. In the structural design of buildings strength is only one criterion, durability and serviceability are of equal importance. Retaining old buildings provides an on-going record of the life-span of different materials and can help engineers avoid repeating past mistakes by demonstrating past pitfalls.

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Old Values and New Approaches

K M Baker, BE, FRMIT(Mgt), MIEAust,
Engineering and Heritage Consultant, Canberra.

SUMMARY Among various groups of people there are different ways of defining heritage, as well as varying ways of looking at what is old or new. The values held by conservationists may have some unconscious bias which makes the result of their conservation work less acceptable to other parts of the community. This paper briefly examines a number of cases where differing or conflicting values affect the conservation of places, and in some cases it draws distinctions between values-conflicts among conservationists. The paper introduces some models for understanding conflict, and mentions techniques used for resolving disputes. It concludes by reviewing the present efforts of the heritage industry in coming to terms with conflicting values where the Burra Charter has not always provided the answers. The aim is to bring to the attention of conference participants the concept that successful conservation involves more than careful research and expert knowledge of conservation techniques, since major conflict can arise between proponents of conservation as well as with opponents.

1 INTRODUCTION

The title of this paper is deliberately ambiguous, because it is about values which are rarely enunciated clearly, and about conflict which often arises in heritage conservation through those differences in values. It leads to recognising some progress in Australia to bring about a better understanding of different values which pervade our conservation work.

The paper draws on the author's research into the conflict which has occurred in the conservation of a central Victorian gold mining town, and on the wider experience of a group of heritage professionals in Australia with whom he has been able to work, who have been wrestling with the question of conflicting heritage values.

It would be appropriate to give a brief history of the heritage conservation movement in Australia, showing how the values that were applied were broadened as time went on. In the early days there was a common view that those who were expert enough to appreciate the cultural values of historical places should protect them from the rest of the community who didn't care about them, or wanted to tear them down in the name of progress. Technical skill, particularly architectural expertise, was the important factor which made the conservation specialists clear in their own minds that they occupied the high moral ground. The specialists generally operated within the National Trust which had formed after the Second World War as an elitist upper middle class Anglophile organisation[1]. The specialists' "ownership" of heritage was challenged to a degree by the spontaneous actions of less expert groups like the builders labourers, lead by Jack Mundey, who imposed green bans in the early 1970s to prevent clearing of remnant bushland and demolition of terrace housing in Sydney. Also during the 1970s, suburban resident action groups grew more vocal in conservation, while National Trust organisations across Australia were becoming more broadly based with a growing participation of historians, planners, landscape designers and engineers.

The formation of the Australian Heritage Commission in 1975 lead to the creation of the Register of the National Estate which covered the natural, Aboriginal and historical environments, giving a broader and more unified perspective to conservation, particularly for archaeologists who were able to span some of the boundaries.

The formation in 1976 of the Australian chapter of the International Council on Monuments and Sites (ICOMOS), under UNESCO, brought heritage specialists within a national professional body with international status. The development of the Burra Charter for Australian heritage conservation gave a sound basis for ongoing work, with emphasis on preserving the cultural significance of places, a concept which has a much broader application than the notions of architectural merit or age as an indicator of significance.

Heritage legislation began in the 1970s and now exists in all States except Tasmania.

Interest in engineering heritage may have long existed among individuals but it did not become publicly evident until the 1980s[2]. Engineering heritage practice has aligned itself with ICOMOS through the development of Engineering Heritage & Conservation Guidelines based on the Burra Charter[3]. It is the nature of the engineering profession to consider the technology represented in places to be important, possibly to the exclusion of factors which may interest other people. There is a danger in concentrating too much on the technology, however, and I would like to spend a short while looking at values which may not always coincide with our own, and see if they may influence the way we approach the conservation or interpretation of our engineering heritage.

This paper is arguing against the engineering heritage fraternity remaining too narrow in its focus, as I believe some other heritage professionals have been in the past.

2 DIFFERING VALUES

The theme of this conference, old ways in a new land, implies a set of values where Australia or New Zealand are regarded as young, while England (or another European state) is regarded as the old country. Yet from an Aboriginal or Maori perspective this is likely to be reversed. Thousands of years of continuous occupation is reasonable justification for the first peoples to regard themselves as having always been here, and others to be newcomers. This has a dramatic effect on perceptions of what we conserve when the places have a particular significance for the original owners. The Swan Brewery site in Perth, Western Australia, exemplifies these differences, and will be discussed further below.

Experience in other parts of the world also show different cultural values being expressed in the destruction or conservation of places. Consider the deliberate shelling of designated culturally significant places in Dubrovnik and Sarajevo, the demolition of a 16th century Ayodhya Mosque built on a sacred Hindu site in India, and by contrast the joint Turkish/Australian commemoration of monuments to the war dead at Gallipoli. The places or structures that one group of people regard as sacred or highly valued are not necessarily valued by other groups, but they may be shared by former opponents in some cases.

3 CONFLICT OVER CONSERVATION

There have been some notable conflicts over the conservation of historic places, including industrial sites. Sometimes the conflict has an economic basis to it. Those who were at the engineering heritage conference at Hobart two years ago would remember the strong reaction from the mining industry to Ray Supple's paper about the lack of conservation of historic quartz kilns at Maldon. Although the issue of the kilns was largely economic, earlier conflict at Maldon from the time it was declared Victoria's first Notable Town by the National Trust in 1964, was very much about the rights of individuals to self determination. Disputes had an economic basis to some degree, but they had more to do with the power of factions in the community and the community's resentment of being powerless in the conservation process, as decision making powers became more remote from the local level. Disputes often revolved around differences between the locals, the newcomers, and the conservation experts and planners from Melbourne, each with their distinct perspectives and agendas. Although there has been some improvement, Maldon has known conflict over conservation for the past 30 years.

4 CONFLICT WITHIN CONSERVATION MOVEMENT

Conflict is not always between the forces of conservation and development, as in the cases mentioned earlier regarding urban renewal, or the resumption of mining in previously mined areas. Sometimes two sides to the dispute want conservation, but they can't agree on what should be conserved. This can arise between people on the one hand who highly value the natural environment, and want to see cultural landscapes in alpine areas returned to their former natural condition, while those on the other side value the evidence of the history of European settlement, and wish to preserve the mountain huts, mining relics, and changes brought about by high country grazing[4].

Value conflict can also occur where buildings have been erected in the past on a site from which the indigenous people had been displaced. Now that Aboriginal people are regaining a voice in the community, their values are sometimes offended by the white decision making process which can take economics and European history into account while giving less credence to their earlier history and spiritual association with the place. The Swan Brewery site, or Goonininup to the Aboriginal people of the Perth area, is a classic example of incompatible values within the conservation movement. To one side it is a case of conserving industrial buildings of historical and architectural merit exhibiting the major characteristics of the Federation warehouse style, demonstrating the evolution of the brewing industry, forming a rare illustration of the historical relationship between industry and the Swan River, and forming an aesthetic relationship between the buildings and the natural features of the Kings Park escarpment. To the other it is a case of ridding a sacred site of intrusive buildings so that the dreaming track of Waugal, the great Rainbow Serpent can be appreciated[5]. The roles of developers with a pro-development government and an ambivalent public did not make the problem easier to resolve. But it highlighted to the Australian conservation movement, particularly through an ICOMOS conference in Fremantle in 1992, the need to reconsider their codes for conserving places where different cultural values may coexist. "In a sense the Goonininup/Swan Brewery site repeats the painful story ... of the Ayodhya Mosque, where a place, said to be sacred since ancient times, has been overbuilt by a different cultural group some time ago and acquired, over time, a new significance defended by the second cultural group."[6]

Different values are not confined to ethnic or Aboriginal groups, nor to those conserving natural places. Different perceptions and values can exist within the historic environment. This can occur in the conservation of a building which has been altered and extended over time. Depending on one's view of its significance, it could be returned to an earlier period by removal of the later additions, or it could have the additions also conserved to represent the changing conditions and processes over time. The latter may result in a less aesthetic outcome but be more educational in its interpretation. Similarly a study to conserve the best elements of an industrial complex which is being redeveloped for housing, could come up with different results depending on the perspective of the conservation consultant. An architect may be more concerned with the styles, siting and integrity of the buildings to be retained, while an engineer may be more concerned with representing the industrial processes which occurred in the buildings, particularly if they were unusual or in danger of being lost. Multi-disciplinary teams should be able to resolve these differences professionally, by looking together at the significance of the various elements, but this does not always happen.

5 MODELS FOR UNDERSTANDING CONFLICT

A simple model for understanding conflict arising over the management or conservation of places is shown at Figure 1 It distinguishes between three elements;
(a) the community or social values, which may relate to ideals about the use and enjoyment of features which the people have available to them, to which they have contributed, or which they hold in esteem.
(b) the commercial values, which may relate to ideals about the owners financially benefiting from the physical features, the association of the place or its attraction to customers.
(c) the conservation or environmental values, which may relate to ideals about conserving the natural, historical or Aboriginal aspects of the physical environment.

These three elements will be in mutual tension, and some form of equilibrium will be reached with respect to the management of the place, depending on their relative dominance or the way they accommodate each other. There can also be tensions within each corner of the triangle, as for example, proponents of different recreational uses compete for a site, businesses compete for customers, or groups with different cultural values offer differing views on the significance of a place for conservation.

A more complex model has also been developed by the author to analyse the elements of a particular conflict, taking into account a range of players. Each has their own agenda, arrived at through logical or emotional processes, including the results of previous encounters. These agendas are then played out through both open interaction, and power plays which take into account the relative power, authority and status of the players. The outcome may resolve the matter to the satisfaction of all the players (a win/win solution), or it may lead to a further round of conflict over another issue if one or more of the players has been forced into accepting an unsatisfactory outcome (a win/lose solution) through lack of power. Thus the result of one conflict will be used in modifying the agenda and determining the approach taken to the next potential conflict.

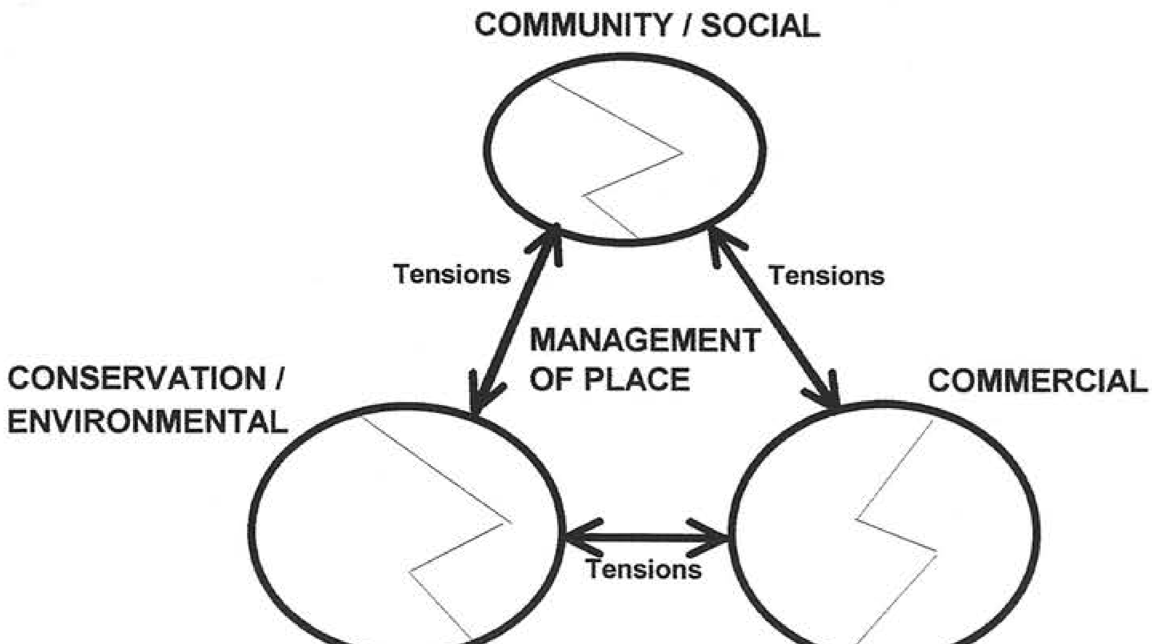

Figure 1. Values Relating to a Place.

6 CONFLICT PREVENTION AND RESOLUTION

Understanding the reasons for conflict may help prevent it in the future, but there are some techniques practised by professional organisations which help to resolve problems while they are in progress[7]. Dispute settlement may be by collaborative problem solving in an ideal world. This is the least interventionist, but relies on both parties being prepared to talk without one overpowering the other, so that a win/win position can hopefully be reached. Mediation is a more formal process where an independent accepted outsider attempts to work with the parties to help them satisfactorily reach a settlement. The most formal and interventionist process is arbitration, where a decision is made by an outsider regarding the content of the conflict. It is usually the least satisfactory solution in the long run, because the participants have not been involved in the process of reaching agreement, and are therefore less likely to feel committed to the outcome.

7 BURRA CHARTER AND AUSTRALIAN CONSERVATION

As mentioned in section 4 above, Australia ICOMOS resolved to look at its approach to places which could be viewed differently by different cultural groups. With funding from the Australian Heritage Commission, a study project examined some cases of conflicting heritage conservation values and produced guidelines for resolution of conservation disputes. The consultants, Joan Domicelj and Duncan Marshall working on behalf of ICOMOS, had access to a wide ranging panel of experts in the cultural heritage conservation and conflict resolution fields. A number of cases were reviewed where conflicting values had emerged in Australia and overseas, and the principles of conflict resolution were considered. It was discussed among the panel, some of whom had been involved in drafting the original Burra Charter, that the Charter needed to be modified to be less focused on the values of the dominant European culture and allow for greater cultural diversity.

8 NEW APPROACHES ALLOWING FOR CULTURAL DIVERSITY

The ideas were workshopped at an ICOMOS conference in Darwin in late 1993, and have since been included in a report entitled "Diversity, Place and the Ethics of Conservation[8]". This will form the basis of a discussion paper to be published later this year. In the report a "Draft Code on the Ethics of Coexistence in Conserving Significant Places" was developed setting out ethical principles and practice. Principles included a statement that conserving the national estate requires acknowledgement of, and sensitivity to the values of all associated cultural groups. Ethical practice covered actions such as adopting a coordinated , multi-disciplinary approach to ensure an open attitude to cultural diversity, and enabling each cultural group to gain access to the decision-making processes which may affect the place. Specific recommendations were also made to Australia ICOMOS regarding the Burra Charter including improving access to the charter for diverse cultural groups, and redrafting some clauses to make the intent clearer, to be less focused on building fabric, to respect the control placed on certain information by cultural groups, and to incorporate reference to the appropriate involvement of associated cultural groups. Review of the Burra Charter and development of the Code of Ethics will be an ongoing task by ICOMOS involving wider consultation in the latter part of 1994..

9 CONCLUSION

Conflicting values may not have been a significant issue for conservation of engineering heritage, but there is no automatic immunity. Engineers involved in heritage conservation therefore need to be mindful of the possibility of other values existing in the community which may be in conflict with their proposed conservation work, and take an active role in bringing about solutions which satisfy both sides to the greatest degree. In particular, they need to be mindful that good conservation work involves more than good technical research and authenticity, and that empowering the community to have a sense of involvement and ownership of the place can be worth a great deal in the overall process. And there must be a recognition that where other cultural values exist, they are not necessarily subordinate to science and engineering principles.

This conferences has looked at many examples of the introduction of technology to Australia and New Zealand, and the impact of the different surroundings on judgements as to the appropriateness of the technology. While it has been good to look in a technical sense at new applications of old ways, let us also be mindful of the impact these ways have had on the original inhabitants as well as a range of culturally diverse new inhabitants, and adjust our conservation accordingly.

10 ACKNOWLEDGMENTS

The author wishes to acknowledge the supervision of Dr Brian Egloff at University of Canberra during his research into conflict in heritage conservation, and also the Australian Heritage Commission and Australia ICOMOS for use of their work on conflicting cultural values.

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Old Masonry Chimneys: Are They Safe?

SIMON WILTSHIER, BE (HONS), MIE (Aust), MICE, Hughes Trueman Ludlow, Australia

SUMMARY Many masonry chimney and towers are recognised or registered as structures with heritage significance. They are usually disused and seldom can perform a useful function as originally intended. They are subject to a high degree of deterioration and are seen by their owners as liabilities rather than assets, with potential danger to the public. This paper discusses the issues, with case studies demonstrating methods for dealing with the problems raised.

NOTATION

H	= stack height in feet (above boiler grate)	
T_a	= absolute air temperature (Fahrenheit)	
T_c	= absolute chimney temperature (Fahrenheit)	
D	= draught (measured in inches head of water)	
E	= effective chimney area (sq. ft)	
W	= weight of coal combusted (lbs per hour)	
t	= wall thickness at chimney top (inches)	
d	= inside diameter of chimney at top (inches)	
h	= stack height (inches)	
h_{inc}	= length of chimney between incremental steps in wall thickness	
i	= increase in wall thickness at each step (feet)	
G	= weight of brickwork (lbs per cubic foot)	
p	= wind pressure (lbs per sq. foot)	
a	= angle of internal batter	
C	= constant	1 for round chimneys
		0.97 for octagonal chimneys
		0.83 for square chimneys
S	= permissible stress (lbs per sq. in)	

1 INTRODUCTION

The industrial development of New South Wales followed convict settlement, the growth of agriculture to supply local and export demand, and early mining and manufacturing ventures.

The earliest industrial projects evolved to meet the needs of the settlers for supply and shelter and to provide some form of export base to try and make the colony economically viable and financially self sufficient.

By the mid-nineteenth century numerous mines had been established, prospecting for and recovering gold, copper and other minerals from very scattered and remote sites. Mine equipment was powered by steam engines, generally fuelled by local timber or coal.

Near or within the growing towns brick manufacturing works were set up to supply bricks to the fledgling construction industry. The bricks were fired in kilns heated by on-site fuel sources.

In both instances the technology and much of the equipment was imported from the home lands of the colonists. Initially Britain but also Germany and other parts of Europe.

These early works have continued to develop and are still major Australian industries, however modern methods have changed and a national energy grid has removed the requirement for sites to generate their own power from local sources. In addition the advent of concrete and steel has superseded the use of masonry and timber for industrial structures. In some instances development has continued on the original industrial sites, however community requirements and economics have usually led to the abandonment of the old sites and new development taking place elsewhere. These processes have left a particular form of industrial relic, the masonry chimney.

Numerous chimneys survive either with or without their surrounding facilities. The proportion that the survivors represent of the original total has not been established but is likely to be small. Those that do remain have survived for one or more of the following reasons:

- They have been recognised either formally or informally for their value as symbols; either of a community, a particular industry or even a particular business enterprise (essentially as an advertisement).
- They are remote.
- They are not a problem because they take up a relatively small useable space.
- Demolition was uneconomical, or involved too much risk to surrounding property, or materials were of little salvage value due to deterioration in use and specialisation of purpose.
- They have remained in use up until a time when heritage legislation recognised them.

2 THE ORIGINAL DESIGN METHOD

Chimneys had two principal functions;

- To remove toxic or unpleasant flue gases to a height where they were not a nuisance.
- To create a draught sufficient for the efficient combustion of whatever material was being burnt or sufficient to generate the heat needed to bake or fire the contents of a kiln.

The principles of chimney design were straight forward. The first requirement was to establish the draught necessary for efficient function. The draught was directly related to the required height of the chimney, the calculation of which was achieved by a formula such as the following[1];

$$H = \frac{1.2D}{[7.6/T_a - 7.9/T_c]}$$

Adjustments were made to account for the altitude of the site above sea level.

It was then necessary to determine the flue area required to accommodate the volume of gases.

A typical formula, to suit a coal fire, was as follows[1];

$$E = \frac{0.06W}{\sqrt{H}}$$

Adjustments were made for other fuels.

The foregoing are simplifications of an analysis process which also involved allowance for materials of construction, losses by friction, fuel variations, combustion requirements and site location. At this stage the functional requirements had been established and the structural design of the chimney took place.

In dealing with masonry chimneys four shapes were commonly used. The variation in drag forces for the different shapes gave different wind pressures applicable to the projected surface areas as shown in Fig 1.

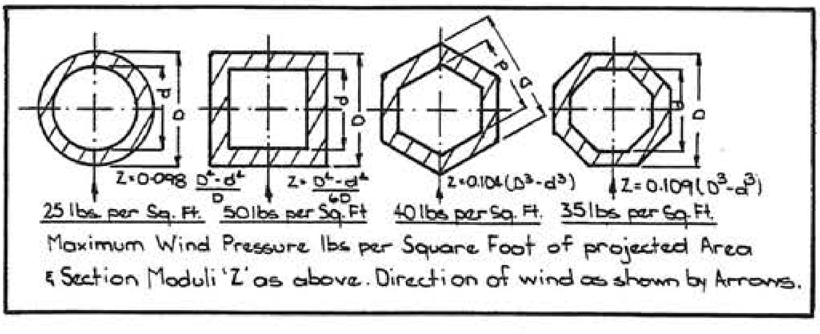


Fig 1

The following formula determined general structural dimensions[1];

$$t = 4 + 0.05d + 0.0005h \quad \text{Gebhardt}$$

t minimum was generally 9 inches

For brick built chimneys the external batter would be in the order of 1:32 and the inside face would step in 4½ inch increments.

The following formula determined the length of sections between incremental steps[1].

$h = C\,(20t + 60i + 0.1056G + 2.5\,d/2 + 656 \tan a - 0.07H - 0.453p - 18.7)$ Lang

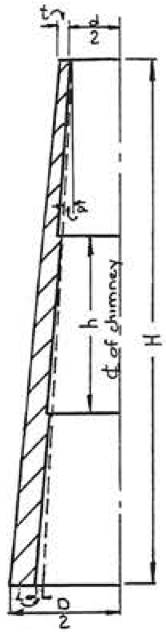


Fig 2

Chimneys were either unlined, partially lined, or fully lined dependent on the required longevity and the flue temperature. Lining was carried out with good, hard burned, common brick or fire brick which was separated from the outer structural skin to allow thermal movement and prevent heat transfer to the structural brick chimney. When the temperature had dropped sufficiently the liner could be discontinued. (Note: at the time of writing, all chimneys accessed internally by the author did not have, or had never had, a separate flue liner.)

In general lime mortar copes with heat and flue gases (particularly CO_2) better than cement, mortar, however the latter is stronger structurally[8].

Unlined chimneys can exhibit considerable damage to materials as a result of temperature and flue gas effects.

The modes of failure which chimneys were designed to resist included:

- toppling due to excessive compressive stresses on the leeward side.
- sliding by shearing through the bed joints
- overturning.

Any of the above modes could occur at any height, consequently it was necessary to check stresses at each change of section.

It is not clear what, if any, buckling analysis of compressive zones in the shell was carried out. It may have been found from empirical data that this was not generally necessary for typical chimneys of normal diameter and wall thickness. Many chimneys were banded with iron or steel bands which would have contributed to control of buckling as well as helping to control cracking due to transverse stresses from temperature and differential expansion effects.

It is worth noting that although designers considered that masonry structures should not be called upon to withstand tensile forces they did recognise that:

- there was a tensile capacity in the mortar
- opening up of the joints in the tensile face did not necessarily precipitate failure of the chimney unless gross overturning resulted or unless it was accompanied by excessive stress in the opposing face. This latter point is significant when considering any form of cyclical loading such as that caused by seismic action or vortex shedding[2]. If bed joints open up under cyclical loading the chimney can rock and either "step" off the next bed joint or cause local high concentrations of cyclical dynamic stress.

Most heritage chimneys are solitary or at sufficient distance from other structures to be unlikely to be subjected to vortex shedding, however the proximity of adjacent chimneys or buildings should be considered.

The American Civil Engineers Handbook (1949 Edition) gave the following permissible stresses for masonry[3].

Tension (lbs per sq in)	$S = 18.5 + 0.056\ H$	for single shell chimneys
	$S = 21.3 + 0.056\ H$	for lined chimneys
Compression (lbs per sq in)	$S = 71 + 0.65H$	for single shell chimneys
	$S = 85 + 0.65H$	for lined chimneys

By comparison the Toronto Building Codes allowed;

Compression	17 tons per sq. ft.
Tension	varying between 0 and 2¼ tons per sq.ft.

The tension allowance was varied depending on chimney height allowing greater tension for lower chimneys. This was in contravention of the American Code and implied some assessment of reduced risk or danger from a lower chimney.

3 SEISMIC ACTIVITY

Australia is not situated on any of the world's major fault zones and is not considered a high risk area for seismic activity. There had only been a couple of earthquakes of greater than 5.9 magnitude since European settlement and none in heavily populated areas. However on December 28th 1989 an earthquake of magnitude 5.6 on the Richter Scale shook Newcastle in New South Wales, costing 12 lives, hundred of injuries and damage to thousands of buildings. The Newcastle earthquake was significant because it happened in a major urban centre and recorded the first loss of life for an earthquake in Australia.

With some notable exceptions the majority of damage was to masonry structures, principally parapets, gables, free standing walls, unsecured brick skins of cavity walls and chimneys. It became obvious that construction methods commonly used were not adequate to resist seismic loads that produced lateral forces any greater than moderate wind loads.

The relevance of that earthquake to this paper is that it served to alert engineers, local and state authorities, and the public in general to the necessity of examining the design, construction and maintenance of new and existing masonry structures. It brought into question the safety of all masonry structures in the country with regard to seismic loads and also to wind loads. It is suggested that if all masonry structures in Newcastle had been designed and constructed to comply with design loads from the current Wind Code, there would have been much less damage than was experienced.

With regard to chimneys, damage was principally noted to domestic brick chimneys. Many toppled completely but the majority sheared sideways and/or rotated at a fracture joint above roof level, generally associated with the level of flashing. This mode of failure is consistent with chimneys which are neither tall nor slender.

4 CURRENT CODES

Australia had an Earthquake Code (AS2121) in place at the time of the Newcastle Earthquake. Immediately after the quake the Newcastle City Council[4] and the New South Wales Public Works Department[5] issued interim design requirements to be used in conjunction with this code giving guidance and minimum requirements for designers. In 1993 a new Earthquake Code (AS 1170 Part 4) came into effect, providing new design loads for use in Australia. In addition, at the time of writing, there is a draft Australian Standard DR91093 in the committee stages for "Strengthening of Existing Buildings for Earthquakes".

Whilst not all of the new documents are a direct response to the Newcastle Earthquake it is apparent that construction professionals, owners and regulatory authorities have now been forced into a more active assessment of existing and future structures for seismic design.

5 HERITAGE STRUCTURES

At the same time as Australians are being reminded of a real risk associated with seismic events (and, by association, wind action) there is a growing awareness of our heritage in the built environment which is regulated under the New South Wales Heritage Act 1977. In 1987 Section 170 was added to the Heritage Act requiring each government instrumentality to prepare a "heritage and conservation register" of heritage assets it either owns or controls. The legislation prevents arbitrary demolition or alterations to structures of heritage significance which are registered under the act or otherwise come under the jurisdiction of the Heritage Council of NSW.

All engineers would agree that if a building or structure is a danger to the public it should be made safe or be demolished. In practice most authorities deem a structure to be "safe" if it complies with all the relevant Ordinances and Codes of Practice. Compliance would generally minimise the risk of a designer, builder, or owner being held liable for negligence in the event of an unforeseen failure and would keep his or her insurance policy intact.

The problem is that many heritage structures do not in part or in whole comply with the codes. The codes are, however, guidelines only. With heritage structures it is often necessary to adopt a "back to basics" approach to analysis to confirm whether or not a structure is "safe" and/or serviceable. Unfortunately this is usually neither as quick or as convenient as the application of a set of code "rules" to determine adequacy.

Obviously an immediate and unavoidable danger to the public outweighs heritage significance but immediate demolition is not always necessary and judicious use of barricades and shoring can usually either stabilise a structure or prevent access to a danger area.

Unfortunately an enormous level of responsibility is placed on an engineer's shoulders when faced with a potentially dangerous structure. Analysis takes time and it is much easier to recommend demolition rather than face the worries of potential liability whilst going through the process of checking and if necessary certifying a structure.

Economic pressures on an owner or developer are often disguised as "safety matters", causing an engineer, who is genuinely trying to ethically fulfil his or her professional role, the dilemma of making decisions which imply a high level of responsibility and risk.

Typical procedures and two case studies are presented which represent action on some of these issues.

6 TYPICAL PROCEDURES

6.1 SURVEY: Survey is surprisingly difficult. To control costs a staged approach is used with initial assessment from the ground using relatively simple techniques. Base diameter is reasonably straightforward although usually complicated by equipment and plinths. Overall height is established by accurate survey with theodolite and tape or at the simplest level by counting bricks. Top diameter, taper and inclination are a little more difficult but the major problem is measuring accurate wall thickness and locating changes in section. With many chimneys it is not possible to even gain base access.

Scaffolding a chimney is very expensive, consequently preliminary investigation is usually carried out by sensible guesswork.

A staged approach is used.

i. Carry out a site inspection taking tape, theodolite and ladder. Measure and record base and top dimensions, height, wall thickness at base (if possible) and with a strong torch from inside record number of wall incremental steps.
   Get a check height dimension by gauging brick height and counting bricks.
   Estimate from rules of thumb (see earlier in paper) number and location of steps.
   Assume minimum wall thickness at top of 230mm then estimate even wall steps at even height increments.
   (NOTE: Some chimneys taper to a 110mm wall).
   Check plumbness all sides and assess quality of brickwork and mortar visually.

ii. Assess effect of deterioration and record cracks (this latter item may not affect analysis if cracks are to be repaired).

iii. Assess expected bearing capacity of the ground.

iv. Analyse the chimney against the current wind and seismic codes.

v. If gross overstress or instability is indicated then strengthening or partial or total demolition may be required.
   If marginal overstress is indicated then it may be necessary to:
   - sample and test bricks and mortar for compressive, shear, and tensile capacity of the materials.
   - carry out more detailed survey to check assumptions. This may be by "Cherrypicker" hoist for lower chimneys or by scaffolding or by crane and basket. The walls can be drilled to check thickness. Top diameter can be confirmed and samples taken at various heights.

6.2 ANALYSIS AND RISK ASSESSMENT: Codes of Practice incorporate various factors of safety to be applied either to loads or stresses. The factors generally fall within the range 1 to 2 depending on the level of certainty associated with loads, materials, construction technique, the level of danger associated with failure (e.g. inner city hospital as opposed to rural farm building) and nature of failure (e.g. gradual and progressive with warning or sudden and catastrophic without warning).

Unfortunately chimneys score badly in any basic risk analysis.

- the time, duration, direction and magnitude of applied load is not totally predictable.
- collapse is likely to be sudden and radius of potential damage is likely to be large.
- there are no, unaccounted for, additional

strengthening elements (c.f. a building where roof cladding, wall and floor finishes, partitions, window and door frames which are not normally taken into account in analysis do have a significant strengthening effect).

- nature of use and lack of accessibility for lifetime maintenance make deterioration of materials significant.

Consequently, any reductions in factors of safety would require careful justification. The main area where advantage can be found is in being able to take accurate as-built measurements and to test as-built samples of material to confirm higher structural capacity if possible.

6.3 STRENGTHENING SYSTEMS: The engineer is likely to be faced with four options.

i. strengthen to a level of code compliance and put in place a maintenance programme.
ii. partially demolish to a level where factors of safety are acceptable and put in place a maintenance programme.
iii. combine the first two options.
iv. totally demolish.

Assuming a decision to strengthen is taken, it is necessary to take into account the following:

- Heritage considerations; visual aspects of strengthening, affect of proposals on interpretation of the structure.
  Requirements of any existing Conservation Plans or Permanent Conservation Orders.
- Repairs required to existing fabric to maximise residual capacity and therefore minimise the strengthening required.
- Capital cost of proposal, longevity (most heritage structures require a longer than normal [50 years] lifespan), maintenance requirements.
- Practicality of access and installation without damaging the structure.
- Staging to suit finance availability.
- Incorporation of ongoing monitoring techniques.
- Reversibility

7 GOODLETT & SMITH BRICKYARDS. MERRYLANDS.

This site has numerous structures of heritage significance[6]. The site is an old brickworks, dating from 1877, currently in the ownership of Holroyd Council. The structures include warehouse and manufacturing buildings, kilns, and chimneys. Public funds are being spent providing fencing and security to safeguard the public and limit vandalism.

There are two brick chimneys remaining. (Fig. 3).Chimney No. 1 is 46.5 metres high and is round in plan. Chimney No. 2 is 30.5 metres high and square in plan. Both chimneys have severe cracking (mainly vertical), mortar loss and both lean significantly to the south at the upper levels. (Fig. 4). (This tendency to lean is not an uncommon feature of old chimneys). They are both iron banded and chimney No. 2 has tie rods at each corner. They do not receive any maintenance and are progressively deteriorating.

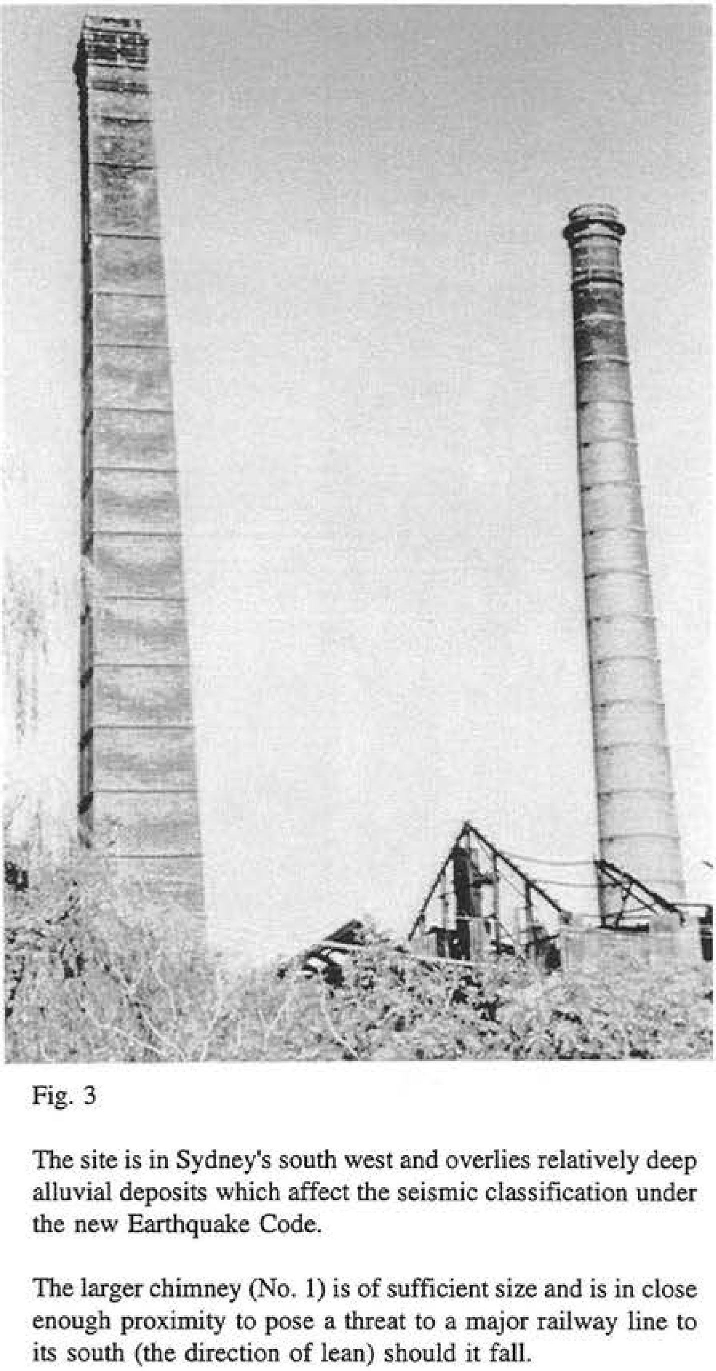


Fig. 3

The site is in Sydney's south west and overlies relatively deep alluvial deposits which affect the seismic classification under the new Earthquake Code.

The larger chimney (No. 1) is of sufficient size and is in close enough proximity to pose a threat to a major railway line to its south (the direction of lean) should it fall.

In addition it is proposed that the site be developed as a recreation space surrounded by new medium density housing.

Preliminary findings indicate the following levels of overstress when applying loads from the current Wind and Earthquake Codes and comparing results with permissible stresses in the current Masonry Code.

Chimney	No. 1	No. 2
Height	46.5m	30.5m
Overstress under wind	30%	40%
Overstress under old earthquake code.	10%	>10%
Overstress under new earthquake code	110%	>110%

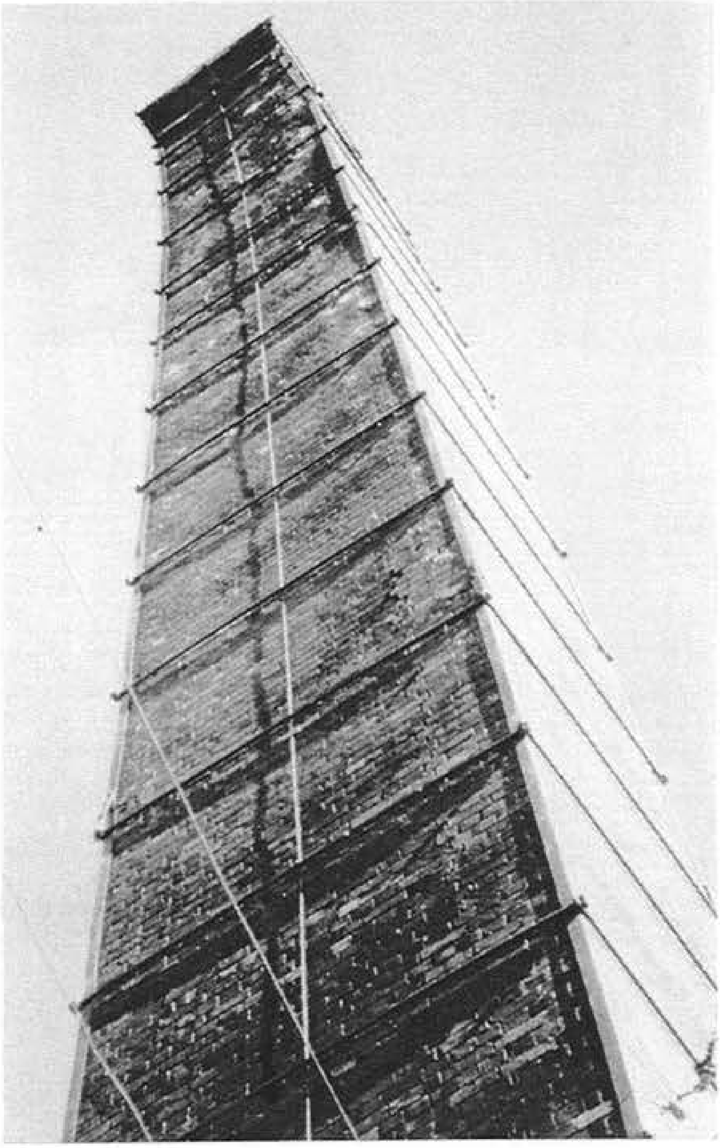


Fig. 4

The chimneys date from 116 years ago and appear to be proportioned in similar fashion to the methods described at the beginning of this paper.

Seismic loads and wind loads are event dependent. That is to say that the fact that a chimney has stood for 116 years is no indication of adequacy under such loads since the chimney may never have been subjected to loads approaching the design wind load nor subjected to a seismic event.

Council has determined that these chimneys have heritage significance and wishes to keep them. They obviously represent an engineering challenge, however offer little or no financial return for any outlay, therefore budget allowances for investigation and repair are small. This scenario could be described as "typical".

7.1 EXAMPLES OF PROPOSALS FOR CHIMNEY NO. 1 AT GOODLETT & SMITH BRICKYARDS

- PRESTRESSING (Refer Fig. 5)

Description: Underpin the chimney and cast a new footing, fit a capping structure and then stress high yield prestressing tendons in protective sheaths between cap and base.

Cost $4,350/metre

Advantages: Minimal intervention to chimney fabric
Easily reversible process
Short construction time

Disadvantages: Relies on increasing compressive stress on existing materials
Monitoring and maintenance required on an ongoing basis and total lifespan uncertain

- REINFORCED CONCRETE CORE (Refer Fig. 6)

Description: Underpin the chimney and cast a new footing, fit reinforcing steel spaced off inside face of chimney flue, fit a sleeve (in sections) as formwork and cast a reinforced concrete liner.

Cost: $4,350/metre

Advantages: Minimal maintenance, long term solution
Does not significantly rely on capacity of existing structure.

Disadvantages: Difficulties of working within the chimney flue, difficulties of fitting sleeves and placing concrete
Non reversible solution

- STEEL LATTICE CORE (Refer Fig. 7)

Description: Underpin the chiney and cast a new footing, then erect a structural steel lattice tower within the chimney which is fixed at intervals to the inside face of the flue.

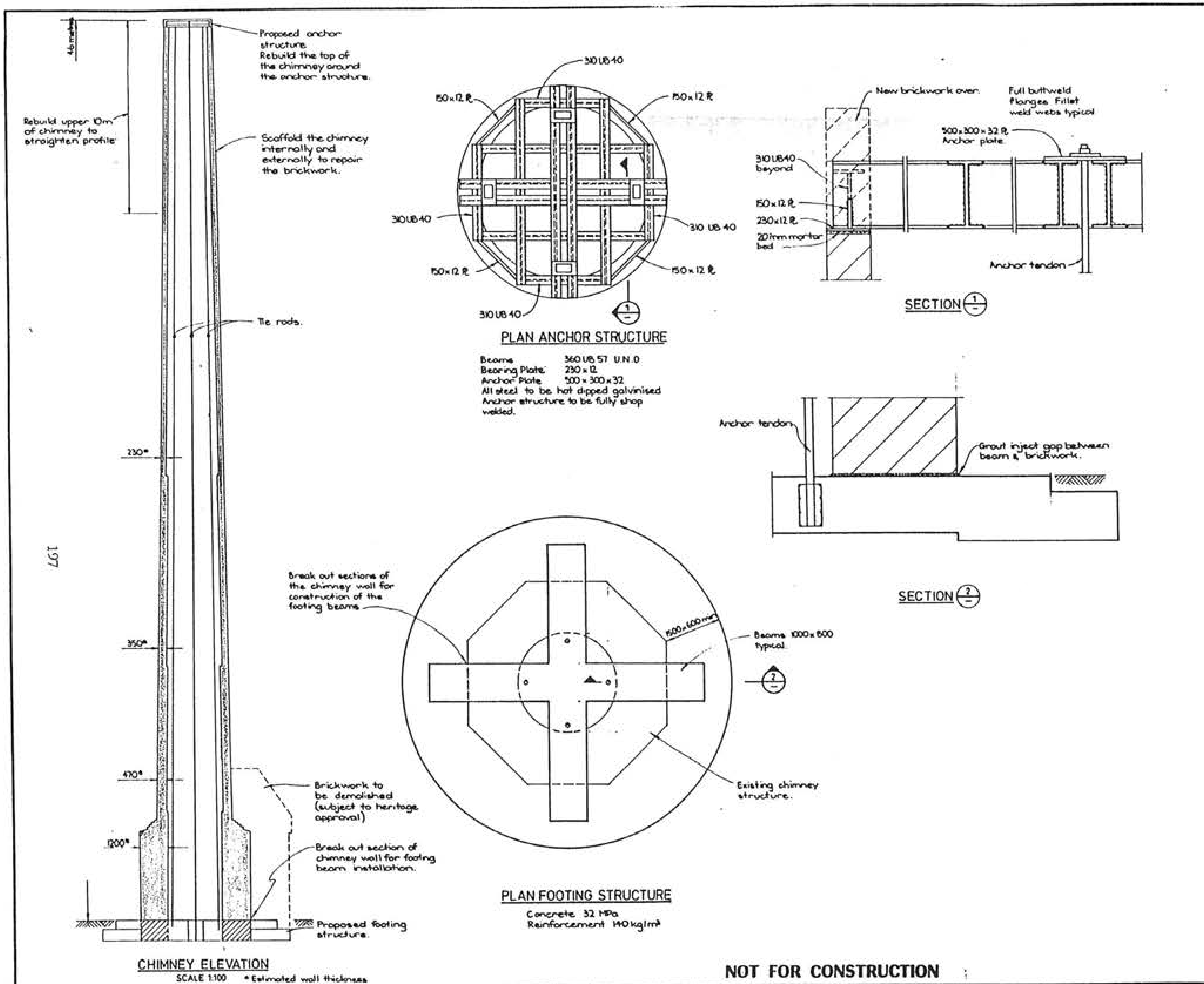
Cost: $5,200/metre

Advantages: Less construction time within the chimney,
More offsite fabrication.
Does not significantly rely on capacity of existing structure.
Reversible solution

Disadvantages: Difficulties of accurately measuring for fabrication and working within the chiney flue. Fixings may have to be made into the flue wall.
Higher maintenance

- EXTERNAL STRAPPING AND GUYING

Description: Fix guy wires to existing or replaced steel / iron bands and anchor external to the structure.



OPTION ONE

Procedure

1 Demolish brick structures on the eastern and southern sides of the chimney.

2 Break out sections of the chimney wall.

3 Construct the footing and footing beams.

4 Repair the cracks in the brickwork and any other areas of weakness in the chimney.

5 Remove the top section of the chimney brickwork.

6 Install the anchor structure on top of the chimney.

7 Install the tie rod anchors and apply a nominal tension to them.

8 Rebuild the brickwork at the top of the chimney.

NOTE

This option relies on the compressive and shear strength of the brickwork for the chimney's stability. The stresses induced in the brickwork from wind and earthquake loads are significant.

The viability of this option is therefore dependant on the brickwork being sound. The condition of the brickwork and brick joints has yet to be determined so there is a possibility that post tensioning may not be suitable for the chimney.

Design Criteria

This design has been carried out in accordance with AS 3600 Concrete Structure Code, AS 3700 Masonry Structures Code and AS 4100 Steel Structures Code for loads in accordance with AS 1170.1 Dead and Live Load Code, AS1170.2 Wind Load Code and the draft of AS 1170.4 Earthquake Load Code.

Design Wind Load	50m/s (ultimate)	
Earthquake Load	Acceleration coefficient	0.11
	Bracing Type	[illegible]

Repair of Brickwork

Stitch across the cracks by replacing broken bricks with new brickwork. Replace any other loose or broken brickwork.

The condition of the steel bands should be checked. Any broken bands should be replaced and any loose bands retensioned.

The lightning conductor straps should be checked and repaired if deemed necessary.

The top of the chimney requires replacement as part of the anchor structure's installation.

ADVANTAGES OF OPTION 1

This option will have a similar cost to Option 2.

The option has the least work required from within the chimney.

The option would have the shortest site construction time.

DISADVANTAGES OF OPTION 1

The option relies on the strength of the brickwork for its stability and at this stage is considered unlikely to be suitable since brick strength is unlikely to be adequate.

The construction is more complex than the other options.

Providing composite action between the rods and the brickwork is difficult to achieve.

There would be a higher maintenance commitment required on the structure than Option 2.

More sub-contractors would be required in the construction than Options 2 and 3.

No estimate has been made for the cost of this option since at this stage it is considered unlikely to be suitable. It will be re-examined in detail only if brick strength proves to be higher than expected.

FIG. 5.

NOT FOR CONSTRUCTION

MARK	DATE	AMENDMENT
A	22.10.93	RE-ISSUE TO COUNCIL

HUGHES TRUEMAN LUDLOW Engineers

NORTH

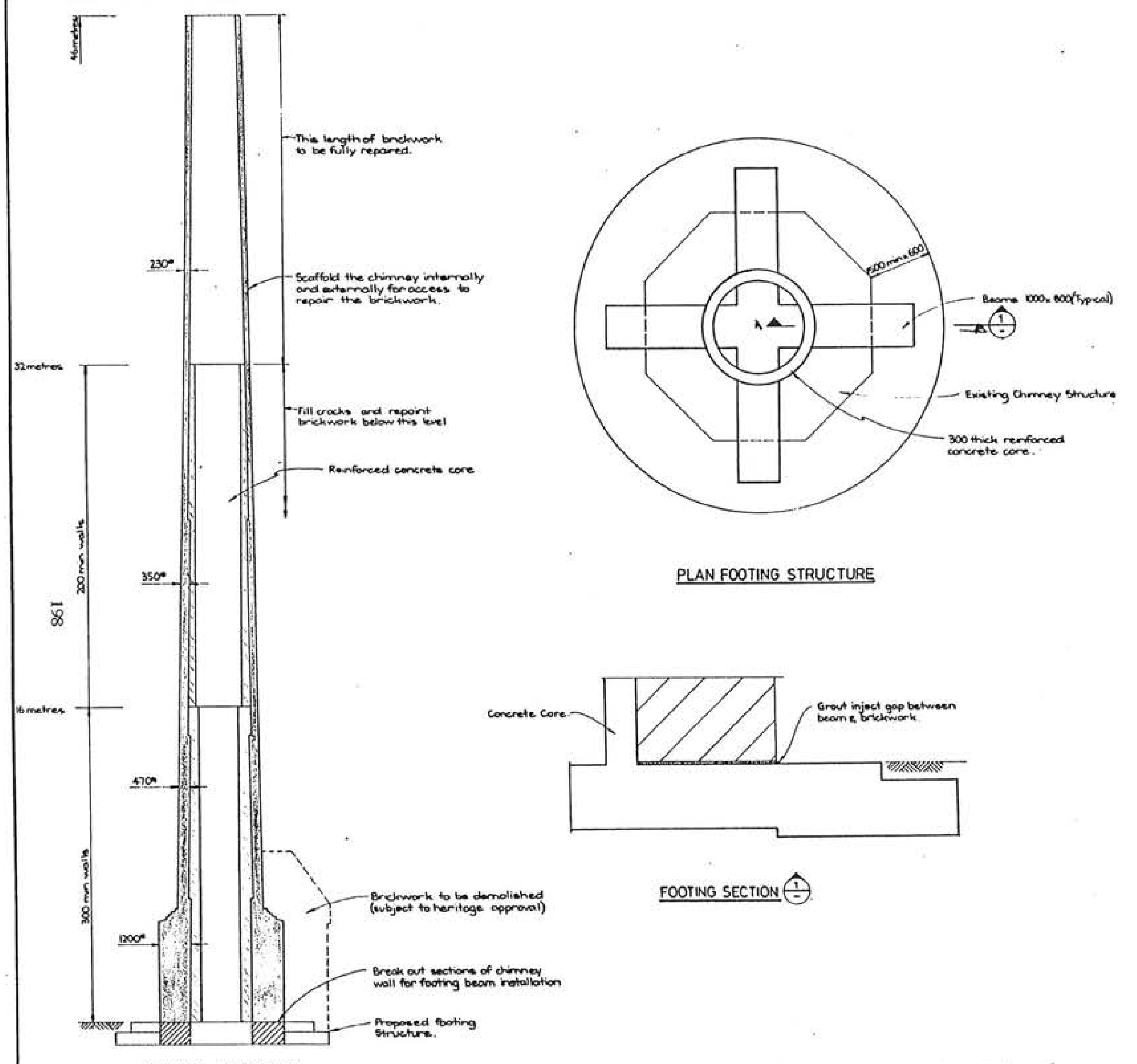
PROJECT: RESTORATION OF CHIMNEY Nº 1 GOODLET & SMITH BRICKWORKS SITE. MERRYLANDS.

HOLROYD CITY COUNCIL.

THIS DRAWING: OPTION 1 POST TENSION CHIMNEY STRUCTURE

SCALE	DATE	SHEET No
1:20, 50, 100	24-8-93	1 of 3

DRAWN	CHECKED	PROJECT No	AMENDMENT
A. J. F	JS	G1081	A



CHIMNEY ELEVATION
SCALE 1:100 * Estimated wall thickness.

OPTION TWO

Procedure

1. Demolish brick structures on the eastern and southern sides of the chimney (subject to heritage approval).
2. Break out sections of the chimney wall for construction of the footing and access during construction.
3. Construct the footing and footing beams.
4. i) Clean and repair internal section of brickwork.
   ii) Install reinforcement for the section.
   iii) Place formwork.
   iv) Pour concrete.
5. Repeat step 4 until the concrete core is completed.
6. Complete the repairs internally on the brickwork then carry out repairs externally on the brickwork.

Design Criteria

This design has been carried out in accordance with AS 3600 Concrete Structure Code, AS 3700 Masonry Structures Code for loads in accordance with AS 1170.1 Dead and Live Load Code, AS1170.2 Wind Load Code and the draft of AS 1170.4 Earthquake Load Code.

Design Wind Load	50m/s (Ultimate)	
Earthquake Load	Acceleration co-efficient	0.11
	Building Type	3

Concrete Notes

Core wall thickness varies 300mm for the first 16 metres and 200mm thickness for 16 to 32 metres.

Concrete Strength	32 MPa
Reinforcement	140kg/m³

Core to be constructed in 3 metre sections.

Repair of Brickwork

Cracks in the brickwork should be repointed to prevent the ingress of water and weathering of brickjoints. Above the level of the core structure stitch across the cracks by replacing broken bricks with new brickwork. Replace any other loose or broken brickwork.

The top of the chimney may require rebuilding.

The condition of the steel bands should be checked. Any broken bands should be replaced and any loose bands retensioned.

There may be steel capping at the top of the chimney. If there is it should be checked and repaired if deemed necessary.

The lightning Conductor straps should be checked and repaired if deemed necessary.

ADVANTAGES OF OPTION 2

This option would cost less than Option 3.

Minimal maintenance commitment would be required after completion.

The construction procedure is simpler than options 1 and 3.

The strength of the brickwork is only required for the stability of the top 16 metres of the chimney.

The number of sub-contractors required in the construction is less than options 1 and 3.

DISADVANTAGES OF OPTION 2

This option would have the longest site construction time.

Most of the construction work would occur within the confines of the chimney.

The estimated budget costing of this option is $203 000.

FIG. 6.

NOT FOR CONSTRUCTION

MARK	DATE	AMENDMENT	MARK	DATE	AMENDMENT
A	22.10.93	RE-ISSUE TO COUNCIL			

SIGNED FOR AND ON BEHALF OF HUGHES-TRUEMAN-LUDLOW ENGINEERS

DATE ....

NORTH

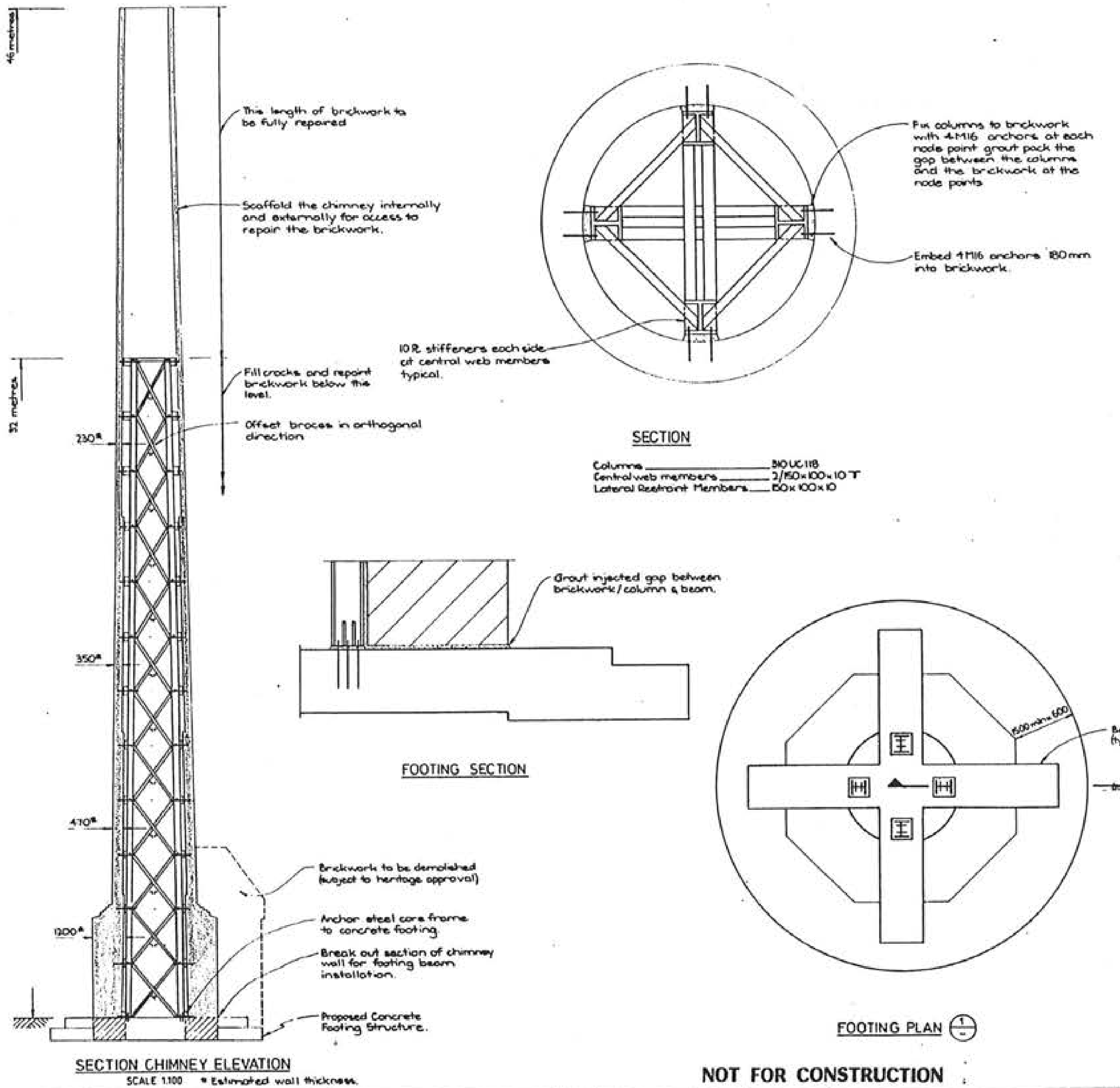
HUGHES TRUEMAN LUDLOW ENGINEERS

PROJECT: RESTORATION OF CHIMNEY Nº 1 GOODLET & SMITH BRICKWORKS SITE MERRYLANDS.

HOLROYD CITY COUNCIL.

THIS DRAWING: OPTION 2 CONCRETE CORE

SCALE	DATE	SHEET No	
1:20, 50, 100	24-8-93	2 of 3	
DRAWN	CHECKED	PROJECT No	AMENDMENT
A.J.F	J.S	G1081	A



OPTION THREE

Procedure

1. Demolish brick structures on the eastern and southern sides of the chimney (subject to heritage approval)
2. Break out sections of the chimney wall for construction of the footing and access during construction
3. Construct the footing and footing beams (similar to options 1 & 2)
4. i) Clean and repair internal section of brickwork
   ii) Lower section of steel framework through the top of the chimney then bolt into place
   iii) Install chemical anchors into the brickwork from the columns then grout pack the gaps between the columns and brickwork
5. Repeat step 4 until the steel core structure is completed
6. Complete the repairs internally on the brickwork then carry out repairs externally on the brickwork

Design Criteria

This design has been carried out in accordance with AS 3600 Concrete Structure Code, AS 3700 Masonry Structures Code for loads in accordance with AS 1170.1 Dead and Live Load Code AS1170.2 Wind Load Code and the draft of AS 1170.4 Earthquake Load Code

Design Wind Load	50m/s (Ultimate)	
Earthquake Load	Acceleration co-efficient	0.11
	Building Type	3

Steel Notes

All steelwork to be hot dip galvanised

The frame sections to be lowered through the top of the chimney

Shop welded connections to be used where ever possible otherwise bolted connections to be used

Concrete Notes

Concrete Strength	32 MPa
Reinforcement	140kg/m³

Core to be constructed in 3 metre sections

Repair of Brickwork

Cracks in the brickwork should be repointed to prevent the ingress of water and weathering of brickworks. Above the level of the core structure stitch across the cracks by replacing broken bricks with new brickwork. Replace any other loose or broken brickwork.

The top of the chimney may require rebuilding

The condition of the steel bands should be checked. Any broken bands should be replaced and any loose bands retensioned

There may be steel capping at the top of the chimney. If there is it should be checked and repaired if deemed necessary

The lightning Conductor straps should be checked and repaired if deemed necessary

ADVANTAGES OF OPTION 3

This option has a shorter site construction time than option 2

There is less construction work within the chimney than option 2

The strength of the brickwork is only required for the stability of the top 14 metres of the chimney

DISADVANTAGES OF OPTION 3

This option costs more than option 2

The construction process is more complex than option 2

There would be a higher maintenance commitment required on the structure than option 2

More sub-contractors would be required in the construction than option 2

The estimated budget costing of this option is $240 000

FIG. 7.

MARK	DATE	AMENDMENT	MARK	DATE	AMENDMENT
A	22.10.93	RE-ISSUE TO COUNCIL			

SIGNED FOR, AND ON BEHALF OF: HUGHES TRUEMAN LUDLOW ENGINEERS

DATE

NORTH

HUGHES TRUEMAN LUDLOW ENGINEERS

PROJECT: RESTORATION OF CHIMNEY No 1 GOODLET & SMITH BRICKWORKS SITE. MERRYLANDS

HOLROYD CITY COUNCIL.

THIS DRAWING: OPTION 3 INTERNAL STEEL CORE STRUCTURE

SCALE	DATE	SHEET No	
1:20,50,100	24-8-93	3 of 3	
DRAWN	CHECKED	PROJECT No	AMENDMENT
A. J. F	J.S	G 1081	A

Advantages: Minimal cost
Minimal disruption to existing fabric

Disadvantages: Visual impact
Large radius for works required
Monitoring and maintenance required
Still relies on compressive capacity of brickwork

8 CADIA MINE SITE : ORANGE

In 1865 a mine was established on the south-eastern slopes of Mt Canobolis near Orange in New South Wales. The mine operated, extracting copper, until 1867 when it became uneconomical[7].

There are remnants of the mine, associated workings, a small village, railway, school and cemetery, abandoned in what is now rural farm land. The principal elements of interest are the old engine house, ore crushing room, boiler house and chimney. (Fig. 8). They are of the Cornish type and have been damaged by salvage works and the elements.

The site has a Permanent Conservation Order over it.

The Cornish mine structures have been examined, assessed and repaired during 1993 and 1994 to minimise further deterioration and secure the structures from the elements (first stage of repair).

The item of particular relevance to this paper is the chimney. (Fig. 9) It is free standing and the lower two-thirds are constructed of rubble masonry with stone from the site. The upper third is of brick construction. This is typical of chimneys for Cornish Engines of which there are other examples in South Australia as well as in Cornwall, England.

The chimney is founded on a pit filled with rubble, mortar and earth fill, forming a variable but reasonably solid mass base. The walls are very thick, however there is bulging at lower levels and vertical cracking.

The mortar between the stones has very low compressive capacity and appears to be from a mixture of sand and clay from the site with particles of uncombined lime.

The chimney has been analysed using a very low compressive capacity for the mortar and has been found adequate for wind and seismic loads (largely because of massive wall thickness).

The complication to this site is that with current techniques the original ore body may become commercially viable for mining again, by open cut methods, up to within 800 metres of the old Cornish mine structures. This mining will involve blasting to loosen the rock.

Theoretical ground accelerations have been established and the chimney has been analysed for those accelerations and has been found to be adequate. However, due to the weakness of the mortar the long term affect of continued blasting requires assessment and monitoring.

At the time of writing blasting tests are being carried out to verify ground acceleration figures.

During the first stage of repairs to the chimney (which included underpinning, infill of openings, joint filling, capping and brickwork reconstruction) crack monitoring tell tales have been installed to provide ongoing data on movement (Fig. 10).

Fig. 8

If ground vibration induces movement it will be detected and options have been put forward for stabilisation which include casting a reinforced concrete core to the chimney and grout injecting voids in the masonry.

Banding or strapping of the chimney is another possible option, however it is not favoured due to its intrusiveness on the fabric.

It may become necessary to devise a total protection system for the chimney which can be removed at completion of mining operations (which could be as much as 20 years hence). Reversibility would be a key issue should this become necessary.

9. CONCLUSION

Old photographs show that urban and rural areas of NSW were dotted with masonry chimneys giving evidence of historical industrial processes. It is only of recent years that Australias industrial heritage has been recognised as important, by which time most of the old chimneys have been lost. Those that do remain are made more valuable by their scarcity. They are landmarks, more readily recognised by the public than most other engineered items, but they present a risk (often exaggerated) to that same public and a level of liability to their owners. By adopting a rational engineering approach they can be saved and stabilised. Recent events in Australia (the Newcastle Earthquake) have made this a critical time for action by the engineering profession to ensure their survival where at all possible.

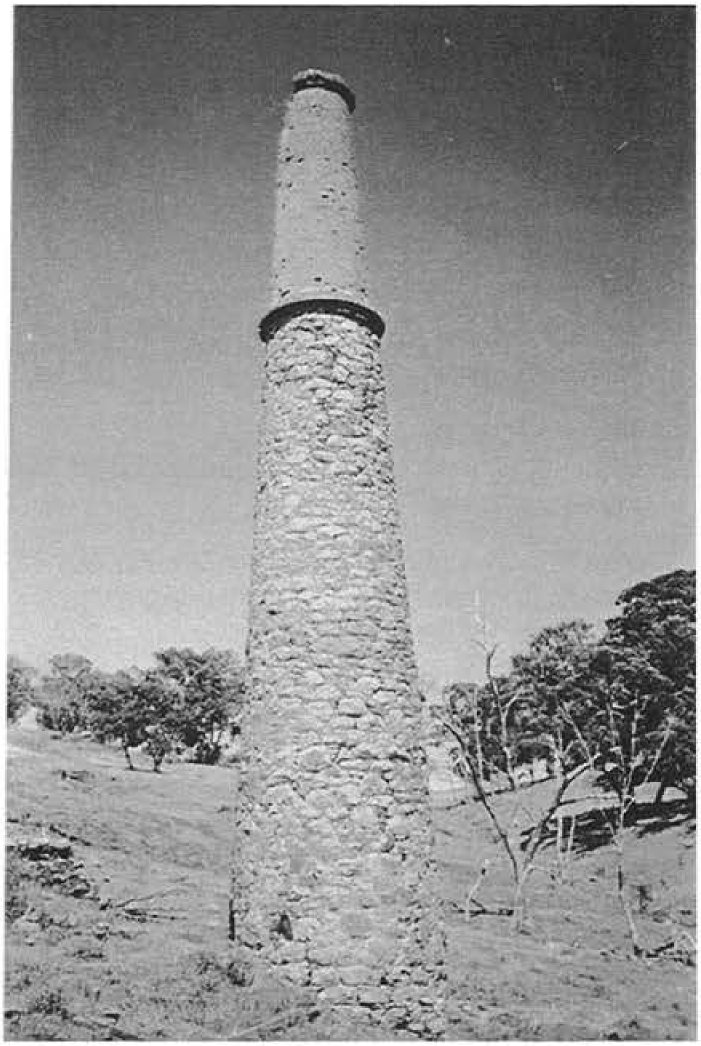


Fig. 9

Installation of overlapping, etched glass tell tales for crack monitoring on chimney stonework. ↓

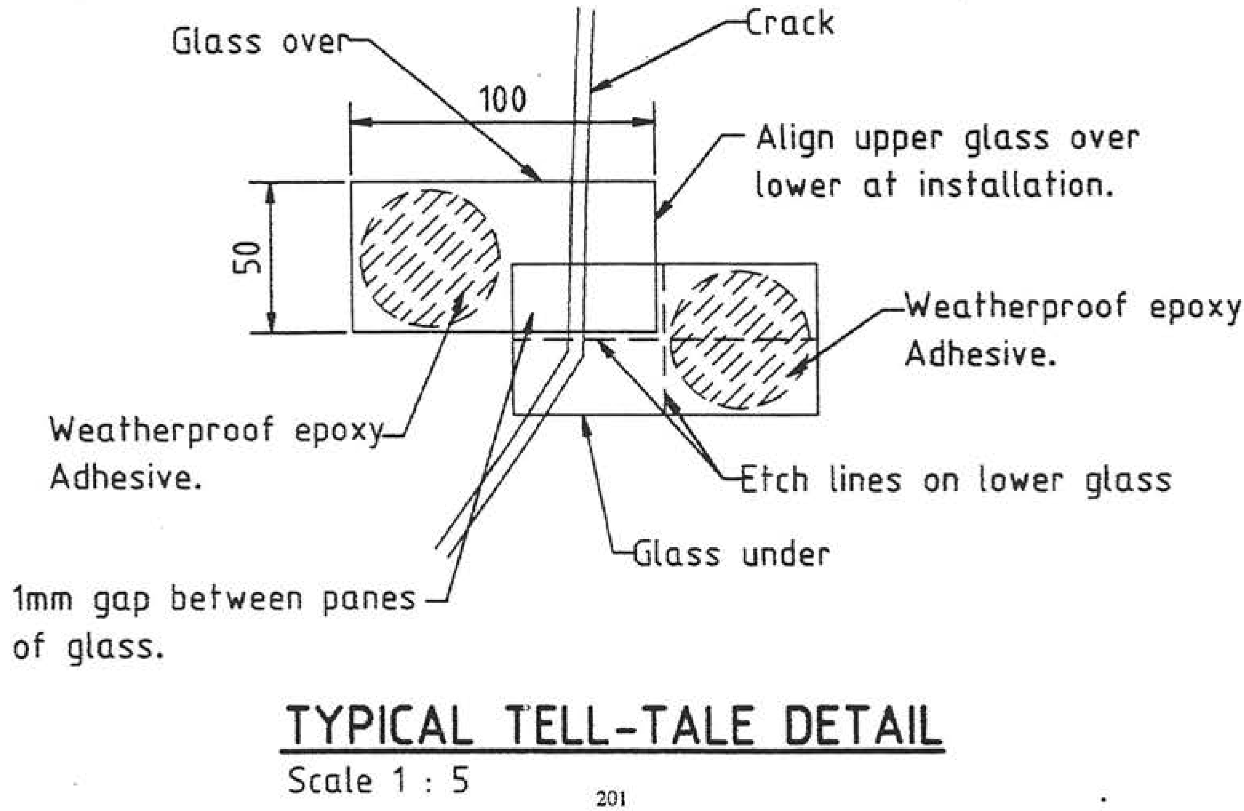


Fig. 10

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(5) Loke, Dr J Y O, 1990, Interim Guidelines, Earthquake - Resistant Design of Buildings, New South Wales Public Works Department.

(6) Romey, Peter, 1989, Heritage Study of Goodlet and Smith Brickworks.

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(8) Jackson, Kenneth R, 1978, A Guide to Chimney Design, IPC Science and Technology Press.

11 SUGGESTED ADDITIONAL READING

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(2) Thorburn, S and MacArthur, E W, 1993, Risk, Liability, and QA in Construction Engineering", Paper; The Structural Engineer, Vol 71, No. 21.

(3) Dias W P S, 1994, Structural Failures and Design Philosophy, Paper: The Structural Engineer, Vol 72, No. 2.

(4) Fanelli, Prof Michele, 1993, The Static Safety of Masonry Towers, Paper: Structural Engineering International.

(5) Drew, G J and Connell J E, 1993, Cornish Beam Engines in South Australian Mines, Department of Mines and Energy, South Australia.

The Evolution of Nineteenth Century Timber Roof Trusses: Design and Fabrication in Britain and her Colonies

K.J.Wyatt, School of Architecture, University of New South Wales

SUMMARY The British colonies in New Zealand and Australia were established and grew during a period of rapid technological change in Great Britain. The paper examines the evolving structural theory and carpentry practices used in the design and erection of timber roof trusses in Britain, and their application in the colonies by tradesmen and designers.

ROOF CARPENTRY AT THE START OF THE 19TH CENTURY

At the start of the nineteenth century, the most common truss forms used in England were the King-post truss and its derivatives.

The roof system based on the king-post truss (Figure 1) consisted of fairly slender common rafters **C** (spaced at 3-400 mm centres) supported on substantial purlins **P** which spanned about 3.0 m to the trusses. The pitch of the roof depended upon the cladding, which was usually a heavy material such as lead (pitch 1:2), pan-tile (3:4) or slate (1:1). The tie-beam **T** was often of nearly-square cross-section, and was carried on a plate on top of the masonry wall. The king-post **K** was tenoned into the beam and was provided with sloping shoulders at top and bottom to receive the ends of the principal rafters **R** and struts **S**. The principal rafters were of rectangular cross-section, tenoned into the tie-beam and into the head of the king-post. Struts were like-wise tenoned at their ends. Tenons were bolted more often than pegged; bolts with square shanks were preferred. Iron straps were used sparingly, often only at the foot of the post and the lower ends of the principals. Figure 2a shows a strapped-and-bolted king-post truss of this period.

It is clear that the carpenters who had developed this truss form over the preceding centuries had a clear qualitative understanding of structural behaviour. They recognised and then avoided the difficulty of making tension joints in timber. The king-post is a tension member; at its lower end it receives the gravity roof loads transmitted through the struts, and then carries those loads up to the top of the rafters for transfer by arching action to the walls. Yet the joints at its ends are compressional ones. The head of the post is shaped like a keystone; its inclined bearing faces were usually perpendicular to the centrelines of the rafters. The shoulders at the bottom of the post were also perpendicular to the struts, and provided a good compressional seating for them. The vertical component of the force in the strut was transferred by compression directly into the king-post. (Modern practice would transfer this force firstly into the lower chord and then by an unavoidable tension joint into the vertical member.) Any shearing component at these joints was taken by the tenon which was usually fairly substantial, being at least one-third of the member thickness. Pegs or bolts were mainly unstressed, being used for locational and erection purposes only.

The timber that had been used for first quality construction since ancient times was English oak. This is a hardwood, prized for its durability and its ability to take fine carving. Other native timbers such as elm, ash and poplar were used in lesser applications. Oak had always been difficult to obtain in long lengths, and softwood had been imported into England from the Baltic countries since medieval times, but from the seventeenth century on, imported fir replaced oak in all but ecclesiastical roofs.

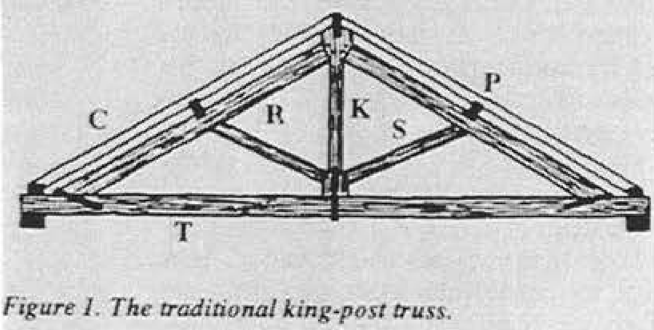


Figure 1. The traditional king-post truss.

THE BEGINNINGS OF STRUCTURAL THEORY

As far back as 1638 Galileo had devised a generalised form of the parallelogram of forces and in 1678 Robert Hooke enunciated his famous law in a public lecture. Varignon stated the Principle of Moments in 1725, Euler published his work on the buckling of columns in 1757, and Coulomb devised a method for stress analysis in a rectangular beam in 1773[1]. These theories were all that were needed for the basic design of roof timbers: equations to test the equilibrium of the structure, a method of resolving forces at joints, an understanding of columns

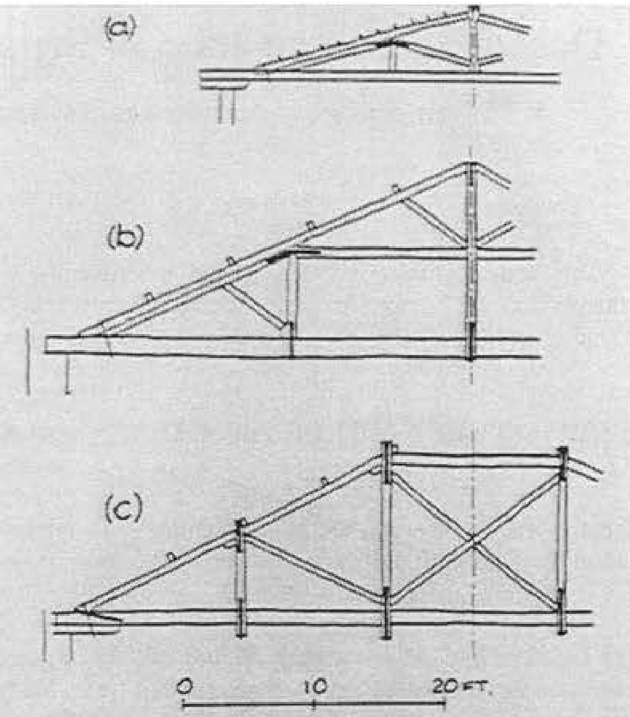
1 See Hamilton's (1962) paper for an outline review of the development of structural theory.

In 1817 Peter Barlow[4] published a long essay on timber in which he reviewed earlier test results and added results from his own work at the Royal Military Academy; by the time the third edition of this work was published in 1826 it was possible to incorporate permissible stresses for bending and compression for many timbers, and Tredgold was able to produce an addendum which showed how to apply the information to the design of structures.

Barlow's tests had been on small specimens of beams, ties and columns; the available theories for strength and deflection, though incomplete, were enough to permit the test-data to be "scaled-up" to full-sized members. This design process, which involved the use of scaling constants, persisted for several decades before more rigorous methods (developed for iron and steel) were applied to timber. Writing in 1886, Tarn[5] was able to conduct a review of all the available experiments and recommend safe stresses for most situations, for local timbers and those imported from the Baltic, North America and some of the colonies. In 1875 Thomas Laslett[6] published the first edition of his "Timber and timber trees", which gave a very thorough account of properties and utilisation of timbers from around the world. Most of what needed to be known to enable the scientific design of timber trusses was now known.

Were these new theories and new experimental results made available to the engineers and craftsmen on the job?

Education was extremely important to the ambitious tradesman of the early nineteenth century; it was the ladder which he would use to climb into the professional ranks. Peter Nicholson was an educator who established a number of technical schools, and then produced textbooks which distiled the available knowledge of the day. His books include an architectural dictionary (1812), the well-known "New practical builder.." (1823), "Practical carpentry..." (1835), "Principles of architecture" (1848). These books emphasised the application of mathematics, geometry and science to design and construction; they were all widely used and frequently quoted; through them, new knowledge was immediately made available to the aspiring professional. The first school of engineering was established in London in 1838, followed by Chairs at universities in London in 1841 and Glasgow in 1854. The Professor at Glasgow for many years was W.J.Rankine, who, like his precursors at the Ecole and Woolwich made a great contribution to the dissemination of knowledge by writing textbooks which consolidated the knowledge available in various fields. The professional engineers had an insatiable thirst for knowledge; they formed institutions, they presented and listened to papers, they had generous sharings of information and they had vitriolic and venomous disagreements. The new technology spread like fire through their numbers.



	(a) St Mary's Bryanston Square	(b) New Church Mary-le-bone	(c) Belgrave Chapel Belgrave
ARCHITECT	R.Smirke	P.Hardwick	R. Smirke
YEAR	1823	1822	1825
SPAN	36.5ft	61ft	60.5 ft
SPACING	6ft 3in	12ft 10in	10ft 6in
TIE-BEAM	9 x 6	12 x 12	12 x 7
PRINCIPAL(S)	8 x 6	8 x 7, 8 x 7	10 x 6
KING-POST	8 x 6	Pair 8.5 x 5	Pair 9 x 5
QUEEN-POST	6 x 5	8 x 7	
BRACE	6 x 6	6 x 5	7 x 6
STRAIN^G BEAM		10 X 8	10 x 6
PURLINS		8 X 6	8 x 4
COMMONS		5 X 3	5 x 2

Figure 2. Three trusses of the 1820s

BRITISH PRACTICE DURING THE NINETEENTH CENTURY

Softwoods had been imported into England probably since the late middle ages, and the trade became significant during the sixteenth and seventeenth centuries. Countries bordering the Baltic Sea were the main source of supply[7], with timber being exported from many districts, notably through the ports of Danzig, Memel and Riga, in the form of square timber (logs squared up by broad-axe) or deals (planks, usually 75 mm or more thick). Deals were produced most often by water-powered sawmills (which had been used in Scandinavia since the thirteenth century), or by pit-saws. By the mid-eighteenth century,

4 Barlow's research, culminating in his Essay, possibly provided the stimulus for the Admiralty's initial interest in Kauri.

5 See E.Wyndham Tarn's 1886 edition of Tredgold's 1820 Elementary Principles of Carpentry.

6 Laslett, Timber and Timber Trees.

7 See Lower (1973) for description of Baltic timber trade.

and an ability to select beam sizes. Yet none of this was applied until well into the nineteenth century.

Before these theories could be applied to practice, it was necessary, firstly, to know the properties of the materials of construction and, secondly, to promulgate all this information to the practitioners.

The lack of interest in the strength of materials seems extraordinary to us, and was perhaps an example of the indifference to finding useful applications for new theories that was a part of the heritage of Greek culture[2]. It was not until 1729 that any useful testing of materials was done (by Musschenbroek in Leiden) and it was only as the century was drawing to a close that Gauthey, Rondelet and Perronet worked to produce testing machines able to crush samples of stone and other materials in compression.

The final link in the chain - the promulgation of technical information in useful form - was forged at about the same time. Joseph Moxon (and others) had produced a series of texts dealing with mechanics. One of the earliest practical English texts on building was produced by Wilsford in 1659; other authors on the art of building included Langley (1730) and Pain (1774)[3]. Early in the eighteenth century, it became apparent to the French military authorities that there was a need for training colleges to give officers specific training in technical matters. In 1741 the Royal Military Academy was established at Woolwich and in 1747 the Ecole des Ponts et Chaussees was founded in Paris. The principals of these technical schools seem to have been among the first to become aware of the need to produce handbooks or manuals which presented theoretical material in a form that could be used in the field by practitioners. In 1720 and 1725 Belidor published short practical works on architecture and mathematics, and later went on to write classic works on military and hydraulic engineering, which remained in use for nearly a century.

One of the earliest, and certainly the most well-known text on carpentry was Francis Price's *The British Carpenter*, first published in 1733, with a second and then a third edition appearing in 1753. Price provided his readers with information on the *craft* of carpentry: there is a lot of geometry (to be used in setting-out), many patterns, and some member sizing, but there is no application of evolving theory.

Hamilton summarises the state of the art of engineering at the end of the eighteenth century as follows: "So long as the materials of construction were limited to masonry, wood, and earth, used according to traditional methods, no elaborate theory was needed, and even Coulomb's simple analyses were avoided as being too mathematical. Belidor had written all that was considered necessary."

2 See Ernst Werner (p199) in Symposium on the role of iron in historical architecture, ICOMOS, FDR, Sept 1978

3 See Nicholson's Dictionary (1819) for review of earlier texts.

STRUCTURAL THEORY DURING THE NINETEENTH CENTURY

The nineteenth century saw a great blossoming of technical theory and a golden age of engineering. The two theoretical developments from this period that were of greatest relevance to roof carpentry were bending theory and truss analysis.

Coulomb's early pioneering work on the bending of beams received little attention for half a century until it was taken up and developed by C.L.M.Navier, of the Ecole des Ponts et Chaussees, who published a comprehensive theory of elasticity in 1826. This incorporated a generalised theory of bending, including the calculation of deflection by double integration of moments, and the analysis of eccentrically-loaded columns. Clapeyron developed a method of dealing with continuous beams in 1857 and in the following year Rankine devised a method for determining the distribution of shear stresses across a section.

The main thrust to develop a theory for analysing the forces in triangulated frameworks resulted from a series of collapses of rail bridges that had occurred in England and in Germany during the 1840s. A Royal Commission was held in England in 1848, and work on truss analysis was published by W.B.Blood in 1850 and by Robert Bow in 1851. In America, timber trusses had been developed on a wide scale, and books had been published by Squire Whipple (1847) and Robert Haupt (1851). Carl Culmann was despatched from Germany to America to study bridge design, and on his return published in 1851 the first general theory of truss design, which incorporated the need for full triangulation, the need for member centre-lines to intersect at points and the importance of providing a simple geometrical arrangement between upper and lower chords. For the first time, trusses could be calculated, using a method of resolving forces at the joints. In 1863, August Ritter developed the method of sections, and in 1864 Culman (then Professor of Engineering at Zurich) published the first work on graphic statics, containing a generalised account of force and link polygons, leading to the general solution of forces in frameworks. In 1863, Clerk-Maxwell published his work on reciprocal diagrams and in 1873 Bow provided a system of notation which greatly simplified the process. Williot's method for determining deflections of trusses was presented in 1877. Finally, the development of methods of dealing with complex and indeterminate structures gradually evolved from about the 1870s.

So much for the development of theory for timber roof construction; what about the materials testing that would enable this theory to be put to use?

Baltic timber had a virtual monopoly of timbers for the building trade in Britain; the two main species constituting this export were *pinus sylvestris* (Scotch pine or Tannenbaum, usually called redwood in the trade) and *picea excelsa* (spruce, or whitewood.)

Because of the Napoleonic Wars, this trade was severely restricted in 1807-09, and, in the interests of national security, Britain introduced heavy duties on Baltic imports so as to encourage the trade in softwoods from the eastern coast of its colony in North America. This policy caused a radical shift in the availability of timber to the British market: in 1790 North American timbers were an insignificant part of the market, whereas by the 1840s the imports from America were three times as large as from the Baltic. In 1847, Britain introduced free-trade policies which reduced the viability of the North American trade, and this, coupled with a progressive shortage of supply, meant that the Baltic states gradually reasserted their trade to the extent that by the 1870s American imports were less than half of those from the Baltic. The dominant species exported from North America during this period were pinus strobus (white pine, often called Quebec or yellow pine in Britain), and p. resinosa (red pine), with smaller quantities of spruce and white oak.

Regardless of the country of origin and the form in which it was imported (squared or in deals), the timber was merchandised through a system of auctions, wholesalers and retailers before being re-sawn into scantlings. Britain was very slow to introduce sawmills; a water-powered circular saw-mill was installed in 1769, but was destroyed by workers, and most timber was converted by pit-saw until well into the eighteenth century.

During the nineteenth century, therefore, the British carpenter was working almost entirely with softwoods. For the first quarter of the century, most of these timbers were of Baltic origin, but thereafter Canadian species were also commonly in use. European oak was being used only in very small quantities. Table 1 gives the properties of these timbers.

In roof carpentry, the use of king-and-queen-post trusses continued from the previous century, but there was greater use of iron and steel for strapping at joints. Initially, straps were restricted mainly to joints where tension was to be transmitted, but later they came to be used more indiscriminately. Bolts also were used even more extensively; the square-shanked bolts that had been advocated by Price and used in the previous century were replaced by round bolts with square heads, and then with the more modern hexagonal-headed bolt. Steel rods, threaded and fitted with nuts and washers, were used for tension members or to correct trusses that had been poorly designed. Iron castings were employed at joints to spread the load where one member was in bearing on the side-grain of another. Gradually the composite steel-timber truss evolved, with timber being used for compression and metal for tension.

It has not proved possible to develop a chronology for truss detailing; often old techniques were not replaced by new ones, but continued to co-exist with them. The joint between king-post and tie-beam, for example, could be accomplished by a single bolt, by a bolted strap, or by a stirrup strap with gib-and-cotter connector. All three methods were used right through this period. The truss in Figure 2c, with its paired king-posts which project below and thus embrace the tie-beam, appears to be far more modern than that of Figure 2a, yet it is of the same era and was designed by the same architect.

ROOF CARPENTRY IN THE COLONIES.

Exploitation of timber in New Zealand commenced long before first permanent settlement[8]. Spars were harvested in the Waihou River area for Admiralty purposes (1794) and for shipment to China (1798-1802), but these are believed to have been kahikatea, a timber of relatively low durability. From 1807 timber was being won from the Bay of Islands area for shipment to Port Jackson in New South Wales, and it was during this period that the superior properties of Kauri first came to attention. In 1820 the *Coromandel* and the *Dromedary* were sent by the British Admiralty specifically to obtain cargos of Kauri spars, and during the ensuing decade timber continued to be exported to New South Wales, predominantly from the Hokianga and Kaipara areas. With the increase in whaling activity during the twenties, and the activities of missionaries during the twenties and thirties, the European population gradually increased (reaching 10,000 by 1842), thereby creating a local market for timber and carpentry.

Although much timber was pit-sawn, a feature of timber production in New Zealand was the early use of power saws for conversion: in 1842 there were two water-powered mills and two steam-powered; in 1855 there were thirteen water-mills and two steam; in 1881, twenty-two water and more than two hundred steam. Both frame-saws and circular-saws were used from 1842 onwards, although logs were usually first "broken down" by pit-sawing into sections able to be sawn by the power-saws. Kauri, rimu and kahikatea were all used for local building construction, but the superior properties of kauri would have been preferred for all quality work such as truss construction. As the century progressed, the native timbers gradually became depleted; the output of kauri exceeded the combined output of all other species until about 1868, but thereafter utilisation of inferior species became more and more common.

The first settlers in New South Wales encountered timbers unlike anything they had previously experienced. Compared with the timbers they had been working with in Britain, the blue gums and blackbuts of the Port Jackson area were at least twice as strong, as tough, as stiff and as hard, and their shrinkage was at least twice as great. Cutting and sawing these trees using axes and saws

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8 See Simpson (1973) for N.Z. timber production and trade with Australia.

devised for British softwoods must have been a devastating experience. Pit-sawing was done by convict gangs in Government sawing establishments, and an oxen-powered "mechanical sawing machine" was installed by private ownership at Lane Cove in about 1827. In Tasmania, a water-powered mill was operating in Hobart in 1825 and a steam-mill in Launceston in 1837. The first steam mill in Sydney was possibly that erected by Australian Saw Mills, in 1838[9]. It seems probable that most of the mills working with native timbers used circular saws; the frame-saw, with its reciprocating motion which produced planks by "through-and-through" sawing, was rather unsuitable for eucalypts, which often have defective timber at their hearts. (The Launceston mill had both frame and circular blades; the Sydney-based Australian Saw Mills, which did use frame saws, was located adjacent to the Harbour, and may have been involved in re-sawing imported softwoods.) By 1880, there were about 400 mills in the country; almost all of these were steam powered, although there were still some water-powered mills and pit-saws were still in use until at least the 1870s.

The Australian building industry has used both the native hardwoods and imported softwoods as traditional sources of supply. The earliest timber imports seem to have come in 1807 from the Bay of Islands area in New Zealand[10], and a Mr Blaxcell advertised for sale "a number of desirable pine logs fit for flooring boards, and spars for masts just imported from New Zealand in the scow *Commerce*". Other shipments must have followed, because in 1813 New South Wales imposed an import duty of one shilling per cubic foot on all timber imported from New Zealand (reduced to sixpence in 1815). Samuel Marsden was active in this trade, with shipments commencing in 1814; in 1818/19 two shipments landed 11,246 feet of plank in Port Jackson. It is probable that the earliest imports were of kahikatea, but by 1814 kauri was being shipped through Sydney and in 1822 (for example) the *Providence* shipped 25,000 cubic feet of kauri from Hokianga to Sydney. In 1827 the Sydney-based merchants Raine, Ramsay and Brown established a settlement and mill at Hokianga, producing deal timber for the Sydney market.

The production of sawn timber on the west coast of North America commenced with the construction of a mill at Fort Vancouver in 1827. By 1860 there were more than 400 mills in operation, producing 10.7 million board feet of softwood lumber (mainly Douglas fir) per annum. These forests were far removed from the existing markets of Europe, and new markets had to be developed around the Pacific; the earliest export was to the Sandwich Islands in 1838, but the trade faced stiff competition from New Zealand and did not prosper immediately[11]. The writer does not know when Douglas fir ("oregon", as it became popularly known) was first imported into Australia, but it was certainly being used in building construction by the 1860s.

It is evident, therefore, that imported timber (mainly softwood) was an important component of the building of Australia for all except the first two decades of the first settlement at Port Jackson. By 1840, the dollar value of timber imports was nearly equal to the value of exports, and from 1853 onwards imports always exceeded exports[12]. It is important to realise that, except at the very beginning, softwoods were quite readily available whenever their use was considered desirable, and they certainly would have been the preferred material to use for the majority of "engineered" roof trusses.

This is not to deny the importance of the use of native timbers in Australian building construction, and most timber carcassing was done in hardwoods until well into the present century. Numerous excellent roof trusses were constructed in hardwood throughout the nineteenth century in many parts of the country. This was especially true of church roofs, where the timbers were exposed and sometimes carved and chamfered in hammer-beam form; hardwood (like oak) was a superb material for this application.

Table 1: Properties of Air-dry Carpentry Timbers in Britain, New Zealand and Australia

SPECIES	AIR-DRY DENSITY kg/m^3	SHRINKAGE (Rad/Tan) %	MOD. OF RUPTURE MPa	YOUNG'S MODULUS GPa	HARDNESS (Janka) kN
Oak	700	3.0/6.0	97	10	5.5
Whitewood	420	1.5/4.0	72	10	2.1
Redwood	500	2.0/4.5	83	10	2.6
White pine	430	1.3/3.7	59	8.5	n.a.
Red pine	560	2.3/4.3	76	11.2	n.a.
Kauri	560	2.5/4.0	90	13	3.3
Rimu	600	3.0/5.0	77	9	3.5
Kahikatea	450	2.5/4.5	66	7.9	3.0
Hoop Pine	530	2.5/3.5	90	13	3.4
Blue Gum	850	5.0/9.0	140	18	9.0
Douglas Fir	530	2.5/4.0	90	13	3.1
Radiata	500	3.0/4.5	81	10	3.3

Sources: Wood in Australia, Encyclopedia of Wood.

In both New Zealand and Australia, then, the carpenter had available timbers that were very similar to those he knew. Table 1 compares some of the mechanical properties of timbers in common usage in Britain, New Zealand and Australia during the nineteenth century (and

9 For Australian timber production see mainly Dargarvel(1988); also Hudson et al (1986) and L.T.Carron's History of Forestry in Australia.

10 Simpson (1973)

11 See I.M.Elchibegoff "US International timber trade in the Pacific area" (1948) and O.O.Winther, "The great North-west".

12 T.C.Grant "History of Forestry in N.S.W."

also two ubiquitous twentieth-century ones). The carpenter in both colonies would have found kauri to be superior to (and rimu the equal of) any of the timbers he had worked with before. Oregon (Douglas fir), when it became available, would also have been familiar in its properties. Blue gum and the eucalypts would have been chosen by the Australian carpenter only where strength, stiffness, economy and durability were required, and where ease of working was of low importance. In trusses, the main requirements were to have a timber that was easy to work to fine tolerances and that had low shrinkage so that joints would remain tight; the imported softwoods satisfied this need, and could be worked by techniques quite familiar to the British craftsman.

In the colonies were carpenters and architect/engineers fully competent to apply their British-learned skills to these timbers with their not-unfamiliar properties. James Smith, for example, was a Scottish carpenter/joiner who arrived in Sydney about 1815 with sufficient capital to obtain a land-grant, and then worked under Francis Greenway before setting up as builder, architect and surveyor as well as carpenter. Other craftsmen working in Sydney during the first third of the century included Robert Reid, James Kay, William Carss, James Houison and many others; in 1831 eighteen carpenters arrived on the one ship. By 1846 there was a Society of Operative Carpenters and Joiners in existence and mechanics classes were being held at the Sydney Mechanics' School of Arts which had been founded in 1833. The country was starting to educate its own sons to continue the traditions of British craft.

CONCLUSION

Although there were radical advances in the theory of structures during the nineteenth century, these had relatively little impact upon the design and construction of softwood roof trusses in Britain, where the evolution of carpentry gained more from new information on timber properties than from structural theory. When designers and tradesmen arrived in the Pacific colonies, they found that their skills were appropriate for the softwood timbers which were available for roof truss construction.

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